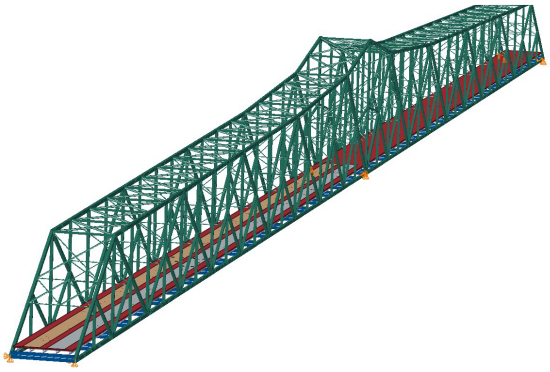
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Evaluating the Potential Benefits of Implementing AASHTO Guide Specifications for the Analysis and Identification of Fracture Critical and System Redundant Members





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16. Abstract

An exploratory study was conducted for some bridges in the state of Indiana that evaluated the implementation potential of the *AASHTO Guide Specifications for Internal Redundancy of Mechanically-Fastened Built-Up Steel Members* (IRM Guide Specification) and the *AASHTO Guide Specifications for the Analysis and Identification of Fracture Critical Members and System Redundant Members* (SRM Guide Specification). The outcomes for the project included (1) determining if the application of the Guide Specifications on a wider scale would be beneficial to INDOT; (2) identifying which bridges or members were "truly" non-redundant in the selected bridges, thus allowing a more targeted inspection program that would minimize the risk associated with member failures; (3) developing a more targeted inspection program for the bridges eligible to be classified as IRMs and SRMs, and (4) proposing a strategy to move forward with a state-wide implementation plan to analyze other bridges presently classified as having NSTMs. This report addresses the bridge selection process used in determining the list of structures in the state of Indiana for IRM and SRM evaluation, as well as a detailed description of the IRM and SRM evaluation processes.

17. Key Words AASHTO, guide specifications, redundancy, Internally Redundant Member (IRM), System Redundant Member (SRM), Non-Redundant Steel Tension Member (NSTM), Fracture Critical Member (FCM), bridge evaluation, Indiana Department of Transportation (INDOT), bridge inspection, steel bridge, bridge instrumentation/monitoring	**18. Distribution Statement** No restrictions. This document is available through the National Technical Information Service, Springfield, VA 22161.

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Evaluation of the Potential Benefits of Implementing the AASHTO Guide Specifications for the Analysis and Identification of Fracture Critical Members and System Redundant Members

EXECUTIVE SUMMARY

In 2018, The AASHTO Committee on Bridges and Structures (COBS) voted to approve the *AASHTO Guide Specifications for the Analysis and Identification of Fracture Critical Members and System Redundant Members* (SRM Guide Specification) (AASHTO, 2018/2022a). The same year, AASHTO COBS also voted to approve *The AASHTO Guide Specifications for Internal Redundancy of Mechanically-Fastened Built-up Steel Members* (IRM Guide Specification) (AASHTO, 2018/2022b). These new guide specifications codified for the first time the procedures and criteria to quantitatively determine whether a steel tension member should be classified as a Non-Redundant Steel Tension Member (NSTM), formerly known as Fracture Critical Members (FCM), System Redundant Member (SRM), or an Internally Redundant Member (IRM).

In this project, the IRM and SRM Guide Specifications were evaluated in an exploratory study on specific bridges in the State of Indiana. Goals for the project included to (1) determine if the application of the guide specifications on a wider scale would be beneficial to INDOT; (2) identify which bridges or members were "truly" non-redundant in the selected bridges, thus allowing a more optimized and targeted inspection program; (3) presuming that some of the bridges (or members) could be classified as IRMs or SRMs, develop a more targeted inspection program for those bridges, and (4) propose a strategy to move forward with a statewide implementation plan to analyze other bridges presently classified as having NSTMs.

Inspection intervals and scope will be set using rational engineering-based approaches. It is likely that in some cases, hands-on inspection can be extended or eliminated without compromising safety and decreasing the risk to the inspectors and the traveling public. The overall quality of the inspections should increase since the inspectors will have a more targeted approach for assessing the condition of the structures. Less time and effort needed at structures with redundant (system or internally redundant) members means that more time and effort can allocated to the critical structures and a cost savings for the bridge owners if redundant members.

This report addresses the bridge selection process used in determining the list of structures in the State of Indiana for IRM and SRM evaluation, as well as a general description of the IRM and SRM evaluation process used for the bridges selected. A brief description of the work performed, lessons learned, and recommendations for each bridge is also provided in this report, with an individual detailed report for each evaluated bridge included as separate volumes.

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Volume IV: Analytical Evaluation of the After-Fracture System Performance of Steel I-Girder Bridge: I-74-170-04684 Over Whitewater River, Simple-Span Truss Bridge: SR1 001-68-03408 Over the Mississinewa River, and Two-Span Truss Bridge: Matthew E. Welsh Memorial Bridge, Mauckport (135-31-06504 B) in the State of Indiana
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1. BACKGROUND

The Non-Redundant Steel Tension Member (NSTM) label has been used on bridge members that have "a steel primary member or portion thereof subject to tension whose failure would probably cause a portion of or the entire bridge to collapse" (Lloyd et al., 2020). Once a bridge has been classified as having NSTMs, the structure has been required to have an in-depth arm's length inspection completed at regular intervals. Typically, the interval is 24 months throughout its service life, however under certain circumstances 48-month intervals are permitted. Additionally, if the bridge condition warrants it, a lesser interval may also be required. Members classified as NSTMs are also subject to additional design and fabrication requirements. Major costs are associated with these hands-on in-service inspection requirements, as well as considerable costs associated with impacts to traffic delays and the risks to the public and inspectors due to accidents which may occur. However, historically fracture of NSTMs in real bridges has not resulted in collapse of the bridge. The applied loading in these cases consists of the nominal dead load and some modest, yet unknown, level of live load. Upon discovery the bridges were closed for repairs and put back into service with no significant further impact on the subsequent performance of the bridge. In fact, in the majority of cases complete member failures have been repaired and the bridge returned to normal service.

Steel tension members can be classified as a Non-Redundant Steel Tension Member (NSTM), an Internally Redundant Member (IRM), or a System Redundant Member (SRM). Per the AASHTO Guide Specifications, IRMs and SRMs are defined as follows.

Internally Redundant Member (IRM)

A built-up steel member which meets the requirements set forth in the AASHTO Guide Specifications for Internal Redundancy of Mechanically-fastened Built-up Steel Members. (It is noted that throughout this report, this guide specification will be referred to as the IRM Guide Specification (AASHTO, 2018/2022b).) An IRM shall not be classified as an NSTM, but shall be inspected using an appropriate technique at an interval specified in Article 3 of these Guide Specifications. IRMs shall be identified on the plans as IRMs. Internal redundancy is further defined as the "ability of a member to provide an alternate resistance mechanism after the failure of an individual component through load redistribution within the member."

System Redundant Member (SRM):

A steel primary member subject to tension for which the redundancy is not known by engineering judgment, but which is demonstrated to have redundancy through a refined analysis. SRMs must be designated on the contract documents to be fabricated according to Clause 12 of the AASHTO/AWS D1.5M/D1.5 Bridge Welding Code (AASHTO/AWS, 2015). An SRM need not be subject to the inspection protocols for an NSTM as described in 23 CFR 650.305 (DOT FHWA, 2022).

Recent research around redundancy of steel members provides updated guidance regarding when a member should be classified as an NSTM and culminated in the creation of both the SRM and IRM Guide Specifications (AASHTO, 2018/2022a; 2018/2022b). The guide specifications for system redundancy and for internal redundancy provide codified methodologies for determining if a member is a redundant member, as well as provide updated requirements regarding design, fabrication, and inspection type and interval for redundant members. Benefits associated with the updated requirements are significant for improving safety, costs, and inspection efficacy.

2. PROJECT SUMMARY

As stated in the title, the purpose of this research project was intended to implement the SRM and IRM concepts and newly appointed laws in order to provide more effective and applicable inspection plans for structures in Indiana. Specific bridges owned and maintained by the Indiana Department of Transportation (INDOT) were evaluated to establish the accuracy of their NSTM categorization. The work performed did not and was not intended to simply remove the NSTM label and replace it with the IRM or SRM label. Furthermore, the purpose of the study was to better understand the behavior of a structure and provide a label that accurately described its ability to be redundant. Bridge members that did not exhibit system level or internal redundancy as prescribed in the respective guide specifications would remain labeled as NSTMs. Bridge members that were evaluated and found to be system redundant members or have internal redundancy would no longer require NSTM treatment, such as arms-length inspections. SRMs would not require any additional inspections above and beyond the typical routine inspections, but the IRMs would be required to have an additional special inspection added to its inspection schedule in order to find broken components as defined by the IRM Guide Specification.

The expected benefits of the project include but are not limited to safety, mobility/reduced congestion, quality, time savings and cost savings. NSTM inspections are expensive due to the additional inspection time/effort and additional maintenance of traffic during the process. The arms-length requirement of the NSTM inspection leads to a challenge in accessing all the members under consideration, leading to additional risk for the inspectors. Traffic congestion due to the lane closures for specific inspection equipment is also a factor. Inspection intervals and scope will be set using rational engineering-based approaches, it is likely that in some cases, hands-on inspection can be extended or eliminated without compromising safety and the risk to the inspectors and the traveling public would be decreased. The overall quality of the inspections should increase since the inspectors will have a more targeted approach to assessing the condition of the structures. More time and effort could be allocated to the critical

structures. With decreased amount of time and effort at structures with redundant (system or internally redundant) members there is a cost savings for the bridge owners.

While an explicit cost/benefit analysis was not performed and was beyond the scope of the project, implementation should not be considered solely based on initial cost of the analysis. Indirect cost benefits have the greatest impact associated with implementation. These are summarized as follows.

- Establishing an engineering-based inspection interval and strategy for members traditionally classified as NSTMs. In the absence of performing SRM or IRM evaluations, INDOT is forced to use a one-size-fits all for these bridges and members. Hence some members are under-inspected while some are over-inspected. Since the member criticality in the context of redundancy is based on engineering and not perception, the reliability of the structure, or possibly more appropriately, the vulnerability should a member fail is better understood allowing inspection resources to be allocated more effectively.
- In cases where the intervals can be extended, risks to inspectors, the traveling public are greatly reduced.
- In cases where NSTM inspections are eliminated entirely, there will be cost savings on a given bridge since the expenses of special access equipment, lane closers, etc., are eliminated or at most, only conducted at extended intervals.

The deliverables for the project include this report in which the work performed is summarized as well as separate reports labeled as volumes dedicated to the evaluation of specific bridges. Volume I contains the work performed to evaluate a steel built-up two girder bridge, US 41 Bridge (041-26-03917 NB and SB) over the White River, for internal redundancy. Volume II contains the work performed to evaluate another steel built-up two-girder bridge, I-74 over the Wabash River (I-74-06-04417 GWBL and FEBL), for internal redundancy. Volume III contains the work performed to evaluate a steel truss bridge, Wabash River Memorial Bridge (062-65-T4020) over the Wabash River, for internal redundancy. Volume IV contains the work performed to evaluate three separate bridges for system level redundancy: I-74-170-04684 over the Whitewater River (steel two-girder bridge), 001-68-03408 over the Mississinewa River (simple-span truss bridge), and Matthew E. Welsh Memorial Bridge (135-31-06504 B) over the Ohio River (two-span truss bridge). The evaluation process described in the above-mentioned volumes contain background and details of the structure, specific calculations/modeling performed to evaluate for redundancy, discussion of the results and the implementation and specific guidance on future inspection plans for the structure based on the results of the evaluation.

Two additional documents were created, Volume V and Volume VI, to assist INDOT in the implementation of the SRM and IRM concepts for future bridge evaluations. Each volume briefly describes the evaluation process and inspection requirements for both methodologies in addition to providing a procedural flowchart that guides INDOT on the full process.

3. BRIDGE SELECTION

For this project, the goal was to evaluate a few structures in the State of Indiana for internal and/or system level redundancy. A thorough selection process was completed as described below. The first and primary filtering characteristics of a bridge for evaluation include the following.

- Owner Agency: State Highway
- Fracture Critical Detail: Y12 or Y24
- Main Design Material: Steel or Steel Continuous
- Main Construction Design: Girder and Floorbeam System, Stringer/Multi-beam or Girder, Truss – Thru, or Arch – Thru
- Bridge Posting: 5, Equal to or Above Legal Loads

Any structure not meeting the previous features was removed from the selection process. These characteristics narrowed down the list of bridges to fifty structures. The next step in determining which bridges would be evaluated was assessing the impact IRM would have on the structures' inspection costs. To complete this, the following bridge characteristics were reviewed.

- Year Built and Year Reconstructed
- Number of Spans
- Structure Length
- Deck Width
- Superstructure Condition
- Average Daily Traffic (ADT)

Using the previous metrics, a list of candidate bridges was gathered and presented to INDOT. These structures were split up into five categories: SRM Girder Bridge, IRM Girder Bridge, SRM Truss, SRM Thru-Arch and IRM Truss. Bridges with higher ADT, longer lengths and wider decks were prioritized. Through discussion with INDOT, some bridges within these categories were removed due to inspections being performed by a neighboring state, or specific knowledge of the structure that would disqualify it from being evaluated for SRM or IRM. The bridges for each bridge type selected for evaluation are as follows.

- SRM Girder: I-74-170-04684 (I-74 Whitewater River)
- SRM Truss: 135-31-06504 B (Matthew E. Welsh Memorial Bridge, Mauckport)
- SRM Thru-Arch: 237-62-06512 C (Cummings Lincoln Trail Bridge, Cannelton)
- IRM Girder: 041-26-03917 (US 41 White River) and I74-06-04417 (I-74 Wabash River)
- IRM Truss: 062-65-T4020 B (Wabash River Memorial Bridge) and 001-68-03408 C (Mississinewa River)

During the evaluation process, with INDOT approval, a change to the original list of bridges was required. Structure 001-68-03408 over the Mississinewa River had insufficient capacity to pass the IRM

requirements, so the bridge was evaluated for system level redundancy instead of internal system redundancy.

The IRM Guide Specification also requires additional screening criteria using more specific data, such as the inspection report, original plan sets, and reconstruction plan sets, to determine if a member or a part of a member would qualify as an IRM. Similarly, the SRM Guide Specification also has screening criteria defined in Section 2.2 that eliminates members from being evaluated. See Section 4 and specific bridge volumes for more information regarding those screening criteria.

4. EVALUATION PROCESS

The evaluation process varies between system redundancy and internal member redundancy. Each process is described below in its respective section below. Additionally, reference documents titled "Procedures for Reclassifying Nonredundant Steel Tension Members as Internally Redundant Members" and "Procedures for Reclassifying Nonredundant Steel Tension Members as System Redundant Members" were created for INDOT to outline the process and procedures used to satisfy Federal Highway Administration's requirements for IRM and SRM evaluation, respectively. The reference document for IRM is included as Volume V and SRM as Volume VI in this report.

4.1 System Redundancy

After a bridge satisfying the Section 2.2 screening criteria of the SRM Guide Specification (AASHTO, 2018/2022a) has been selected, the SRM Guide Specification shall be used to determine if the bridge can be reclassified as having system-level redundancy. The intent of the SRM Guide Specification (AASHTO, 2018/2022a) is to provide a codified methodology "to evaluate system-level redundancy of a bridge after the failure of a member traditionally designated as an FCM."

When considering failure scenarios for evaluation in the faulted state, those that produce the greatest demands on the remaining intact components should be analyzed. Analysis should consider the most critical members and locations to create a worst-case scenario for bridge failure, with minimum basic failure scenarios prescribed in the guide specification. Each scenario assumes the failure of only one member at a given instant. The load combinations for evaluation are specified in Article 3.4 of the SRM Guide Specification and described below. The two load combinations to be investigated separately are the Redundancy I and Redundancy II load combinations.

The Redundancy I load combination is intended to describe the loading condition of the structure at the instant the member fails, evaluating the bridge's ability to immediately survive a sudden brittle fracture. Note that this load combination is not intended to produce the fracture, but rather to represent the average maximum load (particularly live load) that may be on the bridge at the time of the fracture. A target reliability index of 2.5, as prescribed in the guide specification, ensures with high confidence that the bridge will survive the initial fracture (AASHTO, 2018/2022a; Section 3.4).

The Redundancy II load combination is intended to evaluate the structure under a live load that could be expected between the instant of failure and the time the damage is discovered, which is assumed between 5 and 50 years. The Redundancy II load combination also utilizes a target reliability factor of 2.5 (AASHTO, 2018/2022a; Section 3.4). For Redundancy II, loading up to the maximum number of lanes that fit on the bridge is used. Additional analyses with less than the maximum number of lanes with higher multiple presence factors should also be performed. The approach is based on *AASHTO LRFD Bridge Design Specifications* (AASHTO BDS) (AASHTO, 2020) lane configuration for bridges.

The resulting load combinations for the evaluations of existing structures are as follows.

$$\textit{Redundancy I}: (1 + D_{AR})\,[1.15(DC) + 1.25(DW) + 1.0(\mathrm{LL})]$$

(AASHTO, 2018/2022a) Table 3.4-1

$$\text{Redundancy II}: 1.15(DC) + 1.25(DW) + 1.50(1{+}\mathrm{IM})(\mathrm{LL})$$

(AASHTO, 2018/2022a) Table 3.4-2

In these equations, DC is the dead load, DW is the future wearing surface/utilities load, LL is the live load, IM is the impact modifier, and D_{AR} is the dynamic amplification factor due to the sudden fracture. This dynamic amplification factor is calculated as the ratio of the peak stress in a given member in free vibration following the sudden fracture to the stress in that member after the structure comes to rest. In the Redundancy I load combination; the dynamic amplification factor is applied to both the dead and live loads. To avoid the need for complex dynamic analyses during future evaluations, the guide specifications (AASHTO, 2018/2022a) includes a simplified procedure that utilizes a tabulated value for the dynamic amplification factor (AASHTO, 2018/2022a, Table 3.3.1-1).

Once the analysis has been completed, it is necessary to establish whether the structure has adequate capacity (i.e., redundancy) in the faulted state. The minimum strength performance requirements are described in Section 8.2 of the SRM Guide Specifications (AASHTO, 2018/2022a) and outlined below for steel components, reinforced concrete, and the substructure.

Steel Components: Four basic strength criteria for primary steel components must be met when the bridge is subjected to the Redundancy I and II load combinations. These failure criteria are as follows.

1. The average strain across a component of a cross section (e.g., a flange) must be less than the smaller of five times the yield strain or 0.01. The objective of this criterion is to limit the redistribution of forces to other components while the structure remains in service. This criterion is intended to prevent the placement of excessive demands on the intact components.

2. The maximum strain anywhere in a primary component should not exceed the ultimate strain, which is conservatively limited to 0.05.
3. The compression stress must remain below the critical buckling stress of the component in cases where the FEA does not account for the buckling mode.
4. The system must demonstrate a reserve margin of at least 15% of the applied live load in the Redundancy I and II load combinations. In other words, the system must be able to support 1.15 times the expected live load. This requirement ensures the load versus displacement curve is still on the ascending branch. This requirement is not specific to the steel components alone, but rather to the entire bridge as a system.

Reinforced Concrete: The nominal compressive strength of reinforced concrete may be exceeded locally in decks, barriers, or haunches; nevertheless, the system remains capable of carrying the factored loads. In other words, it is acceptable to have localized concrete crushing in decks, barriers, or haunches because its consequence would not lead to the collapse of the bridge. If concrete crushing or deck reinforcement yielding takes place over at least 50% span length of the slab or if concrete crushing results in a flat or negative slope of the load-deflection curve, the structure should not be considered redundant. In these cases, passage of traffic and environmental conditions will rapidly deteriorate the slab to a point where system capacity may be further reduced. In other words, if the portion of the slab where a compressive strain of 0.003 has been exceeded is large enough to compromise the overall load carrying capacity of the system or if significant hinging occurs, the structure should not be considered as sufficiently redundant.

Substructure: In addition to checking the strength of the superstructure, the substructure must also be evaluated. Although the substructure may not be explicitly included in the finite element model in all load combinations, the displacements and reaction forces at support locations are checked in the analysis.

In addition to strength criteria, there are minimum serviceability requirements applicable in the faulted state to alleviate any overall stability problems. According to Section 8.3 of the SRM Guide Specifications (AASHTO, 2018/2022a), the minimum serviceability criteria for the Redundancy I and II load combinations are explained as follows.

1. *The change in the maximum vertical deflections of the superstructure should not exceed L/50.* The deflection change is defined as the difference between before fracture and after fracture displacement under Redundancy II factored dead loads. A load factor of 1.05 is applied and the limit is taken as L/50. This value represents the level of distortion that motorists can navigate without experiencing a decrease in safety. Uplift at supports beneath a joint in the deck should not exceed 3.5 inches. The Redundancy II factored dead loads are used for this check.
2. *Horizontal translation at supports should not result in the bridge falling off a support.* Transverse and longitudinal displacements at support locations should be considered as a member may lose support, particularly at supports that allow for expansion, in the faulted state. Hence, it should be verified that the predicted horizontal displacements can be accommodated by the existing support. This criterion simply requires that the structure does not fall off a support, either due to a bearing tipping over or a girder moving completely off of a pier or abutment.

Additionally, a reference document titled "Procedures for Reclassifying Nonredundant Steel Tension Members as System Redundant Members" was created for INDOT to outline the process and procedures used to satisfy Federal Highway Administration's requirements for SRM evaluation. This document can be found in Volume VI.

4.2 Internal Member Redundancy

After a bridge with mechanically-fastened built-up NSTMs has been selected for internal member redundancy evaluation, the IRM Guide Specification should be used to determine if the NSTMs can be reclassified as IRMs. The intent of the IRM Guide Specification (AASHTO, 2018/2022b) is to provide a codified methodology "on how to establish whether adequate internal redundancy exists in a mechanically-fastened built-up steel member." Note that per AASHTO BDS Section 6.6.2.2, only nonredundant steel members that are subject to net tensile stress under the Strength I load combination shall be designated as an NSTM (AASHTO, 2020). All members and sections being evaluated shall satisfy the general requirements of Article 1.4 of the IRM Guide Specification. The conditions set in Article 1.4 that would preclude primary tension members from evaluation include, but are not limited to, fatigue cracking, significant corrosion, and impact damage. Specific additional requirements are included in Article 1.5 for flexural members and Article 1.6 for axially loaded tension members. These requirements shall apply to the as-built unfaulted state of the member, where a member is considered faulted "when any single tension load-carrying component of the built-up member … is assumed to be completely severed" (AASHTO, 2018/2022b). If a member or section does not satisfy any one of the screening requirements, it shall remain classified as an NSTM. If all screening criteria are met, the member or section may be moved forward for further evaluation.

Article 1.4 also requires the built-up member to meet all applicable strength requirements as well as possess remaining fatigue life in the unfaulted state. Thus, in cases where calculations indicate that the fatigue life has been exhausted in the unfaulted state, the member shall remain classified as an NSTM. However, in such cases INDOT may elect to collect field measurements to produce stress-range histograms to obtain a more accurate estimate of the existing fatigue damage and subsequent remaining life. When such a decision is made, INDOT's processes to be used for field instrumentation and field data analysis are discussed later in this report.

Once it was established that the member possesses adequate remaining fatigue life, the next step was to

evaluate the strength in the faulted state to determine if the member has sufficient capacity and can function in service until the next inspection without further damage. The required load to be applied in the faulted state was calculated according to Article 1.7 of the IRM Guide Specification. Using the calculated loads, factored stresses were calculated per Articles 2.1 and 2.2, and the performance of the faulted member was evaluated using the provisions of Article 2.3.

If it was found the member satisfies the requirements of Article 2.3, the remaining fatigue life of the faulted member was evaluated next to establish the in-service inspection interval. Included in the IRM Guide Specification (AASHTO, 2018/2022b) is a methodology for determining the maximum frequency between special inspections. In the context of the IRM Guide Specifications, a special inspection is defined as:

> *…an inspection of sufficient depth to reliably detect severed or fractured components and other conditions deemed important in a member identified as an IRM. To meet the objectives of the Special Inspection for IRMs, it is understood that special access equipment may be required for some bridges, while for others it may be possible to reliably detect broken components from the ground using normal visual inspection techniques.*

Note that the scope and intervals for routine safety inspections (e.g., inspection for general deck condition, etc.) remain in place for the bridge, and NSTM (formerly FCM) hands-on inspections remain the same for members still classified as NSTMs. A Special IRM Inspection only replaces the NSTM designation and inspection requirements for members that are found to be reclassified as internally redundant. With the adoption of the new National Bridge Inspection Standards found in 23 CFR Part 650 that became law on June 6 of 2022 (DOT FHWA, 2022), once a member, or portion thereof, has been determined to be an Internally Redundant Member (IRM), the NSTM label can be removed and replaced with the IRM designation. Per the CFRs, members that are determined to have system or internal redundancy using an approved methodology in accordance with Section 650.313(f)(1)(i) of the NBIS shall then be designed, fabricated, and inspected at a frequency determined using a "nationally recognized method."

For members determined to satisfy the internal redundancy requirements of the IRM Guide Specification as outlined above, Article 3 of the IRM Guide Specifications (AASHTO, 2018/2022b) was used for determining the maximum interval between special inspections for the IRMs. The scope of the special inspections is such that it is capable of reliably identifying large cracks or completely severed components in IRMs. This may require special access (such as a snooper or rope access) depending on the member and overall bridge geometry. The details associated with the access for each bridge were documented as part of the special inspection for IRMs inspection plan.

While the special inspection is focused on detection of broken components as noted previously, other reportable conditions (corrosion, impact damage, etc.) found on an IRM member should also be documented and reported for use as needed in evaluating if the member needs to be reclassified as an NSTM per Article 3.2 of the IRM Guide Specifications (AASHTO, 2018/2022b). Specifically, "*Any changes in the condition of the structural member that would justify a more frequent interval and/or a different level of rigor for the special inspections for IRMs*" was evaluated to determine if the member could remain classified as an IRM.

If after an initial fatigue evaluation of the bridge, it was found that the calculated stress ranges generated from the AASHTO fatigue truck prevented all or a portion of the bridge from having sufficient remaining fatigue life to be relabeled as IRMs, field monitoring the structure was considered. Additionally, both the strength in the faulted state and the Article 1 criteria of the IRM Guide Specifications was verified to pass before instrumenting the bridge.

Stress-range histograms were developed to estimate the remaining fatigue life as prescribed in Article C7.2.2.2 of the *Manual for Bridge Evaluation* (MBE) (AASHTO, 2018/2022c) as well as other documents. The MBE prescribes that for infinite life checks, maximum stress range should be taken as the greater of the maximum stress range found during field instrumentation or 2.2 times the effective stress range.

The measured stress-range histograms were used to calculate the remaining fatigue life at locations where strain gages were not installed by scaling the calculated force ranges from the initial evaluation process. INDOT agreed to increase the maximum scaling ratio by an additional factor of 10% to account for the variation of load applications, load distributions, etc., that may occur at locations with no instrumentation.

Additionally, a reference document titled "Procedures for Reclassifying Nonredundant Steel Tension Members as Internally Redundant Members" was created for INDOT to outline the process and procedures used to satisfy Federal Highway Administration's requirements for IRM evaluation. This document can be found in Volume V.

5. DISCUSSION

In collaboration between INDOT and Purdue University to implement the guide specifications, a few bridges in the State of Indiana were selected for evaluation. A brief description of each bridge's findings and a reference to the corresponding individual detailed report is shown below.

Volume I: 041-26-03917 Girder Bridge: The evaluation demonstrated that nearly 94% of the main girders of the bridge are eligible to be reclassified as IRMs and contain a special inspection frequency of 10 years. The remainder of the main girders, to remain labeled NSTMs, did not qualify as IRMs due to lack of cover

plates or failing strength checks of fracture net section.

Volume II: I-74-06-04417 Girder Bridge: The evaluation demonstrated that 79% of the main girders of the bridge are eligible to be reclassified as IRMs and contain a special inspection frequency of 10 years. The remaining 21% of the main girders, to remain labeled NSTMs, did not qualify as IRMs due to lack of cover plates or unmitigated damage.

Volume III: 062-65-T4020 Truss Bridge: During this evaluation process it was determined that 53% of the NSTMs satisfied the requirements and were adequate in strength and fatigue to be recategorized as IRMs. Each member that did not pass failed due to the strength check, failing both the net section and gross section strength checks in the faulted state. For the truss members determined to be internally redundant, the maximum special inspection interval was calculated to be 10 years.

Volume IV: 1. Steel I-Girder Bridge: I-74-170-04684 over Whitewater River does not possess sufficient reserve strength in the faulted state when performing SRM analysis, thus bridge members currently listed as NSTMs should remain labeled as such.

2. Simple-Span Truss Bridge: SR 1 001-68-03408 over the Mississinewa River contains thirteen components that meet the performance criteria outlined in the SRM Guide Specification and thus are eligible to have the NSTM label removed and relabeled as SRMs and have the inspections adjusted accordingly. Other tensions members must remain classified as NSTMs.

3. Two-Span Truss Bridge: Matthew E Welsh Memorial Bridge, Mauckport (135-31-06504 B), does not possess considerable reserve strength in the faulted state, thus bridge members currently listed as NSTMs should remain labeled as such.

Volume V: Procedures for Reclassifying Nonredundant Steel Tension Members as Internally Redundant Members

Volume VI: Procedures for Reclassifying Nonredundant Steel Tension Members as System Redundant Members

As previously mentioned, the truss bridge 001-68-03408 over the Mississinewa River was originally included in the list for IRM evaluation. The truss bridge consists of two-component axial members that were found to have insufficient capacity in the faulted state. Thus, with INDOT approval, it was decided to evaluate this bridge for system redundancy instead of internal redundancy.

6. CONCLUSIONS

Based on our findings, the SRM and IRM evaluation process has proven to be beneficial for INDOT not only for the bridges evaluated in this report, but also in developing a standard for a state-wide implementation plan to analyze other bridges. When bridges have a targeted inspection plan at an appropriate inspection interval, there are significant improvements in safety, costs, and inspection efficacy.

Within the scope of this project related to internal and system level redundancy evaluation, INDOT can now reduce the number of NSTMs for four specific bridges evaluated and have a better understanding of the nonredundant behavior of the remaining two bridges evaluated. Furthermore, this report and all its included volumes can now serve as a guide for evaluating other bridges for redundancy in the State of Indiana.

VOLUME I: Evaluation of the Fracture Critical Status of Structure 041-26-03917 US 41 Over White River

EXECUTIVE SUMMARY

Introduction

In this report, 041-26-03917 US 41 Bridge over the White River was evaluated for the case of internal redundancy of the primary load carrying members. Each northbound (NB) and southbound (SB) bridge consists of separated superstructures carried by two riveted built-up steel plate girders. Each consists of sixteen continuous spans with no skew on a tangent alignment. It was originally built in 1958 and has had various rehabilitations and repairs completed over its lifetime.

Findings

The bridge was evaluated using the analysis procedure outlined in the *AASHTO Guide Specifications for Internal Redundancy of Mechanically-Fastened Built-Up Steel Members* adopted in 2018 (AASHTO, 2018/2022a) (IRM Guide Specification). This manual provides guidance on determining if a member that is currently labeled as a Non-Redundant Steel Tension Member (NSTM), formerly known as Fracture Critical Members (FCM), contains adequate internal redundancy to be relabeled as an Internally Redundant Member (IRM). The manual also provides strategy requirements for the inspection scope and frequency of IRMs.

The evaluation was a multi-step process in which the members were subjected to a series of checks. The first step consisted of screening general requirements that would prohibit the member from being evaluated as an IRM. These preliminary screening criteria could be validated using the bridge from the original plans, the current load rating, and inspection reports. The subsequent phases of the evaluation determined the strength and fatigue adequacy of the member. The strength capacity checks examined the yield on the gross section and fracture of the net section of the member in a faulted state. The fatigue checks evaluated the fatigue life of the member in both the unfaulted and faulted state. Using this data, the maximum interval for special inspections was determined.

A spreadsheet developed by the National Steel Bridge Alliance and Purdue University was used as a tool to complete the calculations for determining internal redundancy of a specific point of the girder along the length of the bridge (NSBA, 2020). The spreadsheet also calculates the maximum interval for special inspections, as defined in the IRM Guide Specification. Maximum moments due to dead, live, and fatigue loads were obtained using a AASHTOWare BrR model. The fatigue loads were scaled using in-situ stress ranges collected during a 2012 study performed by Purdue University on the same bridge (Sherman, 2012). To provide consistency and efficiency, an Excel Macro was developed to process each point along the bridge using the NSBA IRM spreadsheet (NSBA, 2020). The spreadsheet was primarily used as-is; however, slight modifications were required to incorporate the effective stresses collected from the long-term monitoring. The full IRM evaluation was completed at 330 points along the entire half length of the bridge. The bridge was symmetric at about Pier 8; thus the 330 points were extrapolated to remaining girder lengths.

Implementation

The evaluation demonstrated that nearly 94% of the main girders of US 41 Bridge over the White River are eligible to be reclassified as internally redundant members and are eligible to receive a special inspection at a 10-year frequency. The remainder of the main girder did not pass the checks due to lack of cover plates or failing strength checks of fracture of net section.

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1. BACKGROUND

The fracture critical member (FCM) label has been used on bridge members that have "a steel primary member or portion thereof subject to tension whose failure would probably cause a portion of or the entire bridge to collapse" (Lloyd, 2020). Once a bridge has been classified as having FCMs, the structure is required to have an in-depth arm's length inspection completed at regular intervals not to exceed 24 months throughout its service life.

Recent advancements in steel member redundancy have been made to provide guidance as to when a member should be classified as an FCM rather than simply considering the basic structural configuration. For example, research has been performed in order to utilize what is referred to as "internal member redundancy" for members comprised of multiple individual components joined using mechanical fasteners. The research focused on mechanically fastened built-up members culminated in the *AASHTO Guide Specifications for Internal Redundancy of Mechanically-Fastened Built-Up Steel Members* adopted in 2018 (AASHTO, 2018/2022b). (It is noted that throughout this report, this guide specification will be referred to as the IRM Guide Specification (AASHTO, 2018/2022b)). The intent of the IRM Guide Specification (AASHTO, 2018/2022b) is to provide a codified methodology "on how to establish whether adequate internal redundancy exists in a mechanically-fastened built-up steel member." Included in the IRM Guide Specification (AASHTO, 2018/2022b) is a methodology for determining the maximum frequency between special inspections. In the context of the IRM Guide Specifications, a special inspection is defined as the following.

> *In the specific context of these Guide Specifications, a (Special Inspection) is an inspection of sufficient depth to reliably detect severed or fractured components and other conditions deemed important in a member identified as an IRM. To meet the objectives of the Special Inspection for IRMs, it is understood that special access equipment may be required for some bridges, while for others it may be possible to reliably detect broken components from the ground using normal visual inspection techniques.*

It is noted that routine safety inspection intervals are not affected.

The analysis described in this report uses the IRM Guide Specifications (AASHTO, 2018/2022b) in conjunction with the *AASHTO Manual for Bridge Evaluation, 3rd Edition* (AASHTO, 2018/2022c) and the *AASHTO LRFD Bridge Design Specifications, 9th Edition* (AASHTO, 2020) to evaluate if members of the 041-26-03917 US 41 Bridge over the White River currently classified as FCMs may be *reclassified* as IRMs. With the adoption of the new National Bridge Inspection Standards found in 23 CFR Part 650 that became law on June 6 of 2022 (DOT FHWA, 2022), once a member, or portion thereof, has been determined to be an Internally Redundant Member (IRM), the FCM label can be removed and replaced with the IRM designation. Those members shall then be inspected using the method provided in the IRM Guide Specifications (AASHTO, 2018/2022b). Additionally, the FC designation was replaced by the term Non-Redundant Steel Tension Member (NSTM), so this report will use the NSTM designation for clarity.

2. BRIDGE DETAILS

The structure discussed in this report, 041-26-03917 US 41 Bridge over the White River, is owned by Indiana Department of Transportation (INDOT). It was originally built in 1958 but has an extensive rehabilitation history since its original construction. The work performed on the bridge includes the following.

- 1958: Originally built
- 1967: Slope wall repair and railings
- 1975: First bridge deck overlay and expansion joint repairs
- 1978: Railing replacement and/or repair
- 1986: Second bridge deck overlay, deck widening and barrier replacement
- 2000: Bridge painting
- 2020: Rigid deck overlay, superstructure repairs at the pin and hanger joint areas, installation of new/additional catch block at expansion hinges, select areas of superstructure cleaned/painted, deck joint replacement, voids filled under the north concrete slopewall, and deck drains replaced.

The bridge is located along the Gibson and Knox County line and carries an estimated average daily traffic (ADT) of over eleven thousand vehicles (based on traffic count data from 2021). The structure consists of two side-by-side twin bridges that are individually carried by two riveted built-up steel plate girders. These girders are currently labeled as NSTMs and are on a 24-month NSTM inspection frequency. A general photograph of the north elevation taken during the 2021 routine and fracture critical inspections can be found in Figure 2.1.

The riveted built-up transverse floor beams are not spaced on center intervals greater than 14 ft and stringers are continuous over the beam; therefore, the transverse floor beams are not considered to be NSTMs (Hartle et al., 2006). The bridge was also the subject of a detailed field instrumentation study performed by Purdue University in 2012 to evaluate the effects of super loads on the bridge as well as to perform a complete fatigue evaluation (Sherman, 2012).

The most recent fracture critical and routine inspection was performed in 2021. The structure was found to be in satisfactory to good condition. The Fracture Critical Members and components were described as predominantly sound and did not exhibit any structural issues, cracking, advanced section loss or problems that would adversely impact the load carrying capacity of the bridge. Some minor areas of section loss (1/16″–1/8″) were noted on each of the girders under the leaking



Figure 2.1 General north elevation view.

deck joints. Additionally, the girders exhibited localized areas of pack rust on the bottom flanges. These minor issues had no effect on the load rating of the structure and therefore did not disqualify the member from being evaluated using the IRM Guide Specification (AASHTO, 2018/2022b). It is to be noted that because the most recent fracture critical inspection was performed in 2021 the evaluation performed shall use 2021 as the "current year" for consumed and remaining fatigue life calculations.

Additional special inspections are performed on a 60-month inspection cycle to perform visual examinations and nondestructive testing of the pin and hanger connections of the bridge. The most recent special inspection of this nature was conducted by WJE in November of 2018. The pin and hangers on the White River Bridge have been retrofitted, but no guidance is provided in the IRM Guide Specifications (AASHTO, 2018/2022b) to evaluate retrofitted pin and hanger assemblies. This special inspection would need to be continued regardless of the outcome of the IRM evaluation described in this report as pin and hanger assemblies do not qualify as internally redundant members.

The load rating of this structure was performed by Michael Baker in 2018 using a AASHTOWare BrR model. The model utilized the LFD rating method with HS20 design load. The rating of the main girders was controlled by overload constructability check and were neglected since the bridge was already constructed and in service. All girder flexure and shear ratings were greater than 1.0 and did not control the rating. Main girder related construction plans from the original construction in 1958 can be found in Appendix E. All remaining bridge related documents including original bridge plans, rehabilitation plans, inspection reports and load ratings can be found in the INDOT BIAS/ERMS database.

2.1 Geometric Information

The bridge consists of sixteen continuous spans with the first and last span measuring 111′–3″ with the remaining spans having a length of 155′–9″. The girders are spaced at 24′–6″ center-to-center with a clear roadway of 29′–0″. The deck has an out-to-out distance of 32′–6″ with a left and right overhang of 4′–0″. The bridge has no skew and is on a tangent alignment. Each superstructure carries two 12′ lanes with 2′–4″ shoulders on both sides. The side-by-side twin superstructures are identical thus the findings of this evaluation apply to both structures. The typical sections of the superstructure/deck are displayed in Figure 2.2 and Figure 2.3.

The main girders are the only NSTMs within the bridge and thus were the only members evaluated for internal redundancy. The built-up girders consist of thirteen different primary cross-sectional variations based on the number of cover plates and cover plate thicknesses. The bridge girders are symmetric about Pier 8 and are haunched (increased web depth) at pier locations to account for negative moments. The bridge also has four hinge locations per girder and some girder areas that have no cover plates. A summary of the girder variation can be found in Figure 2.4, and the elevation view of the bridge with the cross-section variations identified can be found in Appendix B.

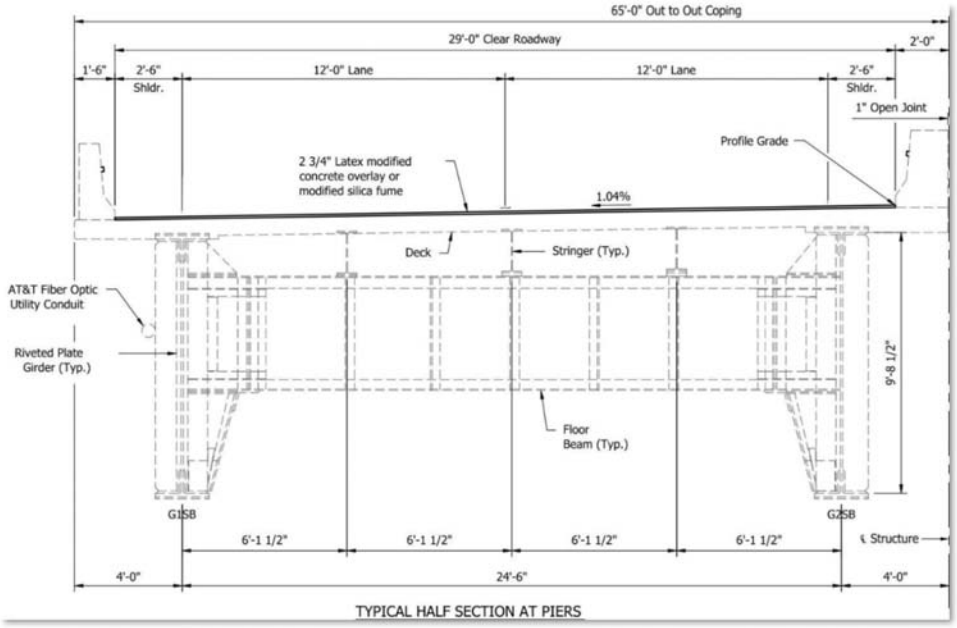


Figure 2.2 Typical half section at piers.

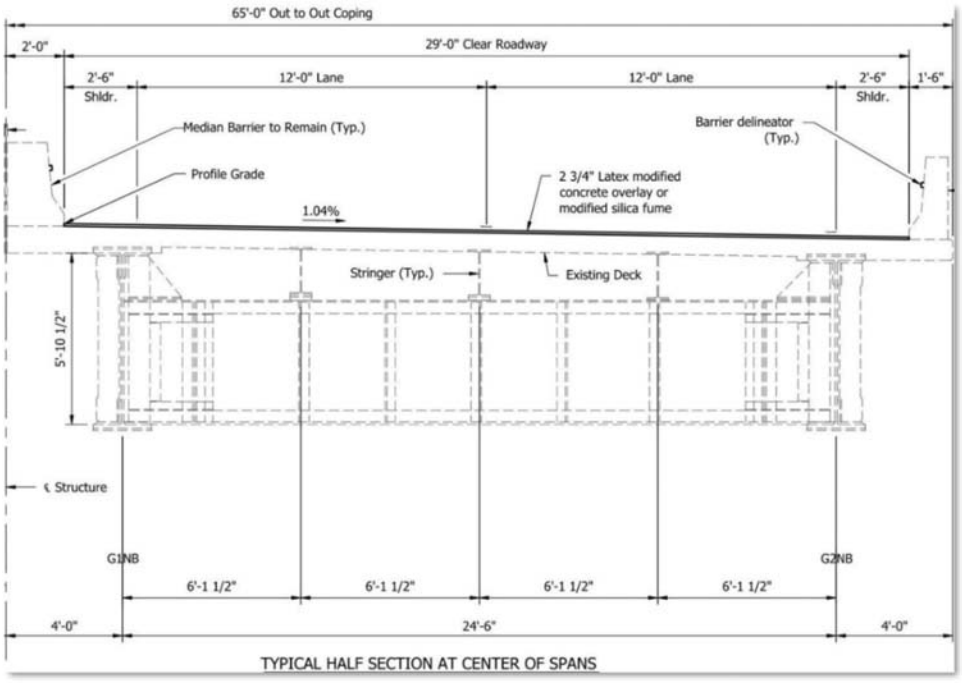


Figure 2.3 Typical half section at center of spans.

XSec Variation	# Cover Plates	Flange Angle	Web Thickness	Cover Plate Top and Bottom (1)	Cover Plate Top and Bottom (2)	Cover Plate Top and Bottom (3)
			in	in	in	in
0	0	L8X8X7/8	1/2	-	-	-
1	1	L8X8X7/8	1/2	20x7/16	-	-
2	2	L8X8X7/8	1/2	20x7/16	20x7/16	-
3	1	L8X8X7/8	1/2	20x11/16	-	-
4	2	L8X8X7/8	1/2	20x11/16	20x5/8	-
5	1	L8X8X7/8	1/2	20x11/16	20x11/16	-
6	1	L8X8X7/8	1/2	20x11/16	20x1/2	-
7	3	L8X8X7/8	1/2	20x11/16	20x1/2	20x7/16
8	2	L8X8X7/8	1/2	20x11/16	20x7/16	-
9	3	L8X8X7/8	1/2	20x11/16	20x7/16	20x7/16
10	3	L8X8X7/8	1/2	20x11/16	20x11/16	20x1/2
11	3	L8X8X7/8	1/2	20x11/16	20x5/8	20x1/2
12	3	L8X8X7/8	1/2	20x11/16	20x1/2	20x1/2

Figure 2.4 Girder cross-sectional variations.

3. PREVIOUS TESTING ON THE US 41 BRIDGE

In 2012 a study was conducted by Sherman, Mueller, Connor, and Bowman of Purdue University on the US 41 bridge over White River. The research project was titled *Evaluation of Effects of Super-Heavy Loading on the US-41 Bridge over the White River* (SPR-3472) and was part of the Joint Transportation Research Program (JTRP) (Sherman et al., 2012). The primary objective of that project was to study and identify any negative effects of a series of super-heavy loads on the overall bridge performance. To accomplish this goal, live load testing and long-term field monitoring of the bridge was conducted over a period of about a year.

The original construction plans, and most recent rehabilitation plans do not show shear studs connecting the deck with the girders. However, as is commonly observed, the experimental work found that the rivet heads of the main girder reduced the slip at contact surface of the deck and girders, initiating the development of full composite action. The results of the 2012 study and the 2018 load rating of the bridge performed by Michael Baker assumed the girder to be fully composite with the deck. Full composite behavior was also assumed during the current IRM evaluation.

During the 2012 study seven cross sections on the main girders were selected for inclusion in a long-term monitoring study of the bridge. The data confirmed that the girders were behaving compositely as previously stated. Additionally, the data showed that the in-situ stress ranges (collected over a period of months) were generally much less than estimated using the AASHTO fatigue truck. This is commonly the case as well reported in many field studies where live load stresses on in-service bridges are measured. The measured stress-range histograms were used to calculate the remaining fatigue life by scaling the calculated moment ranges obtained from AASHTOWare BrR model. This approach is commonly used to provide a more accurate fatigue life estimate and is permitted in the IRM Guide Specifications (AASHTO, 2018/2022b).

The advantage of scaling the calculated values allows stress ranges to be estimated at all locations on the bridge, including those where strain measurements were not made directly. A comparison of the in-service effective stress ranges and those obtained from AASHTOWare BrR is shown in Figure 3.1.

As shown, the actual effective stress ranges found during the 2012 study were consistently lower than calculated assuming the AASHTO fatigue truck by a ratio ranging from 0.29 to 0.45. In fact, the highest effective stress ratio was only 0.45 at the location of the maximum positive moment in span N. However, it is recognized that there may be locations where higher ratios exist, but measurements were not made. To be conservative, the authors applied an adjustment factor of 10% to the 0.45 to provide a conservative correlation between the effective stress range data with the effective stress range calculated from the AASHTOWare BrR model. This factor, selected by the authors, is intended

XSec	Strain Gauge	Location (ft)	Eff Stress BrR (ksi)	Eff Stress Field Test (ksi)	Eff Stress Ratio	Location	Cycles/ day
XSec-10	CH 2	500.625/1902.375	5.8	2.1	0.36	Max Positive Moment Span N	558
XSec-3	CH 4	452.125/1950.875	9.5	2.8	0.29	Inflection Point Span N	1005
XSec-9	CH 5	422.75/1980.25	5.7	2.5	0.44	Max Negative Moment @ Pier 13	0
XSec-9	CH 6	422.75/1980.25	4.9	2.1	0.43	Max Negative Moment @ Pier 13	6
XSec-9	CH 12	422.75/1980.25	4.9	2.2	0.45	Max Negative Moment @ Pier 13	6
XSec-4	CH 24	344.875/2067.75	4.4	2.0	0.45	Max Positive Moment Span P	421
XSec-4	CH 26	344.875/2067.75	4.4	2.0	0.45	Max Positive Moment Span P	38

Figure 3.1 Effective stress ranges of girders.

to account for the variability of application of loads, variation in load distribution, etc. that may be occurring in areas where instrumentation was not installed. After application, this resulted in an amplified scale factor of 0.495. (*It is noted a higher, lower, or even no factor could have been selected; however, 10% is believed to be reasonably conservative.*) As previously stated, this factor was then applied to the moment ranges generated by the fatigue truck using the AASHTOWare BrR model. The scaled maximum moments from the fatigue load were then used to complete the fatigue evaluation of the NSTMs.

It is noted that at one area of the bridge, specifically XSec-3 and XSec-10 shown in Figure 3.1 was identified to be problematic in terms of fatigue. Specifically, unrealistically low fatigue lives were estimated when the amplified 0.495 factor was applied to the moment ranges. In fact, calculated fatigue lives were significantly greater at all other locations on the bridge. However, at XSec-3 and XSec-10, the actual ratios were 0.29 and 0.36, respectively, as noted in Figure 3.1. Therefore, at this specific area, the measured data (i.e., a factor of 0.29 to 0.36) was used to estimate the remaining fatigue life to ensure the most realistic and accurate estimate of the remaining fatigue life. Linear interpolation between the specific cross section points was used to calculate the adjustment factor throughout the area of reference. Appendix A shows the specific adjustment factors used at each location along the girder length.

In addition to the true stress ranges along the length of the girder, the study conducted in 2012 also provided accurate assessment of the cycles experienced by the girder. As expected, the cycles per day varied along the length of the member. As seen in Figure 3.1, the controlling cycles per day occurred at the inflection point (1,005 cycles/day) and maximum positive moment area (558 cycles/day). As seen in Appendix A, these cycles were extrapolated to be used along the entire length of the bridge. The 1,005 cycles were used at and around each inflection point up to ten feet from the specific point of inflection. The remaining locations used the 558 cycles per day for the evaluation. Without true traffic cycle data at the construction of the bridge in 1958 it was deemed acceptable and conservative to use the same cycles found in the 2012 study for the estimation of initial traffic on the bridge.

3.1 Loads

A standard line girder analysis using the AASHTOWare BrR model was used to determine the moments developed due to dead and live loads. The dead loads applied on the girder consisted of the DC1, DC2 and DW loads. The following lists describes these loads.

- DC1 (placed prior to deck hardening and acting on the noncomposite section)
  - Self-load of girder including a percentage of additional self-load due to additional secondary items
  - Floor beam and stringer reactions
  - Deck and haunch loads
- DC2 (placed after deck hardening and acting on the long-term composite section)
  - Loads due to concrete barrier and median
- DW (wearing surfaces and utilities acting on the long-term composite section)
  - Overlay load

The live load distribution factor calculations, material properties and specific geometric details for the dead loads can be found in Appendix D. As per the IRM Guide Specifications (AASHTO, 2018/2022b), the HL-93 design vehicular live load specified in *AASHTO LRFD Bridge Design Specifications* Article 3.6.1.2.1 (AASHTO, 2020) was applied to the girder using Redundancy II load factors as per Table 1.7.1-1 of the IRM Guide Specifications (AASHTO, 2018/2022b). The total factored bending moment due to fatigue was analyzed using the passage of the fatigue truck as specified in the LRFD Design Article 3.6.1.4 for the Fatigue II load combination. A cover plate adjustment factor of 1.0 was applied to the strength checks while Equation 2.1.2-3 from the IRM Guide Specifications

	Detail/Parameter	Value	Unit	Source/Reference
Material Properties	Concrete Compressive Strength, f'_c	3	ksi	Type F Concrete, Original 1958 Plans
	Weight of Concrete, w_c	0.15	kcf	Type F Concrete, Original 1958 Plans
	Concrete Modulus of Elasticity, E_c	3625	ksi	AASHTO LRFD BDS Eq 5.4.2.4-1
	Steel Minimum Yield Strength, F_y	33	ksi	AASHTO MBE Table 6A.6.2.1-1
	Steel Minimum Tensile Strength, F_u	66	ksi	AASHTO MBE Table 6A.6.2.1-1
Traffic - For Information Only	Original ADT	4500	veh/day	Original 1958 Plans
	Original truck percentage	23	%	Original 1958 Plans
	Biodirectional factor	55	%	AASHTO LRFD BDS C3.6.1.4.2
	Fraction of Truck Traffic in a Single Lane, p	0.85		AASHTO LRFD BDS Table 3.6.1.4.2-1
	Present ADT	11322	veh/day	INDOT's online database for vehicle counts (2021)
	Present Truck Percentage	26	%	2021 Inspection Report
Additional Traffic Data	Maximum ADT	20000	veh/day	AAHSTO LRFD BDS C3.6.1.4.2
	Expected Growth Rate	1.0	%	INDOT 2020 Growth Rate data
	Number of Striped Lanes, n_L	2		2021 Inspection Report
	Stress-Range Estimate Partial Load Factor, R_s	1.0		MBE Table 7.2.2.1-1
	Number of Stress-Range Cycles per Truck, n	1.0		AAHSTO LRFD BDS Table 6.6.1.2.5-2
	Resistance Factor for Evaluation - Minimum Life, R_R	1.0		MBE Table 7.2.5.1-1

Figure 3.2 Additional details/parameters.

(AASHTO, 2018/2022b) was used for the fatigue life checks.

3.2 Additional Details

Figure 3.2 lists additional details/parameters needed to complete the IRM evaluation of the bridge NSTMs. This information can also be found in Appendix D where detailed calculations and loading information used for the IRM evaluation can be found as well. As noted in Section 4.2 of the report the true cycles found during the 2012 study were used to complete the IRM evaluation, thus some of the additional traffic parameters in Figure 3.2 are for information only and were not used for the calculations of the IRM evaluation.

4. IRM ANALYSIS/EVALUATION

The following methodology consisted of sequential checks required to evaluate if the member satisfies the requirements of internally redundant members as specified in the IRM Guide Specifications (AASHTO, 2018/2022b). If a specific location along the length of the girder did not pass all the checks, then that location cannot be defined as an IRM and must remain an NSTM.

4.1 Evaluation Requirements

The requirements found in Sections 1.4 and 1.5 of the IRM Guide Specifications (AASHTO, 2018/2022b) were used as the first step of determining the internal redundancy of the flexural members. These conditions were split into three categories: screening criteria, strength capacity check and fatigue life checks. The screening criteria included checks that could be verified with basic knowledge of the bridge found in inspection reports and bridge plans. Once the initial screening criteria were evaluated and verified, the NSTMs were evaluated using the strength capacity check and fatigue life checks.

4.2 Strength Capacity Check

After the screening criteria requirements are fulfilled, the strength capacity of the flexural member in the faulted state is checked. The IRM Guide Specification (AASHTO, 2018/2022b) defines a "faulted state" as "the condition during which an individual component of the built-up member was assumed to have severed." The stress in the faulted state was calculated by dividing the maximum moments (with the Redundancy II load factors applied) by the section properties of the faulted member at each cross section. The factored resistance was calculated using the material properties and the resistance factors specified in *AASHTO LRFD Bridge Design Specifications* Section 6.5.4.2 (AASHTO, 2020). Both yield on gross section and fracture of net section were checked to validate the strength adequacy of the member.

4.3 Fatigue Life in Unfaulted and Faulted State

The fatigue life in the unfaulted state was the next step in the evaluation. The maximum fatigue stress range at each cross section was calculated using the moment range produced by the LRFD fatigue truck using the Fatigue I load coupled with the multiple presence factor, R_p. A dynamic load allowance (impact factor) of 15% was used as prescribed in Table 3.6.2.1-1 of the *AASHTO LRFD Bridge Design Specifications* (AASHTO, 2020). The constant amplitude fatigue limit, correlated with the respective fatigue category (i.e., Category D for this case), was then compared to the maximum calculated fatigue stress range. If the constant amplitude fatigue limit was greater than the calculated maximum fatigue stress range, then that section of the girder had infinite life in the unfaulted state. If the member did not have infinite life, additional calculations were completed using the original, current, and predicted ADT data to determine if and how much total unfaulted remaining fatigue life existed.

A similar process to the unfaulted state was completed in evaluating the fatigue life in the faulted state. For the faulted state, a component was assumed to have severed and was subtracted from the cross section of the member. Additionally, an updated fatigue category based on Table 2.5-1 of the IRM Guide Specification (AASHTO, 2018/2022b) and a calculated cover-plate adjustment factor, β_{AF} was used for the evaluation. The total remaining fatigue life was calculated using the calculated total remaining unfaulted and faulted state fatigue lives in correlation with the number of accumulated years in unfaulted state as seen in Equation 2.5.3-1 of the IRM Guide Specification (AASHTO, 2018/2022b).

4.4 Maximum Interval for Special Inspections

Section 3 of the IRM Guide Specifications (AASHTO, 2018/2022b) provides guidance on determining the maximum interval for special inspections for identifying individual severed components in IRMs. This method uses the total remaining fatigue life and the case for the faulted state to estimate the maximum interval for special inspections. These inspections are intended to identify whether any of the tension components have failed. The depth and equipment used for these inspections should be based off the ability to reliably detect severed component and other conditions deemed important in a member identified as an IRM (AASHTO, 2018/2022b).

5. DISCUSSION OF RESULTS AND IMPLEMENTATION

5.1 Methodology

US 41 over White River bridge was evaluated using the previous steps as specified in the IRM Guide Specifications (AASHTO, 2018/2022b). A spreadsheet, IRM Evaluator (NSBA, 2020), created by the National Steel Bridge Alliance (NSBA), with the help of

S-BRITE Center at Purdue University, was used as a tool to evaluate the specific points along the NSTMs. This spreadsheet was tested and vetted by S-BRITE staff to assure accuracy of the tool. As stated previously, the spreadsheet was primarily used as-is, however slight modifications were required to incorporate for the effective stresses collected from the long-term monitoring. To provide consistency and efficiency an Excel Macro was developed by the research team to process each point along the bridge using the IRM Evaluator (NSBA, 2020) as a function. This process minimized the possibility of human error, increased efficiency, and allowed for many points to be evaluated in a short period of time. The evaluation was completed at 330 points along the entire half length of the bridge at 1/10th points, support locations, and section changes. The bridge contains side-by-side twin superstructures that are symmetric about Pier 8. Thus, the evaluation results can be extrapolated for the entire length of the twin superstructure. An image taken during the 2021 inspection showing both superstructures can be found in Figure 5.1.

5.2 Screening Criteria

The screening criteria included in Article 1.5 of the IRM Guide Specification were checked and verified, with the following results.

- Tack welds were noted in the inspection report; however, do not disqualify the member from the IRM evaluation.
- A traditional fracture-critical member inspection was conducted within the past 24 months with no cracks, significant corrosion or impact damage identified in the components subjected to tension.
- The inspection report did not reveal severe corrosion, impact damage or other forms of damage in the members being evaluated.
- The web plates were mechanically fastened to the tension flange cover plates with angles and rivets.
- Mechanically fastened splices connect continuous girder member however need not be evaluated for internal redundancy.
- Welds were not used to attach the web to the tension flange angles or to attach cover plate.
- All components comprising the portion of the tension flange are adequately fastened with rivets and are assumed to satisfy all strength, stitch and sealing requirements in effect at the time of design.
- All individual tension flange components including the flange angle and cover plate did not exceed 60% of the total flange gross area.

Some areas of member did not include at least one cover plate, failing the first requirement of Section 1.5 of the IRM Guide Specification (AASHTO, 2018/2022b). These areas were disqualified from the IRM evaluation and will continue requiring traditional arms-length inspection. The remaining areas passed the requirement of having at least one cover plate present along the entire length of the tension flange or within 1.5 times the web depth from the end of the member at abutments, or at pin-and-hanger details. Thus, the evaluation may continue for these locations.

5.3 Results Summary

Using the above prescribed methods only about 5% of the length of the main girders did not pass all the evaluation and would not be eligible to be recategorized as IRMs. The specific cross sections and locations failing the screening or strength criteria are summarized in Figure 5.2. The locations specified in Figure 5.2 are only for half the girder length as the bridge is symmetric about Pier 8.



Figure 5.1 Superstructure view of bridge.

Span	Section	Location Start (from Support)	Location Stop (from Support)	Distance Start (from Abutment)	Distance Stop (from Abutment)	Length	Screening Criteria Met	Strength Check	Yield on Gross, Strength Ratio	Fracture on Net, Strength Ratio	Notes
		ft	ft	ft	ft	ft					
1	XSec-0	8.75	10.42	8.75	10.42	1.67	NG	-	-	-	No Cover Plate
1	XSec-0	72.42	79.75	72.42	79.75	7.33	NG	-	-	-	No Cover Plate
2	XSec-0	28.50	36.25	139.75	147.50	7.75	NG	-	-	-	No Cover Plate
2	XSec-0	117.25	121.67	228.50	232.92	4.42	NG	-	-	-	No Cover Plate
3	XSec-0	33.92	37.25	300.92	304.25	3.33	NG	-	-	-	No Cover Plate
3	XSec-0	113.25	113.63	380.25	380.63	0.38	NG	-	-	-	Outside 1.5D by 0.375'
3	XSec-0	122.38	125.05	388.04	390.71	2.67	NG	-	-	-	Pin and Hanger Location
4	XSec-8	18.75	22.25	441.50	445.00	3.50	OK	NG	1.46	0.96	Strength Check Failure
4	XSec-3	27.67	33.38	450.42	456.13	5.71	OK	NG	1.21	0.81	Strength Check Failure
4	XSec-0	119.42	121.17	542.17	543.92	1.75	NG	-	-	-	No Cover Plate
5	XSec-3	26.00	31.15	604.50	609.65	5.15	OK	NG	1.39	0.92	Strength Check Failure
5	XSec-3	124.60	130.00	703.10	708.50	5.40	OK	NG	1.39	0.93	Strength Check Failure
6	XSec-0	34.67	35.67	768.92	769.92	1.00	NG	-	-	-	No Cover Plate
6	XSec-3	125.21	128.75	859.46	863.00	3.54	OK	NG	1.22	0.81	Strength Check Failure
7	XSec-0	32.04	34.71	922.05	924.71	2.67	NG	-	-	-	Pin and Hanger Location
7	XSec-0	43.08	44.04	932.12	933.08	0.96	NG	-	-	-	Outside 1.5D by 0.96'
7	XSec-0	120.08	120.50	1010.08	1010.50	0.42	NG	-	-	-	No Cover Plate
8	XSec-0	32.75	38.00	1078.50	1083.75	5.25	NG	-	-	-	No Cover Plate
8	XSec-0	117.00	120.75	1162.75	1166.50	3.75	NG	-	-	-	No Cover Plate

Figure 5.2 Areas **not** passing IRM checks.

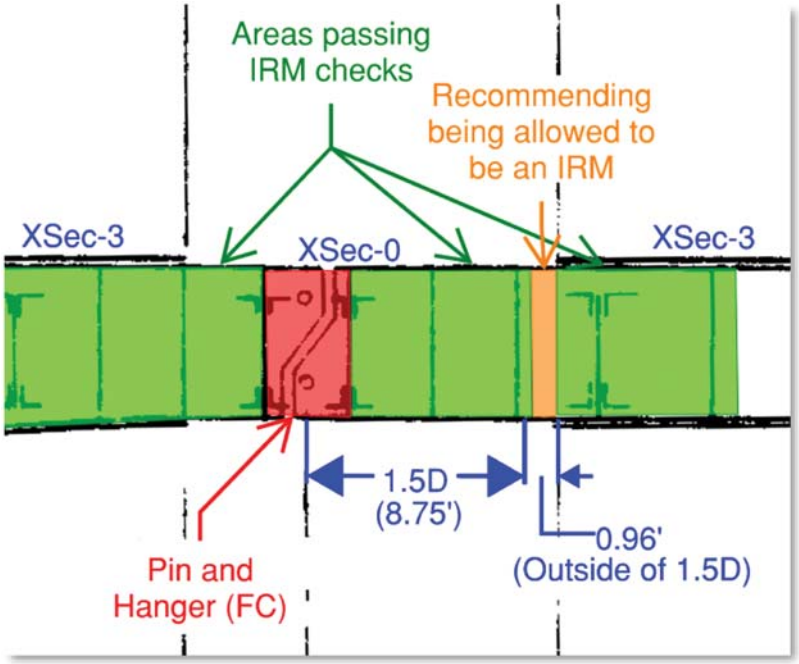


Figure 5.3 Pin and hanger.

Most of the failing sections of girder were due to the lack of cover plates (requirement of Section 1.5 of IRM Guide Specification (AASHTO, 2018/2022b)) and are defined as XSec-0. Additionally, there are four areas along the half length of the main girder that do not pass the net section fracture checks in the faulted state. Two pin and hanger locations exist along the half-length of the main girder and hence, by default, these regions must still be inspected as they are not included in the IRM evaluation.

However, while the pin and hangers themselves must still be inspected as NSTMs, the actual girders in these regions can still be evaluated as IRMs. Specifically, the IRM Guide Specification (AASHTO, 2018/2022b) states that within a distance of 1.5D from the end of the girder, where D is the depth of the web plate, the member need not be evaluated as an IRM since the moment and moment range in the girder is very low at such locations. For these girders, the region within the length of 1.5D includes all the areas without cover plates immediately adjacent to the pin and hangers other than a short length of less than 12 inches. Purdue recommends that an exception be made for these short locations. It is noted that the 1.5D criteria was put forth by Purdue when writing the AASHTO Guide Specifications and arrived at the 1.5D criteria based on group consensus. In other words, there are no engineering reasons why the criteria could not have

been 1.75D for example. It is simply a criterion implemented to avoid eliminating many girders where there are not cover plates in the regions immediately adjacent to the ends of girders. The pin and hanger evaluation and recommendation are illustrated in Figure 5.3.

A 14-foot area in span six (from 122.38′ to 136.5′ from Pier 5) contains an area that did not pass the IRM strength check in addition to having a maximum inspection interval ranging from 0.5 years to 8 years. Even though some of this area qualifies as IRMs, Purdue recommends that this area remain a NSTM and be inspected as such. The remaining regions of the girders, nearly 94% of the full length, satisfy the IRM Guide Specifications and should be relabeled as IRMs. The maximum inspection interval for the IRMs was calculated to be 10 years for the remaining girder length.

The results of the evaluation can be found in a table form in Appendix A as well as graphical form using the elevation view in Appendix B. The maximum moments and variable parameters needed for the evaluation of the girder at points of interest can be found in Appendix C. A specific breakdown of the of the inspection frequency and descriptions can be found in Appendix G which contains the proposed inspection plan for the bridge. There was a controlling location for each cross-section type for both the strength capacity check in the faulted state and the fatigue checks. This is because the maximum moment for strength was not necessarily the exact same location in the section where the fatigue moment range was maximum, which is not uncommon. Both controlling states for each cross-sectional variation can be found in Appendix F.

6. CONCLUSION

Presently (2022), the US 41 Bridge over the White River is classified as having NSTM; hence it is subjected to hands-on and arms-length field inspections every 2 years. During this evaluation process it was determined that the majority of the NSTMs possess internal redundancy and should be reclassified as IRMs.

The bridge was evaluated using the procedures outlined in the IRM Guide Specification adopted in 2018 (AASHTO, 2018/2022b). The loads applied on the bridge for the evaluation included the dead, HL-93 and fatigue truck loads factored using the Redundancy II load factors as specified in Table 1.7.1-1 of the IRM Guide Specification (AASHTO, 2018/2022b) and Table 3.4.1-1 of the *AASHTO LRFD Bridge Design Specification* (AASHTO, 2020). The loads were applied to the girder using a AASHTOWare BrR model in order to determine the maximum moments at 330 points along the entire half length of the bridge at 1/10th points, support locations, and section changes. A NSBA spreadsheet (NSBA, 2020) was then utilized to determine the strength capacity of the faulted member, fatigue life of the unfaulted and faulted member and maximum interval for special inspections (AASHTO, 2018/2022b).

Approximately 94% of the girder length satisfied the requirements of the IRM evaluation and had a maximum special inspection interval of 10 years. The remaining girder length did not pass the evaluation. These unsatisfactory areas were due to either not having a cover plate, which is a requirement of Section 1.5 of the IRM Guide Specification (AASHTO, 2018/2022b) or did not pass the fracture on net section strength check.

APPENDICES

Appendix 1A. Summary Table of Results

Appendix 1B. Graphical Summary of Results

Appendix 1C. Summary Table of Variable Parameters

Appendix 1D. Bridge Geometry, Material Properties, and Loading

Appendix 1E. Original 1958 Plan Set

Appendix 1F. NSBA Spreadsheet Calculations of the Controlling Location at Each Cross-Sectional Variation Location

Appendix 1G. NSTM/IRM Inspection Plan for Structure 041-26-03917, US 41 Over White River

Appendix 1A. Summary Table of Results

Span	Section	Location (from Support)	Distance (from Abut)	Screening Criteria Met	Strength Check	Yield on Gross, Strength Ratio	Fracture on Net, Strength Ratio	Fatigue Case	Stress range in unfaulted state, Δf_{UFS}	Controlling stress range in faulted state, Δf_{FS}	Controlling faulted state remaining fatigue life, Y_{REM}	Total remaining fatigue life, N_f	Maximum Interval	Notes
		ft	ft	OK or NG	OK or NG	Less than 1 = NG	Less than 1 = NG	I(a), I(b), II	ksi	ksi	Years	Years	Years	
1	-	0	0	#N/A										
1	XSec-0	10.42	10.42	NG	-	-	-	-	-	-	-	-	-	First 8.75' (1.5D) -> OK
1	XSec-1	10.42	10.42	OK	OK	3.23	2.13	I(a)	1.14	1.84	Infinite	Infinite	10	
1	XSec-1	11.13	11.13	OK	OK	3.05	2.01	I(a)	1.21	1.95	Infinite	Infinite	10	
1	XSec-1	17.92	17.92	OK	OK	2.09	1.38	I(a)	1.77	2.85	Infinite	Infinite	10	
1	XSec-2	17.92	17.92	OK	OK	2.62	1.72	I(a)	1.49	2.42	Infinite	Infinite	10	
1	XSec-2	22.25	22.25	OK	OK	2.26	1.48	I(a)	1.73	2.82	Infinite	Infinite	10	
1	XSec-2	33.38	33.38	OK	OK	1.85	1.22	I(a)	2.24	3.64	Infinite	Infinite	10	
1	XSec-2	44.5	44.5	OK	OK	1.77	1.16	I(a)	2.50	4.06	Infinite	Infinite	10	XSec-2 Controlling Strength Location
1	XSec-2	55.63	55.63	OK	OK	1.94	1.28	I(a)	2.60	4.23	Infinite	Infinite	10	
1	XSec-2	63.92	63.92	OK	OK	2.31	1.51	I(a)	2.61	4.26	Infinite	Infinite	10	XSec-2 Controlling Fatigue Location
1	XSec-1	63.92	63.92	OK	OK	1.85	1.22	I(b)	3.12	5.02	65.84	65.84	10	XSec-1 Controlling Fatigue and Strength
1	XSec-1	66.75	66.75	OK	OK	2.03	1.33	I(b)	3.09	4.98	66.95	66.95	10	
1	XSec-1	72.42	72.42	OK	OK	2.63	1.72	I(b)	3.00	4.83	71.70	71.70	10	
1	XSec-0	72.42	72.42	NG	-	-	-	-	-	-	-	-	-	No Cover Plate
1	XSec-0	77.88	77.88	NG	-	-	-	-	-	-	-	-	-	No Cover Plate
1	XSec-0	79.75	79.75	NG	-	-	-	-	-	-	-	-	-	No Cover Plate
1	XSec-3	79.75	79.75	OK	OK	2.22	1.48	I(b)	3.06	5.50	53.62	53.62	10	
1	XSec-3	89	89	OK	OK	1.57	1.05	I(a)	2.53	4.53	Infinite	Infinite	10	
1	XSec-3	90.25	90.25	OK	OK	1.53	1.02	I(a)	2.42	4.33	Infinite	Infinite	10	
1	XSec-4	90.25	90.25	OK	OK	2.16	1.43	I(a)	1.89	3.21	Infinite	Infinite	10	
1	XSec-4	100.13	100.13	OK	OK	1.81	1.19	I(a)	1.50	2.53	Infinite	Infinite	10	
1	XSec-4	110.25	110.25	OK	OK	1.70	1.11	I(a)	1.22	2.03	Infinite	Infinite	10	
1	XSec-4	111.25	111.25	OK	OK	1.66	1.09	I(a)	1.22	2.02	Infinite	Infinite	10	
2	XSec-4	0	111.25	OK	OK	1.66	1.09	I(a)	1.22	2.02	Infinite	Infinite	10	
2	XSec-4	1	112.25	OK	OK	1.70	1.12	I(a)	1.18	1.97	Infinite	Infinite	10	
2	XSec-4	11.13	122.38	OK	OK	1.85	1.22	I(a)	1.12	1.89	Infinite	Infinite	10	
2	XSec-4	15.58	126.83	OK	OK	2.04	1.35	I(a)	1.16	1.97	Infinite	Infinite	10	
2	XSec-4	17	128.25	OK	OK	2.13	1.41	I(a)	1.17	1.98	Infinite	Infinite	10	
2	XSec-3	17	128.25	OK	OK	1.51	1.01	I(a)	1.50	2.66	Infinite	Infinite	10	
2	XSec-3	22.25	133.5	OK	OK	1.86	1.24	I(a)	1.87	3.35	Infinite	Infinite	10	
2	XSec-3	28.5	139.75	OK	OK	2.71	1.80	I(a)	2.28	4.10	Infinite	Infinite	10	
2	XSec-0	28.5	139.75	NG	-	-	-	-	-	-	-	-	-	No Cover Plate
2	XSec-0	31.15	142.4	NG	-	-	-	-	-	-	-	-	-	No Cover Plate
2	XSec-0	33.38	144.63	NG	-	-	-	-	-	-	-	-	-	No Cover Plate
2	XSec-3	36.25	147.5	OK	OK	3.37	2.21	I(a)	2.18	3.89	Infinite	Infinite	10	
2	XSec-3	44.5	155.75	OK	OK	2.00	1.31	I(a)	2.45	4.35	Infinite	Infinite	10	
2	XSec-3	46.73	157.97	OK	OK	1.82	1.20	I(a)	2.50	4.46	Infinite	Infinite	10	
2	XSec-3	47.42	158.67	OK	OK	1.78	1.17	I(a)	2.52	4.49	Infinite	Infinite	10	
2	XSec-5	47.42	158.67	OK	OK	2.47	1.62	I(a)	1.98	3.43	Infinite	Infinite	10	
2	XSec-5	55.63	166.88	OK	OK	1.96	1.29	I(a)	2.11	3.65	Infinite	Infinite	10	
2	XSec-5	62.3	173.55	OK	OK	1.75	1.15	I(a)	2.16	3.74	Infinite	Infinite	10	
2	XSec-5	66.75	178	OK	OK	1.67	1.10	I(a)	2.17	3.76	Infinite	Infinite	10	
2	XSec-5	77.88	189.13	OK	OK	1.60	1.05	I(a)	2.21	3.83	Infinite	Infinite	10	
2	XSec-5	89	200.25	OK	OK	1.67	1.10	I(a)	2.32	4.02	Infinite	Infinite	10	
2	XSec-5	93.45	204.7	OK	OK	1.76	1.16	I(a)	2.33	4.03	Infinite	Infinite	10	

Span	Section	Location (from Support)	Distance (from Abut)	Screening Criteria Met	Strength Check	Yield on Gross, Strength Ratio	Fracture on Net, Strength Ratio	Fatigue Case	Stress range in unfaulted state, Δf_{UFS}	Controlling stress range in faulted state, Δf_{FS}	Controlling faulted state remaining fatigue life, Y_{REM}	Total remaining fatigue life, N_f	Maximum Interval	Notes
		ft	ft	OK or NG	OK or NG	Less than 1 = NG	Less than 1 = NG	I(a), I(b), II	ksi	ksi	Years	Years	Years	
2	XSec-5	100.13	211.38	OK	OK	1.98	1.30	I(a)	2.30	3.99	Infinite	Infinite	10	
2	XSec-5	106.42	217.67	OK	OK	2.35	1.54	I(a)	2.23	3.87	Infinite	Infinite	10	
2	XSec-3	106.42	217.67	OK	OK	1.70	1.12	I(b)	2.84	5.06	96.90	96.90	10	
2	XSec-3	109.03	220.28	OK	OK	1.87	1.23	I(b)	2.79	4.97	66.82	66.82	10	
2	XSec-3	111.25	222.5	OK	OK	2.05	1.35	I(b)	2.75	4.89	69.26	69.26	10	
2	Xsec-3	117.25	228.5	OK	OK	2.95	1.94	I(b)	2.59	4.61	78.36	78.36	10	
2	XSec-0	117.25	228.5	NG	-	-	-	-	-	-	-	-	-	No Cover Plate
2	XSec-3	121.67	232.92	OK	OK	2.83	1.86	I(a)	2.46	4.37	Infinite	Infinite	10	
2	XSec-3	122.38	233.63	OK	OK	2.31	1.54	I(b)	2.95	5.30	57.80	57.80	10	
2	XSec-3	124.6	235.85	OK	OK	2.05	1.36	I(b)	2.86	5.14	61.99	61.99	10	
2	XSec-3	130.75	242	OK	OK	1.55	1.03	I(b)	2.53	4.53	118.73	118.73	10	
2	XSec-6	130.75	242	OK	OK	2.19	1.45	I(a)	2.05	3.36	Infinite	Infinite	10	
2	XSec-6	133.5	244.75	OK	OK	1.98	1.31	I(a)	1.89	3.10	Infinite	Infinite	10	
2	XSec-6	139.25	250.5	OK	OK	1.68	1.11	I(a)	1.58	2.57	Infinite	Infinite	10	
2	XSec-7	139.25	250.5	OK	OK	2.03	1.34	I(a)	1.36	2.22	Infinite	Infinite	10	
2	XSec-7	140.18	251.43	OK	OK	1.99	1.32	I(a)	1.34	2.19	Infinite	Infinite	10	
2	XSec-7	144.63	255.88	OK	OK	1.85	1.22	I(a)	1.26	2.05	Infinite	Infinite	10	
2	XSec-7	154.75	266	OK	OK	1.76	1.16	I(a)	1.02	1.65	Infinite	Infinite	10	
2	XSec-7	155.75	267	OK	OK	1.73	1.13	I(a)	1.01	1.64	Infinite	Infinite	10	XSec-7 Controlling Strength Location
3	XSec-7	0	267	OK	OK	1.73	1.13	I(a)	1.01	1.64	Infinite	Infinite	10	
3	XSec-7	1	268	OK	OK	1.76	1.16	I(a)	1.01	1.64	Infinite	Infinite	10	
3	XSec-7	11.13	278.13	OK	OK	1.84	1.21	I(a)	1.25	2.04	Infinite	Infinite	10	
3	XSec-7	15.58	282.58	OK	OK	1.96	1.30	I(a)	1.34	2.19	Infinite	Infinite	10	
3	XSec-7	16.5	283.5	OK	OK	2.00	1.32	I(a)	1.36	2.21	Infinite	Infinite	10	
3	XSec-6	16.5	283.5	OK	OK	1.65	1.09	I(a)	1.57	2.57	Infinite	Infinite	10	XSec-6 Controlling Strength Location
3	XSec-6	22.25	289.25	OK	OK	1.90	1.26	I(a)	1.89	3.09	Infinite	Infinite	10	
3	XSec-6	25	292	OK	OK	2.12	1.41	I(a)	2.03	3.33	Infinite	Infinite	10	
3	XSec-3	25	292	OK	OK	1.51	1.00	I(a)	2.50	4.48	Infinite	Infinite	10	
3	XSec-3	31.15	298.15	OK	OK	1.94	1.29	I(b)	2.85	5.13	62.43	62.43	10	
3	XSec-3	33.38	300.38	OK	OK	2.19	1.45	I(b)	2.94	5.29	58.24	58.24	10	
3	XSec-3	33.92	300.92	OK	OK	2.25	1.50	I(b)	2.96	5.32	57.30	57.30	10	
3	XSec-0	33.92	300.92	NG	-	-	-	-	-	-	-	-	-	No Cover Plate
3	XSec-0	37.25	304.25	NG	-	-	-	-	-	-	-	-	-	No Cover Plate
3	XSec-3	37.25	304.25	OK	OK	2.97	1.95	I(b)	2.54	4.53	81.51450209	81.51450209	10	
3	XSec-3	44.5	311.5	OK	OK	2.01	1.32	I(b)	2.72	4.84	70.71455067	70.71455067	10	
3	XSec-3	46.73	313.72	OK	OK	1.84	1.21	I(b)	2.76	4.91	68.57	68.57	10	
3	XSec-3	48.58	315.58	OK	OK	1.73	1.14	I(b)	2.79	4.96	100.50	100.50	10	
3	XSec-4	48.58	315.58	OK	OK	2.39	1.57	I(a)	2.23	3.80	Infinite	Infinite	10	
3	XSec-4	55.63	322.63	OK	OK	2.00	1.31	I(a)	2.28	3.88	Infinite	Infinite	10	
3	XSec-4	62.3	329.3	OK	OK	1.80	1.18	I(a)	2.27	3.86	Infinite	Infinite	10	
3	XSec-4	66.75	333.75	OK	OK	1.72	1.13	I(a)	2.28	3.87	Infinite	Infinite	10	
3	XSec-4	77.88	344.88	OK	OK	1.67	1.10	I(a)	2.19	3.72	Infinite	Infinite	10	
3	XSec-4	89	356	OK	OK	1.80	1.19	I(a)	1.92	3.27	Infinite	Infinite	10	
3	XSec-4	93.45	360.45	OK	OK	1.94	1.27	I(a)	1.76	2.99	Infinite	Infinite	10	
3	XSec-4	100.13	367.13	OK	OK	2.28	1.50	I(a)	1.47	2.51	Infinite	Infinite	10	
3	XSec-4	102.58	369.58	OK	OK	2.47	1.62	I(a)	1.36	2.30	Infinite	Infinite	10	

Span	Section	Location (from Support)	Distance (from Abut)	Screening Criteria Met	Strength Check	Yield on Gross, Strength Ratio	Fracture on Net, Strength Ratio	Fatigue Case	Stress range in unfaulted state, Δf_{UFS}	Controlling stress range in faulted state, Δf_{FS}	Controlling faulted state remaining fatigue life, Y_{REM}	Total remaining fatigue life, N_f	Maximum Interval	Notes
		ft	ft	OK or NG	OK or NG	Less than 1 = NG	Less than 1 = NG	I(a), I(b), II	ksi	ksi	Years	Years	Years	
3	XSec-3	102.58	369.58	OK	OK	1.78	1.17	I(a)	1.69	3.01	Infinite	Infinite	10	
3	XSec-3	109.03	376.03	OK	OK	2.41	1.59	I(a)	1.24	2.20	Infinite	Infinite	10	
3	XSec-3	111.25	378.25	OK	OK	2.81	1.85	I(a)	1.06	1.89	Infinite	Infinite	10	
3	XSec-3	113.25	380.25	OK	OK	3.34	2.20	I(a)	0.89	1.59	Infinite	Infinite	10	
3	XSec-0	113.25	380.25	NG	-	-	-	-	-	-	-	-	-	Outside 1.5D by 0.375'
3	XSec-0	116.14	383.14	OK	OK	4.57	3.02	I(a)	0.70	1.13	Infinite	Infinite	10	8.75' (1.5D) from Pin -> OK
3	XSec-0	121.03	388.03	OK	OK	19.80	13.09	I(a)	0.16	0.26	Infinite	Infinite	10	8.75' (1.5D) from Pin -> OK
3	XSec-0	122.38	389.38	NG	-	-	-	-	-	-	-	-	-	Pin and Hanger Location
3	XSec-0	123.73	390.73	OK	OK	16.31	10.90	I(a)	0.22	0.35	Infinite	Infinite	10	8.75' (1.5D) from Pin -> OK
3	XSec-0	124.6	391.6	OK	OK	9.81	6.56	I(a)	0.36	0.58	Infinite	Infinite	10	8.75' (1.5D) from Pin -> OK
3	XSec-0	127.17	394.17	OK	OK	4.48	3.00	I(a)	0.77	1.25	Infinite	Infinite	10	8.75' (1.5D) from Pin -> OK
3	XSec-3	127.17	394.17	OK	OK	4.79	3.19	I(a)	0.65	1.17	Infinite	Infinite	10	
3	XSec-3	128.61	395.61	OK	OK	3.66	2.44	I(a)	0.84	1.51	Infinite	Infinite	10	
3	XSec-3	133.5	400.5	OK	OK	2.09	1.39	I(a)	1.43	2.56	Infinite	Infinite	10	
3	XSec-3	133.51	400.51	OK	OK	2.10	1.39	I(a)	1.43	2.56	Infinite	Infinite	10	
3	XSec-3	134.42	401.42	OK	OK	1.95	1.30	I(a)	1.53	2.74	Infinite	Infinite	10	
3	XSec-8	134.42	401.42	OK	OK	2.73	1.81	I(a)	1.28	2.05	Infinite	Infinite	10	
3	XSec-8	140.18	407.18	OK	OK	1.99	1.32	I(a)	1.69	2.70	Infinite	Infinite	10	
3	XSec-8	140.5	407.5	OK	OK	1.97	1.30	I(a)	1.71	2.73	Infinite	Infinite	10	
3	XSec-9	140.5	407.5	OK	OK	2.34	1.55	I(a)	1.47	2.40	Infinite	Infinite	10	
3	XSec-9	144.63	411.63	OK	OK	2.06	1.36	I(a)	1.63	2.66	Infinite	Infinite	10	
3	XSec-9	154.75	421.75	OK	OK	1.82	1.20	I(a)	1.76	2.85	Infinite	Infinite	10	
3	XSec-9	155.75	422.75	OK	OK	1.78	1.17	I(a)	1.79	2.90	Infinite	Infinite	10	
4	XSec-9	0	422.75	OK	OK	1.78	1.17	I(a)	1.79	2.90	Infinite	Infinite	10	
4	XSec-9	1	423.75	OK	OK	1.80	1.19	I(a)	1.80	2.92	Infinite	Infinite	10	
4	XSec-9	11.13	433.88	OK	OK	1.69	1.11	I(a)	2.61	4.26	Infinite	Infinite	10	
4	XSec-9	15.58	438.33	OK	OK	1.69	1.12	I(b)	3.08	5.03	97.82	97.82	10	
4	XSec-9	18.75	441.5	OK	OK	1.73	1.15	II	3.39	5.55	52.03	25.87	10	XSec-9 Controlling Fatigue Location
4	XSec-8	18.75	441.5	OK	NG	1.46	0.96	-	-	-	-	-	-	Strength Check Failure
4	XSec-8	22.25	445	OK	OK	1.52	1.01	I(a)	2.52	4.05	Infinite	Infinite	10	
4	XSec-8	27.67	450.42	OK	OK	1.70	1.13	I(a)	2.74	4.41	Infinite	Infinite	10	
4	XSec-3	27.67	450.42	OK	NG	1.21	0.81	-	-	-	-	-	-	Strength Check Failure
4	XSec-3	31.15	453.9	OK	NG	1.35	0.90	-	-	-	-	-	-	Strength Check Failure
4	XSec-3	33.38	456.13	OK	OK	1.77	1.16	I(b)	2.86	5.10	63.24	63.24	10	
4	XSec-3	36.5	459.25	OK	OK	1.56	1.03	I(b)	2.94	5.23	59.56	59.56	10	
4	XSec-5	36.5	459.25	OK	OK	2.15	1.41	I(a)	2.31	4.00	Infinite	Infinite	10	
4	XSec-5	44.5	467.25	OK	OK	1.67	1.10	I(a)	2.43	4.21	Infinite	Infinite	10	
4	XSec-5	46.73	469.47	OK	OK	1.59	1.05	I(a)	2.46	4.26	Infinite	Infinite	10	
4	XSec-5	48.5	471.25	OK	OK	1.54	1.01	I(a)	2.48	4.29	Infinite	Infinite	10	XSec-5 Controlling Strength Location
4	XSec-10	48.5	471.25	OK	OK	1.96	1.28	I(a)	2.14	3.53	Infinite	Infinite	10	
4	XSec-10	55.63	478.38	OK	OK	1.76	1.15	I(a)	2.18	3.59	Infinite	Infinite	10	
4	XSec-10	62.3	485.05	OK	OK	1.65	1.08	I(a)	2.18	3.59	Infinite	Infinite	10	
4	XSec-10	66.75	489.5	OK	OK	1.61	1.06	I(a)	2.15	3.56	Infinite	Infinite	10	XSec-10 Controlling Strength Location
4	XSec-10	77.88	500.63	OK	OK	1.61	1.06	I(b)	2.85	4.71	110.69	110.69	10	
4	XSec-10	89	511.75	OK	OK	1.75	1.15	I(a)	2.55	4.20	Infinite	Infinite	10	
4	XSec-10	93.45	516.2	OK	OK	1.87	1.22	I(a)	2.48	4.09	Infinite	Infinite	10	

Span	Section	Location (from Support)	Distance (from Abut)	Screening Criteria Met	Strength Check	Yield on Gross, Strength Ratio	Fracture on Net, Strength Ratio	Fatigue Case	Stress range in unfaulted state, Δf_{UFS}	Controlling stress range in faulted state, Δf_{FS}	Controlling faulted state remaining fatigue life, Y_{REM}	Total remaining fatigue life, N_f	Maximum Interval	Notes
		ft	ft	OK or NG	OK or NG	Less than 1 = NG	Less than 1 = NG	I(a), I(b), II	ksi	ksi	Years	Years	Years	
4	XSec-10	98.5	521.25	OK	OK	2.05	1.35	I(a)	2.38	3.94	Infinite	Infinite	10	
4	XSec-5	98.5	521.25	OK	OK	1.61	1.06	I(b)	2.76	4.78	107.89	107.89	10	
4	XSec-5	100.13	522.88	OK	OK	1.67	1.10	I(b)	2.72	4.71	110.79	110.79	10	
4	XSec-5	109.03	531.78	OK	OK	2.19	1.44	I(a)	2.46	4.26	Infinite	Infinite	10	
4	XSec-5	110.5	533.25	OK	OK	2.33	1.53	I(a)	2.41	4.18	Infinite	Infinite	10	
4	XSec-3	110.5	533.25	OK	OK	1.69	1.11	I(b)	3.07	5.46	53.97	53.97	10	
4	XSec-3	111.25	534	OK	OK	1.75	1.15	I(b)	3.04	5.41	55.26	55.26	10	
4	XSec-3	119.42	542.17	OK	OK	2.91	1.91	I(b)	2.67	4.75	73.58	73.58	10	
4	XSec-0	121.17	543.92	NG	-	-	-	-	-	-	-	-	-	No Cover Plate
4	Xsec-3	121.17	543.92	OK	OK	2.82	1.85	I(b)	2.59	4.61	78.56281534	78.56281534	10	
4	XSec-3	122.38	545.13	OK	OK	2.27	1.51	I(b)	3.07	5.51	52.82	52.82	10	
4	XSec-3	124.6	547.35	OK	OK	2.02	1.34	I(b)	2.94	5.28	58.38	58.38	10	
4	XSec-3	129.75	552.5	OK	OK	1.58	1.05	I(b)	2.59	4.64	77.33996644	77.33996644	10	
4	XSec-4	129.75	552.5	OK	OK	2.25	1.49	I(a)	2.01	3.42	Infinite	Infinite	10	
4	XSec-4	133.5	556.25	OK	OK	1.91	1.26	I(a)	1.77	3.01	Infinite	Infinite	10	
4	XSec-4	140.18	562.93	OK	OK	1.57	1.04	I(a)	1.61	2.72	Infinite	Infinite	10	
4	XSec-4	140.25	563	OK	OK	1.57	1.04	I(a)	1.61	2.72	Infinite	Infinite	10	
4	XSec-11	140.25	563	OK	OK	1.98	1.30	I(a)	1.37	2.26	Infinite	Infinite	10	
4	XSec-11	144.63	567.38	OK	OK	1.84	1.21	I(a)	1.33	2.19	Infinite	Infinite	10	
4	XSec-11	154.75	577.5	OK	OK	1.74	1.14	I(a)	1.36	2.22	Infinite	Infinite	10	
4	XSec-11	155.75	578.5	OK	OK	1.71	1.12	I(a)	1.39	2.27	Infinite	Infinite	10	XSec-11 Controlling Strength Location
5	XSec-11	0	578.5	OK	OK	1.71	1.12	I(a)	1.39	2.27	Infinite	Infinite	10	
5	XSec-11	1	579.5	OK	OK	1.74	1.14	I(a)	1.40	2.28	Infinite	Infinite	10	
5	XSec-11	11.13	589.63	OK	OK	1.81	1.19	I(a)	1.72	2.84	Infinite	Infinite	10	
5	XSec-11	15.58	594.08	OK	OK	1.92	1.27	I(a)	1.84	3.04	Infinite	Infinite	10	
5	XSec-11	19	597.5	OK	OK	2.07	1.37	I(a)	1.91	3.16	Infinite	Infinite	10	XSec-11 Controlling Fatigue Location
5	XSec-4	19	597.5	OK	OK	1.64	1.08	I(a)	2.25	3.82	Infinite	Infinite	10	
5	XSec-4	22.25	600.75	OK	OK	1.76	1.17	I(a)	2.29	3.90	Infinite	Infinite	10	
5	XSec-4	26	604.5	OK	OK	1.97	1.30	I(a)	2.42	4.12	Infinite	Infinite	10	XSec-4 Controlling Fatigue Location
5	XSec-3	26	604.5	OK	NG	1.39	0.92	-	-	-	-	-	-	Strength Check Failure
5	XSec-3	31.15	609.65	OK	OK	1.70	1.13	II	3.38	6.07	66.41	42.66	10	
5	XSec-3	33.38	611.88	OK	OK	1.89	1.25	II	3.47	6.23	62.79	39.45	10	
5	XSec-3	43.42	621.92	OK	OK	1.98	1.30	I(b)	3.13	5.57	51.51	51.51	10	
5	XSec-8	43.42	621.92	OK	OK	2.71	1.78	I(a)	2.67	4.28	Infinite	Infinite	10	
5	XSec-8	44.5	623	OK	OK	2.58	1.69	I(a)	2.69	4.31	Infinite	Infinite	10	
5	XSec-8	46.73	625.22	OK	OK	2.37	1.55	I(a)	2.72	4.36	Infinite	Infinite	10	
5	XSec-8	55.63	634.13	OK	OK	1.86	1.22	I(a)	2.82	4.51	Infinite	Infinite	10	
5	XSec-8	55.92	634.42	OK	OK	1.85	1.21	I(a)	2.82	4.52	Infinite	Infinite	10	
5	XSec-9	55.92	634.42	OK	OK	2.17	1.43	I(a)	2.45	4.02	Infinite	Infinite	10	
5	XSec-9	62.3	640.8	OK	OK	1.96	1.29	I(a)	2.46	4.04	Infinite	Infinite	10	
5	XSec-9	66.75	645.25	OK	OK	1.87	1.23	I(a)	2.45	4.01	Infinite	Infinite	10	
5	XSec-9	77.88	656.38	OK	OK	1.79	1.17	I(a)	2.32	3.81	Infinite	Infinite	10	
5	XSec-9	89	667.5	OK	OK	1.87	1.23	I(a)	2.44	4.00	Infinite	Infinite	10	
5	XSec-9	93.45	671.95	OK	OK	1.96	1.29	I(a)	2.45	4.02	Infinite	Infinite	10	
5	XSec-9	99.92	678.42	OK	OK	2.18	1.43	I(a)	2.43	3.99	Infinite	Infinite	10	
5	XSec-8	99.92	678.42	OK	OK	1.85	1.21	I(a)	2.79	4.48	Infinite	Infinite	10	

Span	Section	Location (from Support)	Distance (from Abut)	Screening Criteria Met	Strength Check	Yield on Gross, Strength Ratio	Fracture on Net, Strength Ratio	Fatigue Case	Stress range in unfaulted state, Δf_{UFS}	Controlling stress range in faulted state, Δf_{FS}	Controlling faulted state remaining fatigue life, Y_{REM}	Total remaining fatigue life, N_f	Maximum Interval	Notes
		ft	ft	OK or NG	OK or NG	Less than 1 = NG	Less than 1 = NG	I(a), I(b), II	ksi	ksi	Years	Years	Years	
5	XSec-8	100.13	678.63	OK	OK	1.86	1.22	I(a)	2.79	4.48	Infinite	Infinite	10	
5	XSec-8	109.03	687.53	OK	OK	2.37	1.56	I(a)	2.69	4.31	Infinite	Infinite	10	
5	XSec-8	111.25	689.75	OK	OK	2.59	1.70	I(a)	2.65	4.25	Infinite	Infinite	10	
5	XSec-8	112.42	690.92	OK	OK	2.73	1.79	I(a)	2.63	4.22	Infinite	Infinite	10	
5	XSec-3	112.42	690.92	OK	OK	1.99	1.31	I(b)	3.09	5.50	53.20	53.20	10	
5	XSec-3	122.38	700.88	OK	OK	1.92	1.28	II	3.42	6.14	40.86	19.98	10	XSec-3 Controlling Fatigue Location
5	XSec-3	124.6	703.1	OK	OK	1.73	1.15	II	3.33	5.98	68.71	44.70	10	
5	XSec-3	130	708.5	OK	NG	1.39	0.93	-	-	-	-	-	-	Strength Check Failure
5	XSec-4	130	708.5	OK	OK	1.98	1.31	I(a)	2.36	4.03	Infinite	Infinite	10	
5	XSec-4	133.5	712	OK	OK	1.78	1.18	I(a)	2.22	3.78	Infinite	Infinite	10	
5	XSec-4	136.75	715.25	OK	OK	1.65	1.09	I(a)	2.18	3.70	Infinite	Infinite	10	
5	XSec-11	136.75	715.25	OK	OK	2.09	1.38	I(a)	1.85	3.06	Infinite	Infinite	10	
5	XSec-11	140.18	718.68	OK	OK	1.94	1.28	I(a)	1.79	2.95	Infinite	Infinite	10	
5	XSec-11	144.63	723.13	OK	OK	1.82	1.20	I(a)	1.67	2.76	Infinite	Infinite	10	
5	XSec-11	154.75	733.25	OK	OK	1.75	1.15	I(a)	1.36	2.22	Infinite	Infinite	10	
5	XSec-11	155.75	734.25	OK	OK	1.72	1.13	I(a)	1.35	2.20	Infinite	Infinite	10	
6	XSec-11	0	734.25	OK	OK	1.72	1.13	I(a)	1.35	2.20	Infinite	Infinite	10	
6	XSec-11	1	735.25	OK	OK	1.75	1.15	I(a)	1.32	2.15	Infinite	Infinite	10	
6	XSec-11	11.13	745.38	OK	OK	1.85	1.22	I(a)	1.31	2.16	Infinite	Infinite	10	
6	XSec-11	15.58	749.83	OK	OK	1.99	1.32	I(a)	1.37	2.25	Infinite	Infinite	10	
6	XSec-11	17	751.25	OK	OK	2.06	1.36	I(a)	1.39	2.30	Infinite	Infinite	10	
6	XSec-4	17	751.25	OK	OK	1.63	1.08	I(a)	1.64	2.78	Infinite	Infinite	10	
6	XSec-4	22.25	756.5	OK	OK	1.92	1.27	I(a)	1.77	3.01	Infinite	Infinite	10	
6	XSec-4	27.25	761.5	OK	OK	2.38	1.58	I(a)	2.08	3.54	Infinite	Infinite	10	
6	XSec-3	27.25	761.5	OK	OK	1.67	1.11	I(b)	2.68	4.81	71.87524581	71.87524581	10	
6	XSec-3	31.15	765.4	OK	OK	2.03	1.35	I(b)	2.93	5.26	58.79	58.79	10	
6	XSec-3	33.38	767.63	OK	OK	2.29	1.52	I(b)	3.06	5.49	53.28	53.28	10	
6	XSec-3	34.67	768.92	OK	OK	2.84	1.87	I(b)	2.58	4.59	79.01	79.01	10	
6	XSec-0	34.67	768.92	NG	-	-	-	-	-	-	-	-	-	No Cover Plate
6	XSec-3	35.67	769.92	OK	OK	2.90	1.90	I(b)	2.63	4.68	76.15331949	76.15331949	10	
6	XSec-3	44.37	778.62	OK	OK	1.76	1.16	I(b)	3.01	5.36	56.49	56.49	10	
6	XSec-5	44.37	778.62	OK	OK	2.43	1.59	I(a)	2.36	4.10	Infinite	Infinite	10	
6	XSec-5	44.5	778.75	OK	OK	2.41	1.58	I(a)	2.37	4.10	Infinite	Infinite	10	
6	XSec-5	46.73	780.97	OK	OK	2.20	1.44	I(a)	2.44	4.22	Infinite	Infinite	10	
6	XSec-5	55.63	789.88	OK	OK	1.68	1.10	I(b)	2.69	4.65	113.1072583	113.1072583	10	
6	XSec-5	57.25	791.5	OK	OK	1.62	1.06	I(b)	2.72	4.72	110.3050081	110.3050081	10	
6	XSec-10	57.25	791.5	OK	OK	2.06	1.35	I(a)	2.35	3.89	Infinite	Infinite	10	
6	XSec-10	62.3	796.55	OK	OK	1.88	1.23	I(a)	2.44	4.04	Infinite	Infinite	10	
6	XSec-10	66.75	801	OK	OK	1.77	1.16	I(a)	2.51	4.14	Infinite	Infinite	10	
6	XSec-10	77.88	812.13	OK	OK	1.63	1.07	I(b)	2.79	4.61	115.0513979	115.0513979	10	
6	XSec-10	89	823.25	OK	OK	1.63	1.07	I(b)	3.03	5.00	99.01	99.01	10	
6	XSec-10	93.45	827.7	OK	OK	1.67	1.10	I(b)	3.11	5.14	93.97	93.97	10	
6	XSec-10	100.13	834.38	OK	OK	1.78	1.17	II	3.20	5.28	88.92	59.57	10	
6	XSec-10	108.25	842.5	OK	OK	2.03	1.33	II	3.24	5.35	86.64	57.51	10	XSec-10 Controlling Fatigue Location
6	XSec-5	108.25	842.5	OK	OK	1.60	1.05	II	3.75	6.50	57.12	32.99	10	
6	XSec-5	109.03	843.28	OK	OK	1.62	1.06	II	3.75	6.50	57.10	32.97	10	

Span	Section	Location (from Support)	Distance (from Abut)	Screening Criteria Met	Strength Check	Yield on Gross, Strength Ratio	Fracture on Net, Strength Ratio	Fatigue Case	Stress range in unfaulted state, Δf_{UFS}	Controlling stress range in faulted state, Δf_{FS}	Controlling faulted state remaining fatigue life, Y_{REM}	Total remaining fatigue life, N_f	Maximum Interval	Notes
		ft	ft	OK or NG	OK or NG	Less than 1 = NG	Less than 1 = NG	I(a), I(b), II	ksi	ksi	Years	Years	Years	
6	XSec-5	111.25	845.5	OK	OK	1.71	1.12	II	3.75	6.49	57.20	33.06	10	
6	XSec-5	122.38	856.63	OK	OK	2.49	1.63	II	3.64	6.30	38.25	16.01	10	
6	XSec-5	124.6	858.85	OK	OK	1.98	1.31	II	4.21	7.32	26.00	4.53	2	XSec-5 Controlling Fatigue Location
6	XSec-5	125.21	859.46	OK	OK	1.94	1.28	II	4.20	7.30	26.22	4.75	2	
6	XSec-3	125.21	859.46	OK	NG	1.36	0.90	-	-	-	-	-	-	Strength Check Failure
6	XSec-3	128.75	863	OK	NG	1.22	0.81	-	-	-	-	-	-	Strength Check Failure
6	XSec-8	128.75	863	OK	OK	1.71	1.14	II	4.48	7.19	27.26	0.52	0.5	XSec-8 Controlling Fatigue Location
6	XSec-8	133.5	867.75	OK	OK	1.55	1.03	II	4.14	6.64	33.57	7.16	4	
6	XSec-8	136.5	870.75	OK	OK	1.51	1.00	II	3.81	6.09	41.56	14.88	8	
6	XSec-9	136.5	870.75	OK	OK	1.80	1.19	II	3.26	5.35	56.65	30.07	10	
6	XSec-9	140.18	874.43	OK	OK	1.72	1.14	I(b)	2.95	4.82	106.0188082	106.0188082	10	
6	XSec-9	144.63	878.88	OK	OK	1.71	1.13	I(a)	2.50	4.07	Infinite	Infinite	10	XSec-9 Controlling Strength Location
6	XSec-9	154.75	889	OK	OK	1.81	1.19	I(a)	1.74	2.82	Infinite	Infinite	10	
6	XSec-9	155.75	890	OK	OK	1.78	1.17	I(a)	1.73	2.81	Infinite	Infinite	10	
7	XSec-9	0	890	OK	OK	1.78	1.17	I(a)	1.73	2.81	Infinite	Infinite	10	
7	XSec-9	1	891	OK	OK	1.82	1.20	I(a)	1.70	2.75	Infinite	Infinite	10	
7	XSec-9	11.13	901.13	OK	OK	2.07	1.36	I(a)	1.58	2.57	Infinite	Infinite	10	
7	XSec-9	14.75	904.75	OK	OK	2.30	1.52	I(a)	1.44	2.36	Infinite	Infinite	10	
7	XSec-8	14.75	904.75	OK	OK	1.94	1.28	I(a)	1.68	2.68	Infinite	Infinite	10	
7	XSec-8	15.58	905.58	OK	OK	2.00	1.32	I(a)	1.64	2.61	Infinite	Infinite	10	
7	XSec-8	21	911	OK	OK	2.67	1.77	I(a)	1.26	2.02	Infinite	Infinite	10	
7	XSec-3	21	911	OK	OK	1.91	1.27	I(a)	1.51	2.70	Infinite	Infinite	10	
7	XSec-3	22.25	912.25	OK	OK	2.10	1.39	I(a)	1.39	2.48	Infinite	Infinite	10	
7	XSec-3	27.14	917.14	OK	OK	3.67	2.44	I(a)	0.81	1.46	Infinite	Infinite	10	
7	XSec-3	28.92	918.92	OK	OK	5.15	3.43	I(a)	0.59	1.05	Infinite	Infinite	10	
7	XSec-0	28.92	918.92	OK	OK	4.82	3.22	I(a)	0.69	1.12	Infinite	Infinite	10	8.75' (1.5D) from Pin -> OK
7	XSec-0	31.15	921.15	OK	OK	9.82	6.56	I(a)	0.35	0.56	Infinite	Infinite	10	8.75' (1.5D) from Pin -> OK
7	XSec-0	32.03	922.03	OK	OK	16.39	10.96	I(a)	0.21	0.34	Infinite	Infinite	10	8.75' (1.5D) from Pin -> OK
7	XSec-0	33.38	923.38	NG	-	-	-	-	-	-	-	-	-	Pin and Hanger Location
7	XSec-0	34.73	924.73	OK	OK	19.54	12.91	I(a)	0.16	0.26	Infinite	Infinite	10	8.75' (1.5D) from Pin -> OK
7	XSec-0	39.62	929.62	OK	OK	4.53	2.99	I(a)	0.70	1.13	Infinite	Infinite	10	8.75' (1.5D) from Pin -> OK
7	XSec-0	43.08	933.08	NG	-	-	-	-	-	-	-	-	-	Outside 1.5D by 0.96'
7	XSec-3	43.08	933.08	OK	OK	3.13	2.06	I(a)	0.94	1.68	Infinite	Infinite	10	
7	XSec-3	44.5	934.5	OK	OK	2.77	1.83	I(a)	1.06	1.89	Infinite	Infinite	10	
7	XSec-3	44.51	934.51	OK	OK	2.77	1.83	I(a)	1.06	1.89	Infinite	Infinite	10	
7	XSec-3	46.73	936.72	OK	OK	2.38	1.57	I(a)	1.24	2.21	Infinite	Infinite	10	
7	XSec-3	54.79	944.79	OK	OK	1.66	1.09	I(a)	1.80	3.20	Infinite	Infinite	10	
7	XSec-4	54.79	944.79	OK	OK	2.30	1.51	I(a)	1.44	2.45	Infinite	Infinite	10	
7	XSec-4	55.63	945.63	OK	OK	2.24	1.48	I(a)	1.48	2.52	Infinite	Infinite	10	
7	XSec-4	62.3	952.3	OK	OK	1.91	1.25	I(a)	1.77	3.00	Infinite	Infinite	10	
7	XSec-4	66.75	956.75	OK	OK	1.77	1.17	I(a)	1.93	3.28	Infinite	Infinite	10	
7	XSec-4	77.88	967.88	OK	OK	1.63	1.07	I(a)	2.20	3.74	Infinite	Infinite	10	
7	XSec-4	89	979	OK	OK	1.67	1.10	I(a)	2.29	3.90	Infinite	Infinite	10	
7	XSec-4	93.45	983.45	OK	OK	1.74	1.14	I(a)	2.29	3.89	Infinite	Infinite	10	
7	XSec-4	100.13	990.13	OK	OK	1.92	1.26	I(a)	2.31	3.92	Infinite	Infinite	10	
7	XSec-4	108.79	998.79	OK	OK	2.38	1.56	I(a)	2.24	3.81	Infinite	Infinite	10	

Span	Section	Location (from Support)	Distance (from Abut)	Screening Criteria Met	Strength Check	Yield on Gross, Strength Ratio	Fracture on Net, Strength Ratio	Fatigue Case	Stress range in unfaulted state, Δf_{UFS}	Controlling stress range in faulted state, Δf_{FS}	Controlling faulted state remaining fatigue life, Y_{REM}	Total remaining fatigue life, N_f	Maximum Interval	Notes
		ft	ft	OK or NG	OK or NG	Less than 1 = NG	Less than 1 = NG	I(a), I(b), II	ksi	ksi	Years	Years	Years	
7	XSec-3	108.79	998.79	OK	OK	1.73	1.13	I(b)	2.80	4.98	99.85	99.85	10	
7	XSec-3	109.03	999.03	OK	OK	1.74	1.14	I(b)	2.79	4.97	66.75	66.75	10	
7	XSec-3	111.25	1001.25	OK	OK	1.89	1.24	I(b)	2.76	4.90	68.7956933	68.7956933	10	
7	XSec-3	115.5	1005.5	OK	OK	2.31	1.51	I(b)	2.66	4.74	74.09556233	74.09556233	10	
7	XSec-3	120.5	1010.5	OK	OK	2.79	1.83	I(a)	2.52	4.49	Infinite	Infinite	10	
7	XSec-0	120.5	1010.5	NG	-	-	-	-	-	-	-	-	-	No Cover Plate
7	XSec-3	122.38	1012.38	OK	OK	2.19	1.46	I(b)	2.99	5.37	56.15	56.15	10	
7	XSec-3	124.6	1014.6	OK	OK	1.94	1.29	I(b)	2.90	5.21	60.09	60.09	10	
7	XSec-3	130.5	1020.5	OK	OK	1.51	1.00	I(b)	2.57	4.61	114.8671952	114.8671952	10	
7	XSec-6	130.5	1020.5	OK	OK	2.12	1.41	I(a)	2.09	3.43	Infinite	Infinite	10	
7	XSec-6	133.5	1023.5	OK	OK	1.91	1.26	I(a)	1.93	3.15	Infinite	Infinite	10	
7	XSec-6	137.09	1027.09	OK	OK	1.73	1.15	I(a)	1.71	2.79	Infinite	Infinite	10	
7	XSec-7	137.09	1027.09	OK	OK	2.11	1.39	I(a)	1.47	2.41	Infinite	Infinite	10	XSec-7 Controlling Fatigue Location
7	XSec-7	140.18	1030.18	OK	OK	1.97	1.30	I(a)	1.43	2.33	Infinite	Infinite	10	
7	XSec-7	144.63	1034.63	OK	OK	1.84	1.22	I(a)	1.33	2.17	Infinite	Infinite	10	
7	XSec-7	154.75	1044.75	OK	OK	1.76	1.16	I(a)	1.08	1.74	Infinite	Infinite	10	
7	XSec-7	155.75	1045.75	OK	OK	1.73	1.14	I(a)	1.07	1.73	Infinite	Infinite	10	
8	XSec-7	0	1045.75	OK	OK	1.73	1.14	I(a)	1.07	1.73	Infinite	Infinite	10	
8	XSec-7	1	1046.75	OK	OK	1.76	1.16	I(a)	1.05	1.70	Infinite	Infinite	10	
8	XSec-7	11.13	1056.88	OK	OK	1.85	1.22	I(a)	1.23	2.00	Infinite	Infinite	10	
8	XSec-7	15.58	1061.33	OK	OK	1.99	1.32	I(a)	1.31	2.14	Infinite	Infinite	10	
8	XSec-7	18.67	1064.42	OK	OK	2.15	1.42	I(a)	1.40	2.28	Infinite	Infinite	10	
8	XSec-6	18.67	1064.42	OK	OK	1.77	1.17	I(a)	1.62	2.65	Infinite	Infinite	10	
8	XSec-6	22.25	1068	OK	OK	1.98	1.31	I(a)	1.86	3.04	Infinite	Infinite	10	
8	XSec-6	23.75	1069.5	OK	OK	2.12	1.41	I(a)	1.94	3.17	Infinite	Infinite	10	
8	XSec-3	23.75	1069.5	OK	OK	1.51	1.00	I(a)	2.38	4.27	Infinite	Infinite	10	
8	XSec-3	31.15	1076.9	OK	OK	2.06	1.37	I(b)	2.82	5.07	64.02	64.02	10	
8	XSec-3	32.75	1078.5	OK	OK	2.24	1.49	I(b)	2.89	5.18	60.83	60.83	10	
8	XSec-0	32.75	1078.5	NG	-	-	-	-	-	-	-	-	-	No Cover Plate
8	XSec-0	33.38	1079.13	NG	-	-	-	-	-	-	-	-	-	No Cover Plate
8	XSec-3	38	1083.75	OK	OK	3.14	2.06	I(b)	2.55	4.53	81.27402348	81.27402348	10	
8	XSec-3	44.5	1090.25	OK	OK	2.10	1.38	I(b)	2.72	4.84	70.72998411	70.72998411	10	
8	XSec-3	46.73	1092.47	OK	OK	1.91	1.25	I(b)	2.77	4.92	68.16424138	68.16424138	10	
8	XSec-3	50	1095.75	OK	OK	1.69	1.11	I(b)	2.83	5.04	97.62	97.62	10	
8	XSec-4	50	1095.75	OK	OK	2.34	1.54	I(a)	2.27	3.86	Infinite	Infinite	10	
8	XSec-4	55.63	1101.38	OK	OK	2.01	1.32	I(a)	2.33	3.96	Infinite	Infinite	10	
8	XSec-4	62.3	1108.05	OK	OK	1.79	1.18	I(a)	2.36	4.02	Infinite	Infinite	10	
8	XSec-4	66.75	1112.5	OK	OK	1.70	1.12	I(a)	2.36	4.01	Infinite	Infinite	10	
8	XSec-4	77.88	1123.63	OK	OK	1.62	1.06	I(a)	2.27	3.85	Infinite	Infinite	10	XSec-4 Controlling Strength Location
8	XSec-4	89	1134.75	OK	OK	1.69	1.11	I(a)	2.37	4.04	Infinite	Infinite	10	
8	XSec-4	93.45	1139.2	OK	OK	1.77	1.17	I(a)	2.38	4.04	Infinite	Infinite	10	
8	XSec-4	100.13	1145.88	OK	OK	1.99	1.31	I(a)	2.35	4.00	Infinite	Infinite	10	
8	XSec-4	105	1150.75	OK	OK	2.25	1.48	I(a)	2.30	3.91	Infinite	Infinite	10	
8	XSec-3	105	1150.75	OK	OK	1.63	1.07	I(b)	2.87	5.11	95.15	95.15	10	
8	XSec-3	109.03	1154.78	OK	OK	1.87	1.23	I(b)	2.79	4.97	66.77	66.77	10	
8	XSec-3	111.25	1157	OK	OK	2.05	1.35	I(b)	2.75	4.89	69.24886659	69.24886659	10	

Span	Section	Location (from Support)	Distance (from Abut)	Screening Criteria Met	Strength Check	Yield on Gross, Strength Ratio	Fracture on Net, Strength Ratio	Fatigue Case	Stress range in unfaulted state, Δf_{UFS}	Controlling stress range in faulted state, Δf_{FS}	Controlling faulted state remaining fatigue life, Y_{REM}	Total remaining fatigue life, N_f	Maximum Interval	Notes
		ft	ft	OK or NG	OK or NG	Less than 1 = NG	Less than 1 = NG	I(a), I(b), II	ksi	ksi	Years	Years	Years	
8	XSec-3	117	1162.75	OK	OK	2.87	1.88	I(b)	2.60	4.62	77.95727128	77.95727128	10	
8	XSec-0	117	1162.75	NG	-	-	-	-	-	-	-	-	-	No Cover Plate
8	XSec-3	120.75	1166.5	OK	OK	2.94	1.93	I(a)	2.48	4.42	Infinite	Infinite	10	
8	XSec-3	122.38	1168.13	OK	OK	2.32	1.54	I(b)	2.95	5.30	57.89	57.89	10	
8	XSec-3	124.6	1170.35	OK	OK	2.05	1.37	I(b)	2.86	5.14	62.09	62.09	10	
8	XSec-3	129.75	1175.5	OK	OK	1.62	1.08	I(b)	2.59	4.65	113.29	113.29	10	
8	XSec-6	129.75	1175.5	OK	OK	2.28	1.51	I(a)	2.11	3.45	Infinite	Infinite	10	XSec-6 Controlling Fatigue Location
8	XSec-6	133.5	1179.25	OK	OK	1.99	1.32	I(a)	1.89	3.10	Infinite	Infinite	10	
8	XSec-6	137.09	1182.84	OK	OK	1.78	1.18	I(a)	1.69	2.76	Infinite	Infinite	10	
8	XSec-12	137.09	1182.84	OK	OK	2.16	1.43	I(a)	1.43	2.37	Infinite	Infinite	10	XSec-12 Controlling Fatigue Location
8	XSec-12	140.18	1185.93	OK	OK	2.00	1.32	I(a)	1.38	2.29	Infinite	Infinite	10	
8	XSec-12	144.63	1190.38	OK	OK	1.87	1.23	I(a)	1.29	2.14	Infinite	Infinite	10	
8	XSec-12	154.75	1200.5	OK	OK	1.77	1.16	I(a)	1.05	1.72	Infinite	Infinite	10	
8	XSec-12	155.75	1201.5	OK	OK	1.74	1.14	I(a)	1.05	1.72	Infinite	Infinite	10	XSec-12 Controlling Strength Location

Bridge is symmetric about the above specified point, thus all points along length of bridge can be correlated accordingly

Appendix 1B. Graphical Summary of Results

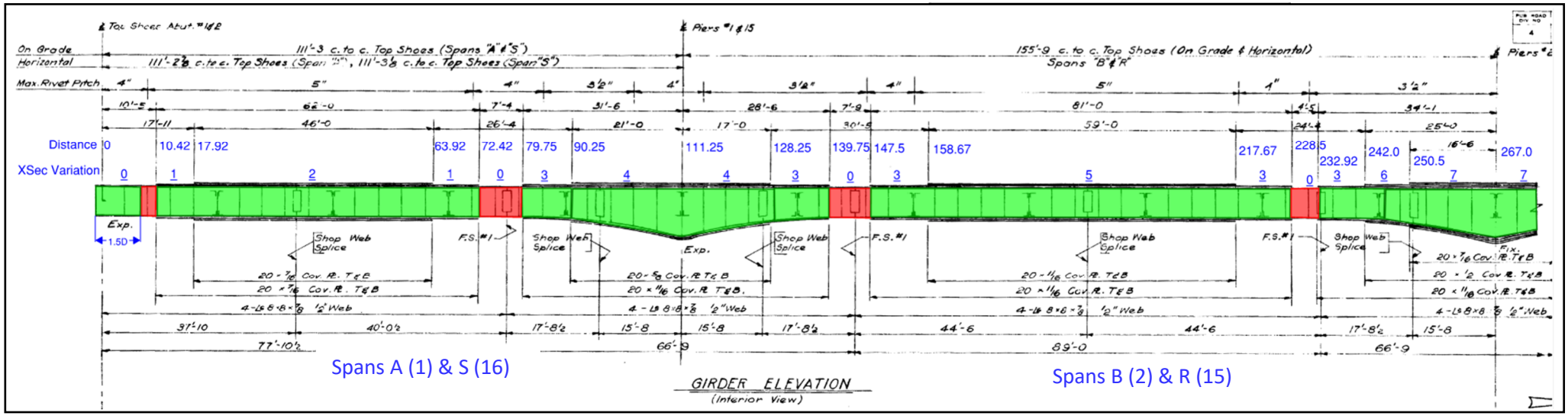


Figure 1B.1 Girder elevation of Spans 1 and 2, summary of results.

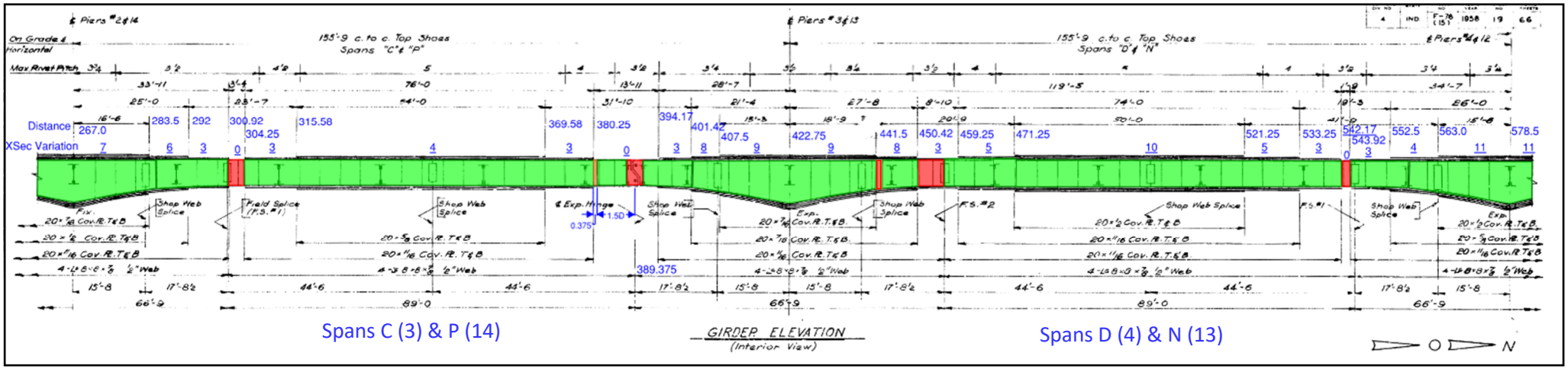


Figure 1B.2 Girder elevation of Spans 3 and 4, summary of results.

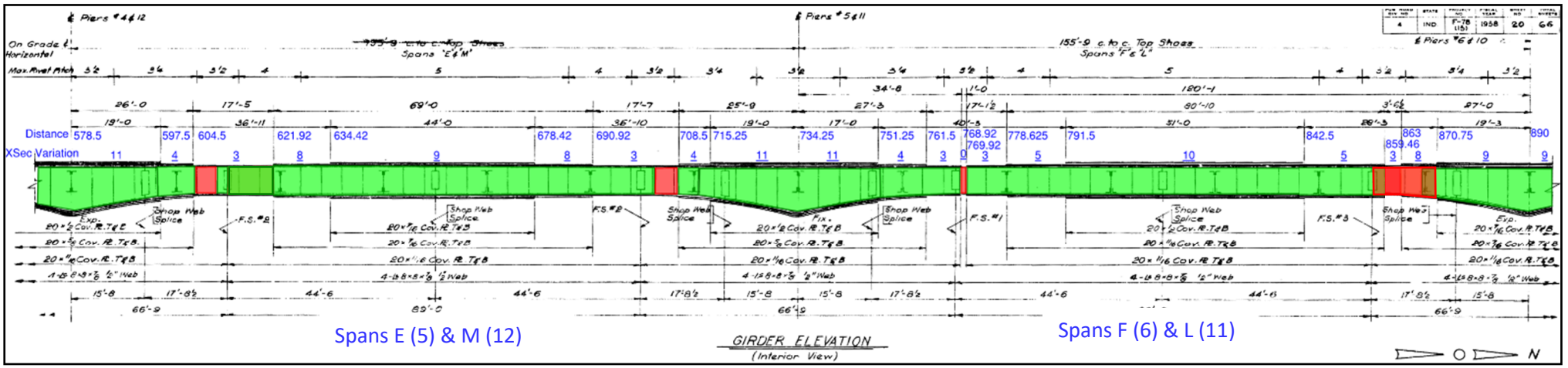


Figure 1B.3 Girder elevation of Spans 5 and 6, summary of results.

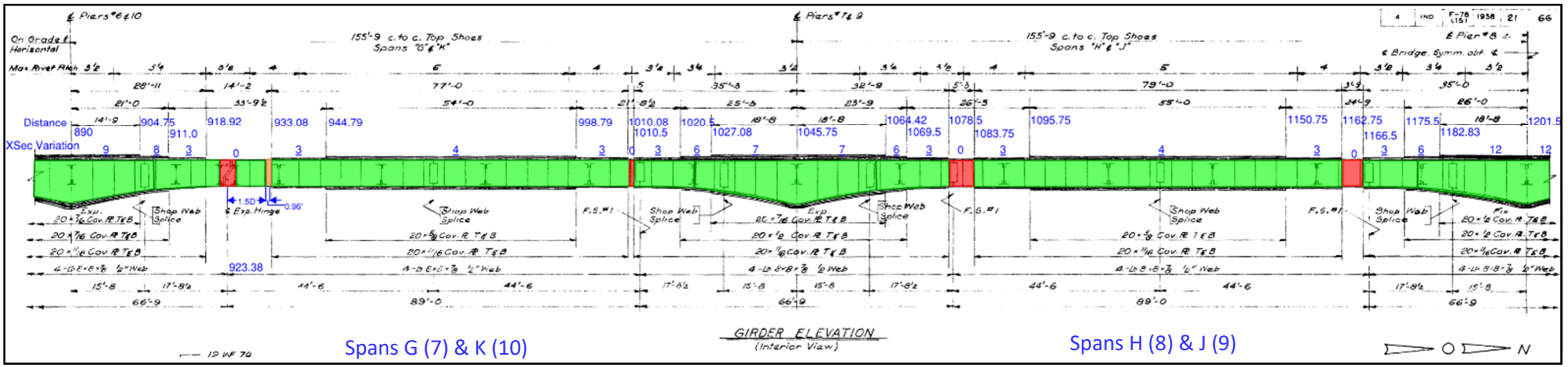


Figure 1B.4 Girder elevation of Spans 7 and 8 summary of results.

Appendix 1C. Summary Table of Variable Parameters

Span	Section	Location (from Support)	Distance (from Abut)	($ADTT_{sl}$) present = original	M_{LL+IM}	M_{FAT+IM}	Adjustment Factor	M_{DC1}	M_{DC2}	M_{DW}	Negative Moment	Span Length	Web Plate Depth, D_w	Flange Angles Out-to-out Depth, D_{oto}	Screening Criteria Met	Strength Check	Notes
		ft	ft		k-ft	k-ft		k-ft	k-ft	k-ft	-	ft	in	in	OK or NG	OK or NG	
1	-	0	0		0	0	0	0	0	0	No	111.25	70.0	70.5	#N/A		
1	XSec-0	10.42	10.42	558	1207.8	277.2	0.495	661.6	193.0	162.2	No	111.25	70.0	70.5	NG	-	First 8.75' (1.5D) -> OK
1	XSec-1	10.42	10.42	558	1207.8	277.2	0.495	661.6	193.0	162.2	No	111.25	70.0	70.5	OK	OK	
1	XSec-1	11.13	11.13	558	1278.0	293.2	0.495	699.5	203.9	171.3	No	111.25	70.0	70.5	OK	OK	
1	XSec-1	17.92	17.92	558	1873.7	429.7	0.495	1017.1	293.5	246.6	No	111.25	70.0	70.5	OK	OK	
1	XSec-2	17.92	17.92	558	1873.7	429.7	0.495	1017.1	293.5	246.6	No	111.25	70.0	70.5	OK	OK	
1	XSec-2	22.25	22.25	558	2183.0	500.6	0.495	1176.1	336.8	283.0	No	111.25	70.0	70.5	OK	OK	
1	XSec-2	33.38	33.38	558	2737.0	647.4	0.495	1377.1	398.8	335.1	No	111.25	70.0	70.5	OK	OK	
1	XSec-2	44.5	44.5	558	2990.0	722.5	0.495	1348.2	389.8	327.5	No	111.25	70.0	70.5	OK	OK	XSec-2 Controlling Strength Location
1	XSec-2	55.63	55.63	558	2960.0	751.9	0.495	1052.3	309.8	260.3	No	111.25	70.0	70.5	OK	OK	
1	XSec-2	63.92	63.92	1005	2770.0	756.5	0.495	682.2	204.0	171.4	No	111.25	70.0	70.5	OK	OK	XSec-2 Controlling Fatigue Location
1	XSec-1	63.92	63.92	1005	2770.0	756.5	0.495	682.2	204.0	171.4	No	111.25	70.0	70.5	OK	OK	XSec-1 Controlling Fatigue and Strength
1	XSec-1	66.75	66.75	1005	2669.2	750.8	0.495	526.7	158.8	133.5	No	111.25	70.0	70.5	OK	OK	
1	XSec-1	72.42	72.42	1005	2418.5	727.4	0.495	148.8	54.7	45.9	No	111.25	70.0	70.5	OK	OK	
1	XSec-0	72.42	72.42	1005	2418.5	727.4	0.495	148.8	54.7	45.9	No	111.25	70.0	70.5	NG	-	No Cover Plate
1	XSec-0	77.88	77.88	1005	2118.2	693.3	0.495	269.9	63.1	53.0	No	111.25	70.0	70.5	NG	-	No Cover Plate
1	XSec-0	79.75	79.75	1005	2089.9	679.4	0.495	426.1	107.5	90.3	Yes	111.25	70.0	70.5	NG	-	No Cover Plate
1	XSec-3	79.75	79.75	1005	2089.9	679.4	0.495	426.1	107.5	90.3	Yes	111.25	70.0	70.5	OK	OK	
1	XSec-3	89	89	558	2340.1	593.3	0.495	1291.0	356.0	299.1	Yes	111.25	73.2	73.7	OK	OK	
1	XSec-3	90.25	90.25	558	2383.3	580.0	0.495	1424.0	393.3	330.5	Yes	111.25	74.4	74.9	OK	OK	
1	XSec-4	90.25	90.25	558	2383.3	580.0	0.495	1424.0	393.3	330.5	Yes	111.25	74.4	74.9	OK	OK	
1	XSec-4	100.13	100.13	558	3007.2	571.6	0.495	2581.8	719.9	604.8	Yes	111.25	89.0	89.5	OK	OK	
1	XSec-4	110.25	110.25	558	4173.7	629.4	0.495	3968.2	1112.7	934.9	Yes	111.25	114.7	115.2	OK	OK	
1	XSec-4	111.25	111.25	558	4304.5	635.2	0.495	4116.7	1154.7	970.2	Yes	111.25	116.0	116.5	OK	OK	
2	XSec-4	0	111.25	558	4304.5	635.2	0.495	4116.7	1154.7	970.2	Yes	155.75	116.0	116.5	OK	OK	
2	XSec-4	1	112.25	558	4170.0	610.9	0.495	3962.2	1111.4	933.8	Yes	155.75	114.7	115.2	OK	OK	
2	XSec-4	11.13	122.38	558	2940.6	426.5	0.495	2511.0	704.5	591.9	Yes	155.75	89.0	89.5	OK	OK	
2	XSec-4	15.58	126.83	558	2478.6	395.7	0.495	1937.5	544.3	457.3	Yes	155.75	81.1	81.6	OK	OK	
2	XSec-4	17	128.25	558	2344.1	385.8	0.495	1762.1	495.5	416.3	Yes	155.75	79.0	79.5	OK	OK	
2	XSec-3	17	128.25	558	2344.1	385.8	0.495	1762.1	495.5	416.3	Yes	155.75	79.0	79.5	OK	OK	
2	XSec-3	22.25	133.5	558	1896.7	438.8	0.495	1148.2	325.3	273.3	Yes	155.75	73.2	73.7	OK	OK	
2	XSec-3	28.5	139.75	1005	1516.5	509.4	0.495	504.5	143.5	120.5	Yes	155.75	70.2	70.7	OK	OK	
2	XSec-0	28.5	139.75	1005	1516.5	509.4	0.495	504.5	143.5	120.5	Yes	155.75	70.2	70.7	NG	-	No Cover Plate
2	XSec-0	31.15	142.4	1005	1495.6	537.3	0.495	252.9	73.1	61.4	No	155.75	70.0	70.5	NG	-	No Cover Plate
2	XSec-0	33.38	144.63	1005	1630.6	560.1	0.495	51.6	17.1	14.4	No	155.75	70.0	70.5	NG	-	No Cover Plate
2	XSec-3	36.25	147.5	1005	1807.9	588.1	0.495	195.2	51.0	42.9	No	155.75	70.0	70.5	OK	OK	
2	XSec-3	44.5	155.75	558	2368.8	659.1	0.495	820.1	220.2	185.0	No	155.75	70.0	70.5	OK	OK	
2	XSec-3	46.73	157.97	558	2508.9	674.5	0.495	957.8	259.1	217.7	No	155.75	70.0	70.5	OK	OK	
2	XSec-3	47.42	158.67	558	2550.5	678.9	0.495	998.7	270.6	227.4	No	155.75	70.0	70.5	OK	OK	
2	XSec-5	47.42	158.67	558	2550.5	678.9	0.495	998.7	270.6	227.4	No	155.75	70.0	70.5	OK	OK	
2	XSec-5	55.63	166.88	558	2987.8	723.3	0.495	1414.4	386.5	324.7	No	155.75	70.0	70.5	OK	OK	
2	XSec-5	62.3	173.55	558	3249.0	741.1	0.495	1656.0	452.2	379.9	No	155.75	70.0	70.5	OK	OK	
2	XSec-5	66.75	178	558	3377.8	744.9	0.495	1769.0	481.8	404.8	No	155.75	70.0	70.5	OK	OK	

Span	Section	Location (from Support)	Distance (from Abut)	($ADTT_{sl}$) present = original	M_{LL+IM}	M_{FAT+IM}	Adjustment Factor	M_{DC1}	M_{DC2}	M_{DW}	Negative Moment	Span Length	Web Plate Depth, D_w	Flange Angles Out-to-out Depth, D_{oto}	Screening Criteria Met	Strength Check	Notes
		ft	ft		k-ft	k-ft		k-ft	k-ft	k-ft	-	ft	in	in	OK or NG	OK or NG	
2	XSec-5	77.88	189.13	558	3526.1	757.7	0.495	1846.0	506.1	425.2	No	155.75	70.0	70.5	OK	OK	
2	XSec-5	89	200.25	558	3470.1	794.8	0.495	1682.8	459.5	386.1	No	155.75	70.0	70.5	OK	OK	
2	XSec-5	93.45	204.7	558	3379.0	797.2	0.495	1531.2	421.0	353.7	No	155.75	70.0	70.5	OK	OK	
2	XSec-5	100.13	211.38	558	3174.0	788.7	0.495	1231.7	341.9	287.3	No	155.75	70.0	70.5	OK	OK	
2	XSec-5	106.42	217.67	558	2901.9	765.5	0.495	870.3	244.0	205.0	No	155.75	70.0	70.5	OK	OK	
2	XSec-3	106.42	217.67	558	2901.9	765.5	0.495	870.3	244.0	205.0	No	155.75	70.0	70.5	OK	OK	
2	XSec-3	109.03	220.28	1005	2769.9	752.3	0.495	698.3	196.7	165.3	No	155.75	70.0	70.5	OK	OK	
2	XSec-3	111.25	222.5	1005	2648.3	740.0	0.495	541.8	153.3	128.8	No	155.75	70.0	70.5	OK	OK	
2	Xsec-3	117.25	228.5	1005	2279.4	698.2	0.495	54.6	22.2	18.6	No	155.75	70.0	70.5	OK	OK	
2	XSec-0	117.25	228.5	1005	2279.4	698.2	0.495	54.6	22.2	18.6	No	155.75	70.0	70.5	NG	-	No Cover Plate
2	XSec-3	121.67	232.92	1005	1998.8	661.9	0.495	345.9	87.6	73.6	No	155.75	70.0	70.5	OK	OK	
2	XSec-3	122.38	233.63	1005	1996.3	655.7	0.495	413.5	106.2	89.3	Yes	155.75	70.0	70.5	OK	OK	
2	XSec-3	124.6	235.85	1005	2062.0	635.6	0.495	631.6	166.7	140.0	Yes	155.75	70.0	70.5	OK	OK	
2	XSec-3	130.75	242	558	2288.7	574.8	0.495	1281.2	348.4	292.7	Yes	155.75	71.4	71.9	OK	OK	
2	XSec-6	130.75	242	558	2288.7	574.8	0.495	1281.2	348.4	292.7	Yes	155.75	71.4	71.9	OK	OK	
2	XSec-6	133.5	244.75	558	2437.2	545.7	0.495	1594.6	436.8	367.0	Yes	155.75	73.2	73.7	OK	OK	
2	XSec-6	139.25	250.5	558	2932.2	502.7	0.495	2320.9	635.4	533.8	Yes	155.75	79.7	80.2	OK	OK	
2	XSec-7	139.25	250.5	558	2932.2	502.7	0.495	2320.9	635.4	533.8	Yes	155.75	79.7	80.2	OK	OK	
2	XSec-7	140.18	251.43	558	3021.1	507.3	0.495	2443.9	669.1	562.2	Yes	155.75	81.1	81.6	OK	OK	
2	XSec-7	144.63	255.88	558	3484.9	529.4	0.495	3059.0	838.3	704.3	Yes	155.75	89.0	89.5	OK	OK	
2	XSec-7	154.75	266	558	4730.3	579.7	0.495	4608.2	1265.3	1063.1	Yes	155.75	114.7	115.2	OK	OK	
2	XSec-7	155.75	267	558	4867.4	584.7	0.495	4773.1	1310.7	1101.2	Yes	155.75	116.0	116.5	OK	OK	XSec-7 Controlling Strength Location
3	XSec-7	0	267	558	4867.4	584.7	0.495	4773.1	1310.7	1101.2	Yes	155.75	116.0	116.5	OK	OK	
3	XSec-7	1	268	558	4735.0	575.6	0.495	4608.3	1265.3	1063.0	Yes	155.75	114.7	115.2	OK	OK	
3	XSec-7	11.13	278.13	558	3544.3	527.5	0.495	3055.5	836.7	703.0	Yes	155.75	89.0	89.5	OK	OK	
3	XSec-7	15.58	282.58	558	3114.9	506.4	0.495	2439.1	667.0	560.4	Yes	155.75	81.1	81.6	OK	OK	
3	XSec-7	16.5	283.5	558	3031.9	502.0	0.495	2316.1	633.1	531.9	Yes	155.75	79.7	80.2	OK	OK	
3	XSec-6	16.5	283.5	558	3031.9	502.0	0.495	2316.1	633.1	531.9	Yes	155.75	79.7	80.2	OK	OK	XSec-6 Controlling Strength Location
3	XSec-6	22.25	289.25	558	2625.8	543.5	0.495	1587.7	433.6	364.3	Yes	155.75	73.2	73.7	OK	OK	
3	XSec-6	25	292	558	2490.3	572.7	0.495	1210.0	345.0	289.9	Yes	155.75	71.8	72.3	OK	OK	
3	XSec-3	25	292	558	2490.3	572.7	0.495	1210.0	345.0	289.9	Yes	155.75	71.8	72.3	OK	OK	
3	XSec-3	31.15	298.15	1005	2233.5	633.7	0.495	621.9	162.3	136.4	Yes	155.75	70.0	70.5	OK	OK	
3	XSec-3	33.38	300.38	1005	2154.6	653.5	0.495	403.2	101.6	85.3	Yes	155.75	70.0	70.5	OK	OK	
3	XSec-3	33.92	300.92	1005	2136.0	658.1	0.495	351.3	87.2	73.3	Yes	155.75	70.0	70.5	OK	OK	
3	XSec-0	33.92	300.92	1005	2136.0	658.1	0.495	351.3	87.2	73.3	Yes	155.75	70.0	70.5	NG	-	No Cover Plate
3	XSec-0	37.25	304.25	1005	2305.7	685.1	0.495	43.8	2.6	2.2	No	155.75	70.0	70.5	NG	-	No Cover Plate
3	XSec-3	37.25	304.25	1005	2305.7	685.1	0.495	43.8	2.6	2.2	No	155.75	70.0	70.5	OK	OK	
3	XSec-3	44.5	311.5	1005	2690.7	732.9	0.495	555.5	159.5	134.0	No	155.75	70.0	70.5	OK	OK	
3	XSec-3	46.73	313.72	1005	2792.0	743.4	0.495	712.6	203.2	170.8	No	155.75	70.0	70.5	OK	OK	
3	XSec-3	48.58	315.58	558	2869.6	751.0	0.495	836.9	237.6	199.6	No	155.75	70.0	70.5	OK	OK	
3	XSec-4	48.58	315.58	558	2869.6	751.0	0.495	836.9	237.6	199.6	No	155.75	70.0	70.5	OK	OK	
3	XSec-4	55.63	322.63	558	3108.4	767.7	0.495	1248.4	349.7	293.8	No	155.75	70.0	70.5	OK	OK	
3	XSec-4	62.3	329.3	558	3237.3	762.9	0.495	1550.0	429.7	361.0	No	155.75	70.0	70.5	OK	OK	

Span	Section	Location (from Support)	Distance (from Abut)	($ADTT_{sl}$) present = original	M_{LL+IM}	M_{FAT+IM}	Adjustment Factor	M_{DC1}	M_{DC2}	M_{DW}	Negative Moment	Span Length	Web Plate Depth, D_w	Flange Angles Out-to-out Depth, D_{oto}	Screening Criteria Met	Strength Check	Notes
		ft	ft		k-ft	k-ft		k-ft	k-ft	k-ft	-	ft	in	in	OK or NG	OK or NG	
3	XSec-4	66.75	333.75	558	3285.2	765.1	0.495	1703.2	468.8	393.9	No	155.75	70.0	70.5	OK	OK	
3	XSec-4	77.88	344.88	558	3227.6	735.1	0.495	1871.6	517.0	434.4	No	155.75	70.0	70.5	OK	OK	
3	XSec-4	89	356	558	2884.7	645.7	0.495	1800.9	494.2	415.2	No	155.75	70.0	70.5	OK	OK	
3	XSec-4	93.45	360.45	558	2671.4	591.2	0.495	1688.7	465.2	390.9	No	155.75	70.0	70.5	OK	OK	
3	XSec-4	100.13	367.13	558	2255.9	495.6	0.495	1448.7	400.5	336.5	No	155.75	70.0	70.5	OK	OK	
3	XSec-4	102.58	369.58	558	2072.8	455.7	0.495	1338.7	370.2	311.0	No	155.75	70.0	70.5	OK	OK	
3	XSec-3	102.58	369.58	558	2072.8	455.7	0.495	1338.7	370.2	311.0	No	155.75	70.0	70.5	OK	OK	
3	XSec-3	109.03	376.03	558	1516.4	333.7	0.495	997.1	274.4	230.5	No	155.75	70.0	70.5	OK	OK	
3	XSec-3	111.25	378.25	558	1298.0	285.9	0.495	861.5	235.7	198.1	No	155.75	70.0	70.5	OK	OK	
3	XSec-3	113.25	380.25	1005	1090.1	240.2	0.495	724.2	198.6	166.9	No	155.75	70.0	70.5	OK	OK	
3	XSec-0	113.25	380.25	1005	1090.1	240.2	0.495	724.2	198.6	166.9	No	155.75	70.0	70.5	NG	-	Outside 1.5D by 0.375'
3	XSec-0	116.14	383.14	1005	770.1	169.9	0.495	513.0	140.9	118.4	No	155.75	70.0	70.5	OK	OK	8.75' (1.5D) from Pin -> OK
3	XSec-0	121.03	388.03	1005	175.7	38.8	0.495	121.1	32.3	27.2	No	155.75	70.0	70.5	OK	OK	8.75' (1.5D) from Pin -> OK
3	XSec-0	122.38	389.38	1005	0.1	0.0	0.495	0.1	0.0	0.0	Yes	155.75	70.0	70.5	NG	-	Pin and Hanger Location
3	XSec-0	123.73	390.73	1005	182.7	41.0	0.495	124.9	33.6	28.3	Yes	155.75	70.0	70.5	OK	OK	8.75' (1.5D) from Pin -> OK
3	XSec-0	124.6	391.6	1005	301.1	67.3	0.495	210.8	55.9	47.0	Yes	155.75	70.0	70.5	OK	OK	8.75' (1.5D) from Pin -> OK
3	XSec-0	127.17	394.17	1005	653.2	144.8	0.495	471.6	123.9	104.1	Yes	155.75	70.2	70.7	OK	OK	8.75' (1.5D) from Pin -> OK
3	XSec-3	127.17	394.17	1005	653.2	144.8	0.495	471.6	123.9	104.1	Yes	155.75	70.2	70.7	OK	OK	
3	XSec-3	128.61	395.61	1005	854.3	188.6	0.495	624.1	163.9	137.7	Yes	155.75	70.5	71.0	OK	OK	
3	XSec-3	133.5	400.5	558	1545.9	336.3	0.495	1167.0	307.9	258.7	Yes	155.75	73.2	73.7	OK	OK	
3	XSec-3	133.51	400.51	558	1546.4	336.4	0.495	1167.5	308.1	258.8	Yes	155.75	73.3	73.8	OK	OK	
3	XSec-3	134.42	401.42	558	1677.4	363.9	0.495	1276.5	336.4	282.6	Yes	155.75	74.0	74.5	OK	OK	
3	XSec-8	134.42	401.42	558	1677.4	363.9	0.495	1276.5	336.4	282.6	Yes	155.75	74.0	74.5	OK	OK	
3	XSec-8	140.18	407.18	558	2522.2	538.0	0.495	2002.8	526.7	442.5	Yes	155.75	81.1	81.6	OK	OK	
3	XSec-8	140.5	407.5	558	2570.5	547.8	0.495	2045.6	538.0	452.0	Yes	155.75	81.6	82.1	OK	OK	
3	XSec-9	140.5	407.5	558	2570.5	547.8	0.495	2045.6	538.0	452.0	Yes	155.75	81.6	82.1	OK	OK	
3	XSec-9	144.63	411.63	558	3194.0	672.6	0.495	2608.5	686.8	577.0	Yes	155.75	89.0	89.5	OK	OK	
3	XSec-9	154.75	421.75	558	4783.7	980.5	0.495	4135.3	1093.2	918.5	Yes	155.75	114.7	115.2	OK	OK	
3	XSec-9	155.75	422.75	558	4945.3	1012.3	0.495	4297.6	1136.5	954.9	Yes	155.75	116.0	116.5	OK	OK	
4	XSec-9	0	422.75	558	4945.3	1012.3	0.495	4297.6	1136.5	954.9	Yes	155.75	116.0	116.5	OK	OK	
4	XSec-9	1	423.75	558	4887.5	1004.2	0.495	4136.5	1093.3	918.6	Yes	155.75	114.7	115.2	OK	OK	
4	XSec-9	11.13	433.88	558	4575.3	1077.4	0.495	2617.2	686.7	577.0	Yes	155.75	89.0	89.5	OK	OK	
4	XSec-9	15.58	438.33	558	4438.2	1138.9	0.495	2015.5	526.7	442.6	Yes	155.75	81.1	81.6	OK	OK	
4	XSec-9	18.75	441.5	1005	4340.3	1176.8	0.495	1610.3	419.5	352.5	Yes	155.75	76.8	77.3	OK	OK	XSec-9 Controlling Fatigue Location
4	XSec-8	18.75	441.5	1005	4340.3	689.5	0.290	1610.3	419.5	352.5	Yes	155.75	76.8	77.3	OK	NG	Strength Check Failure
4	XSec-8	22.25	445	1005	4232.3	710.6	0.290	1186.5	307.9	258.7	Yes	155.75	73.2	73.7	OK	OK	
4	XSec-8	27.67	450.42	1005	4065.8	736.4	0.290	597.2	148.9	125.1	Yes	155.75	70.3	70.8	OK	OK	
4	XSec-3	27.67	450.42	1005	4065.8	736.4	0.290	597.2	148.9	125.1	Yes	155.75	70.3	70.8	OK	NG	Strength Check Failure
4	XSec-3	31.15	453.9	1005	3958.6	755.2	0.293	247.3	55.5	46.6	Yes	155.75	70.0	70.5	OK	NG	Strength Check Failure
4	XSec-3	33.38	456.13	1005	3911.9	771.3	0.296	35.2	0.6	0.5	No	155.75	70.0	70.5	OK	OK	
4	XSec-3	36.5	459.25	1005	4116.3	792.2	0.300	246.9	74.5	62.6	No	155.75	70.0	70.5	OK	OK	
4	XSec-5	36.5	459.25	1005	4116.3	792.2	0.300	246.9	74.5	62.6	No	155.75	70.0	70.5	OK	OK	
4	XSec-5	44.5	467.25	558	4540.5	834.0	0.312	885.0	238.2	200.1	No	155.75	70.0	70.5	OK	OK	

Span	Section	Location (from Support)	Distance (from Abut)	($ADTT_{sl}$) present = original	M_{LL+IM}	M_{FAT+IM}	Adjustment Factor	M_{DC1}	M_{DC2}	M_{DW}	Negative Moment	Span Length	Web Plate Depth, D_w	Flange Angles Out-to-out Depth, D_{oto}	Screening Criteria Met	Strength Check	Notes
		ft	ft		k-ft	k-ft		k-ft	k-ft	k-ft	-	ft	in	in	OK or NG	OK or NG	
4	XSec-5	46.73	469.47	558	4640.8	842.7	0.315	1030.7	277.2	232.9	No	155.75	70.0	70.5	OK	OK	
4	XSec-5	48.5	471.25	558	4712.9	848.6	0.318	1140.1	306.2	257.3	No	155.75	70.0	70.5	OK	OK	XSec-5 Controlling Strength Location
4	XSec-10	48.5	471.25	558	4712.9	848.6	0.318	1140.1	306.2	257.3	No	155.75	70.0	70.5	OK	OK	
4	XSec-10	55.63	478.38	558	4934.1	863.3	0.328	1516.0	404.8	340.1	No	155.75	70.0	70.5	OK	OK	
4	XSec-10	62.3	485.05	558	5040.3	862.7	0.338	1774.5	470.7	395.5	No	155.75	70.0	70.5	OK	OK	
4	XSec-10	66.75	489.5	558	5059.5	854.7	0.344	1896.9	500.5	420.5	No	155.75	70.0	70.5	OK	OK	XSec-10 Controlling Strength Location
4	XSec-10	77.88	500.63	558	4944.7	1131.4	0.495	1989.5	525.2	441.2	No	155.75	70.0	70.5	OK	OK	
4	XSec-10	89	511.75	558	4562.2	1009.6	0.495	1830.5	478.8	402.3	No	155.75	70.0	70.5	OK	OK	
4	XSec-10	93.45	516.2	558	4332.0	983.1	0.495	1677.6	441.0	370.5	No	155.75	70.0	70.5	OK	OK	
4	XSec-10	98.5	521.25	558	4030.3	945.4	0.495	1455.4	384.3	322.9	No	155.75	70.0	70.5	OK	OK	
4	XSec-5	98.5	521.25	558	4030.3	945.4	0.495	1455.4	384.3	322.9	No	155.75	70.0	70.5	OK	OK	
4	XSec-5	100.13	522.88	558	3923.4	931.8	0.495	1372.9	362.9	304.9	No	155.75	70.0	70.5	OK	OK	
4	XSec-5	109.03	531.78	558	3266.1	843.1	0.495	830.9	219.1	184.0	No	155.75	70.0	70.5	OK	OK	
4	XSec-5	110.5	533.25	1005	3146.5	826.9	0.495	726.2	190.8	160.3	No	155.75	70.0	70.5	OK	OK	
4	XSec-3	110.5	533.25	1005	3146.5	826.9	0.495	726.2	190.8	160.3	No	155.75	70.0	70.5	OK	OK	
4	XSec-3	111.25	534	1005	3084.3	818.5	0.495	671.2	176.0	147.8	No	155.75	70.0	70.5	OK	OK	
4	XSec-3	119.42	542.17	1005	2369.6	719.4	0.495	19.7	6.9	5.8	No	155.75	70.0	70.5	OK	OK	
4	XSec-0	121.17	543.92	1005	2220.9	697.4	0.495	183.6	51.0	42.9	No	155.75	70.0	70.5	NG	-	No Cover Plate
4	Xsec-3	121.17	543.92	1005	2220.9	697.4	0.495	183.6	51.0	42.9	No	155.75	70.0	70.5	OK	OK	
4	XSec-3	122.38	545.13	1005	2160.0	681.8	0.495	300.2	82.6	69.4	Yes	155.75	70.0	70.5	OK	OK	
4	XSec-3	124.6	547.35	1005	2223.8	652.8	0.495	521.4	142.8	120.0	Yes	155.75	70.0	70.5	OK	OK	
4	XSec-3	129.75	552.5	1005	2426.3	583.7	0.495	1068.4	293.0	246.2	Yes	155.75	70.9	71.4	OK	OK	
4	XSec-4	129.75	552.5	1005	2426.3	583.7	0.495	1068.4	293.0	246.2	Yes	155.75	70.9	71.4	OK	OK	
4	XSec-4	133.5	556.25	558	2743.9	533.2	0.495	1498.6	412.1	346.3	Yes	155.75	73.2	73.7	OK	OK	
4	XSec-4	140.18	562.93	558	3441.5	546.8	0.495	2360.0	644.1	541.2	Yes	155.75	81.1	81.6	OK	OK	
4	XSec-4	140.25	563	558	3450.0	547.5	0.495	2370.0	646.8	543.5	Yes	155.75	81.2	81.7	OK	OK	
4	XSec-11	140.25	563	558	3450.0	547.5	0.495	2370.0	646.8	543.5	Yes	155.75	81.2	81.7	OK	OK	
4	XSec-11	144.63	567.38	558	3975.3	592.6	0.495	2983.7	813.1	683.1	Yes	155.75	89.0	89.5	OK	OK	
4	XSec-11	154.75	577.5	558	5359.6	813.6	0.495	4554.4	1239.6	1041.5	Yes	155.75	114.7	115.2	OK	OK	
4	XSec-11	155.75	578.5	558	5506.8	844.3	0.495	4721.3	1284.9	1079.5	Yes	155.75	116.0	116.5	OK	OK	XSec-11 Controlling Strength Location
5	XSec-11	0	578.5	558	5506.8	844.3	0.495	4721.3	1284.9	1079.5	Yes	155.75	116.0	116.5	OK	OK	
5	XSec-11	1	579.5	558	5360.9	837.5	0.495	4559.2	1240.6	1042.3	Yes	155.75	114.7	115.2	OK	OK	
5	XSec-11	11.13	589.63	558	4038.1	768.3	0.495	3032.7	823.4	691.8	Yes	155.75	89.0	89.5	OK	OK	
5	XSec-11	15.58	594.08	558	3543.6	737.9	0.495	2429.3	658.8	553.5	Yes	155.75	81.1	81.6	OK	OK	
5	XSec-11	19	597.5	558	3206.8	714.5	0.495	1992.3	539.8	453.5	Yes	155.75	76.5	77.0	OK	OK	XSec-11 Controlling Fatigue Location
5	XSec-4	19	597.5	558	3206.8	714.5	0.495	1992.3	539.8	453.5	Yes	155.75	76.5	77.0	OK	OK	
5	XSec-4	22.25	600.75	558	3011.1	692.2	0.495	1598.7	433.0	363.8	Yes	155.75	73.2	73.7	OK	OK	
5	XSec-4	26	604.5	558	2817.2	702.1	0.495	1186.8	317.4	266.7	Yes	155.75	70.9	71.4	OK	OK	XSec-4 Controlling Fatigue Location
5	XSec-3	26	604.5	558	2817.2	702.1	0.495	1186.8	317.4	266.7	Yes	155.75	70.9	71.4	OK	NG	Strength Check Failure
5	XSec-3	31.15	609.65	558	2597.7	751.1	0.495	663.4	171.7	144.3	Yes	155.75	70.0	70.5	OK	OK	
5	XSec-3	33.38	611.88	558	2516.4	770.3	0.495	452.1	113.4	95.3	Yes	155.75	70.0	70.5	OK	OK	
5	XSec-3	43.42	621.92	1005	2985.7	843.6	0.495	388.0	114.1	95.8	No	155.75	70.0	70.5	OK	OK	
5	XSec-8	43.42	621.92	1005	2985.7	843.6	0.495	388.0	114.1	95.8	No	155.75	70.0	70.5	OK	OK	

Span	Section	Location (from Support)	Distance (from Abut)	($ADTT_{sl}$) present = original	M_{LL+IM}	M_{FAT+IM}	Adjustment Factor	M_{DC1}	M_{DC2}	M_{DW}	Negative Moment	Span Length	Web Plate Depth, D_w	Flange Angles Out-to-out Depth, D_{oto}	Screening Criteria Met	Strength Check	Notes
		ft	ft		k-ft	k-ft		k-ft	k-ft	k-ft	-	ft	in	in	OK or NG	OK or NG	
5	XSec-8	44.5	623	1005	3053.5	849.7	0.495	467.8	135.2	113.6	No	155.75	70.0	70.5	OK	OK	
5	XSec-8	46.73	625.22	1005	3183.3	860.4	0.495	616.7	176.4	148.2	No	155.75	70.0	70.5	OK	OK	
5	XSec-8	55.63	634.13	558	3619.9	890.1	0.495	1119.2	312.9	262.9	No	155.75	70.0	70.5	OK	OK	
5	XSec-8	55.92	634.42	558	3631.7	890.5	0.495	1133.0	316.6	266.0	No	155.75	70.0	70.5	OK	OK	
5	XSec-9	55.92	634.42	558	3631.7	890.5	0.495	1133.0	316.6	266.0	No	155.75	70.0	70.5	OK	OK	
5	XSec-9	62.3	640.8	558	3849.8	893.8	0.495	1395.6	385.5	323.9	No	155.75	70.0	70.5	OK	OK	
5	XSec-9	66.75	645.25	558	3957.5	888.1	0.495	1531.2	419.7	352.6	No	155.75	70.0	70.5	OK	OK	
5	XSec-9	77.88	656.38	558	4060.9	843.8	0.495	1654.5	455.8	383.0	No	155.75	70.0	70.5	OK	OK	
5	XSec-9	89	667.5	558	3960.8	884.8	0.495	1532.0	420.9	353.6	No	155.75	70.0	70.5	OK	OK	
5	XSec-9	93.45	671.95	558	3846.9	888.9	0.495	1399.1	387.2	325.3	No	155.75	70.0	70.5	OK	OK	
5	XSec-9	99.92	678.42	558	3616.4	883.2	0.495	1136.3	317.9	267.1	No	155.75	70.0	70.5	OK	OK	
5	XSec-8	99.92	678.42	558	3616.4	883.2	0.495	1136.3	317.9	267.1	No	155.75	70.0	70.5	OK	OK	
5	XSec-8	100.13	678.63	558	3607.5	882.8	0.495	1126.3	315.3	264.9	No	155.75	70.0	70.5	OK	OK	
5	XSec-8	109.03	687.53	1005	3159.1	850.1	0.495	629.1	179.7	151.0	No	155.75	70.0	70.5	OK	OK	
5	XSec-8	111.25	689.75	1005	3026.3	838.7	0.495	481.2	138.7	116.5	No	155.75	70.0	70.5	OK	OK	
5	XSec-8	112.42	690.92	1005	2953.3	832.1	0.495	395.0	116.1	97.5	No	155.75	70.0	70.5	OK	OK	
5	XSec-3	112.42	690.92	1005	2953.3	832.1	0.495	395.0	116.1	97.5	No	155.75	70.0	70.5	OK	OK	
5	XSec-3	122.38	700.88	1005	2469.3	758.8	0.495	444.3	109.1	91.6	Yes	155.75	70.0	70.5	OK	OK	XSec-3 Controlling Fatigue Location
5	XSec-3	124.6	703.1	558	2550.7	739.5	0.495	656.3	167.1	140.4	Yes	155.75	70.0	70.5	OK	OK	
5	XSec-3	130	708.5	558	2782.9	687.8	0.495	1208.8	319.8	268.7	Yes	155.75	71.0	71.5	OK	NG	Strength Check Failure
5	XSec-4	130	708.5	558	2782.9	687.8	0.495	1208.8	319.8	268.7	Yes	155.75	71.0	71.5	OK	OK	
5	XSec-4	133.5	712	558	2965.8	671.0	0.495	1596.5	427.8	359.4	Yes	155.75	73.2	73.7	OK	OK	
5	XSec-4	136.75	715.25	558	3171.5	692.8	0.495	1987.8	534.2	448.8	Yes	155.75	76.5	77.0	OK	OK	
5	XSec-11	136.75	715.25	558	3171.5	692.8	0.495	1987.8	534.2	448.8	Yes	155.75	76.5	77.0	OK	OK	
5	XSec-11	140.18	718.68	558	3509.7	715.8	0.495	2423.4	653.0	548.6	Yes	155.75	81.1	81.6	OK	OK	
5	XSec-11	144.63	723.13	558	4003.8	745.8	0.495	3025.2	817.4	686.8	Yes	155.75	89.0	89.5	OK	OK	
5	XSec-11	154.75	733.25	558	5325.8	813.8	0.495	4546.2	1233.6	1036.5	Yes	155.75	114.7	115.2	OK	OK	
5	XSec-11	155.75	734.25	558	5469.8	820.5	0.495	4708.1	1277.9	1073.7	Yes	155.75	116.0	116.5	OK	OK	
6	XSec-11	0	734.25	558	5469.8	820.5	0.495	4708.1	1277.9	1073.7	Yes	155.75	116.0	116.5	OK	OK	
6	XSec-11	1	735.25	558	5323.8	790.5	0.495	4542.0	1232.9	1035.9	Yes	155.75	114.7	115.2	OK	OK	
6	XSec-11	11.13	745.38	558	3943.8	583.6	0.495	2974.8	808.0	678.9	Yes	155.75	89.0	89.5	OK	OK	
6	XSec-11	15.58	749.83	558	3413.1	546.3	0.495	2353.5	640.0	537.7	Yes	155.75	81.1	81.6	OK	OK	
6	XSec-11	17	751.25	558	3253.1	541.0	0.495	2163.1	588.6	494.5	Yes	155.75	79.0	79.5	OK	OK	
6	XSec-4	17	751.25	558	3253.1	541.0	0.495	2163.1	588.6	494.5	Yes	155.75	79.0	79.5	OK	OK	
6	XSec-4	22.25	756.5	558	2719.6	533.7	0.495	1495.2	409.1	343.7	Yes	155.75	73.2	73.7	OK	OK	
6	XSec-4	27.25	761.5	1005	2363.1	599.7	0.495	926.3	252.9	212.5	Yes	155.75	70.5	71.0	OK	OK	
6	XSec-3	27.25	761.5	1005	2363.1	599.7	0.495	926.3	252.9	212.5	Yes	155.75	70.5	71.0	OK	OK	
6	XSec-3	31.15	765.4	1005	2216.2	650.8	0.495	514.8	140.9	118.4	Yes	155.75	70.0	70.5	OK	OK	
6	XSec-3	33.38	767.63	1005	2151.9	679.2	0.495	292.4	80.9	68.0	Yes	155.75	70.0	70.5	OK	OK	
6	XSec-3	34.67	768.92	1005	2223.0	695.5	0.495	167.8	47.4	39.9	No	155.75	70.0	70.5	OK	OK	
6	XSec-0	34.67	768.92	1005	2223.0	695.5	0.495	167.8	47.4	39.9	No	155.75	70.0	70.5	NG	-	No Cover Plate
6	XSec-3	35.67	769.92	1005	2307.1	707.8	0.495	73.2	22.1	18.6	No	155.75	70.0	70.5	OK	OK	
6	XSec-3	44.37	778.62	1005	3059.8	810.8	0.495	673.3	173.8	146.0	No	155.75	70.0	70.5	OK	OK	

Span	Section	Location (from Support)	Distance (from Abut)	($ADTT_{sl}$) present = original	M_{LL+IM}	M_{FAT+IM}	Adjustment Factor	M_{DC1}	M_{DC2}	M_{DW}	Negative Moment	Span Length	Web Plate Depth, D_w	Flange Angles Out-to-out Depth, D_{oto}	Screening Criteria Met	Strength Check	Notes
		ft	ft		k-ft	k-ft		k-ft	k-ft	k-ft	-	ft	in	in	OK or NG	OK or NG	
6	XSec-5	44.37	778.62	1005	3059.8	810.8	0.495	673.3	173.8	146.0	No	155.75	70.0	70.5	OK	OK	
6	XSec-5	44.5	778.75	1005	3070.2	812.1	0.495	683.3	176.4	148.2	No	155.75	70.0	70.5	OK	OK	
6	XSec-5	46.73	780.97	558	3248.4	835.9	0.495	841.4	219.2	184.2	No	155.75	70.0	70.5	OK	OK	
6	XSec-5	55.63	789.88	558	3891.3	921.2	0.495	1378.3	362.3	304.4	No	155.75	70.0	70.5	OK	OK	
6	XSec-5	57.25	791.5	558	3994.9	934.0	0.495	1459.6	383.5	322.2	No	155.75	70.0	70.5	OK	OK	
6	XSec-10	57.25	791.5	558	3994.9	934.0	0.495	1459.6	383.5	322.2	No	155.75	70.0	70.5	OK	OK	
6	XSec-10	62.3	796.55	558	4287.5	969.5	0.495	1678.9	439.8	369.5	No	155.75	70.0	70.5	OK	OK	
6	XSec-10	66.75	801	558	4509.5	994.1	0.495	1829.3	477.2	401.0	No	155.75	70.0	70.5	OK	OK	
6	XSec-10	77.88	812.13	558	4882.4	1107.4	0.495	1992.1	521.5	438.2	No	155.75	70.0	70.5	OK	OK	
6	XSec-10	89	823.25	558	4985.1	1201.1	0.495	1901.4	495.2	416.1	No	155.75	70.0	70.5	OK	OK	
6	XSec-10	93.45	827.7	558	4961.3	1234.1	0.495	1775.9	465.6	391.2	No	155.75	70.0	70.5	OK	OK	
6	XSec-10	100.13	834.38	558	4848.5	1269.2	0.495	1512.2	399.9	336.0	No	155.75	70.0	70.5	OK	OK	
6	XSec-10	108.25	842.5	558	4580.8	1285.8	0.495	1069.8	285.5	239.9	No	155.75	70.0	70.5	OK	OK	XSec-10 Controlling Fatigue Location
6	XSec-5	108.25	842.5	558	4580.8	1285.8	0.495	1069.8	285.5	239.9	No	155.75	70.0	70.5	OK	OK	
6	XSec-5	109.03	843.28	558	4547.9	1286.0	0.495	1020.5	272.6	229.0	No	155.75	70.0	70.5	OK	OK	
6	XSec-5	111.25	845.5	558	4445.9	1285.1	0.495	872.7	233.6	196.3	No	155.75	70.0	70.5	OK	OK	
6	XSec-5	122.38	856.63	1005	3805.6	1247.3	0.495	45.4	3.6	3.0	No	155.75	70.0	70.5	OK	OK	
6	XSec-5	124.6	858.85	1005	3838.3	1233.0	0.495	257.7	59.5	50.0	Yes	155.75	70.0	70.5	OK	OK	XSec-5 Controlling Fatigue Location
6	XSec-5	125.21	859.46	1005	3856.1	1229.0	0.495	317.3	75.3	63.2	Yes	155.75	70.0	70.5	OK	OK	
6	XSec-3	125.21	859.46	1005	3856.1	1229.0	0.495	317.3	75.3	63.2	Yes	155.75	70.0	70.5	OK	NG	Strength Check Failure
6	XSec-3	128.75	863	1005	3960.1	1205.5	0.495	678.8	171.4	144.0	Yes	155.75	70.5	71.0	OK	NG	Strength Check Failure
6	XSec-8	128.75	863	1005	3960.1	1205.5	0.495	678.8	171.4	144.0	Yes	155.75	70.5	71.0	OK	OK	XSec-8 Controlling Fatigue Location
6	XSec-8	133.5	867.75	1005	4099.7	1164.8	0.495	1200.7	311.8	262.0	Yes	155.75	73.2	73.7	OK	OK	
6	XSec-8	136.5	870.75	1005	4190.4	1134.4	0.495	1533.5	406.9	341.9	Yes	155.75	76.8	77.3	OK	OK	
6	XSec-9	136.5	870.75	1005	4190.4	1134.4	0.495	1533.5	406.9	341.9	Yes	155.75	76.8	77.3	OK	OK	
6	XSec-9	140.18	874.43	558	4301.6	1091.3	0.495	2035.3	530.6	445.8	Yes	155.75	81.1	81.6	OK	OK	
6	XSec-9	144.63	878.88	558	4436.3	1030.6	0.495	2641.1	690.7	580.3	Yes	155.75	89.0	89.5	OK	OK	XSec-9 Controlling Strength Location
6	XSec-9	154.75	889	558	4817.4	971.3	0.495	4168.2	1097.3	921.9	Yes	155.75	114.7	115.2	OK	OK	
6	XSec-9	155.75	890	558	4906.3	979.2	0.495	4330.5	1140.6	958.3	Yes	155.75	116.0	116.5	OK	OK	
7	XSec-9	0	890	558	4906.3	979.2	0.495	4330.5	1140.6	958.3	Yes	155.75	116.0	116.5	OK	OK	
7	XSec-9	1	891	558	4746.3	948.5	0.495	4167.5	1097.2	921.9	Yes	155.75	114.7	115.2	OK	OK	
7	XSec-9	11.13	901.13	558	3168.8	650.5	0.495	2628.7	689.4	579.2	Yes	155.75	89.0	89.5	OK	OK	
7	XSec-9	14.75	904.75	558	2625.7	544.6	0.495	2128.9	557.8	468.6	Yes	155.75	82.4	82.9	OK	OK	
7	XSec-8	14.75	904.75	558	2625.7	544.6	0.495	2128.9	557.8	468.6	Yes	155.75	82.4	82.9	OK	OK	
7	XSec-8	15.58	905.58	558	2503.3	520.4	0.495	2018.6	528.8	444.3	Yes	155.75	81.1	81.6	OK	OK	
7	XSec-8	21	911	558	1713.8	361.9	0.495	1326.6	348.4	292.7	Yes	155.75	74.4	74.9	OK	OK	
7	XSec-3	21	911	558	1713.8	361.9	0.495	1326.6	348.4	292.7	Yes	155.75	74.4	74.9	OK	OK	
7	XSec-3	22.25	912.25	558	1534.8	325.3	0.495	1174.7	309.2	259.7	Yes	155.75	73.2	73.7	OK	OK	
7	XSec-3	27.14	917.14	1005	848.4	182.3	0.495	628.3	164.6	138.3	Yes	155.75	70.5	71.0	OK	OK	
7	XSec-3	28.92	918.92	1005	603.6	130.4	0.495	440.5	115.4	97.0	Yes	155.75	70.1	70.6	OK	OK	
7	XSec-0	28.92	918.92	1005	603.6	130.4	0.495	440.5	115.4	97.0	Yes	155.75	70.1	70.6	OK	OK	8.75' (1.5D) from Pin -> OK
7	XSec-0	31.15	921.15	1005	299.3	65.1	0.495	212.5	56.2	47.2	Yes	155.75	70.0	70.5	OK	OK	8.75' (1.5D) from Pin -> OK
7	XSec-0	32.03	922.03	1005	180.7	39.4	0.495	125.4	33.7	28.3	Yes	155.75	70.0	70.5	OK	OK	8.75' (1.5D) from Pin -> OK

Span	Section	Location (from Support)	Distance (from Abut)	($ADTT_{sl}$) present = original	M_{LL+IM}	M_{FAT+IM}	Adjustment Factor	M_{DC1}	M_{DC2}	M_{DW}	Negative Moment	Span Length	Web Plate Depth, D_w	Flange Angles Out-to-out Depth, D_{oto}	Screening Criteria Met	Strength Check	Notes
		ft	ft		k-ft	k-ft		k-ft	k-ft	k-ft	-	ft	in	in	OK or NG	OK or NG	
7	XSec-0	33.38	923.38	1005	0.4	0.1	0.495	0.3	0.1	0.1	No	155.75	70.0	70.5	NG	-	Pin and Hanger Location
7	XSec-0	34.73	924.73	1005	178.3	39.0	0.495	122.6	32.8	27.5	No	155.75	70.0	70.5	OK	OK	8.75' (1.5D) from Pin -> OK
7	XSec-0	39.62	929.62	1005	779.6	170.1	0.495	517.6	142.4	119.6	No	155.75	70.0	70.5	OK	OK	8.75' (1.5D) from Pin -> OK
7	XSec-0	43.08	933.08	558	1165.8	254.0	0.495	771.5	211.9	178.0	No	155.75	70.0	70.5	NG	-	Outside 1.5D by 0.96'
7	XSec-3	43.08	933.08	558	1165.8	254.0	0.495	771.5	211.9	178.0	No	155.75	70.0	70.5	OK	OK	
7	XSec-3	44.5	934.5	558	1314.5	286.2	0.495	869.3	238.3	200.2	No	155.75	70.0	70.5	OK	OK	
7	XSec-3	44.51	934.51	558	1314.7	286.3	0.495	869.4	238.4	200.3	No	155.75	70.0	70.5	OK	OK	
7	XSec-3	46.73	936.72	558	1536.2	334.3	0.495	1006.9	277.4	233.0	No	155.75	70.0	70.5	OK	OK	
7	XSec-3	54.79	944.79	558	2228.7	484.0	0.495	1431.2	395.4	332.2	No	155.75	70.0	70.5	OK	OK	
7	XSec-4	54.79	944.79	558	2228.7	484.0	0.495	1431.2	395.4	332.2	No	155.75	70.0	70.5	OK	OK	
7	XSec-4	55.63	945.63	558	2290.7	497.3	0.495	1468.4	405.5	340.7	No	155.75	70.0	70.5	OK	OK	
7	XSec-4	62.3	952.3	558	2716.8	593.6	0.495	1716.3	471.7	396.3	No	155.75	70.0	70.5	OK	OK	
7	XSec-4	66.75	956.75	558	2937.4	648.7	0.495	1834.1	501.6	421.5	No	155.75	70.0	70.5	OK	OK	
7	XSec-4	77.88	967.88	558	3299.5	739.7	0.495	1912.7	526.9	442.7	No	155.75	70.0	70.5	OK	OK	
7	XSec-4	89	979	558	3376.4	771.2	0.495	1752.0	481.2	404.3	No	155.75	70.0	70.5	OK	OK	
7	XSec-4	93.45	983.45	558	3336.4	769.4	0.495	1606.0	443.1	372.3	No	155.75	70.0	70.5	OK	OK	
7	XSec-4	100.13	990.13	558	3217.7	775.7	0.495	1314.8	364.7	306.4	No	155.75	70.0	70.5	OK	OK	
7	XSec-4	108.79	998.79	558	2925.1	753.6	0.495	809.0	224.8	188.9	No	155.75	70.0	70.5	OK	OK	
7	XSec-3	108.79	998.79	558	2925.1	753.6	0.495	809.0	224.8	188.9	No	155.75	70.0	70.5	OK	OK	
7	XSec-3	109.03	999.03	1005	2915.3	752.6	0.495	793.3	220.4	185.2	No	155.75	70.0	70.5	OK	OK	
7	XSec-3	111.25	1001.25	1005	2816.9	742.3	0.495	639.0	177.1	148.8	No	155.75	70.0	70.5	OK	OK	
7	XSec-3	115.5	1005.5	1005	2606.3	717.1	0.495	301.8	86.9	73.0	No	155.75	70.0	70.5	OK	OK	
7	XSec-3	120.5	1010.5	1005	2326.4	679.6	0.495	137.4	32.6	27.4	No	155.75	70.0	70.5	OK	OK	
7	XSec-0	120.5	1010.5	1005	2326.4	679.6	0.495	137.4	32.6	27.4	No	155.75	70.0	70.5	NG	-	No Cover Plate
7	XSec-3	122.38	1012.38	1005	2245.5	664.0	0.495	314.2	81.3	68.3	Yes	155.75	70.0	70.5	OK	OK	
7	XSec-3	124.6	1014.6	1005	2325.6	644.5	0.495	531.5	141.4	118.8	Yes	155.75	70.0	70.5	OK	OK	
7	XSec-3	130.5	1020.5	558	2572.1	586.7	0.495	1129.2	314.7	264.4	Yes	155.75	71.5	72.0	OK	OK	
7	XSec-6	130.5	1020.5	558	2572.1	586.7	0.495	1129.2	314.7	264.4	Yes	155.75	71.5	72.0	OK	OK	
7	XSec-6	133.5	1023.5	558	2721.3	555.2	0.495	1493.4	410.7	345.1	Yes	155.75	73.2	73.7	OK	OK	
7	XSec-6	137.09	1027.09	558	2958.9	522.8	0.495	1934.7	531.9	446.9	Yes	155.75	76.9	77.4	OK	OK	
7	XSec-7	137.09	1027.09	558	2958.9	522.8	0.495	1934.7	531.9	446.9	Yes	155.75	76.9	77.4	OK	OK	XSec-7 Controlling Fatigue Location
7	XSec-7	140.18	1030.18	558	3217.2	538.4	0.495	2335.2	642.2	539.6	Yes	155.75	81.1	81.6	OK	OK	
7	XSec-7	144.63	1034.63	558	3651.8	561.0	0.495	2946.4	811.0	681.4	Yes	155.75	89.0	89.5	OK	OK	
7	XSec-7	154.75	1044.75	558	4853.5	612.2	0.495	4486.7	1237.1	1039.4	Yes	155.75	114.7	115.2	OK	OK	
7	XSec-7	155.75	1045.75	558	4986.8	617.1	0.495	4649.2	1282.0	1077.1	Yes	155.75	116.0	116.5	OK	OK	
8	XSec-7	0	1045.75	558	4986.8	617.1	0.495	4649.2	1282.0	1077.1	Yes	155.75	116.0	116.5	OK	OK	
8	XSec-7	1	1046.75	558	4846.9	597.7	0.495	4488.8	1237.5	1039.8	Yes	155.75	114.7	115.2	OK	OK	
8	XSec-7	11.13	1056.88	558	3567.7	518.4	0.495	2982.7	819.6	688.6	Yes	155.75	89.0	89.5	OK	OK	
8	XSec-7	15.58	1061.33	558	3088.2	495.5	0.495	2387.3	654.6	550.0	Yes	155.75	81.1	81.6	OK	OK	
8	XSec-7	18.67	1064.42	558	2783.9	495.4	0.495	1996.1	546.5	459.1	Yes	155.75	76.9	77.4	OK	OK	
8	XSec-6	18.67	1064.42	558	2783.9	495.4	0.495	1996.1	546.5	459.1	Yes	155.75	76.9	77.4	OK	OK	
8	XSec-6	22.25	1068	558	2477.2	536.0	0.495	1566.9	428.2	359.7	Yes	155.75	73.2	73.7	OK	OK	
8	XSec-6	23.75	1069.5	558	2360.9	552.2	0.495	1371.5	380.8	319.9	Yes	155.75	72.5	73.0	OK	OK	

Span	Section	Location (from Support)	Distance (from Abut)	($ADTT_{sl}$) present = original	M_{LL+IM}	M_{FAT+IM}	Adjustment Factor	M_{DC1}	M_{DC2}	M_{DW}	Negative Moment	Span Length	Web Plate Depth, D_w	Flange Angles Out-to-out Depth, D_{oto}	Screening Criteria Met	Strength Check	Notes
		ft	ft		k-ft	k-ft		k-ft	k-ft	k-ft	-	ft	in	in	OK or NG	OK or NG	
8	XSec-3	23.75	1069.5	558	2360.9	552.2	0.495	1371.5	380.8	319.9	Yes	155.75	72.5	73.0	OK	OK	
8	XSec-3	31.15	1076.9	1005	2048.8	626.5	0.495	634.8	166.2	139.7	Yes	155.75	70.0	70.5	OK	OK	
8	XSec-3	32.75	1078.5	1005	1994.6	641.0	0.495	482.1	123.8	104.0	Yes	155.75	70.0	70.5	OK	OK	
8	XSec-0	32.75	1078.5	1005	1994.6	641.0	0.495	482.1	123.8	104.0	Yes	155.75	70.0	70.5	NG	-	No Cover Plate
8	XSec-0	33.38	1079.13	1005	1974.5	646.7	0.495	423.9	107.7	90.5	Yes	155.75	70.0	70.5	NG	-	No Cover Plate
8	XSec-3	38	1083.75	1005	2206.5	686.0	0.495	15.1	4.6	3.9	No	155.75	70.0	70.5	OK	OK	
8	XSec-3	44.5	1090.25	1005	2636.9	732.8	0.495	493.6	141.8	119.1	No	155.75	70.0	70.5	OK	OK	
8	XSec-3	46.73	1092.47	1005	2767.8	745.4	0.495	640.2	183.1	153.8	No	155.75	70.0	70.5	OK	OK	
8	XSec-3	50	1095.75	558	2946.6	762.6	0.495	840.3	238.9	200.7	No	155.75	70.0	70.5	OK	OK	
8	XSec-4	50	1095.75	558	2946.6	762.6	0.495	840.3	238.9	200.7	No	155.75	70.0	70.5	OK	OK	
8	XSec-4	55.63	1101.38	558	3211.8	783.8	0.495	1136.2	320.2	269.1	No	155.75	70.0	70.5	OK	OK	
8	XSec-4	62.3	1108.05	558	3447.1	793.9	0.495	1407.8	393.2	330.4	No	155.75	70.0	70.5	OK	OK	
8	XSec-4	66.75	1112.5	558	3558.8	792.7	0.495	1541.4	427.7	359.4	No	155.75	70.0	70.5	OK	OK	
8	XSec-4	77.88	1123.63	558	3667.8	762.1	0.495	1669.9	464.3	390.1	No	155.75	70.0	70.5	OK	OK	XSec-4 Controlling Strength Location
8	XSec-4	89	1134.75	558	3573.1	798.2	0.495	1558.8	430.0	361.3	No	155.75	70.0	70.5	OK	OK	
8	XSec-4	93.45	1139.2	558	3466.0	799.8	0.495	1428.6	396.5	333.1	No	155.75	70.0	70.5	OK	OK	
8	XSec-4	100.13	1145.88	558	3236.9	790.1	0.495	1161.1	324.8	272.9	No	155.75	70.0	70.5	OK	OK	
8	XSec-4	105	1150.75	558	3015.0	772.7	0.495	911.5	256.3	215.4	No	155.75	70.0	70.5	OK	OK	
8	XSec-3	105	1150.75	558	3015.0	772.7	0.495	911.5	256.3	215.4	No	155.75	70.0	70.5	OK	OK	
8	XSec-3	109.03	1154.78	1005	2802.6	752.5	0.495	671.9	189.6	159.3	No	155.75	70.0	70.5	OK	OK	
8	XSec-3	111.25	1157	1005	2673.5	740.0	0.495	526.4	148.6	124.9	No	155.75	70.0	70.5	OK	OK	
8	XSec-3	117	1162.75	1005	2302.4	700.0	0.495	89.9	29.7	25.0	No	155.75	70.0	70.5	OK	OK	
8	XSec-0	117	1162.75	1005	2302.4	700.0	0.495	89.9	29.7	25.0	No	155.75	70.0	70.5	NG	-	No Cover Plate
8	XSec-3	120.75	1166.5	1005	2073.0	669.3	0.495	227.2	58.0	48.7	No	155.75	70.0	70.5	OK	OK	
8	XSec-3	122.38	1168.13	1005	2034.1	655.2	0.495	372.6	98.5	82.8	Yes	155.75	70.0	70.5	OK	OK	
8	XSec-3	124.6	1170.35	1005	2108.5	635.2	0.495	579.0	156.4	131.4	Yes	155.75	70.0	70.5	OK	OK	
8	XSec-3	129.75	1175.5	558	2314.3	584.7	0.495	1092.8	301.5	253.3	Yes	155.75	70.9	71.4	OK	OK	
8	XSec-6	129.75	1175.5	558	2314.3	584.7	0.495	1092.8	301.5	253.3	Yes	155.75	70.9	71.4	OK	OK	XSec-6 Controlling Fatigue Location
8	XSec-6	133.5	1179.25	558	2532.4	545.2	0.495	1497.7	416.7	350.1	Yes	155.75	73.2	73.7	OK	OK	
8	XSec-6	137.09	1182.84	558	2841.6	516.4	0.495	1925.1	534.2	448.8	Yes	155.75	76.9	77.4	OK	OK	
8	XSec-12	137.09	1182.84	558	2841.6	516.4	0.495	1925.1	534.2	448.8	Yes	155.75	76.9	77.4	OK	OK	XSec-12 Controlling Fatigue Location
8	XSec-12	140.18	1185.93	558	3143.6	532.4	0.495	2313.6	641.4	538.9	Yes	155.75	81.1	81.6	OK	OK	
8	XSec-12	144.63	1190.38	558	3624.1	555.4	0.495	2907.7	805.6	676.9	Yes	155.75	89.0	89.5	OK	OK	
8	XSec-12	154.75	1200.5	558	4904.0	607.9	0.495	4410.0	1221.5	1026.3	Yes	155.75	114.7	115.2	OK	OK	
8	XSec-12	155.75	1201.5	558	5042.9	614.7	0.495	4568.8	1265.4	1063.2	Yes	155.75	116.0	116.5	OK	OK	XSec-12 Controlling Strength Location

Bridge is symmetric about the above specified point, thus all points along length of bridge can be correlated accordingly

Appendix 1D. Bridge Geometry, Material Properties, and Loading

Fracture Critical Members

- Riveted built-up plate girders

- The riveted, built-up, plate transverse floor beams are not spaced on center at intervals greater than 14 ft and stringers are continous over the beams; therefore, the transverse floor beams are not considered to be fracture critical bridge members. [BIRM Sec 8.3.2 {pg. 8.3.8}]

Material Properties

Concrete

$f'_c := 3$ ksi Type F (original slab)
$w_c := .145$ kcf
$K_1 := 1.0$

$E_c := 120000 \cdot K_1 \cdot {w_c}^{2.0} \cdot {f'_c}^{0.33} = 3625.495$ ksi [AASHTO LRFD BDS Eq 5.4.2.4-1]

Steel

$F_y := 33\ ksi$ [AASHTO MBE Table 6A.6.2.1-1]

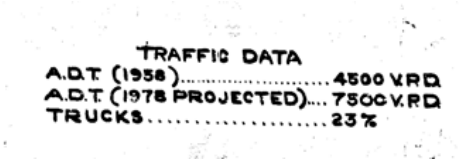
$F_u := 66\ ksi$ [AASHTO MBE Table 6A.6.2.1-1]

Traffic Data - for information only because true cycles used for evaluation

Original

$ADT_o := 4500$ vehicles per day for both twin bridges

$truck_{per} := 23\%$



Screenshot from 1958 plans

There are two bridges carrying traffic in opposite directions. Per AASHTO LRFD BDS C3.6.1.4.2, 55% of the bidirectional ADTT is used

$directional := 55\%$

$p := 0.85$ [AASHTO LRFD BDS Table 3.6.1.4.2-1]

Average original number of trucks per day in a single lane [AASHTO LRFD BDS Eq 3.6.1.4.2-1]

$ADTT_{sl_o} := ADT_o \cdot truck_{per} \cdot directional \cdot p = 483.863$

Present

Largest estimated ADT for 2-way traffic during lifetime of the bridge (taken from 2002 count) using INDOT's online database for vehicle counts

$ADT := 13180$

$ADT := 12500$

$truck_{per} := 26\%$ From Inspection Report

There are two superstructures carrying traffic in opposite directions. Per AASHTO LRFD BDS C3.6.1.4.2, 55% of the bidirectional ADTT is used

$directional := 55\%$

$p := 0.85$ [AASHTO LRFD BDS Table 3.6.1.4.2-1]

Average present number of trucks per day in a single lane [AASHTO LRFD BDS Eq 3.6.1.4.2-1]

$ADTT_{sl_present} := ADT \cdot truck_{per} \cdot directional \cdot p = 1519.375$

Limit

$ADT_{Max} := 20000$ Vehicles per lane per day [AAHSTO LRFD BDS C3.6.1.4.2]

$truck_{per} := 26\%$ $lanes := 2$

$p := 0.85$ [AASHTO LRFD BDS Table 3.6.1.4.2-1]

$ADTT_{sl_limit} := ADT_{Max} \cdot truck_{per} \cdot lanes \cdot p = 8840$ Trucks per lane per day

Additional Parameters

$g := 1.0\%$ Exepected Annual Growth Rate. Conservative growth rate from INDOT 2020 Growth Rate data [https://www.in.gov/indot/files/INDOT_2020_Adjustment_Factors.pdf]

$n_L := 2$ Number of striped lanes

$R_s := 1.0$ Stress-Range Estimate Partial LF, [MBE Table 7.2.2.1-1]

Number of Stress-Range Cycles per Truck

$n := 1.5$ Near Interior Supports = Distance 0.1*span length

$n := 1$ Elsewhere [AAHSTO LRFD BDS Table 6.6.1.2.5-2]

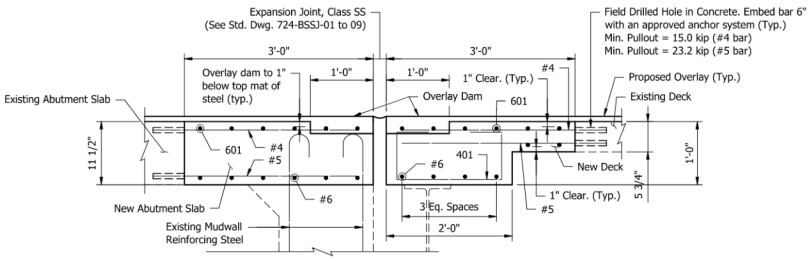
$R_r := 1.0$ Resistance Factor for Evaulation - Minimum Life [MBE Table 7.2.5.1-1]

Geometry for Dead Load Determination

Deck

$$t_{deck} := 5\ in + \frac{3}{4}\ in$$

$$t_{overlay} := 2\ in + \frac{3}{4}\ in$$



SECTION A-A

Scale: 1" = 1'-0"

Eff Flange Width

$$w_{overhang} := 4\ ft$$

$$spac_{girder} := 6\ ft + 1.5\ in$$

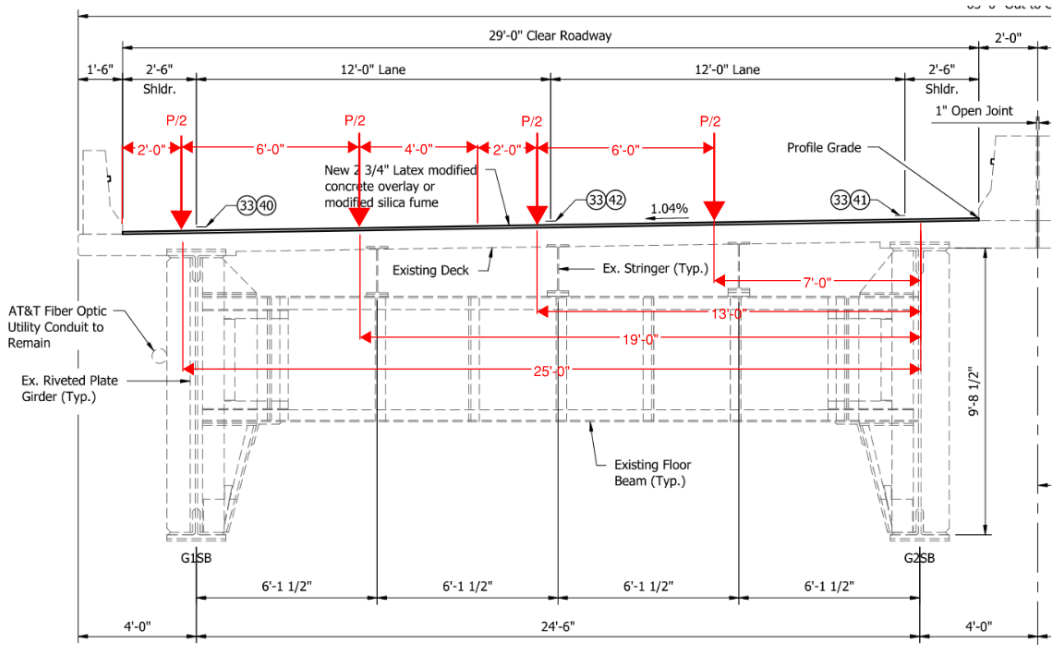
$$w_{eff} := w_{overhang} + \frac{spac_{girder}}{2} = 84.75\ in$$

(A) Remove existing 2 1/2" overlay and surface mill 1/4" of existing bridge deck, perform hydrodemolition and partial and full depth patching as required. Install new 2 3/4" latex modified concrete overlay or 2 3/4" Silica Fume Modified Structural Concrete. (See Provisions for details)

Trib Slab Width - [deck dead load is assumed to be split in half between the girders]

$$\frac{29\ ft + 1.5\ ft + 2.5\ ft}{2} = 198\ in$$

Live Load Distribution Factors - Using Lever Rule



Multiple (29'-0" Clear Roadway can only fit two HL93 trucks)

$$24.5 \cdot R = 25 \cdot \frac{P}{2} + 19 \cdot \frac{P}{2} + 13 \cdot \frac{P}{2} + 7 \cdot \frac{P}{2}$$

$$24.5 \cdot R = \frac{25 + 19 + 13 + 7}{2} \cdot P \rightarrow 24.5 \cdot R = 32 \cdot P$$

$$R = \frac{32}{24.5} \cdot P \qquad R_{mult} := \frac{32}{24.5} = 1.306$$

Table 3.6.1.1.2-1—Multiple Presence Factors, *m*

[AAHSTO LRFD Table 3.6.1.1.2-1]

Number of Loaded Lanes	Multiple Presence Factors, *m*
1	1.20
2	1.00
3	0.85
>3	0.65

$m_1 := 1.20$

$m_2 := 1.00$

$DF_{Multiple} := R_{mult} \cdot m_2 = 1.306$

Single

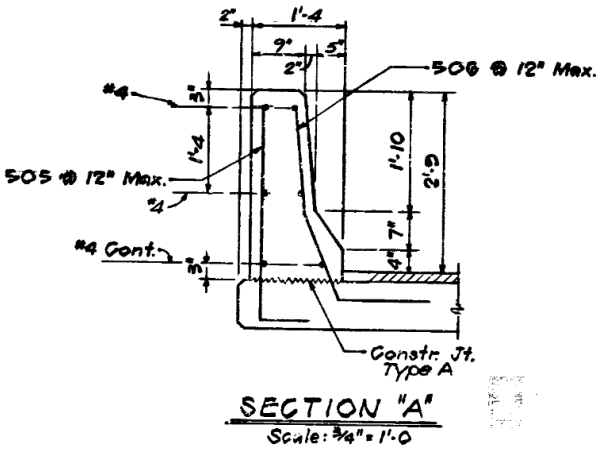
$$24.5 \cdot R = 25 \cdot \frac{P}{2} + 19 \cdot \frac{P}{2}$$

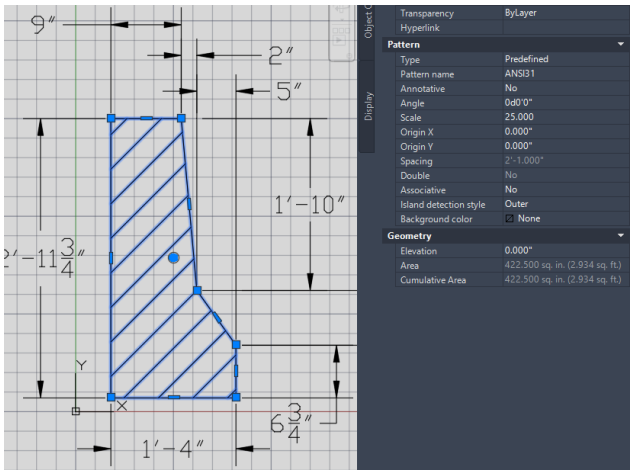
$$24.5 \cdot R = \frac{25 + 19}{2} \cdot P \rightarrow 24.5 \cdot R = 22 \cdot P$$

$$R = \frac{22}{24.5} \cdot P \qquad R_{single} := \frac{22}{24.5} = 0.898$$

$DF_{Single} := R_{single} \cdot m_1 = 1.078$

Outside Barrier (No Railings)



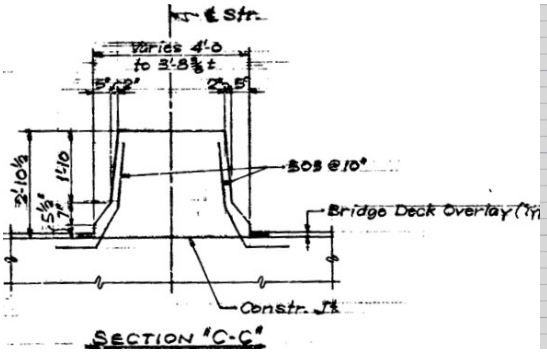


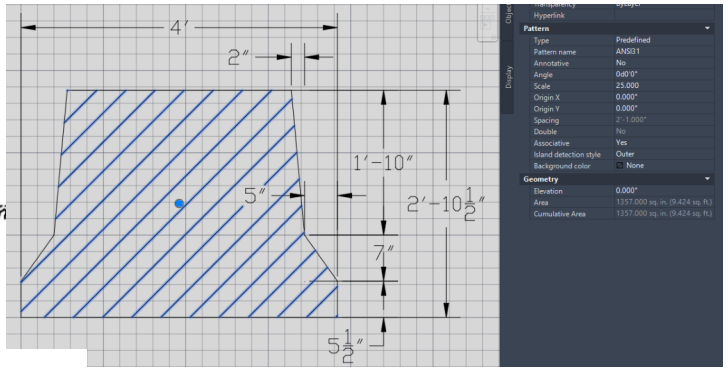
$A_{Total_Barrier} := 2.934\ ft^2$

$w_{Class3} := 150\ \frac{lbf}{ft^3} = 0.15\ \frac{kip}{ft^3}$ Class C Concrete

$DL_{Barrier} := A_{Total_Barrier} \cdot w_{Class3} = 0.44\ \frac{kip}{ft}$ Per Barrier

Median Barrier (No Railings)





NOTES:
- Reconstructed Conc. Median Railing to be paid for as Class "C" Concrete Median Railing.

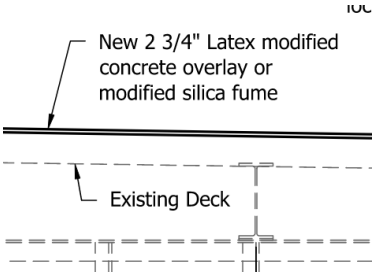
Class C Concrete

$A_{Total_Median} := 9.424\ ft^2$

$DL_{Median} := \frac{A_{Total_Median} \cdot w_{Class3}}{2} = 0.707\ \frac{kip}{ft}$ One side of median

$Total_{Barrier\&Median} := \frac{DL_{Barrier} + DL_{Median}}{2} = 0.573\ \frac{kip}{ft}$ per girder

Overlay



$Depth_{Overlay} := 2.75\ in$

$Width_{Overlay} := 29\ ft$

$A_{Overlay} := Depth_{Overlay} \cdot Width_{Overlay} = 6.646\ ft^2$

Weight of LMC concrete is slightly reduced so, 145 lbs/cubic foot was assumed and that each girder will take half of the overlay DL

$w_{LMC} := 0.145\ \frac{kip}{ft^3}$

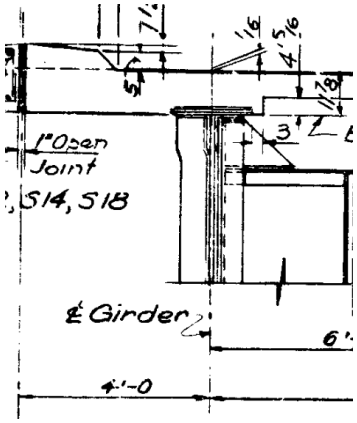
$DL_{Overlay} := \frac{A_{Overlay} \cdot w_{LMC}}{2} = 0.482\ \frac{kip}{ft}$ Per Girder

Haunch

$H_{Haunch_G1} := 4\ in + \frac{15}{16}\ in = 4.938\ in$

W_{Haunch_G1} = overhang + web/2 + angle + haunch

$W_{Haunch_G1} := 4\ ft + \frac{0.5\ in}{2} + 8\ in + 3\ in = 59.25\ in$



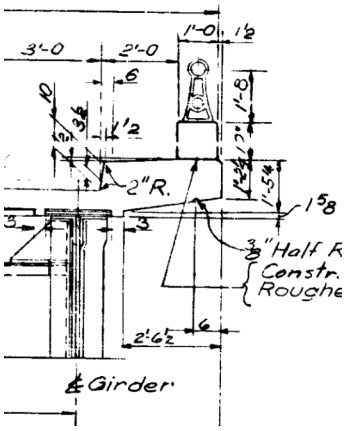
Sheet S27 (1958 Plans)

$H_{Haunch_G2} := 1\ in + \frac{7}{8}\ in = 1.875\ in$

Wtihout having field measurements of the true haunch sizes, it was determined reasonable and conservative to use average haunch height and the max haunch width in determing the area of the haunch.

$H_{Haunch_avg} := \frac{H_{Haunch_G1} + H_{Haunch_G2}}{2} = 3.406\ in$

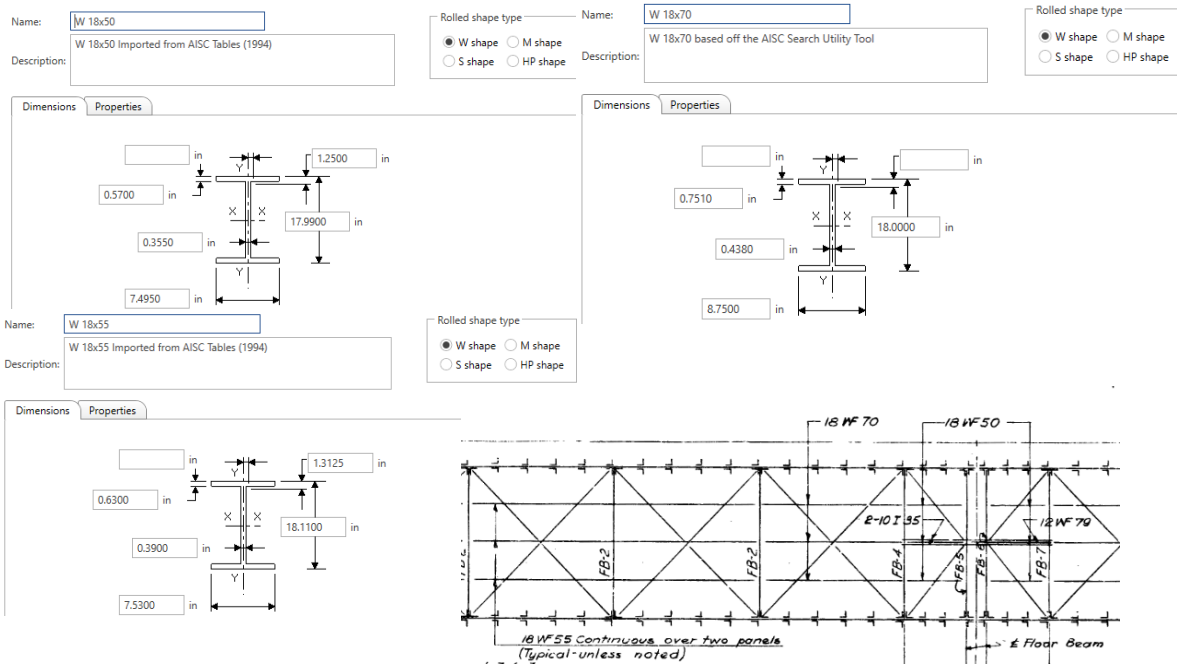
$A_{Haunch} := H_{Haunch_avg} \cdot W_{Haunch_G1} = 201.82\ in^2$



Sheet S27 (1958 Plans)

Stringers

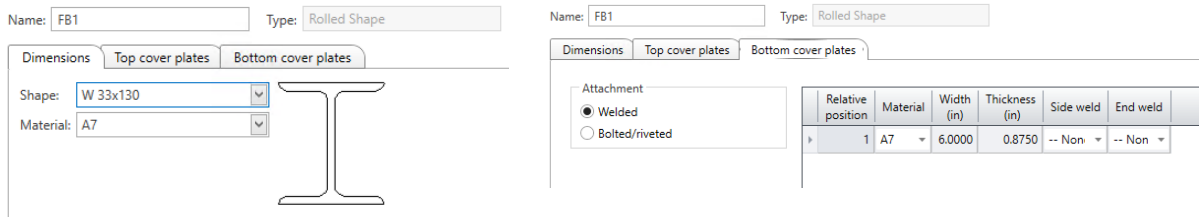
Three stringers spaced at 6'-1 1/2"
Stringer shapes consisted of 18WF50 and 18WF70 at hinge locations and 18WF55 at remaining locations.



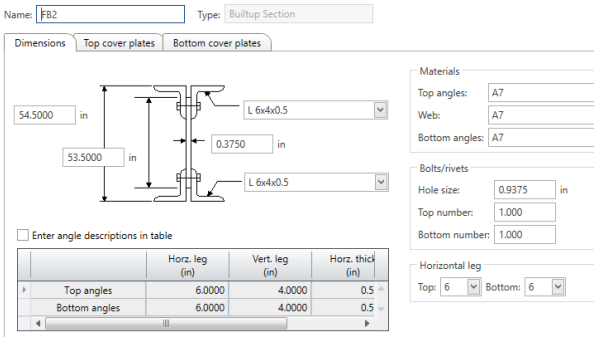
Floor Beams

7 variations of floor beams spaced at 22'-3" outside of hinge locations and 9'-9 5/16" at hinge locations for a total of 117 Floor Beams
Self load of beams was calculated by BrR
Using % self load determined in Michael Baker's Load Rating of the bridge completed in 2018
Layout/placement of floor beams can be found in full plan set

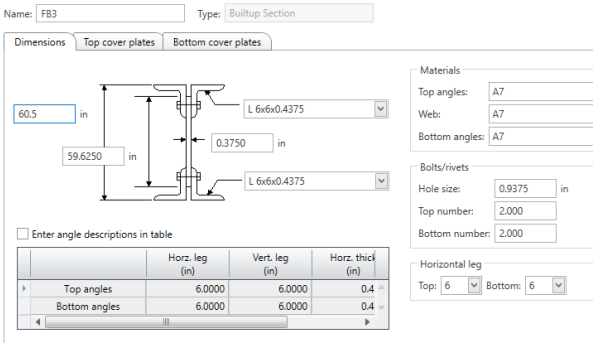
Floor Beam 1: 10% of Self Load



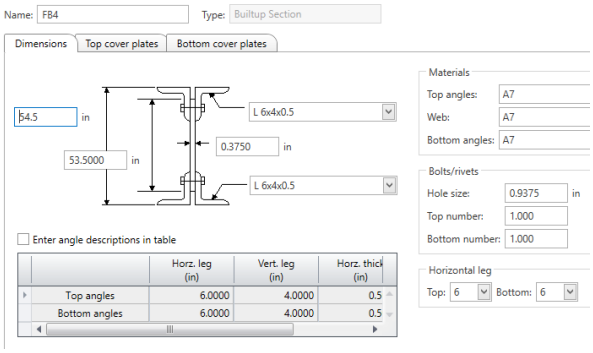
Floor Beam 2: 21% of Self Load



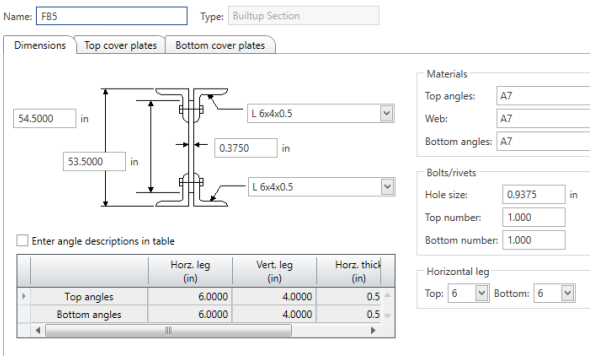
Floor Beam 3: 50% of Self Load



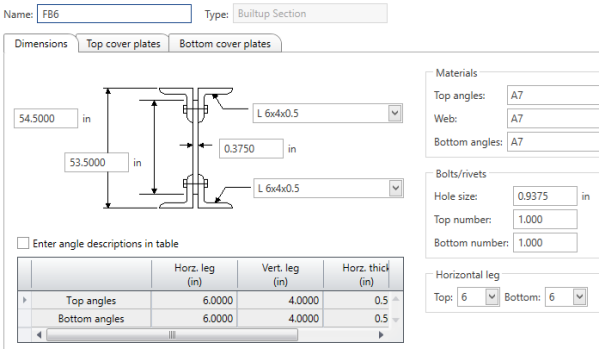
Floor Beam 4: 43% of Self Load



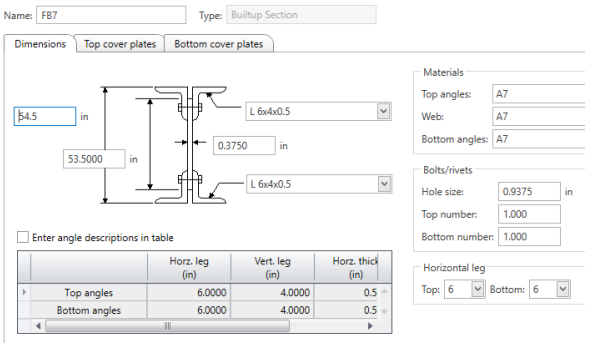
Floor Beam 5: 127% of Self Load



Floor Beam 6: 127% of Self Load

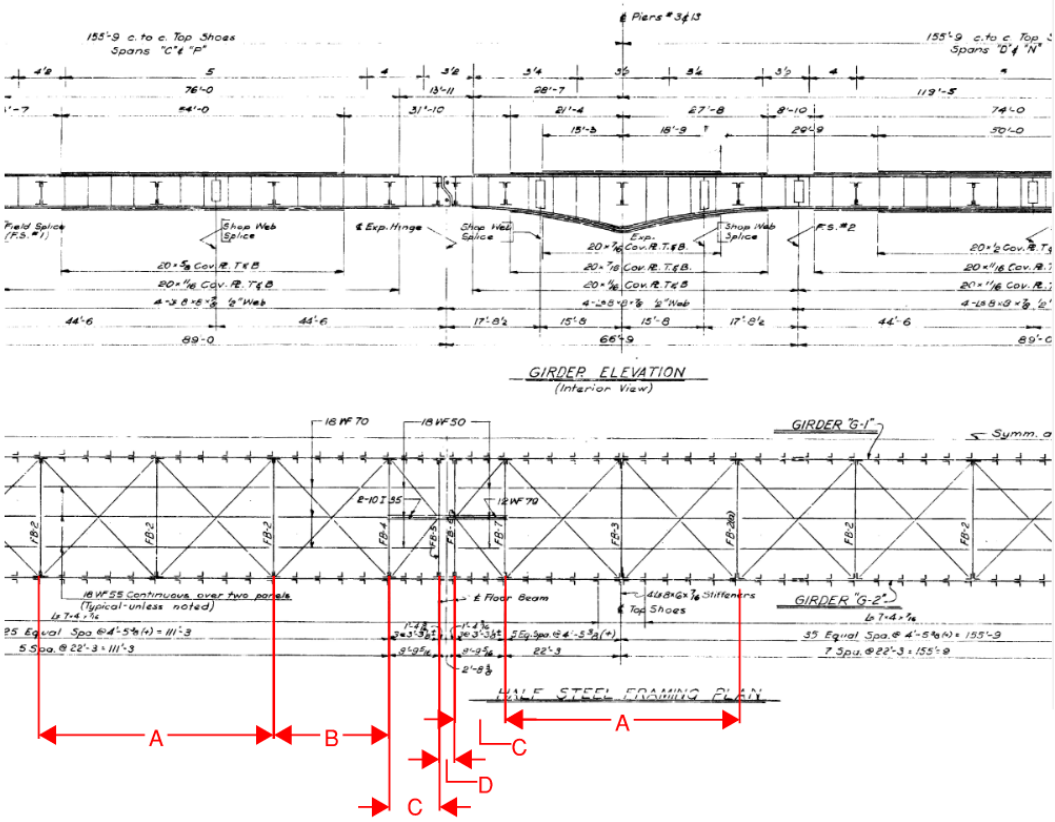


Floor Beam 7: 43% of Self Load



FB reactions on girders from Michael Baker's BrR Model were verified. See below summary of verification

Stringer reactions on FB were computed using BrR with using only Self Dead Load



2 @22'-3" Stringer Reactions [A]			
	S1	S2	S3
FB1	0.46	0.46	0.46
FB2	1.534	1.534	1.534
FB3	0.46	0.46	0.46

1 @22'-3" Stringer Reactions [B]			
	S1	S2	S3
FB1	0.78	0.78	0.78
FB2	0.78	0.78	0.78

1 @9'-9 5/16" Stringer Reactions [C]			
	S1	S2	S3
FB1	0.24	0.24	0.24
FB2	0.24	0.24	0.24

1 @2'-8 3/8" Stringer Reactions [D]			
	S1	S2	S3
FB1	0.068	0.068	0.068
FB2	0.068	0.068	0.068

Floor Beam Reactions [Self + Add Load]			
	Self [kip]	Add [kip]	Sum [kip]
FB1	1.82	0.18	2
FB2	1.63	0.34	1.97
FB3	1.78	0.91	2.69
FB4	1.63	0.7	2.33
FB5	1.63	2.07	3.7
FB6	1.63	2.07	3.7
FB7	1.63	0.7	2.33

FB reactions from self and additional dead load were computed using BrR

Point loads on girders were calculated using floor beam reactions and stringer reactions that reflected the specific floor beam and stringer situation for the given location. It was assumed that the stringer loads were split evenly between each of the girders.

FB effects on Girder (symmetrical about FB59)				
BrR Name	FB Type	Left Stringer Type	Right Stringer Type	Load [kip]
FB1	1	A	A	2.69
FB2	2	A	A	4.271
FB3	2	A	A	3.35
FB4	2	A	A	4.271
FB5	2	A	A	3.35
FB6	3	A	A	4.991
FB7	2	A	A	3.35
FB8	2	A	A	4.271
FB9	2	A	A	3.35
FB10	2	A	A	4.271
FB11	2	A	A	3.35
FB12	2	A	A	4.271
FB13	3	A	A	4.07
FB14	2	A	A	4.271
FB15	2	A	A	3.35
FB16	2	A	A	4.271
FB17	2	A	B	3.83
FB18	4	B	C	3.86
FB19	5	C	D	4.162
FB20	6	D	C	4.162
FB21	7	C	A	3.38
FB22	3	A	A	4.991
FB23	2	A	A	3.35
FB24	2	A	A	4.271
FB25	2	A	A	3.35
FB26	2	A	A	4.271
FB27	2	A	A	3.35
FB28	2	A	A	4.271
FB29	3	A	A	4.07

FB effects on Girder (symmetrical about FB59)				
BrR Name	FB Type	Left Stringer Type	Right Stringer Type	Load [kip]
FB30	2	A	A	4.271
FB31	2	A	A	3.35
FB32	2	A	A	4.271
FB33	2	A	A	3.35
FB34	2	A	A	4.271
FB35	2	A	A	3.35
FB36	3	A	A	4.991
FB37	2	A	A	3.35
FB38	2	A	A	4.271
FB39	2	A	A	3.35
FB40	2	A	A	4.271
FB41	2	A	A	3.35
FB42	2	A	A	4.271
FB43	3	A	B	4.55
FB44	7	B	C	3.86
FB45	6	C	D	4.162
FB46	5	D	C	4.162
FB47	4	C	A	3.38
FB48	2	A	A	4.271
FB49	2	A	A	3.35
FB50	2	A	A	4.271
FB51	2	A	A	3.35
FB52	3	A	A	4.271
FB53	2	A	A	3.35
FB54	2	A	A	4.271
FB55	2	A	A	3.35
FB56	2	A	A	4.271
FB57	2	A	A	3.35
FB58	2	A	A	4.271
FB59	3	A	A	4.07

The above loads were applied to girders as point loads along the length of the girder

Uniform | Distributed | Concentrated | Settlement

Load case name	Support number	Distance (ft)	Px (kip)	Py (kip)	M (kip-ft)
Floorbeam Reactions	1	22.25		4.27	
Floorbeam Reactions	1	44.50		3.35	
Floorbeam Reactions	1	66.75		4.27	
Floorbeam Reactions	1	89.00		3.35	
Floorbeam Reactions	2	0.00		4.98	
Floorbeam Reactions	2	22.25		3.35	
Floorbeam Reactions	2	44.50		4.27	
Floorbeam Reactions	2	66.75		3.35	
Floorbeam Reactions	2	89.00		4.27	
Floorbeam Reactions	2	111.25		3.35	
Floorbeam Reactions	2	133.50		4.27	
Floorbeam Reactions	3	0.00		4.06	
Floorbeam Reactions	3	22.25		4.27	
Floorbeam Reactions	3	44.50		3.35	
Floorbeam Reactions	3	66.75		4.27	
Floorbeam Reactions	3	89.00		3.83	
Floorbeam Reactions	3	111.25		3.87	
Floorbeam Reactions	3	121.03		4.16	
Floorbeam Reactions	3	123.73		4.16	
Floorbeam Reactions	3	133.51		3.39	
Floorbeam Reactions	4	0.00		4.98	
Floorbeam Reactions	4	22.25		3.35	
Floorbeam Reactions	4	44.50		4.27	
Floorbeam Reactions	4	66.75		3.35	
Floorbeam Reactions	4	89.00		4.27	
Floorbeam Reactions	4	111.25		3.35	
Floorbeam Reactions	4	133.50		4.27	
Floorbeam Reactions	5	0.00		4.06	
Floorbeam Reactions	5	22.25		4.27	

Load case name	Support number	Distance (ft)	Px (kip)	Py (kip)	M (kip-ft)
Floorbeam Reactions	9	22.25		4.27	
Floorbeam Reactions	9	44.50		3.35	
Floorbeam Reactions	9	66.75		4.27	
Floorbeam Reactions	9	89.00		3.35	
Floorbeam Reactions	9	111.25		4.27	
Floorbeam Reactions	9	133.50		3.35	
Floorbeam Reactions	10	0.00		4.98	
Floorbeam Reactions	10	22.25		3.35	
Floorbeam Reactions	10	44.50		4.27	
Floorbeam Reactions	10	66.75		3.35	
Floorbeam Reactions	10	89.00		4.27	
Floorbeam Reactions	10	111.25		3.39	
Floorbeam Reactions	10	121.03		4.16	
Floorbeam Reactions	10	123.73		4.16	
Floorbeam Reactions	10	133.51		3.87	
Floorbeam Reactions	11	0.00		4.54	
Floorbeam Reactions	11	22.25		4.27	
Floorbeam Reactions	11	44.50		3.35	
Floorbeam Reactions	11	66.75		4.27	
Floorbeam Reactions	11	89.00		3.35	
Floorbeam Reactions	11	111.25		4.27	
Floorbeam Reactions	11	133.50		3.35	
Floorbeam Reactions	12	0.00		4.98	
Floorbeam Reactions	12	22.25		3.35	
Floorbeam Reactions	12	44.50		4.27	
Floorbeam Reactions	12	66.75		3.35	
Floorbeam Reactions	12	89.00		4.27	
Floorbeam Reactions	12	111.25		3.35	
Floorbeam Reactions	12	133.50		4.27	

Load case name	Support number	Distance (ft)	Px (kip)	Py (kip)	M (kip-ft)
Floorbeam Reactions	5	44.50		3.35	
Floorbeam Reactions	5	66.75		4.27	
Floorbeam Reactions	5	89.00		3.35	
Floorbeam Reactions	5	111.25		4.27	
Floorbeam Reactions	5	133.50		3.35	
Floorbeam Reactions	6	0.00		4.98	
Floorbeam Reactions	6	22.25		3.35	
Floorbeam Reactions	6	44.50		4.27	
Floorbeam Reactions	6	66.75		3.35	
Floorbeam Reactions	6	89.00		4.27	
Floorbeam Reactions	6	111.25		3.35	
Floorbeam Reactions	6	133.50		4.27	
Floorbeam Reactions	7	0.00		4.54	
Floorbeam Reactions	7	22.25		3.87	
Floorbeam Reactions	7	32.03		4.16	
Floorbeam Reactions	7	34.73		4.16	
Floorbeam Reactions	7	44.51		3.39	
Floorbeam Reactions	7	66.75		4.27	
Floorbeam Reactions	7	89.00		3.35	
Floorbeam Reactions	7	111.25		4.27	
Floorbeam Reactions	7	133.50		3.35	
Floorbeam Reactions	8	0.00		4.98	
Floorbeam Reactions	8	22.25		3.35	
Floorbeam Reactions	8	44.50		4.27	
Floorbeam Reactions	8	66.75		3.35	
Floorbeam Reactions	8	89.00		4.27	
Floorbeam Reactions	8	111.25		3.35	
Floorbeam Reactions	8	133.50		4.27	
Floorbeam Reactions	9	0.00		4.06	

Load case name	Support number	Distance (ft)	Px (kip)	Py (kip)	M (kip-ft)
Floorbeam Reactions	13	0.00		4.06	
Floorbeam Reactions	13	22.25		4.27	
Floorbeam Reactions	13	44.50		3.35	
Floorbeam Reactions	13	66.75		4.27	
Floorbeam Reactions	13	89.00		3.35	
Floorbeam Reactions	13	111.25		4.27	
Floorbeam Reactions	13	133.50		3.35	
Floorbeam Reactions	14	0.00		4.98	
Floorbeam Reactions	14	22.25		3.39	
Floorbeam Reactions	14	32.03		4.16	
Floorbeam Reactions	14	34.73		4.16	
Floorbeam Reactions	14	44.51		3.87	
Floorbeam Reactions	14	66.75		3.83	
Floorbeam Reactions	14	89.00		4.27	
Floorbeam Reactions	14	111.25		3.35	
Floorbeam Reactions	14	133.50		4.27	
Floorbeam Reactions	15	0.00		4.06	
Floorbeam Reactions	15	22.25		4.27	
Floorbeam Reactions	15	44.50		3.35	
Floorbeam Reactions	15	66.75		4.27	
Floorbeam Reactions	15	89.00		3.35	
Floorbeam Reactions	15	111.25		4.27	
Floorbeam Reactions	15	133.50		3.35	
Floorbeam Reactions	16	0.00		4.98	
Floorbeam Reactions	16	22.25		3.35	
Floorbeam Reactions	16	44.50		4.27	
Floorbeam Reactions	16	66.75		3.35	
Floorbeam Reactions	16	89.00		4.27	

Girders

Girder Span 1 (2 total spans per bridge): 27% of Self Load
Girder Span 2 (14 total spans per bridge): 23% of Self Load
Scaled/Average Girder Self Load ~ 24% of Self Load

Other Notes

- Rivets: All rivets are 7/8" with 15/16" holes.
- Splices: Subpunch holes 3/16" below nominal diameter and ream to size for all shop and field splices
- Web height is assumed to be 1/2" less than back to back of angle height (1/4" per side)
- Impact factor had to be adjusted in the BrR model to include the 15% constant impact override per Sec 1.7.1 of the AASHTO IRM GSBSM
- BrR Model is available upon request

Appendix 1E. Original 1958 Plan Set

BRIDGE CONTRACT No. 4339

INDEX

PROJECT	STRUCTURE	TYPE	SPAN	OVER	STATION	CONTRACT NO
F-78 (15)	41-E-3917	CONTINUOUS STEEL PLATE GIRDER BRIDGE	2 AT 111'-3 14 AT 155'-9	WHITE RIVER	519 +85.00	4339

SHEET NO.	SHEET DESIGNATION	SUBJECT
1	ONE SHEET	INDEX AND TITLE SHEET
2	ROAD PLAN SHT. NO. 4	TYPICAL CROSS SECTION PROJ. F-78 (14)
3	ROAD PLAN SHT. NO. 9	ROAD PLAN & PROFILE PROJ. F-78 (14)
4	ROAD PLAN SHT. NO. 10	ROAD PLAN & PROFILE PROJ. F-78 (14)
5	ROAD PLAN SHT. NO. 2	TYPICAL CROSS SECTION PROJ. F-78 (14)
6	ROAD PLAN SHT. NO. 28	DETAILS PROJ. F-78 (14)
7	ONE SHEET	THICKENED PAVEMENT DETAILS
8	S1	LAYOUT
9	S2	LAYOUT
10	S3	CORE BORING LOGS
11	S4	APPROACH DETAILS & TIE UP DATA
12	S5	GENERAL PLAN
13	S6	GENERAL PLAN
14	S7	DESIGN DATA - SPANS "A" & "S"
15	S8	DESIGN DATA - SPANS "C", "D", "N" & "O"
16	S9	DESIGN DATA - SPANS "E", "F", "L" & "M"
17	S10	DESIGN DATA - SPANS "G", "H", "J" & "K"
18	S11	FRAMING PLAN - SPANS "A", "B", "R" & "S"
19	S12	FRAMING PLAN - SPANS "C", "D", "N" & "P"
20	S13	FRAMING PLAN - SPANS "E", "F", "L" & "M"
21	S14	FRAMING PLAN - SPANS "G", "H", "J" & "K"
22	S15	DETAILS - FLOOR BEAMS FB-1, 2 & 2A
23	S16	DETAILS - FLOOR BEAMS FB-3
24	S17	DETAILS - FLOOR BEAMS FB-4, 5, 6 & 7
25	S18	GIRDER DETAILS - SPANS "A" & "S"
26	S19	GIRDER DETAILS - TYPICAL HAUNCH
27	S20	GIRDER DETAILS - TYPICAL INTERIOR SPAN
28	S21	GIRDER DETAILS - TYPICAL EXPANSION HINGE
29	S22	SHOE DETAILS
30	S23	EXPANSION DIAMS - SPANS "A" & "S"
31	S24	EXPANSION DIAMS - SPANS "C", "G", "K" & "P"
32	S25	EXPANSION DIAMS - SPANS "C", "G", "K" & "P"
33	S26	RAILING DETAILS
34	S27	FLOOR DETAILS - SPANS "A" & "S"
35	S28	FLOOR DETAILS - SPANS "B", "D", "C", "F", "H", "J", "L", "M", "N" & "R"
36	S29	FLOOR DETAILS - SPANS "C", "G", "K" & "P"
37	S30	BILL OF MATERIAL - FLOOR & SLAB
38	S31	SCPTTDG - SPANS "A", "B", "C", "D" & "E"
39	S32	SCREEDS - SPANS "F", "G", "H", "J" & "K"
40	S33	SCREEDS - SPANS "L", "M", "N", "P" & "R"
41	S34	SCREEDS - SPANS "S" & SHOE SETTING & ERECTION DATA
42	S35	ABUTMENT DETAILS
43	S36	ABUTMENT DETAILS
44	S37	DETAILS - PIER NO. 1
45	S38	DETAILS - PIERS NO 2, 11, 14
46	S39	DETAILS - PIERS NO. 3, 4, 9, 10, 12, 13 & 15
47	S40	DETAILS - PIERS NO. 1, 2, 3, 4, 9, 10, 11, 12, 13, 14 & 15
48	S41	DETAILS - PIERS NO. 5 & 8
49	S42	DETAILS - PIERS NO. 6 & 7
50	S43	DETAILS - PIERS NO. 5, 6, 7 & 8
51	S44	DETAILS - ALL PIERS
52	S45	BILL OF MATERIAL - ALL PIERS
53	ONE SHEET	SUMMARY
54	BRIDGE STD. C1	STANDARD MISCELLANEOUS DETAILS (REV. 6-3-57)
55	BRIDGE STD. D	CASTING DETAILS - ROADWAY DRAINS (1-3-50)
56	BRIDGE STD. M1	MISCELLANEOUS APPROACH DETAILS (REV. 6-3-57)
57	BRIDGE STD. M2	MISCELLANEOUS APPROACH DETAILS (REV. 6-3-57)
58	BRIDGE STD. R1	ALUMINUM RAILING DETAILS (REV. 1-2-58)
59	BRIDGE STD. S1	TYP. DETAILS FOR PLACING SPECIAL FILLING MATERIAL (REV. 9-20-52)
60	ROAD STD. MA	MISCELLANEOUS STANDARDS (REV. 12-19-57)
61	ROAD STD. MC	MISCELLANEOUS STANDARDS (REV. 3-8-57)
62	ROAD STD. MD	MISCELLANEOUS STANDARDS (REV. 2-1-54)
63	ROAD STD. ME	MISCELLANEOUS STANDARDS (REV. 2-11-57)
64	ROAD STD. MG	MISCELLANEOUS STANDARDS (REV. 4-27-55)
65	ROAD STD. MR	MISCELLANEOUS STANDARDS (REV. 10-9-57)
66	ROAD STD. GR	STEEL BEAM GUARD RAIL (REV. 1-10-57)

STATE OF INDIANA
STATE HIGHWAY DEPARTMENT

BRIDGE PLANS

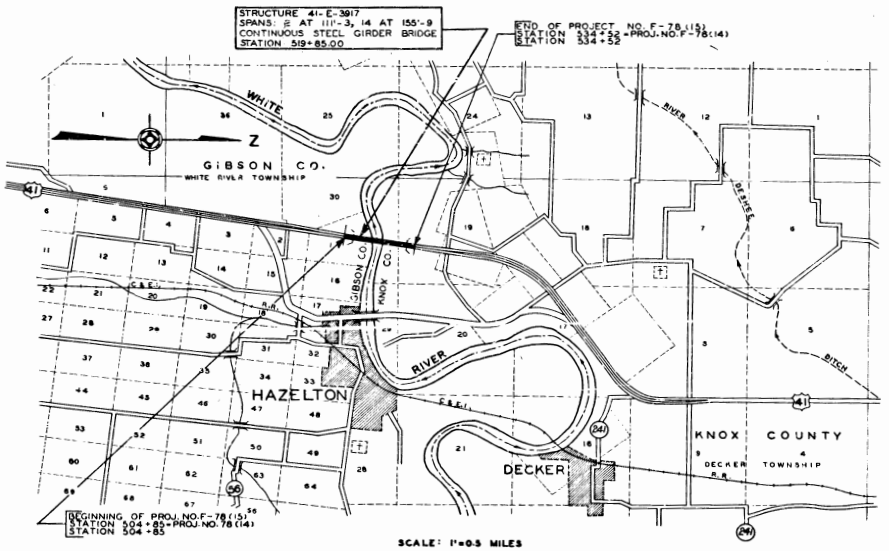
FOR SPANS OVER 20 FEET ON STATE ROAD NO. 41 SECTION E F PROJECT NO. 78 (15)

STRUCTURE 41-E-3917 IS LOCATED ON THE PROPOSED RELOCATION OF STATE RTE. 41 OVER THE WHITE RIVER, BEGINNING AT A POINT APPROX. 2354 FT. SOUTH OF THE NORTH LINE OF SECTION 30, T-1-N R-10-W, GIBSON COUNTY, AND RUNNING IN A NORTHERLY DIRECTION TO A POINT APPROX. 613 FT. NORTH OF THE SOUTH LINE OF SECTION 19, T-1-N, R-10-W, KNOX AND GIBSON COUNTIES.

ROADWAY LENGTH = 0.107 MI.
BRIDGE LENGTH = 0.455 MI.
TOTAL LENGTH = 0.562 MI.

MAX. GRADE: -0.30 %

Note:
Only relevant superstructure sheets are shown



BRIDGES OVER 20' SPAN

PUB. ROAD REG. NO.	STATE	PROJECT NO.	FISCAL YEAR	SHEET NO.	TOTAL SHEETS
4	IND.	F-78 (15)	1958	1	66

THESE PLANS PREPARED BY
PACE ASSOCIATES
PLANNERS - ARCHITECTS - CONSULTING ENGINEERS
CHICAGO, ILLINOIS

CERTIFIED DATE 2-18-58

TRAFFIC DATA
A.D.T. (1958) ..... 4500 V.P.D.
A.D.T. (1978 PROJECTED) ... 7500 V.P.D.
TRUCKS ..... 23 %

APPROVED AND ADOPTED DATE 2-17-58
BY STATE HIGHWAY DEPARTMENT OF INDIANA
CHAIRMAN, STATE HIGHWAY DEPARTMENT OF INDIANA

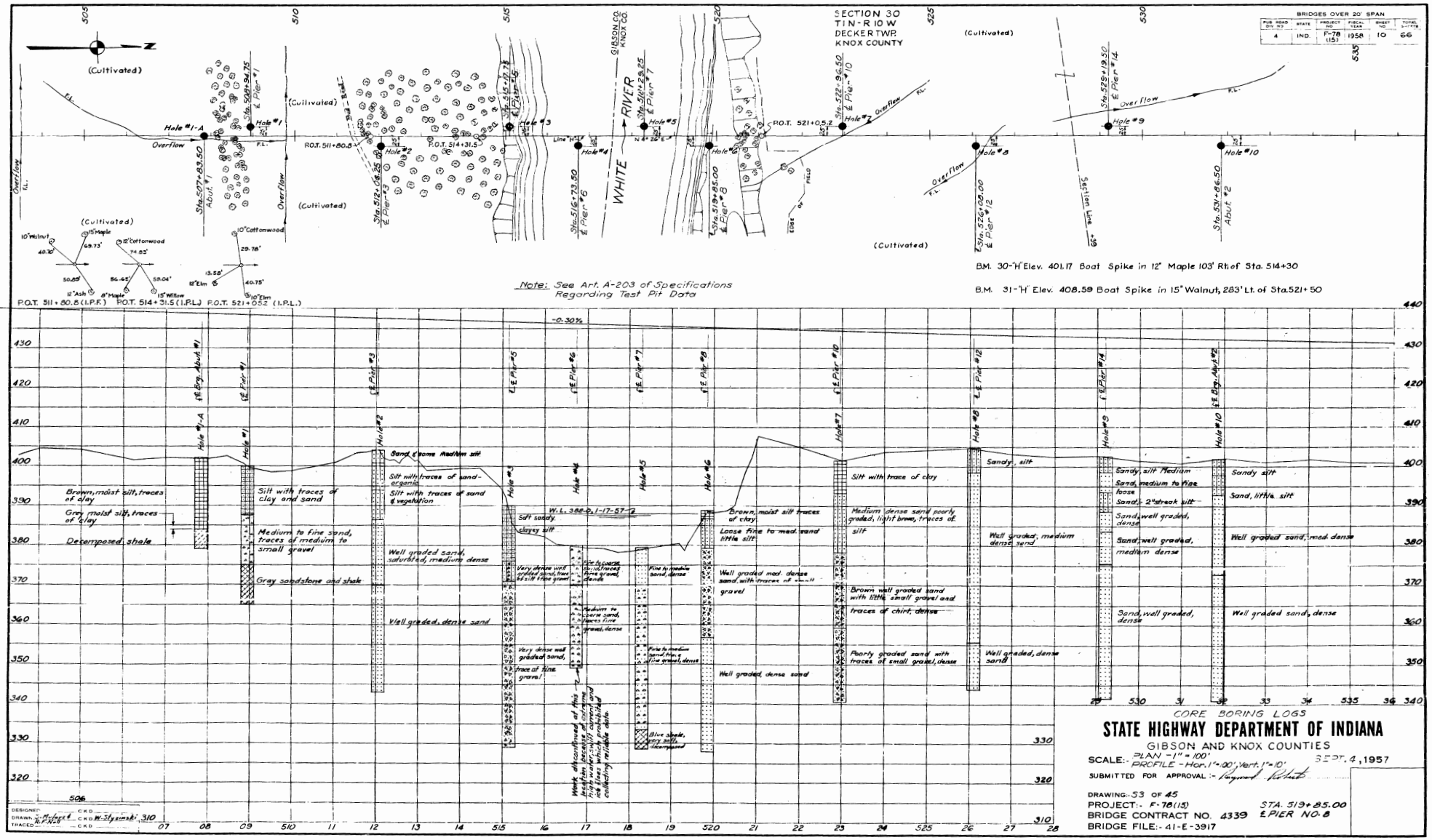
APPROVED DATE 2-17-58
CHIEF ENGINEER, STATE HIGHWAY DEPARTMENT OF INDIANA

RECOMMENDED FOR APPROVAL DATE 2-17-58
ENGINEER OF BRIDGE DESIGN, STATE HIGHWAY DEPARTMENT OF INDIANA

DEPARTMENT OF COMMERCE
BUREAU OF PUBLIC ROADS
APPROVED:
DIVISION ENGINEER DATE

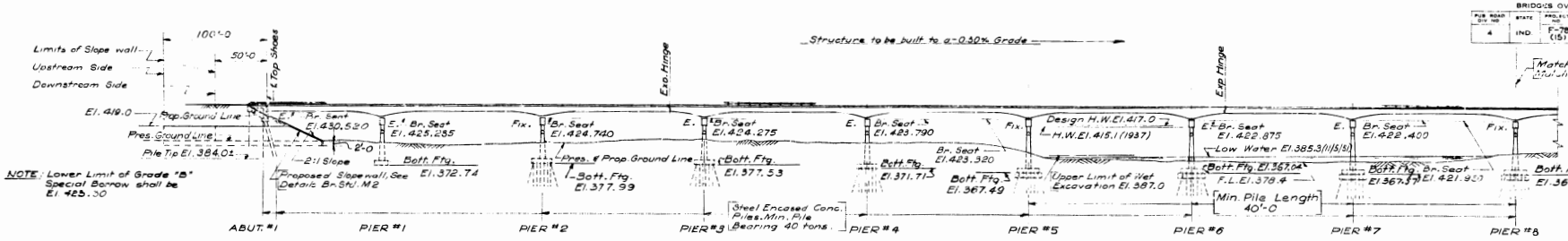
BRIDGE FILE: 41-E-3917

STATE HIGHWAY DEPARTMENT OF INDIANA
1957 STANDARD ROAD AND BRIDGE SPECIFICATIONS
TO BE USED WITH THESE PLANS

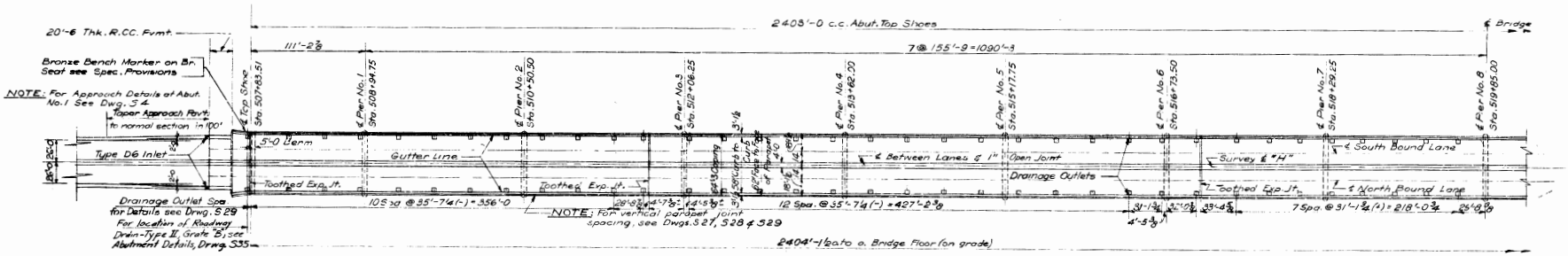


BRIDGES OVER 20' SPAN					
FUR. ROAD DIV. NO.	STATE	PROJECT NO.	FISCAL YEAR	SHEET NO.	TOTAL SHEETS
4	IND.	F-78 (15)	1958	10	66

BRIDGES OVER 20' SPAN					
PUB. ROAD DIV. NO.	STATE	PROJECT NO.	FISCAL YEAR	SHEET NO.	TOTAL SHEETS
4	IND.	F-78 (15)	1958	12	66



ELEVATION



PLAN

GENERAL NOTES

No present Structure of proposed bridge site.
Depth of footings to be extended if found necessary. See Art. B 403.2 (a) of specifications.
Piles shall have minimum bearing Value shown on detail drawings. Determine pile lengths by Arts. F 103 and F 203 of Specifications.
For details of steel encased piles, see Bridge Standard Drawings, the special provisions and applicable parts in the specifications.
Piles at Abutments No. 1 & 2 shall be driven to elevations shown on plans or below if necessary to obtain desired bearing.
Reinforcing Steel covering shall be one inch in Floor slabs, 3 inches in footings, except bottom steel, which shall be 4 inches, and 2 inches in all other parts unless noted.
Concrete in Pier and Abutment footings and Pier stems to bottom of Cantilevers to be Class "E".
Concrete in Superstructure including Abutments above Footings, top of Piers above bottom of Cantilevers to be Class "F".
Concrete in steel encased concrete piles and concrete slope walls to be Class "D".
Continuous concrete pours shall be required between Construction joints as shown on detail plans.
Bevel forms ¼" under copings and chamfer exposed edges one inch unless noted.
Construct 5" conc. slope wall or alternate 12" hand laid riprap slope walls at locations as shown on General Plans, Drwg. 3516.
Tolerance in position of pile head at Abutments No. 1 & 2 maximum 2 inches.
3" Expansion joint to be placed in approach pavement approximately 60' from each end of abutment.
All railings to be constructed perpendicular to grade.
6" Traffic lane stripe to be placed along ℄ Lane on bridge floor and pavement.
See special provisions for items included in this contract.
Waterproof abutments in accordance with Specifications.
No. Drainage Outlets = 140
No. Roadway Drains = 2

DESIGNED ____ CKD ____
DRAWN S. Hulers CKD R.F. Null
TRACED ____ CKD ____

STANDARD DRAWINGS

STANDARD BRIDGE	STANDARD ROAD	DATE	PURPOSE
B			Bar bending Details; test bar samples, exp. Joint
F1			Details of steel encased piles with splicing pile shells in field
D		1-3-50	Roadway drains
Mi		Rev. 6-3-57	R/W Markers
M2		Rev. 6-3-57	Concrete Slope wall or Riprap Slope wall.
R1		Rev. 11-6-57	Aluminum Railing Details.
S1		Rev. 9-20-56	Typical Details for placing Grade "B" Special Borrow
	MA	Rev. 12-19-57	Pavement Offsets.
	MC	Rev. 3-6-57	Inlet Casting.
	MD	Rev. 2-1-54	Inlets
	ME	Rev. 1-11-57	Standard Lip Gutter.
	MP	Rev. 8-28-57	Pipe
	MR	Rev. 10-9-57	R/W Fence.
	GR	Rev. 1-10-57	Steel Beam Guard Rail.

DESIGN DATA

Designed for H20-S16-44 loading in accordance with 1953 AASHO Specifications.
The Contractor shall prepare detailed bills of material giving final pay weights of Structural Steel and detailed working or shop drawings to enable him to fabricate, erect, and construct all parts of the work in conformity with the Engineers drawings and specifications and shall submit five (5) copies of these to the Engineer.

GENERAL PLAN

CONTINUOUS STEEL PLATE GIRDER BRIDGE
16 SPANS-2 SPANS AT 111'-3 & 14 SPANS AT 155'-9
OVER WHITE RIVER, 2-2'0 WALKS, 54'0 ROADWAY,
4'-0 DIVIDER ON S.R. 41

STATE HIGHWAY DEPARTMENT OF INDIANA

GIBSON AND KNOX COUNTIES

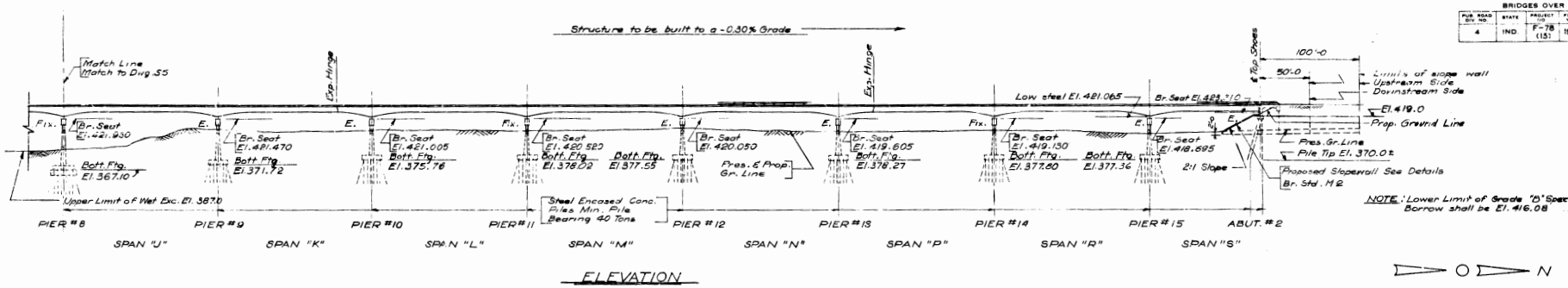
SCALE:- 1"=50'-0 SEPT. 4, 1957

SUBMITTED FOR APPROVAL:- [signature]

DRAWING:- 35 OF 45
PROJECT:- F-78 (15) STATION: 519+85.00 ℄ PIER NO. 8
BRIDGE CONTRACT NO. 4339
BRIDGE FILE:- 41-E-3917

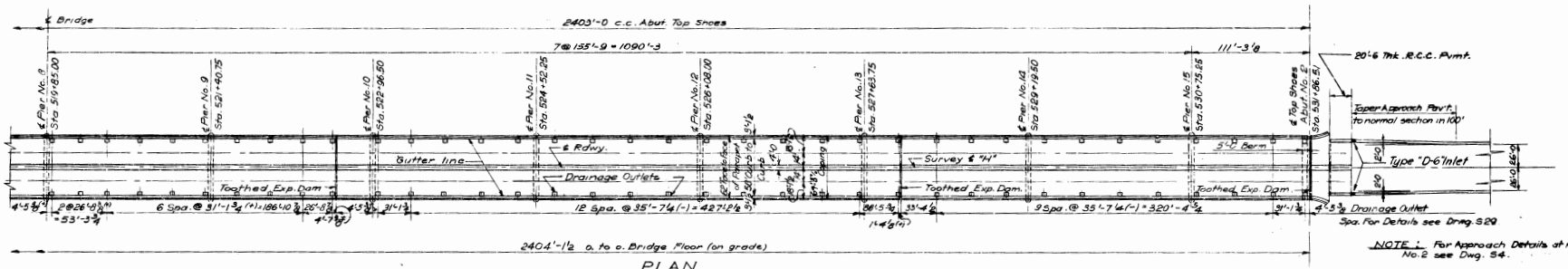
BRIDGES OVER 20' SPAN

PUB. ROAD DIV. NO.	STATE	PROJECT NO.	FISCAL YEAR	SH. NO.	TOTAL SHTS.
4	IND.	F-78 (15)	1958	15	66



ELEVATION

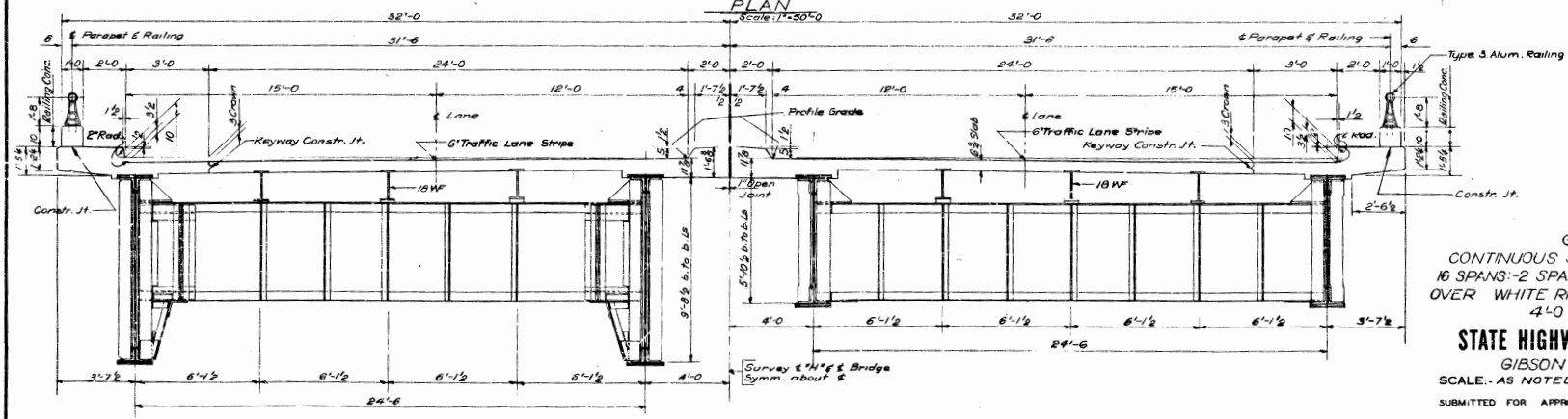
Scale 1" = 50'-0



NOTE 1. For Approach Details at Abut. No. 2 see Dwg. S4.

PLAN

Scale 1" = 50'-0



GENERAL PLAN
CONTINUOUS STEEL PLATE GIRDER BRIDGE
16 SPANS:-2 SPANS AT 111'-3 & 14 SPANS AT 155'-9
OVER WHITE RIVER, 2-2'-0 WALKS, 54'-0 ROADWAY
4'-0 DIVIDER ON S.R 41

STATE HIGHWAY DEPARTMENT OF INDIANA

GIBSON AND KNOX COUNTIES

SCALE:- AS NOTED SEPT. 4, 1957

SUBMITTED FOR APPROVAL:- Raymond Abbott

DRAWING:- 56 OF 45

PROJECT:- F-78(15) S.R. 41 STATION 519+85.00 ℄ PIER NO. 8

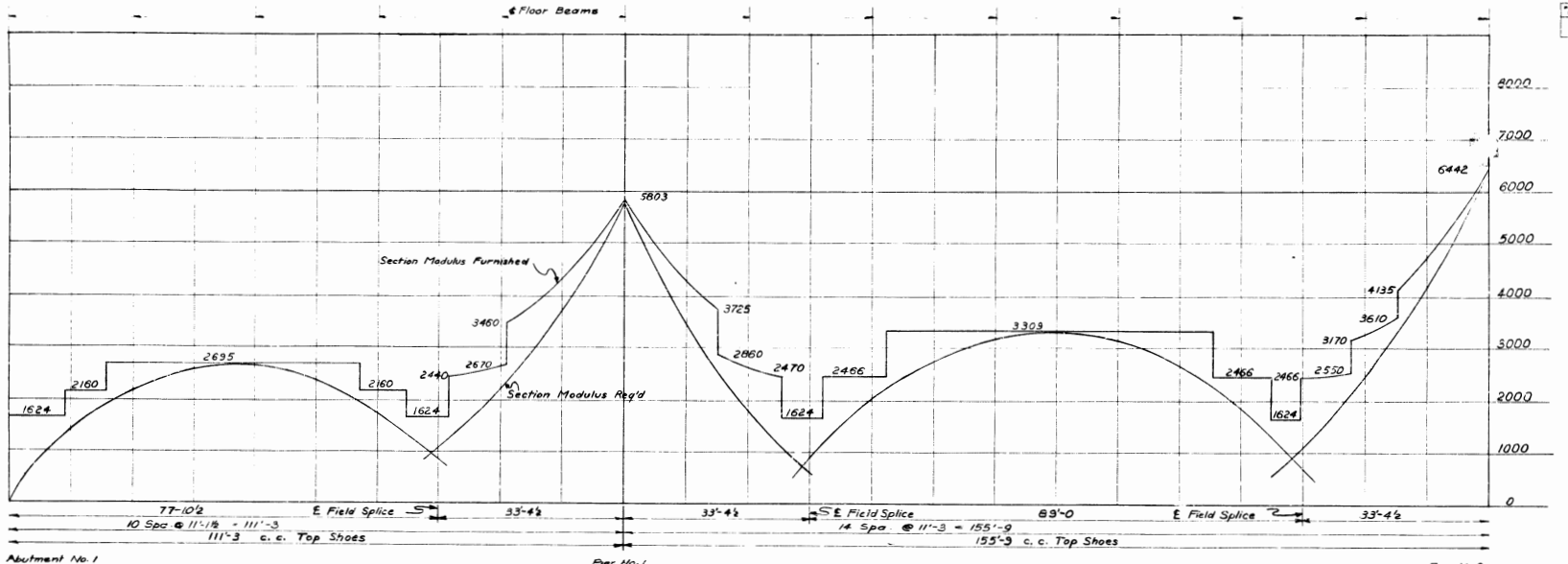
BRIDGE CONTRACT NO. 4339

BRIDGE FILE:- 41-E-3917

DESIGNED ____ CKD. ____
DRAWN S. Mulvey CKD. R.F. Nell
TRACED ____ CKD. ____

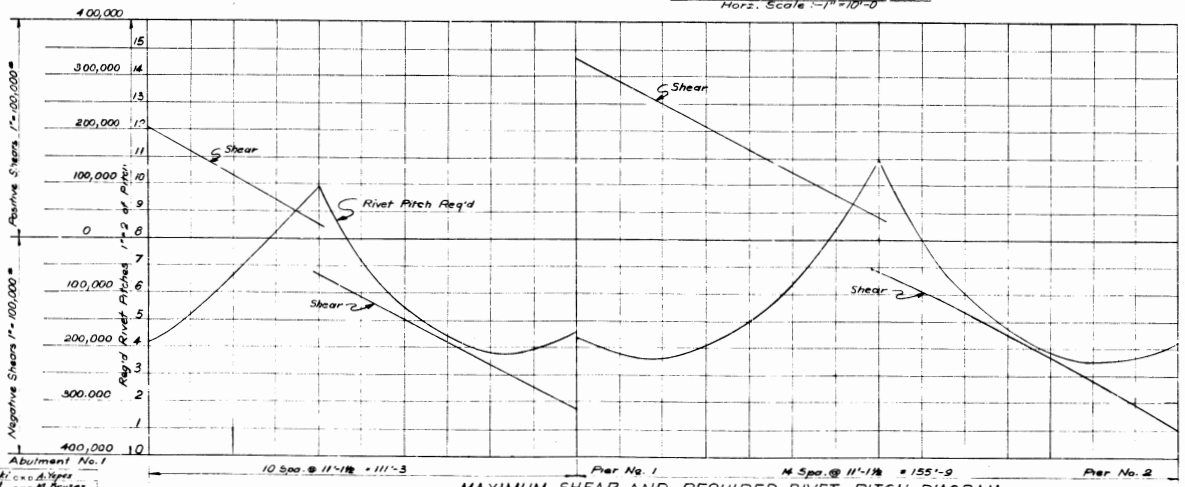
BRIDGES OVER 20' SPAN

PUB. ROAD DIV. NO.	STATE	PROJECT NO.	FISCAL YEAR	SHEET NO.	TOTAL SHEETS
4	IND	F-78 (15)	1958	14	66



MAXIMUM SECTION MODULUS

Horz. Scale :- 1" = 10'-0



MAXIMUM SHEAR AND REQUIRED RIVET PITCH DIAGRAM

Horz. Scale 1" = 15'-0

DESIGNED E. Lenthi CKD A. Yepes
DRAWN S. Myers Jr. CKD M. Bruzas
TRACED A. Yepes CKD

DATA USED FOR DESIGN AND DETAILS

LIVE LOAD :- H 20-S16-44 with impact and distribution of loads in accordance with 1953 Specifications.

DEAD LOAD :- Actual weight plus 15 pounds per sq. ft. of Roadway to provide for future wearing surface.

SLAB :- Designed with 16,000 # wheel plus impact and with ½ in wearing surface & 15 #/sq. ft future wearing surface.

UNIT STRESSES :-

Structural Carbon Steel Bending (Tension)	18 000 #/sq. in.
Structural Carbon Steel (Compression)	[15600- 4(l÷r)²] #/sq. in.
Shear on Rivets	13 500 #/sq. in.
Structural Steel Bearing (Including Rivets)	27000 #/sq. in.
Bearing - Steel on concrete (Including overturning and eccentric loading.	1000 #/sq. in.
Reinforcing Steel (Tension)	20000 #/sq. in.
Structural Aluminum Alloy Bending (Tension)	15000 #/sq. in.
Concrete (Compression)	1200 #/sq. in.

Stresses in Expansion Joint Material:
Stress in Extreme Fiber of Forged Steel Pins 27000 #/Sq.in.
Structural Low-Alloy Steel (ASTM A242-49T) Bending (Tension) 27000 #/sq.in.

NOTE:

For Moments and Reactions of stringers see Drwg. S8
For General Steel Notes, see Drwg. S11

DESIGN DATA - SPANS "A" & "S"

STATE HIGHWAY DEPARTMENT OF INDIANA

SCALE:- AS NOTED

SEPT. 4, 1957

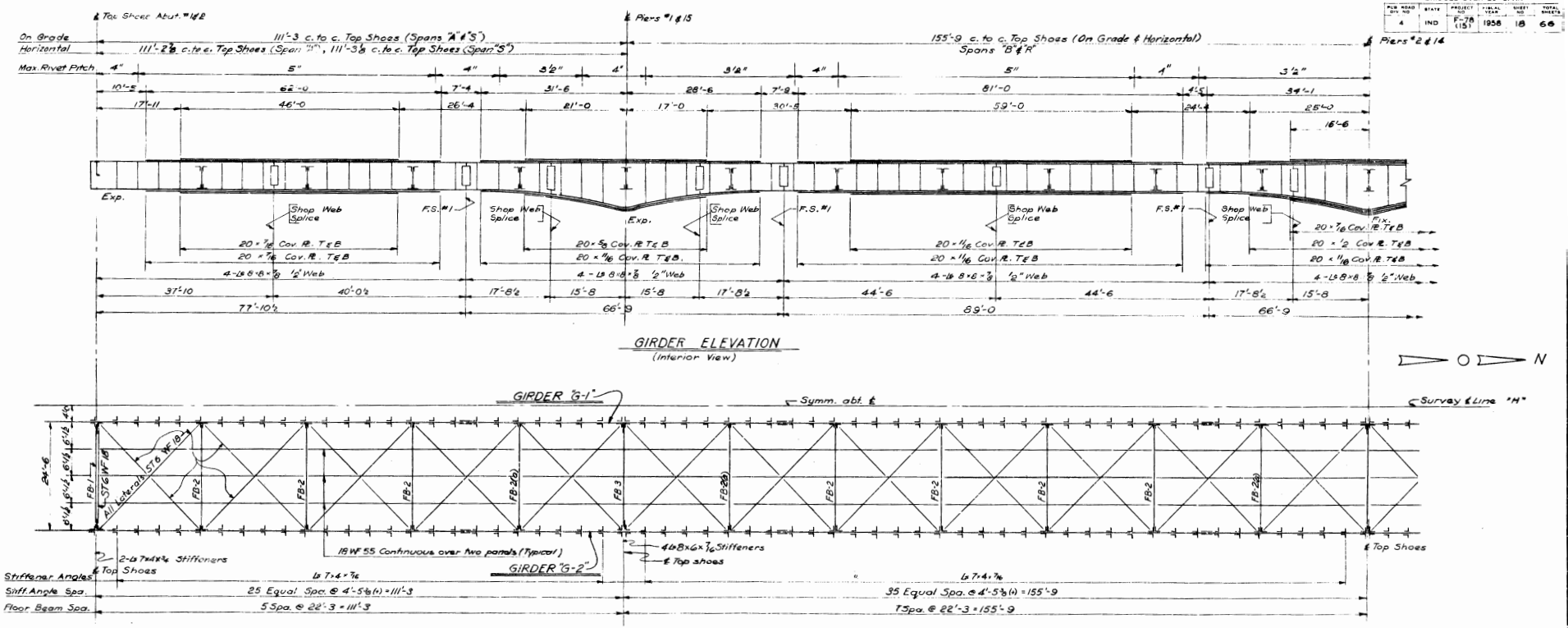
SUBMITTED FOR APPROVAL :- Raymond E. White

DRAWING:- 57 OF 45
PROJECT:- F-78(15) STA. 519+85.00
BRIDGE CONTRACT NO. 4339 & PIER NO. 8
BRIDGE FILE:- 41-E-3917

14

BRIDGES OVER 20' SPAN

PUB. ROAD DIV. NO.	STATE	PROJECT NO.	FISCAL YEAR	SHEET NO.	TOTAL SHEETS
4	IND	F-78 (15)	1958	18	66



HALF STEEL FRAMING PLAN

GENERAL STEEL NOTES

All material Structural Carbon Steel of ASTM Designation A7-46 except that marked A242-49T which is Structural Low-Alloy Steel or as otherwise noted.
All Floorbeams shall be normal to grade.
Camber: Girders shall be cambered for Total Dead Load as shown in Camber Diagram. For Camber Diagram See Dwgs. S12 & S13
To insure continuity Girders shall be fabricated to their correct no-load camber in the shop and shop-assembled two spans at a time, laid flat with bearings in correct relation, reaming field-splice rivet holes in this condition.
Erection Procedure:
The following procedure shall be used in erection of Girder Spans:
1:- Structural Steel shall be erected with Girders supported on falsework at field splices and expansion hinges.
2:- Rivets in stringers and laterals to be driven after falsework is removed.
Rivets: All rivets ⅞"ϕ; Holes 15/16"ϕ unless noted.
Splices: Subpunch holes ⅜" below nominal diameter and ream to size for all shop and field splices. For El. & Field Splices see Drwg. S14.

NOTE

The contractor shall prepare detailed bills of material giving final pay weight of structural steel and detailed work of shop drawings to enable him to fabricate, erect and construct all parts of the work in conformity with the engineer's drawings and specifications and shall submit five (5) copies of these to the Engineer.
For Data Used For Design and Details, see Drwg. S 7
For General Notes see Drwg. S 5

NOTE:
Estimated Wt. Structural Steel 8,230,400 Lbs.

FRAMING PLAN - SPANS "A", "B", "R" & "S"

STATE HIGHWAY DEPARTMENT OF INDIANA

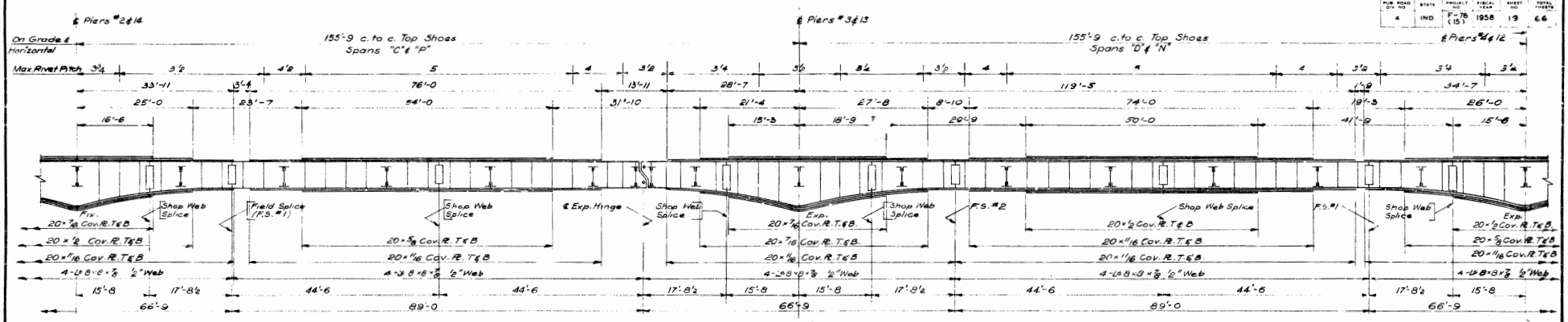
SCALE:- 1" = 10'-0
SEPT. 4, 1957
SUBMITTED FOR APPROVAL:- Raymond Hirst

DESIGNED E. Landski CKD A. Yepes
DRAWN S. Mulara CKD R. F. Nell
TRACED ____ CKD ____

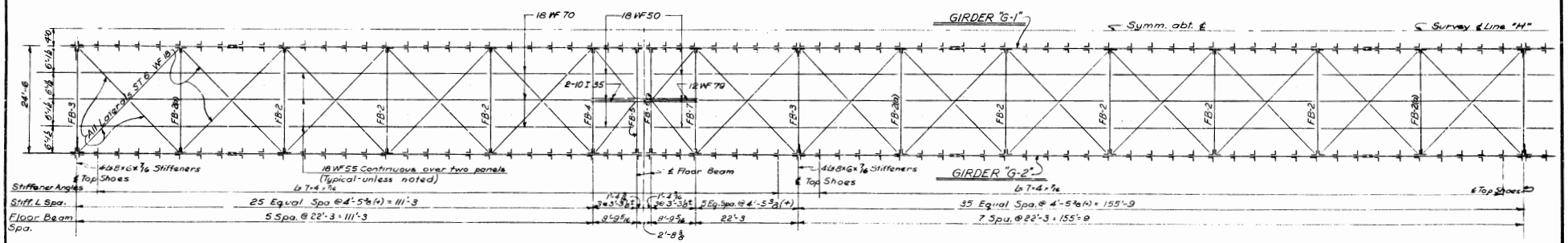
DRAWING:- S11 OF 45
PROJECT:- F-78(15)
BRIDGE CONTRACT NO. 4339
BRIDGE FILE:- 41-E-3917
STA. 519 + 85.00 ℄ PIER NO. 8

BRIDGES OVER 20' SPAN

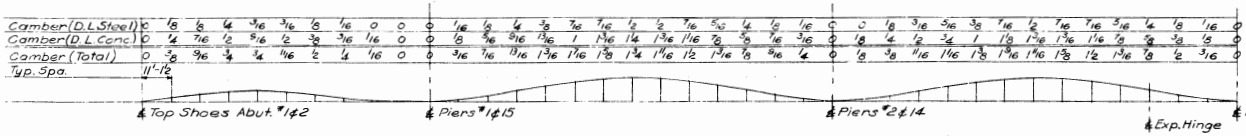
PUB. ROAD DIV. NO.	STATE	PROJECT NO.	FISCAL YEAR	SHEET NO.	TOTAL SHEETS
4	IND.	F-78 (15)	1958	19	66

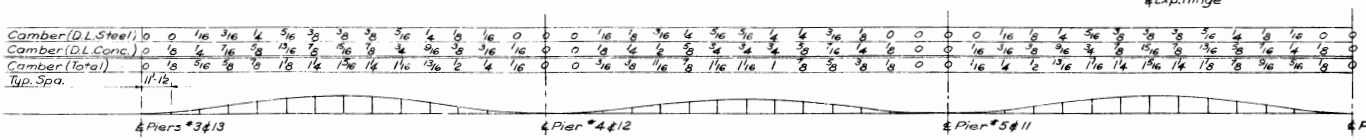


GIRDER ELEVATION
(Interior View)



HALF STEEL FRAMING PLAN





CAMBER DIAGRAM - SPANS "A" THRU "F" & "L" THRU "S"
Not to Scale

NOTE:
For General Steel Notes see Drwg. S11
For General Notes see Drwg. S5

FRAMING PLAN - SPANS "C", "D", "N" & "P"

STATE HIGHWAY DEPARTMENT OF INDIANA

SCALE:- 1" = 10'-0 SEPT. 4, 1957

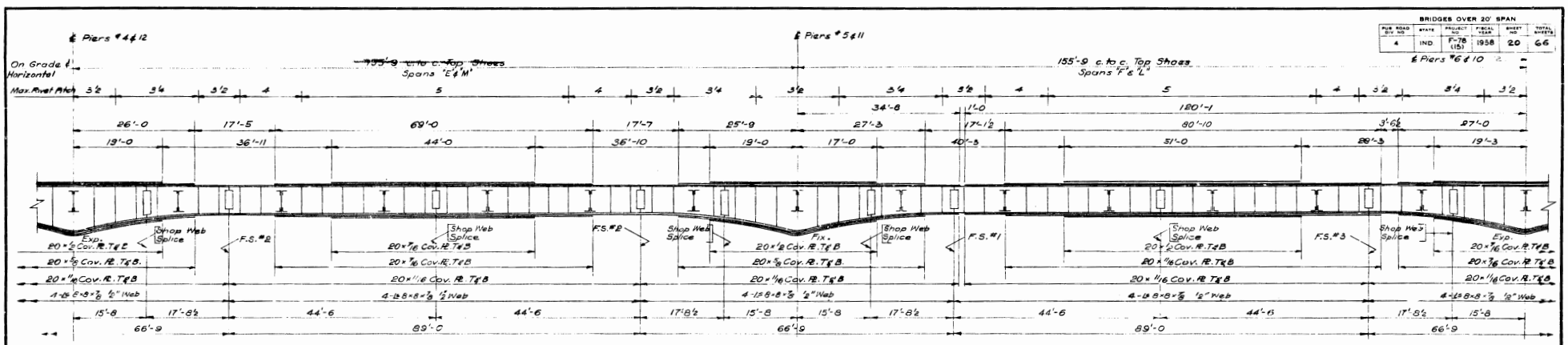
SUBMITTED FOR APPROVAL :- [signature]

DRAWING:- S12 OF 45
PROJECT:- F-78(15) STA. 519+85.00
BRIDGE CONTRACT NO. 4339 ℄ PIER NO. 8
BRIDGE FILE:- 41-E-3917

DESIGNED E. Lentz CKD A. Yepes
DRAWN Myers CKD R.F. Nall
TRACED CKD

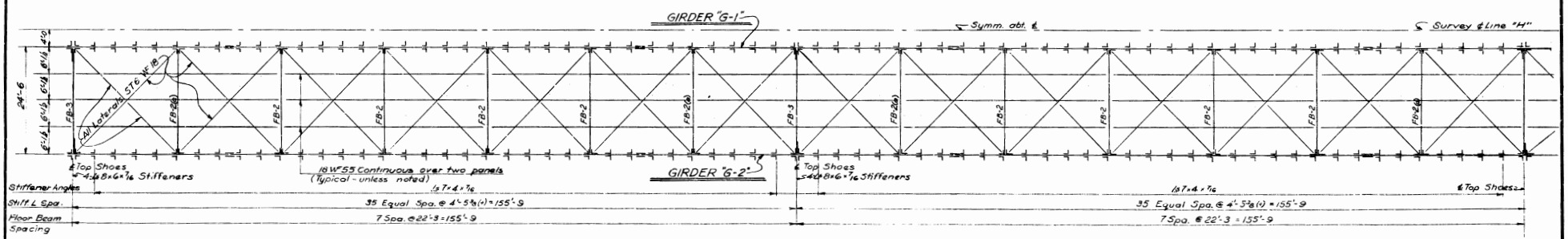
BRIDGES OVER 20' SPAN

PUB ROAD DIV NO	STATE	PROJECT NO	FISCAL YEAR	SHEET NO	TOTAL SHEETS
4	IND	F-78 (15)	1958	20	66
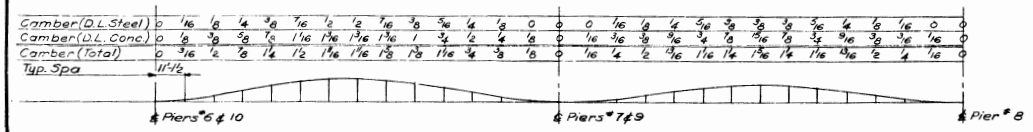


GIRDER ELEVATION
(Interior View)

N



HALF STEEL FRAMING PLAN



CAMBER DIAGRAM - SPANS "G" THRU "K"
Not to Scale

NOTE:
For General Steel Notes see Drwg. 811
For General Notes see Drwg. 3.5

FRAMING PLAN - SPANS "E", "F", "L" & "M"

STATE HIGHWAY DEPARTMENT OF INDIANA

SCALE:- 1" = 10'-0 SEPT. 4, 1957

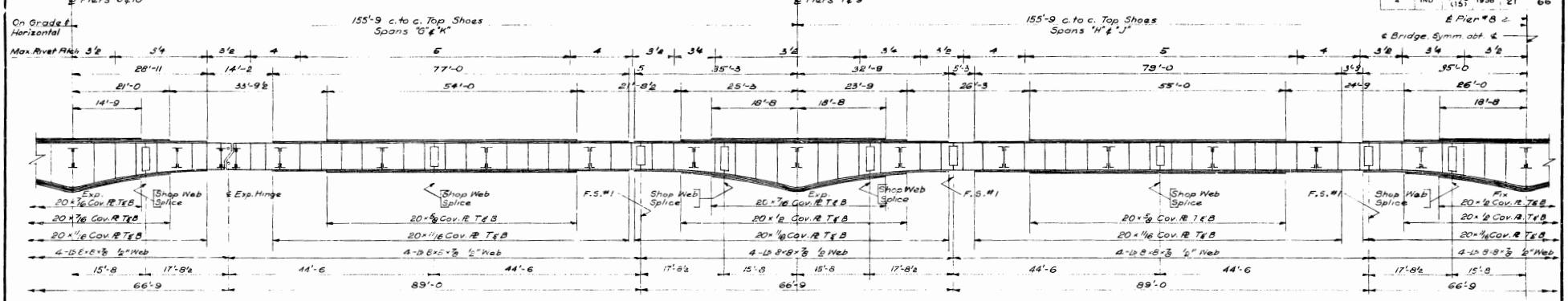
SUBMITTED FOR APPROVAL:- Raymond Kirsch

DRAWING: 513 OF 45
PROJECT:- F-78(15) STA. 519+85.00
BRIDGE CONTRACT NO. 4339 ℄ PIER NO. 8
BRIDGE FILE:- 41-E-3917

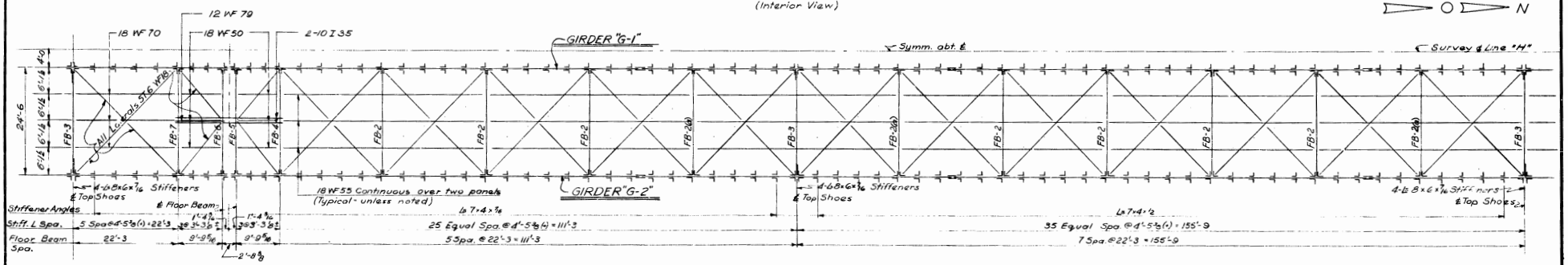
DESIGNED E. Lenthe CKD. A. Yepes
DRAWN S. Nadeau CKD. R.F. Noll
TRACED ——— CKD. ———

BRIDGES OVER 20' SPAN

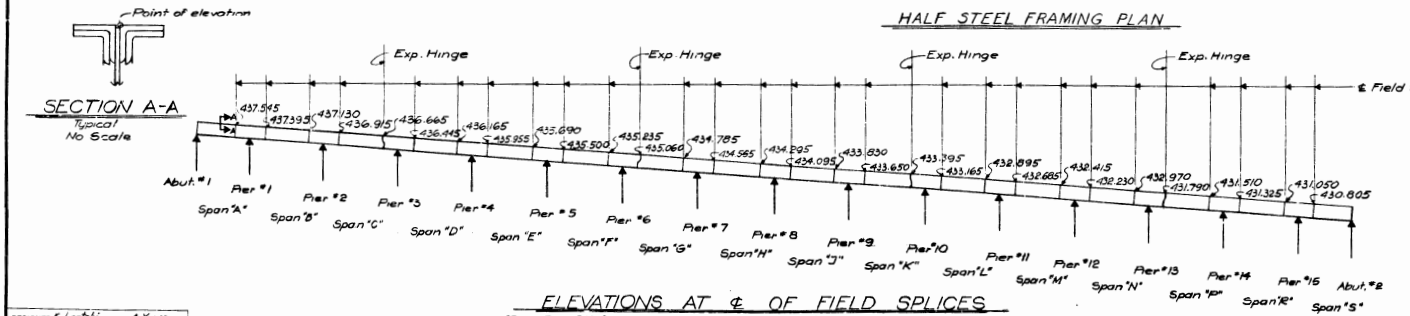
FUR ROAD DIV NO	STATE	PROJECT NO	F.A. SEC YEAR	SHEET NO	TOTAL SHEETS
4	IND	F-78 (15)	1958	21	66



GIRDER ELEVATION
(Interior View)



HALF STEEL FRAMING PLAN



ELEVATIONS AT ℄ OF FIELD SPLICES
(See Drg. S11 for note regarding riveting of girder Spans.) No Scale.

NOTE:
For General Steel Notes see Drwg. S11
For General Notes see Drwg. S5

FRAMING PLAN - SPANS "G", "H", "J" & "K"

STATE HIGHWAY DEPARTMENT OF INDIANA

SCALE:- 1"=10'-0" SEPT. 4, 1957

SUBMITTED FOR APPROVAL :- Raymond Kirk

DRAWING:- S14 OF 45

PROJECT:- F-78(15) STA. 519+85.00

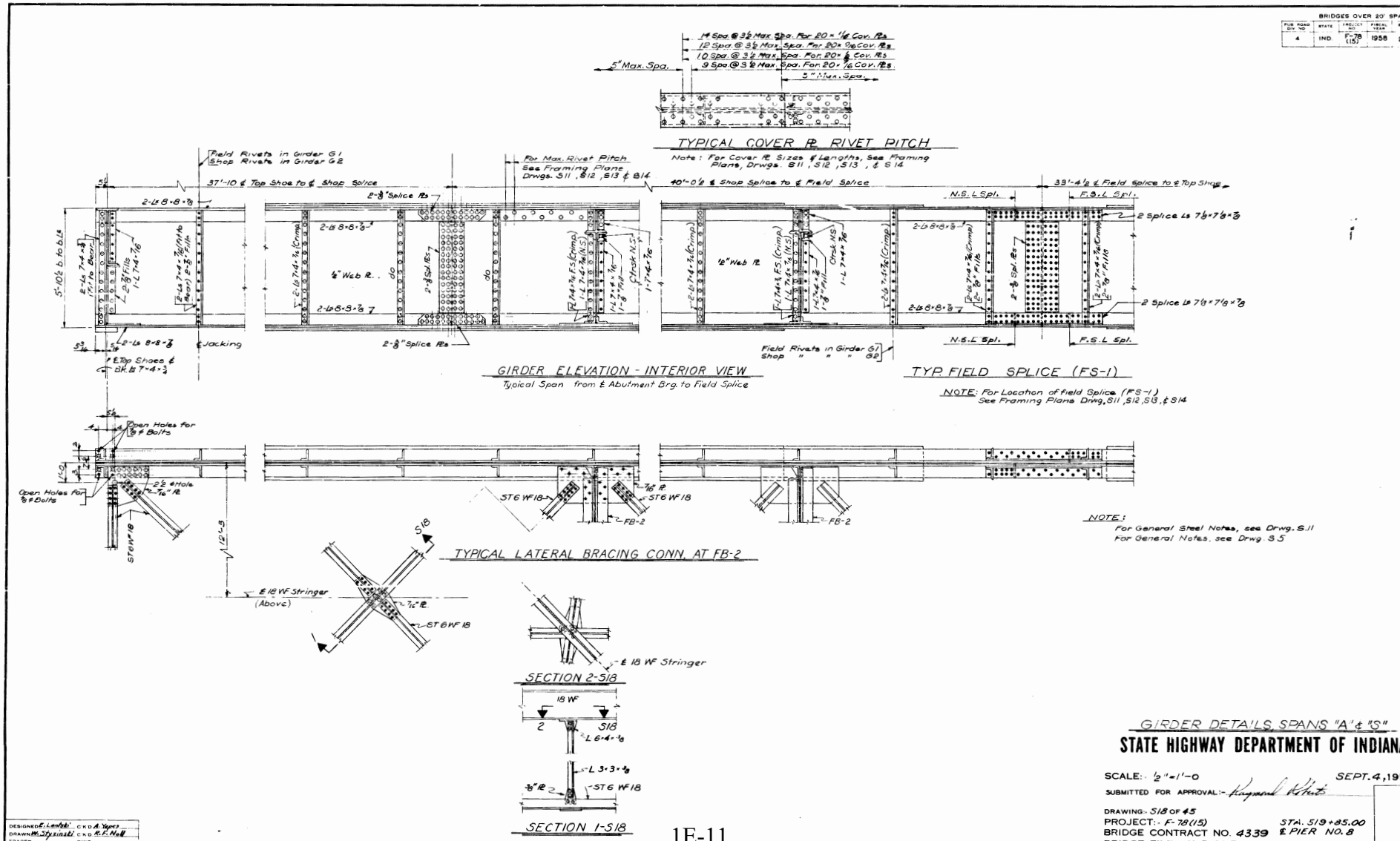
BRIDGE CONTRACT NO. 4339 ℄ PIER NO. 8

BRIDGE FILE:- 41-E-3917

DESIGNED E. Lentz CK'D. A. Yoos
DRAWN S. Hulvey CK'D. R.F.N-II
TRACED CK'D.

BRIDGES OVER 20' SPAN

FUR ROAD DIV. NO	STATE	PROJECT	FISCAL YEAR	SHEET NO	TOTAL SHEETS
4	IND	F-78 (15)	1958	25	66



GIRDER DETAILS, SPANS "A" & "S"

STATE HIGHWAY DEPARTMENT OF INDIANA

SCALE: ½"=1'-0 SEPT. 4, 1957

SUBMITTED FOR APPROVAL:- Raymond Roberts

DRAWING:- S18 OF 45

PROJECT:- F-78(15) STA. 519+85.00

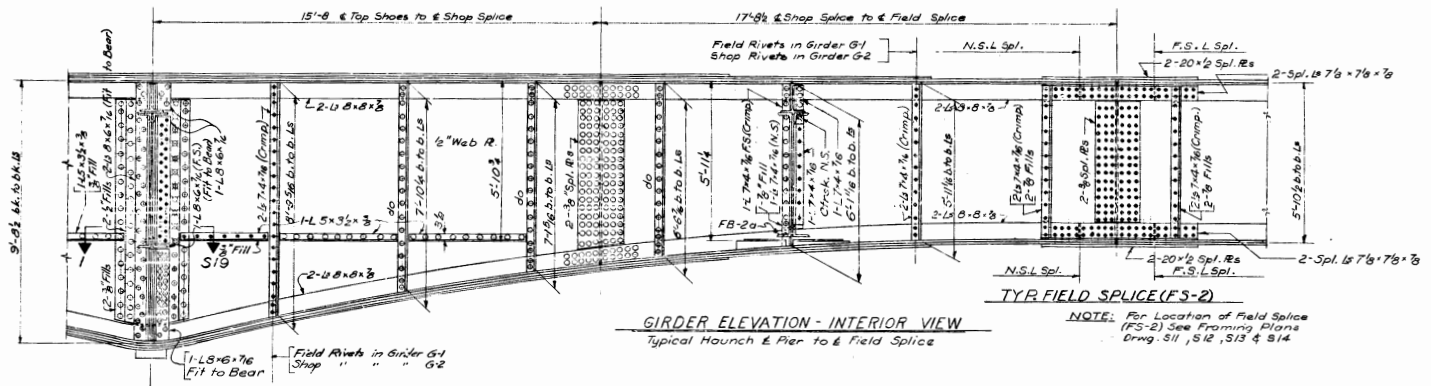
BRIDGE CONTRACT NO. 4339 & PIER NO. 8

BRIDGE FILE:- 41-E-3917

DESIGNED E. Lenski CKD A. Yates
DRAWN W. Styczinski CKD R.F. Noll
TRACED CKD

BRIDGES OVER 20' SPAN

PUB. ROAD DIV. NO.	STATE	PROJECT NO.	FISCAL YEAR	SHEET NO.	TOTAL SHEETS
4	IND.	F-78 (15)	1958	26	66



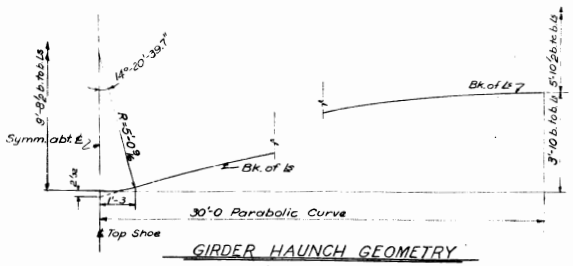
GIRDER ELEVATION - INTERIOR VIEW
Typical Haunch ℄ Pier to ℄ Field Splice

TYP. FIELD SPLICE (FS-2)

NOTE: For Location of Field Splice (FS-2) See Framing Plans Drwg. S11, S12, S13 & S14

SECTION 1-S19

TYPICAL LATERAL BRACING CONN. AT FB-2a



GIRDER HAUNCH GEOMETRY
(Not to Scale)

NOTE:
For General Steel Notes, see Drwg. S11
For Cover Pl. Rivet Pitch see Drwg. S 18
For Cover Pl. sizes & lengths, see Framing Plans, Drwgs. S11, S12, S13 & S14
For General Notes, see Drwg. S5

GIRDER DETAILS-TYPICAL HAUNCH

STATE HIGHWAY DEPARTMENT OF INDIANA

SCALE:- ½"=1'-0 SEPT. 4, 1957

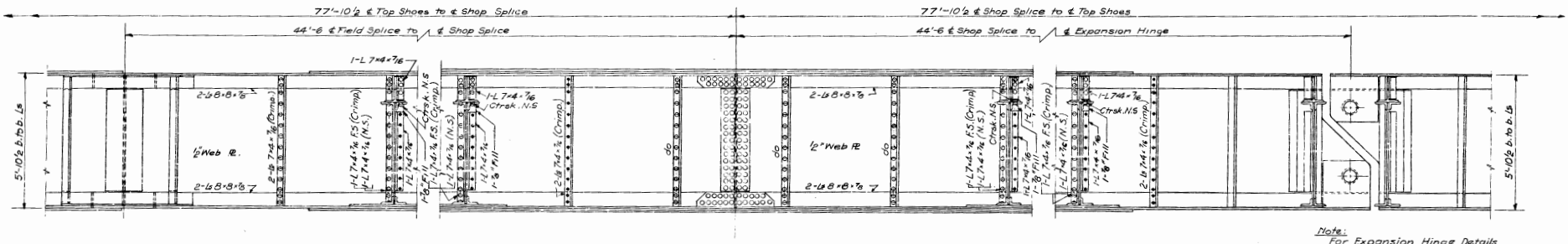
SUBMITTED FOR APPROVAL:- Raymond Roberts

DRAWING:- S19 OF 45
PROJECT:- F-78(15) STA. 519+85.00
BRIDGE CONTRACT NO. 4339 ℄ PIER NO. 8
BRIDGE FILE:- 41-E-3917

DESIGNED E. Leyhe CKD A. Yopes
DRAWN W. Stynes CKD R.F. Noll
TRACED CKD

BRIDGES OVER 20' SPAN

PUB. ROAD DIV. NO.	STATE	PROJECT NO.	FISCAL YEAR	SHEET NO.	TOTAL SHEETS
4	IND.	F-78 115	1958	27	66

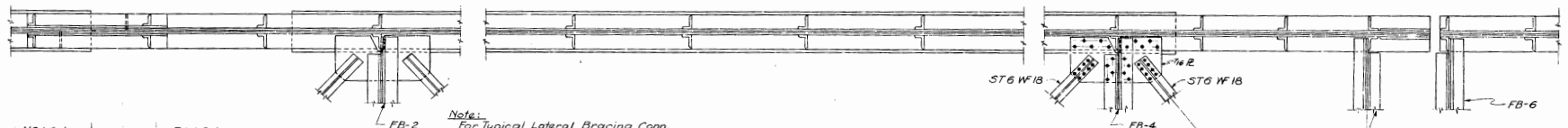


TYPICAL INTERIOR SPAN FROM FIELD SPLICE TO ℄ SPAN

TYPICAL INTERIOR SPAN FROM ℄ SPAN TO EXPANSION HINGE

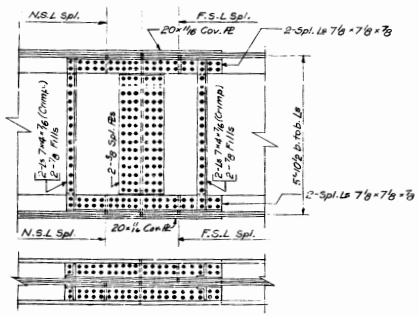
Note: For Expansion Hinge Details See Drawing S21

GIRDER ELEVATION - INTERIOR VIEW



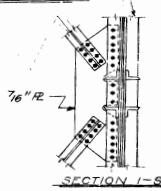
Note: For Typical Lateral Bracing Conn. See Drawing S18

TYPICAL LATERAL BRACING CONN. AT FB-4



TYP. FIELD SPLICE (FS-3)

NOTE: For Location of field Splice (FS-3) see Framing Plan Drwg. S13



SECTION 1-S20

NOTE:
For General Steel Notes, see Drwg. S11
For Cover Pl. Rivet Pitch, see Drwg. S18
For Cover Pl. sizes & lengths, see Framing Plans, Drwgs. S11, S12, S13 & S14
For General Notes, see Drwg. S5

GIRDER DETAILS-TYP. INTERIOR SPAN

STATE HIGHWAY DEPARTMENT OF INDIANA

SCALE:- ½" = 1'-0 SEPT. 4, 1957

SUBMITTED FOR APPROVAL:- Raymond Roberts

DRAWING:- S20 OF 45

PROJECT:- F-78(15) STA. 519+85.00

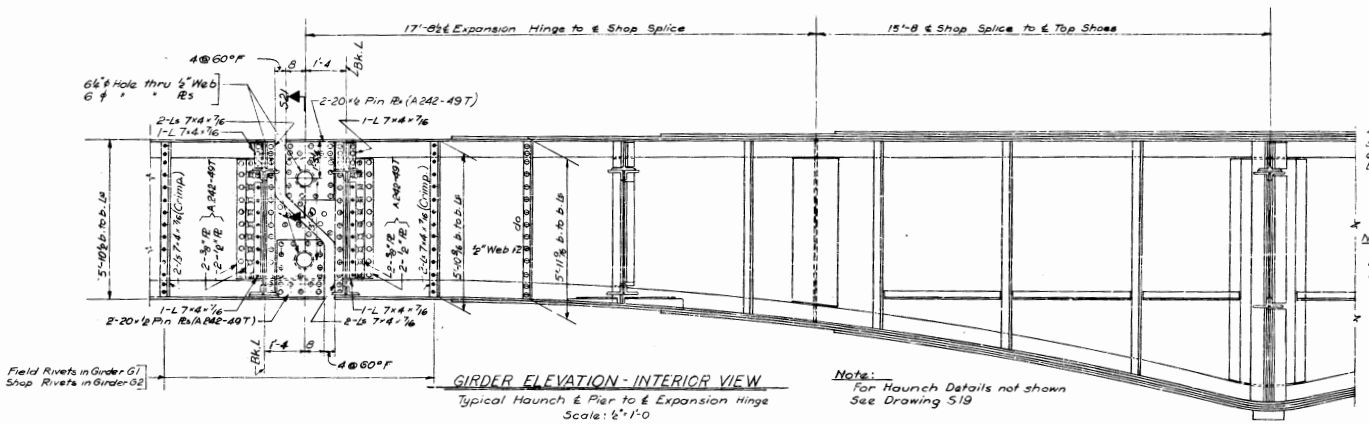
BRIDGE CONTRACT NO. 4339 ℄ PIER NO. 8

BRIDGE FILE:- 41-E-3917

DESIGNED E. Lenfski CK'D A. Yates
DRAWN W. Zyzinski CK'D R. F. Nell
TRACED CK'D

BRIDGES OVER 20' SPAN

PUB ROAD DIV NO	STATE	PROJECT NO	FISCAL YEAR	SHEET NO	TOTAL SHEETS
4	IND.	F-78 (15)	1958	28	66

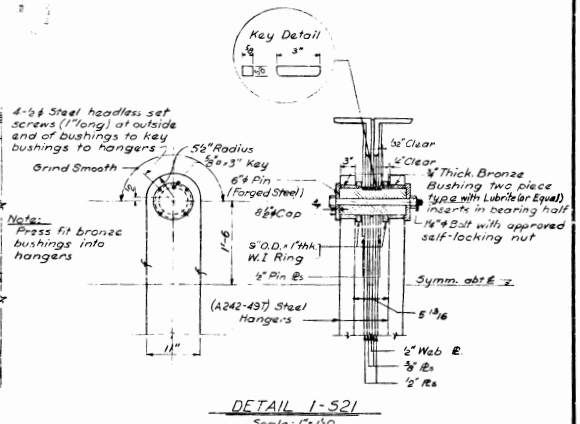


GIRDER ELEVATION - INTERIOR VIEW

Typical Haunch ℄ Pier to ℄ Expansion Hinge

Scale: ½"=1'-0

Note:
For Haunch Details not shown
See Drawing S19



Note:
Press fit bronze bushings into hangers

DETAIL 1-S21

Scale: 1"=1'-0

Notes:

Low Alloy Steel (A242-49T), Bronze Bushing & W.I. Ring to be included in price of Structural Steel.

Bronze Bushing metal shall conform to ASTM B22-52 Alloy E.

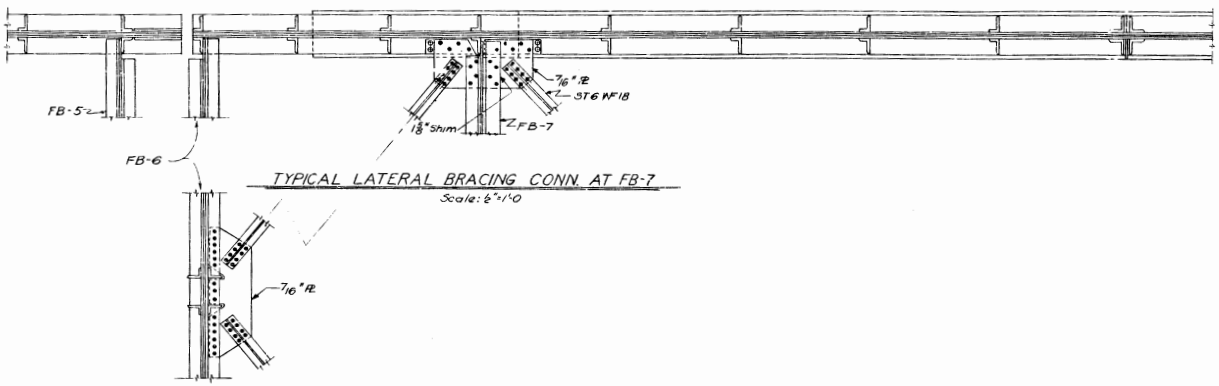
Pin holes for Hangers shall be accurately located before boring after girders are assembled for reaming.

For General Steel Notes, see Drwg. S11

For Cover Pl Rivet Pitch, see Drwg. S18

For Cover Pl Sizes & Lengths, see Framing Plans, Drwgs. S11, S12, S13 & S14

For General Notes, see Drwg. S5



TYPICAL LATERAL BRACING CONN. AT FB-7

Scale: ½"=1'-0

GIRDER DETAILS - TYP. EXPANSION HINGE

STATE HIGHWAY DEPARTMENT OF INDIANA

SCALE:- AS NOTED SEPT. 4, 1957

SUBMITTED FOR APPROVAL:- Raymond Rhodes

DRAWING:- S21 OF 45

PROJECT:- F-79(15) STA. 519+85.00

BRIDGE CONTRACT NO. 4339 ℄ PIER NO. 8

BRIDGE FILE:- 41-E-3917

DESIGNED: L. Lantzki CK'D A. Yepes

DRAWN: H. Stysinski CK'D R.F. Hall

TRACED CK'D

Appendix 1F. NSBA Spreadsheet Calculations of the Controlling Location at Each Cross-Sectional Variation Location

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-0**

Variation Desciption: **Variation 0 - No Cover Plates**

Distance from Abut **72.42** ft

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.
4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

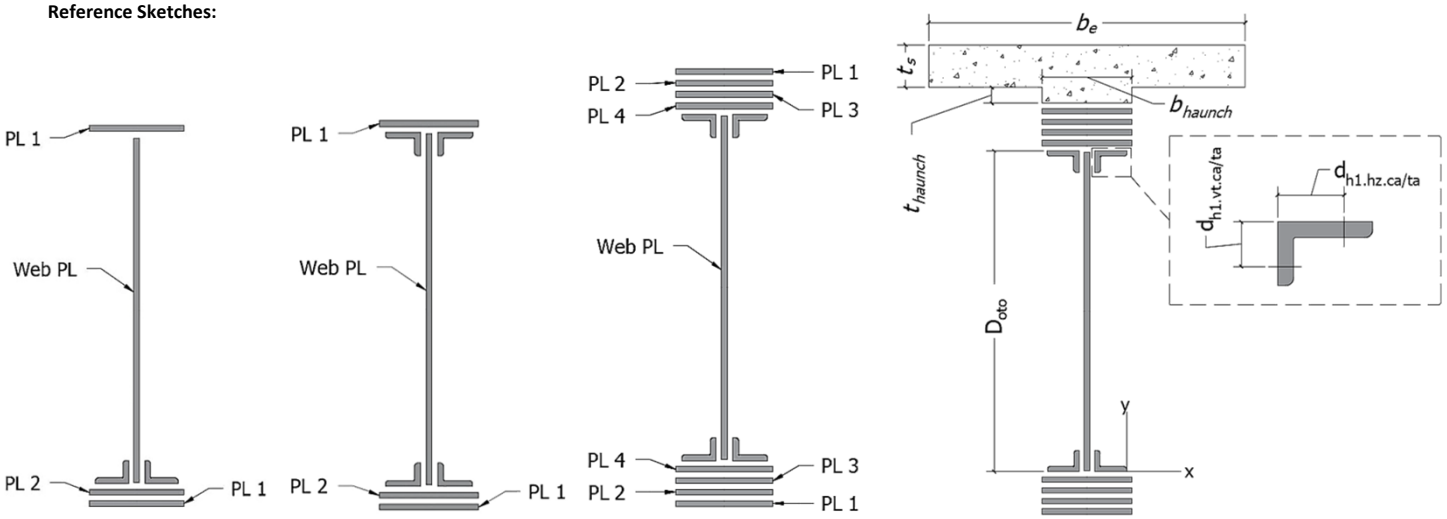
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all provisions of Section 1.5?	**No**	Yes

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**Yes**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**No**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	**84.8**	in	Haunch Width, b_{haunch}	**59.3**	in
Deck Slab Thickness, t_s	**5.8**	in	Haunch Thickness, t_{haunch}	**3.4**	in
Concrete Modulus of Elasticity, E_c	**3625.5**	ksi	Modular Ratio of the concrete, n	8.0	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **0** (1 to 4)

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**0.000**	0.000	0.000	0.000	in
$t_{ccp,i}$	**0.0000**	0.0000	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L8X8X7/8**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	13.3	in^2
Thickness of the angle, t_{ca}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ca}	2.31	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.00**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.00**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-0** Distance from Abut **72.42** ft

Variation Desciption: **Variation 0 - No Cover Plates**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	**70.00**	in	Flange Angles Out-to-out Depth, D_{oto}	**70.50**	in
Web Thickness, t_w	**0.5000**	in			

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **0** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	**0.000**	0.000	0.000	0.000	in
$t_{tcp,i}$	**0.0000**	0.0000	0.0000	#REF!	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	**L8X8X7/8**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ta.g}$	13.3	in^2
Thickness of the angle, t_{ta}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ta}	2.31	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ta}$	**4.00**	in	Distance to Hole 1, $d_{h1.hz.ta}$	**4.00**	in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00	in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	**1,005**	trucks/day	Current Year, $Y_{current}$	**2021**	year
$(ADTT_{sl})_0$	**1,005**	trucks/day	Span Length, L	**111.25**	ft
$(ADTT_{sl})_{limit}$	**8,840**	trucks/day	Number of striped lanes, n_L	**2**	lanes
Year Built, Y_{built}	**1958**	year	Stress-Range Estimate Partial LF, R_s	**1.00**	
Expected annual $(ADTT)_{SL}$ growth rate, g	**0.010**	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	**1**	cycles
			Is this a transverse member?	**No**	Y or N

Note: Growth rate is for future growth from today on

Unfactored Moments:

M_{DC1}	**149**	k-ft	M_{DW}	**46**	k-ft	M_{LL+IM}	**2,419**	k-ft
M_{DC2}	**55**	k-ft				M_{FAT+IM}	**727**	k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{G,COMP}$	#REF!	in	$\bar{y}_{C,G,NC}$	#REF!	in
$c_{G,COMP}$	#REF!	in	$c_{G,NC}$	#REF!	in
$A_{G,COMP}$	174.4	in^2	$A_{G,NC}$	88.2	in^2
$I_{xG,COMP}$	#REF!	in^4	$I_{xG,NC}$	#REF!	in^4
$S_{xG,COMP}$	#REF!	in^3	$S_{xG,NC}$	#REF!	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{N,COMP}$	#REF!	in	$\bar{y}_{N,NC}$	#REF!	in
$c_{N,COMP}$	#REF!	in	$c_{N,NC}$	#REF!	in
$A_{N,COMP}$	166.9	in^2	$A_{N,NC}$	80.7	in^2
$I_{xN,COMP}$	#REF!	in^4	$I_{xN,NC}$	#REF!	in^4
$S_{xN,COMP}$	#REF!	in^3	$S_{xN,NC}$	#REF!	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFG,COMP}$	#REF!	in	$\bar{y}_{AFG,NC}$	#REF!	in
$c_{AFG,COMP}$	#REF!	in	$c_{AFG,NC}$	#REF!	in
$A_{AFG,COMP}$	174.4	in^2	$A_{AFG,NC}$	88.2	in^2
$I_{x,AFG,COMP}$	#REF!	in^4	$I_{x,AFG,NC}$	#REF!	in^4
$S_{x\text{-}AFG,COMP}$	#REF!	in^3	$S_{x\text{-}AFG,NC}$	#REF!	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFN,COMP}$	#REF!	in	$\bar{y}_{AFN,NC}$	#REF!	in
$c_{AFN,COMP}$	#REF!	in	$c_{AFN,NC}$	#REF!	in
$A_{AFN,COMP}$	166.9	in^2	$A_{AFN,NC}$	80.7	in^2
$I_{x,AFN,COMP}$	#REF!	in^4	$I_{x,AFN,NC}$	#REF!	in^4
$S_{x\text{-}AFN,COMP}$	#REF!	in^3	$S_{x\text{-}AFN,NC}$	#REF!	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-0** Distance from Abut **72.42** ft

Variation Desciption: **Variation 0 - No Cover Plates**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = -

Number of tension CPs, N_{FL} = 0

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 3,919 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = - ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = #REF! ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = #REF! ksi GS Eq. 2.1.3-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	**#REF!**	OK or NG	GS Eq. 2.3-2	#REF!
$f_{AFG} \le f_{u,g}$?	**#REF!**	OK or NG	GS Eq. 2.3-1	#REF!

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-0** Distance from Abut **72.42** ft

Variation Desciption: **Variation 0 - No Cover Plates**

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	**#REF!**	ksi	GS Eq. 2.1.3-1

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	#REF!	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	#REF!	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	**#REF!**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	#REF!	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	#REF!	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	#REF!	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	#REF!	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	#REF!	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	#REF!	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	#REF!	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	#REF!	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	#REF!	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**#REF!**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**#REF!**	I or II	GS 2.5

Unfaulted fatigue life? **#REF!**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-0** Distance from Abut **72.42** ft

Variation Desciption: **Variation 0 - No Cover Plates**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ = **#VALUE!** ksi GS Eq. 2.1.3-1

Faulted state stress range, Δf =	#VALUE!	ksi	MBE 7.2.2
Faulted state effective stress range, $(\Delta f)_{eff}$ =	#VALUE!	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	#VALUE!	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	#VALUE!	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	#VALUE!	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	#VALUE!	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	#VALUE!	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	#VALUE!	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	#VALUE!	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	#VALUE!	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	#VALUE!	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**#VALUE!**	Years	MBE 7.2.5.1
Case I or II for faulted state?	**#VALUE!**	I(a), I(b), II	GS 2.5

Faulted fatigue life? **#VALUE!**

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	63.0	Years	GS 2.5.3
Total remaining fatigue life only in **unfaulted** state, Y_u	#REF!	Years	GS 2.5.3
Total remaining fatigue life only in **faulted** state, Y_f	#VALUE!	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**#REF!**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	-	OK or NG	GS 2.1 & 2.3
Fatigue case =	-	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	-	ksi	
Controlling stress range in faulted state, Δf_{FS} =	-	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	-	Years	
Total remaining fatigue life, N_f	-	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	-	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-1**

Distance from Abut: **63.92** ft

Variation Desciption: **Variation 1 - Controlling Fatigue and Strength Location**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.
4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

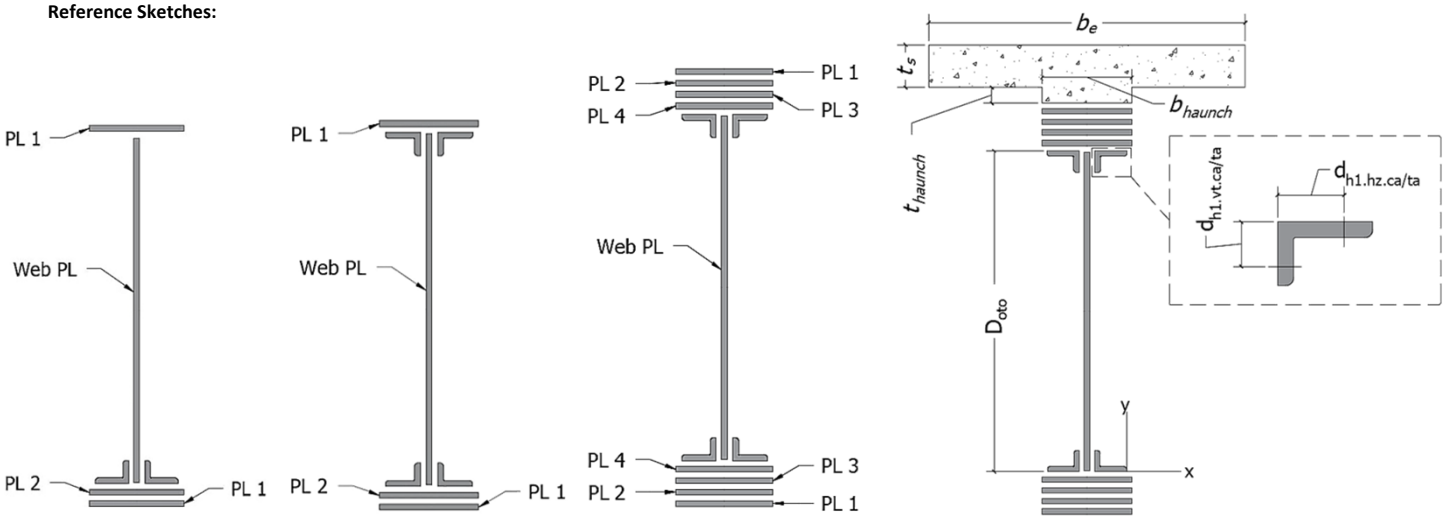
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all provisions of Section 1.5?	**Yes**	Yes

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**Yes**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**No**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	**84.8**	in	Haunch Width, b_{haunch}	**59.3**	in
Deck Slab Thickness, t_s	**5.8**	in	Haunch Thickness, t_{haunch}	**3.4**	in
Concrete Modulus of Elasticity, E_c	**3625.5**	ksi	Modular Ratio of the concrete, n	8.0	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp}: **1** (1 to 4)

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**20.000**	0.000	0.000	0.000	in
$t_{ccp,i}$	**0.4375**	0.0000	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L8X8X7/8**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	13.3	in^2
Thickness of the angle, t_{ca}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ca}	2.31	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.00**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.00**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-1** Distance from Abut **63.92** ft

Variation Desciption: **Variation 1 - Controlling Fatigue and Strength Location**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	70.00	in	Flange Angles Out-to-out Depth, D_{oto}	70.50	in
Web Thickness, t_w	0.5000	in			

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **1** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	20.000	0.000	0.000	0.000	in
$t_{tcp,i}$	0.4375	0.0000	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L8X8X7/8	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	13.3	in^2
Thickness of the angle, t_{ta}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ta}	2.31	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1	holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.00	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.00	in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00	in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	1,005	trucks/day	Current Year, $Y_{current}$	2021	year
$(ADTT_{sl})_0$	1,005	trucks/day	Span Length, L	111.25	ft
$(ADTT_{sl})_{limit}$	8,840	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
			Is this a transverse member?	No	Y or N

Note: Growth rate is for future growth from today on

Unfactored Moments:

M_{DC1}	682	k-ft	M_{DW}	171	k-ft	M_{LL+IM}	2,770	k-ft
M_{DC2}	204	k-ft				M_{FAT+IM}	756	k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{G,COMP}$	53.5	in	$\bar{y}_{C,G,NC}$	35.3	in
$c_{G,COMP}$	53.9	in	$c_{G,NC}$	35.7	in
$A_{G,COMP}$	191.9	in^2	$A_{G,NC}$	105.7	in^2
$I_{xG,COMP}$	173,263.4	in^4	$I_{xG,NC}$	94,350.6	in^4
$S_{xG,COMP}$	3,212.7	in^3	$S_{xG,NC}$	2,643.8	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{N,COMP}$	54.4	in	$\bar{y}_{N,NC}$	35.3	in
$c_{N,COMP}$	54.8	in	$c_{N,NC}$	35.7	in
$A_{N,COMP}$	182.7	in^2	$A_{N,NC}$	96.6	in^2
$I_{xN,COMP}$	159,748.0	in^4	$I_{xN,NC}$	84,189.7	in^4
$S_{xN,COMP}$	2,912.8	in^3	$S_{xN,NC}$	2,359.1	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFG,COMP}$	56.1	in	$\bar{y}_{AFG,NC}$	38.5	in
$c_{AFG,COMP}$	56.1	in	$c_{AFG,NC}$	38.5	in
$A_{AFG,COMP}$	183.1	in^2	$A_{AFG,NC}$	97.0	in^2
$I_{x,AFG,COMP}$	146,812.6	in^4	$I_{x,AFG,NC}$	82,349.2	in^4
$S_{x\text{-}AFG,COMP}$	2,618.8	in^3	$S_{x\text{-}AFG,NC}$	2,141.7	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFN,COMP}$	56.9	in	$\bar{y}_{AFN,NC}$	38.4	in
$c_{AFN,COMP}$	56.9	in	$c_{AFN,NC}$	38.4	in
$A_{AFN,COMP}$	174.8	in^2	$A_{AFN,NC}$	88.6	in^2
$I_{x,AFN,COMP}$	135,048.0	in^4	$I_{x,AFN,NC}$	73,321.1	in^4
$S_{x\text{-}AFN,COMP}$	2,374.0	in^3	$S_{x\text{-}AFN,NC}$	1,908.2	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-1** Distance from Abut **63.92** ft

Variation Desciption: **Variation 1 - Controlling Fatigue and Strength Location**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.313

Number of tension CPs, N_{FL} = 1

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 5,388 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = - ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = 28.49 ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = 25.73 ksi GS Eq. 2.1.3-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	1.85
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.22

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-1** Distance from Abut **63.92** ft

Variation Desciption: **Variation 1 - Controlling Fatigue and Strength Location**

1.85

1.22

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	**3.12**	ksi	GS Eq. 2.1.3-1

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	3.12	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	3.13	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	**6.89**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-1** Distance from Abut **63.92** ft

Variation Desciption: **Variation 1 - Controlling Fatigue and Strength Location**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ =	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ =	**5.02**	ksi	GS Eq. 2.1.3-1
Faulted state stress range, Δf =	5.02	ksi	MBE 7.2.2
Faulted state effective stress range, $(\Delta f)_{eff}$ =	5.04	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	11.10	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	3.43E+07	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	65.8	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	1,935	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**65.8**	Years	MBE 7.2.5.1
Case I or II for faulted state?	**I(b)**	I(a), I(b), II	GS 2.5

Faulted fatigue life? **OK**

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	63.0	Years	GS 2.5.3
Total remaining fatigue life only in **unfaulted** state, Y_u	∞	Years	GS 2.5.3
Total remaining fatigue life only in **faulted** state, Y_f	65.8	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**65.8**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	I(b)	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	3.12	ksi	
Controlling stress range in faulted state, Δf_{FS} =	5.02	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**65.8**	Years	
Total remaining fatigue life, N_f	**65.8**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-2** Distance from Abut **44.5** ft

Variation Desciption: **Variation 2 - Controlling Strength Location**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

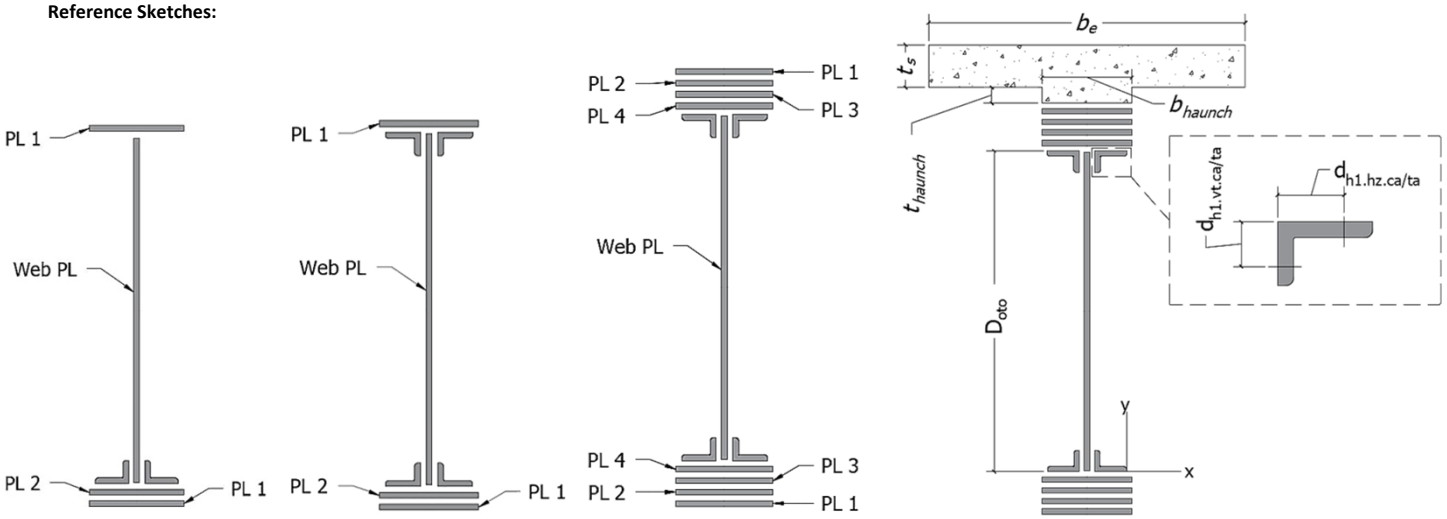
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all provisions of Section 1.5?	**Yes**	Yes

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**Yes**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**No**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	**84.8**	in	Haunch Width, b_{haunch}	**59.3**	in
Deck Slab Thickness, t_s	**5.8**	in	Haunch Thickness, t_{haunch}	**3.4**	in
Concrete Modulus of Elasticity, E_c	**3625.5**	ksi	Modular Ratio of the concrete, n	8.0	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **2** (1 to 4)

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**20.000**	**20.000**	0.000	0.000	in
$t_{ccp,i}$	**0.4375**	**0.4375**	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L8X8X7/8**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	13.3	in^2
Thickness of the angle, t_{ca}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ca}	2.31	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.00**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.00**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-2** Distance from Abut **44.5** ft

Variation Desciption: **Variation 2 - Controlling Strength Location**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	70.00	in	Flange Angles Out-to-out Depth, D_{oto}	70.50	in
Web Thickness, t_w	0.5000	in			

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **2** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	20.000	20.000	0.000	0.000	in
$t_{tcp,i}$	0.4375	0.4375	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L8X8X7/8	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	13.3	in^2
Thickness of the angle, t_{ta}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ta}	2.31	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1	holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.00	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.00	in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00	in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	558	trucks/day	Current Year, $Y_{current}$	2021	year
$(ADTT_{sl})_0$	558	trucks/day	Span Length, L	111.25	ft
$(ADTT_{sl})_{limit}$	8,840	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
			Is this a transverse member?	No	Y or N

Note: Growth rate is for future growth from today on

Unfactored Moments:

M_{DC1}	1,348	k-ft	M_{DW}	327	k-ft	M_{LL+IM}	2,990	k-ft
M_{DC2}	390	k-ft				M_{FAT+IM}	722	k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{G,COMP}$	52.1	in	$\bar{y}_{C,G,NC}$	35.3	in
$c_{G,COMP}$	53.0	in	$c_{G,NC}$	36.1	in
$A_{G,COMP}$	209.4	in^2	$A_{G,NC}$	123.2	in^2
$I_{xG,COMP}$	202,975.6	in^4	$I_{xG,NC}$	116,912.9	in^4
$S_{xG,COMP}$	3,828.0	in^3	$S_{xG,NC}$	3,236.3	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{N,COMP}$	53.1	in	$\bar{y}_{N,NC}$	35.3	in
$c_{N,COMP}$	53.9	in	$c_{N,NC}$	36.1	in
$A_{N,COMP}$	198.6	in^2	$A_{N,NC}$	112.4	in^2
$I_{xN,COMP}$	187,277.2	in^4	$I_{xN,NC}$	104,636.8	in^4
$S_{xN,COMP}$	3,471.9	in^3	$S_{xN,NC}$	2,896.5	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFG,COMP}$	54.5	in	$\bar{y}_{AFG,NC}$	38.0	in
$c_{AFG,COMP}$	54.9	in	$c_{AFG,NC}$	38.4	in
$A_{AFG,COMP}$	200.6	in^2	$A_{AFG,NC}$	114.5	in^2
$I_{x,AFG,COMP}$	177,512.8	in^4	$I_{x,AFG,NC}$	104,769.3	in^4
$S_{x\text{-}AFG,COMP}$	3,234.0	in^3	$S_{x\text{-}AFG,NC}$	2,726.1	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFN,COMP}$	55.3	in	$\bar{y}_{AFN,NC}$	38.0	in
$c_{AFN,COMP}$	55.7	in	$c_{AFN,NC}$	38.4	in
$A_{AFN,COMP}$	190.6	in^2	$A_{AFN,NC}$	104.5	in^2
$I_{x,AFN,COMP}$	163,470.6	in^4	$I_{x,AFN,NC}$	93,637.3	in^4
$S_{x\text{-}AFN,COMP}$	2,932.8	in^3	$S_{x\text{-}AFN,NC}$	2,437.7	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-2** Distance from Abut **44.5** ft

Variation Desciption: **Variation 2 - Controlling Strength Location**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.375

Number of tension CPs, N_{FL} = 2

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 6,893 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = - ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = 29.87 ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = 26.96 ksi GS Eq. 2.1.3-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	1.77
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.16

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-2** Distance from Abut **44.5** ft

Variation Desciption: **Variation 2 - Controlling Strength Location**

1.77

1.16

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	**2.50**	ksi	GS Eq. 2.1.3-1

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.00		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	2.50	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	2.51	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	**5.51**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-2** Distance from Abut **44.5** ft

Variation Desciption: **Variation 2 - Controlling Strength Location**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ =	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \beta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ =	**4.06**	ksi	GS Eq. 2.1.3-1
Faulted state stress range, Δf =	4.06	ksi	MBE 7.2.2
Faulted state effective stress range, $(\Delta f)_{eff}$ =	4.08	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	8.97	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for faulted state?	**I(a)**	I(a), I(b), II	GS 2.5

Faulted fatigue life? **OK**

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	63.0	Years	GS 2.5.3
Total remaining fatigue life only in **unfaulted** state, Y_u	∞	Years	GS 2.5.3
Total remaining fatigue life only in **faulted** state, Y_f	Infinite	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**Infinite**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	I(a)	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	2.50	ksi	
Controlling stress range in faulted state, Δf_{FS} =	4.06	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	
Total remaining fatigue life, N_f	**Infinite**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-2** Distance from Abut **63.92** ft

Variation Desciption: **Variation 2 - Controlling Fatigue Location**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

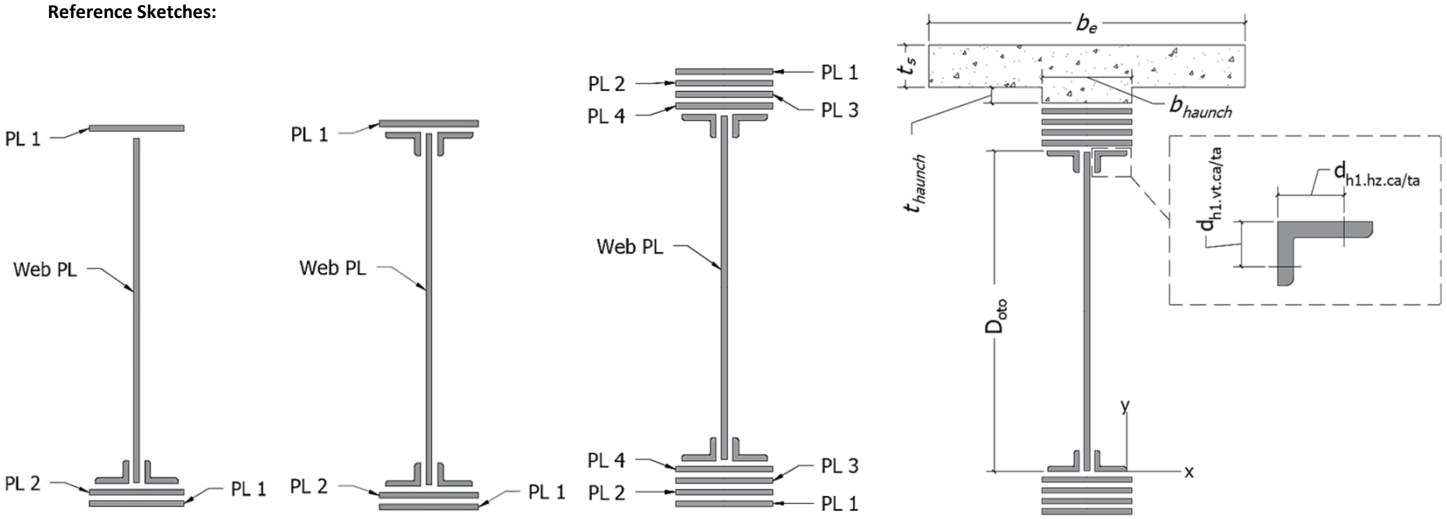
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all provisions of Section 1.5?	**Yes**	Yes

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**Yes**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**No**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	**84.8**	in	Haunch Width, b_{haunch}	**59.3**	in
Deck Slab Thickness, t_s	**5.8**	in	Haunch Thickness, t_{haunch}	**3.4**	in
Concrete Modulus of Elasticity, E_c	**3625.5**	ksi	Modular Ratio of the concrete, n	8.0	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **2** (1 to 4)

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**20.000**	**20.000**	0.000	0.000	in
$t_{ccp,i}$	**0.4375**	**0.4375**	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L8X8X7/8**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	13.3	in^2
Thickness of the angle, t_{ca}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ca}	2.31	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.00**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.00**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-2** Distance from Abut **63.92** ft

Variation Desciption: **Variation 2 - Controlling Fatigue Location**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	70.00	in	Flange Angles Out-to-out Depth, D_{oto}	70.50	in
Web Thickness, t_w	0.5000	in			

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **2** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	20.000	20.000	0.000	0.000	in
$t_{tcp,i}$	0.4375	0.4375	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L8X8X7/8	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	13.3	in^2
Thickness of the angle, t_{ta}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ta}	2.31	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1	holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.00	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.00	in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00	in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	1,005	trucks/day	Current Year, $Y_{current}$	2021	year
$(ADTT_{sl})_0$	1,005	trucks/day	Span Length, L	111.25	ft
$(ADTT_{sl})_{limit}$	8,840	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
			Is this a transverse member?	No	Y or N

Note: Growth rate is for future growth from today on

Unfactored Moments:

M_{DC1}	682	k-ft	M_{DW}	171	k-ft	M_{LL+IM}	2,770	k-ft
M_{DC2}	204	k-ft				M_{FAT+IM}	756	k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{G,COMP}$	52.1	in	$\bar{y}_{G,NC}$	35.3	in
$c_{G,COMP}$	53.0	in	$c_{G,NC}$	36.1	in
$A_{G,COMP}$	209.4	in^2	$A_{G,NC}$	123.2	in^2
$I_{xG,COMP}$	202,975.6	in^4	$I_{xG,NC}$	116,912.9	in^4
$S_{xG,COMP}$	3,828.0	in^3	$S_{xG,NC}$	3,236.3	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{N,COMP}$	53.1	in	$\bar{y}_{N,NC}$	35.3	in
$c_{N,COMP}$	53.9	in	$c_{N,NC}$	36.1	in
$A_{N,COMP}$	198.6	in^2	$A_{N,NC}$	112.4	in^2
$I_{xN,COMP}$	187,277.2	in^4	$I_{xN,NC}$	104,636.8	in^4
$S_{xN,COMP}$	3,471.9	in^3	$S_{xN,NC}$	2,896.5	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFG,COMP}$	54.5	in	$\bar{y}_{AFG,NC}$	38.0	in
$c_{AFG,COMP}$	54.9	in	$c_{AFG,NC}$	38.4	in
$A_{AFG,COMP}$	200.6	in^2	$A_{AFG,NC}$	114.5	in^2
$I_{x,AFG,COMP}$	177,512.8	in^4	$I_{x,AFG,NC}$	104,769.3	in^4
$S_{x\text{-}AFG,COMP}$	3,234.0	in^3	$S_{x\text{-}AFG,NC}$	2,726.1	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFN,COMP}$	55.3	in	$\bar{y}_{AFN,NC}$	38.0	in
$c_{AFN,COMP}$	55.7	in	$c_{AFN,NC}$	38.4	in
$A_{AFN,COMP}$	190.6	in^2	$A_{AFN,NC}$	104.5	in^2
$I_{x,AFN,COMP}$	163,470.6	in^4	$I_{x,AFN,NC}$	93,637.3	in^4
$S_{x\text{-}AFN,COMP}$	2,932.8	in^3	$S_{x\text{-}AFN,NC}$	2,437.7	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-2** Distance from Abut **63.92** ft

Variation Desciption: **Variation 2 - Controlling Fatigue Location**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.375

Number of tension CPs, N_{FL} = 2

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 5,388 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = - ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = 22.89 ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = 20.70 ksi GS Eq. 2.1.3-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	2.31
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.51

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-2** Distance from Abut **63.92** ft

Variation Desciption: **Variation 2 - Controlling Fatigue Location**

2.31
1.51

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	**2.61**	ksi	GS Eq. 2.1.3-1

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	2.61	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	2.63	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	**5.78**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-2** Distance from Abut **63.92** ft

Variation Desciption: **Variation 2 - Controlling Fatigue Location**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ =	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \beta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ =	**4.26**	ksi	GS Eq. 2.1.3-1
Faulted state stress range, Δf =	4.26	ksi	MBE 7.2.2
Faulted state effective stress range, $(\Delta f)_{eff}$ =	4.28	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	9.41	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for faulted state?	**I(a)**	I(a), I(b), II	GS 2.5

Faulted fatigue life? **OK**

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	63.0	Years	GS 2.5.3
Total remaining fatigue life only in **unfaulted** state, Y_u	∞	Years	GS 2.5.3
Total remaining fatigue life only in **faulted** state, Y_f	Infinite	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**Infinite**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	I(a)	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	2.61	ksi	
Controlling stress range in faulted state, Δf_{FS} =	4.26	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	
Total remaining fatigue life, N_f	**Infinite**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-3** Distance from Abut **450.42** ft

Variation Desciption: **Variation 3 - Controlling Strength Location**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

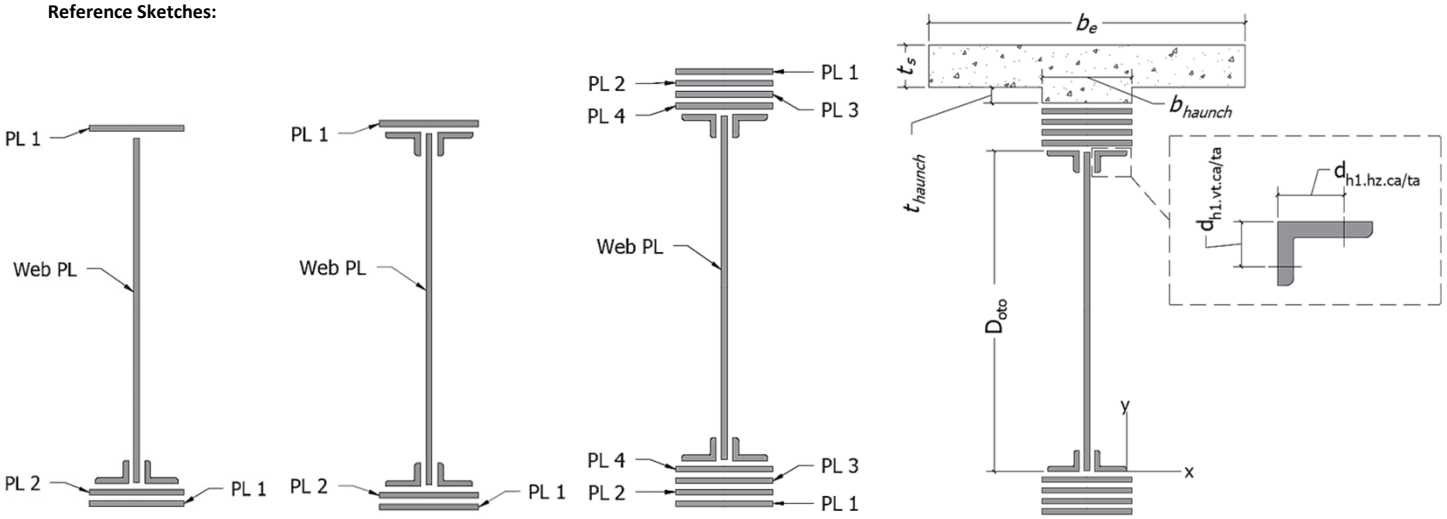
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all provisions of Section 1.5?	**Yes**	Yes

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**Yes**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**Yes**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	**84.8**	in	Haunch Width, b_{haunch}	**59.3**	in
Deck Slab Thickness, t_s	**5.8**	in	Haunch Thickness, t_{haunch}	**3.4**	in
Concrete Modulus of Elasticity, E_c	**3625.5**	ksi	Modular Ratio of the concrete, n	8.0	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **1** (1 to 4)

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**20.000**	0.000	0.000	0.000	in
$t_{ccp,i}$	**0.6875**	0.0000	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L8X8X7/8**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	13.3	in^2
Thickness of the angle, t_{ca}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ca}	2.31	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.00**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.00**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-3** Distance from Abut **450.42** ft

Variation Desciption: **Variation 3 - Controlling Strength Location**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	70.30	in	Flange Angles Out-to-out Depth, D_{oto}	70.80	in
Web Thickness, t_w	0.5000	in			

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **1** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	20.000	0.000	0.000	0.000	in
$t_{tcp,i}$	0.6875	0.0000	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L8X8X7/8	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	13.3	in^2
Thickness of the angle, t_{ta}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ta}	2.31	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1	holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.00	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.00	in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00	in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	1,005	trucks/day	Current Year, $Y_{current}$	2021	year
$(ADTT_{sl})_0$	1,005	trucks/day	Span Length, L	155.75	ft
$(ADTT_{sl})_{limit}$	8,840	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
			Is this a transverse member?	No	Y or N

Note: Growth rate is for future growth from today on

Unfactored Moments:

M_{DC1}	597	k-ft	M_{DW}	125	k-ft	M_{LL+IM}	4,066	k-ft
M_{DC2}	149	k-ft				M_{FAT+IM}	736	k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{G,COMP}$	22.7	in	$\bar{y}_{C,G,NC}$	35.4	in
$c_{G,COMP}$	23.4	in	$c_{G,NC}$	36.1	in
$A_{G,COMP}$	202.0	in^2	$A_{G,NC}$	115.9	in^2
$I_{xG,COMP}$	152,542.9	in^4	$I_{xG,NC}$	108,181.8	in^4
$S_{xG,COMP}$	6,521.7	in^3	$S_{xG,NC}$	2,997.8	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{N,COMP}$	22.0	in	$\bar{y}_{N,NC}$	35.4	in
$c_{N,COMP}$	22.7	in	$c_{N,NC}$	36.1	in
$A_{N,COMP}$	191.9	in^2	$A_{N,NC}$	105.8	in^2
$I_{xN,COMP}$	139,278.0	in^4	$I_{xN,NC}$	96,716.8	in^4
$S_{xN,COMP}$	6,129.3	in^3	$S_{xN,NC}$	2,680.1	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFG,COMP}$	24.4	in	$\bar{y}_{AFG,NC}$	40.2	in
$c_{AFG,COMP}$	24.4	in	$c_{AFG,NC}$	40.2	in
$A_{AFG,COMP}$	188.3	in^2	$A_{AFG,NC}$	102.1	in^2
$I_{x,AFG,COMP}$	144,705.9	in^4	$I_{x,AFG,NC}$	88,248.2	in^4
$S_{x\text{-}AFG,COMP}$	5,934.0	in^3	$S_{x\text{-}AFG,NC}$	2,194.5	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFN,COMP}$	23.6	in	$\bar{y}_{AFN,NC}$	40.2	in
$c_{AFN,COMP}$	23.6	in	$c_{AFN,NC}$	40.2	in
$A_{AFN,COMP}$	179.5	in^2	$A_{AFN,NC}$	93.3	in^2
$I_{x,AFN,COMP}$	132,573.7	in^4	$I_{x,AFN,NC}$	78,669.9	in^4
$S_{x\text{-}AFN,COMP}$	5,620.0	in^3	$S_{x\text{-}AFN,NC}$	1,958.3	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-3** Distance from Abut **450.42** ft

Variation Desciption: **Variation 3 - Controlling Strength Location**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.313

Number of tension CPs, N_{FL} = 1

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 7,113 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = - ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = 43.59 ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = 38.90 ksi GS Eq. 2.1.3-2

Note: Outputs are based on noncomposite section properties for a negative moment region

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	1.21
$f_{AFG} \le f_{u,g}$?	NG	OK or NG	GS Eq. 2.3-1	0.81

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-3** Distance from Abut **450.42** ft

Variation Desciption: **Variation 3 - Controlling Strength Location**

1.21

0.81

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	**3.30**	ksi	GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	3.30	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	3.32	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	**7.31**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	5.99E+07	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	2.35E+07	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	68.8	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	1,993	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**68.8**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**II**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-3** Distance from Abut **450.42** ft

Variation Desciption: **Variation 3 - Controlling Strength Location**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ =	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \beta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ =	**5.92**	ksi	GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Faulted state stress range, Δf =	5.92	ksi	MBE 7.2.2
Faulted state effective stress range, $(\Delta f)_{eff}$ =	5.97	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	13.14	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	2.07E+07	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	44.6	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	1,566	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8

Total faulted state remaining fatigue life, Y_{REM}	**44.6**	Years	MBE 7.2.5.1	Faulted fatigue life?	**OK**
Case I or II for faulted state?	**II**	I(a), I(b), II	GS 2.5		

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	63.0	Years	GS 2.5.3
Total remaining fatigue life only in **unfaulted** state, Y_u	131.8	Years	GS 2.5.3
Total remaining fatigue life only in **faulted** state, Y_f	44.6	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**23.3**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**NG**	OK or NG	GS 2.1 & 2.3
Fatigue case =	-	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	-	ksi	
Controlling stress range in faulted state, Δf_{FS} =	-	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	-	Years	
Total remaining fatigue life, N_f	-	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	-	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-3** Distance from Abut **700.88** ft

Variation Desciption: **Variation 3 - Controlling Fatigue Location**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

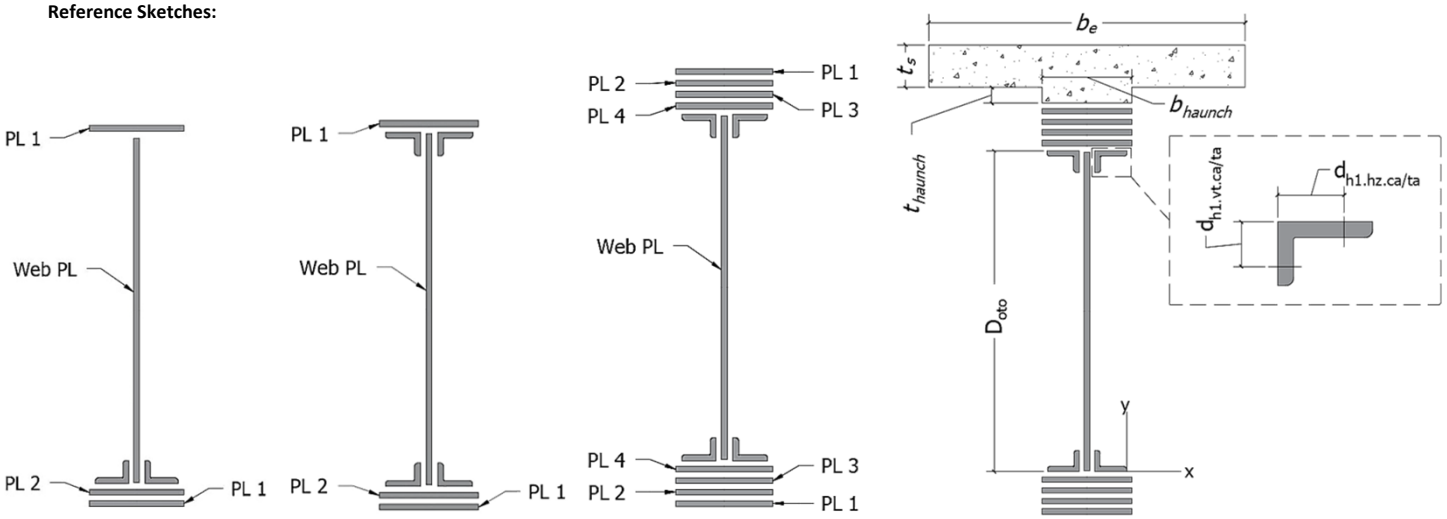
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all provisions of Section 1.5?	**Yes**	Yes

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**Yes**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**Yes**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	**84.8**	in	Haunch Width, b_{haunch}	**59.3**	in
Deck Slab Thickness, t_s	**5.8**	in	Haunch Thickness, t_{haunch}	**3.4**	in
Concrete Modulus of Elasticity, E_c	**3625.5**	ksi	Modular Ratio of the concrete, n	8.0	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **1** (1 to 4)

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**20.000**	0.000	0.000	0.000	in
$t_{ccp,i}$	**0.6875**	0.0000	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L8X8X7/8**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	13.3	in^2
Thickness of the angle, t_{ca}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ca}	2.31	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.00**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.00**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-3** Distance from Abut **700.88** ft

Variation Desciption: **Variation 3 - Controlling Fatigue Location**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	70.00	in	Flange Angles Out-to-out Depth, D_{oto}	70.50	in
Web Thickness, t_w	0.5000	in			

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **1** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	20.000	0.000	0.000	0.000	in
$t_{tcp,i}$	0.6875	0.0000	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L8X8X7/8	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	13.3	in^2
Thickness of the angle, t_{ta}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ta}	2.31	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1	holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.00	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.00	in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00	in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	1,005	trucks/day	Current Year, $Y_{current}$	2021	year
$(ADTT_{sl})_0$	1,005	trucks/day	Span Length, L	155.75	ft
$(ADTT_{sl})_{limit}$	8,840	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
			Is this a transverse member?	No	Y or N

Note: Growth rate is for future growth from today on

Unfactored Moments:

M_{DC1}	444	k-ft	M_{DW}	92	k-ft	M_{LL+IM}	2,469	k-ft
M_{DC2}	109	k-ft				M_{FAT+IM}	759	k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{G,COMP}$	22.6	in	$\bar{y}_{C,G,NC}$	35.3	in
$c_{G,COMP}$	23.3	in	$c_{G,NC}$	35.9	in
$A_{G,COMP}$	201.9	in^2	$A_{G,NC}$	115.7	in^2
$I_{xG,COMP}$	151,073.1	in^4	$I_{xG,NC}$	107,176.0	in^4
$S_{xG,COMP}$	6,485.3	in^3	$S_{xG,NC}$	2,982.3	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{N,COMP}$	21.9	in	$\bar{y}_{N,NC}$	35.3	in
$c_{N,COMP}$	22.6	in	$c_{N,NC}$	35.9	in
$A_{N,COMP}$	191.8	in^2	$A_{N,NC}$	105.6	in^2
$I_{xN,COMP}$	137,925.0	in^4	$I_{xN,NC}$	95,812.7	in^4
$S_{xN,COMP}$	6,094.7	in^3	$S_{xN,NC}$	2,666.1	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFG,COMP}$	24.3	in	$\bar{y}_{AFG,NC}$	40.1	in
$c_{AFG,COMP}$	24.3	in	$c_{AFG,NC}$	40.1	in
$A_{AFG,COMP}$	188.1	in^2	$A_{AFG,NC}$	102.0	in^2
$I_{x,AFG,COMP}$	143,300.4	in^4	$I_{x,AFG,NC}$	87,406.0	in^4
$S_{x\text{-}AFG,COMP}$	5,900.8	in^3	$S_{x\text{-}AFG,NC}$	2,182.4	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFN,COMP}$	23.5	in	$\bar{y}_{AFN,NC}$	40.0	in
$c_{AFN,COMP}$	23.5	in	$c_{AFN,NC}$	40.0	in
$A_{AFN,COMP}$	179.3	in^2	$A_{AFN,NC}$	93.2	in^2
$I_{x,AFN,COMP}$	131,276.0	in^4	$I_{x,AFN,NC}$	77,913.5	in^4
$S_{x\text{-}AFN,COMP}$	5,588.3	in^3	$S_{x\text{-}AFN,NC}$	1,947.3	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-3** Distance from Abut **700.88** ft

Variation Desciption: **Variation 3 - Controlling Fatigue Location**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No Optional FCP override: "Override" or blank

(This is based on the year built; "No" if prior to 1978) (This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95 Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.313

Number of tension CPs, N_{FL} = 1

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 4,455 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = - ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = 27.45 ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = 24.50 ksi GS Eq. 2.1.3-2

Note: Outputs are based on noncomposite section properties for a negative moment region

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	1.92
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.28

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-3** Distance from Abut **700.88** ft

Variation Desciption: **Variation 3 - Controlling Fatigue Location**

1.92

1.28

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	**3.42**	ksi	GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	3.42	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	3.44	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	**7.57**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	5.39E+07	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	2.35E+07	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	60.3	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	1,831	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**60.3**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**II**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-3** Distance from Abut **700.88** ft

Variation Desciption: **Variation 3 - Controlling Fatigue Location**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ =	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \beta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ =	**6.14**	ksi	GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Faulted state stress range, Δf =	6.14	ksi	MBE 7.2.2
Faulted state effective stress range, $(\Delta f)_{eff}$ =	6.19	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	13.61	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	1.86E+07	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	40.9	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	1,509	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8

Total faulted state remaining fatigue life, Y_{REM}	**40.9**	Years	MBE 7.2.5.1	Faulted fatigue life?	**OK**
Case I or II for faulted state?	**II**	I(a), I(b), II	GS 2.5		

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	63.0	Years	GS 2.5.3
Total remaining fatigue life only in **unfaulted** state, Y_u	123.3	Years	GS 2.5.3
Total remaining fatigue life only in **faulted** state, Y_f	40.9	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1\text{-}N_u/Y_u)$	**20.0**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	II	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	3.42	ksi	
Controlling stress range in faulted state, Δf_{FS} =	6.14	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**40.9**	Years	
Total remaining fatigue life, N_f	**20.0**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-4** Distance from Abut **1123.63** ft

Variation Desciption: **Variation 4 - Controlling Strength Location**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

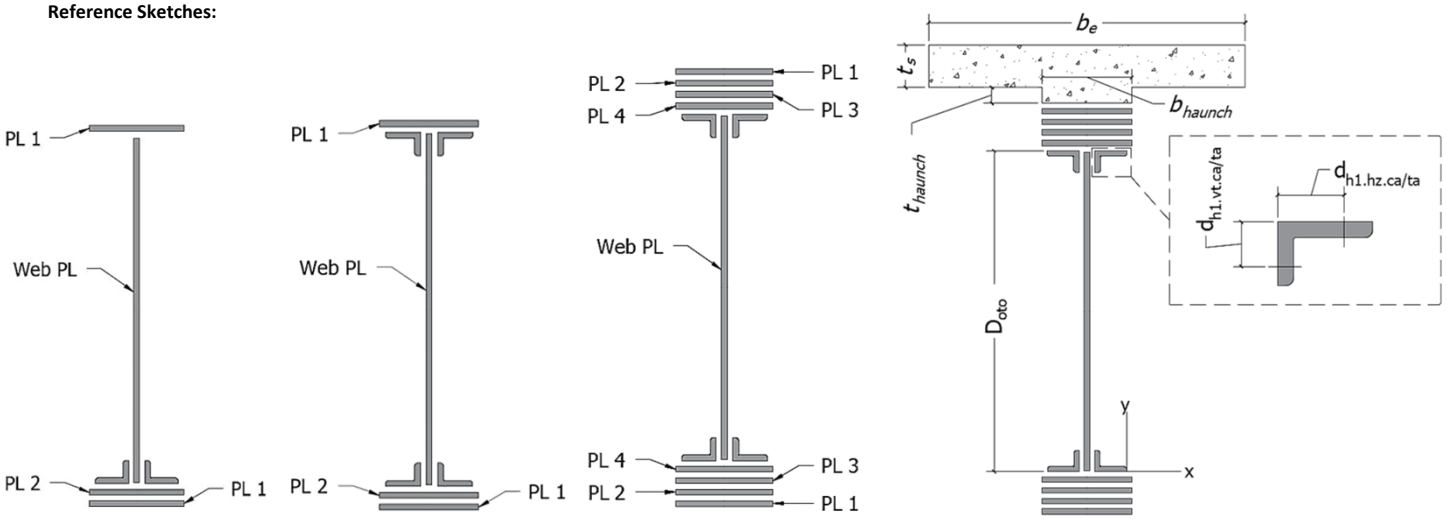
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all provisions of Section 1.5?	**Yes**	Yes

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**Yes**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**No**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	**84.8**	in	Haunch Width, b_{haunch}	**59.3**	in
Deck Slab Thickness, t_s	**5.8**	in	Haunch Thickness, t_{haunch}	**3.4**	in
Concrete Modulus of Elasticity, E_c	**3625.5**	ksi	Modular Ratio of the concrete, n	8.0	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **2** 1 to 4

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**20.000**	**20.000**	0.000	0.000	in
$t_{ccp,i}$	**0.6250**	**0.6875**	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L8X8X7/8**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	13.3	in^2
Thickness of the angle, t_{ca}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ca}	2.31	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.00**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.00**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-4** Distance from Abut **1123.63** ft

Variation Desciption: **Variation 4 - Controlling Strength Location**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	70.00	in	Flange Angles Out-to-out Depth, D_{oto}	70.50	in
Web Thickness, t_w	0.5000	in			

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **2** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	20.000	20.000	0.000	0.000	in
$t_{tcp,i}$	0.6250	0.6875	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L8X8X7/8	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	13.3	in^2
Thickness of the angle, t_{ta}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ta}	2.31	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1	holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.00	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.00	in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00	in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	558	trucks/day	Current Year, $Y_{current}$	2021	year
$(ADTT_{sl})_0$	558	trucks/day	Span Length, L	155.75	ft
$(ADTT_{sl})_{limit}$	8,840	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
			Is this a transverse member?	No	Y or N

Note: Growth rate is for future growth from today on

Unfactored Moments:

M_{DC1}	1,670	k-ft	M_{DW}	390	k-ft	M_{LL+IM}	3,668	k-ft
M_{DC2}	464	k-ft				M_{FAT+IM}	762	k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{G,COMP}$	51.0	in	$\bar{y}_{C,G,NC}$	35.3	in
$c_{G,COMP}$	52.3	in	$c_{G,NC}$	36.6	in
$A_{G,COMP}$	226.9	in^2	$A_{G,NC}$	140.7	in^2
$I_{xG,COMP}$	232,633.4	in^4	$I_{xG,NC}$	140,028.4	in^4
$S_{xG,COMP}$	4,446.0	in^3	$S_{xG,NC}$	3,829.8	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{N,COMP}$	51.9	in	$\bar{y}_{N,NC}$	35.3	in
$c_{N,COMP}$	53.2	in	$c_{N,NC}$	36.6	in
$A_{N,COMP}$	214.4	in^2	$A_{N,NC}$	128.3	in^2
$I_{xN,COMP}$	214,736.3	in^4	$I_{xN,NC}$	125,585.2	in^4
$S_{xN,COMP}$	4,033.6	in^3	$S_{xN,NC}$	3,434.8	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFG,COMP}$	54.0	in	$\bar{y}_{AFG,NC}$	38.8	in
$c_{AFG,COMP}$	54.7	in	$c_{AFG,NC}$	39.5	in
$A_{AFG,COMP}$	214.4	in^2	$A_{AFG,NC}$	128.2	in^2
$I_{x,AFG,COMP}$	196,846.0	in^4	$I_{x,AFG,NC}$	122,000.6	in^4
$S_{x\text{-}AFG,COMP}$	3,596.5	in^3	$S_{x\text{-}AFG,NC}$	3,090.8	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFN,COMP}$	54.9	in	$\bar{y}_{AFN,NC}$	38.8	in
$c_{AFN,COMP}$	55.6	in	$c_{AFN,NC}$	39.4	in
$A_{AFN,COMP}$	203.1	in^2	$A_{AFN,NC}$	117.0	in^2
$I_{x,AFN,COMP}$	181,276.7	in^4	$I_{x,AFN,NC}$	109,257.0	in^4
$S_{x\text{-}AFN,COMP}$	3,262.5	in^3	$S_{x\text{-}AFN,NC}$	2,769.6	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-4** Distance from Abut **1123.63** ft

Variation Desciption: **Variation 4 - Controlling Strength Location**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.375

Number of tension CPs, N_{FL} = 2

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 8,444 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = - ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = 32.66 ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = 29.51 ksi GS Eq. 2.1.3-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	1.62
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.06

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-4** Distance from Abut **1123.63** ft

Variation Desciption: **Variation 4 - Controlling Strength Location**

1.62

1.06

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	**2.27**	ksi	GS Eq. 2.1.3-1

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	2.27	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	2.28	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	**5.02**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-4** Distance from Abut **1123.63** ft

Variation Desciption: **Variation 4 - Controlling Strength Location**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ =	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \beta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ =	**3.85**	ksi	GS Eq. 2.1.3-1
Faulted state stress range, Δf =	3.85	ksi	MBE 7.2.2
Faulted state effective stress range, $(\Delta f)_{eff}$ =	3.88	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	8.53	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for faulted state?	**I(a)**	I(a), I(b), II	GS 2.5

Faulted fatigue life? **OK**

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	63.0	Years	GS 2.5.3
Total remaining fatigue life only in **unfaulted** state, Y_u	∞	Years	GS 2.5.3
Total remaining fatigue life only in **faulted** state, Y_f	Infinite	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**Infinite**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	I(a)	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	2.27	ksi	
Controlling stress range in faulted state, Δf_{FS} =	3.85	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	
Total remaining fatigue life, N_f	**Infinite**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-4** Distance from Abut **604.5** ft

Variation Desciption: **Variation 4 - Controlling Fatigue Location**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

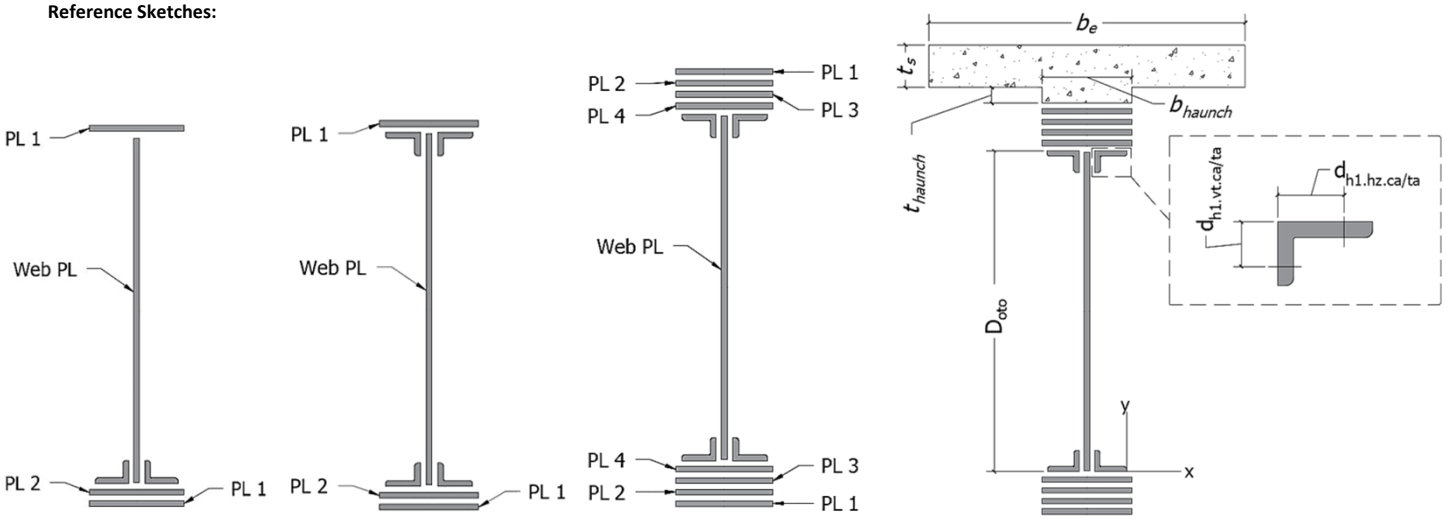
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all provisions of Section 1.5?	**Yes**	Yes

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**Yes**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**Yes**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	**84.8**	in	Haunch Width, b_{haunch}	**59.3**	in
Deck Slab Thickness, t_s	**5.8**	in	Haunch Thickness, t_{haunch}	**3.4**	in
Concrete Modulus of Elasticity, E_c	**3625.5**	ksi	Modular Ratio of the concrete, n	8.0	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **2** 1 to 4

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**20.000**	**20.000**	0.000	0.000	in
$t_{ccp,i}$	**0.6250**	**0.6875**	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L8X8X7/8**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	13.3	in^2
Thickness of the angle, t_{ca}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ca}	2.31	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.00**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.00**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-4** Distance from Abut **604.5** ft

Variation Desciption: **Variation 4 - Controlling Fatigue Location**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	70.90	in	Flange Angles Out-to-out Depth, D_{oto}	71.40	in
Web Thickness, t_w	0.5000	in			

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **2** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	20.000	20.000	0.000	0.000	in
$t_{tcp,i}$	0.6250	0.6875	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L8X8X7/8	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	13.3	in^2
Thickness of the angle, t_{ta}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ta}	2.31	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1	holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.00	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.00	in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00	in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	558	trucks/day	Current Year, $Y_{current}$	2021	year
$(ADTT_{sl})_0$	558	trucks/day	Span Length, L	155.75	ft
$(ADTT_{sl})_{limit}$	8,840	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
			Is this a transverse member?	No	Y or N

Note: Growth rate is for future growth from today on

Unfactored Moments:

M_{DC1}	1,187	k-ft	M_{DW}	267	k-ft	M_{LL+IM}	2,817	k-ft
M_{DC2}	317	k-ft				M_{FAT+IM}	702	k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{G,COMP}$	24.5	in	$\bar{y}_{C,G,NC}$	35.7	in
$c_{G,COMP}$	25.9	in	$c_{G,NC}$	37.0	in
$A_{G,COMP}$	227.3	in^2	$A_{G,NC}$	141.2	in^2
$I_{xG,COMP}$	190,838.5	in^4	$I_{xG,NC}$	143,881.9	in^4
$S_{xG,COMP}$	7,382.1	in^3	$S_{xG,NC}$	3,887.4	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{N,COMP}$	23.9	in	$\bar{y}_{N,NC}$	35.7	in
$c_{N,COMP}$	25.2	in	$c_{N,NC}$	37.0	in
$A_{N,COMP}$	214.9	in^2	$A_{N,NC}$	128.7	in^2
$I_{xN,COMP}$	174,280.7	in^4	$I_{xN,NC}$	129,055.6	in^4
$S_{xN,COMP}$	6,914.2	in^3	$S_{xN,NC}$	3,486.8	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{AFG,COMP}$	26.0	in	$\bar{y}_{AFG,NC}$	39.3	in
$c_{AFG,COMP}$	26.7	in	$c_{AFG,NC}$	40.0	in
$A_{AFG,COMP}$	214.8	in^2	$A_{AFG,NC}$	128.7	in^2
$I_{x,AFG,COMP}$	182,210.6	in^4	$I_{x,AFG,NC}$	125,409.5	in^4
$S_{x\text{-}AFG,COMP}$	6,821.1	in^3	$S_{x\text{-}AFG,NC}$	3,138.9	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{AFN,COMP}$	25.3	in	$\bar{y}_{AFN,NC}$	39.2	in
$c_{AFN,COMP}$	26.0	in	$c_{AFN,NC}$	39.9	in
$A_{AFN,COMP}$	203.6	in^2	$A_{AFN,NC}$	117.4	in^2
$I_{x,AFN,COMP}$	166,844.7	in^4	$I_{x,AFN,NC}$	112,325.2	in^4
$S_{x\text{-}AFN,COMP}$	6,425.3	in^3	$S_{x\text{-}AFN,NC}$	2,813.1	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-4** Distance from Abut **604.5** ft

Variation Desciption: **Variation 4 - Controlling Fatigue Location**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.375

Number of tension CPs, N_{FL} = 2

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 6,289 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = - ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = 26.83 ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = 24.04 ksi GS Eq. 2.1.3-2

Note: Outputs are based on noncomposite section properties for a negative moment region

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	1.97
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.30

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-4** Distance from Abut **604.5** ft

Variation Desciption: **Variation 4 - Controlling Fatigue Location**

1.97

1.30

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	**2.42**	ksi	GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	2.42	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	2.43	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	**5.35**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-4** Distance from Abut **604.5** ft

Variation Desciption: **Variation 4 - Controlling Fatigue Location**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ = **4.12** ksi GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Faulted state stress range, Δf =	4.12	ksi	MBE 7.2.2
Faulted state effective stress range, $(\Delta f)_{eff}$ =	4.14	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	9.12	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for faulted state?	**I(a)**	I(a), I(b), II	GS 2.5

Faulted fatigue life? **OK**

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	63.0	Years	GS 2.5.3
Total remaining fatigue life only in **unfaulted** state, Y_u	∞	Years	GS 2.5.3
Total remaining fatigue life only in **faulted** state, Y_f	Infinite	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**Infinite**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	I(a)	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	2.42	ksi	
Controlling stress range in faulted state, Δf_{FS} =	4.12	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	
Total remaining fatigue life, N_f	**Infinite**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-5** Distance from Abut **471.25** ft

Variation Desciption: **Variation 5 - Controlling Strength Location**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

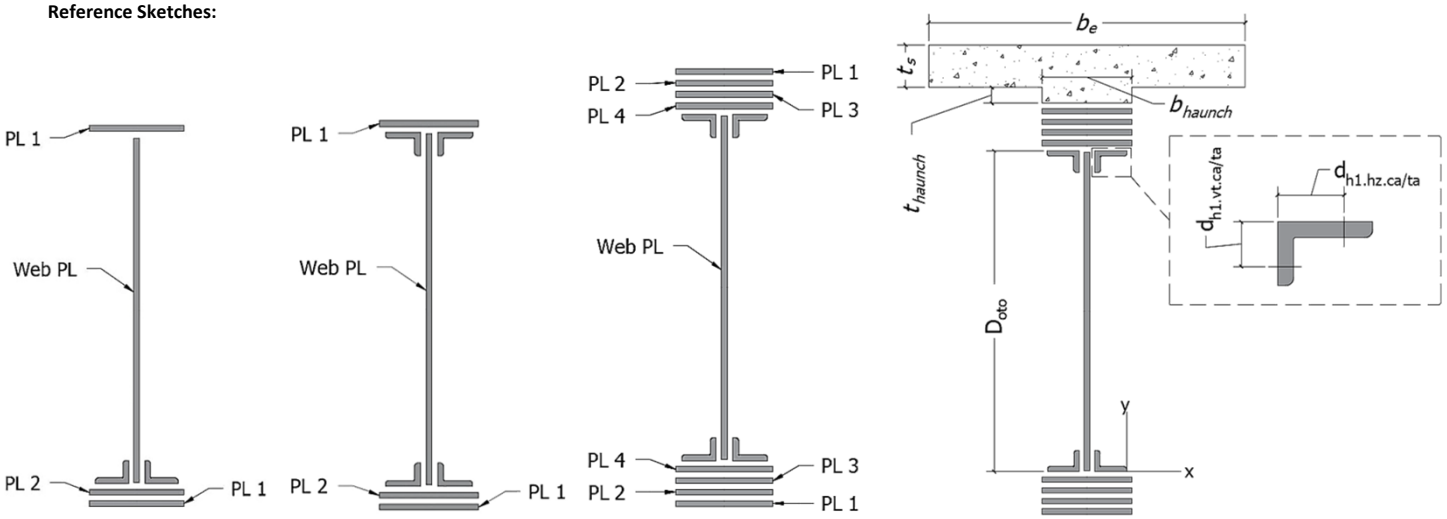
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all provisions of Section 1.5?	**Yes**	Yes

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**Yes**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**No**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	**84.8**	in	Haunch Width, b_{haunch}	**59.3**	in
Deck Slab Thickness, t_s	**5.8**	in	Haunch Thickness, t_{haunch}	**3.4**	in
Concrete Modulus of Elasticity, E_c	**3625.5**	ksi	Modular Ratio of the concrete, n	8.0	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **2** (1 to 4)

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**20.000**	**20.000**	0.000	0.000	in
$t_{ccp,i}$	**0.6875**	**0.6875**	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L8X8X7/8**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	13.3	in^2
Thickness of the angle, t_{ca}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ca}	2.31	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.00**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.00**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-5** Distance from Abut **471.25** ft

Variation Desciption: **Variation 5 - Controlling Strength Location**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	70.00	in	Flange Angles Out-to-out Depth, D_{oto}	70.50	in
Web Thickness, t_w	0.5000	in			

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **2** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	20.000	20.000	0.000	0.000	in
$t_{tcp,i}$	0.6875	0.6875	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L8X8X7/8	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	13.3	in^2
Thickness of the angle, t_{ta}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ta}	2.31	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1	holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.00	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.00	in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00	in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	558	trucks/day	Current Year, $Y_{current}$	2021	year
$(ADTT_{sl})_0$	558	trucks/day	Span Length, L	155.75	ft
$(ADTT_{sl})_{limit}$	8,840	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
			Is this a transverse member?	No	Y or N

Note: Growth rate is for future growth from today on

Unfactored Moments:

M_{DC1}	1,140	k-ft	M_{DW}	257	k-ft	M_{LL+IM}	4,713	k-ft
M_{DC2}	306	k-ft				M_{FAT+IM}	849	k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{G,COMP}$	50.9	in	$\bar{y}_{C,G,NC}$	35.3	in
$c_{G,COMP}$	52.2	in	$c_{G,NC}$	36.6	in
$A_{G,COMP}$	229.4	in^2	$A_{G,NC}$	143.2	in^2
$I_{xG,COMP}$	236,874.7	in^4	$I_{xG,NC}$	143,376.2	in^4
$S_{xG,COMP}$	4,534.5	in^3	$S_{xG,NC}$	3,914.7	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{N,COMP}$	51.8	in	$\bar{y}_{N,NC}$	35.3	in
$c_{N,COMP}$	53.2	in	$c_{N,NC}$	36.6	in
$A_{N,COMP}$	216.7	in^2	$A_{N,NC}$	130.5	in^2
$I_{xN,COMP}$	218,661.5	in^4	$I_{xN,NC}$	128,619.1	in^4
$S_{xN,COMP}$	4,114.0	in^3	$S_{xN,NC}$	3,511.8	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{AFG,COMP}$	54.2	in	$\bar{y}_{AFG,NC}$	39.1	in
$c_{AFG,COMP}$	54.9	in	$c_{AFG,NC}$	39.8	in
$A_{AFG,COMP}$	215.6	in^2	$A_{AFG,NC}$	129.5	in^2
$I_{x,AFG,COMP}$	197,483.4	in^4	$I_{x,AFG,NC}$	123,353.6	in^4
$S_{x\text{-}AFG,COMP}$	3,599.8	in^3	$S_{x\text{-}AFG,NC}$	3,100.0	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{AFN,COMP}$	55.0	in	$\bar{y}_{AFN,NC}$	39.1	in
$c_{AFN,COMP}$	55.7	in	$c_{AFN,NC}$	39.8	in
$A_{AFN,COMP}$	204.2	in^2	$A_{AFN,NC}$	118.1	in^2
$I_{x,AFN,COMP}$	181,837.7	in^4	$I_{x,AFN,NC}$	110,484.9	in^4
$S_{x\text{-}AFN,COMP}$	3,265.5	in^3	$S_{x\text{-}AFN,NC}$	2,778.4	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-5** Distance from Abut **471.25** ft

Variation Desciption: **Variation 5 - Controlling Strength Location**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.375

Number of tension CPs, N_{FL} = 2

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 9,054 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = - ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = 34.34 ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = 31.08 ksi GS Eq. 2.1.3-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	1.54
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.01

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-5** Distance from Abut **471.25** ft

Variation Desciption: **Variation 5 - Controlling Strength Location**

1.54

1.01

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	**2.48**	ksi	GS Eq. 2.1.3-1

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	2.48	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	2.49	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	**5.48**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-5** Distance from Abut **471.25** ft

Variation Desciption: **Variation 5 - Controlling Strength Location**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ =	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \beta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ =	**4.29**	ksi	GS Eq. 2.1.3-1
Faulted state stress range, Δf =	4.29	ksi	MBE 7.2.2
Faulted state effective stress range, $(\Delta f)_{eff}$ =	4.31	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	9.49	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for faulted state?	**I(a)**	I(a), I(b), II	GS 2.5

Faulted fatigue life? **OK**

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	63.0	Years	GS 2.5.3
Total remaining fatigue life only in **unfaulted** state, Y_u	∞	Years	GS 2.5.3
Total remaining fatigue life only in **faulted** state, Y_f	Infinite	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**Infinite**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	I(a)	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	2.48	ksi	
Controlling stress range in faulted state, Δf_{FS} =	4.29	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	
Total remaining fatigue life, N_f	**Infinite**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-5** Distance from Abut **858.85** ft

Variation Desciption: **Variation 5 - Controlling Fatigue Location**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

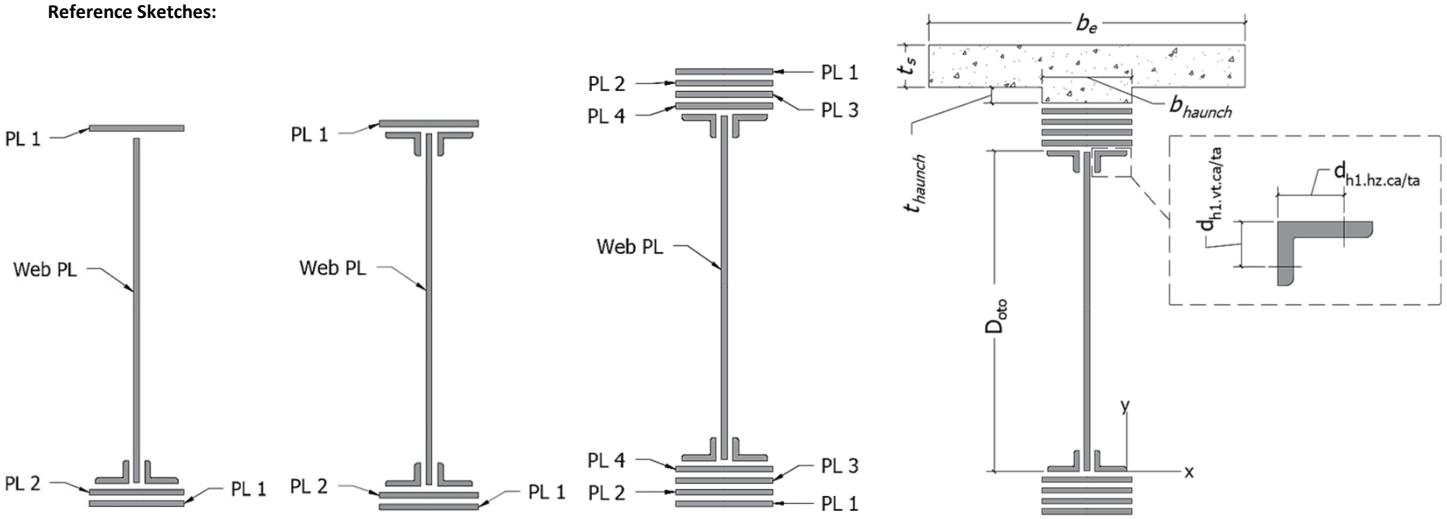
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all provisions of Section 1.5?	**Yes**	Yes

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**Yes**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**Yes**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	**84.8**	in	Haunch Width, b_{haunch}	**59.3**	in
Deck Slab Thickness, t_s	**5.8**	in	Haunch Thickness, t_{haunch}	**3.4**	in
Concrete Modulus of Elasticity, E_c	**3625.5**	ksi	Modular Ratio of the concrete, n	8.0	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **2** (1 to 4)

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**20.000**	**20.000**	0.000	0.000	in
$t_{ccp,i}$	**0.6875**	**0.6875**	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L8X8X7/8**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	13.3	in^2
Thickness of the angle, t_{ca}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ca}	2.31	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.00**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.00**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-5** Distance from Abut **858.85** ft

Variation Desciption: **Variation 5 - Controlling Fatigue Location**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	70.00	in	Flange Angles Out-to-out Depth, D_{oto}	70.50	in
Web Thickness, t_w	0.5000	in			

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **2** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	20.000	20.000	0.000	0.000	in
$t_{tcp,i}$	0.6875	0.6875	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L8X8X7/8	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	13.3	in^2
Thickness of the angle, t_{ta}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ta}	2.31	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1	holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.00	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.00	in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00	in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	1,005	trucks/day	Current Year, $Y_{current}$	2021	year
$(ADTT_{sl})_0$	1,005	trucks/day	Span Length, L	155.75	ft
$(ADTT_{sl})_{limit}$	8,840	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
			Is this a transverse member?	No	Y or N

Note: Growth rate is for future growth from today on

Unfactored Moments:

M_{DC1}	258	k-ft	M_{DW}	50	k-ft	M_{LL+IM}	3,838	k-ft
M_{DC2}	59	k-ft				M_{FAT+IM}	1,233	k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{G,COMP}$	24.4	in	$\bar{y}_{C,G,NC}$	35.3	in
$c_{G,COMP}$	25.8	in	$c_{G,NC}$	36.6	in
$A_{G,COMP}$	229.4	in^2	$A_{G,NC}$	143.2	in^2
$I_{xG,COMP}$	188,976.3	in^4	$I_{xG,NC}$	143,376.2	in^4
$S_{xG,COMP}$	7,337.1	in^3	$S_{xG,NC}$	3,914.7	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{N,COMP}$	23.7	in	$\bar{y}_{N,NC}$	35.3	in
$c_{N,COMP}$	25.1	in	$c_{N,NC}$	36.6	in
$A_{N,COMP}$	216.7	in^2	$A_{N,NC}$	130.5	in^2
$I_{xN,COMP}$	172,544.4	in^4	$I_{xN,NC}$	128,619.1	in^4
$S_{xN,COMP}$	6,868.4	in^3	$S_{xN,NC}$	3,511.8	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFG,COMP}$	26.0	in	$\bar{y}_{AFG,NC}$	39.1	in
$c_{AFG,COMP}$	26.7	in	$c_{AFG,NC}$	39.8	in
$A_{AFG,COMP}$	215.6	in^2	$A_{AFG,NC}$	129.5	in^2
$I_{x,AFG,COMP}$	179,529.8	in^4	$I_{x,AFG,NC}$	123,353.6	in^4
$S_{x\text{-}AFG,COMP}$	6,726.6	in^3	$S_{x\text{-}AFG,NC}$	3,100.0	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFN,COMP}$	25.3	in	$\bar{y}_{AFN,NC}$	39.1	in
$c_{AFN,COMP}$	25.9	in	$c_{AFN,NC}$	39.8	in
$A_{AFN,COMP}$	204.2	in^2	$A_{AFN,NC}$	118.1	in^2
$I_{x,AFN,COMP}$	164,400.1	in^4	$I_{x,AFN,NC}$	110,484.9	in^4
$S_{x\text{-}AFN,COMP}$	6,336.3	in^3	$S_{x\text{-}AFN,NC}$	2,778.4	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-5** Distance from Abut **858.85** ft

Variation Desciption: **Variation 5 - Controlling Fatigue Location**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.375

Number of tension CPs, N_{FL} = 2

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 6,185 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = - ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = 26.71 ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = 23.94 ksi GS Eq. 2.1.3-2

Note: Outputs are based on noncomposite section properties for a negative moment region

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	1.98
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.31

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-5** Distance from Abut **858.85** ft

Variation Desciption: **Variation 5 - Controlling Fatigue Location**

1.98

1.31

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	**4.21**	ksi	GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	4.21	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	4.25	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	**9.34**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	2.87E+07	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	2.35E+07	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	13.3	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	1,147	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**13.3**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**II**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-5** Distance from Abut **858.85** ft

Variation Desciption: **Variation 5 - Controlling Fatigue Location**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ =	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ =	**7.32**	ksi	GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Faulted state stress range, Δf =	7.32	ksi	MBE 7.2.2
Faulted state effective stress range, $(\Delta f)_{eff}$ =	7.38	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	16.24	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	1.09E+07	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	26.0	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	1,302	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8

Total faulted state remaining fatigue life, Y_{REM}	**26.0**	Years	MBE 7.2.5.1	Faulted fatigue life?	**OK**
Case I or II for faulted state?	**II**	I(a), I(b), II	GS 2.5		

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	63.0	Years	GS 2.5.3
Total remaining fatigue life only in **unfaulted** state, Y_u	76.3	Years	GS 2.5.3
Total remaining fatigue life only in **faulted** state, Y_f	26.0	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1\text{-}N_u/Y_u)$	**4.5**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	II	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	4.21	ksi	
Controlling stress range in faulted state, Δf_{FS} =	7.32	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**26.0**	Years	
Total remaining fatigue life, N_f	**4.5**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**2.0**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-6** Distance from Abut **283.5** ft

Variation Desciption: **Variation 6 - Controlling Strength Location**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

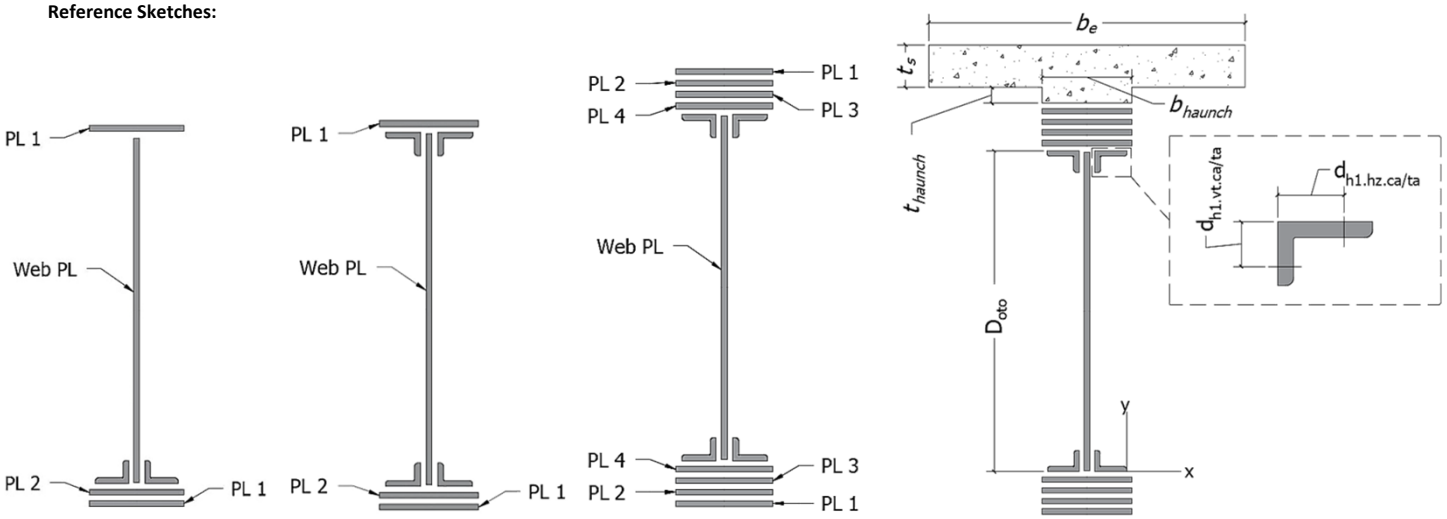
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all provisions of Section 1.5?	**Yes**	Yes

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**Yes**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**Yes**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	**84.8**	in	Haunch Width, b_{haunch}	**59.3**	in
Deck Slab Thickness, t_s	**5.8**	in	Haunch Thickness, t_{haunch}	**3.4**	in
Concrete Modulus of Elasticity, E_c	**3625.5**	ksi	Modular Ratio of the concrete, n	8.0	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **2** 1 to 4

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**20.000**	**20.000**	0.000	0.000	in
$t_{ccp,i}$	**0.5000**	**0.6875**	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L8X8X7/8**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	13.3	in^2
Thickness of the angle, t_{ca}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ca}	2.31	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.00**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.00**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-6** Distance from Abut **283.5** ft

Variation Desciption: **Variation 6 - Controlling Strength Location**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	79.70	in	Flange Angles Out-to-out Depth, D_{oto}	80.20	in
Web Thickness, t_w	0.5000	in			

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **2** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	20.000	20.000	0.000	0.000	in
$t_{tcp,i}$	0.5000	0.6875	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L8X8X7/8	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	13.3	in^2
Thickness of the angle, t_{ta}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ta}	2.31	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1	holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.00	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.00	in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00	in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	558	trucks/day	Current Year, $Y_{current}$	2021	year
$(ADTT_{sl})_0$	558	trucks/day	Span Length, L	155.75	ft
$(ADTT_{sl})_{limit}$	8,840	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
			Is this a transverse member?	No	Y or N

Note: Growth rate is for future growth from today on

Unfactored Moments:

M_{DC1}	2,316	k-ft	M_{DW}	532	k-ft	M_{LL+IM}	3,032	k-ft
M_{DC2}	633	k-ft				M_{FAT+IM}	502	k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{G,COMP}$	27.2	in	$\bar{y}_{C,G,NC}$	40.1	in
$c_{G,COMP}$	28.4	in	$c_{G,NC}$	41.3	in
$A_{G,COMP}$	226.7	in^2	$A_{G,NC}$	140.6	in^2
$I_{xG,COMP}$	238,261.2	in^4	$I_{xG,NC}$	176,051.8	in^4
$S_{xG,COMP}$	8,396.2	in^3	$S_{xG,NC}$	4,264.0	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{N,COMP}$	26.5	in	$\bar{y}_{N,NC}$	40.1	in
$c_{N,COMP}$	27.7	in	$c_{N,NC}$	41.3	in
$A_{N,COMP}$	214.7	in^2	$A_{N,NC}$	128.6	in^2
$I_{xN,COMP}$	218,005.9	in^4	$I_{xN,NC}$	158,016.8	in^4
$S_{xN,COMP}$	7,882.0	in^3	$S_{xN,NC}$	3,827.2	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFG,COMP}$	28.5	in	$\bar{y}_{AFG,NC}$	43.2	in
$c_{AFG,COMP}$	29.2	in	$c_{AFG,NC}$	43.9	in
$A_{AFG,COMP}$	216.7	in^2	$A_{AFG,NC}$	130.6	in^2
$I_{x,AFG,COMP}$	229,984.4	in^4	$I_{x,AFG,NC}$	157,920.8	in^4
$S_{x\text{-}AFG,COMP}$	7,882.8	in^3	$S_{x\text{-}AFG,NC}$	3,594.8	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFN,COMP}$	27.7	in	$\bar{y}_{AFN,NC}$	43.2	in
$c_{AFN,COMP}$	28.4	in	$c_{AFN,NC}$	43.9	in
$A_{AFN,COMP}$	205.7	in^2	$A_{AFN,NC}$	119.5	in^2
$I_{x,AFN,COMP}$	210,872.9	in^4	$I_{x,AFN,NC}$	141,597.4	in^4
$S_{x\text{-}AFN,COMP}$	7,433.9	in^3	$S_{x\text{-}AFN,NC}$	3,225.5	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-6** Distance from Abut **283.5** ft

Variation Desciption: **Variation 6 - Controlling Strength Location**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.375

Number of tension CPs, N_{FL} = 2

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 8,604 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = - ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = 32.01 ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = 28.72 ksi GS Eq. 2.1.3-2

Note: Outputs are based on noncomposite section properties for a negative moment region

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	1.65
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.09

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-6** Distance from Abut **283.5** ft

Variation Desciption: **Variation 6 - Controlling Strength Location**

1.65
1.09

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	**1.57**	ksi	GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	1.57	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	1.58	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	**3.48**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-6** Distance from Abut **283.5** ft

Variation Desciption: **Variation 6 - Controlling Strength Location**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \beta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ = **2.57** ksi GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Faulted state stress range, Δf =	2.57	ksi	MBE 7.2.2
Faulted state effective stress range, $(\Delta f)_{eff}$ =	2.58	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	5.69	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for faulted state?	**I(a)**	I(a), I(b), II	GS 2.5

Faulted fatigue life? **OK**

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	63.0	Years	GS 2.5.3
Total remaining fatigue life only in **unfaulted** state, Y_u	∞	Years	GS 2.5.3
Total remaining fatigue life only in **faulted** state, Y_f	Infinite	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**Infinite**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	I(a)	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	1.57	ksi	
Controlling stress range in faulted state, Δf_{FS} =	2.57	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	
Total remaining fatigue life, N_f	**Infinite**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-6** Distance from Abut **1175.5** ft

Variation Desciption: **Variation 6 - Controlling Fatigue Location**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

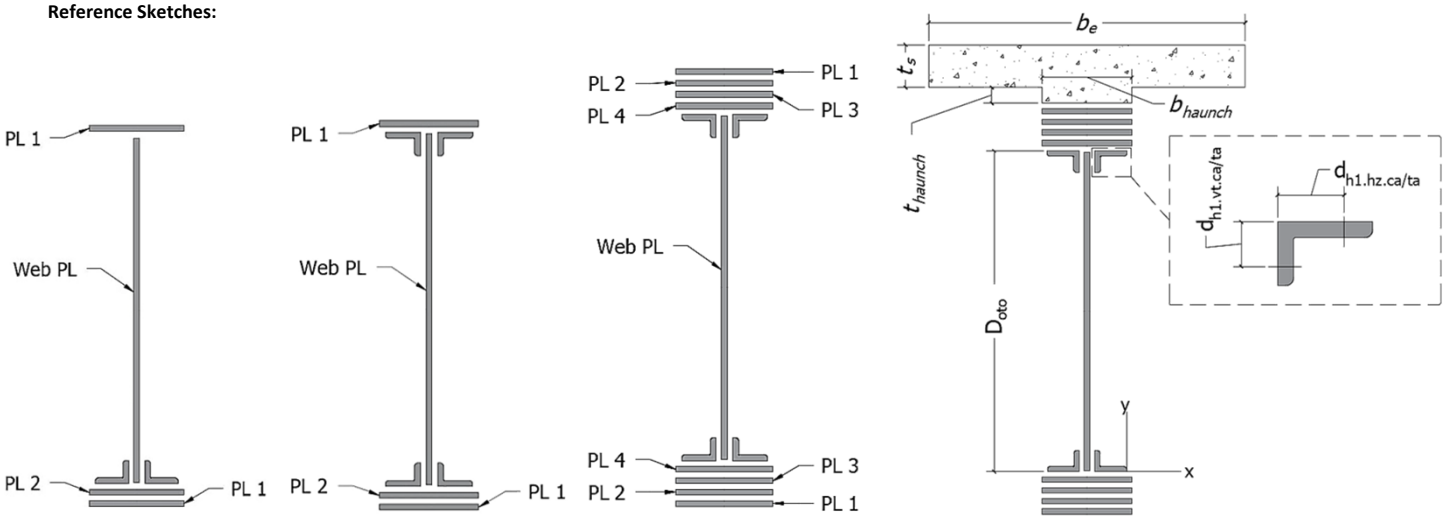
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all provisions of Section 1.5?	**Yes**	Yes

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**Yes**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**Yes**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	**84.8**	in	Haunch Width, b_{haunch}	**59.3**	in
Deck Slab Thickness, t_s	**5.8**	in	Haunch Thickness, t_{haunch}	**3.4**	in
Concrete Modulus of Elasticity, E_c	**3625.5**	ksi	Modular Ratio of the concrete, n	8.0	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **2** (1 to 4)

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**20.000**	**20.000**	0.000	0.000	in
$t_{ccp,i}$	**0.5000**	**0.6875**	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L8X8X7/8**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	13.3	in^2
Thickness of the angle, t_{ca}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ca}	2.31	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.00**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.00**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-6** Distance from Abut **1175.5** ft

Variation Desciption: **Variation 6 - Controlling Fatigue Location**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No — Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	70.90	in	Flange Angles Out-to-out Depth, D_{oto}	71.40	in
Web Thickness, t_w	0.5000	in			

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **2** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	20.000	20.000	0.000	0.000	in
$t_{tcp,i}$	0.5000	0.6875	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L8X8X7/8	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	13.3	in^2
Thickness of the angle, t_{ta}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ta}	2.31	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1	holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.00	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.00	in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00	in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No — Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	558	trucks/day	Current Year, $Y_{current}$	2021	year
$(ADTT_{sl})_0$	558	trucks/day	Span Length, L	155.75	ft
$(ADTT_{sl})_{limit}$	8,840	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
			Is this a transverse member?	No	Y or N

Note: Growth rate is for future growth from today on

Unfactored Moments:

M_{DC1}	1,093	k-ft	M_{DW}	253	k-ft	M_{LL+IM}	2,314	k-ft
M_{DC2}	301	k-ft				M_{FAT+IM}	585	k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{G,COMP}$	24.2	in	$\bar{y}_{C,G,NC}$	35.7	in
$c_{G,COMP}$	25.4	in	$c_{G,NC}$	36.9	in
$A_{G,COMP}$	222.3	in^2	$A_{G,NC}$	136.2	in^2
$I_{xG,COMP}$	183,764.4	in^4	$I_{xG,NC}$	137,055.4	in^4
$S_{xG,COMP}$	7,227.1	in^3	$S_{xG,NC}$	3,715.5	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{N,COMP}$	23.6	in	$\bar{y}_{N,NC}$	35.7	in
$c_{N,COMP}$	24.8	in	$c_{N,NC}$	36.9	in
$A_{N,COMP}$	210.3	in^2	$A_{N,NC}$	124.2	in^2
$I_{xN,COMP}$	167,824.6	in^4	$I_{xN,NC}$	122,869.1	in^4
$S_{xN,COMP}$	6,773.7	in^3	$S_{xN,NC}$	3,330.9	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{AFG,COMP}$	25.4	in	$\bar{y}_{AFG,NC}$	38.6	in
$c_{AFG,COMP}$	26.1	in	$c_{AFG,NC}$	39.3	in
$A_{AFG,COMP}$	212.3	in^2	$A_{AFG,NC}$	126.2	in^2
$I_{x,AFG,COMP}$	177,126.8	in^4	$I_{x,AFG,NC}$	122,568.1	in^4
$S_{x\text{-}AFG,COMP}$	6,783.1	in^3	$S_{x\text{-}AFG,NC}$	3,119.4	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{AFN,COMP}$	24.7	in	$\bar{y}_{AFN,NC}$	38.6	in
$c_{AFN,COMP}$	25.4	in	$c_{AFN,NC}$	39.3	in
$A_{AFN,COMP}$	201.3	in^2	$A_{AFN,NC}$	115.1	in^2
$I_{x,AFN,COMP}$	162,108.0	in^4	$I_{x,AFN,NC}$	109,746.7	in^4
$S_{x\text{-}AFN,COMP}$	6,387.2	in^3	$S_{x\text{-}AFN,NC}$	2,794.6	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-6** Distance from Abut **1175.5** ft

Variation Desciption: **Variation 6 - Controlling Fatigue Location**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.375

Number of tension CPs, N_{FL} = 2

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 5,392 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = - ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = 23.15 ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = 20.74 ksi GS Eq. 2.1.3-2

Note: Outputs are based on noncomposite section properties for a negative moment region

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	2.28
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.51

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-6**

Distance from Abut **1175.5** ft

Variation Desciption: **Variation 6 - Controlling Fatigue Location**

2.28

1.51

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	**2.11**	ksi	GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	2.11	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	2.12	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	**4.66**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-6** Distance from Abut **1175.5** ft

Variation Desciption: **Variation 6 - Controlling Fatigue Location**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ =	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ =	**3.45**	ksi	GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Faulted state stress range, Δf =	3.45	ksi	MBE 7.2.2
Faulted state effective stress range, $(\Delta f)_{eff}$ =	3.47	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	7.64	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8

Total faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1	Faulted fatigue life?	**OK**
Case I or II for faulted state?	**I(a)**	I(a), I(b), II	GS 2.5		

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	63.0	Years	GS 2.5.3
Total remaining fatigue life only in **unfaulted** state, Y_u	∞	Years	GS 2.5.3
Total remaining fatigue life only in **faulted** state, Y_f	Infinite	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**Infinite**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	I(a)	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	2.11	ksi	
Controlling stress range in faulted state, Δf_{FS} =	3.45	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	
Total remaining fatigue life, N_f	**Infinite**	Years	GS Eq. 2.5.3-1

Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-7** Distance from Abut **267** ft

Variation Desciption: **Variation 7 - Controlling Strength Location**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

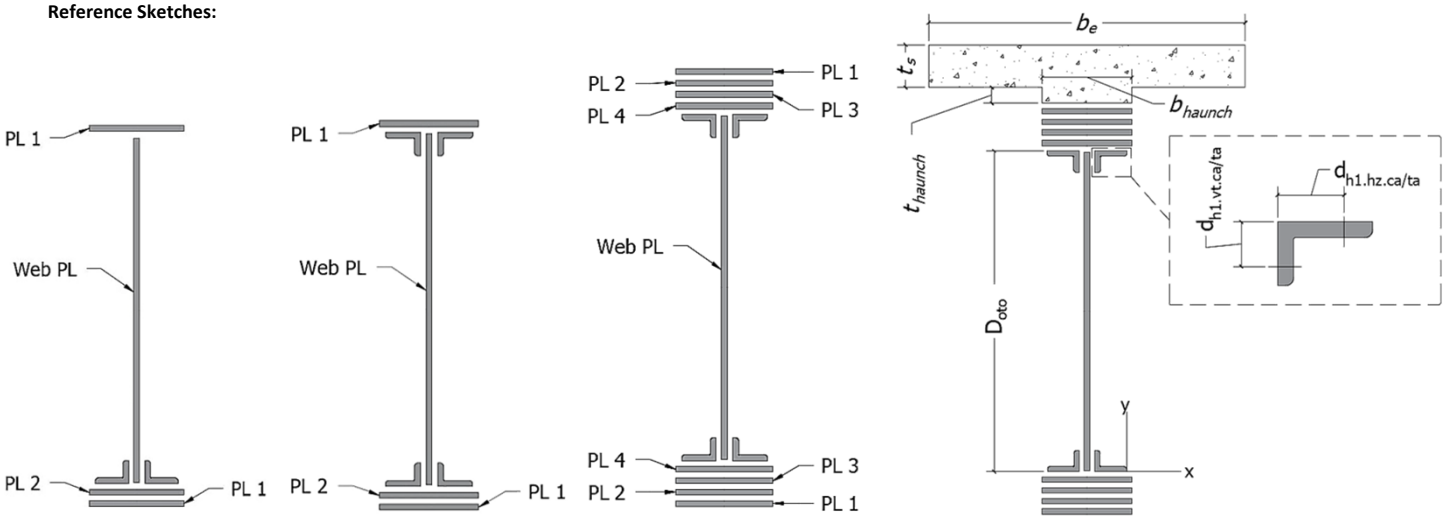
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all provisions of Section 1.5?	**Yes**	Yes

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**Yes**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**Yes**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	**84.8**	in	Haunch Width, b_{haunch}	**59.3**	in
Deck Slab Thickness, t_s	**5.8**	in	Haunch Thickness, t_{haunch}	**3.4**	in
Concrete Modulus of Elasticity, E_c	**3625.5**	ksi	Modular Ratio of the concrete, n	8.0	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **3** (1 to 4)

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**20.000**	**20.000**	**20.000**	0.000	in
$t_{ccp,i}$	**0.4375**	**0.5000**	**0.6875**	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L8X8X7/8**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	13.3	in^2
Thickness of the angle, t_{ca}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ca}	2.31	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.00**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.00**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-7** Distance from Abut **267** ft

Variation Desciption: **Variation 7 - Controlling Strength Location**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	116.00	in	Flange Angles Out-to-out Depth, D_{oto}	116.50 in
Web Thickness, t_w	0.5000	in		

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **3** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	20.000	20.000	20.000	0.000	in
$t_{tcp,i}$	0.4375	0.5000	0.6875	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L8X8X7/8	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	13.3	in^2
Thickness of the angle, t_{ta}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ta}	2.31	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1 holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.00	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.00 in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00 in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	558	trucks/day	Current Year, $Y_{current}$	2021	year
$(ADTT_{sl})_0$	558	trucks/day	Span Length, L	155.75	ft
$(ADTT_{sl})_{limit}$	8,840	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
			Is this a transverse member?	No	Y or N

Note: Growth rate is for future growth from today on

Unfactored Moments:

M_{DC1}	4,773	k-ft	M_{DW}	1,101	k-ft	M_{LL+IM}	4,867 k-ft
M_{DC2}	1,311	k-ft				M_{FAT+IM}	585 k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{G,COMP}$	41.3	in	$\bar{y}_{C,G,NC}$	58.3 in
$c_{G,COMP}$	42.9	in	$c_{G,NC}$	59.9 in
$A_{G,COMP}$	262.4	in^2	$A_{G,NC}$	176.2 in^2
$I_{xG,COMP}$	613,723.1	in^4	$I_{xG,NC}$	458,593.0 in^4
$S_{xG,COMP}$	14,305.0	in^3	$S_{xG,NC}$	7,659.2 in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{N,COMP}$	40.4	in	$\bar{y}_{N,NC}$	58.3 in
$c_{N,COMP}$	42.0	in	$c_{N,NC}$	59.9 in
$A_{N,COMP}$	248.8	in^2	$A_{N,NC}$	162.6 in^2
$I_{xN,COMP}$	564,725.6	in^4	$I_{xN,NC}$	413,950.9 in^4
$S_{xN,COMP}$	13,453.8	in^3	$S_{xN,NC}$	6,913.6 in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{AFG,COMP}$	42.8	in	$\bar{y}_{AFG,NC}$	61.4 in
$c_{AFG,COMP}$	43.9	in	$c_{AFG,NC}$	62.6 in
$A_{AFG,COMP}$	253.6	in^2	$A_{AFG,NC}$	167.5 in^2
$I_{x,AFG,COMP}$	597,231.2	in^4	$I_{x,AFG,NC}$	425,825.5 in^4
$S_{x\text{-}AFG,COMP}$	13,592.6	in^3	$S_{x\text{-}AFG,NC}$	6,807.2 in^3

Net Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{AFN,COMP}$	41.7	in	$\bar{y}_{AFN,NC}$	61.3 in
$c_{AFN,COMP}$	42.9	in	$c_{AFN,NC}$	62.5 in
$A_{AFN,COMP}$	240.8	in^2	$A_{AFN,NC}$	154.7 in^2
$I_{x,AFN,COMP}$	550,403.1	in^4	$I_{x,AFN,NC}$	384,282.7 in^4
$S_{x\text{-}AFN,COMP}$	12,826.1	in^3	$S_{x\text{-}AFN,NC}$	6,148.9 in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-7** Distance from Abut **267** ft

Variation Desciption: **Variation 7 - Controlling Strength Location**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.438

Number of tension CPs, N_{FL} = 3

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 15,674 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = - ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = 30.59 ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = 27.63 ksi GS Eq. 2.1.3-2

Note: Outputs are based on noncomposite section properties for a negative moment region

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	1.73
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.13

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-7** Distance from Abut **267** ft

Variation Desciption: **Variation 7 - Controlling Strength Location**

1.73

1.13

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	**1.01**	ksi	GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	1.01	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	1.02	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	**2.25**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-7** Distance from Abut **267** ft

Variation Desciption: **Variation 7 - Controlling Strength Location**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ = **1.64** ksi GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Faulted state stress range, Δf =	1.64	ksi	MBE 7.2.2
Faulted state effective stress range, $(\Delta f)_{eff}$ =	1.65	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	3.63	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for faulted state?	**I(a)**	I(a), I(b), II	GS 2.5

Faulted fatigue life? **OK**

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	63.0	Years	GS 2.5.3
Total remaining fatigue life only in **unfaulted** state, Y_u	∞	Years	GS 2.5.3
Total remaining fatigue life only in **faulted** state, Y_f	Infinite	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**Infinite**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	I(a)	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	1.01	ksi	
Controlling stress range in faulted state, Δf_{FS} =	1.64	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	
Total remaining fatigue life, N_f	**Infinite**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-7** Distance from Abut **1027.09** ft

Variation Desciption: **Variation 7 - Controlling Fatigue Location**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

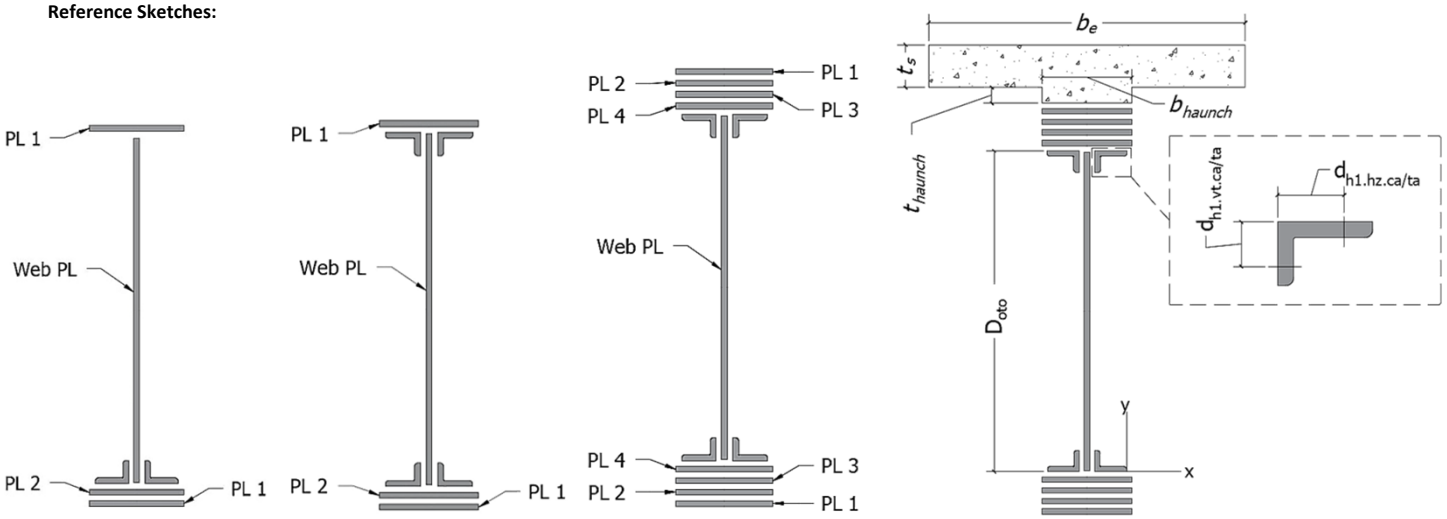
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all provisions of Section 1.5?	**Yes**	Yes

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**Yes**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**Yes**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	**84.8**	in	Haunch Width, b_{haunch}	**59.3**	in
Deck Slab Thickness, t_s	**5.8**	in	Haunch Thickness, t_{haunch}	**3.4**	in
Concrete Modulus of Elasticity, E_c	**3625.5**	ksi	Modular Ratio of the concrete, n	8.0	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **3** (1 to 4)

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**20.000**	**20.000**	**20.000**	0.000	in
$t_{ccp,i}$	**0.4375**	**0.5000**	**0.6875**	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L8X8X7/8**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	13.3	in^2
Thickness of the angle, t_{ca}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ca}	2.31	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.00**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.00**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-7** Distance from Abut **1027.09** ft

Variation Desciption: **Variation 7 - Controlling Fatigue Location**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No — Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	76.90	in	Flange Angles Out-to-out Depth, D_{oto}	77.40 in
Web Thickness, t_w	0.5000	in		

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **3** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	20.000	20.000	20.000	0.000	in
$t_{tcp,i}$	0.4375	0.5000	0.6875	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L8X8X7/8	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	13.3	in^2
Thickness of the angle, t_{ta}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ta}	2.31	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1 holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.00	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.00 in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00 in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No — Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	558	trucks/day	Current Year, $Y_{current}$	2021	year
$(ADTT_{sl})_0$	558	trucks/day	Span Length, L	155.75	ft
$(ADTT_{sl})_{limit}$	8,840	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
			Is this a transverse member?	No	Y or N

Note: Growth rate is for future growth from today on

Unfactored Moments:

M_{DC1}	1,935	k-ft	M_{DW}	447	k-ft	M_{LL+IM}	2,959 k-ft
M_{DC2}	532	k-ft				M_{FAT+IM}	523 k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{G,COMP}$	27.3	in	$\bar{y}_{C,G,NC}$	38.7 in
$c_{G,COMP}$	28.9	in	$c_{G,NC}$	40.3 in
$A_{G,COMP}$	242.8	in^2	$A_{G,NC}$	156.7 in^2
$I_{xG,COMP}$	249,174.0	in^4	$I_{xG,NC}$	191,210.9 in^4
$S_{xG,COMP}$	8,615.1	in^3	$S_{xG,NC}$	4,741.7 in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{N,COMP}$	26.6	in	$\bar{y}_{N,NC}$	38.7 in
$c_{N,COMP}$	28.2	in	$c_{N,NC}$	40.3 in
$A_{N,COMP}$	229.2	in^2	$A_{N,NC}$	143.1 in^2
$I_{xN,COMP}$	227,791.7	in^4	$I_{xN,NC}$	171,811.7 in^4
$S_{xN,COMP}$	8,064.4	in^3	$S_{xN,NC}$	4,260.7 in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{AFG,COMP}$	28.4	in	$\bar{y}_{AFG,NC}$	41.1 in
$c_{AFG,COMP}$	29.6	in	$c_{AFG,NC}$	42.3 in
$A_{AFG,COMP}$	234.1	in^2	$A_{AFG,NC}$	147.9 in^2
$I_{x,AFG,COMP}$	241,695.0	in^4	$I_{x,AFG,NC}$	176,303.6 in^4
$S_{x\text{-}AFG,COMP}$	8,176.8	in^3	$S_{x\text{-}AFG,NC}$	4,171.9 in^3

Net Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{AFN,COMP}$	27.6	in	$\bar{y}_{AFN,NC}$	41.1 in
$c_{AFN,COMP}$	28.8	in	$c_{AFN,NC}$	42.2 in
$A_{AFN,COMP}$	221.3	in^2	$A_{AFN,NC}$	135.1 in^2
$I_{x,AFN,COMP}$	221,320.2	in^4	$I_{x,AFN,NC}$	158,308.0 in^4
$S_{x\text{-}AFN,COMP}$	7,681.1	in^3	$S_{x\text{-}AFN,NC}$	3,747.7 in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-7** Distance from Abut **1027.09** ft

Variation Desciption: **Variation 7 - Controlling Fatigue Location**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.438

Number of tension CPs, N_{FL} = 3

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 7,833 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = - ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = 25.08 ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = 22.53 ksi GS Eq. 2.1.3-2

Note: Outputs are based on noncomposite section properties for a negative moment region

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	2.11
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.39

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-7** Distance from Abut **1027.09** ft

Variation Desciption: **Variation 7 - Controlling Fatigue Location**

2.11
1.39

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	**1.47**	ksi	GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	1.47	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	1.48	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	**3.26**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-7** Distance from Abut **1027.09** ft

Variation Desciption: **Variation 7 - Controlling Fatigue Location**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \beta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ = **2.41** ksi GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Faulted state stress range, Δf =	2.41	ksi	MBE 7.2.2
Faulted state effective stress range, $(\Delta f)_{eff}$ =	2.42	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	5.33	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for faulted state?	**I(a)**	I(a), I(b), II	GS 2.5

Faulted fatigue life? **OK**

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	63.0	Years	GS 2.5.3
Total remaining fatigue life only in **unfaulted** state, Y_u	∞	Years	GS 2.5.3
Total remaining fatigue life only in **faulted** state, Y_f	Infinite	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**Infinite**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	I(a)	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	1.47	ksi	
Controlling stress range in faulted state, Δf_{FS} =	2.41	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	
Total remaining fatigue life, N_f	**Infinite**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-8** Distance from Abut **441.5** ft

Variation Desciption: **Variation 8 - Controlling Strength Location**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

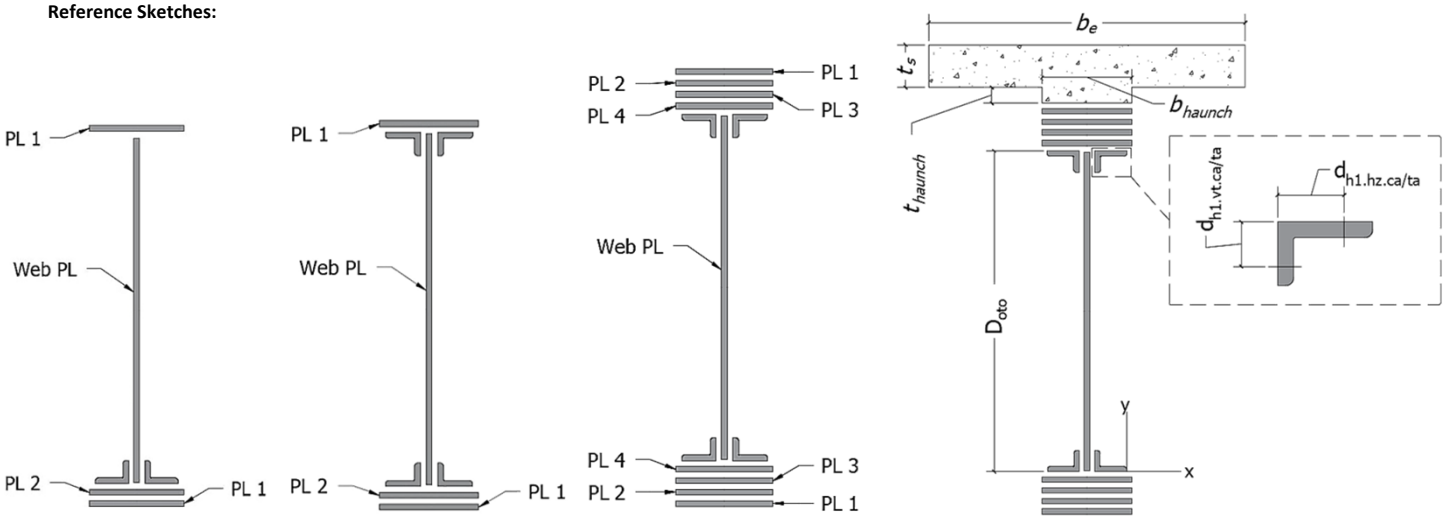
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all provisions of Section 1.5?	**Yes**	Yes

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**Yes**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**Yes**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	**84.8**	in	Haunch Width, b_{haunch}	**59.3**	in
Deck Slab Thickness, t_s	**5.8**	in	Haunch Thickness, t_{haunch}	**3.4**	in
Concrete Modulus of Elasticity, E_c	**3625.5**	ksi	Modular Ratio of the concrete, n	8.0	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **2** 1 to 4

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**20.000**	**20.000**	0.000	0.000	in
$t_{ccp,i}$	**0.4375**	**0.6875**	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L8X8X7/8**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	13.3	in^2
Thickness of the angle, t_{ca}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ca}	2.31	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.00**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.00**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-8** Distance from Abut **441.5** ft

Variation Desciption: **Variation 8 - Controlling Strength Location**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	76.80	in	Flange Angles Out-to-out Depth, D_{oto}	77.30	in
Web Thickness, t_w	0.5000	in			

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **2** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	20.000	20.000	0.000	0.000	in
$t_{tcp,i}$	0.4375	0.6875	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L8X8X7/8	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	13.3	in^2
Thickness of the angle, t_{ta}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ta}	2.31	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1	holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.00	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.00	in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00	in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	1,005	trucks/day	Current Year, $Y_{current}$	2021	year
$(ADTT_{sl})_0$	1,005	trucks/day	Span Length, L	155.75	ft
$(ADTT_{sl})_{limit}$	8,840	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
			Is this a transverse member?	No	Y or N

Note: Growth rate is for future growth from today on

Unfactored Moments:

M_{DC1}	1,610	k-ft	M_{DW}	352	k-ft	M_{LL+IM}	4,340	k-ft
M_{DC2}	420	k-ft				M_{FAT+IM}	689	k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{G,COMP}$	26.0	in	$\bar{y}_{C,G,NC}$	38.7	in
$c_{G,COMP}$	27.2	in	$c_{G,NC}$	39.8	in
$A_{G,COMP}$	222.8	in^2	$A_{G,NC}$	136.6	in^2
$I_{xG,COMP}$	215,307.0	in^4	$I_{xG,NC}$	158,646.5	in^4
$S_{xG,COMP}$	7,923.7	in^3	$S_{xG,NC}$	3,988.6	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{N,COMP}$	25.3	in	$\bar{y}_{N,NC}$	38.7	in
$c_{N,COMP}$	26.5	in	$c_{N,NC}$	39.8	in
$A_{N,COMP}$	211.0	in^2	$A_{N,NC}$	124.9	in^2
$I_{xN,COMP}$	196,889.2	in^4	$I_{xN,NC}$	142,302.3	in^4
$S_{xN,COMP}$	7,437.4	in^3	$S_{xN,NC}$	3,577.7	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFG,COMP}$	27.1	in	$\bar{y}_{AFG,NC}$	41.4	in
$c_{AFG,COMP}$	27.8	in	$c_{AFG,NC}$	42.0	in
$A_{AFG,COMP}$	214.0	in^2	$A_{AFG,NC}$	127.9	in^2
$I_{x,AFG,COMP}$	208,690.0	in^4	$I_{x,AFG,NC}$	144,018.3	in^4
$S_{x\text{-}AFG,COMP}$	7,496.8	in^3	$S_{x\text{-}AFG,NC}$	3,425.4	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFN,COMP}$	26.4	in	$\bar{y}_{AFN,NC}$	41.3	in
$c_{AFN,COMP}$	27.1	in	$c_{AFN,NC}$	42.0	in
$A_{AFN,COMP}$	203.1	in^2	$A_{AFN,NC}$	117.0	in^2
$I_{x,AFN,COMP}$	191,189.9	in^4	$I_{x,AFN,NC}$	129,053.3	in^4
$S_{x\text{-}AFN,COMP}$	7,065.3	in^3	$S_{x\text{-}AFN,NC}$	3,071.3	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-8** Distance from Abut **441.5** ft

Variation Desciption: **Variation 8 - Controlling Strength Location**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.375

Number of tension CPs, N_{FL} = 2

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 9,285 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = - ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = 36.28 ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = 32.53 ksi GS Eq. 2.1.3-2

Note: Outputs are based on noncomposite section properties for a negative moment region

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	1.46
$f_{AFG} \le f_{u,g}$?	NG	OK or NG	GS Eq. 2.3-1	0.96

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-8** Distance from Abut **441.5** ft

Variation Desciption: **Variation 8 - Controlling Strength Location**

1.46

0.96

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	**2.31**	ksi	GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	2.31	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	2.33	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	**5.13**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-8** Distance from Abut **441.5** ft

Variation Desciption: **Variation 8 - Controlling Strength Location**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ = **3.70** ksi GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Faulted state stress range, Δf =	3.70	ksi	MBE 7.2.2
Faulted state effective stress range, $(\Delta f)_{eff}$ =	3.73	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	8.21	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for faulted state?	**I(a)**	I(a), I(b), II	GS 2.5

Faulted fatigue life? **OK**

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	63.0	Years	GS 2.5.3
Total remaining fatigue life only in **unfaulted** state, Y_u	∞	Years	GS 2.5.3
Total remaining fatigue life only in **faulted** state, Y_f	Infinite	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**Infinite**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**NG**	OK or NG	GS 2.1 & 2.3
Fatigue case =	-	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	-	ksi	
Controlling stress range in faulted state, Δf_{FS} =	-	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	-	Years	
Total remaining fatigue life, N_f	-	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	-	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-8** Distance from Abut **863** ft

Variation Desciption: **Variation 8 - Controlling Fatigue Location**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

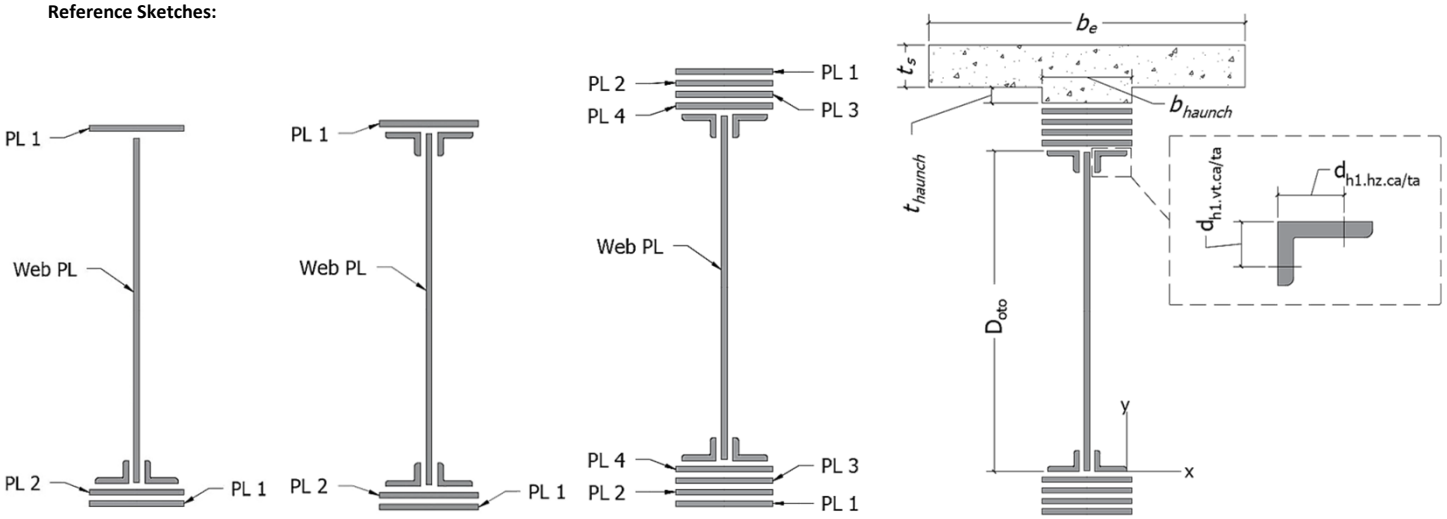
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all provisions of Section 1.5?	**Yes**	Yes

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**Yes**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**Yes**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	**84.8**	in	Haunch Width, b_{haunch}	**59.3**	in
Deck Slab Thickness, t_s	**5.8**	in	Haunch Thickness, t_{haunch}	**3.4**	in
Concrete Modulus of Elasticity, E_c	**3625.5**	ksi	Modular Ratio of the concrete, n	8.0	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **2** (1 to 4)

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**20.000**	**20.000**	0.000	0.000	in
$t_{ccp,i}$	**0.4375**	**0.6875**	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L8X8X7/8**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	13.3	in^2
Thickness of the angle, t_{ca}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ca}	2.31	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.00**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.00**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-8** Distance from Abut **863** ft

Variation Desciption: **Variation 8 - Controlling Fatigue Location**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	70.50	in	Flange Angles Out-to-out Depth, D_{oto}	71.00	in
Web Thickness, t_w	0.5000	in			

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **2** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	20.000	20.000	0.000	0.000	in
$t_{tcp,i}$	0.4375	0.6875	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L8X8X7/8	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	13.3	in^2
Thickness of the angle, t_{ta}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ta}	2.31	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1	holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.00	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.00	in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00	in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	1,005	trucks/day	Current Year, $Y_{current}$	2021	year
$(ADTT_{sl})_0$	1,005	trucks/day	Span Length, L	155.75	ft
$(ADTT_{sl})_{limit}$	8,840	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
			Is this a transverse member?	No	Y or N

Note: Growth rate is for future growth from today on

Unfactored Moments:

M_{DC1}	679	k-ft	M_{DW}	144	k-ft	M_{LL+IM}	3,960	k-ft
M_{DC2}	171	k-ft				M_{FAT+IM}	1,205	k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{G,COMP}$	24.0	in	$\bar{y}_{C,G,NC}$	35.5	in
$c_{G,COMP}$	25.1	in	$c_{G,NC}$	36.6	in
$A_{G,COMP}$	219.6	in^2	$A_{G,NC}$	133.5	in^2
$I_{xG,COMP}$	177,975.4	in^4	$I_{xG,NC}$	132,050.2	in^4
$S_{xG,COMP}$	7,097.0	in^3	$S_{xG,NC}$	3,605.5	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{N,COMP}$	23.3	in	$\bar{y}_{N,NC}$	35.5	in
$c_{N,COMP}$	24.4	in	$c_{N,NC}$	36.6	in
$A_{N,COMP}$	207.9	in^2	$A_{N,NC}$	121.7	in^2
$I_{xN,COMP}$	162,524.2	in^4	$I_{xN,NC}$	118,342.8	in^4
$S_{xN,COMP}$	6,653.6	in^3	$S_{xN,NC}$	3,231.2	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{AFG,COMP}$	25.0	in	$\bar{y}_{AFG,NC}$	38.1	in
$c_{AFG,COMP}$	25.7	in	$c_{AFG,NC}$	38.7	in
$A_{AFG,COMP}$	210.9	in^2	$A_{AFG,NC}$	124.7	in^2
$I_{x,AFG,COMP}$	172,343.7	in^4	$I_{x,AFG,NC}$	119,638.9	in^4
$S_{x\text{-}AFG,COMP}$	6,713.4	in^3	$S_{x\text{-}AFG,NC}$	3,088.1	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{AFN,COMP}$	24.3	in	$\bar{y}_{AFN,NC}$	38.0	in
$c_{AFN,COMP}$	24.9	in	$c_{AFN,NC}$	38.7	in
$A_{AFN,COMP}$	200.0	in^2	$A_{AFN,NC}$	113.8	in^2
$I_{x,AFN,COMP}$	157,675.8	in^4	$I_{x,AFN,NC}$	107,100.1	in^4
$S_{x\text{-}AFN,COMP}$	6,319.9	in^3	$S_{x\text{-}AFN,NC}$	2,765.7	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-8** Distance from Abut **863** ft

Variation Desciption: **Variation 8 - Controlling Fatigue Location**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.375

Number of tension CPs, N_{FL} = 2

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 7,098 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = - ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = 30.80 ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = 27.58 ksi GS Eq. 2.1.3-2

Note: Outputs are based on noncomposite section properties for a negative moment region

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	1.71
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.14

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-8** Distance from Abut **863** ft

Variation Desciption: **Variation 8 - Controlling Fatigue Location**

1.71

1.14

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	**4.48**	ksi	GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	4.48	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	4.51	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	**9.93**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	2.39E+07	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	2.35E+07	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	1.2	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	1,017	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**1.2**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**II**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-8** Distance from Abut **863** ft

Variation Desciption: **Variation 8 - Controlling Fatigue Location**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ = **7.19** ksi GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Faulted state stress range, Δf =	7.19	ksi	MBE 7.2.2
Faulted state effective stress range, $(\Delta f)_{eff}$ =	7.25	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	15.95	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	1.15E+07	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	27.3	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	1,318	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**27.3**	Years	MBE 7.2.5.1
Case I or II for faulted state?	**II**	I(a), I(b), II	GS 2.5

Faulted fatigue life? **OK**

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	63.0	Years	GS 2.5.3
Total remaining fatigue life only in **unfaulted** state, Y_u	64.2	Years	GS 2.5.3
Total remaining fatigue life only in **faulted** state, Y_f	27.3	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**0.5**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	II	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	4.48	ksi	
Controlling stress range in faulted state, Δf_{FS} =	7.19	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**27.3**	Years	
Total remaining fatigue life, N_f	**0.5**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**0.5**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-9** Distance from Abut **878.88** ft

Variation Desciption: **Variation 9 - Controlling Strength Location**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

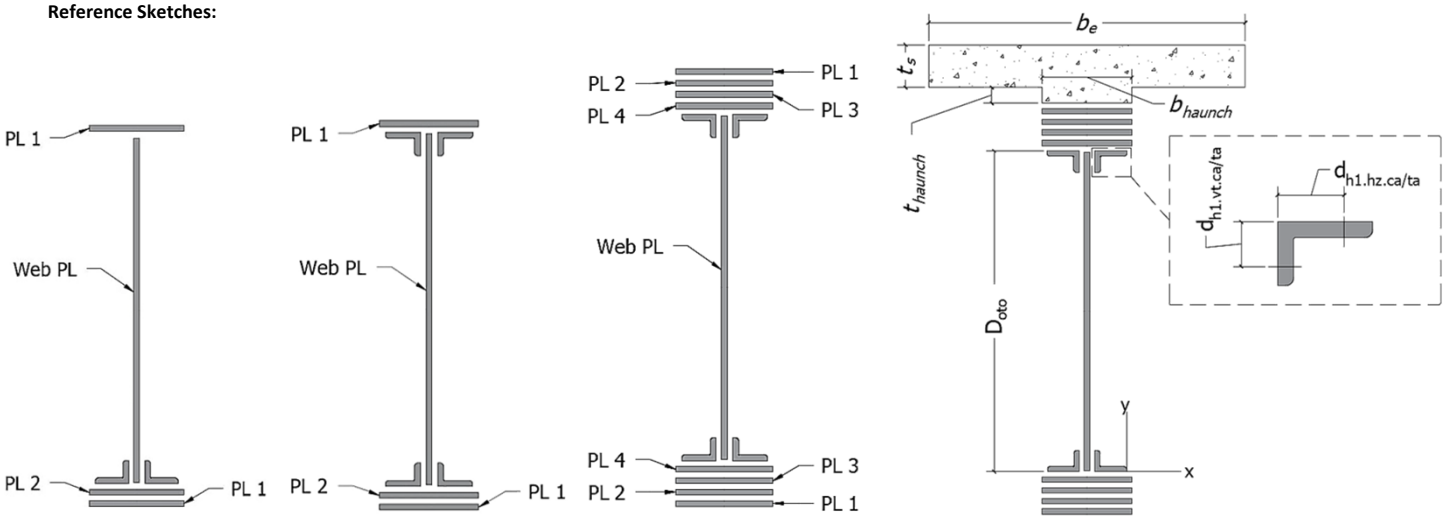
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all provisions of Section 1.5?	**Yes**	Yes

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**Yes**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**Yes**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	**84.8**	in	Haunch Width, b_{haunch}	**59.3**	in
Deck Slab Thickness, t_s	**5.8**	in	Haunch Thickness, t_{haunch}	**3.4**	in
Concrete Modulus of Elasticity, E_c	**3625.5**	ksi	Modular Ratio of the concrete, n	8.0	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **3** (1 to 4)

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**20.000**	**20.000**	**20.000**	0.000	in
$t_{ccp,i}$	**0.4375**	**0.4375**	**0.6875**	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L8X8X7/8**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	13.3	in^2
Thickness of the angle, t_{ca}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ca}	2.31	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.00**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.00**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-9** Distance from Abut **878.88** ft

Variation Desciption: **Variation 9 - Controlling Strength Location**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	89.00	in	Flange Angles Out-to-out Depth, D_{oto}	89.50	in
Web Thickness, t_w	0.5000	in			

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **3** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	20.000	20.000	20.000	0.000	in
$t_{tcp,i}$	0.4375	0.4375	0.6875	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L8X8X7/8	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	13.3	in^2
Thickness of the angle, t_{ta}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ta}	2.31	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1	holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.00	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.00	in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00	in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	558	trucks/day	Current Year, $Y_{current}$	2021	year
$(ADTT_{sl})_0$	558	trucks/day	Span Length, L	155.75	ft
$(ADTT_{sl})_{limit}$	8,840	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
			Is this a transverse member?	No	Y or N

Note: Growth rate is for future growth from today on

Unfactored Moments:

M_{DC1}	2,641	k-ft	M_{DW}	580	k-ft	M_{LL+IM}	4,436	k-ft
M_{DC2}	691	k-ft				M_{FAT+IM}	1,031	k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{G,COMP}$	31.4	in	$\bar{y}_{C,G,NC}$	44.8	in
$c_{G,COMP}$	32.9	in	$c_{G,NC}$	46.3	in
$A_{G,COMP}$	246.4	in^2	$A_{G,NC}$	160.2	in^2
$I_{xG,COMP}$	337,614.8	in^4	$I_{xG,NC}$	255,095.0	in^4
$S_{xG,COMP}$	10,250.3	in^3	$S_{xG,NC}$	5,508.1	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{N,COMP}$	30.6	in	$\bar{y}_{N,NC}$	44.8	in
$c_{N,COMP}$	32.2	in	$c_{N,NC}$	46.3	in
$A_{N,COMP}$	233.0	in^2	$A_{N,NC}$	146.8	in^2
$I_{xN,COMP}$	309,345.6	in^4	$I_{xN,NC}$	229,497.7	in^4
$S_{xN,COMP}$	9,615.9	in^3	$S_{xN,NC}$	4,955.4	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFG,COMP}$	32.6	in	$\bar{y}_{AFG,NC}$	47.4	in
$c_{AFG,COMP}$	33.7	in	$c_{AFG,NC}$	48.5	in
$A_{AFG,COMP}$	237.6	in^2	$A_{AFG,NC}$	151.5	in^2
$I_{x,AFG,COMP}$	327,902.9	in^4	$I_{x,AFG,NC}$	235,430.3	in^4
$S_{x\text{-}AFG,COMP}$	9,728.8	in^3	$S_{x\text{-}AFG,NC}$	4,850.4	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFN,COMP}$	31.7	in	$\bar{y}_{AFN,NC}$	47.4	in
$c_{AFN,COMP}$	32.9	in	$c_{AFN,NC}$	48.5	in
$A_{AFN,COMP}$	225.1	in^2	$A_{AFN,NC}$	138.9	in^2
$I_{x,AFN,COMP}$	300,939.7	in^4	$I_{x,AFN,NC}$	211,688.0	in^4
$S_{x\text{-}AFN,COMP}$	9,158.7	in^3	$S_{x\text{-}AFN,NC}$	4,364.1	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-9** Distance from Abut **878.88** ft

Variation Desciption: **Variation 9 - Controlling Strength Location**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.438

Number of tension CPs, N_{FL} = 3

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 11,212 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = - ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = 30.83 ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = 27.74 ksi GS Eq. 2.1.3-2

Note: Outputs are based on noncomposite section properties for a negative moment region

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	1.71
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.13

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-9** Distance from Abut **878.88** ft

Variation Desciption: **Variation 9 - Controlling Strength Location**

1.71

1.13

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	**2.50**	ksi	GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	2.50	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	2.51	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	**5.53**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-9** Distance from Abut **878.88** ft

Variation Desciption: **Variation 9 - Controlling Strength Location**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ = **4.07** ksi GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Faulted state stress range, Δf =	4.07	ksi	MBE 7.2.2
Faulted state effective stress range, $(\Delta f)_{eff}$ =	4.10	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	9.02	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for faulted state?	**I(a)**	I(a), I(b), II	GS 2.5

Faulted fatigue life? **OK**

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	63.0	Years	GS 2.5.3
Total remaining fatigue life only in **unfaulted** state, Y_u	∞	Years	GS 2.5.3
Total remaining fatigue life only in **faulted** state, Y_f	Infinite	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**Infinite**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	I(a)	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	2.50	ksi	
Controlling stress range in faulted state, Δf_{FS} =	4.07	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	
Total remaining fatigue life, N_f	**Infinite**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-9** Distance from Abut **441.5** ft

Variation Desciption: **Variation 9 - Controlling Fatigue Location**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

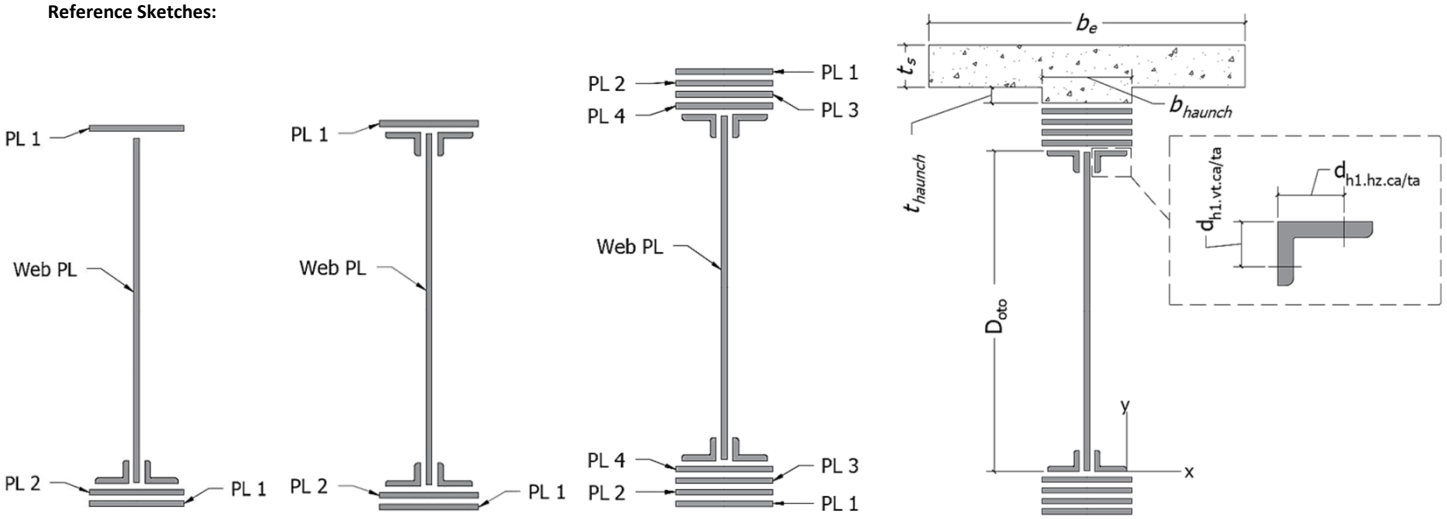
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all provisions of Section 1.5?	**Yes**	Yes

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**Yes**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**Yes**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	**84.8**	in	Haunch Width, b_{haunch}	**59.3**	in
Deck Slab Thickness, t_s	**5.8**	in	Haunch Thickness, t_{haunch}	**3.4**	in
Concrete Modulus of Elasticity, E_c	**3625.5**	ksi	Modular Ratio of the concrete, n	8.0	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **3** (1 to 4)

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**20.000**	**20.000**	**20.000**	0.000	in
$t_{ccp,i}$	**0.4375**	**0.4375**	**0.6875**	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L8X8X7/8**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	13.3	in^2
Thickness of the angle, t_{ca}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ca}	2.31	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.00**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.00**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-9** Distance from Abut **441.5** ft

Variation Desciption: **Variation 9 - Controlling Fatigue Location**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	76.80	in	Flange Angles Out-to-out Depth, D_{oto}	77.30	in
Web Thickness, t_w	0.5000	in			

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **3** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	20.000	20.000	20.000	0.000	in
$t_{tcp,i}$	0.4375	0.4375	0.6875	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L8X8X7/8	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	13.3	in^2
Thickness of the angle, t_{ta}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ta}	2.31	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1	holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.00	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.00	in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00	in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	1,005	trucks/day	Current Year, $Y_{current}$	2021	year
$(ADTT_{sl})_0$	1,005	trucks/day	Span Length, L	155.75	ft
$(ADTT_{sl})_{limit}$	8,840	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
			Is this a transverse member?	No	Y or N

Note: Growth rate is for future growth from today on

Unfactored Moments:

M_{DC1}	1,610	k-ft	M_{DW}	352	k-ft	M_{LL+IM}	4,340	k-ft
M_{DC2}	420	k-ft				M_{FAT+IM}	1,177	k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{G,COMP}$	27.1	in	$\bar{y}_{C,G,NC}$	38.7	in
$c_{G,COMP}$	28.7	in	$c_{G,NC}$	40.2	in
$A_{G,COMP}$	240.3	in^2	$A_{G,NC}$	154.1	in^2
$I_{xG,COMP}$	244,310.5	in^4	$I_{xG,NC}$	186,638.0	in^4
$S_{xG,COMP}$	8,517.0	in^3	$S_{xG,NC}$	4,641.3	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{N,COMP}$	26.4	in	$\bar{y}_{N,NC}$	38.7	in
$c_{N,COMP}$	28.0	in	$c_{N,NC}$	40.2	in
$A_{N,COMP}$	226.9	in^2	$A_{N,NC}$	140.7	in^2
$I_{xN,COMP}$	223,351.7	in^4	$I_{xN,NC}$	167,669.6	in^4
$S_{xN,COMP}$	7,975.1	in^3	$S_{xN,NC}$	4,169.6	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFG,COMP}$	28.2	in	$\bar{y}_{AFG,NC}$	41.1	in
$c_{AFG,COMP}$	29.3	in	$c_{AFG,NC}$	42.2	in
$A_{AFG,COMP}$	231.5	in^2	$A_{AFG,NC}$	145.4	in^2
$I_{x,AFG,COMP}$	236,952.1	in^4	$I_{x,AFG,NC}$	171,799.7	in^4
$S_{x\text{-}AFG,COMP}$	8,080.7	in^3	$S_{x\text{-}AFG,NC}$	4,072.8	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFN,COMP}$	27.4	in	$\bar{y}_{AFN,NC}$	41.0	in
$c_{AFN,COMP}$	28.6	in	$c_{AFN,NC}$	42.2	in
$A_{AFN,COMP}$	219.0	in^2	$A_{AFN,NC}$	132.8	in^2
$I_{x,AFN,COMP}$	216,988.0	in^4	$I_{x,AFN,NC}$	154,228.6	in^4
$S_{x\text{-}AFN,COMP}$	7,593.6	in^3	$S_{x\text{-}AFN,NC}$	3,657.9	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-9** Distance from Abut **441.5** ft

Variation Desciption: **Variation 9 - Controlling Fatigue Location**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No Optional FCP override: "Override" or blank

(This is based on the year built; "No" if prior to 1978) (This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95 Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.438

Number of tension CPs, N_{FL} = 3

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 9,285 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = - ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = 30.46 ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = 27.36 ksi GS Eq. 2.1.3-2

Note: Outputs are based on noncomposite section properties for a negative moment region

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	1.73
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.15

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-9** Distance from Abut **441.5** ft

Variation Desciption: **Variation 9 - Controlling Fatigue Location**

1.73

1.15

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	**3.39**	ksi	GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	3.39	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	3.41	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	**7.51**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	5.53E+07	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	2.35E+07	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	62.3	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	1,868	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**62.3**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**II**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-9** Distance from Abut **441.5** ft

Variation Desciption: **Variation 9 - Controlling Fatigue Location**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ = **5.55** ksi GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Faulted state stress range, Δf =	5.55	ksi	MBE 7.2.2
Faulted state effective stress range, $(\Delta f)_{eff}$ =	5.59	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	12.31	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	2.51E+07	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	52.0	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	1,687	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**52.0**	Years	MBE 7.2.5.1
Case I or II for faulted state?	**II**	I(a), I(b), II	GS 2.5

Faulted fatigue life? **OK**

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	63.0	Years	GS 2.5.3
Total remaining fatigue life only in **unfaulted** state, Y_u	125.3	Years	GS 2.5.3
Total remaining fatigue life only in **faulted** state, Y_f	52.0	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**25.9**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	II	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	3.39	ksi	
Controlling stress range in faulted state, Δf_{FS} =	5.55	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**52.0**	Years	
Total remaining fatigue life, N_f	**25.9**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-10** Distance from Abut **489.5** ft

Variation Desciption: **Variation 10 - Controlling Strength Location**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

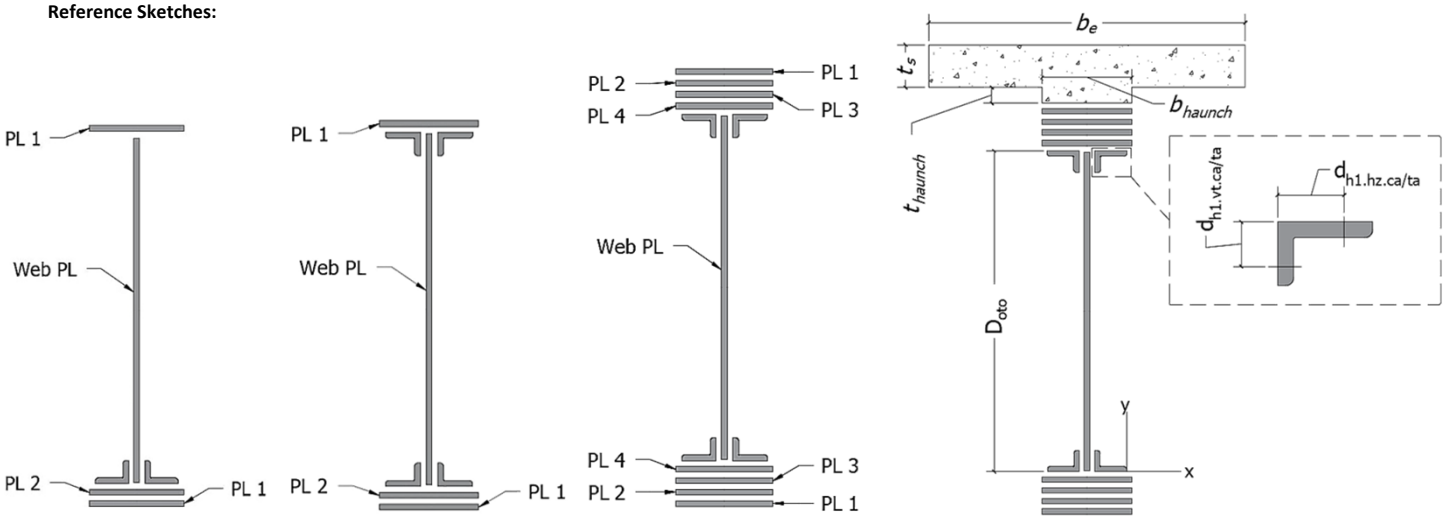
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all provisions of Section 1.5?	**Yes**	Yes

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**Yes**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**No**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	**84.8**	in	Haunch Width, b_{haunch}	**59.3**	in
Deck Slab Thickness, t_s	**5.8**	in	Haunch Thickness, t_{haunch}	**3.4**	in
Concrete Modulus of Elasticity, E_c	**3625.5**	ksi	Modular Ratio of the concrete, n	8.0	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **3** (1 to 4)

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**20.000**	**20.000**	**20.000**	0.000	in
$t_{ccp,i}$	**0.5000**	**0.6875**	**0.6875**	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L8X8X7/8**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	13.3	in^2
Thickness of the angle, t_{ca}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ca}	2.31	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.00**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.00**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-10** Distance from Abut **489.5** ft

Variation Desciption: **Variation 10 - Controlling Strength Location**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	**70.00**	in	Flange Angles Out-to-out Depth, D_{oto}	**70.50** in
Web Thickness, t_w	**0.5000**	in		

Tension Flange Plate Dimensions (in)**:**

No. of Tension Flange Cover Plates, N_{tcp} **3** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	20.000	20.000	20.000	0.000	in
$t_{tcp,i}$	0.5000	0.6875	0.6875	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	**L8X8X7/8**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ta.g}$	13.3	in^2
Thickness of the angle, t_{ta}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ta}	2.31	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	**1** holes
Distance to Hole 1, $d_{h1.vt.ta}$	**4.00**	in	Distance to Hole 1, $d_{h1.hz.ta}$	**4.00** in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00 in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	**558**	trucks/day	Current Year, $Y_{current}$	**2021** year
$(ADTT_{sl})_0$	**558**	trucks/day	Span Length, L	**155.75** ft
$(ADTT_{sl})_{limit}$	**8,840**	trucks/day	Number of striped lanes, n_L	**2** lanes
Year Built, Y_{built}	**1958**	year	Stress-Range Estimate Partial LF, R_s	**1.00**
Expected annual $(ADTT)_{SL}$ growth rate, g	**0.010**	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	**1** cycles
Note: Growth rate is for future growth from today on			Is this a transverse member?	**No** Y or N

Unfactored Moments:

M_{DC1}	**1,897**	k-ft	M_{DW}	**421**	k-ft	M_{LL+IM}	**5,060** k-ft
M_{DC2}	**501**	k-ft				M_{FAT+IM}	**855** k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{G,COMP}$	49.8	in	$\bar{y}_{C,G,NC}$	35.3 in
$c_{G,COMP}$	51.7	in	$c_{G,NC}$	37.1 in
$A_{G,COMP}$	249.4	in^2	$A_{G,NC}$	163.2 in^2
$I_{xG,COMP}$	270,912.7	in^4	$I_{xG,NC}$	170,571.9 in^4
$S_{xG,COMP}$	5,244.3	in^3	$S_{xG,NC}$	4,594.5 in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{N,COMP}$	50.7	in	$\bar{y}_{N,NC}$	35.3 in
$c_{N,COMP}$	52.6	in	$c_{N,NC}$	37.1 in
$A_{N,COMP}$	234.8	in^2	$A_{N,NC}$	148.7 in^2
$I_{xN,COMP}$	250,144.9	in^4	$I_{xN,NC}$	153,265.2 in^4
$S_{xN,COMP}$	4,759.4	in^3	$S_{xN,NC}$	4,128.4 in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{AFG,COMP}$	51.9	in	$\bar{y}_{AFG,NC}$	37.7 in
$c_{AFG,COMP}$	53.3	in	$c_{AFG,NC}$	39.0 in
$A_{AFG,COMP}$	239.4	in^2	$A_{AFG,NC}$	153.2 in^2
$I_{x,AFG,COMP}$	243,379.8	in^4	$I_{x,AFG,NC}$	156,086.5 in^4
$S_{x\text{-}AFG,COMP}$	4,565.7	in^3	$S_{x\text{-}AFG,NC}$	3,998.9 in^3

Net Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{AFN,COMP}$	52.8	in	$\bar{y}_{AFN,NC}$	37.6 in
$c_{AFN,COMP}$	54.2	in	$c_{AFN,NC}$	39.0 in
$A_{AFN,COMP}$	225.8	in^2	$A_{AFN,NC}$	139.6 in^2
$I_{x,AFN,COMP}$	224,381.4	in^4	$I_{x,AFN,NC}$	140,142.2 in^4
$S_{x\text{-}AFN,COMP}$	4,143.1	in^3	$S_{x\text{-}AFN,NC}$	3,591.7 in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-10** Distance from Abut **489.5** ft

Variation Desciption: **Variation 10 - Controlling Strength Location**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.438

Number of tension CPs, N_{FL} = 3

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 10,872 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = - ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = 32.72 ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = 29.60 ksi GS Eq. 2.1.3-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	1.61
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.06

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-10** Distance from Abut **489.5** ft

Variation Desciption: **Variation 10 - Controlling Strength Location**

1.61
1.06

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	**2.15**	ksi	GS Eq. 2.1.3-1

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	2.15	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	2.17	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	**4.77**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-10** Distance from Abut **489.5** ft

Variation Desciption: **Variation 10 - Controlling Strength Location**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ =	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ =	**3.56**	ksi	GS Eq. 2.1.3-1
Faulted state stress range, Δf =	3.56	ksi	MBE 7.2.2
Faulted state effective stress range, $(\Delta f)_{eff}$ =	3.58	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	7.88	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for faulted state?	**I(a)**	I(a), I(b), II	GS 2.5

Faulted fatigue life? **OK**

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	63.0	Years	GS 2.5.3
Total remaining fatigue life only in **unfaulted** state, Y_u	∞	Years	GS 2.5.3
Total remaining fatigue life only in **faulted** state, Y_f	Infinite	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**Infinite**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	I(a)	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	2.15	ksi	
Controlling stress range in faulted state, Δf_{FS} =	3.56	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	
Total remaining fatigue life, N_f	**Infinite**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-10** Distance from Abut **842.5** ft

Variation Desciption: **Variation 10 - Controlling Fatigue Location**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

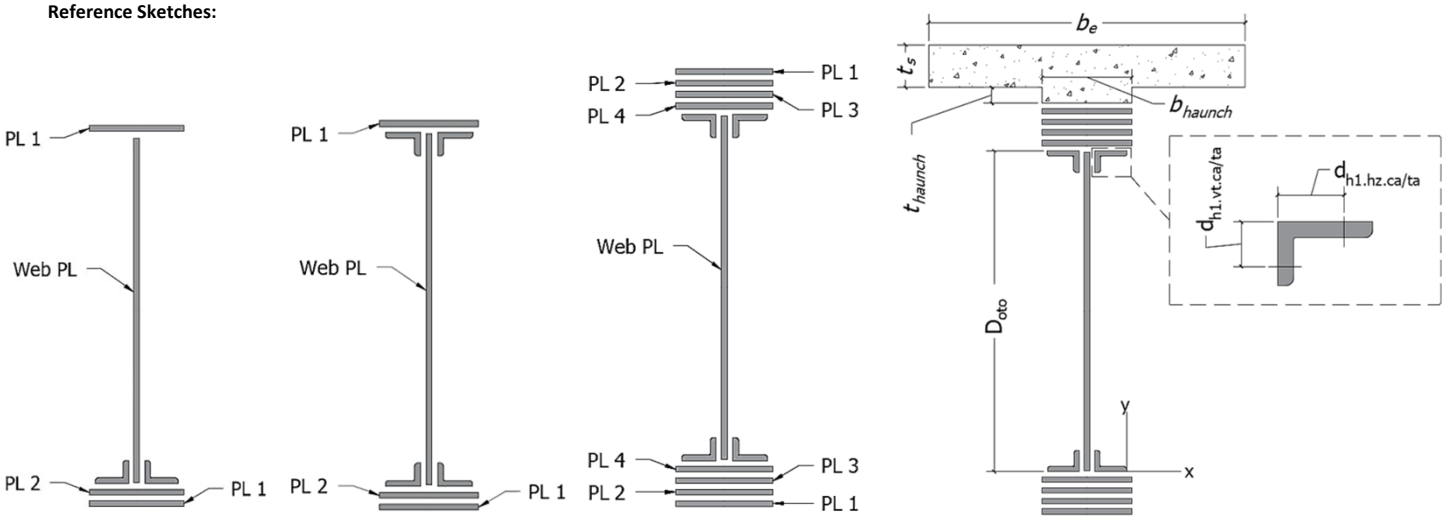
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all provisions of Section 1.5?	**Yes**	Yes

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**Yes**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**No**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	**84.8**	in	Haunch Width, b_{haunch}	**59.3**	in
Deck Slab Thickness, t_s	**5.8**	in	Haunch Thickness, t_{haunch}	**3.4**	in
Concrete Modulus of Elasticity, E_c	**3625.5**	ksi	Modular Ratio of the concrete, n	8.0	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **3** (1 to 4)

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**20.000**	**20.000**	**20.000**	0.000	in
$t_{ccp,i}$	**0.5000**	**0.6875**	**0.6875**	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L8X8X7/8**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	13.3	in^2
Thickness of the angle, t_{ca}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ca}	2.31	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.00**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.00**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-10** Distance from Abut **842.5** ft

Variation Desciption: **Variation 10 - Controlling Fatigue Location**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No — Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	70.00	in	Flange Angles Out-to-out Depth, D_{oto}	70.50 in
Web Thickness, t_w	0.5000	in		

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} = 3 (1 to 4)

Plate(i):	1	2	3	4	
$b_{tcp,i}$	20.000	20.000	20.000	0.000	in
$t_{tcp,i}$	0.5000	0.6875	0.6875	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L8X8X7/8	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	13.3	in^2
Thickness of the angle, t_{ta}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ta}	2.31	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1 holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.00	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.00 in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00 in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No — Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	558	trucks/day	Current Year, $Y_{current}$	2021 year
$(ADTT_{sl})_0$	558	trucks/day	Span Length, L	155.75 ft
$(ADTT_{sl})_{limit}$	8,840	trucks/day	Number of striped lanes, n_L	2 lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1 cycles
			Is this a transverse member?	No Y or N

Note: Growth rate is for future growth from today on

Unfactored Moments:

M_{DC1}	1,070	k-ft	M_{DW}	240	k-ft	M_{LL+IM}	4,581 k-ft
M_{DC2}	286	k-ft				M_{FAT+IM}	1,286 k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{G,COMP}$	49.8	in	$\bar{y}_{C,G,NC}$	35.3 in
$c_{G,COMP}$	51.7	in	$c_{G,NC}$	37.1 in
$A_{G,COMP}$	249.4	in^2	$A_{G,NC}$	163.2 in^2
$I_{xG,COMP}$	270,912.7	in^4	$I_{xG,NC}$	170,571.9 in^4
$S_{xG,COMP}$	5,244.3	in^3	$S_{xG,NC}$	4,594.5 in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{N,COMP}$	50.7	in	$\bar{y}_{N,NC}$	35.3 in
$c_{N,COMP}$	52.6	in	$c_{N,NC}$	37.1 in
$A_{N,COMP}$	234.8	in^2	$A_{N,NC}$	148.7 in^2
$I_{xN,COMP}$	250,144.9	in^4	$I_{xN,NC}$	153,265.2 in^4
$S_{xN,COMP}$	4,759.4	in^3	$S_{xN,NC}$	4,128.4 in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{AFG,COMP}$	51.9	in	$\bar{y}_{AFG,NC}$	37.7 in
$c_{AFG,COMP}$	53.3	in	$c_{AFG,NC}$	39.0 in
$A_{AFG,COMP}$	239.4	in^2	$A_{AFG,NC}$	153.2 in^2
$I_{x,AFG,COMP}$	243,379.8	in^4	$I_{x,AFG,NC}$	156,086.5 in^4
$S_{x\text{-}AFG,COMP}$	4,565.7	in^3	$S_{x\text{-}AFG,NC}$	3,998.9 in^3

Net Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{AFN,COMP}$	52.8	in	$\bar{y}_{AFN,NC}$	37.6 in
$c_{AFN,COMP}$	54.2	in	$c_{AFN,NC}$	39.0 in
$A_{AFN,COMP}$	225.8	in^2	$A_{AFN,NC}$	139.6 in^2
$I_{x,AFN,COMP}$	224,381.4	in^4	$I_{x,AFN,NC}$	140,142.2 in^4
$S_{x\text{-}AFN,COMP}$	4,143.1	in^3	$S_{x\text{-}AFN,NC}$	3,591.7 in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-10** Distance from Abut **842.5** ft

Variation Desciption: **Variation 10 - Controlling Fatigue Location**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.438

Number of tension CPs, N_{FL} = 3

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 8,730 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = - ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = 25.98 ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = 23.52 ksi GS Eq. 2.1.3-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	2.03
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.33

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-10** Distance from Abut **842.5** ft

Variation Desciption: **Variation 10 - Controlling Fatigue Location**

2.03

1.33

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	**3.24**	ksi	GS Eq. 2.1.3-1

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	3.24	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	3.26	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	**7.18**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	6.34E+07	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	1.30E+07	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	124.4	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	1,923	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**124.4**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**II**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-10** Distance from Abut **842.5** ft

Variation Desciption: **Variation 10 - Controlling Fatigue Location**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ =	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \beta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ =	**5.35**	ksi	GS Eq. 2.1.3-1
Faulted state stress range, Δf =	5.35	ksi	MBE 7.2.2
Faulted state effective stress range, $(\Delta f)_{eff}$ =	5.39	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	11.85	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	2.81E+07	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	86.6	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	1,321	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**86.6**	Years	MBE 7.2.5.1
Case I or II for faulted state?	**II**	I(a), I(b), II	GS 2.5

Faulted fatigue life? **OK**

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	63.0	Years	GS 2.5.3
Total remaining fatigue life only in **unfaulted** state, Y_u	187.4	Years	GS 2.5.3
Total remaining fatigue life only in **faulted** state, Y_f	86.6	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**57.5**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	II	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	3.24	ksi	
Controlling stress range in faulted state, Δf_{FS} =	5.35	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**86.6**	Years	
Total remaining fatigue life, N_f	**57.5**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-11** Distance from Abut **578.5** ft

Variation Desciption: **Variation 11 - Controlling Strength Location**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

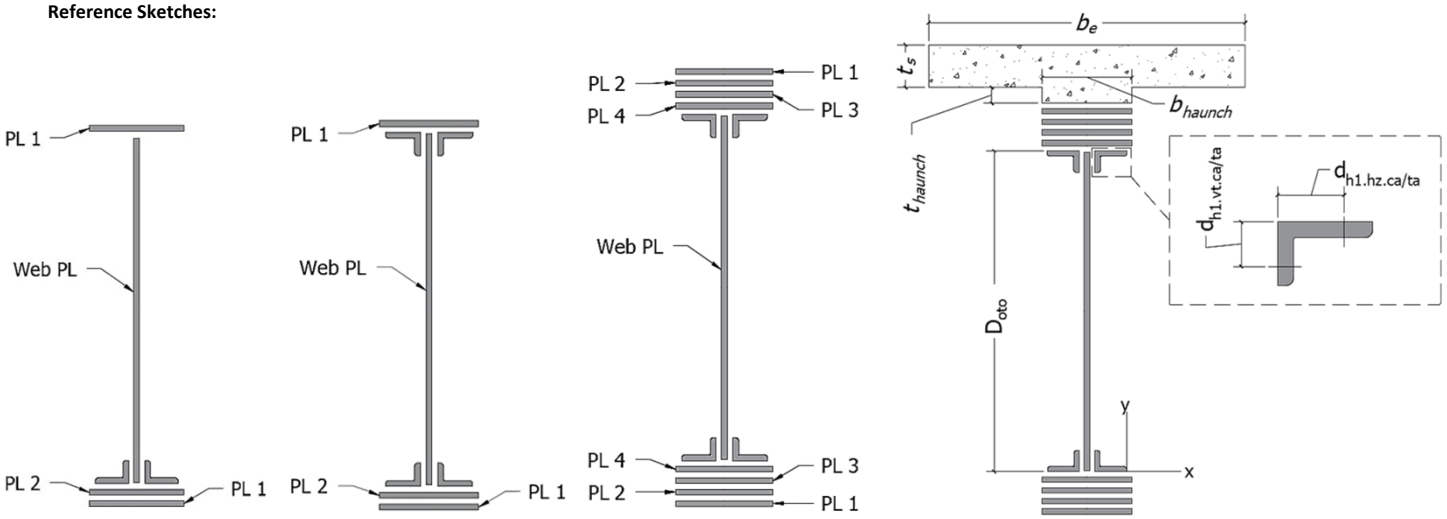
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all provisions of Section 1.5?	**Yes**	Yes

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**Yes**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**Yes**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	**84.8**	in	Haunch Width, b_{haunch}	**59.3**	in
Deck Slab Thickness, t_s	**5.8**	in	Haunch Thickness, t_{haunch}	**3.4**	in
Concrete Modulus of Elasticity, E_c	**3625.5**	ksi	Modular Ratio of the concrete, n	8.0	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **3** (1 to 4)

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**20.000**	**20.000**	**20.000**	0.000	in
$t_{ccp,i}$	**0.5000**	**0.6250**	**0.6875**	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L8X8X7/8**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	13.3	in^2
Thickness of the angle, t_{ca}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ca}	2.31	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.00**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.00**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-11** Distance from Abut **578.5** ft

Variation Desciption: **Variation 11 - Controlling Strength Location**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	116.00	in	Flange Angles Out-to-out Depth, D_{oto}	116.50 in
Web Thickness, t_w	0.5000	in		

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **3** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	20.000	20.000	20.000	0.000	in
$t_{tcp,i}$	0.5000	0.6250	0.6875	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L8X8X7/8	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	13.3	in^2
Thickness of the angle, t_{ta}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ta}	2.31	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1 holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.00	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.00 in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00 in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	558	trucks/day	Current Year, $Y_{current}$	2021	year
$(ADTT_{sl})_0$	558	trucks/day	Span Length, L	155.75	ft
$(ADTT_{sl})_{limit}$	8,840	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
			Is this a transverse member?	No	Y or N

Note: Growth rate is for future growth from today on

Unfactored Moments:

M_{DC1}	4,721	k-ft	M_{DW}	1,080	k-ft	M_{LL+IM}	5,507 k-ft
M_{DC2}	1,285	k-ft				M_{FAT+IM}	844 k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{G,COMP}$	41.8	in	$\bar{y}_{C,G,NC}$	58.3 in
$c_{G,COMP}$	43.6	in	$c_{G,NC}$	60.1 in
$A_{G,COMP}$	269.9	in^2	$A_{G,NC}$	183.7 in^2
$I_{xG,COMP}$	641,660.8	in^4	$I_{xG,NC}$	485,564.9 in^4
$S_{xG,COMP}$	14,709.6	in^3	$S_{xG,NC}$	8,084.3 in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{N,COMP}$	40.9	in	$\bar{y}_{N,NC}$	58.3 in
$c_{N,COMP}$	42.7	in	$c_{N,NC}$	60.1 in
$A_{N,COMP}$	255.6	in^2	$A_{N,NC}$	169.4 in^2
$I_{xN,COMP}$	590,181.2	in^4	$I_{xN,NC}$	438,394.2 in^4
$S_{xN,COMP}$	13,820.9	in^3	$S_{xN,NC}$	7,299.0 in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{AFG,COMP}$	43.5	in	$\bar{y}_{AFG,NC}$	61.7 in
$c_{AFG,COMP}$	44.8	in	$c_{AFG,NC}$	63.0 in
$A_{AFG,COMP}$	259.9	in^2	$A_{AFG,NC}$	173.7 in^2
$I_{x,AFG,COMP}$	622,125.6	in^4	$I_{x,AFG,NC}$	447,729.7 in^4
$S_{x\text{-}AFG,COMP}$	13,889.6	in^3	$S_{x\text{-}AFG,NC}$	7,106.2 in^3

Net Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{AFN,COMP}$	42.5	in	$\bar{y}_{AFN,NC}$	61.6 in
$c_{AFN,COMP}$	43.8	in	$c_{AFN,NC}$	62.9 in
$A_{AFN,COMP}$	246.5	in^2	$A_{AFN,NC}$	160.3 in^2
$I_{x,AFN,COMP}$	573,202.0	in^4	$I_{x,AFN,NC}$	404,139.4 in^4
$S_{x\text{-}AFN,COMP}$	13,097.9	in^3	$S_{x\text{-}AFN,NC}$	6,420.7 in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-11** Distance from Abut **578.5** ft

Variation Desciption: **Variation 11 - Controlling Strength Location**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.438

Number of tension CPs, N_{FL} = 3

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 16,517 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = - ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = 30.87 ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = 27.89 ksi GS Eq. 2.1.3-2

Note: Outputs are based on noncomposite section properties for a negative moment region

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	1.71
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.12

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-11** Distance from Abut **578.5** ft

Variation Desciption: **Variation 11 - Controlling Strength Location**

1.71

Fatigue Life Estimate (GS 2.5) 1.12

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	**1.39**	ksi	GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	1.39	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	1.40	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	**3.07**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-11** Distance from Abut **578.5** ft

Variation Desciption: **Variation 11 - Controlling Strength Location**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ = **2.27** ksi GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Faulted state stress range, Δf =	2.27	ksi	MBE 7.2.2
Faulted state effective stress range, $(\Delta f)_{eff}$ =	2.28	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	5.02	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for faulted state?	**I(a)**	I(a), I(b), II	GS 2.5

Faulted fatigue life? **OK**

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	63.0	Years	GS 2.5.3
Total remaining fatigue life only in **unfaulted** state, Y_u	∞	Years	GS 2.5.3
Total remaining fatigue life only in **faulted** state, Y_f	Infinite	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**Infinite**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	I(a)	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	1.39	ksi	
Controlling stress range in faulted state, Δf_{FS} =	2.27	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	
Total remaining fatigue life, N_f	**Infinite**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-11** Distance from Abut **597.5** ft

Variation Desciption: **Variation 11 - Controlling Fatigue Location**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

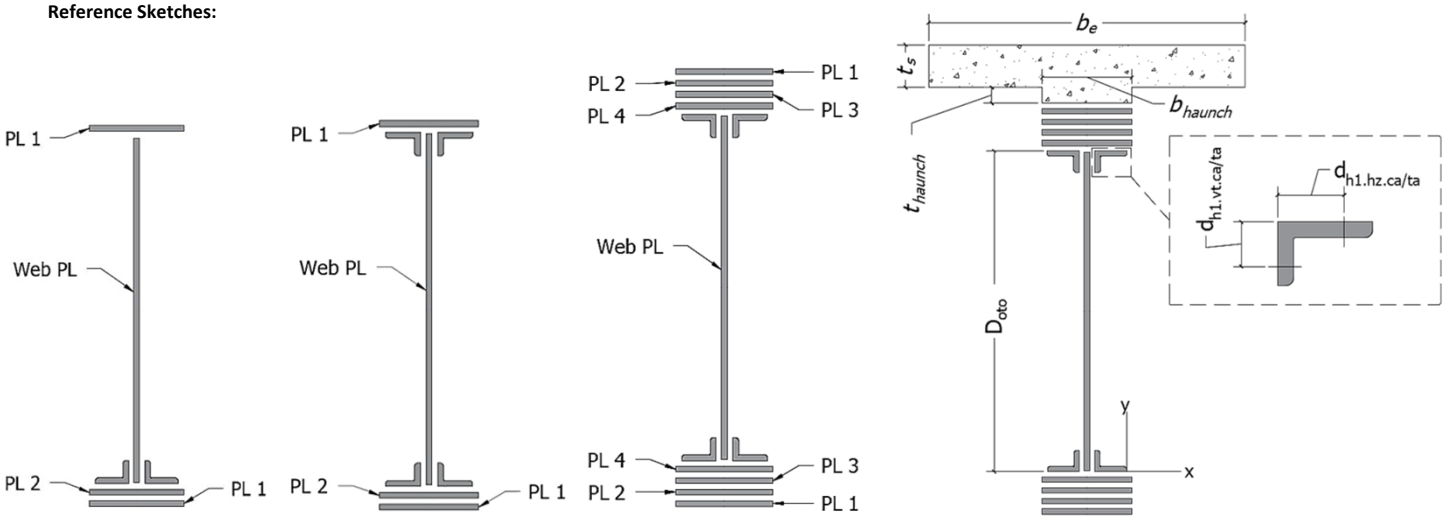
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all provisions of Section 1.5?	**Yes**	Yes

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**Yes**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**Yes**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	**84.8**	in	Haunch Width, b_{haunch}	**59.3**	in
Deck Slab Thickness, t_s	**5.8**	in	Haunch Thickness, t_{haunch}	**3.4**	in
Concrete Modulus of Elasticity, E_c	**3625.5**	ksi	Modular Ratio of the concrete, n	8.0	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **3** (1 to 4)

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**20.000**	**20.000**	**20.000**	0.000	in
$t_{ccp,i}$	**0.5000**	**0.6250**	**0.6875**	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L8X8X7/8**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	13.3	in^2
Thickness of the angle, t_{ca}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ca}	2.31	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.00**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.00**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-11** Distance from Abut **597.5** ft

Variation Desciption: **Variation 11 - Controlling Fatigue Location**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	76.50	in	Flange Angles Out-to-out Depth, D_{oto}	77.00 in
Web Thickness, t_w	0.5000	in		

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **3** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	20.000	20.000	20.000	0.000	in
$t_{tcp,i}$	0.5000	0.6250	0.6875	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L8X8X7/8	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	13.3	in^2
Thickness of the angle, t_{ta}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ta}	2.31	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1 holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.00	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.00 in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00 in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	558	trucks/day	Current Year, $Y_{current}$	2021 year
$(ADTT_{sl})_0$	558	trucks/day	Span Length, L	155.75 ft
$(ADTT_{sl})_{limit}$	8,840	trucks/day	Number of striped lanes, n_L	2 lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1 cycles
			Is this a transverse member?	No Y or N

Note: Growth rate is for future growth from today on

Unfactored Moments:

M_{DC1}	1,992	k-ft	M_{DW}	454	k-ft	M_{LL+IM}	3,207 k-ft
M_{DC2}	540	k-ft				M_{FAT+IM}	714 k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{G,COMP}$	27.6	in	$\bar{y}_{C,G,NC}$	38.5	in
$c_{G,COMP}$	29.4	in	$c_{G,NC}$	40.3	in
$A_{G,COMP}$	250.1	in^2	$A_{G,NC}$	164.0	in^2
$I_{xG,COMP}$	258,737.9	in^4	$I_{xG,NC}$	201,251.4	in^4
$S_{xG,COMP}$	8,807.6	in^3	$S_{xG,NC}$	4,992.3	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{N,COMP}$	26.9	in	$\bar{y}_{N,NC}$	38.5	in
$c_{N,COMP}$	28.7	in	$c_{N,NC}$	40.3	in
$A_{N,COMP}$	235.8	in^2	$A_{N,NC}$	149.7	in^2
$I_{xN,COMP}$	236,482.5	in^4	$I_{xN,NC}$	180,919.4	in^4
$S_{xN,COMP}$	8,235.9	in^3	$S_{xN,NC}$	4,487.9	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFG,COMP}$	28.8	in	$\bar{y}_{AFG,NC}$	41.1	in
$c_{AFG,COMP}$	30.1	in	$c_{AFG,NC}$	42.4	in
$A_{AFG,COMP}$	240.1	in^2	$A_{AFG,NC}$	154.0	in^2
$I_{x,AFG,COMP}$	249,900.7	in^4	$I_{x,AFG,NC}$	184,158.6	in^4
$S_{x\text{-}AFG,COMP}$	8,305.2	in^3	$S_{x\text{-}AFG,NC}$	4,341.8	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFN,COMP}$	28.0	in	$\bar{y}_{AFN,NC}$	41.1	in
$c_{AFN,COMP}$	29.4	in	$c_{AFN,NC}$	42.4	in
$A_{AFN,COMP}$	226.7	in^2	$A_{AFN,NC}$	140.6	in^2
$I_{x,AFN,COMP}$	228,825.6	in^4	$I_{x,AFN,NC}$	165,436.2	in^4
$S_{x\text{-}AFN,COMP}$	7,796.1	in^3	$S_{x\text{-}AFN,NC}$	3,902.3	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-11** Distance from Abut **597.5** ft

Variation Desciption: **Variation 11 - Controlling Fatigue Location**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No — Optional FCP override: "Override" or blank

(This is based on the year built; "No" if prior to 1978) (This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95 — Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.438

Number of tension CPs, N_{FL} = 3

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 8,289 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = - ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = 25.49 ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = 22.91 ksi GS Eq. 2.1.3-2

Note: Outputs are based on noncomposite section properties for a negative moment region

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	2.07
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.37

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-11** Distance from Abut **597.5** ft

Variation Desciption: **Variation 11 - Controlling Fatigue Location**

2.07

Fatigue Life Estimate (GS 2.5) 1.37

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$ - ksi GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$ **1.91** ksi GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	1.91	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	1.92	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	**4.23**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-11** Distance from Abut **597.5** ft

Variation Desciption: **Variation 11 - Controlling Fatigue Location**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ = **3.16** ksi GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Faulted state stress range, Δf =	3.16	ksi	MBE 7.2.2
Faulted state effective stress range, $(\Delta f)_{eff}$ =	3.18	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	6.99	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for faulted state?	**I(a)**	I(a), I(b), II	GS 2.5

Faulted fatigue life? **OK**

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	63.0	Years	GS 2.5.3
Total remaining fatigue life only in **unfaulted** state, Y_u	∞	Years	GS 2.5.3
Total remaining fatigue life only in **faulted** state, Y_f	Infinite	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**Infinite**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	I(a)	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	1.91	ksi	
Controlling stress range in faulted state, Δf_{FS} =	3.16	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	
Total remaining fatigue life, N_f	**Infinite**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-12** Distance from Abut **1201.5** ft

Variation Desciption: **Variation 12 - Controlling Strength Location**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

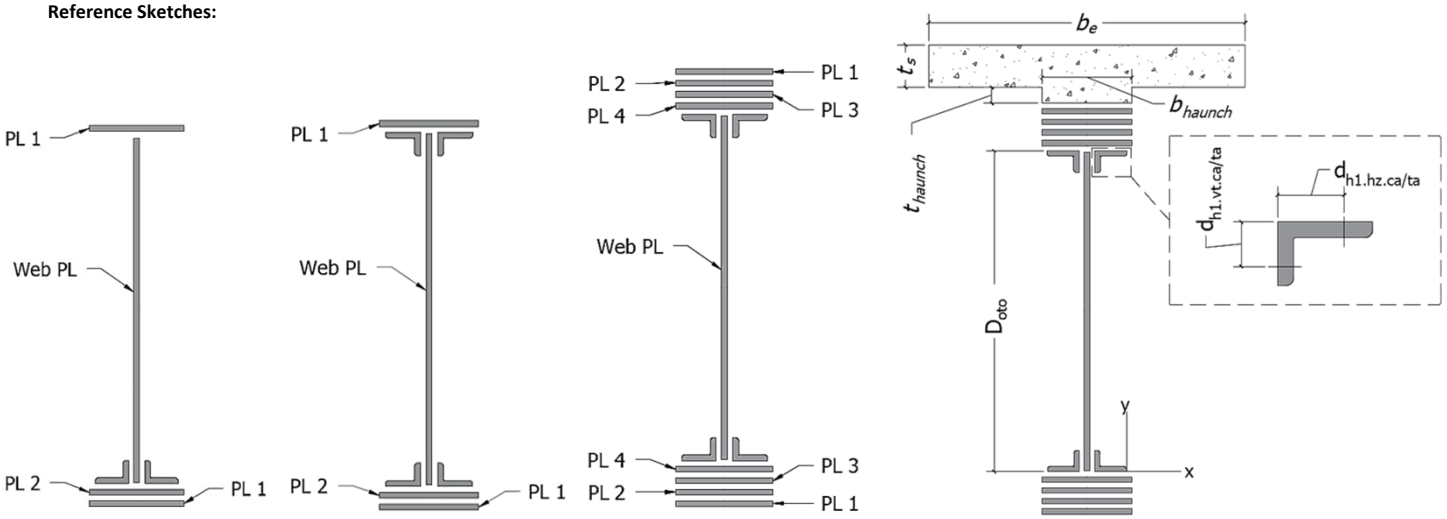
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all provisions of Section 1.5?	**Yes**	Yes

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**Yes**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**Yes**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	**84.8**	in	Haunch Width, b_{haunch}	**59.3**	in
Deck Slab Thickness, t_s	**5.8**	in	Haunch Thickness, t_{haunch}	**3.4**	in
Concrete Modulus of Elasticity, E_c	**3625.5**	ksi	Modular Ratio of the concrete, n	8.0	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **3** (1 to 4)

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**20.000**	**20.000**	**20.000**	0.000	in
$t_{ccp,i}$	**0.5000**	**0.5000**	**0.6875**	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L8X8X7/8**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	13.3	in^2
Thickness of the angle, t_{ca}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ca}	2.31	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.00**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.00**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-12** Distance from Abut **1201.5** ft

Variation Desciption: **Variation 12 - Controlling Strength Location**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No — Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	116.00	in	Flange Angles Out-to-out Depth, D_{oto}	116.50 in
Web Thickness, t_w	0.5000	in		

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} = 3 (1 to 4)

Plate(i):	1	2	3	4	
$b_{tcp,i}$	20.000	20.000	20.000	0.000	in
$t_{tcp,i}$	0.5000	0.5000	0.6875	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L8X8X7/8	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	13.3	in^2
Thickness of the angle, t_{ta}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ta}	2.31	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1 holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.00	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.00 in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00 in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No — Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	558	trucks/day	Current Year, $Y_{current}$	2021	year
$(ADTT_{sl})_0$	558	trucks/day	Span Length, L	155.75	ft
$(ADTT_{sl})_{limit}$	8,840	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
			Is this a transverse member?	No	Y or N

Note: Growth rate is for future growth from today on

Unfactored Moments:

M_{DC1}	4,569	k-ft	M_{DW}	1,063	k-ft	M_{LL+IM}	5,043 k-ft
M_{DC2}	1,265	k-ft				M_{FAT+IM}	615 k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{G,COMP}$	41.5	in	$\bar{y}_{C,G,NC}$ 58.3	in
$c_{G,COMP}$	43.1	in	$c_{G,NC}$ 59.9	in
$A_{G,COMP}$	264.9	in^2	$A_{G,NC}$ 178.7	in^2
$I_{xG,COMP}$	623,033.1	in^4	$I_{xG,NC}$ 467,564.9	in^4
$S_{xG,COMP}$	14,440.2	in^3	$S_{xG,NC}$ 7,800.9	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{N,COMP}$	40.5	in	$\bar{y}_{N,NC}$ 58.3	in
$c_{N,COMP}$	42.2	in	$c_{N,NC}$ 59.9	in
$A_{N,COMP}$	251.0	in^2	$A_{N,NC}$ 164.9	in^2
$I_{xN,COMP}$	573,209.4	in^4	$I_{xN,NC}$ 422,081.6	in^4
$S_{xN,COMP}$	13,576.5	in^3	$S_{xN,NC}$ 7,042.0	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{AFG,COMP}$	43.1	in	$\bar{y}_{AFG,NC}$ 61.8	in
$c_{AFG,COMP}$	44.3	in	$c_{AFG,NC}$ 63.0	in
$A_{AFG,COMP}$	254.9	in^2	$A_{AFG,NC}$ 168.7	in^2
$I_{x,AFG,COMP}$	603,910.4	in^4	$I_{x,AFG,NC}$ 429,826.9	in^4
$S_{x\text{-}AFG,COMP}$	13,623.4	in^3	$S_{x\text{-}AFG,NC}$ 6,825.3	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{AFN,COMP}$	42.1	in	$\bar{y}_{AFN,NC}$ 61.7	in
$c_{AFN,COMP}$	43.3	in	$c_{AFN,NC}$ 62.9	in
$A_{AFN,COMP}$	242.0	in^2	$A_{AFN,NC}$ 155.8	in^2
$I_{x,AFN,COMP}$	556,600.3	in^4	$I_{x,AFN,NC}$ 387,916.8	in^4
$S_{x\text{-}AFN,COMP}$	12,856.7	in^3	$S_{x\text{-}AFN,NC}$ 6,166.3	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-12** Distance from Abut **1201.5** ft

Variation Desciption: **Variation 12 - Controlling Strength Location**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.438

Number of tension CPs, N_{FL} = 3

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 15,603 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = - ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = 30.36 ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = 27.43 ksi GS Eq. 2.1.3-2

Note: Outputs are based on noncomposite section properties for a negative moment region

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	1.74
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.14

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-12** Distance from Abut **1201.5** ft

Variation Desciption: **Variation 12 - Controlling Strength Location**

1.74

Fatigue Life Estimate (GS 2.5) 1.14

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	**1.05**	ksi	GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	1.05	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	1.05	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	**2.32**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-12** Distance from Abut **1201.5** ft

Variation Desciption: **Variation 12 - Controlling Strength Location**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \beta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ = **1.72** ksi GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Faulted state stress range, Δf =	1.72	ksi	MBE 7.2.2
Faulted state effective stress range, $(\Delta f)_{eff}$ =	1.73	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	3.81	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for faulted state?	**I(a)**	I(a), I(b), II	GS 2.5

Faulted fatigue life? **OK**

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	63.0	Years	GS 2.5.3
Total remaining fatigue life only in **unfaulted** state, Y_u	∞	Years	GS 2.5.3
Total remaining fatigue life only in **faulted** state, Y_f	Infinite	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**Infinite**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	I(a)	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	1.05	ksi	
Controlling stress range in faulted state, Δf_{FS} =	1.72	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	
Total remaining fatigue life, N_f	**Infinite**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-12** Distance from Abut **1182.84** ft

Variation Desciption: **Variation 12 - Controlling Fatigue Location**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

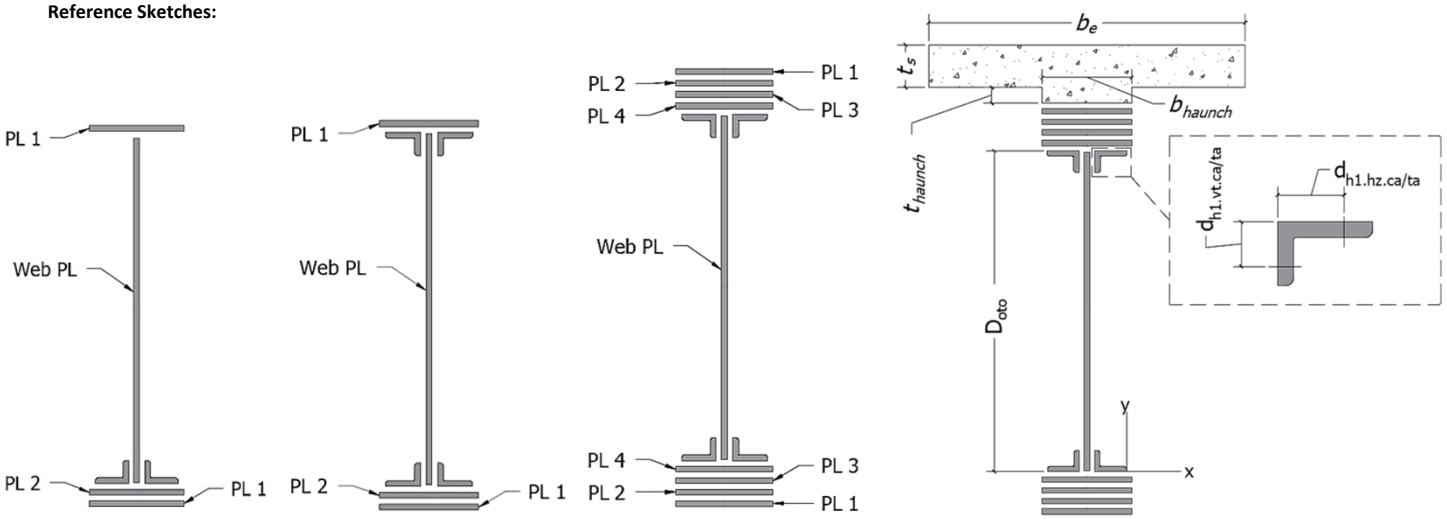
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all provisions of Section 1.5?	**Yes**	Yes

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**Yes**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**Yes**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	**84.8**	in	Haunch Width, b_{haunch}	**59.3**	in
Deck Slab Thickness, t_s	**5.8**	in	Haunch Thickness, t_{haunch}	**3.4**	in
Concrete Modulus of Elasticity, E_c	**3625.5**	ksi	Modular Ratio of the concrete, n	8.0	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **3** (1 to 4)

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**20.000**	**20.000**	**20.000**	0.000	in
$t_{ccp,i}$	**0.5000**	**0.5000**	**0.6875**	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L8X8X7/8**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	13.3	in^2
Thickness of the angle, t_{ca}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ca}	2.31	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.00**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.00**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-12** Distance from Abut **1182.84** ft

Variation Desciption: **Variation 12 - Controlling Fatigue Location**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	76.90	in	Flange Angles Out-to-out Depth, D_{oto}	77.40	in
Web Thickness, t_w	0.5000	in			

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **3** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	20.000	20.000	20.000	0.000	in
$t_{tcp,i}$	0.5000	0.5000	0.6875	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L8X8X7/8	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	13.3	in^2
Thickness of the angle, t_{ta}	0.875	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	79.7	in^4
Outer Horiz. Leg to N.A., y_{ta}	2.31	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1	holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.00	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.00	in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00	in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	558	trucks/day	Current Year, $Y_{current}$	2021	year
$(ADTT_{sl})_0$	558	trucks/day	Span Length, L	155.75	ft
$(ADTT_{sl})_{limit}$	8,840	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
			Is this a transverse member?	No	Y or N

Note: Growth rate is for future growth from today on

Unfactored Moments:

M_{DC1}	1,925	k-ft	M_{DW}	449	k-ft	M_{LL+IM}	2,842	k-ft
M_{DC2}	534	k-ft				M_{FAT+IM}	516	k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{G,COMP}$	27.4	in	$\bar{y}_{C,G,NC}$	38.7	in
$c_{G,COMP}$	29.1	in	$c_{G,NC}$	40.4	in
$A_{G,COMP}$	245.3	in^2	$A_{G,NC}$	159.2	in^2
$I_{xG,COMP}$	253,343.0	in^4	$I_{xG,NC}$	195,282.5	in^4
$S_{xG,COMP}$	8,698.9	in^3	$S_{xG,NC}$	4,835.2	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{N,COMP}$	26.8	in	$\bar{y}_{N,NC}$	38.7	in
$c_{N,COMP}$	28.5	in	$c_{N,NC}$	40.4	in
$A_{N,COMP}$	231.5	in^2	$A_{N,NC}$	145.3	in^2
$I_{xN,COMP}$	231,591.7	in^4	$I_{xN,NC}$	175,501.5	in^4
$S_{xN,COMP}$	8,140.1	in^3	$S_{xN,NC}$	4,345.4	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFG,COMP}$	28.7	in	$\bar{y}_{AFG,NC}$	41.4	in
$c_{AFG,COMP}$	29.9	in	$c_{AFG,NC}$	42.6	in
$A_{AFG,COMP}$	235.3	in^2	$A_{AFG,NC}$	149.2	in^2
$I_{x,AFG,COMP}$	244,651.7	in^4	$I_{x,AFG,NC}$	178,091.9	in^4
$S_{x\text{-}AFG,COMP}$	8,195.9	in^3	$S_{x\text{-}AFG,NC}$	4,182.7	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFN,COMP}$	27.9	in	$\bar{y}_{AFN,NC}$	41.4	in
$c_{AFN,COMP}$	29.1	in	$c_{AFN,NC}$	42.6	in
$A_{AFN,COMP}$	222.4	in^2	$A_{AFN,NC}$	136.3	in^2
$I_{x,AFN,COMP}$	224,069.1	in^4	$I_{x,AFN,NC}$	159,930.4	in^4
$S_{x\text{-}AFN,COMP}$	7,700.0	in^3	$S_{x\text{-}AFN,NC}$	3,758.0	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-12**

Distance from Abut **1182.84** ft

Variation Desciption: **Variation 12 - Controlling Fatigue Location**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-12** Distance from Abut **1182.84** ft

Variation Desciption: **Variation 12 - Controlling Fatigue Location**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.438

Number of tension CPs, N_{FL} = 3

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 7,652 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = - ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = 24.43 ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = 21.95 ksi GS Eq. 2.1.3-2

Note: Outputs are based on noncomposite section properties for a negative moment region

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	2.16
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.43

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-12**

Variation Desciption: **Variation 12 - Controlling Fatigue Location**

Distance from Abut **1182.84** ft

2.16

1.43

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC}$ =	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP}$ =	**1.43**	ksi	GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

R_p =	1.01		MBE 7.2.2.1
Unfaulted state stress range, Δf =	1.43	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff}$ =	1.43	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	**3.16**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-12** Distance from Abut **1182.84** ft

Variation Desciption: **Variation 12 - Controlling Fatigue Location**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ = **2.37** ksi GS Eq. 2.1.3-1

Note: Outputs are based on noncomposite section properties for a negative moment region

Faulted state stress range, Δf =	2.37	ksi	MBE 7.2.2
Faulted state effective stress range, $(\Delta f)_{eff}$ =	2.39	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	5.25	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for faulted state?	**I(a)**	I(a), I(b), II	GS 2.5

Faulted fatigue life? **OK**

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	63.0	Years	GS 2.5.3
Total remaining fatigue life only in **unfaulted** state, Y_u	∞	Years	GS 2.5.3
Total remaining fatigue life only in **faulted** state, Y_f	Infinite	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**Infinite**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	I(a)	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	1.43	ksi	
Controlling stress range in faulted state, Δf_{FS} =	2.37	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	
Total remaining fatigue life, N_f	**Infinite**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Appendix 1G. NSTM/IRM Inspection Plan for Structure 041-26-03917, US 41 Over White River

1. INTRODUCTION

This document was prepared as an appendix to the *Evaluation of the Fracture Critical Status of Structure 041-26-03917 US 41 over White River*, but also serves as a standalone document for the inspection plan for main spans of the aforementioned structure. The bridge consists of two twin superstructures each carried by two riveted built-up steel plate girders. It consists of 16 continuous main spans with no skew on a tangent alignment. It was originally built in 1958 and has had several rehabilitations and repairs completed. A brief description of the bridge attributes can be found in Table 1G.1.

Table 1G.1 Bridge details

Attribute (NBI Code)	Value
Bridge Name	041-26-03917
Structure Number (8)	14560
State Name (1)	18 - Indiana
County Name (3)	051 - Gibson County
Features Intersected (6A)	White River
Facility Carried By Structure (7)	US 41
Location (9)	00.90 N of SR 56
Latitude, (16)	38.491
Longitude, (17)	-87.56406
Year Built (27)	1958
Main Span Material (43A)	4 - Steel Continuous
Main Span Design (43B)	3 - Girder and Floorbeam System
Number of Spans in Main Unit (45)	16
Bridge Posting Code (70)	5 - Equal to or above legal loads

Previous to the internally redundant member (IRM) evaluation, the full length of the main girders was considered a non-redundant steel tension member (NSTM) and thus was subjected to hands-on and arm's length field inspection at a maximum interval not to exceed 2 years.

The bridge has been evaluated using the procedures outlined in the A*ASHTO Guide Specifications for Internal Redundancy of Mechanically-Fastened Built-Up Steel Members* (IRM Guide Specifications) adopted in 2018 (AASHTO, 2018a). The evaluation demonstrated that nearly 94% of the main girders may be reclassified as internally redundant members and receive a Special Inspection frequency of not to exceed 10 years. In the context of the IRM Guide Specifications, a Special Inspection is defined as:

> *In the specific context of these Guide Specifications, a (Special Inspection) is an inspection of sufficient depth to reliably detect severed or fractured components and other conditions deemed important in a member identified as an IRM. To meet the objectives of the Special Inspection for IRMs, it is understood that special access equipment may be required for some bridges, while for others it may be possible to reliably detect broken components from the ground using normal visual inspection techniques.*

It is noted that routine safety inspection intervals are not affected.

The remaining 6% of the main girders did not pass the checks due to lack of cover plates, failing strength checks of fracture on the net section assuming a component failed, or it was determined for simplicity to continue to classify specific areas as NSTMs. This document will adapt the findings of the IRM evaluation to propose a specific inspection plan that will modify the existing inspection plan that was been implemented when the members were classified as NSTMs (formerly FCMs).

It should be mentioned that the girder areas specified in this appendix are for one half (longitudinally) of the symmetrical superstructures. Therefore, the inspection scope and frequencies shall be extrapolated to the other half of the superstructure in addition to both main girders of both twin superstructures (4 total girders).

2. INSPECTION SCOPE AND FREQUENCY

The areas of the main girders that are not reclassified as IRMs should continue to be inspected as NSTMs which includes hands-on and arm's length field inspections every 2 years. The most recent NSTM inspection was conducted in 2021, so the next inspection will be conducted in 2023 and so forth. These NSTM areas are included in Table 1G.2. The remaining areas of the girder may be inspected as IRMs during a Special Inspection (SI) conducted every 10 years from 2021 (last NSTM inspection).

Table 1G.2 Areas to remain with NSTM designation

Span	Location Start (from Support)	Location Stop (from Support)	Referenced Support	Distance Start (from Abutment)	Distance Stop (from Abutment)	Area Length	Notes
	ft	ft		ft	ft	ft	
1	8.75	10.42	Abut. 1	8.75	10.42	1.67	No Cover Plate
1	72.42	79.75	Abut. 1	72.42	79.75	7.33	No Cover Plate
2	28.50	36.25	Pier 1	139.75	147.50	7.75	No Cover Plate
2	117.25	121.67	Pier 1	228.50	232.92	4.42	No Cover Plate
3	33.92	37.25	Pier 2	300.92	304.25	3.33	No Cover Plate
3	122.38	125.05	Pier 2	388.04	390.71	2.67	Pin and Hanger Location
4	18.75	22.25	Pier 3	441.50	445.00	3.50	Strength Check Failure
4	27.67	33.38	Pier 3	450.42	456.13	5.71	Strength Check Failure
4	119.42	121.17	Pier 3	542.17	543.92	1.75	No Cover Plate
5	26.00	31.15	Pier 4	604.50	609.65	5.15	Strength Check Failure
5	124.60	130.00	Pier 4	703.10	708.50	5.40	Strength Check Failure
6	34.67	35.67	Pier 5	768.92	769.92	1.00	No Cover Plate
6	124.60	125.21	Pier 5	858.85	859.46	0.61	Low Fatigue Life
6	125.21	128.75	Pier 5	859.46	863.00	3.54	Strength Check Failure
6	128.75	136.50	Pier 5	863.00	870.75	7.75	Low Fatigue Life
7	32.04	34.71	Pier 6	922.05	924.71	2.67	Pin and Hanger Location
7	120.08	120.50	Pier 6	1010.08	1010.50	0.42	No Cover Plate
8	32.75	38.00	Pier 7	1078.50	1083.75	5.25	No Cover Plate
8	117.00	120.75	Pier 7	1162.75	1166.50	3.75	No Cover Plate

It is noted that specific areas near the pin and hanger locations where no cover plate exists are longer than permitted by the AASHTO IRM Guide Spec. provisions. Specifically, the IRM Guide Specification (AASHTO, 2018a) states that within a distance of 1.5D from the end of the girder, where D is the depth of the web plate, the member need not be evaluated as an IRM since the moment and moment range in the girder is very low at such locations. For these girders, the region within the length of 1.5D includes all the areas without cover plates immediately adjacent to the pin and hangers other than a very short length of less than 12 inches. It is proposed to areas that extend beyond the pin and hangers more than 1.5D distance described in the body of the report are permitted to be re-labeled as IRMs. As stated, this is only about 12 inches of girder.

The purpose of the SI is to identify whether any of the tension components have failed. The IRM Guide Specifications defines the process to have "sufficient depth to reliably detect a severed component and other conditions deemed important in a member deemed as an IRM. To meet the objectives of the Special Inspection for IRMs, it is understood that special access equipment may be required for some bridges, while for others it may be possible to reliably detect broken components from the ground using normal visual inspection techniques". The NSTMs and pin and hangers will continue requiring traditional arms-length inspection. For efficiency, the snooper used for the arm's length inspections could be used to "glide" along the girder and complete the IRM SI during the same visit.

The following figures graphically display the areas to be inspected as NSTMs (blue) and IRMs (green).

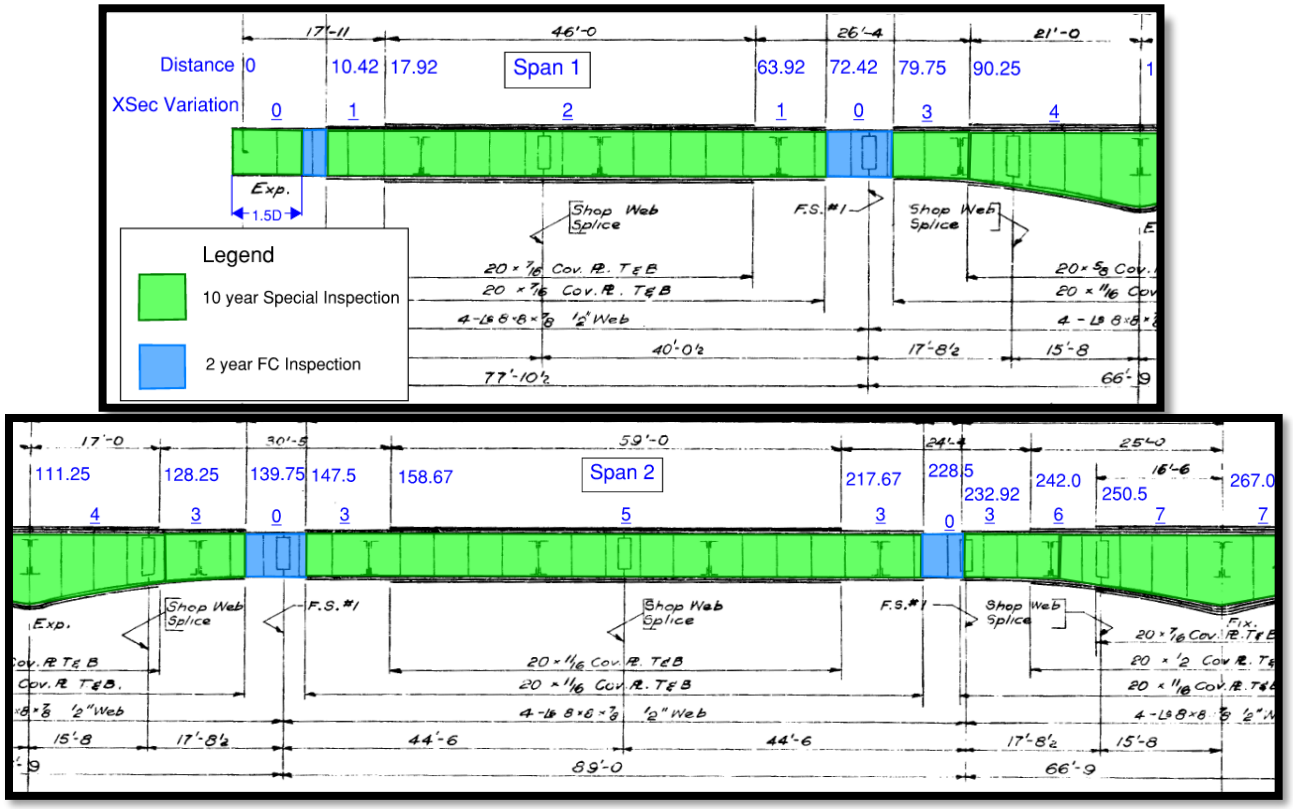


Figure 1G.1 Elevation view of bridge depicting IRM (green) and NSTM (blue) areas, Spans 1-2.

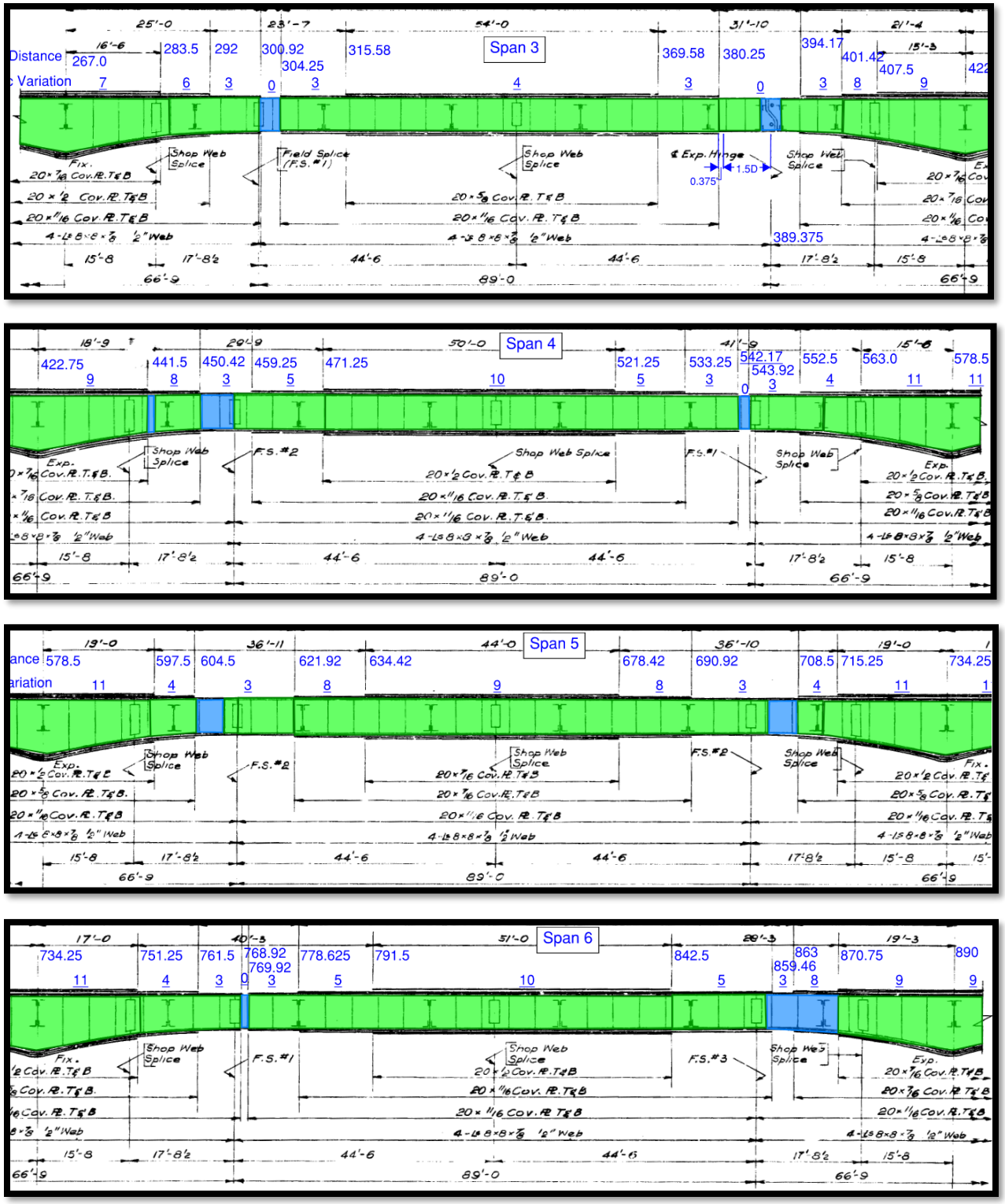


Figure 1G.2 Elevation view of bridge depicting IRM (green) and NSTM (blue) areas, Spans 3-6.

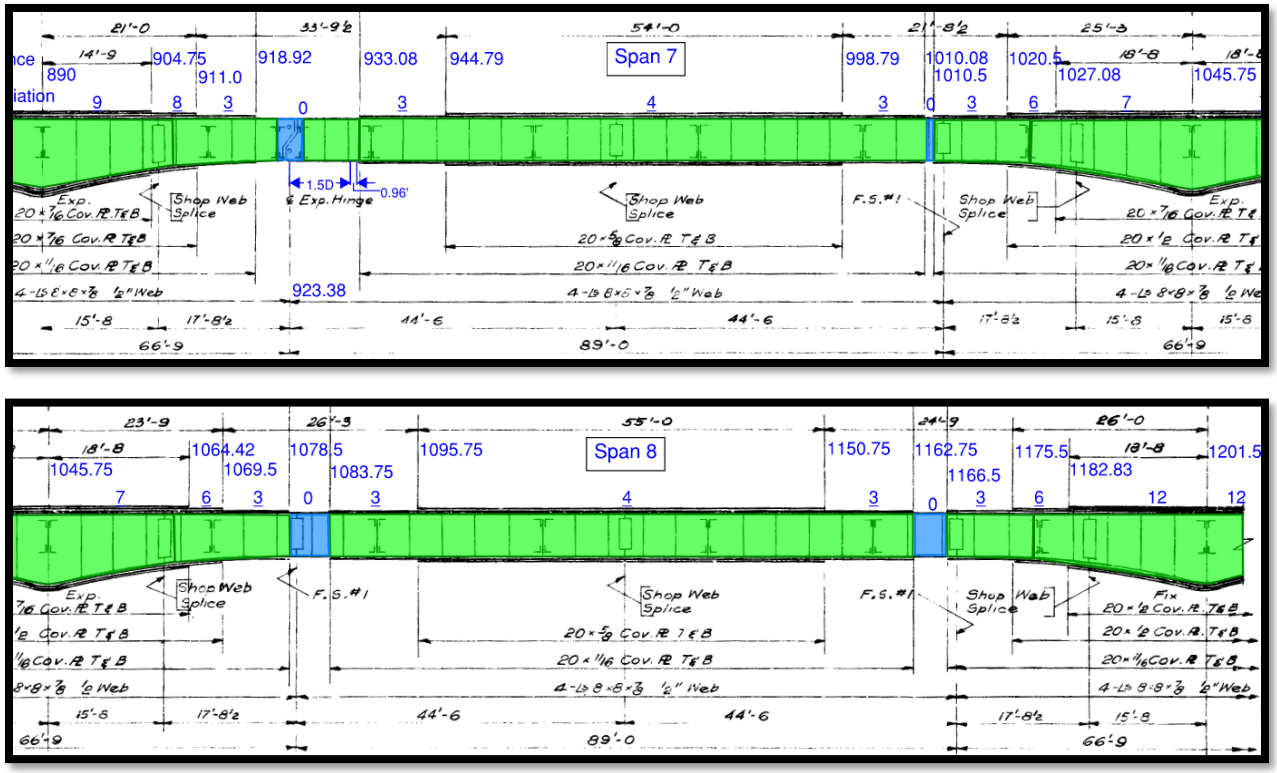


Figure 1G.3 Elevation view of bridge depicting IRM (green) and NSTM (blue) areas, Spans 7-8.

3. FUTURE INSPECTIONS AND EVALUATIONS

The current inspections scheduled for this bridge include a Fracture Critical, Routine, Underwater, and Special Inspection (condition of pin and hangers). Following this evaluation an additional Special Inspection would be added to inspect the IRM members. Additionally, the Fracture Critical inspection would be relabeled as a NSTM inspection and the areas to be inspected would be changed as depicted in Figure 1G.1, Figure 1G.2, and Figure 1G.3. Assuming current bridge conditions remained unchanged, the timeline of these inspections is depicted in the Table 1G.3. Items that could affect the given schedule include but are not limited to change in live loads due to changes in traffic patterns or uses and changes in condition of structure such as corrosion significant to require load posting, cracking, or damage due to vehicle impact in primary members.

Table 1G.3 Inspection schedule

		Frequency	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Inspection Type	Routine	24 months	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
	NSTM	24 months	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
	Special (IRM)	10 years	N/A	N/A	No	No	No	No	No	No	No	No	Yes	No	No	No	No	No
	Underwater	60 months	No	No	Yes	No	No	No	No	Yes	No	No	No	No	Yes	No	No	No
	Special (Pin and Hangers)	60 months	No	No	Yes	No	No	No	No	Yes	No	No	No	No	Yes	No	No	No

		Frequency	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051
Inspection Type	Routine	24 months	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
	NSTM	24 months	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
	Special (IRM)	10 years	No	No	No	No	Yes	No	No	No	No	No	No	No	Yes	No	Yes
	Underwater	60 months	No	Yes	No	No	No	No	Yes	No	No	No	No	Yes	No	No	No
	Special (Pin and Hangers)	60 months	No	Yes	No	No	No	No	Yes	No	No	No	No	Yes	No	No	No

As described previously, the current inspection frequency for the Special (IRM) Inspection is 10 years, however an additional evaluation was completed to determine when that frequency might change. A decreased frequency occurs after the 2041 inspection, in which a small 13-foot area (700.88 feet from the abutment) switches to an 8-year frequency. The Special (IRM) Inspection for this minor area could be conducted during the 2049 NSTM inspection. All other previous IRM areas still remain at a 10-year inspection frequency through 2051. As the bridge conditions might change, warranting additional evaluations and inspections, projecting further inspection intervals was not conducted.

VOLUME II: Evaluation of the Redundancy Status of Structures I-74-06-04417 FEBL and GWBL Over the Wabash River

EXECUTIVE SUMMARY

Introduction

In this report, the I-74-06-04417 GWBL and FEBL Bridges over the Wabash River were evaluated to determine if the primary members satisfy the internal redundancy provisions of the *AASHTO Guide Specifications for Internal Redundancy of Mechanically-Fastened Built-Up Steel Members* adopted in 2018 (AASHTO, 2018/2022b) (IRM Guide Specification). Both westbound (GWBL) and eastbound (FEBL) bridges consist of separated superstructures carried by two riveted built-up steel plate girders. Each consists of five continuous spans with no skew on a tangent alignment. They were originally built in 1958 and has had various rehabilitations and repairs completed over its lifetime.

Findings

The IRM Guide Specification provides a methodology for determining if a member that is currently labeled as a non-redundant steel tension member. NSTM (formerly referred to as Fracture Critical Members (FCMs)), contains adequate internal redundancy to be relabeled as an Internally Redundant Member (IRM). The manual also provides strategy requirements for inspection scope and frequency of IRMs. The evaluation was a multi-step process in which the members were subjected to a series of checks. The first step consisted of screening general requirements to determine if the member was eligible for IRM evaluation. The preliminary screening criteria were validated using the bridge from the original plans, current load rating, and inspection reports. The subsequent phases of the evaluation determined the strength and fatigue adequacy of the member. The strength capacity checks examined the yield on the gross section and the fracture of net section of the member in a faulted state. The fatigue checks evaluated the fatigue life of the member in both the unfaulted and faulted state. Using this data, the maximum interval for special inspections was determined.

A spreadsheet developed by the National Steel Bridge Alliance and Purdue University was used for evaluating the internal redundancy at specific points along the main riveted girders throughout the bridge (NSBA, 2020). The spreadsheet was primarily used as-is; however, slight modifications were required to incorporate the effective stresses collected from the long-term monitoring. It also calculated the maximum interval for special inspections, as defined in the IRM Guide Specification. Maximum moments due to dead, live and fatigue loads were obtained using an AASHTOWare BrR model. The fatigue loads were scaled using in-situ stress ranges collected during Purdue University's long-term monitoring of the bridge. To provide consistency and efficiency, an Excel Macro was developed in combination with the NSBA spreadsheet to evaluate selected locations along the bridge (NSBA, 2020). These locations corresponded to the changes in cross-section as well as changing moment demand (i.e., DL, LL, and fatigue). The full IRM evaluation was completed for 112 points along half of the entire length of the bridge. The bridge was symmetric about the midspan of span J; thus the 112 points can be extrapolated to the remaining girder lengths.

Implementation

The evaluation demonstrated that 79% of the main girders of the I-74 Bridge over the Wabash River were eligible to be reclassified as internally redundant members and were eligible to receive a special inspection at a 10-year frequency. The remaining 21% of the main girder did not pass the initial screening criteria primarily due to a lack of cover plates.

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1. BACKGROUND

The Fracture Critical Member (FCM) label has been used on bridge members that have "a steel primary member or portion thereof subject to tension whose failure would probably cause a portion of or the entire bridge to collapse" (Lloyd, 2020). Once a bridge has been classified as having FCMs, the structure had been required to have an in-depth arm's length inspection completed at regular intervals not to exceed 24 months throughout its service life. Today, these members are referred to as Nonredundant Steel Tension Members (NSTMs).

Recent research in how redundancy of steel members is viewed provides updated guidance as to when a member should be classified as an NSTM. One form of redundancy that may now be explicitly considered is "internal member redundancy" and is applicable to members comprised of multiple individual components joined using mechanical fasteners. The research focused on mechanically fastened built-up members and culminated in the *AASHTO Guide Specifications for Internal Redundancy of Mechanically-Fastened Built-Up Steel Members* adopted in 2018 (AASHTO, 2018/2022b). (Please note that throughout this report, this guide specification will be referred to as the IRM Guide Specification (AASHTO, 2018/2022b)). The intent of the IRM Guide Specification (AASHTO, 2018/2022b) is to provide a codified methodology "on how to establish whether adequate internal redundancy exists in a mechanically-fastened built-up steel member." Included in the IRM Guide Specification (AASHTO, 2018/2022b) is a methodology for determining the maximum frequency between special inspections. In the context of the IRM Guide Specifications, a special inspection is defined as:

> *In the specific context of these Guide Specifications, a (Special Inspection) is an inspection of sufficient depth to reliably detect severed or fractured components and other conditions deemed important in a member identified as an IRM. To meet the objectives of the Special Inspection for IRMs, it is understood that special access equipment may be required for some bridges, while for others it may be possible to reliably detect broken components from the ground using normal visual inspection techniques.*

It is noted that intervals for routine safety inspection (e.g., general deck condition, etc.) are not affected. It is only the NSTM (formerly FCM) hands-on inspection scope and interval that are altered.

The analysis described in this report uses the IRM Guide Specifications (AASHTO, 2018/2022b) in conjunction with the *AASHTO Manual for Bridge Evaluation, 3rd Edition* (AASHTO, 2018/2022c) and the *AASHTO LRFD Bridge Design Specifications, 9th Edition* (AASHTO, 2020) to evaluate if members of the I-74 Bridge over the Wabash River currently classified as NSTMs may be *reclassified* as IRMs. With the adoption of the new National Bridge Inspection Standards found in 23 CFR Part 650 that became law on June 6 of 2022 (DOT FHWA, 2022), once a member, or portion thereof, has been determined to be an Internally Redundant Member (IRM), the NSTM label can be removed and replaced with the IRM designation. Those members shall then be inspected using the method provided in the IRM Guide Specifications (AASHTO, 2018/2022b). Additionally, the FC designation was replaced by the term Non-Redundant Steel Tension Member (NSTM), so this report will use the NSTM designation for clarity.

2. BRIDGE DETAILS

The bridges discussed in this report are I-74-06-04417 GWBL and FEBL and are owned and maintained by Indiana Department of Transportation (INDOT). They were originally built in 1958 but have an extensive rehabilitation history since their original construction. The work performed on the bridges include the following.

- 1958: Year of Original Construction
- 1969: Aluminum Rail Reconstruction
- 1972: Bridge Deck Overlay
- 1985: Expansion Joint Replacement/Repair
- 1994: Bridge Deck Replacement and Widening
- 2019: Bridge Thin Deck Overlay

The bridges are located along the Vermillion and Fountain County line. The GWBL bridge is the westbound structure while the FEBL is the eastbound structure. The average daily traffic (ADT) counts of GWBL and FEBL are 10,510 and 10,820, respectively, based on the 2022 inspection report. The structure consists of two side-by-side twin bridges with five main span units that are individually carried by two riveted built-up steel plate girders and twelve approach spans. The primary girders of the main spans are currently labeled as NSTMs and are on a 24-month NSTM inspection frequency. Because these two bridges are identical twin structures, the results will be presented as a singular structure. The results should be extrapolated to both bridges, unless otherwise noted. A general photograph of the south elevation taken during the bridge instrumentation in 2023 can be found in Figure 2.1.

The most recent fracture critical and routine inspection was performed in 2022. The GWBL superstructure was found to be in satisfactory condition, while the FEBL superstructure was labeled as in poor condition. The poor condition rating was primarily affected by issues found in the stringers and floor beams and not by the condition of the primary girders. The inspection report describes typical widespread pitting along the bottom flange and minor to moderate pack rust at splice plates along the bottom flange for the primary girders. These minor issues had no effect on the load rating of the structure and therefore did not disqualify the member from being evaluated using the IRM Guide Specification (AASHTO, 2018/2022b). There is one specific area of unmitigated damage on the primary girder described in the inspection report that disqualifies



Figure 2.1 General south elevation view (looking north).

that area from being evaluated as an IRM. The area of concern is discussed in more detail in Section 5 of this report. Because the most recent fracture critical inspection was performed in 2022, the evaluation performed shall use 2022 as the "current year" for consumed and remaining fatigue life calculations.

The load rating of this structure was performed by Jennifer L. Hart (RQAW Corp.) in 2006 and then performed in AASHTOWare BrR 6.8.1 in 2018 by Michael Baker. During the 2018 rating, no QA of the 2006 rating file was performed. The model utilized the LFR rating method with HS20-44 design load. All ratings were greater than 1.0, thus no posting is required on the structure. Construction plans for the main girder from the original 1958 construction and 1994 rehabilitation can be found in Appendix H. All remaining bridge related documents, including original bridge plans, rehabilitation plans, inspection reports and load ratings, can be found in the INDOT BIAS/ERMS database.

2.1 Geometric Information

The bridge consists of seventeen spans, which includes twelve approach spans (spans A through F and spans M through R) and five main spans (spans G through L). Spans G and L have a length of 95′-7″, while the remaining main spans have a length of 125′-0″. The bridge is symmetric about the midspan of span J. The primary girders are spaced at 26′-0″ center to center. In 1994, the bridge was widened, and a third girder was added 8′-2″ center-to-center from exterior girder. The deck has a clear roadway width of 39′-4″ and out-to-out coping of 42′-4″ with a left overhang of 5′-2″ and a right overhang of 3′-0″. The bridge has no skew and is on a tangent alignment. Each superstructure carries two 12′ lanes with 4′-8″ and 10′-8″ shoulders. The twin bridges are identical and symmetric about the median centerline; thus, the findings of this evaluation apply to both structures. Typical half sections of the superstructure and deck are displayed in Figure 2.2.

The main girders are the only NSTMs within the bridge and thus were the only members evaluated for internal redundancy. The built-up girders consist of seven different primary cross-sectional variations based on the number of cover plates, cover plate thicknesses and flange angle sizes. A summary of the girder variation can be found in Figure 2.3.

2.2 Long Term Monitoring of Bridge

After an initial evaluation of the bridge, it was found that the stresses generated from the AASHTO fatigue truck using a AASHTOWare BrR model prevented a majority of the bridge from having sufficient remaining fatigue life and thus were ineligible to be relabeled as IRMs. This is not surprising as the simplified analysis approach in AASHTOWare BrR generally overpredicts live load stress ranges and hence, results in low remaining fatigue life. However, it has been consistently shown that a more accurate estimate of remaining fatigue life can be obtained using field instrumentation. Therefore, to obtain in-service stress range measurements, the bridge was instrumented with strain gages to collect data at selected locations on the primary members. Specifically, the girders on the east bound bridge were instrumented in spans G and H. To collect data from the bridge, thirteen 350-ohm weldable gages were installed at various locations on the primary members. These locations included near the inflection area, maximum positive moment, maximum negative moment, and specific locations to better understand the behavior at specific cross section variation locations. Gages were installed on both the left (G3) and right (G4) girders of the FEBL bridge. The data acquisition system used for the collection was a Campbell Scientific Granite 9 datalogger, as shown in Figure 2.4.

For specific locations of all the strain gages see Appendix E. Data were collected between the end of December of 2022 and the end of January 2023, for approximately 30 days. Using the *RainFlow* cycle counting method, stress-range histograms were developed. As discussed and prescribed in the *Manual for*

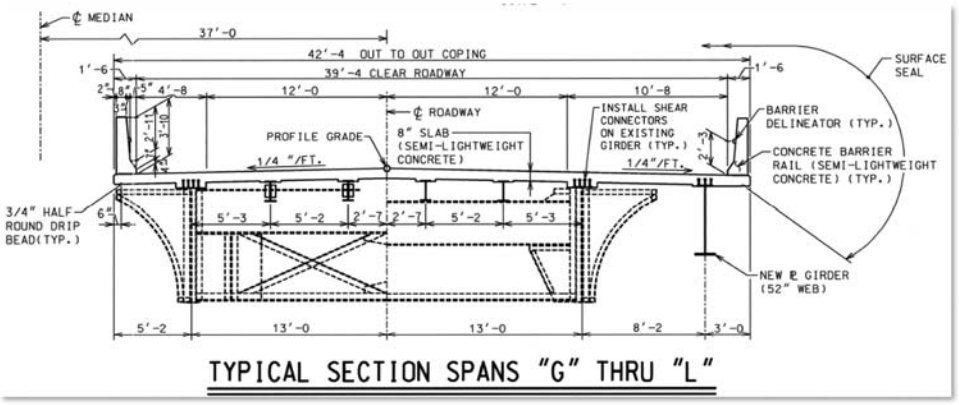


Figure 2.2 Typical half section.

XSec Variation	# Cover Plates	Flange Angle	Web Plate	Cover Plate Top and Bottom (1)	Cover Plate Top and Bottom (2)	Cover Plate Top and Bottom (3)
			in	in	in	in
XSec-0	0	L6X6X1/2	83.5 x 1/2	-	-	-
XSec-00	0	L6X6X1	83.5 x 1/2	-	-	-
XSec-1	1	L6X6X1/2	83.5 x 1/2	16x1/2	-	-
XSec-2	2	L6X6X1/2	83.5 x 1/2	16x1/2	16x1/2	-
XSec-3	1	L6X6X1	83.5 x 1/2	16x7/8	-	-
XSec-4	2	L6X6X1	83.5 x 1/2	16x7/8	16x7/8	-
XSec-5	3	L6X6X1	83.5 x 1/2	16x7/8	16x7/8	16x3/4

Figure 2.3 Girder cross-sectional variations.



Figure 2.4 Data acquisition system inside of job box located on site.

Bridge Evaluation (MBE) (AASHTO, 2018/2022c) as well as other documents, the lower portion of the field measured stress range histogram was truncated to avoid underestimating the effective stress range. This truncation value can vary but is typically calculated as a quarter to a third of the constant amplitude fatigue threshold of a detail D category (7 ksi). In this case, it was determined to use a truncation value of 2 ksi, thus eliminating any stress ranges under 2 ksi. The maximum stress range that was recorded during the data collection period was captured in the 5.5 ksi to 6 ksi bin, thus 6 ksi was used as the maximum stress range used to determine infinite or finite life. From the truncated histogram data, an effective stress could be computed for each strain gage. It should also be noted that the average stress ranges of individual stress range bins were used to calculate the effective stress range.

The data collected showed that the in-situ stress ranges were generally much less than calculated by AASHTOWare BrR using the AASHTO fatigue truck. As stated, this observation is typical in many documented field studies where live load stresses on in-service bridges are measured. The measured stress-range histograms were used to calculate the remaining fatigue life at locations where strain gages were not installed by scaling the calculated moment ranges obtained from AASHTOWare BrR model. This approach is commonly used to provide a more accurate fatigue life estimate and is permitted in the IRM Guide Specifications (AASHTO, 2018/2022b).

The advantage of scaling the calculated values allows stress ranges to be estimated at all locations on the bridge, including those where strain measurements were not made directly. A comparison of the in-service effective stress ranges and those obtained from AASHTOWare BrR is shown in Figure 2.5. Not all effective stress ranges were presented due to the lack of valuable data above the truncation value of 2 ksi. See Appendix F for the raw histogram data collected, effective stress ranges, collection period and cycles per day calculations for each strain gage.

As shown, the effective stress ranges measured during the long-term monitoring were consistently lower than calculated assuming the AASHTO fatigue truck using the Fatigue II load factor by a ratio ranging from 0.424 to 0.604. In fact, the highest effective stress ratio was only 0.604 at the location of the maximum positive moment in span H. However, it is possible that there may be locations where higher ratios exist, but measurements were not taken. To be conservative, the authors increased the maximum ratio of 0.604 by 10% to be conservative. This increase of 10% is intended to account for the variability of application of loads, variation in load distribution, etc., that may be occurring in areas where instrumentation was not installed. (*Note that a higher, lower, or even no factor could have been selected; however, 10% is believed to be reasonably conservative.*) This resulted in a scale factor of 0.664. As previously stated, this factor was then applied to the moment ranges generated by the fatigue truck using the AASHTOWare BrR model. The scaled moments from the fatigue load were then used to complete the fatigue evaluation of the NSTMs.

In addition to the measured stress ranges along the length of the girder, the long-term monitoring also provided accurate assessment of the cycles experienced by the girder. As expected, the cycles per day varied along the length of the member. As shown in Figure 2.5, the controlling cycles per day occurred at SG2 (1,129 cycles/day). To be conservative, a value of 1,129 cycles per day was used along the entire length of the girder. Without measured historic traffic cycle data beginning at the construction of the bridge in 1958, it was deemed acceptable and conservative to use the same cycles found in the long-term monitoring for the estimation of initial traffic on the bridge.

2.3 Loads

A standard line girder analysis using the AASHTOWare BrR model was used to determine the moments developed due to dead and live loads. The dead loads applied on the girder consisted of the DC1, DC2, and DW loads. The following lists describes these loads.

- DC1 (placed prior to deck hardening and acting on the noncomposite section)
  - Self-load of girder including a percentage of additional self-load due to additional secondary items
  - Floor beam and stringer reactions
  - Deck and haunch loads

XSec	Strain Gauge	Distance from Pier 7 (ft)	Eff Stress Fatigue Truck (ksi)*	Eff Stress Field Test (ksi)	Eff Stress Ratio	Cycles/day	Location Description
XSec-1	SG1	56.95	4.92	2.75	0.559	182.8	Specific Cross Section Check
XSec-1	SG2	56.95	4.92	2.33	0.474	1128.9	Specific Cross Section Check
Xsec-2	SG6	163.67	4.23	2.56	0.604	161.6	Near Max Positive Moment Region
Xsec-2	SG7	163.67	4.23	2.34	0.553	58.7	Near Max Positive Moment Region
XSec-00	SG8	194.92	5.43	2.63	0.484	162.8	Near Inflection Area
XSec-00	SG10	194.92	5.43	2.30	0.424	940.0	Near Inflection Area

*Effective stresses calculated using AASHTO fatigue truck using AASHTOWare BrR and Fatigue II load factor

Figure 2.5 Effective stress ranges of girders.

	Detail/Parameter	Value	Unit	Source/Reference
Material Properties	Concrete Compressive Strength, f'_c	4	ksi	Semi-Lightweight Concrete (1994 Recon Plans)
	Weight of Concrete (without reinforcing), w_c	0.12	kcf	Semi-Lightweight Concrete (1994 Recon Plans)
	Weight of Concrete (with reinforcing), w_{c_reinf}	0.125	kcf	Semi-Lightweight Concrete (1994 Recon Plans)
	Concrete Modulus of Elasticity, E_c	2731	ksi	AASHTO LRFD BDS Eq 5.4.2.4-1
	Steel Minimum Yield Strength, F_y	33	ksi	AASHTO MBE Table 6A.6.2.1-1
	Steel Minimum Tensile Strength, F_u	66	ksi	AASHTO MBE Table 6A.6.2.1-1
Traffic - For Information Only	Original ADT	2778	veh/day	Original 1958 Plans
	Original truck percentage	10	%	Original 1958 Plans
	Biodirectional factor	55	%	AASHTO LRFD BDS C3.6.1.4.2
	Fraction of Truck Traffic in a Single Lane, p	0.85		AASHTO LRFD BDS Table 3.6.1.4.2-1
	Original average daily truck traffic in a single lane	130	veh/day	AASHTO LRFD BDS Eq 3.6.1.4.2-1
	Present ADT	17310	veh/day	INDOT's online database for vehicle counts (2021)
	Present Truck Percentage	59	%	INDOT's online database for vehicle counts (2021)
	Current average daily truck traffic in a single lane	4774.5	veh/day	AASHTO LRFD BDS Eq 3.6.1.4.2-1
Additional Traffic Data	Maximum ADT	20000	veh/day	AAHSTO LRFD BDS C3.6.1.4.2
	Expected Growth Rate	1.0	%	INDOT 2020 Growth Rate data
	Max limit for ADTT in a single lane	20060	veh/day	AAHSTO LRFD BDS C3.6.1.4.2
	Number of Striped Lanes, n_L	2	lanes	2022 Inspection Report
	Stress-Range Estimate Partial Load Factor, R_s	1.0		MBE Table 7.2.2.1-1
	Number of Stress-Range Cycles per Truck, n	1.0		AAHSTO LRFD BDS Table 6.6.1.2.5-2
	Resistance Factor for Evaluation - Minimum Life, R_R	1.0		MBE Table 7.2.5.1-1

Figure 2.6 Additional details/parameters.

- DC2 (placed after deck hardening and acting on the long-term composite section)
  - Loads due to concrete barrier and median
- DW (wearing surfaces and utilities acting on the long-term composite section)
  - Overlay load

The live load distribution factor calculations, material properties and specific geometric details for the dead loads can be found in Appendix D. As per the IRM Guide Specifications (AASHTO, 2018/2022b), the HL-93 design vehicular live load specified in *AASHTO LRFD Bridge Design Specifications* Article 3.6.1.2.1 (AASHTO, 2020) was applied to the girder using Redundancy II load factors as per Table 1.7.1-1 of the IRM Guide Specifications (AASHTO, 2018/2022b). The total factored bending moment due to fatigue was analyzed using the passage of the fatigue truck as specified in the LRFD Design Article 3.6.1.4 for the Fatigue II load combination. A cover plate adjustment factor of 1.0 was applied to the strength checks while Equation 2.1.2-3 from the IRM Guide Specifications (AASHTO, 2018/2022b) was used for the fatigue life checks.

2.4 Additional Details

Figure 2.6 lists additional details and parameters needed to complete the IRM evaluation of the bridge NSTMs. This information can also be found in Appendix D with detailed calculations and loading information used for the IRM evaluation. As noted in Section 4.2 of the report, the true cycles found during the long-term instrumentation of the bridge were used to complete the IRM evaluation, thus some of the additional traffic parameters in Figure 2.6 are for information only and were not used for the calculations of the IRM evaluation.

3. IRM ANALYSIS/EVALUATION

The IRM evaluation consists of sequential checks required to determine if the member satisfies the requirements of internally redundant members as specified in the IRM Guide Specifications (AASHTO, 2018/2022b). If a specific location along the length of the girder did not pass all the checks, then that location cannot be defined as an IRM and must remain an NSTM.

3.1 Evaluation Requirements

The requirements found in Sections 1.4 and 1.5 of the IRM Guide Specifications (AASHTO, 2018/2022b) were used as the first step of determining the internal redundancy of the flexural members. These conditions were split into three categories: screening criteria, strength capacity check and fatigue life checks. The screening criteria included checks that could be verified with basic knowledge of the bridge found in inspection reports and bridge plans. Once the initial screening criteria were evaluated and verified, the NSTMs were evaluated using the strength capacity check and fatigue life checks.

3.2 Strength Capacity Check

After the screening criteria requirements were found to be met, the strength capacity of the flexural member in the faulted state was checked. The IRM Guide Specification (AASHTO, 2018/2022b) defines a "faulted state" as "the condition during which an individual component of the built-up member was assumed to have severed." The stress in the faulted state was calculated by dividing the maximum moments (with the Redundancy II load factors applied) by the section properties of the faulted member at each cross section. The factored resistance was calculated using the

material properties and the resistance factors specified in *AASHTO LRFD Bridge Design Specifications* Section 6.5.4.2 (AASHTO, 2020). Both yield on gross section and fracture of net section were checked to validate the strength adequacy of the member.

3.3 Fatigue Life in Unfaulted and Faulted State

The fatigue life in the unfaulted state was the next step in the evaluation. Typically, the maximum fatigue stress range at each cross section was calculated using the moment range produced by the LRFD fatigue truck using the Fatigue II load factor. A dynamic load allowance (impact factor) of 15% was used as prescribed in Table 3.6.2.1-1 of the *AASHTO LRFD Bridge Design Specifications* (AASHTO, 2020). True stress ranges were found using field-measured strains from long term monitoring, thus the moments calculated using the LRFD fatigue truck were multiplied by an amplified scale factor, as specified in Section 3.2 of this report. The constant amplitude fatigue limit, correlated with the respective fatigue category (i.e., Category D for this case), was then compared to the maximum calculated fatigue stress range. If the constant amplitude fatigue limit was greater than the calculated maximum fatigue stress range, then that section of the girder had infinite life in the unfaulted state. If the member did not have infinite life, additional calculations using the original, current, and predicted ADT data were completed to determine if and how much total unfaulted remaining fatigue life existed. For this case, the exact cycles that affect the fatigue life found from the long-term bridge monitoring were used to calculate the total remaining unfaulted fatigue life.

The next step of the evaluation was to calculate the fatigue life in the faulted state. This process was similar to the calculations performed for the fatigue life estimates in the unfaulted state. For the faulted state, a component was assumed to have severed, and the area was subtracted from the cross section of the member. Additionally, the fatigue category based on Table 2.5-1 of the IRM Guide Specification (AASHTO, 2018/2022b) and a calculated cover-plate adjustment factor, β_{AF} was used for the evaluation. The total remaining fatigue life was calculated using the calculated total remaining unfaulted and faulted state fatigue lives in correlation with the number of accumulated years in the unfaulted state as seen in Equation 2.5.3-1 of the IRM Guide Specification (AASHTO, 2018/2022b).

3.4 Maximum Interval for Special Inspections

Section 3 of the IRM Guide Specifications (AASHTO, 2018/2022b) provides guidance on determining the maximum interval for special inspections for identifying individual severed components in IRMs. This method uses the total remaining fatigue life and the case for the faulted state to estimate the maximum interval for special inspections. These inspections are intended to identify whether any of the tension components have failed. The depth and equipment used for these inspections should be based off the ability to reliably detect severed component and other conditions deemed important in a member identified as an IRM (AASHTO, 2018/2022b).

4. DISCUSSION OF RESULTS AND IMPLEMENTATION

4.1 Methodology

The I-74 Bridge over the Wabash River was evaluated using the steps described above as specified in the IRM Guide Specifications (AASHTO, 2018/2022b). A spreadsheet, *IRM Evaluator* (NSBA, 2020), created by the National Steel Bridge Alliance (NSBA), with the help of S-BRITE Center at Purdue University, was used as a tool to evaluate the specific points along the NSTMs. This spreadsheet was tested and checked by S-BRITE staff to assure accuracy of the tool. Some minor adjustments of the spreadsheet were needed to incorporate the long-term field monitoring of the bridge. An Excel Macro was developed by the research team to calculate each point along the bridge using the *IRM Evaluator* (NSBA, 2020) as a function. This process minimized the risk of human error, increased efficiency, and allowed for many points to be evaluated in a short period of time. The evaluation was completed at 112 points along half the entire length of the bridge at 1/10th points, support locations, and section changes. The bridge contains side-by-side twin superstructures that are symmetric about the midspan of span J. Thus, the evaluation results can be extrapolated for the entire length of the twin superstructures. Images taken during the 2022 inspection showing the superstructures can be found in Figure 4.1 and Figure 4.2.

4.2 Screening Criteria

The screening criteria included in Article 1.5 of the IRM Guide Specification were checked and verified to obtain the following results.

- A traditional fracture-critical member inspection was conducted within the past 24 months and identified the following.
  - GWBL North Girder: “minor deformation (“a wave”) in the lower flange between floor beams 7 and 8”—this defect disqualifies this area from being relabeled as an IRM.
  - GWBL and FEBL, North and South Girder: “widespread pitting along the bottom flange, minor to moderate pack rust at splice plates along the bottom flange”—did not affect the load posting thus does not disqualify from the IRM evaluation.
  - GWBL and FEBL, North and South Girder: “old tack welds left from construction of bridge”—do not disqualify the member from the IRM evaluation.
  - The remaining main member areas subjected to tension did not exhibit any cracks, significant corrosion, or impact damage.



Figure 4.1 GWBL superstructure view.



Figure 4.2 FEBL superstructure view.

- The web plates were mechanically fastened to the tension flange cover plates with angles and rivets.
- Mechanically fastened splices connect continuous girder members however need not be evaluated for internal redundancy.
- Welds were not used to attach the web to the tension flange angles or to attach cover plate.
- All components comprising the portion of the tension flange are adequately fastened with rivets and are assumed to satisfy all strength, stitch and sealing requirements in effect at the time of design.
- All individual tension flange components, including the flange angle and cover plate, did not exceed 60% of the total flange gross area.

Some areas of the member did not include at least one cover plate as outlined in the first requirement of Section 1.5 of the IRM Guide Specification (AASHTO, 2018/2022b). These areas were disqualified from the IRM evaluation and will continue requiring a traditional arms-length inspection. The remaining areas passed the requirement of having at least one cover

plate present along the entire length of the tension flange or within 1.5 times the web depth from the end of the member at abutments, or at pin-and-hanger details. Thus, the evaluation was conducted for these locations.

4.3 Results Summary

Using the above prescribed methods, *about 21% of the total length of the main girders did not pass every aspect of the evaluation and were not eligible to be reclassified as IRMs.* The specific cross sections and locations failing the screening or strength criteria are summarized in Figure 4.3.

All but one of the sections of the girder that did not meet the IRM requirements were due to the lack of cover plates (a requirement of Section 1.5 of IRM Guide Specification (AASHTO, 2018/2022b)) and are defined as XSec-0 and XSec-00. Additionally, there is one specific area that did not pass the requirements of Section 1.4 of the IRM Guide Specifications (AASHTO, 2018/2022b), due to unmitigated damage labeled as "a wave" in the 2022 NSTM inspection report (see Figure 4.4). Left unmitigated, this area should remain as a NSTM and should continue to be inspected as such.

The IRM Guide Specification (AASHTO, 2018/2022b) states that within a distance of 1.5D from the end of the girder, where D is the depth of the web plate, the member need not be evaluated as an IRM since the moment and moment range in the girder is very low at such locations. For these girders, the region within the length of 1.5D includes all the areas without cover plates immediately adjacent to Piers 7 and 12.

The remaining regions of the girders, 79% of the total length, satisfy the IRM Guide Specifications and may be reclassified as IRMs. The maximum inspection interval for these IRMs was calculated to be 10 years. The detailed results of the evaluation can be found in tabulated form in Appendix A as well as graphical form in Appendix B. The maximum moments and variable parameters needed for the evaluation of the girder at points of interest can be found in Appendix C. A specific breakdown of the of the inspection frequency and descriptions can be found in Appendix G, which contains the proposed inspection plan for the bridge. There was a controlling location for each cross-section type for both the strength capacity check in the faulted state and the fatigue checks. This was because the maximum moment for strength was not necessarily the exact same location in the section as the maximum fatigue moment range, which is not uncommon. Both controlling states for each cross-sectional variation can be found in Appendix I.

Span	Section	Location Start (from Support)	Location Stop (from Support)	Distance Start (from Pier 7)	Distance Stop (from Pier 7)	Length	Screening Criteria Met	Notes
		ft	ft	ft	ft	ft		
G	XSec-0/Xsec-00	63.00	76.92	63	76.92	13.92	NG	No Cover Plate*
H	XSec-00/Xsec-0	17.00	33.00	111.92	127.92	16.00	NG	No Cover Plate*
H	XSec-0/Xsec-00	91.00	106.00	185.92	200.92	15.00	NG	No Cover Plate*
J	XSec-00/Xsec-0	19.00	33.00	238.92	252.92	14.00	NG	No Cover Plate*
J	XSec-2	79.50	81.50	299.42	301.42	2.00	NG	Unmitigaged damage**

*Bridge is symmetric about midspan of Span J, thus all points can be correlated accordingly

**North girder on bridge GWBL at span J between FB 7-8 exhibits unmitigated damage due (see "wave" in inspection report)

Figure 4.3 Areas not passing IRM checks.



Figure 4.4 Unmitigated damage ("wave") taken during inspection.

5. CONCLUSION

Presently, the I-74 Bridge over the Wabash River is classified as having NSTMs; hence it is subjected to hands-on and arms-length field inspections every 2 years. During this evaluation process it was determined that the majority of the NSTMs possess internal redundancy and should be reclassified as IRMs.

The bridge was evaluated using the procedures outlined in the IRM Guide Specification that was adopted in 2018 (AASHTO, 2018/2022b). The loads applied on the bridge for the evaluation included the dead load and HL-93 and fatigue truck live loads factored using the Redundancy II load factors, as specified in Table 1.7.1-1 of the IRM Guide Specification (AASHTO, 2018/2022b) and Table 3.4.1-1 of the *AASHTO LRFD Bridge Design Specification* (AASHTO, 2020). The fatigue loads were scaled using in-situ stress ranges collected during long term monitoring of the bridge by Purdue University. The loads were applied to the girder using a AASHTOWare BrR model in order to determine the maximum moments at 112 points along half the entire length of the bridge at 1/10th points, support locations, and section changes. An NSBA spreadsheet (NSBA, 2020) was then utilized to determine the strength capacity of the faulted member, fatigue life of the unfaulted and faulted member and maximum interval for special inspections.

Approximately 21% of the main girder's total length did not pass the IRM evaluation. These failing areas were due to either not having a cover plate or having unmitigated damage, which are requirements of Section 1.4 and 1.5 of the IRM Guide Specification (AASHTO, 2018/2022b). The passing sections contained a maximum special inspection interval of 10 years for the remaining girder length.

APPENDICES

Appendix 2A. Summary Table of Results

Appendix 2B. Graphical Summary of Results

Appendix 2C. Summary Table of Variable Parameters

Appendix 2D. Bridge Geometry, Material Properties, and Loading

Appendix 2E. As-Built Strain Gage Plan Set

Appendix 2F. Histogram Data and Effective Stress Calculations

Appendix 2G. NSTM/IRM Inspection Plan for Structures I-74-06-04417 FEBL and GWBL Over the Wabash River

Appendix 2H. Relevant 1958 Original and 1994 Rehabilitation Plan Sets

Appendix 2I. NSBA Spreadsheet Calculations of Each Controlling Location at Each Cross-Sectional Variation Location

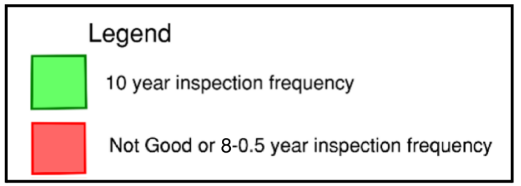
Appendix 2A. Summary Table of Results

Span	Section	Location (from Support)	Distance (from Pier 7)	Screening Criteria Met	Strength Check	Yield on Gross, Strength Ratio	Fracture on Net, Strength Ratio	Fatigue Case	Effective stress range in unfaulted state, Δf_{UFS}	Effective stress range in faulted state, Δf_{FS}	Total Unfaulted Fatigue Life	Total Faulted Fatigue Life	Total remaining fatigue life, N_f	Maximum Inspection Interval	Notes
		ft	ft	OK or NG	OK or NG	Less than 1 = NG	Less than 1 = NG	I(a), I(b), II	ksi	ksi	Years	Years	Years	Years	
G	XSec-0	0	0	NG	-	-	-	-	-	-	-	-	-		First 10.5' (1.5D) -> OK
G	XSec-0	5.9	5.9	NG	-	-	-	-	-	-	-	-	-	-	First 10.5' (1.5D) -> OK
G	XSec-0	8	8	NG	-	-	-	-	-	-	-	-	-	-	First 10.5' (1.5D) -> OK
G	XSec-1	8	8	OK	OK	3.67	2.41	I(b)	1.11	1.88	∞	283.6	283.6	10	
G	XSec-1	9.49	9.49	OK	OK	3.16	2.08	I(b)	1.28	2.17	∞	242.4	242.4	10	
G	XSec-1	11.79	11.79	OK	OK	2.64	1.74	I(b)	1.54	2.60	∞	194.4	194.4	10	
G	XSec-1	16	16	OK	OK	2.09	1.37	I(b)	1.94	3.29	∞	137.6	137.6	10	
G	XSec-2	16	16	OK	OK	2.80	1.85	I(b)	1.58	2.65	∞	189.3	189.3	10	
G	XSec-2	17.73	17.73	OK	OK	2.60	1.72	I(b)	1.70	2.85	∞	171.1	171.1	10	
G	XSec-2	18.98	18.98	OK	OK	2.49	1.64	I(b)	1.78	2.99	∞	159.9	159.9	10	
G	XSec-2	23.67	23.67	OK	OK	2.19	1.44	I(b)	2.06	3.47	∞	126.0	126.0	10	
G	XSec-2	28.48	28.48	OK	OK	2.01	1.33	I(b)	2.29	3.86	∞	104.0	104.0	10	
G	XSec-2	29.6	29.6	OK	OK	1.99	1.31	I(b)	2.34	3.93	∞	100.4	100.4	10	
G	XSec-2	35.54	35.54	OK	OK	1.90	1.25	I(b)	2.51	4.22	∞	87.6	87.6	10	
G	XSec-2	37.97	37.97	OK	OK	1.90	1.25	I(b)	2.55	4.28	∞	84.9	84.9	10	
G	XSec-2	41.48	41.48	OK	OK	1.92	1.26	I(b)	2.58	4.33	∞	82.9	82.9	10	
G	XSec-2	47.42	47.42	OK	OK	2.02	1.33	I(b)	2.64	4.44	∞	78.9	78.9	10	
G	XSec-2	47.46	47.46	OK	OK	2.02	1.33	I(b)	2.64	4.44	∞	78.8	78.8	10	
G	XSec-2	53.35	53.35	OK	OK	2.25	1.48	I(b)	2.68	4.51	∞	76.5	76.5	10	
G	XSec-2	56	56	OK	OK	2.42	1.59	I(b)	2.66	4.48	∞	77.4	77.4	10	
G	XSec-1	56	56	OK	OK	1.83	1.19	II	3.28	5.55	125.0	47.9	23.4	10	
G	XSec-1	56.95	56.95	OK	OK	1.89	1.23	II	3.27	5.53	126.0	48.3	23.8	10	Location of SG1 and SG2
G	XSec-1	59.29	59.29	OK	OK	2.06	1.34	II	3.22	5.45	129.3	49.9	25.2	10	
G	XSec-1	63	63	OK	OK	2.47	1.61	I(b)	3.12	5.28	∞	53.9	53.9	10	
G	XSec-0	63	63	NG	-	-	-	-	-	-	-	-	-	-	
G	XSec-0	65.23	65.23	NG	-	-	-	-	-	-	-	-	-	-	
G	XSec-0	66.44	66.44	NG	-	-	-	-	-	-	-	-	-	-	
G	XSec-0	67.23	67.23	NG	-	-	-	-	-	-	-	-	-	-	
G	XSec-00	67.23	67.23	NG	-	-	-	-	-	-	-	-	-	-	
G	XSec-00	71.17	71.17	NG	-	-	-	-	-	-	-	-	-	-	
G	XSec-00	75.93	75.93	NG	-	-	-	-	-	-	-	-	-	-	
G	XSec-00	76.43	76.43	NG	-	-	-	-	-	-	-	-	-	-	Location of SG3
G	XSec-00	76.92	76.92	NG	-	-	-	-	-	-	-	-	-	-	
G	XSec-3	76.92	76.92	OK	OK	2.59	1.77	I(b)	2.15	3.94	∞	99.9	99.9	10	
G	XSec-3	77.1	77.1	OK	OK	2.57	1.76	I(b)	2.14	3.92	∞	100.9	100.9	10	Location of SG4 and SG5
G	XSec-3	82.92	82.92	OK	OK	1.98	1.36	I(b)	1.78	3.26	∞	139.5	139.5	10	
G	XSec-4	82.92	82.92	OK	OK	2.90	1.97	I(b)	1.33	2.34	∞	222.9	222.9	10	
G	XSec-4	83.04	83.04	OK	OK	2.89	1.96	I(b)	1.32	2.32	∞	224.2	224.2	10	
G	XSec-4	85.43	85.43	OK	OK	2.58	1.76	I(b)	1.34	2.35	∞	220.8	220.8	10	
G	XSec-4	86.42	86.42	OK	OK	2.45	1.66	I(b)	1.36	2.38	∞	217.8	217.8	10	XSec-4 Controlling Fatigue
G	XSec-5	86.42	86.42	OK	OK	3.12	2.11	I(b)	1.11	1.95	∞	272.1	272.1	10	
G	XSec-5	88.98	88.98	OK	OK	2.71	1.84	I(b)	1.15	2.01	∞	263.9	263.9	10	
G	XSec-5	94.92	94.92	OK	OK	2.03	1.38	I(b)	1.22	2.15	∞	246.0	246.0	10	
H	XSec-5	0	94.92	OK	OK	2.03	1.38	I(b)	1.22	2.15	∞	245.4	245.4	10	XSec-5 Controlling Fatigue
H	XSec-5	6.25	101.17	OK	OK	2.78	1.88	I(b)	0.85	1.49	∞	372.7	372.7	10	
H	XSec-5	8.5	103.42	OK	OK	3.15	2.14	I(b)	0.81	1.42	∞	398.4	398.4	10	
H	XSec-4	8.5	103.42	OK	OK	2.47	1.68	I(b)	0.99	1.73	∞	306.9	306.9	10	
H	XSec-4	12	106.92	OK	OK	3.07	2.09	I(b)	0.92	1.61	∞	334.9	334.9	10	
H	XSec-3	12	106.92	OK	OK	2.10	1.43	I(b)	1.23	2.25	∞	232.6	232.6	10	

Span	Section	Location (from Support)	Distance (from Pier 7)	Screening Criteria Met	Strength Check	Yield on Gross, Strength Ratio	Fracture on Net, Strength Ratio	Fatigue Case	Effective stress range in unfaulted state, Δf_{UFS}	Effective stress range in faulted state, Δf_{FS}	Total Unfaulted Fatigue Life	Total Faulted Fatigue Life	Total remaining fatigue life, N_f	Maximum Inspection Interval	Notes
		ft	ft	OK or NG	OK or NG	Less than 1 = NG	Less than 1 = NG	I(a), I(b), II	ksi	ksi	Years	Years	Years	Years	
H	XSec-3	12.5	107.42	OK	OK	2.17	1.48	I(b)	1.24	2.26	∞	231.1	231.1	10	
H	XSec-3	17	111.92	OK	OK	2.96	2.02	I(b)	1.54	2.81	∞	174.1	174.1	10	
H	XSec-00	17	111.92	NG	-	-	-	-	-	-	-	-	-	-	
H	XSec-00	18.75	113.67	NG	-	-	-	-	-	-	-	-	-	-	
H	XSec-00	25	119.92	NG	-	-	-	-	-	-	-	-	-	-	
H	XSec-00	29.19	124.11	NG	-	-	-	-	-	-	-	-	-	-	
H	XSec-0	29.19	124.11	NG	-	-	-	-	-	-	-	-	-	-	
H	XSec-0	31.25	126.17	NG	-	-	-	-	-	-	-	-	-	-	
H	XSec-0	33	127.92	NG	-	-	-	-	-	-	-	-	-	-	
H	XSec-1	33	127.92	OK	OK	2.51	1.63	I(b)	2.73	4.62	∞	72.1	72.1	10	
H	XSec-1	37.5	132.42	OK	OK	1.97	1.29	I(b)	2.94	4.98	∞	61.3	61.3	10	
H	XSec-1	40	134.92	OK	OK	1.79	1.17	I(b)	3.04	5.14	∞	57.0	57.0	10	
H	XSec-2	40	134.92	OK	OK	2.36	1.56	I(b)	2.47	4.15	∞	90.1	90.1	10	
H	XSec-2	43.75	138.67	OK	OK	2.11	1.39	I(b)	2.56	4.31	∞	83.6	83.6	10	
H	XSec-2	50	144.92	OK	OK	1.85	1.22	I(b)	2.66	4.47	∞	77.6	77.6	10	
H	XSec-2	56.25	151.17	OK	OK	1.73	1.14	I(b)	2.67	4.48	∞	77.0	77.0	10	
H	XSec-2	62.5	157.42	OK	OK	1.69	1.11	I(b)	2.71	4.56	∞	74.4	74.4	10	
H	XSec-2	68.75	163.67	OK	OK	1.72	1.13	I(b)	2.81	4.73	∞	68.6	68.6	10	Location of SG6 and SG7
H	XSec-2	75	169.92	OK	OK	1.83	1.21	I(b)	2.84	4.78	∞	67.1	67.1	10	
H	XSec-2	81.25	176.17	OK	OK	2.07	1.36	I(b)	2.79	4.69	∞	70.0	70.0	10	
H	XSec-2	85	179.92	OK	OK	2.30	1.51	I(b)	2.71	4.57	∞	74.1	74.1	10	
H	XSec-1	85	179.92	OK	OK	1.74	1.14	II	3.34	5.66	119.9	45.5	21.2	10	
H	XSec-1	87.5	182.42	OK	OK	1.91	1.25	II	3.26	5.53	125.6	48.2	23.6	10	
H	XSec-1	91	185.92	OK	OK	2.27	1.48	I(b)	3.13	5.30	∞	53.1	53.1	10	
H	XSec-0	91	185.92	NG	-	-	-	-	-	-	-	-	-	-	
H	XSec-0	93.75	188.67	NG	-	-	-	-	-	-	-	-	-	-	
H	XSec-0	95.86	190.78	NG	-	-	-	-	-	-	-	-	-	-	
H	XSec-00	95.86	190.78	NG	-	-	-	-	-	-	-	-	-	-	
H	XSec-00	100	194.92	NG	-	-	-	-	-	-	-	-	-	-	Location of SG8, SG9 and SG10
H	XSec-00	106	200.92	NG	-	-	-	-	-	-	-	-	-	-	
H	XSec-3	106	200.92	OK	OK	2.67	1.82	I(b)	2.06	3.76	∞	108.6	108.6	10	XSec-3 Controlling Fatigue
H	XSec-3	106.25	201.17	OK	OK	2.63	1.80	I(b)	2.04	3.74	∞	110.0	110.0	10	
H	XSec-3	112	206.92	OK	OK	1.95	1.33	I(b)	1.68	3.08	∞	152.6	152.6	10	XSec-3 Controlling Strength
H	XSec-4	112	206.92	OK	OK	2.85	1.94	I(b)	1.26	2.20	∞	238.2	238.2	10	
H	XSec-4	112.5	207.42	OK	OK	2.77	1.88	I(b)	1.24	2.18	∞	241.1	241.1	10	
H	XSec-4	116.5	211.42	OK	OK	2.22	1.51	I(b)	1.30	2.28	∞	228.7	228.7	10	XSec-4 Controlling Strength
H	XSec-5	116.5	211.42	OK	OK	2.83	1.92	I(b)	1.07	1.87	∞	283.6	283.6	10	
H	XSec-5	118.75	213.67	OK	OK	2.52	1.71	I(b)	1.09	1.92	∞	276.6	276.6	10	
H	XSec-5	122	216.92	OK	OK	2.15	1.46	I(b)	1.13	1.99	∞	266.9	266.9	10	Location of SG11
H	XSec-5	123	217.92	OK	OK	2.05	1.39	I(b)	1.14	2.01	∞	264.0	264.0	10	Location of SG12 and SG13
H	XSec-5	125	219.92	OK	OK	1.89	1.28	I(b)	1.17	2.05	∞	258.3	258.3	10	XSec-5 Controlling Strength
J	XSec-5	0	219.92	OK	OK	1.89	1.28	I(b)	1.17	2.05	∞	258.3	258.3	10	
J	XSec-5	6.25	226.17	OK	OK	2.52	1.71	I(b)	1.02	1.78	∞	297.7	297.7	10	
J	XSec-5	8.5	228.42	OK	OK	2.84	1.92	I(b)	0.99	1.73	∞	307.5	307.5	10	
J	XSec-4	8.5	228.42	OK	OK	2.23	1.51	I(b)	1.20	2.11	∞	250.1	250.1	10	
J	XSec-4	12.5	232.42	OK	OK	2.78	1.89	I(b)	1.19	2.08	∞	253.5	253.5	10	
J	XSec-4	13	232.92	OK	OK	2.86	1.94	I(b)	1.21	2.13	∞	247.6	247.6	10	
J	XSec-3	13	232.92	OK	OK	1.96	1.34	I(b)	1.62	2.97	∞	160.7	160.7	10	
J	XSec-3	18.75	238.67	OK	OK	2.66	1.82	I(b)	2.01	3.68	∞	113.1	113.1	10	

Span	Section	Location (from Support)	Distance (from Pier 7)	Screening Criteria Met	Strength Check	Yield on Gross, Strength Ratio	Fracture on Net, Strength Ratio	Fatigue Case	Effective stress range in unfaulted state, Δf_{UFS}	Effective stress range in faulted state, Δf_{FS}	Total Unfaulted Fatigue Life	Total Faulted Fatigue Life	Total remaining fatigue life, N_f	Maximum Inspection Interval	Notes
		ft	ft	OK or NG	OK or NG	Less than 1 = NG	Less than 1 = NG	I(a), I(b), II	ksi	ksi	Years	Years	Years	Years	
J	XSec-3	19	238.92	OK	OK	2.70	1.84	I(b)	2.03	3.71	∞	111.6	111.6	10	
J	XSec-00	19	238.92	NG	-	-	-	-	-	-	-	-	-	-	
J	XSec-00	25	244.92	NG	-	-	-	-	-	-	-	-	-	-	
J	XSec-00	29.19	249.11	NG	-	-	-	-	-	-	-	-	-	-	
J	XSec-0	29.19	249.11	NG	-	-	-	-	-	-	-	-	-	-	
J	XSec-0	31.25	251.17	NG	-	-	-	-	-	-	-	-	-	-	
J	XSec-0	33	252.92	NG	-	-	-	-	-	-	-	-	-	-	
J	XSec-1	33	252.92	OK	OK	2.46	1.60	I(b)	3.12	5.28	∞	53.7	53.7	10	
J	XSec-1	37.5	257.42	OK	OK	1.95	1.27	II	3.30	5.58	123.1	47.0	22.6	10	
J	XSec-1	41	260.92	OK	OK	1.71	1.12	II	3.41	5.76	115.4	43.5	19.4	10	XSec-1 Controlling Strength and Fatigue
J	XSec-2	41	260.92	OK	OK	2.26	1.49	I(b)	2.77	4.65	∞	71.1	71.1	10	
J	XSec-2	43.75	263.67	OK	OK	2.09	1.38	I(b)	2.82	4.74	∞	68.4	68.4	10	
J	XSec-2	50	269.92	OK	OK	1.85	1.22	I(b)	2.88	4.84	∞	65.3	65.3	10	XSec-2 Controlling Fatigue
J	XSec-2	56.25	276.17	OK	OK	1.73	1.14	I(b)	2.85	4.80	∞	66.6	66.6	10	
J	XSec-2	62.5	282.42	OK	OK	1.70	1.12	I(b)	2.75	4.62	∞	72.2	72.2	10	XSec-2 Controlling Strength

Appendix 2B. Graphical Summary of Results



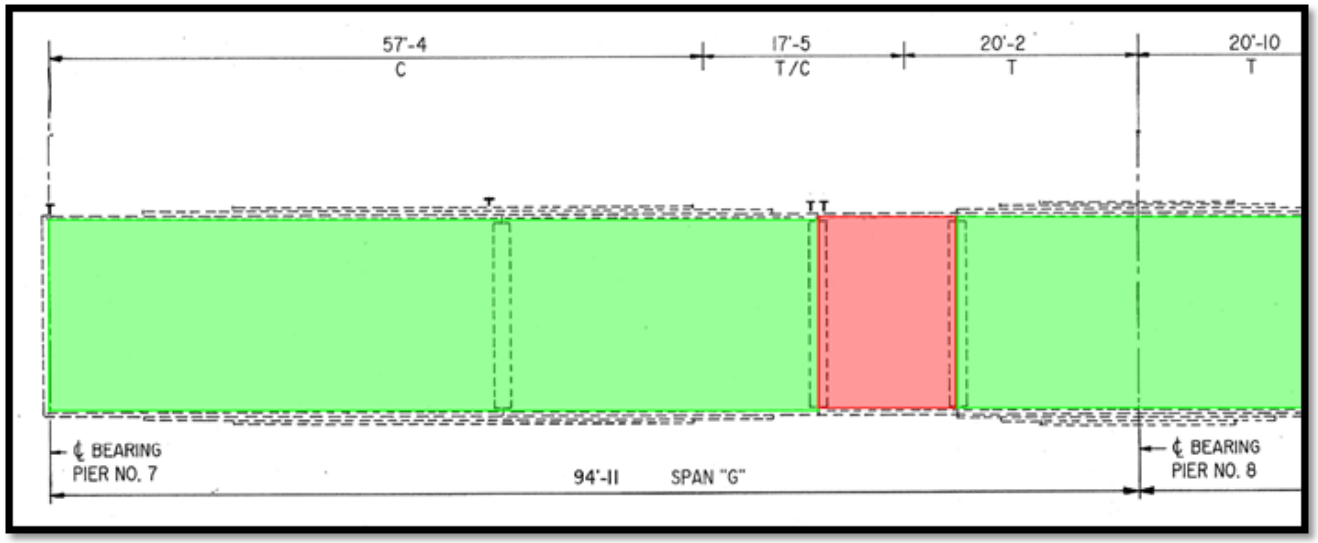


Figure 2.B1 Girder elevation of Span G, summary of results.

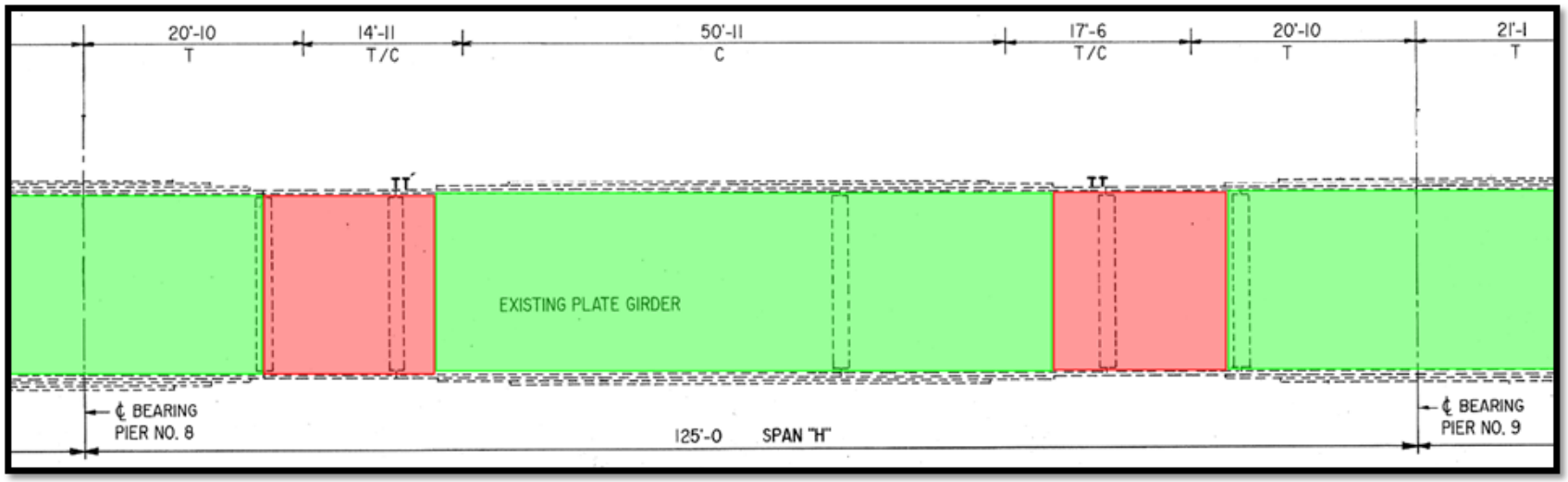


Figure 2.B2 Girder elevation of Span H, summary of results.

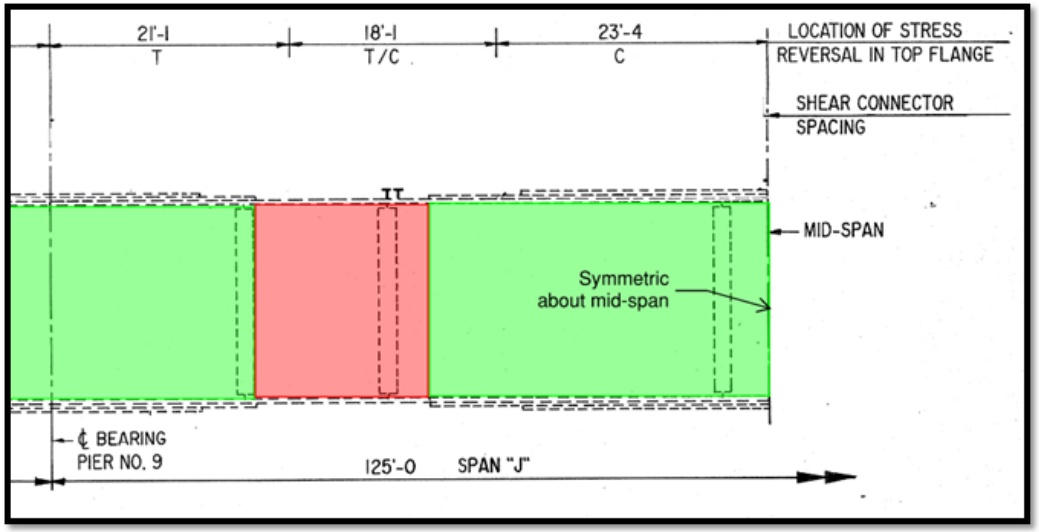


Figure 2.B3 Girder elevation of Span J, summary of results.

Appendix 2C. Summary Table of Variable Parameters

Span	Section	Location (from Support)	Distance (from Pier 7)	Cycles per day	M_{LL+IM}	M_{FAT+IM}	Adjustment Factor	M_{DC1}	M_{DC2}	M_{DW}	Negative Moment	Composite	Screening Criteria Met	Strength Check	Maximum Inspection Interval	Notes
		ft	ft		k-ft	k-ft		k-ft	k-ft	k-ft	-		OK or NG	OK or NG	Years	
G	XSec-0	0	0	**1129**	0	0	0.664	0	0	0	No	Yes	NG	-		First 10.5' (1.5D) -> OK
G	XSec-0	5.9	5.9	1129	729.06	232.31	0.664	376.42	78.52	18.62	No	Yes	NG	-	-	First 10.5' (1.5D) -> OK
G	XSec-0	8	8	1129	959.25	305.18	0.664	493.59	102.95	24.41	No	Yes	NG	-	-	First 10.5' (1.5D) -> OK
G	XSec-1	8	8	1129	959.25	305.18	0.664	493.59	102.95	24.41	No	Yes	OK	OK	10	
G	XSec-1	9.49	9.49	1129	1112.95	353.69	0.664	571.12	119.13	28.24	No	Yes	OK	OK	10	
G	XSec-1	11.79	11.79	1129	1334.66	423.42	0.664	681.56	142.22	33.72	No	Yes	OK	OK	10	
G	XSec-1	16	16	1129	1692.26	535.28	0.664	854.89	178.64	42.35	No	Yes	OK	OK	10	
G	XSec-2	16	16	1129	1692.26	535.28	0.664	854.89	178.64	42.35	No	Yes	OK	OK	10	
G	XSec-2	17.73	17.73	1129	1821.50	575.38	0.664	915.3	191.42	45.38	No	Yes	OK	OK	10	
G	XSec-2	18.98	18.98	1129	1908.68	602.44	0.664	955.07	199.88	47.39	No	Yes	OK	OK	10	
G	XSec-2	23.67	23.67	1129	2186.80	698.88	0.664	1073.66	225.59	53.48	No	Yes	OK	OK	10	
G	XSec-2	28.48	28.48	1129	2398.21	778.00	0.664	1146.3	242.26	57.44	No	Yes	OK	OK	10	
G	XSec-2	29.6	29.6	1129	2442.24	792.97	0.664	1156.15	244.74	58.03	No	Yes	OK	OK	10	
G	XSec-2	35.54	35.54	1129	2604.00	850.09	0.664	1162.75	248.88	59.01	No	Yes	OK	OK	10	
G	XSec-2	37.97	37.97	1129	2637.05	863.61	0.664	1143.61	246.25	58.38	No	Yes	OK	OK	10	
G	XSec-2	41.48	41.48	1129	2651.77	873.79	0.664	1093.47	238	56.43	No	Yes	OK	OK	10	
G	XSec-2	47.42	47.42	1129	2629.19	895.16	0.664	948.3	212.1	50.29	No	Yes	OK	OK	10	
G	XSec-2	47.46	47.46	1129	2628.75	895.38	0.664	947.02	211.86	50.23	No	Yes	OK	OK	10	
G	XSec-2	53.35	53.35	1129	2512.45	908.37	0.664	727.26	171.18	40.58	No	Yes	OK	OK	10	
G	XSec-2	56	56	1129	2427.00	903.13	0.664	604.34	148.11	35.12	No	Yes	OK	OK	10	
G	XSec-1	56	56	1129	2427.00	903.13	0.664	604.34	148.11	35.12	No	Yes	OK	OK	10	
G	XSec-1	56.95	56.95	1129	2391.49	899.52	0.664	556.54	139.1	32.98	No	Yes	OK	OK	10	Location of SG1 and SG2
G	XSec-1	59.29	59.29	1129	2293.61	887.40	0.664	430.66	115.24	27.32	No	Yes	OK	OK	10	
G	XSec-1	63	63	1129	2107.63	858.44	0.664	207.82	72.69	17.23	No	Yes	OK	OK	10	
G	XSec-0	63	63	1129	2107.63	858.44	0.664	207.82	72.69	17.23	No	Yes	NG	-	-	
G	XSec-0	65.23	65.23	1129	1983.46	835.62	0.664	60.11	44.29	10.5	No	Yes	NG	-	-	
G	XSec-0	66.44	66.44	1129	1910.04	821.58	0.664	-24.45	27.95	6.63	No	Yes	NG	-	-	
G	XSec-0	67.23	67.23	1129	1859.88	811.78	0.664	-81.33	16.94	4.02	No	Yes	NG	-	-	
G	XSec-00	67.23	67.23	1129	1859.88	811.78	0.664	-81.33	16.94	4.02	No	Yes	NG	-	-	
G	XSec-00	71.17	71.17	1129	-1467.90	757.29	0.664	-383.24	-41.69	-9.88	Yes	No	NG	-	-	
G	XSec-00	75.93	75.93	1129	-1566.22	680.68	0.664	-792.95	-121.57	-28.82	Yes	No	NG	-	-	
G	XSec-00	76.43	76.43	1129	-1576.45	671.95	0.664	-838.61	-130.49	-30.94	Yes	No	NG	-	-	Location of SG3
G	XSec-00	76.92	76.92	1129	-1586.48	663.42	0.664	-883.36	-139.24	-33.01	Yes	No	NG	-	-	
G	XSec-3	76.92	76.92	1129	-1586.48	663.42	0.664	-883.36	-139.24	-33.01	Yes	No	OK	OK	10	
G	XSec-3	77.1	77.1	1129	-1590.37	660.04	0.664	-900.95	-142.68	-33.83	Yes	No	OK	OK	10	Location of SG4 and SG5
G	XSec-3	82.92	82.92	1129	-1750.07	548.61	0.664	-1481.6	-256.07	-60.71	Yes	No	OK	OK	10	
G	XSec-4	82.92	82.92	1129	-1750.07	548.61	0.664	-1481.6	-256.07	-60.71	Yes	No	OK	OK	10	
G	XSec-4	83.04	83.04	1129	-1755.06	546.00	0.664	-1495.01	-258.69	-61.33	Yes	No	OK	OK	10	
G	XSec-4	85.43	85.43	1129	-1875.62	552.84	0.664	-1755.72	-309.48	-73.37	Yes	No	OK	OK	10	
G	XSec-4	86.42	86.42	1129	-1968.11	559.25	0.664	-1867.98	-331.3	-78.55	Yes	No	OK	OK	10	XSec-4 Controlling Fatigue
G	XSec-5	86.42	86.42	1129	-1968.11	559.25	0.664	-1867.98	-331.3	-78.55	Yes	No	OK	OK	10	
G	XSec-5	88.98	88.98	1129	-2231.80	575.84	0.664	-2169.23	-389.71	-92.4	Yes	No	OK	OK	10	
G	XSec-5	94.92	94.92	1129	-2937.90	614.26	0.664	-2927.52	-535.76	-127.02	Yes	No	OK	OK	10	
H	XSec-5	0	94.92	1129	-2937.90	614.26	0.664	-2927.52	-535.76	-127.02	Yes	No	OK	OK	10	XSec-5 Controlling Fatigue
H	XSec-5	6.25	101.17	1129	-2176.47	425.99	0.664	-2129.77	-379.47	-89.97	Yes	No	OK	OK	10	
H	XSec-5	8.5	103.42	1129	-1930.44	407.36	0.664	-1865.63	-327.3	-77.6	Yes	No	OK	OK	10	
H	XSec-4	8.5	103.42	1129	-1930.44	407.36	0.664	-1865.63	-327.3	-77.6	Yes	No	OK	OK	10	
H	XSec-4	12	106.92	1129	-1589.76	378.36	0.664	-1478.17	-250.41	-59.37	Yes	No	OK	OK	10	

Span	Section	Location (from Support)	Distance (from Pier 7)	Cycles per day	M_{LL+IM}	M_{FAT+IM}	Adjustment Factor	M_{DC1}	M_{DC2}	M_{DW}	Negative Moment	Composite	Screening Criteria Met	Strength Check	Maximum Inspection Interval	Notes
		ft	ft		k-ft	k-ft		k-ft	k-ft	k-ft	-		OK or NG	OK or NG	Years	
H	XSec-3	12	106.92	1129	-1589.76	378.36	0.664	-1478.17	-250.41	-59.37	Yes	No	OK	OK	10	
H	XSec-3	12.5	107.42	1129	-1546.07	380.44	0.664	-1425.03	-239.82	-56.86	Yes	No	OK	OK	10	
H	XSec-3	17	111.92	1129	-1210.59	473.36	0.664	-972.58	-149.6	-35.47	Yes	No	OK	OK	10	
H	XSec-00	17	111.92	1129	-1210.59	473.36	0.664	-972.58	-149.6	-35.47	Yes	No	NG	-	-	
H	XSec-00	18.75	113.67	1129	-1125.51	507.59	0.664	-808.44	-116.82	-27.7	Yes	No	NG	-	-	
H	XSec-00	25	119.92	1129	-987.54	623.99	0.664	-275.41	-10.45	-2.48	Yes	No	NG	-	-	
H	XSec-00	29.19	124.11	1129	1660.87	695.12	0.664	35.84	51.57	12.23	No	Yes	NG	-	-	
H	XSec-0	29.19	124.11	1129	1660.87	695.12	0.664	35.84	51.57	12.23	No	Yes	NG	-	-	
H	XSec-0	31.25	126.17	1129	1820.21	726.89	0.664	175.23	79.27	18.79	No	Yes	NG	-	-	
H	XSec-0	33	127.92	1129	1948.00	752.25	0.664	286.88	101.4	24.04	No	Yes	NG	-	-	
H	XSec-1	33	127.92	1129	1948.00	752.25	0.664	286.88	101.4	24.04	No	Yes	OK	OK	10	
H	XSec-1	37.5	132.42	1129	2247.91	810.06	0.664	545.01	152.36	36.12	No	Yes	OK	OK	10	
H	XSec-1	40	134.92	1129	2395.81	836.46	0.664	670	176.92	41.95	No	Yes	OK	OK	10	
H	XSec-2	40	134.92	1129	2395.81	836.46	0.664	670	176.92	41.95	No	Yes	OK	OK	10	
H	XSec-2	43.75	138.67	1129	2590.72	868.60	0.664	832.65	208.8	49.5	No	Yes	OK	OK	10	
H	XSec-2	50	144.92	1129	2840.76	900.46	0.664	1036.37	248.6	58.94	No	Yes	OK	OK	10	
H	XSec-2	56.25	151.17	1129	2993.13	903.65	0.664	1156.02	271.77	64.43	No	Yes	OK	OK	10	
H	XSec-2	62.5	157.42	1129	3046.51	918.78	0.664	1191.6	278.29	65.98	No	Yes	OK	OK	10	
H	XSec-2	68.75	163.67	1129	3033.61	953.73	0.664	1143.1	268.17	63.58	No	Yes	OK	OK	10	Location of SG6 and SG7
H	XSec-2	75	169.92	1129	2924.34	963.69	0.664	1010.53	241.41	57.24	No	Yes	OK	OK	10	
H	XSec-2	81.25	176.17	1129	2716.89	944.91	0.664	793.86	198.01	46.95	No	Yes	OK	OK	10	
H	XSec-2	85	179.92	1129	2547.06	920.46	0.664	623.56	163.99	38.88	No	Yes	OK	OK	10	
H	XSec-1	85	179.92	1129	2547.06	920.46	0.664	623.56	163.99	38.88	No	Yes	OK	OK	10	
H	XSec-1	87.5	182.42	1129	2415.39	899.04	0.664	493.31	137.97	32.71	No	Yes	OK	OK	10	
H	XSec-1	91	185.92	1129	2207.43	862.21	0.664	289.07	97.09	23.02	No	Yes	OK	OK	10	
H	XSec-0	91	185.92	1129	2207.43	862.21	0.664	289.07	97.09	23.02	No	Yes	NG	-	-	
H	XSec-0	93.75	188.67	1129	2027.15	828.09	0.664	110.72	61.29	14.53	No	Yes	NG	-	-	
H	XSec-0	95.86	190.78	1129	1877.29	799.21	0.664	-36.46	31.66	7.51	No	Yes	NG	-	-	
H	XSec-00	95.86	190.78	1129	1877.29	799.21	0.664	-36.46	31.66	7.51	No	Yes	NG	-	-	
H	XSec-00	100	194.92	1129	-1388.70	735.84	0.664	-352.48	-32.03	-7.59	Yes	No	NG	-	-	Location of SG8, SG9 and SG10
H	XSec-00	106	200.92	1129	-1527.18	633.05	0.664	-874.63	-137.28	-32.55	Yes	No	NG	-	-	
H	XSec-3	106	200.92	1129	-1527.18	633.05	0.664	-874.63	-137.28	-32.55	Yes	No	OK	OK	10	XSec-3 Controlling Fatigue
H	XSec-3	106.25	201.17	1129	-1534.47	628.58	0.664	-898.05	-141.99	-33.67	Yes	No	OK	OK	10	
H	XSec-3	112	206.92	1129	-1814.27	517.44	0.664	-1474.67	-257.86	-61.14	Yes	No	OK	OK	10	XSec-3 Controlling Strength
H	XSec-4	112	206.92	1129	-1814.27	517.44	0.664	-1474.67	-257.86	-61.14	Yes	No	OK	OK	10	
H	XSec-4	112.5	207.42	1129	-1854.82	511.94	0.664	-1528.29	-268.6	-63.68	Yes	No	OK	OK	10	
H	XSec-4	116.5	211.42	1129	-2232.22	535.77	0.664	-1978	-358.36	-84.96	Yes	No	OK	OK	10	XSec-4 Controlling Strength
H	XSec-5	116.5	211.42	1129	-2232.22	535.77	0.664	-1978	-358.36	-84.96	Yes	No	OK	OK	10	
H	XSec-5	118.75	213.67	1129	-2475.12	549.18	0.664	-2247.44	-411.84	-97.64	Yes	No	OK	OK	10	
H	XSec-5	122	216.92	1129	-2873.11	568.54	0.664	-2669.77	-494.98	-117.35	Yes	No	OK	OK	10	Location of SG11
H	XSec-5	123	217.92	1129	-2995.57	574.50	0.664	-2799.72	-520.57	-123.42	Yes	No	OK	OK	10	Location of SG12 and SG13
H	XSec-5	125	219.92	1129	-3240.49	586.41	0.664	-3059.62	-571.73	-135.55	Yes	No	OK	OK	10	XSec-5 Controlling Strength
J	XSec-5	0	219.92	1129	-3240.49	586.41	0.664	-3059.62	-571.73	-135.55	Yes	No	OK	OK	10	
J	XSec-5	6.25	226.17	1129	-2461.60	510.56	0.664	-2255.67	-414.21	-98.2	Yes	No	OK	OK	10	
J	XSec-5	8.5	228.42	1129	-2213.18	495.48	0.664	-1989.2	-361.58	-85.73	Yes	No	OK	OK	10	
J	XSec-4	8.5	228.42	1129	-2213.18	495.48	0.664	-1989.2	-361.58	-85.73	Yes	No	OK	OK	10	
J	XSec-4	12.5	232.42	1129	-1825.42	489.38	0.664	-1544.75	-273.34	-64.8	Yes	No	OK	OK	10	
J	XSec-4	13	232.92	1129	-1783.35	500.10	0.664	-1491.8	-262.78	-62.3	Yes	No	OK	OK	10	

Span	Section	Location (from Support)	Distance (from Pier 7)	Cycles per day	M_{LL+IM}	M_{FAT+IM}	Adjustment Factor	M_{DC1}	M_{DC2}	M_{DW}	Negative Moment	Composite	Screening Criteria Met	Strength Check	Maximum Inspection Interval	Notes
		ft	ft		k-ft	k-ft		k-ft	k-ft	k-ft	-		OK or NG	OK or NG	Years	
J	XSec-3	13	232.92	1129	-1783.35	500.10	0.664	-1491.8	-262.78	-62.3	Yes	No	OK	OK	10	
J	XSec-3	18.75	238.67	1129	-1484.28	618.94	0.664	-922.76	-149.1	-35.35	Yes	No	OK	OK	10	
J	XSec-3	19	238.92	1129	-1477.19	623.79	0.664	-899.68	-144.48	-34.25	Yes	No	OK	OK	10	
J	XSec-00	19	238.92	1129	-1477.19	623.79	0.664	-899.68	-144.48	-34.25	Yes	No	NG	-	-	
J	XSec-00	25	244.92	1129	-1347.80	736.14	0.664	-385.42	-41.51	-9.84	Yes	No	NG	-	-	
J	XSec-00	29.19	249.11	1129	1875.94	807.53	0.664	-71.19	21.35	5.06	No	Yes	NG	-	-	
J	XSec-0	29.19	249.11	1129	1875.94	807.53	0.664	-71.19	21.35	5.06	No	Yes	NG	-	-	
J	XSec-0	31.25	251.17	1129	2026.98	836.14	0.664	70.38	49.66	11.77	No	Yes	NG	-	-	
J	XSec-0	33	252.92	1129	2147.61	858.40	0.664	184.04	72.33	17.15	No	Yes	NG	-	-	
J	XSec-1	33	252.92	1129	2147.61	858.40	0.664	184.04	72.33	17.15	No	Yes	OK	OK	10	
J	XSec-1	37.5	257.42	1129	2428.84	908.31	0.664	447.08	124.63	29.55	No	Yes	OK	OK	10	
J	XSec-1	41	260.92	1129	2617.17	937.99	0.664	622.33	159.35	37.78	No	Yes	OK	OK	10	XSec-1 Controlling Strength and Fatigue
J	XSec-2	41	260.92	1129	2617.17	937.99	0.664	622.33	159.35	37.78	No	Yes	OK	OK	10	
J	XSec-2	43.75	263.67	1129	2745.09	955.39	0.664	741.81	182.97	43.38	No	Yes	OK	OK	10	
J	XSec-2	50	269.92	1129	2967.45	975.46	0.664	952.8	224.66	53.26	No	Yes	OK	OK	10	XSec-2 Controlling Fatigue
J	XSec-2	56.25	276.17	1129	3091.64	966.87	0.664	1079.71	249.71	59.2	No	Yes	OK	OK	10	
J	XSec-2	62.5	282.42	1129	3118.41	931.63	0.664	1122.57	258.12	61.2	No	Yes	OK	OK	10	XSec-2 Controlling Strength

Appendix 2D. Bridge Geometry, Material Properties, and Loading

Fracture Critical Members

- Riveted built-up plate girders

- The riveted, built-up, plate transverse floor beams are not spaced on center at intervals greater than 14 ft and stringers are continuous over the beams; therefore, the transverse floor beams are not considered to be fracture critical bridge members. [BIRM Sec 8.3.2 {pg. 8.3.8}]

Bridge Brief History/Timeline

1958 - Year built
1994 - Year reconstructed
2022 - Most recent NSTM/FC inspection
2022-2023 - Long term monitoring of bridge for in-situ fatigue data (stress ranges and cycles)

Material Properties

DESIGN DATA

LIVE LOAD: DESIGNED FOR HS20-44 LOADING IN ACCORDANCE WITH 1992 A.A.S.H.T.O. SPECIFICATIONS AND SUBSEQUENT INTERIM SPECIFICATIONS.

DEAD LOAD: ACTUAL WEIGHT PLUS 35 #/SF (COMPOSITE) FOR FUTURE WEARING SURFACE AND 15 PSF (NON-COMPOSITE) FOR PERMANENT METAL DECK FORMS. LOADS FOR CONCRETE DECK AND RAIL IN SPANS G THRU L ARE BASED ON UTILIZING SEMI-LIGHTWEIGHT CONCRETE AT 125 PCF (INCLUDES 5 PCF ALLOWANCE FOR REINFORCING STEEL).

ALLOWABLE DESIGN STRESSES:

CLASS SL CONCRETE	f'c = 4000 PSI
CLASS C CONCRETE	f'c = 4000 PSI
CLASS A CONCRETE	f'c = 3500 PSI
CLASS B CONCRETE	f'c = 3000 PSI
REINFORCING STEEL (GRADE 60)	fy = 60,000 PSI

5. ALL STRUCTURAL STEEL TO BE A36 UNLESS OTHERWISE NOTED. ESTIMATED WEIGHT OF STRUCTURAL STEEL IS 463,000 LBS, WHICH INCLUDES 56,400 LBS OF A572-50.

MATERIAL NOTES

BRIDGE DECK OVERLAY:

1-3/4" MODIFIED PORTLAND CEMENT CONCRETE OVERLAY

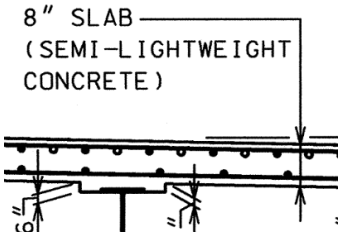
OR

2-1/2" DENSE PORTLAND CEMENT CONCRETE OVERLAY

(1-1/2" OR 2-1/4" RESPECTIVELY ABOVE THE ORIGINAL SURFACE.)

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Concrete



$f'_c := 4$ ksi Semi-Lightweight Concrete

$w_{c_reinf} := .125$ kcf Dead load weight (including reinforcing)

$K_1 := 1.0$

$w_c := .120$ kcf Concrete weight (without reinforcing)

$E_c := 120000 \cdot K_1 \cdot {w_c}^{2.0} \cdot {f'_c}^{0.33} = 2730.383$ ksi [AASHTO LRFD BDS Eq 5.4.2.4-1]

Steel

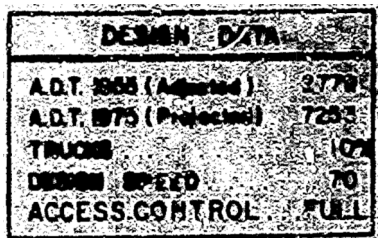
$F_y := 33$ ***ksi*** [AASHTO MBE Table 6A.6.2.1-1]

$F_u := 66$ ***ksi*** [AASHTO MBE Table 6A.6.2.1-1]

Traffic Data - for information only because true cycles from long term monitoring was used for evaluation

Original Screenshot from 1958 plans

$ADT_o := 2778$ vehicles per day for both twin bridges



$truck_{per} := 10\%$

$lanes := 2$

There are two bridges carrying traffic in opposite directions. Per AASHTO LRFD BDS C3.6.1.4.2, 55% of the bidirectional ADTT is used

$directional := 55\%$

$p := 0.85$ [AASHTO LRFD BDS Table 3.6.1.4.2-1]

Average original number of trucks per day in a single lane [AASHTO LRFD BDS Eq 3.6.1.4.2-1]

$ADTT_{sl_o} := ADT_o \cdot truck_{per} \cdot directional \cdot p = 129.872$

Present

$ADT := 17310$ [2022 Data] From INDOT Database

$truck_{per} := 59\%$ [2021 Data] From INDOT Database

There are two bridges carrying traffic in opposite directions. Per AASHTO LRFD BDS C3.6.1.4.2, a conservative 55% of the bidirectional ADTT is used

Non-Commercial Use Only

$directional := 55\%$

$p := 0.85$ [AASHTO LRFD BDS Table 3.6.1.4.2-1]

Average original number of trucks per day in a single lane [AASHTO LRFD BDS Eq 3.6.1.4.2-1]

$ADTT_{sl_present} := ADT \cdot truck_{per} \cdot directional \cdot p = 4774.531$

Limit

$ADT_{Max} := 20000$ Vehicles per lane per day [AAHSTO LRFD BDS C3.6.1.4.2]

$lanes := 2$

$p := 0.85$ [AASHTO LRFD BDS Table 3.6.1.4.2-1]

$ADTT_{sl_limit} := ADT_{Max} \cdot truck_{per} \cdot lanes \cdot p = 20060$ Trucks per lane per day

Additional Parameters

$g := 1.0\%$ Conservative Expected Annual Growth Rate. Conservative growth rate from INDOT 2020 Growth Rate data [https://www.in.gov/indot/files/INDOT_2020_Adjustment_Factors.pdf]

$n_L := 2$ Number of striped lanes

$R_s := 1.0$ Stress-Range Estimate Partial LF, [MBE Table 7.2.2.1-1]
Table would indicate to use 0.85, but for a conservative evaluation a factor of 1.0 was used due to knowledge of true stress ranges and cycles from in-situ data

$R_R := 1.0$ Resistance Factor for Evaluation - Minimum Life [MBE Table 7.2.5.1-1]

$n := 1.0$ Number of Stress-Range Cycles per Truck [MBE Sec 7.2.5.2]

Non-Commercial Use Only

Geometry for Dead Load Determination

Deck

$t_{deck} := 8\ in$

$t_{overlay} := 0.5\ in$ polymeric overlay assumed to have 0.5" thickness and weight of concrete

$w_{overlay} := 0.145\ \frac{kip}{ft^3}$ $width_{overlay} := 12\ ft + 4\ ft + 8\ in = 16.667\ ft$

$load_{overlay} := w_{overlay} \cdot width_{overlay} \cdot t_{overlay} = 0.101\ \frac{kip}{ft}$

No stay in place forms present and future wearing surface not a part of analysis

Eff Flange Width [4.6.2.6 LRFD Bridge Spec]

Girder not next to added girder (Girder A):

$w_{overhang} := 5\ ft + 2\ in$

$spac_{girder} := 5\ ft + 3\ in$

$w_{eff} := w_{overhang} + \frac{spac_{girder}}{2} = 129.5\ in$ Controls

Girder next to the added girder (Girder B):

$w_{overhang} := 8\ ft + 2\ in$

$spac_{girder} := 5\ ft + 3\ in$

$w_{eff} := \frac{w_{overhang} + spac_{girder}}{2} = 80.5\ in$

Tributary Slab Width

Option 1, Girder A is worst case scenario

$5\ ft + 2\ in + 13\ ft = 218\ in$ Controls

Option 2, Girder B splits deck with added girder

$13\ ft + \frac{8\ ft + 2\ in}{2} = 205\ in$

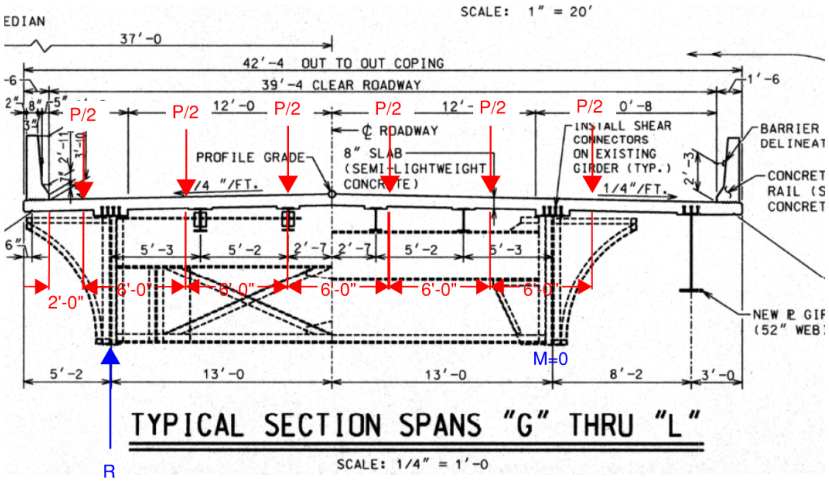
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Live Load Distribution Factors - Using Lever Rule

CASE I - Analyzing left girder - 3 lanes loaded (with all loads shifted to the left)

$Design_Lane := 12\ ft$ AASHTO LRFD Sec 3.6.1.1.1

Multiple (39'-4" Clear Roadway can fit 3 HL93 trucks) LLDF of left girder



$$26 \cdot R = 27.667 \cdot \frac{P}{2} + 21.667 \cdot \frac{P}{2} + 15.667 \cdot \frac{P}{2} + 9.667 \cdot \frac{P}{2} + 3.667 \cdot \frac{P}{2}$$

$$26 \cdot R = \frac{27.667 + 21.667 + 15.667 + 9.667 + 3.667}{2} \cdot P \rightarrow 26 \cdot R = 39.1675 \cdot P$$

$$R = \frac{39.1675}{26} \cdot P \qquad g_{mult} := \frac{39.1675}{26} = 1.506$$

Table 3.6.1.1.2-1—Multiple Presence Factors, *m*

[AAHSTO LRFD Table 3.6.1.1.2-1]

Number of Loaded Lanes	Multiple Presence Factors, *m*
1	1.20
2	1.00
3	0.85
>3	0.65

$m_1 := 1.20$
$m_2 := 1.00$
$m_3 := 0.85$

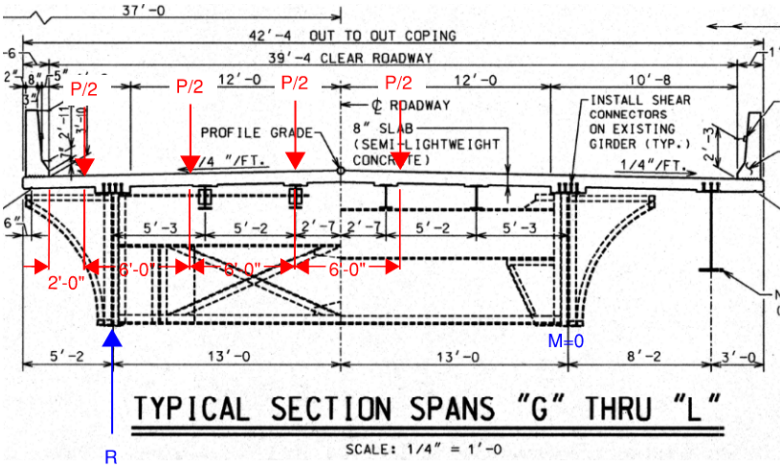
$DF_{Multiple_CaseI} := g_{mult} \cdot m_3 = 1.28$

Non-Commercial Use Only

CASE II - Analyzing left girder - 2 lanes loaded (with all loads shifted to the left)

$Design_Lane := 12\ ft$ AASHTO LRFD Sec 3.6.1.1.1

Multiple (39'-4" Clear Roadway can fit 3 HL93 trucks) LLDF of left girder



$$26 \cdot R = 27.667 \cdot \frac{P}{2} + 21.667 \cdot \frac{P}{2} + 15.667 \cdot \frac{P}{2} + 9.667 \cdot \frac{P}{2}$$

$$26 \cdot R = \frac{27.667 + 21.667 + 15.667 + 9.667}{2} \cdot P \rightarrow 26 \cdot R = 37.334 \cdot P$$

$$R = \frac{37.334}{26} \cdot P \qquad g_{mult} := \frac{37.334}{26} = 1.436$$

Table 3.6.1.1.2-1—Multiple Presence Factors, *m*

[AAHSTO LRFD Table 3.6.1.1.2-1]

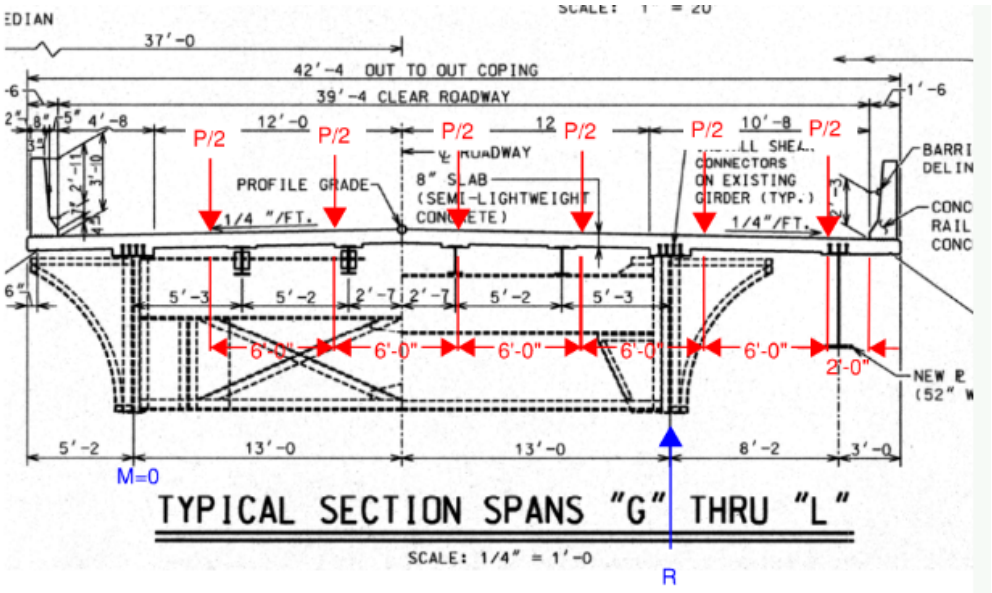
Number of Loaded Lanes	Multiple Presence Factors, *m*
1	1.20
2	1.00
3	0.85
>3	0.65

$m_1 := 1.20$
$m_2 := 1.00$
$m_3 := 0.85$

$DF_{Multiple_CaseII} := g_{mult} \cdot m_2 = 1.436$

Non-Commercial Use Only

CASE III - Analyzing right girder assuming added girder fully takes the far right wheel load



$$26 \cdot R = 3.667 \cdot \frac{P}{2} + 9.667 \cdot \frac{P}{2} + 15.667 \cdot \frac{P}{2} + 21.667 \cdot \frac{P}{2} + 27.667 \cdot \frac{P}{2}$$

$$26 \cdot R = \frac{3.667 + 9.667 + 15.667 + 21.667 + 27.667}{2} \cdot P \rightarrow 26 \cdot R = 39.1675 \cdot P$$

$$R = \frac{39.1675}{26} \cdot P \qquad R_{mult} := \frac{39.1675}{26} = 1.506$$

Table 3.6.1.1.2-1—Multiple Presence Factors, *m*

Number of Loaded Lanes	Multiple Presence Factors, *m*
1	1.20
2	1.00
3	0.85
>3	0.65

[AAHSTO LRFD Table 3.6.1.1.2-1]

$$m_1 := 1.20$$
$$m_2 := 1.00$$
$$m_3 := 0.85$$

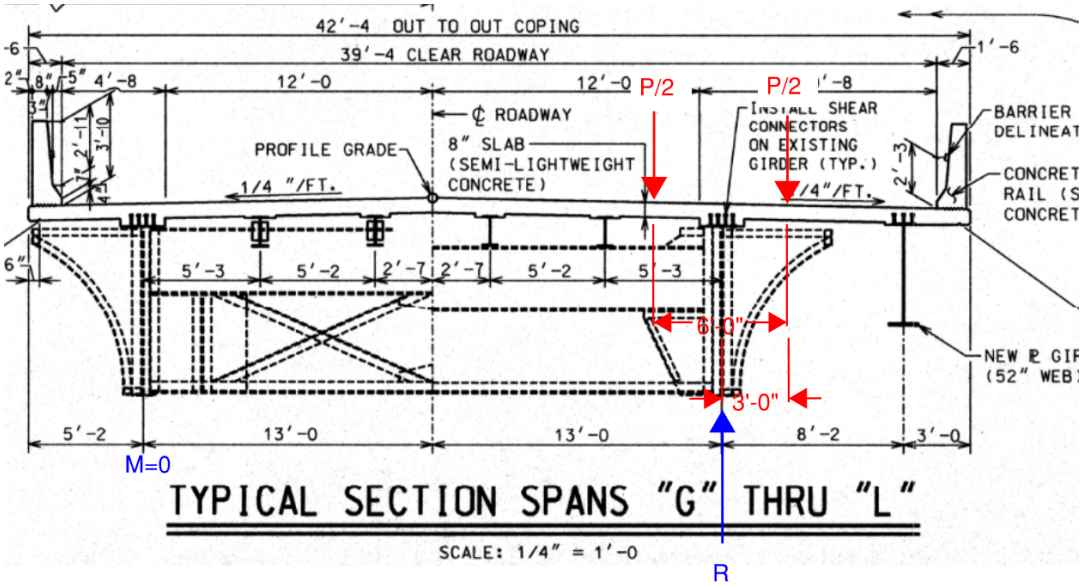
$$DF_{Multiple_CaseIII} := R_{mult} \cdot m_3 = 1.28$$

Controlling Case:

$$DF_{Multiple} := \max\left(DF_{Multiple_CaseI}, DF_{Multiple_CaseII}, DF_{Multiple_CaseIII}\right) = 1.436$$

Non-Commercial Use Only

Single Lane Loaded



LLDF of the right girder, ignoring all action of the additional girder

$$26 \cdot R = 29 \cdot \frac{P}{2} + 23 \cdot \frac{P}{2}$$

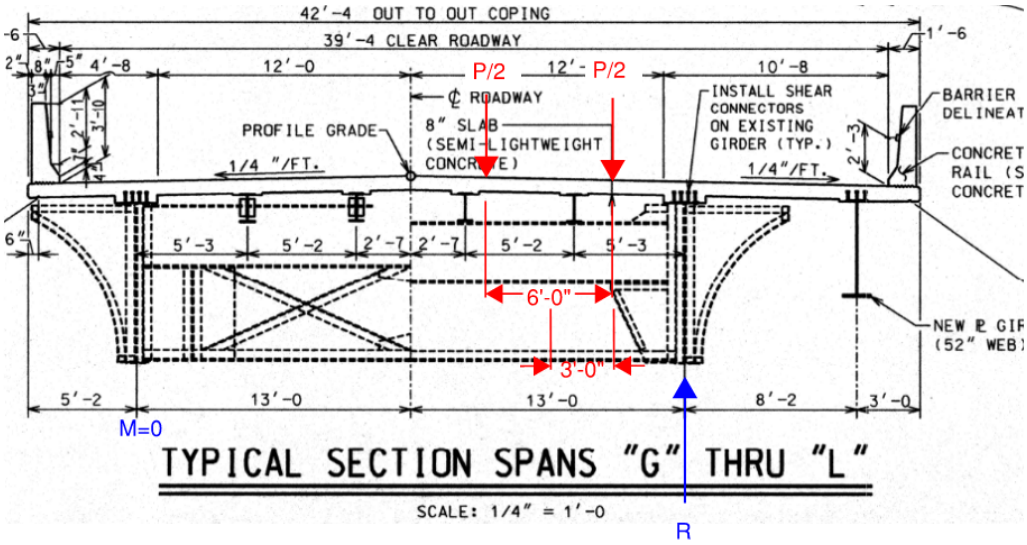
$$26 \cdot R = \frac{29+23}{2} \cdot P \rightarrow 26 \cdot R = 26 \cdot P$$

$$R = \frac{26}{26} \cdot P \qquad R_{single} := \frac{26}{26} = 1$$

$$DF_{Single} := R_{single} \cdot m_1 = 1.2$$

Non-Commercial Use Only

Calculating LLDF of real case scenario with truck in right lane (for information only - not used for any calculations)



Right Girder (Moment about Left Girder)

$$26 \cdot R = 17 \cdot \frac{P}{2} + 23 \cdot \frac{P}{2}$$

$$26 \cdot R = \frac{17+23}{2} \cdot P \rightarrow 26 \cdot R = 20 \cdot P$$

$$R = \frac{20}{26} \cdot P \qquad R_{single_LG} := \frac{20}{26} = 0.769$$

Left Girder (Moment about Right Girder)

$$26 \cdot R = 3 \cdot \frac{P}{2} + 9 \cdot \frac{P}{2}$$

$$26 \cdot R = \frac{3+9}{2} \cdot P \rightarrow 26 \cdot R = 6 \cdot P$$

$$R = \frac{6}{26} \cdot P \qquad R_{single_RG} := \frac{6}{26} = 0.231$$

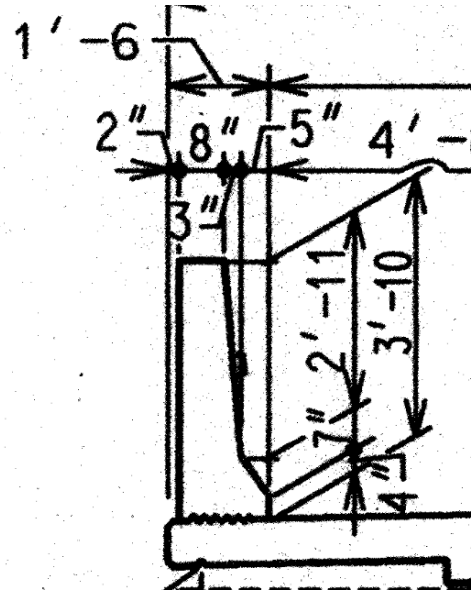
$$ratio := \frac{R_{single_LG}}{R_{single_RG}} = 3.333$$

LLDF of real case scenario with truck in left lane is same as compared to truck in right lane due to symmetry of driving lanes and girders

Non-Commercial Use Only

Dead Load Calculations:

Outside Barrier (No Railings)



Concrete Barrier Rail (Semi-Lightweight Concrete)

$A1 := (3\ ft + 10\ in) \cdot 8\ in = 2.556\ ft^2$
$A2 := 3\ in \cdot (2\ ft + 11\ in) \cdot 0.5 = 0.365\ ft^2$
$A3 := 7\ in \cdot 5\ in \cdot 0.5 = 0.122\ ft^2$
$A4 := 3\ in \cdot 11\ in = 0.229\ ft^2$
$A5 := 4\ in \cdot 5\ in = 0.139\ ft^2$

$A_{Total_Barrier} := A1 + A2 + A3 + A4 + A5 = 3.41\ ft^2$

$w_{Class3} := 125\ \frac{lbf}{ft^3} = 0.125\ \frac{kip}{ft^3}$ Semi Lightweight Concrete

$DL_{Barrier} := A_{Total_Barrier} \cdot w_{Class3} = 0.426\ \frac{kip}{ft}$ Per Barrier

Barrier loads are split between the two main girders (conservative decision)

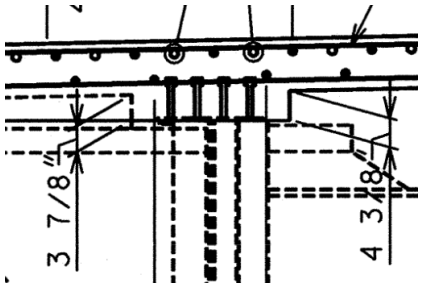
$Total_{Barrier\&Median} := \frac{DL_{Barrier} \cdot 2}{2} = 0.426\ \frac{kip}{ft}$ per girder

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Haunch

$$H_{Avg_Haunch} := \frac{3\ in + \frac{7}{8}\ in + 4\ in + \frac{3}{8}\ in}{2} = 4.125\ in$$

$W_{Haunch_G1} := 2\ ft$ *conservative estimate*

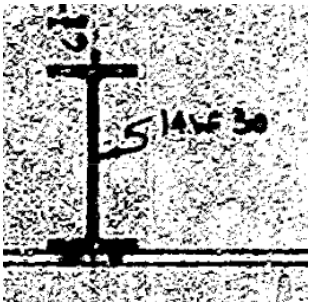


Stringers

Four stringers spaced at 5'-3", 5'-2", 5'-4", 5'-2", 5'-3"
14WF30 Stringer Sizes

Each primary girder (2) takes 2 stringer dead loads.

$w_{stringers} := 30\ plf + 30\ plf = 60\ plf$



Floor Beams

3 variations of floor beams (26LF) -> $L := 26\ ft$

- 33WF130 @ End of Panel
- 33WF141 @ Center of Panel and Piers 7 & 12
- 33WF160 @ Piers 8,9,10 & 11

BrR uses a distributed load to account for both the stringer and floor beam loads (DC1)
A total load will be divided by the full length of girder to get a representative distributed load

$\#33WF130 := 3 \cdot 2 + 4 \cdot 3 = 18$ $\quad w_{33WF130} := \#33WF130 \cdot L \cdot 130\ \frac{lbf}{ft} = 60.84\ kip$

$\#33WF141 := 5 \cdot 5 = 25$ $\quad w_{33WF141} := \#33WF141 \cdot L \cdot 141\ \frac{lbf}{ft} = 91.65\ kip$

$\#33WF160 := 4$ $\quad w_{33WF160} := \#33WF160 \cdot L \cdot 160\ \frac{lbf}{ft} = 16.64\ kip$

$W_{total_FB} := w_{33WF130} + w_{33WF141} + w_{33WF160} = 169.13\ kip$

$L_{girder} := (94\ ft + 11\ in) \cdot 2 + (125\ ft) \cdot 3 = 564.833\ ft$

$w_{FB} := \frac{W_{total_FB}}{L_{girder}} \cdot \frac{1}{2} = 0.1497\ \frac{kip}{ft}$ load split between two primary girders

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Additional Loads

BrR accounts for transverse stiffeners, outriggers, diagonal bracing, lateral bracing and knee bracing

Total Distributed Load to Primary Girder

$$w := w_{FB} + w_{stringers} = 0.21 \ \frac{kip}{ft}$$

Previous load rating used a value of 0.226 kip/ft, so 0.226 kip/ft was used for dead load calculations in BrR

Girders Load rating applied a 5% additional self load percentage

Cross Section Variations

Applicable to All Cross Section Variations:

- Member does not exhibit severe, corrosion, impact damage, or other forms of significant damage that affected the load rating
- Meets requirements of section 1.4 of the AASHTO IRM GSBSM unless otherwise noted
- Meets requirements of section 1.5 of the AASHTO IRM GSBSM unless otherwise noted

XSec-0 and XSec-00 -> Do not have tension or compression flange cover plate, so these locations fail requirements of section 1.5 of the AASHTO IRM GSBSM. Will not be analyzed for IRM compliance.

See XSec Variation Types spreadsheet for details of all the cross sectional variations of the girder

BrR Changes to previous load rating:

- Included 15% constant impact override per Sec 1.7.1 of the AASHTO IRM GSBSM
- Added Wearing Surface
- Removed SIP forms dead load
- Edited DC2 loads (barrier)
- Edited Cross Section Definitions -> Label, Effective Flange Width, Tributary Slab Width, Structural Thickness, and Concrete Slab Material

Other Factors:

- Rivets: All rivets are 7/8" with 15/16" holes.
- Splices: Subpunch holes 3/16" below nominal diameter and ream to size for all shop and field splices
- Girder are composite with the deck at locations where shear studs exist

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Effective stress calculation sample (SG6)

The data used for these calculations was collected using a 350 ohm weldable strain gages and processes using the rainflow method to collect cycles in a specific stress range (histogram). Miner's rule was then used to calculate the effective stress range. The following example shows the calculations associated with SG6, for calculations of remaining strain gages see the Histogram Data and Effective Stress Calculations Appendix.

$$\sigma_{range_avg_pre_trunc} := \begin{bmatrix} 0.375 \\ 0.75 \\ 1.25 \\ 1.75 \\ 2.25 \\ 2.75 \\ 3.25 \\ 3.75 \\ 4.25 \\ 4.75 \\ 5.25 \\ 5.75 \end{bmatrix} \qquad Cycles_{pre_trunc} := \begin{bmatrix} 155247 \\ 39908 \\ 34710 \\ 8723 \\ 2406 \\ 906 \\ 320 \\ 75 \\ 6 \\ 4 \\ 0 \\ 1 \end{bmatrix}$$

$$CAFL_{Cat_D} := 7\ ksi \qquad \frac{CAFL_{Cat_D}}{4} = 1.75\ ksi \qquad \frac{CAFL_{Cat_D}}{3} = 2.333\ ksi$$

Truncation Value = Minimum Stress Range used = 2.0

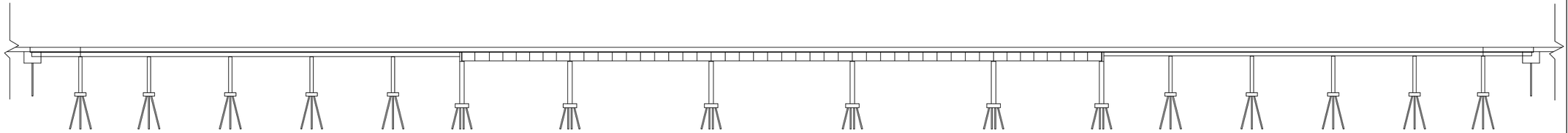
$$\sigma_{range_avg} := \begin{bmatrix} 2.25 \\ 2.75 \\ 3.25 \\ 3.75 \\ 4.25 \\ 4.75 \\ 5.25 \\ 5.75 \end{bmatrix} \qquad Cycles := \begin{bmatrix} 2406 \\ 906 \\ 320 \\ 75 \\ 6 \\ 4 \\ 0 \\ 1 \end{bmatrix} \qquad A := \overrightarrow{\sigma_{range_avg}{}^{3} \cdot Cycles} = \begin{bmatrix} 27405.844 \\ 18841.969 \\ 10985 \\ 3955.078 \\ 460.594 \\ 428.688 \\ 0 \\ 190.109 \end{bmatrix}$$

$$Cycles_{sum} := \sum Cycles = 3718 \qquad A_{sum} := \sum A = 62267.281$$

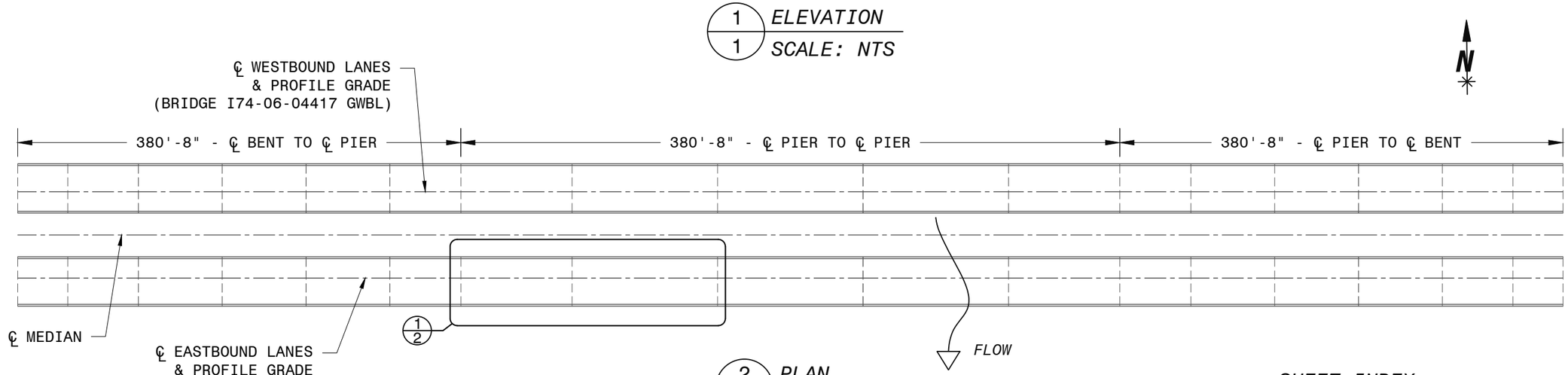
$$\sigma_{effective} := \sqrt[3]{\frac{A_{sum}}{Cycles_{sum}}} = 2.558$$

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Appendix 2E. As-Built Strain Gage Plan Set



1/1 *ELEVATION*
SCALE: NTS



2/1 *PLAN*
SCALE: NTS

GAGE LIST

GAGE LABEL	DETAIL	SPAN	GIRDER	LOCATION	FLOOR BEAM LOCATION	WIRE LENGTH
SG1	1/3	SPAN G	G1	BOT OF BOT FLANGE CP	WEST OF FB5	
SG2	1/3	SPAN G	G2	BOT OF BOT FLANGE CP	WEST OF FB5	
SG3	2/3	SPAN G	G1	BOT OF TOP FLANGE	BETWEEN FB6 AND FB7	
SG4	2/3	SPAN G	G2	BOT OF TOP FLANGE	BETWEEN FB6 AND FB7	
SG5	2/3	SPAN G	G2	BOT OF BOT FLANGE CP	BETWEEN FB6 AND FB7	
SG6	3/3	SPAN H	G1	BOT OF BOT FLANGE CP	BETWEEN FB13 AND FB14	
SG7	3/3	SPAN H	G2	BOT OF BOT FLANGE CP	BETWEEN FB13 AND FB14	
SG8	4/3	SPAN H	G1	BOT OF BOT FLANGE	FB16	
SG9	4/3	SPAN H	G2	BOT OF TOP FLANGE	FB16	
SG10	4/3	SPAN H	G2	BOT OF BOT FLANGE	FB16	
SG11	1/4	SPAN H	G1	BOT OF TOP FLANGE	WEST OF FB18/PIER 9	
SG12	1/4	SPAN H	G2	BOT OF TOP FLANGE	WEST OF FB18/PIER 9	
SG13	1/4	SPAN H	G2	BOT OF BOT FLANGE CP	WEST OF FB18/PIER 9	

GENERAL NOTES

STRAIN GAGE LOCATIONS ARE APPROXIMATE AND CAN BE MODIFIED IN THE FIELD, PER ENGINEERS DIRECTION.

GAGES TO BE USED CONSIST OF THE 350 OHM WELDABLE STRAIN GAGES (LWK-06-W250B-350) USING THE GRANITE 9 LOGGER SYSTEM

SHEET INDEX

SHEET NUMBER	SHEET NAME
1	BRIDGE GENERAL PLAN AND ELEVATION
2	FRAMING PLAN AND TYPICAL SECTION WITHIN SPANS "G" THRU "L"
3	GAGE DETAILS ON MAIN GIRDERS
4	GAGE DETAILS ON MAIN GIRDERS - CONTINUED
5	STRAIN GAGE LOGGER WORK BOX LOCATION

ABREVIATIONS

BOT - BOTTOM
℄ - CENTER LINE
CP - COVER PLATE
FB - FLOOR BEAM
G - GIRDER
NO. - NUMBER
NTS - NOT TO SCALE
℔ - PLATE
SG - STRAIN GAGE
SPA - SPACES
TYP - TYPICAL

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PROJECT:
SPR 4631
SRM/IRM
BRIDGE ID:
I74-06-04417

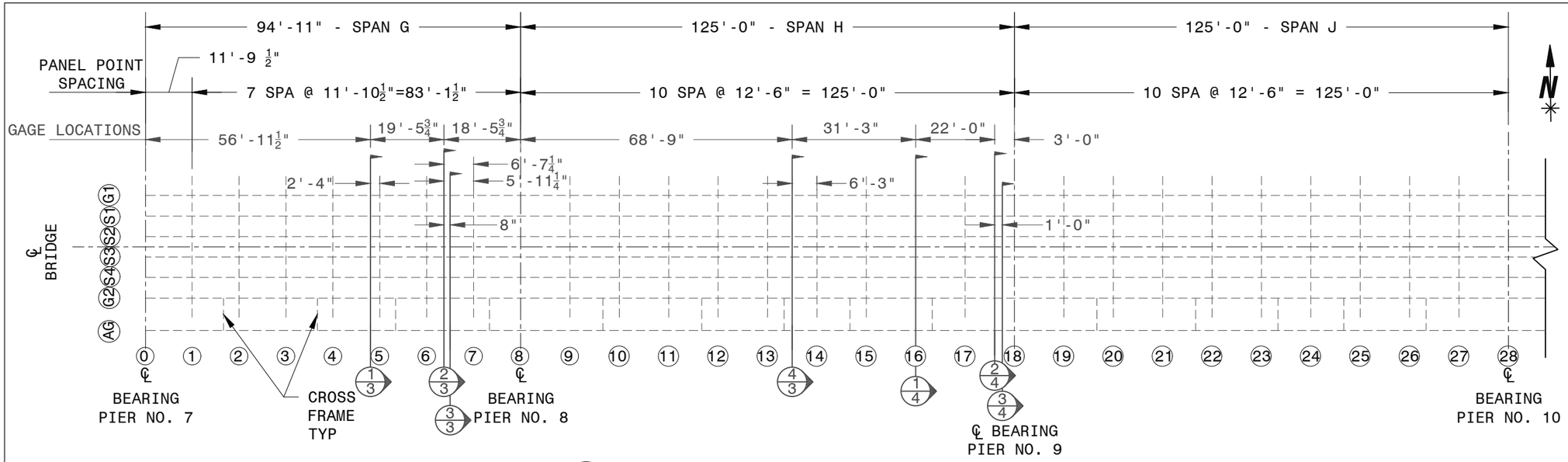
SHEET NOTES:

REVISIONS:

NO.	DATE	BY

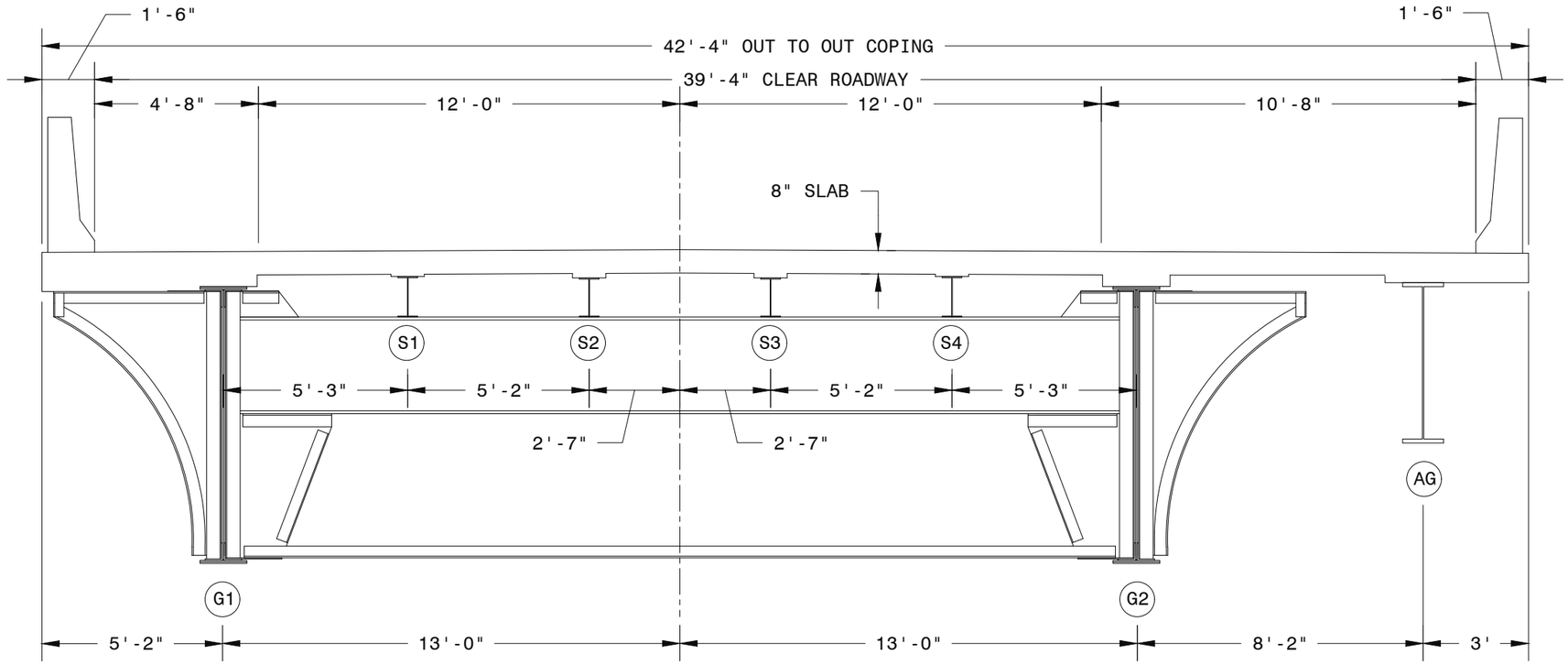
DESIGNED BY: CJK
DRAWN BY: CJK
CHECKED BY: RJC
DATE: JANUARY 2023
PROJECT NO.: SPR-4631
SHEET TITLE:
BRIDGE GENERAL PLAN AND ELEVATION

SHEET NO.: 1 of 5



1/2 *PARTIAL FRAMING PLAN OF BRIDGE*

SCALE: NTS



2/2 *TYPICAL SECTION WITHIN SPANS "G" THRU "L"*

SCALE: NTS

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PROJECT:
SPR 4631
SRM/IRM
BRIDGE ID:
I74-06-04417

SHEET NOTES:

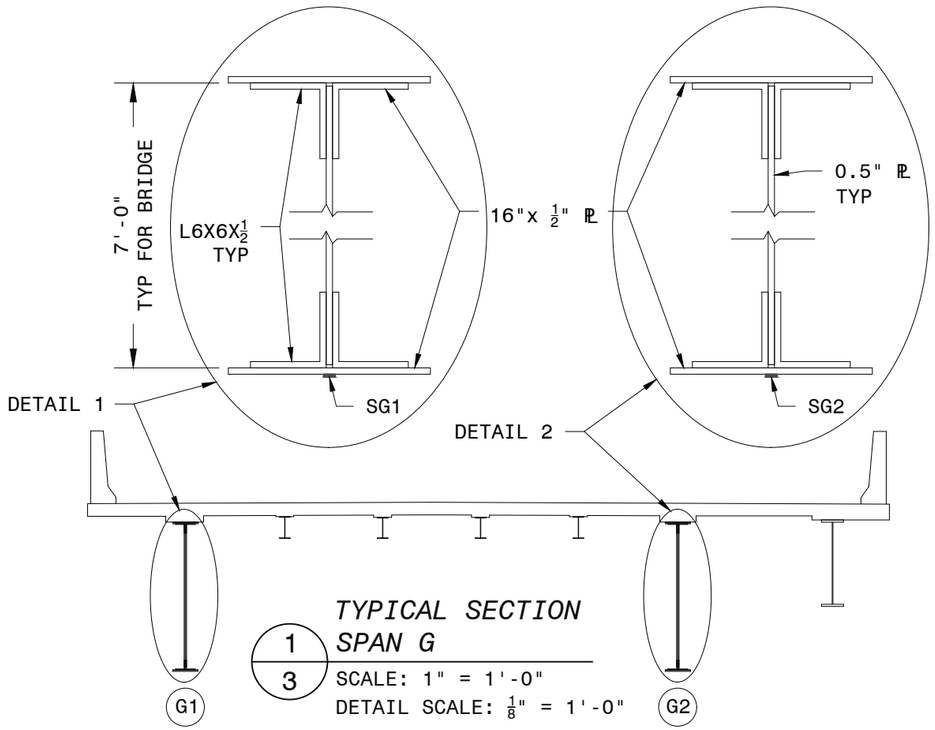
REVISIONS:

NO.	DATE	BY

DESIGNED BY:	CJK
DRAWN BY:	CJK
CHECKED BY:	RJC
DATE:	AUGUST 2022
PROJECT NO.:	SPR-4631

SHEET TITLE:
FRAMING PLAN AND TYPICAL SECTION WITHIN SPANS "G" THRU "L"

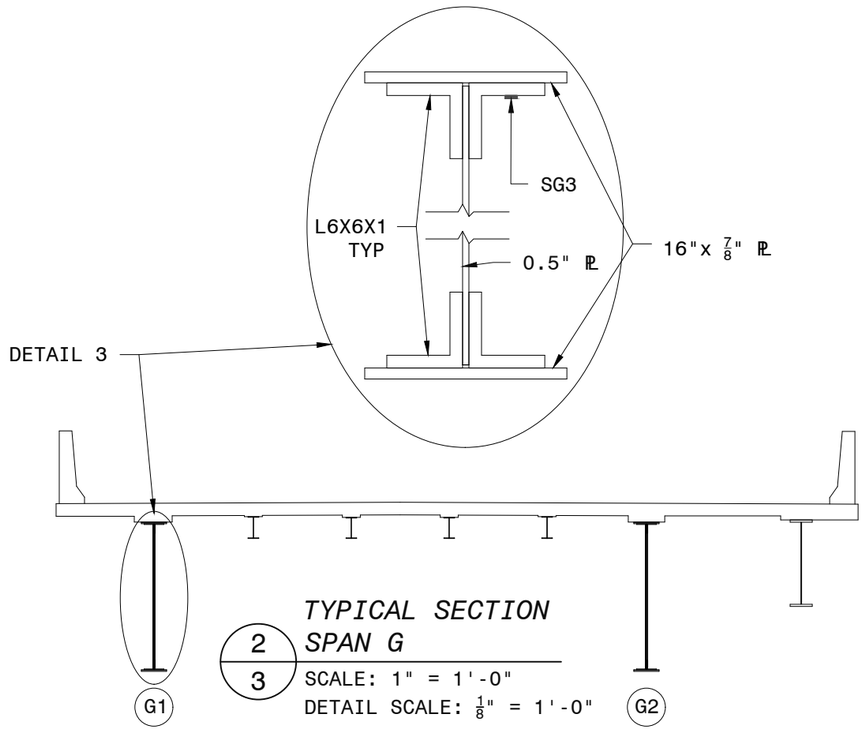
SHEET NO.: 2 of 5



TYPICAL SECTION
SPAN G

1/3

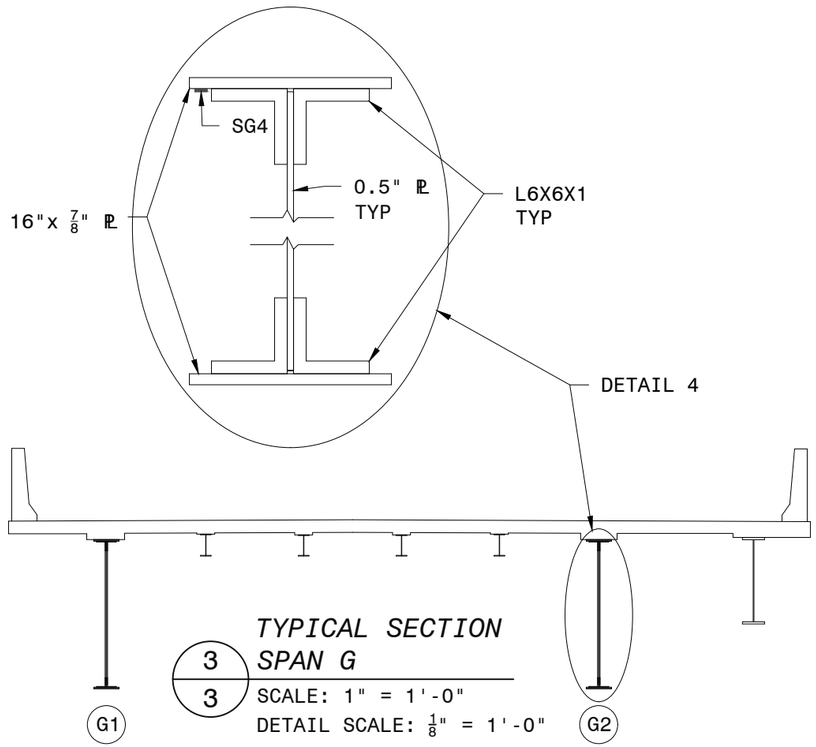
SCALE: 1" = 1'-0"
DETAIL SCALE: ⅛" = 1'-0"



TYPICAL SECTION
SPAN G

2/3

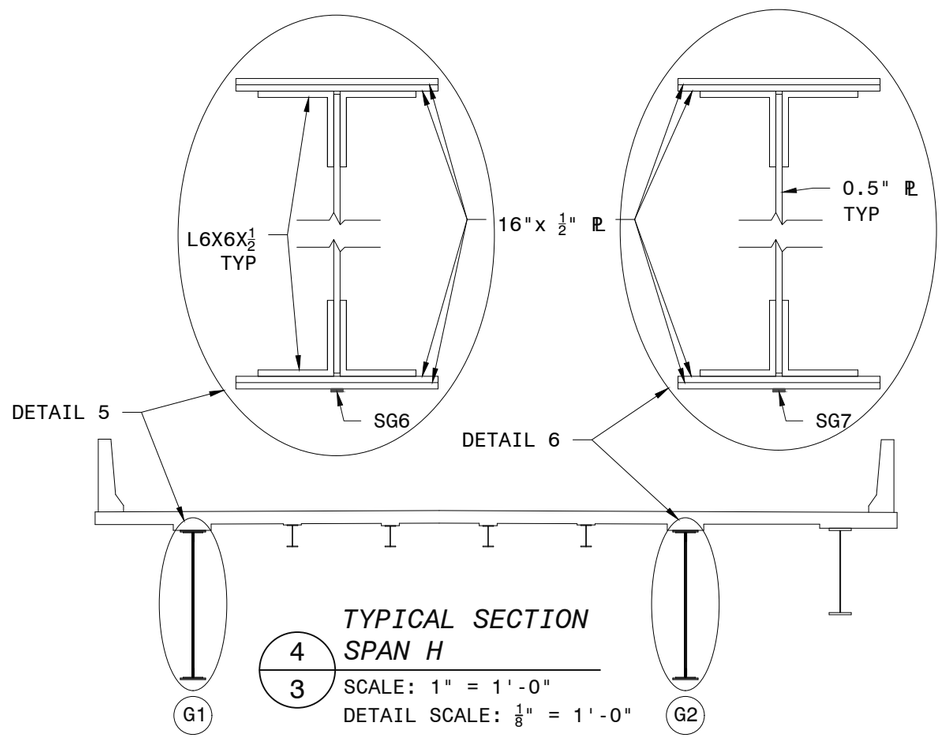
SCALE: 1" = 1'-0"
DETAIL SCALE: ⅛" = 1'-0"



TYPICAL SECTION
SPAN G

3/3

SCALE: 1" = 1'-0"
DETAIL SCALE: ⅛" = 1'-0"



TYPICAL SECTION
SPAN H

4/3

SCALE: 1" = 1'-0"
DETAIL SCALE: ⅛" = 1'-0"

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PROJECT:

SPR 4631
SRM/IRM

BRIDGE ID:
I74-06-04417

SHEET NOTES:

1. STRAIN GAGES ARE NOT TO SCALE
2. SG# REPRESENTS THE STRAIN GAGE NUMBER
3. ▬ REPRESENTS THE APPROXIMATE STRAIN GAGE LOCATION

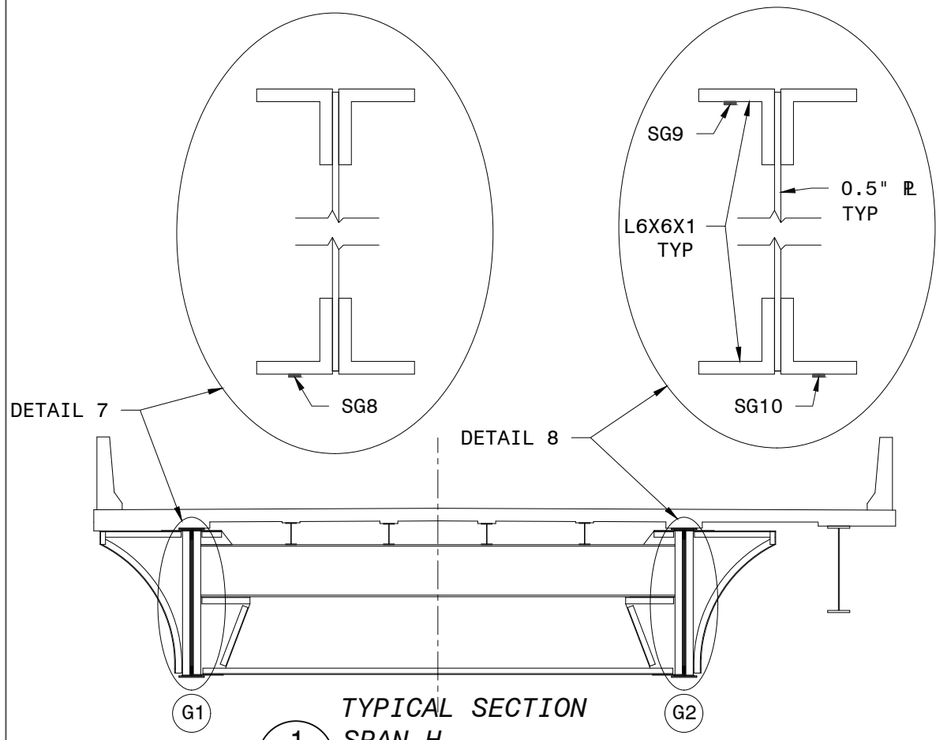
REVISIONS:

NO.	DATE	BY

DESIGNED BY: CJK
DRAWN BY: CJK
CHECKED BY: RJC
DATE: AUGUST 2022
PROJECT NO.: SPR-4631

SHEET TITLE:
GAGE DETAILS ON MAIN GIRDERS

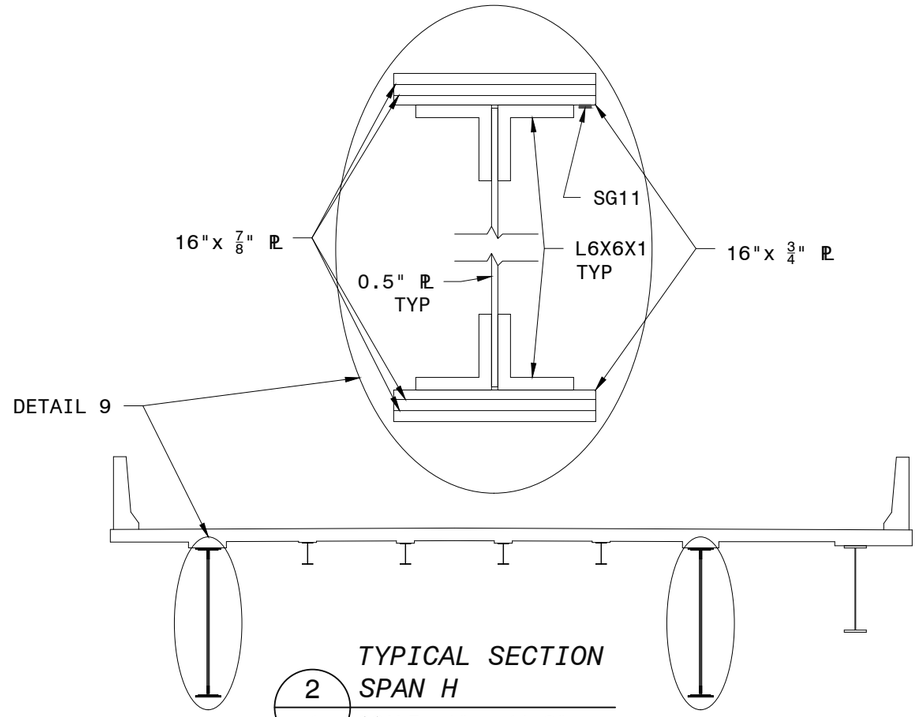
SHEET NO.: 3 of 5



1/4 *TYPICAL SECTION SPAN H*

SCALE: 1" = 1'-0"

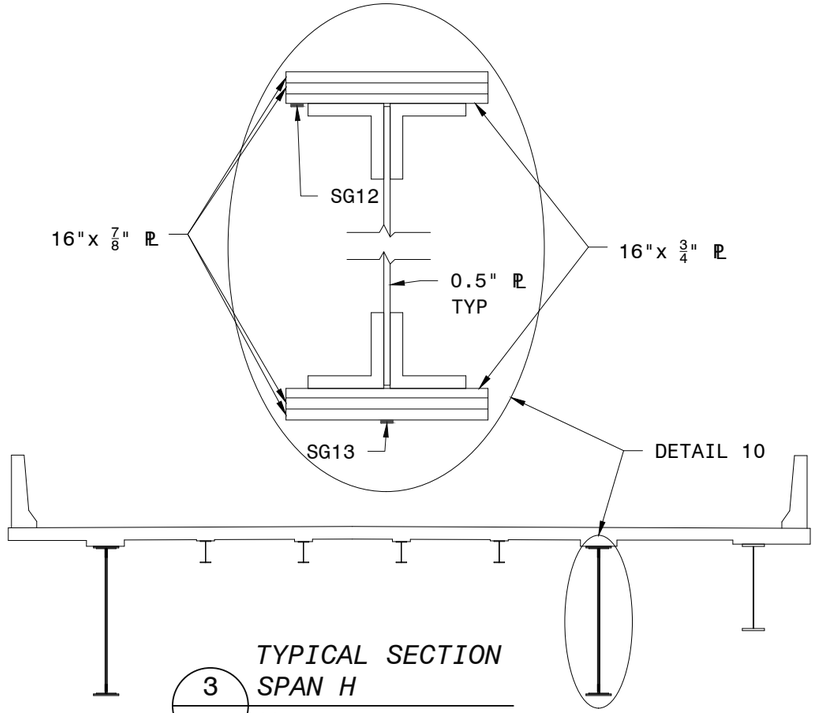
DETAIL SCALE: 1/8" = 1'-0"



2/4 *TYPICAL SECTION SPAN H*

SCALE: 1" = 1'-0"

DETAIL SCALE: 1/8" = 1'-0"



3/4 *TYPICAL SECTION SPAN H*

SCALE: 1" = 1'-0"

DETAIL SCALE: 1/8" = 1'-0"

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PROJECT:

SPR 4631
SRM/IRM

BRIDGE ID:
I74-06-04417

SHEET NOTES:

1. STRAIN GAGES ARE NOT TO SCALE
2. SG# REPRESENTS THE STRAIN GAGE NUMBER
3. ▬ REPRESENTS THE APPROXIMATE STRAIN GAGE LOCATION
4. FASTENERS NOT SHOWN FOR CLARITY

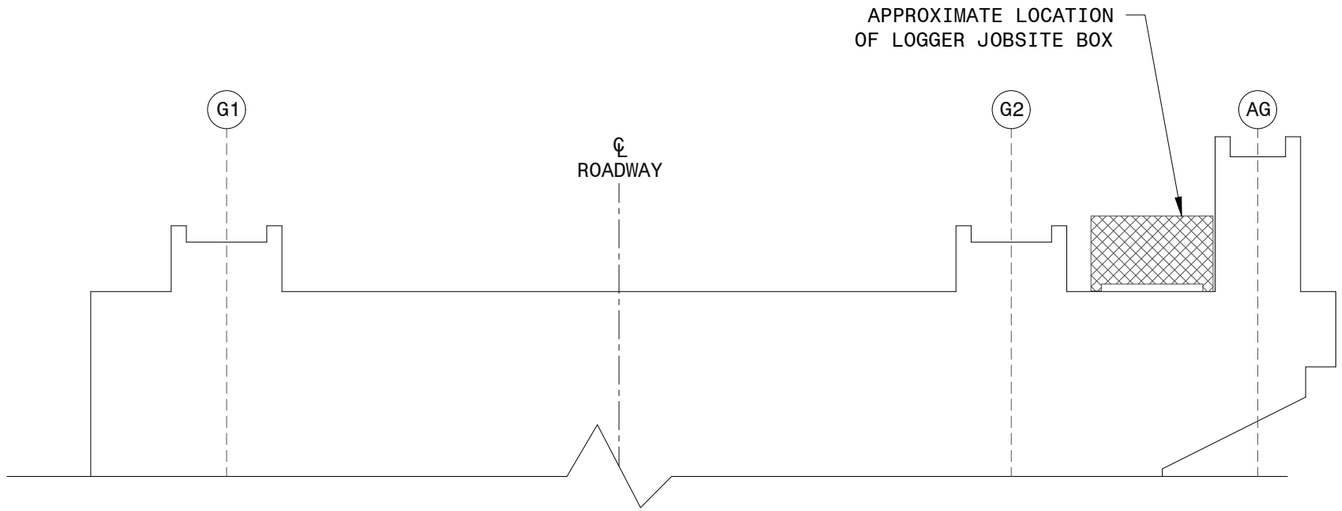
REVISIONS:

NO.	DATE	BY

DESIGNED BY:	CJK
DRAWN BY:	CJK
CHECKED BY:	RJC
DATE:	AUGUST 2022
PROJECT NO.:	SPR-4631

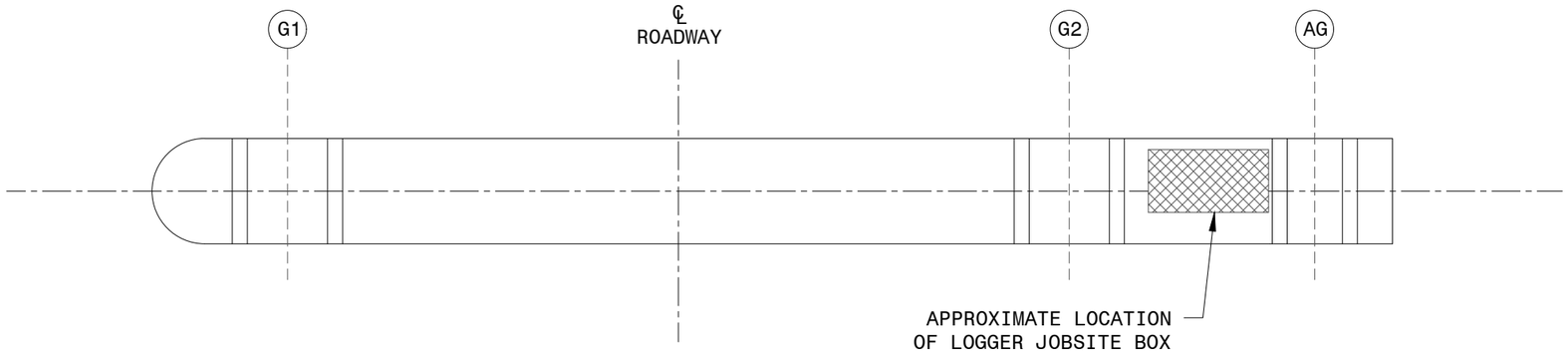
SHEET TITLE:

GAGE DETAILS ON MAIN GIRDERS - CONTINUED



1/5 *PARTIAL ELEVATION @ PIER 8*

SCALE: NTS



2/5 *CAP PLAN @ PIER 8*

SCALE: NTS

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BRIDGE ID:
I74-06-04417

SHEET NOTES:

REVISIONS:

NO.	DATE	BY

DESIGNED BY:	CJK
DRAWN BY:	CJK
CHECKED BY:	RJC
DATE:	AUGUST 2022
PROJECT NO.:	SPR-4631

SHEET TITLE:
STRAIN GAGE LOGGER
WORK BOX LOCATION

SHEET NO.: 5 of 5

Appendix 2F. Histogram Data and Effective Stress Calculations

Raw Data

Average Stress Range	Stress Range	Cycles												
		SG 1	SG 2	SG 3	SG 4	SG 5	SG 6	SG 7	SG 8	SG 9	SG 10	SG 11	SG 12	SG 13
0.375	0.25 -> 0.5	205218	244495	35215	50693	71926	155247	154340	201412	66901	239594	9196	128174	85441
0.75	0.5 -> 1.0	43503	30859	2079	47576	48054	39908	29861	40054	36328	57181	147	48594	47078
1.25	1.0 -> 1.5	23194	21960	1	32851	20526	34710	24460	30712	39674	19730	0	216	11189
1.75	1.5 -> 2.0	25702	13937	0	319	258	8723	25523	18302	11069	15655	0	11	155
2.25	2.0 -> 2.5	2127	27687	0	3	9	2406	1224	2438	264	23794	0	0	14
2.75	2.5 -> 3.0	1982	2709	0	0	0	906	181	1440	15	1451	0	0	3
3.25	3.0 -> 3.5	559	393	0	0	0	320	12	401	0	265	0	0	0
3.75	3.5 -> 4.0	231	94	0	0	0	75	0	132	0	24	0	0	0
4.25	4.0 -> 4.5	73	18	0	0	0	6	1	16	0	2	0	0	0
4.75	4.5 -> 5.0	3	1	0	0	0	4	0	2	0	0	0	0	0
5.25	5.0 -> 5.5	2	1	0	0	0	0	0	3	0	1	0	0	0
5.75	5.5 -> 6.0	2	0	0	0	0	1	0	1	0	0	0	0	0

Min Stress Range: **2.0**

Truncated Data

		SG 1		SG 2		SG 3		SG 4		SG 5		SG 6		SG 7	
	Distance from Pier 7	56.95		56.95		76.43		77.1		77.1		163.67		163.67	
	Descriptor	Specific Cross Section Check				Near Inflection Area						Near Max Positive Moment Region			
	XSec Type	XSec-1		XSec-1		XSec-00		XSec-3		XSec-3		XSec-2		XSec-2	
	Shear Studs	No		No		No		No		No		Yes		Yes	
		Bot Flange		Bot Flange		Top Flange		Top Flange		Bot Flange		Bot Flange		Bot Flange	
Average Stress	Girder	Left Girder		Right Girder		Left Girder		Right Girder		Right Girder		Left Girder		Right Girder	
Range	Stress Range	Cycles													
0.375	0.25 -> 0.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
0.75	0.5 -> 1.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1.25	1.0 -> 1.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1.75	1.5 -> 2.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2.25	2.0 -> 2.5	2127	24227.86	27687	315372.23	0	0.00	3	34.17	9	102.52	2406	27405.84	1224	13942.13
2.75	2.5 -> 3.0	1982	41219.41	2709	56338.73	0	0.00	0	0.00	0	0.00	906	18841.97	181	3764.23
3.25	3.0 -> 3.5	559	19189.42	393	13490.95	0	0.00	0	0.00	0	0.00	320	10985.00	12	411.94
3.75	3.5 -> 4.0	231	12181.64	94	4957.03	0	0.00	0	0.00	0	0.00	75	3955.08	0	0.00
4.25	4.0 -> 4.5	73	5603.89	18	1381.78	0	0.00	0	0.00	0	0.00	6	460.59	1	76.77
4.75	4.5 -> 5.0	3	321.52	1	107.17	0	0.00	0	0.00	0	0.00	4	428.69	0	0.00
5.25	5.0 -> 5.5	2	289.41	1	144.70	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
5.75	5.5 -> 6.0	2	380.22	0	0.00	0	0.00	0	0.00	0	0.00	1	190.11	0	0.00
6.25	6.0 -> 6.5	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
	Sum	4979	103413.3594	30903	391792.6094	0	0	3	34.17188	9	102.515625	3718	62267.28125	1418	18195.0625

Effective Stress	**2.75**	ksi	**2.33**	ksi	**#DIV/0!**	ksi	**2.25**	ksi	**2.25**	ksi	**2.56**	ksi	**2.34**
BrR Effective Stress (Unfaulted)	6.15	ksi	6.15	ksi	6.13	ksi	3.90	ksi	4.03	ksi	5.29	ksi	5.29
Ratio Fatigue Truck vs In-Situ Data	**0.447**		**0.379**		**#DIV/0!**		**0.577**		**0.558**		**0.483**		**0.442**
Data Collection Period (days)	27.2	days	27.4	days	26.5	days	25.4	days	27.2	days	23.0	days	24.2
Cycles per day	182.8		1128.9		0.0		0.1		0.3		161.6		58.7
A value	3796.92		14312.06		#DIV/0!		1.35		3.76		2705.64		753.33

Truncated Data

		SG 8		SG 9		SG 10		SG 11		SG 12		SG 13	
	Distance from Pier 7	194.92		194.92		194.92		216.92		217.92		217.92	
	Descriptor	Near Inflection Area						Near Max Negative Moment Region					
	XSec Type	XSec-00		XSec-00		XSec-00		XSec-5		XSec-5		XSec-5	
	Shear Studs	No (@ edge)		No (@ edge)		No (@ edge)		No		No		No	
		Bot Flange		Top Flange		Bot Flange		Top Flange		Top Flange		Bot Flange	
Average Stress	Girder	Left Girder		Right Girder		Right Girder		Left Girder		Right Girder		Right Girder	
Range	Stress Range	Cycles											
0.375	0.25 -> 0.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
0.75	0.5 -> 1.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1.25	1.0 -> 1.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1.75	1.5 -> 2.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2.25	2.0 -> 2.5	2438	27770.34	264	3007.13	23794	271028.53	0	0.00	0	0.00	14	159.47
2.75	2.5 -> 3.0	1440	29947.50	15	311.95	1451	30176.27	0	0.00	0	0.00	3	62.39
3.25	3.0 -> 3.5	401	13765.58	0	0.00	265	9096.95	0	0.00	0	0.00	0	0.00
3.75	3.5 -> 4.0	132	6960.94	0	0.00	24	1265.63	0	0.00	0	0.00	0	0.00
4.25	4.0 -> 4.5	16	1228.25	0	0.00	2	153.53	0	0.00	0	0.00	0	0.00
4.75	4.5 -> 5.0	2	214.34	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
5.25	5.0 -> 5.5	3	434.11	0	0.00	1	144.70	0	0.00	0	0.00	0	0.00
5.75	5.5 -> 6.0	1	190.11	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
6.25	6.0 -> 6.5	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
	Sum	4433	80511.17188	279	3319.078125	25537	311865.6094	0	0	0	0	17	221.859375

Effective Stress	**2.63**	ksi	**2.28**	ksi	**2.30**	ksi	**#DIV/0!**	ksi	**#DIV/0!**	ksi	**2.35**	ksi
BrR Effective Stress (Unfaulted)	6.79	ksi	6.71	ksi	6.79	ksi	1.99	ksi	2.01	ksi	2.15	ksi
Ratio Fatigue Truck vs In-Situ Data	**0.387**		**0.340**		**0.339**		**#DIV/0!**		**#DIV/0!**		**1.093**	
Data Collection Period (days)	27.2	days	34.6	days	27.2	days	24.4	days	34.7	days	24.0	days
Cycles per day	162.8		8.1		940.0		0.0		0.0		0.7	
A value	2956.05		95.93		11479.72		#DIV/0!		#DIV/0!		9.24	

Notes:
- For sample effective stress calculation see Appendix D
- Stress ranges acquired from AASHTO Fatigue Truck for the top of a girder were adjusted/calculated to show stress ranges for the bottom of the top angle

Appendix 2G. NSTM/IRM Inspection Plan for Structures I-74-06-04417 FEBL and GWBL Over the Wabash River

1. INTRODUCTION

This document was prepared as an appendix to the *Evaluation of the Redundancy Status of Structures I-74-06-04417 FEBL and GWBL Over Wabash River*, but also serves as a standalone document for the inspection plan for main spans of the aforementioned structures. The structure consists of two side-by-side twin bridges with 5 main span units that are individually carried by two riveted built-up steel plate girders and 12 approach spans. The continuous main spans do not have a skew and are on a tangent alignment. It was originally built in 1958 and has had several rehabilitations and repairs completed. A brief description of the bridge attributes can be found in Table 2G.1.

Table 2G.1 Bridge details

Attribute (NBI Code)	Value
Bridge Name	I74-06-04417 FEBL and GWBL
Structure Number (8)	043830 and 048320
State Name (1)	18 - Indiana
County Name (3)	083 - Vermillion
Features Intersected (6A)	Wabash River
Facility Carried By Structure (7)	I-74 EB and WB
Location (9)	02.38 E SR 63
Latitude, (16)	40.12209
Longitude, (17)	-87.40686
Year Built (27)	1958
Main Span Material (43A)	4 - Steel Continuous
Main Span Design (43B)	3 - Girder and Floorbeam System
Number of Spans in Main Unit (45)	5
Number of Approach Spans (46)	12
Bridge Posting Code (70)	5 - Equal to or above legal loads

Previous to the internally redundant member (IRM) evaluation, the full length of the main girders was considered a non-redundant steel tension member (NSTM) and thus was subjected to hands-on and arm's length field inspection at a maximum interval not to exceed 2 years.

The bridge has been evaluated using the procedures outlined in the AASHTO Guide Specifications for Internal Redundancy of Mechanically-Fastened Built-Up Steel Members (IRM Guide Specifications) adopted in 2018 (AASHTO, 2018a). The evaluation demonstrated that 79% of the main girders may be reclassified as internally redundant members and receive a Special Inspection frequency of not to exceed 10 years. In the context of the IRM Guide Specifications, a Special Inspection is defined as:

> *In the specific context of these Guide Specifications, a (Special Inspection) is an inspection of sufficient depth to reliably detect severed or fractured components and other conditions deemed important in a member identified as an IRM. To meet the objectives of the Special Inspection for IRMs, it is understood that special access equipment may be required for some bridges, while for others it may be possible to reliably detect broken components from the ground using normal visual inspection techniques.*

It is noted that routine safety inspection intervals are not affected.

The remaining 21% of the main girders did not pass the checks due to lack of cover plates or having unmitigated damage. This document will adapt the findings of the IRM evaluation to propose a specific inspection plan that will modify the existing inspection plan that was been implemented when the members were classified as NSTMs (formerly FCMs).

It should be mentioned that the girder areas specified in this appendix are for one half (longitudinally) of the symmetrical superstructures. Therefore, the inspection scope and frequencies shall be extrapolated to the other half of the superstructure in addition to both main girders of both twin superstructures (4 total girders).

2. INSPECTION SCOPE AND FREQUENCY

The areas of the main girders that are not reclassified as IRMs should continue to be inspected as NSTMs which includes hands-on and arm's length field inspections every two years. The most recent NSTM inspection was conducted in 2022, so the next inspection will be conducted in 2024 and so forth. These NSTM areas are included in Table 2G.2.

Table 2G.2 Areas to remain with NSTM designation

Span	Section	Location Start (from Support)	Location Stop (from Support)	Distance Start (from Pier 7)	Distance Stop (from Pier 7)	Length	Notes
		ft	ft	ft	ft	ft	
G	XSec-0/Xsec-00	63.00	76.92	63	76.92	13.92	No Cover Plate*
H	XSec-00/Xsec-0	17.00	33.00	111.92	127.92	16.00	No Cover Plate*
H	XSec-0/Xsec-00	91.00	106.00	185.92	200.92	15.00	No Cover Plate*
J	XSec-00/Xsec-0	19.00	33.00	238.92	252.92	14.00	No Cover Plate*
J	XSec-2	79.50	81.50	299.42	301.42	2.00	Unmitigaged damage**

*Bridge is symmetric about midspan of Span J, thus all points can be correlated accordingly

**North girder on bridge GWBL at span J between FB 7-8 exhibits unmitigated damage due (see "wave" in inspection report)

The remaining areas of the girder may be inspected as IRMs during a Special Inspection (SI) conducted every 10 years from 2021 (last NSTM inspection).

The IRM Guide Specification (AASHTO, 2018a) states that within a distance of 1.5D from the end of the girder, where D is the depth of the web plate, the member need not be evaluated as an IRM since the moment and moment range in the girder is very low at such locations. For these girders, the region within the length of 1.5D includes all the areas without cover plates immediately adjacent to Pier 7 and 12, thus these areas can be considered as IRMs.

The purpose of the SI is to identify whether any of the tension components have failed. The IRM Guide Specifications defines the process to have "sufficient depth to reliably detect a severed component and other conditions deemed important in a member deemed as an IRM. To meet the objectives of the Special Inspection for IRMs, it is understood that special access equipment may be required for some bridges, while for others it may be possible to reliably detect broken components from the ground using normal visual inspection techniques." For efficiency, the snooper used for the arm's length inspections could be used to "glide" along the girder and complete the IRM SI during the same visit.

The following figures graphically display the areas to be inspected as NSTMs (blue) and IRMs (green).

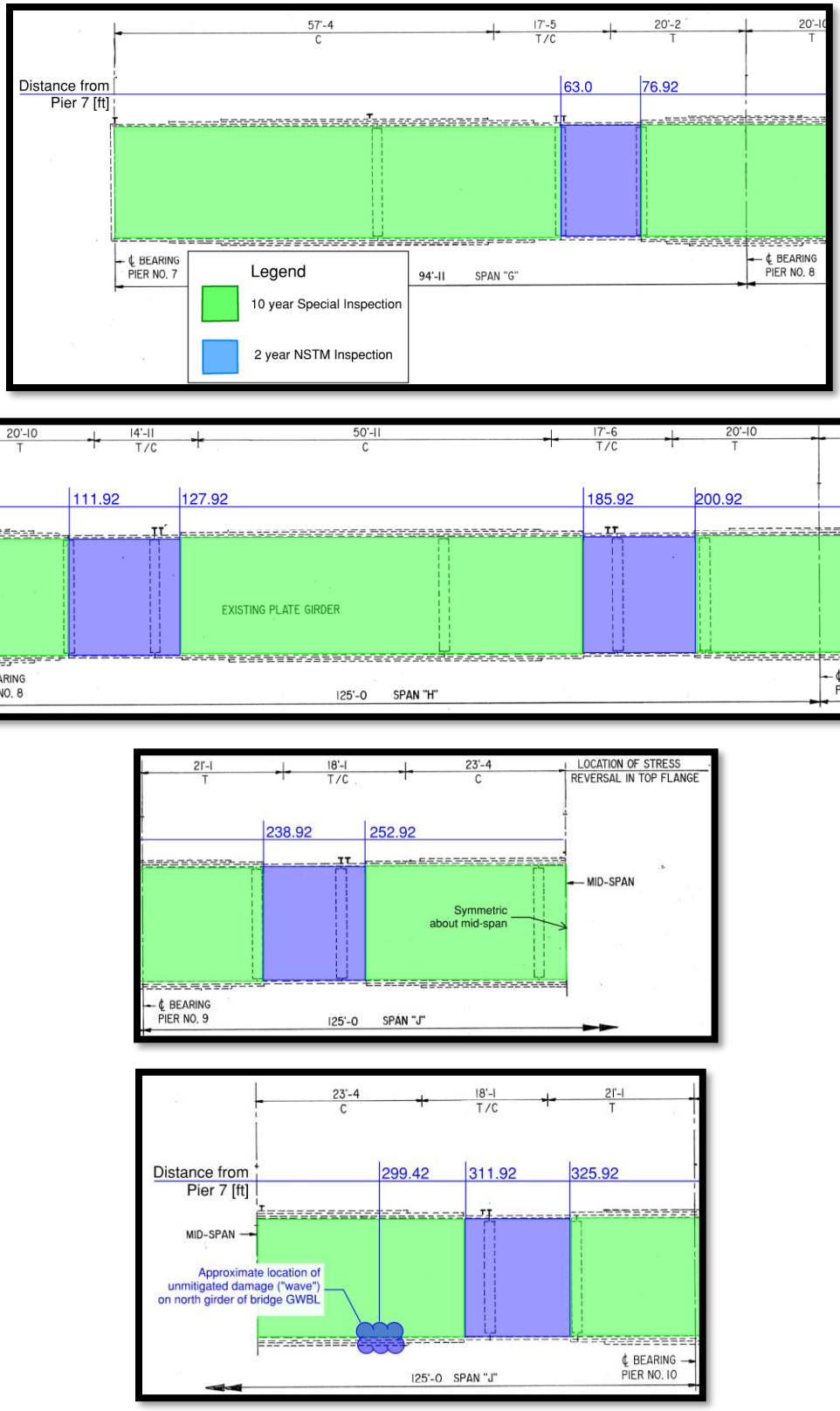


Figure 2G.1 Elevation view of bridge depicting IRM (green) and NSTM (blue) areas, Spans G, H and J.

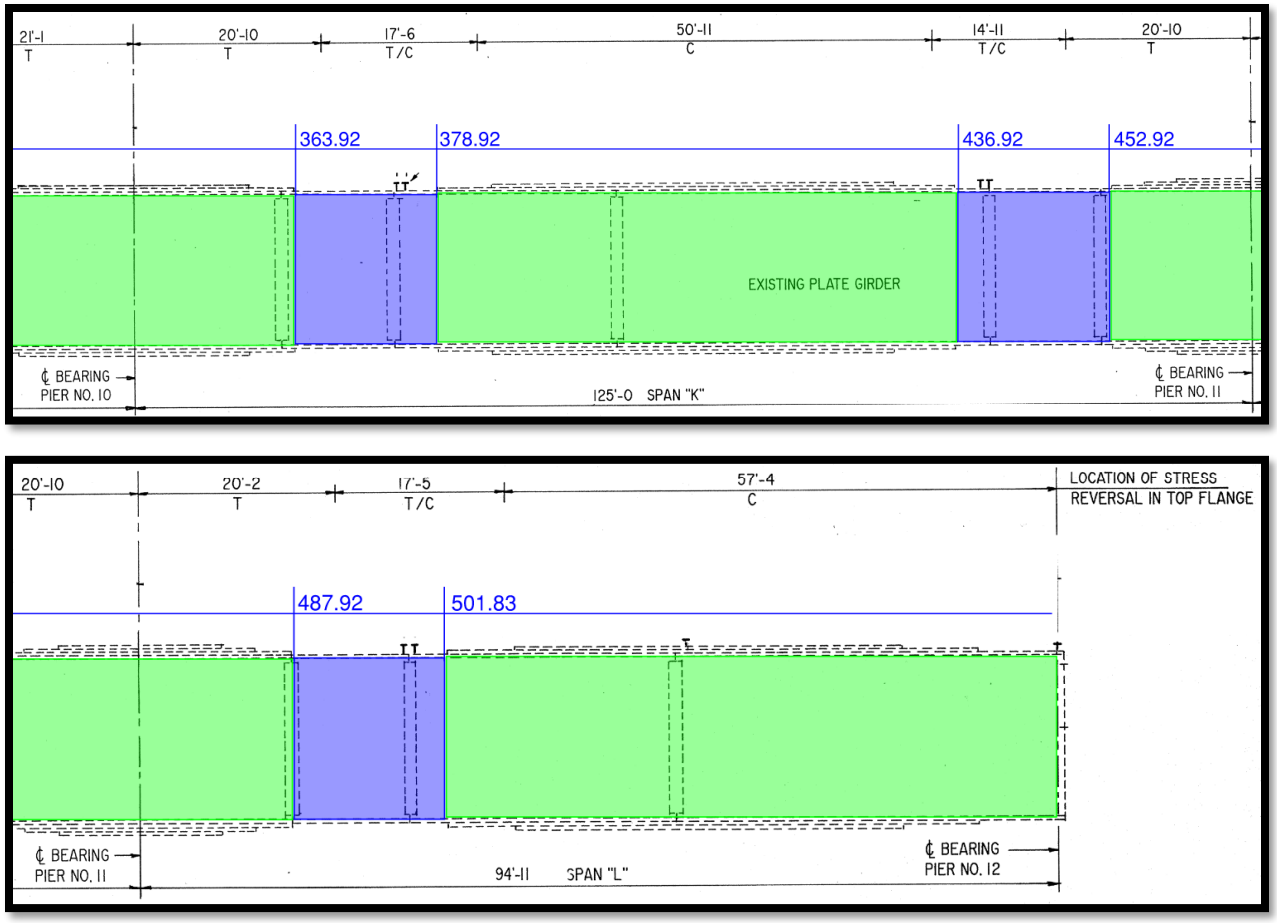


Figure 2G.2 Elevation view of bridge depicting IRM (green) and NSTM (blue) areas, Spans K and L.

3. FUTURE INSPECTIONS AND EVALUATIONS

The current inspections scheduled for this bridge include a Fracture Critical, Routine and Underwater. Following this evaluation an additional Special Inspection would be added to inspect the IRM members. Additionally, the Fracture Critical inspection would be relabeled as a NSTM inspection and the areas to be inspected would be changed as depicted in Figure 2G.1 and Figure 2G.2. Assuming current bridge conditions remained unchanged, the timeline of these inspections is depicted in the Table 2G.3. Items that could affect the given schedule include but are not limited to change in live loads due to changes in traffic patterns or uses and changes in condition of structure such as corrosion significant to require load posting, cracking, or damage due to vehicle impact in primary members.

Table 2G.3 Inspection schedule

		Frequency	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Inspection Type	Routine	24 months	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
	NSTM	24 months	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
	Special (IRM)	10 years	N/A	No	No	No	No	No	No	No	No	No	Yes	No	No	No	No
	Underwater	60 months	No	No	No	No	Yes	No	No	No	No	Yes	No	No	No	No	Yes

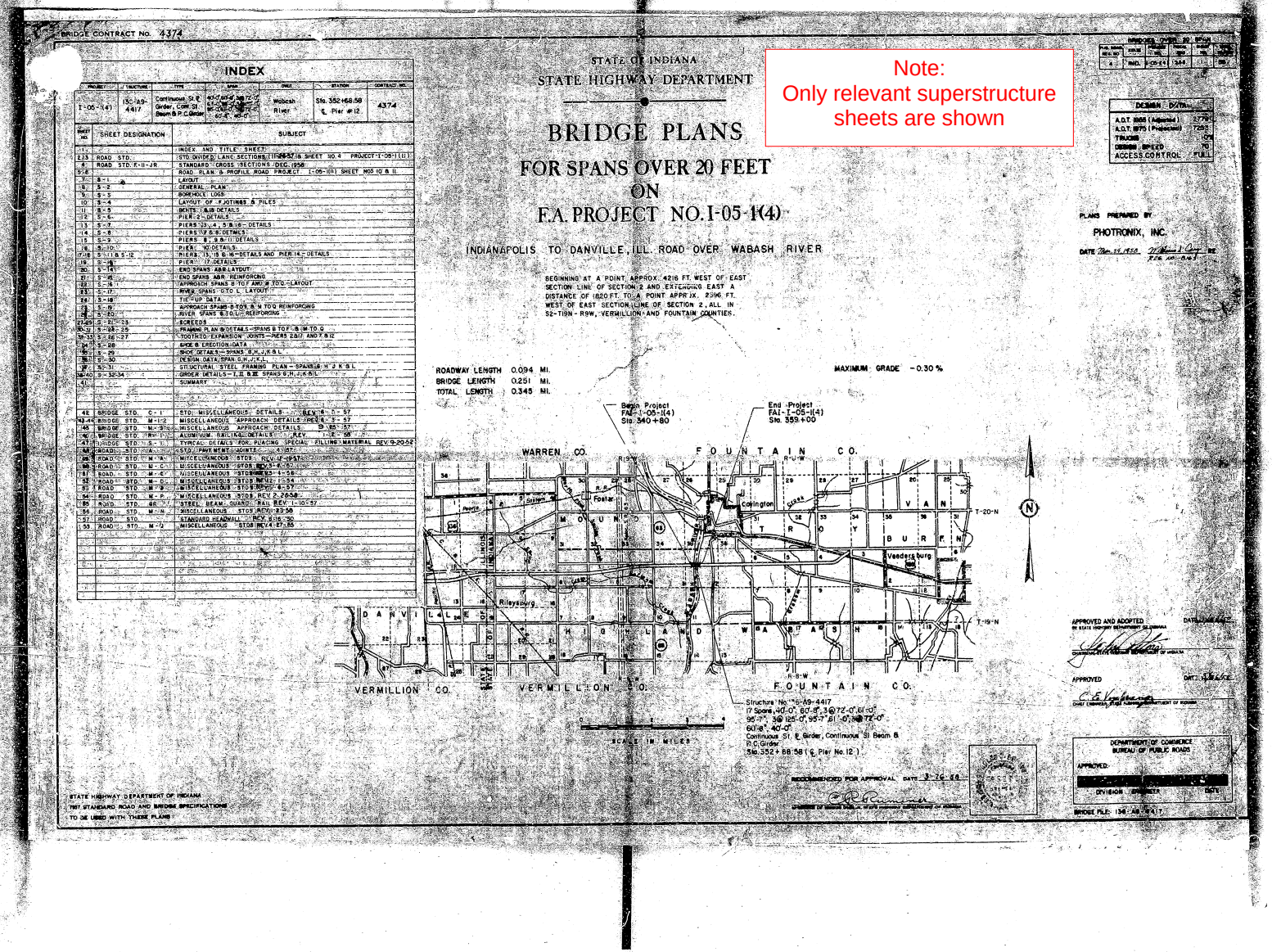
		Frequency	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052
Inspection Type	Routine	24 months	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
	NSTM	24 months	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
	Special (IRM)	10 years	No	No	No	No	No	Yes	No	No	No	No	No	No	No	Yes	No	Yes
	Underwater	60 months	No	No	No	No	Yes	No	No	No	No	Yes	No	No	No	No	Yes	No

As described previously, the current inspection frequency for the Special (IRM) Inspection is 10 years, however an additional evaluation was completed to determine when that frequency might change. A decreased frequency occurs after the 2042 inspection, in which two small areas switch to an 8-year frequency:

- Span H, 85′-0″ to 87′-6″ from Pier 8 (2.5′ of girder length)
- Span J, 37′-6″ to 41′-0″ from Pier 9 (3.5′ of girder length)

The Special (IRM) Inspection for this minor area could be conducted during the 2050 NSTM inspection. All other previous IRM areas remain at a 10-year inspection frequency through 2052. As the bridge conditions might change, warranting additional evaluations and inspections, projecting further inspection intervals was not conducted.

Appendix 2H. Relevant 1958 Original and 1994 Rehabilitation Plan Sets



BRIDGE CONTRACT No. 4374

STATE OF INDIANA
STATE HIGHWAY DEPARTMENT

BRIDGE PLANS
FOR SPANS OVER 20 FEET ON F.A. PROJECT NO. I-05-1(4)

INDIANAPOLIS TO DANVILLE, ILL. ROAD OVER WABASH RIVER

BEGINNING AT A POINT, APPROX. 4216 FT. WEST OF EAST SECTION LINE OF SECTION 2 AND EXTENDING EAST A DISTANCE OF 1820 FT. TO A POINT APPR'IX. 2396 FT. WEST OF EAST SECTION LINE OF SECTION 2, ALL IN S2-T15N-R5W, VERMILLION AND FOUNTAIN COUNTIES.

ROADWAY LENGTH 0.094 MI.
BRIDGE LENGTH 0.251 MI.
TOTAL LENGTH 0.345 MI.

MAXIMUM GRADE -0.30 %

Note:
Only relevant superstructure sheets are shown

INDEX

PROJECT	STRUCTURE	TYPE	SPAN	ONLY	STATION	CONTRACT NO.
I-05-1(4)	15-A9-4417	Continuous St. Bm. Girder, Cont. St. Beam & P.C. Girder	60'-8", 40'-0"	Wabash River	Sta. 352+68.58 ℄ Pier #12	4374

SHEET NO.	SHEET DESIGNATION	SUBJECT
1		INDEX AND TITLE SHEET
2,3	ROAD STD.	STD. DIVIDED LANE SECTIONS (TH-24-57) & SHEET NO. 4 PROJECT I-05-1(4)
4	ROAD STD. F-II-JR	STANDARD CROSS SECTIONS DEC. 1956
5-8		ROAD PLAN & PROFILE ROAD PROJECT I-05-1(4) SHEET NOS 10 & 11
9	S-1	LAYOUT
10	S-2	GENERAL PLAN
11	S-3	BOREHOLE LOGS
12	S-4	LAYOUT OF FOOTINGS & PILES
13	S-5	BENTS 1 & 18 DETAILS
14	S-6	PIER 2 DETAILS
15	S-7	PIERS 3, 4, 5 & 6 DETAILS
16	S-8	PIERS 7 & 8 DETAILS
17	S-9	PIERS 9, 10 & 11 DETAILS
18	S-10	PIERS 12 DETAILS
17-18	S-11 & S-12	PIERS 13, 15 & 16 DETAILS AND PIER 14 DETAILS
19	S-13	PIER 17 DETAILS
20	S-14	END SPANS A & B LAYOUT
21	S-15	END SPANS A & B REINFORCING
22	S-16	APPROACH SPANS B TO F AND M TO G LAYOUT
23	S-17	RIVER SPANS G TO L LAYOUT
24	S-18	TIE-UP DATA
25	S-19	APPROACH SPANS B TO F & M TO G REINFORCING
26	S-20	RIVER SPANS G TO L REINFORCING
27-29	S-21-23	SCREEDS
30-32	S-24-25	FRAMING PLAN & DETAILS - SPANS B TO F & M TO G
33-35	S-26-27	TOOTHED EXPANSION JOINTS - PIERS 2 & 17 AND 7 & 12
36	S-28	SHOE & ERECTION DATA
37	S-29	SHOE DETAILS - SPANS G, H, J, K & L
38	S-30	DESIGN DATA, SPAN G, H, J, K, L
39	S-31	STRUCTURAL STEEL FRAMING PLAN - SPANS G, H, J, K & L
38-40	S-32-34	GIRDER DETAILS - L, J, & K SPANS G, H, J, K & L
41		SUMMARY
48	BRIDGE STD. C-1	STD. MISCELLANEOUS DETAILS REV. 4-1-57
43-44	BRIDGE STD. M-1-2	MISCELLANEOUS APPROACH DETAILS SHEETS 1 & 2 - 5-57
45	BRIDGE STD. M-3	MISCELLANEOUS APPROACH DETAILS 9-65-57
46	BRIDGE STD. RH-1	ALUMINUM RAILING DETAILS REV. 1-15-58
47	BRIDGE STD. S-1	TYPICAL DETAILS FOR PLACING SPECIAL FILLING MATERIAL REV. 9-20-52
48	ROAD STD. M-A	STD. PAVEMENT JOINTS 4-1-57
49	ROAD STD. M-A	MISCELLANEOUS STDS. REV. 12-9-57
50	ROAD STD. M-C	MISCELLANEOUS STDS. REV. 1-1-58
51	ROAD STD. M-C	MISCELLANEOUS STDS. REV. 8-1-58
52	ROAD STD. M-D	MISCELLANEOUS STDS. REV. 2-1-54
53	ROAD STD. M-F	MISCELLANEOUS STDS. REV. 8-1-57
54	ROAD STD. M-P	MISCELLANEOUS STDS. REV. 2-2-58
55	ROAD STD. GR	STEEL BEAM GUARD RAIL REV. 1-10-57
56	ROAD STD. M-N	MISCELLANEOUS STDS. REV. 8-1-58
57	ROAD STD.	STANDARD HEADWALL REV. 6-15-50
58	ROAD STD. M-2	MISCELLANEOUS STDS. REV. 4-1-55

Begin Project FAI-I-05-1(4) Sta. 340+80

End Project FAI-I-05-1(4) Sta. 359+00

WARREN CO. FOUNTAIN CO.

VERMILLION CO. VERMILLION CO. FOUNTAIN CO.

Foster, Covington, Veedersburg, Rileysburg, DANVILLE, HIGHLAND, WABASH, MOUNTAIN, VAN BUREN, T-20-N, T-19-N, R-5-W, R-4-W

SCALE IN MILES

Structure No. 15-A9-4417
17 Spans, 40'-0", 60'-8", 3@72'-0", 60'-8", 40'-0"
Total Length = 1258'-0"
Continuous St. ℄ Girder, Continuous St. Beam & P.C. Girder
Sta. 352+68.58 (℄ Pier No. 12)

RECOMMENDED FOR APPROVAL DATE 3-26-58

DESIGN DATA

A.D.T. 1956 (Adopted)	5770
A.D.T. 1975 (Projected)	7283
TRUCKS	10%
DESIGN SPEED	70
ACCESS CONTROL	FULL

PLANS PREPARED BY
PHOTRONIX, INC.
DATE Nov. 15, 1956

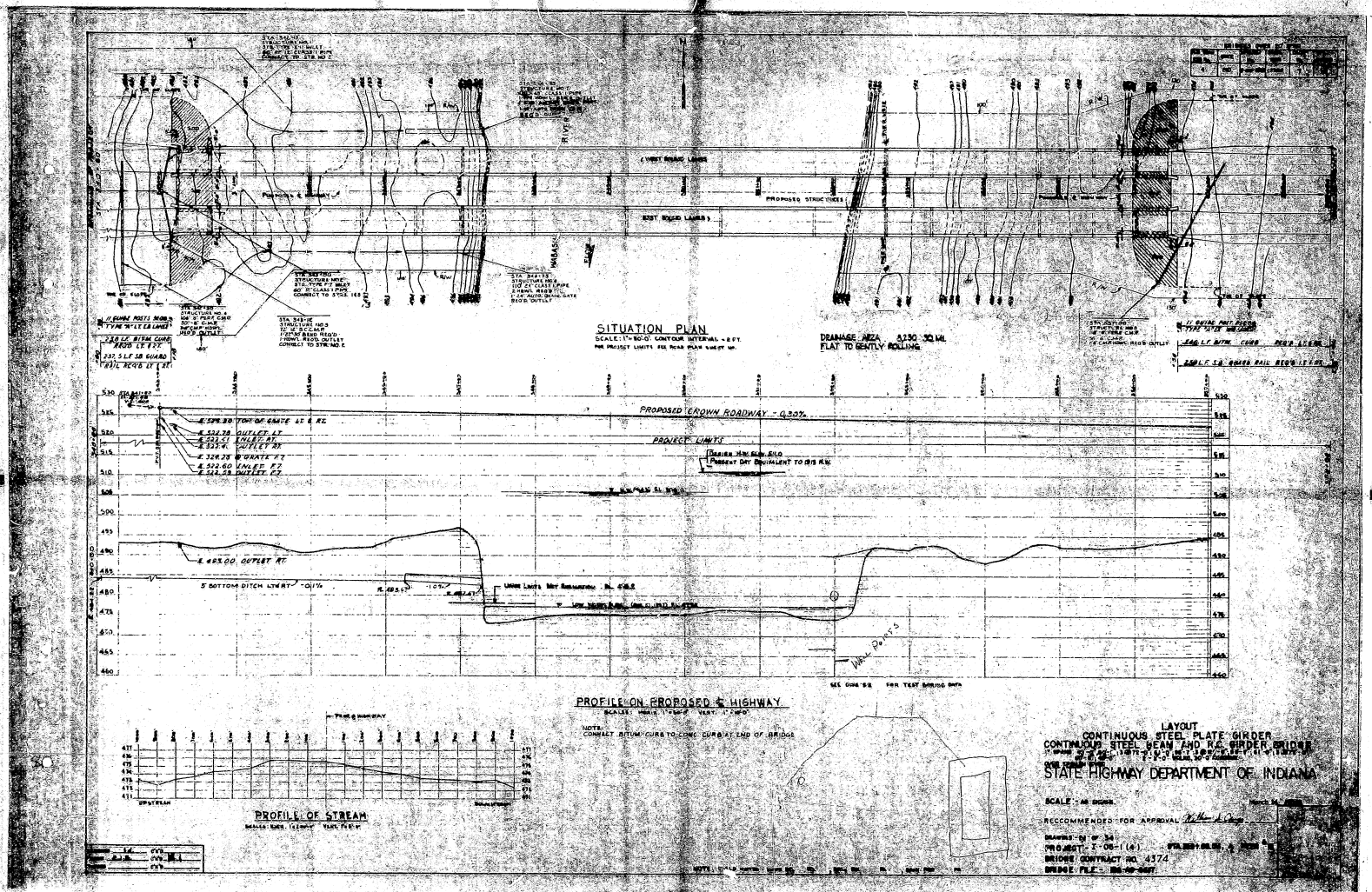
APPROVED AND ADOPTED
BY STATE HIGHWAY DEPARTMENT OF INDIANA
DATE June 4, 1958

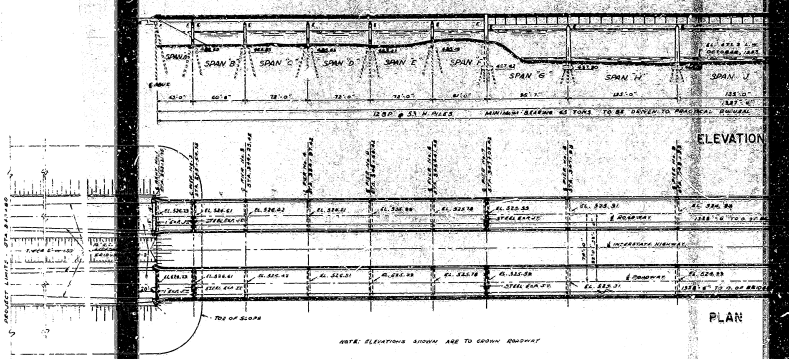
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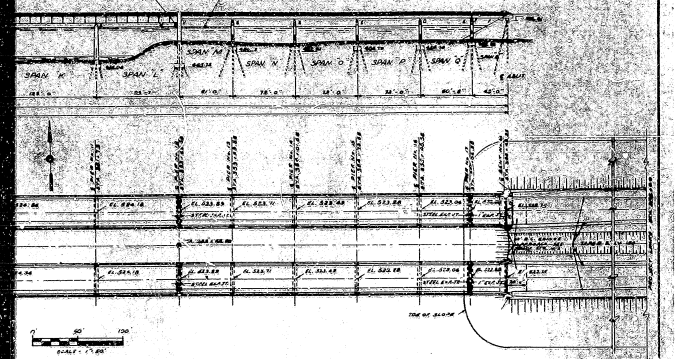
DEPARTMENT OF COMMERCE
BUREAU OF PUBLIC ROADS
APPROVED:
DIVISION ENGINEER
DATE

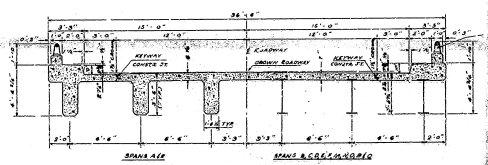
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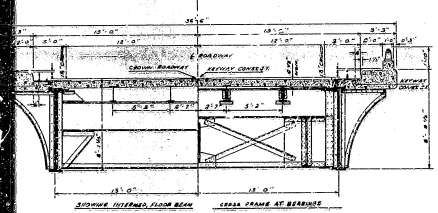
STATE HIGHWAY DEPARTMENT OF INDIANA
1957 STANDARD ROAD AND BRIDGE SPECIFICATIONS
TO BE USED WITH THESE PLANS


SITUATION PLAN
DRAINAGE AREA 8230 SQ MI
FLAT TO GENTLY ROLLING
PROPOSED CROWN ROADWAY - 0.30%
PROJECT LIMITS
PROFILE ON PROPOSED ℄ HIGHWAY
PROFILE OF STREAM
LAYOUT
CONTINUOUS STEEL PLATE GIRDER
CONTINUOUS STEEL BEAM AND R.C. GIRDER BRIDGE
STATE HIGHWAY DEPARTMENT OF INDIANA









GENERAL NOTES:

NO PRESENT STRUCTURES AT PROPOSED SITE

DEPTH OF FOOTINGS TO BE ADJUSTED AS FOUND NECESSARY. SEE ART. 8402.2.01 OF SPECIFICATIONS.

PILE TOLERANCE: THE DRIVING RESISTANCE VALUE SHOWN ON DETAIL DRAWINGS DETERMINE PILE LENGTHS BY FORM 304-A OF THE 1953 SPECIFICATIONS. REINFORCING STEEL COVERING SHALL BE 2 INCH IN FLOOR SLABS, 3 INCHES IN FOOTINGS, EXCEPT BOTTOM STEEL WHICH SHALL BE 4 INCHES, AND 3 INCHES IN ALL OTHER PARTS UNLESS NOTED. CONCRETE IN FOOTINGS, WINGWALLS, ABUTMENTS AND PIER STEMS TO BOTTOM OF PARTS UNLESS NOTED. CONCRETE IN SUPERSTRUCTURE, INCLUDING RAILING, BENT CAPS, TOP OF PILES ABOVE BOTTOM OF COPING TO BE CLASS B.

CONTINUOUS CONCRETE POURS SHALL BE SECURED BETWEEN CONSTRUCTION JOINTS AS SHOWN ON DETAIL PLANS. ALL EXPOSED CORNERS OF WINGWALLS AND CHAMFER 2 INCHES UNLESS NOTED.

CONSTRUCT 5' CONCRETE SLOPE WALL OR 12" HANDLAID RIP-RAP SLOPEWALL AT LOCATIONS SHOWN ON LAYOUT. TOLERANCE IN POSITION OF PILE HEAD AT BENT No. 1 AND 10 MAXIMUM 2 INCHES.

ALL RAILING TO BE CONSTRUCTED PERPENDICULAR TO GRADE.

6" INCH TRAFFIC LANE STRIPE TO BE PLACED ALONG CENTERLINE ROADWAY ON BRIDGE FLOOR.

THE CONTRACTOR SHALL PREPARE DETAILED BILL OF MATERIAL GIVING FINAL PAY WEIGHTS OF STRUCTURAL STEEL AND DETAILED WORKING OR SHOP DRAWINGS FOR ALL OF THE STRUCTURAL STEEL IN THIS BRIDGE. ALL PARTS OF THE WORK IN CONFORMITY WITH THE CONTRACT DRAWINGS AND SPECIFICATIONS. FOR THIS BILL, SUBMIT FIVE (5) COPIES OF THESE TO THE ENGINEER. SEE SPECIAL PROVISIONS FOR ITEMS INCLUDED IN THIS CONTRACT.

PLACE ¾" EXPANSION JOINT IN APPROACH PAVEMENT APPROXIMATELY 80' FROM END OF BRIDGE FLOOR.

FOR PAVEMENT EDGE TRANSITION 3" FLAT TO 1½" CROWN SEE ROAD STANDARD DIVIDED LANE SECTIONS (JAN 1957)

ALL TREES, BRUSH, & DEBRIS WITHIN R/W LIMITS SHALL BE REMOVED.

...TA:

H20-S16-44 LOADING IN ACCORDANCE WITH 1953 A.A.S.H.O. EXCEPT FLOOR SLAB DESIGNED FOR 16,000# WHEEL LOAD. ...AND 4 A&E LOADS 4" APART.

GENERAL PLAN
...ONTINUOUS STEEL PLATE GIRDER
...US STEEL BEAM AND R.C. GIRDER BRIDGE
...', 80'-8", 3@ 78'-0"; 61'-0", 85'-7", @125'-0"; 85'-7", 61'-0"; ...'-0", 80'-8", 40'-0" 2-2'-0" WALKS, 30'-0" ROADWAY.
...RIVER ON STATE ROAD U.S. 136

STATE HIGHWAY DEPARTMENT OF INDIANA

SCALE:- AS SHOWN March 24, 1958

RECOMMENDED FOR APPROVAL: William A. Ogg

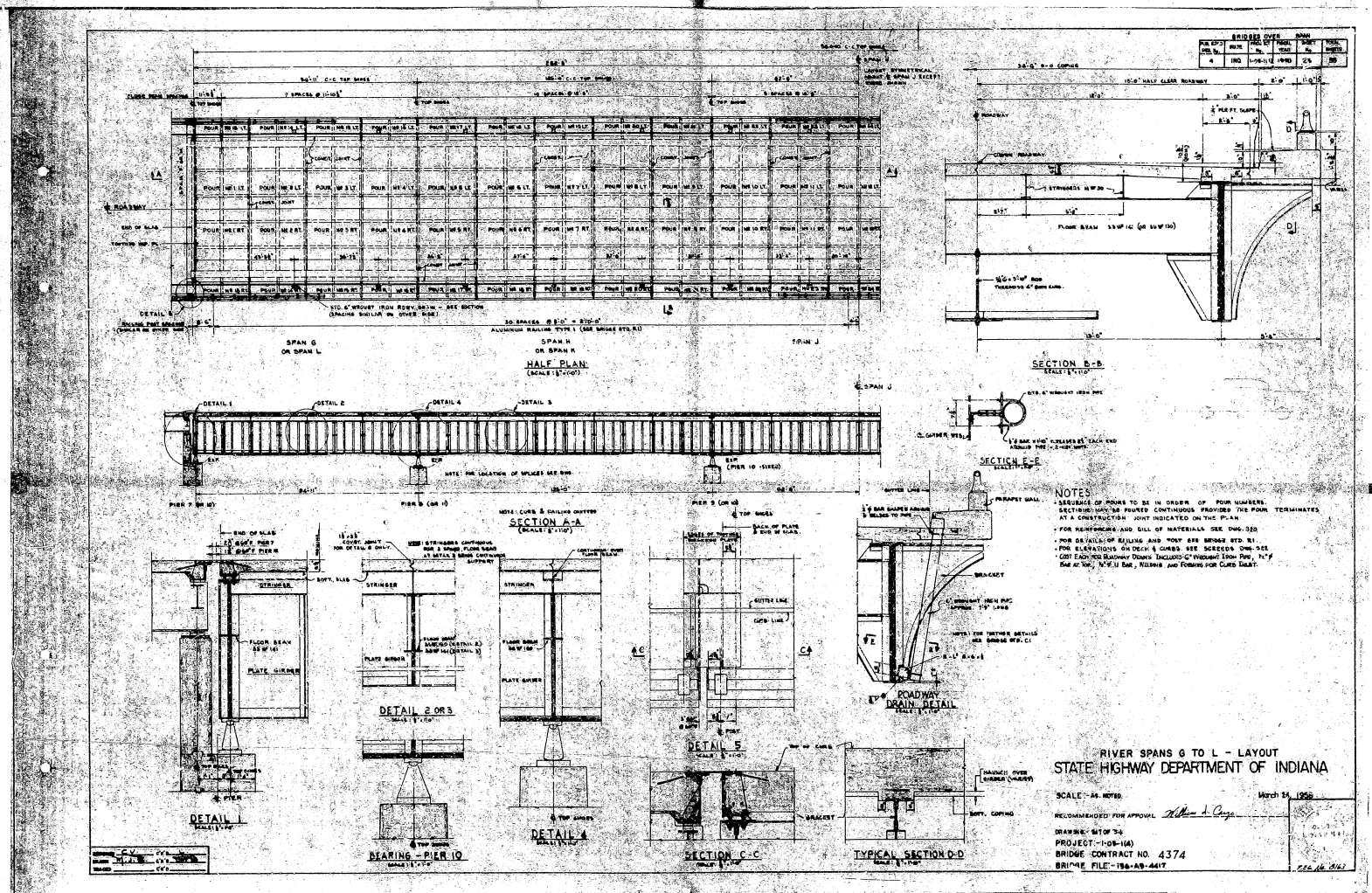
DRAWING 32 OF 34

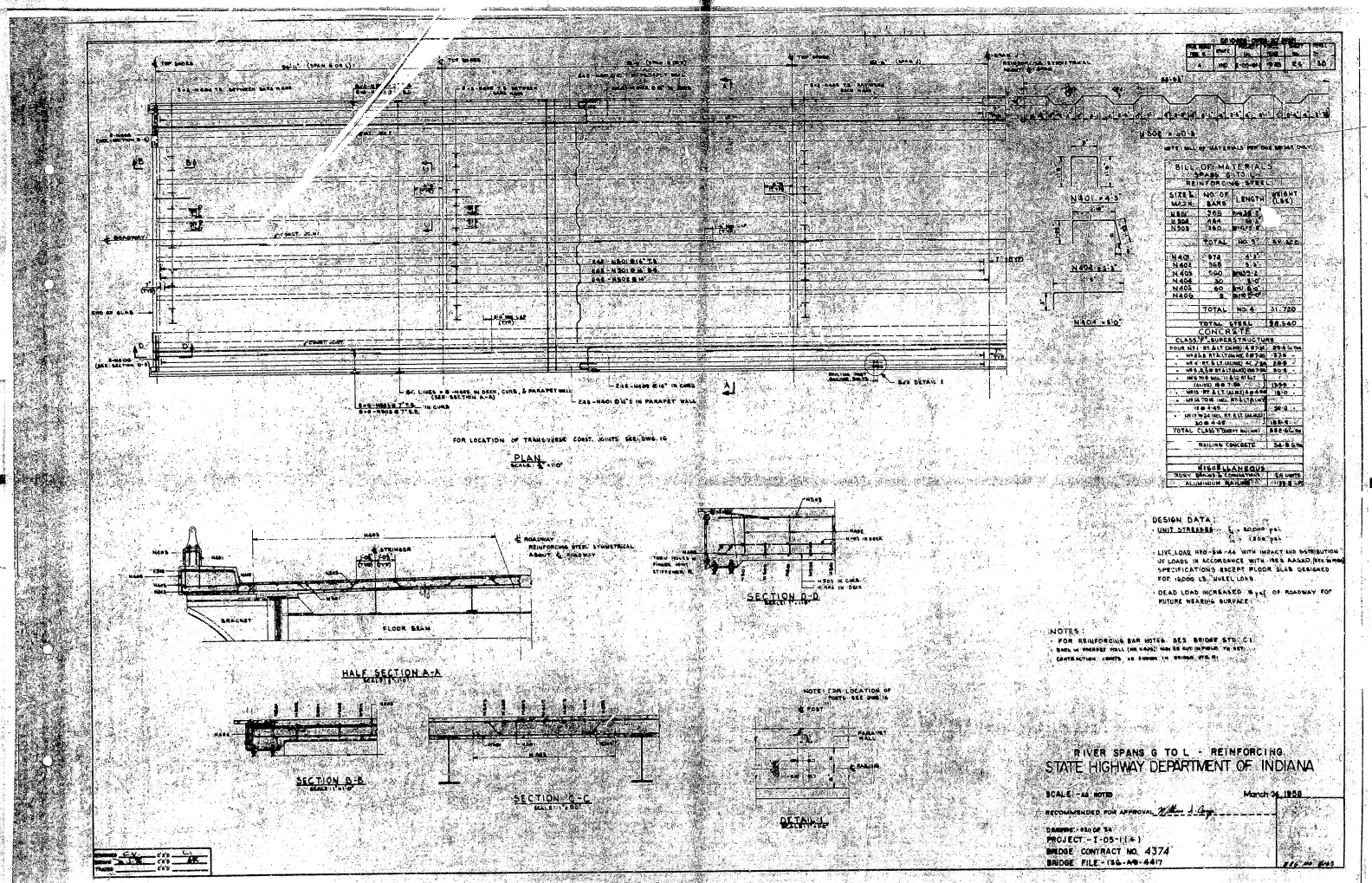
PROJECT:- I-05-1(41) STA. 352+68.58 ℄ PIER 2

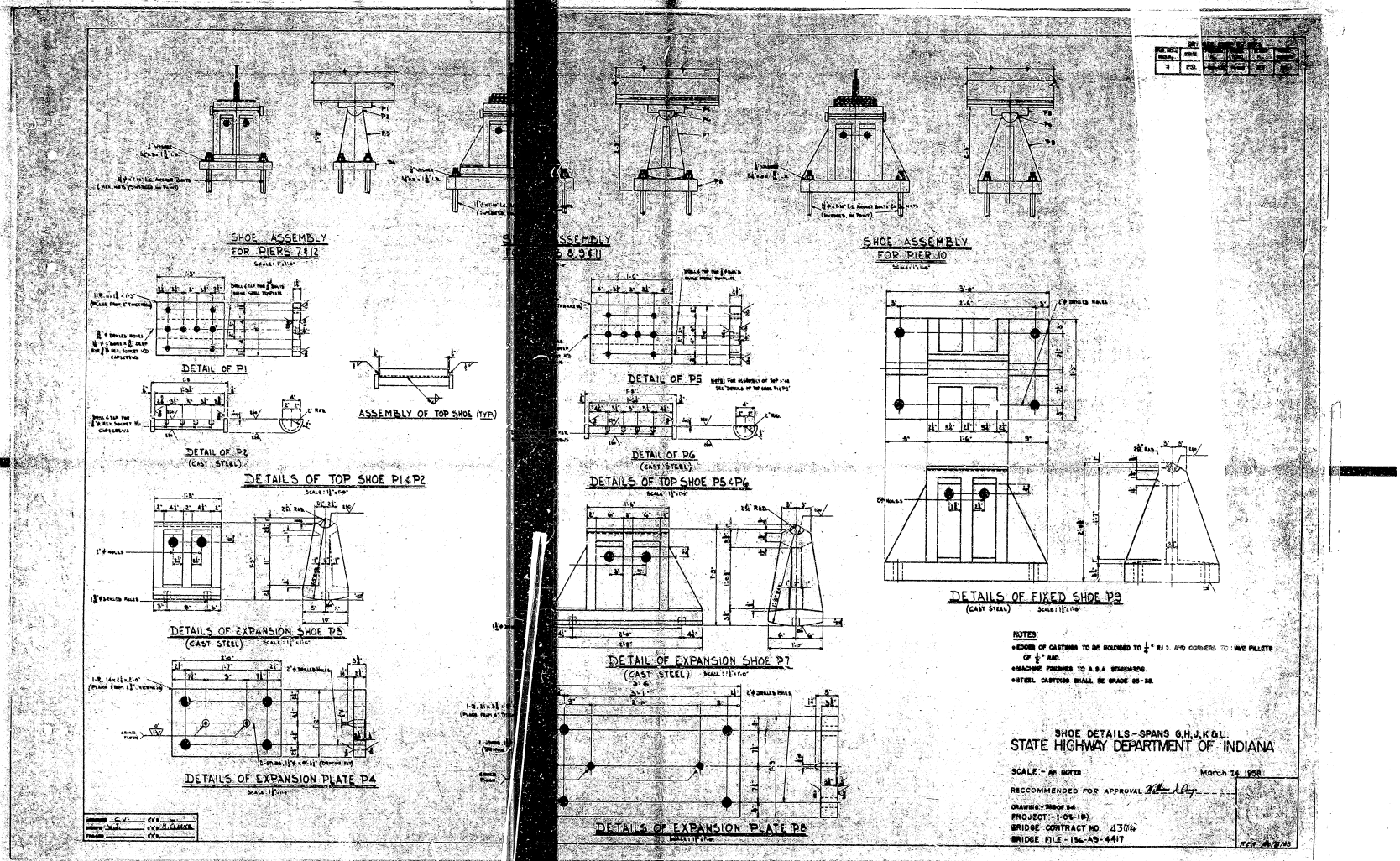
BRIDGE CONTRACT NO. 4374

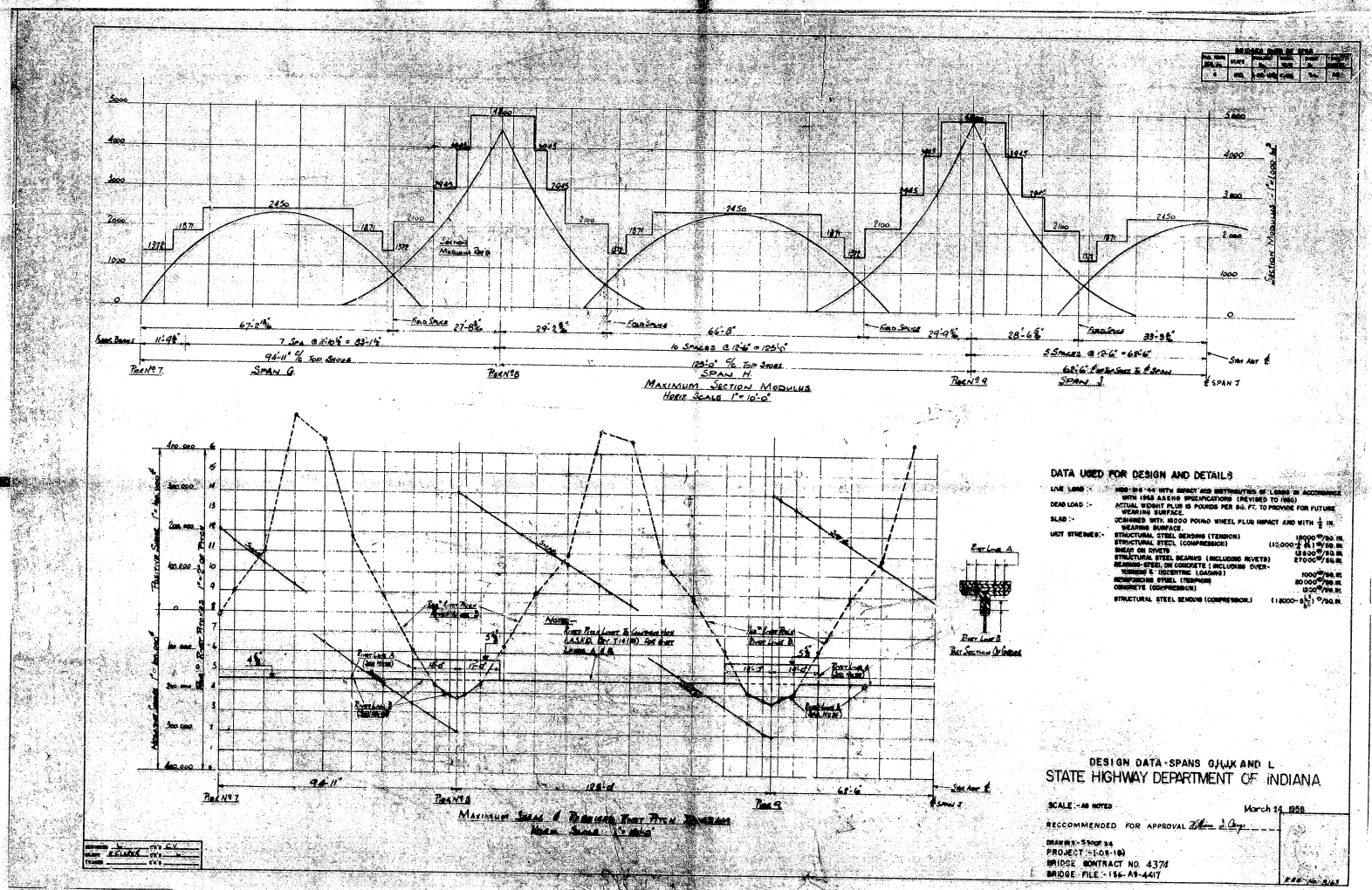
BRIDGE FILE:- 136-A9-4417

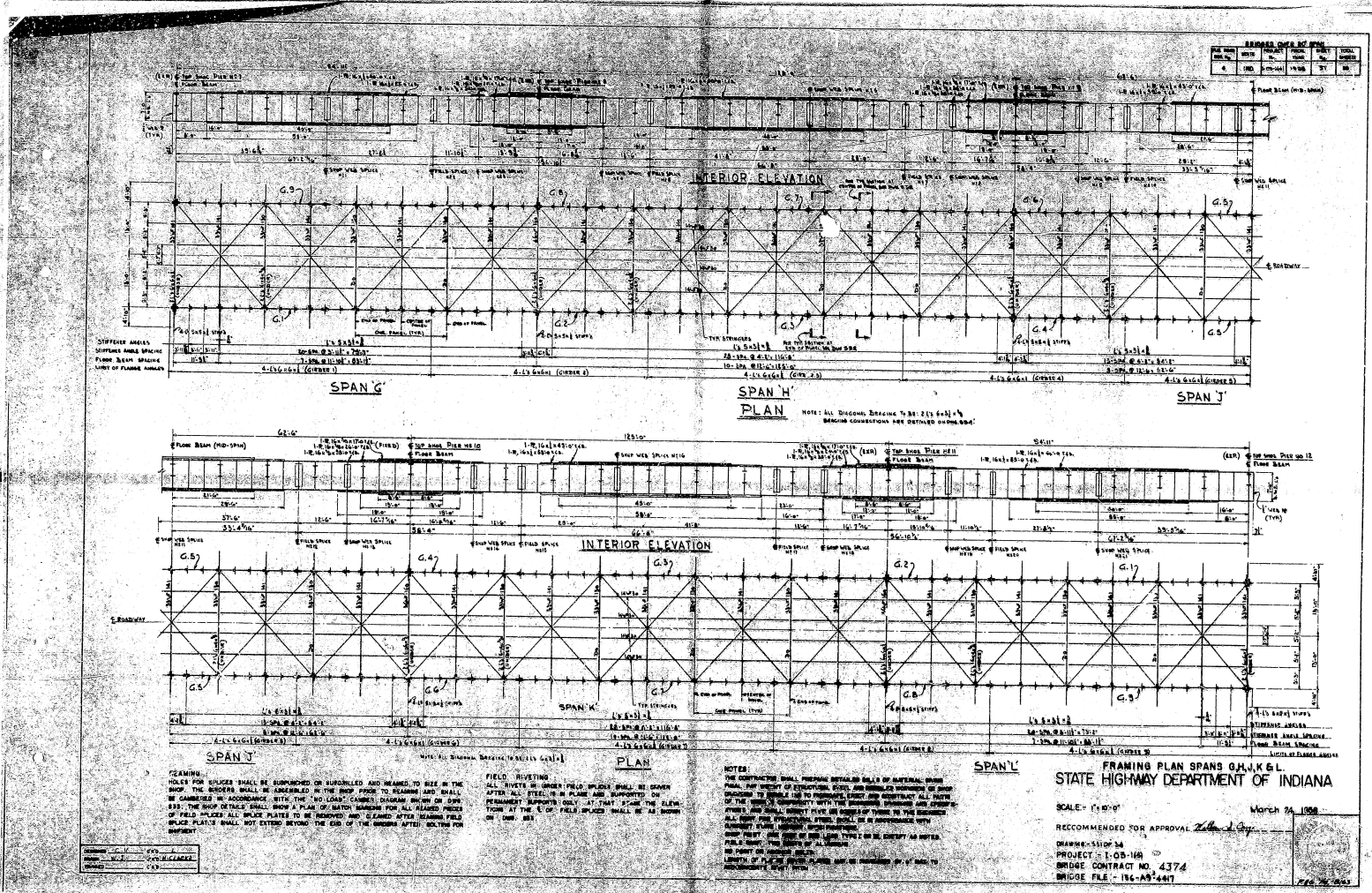
FHWA No. A-41

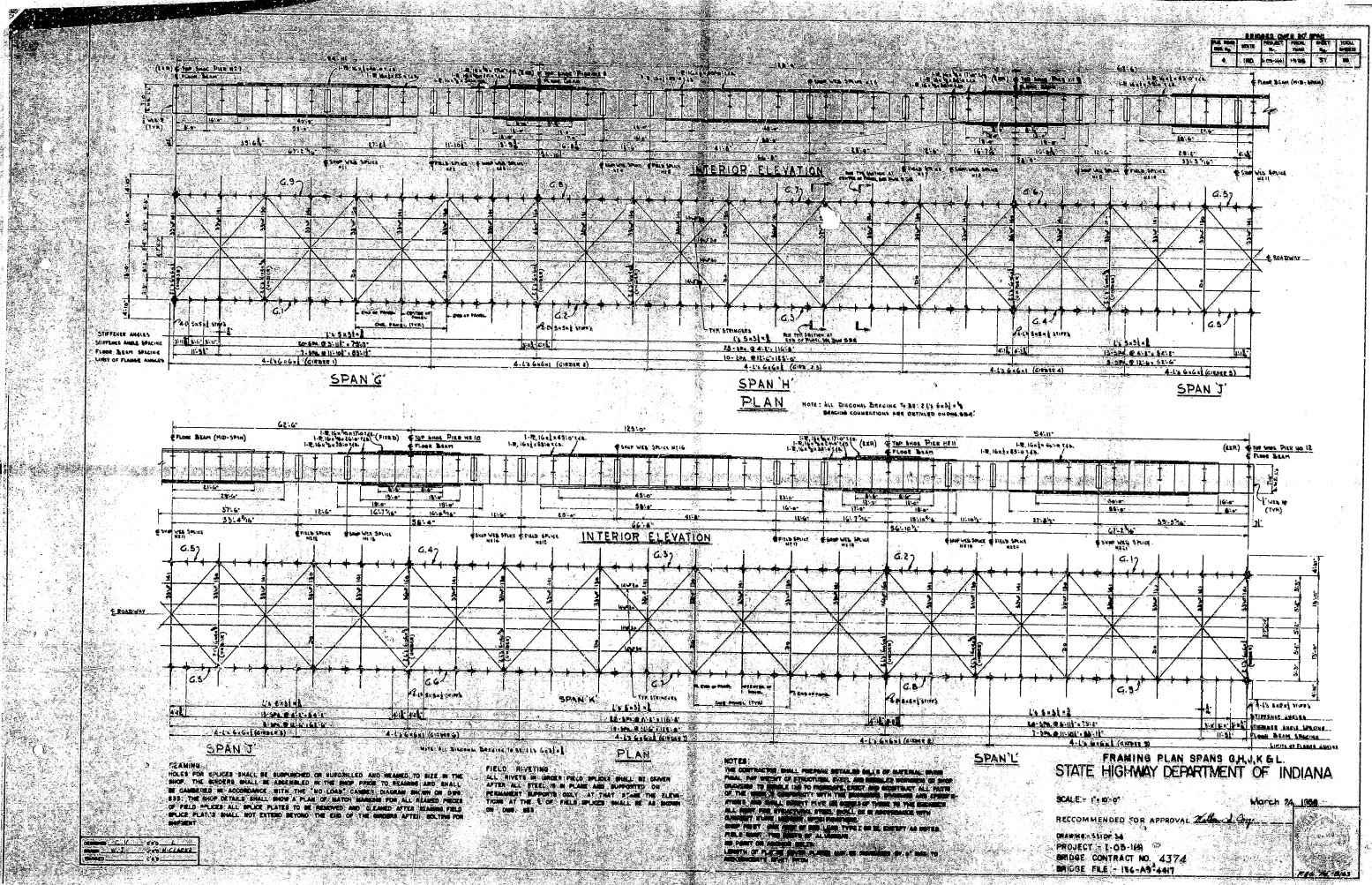

HALF PLAN
SECTION A-A
SECTION B-B
SECTION E-E
DETAIL 1
DETAIL 2 OR 3
DETAIL 4
DETAIL 5
BEARING - PIER 10
SECTION C-C
TYPICAL SECTION D-D
ROADWAY DRAIN DETAIL
NOTES
RIVER SPANS G TO L - LAYOUT
STATE HIGHWAY DEPARTMENT OF INDIANA
SCALE - AS NOTED
March 24, 1958
PROJECT:-I-65-1(A)
BRIDGE CONTRACT NO. 4374
BRIDGE FILE:-156-A9-4417

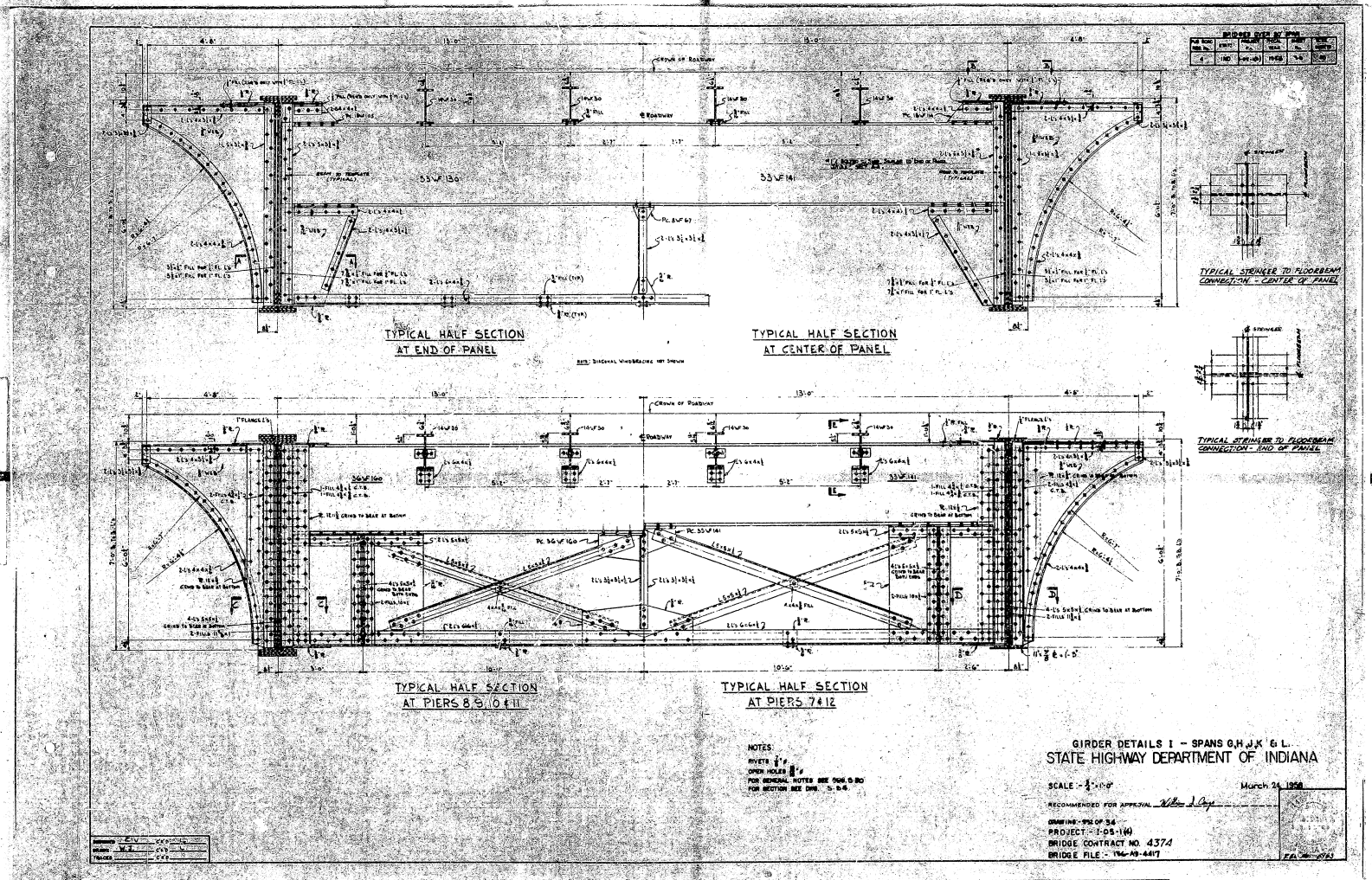

PLAN
SCALE: 1"=10'
HALF SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D
DETAIL 1
BILL OF MATERIALS
SPANS G TO L
REINFORCING STEEL
CONCRETE
CLASS "A" SUPERSTRUCTURE
MISCELLANEOUS
DESIGN DATA:
UNIT STRESSES
LIVE LOAD H20-S16-44 WITH IMPACT AND DISTRIBUTION OF LOADS IN ACCORDANCE WITH 1953 AASHO SPECIFICATIONS EXCEPT FLOOR SLAB DESIGNED FOR 18000 LB. WHEEL LOAD.
DEAD LOAD INCREASED 15 psf OF ROADWAY FOR FUTURE WEARING SURFACE.
NOTES:
FOR REINFORCING BAR NOTES SEE BRIDGE STD. C1
RIVER SPANS G TO L - REINFORCING
STATE HIGHWAY DEPARTMENT OF INDIANA
SCALE: - AS NOTED
March 24, 1958
RECOMMENDED FOR APPROVAL
DRAWING - 9(b) OF 34
PROJECT:- I-05-1(14)
BRIDGE CONTRACT NO. 4374
BRIDGE FILE:- 156-A49-4417

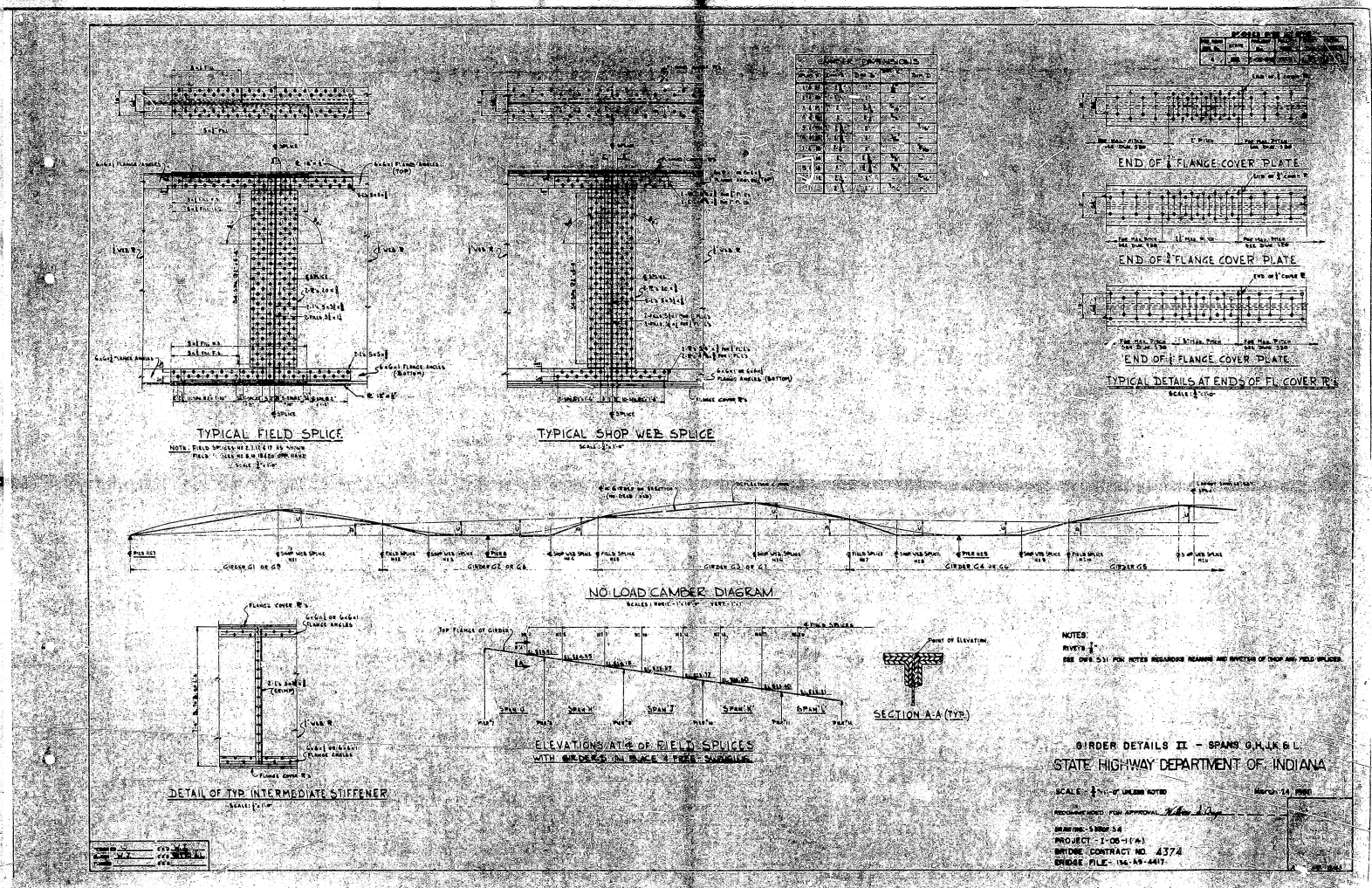

SHOE ASSEMBLY FOR PIERS 7 & 12
SHOE ASSEMBLY FOR PIER 10
DETAIL OF P1
DETAIL OF P2 (CAST STEEL)
ASSEMBLY OF TOP SHOE (TYP.)
DETAILS OF TOP SHOE P1 & P2
DETAILS OF EXPANSION SHOE P3 (CAST STEEL)
DETAILS OF EXPANSION PLATE P4
DETAIL OF P5
DETAIL OF P6 (CAST STEEL)
DETAILS OF TOP SHOE P5 & P6
DETAIL OF EXPANSION SHOE P7 (CAST STEEL)
DETAILS OF EXPANSION PLATE P8
DETAILS OF FIXED SHOE P9 (CAST STEEL)
NOTES:
• EDGES OF CASTINGS TO BE ROUNDED TO 1/4" RAD. AND CORNERS TO HAVE FILLETS OF 1/4" RAD.
• MACHINE FINISHED TO A.S.A. STANDARDS.
• STEEL CASTINGS SHALL BE GRADE 65-35.
SHOE DETAILS - SPANS G, H, J, K & L
STATE HIGHWAY DEPARTMENT OF INDIANA
SCALE: - As NOTED
March 24, 1958
RECOMMENDED FOR APPROVAL
PROJECT:- I-065-1(8)
BRIDGE CONTRACT NO. 4304
BRIDGE FILE:- 136-A9-4417

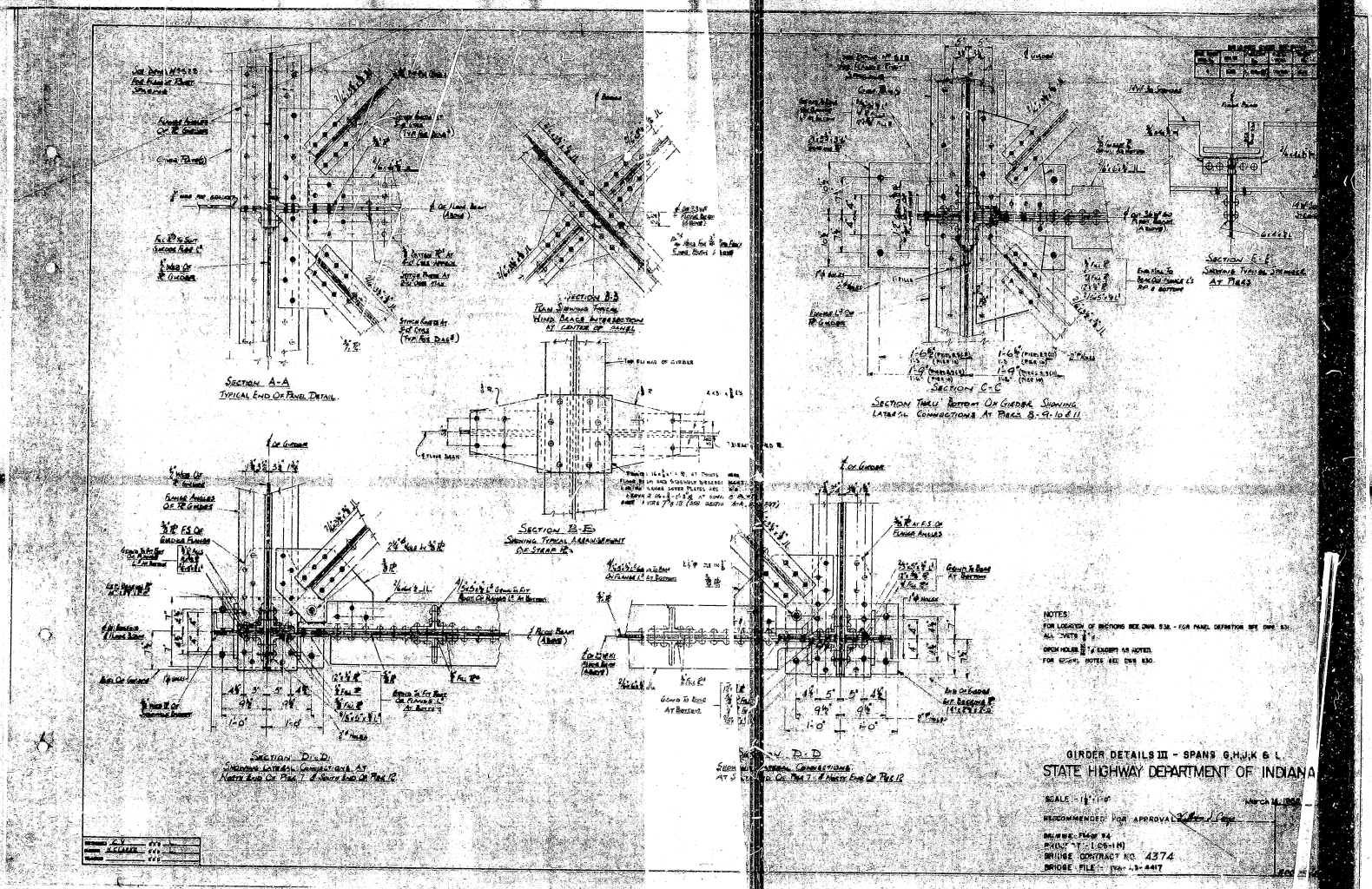

Maximum Section Modulus
Horiz. Scale 1"=10'-0"
DATA USED FOR DESIGN AND DETAILS
DESIGN DATA-SPANS G,H,K AND L
STATE HIGHWAY DEPARTMENT OF INDIANA
March 24, 1958
PROJECT:-I-65-1(9)
BRIDGE CONTRACT NO. 4374
BRIDGE FILE:-156-A9-4417


INTERIOR ELEVATION
SPAN 'G'
SPAN 'H'
SPAN 'J'
PLAN
INTERIOR ELEVATION
SPAN 'J'
SPAN 'K'
SPAN 'L'
PLAN
FRAMING PLAN SPANS G,H,J,K & L.
STATE HIGHWAY DEPARTMENT OF INDIANA
SCALE:- 1"=10'-0"
March 24, 1958
RECOMMENDED FOR APPROVAL
DRAWING - SSIOF 34
PROJECT - I-05-169
BRIDGE CONTRACT NO. 4374
BRIDGE FILE - 186-A9-4417


INTERIOR ELEVATION
SPAN 'G'
SPAN 'H'
SPAN 'J'
PLAN
INTERIOR ELEVATION
SPAN 'J'
SPAN 'K'
SPAN 'L'
PLAN
FRAMING PLAN SPANS G,H,J,K & L.
STATE HIGHWAY DEPARTMENT OF INDIANA
SCALE:- 1"=10'-0"
March 24, 1958
RECOMMENDED FOR APPROVAL
DRAWING-SSIOF 34
PROJECT - I-05-1(6)
BRIDGE CONTRACT NO. 4374
BRIDGE FILE - 186-A9-4417


TYPICAL HALF SECTION AT END OF PANEL
TYPICAL HALF SECTION AT CENTER OF PANEL
TYPICAL STRINGER TO FLOORBEAM CONNECTION - CENTER OF PANEL
TYPICAL STRINGER TO FLOORBEAM CONNECTION - END OF PANEL
TYPICAL HALF SECTION AT PIERS 8, 9, 10 & 11
TYPICAL HALF SECTION AT PIERS 7 & 12
NOTES:
GIRDER DETAILS I - SPANS G,H,J,K & L.
STATE HIGHWAY DEPARTMENT OF INDIANA
March 24, 1958
DRAWING - 9 OF 34
PROJECT - I-65-1(4)
BRIDGE CONTRACT NO. 4374
BRIDGE FILE - 196-A9-4417


TYPICAL FIELD SPLICE
TYPICAL SHOP WEB SPLICE
END OF ¼ FLANGE COVER PLATE
END OF ¼ FLANGE COVER PLATE
END OF ¼ FLANGE COVER PLATE
TYPICAL DETAILS AT ENDS OF FL COVER PLS
NO LOAD CAMBER DIAGRAM
DETAIL OF TYP INTERMEDIATE STIFFENER
ELEVATIONS AT ¼ OF FIELD SPLICES
SECTION A-A (TYP.)
NOTES:
GIRDER DETAILS II - SPANS G, H, J, K & L
STATE HIGHWAY DEPARTMENT OF INDIANA


SECTION A-A
TYPICAL END OF PANEL DETAIL.
SECTION B-B
SHOWING TYPICAL ARRANGEMENT OF STRAP 12
SECTION C-C
SECTION THRU BOTTOM OF GIRDER SHOWING LATERAL CONNECTIONS AT PIERS 8-9-10 & 11
SECTION D-D
SHOWING LATERAL CONNECTIONS AT NORTH END OF PIER 7 & SOUTH END OF PIER 12
SECTION E-E
SHOWING TYPICAL STIFFENER AT PIERS
NOTES:
FOR LOCATION OF SECTIONS SEE DWG. 530. - FOR PANEL DEFINITION SEE DWG. 531.
ALL RIVETS 7/8"ø.
OPEN HOLES 15/16"ø EXCEPT AS NOTED.
FOR WELDING NOTES SEE DWG. 530.
GIRDER DETAILS III - SPANS G,H,J,K & L
STATE HIGHWAY DEPARTMENT OF INDIANA
SCALE - 1½"=1'-0"
RECOMMENDED FOR APPROVAL
BRIDGE PROJECT NO. (LOCAL)
BRIDGE CONTRACT NO. 4374
BRIDGE FILE - (PROJ. NO. 53-4417

CONTRACT NO. B-21615

B 21615

INDEX

PROJECT	STRUCTURE	TYPE	SPAN	OVER	STATION
IM/74-I (117)6	I-74-6-4417 DEB & EWB	DECK REPLACEMENT AND STRUCTURE WIDENING	17-SPANS	WABASH RIVER	352+68.58 ℄ PIER #12

SHEET NO.	SHEET DESIGNATION	SUBJECT	F.H.W.A. APPROVAL
1		TITLE SHEET AND INDEX	
2 & 3		TRAFFIC MAINTENANCE	
4-7		DETAILS	
8-10	WI-W3	GENERAL PLAN	
11 & 12	W4 & W5	REMOVALS	
13	W6	BENT NO. 1	
14 & 15	W7 & W8	PIER NO. 2	
16	W9	PIERS 3, 4, 5, & 6	
17	W10	PIER NO. 7	
18	W11	PIERS 8, 9, & 11	
19	W12	PIER NO. 10	
20	W13	PIER NO. 12	
21	W14	PIERS 13, 15, & 16	
22	W15	PIER NO. 14	
23 & 24	W16 & W17	PIER NO. 17	
25	W18	BENT NO. 18	
		SPANS "A" & "R"	
26	W19	FLOOR PLAN	
27 & 28	W20 & W21	SUPERSTRUCTURE DETAILS	
29	W22	BEAM DETAILS	
		SPANS "B" THRU "F" AND "M" THRU "Q"	
30	W23	FRAMING PLAN	
31 & 32	W24 & W25	STRUCTURAL STEEL DETAILS	
33	W26	FLOOR PLAN	
34 & 35	W27 & W28	SUPERSTRUCTURE DETAILS	
		SPANS "G" THRU "L"	
36 & 37	W29 & W30	FRAMING PLAN	
38 - 40	W31 - W33	STRUCTURAL STEEL DETAILS	
41	W34	FLOOR PLAN	
42 - 44	W35 - W37	SUPERSTRUCTURE DETAILS	
45	W38	SUGGESTED JACKING SCHEME AT PIERS 7 & 12	
46		BRIDGE SUMMARY	

TRAFFIC DATA		
A.D.T. (1986)		10,400 V.P.D.
A.D.T. (PROJECTED)		V.P.D.
D.H.V. (PROJECTED)		V.P.D.
TRUCKS		D.H.V. A.D.T.
DESIGN SPEED		70 M.P.H.
ACCESS CONTROL		FULL
FUNCTIONAL CLASSIFICATION	RURAL INTERSTATE; LEVEL TERRAIN	

PLANS PREPARED BY

SEG ENGINEERS & CONSULTANTS, INC.
ENGINEERS - LANDSCAPE ARCHITECTS - SURVEYORS
360 CENTURY BLDG., 36 S. PENNSYLVANIA ST.
INDIANAPOLIS, INDIANA 46204
(317) 633-4120

CERTIFIED Stephen J. Christian DATE SEPTEMBER 16, 1994

STEPHEN J. CHRISTIAN REGISTERED No. 20379 STATE OF INDIANA PROFESSIONAL ENGINEER

INDIANA DEPARTMENT OF HIGHWAYS
STANDARD SPECIFICATIONS DATED 1993
TO BE USED WITH THESE PLANS.

DES. NO. 8716715

INDIANA DEPARTMENT OF TRANSPORTATION

BRIDGE PLANS

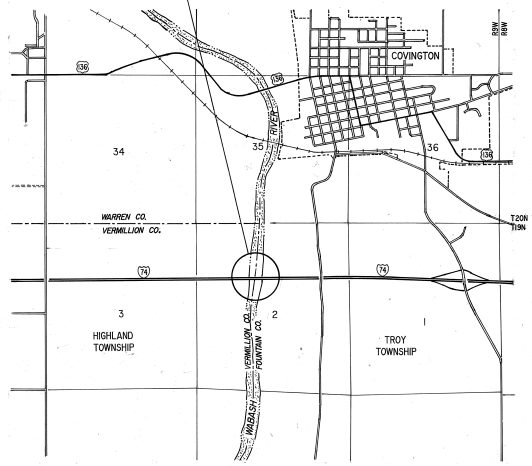
FOR SPANS OVER 20 FEET ON I-74

PROJECT NO. IM/74-I (117)6

DECK REPLACEMENT AND STRUCTURE WIDENING FOR BRIDGES ON I-74 OVER THE WABASH RIVER, APPROXIMATELY 2.4 MILES EAST OF S.R. 63, LOG MILE 6.63, ALL IN SECTION 2, T-19-N, R-9-W, VERMILLION AND FOUNTAIN COUNTIES.

INTERSTATE I-74 AT RP. 6+64

STRUCTURES I-74-6-4417 DEB AND I-74-6-4417 EWB
DECK REPLACEMENT AND STRUCTURE WIDENING FOR PRESENT STRUCTURES I-74-6-4417 CEB AND I-74-6-4417 DWB



SCALE: 1" = 2000'

VERMILLION COUNTY

FOUNTAIN COUNTY

BRIDGES OVER 20' SPAN

FEDERAL REGION NO.	STATE	PROJECT NO.	FISCAL YEAR	SHEET NO.	TOTAL SHEETS
5	IND.	IM/74-I (117)6	1994	1	79

INDEX CONTINUED
STANDARD DRAWINGS

SHEET NO.	SHEET DESIGNATION	SUBJECT	F.H.W.A. APPROVAL	ADOPTED "A" REVISION "R"
47	BRIDGE STD. BR1	CONCRETE BRIDGE RAILING TRANSITION TYPE TGB	3-9-93	A AUG 1992
48	BRIDGE STD. BR1A	CONCRETE BRIDGE RAILING TRANSITION TYPE TGB	3-9-93	A AUG 1992
	BRIDGE STD. BR3	STEEL BRIDGE RAIL		
	BRIDGE STD. BR4	STEEL BRIDGE RAILING DETAILS		
	BRIDGE STD. BR5	RAILING CONNECTION DETAILS		
	BRIDGE STD. BR6	RAILING CONNECTION DETAILS		
49	BRIDGE STD. C1	MISCELLANEOUS DETAILS	I-26-93	A DEC. 1992
	BRIDGE STD. C2	MISCELLANEOUS DETAILS		
50	BRIDGE STD. C3	MISCELLANEOUS DETAILS	I-26-93	A NOV. 1992
	BRIDGE STD. C4	MISCELLANEOUS DETAILS		
51	BRIDGE STD. D	CASTING DETAILS ROADWAY DRAINS	I-11-89	R 9-1-88
	BRIDGE STD. D1	ADJUSTING FRAME DETAILS FOR ROADWAY DRAINS		
	BRIDGE STD.			
52	BRIDGE STD. PB3	PRESTRESSED CONCRETE TYPE III I-BEAMS	4-16-62	A JAN. 1992
	BRIDGE STD. PB	PRESTRESSED CONCRETE TYPE I-BEAMS		
	BRIDGE STD. PB6	PRESTRESSED BOX BEAMS		
	BRIDGE STD. PB	PRESTRESSED COMPOSITE BOX BEAMS WIDE		
	BRIDGE STD. PB	PRESTRESSED COMPOSITE BOX BEAMS WIDE		
53	BRIDGE STD. PB10	TOLERANCES FOR FABRICATION OF PRESTRESSED BEAMS	8-14-63	A NOV. 1962
54	BRIDGE STD. PB11	ELASTOMERIC BEARING PAD DETAILS	2-3-87	R 2-02-87
55	BRIDGE STD. SS-I	EXPANSION JOINTS CLASS SS	6-20-91	A APR. 1991
56	BRIDGE STD. SS-2	EXPANSION JOINTS CLASS SS	6-20-91	A APR. 1991
	BRIDGE STD. R2A	BRIDGE LIGHTING DETAILS		
	BRIDGE STD. R2B	BRIDGE LIGHTING DETAILS		
	BRIDGE STD. S1	MISCELLANEOUS DETAILS		
	BRIDGE STD. SH1	STEEL SHOE DETAILS		
	BRIDGE STD. T SHEET A	STANDARD TEMPORARY BRIDGE		
	BRIDGE STD. T SHEET B	STANDARD TEMPORARY BRIDGE		
	BRIDGE STD.			
	BRIDGE STD.			
	BRIDGE STD.			
	BRIDGE STD.			
	BRIDGE STD.			
57	ROAD STD. SHEET JTS-A	PAVEMENT JOINTS: R. C. PAVEMENT REINFORCING	*	R 3-1-90
58	ROAD STD. SHEET JTS-B	TERMINAL JOINTS	I-26-93	A NOV. 1992
	ROAD STD. SHEET	MISCELLANEOUS DETAILS		
	ROAD STD. SHEET	MISCELLANEOUS DETAILS		
	ROAD STD. SHEET	MISCELLANEOUS DETAILS		
	ROAD STD. SHEET	MISCELLANEOUS DETAILS		
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	ROAD STD. SHEET	MISCELLANEOUS DETAILS		
	ROAD STD. SHEET	MISCELLANEOUS DETAILS		
	ROAD STD. SHEET	MISCELLANEOUS DETAILS		
59	ROAD STD. SHEET G-I	W-BEAM GUARDRAIL COMPONENTS	3-9-93	A AUG. 1992
60	ROAD STD. SHEET G-2	THRIE-BEAM GUARDRAIL COMPONENTS	7-20-92	A DEC. 1991
61	ROAD STD. SHEET G-3	W-BEAM GUARDRAIL ASSEMBLIES.	7-20-92	A DEC. 1991
62	ROAD STD. SHEET T-I	GUARDRAIL TRANSITION TYPE TGB	3-9-93	A AUG. 1992
63	ROAD STD. SHEET T-3	GUARDRAIL TRANSITION TYPE VH	3-9-93	A AUG. 1992
64	ROAD STD. SHEET E-2	GUARDRAIL END TREATMENT TYPE 0S	7-20-92	A DEC. 1991
65	ROAD STD. SHEET E-3	GUARDRAIL END TREATMENT TYPE MS	7-20-92	A DEC. 1991
66	ROAD STD. SHEET B-I	TYPICAL BRIDGE APPROACH GUARDRAIL	3-9-93	A AUG. 1992
	ROAD STD. SHEET GR9	ALUMINUM GUARD RAIL		
	ROAD STD. SHEET GR10	GUARD RAIL BURIED ENDS		
	ROAD STD. SHEET GR10A	GUARD RAIL BREAKAWAY CABLE TERM.		
67	ROAD STD. SHEET CB-I	CONCRETE MEDIAN BARRIER	I-11-89	R 9-1-88
68	TRAFFIC STD. SHEET MT-3	SHEET SIGN IDENTIFICATION CODES; SIGN RETLECTORIZATION SCHEDULE	8-5-88	R 8-1-88
69	TRAFFIC STD. SHEET MT-18	SNOWPLOWABLE RAISED PAVEMENT MARKER PLACEMENT ON ROADWAYS	I-6-88	A NOV. 1987
70	TRAFFIC STD. SHEET MT-19	SNOWPLOWABLE RAISED PAVEMENT MARKER DETAILS & INSTALLATION	I-6-88	A NOV. 1987
	ROAD STD. SHEET			
71	ROAD STD. SHEET DET-IA	TEMPORARY CROSSOVERS TYPE A AND B	6-20-91	R 4-1-91
72	ROAD STD. SHEET DET-2A	BARRICADE, DRUM, CONE, TUBULAR MARKER & TYPICAL SIGN STANDARD. DETAILS	*	A SEP. 1988
73	ROAD STD. SHEET DET-3	SIGN DESIGN DETAILS	*	R 9-1-88
74	ROAD STD. SHEET DET-3A	SIGN DESIGN DETAILS (WITH TABLES)	*	R 9-1-88
75	ROAD STD. SHEET DET-4	SIGN DESIGN DETAIL	I-11-89	R 9-1-88
76	ROAD STD. SHEET DET-5A	SIGN DESIGN DETAIL TABLES	*	R 9-1-88
77	ROAD STD. SHEET TEC-I	TEMPORARY EROSION CONTROL, PERIMETER PROTECTION	11-10-93	A SEP. 1993
78	ROAD STD. SHEET TEC-2	TEMPORARY EROSION CONTROL, PERIMETER PROTECTION	11-10-93	A SEP. 1993
79	ROAD STD. SHEET TEC-3	TEMPORARY EROSION CONTROL, PERIMETER PROTECTION	11-10-93	A SEP. 1993

* PENDING

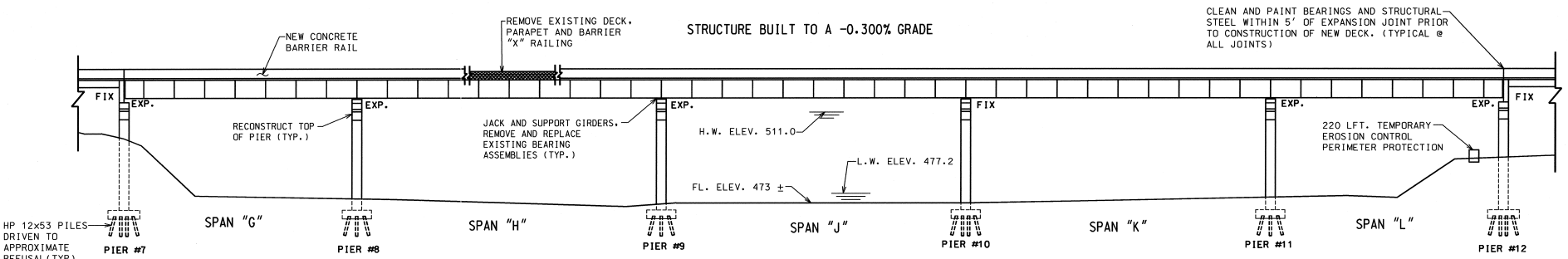
APPROVED FOR LETTING:
CHIEF, DIVISION OF DESIGN, INDIANA DEPARTMENT OF TRANSPORTATION

FEDERAL HIGHWAY ADMINISTRATION
DEPARTMENT OF TRANSPORTATION
APPROVED
DIVISION ADMINISTRATOR DATE

BRIDGE FILE: I-74-6-4417 DEB & EWB

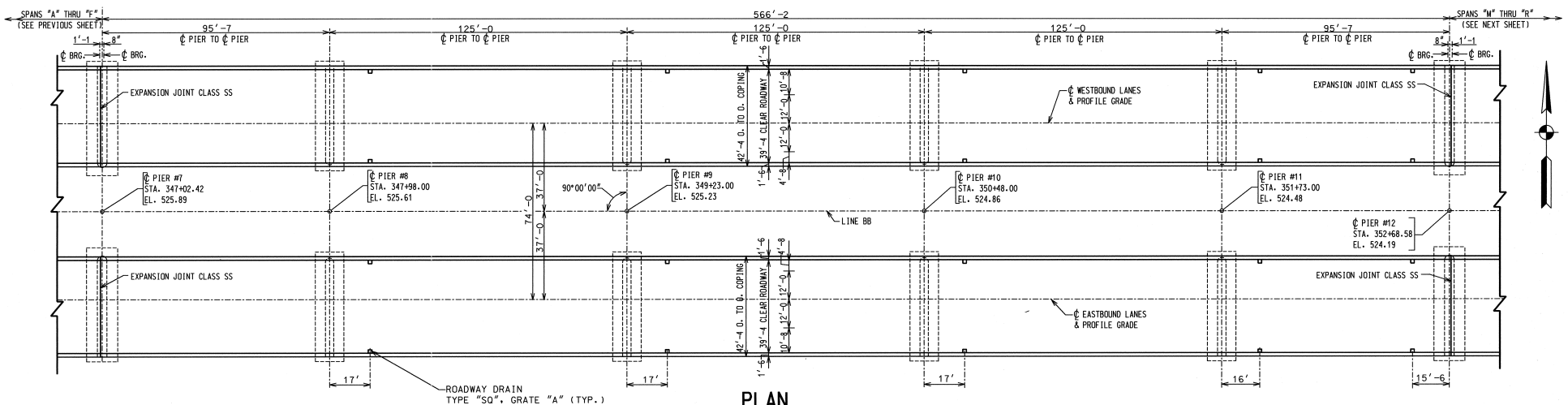
REVISIONS	
DATE	SHEET NO.
02-27-95	18, 19, 20

REVISIONS	
DATE	SHEET NO.



ELEVATION

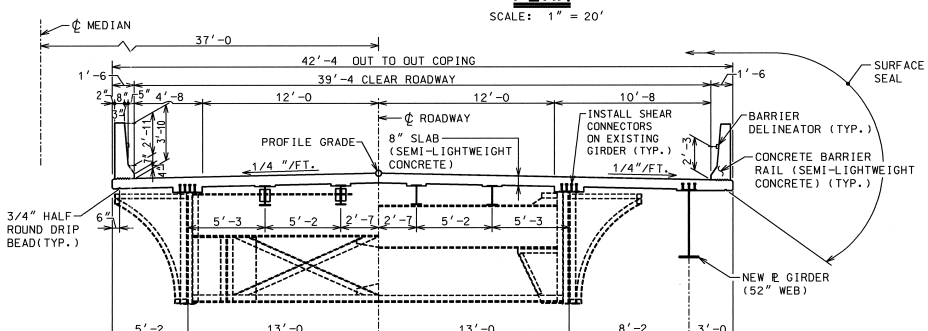
SCALE: 1" = 20'



PLAN

SCALE: 1" = 20'

NOTE: SEE DWG. W1 FOR SPANS "A THRU "F" AND DWG. W3 FOR SPANS "M" THRU "R".



TYPICAL SECTION SPANS "G" THRU "L"

SCALE: 1/4" = 1'-0

GENERAL PLAN-SPANS "G" THRU "L"

DECK REPLACEMENT AND STRUCTURE WIDENING
CONTINUOUS STEEL PLATE GIRDER
CONTINUOUS STEEL BEAM AND P.C. I-BEAM BRIDGES
17 SPANS: 43'-0; 60'-8; 3 @ 72'-0; 61'-0;
95'-7; 3 @ 125'-0; 95'-7;
61'-0; 3@ 72'-0; 60'-8; 43'-0 SQUARE
OVER WABASH RIVER ON INTERSTATE ROUTE NO. 74

INDIANA DEPARTMENT OF TRANSPORTATION

FOUNTAIN AND VERMILLION COUNTIES

SCALE: AS NOTED DATE: SEPTEMBER 16, 1994

DESIGNED S.J.C. C'K'D' D.M.S.
DRAWN D.M.S. C'K'D' S.J.C.
TRACED C'K'D'

DRAWING: W2 OF 38 SHEET 9 OF 79
PROJECT: IM-74-1(117)6
CONTRACT NO. B-21615
BRIDGE FILE: I-74-6-4417 DEB & EWB

STEVEN J. CHRISTIAN REGISTERED No. 20379 STATE OF INDIANA PROFESSIONAL ENGINEER

CONSTRUCTION PROCEDURE

STR. I-74-31-4943B & I-74-35-4948A

1. CLOSE STRUCTURE TO TRAFFIC.
2. REMOVE EXISTING ALUMINUM RAILING, CONCRETE PARAPET WALLS, PORTION OF CURBS AND DECK, CONCRETE WING RAILING, 5'-0 OF EXISTING R.C. BRIDGE APPROACHES AT BENTS NO. 1 & 5, AND CONCRETE OVERLAY DAMS AS SHOWN ON THE DETAILS. SCARIFY THE REMAINING BRIDGE FLOOR TO A DEPTH OF 1/4". REMOVE THE SCARIFIED DUST.
3. REMOVE ALL DETERIORATED CONCRETE BELOW THE LEVEL OF SCARIFICATION AND REMOVE CONCRETE AROUND REINFORCING STEEL BY HAND CHIPPING AND CLEANING IN ACCORDANCE WITH THE "SPECIAL PROVISIONS."
4. RECONSTRUCT REMOVED R.C. BRIDGE APPROACH PORTIONS AT BENTS NO. 1 & 5 TO ACCOMODATE TYPE BS-6 EXPANSION JOINTS. CONSTRUCT NEW CONCRETE BRIDGE BARRIER RAILING.
5. BLAST AND CLEAN ALL SCARIFIED AREAS.
6. PLACE BRIDGE DECK PATCHES AND BRIDGE DECK OVERLAY AS SHOWN ON THE PLANS AND IN ACCORDANCE WITH THE "SPECIAL PROVISIONS". INSTALL TYPE BS EXPANSION JOINTS.
7. SURFACE SEAL NEW CONCRETE BARRIER BRIDGE RAILING, COPINGS, BOTTOM OF DECK BETWEEN COPING AND OUTSIDE GIRDER, AND 1'-0 OF NEW R.C. BRIDGE APPROACH ADJACENT TO NEW BS JOINT.
8. PERFORM ALL OTHER WORK AS SHOWN AND/OR NOTED ON THE PLANS.
9. OPEN STRUCTURE TO TRAFFIC.

THE NUMBERS DO NOT NECESSARILY INDICATE THE SEQUENCE OF OPERATIONS.

STANDARD DRAWINGS

BR. STD.	RD. STD.	PURPOSE
BR 5		RAILING CONNECTION DETAILS
C 1		REINFORCING BAR NOTES
	SHT A	STANDARD PAVEMENT JOINTS
	MA	R.C. BRIDGE APPROACH
	MT 3	TRAFFIC SIGN DETAILS
	GR 2	GUARD RAIL CLASS "BS" & "HS"
	GR 4A	GUARD RAIL CLASS "HA" & "HS"
	GR 7	STEEL OFFSET BRACKET
	GR 10	GUARD RAIL END TREATMENT TYPE I
	CB 2	TEMPORARY CONCRETE BARRIER
	SHT. 1	STANDARD DETOUR SIGNS
	SHT. 2	STANDARD DETOUR SIGNS
	SHT. 2A	STANDARD DETOUR SIGNS
	SHT. 3	STANDARD DETOUR SIGNS
	SHT. 4	STANDARD DETOUR SIGNS
	SHT. 5	STANDARD DETOUR SIGNS

THIS LIST APPLIES TO BOTH STRUCTURES

GENERAL NOTES

PLANS FOR EXISTING STRUCTURE ARE ON FILE IN THE BRIDGE DEPARTMENT INDIANA DEPARTMENT OF HIGHWAYS, AS BRIDGE FILE NOS. I-74-31-4943, I-74-31-4943A, I-74-35-4948 AND ARE AVAILABLE UPON REQUEST.

WHERE NEW WORK IS TO BE FITTED TO OLD WORK, THE CONTRACTOR SHALL CHECK ALL DIMENSIONS AND CONDITIONS IN THE FIELD AND REPORT ANY ERRORS OR DISCREPANCIES TO THE ENGINEER AND ASSUME RESPONSIBILITY FOR THEIR CORRECTNESS AND THE FIT OF NEW PART TO OLD.

THE HAND CHIPPING AND CLEANING OF DETERIORATED DECK AREAS SHALL BE AS DIRECTED BY THE ENGINEER. IT IS THE INTENT OF THESE PLANS THAT ALL SUCH DETERIORATED CONCRETE BE REMOVED AND SHOULD THERE BE ANY DOUBT AS TO THE QUALITY OF THE CONCRETE, REMOVAL SHALL CONTINUE UNTIL PERFECTLY SOUND CONCRETE IS EXPOSED. ALL EXISTING NON-FULL DEPTH PATCHES SHALL BE REMOVED.

CONCRETE FOR PATCHES IN DETERIORATED DECK AREAS SHALL BE SPECIAL CLASS "A" CONCRETE OR MODIFIED PORTLAND CEMENT CONCRETE.

ALL BITUMINOUS MATERIAL REQUIRED IN THIS CONTRACT TO BE INCLUDED IN THE PAY ITEM "BITUMINOUS MIXTURE FOR APPROACHES" EXCEPT TACK COAT WHICH SHALL BE PAID FOR AS "BITUMINOUS MATERIAL FOR TACK COAT" IN SQUARE YARDS.

SEAL ALL EXPOSED CONCRETE SURFACES, AS NOTED ON THE PLANS, WITH A PENETRATING EPOXY SEALER.

SEAL ALL CRACKS AND JOINTS IN THE APPROACH PAVEMENT WITH A HOT POURED JOINT SEALER BEFORE PLACING THE BITUMINOUS WEDGE. THE COST OF THIS SEALING TO BE INCLUDED IN THE COST OF OTHER ITEMS IN THE CONTRACT.

SEE THE "SPECIAL PROVISIONS" FOR THE COMPOSITION OF CONCRETE IN THE OVERLAY DAMS.

CONCRETE IN FULL DEPTH REMOVAL AREAS TO BE CLASS "A".

THE BOUNDARIES OF FULL DEPTH REMOVAL AREAS SHALL BE SAW CUT. ALL SAW CUTS FOR FULL DEPTH REMOVALS AND FOR CURB PATCHING SHALL BE MADE TO MINIMUM OF 1 INCH (1") BELOW THE ORIGINAL SURFACE OR TO THE TOP OF THE REINFORCING IF COVER IS LESS THAN 1 INCH (1").

ALL REMOVAL EQUIPMENT USED FOR PARTIAL REMOVAL OF BRIDGE STRUCTURES SHALL BE HAND HELD. PNEUMATIC HAMMERS, 30 POUNDS MAXIMUM WEIGHT, SHALL BE USED FOR ALL REMOVAL AREAS TO BE PATCHED AND ALL AREAS WITHIN 24 INCHES (24") OF FULL DEPTH REMOVAL LINES. PNEUMATIC HAMMERS, UP TO 90 POUNDS MAXIMUM WEIGHT, MAY BE USED FOR ALL OTHER REMOVALS OUTSIDE THESE LIMITS. DECK AREAS THAT ARE TO BE REMOVED FULL DEPTH SHALL BE COMPLETELY SEPARATED FROM ADJACENT CONCRETE BEFORE HAMMERS HEAVIER THAN 30 POUNDS MAY BE USED.

MATERIAL NOTES

BRIDGE DECK OVERLAY:

1-3/4" MODIFIED PORTLAND CEMENT CONCRETE OVERLAY ✓

OR

2-1/2" DENSE PORTLAND CEMENT CONCRETE OVERLAY

(1-1/2" OR 2-1/4" RESPECTIVELY ABOVE THE ORIGINAL SURFACE.)

BITUMINOUS WEDGE:

110 POUNDS PER SQUARE YARD H.A.C. SURFACE TYPE II OVER VARIABLE DEPTH BITUMINOUS BINDER.

BITUMINOUS WIDENING:

990 POUNDS PER SQUARE YARD BITUMINOUS BASE (SIZE NO. 50.)

GENERAL NOTES AND CONSTRUCTION PROCEDURES

INDIANA DEPARTMENT OF HIGHWAYS

SCALE:- NO SCALE DATE:- DECEMBER 31, 1985

SUBMITTED FOR APPROVAL: Roman D. Pavlec

DRAWING:- D-8 OF D-8 SHEET:- 10 OF 27

PROJECT:- IR-74-1 (102)

BRIDGE CONTRACT NO. B-16520

BRIDGE FILE:- I-74-31-4943B & I-74-35-4948A

ROMAN D. PAVLEC No. 13050 STATE OF INDIANA REGISTERED PROFESSIONAL ENGINEER

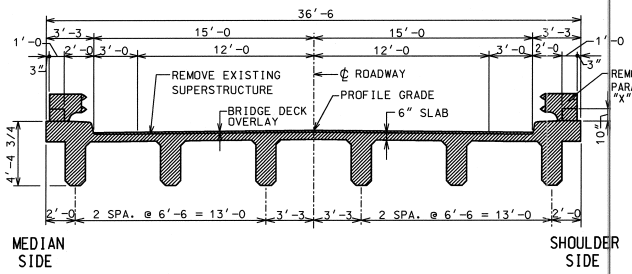
DESIGNED _____ C'K'D _____
DRAWN SLO C'K'D JLF
TRACED _____ C'K'D _____

SF-22317

2H-16

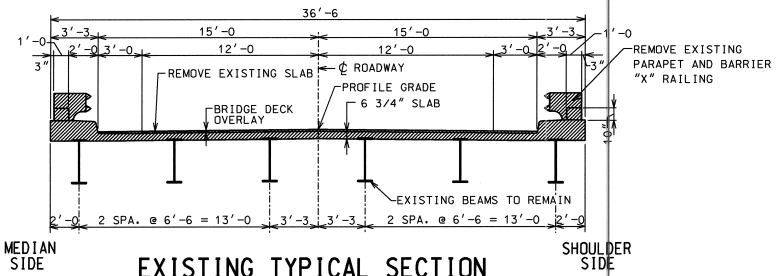
No Changes

TP118



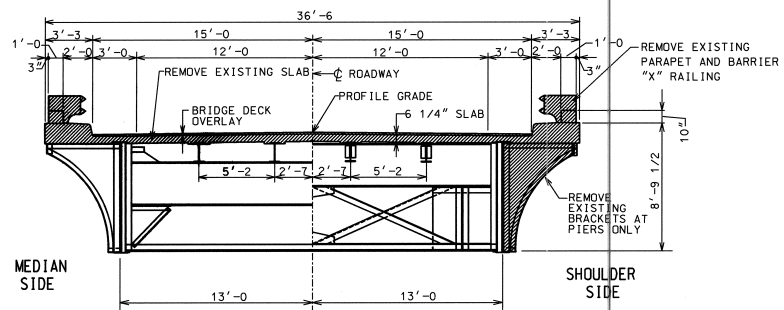
EXISTING TYPICAL SECTION SPANS A AND R

SCALE: 1/4" = 1'-0



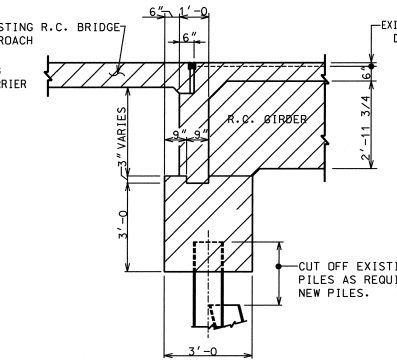
EXISTING TYPICAL SECTION SPANS B THRU F AND M THRU Q

SCALE: 1/4" = 1'-0



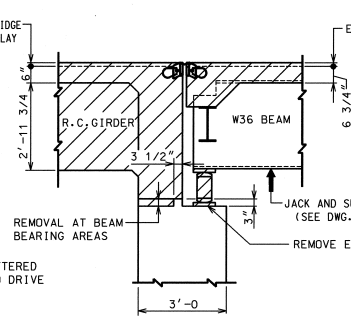
EXISTING TYPICAL SECTION SPANS G THRU L

SCALE: 1/4" = 1'-0



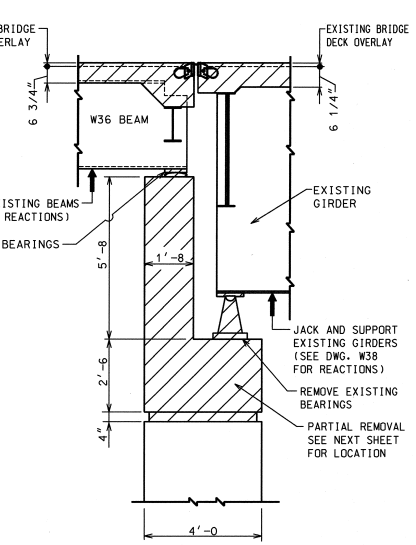
SECTION @ BENT NO. 1 & 18

SCALE: 1/2" = 1'-0



SECTION @ PIERS NO. 2 & 17

SCALE: 1/2" = 1'-0



SECTION @ PIERS NO. 7 & 12

SCALE: 1/2" = 1'-0

INDICATES REMOVAL

REMOVALS

INDIANA DEPARTMENT OF TRANSPORTATION

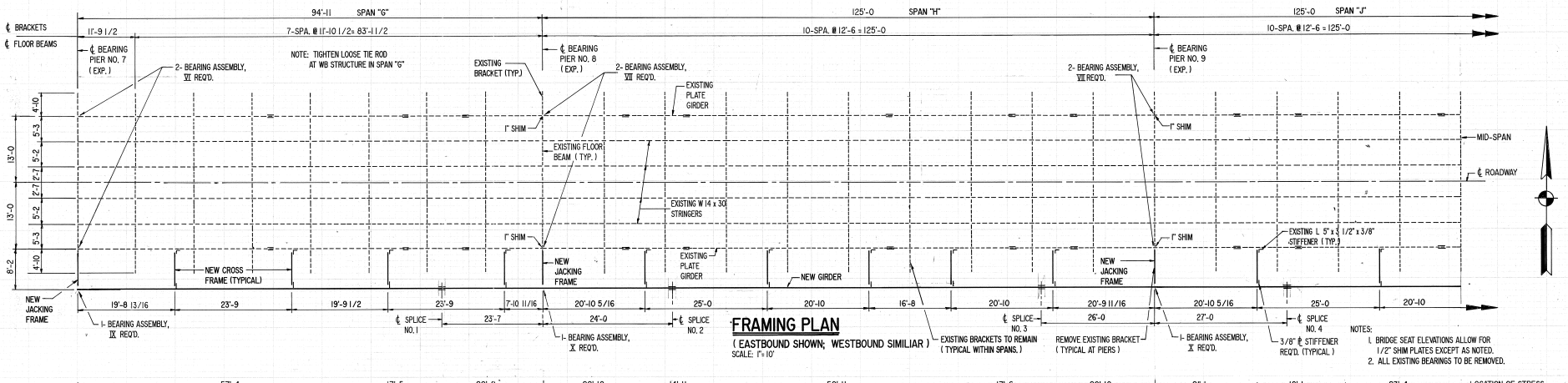
SCALE: AS NOTED DATE: SEPTEMBER 16, 1994

Stephen J. Christian

DRAWING: W4 OF 38 SHEET 11 OF 79
PROJECT: IM-74-1(117)6
CONTRACT NO. B-21615
BRIDGE FILE: I-74-6-4417 DEB & EWB

STEPHEN J. CHRISTIAN REGISTERED PROFESSIONAL ENGINEER No. 20379 STATE OF INDIANA

DESIGNED _____ C'K'D' _____
DRAWN D.M.S. C'K'D' S.J.C.
TRACED _____ C'K'D' _____

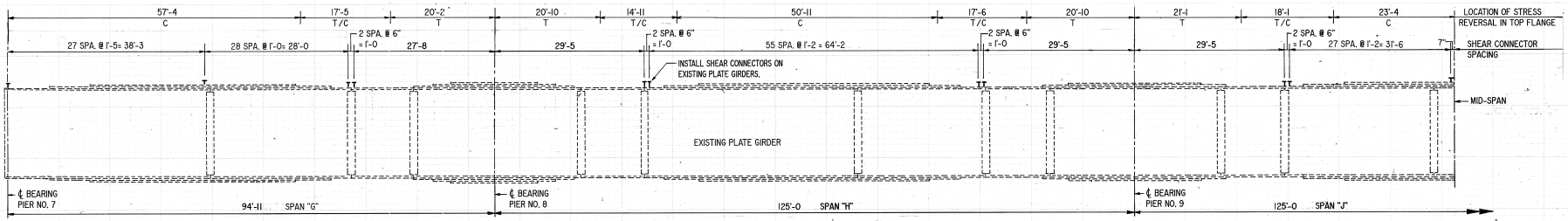


FRAMING PLAN

(EASTBOUND SHOWN; WESTBOUND SIMILIAR)

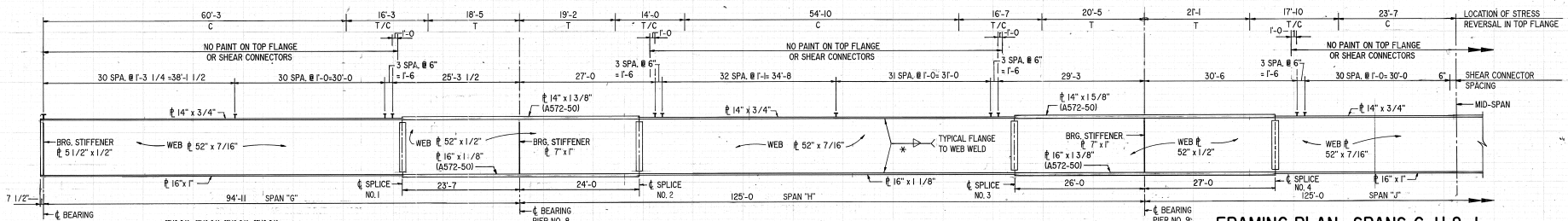
SCALE: 1"= 10'

NOTES:
1. BRIDGE SEAT ELEVATIONS ALLOW FOR 1/2" SHIM PLATES EXCEPT AS NOTED.
2. ALL EXISTING BEARINGS TO BE REMOVED.



EXISTING GIRDER ELEVATION

NO SCALE



NEW GIRDER ELEVATION

NO SCALE

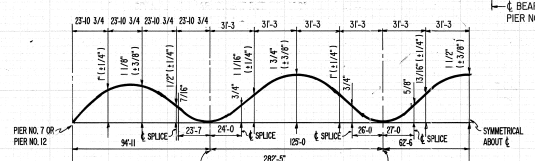
* 1/4" FOR 3/4" FLANGES AND 5/16" FOR ALL OTHERS.

NOTE:
1. STRUCTURAL STEEL SHALL BE A36 EXCEPT AS NOTED.
2. REPLACE LOOSE AND MISSING BOLTS AS DIRECTED BY THE ENGINEER. (ESTIMATED QUANTITY 150 EACH.)

SEE DWG. W30 FOR CONTINUATION OF FRAMING PLAN.

SEE DWG. W31 FOR JACKING FRAME, CROSS FRAME, AND SPLICE AND SHEAR CONNECTOR DETAILS.

SEE DWG. W32 AND W33 FOR BEARING DETAILS.



NO-LOAD CAMBER & REAMING DIAGRAM

NO SCALE

FRAMING PLAN- SPANS G, H & J

INDIANA DEPARTMENT OF TRANSPORTATION

SCALE:— AS NOTED

DATE:- SEPTEMBER 16, 1994

Stephen J. Christian

STEPHEN J. CHRISTIAN REGISTERED NO. 20379 PROFESSIONAL ENGINEER

DRAWING:- W29 OF 38 SHEET:- 36 OF 79

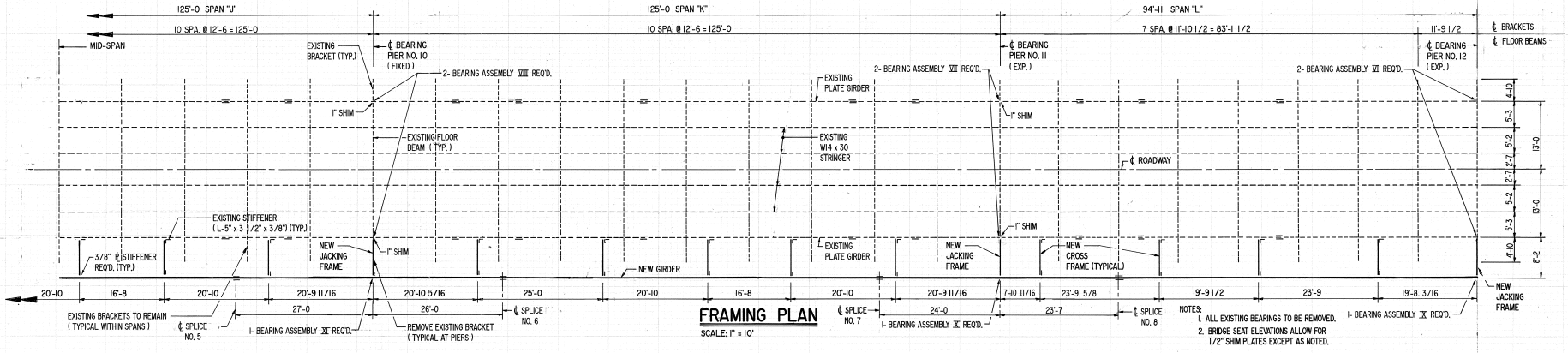
PROJECT:- IM-74-1 (117) 6

BRIDGE CONTRACT NO. B-21615

BRIDGE FILE:- I-74-6-4417 DEB & EWB

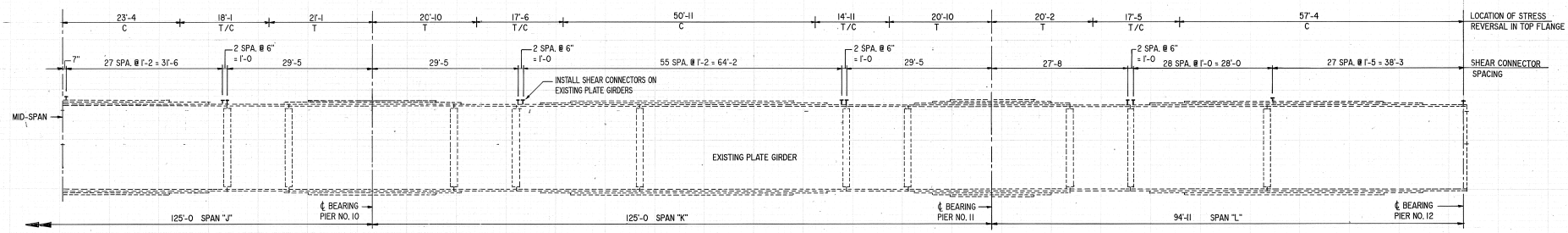
DESIGNED	SJC	C'K'D	DMS
DRAWN	DHJ	C'K'D	SJC
TRACED		C'K'D	

SF-22317



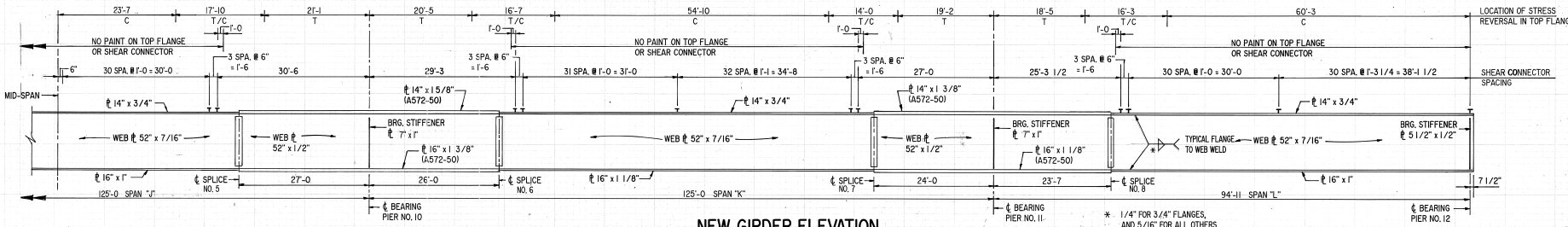
FRAMING PLAN

SCALE: 1" = 10'



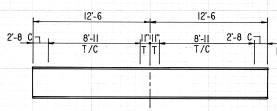
EXISTING GIRDER ELEVATION

NO SCALE



NEW GIRDER ELEVATION

NO SCALE



TENSION/COMPRESSION DIAGRAM FOR STRINGERS

NO SCALE

TABLE OF SPLICE ELEVATIONS								
SPLICE NO.	1	2	3	4	5	6	7	8
ELEVATION	524.58	524.45	524.25	524.09	523.88	523.72	523.47	523.31

SEE DWG. W29 FOR CONTINUATION OF FRAMING PLAN.
SEE DWG. W31 FOR JACKING FRAME, CROSS FRAME, AND SPLICE AND SHEAR CONNECTOR DETAILS.
SEE DWG. W32 AND W33 FOR BEARING DETAILS.

FRAMING PLAN- SPANS J, K & L

INDIANA DEPARTMENT OF TRANSPORTATION

SCALE:— AS NOTED

DATE:- SEPTEMBER 16, 1994

Stephen J. Christian

STEPHEN J. CHRISTIAN REGISTERED No. 20375 STATE OF INDIANA PROFESSIONAL ENGINEER

DRAWING:- W30 OF 38 SHEET:- 37 OF 79

PROJECT:- IM-74-1 (117) 6

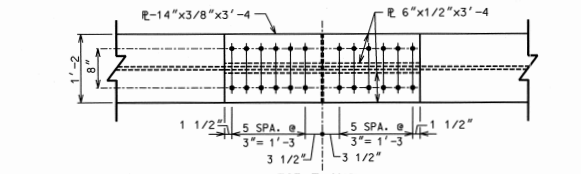
BRIDGE CONTRACT NO. B-21615

BRIDGE FILE:- I-74-6-4417 DEB & EWB

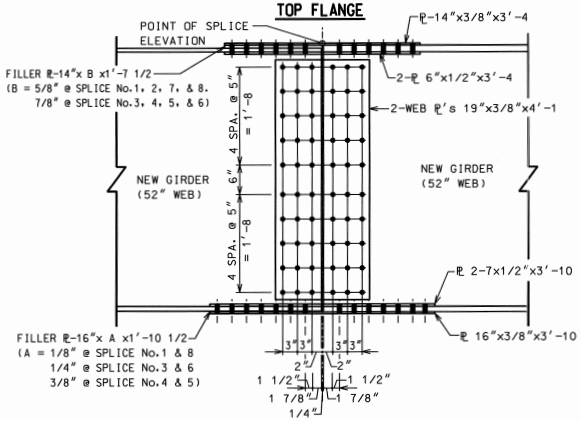
DESIGNED	SJC	C'K'D	DMS
DRAWN	DHJ	C'K'D	SJC
TRACED		C'K'D	

SF-22317

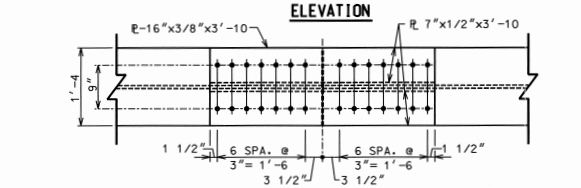
TP118



TOP FLANGE



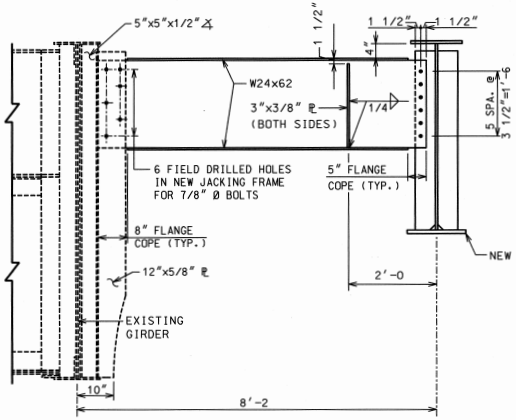
ELEVATION



BOTTOM FLANGE

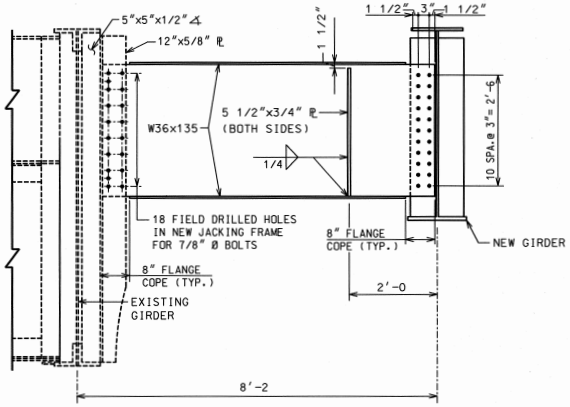
TYPICAL SPLICE DETAIL

SCALE: 1" = 1'-0



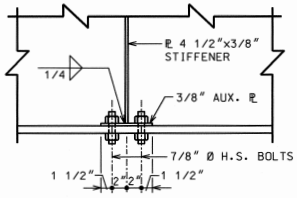
JACKING FRAME @ PIERS 7 & 12

SCALE: 3/4"= 1'-0



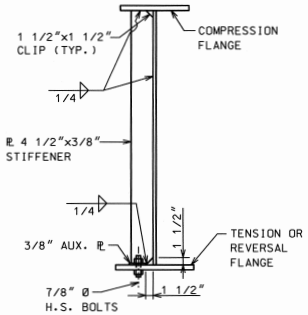
JACKING FRAME @ PIERS 8 THRU 11

SCALE: 3/4"= 1'-0



ELEVATION

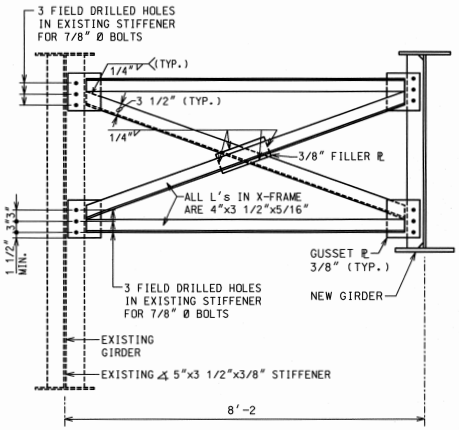
SCALE: 1 1/2"= 1'-0



SECTION

SCALE: 1"= 1'-0

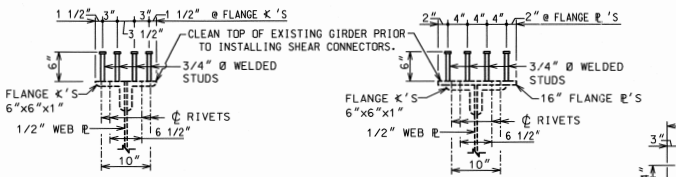
BEARING STIFFENER @ CROSS FRAMES



CROSS FRAME DETAIL

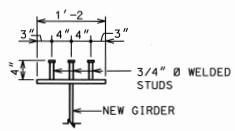
SCALE: 3/4"= 1'-0

SEE DWG. W36 FOR BRACKET DETAIL AT ROADWAY DRAINS.



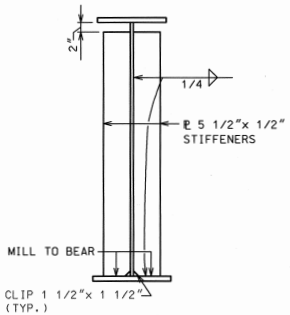
TYPICAL SHEAR CONNECTOR DETAILS

(SHOWING EXISTING GIRDER)
SCALE: 1"= 1'-0



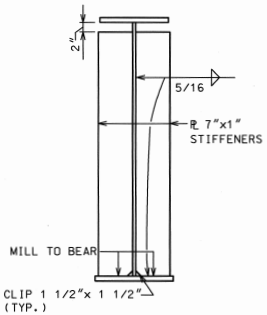
TYPICAL SHEAR CONNECTOR DETAILS

(SHOWING NEW GIRDER)
SCALE: 1"= 1'-0



BEARING STIFFENER AT PIERS 7 & 12

SCALE: 1"= 1'-0



BEARING STIFFENER AT PIERS 8 THRU 11

SCALE: 1"= 1'-0

STRUCTURAL STEEL DETAILS

SPANS "G" THRU "L"

INDIANA DEPARTMENT OF TRANSPORTATION

SCALE: AS NOTED

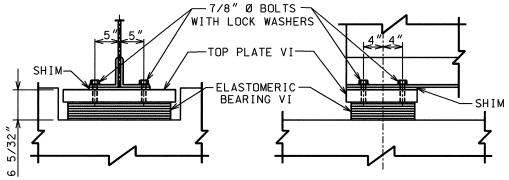
DATE: SEPTEMBER 16, 1994

Stephen J. Christian

DRAWING: W31 OF 38 SHEET 38 OF 79
PROJECT: IM-74-1(117)6
CONTRACT NO. B-21615
BRIDGE FILE: I-74-6-4417 DEB & EWB

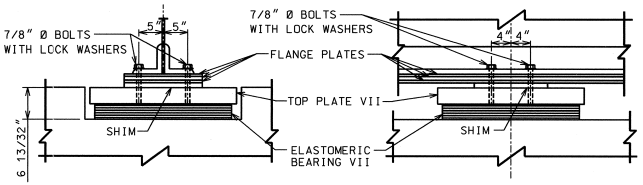
STEPHEN J. CHRISTIAN REGISTERED No. 20379 STATE OF INDIANA PROFESSIONAL ENGINEER

DESIGNED	D.M.S.	C'K'D'	J.G.J.
DRAWN	S.K.M.	C'K'D'	S.J.C.
TRACED		C'K'D'	



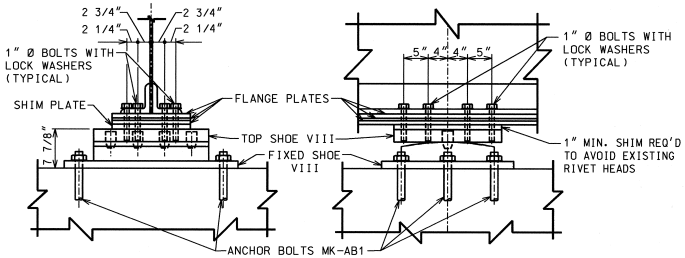
BEARING ASSEMBLY VI @ PIERS 7 & 12 (EXISTING GIRDER)

SCALE: 1"= 1'-0



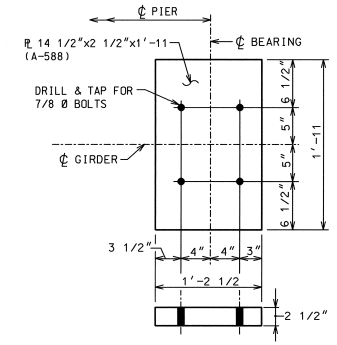
BEARING ASSEMBLY VII @ PIERS 8, 9 & 11 (EXISTING GIRDER)

SCALE: 1"= 1'-0



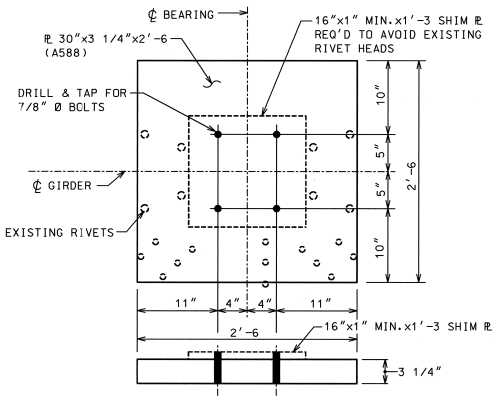
BEARING ASSEMBLY VIII @ PIER 10 (EXISTING GIRDER)

SCALE: 1"= 1'-0



TOP PLATE VI

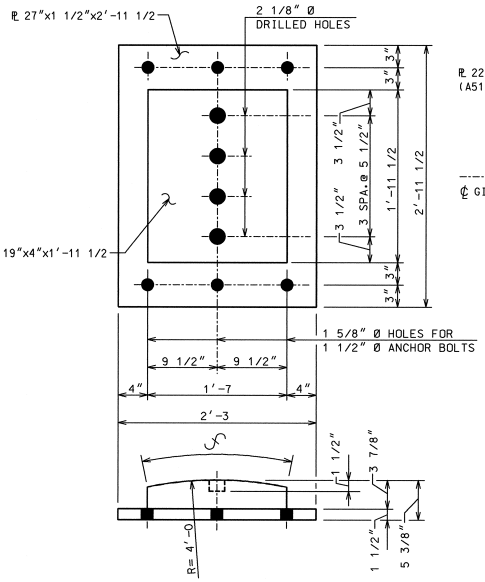
SCALE: 1 1/2"= 1'-0



NOTE: BEARING PADS TO BE BONDED TO TOP PLATE

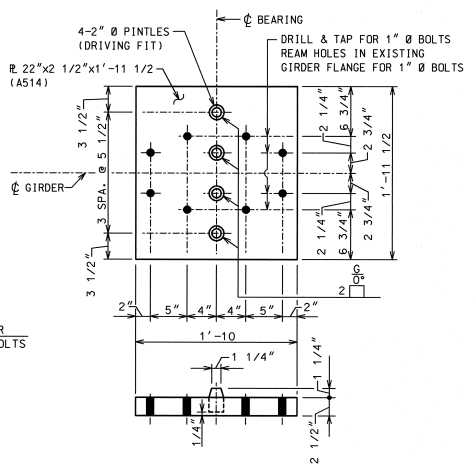
TOP PLATE VII

SCALE: 1 1/2"= 1'-0



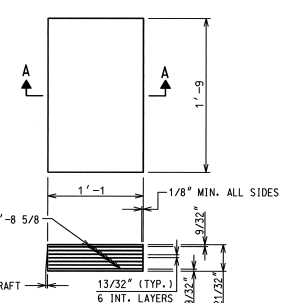
FIXED SHOE VIII

SCALE: 1 1/2"= 1'-0



TOP SHOE VIII

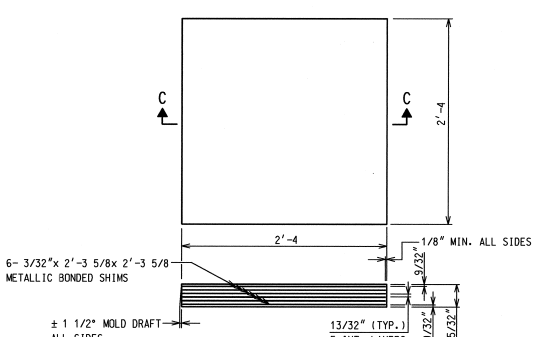
SCALE: 1 1/2"= 1'-0



SECTION A-A

ELASTOMERIC BEARING VI

SCALE: 1 1/2"= 1'-0



SECTION C-C

ELASTOMERIC BEARING VII

SCALE: 1 1/2"= 1'-0

STRUCTURAL STEEL DETAILS

SPANS "G" THRU "L"

INDIANA DEPARTMENT OF TRANSPORTATION

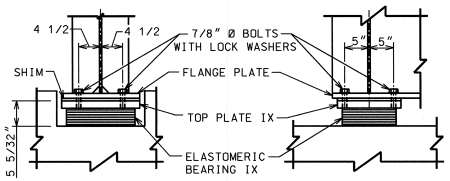
SCALE: AS NOTED DATE: SEPTEMBER 16, 1994

Stephen J. Christian

DRAWING: W32 OF 38 SHEET 39 OF 79
PROJECT: IM-74-1(117)6
CONTRACT NO. B-21615
BRIDGE FILE: I-74-6-4417 DEB & EWB

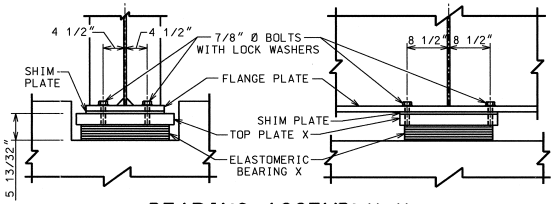
DESIGNED	D.M.S.	C'K'D'	J.G.J./S.J.C.
DRAWN	M.A.B.	C'K'D'	S.J.C.
TRACED		C'K'D'	

STEPHEN J. CHRISTIAN REGISTERED No. 20379 STATE OF INDIANA PROFESSIONAL ENGINEER



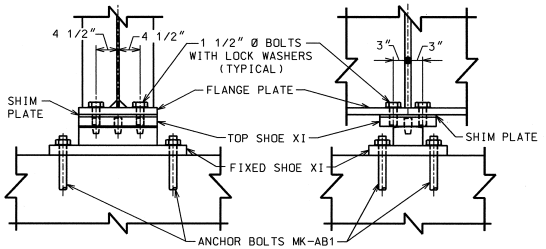
BEARING ASSEMBLY IX
@ PIERS 7 & 12 (NEW GIRDER)

SCALE: 1"= 1'-0



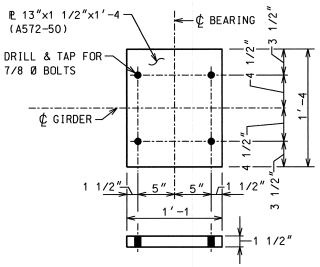
BEARING ASSEMBLY X
@ PIERS 8, 9 & 11 (NEW GIRDER)

SCALE: 1"= 1'-0



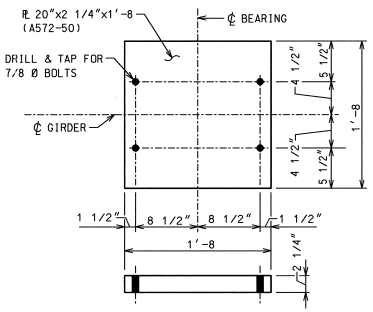
BEARING ASSEMBLY XI
@ PIER 10 (NEW GIRDER)

SCALE: 1"= 1'-0



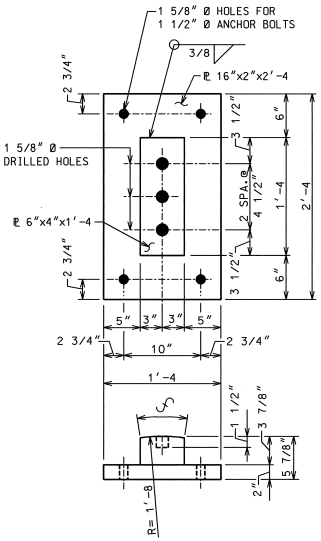
TOP PLATE IX

SCALE: 1 1/2"= 1'-0



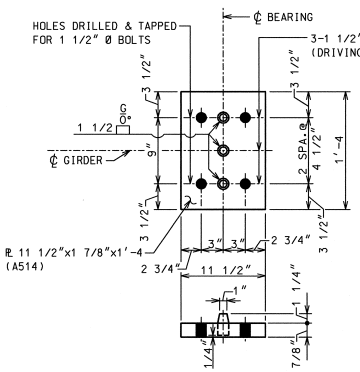
TOP PLATE X

SCALE: 1 1/2"= 1'-0



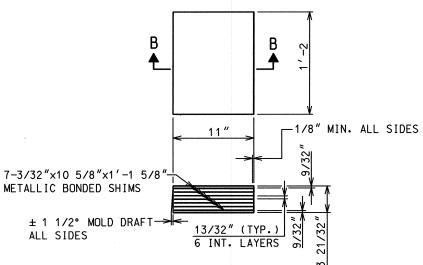
FIXED SHOE X

SCALE: 1 1/2"= 1'-0



TOP SHOE XI

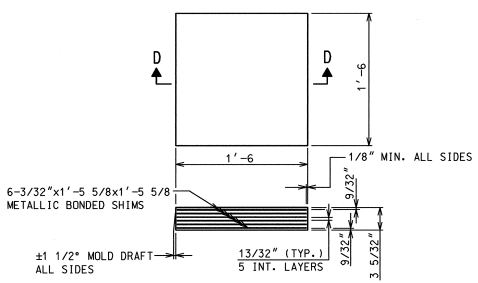
SCALE: 1 1/2"= 1'-0



SECTION B-B

ELASTOMERIC BEARING IX

SCALE: 1 1/2"= 1'-0



SECTION D-D

ELASTOMERIC BEARING X

SCALE: 1 1/2"= 1'-0

STRUCTURAL STEEL DETAILS
SPANS "G" THRU "L"
INDIANA DEPARTMENT OF TRANSPORTATION

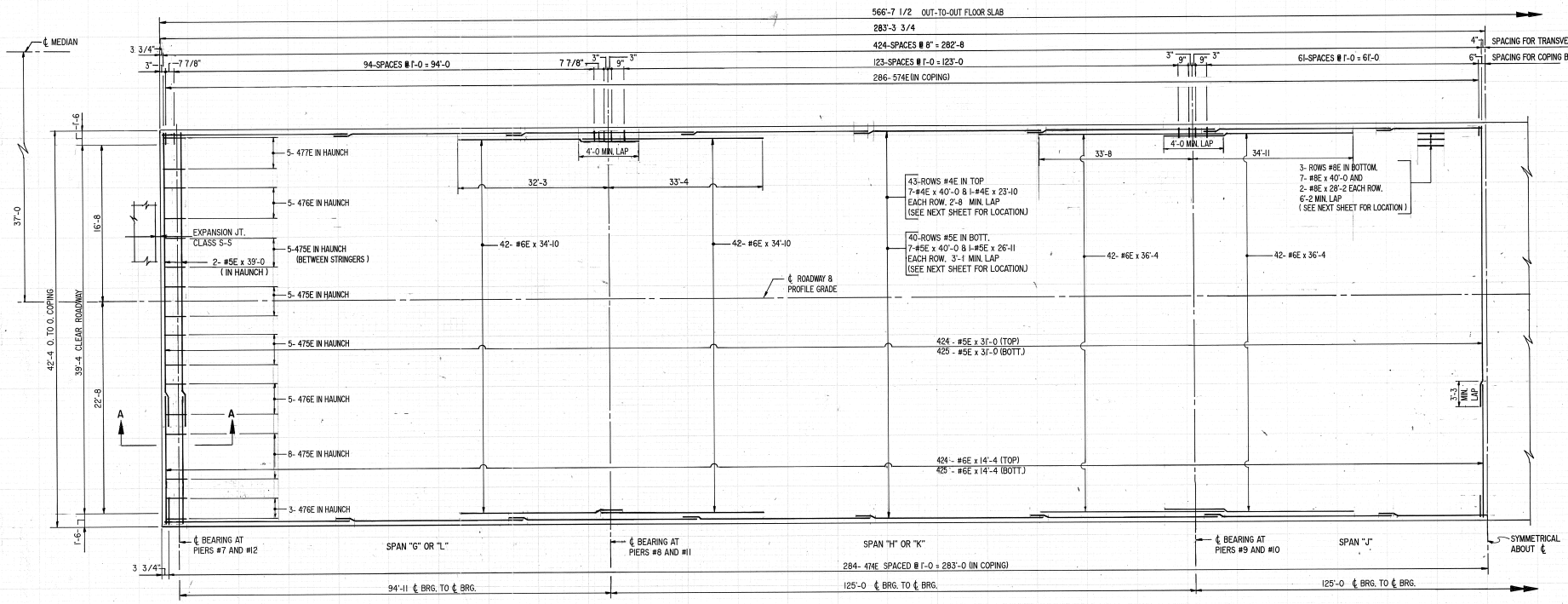
SCALE: AS NOTED DATE: SEPTEMBER 16, 1994

Stephen J. Christian

DRAWING: W33 OF 38 SHEET 40 OF 79
PROJECT: IM-74-1(117)6
CONTRACT NO. B-21615
BRIDGE FILE: I-74-6-4417 DEB & EWB

STEPHEN J. CHRISTIAN REGISTERED No. 20379 STATE OF INDIANA PROFESSIONAL ENGINEER

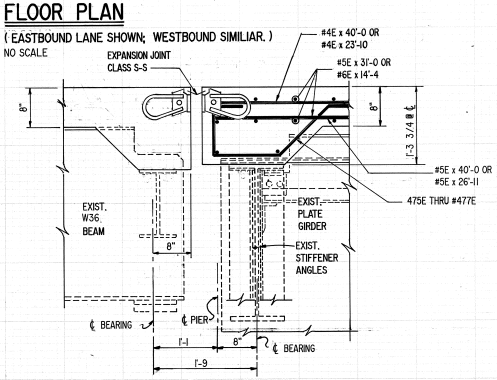
DESIGNED	D.M.S.	C'K'D'	J.G.J./S.J.C.
DRAWN	M.A.B.	C'K'D'	S.J.C.
TRACED		C'K'D'	



FLOOR PLAN

(EASTBOUND LANE SHOWN; WESTBOUND SIMILIAR.)

NO SCALE



SECTION A-A

SCALE: 1" = 1'-0

SEE DWG. W35 FOR TYPICAL SECTIONS.

SEE DWG. W36 FOR RAIL AND ROADWAY DRAIN DETAILS.

SEE DWG. W37 FOR RAIL DETAILS, ROADWAY DRAIN DETAILS, BAR BENDING DETAILS, AND BILL OF MATERIALS.

FLOOR PLAN SPANS "G" THRU "L"

INDIANA DEPARTMENT OF TRANSPORTATION

SCALE:— **AS NOTED**

DATE:- SEPTEMBER 16, 1994

Stephen J. Christian

DRAWING:- W34 OF 38 SHEET:- 41 OF 79

PROJECT:- **IM-74-1 (117) 6**

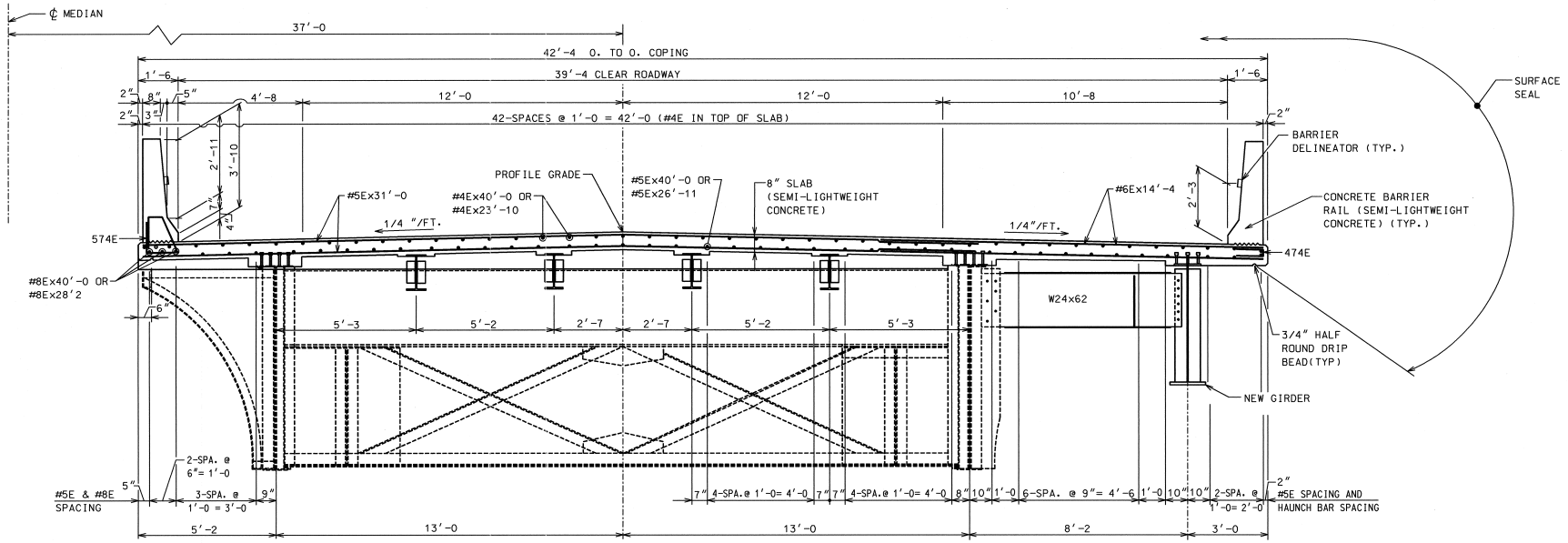
BRIDGE CONTRACT NO. **B-21615**

BRIDGE FILE:- **I-74-6-4417 DEB & EWB**

DESIGNED	SJC	C'K'D	DMS
DRAWN	DHJ	C'K'D	SJC
TRACED		C'K'D	

SF-22317

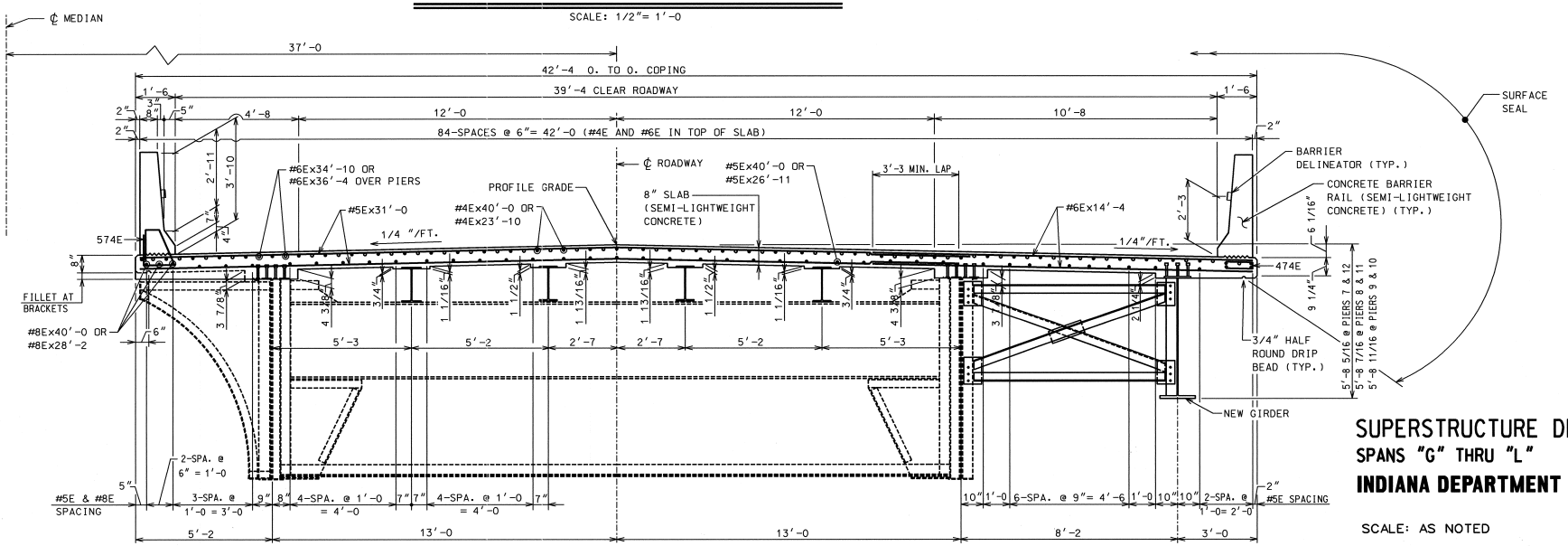
TP118



TYPICAL SECTION @ PIERS 7 AND 12

SCALE: 1/2″= 1′-0

NOTE: DIMENSIONS NOT SHOWN ARE SAME AS BELOW.



TYPICAL SECTION WITHIN SPANS

SCALE: 1/2″= 1′-0

NOTE: BEAM FILLET DIMENSIONS ARE NOMINAL AND WILL VARY DUE TO CAMBER IRREGULARITIES.

SUPERSTRUCTURE DETAILS

SPANS "G" THRU "L"

INDIANA DEPARTMENT OF TRANSPORTATION

SCALE: AS NOTED

DATE: SEPTEMBER 16, 1994

Stephen J. Christian

STEPHEN J. CHRISTIAN REGISTERED No. 20379 STATE OF INDIANA PROFESSIONAL ENGINEER

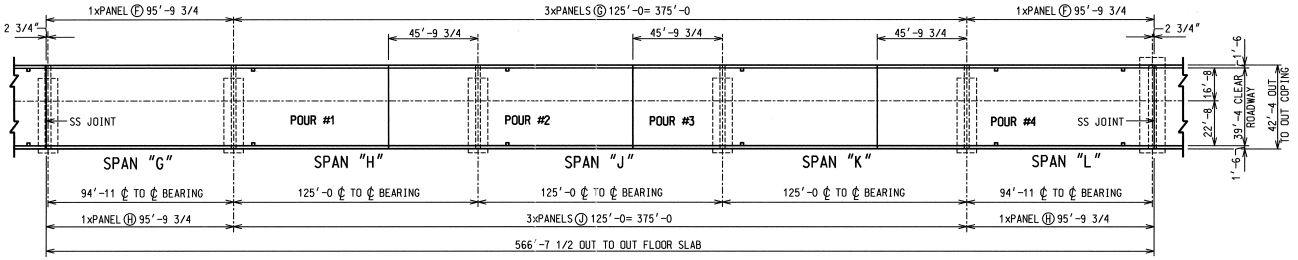
DESIGNED S.J.C. C'K'D' D.M.S.
DRAWN S.K.M. C'K'D' S.J.C.
TRACED C'K'D'

DRAWING: W35 OF 38 SHEET 42 OF 79

PROJECT: IM-74-1(117)6

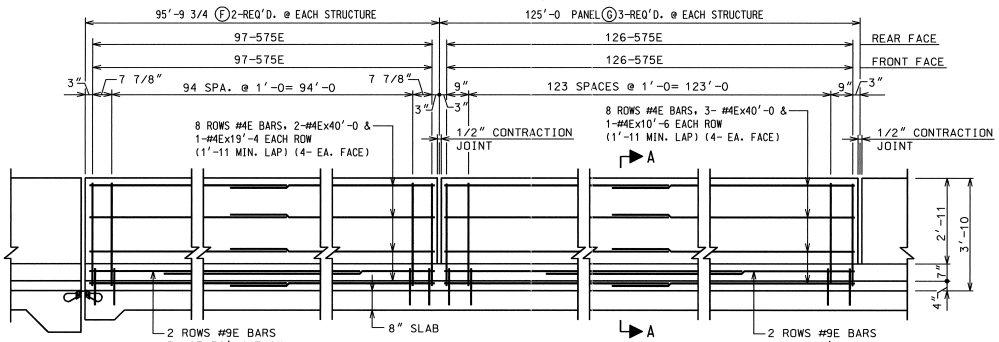
CONTRACT NO. B-21615

BRIDGE FILE: I-74-6-4417 DEB & EWB



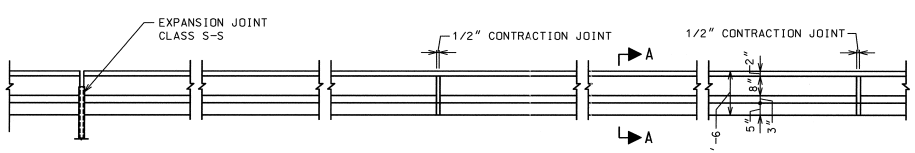
RAILING PLAN AND POUR DIAGRAM

(EASTBOUND LANE SHOWN, WESTBOUND SIMILAR)
SCALE: 1" = 30'-0



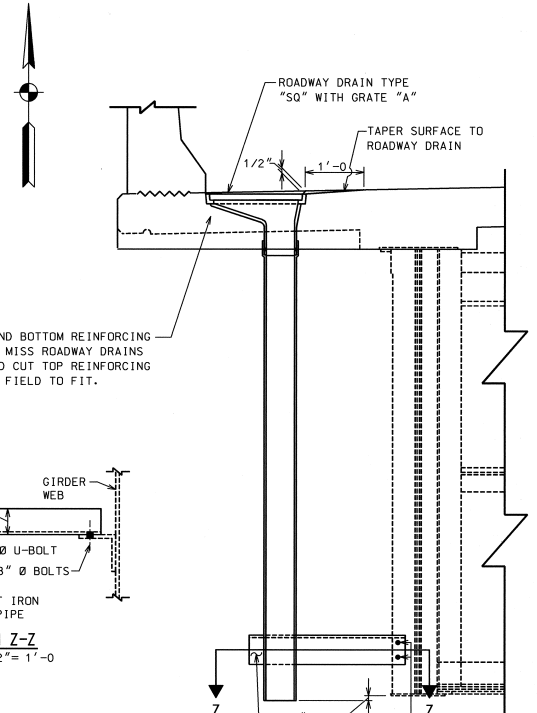
ELEVATION @ MEDIAN

SCALE: 1/2" = 1'-0



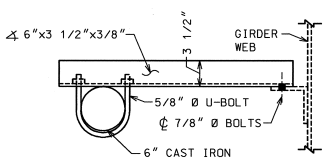
PLAN @ MEDIAN

SCALE: 1/2" = 1'-0



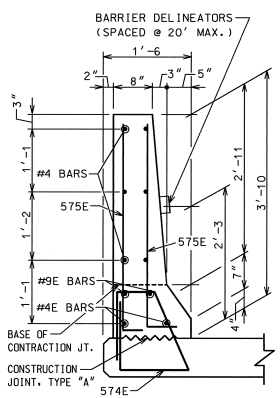
SECTION @ MEDIAN ROADWAY DRAIN

SCALE: 1"= 1'-0



SECTION Z-Z

SCALE: 1 1/2"= 1'-0



SECTION A-A

SCALE: 1"= 1'-0

NOTES: SEE BRIDGE STD. C3 FOR OPTIONAL RAILING VERTICAL REINFORCING SPLICE.
FOR CLASS S-S JOINT INSTALLATION AT BARRIER RAIL SEE BRIDGE STANDARD SS-2.
FOR ELEVATION AND PLAN AT OUTSIDE SHOULDER SEE DWG. W37.

SUPERSTRUCTURE DETAILS

SPANS "G" THRU "L"

INDIANA DEPARTMENT OF TRANSPORTATION

SCALE: AS NOTED

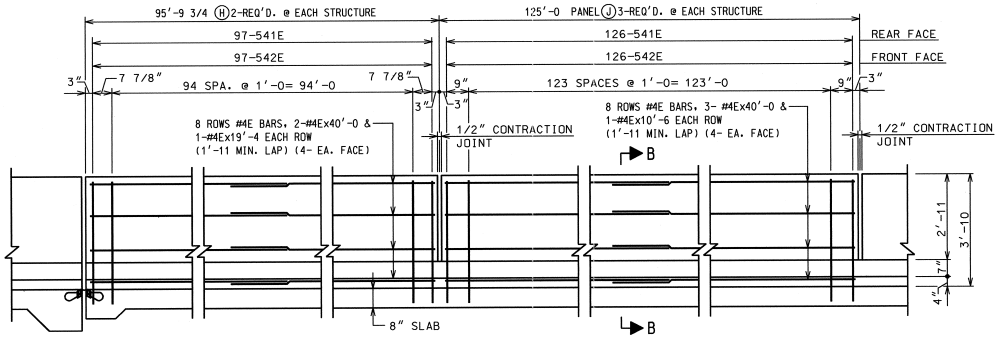
DATE: SEPTEMBER 16, 1994

Stephen J. Christian

DRAWING: W36 OF 38 SHEET 43 OF 79
PROJECT: IM-74-1(117)6
CONTRACT NO. B-21615
BRIDGE FILE: I-74-6-4417 DEB & EWB

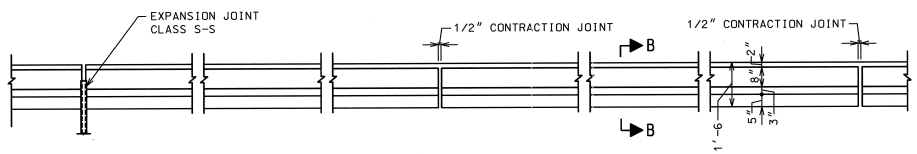
STEPHEN J. CHRISTIAN REGISTERED No. 20279 STATE OF INDIANA PROFESSIONAL ENGINEER

DESIGNED	S.J.C.	C'K'D'	D.M.S.
DRAWN	S.K.M.	C'K'D'	S.J.C.
TRACED		C'K'D'	



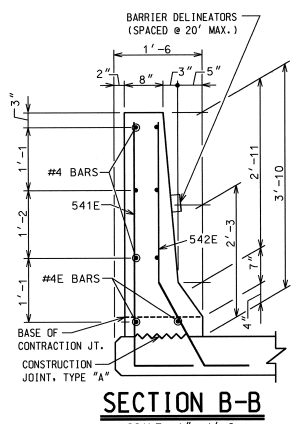
ELEVATION @ OUTSIDE SHOULDER

SCALE: 1/2"= 1'-0



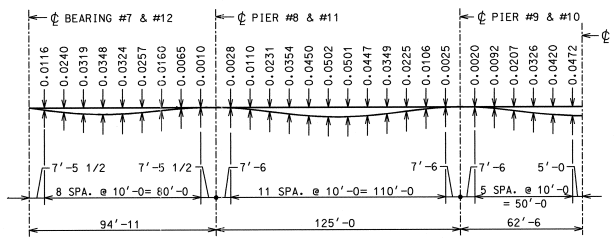
PLAN @ OUTSIDE SHOULDER

SCALE: 1/2"= 1'-0



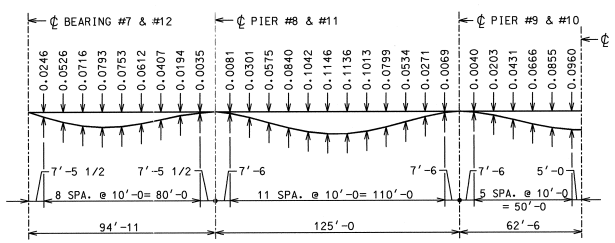
SECTION B-B

SCALE: 1"= 1'-0



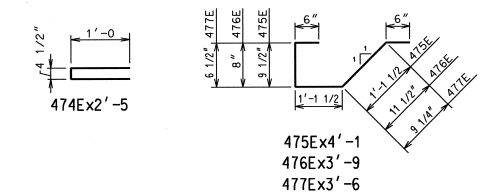
CONCRETE D.L. DEFLECTIONS-EXISTING GIRDERS (FT.)

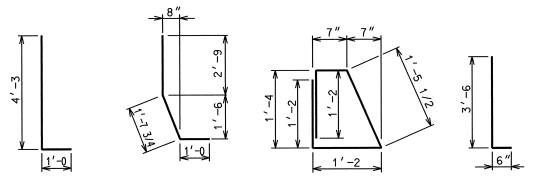
DEFLECTIONS ARE SYMMETRICAL ABOUT ℄
NOT TO SCALE

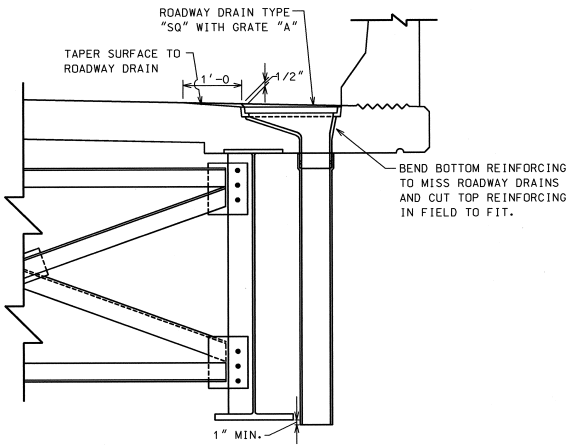


CONCRETE D.L. DEFLECTIONS-NEW GIRDERS (FT.)

DEFLECTIONS ARE SYMMETRICAL ABOUT ℄
NOT TO SCALE







SECTION @ SHOULDER ROADWAY DRAIN

SCALE: 1"= 1'-0

BILL OF MATERIALS SUPERSTRUCTURE

TOTALS FOR ONE 2 REQUIRED

EPOXY COATED REINFORCING STEEL			
SIZE OR MARK	NUMBER OF BARS	LENGTH (FT.)	WEIGHT (LBS.)
#9E	12	36'-4	
#9E	24	36'-3	
TOTAL NO. 9			4440
#8E	42	40'-0	
#8E	12	28'-2	
TOTAL NO. 8			5388
#6E	168	36'-4	
#6E	168	34'-10	
#6E	1696	14'-4	
TOTAL NO. 6			54,471
541E	572	5'-3	
542E	572	5'-5	
574E	572	5'-7	
575E	1144	4'-0	
#5E	560	40'-0	
#5E	4	39'-0	
#5E	1696	31'-0	
#5E	80	26'-11	
TOTAL NO. 5			95,076
474E	567	2'-5	
475E	46	4'-1	
476E	26	3'-9	
477E	10	3'-6	
#4E	810	40'-0	
#4E	86	23'-10	
#4E	32	19'-4	
#4E	48	10'-6	
TOTAL NO. 4			22,892
TOTAL EPOXY COATED REINFORCING STEEL			184,267
CONCRETE			
POUR NO. 1			198.4 CYS
POUR NO. 2			140.8 CYS
POUR NO. 3			140.8 CYS
POUR NO. 4			160.7 CYS
TOTAL CONCRETE CLASS "SL" IN SUPERSTRUCTURE			640.7 CYS
PANEL "F" (12.10 CYS x 4)			48.4 CYS
PANEL "G" (15.79 CYS x 6)			94.8 CYS
TOTAL CLASS "SL" CONCRETE RAILING			143.2 CYS
MISCELLANEOUS			
BARRIER DELINEATORS			58 EACH
CAST IRON GRATES, BASINS AND FITTINGS			1920 LBS
DRAIN PIPE, CAST IRON, 6"			1138 LBS
SURFACE SEAL (33,500 SFT.)			L.S. ITEM
STRUCTURAL EXPANSION JOINT,SS			84 LFT

SUPERSTRUCTURE DETAILS

SPANS "G" THRU "L"

INDIANA DEPARTMENT OF TRANSPORTATION

SCALE: AS NOTED

DATE: SEPTEMBER 16, 1994

Stephen J. Christian

DRAWING: W37 OF 38 SHEET 44 OF 79

PROJECT: IM-74-1(117)6

CONTRACT NO. B-21615

BRIDGE FILE: I-74-6-4417 DEB & EWB

STEPHEN J. CHRISTIAN REGISTERED No. 20379 STATE OF INDIANA PROFESSIONAL ENGINEER

DESIGNED	S.J.C.	C'K'D'	D.M.S.
DRAWN	S.K.M.	C'K'D'	S.J.C.
TRACED		C'K'D'	

BRIDGE FILE I-74-6-4417 DEB & EWB

STRUCTURE QUANTITIES

ITEM	CONCRETE CLASS C SUPERSTR CU. YDS.	CONCRETE CLASS SL SUPERSTR CU. YDS.	CONCRETE CLASS A SUBSTR CU. YDS.	CONCRETE CLASS B IN FTG. CU. YDS.	CONCRETE RAILING, CLASS C CU. YDS.	CONCRETE RAILING, CLASS SL CU. YDS.	REINF. STEEL TOTAL LBS.	EPOXY COATED REINF. STEEL LBS.	STRUCT. STEEL x LBS.	ANCHOR PLATES MK-AP 4 EACH	ANCHOR BOLT MK-AB 1 EACH	ANCHOR BOLT MK-AB 2 EACH	ANCHOR BOLT MK-AB 3 EACH	ANCHOR BOLT MK-AB 4 EACH	ANCHOR BOLT MK-AB 5 EACH	STEEL H PILE NO.	STEEL H PILE LIN. FT.	CAST IRON DRAIN PIPE LBS.	CAST IRON GRATES, BASINS, & FITTINGS LBS.	BOLT, REMOVE EACH	EXP. JOINT CLASS S-S LIN. FT.	CONCRETE I-BEAMS TYPE III LIN. FT.	FIELD DRILLED HOLES EACH	SHEAR CONNECTORS EACH	FIELD DRILLED HOLES IN CONCRETE EACH	CORED HOLES EACH	SURFACE SEAL x SQ. FT.	BARRIER DELINEATORS EACH	FOUNDATION EXCAVATION UNCLASSIFIED CU. YDS.
EASTBOUND STRUCTURE																														
SUPERSTRUCTURE																														
SPAN "A"	77.5				10.9			17,423										124	644				215					2500		4	
SPANS "B" THRU "F"	367.8				85.1			93,513	52,200									336	1152		187	42		50	5229			19,920		34	
SPANS "G" THRU "L"		640.7				143.2		184,267	127,100									1138	1920		267	84		232	3379			33,500		58	
SPANS "M" THRU "Q"	367.8				85.1			93,513	52,200									336	1152		187	42		50	5229			19,920		34	
SPAN "R"	77.5				10.9			17,423															215					2500		4	
SUBSTRUCTURE																														
BENT NO. 1			17.4					3407		5						3	207										87			34
PIER NO. 2			46.5	16.0			3231	933				10	7			10	380								146		422			103
PIER NO. 3			43.1	16.0			4953									6	216								82					58
PIER NO. 4			43.1	16.0			4953									6	216								82					41
PIER NO. 5			43.1	16.0			4953									6	216								82					55
PIER NO. 6			43.1	16.0			4953									6	216								82					82
PIER NO. 7			22.2					1740						8	14										38	6	1120			
PIER NO. 8			14.8				2166																		30	9				
PIER NO. 9			14.8				2166																		30	9				
PIER NO. 10			14.7				2160				16														30	9				
PIER NO. 11			14.8				2166																		30	9				
PIER NO. 12			22.2					1740						8	14										38	6	1119			
PIER NO. 13			38.8	16.0			4648									6	222								82					53
PIER NO. 14			43.1	16.0			4953									6	198								82					47
PIER NO. 15			38.8	16.0			4648									6	174								82					61
PIER NO. 16			38.8	16.0			4648									6	150								82					55
PIER NO. 17			39.6	16.0			2310	933				10	7			10	270								146		422			67
BENT NO. 18			17.4					3407		5						3	153										87			34
APPROACHES (EASTBOUND)					12.2		4588	3237																			2318		7	
TOTAL EASTBOUND STRUCTURE	890.6	640.7	556.3	160.0	204.2	143.2	58,096	421,536	231,500	10	16	20	14	16	28		2618	1934	4868		641	168	430	332	13,837	1144		48	83,915		141	690
TOTAL WESTBOUND STRUCTURE	890.6	640.7	556.3	160.0	204.2	143.2	58,096	421,536	231,500	10	16	20	14	16	28		2618	1934	4868		641	168	430	332	13,837	1144		48	83,915		141	690
TOTALS	1781.2	1281.4	1112.6	320.0	408.4	286.4	116,192	843,072	x 463,000	20	32	40	28	32	56		5236	3868	9736		1282	336	860	664	27,674	2288		96	x 167,830		282	1380

x LUMP SUM ITEM

BRIDGE FILE I-74-6-4417 DEB & EWB

APPROACH STRUCTURES

STRUCT. NO.	LOCATION	DESCRIPTION SIZE	DESCRIPTION KIND	LENGTH LIN. FT.	CONCR. CL. A IN STRS. CU. YDS.	REINF. STEEL LBS.	PIPE END SEC. EACH		REMARKS
1	343+20 LT.	6"	PERF. C.P. PIPE	60					PLUG RIGHT END, DRAIN LEFT
2	343+20 RT.	6"	PERF. C.P. PIPE	60					PLUG LEFT END, DRAIN RIGHT
3	356+51 LT.	6"	PERF. C.P. PIPE	60					PLUG RIGHT END, DRAIN LEFT
4	356+51 RT.	6"	PERF. C.P. PIPE	60					PLUG LEFT END, DRAIN RIGHT
				TOTALS					Total of Reinforcing Steel Carried to "Structure Quantities"

BEARING ASSEMBLIES

ITEM	BEARING ASSEMBLY I	BEARING ASSEMBLY II	BEARING ASSEMBLY III	BEARING ASSEMBLY IV	BEARING ASSEMBLY V	BEARING ASSEMBLY VI	BEARING ASSEMBLY VII	BEARING ASSEMBLY VIII	BEARING ASSEMBLY IX	BEARING ASSEMBLY X	BEARING ASSEMBLY XI
EASTBOUND SUPERSTRUCTURE											
SPAN "A"	5	5									
SPANS "B" THRU "F"			7	28	7						
SPANS "G" THRU "L"						4	6	2	2	3	1
SPANS "M" THRU "Q"			7	28	7						
SPAN "R"	5	5									
WESTBOUND SUPERSTRUCTURE											
SPAN "A"	5	5									
SPANS "B" THRU "F"			7	28	7						
SPANS "G" THRU "L"						4	6	2	2	3	1
SPANS "M" THRU "Q"			7	28	7						
SPAN "R"	5	5									
TOTALS	20	20	28	112	28	8	12	4	4	6	2

APPROACH TABLE

LOCATION LT/RT	LOCATION STATION	DESCRIPTION	WIDTH FT.	RADII FT.	GRADE %	LENGTH FT.	DIST. BETWEEN R/W FT.	EXCAVATION (CYS) CUT	EXCAVATION (CYS) FILL	BITUAL SURFACE */ SQ. YD.	BITUAL SURFACE TONS	BITUAL BINDER */ SQ. YD.	BITUAL BINDER TONS	BITUAL BASE */ SQ. YD.	BITUAL BASE TONS	COMP. AGG. BASE DEPTH (in)	COMP. AGG. BASE TONS

REVISIONS	
DATE	ITEM

NOTES:
Weight of Spirals includes weight of 1½ extra turns top and bottom.
Spacers and 1½ turns at laps included in cost of Spiral.
*** The weight of structural steel is approximate only, and it shall be the Contractor's responsibility to determine the weight on which he bases his bid.
For Test Bar Samples See Bridge Standard C1.

SUMMARIZED D.J.H. CK'D S.J.C.
TRACED M.A.B. CK'D D.J.H.

BRIDGE SUMMARY
INDIANA DEPARTMENT OF TRANSPORTATION

DATE SEPTEMBER 16, 1994

Stephen J. Christian

SHEET 46 OF 79

PROJECT: IM-74-1(117)6
CONTRACT NO.: B-21615
BRIDGE FILE: I-74-6-4417 DEB & EWB

STEPHEN J. CHRISTIAN REGISTERED No. 20379 STATE OF INDIANA PROFESSIONAL ENGINEER

Appendix 2I. NSBA Spreadsheet Calculations of Each Controlling Location at Each Cross-Sectional Variation Location

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-1** Distance from Abut **260.92** ft

Variation Desciption: **Variation 1 - Controlling Fatigue and Strength Location**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

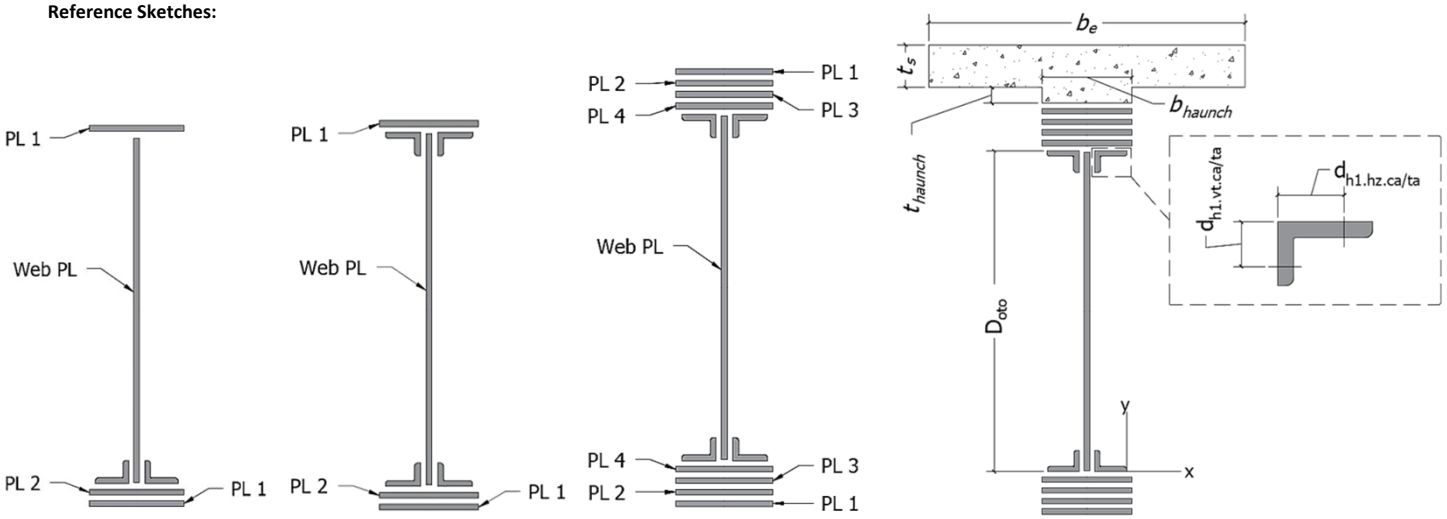
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**
Does the member meet all other provisions of Section 1.4?	**Yes**
Does the member meet all provisions of Section 1.5?	**Yes**

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0** ksi		Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0** ksi		Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**Yes**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**No**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	**129.5** in		Haunch Width, b_{haunch}	**24.0** in	
Deck Slab Thickness, t_s	**8.0** in		Haunch Thickness, t_{haunch}	**4.1** in	
Concrete Modulus of Elasticity, E_c	**2730.4** ksi		Modular Ratio of the concrete, n	10.6	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **1** 1 to 4

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**16.000**	0.000	0.000	0.000	in
$t_{ccp,i}$	**0.5000**	0.0000	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L6X6X1/2**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	5.77	in^2
Thickness of the angle, t_{ca}	0.5	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	19.9	in^4
Outer Horiz. Leg to N.A., y_{ca}	1.67	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1** holes		Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.50** in		Distance to Hole 1, $d_{h1.hz.ca}$	**4.50**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00 in		Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-1** Distance from Abut **260.92** ft

Variation Desciption: **Variation 1 - Controlling Fatigue and Strength Location**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No — Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	83.50	in	Flange Angles Out-to-out Depth, D_{oto}	84.00	in
Web Thickness, t_w	0.5000	in			

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **1** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	16.000	0.000	0.000	0.000	in
$t_{tcp,i}$	0.5000	0.0000	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L6X6X1/2	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	5.77	in^2
Thickness of the angle, t_{ta}	0.5	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	19.9	in^4
Outer Horiz. Leg to N.A., y_{ta}	1.67	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1	holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.50	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.50	in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00	in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No — Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$ or present cycles per day	1,129	trucks/day	Current Year, $Y_{current}$	2022	year
$(ADTT_{sl})_0$ or original cycles per day	1,129	trucks/day	Span Length, L	125.00	ft
$(ADTT_{sl})_{limit}$	20,060	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
Note: Growth rate is for future growth from today on			Is this a transverse member?	No	Y or N

Unfactored Moments:

M_{DC1}	622	k-ft	M_{DW}	38	k-ft	M_{LL+IM}	2,617	k-ft
M_{DC2}	159	k-ft				M_{FAT+IM}	938	k-ft

$M_{FAT\ II\ +IM}$ 750 k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{G,COMP}$	70.5	in	$\bar{y}_{C,G,NC}$	42.0	in
$c_{G,COMP}$	71.0	in	$c_{G,NC}$	42.5	in
$A_{G,COMP}$	187.7	in^2	$A_{G,NC}$	80.8	in^2
$I_{xG,COMP}$	206,778.4	in^4	$I_{xG,NC}$	90,438.4	in^4
$S_{xG,COMP}$	2,911.5	in^3	$S_{xG,NC}$	2,128.0	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{N,COMP}$	71.6	in	$\bar{y}_{N,NC}$	42.0	in
$c_{N,COMP}$	72.1	in	$c_{N,NC}$	42.5	in
$A_{N,COMP}$	181.1	in^2	$A_{N,NC}$	74.3	in^2
$I_{xN,COMP}$	190,475.3	in^4	$I_{xN,NC}$	79,867.8	in^4
$S_{xN,COMP}$	2,643.5	in^3	$S_{xN,NC}$	1,879.2	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFG,COMP}$	73.7	in	$\bar{y}_{AFG,NC}$	46.6	in
$c_{AFG,COMP}$	73.7	in	$c_{AFG,NC}$	46.6	in
$A_{AFG,COMP}$	179.7	in^2	$A_{AFG,NC}$	72.8	in^2
$I_{x,AFG,COMP}$	164,924.8	in^4	$I_{x,AFG,NC}$	74,589.1	in^4
$S_{x\text{-}AFG,COMP}$	2,238.6	in^3	$S_{x\text{-}AFG,NC}$	1,599.2	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFN,COMP}$	74.5	in	$\bar{y}_{AFN,NC}$	46.4	in
$c_{AFN,COMP}$	74.5	in	$c_{AFN,NC}$	46.4	in
$A_{AFN,COMP}$	174.1	in^2	$A_{AFN,NC}$	67.2	in^2
$I_{x,AFN,COMP}$	152,669.8	in^4	$I_{x,AFN,NC}$	65,932.8	in^4
$S_{x\text{-}AFN,COMP}$	2,050.1	in^3	$S_{x\text{-}AFN,NC}$	1,419.7	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-1** Distance from Abut **260.92** ft

Variation Desciption: **Variation 1 - Controlling Fatigue and Strength Location**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.313

Number of tension CPs, N_{FL} = 1

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 4,872 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = - ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = 30.85 ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = 28.04 ksi GS Eq. 2.1.3-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	1.71
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.12

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-1** Distance from Abut **260.92** ft

Variation Desciption: **Variation 1 - Controlling Fatigue and Strength Location**

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	**3.41**	ksi	GS Eq. 2.1.3-1

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	3.41	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	3.43	ksi	MBE Eq. 7.2.2-1
$(\Delta f_i)_{max}$ from field measured strain (leave blank if N/A)	**6.00**	ksi	MBE 7.2.2
$(\Delta f)_{max} = \max[(\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}, (\Delta f_i)_{max}]$	**7.54**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1	
Detail Category Constant	22.00	$x10^8$ ksi^3		
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi		
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1	
Infinite Fatigue Life Check (Unfaulted State):				
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1	
Finite Fatigue Life Estimate (Unfaulted State):				
Initially available stress cycles, N_{av}	5.46E+07	cycles	MBE Eq. 7.2.5.1-2	
No. of consumed stress cycles, N_1	2.68E+07	cycles	MBE Eq. 7.2.5.1-3	
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1	
Remaining fatigue life, Y_{REM}	51.4	Years	MBE Eq. 7.2.5.1-4	
Future ADTT for single lane, $ADTT_{FUTURE}$	1,883	trucks/day	MBE Eq. 7.2.5.1-6	
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5	
$(Y_{ADTT})_{LIMIT} =$	N.A.	Years	MBE Eq. 7.2.5.1-7	
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8	
Total unfaulted state remaining fatigue life, Y_{REM}	**51.4**	Years	MBE 7.2.5.1	Unfaulted fatigue life? **OK**
Case I or II for unfaulted state?	**II**	I or II	GS 2.5	

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-1** Distance from Abut **260.92** ft

Variation Desciption: **Variation 1 - Controlling Fatigue and Strength Location**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ = **5.76** ksi GS Eq. 2.1.3-1

Faulted state stress range, Δf =	5.76	ksi	MBE 7.2.2	
Faulted state effective stress range, $(\Delta f)_{eff}$ =	5.80	ksi	MBE Eq. 7.2.2-1	
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	69.63	ksi	MBE 7.2.4	*If field measurements is used, the $(\Delta f)_{max}$ is multiplied by 12 to force member to be computed using finite life*

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1	
Detail Category Constant	44.00	$x10^8$ ksi^3		
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi		
Infinite Fatigue Life Check (Faulted State):				
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1	
Finite Fatigue Life Estimate (Faulted State):				
Initially available stress cycles, N_{av}	2.25E+07	cycles	MBE Eq. 7.2.5.1-2	
No. of consumed stress cycles, N_1	0	cycles		
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1	
Remaining fatigue life, Y_{REM}	43.5	Years	MBE Eq. 7.2.5.1-4	
Future ADTT for single lane, $ADTT_{FUTURE}$	1,740	trucks/day	MBE Eq. 7.2.5.1-6	
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5	
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7	
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8	
Total faulted state remaining fatigue life, Y_{REM}	**43.5**	Years	MBE 7.2.5.1	Faulted fatigue life? **OK**
Case I or II for faulted state?	**II**	I(a), I(b), II	GS 2.5	

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	64.0	Years	GS 2.5.3
Total fatigue life only in **unfaulted** state, Y_u	115.4	Years	GS 2.5.3
Total fatigue life only in **faulted** state, Y_f	43.5	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**19.4**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	II	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	3.41	ksi	
Controlling stress range in faulted state, Δf_{FS} =	5.76	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**43.5**	Years	
Total remaining fatigue life, N_f	**19.4**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-2** Distance from Abut **269.92** ft

Variation Desciption: **Variation 2 - Controlling Fatigue**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

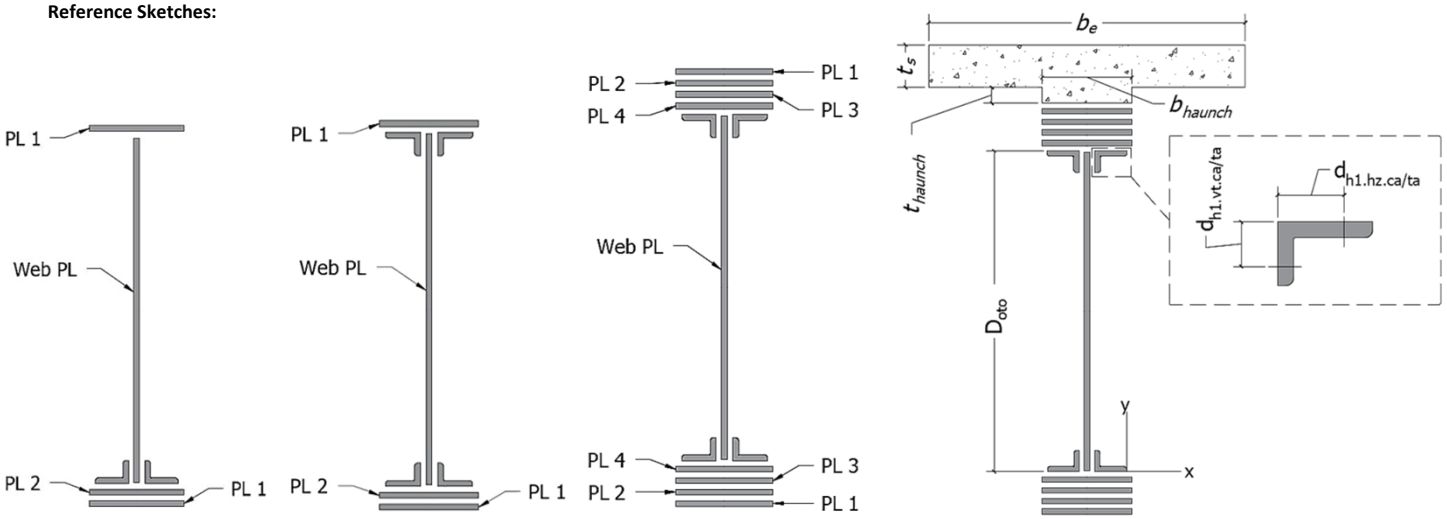
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**
Does the member meet all other provisions of Section 1.4?	**Yes**
Does the member meet all provisions of Section 1.5?	**Yes**

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**Yes**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**No**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	**129.5**	in	Haunch Width, b_{haunch}	**24.0**	in
Deck Slab Thickness, t_s	**8.0**	in	Haunch Thickness, t_{haunch}	**4.1**	in
Concrete Modulus of Elasticity, E_c	**2730.4**	ksi	Modular Ratio of the concrete, n	10.6	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **2** 1 to 4

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**16.000**	**16.000**	0.000	0.000	in
$t_{ccp,i}$	**0.5000**	**0.5000**	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L6X6X1/2**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	5.77	in^2
Thickness of the angle, t_{ca}	0.5	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	19.9	in^4
Outer Horiz. Leg to N.A., y_{ca}	1.67	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.50**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.50**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-2** Distance from Abut **269.92** ft

Variation Desciption: **Variation 2 - Controlling Fatigue**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No — Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	83.50	in	Flange Angles Out-to-out Depth, D_{oto}	84.00	in
Web Thickness, t_w	0.5000	in			

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **2** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	16.000	16.000	0.000	0.000	in
$t_{tcp,i}$	0.5000	0.5000	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L6X6X1/2	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	5.77	in^2
Thickness of the angle, t_{ta}	0.5	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	19.9	in^4
Outer Horiz. Leg to N.A., y_{ta}	1.67	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1	holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.50	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.50	in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00	in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No — Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$ or present cycles per day	1,129	trucks/day	Current Year, $Y_{current}$	2022	year
$(ADTT_{sl})_0$ or original cycles per day	1,129	trucks/day	Span Length, L	125.00	ft
$(ADTT_{sl})_{limit}$	20,060	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
Note: Growth rate is for future growth from today on			Is this a transverse member?	No	Y or N

Unfactored Moments:

M_{DC1}	953	k-ft	M_{DW}	53	k-ft	M_{LL+IM}	2,967	k-ft
M_{DC2}	225	k-ft				M_{FAT+IM}	975	k-ft

$M_{FAT\ II\ +IM}$ 780 k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{G,COMP}$	68.5	in	$\bar{y}_{C,G,NC}$	42.0	in
$c_{G,COMP}$	69.5	in	$c_{G,NC}$	43.0	in
$A_{G,COMP}$	203.7	in^2	$A_{G,NC}$	96.8	in^2
$I_{xG,COMP}$	250,571.0	in^4	$I_{xG,NC}$	119,679.7	in^4
$S_{xG,COMP}$	3,603.1	in^3	$S_{xG,NC}$	2,783.2	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{N,COMP}$	69.7	in	$\bar{y}_{N,NC}$	42.0	in
$c_{N,COMP}$	70.7	in	$c_{N,NC}$	43.0	in
$A_{N,COMP}$	195.3	in^2	$A_{N,NC}$	88.4	in^2
$I_{xN,COMP}$	230,103.9	in^4	$I_{xN,NC}$	105,682.4	in^4
$S_{xN,COMP}$	3,255.1	in^3	$S_{xN,NC}$	2,457.7	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFG,COMP}$	71.4	in	$\bar{y}_{AFG,NC}$	45.9	in
$c_{AFG,COMP}$	71.9	in	$c_{AFG,NC}$	46.4	in
$A_{AFG,COMP}$	195.7	in^2	$A_{AFG,NC}$	88.8	in^2
$I_{x,AFG,COMP}$	210,587.2	in^4	$I_{x,AFG,NC}$	103,742.3	in^4
$S_{x\text{-}AFG,COMP}$	2,929.8	in^3	$S_{x\text{-}AFG,NC}$	2,238.2	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFN,COMP}$	72.3	in	$\bar{y}_{AFN,NC}$	45.7	in
$c_{AFN,COMP}$	72.8	in	$c_{AFN,NC}$	46.2	in
$A_{AFN,COMP}$	188.2	in^2	$A_{AFN,NC}$	81.3	in^2
$I_{x,AFN,COMP}$	193,833.4	in^4	$I_{x,AFN,NC}$	91,652.6	in^4
$S_{x\text{-}AFN,COMP}$	2,661.3	in^3	$S_{x\text{-}AFN,NC}$	1,983.3	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-2** Distance from Abut **269.92** ft

Variation Desciption: **Variation 2 - Controlling Fatigue**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.375

Number of tension CPs, N_{FL} = 2

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 5,872 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = - ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = 28.56 ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = 25.76 ksi GS Eq. 2.1.3-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	1.85
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.22

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-2** Distance from Abut **269.92** ft

Variation Desciption: **Variation 2 - Controlling Fatigue**

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	**2.88**	ksi	GS Eq. 2.1.3-1

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	2.88	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	2.90	ksi	MBE Eq. 7.2.2-1
$(\Delta f_i)_{max}$ from field measured strain (leave blank if N/A)	**6.00**	ksi	MBE 7.2.2
$(\Delta f)_{max} = \max[(\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}, (\Delta f_i)_{max}]$	**6.37**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-2** Distance from Abut **269.92** ft

Variation Desciption: **Variation 2 - Controlling Fatigue**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ = **4.84** ksi GS Eq. 2.1.3-1

Faulted state stress range, Δf =	4.84	ksi	MBE 7.2.2	
Faulted state effective stress range, $(\Delta f)_{eff}$ =	4.87	ksi	MBE Eq. 7.2.2-1	
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	58.43	ksi	MBE 7.2.4	*If field measurements is used, the $(\Delta f)_{max}$ is multiplied by 12 to force member to be computed using finite life*

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1	
Detail Category Constant	44.00	$x10^8$ ksi^3		
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi		
Infinite Fatigue Life Check (Faulted State):				
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1	
Finite Fatigue Life Estimate (Faulted State):				
Initially available stress cycles, N_{av}	3.81E+07	cycles	MBE Eq. 7.2.5.1-2	
No. of consumed stress cycles, N_1	0	cycles		
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1	
Remaining fatigue life, Y_{REM}	65.3	Years	MBE Eq. 7.2.5.1-4	
Future ADTT for single lane, $ADTT_{FUTURE}$	2,163	trucks/day	MBE Eq. 7.2.5.1-6	
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5	
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7	
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8	
Total faulted state remaining fatigue life, Y_{REM}	**65.3**	Years	MBE 7.2.5.1	Faulted fatigue life? **OK**
Case I or II for faulted state?	**I(b)**	I(a), I(b), II	GS 2.5	

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	64.0	Years	GS 2.5.3
Total fatigue life only in **unfaulted** state, Y_u	∞	Years	GS 2.5.3
Total fatigue life only in **faulted** state, Y_f	65.3	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**65.3**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	I(b)	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	2.88	ksi	
Controlling stress range in faulted state, Δf_{FS} =	4.84	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**65.3**	Years	
Total remaining fatigue life, N_f	**65.3**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-2** Distance from Abut **282.42** ft

Variation Desciption: **Variation 2 - Controlling Strength**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

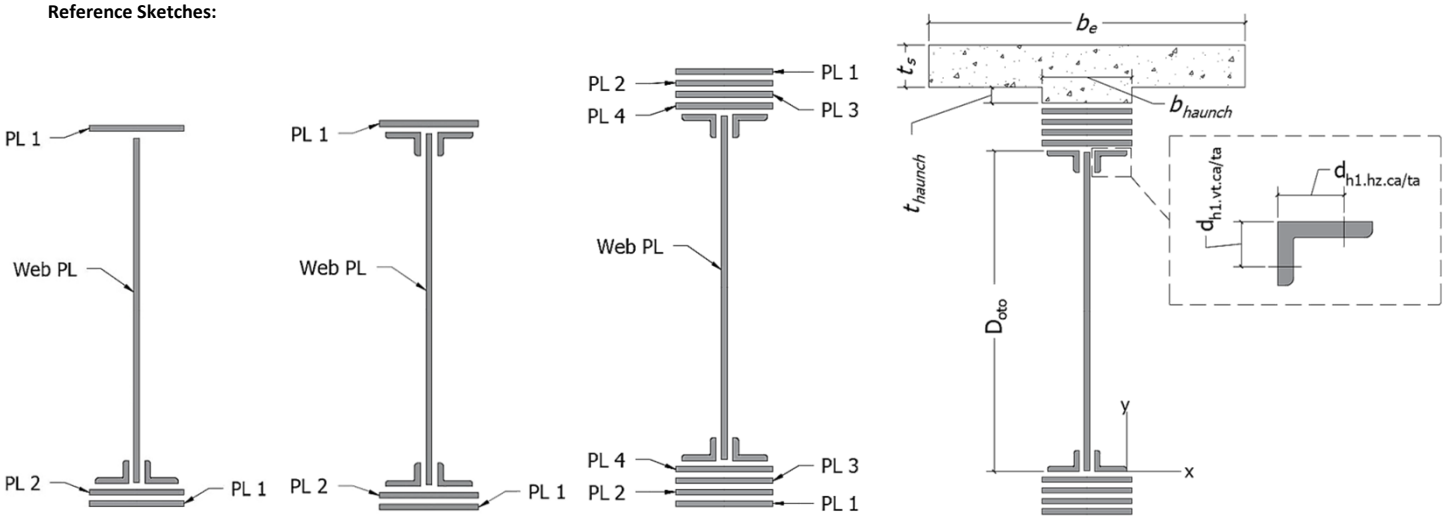
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**
Does the member meet all other provisions of Section 1.4?	**Yes**
Does the member meet all provisions of Section 1.5?	**Yes**

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**Yes**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**No**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	**129.5**	in	Haunch Width, b_{haunch}	**24.0**	in
Deck Slab Thickness, t_s	**8.0**	in	Haunch Thickness, t_{haunch}	**4.1**	in
Concrete Modulus of Elasticity, E_c	**2730.4**	ksi	Modular Ratio of the concrete, n	10.6	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **2** 1 to 4

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**16.000**	**16.000**	0.000	0.000	in
$t_{ccp,i}$	**0.5000**	**0.5000**	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L6X6X1/2**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	5.77	in^2
Thickness of the angle, t_{ca}	0.5	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	19.9	in^4
Outer Horiz. Leg to N.A., y_{ca}	1.67	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.50**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.50**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-2** Distance from Abut **282.42** ft

Variation Desciption: **Variation 2 - Controlling Strength**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No — Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	83.50	in	Flange Angles Out-to-out Depth, D_{oto}	84.00	in
Web Thickness, t_w	0.5000	in			

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **2** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	16.000	16.000	0.000	0.000	in
$t_{tcp,i}$	0.5000	0.5000	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L6X6X1/2	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	5.77	in^2
Thickness of the angle, t_{ta}	0.5	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	19.9	in^4
Outer Horiz. Leg to N.A., y_{ta}	1.67	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1	holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.50	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.50	in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00	in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No — Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$ or present cycles per day	1,129	trucks/day	Current Year, $Y_{current}$	2022	year
$(ADTT_{sl})_0$ or original cycles per day	1,129	trucks/day	Span Length, L	125.00	ft
$(ADTT_{sl})_{limit}$	20,060	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
Note: Growth rate is for future growth from today on			Is this a transverse member?	No	Y or N

Unfactored Moments:

M_{DC1}	1,123	k-ft	M_{DW}	61	k-ft	M_{LL+IM}	3,118	k-ft
M_{DC2}	258	k-ft				M_{FAT+IM}	932	k-ft

$M_{FAT\ II\ +IM}$ 745 k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{G,COMP}$	68.5	in	$\bar{y}_{C,G,NC}$	42.0	in
$c_{G,COMP}$	69.5	in	$c_{G,NC}$	43.0	in
$A_{G,COMP}$	203.7	in^2	$A_{G,NC}$	96.8	in^2
$I_{xG,COMP}$	250,571.0	in^4	$I_{xG,NC}$	119,679.7	in^4
$S_{xG,COMP}$	3,603.1	in^3	$S_{xG,NC}$	2,783.2	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{N,COMP}$	69.7	in	$\bar{y}_{N,NC}$	42.0	in
$c_{N,COMP}$	70.7	in	$c_{N,NC}$	43.0	in
$A_{N,COMP}$	195.3	in^2	$A_{N,NC}$	88.4	in^2
$I_{xN,COMP}$	230,103.9	in^4	$I_{xN,NC}$	105,682.4	in^4
$S_{xN,COMP}$	3,255.1	in^3	$S_{xN,NC}$	2,457.7	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFG,COMP}$	71.4	in	$\bar{y}_{AFG,NC}$	45.9	in
$c_{AFG,COMP}$	71.9	in	$c_{AFG,NC}$	46.4	in
$A_{AFG,COMP}$	195.7	in^2	$A_{AFG,NC}$	88.8	in^2
$I_{x,AFG,COMP}$	210,587.2	in^4	$I_{x,AFG,NC}$	103,742.3	in^4
$S_{x\text{-}AFG,COMP}$	2,929.8	in^3	$S_{x\text{-}AFG,NC}$	2,238.2	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFN,COMP}$	72.3	in	$\bar{y}_{AFN,NC}$	45.7	in
$c_{AFN,COMP}$	72.8	in	$c_{AFN,NC}$	46.2	in
$A_{AFN,COMP}$	188.2	in^2	$A_{AFN,NC}$	81.3	in^2
$I_{x,AFN,COMP}$	193,833.4	in^4	$I_{x,AFN,NC}$	91,652.6	in^4
$S_{x\text{-}AFN,COMP}$	2,661.3	in^3	$S_{x\text{-}AFN,NC}$	1,983.3	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-2** Distance from Abut **282.42** ft

Variation Desciption: **Variation 2 - Controlling Strength**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.375

Number of tension CPs, N_{FL} = 2

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 6,342 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = - ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = - ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = 31.04 ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = 27.98 ksi GS Eq. 2.1.3-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	1.70
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.12

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-2** Distance from Abut **282.42** ft

Variation Desciption: **Variation 2 - Controlling Strength**

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	**2.75**	ksi	GS Eq. 2.1.3-1

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	2.75	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	2.77	ksi	MBE Eq. 7.2.2-1
$(\Delta f_i)_{max}$ from field measured strain (leave blank if N/A)	**6.00**	ksi	MBE 7.2.2
$(\Delta f)_{max} = \max[(\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}, (\Delta f_i)_{max}]$	**6.08**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-2** Distance from Abut **282.42** ft

Variation Desciption: **Variation 2 - Controlling Strength**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ =	-	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ =	**4.62**	ksi	GS Eq. 2.1.3-1
Faulted state stress range, Δf =	4.62	ksi	MBE 7.2.2
Faulted state effective stress range, $(\Delta f)_{eff}$ =	4.65	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	55.81	ksi	MBE 7.2.4 *If field measurements is used, the $(\Delta f)_{max}$ is multiplied by 12 to force member to be computed using finite life*

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1	
Detail Category Constant	44.00	$x10^8$ ksi^3		
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi		
Infinite Fatigue Life Check (Faulted State):				
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1	
Finite Fatigue Life Estimate (Faulted State):				
Initially available stress cycles, N_{av}	4.37E+07	cycles	MBE Eq. 7.2.5.1-2	
No. of consumed stress cycles, N_1	0	cycles		
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1	
Remaining fatigue life, Y_{REM}	72.2	Years	MBE Eq. 7.2.5.1-4	
Future ADTT for single lane, $ADTT_{FUTURE}$	2,315	trucks/day	MBE Eq. 7.2.5.1-6	
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5	
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7	
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8	
Total faulted state remaining fatigue life, Y_{REM}	**72.2**	Years	MBE 7.2.5.1	Faulted fatigue life? **OK**
Case I or II for faulted state?	**I(b)**	I(a), I(b), II	GS 2.5	

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	64.0	Years	GS 2.5.3
Total fatigue life only in **unfaulted** state, Y_u	∞	Years	GS 2.5.3
Total fatigue life only in **faulted** state, Y_f	72.2	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**72.2**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	I(b)	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	2.75	ksi	
Controlling stress range in faulted state, Δf_{FS} =	4.62	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**72.2**	Years	
Total remaining fatigue life, N_f	**72.2**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-3** Distance from Abut **200.92** ft

Variation Desciption: **Variation 3 - Controlling Fatigue**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

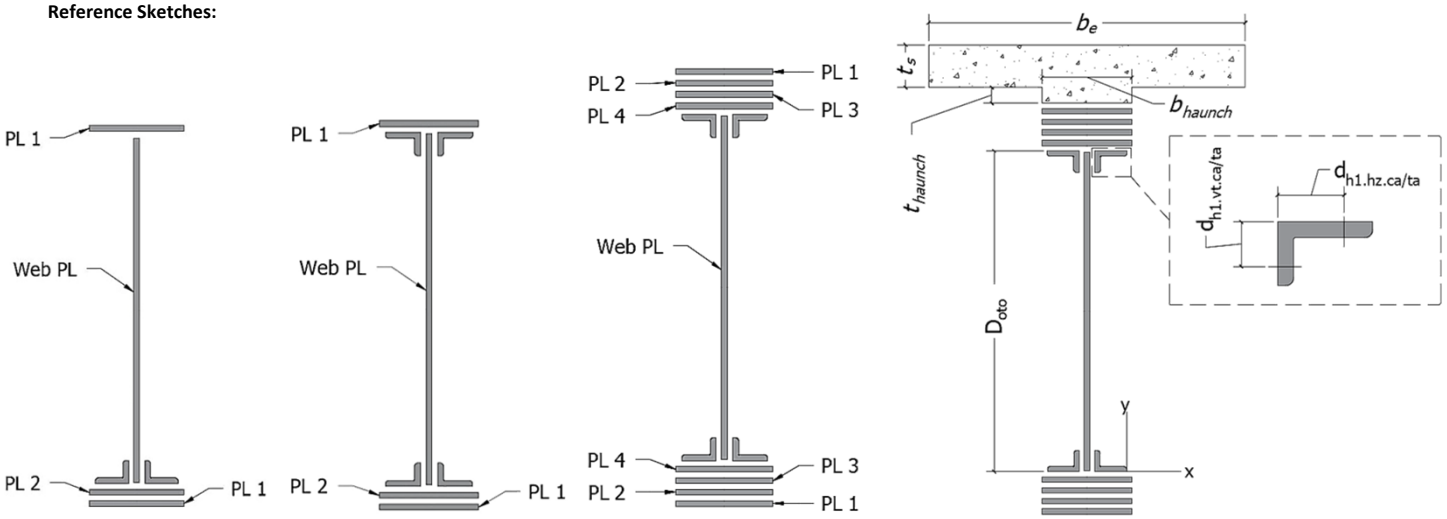
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**
Does the member meet all other provisions of Section 1.4?	**Yes**
Does the member meet all provisions of Section 1.5?	**Yes**

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**No**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**Yes**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	129.5	in	Haunch Width, b_{haunch}	**24.0**	in
Deck Slab Thickness, t_s	8.0	in	Haunch Thickness, t_{haunch}	**4.1**	in
Concrete Modulus of Elasticity, E_c	2730.4	ksi	Modular Ratio of the concrete, n	10.6	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **1** 1 to 4

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**16.000**	0.000	0.000	0.000	in
$t_{ccp,i}$	**0.8750**	0.0000	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L6X6X1**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	11	in^2
Thickness of the angle, t_{ca}	1	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	35.4	in^4
Outer Horiz. Leg to N.A., y_{ca}	1.86	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.50**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.50**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-3** Distance from Abut **200.92** ft

Variation Desciption: **Variation 3 - Controlling Fatigue**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No — Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	83.50	in	Flange Angles Out-to-out Depth, D_{oto}	84.00	in
Web Thickness, t_w	0.5000	in			

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **1** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	16.000	0.000	0.000	0.000	in
$t_{tcp,i}$	0.8750	0.0000	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L6X6X1	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	11	in^2
Thickness of the angle, t_{ta}	1	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	35.4	in^4
Outer Horiz. Leg to N.A., y_{ta}	1.86	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1	holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.50	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.50	in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00	in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No — Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$ or present cycles per day	1,129	trucks/day	Current Year, $Y_{current}$	2022	year
$(ADTT_{sl})_0$ or original cycles per day	1,129	trucks/day	Span Length, L	125.00	ft
$(ADTT_{sl})_{limit}$	20,060	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
Note: Growth rate is for future growth from today on			Is this a transverse member?	No	Y or N

Unfactored Moments:

M_{DC1}	-875	k-ft	M_{DW}	-33	k-ft	M_{LL+IM}	-1,527	k-ft
M_{DC2}	-137	k-ft				M_{FAT+IM}	633	k-ft

$M_{FAT\ II\ +IM}$ 506 k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{G,COMP}$	-	in	$\bar{y}_{C,G,NC}$ 42.0	in
$c_{G,COMP}$	-	in	$c_{G,NC}$ 42.9	in
$A_{G,COMP}$	-	in^2	$A_{G,NC}$ 113.8	in^2
$I_{xG,COMP}$	-	in^4	$I_{xG,NC}$ 145,721.0	in^4
$S_{xG,COMP}$	-	in^3	$S_{xG,NC}$ 3,398.7	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{N,COMP}$	-	in	$\bar{y}_{N,NC}$ 42.0	in
$c_{N,COMP}$	-	in	$c_{N,NC}$ 42.9	in
$A_{N,COMP}$	-	in^2	$A_{N,NC}$ 102.0	in^2
$I_{xN,COMP}$	-	in^4	$I_{xN,NC}$ 126,760.6	in^4
$S_{xN,COMP}$	-	in^3	$S_{xN,NC}$ 2,956.5	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{AFG,COMP}$	-	in	$\bar{y}_{AFG,NC}$ 48.0	in
$c_{AFG,COMP}$	-	in	$c_{AFG,NC}$ 48.0	in
$A_{AFG,COMP}$	-	in^2	$A_{AFG,NC}$ 99.8	in^2
$I_{x,AFG,COMP}$	-	in^4	$I_{x,AFG,NC}$ 116,968.3	in^4
$S_{x\text{-}AFG,COMP}$	-	in^3	$S_{x\text{-}AFG,NC}$ 2,439.1	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{AFN,COMP}$	-	in	$\bar{y}_{AFN,NC}$ 47.8	in
$c_{AFN,COMP}$	-	in	$c_{AFN,NC}$ 47.8	in
$A_{AFN,COMP}$	-	in^2	$A_{AFN,NC}$ 89.7	in^2
$I_{x,AFN,COMP}$	-	in^4	$I_{x,AFN,NC}$ 101,432.3	in^4
$S_{x\text{-}AFN,COMP}$	-	in^3	$S_{x\text{-}AFN,NC}$ 2,119.8	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-3** Distance from Abut **200.92** ft

Variation Desciption: **Variation 3 - Controlling Fatigue**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.313

Number of tension CPs, N_{FL} = 1

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 3,495 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = 19.79 ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = 17.20 ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	2.67
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.82

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = - ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = - ksi GS Eq. 2.1.3-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-3** Distance from Abut **200.92** ft

Variation Desciption: **Variation 3 - Controlling Fatigue**

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	2.06	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	-	ksi	GS Eq. 2.1.3-1

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	2.06	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	2.07	ksi	MBE Eq. 7.2.2-1
$(\Delta f_i)_{max}$ from field measured strain (leave blank if N/A)	**6.00**	ksi	MBE 7.2.2
$(\Delta f)_{max} = \max[(\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}, (\Delta f_i)_{max}]$	**6.00**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-3** Distance from Abut **200.92** ft

Variation Desciption: **Variation 3 - Controlling Fatigue**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ = 3.8 ksi GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ = - ksi GS Eq. 2.1.3-1

Faulted state stress range, Δf =	3.76	ksi	MBE 7.2.2	
Faulted state effective stress range, $(\Delta f)_{eff}$ =	3.79	ksi	MBE Eq. 7.2.2-1	
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	45.44	ksi	MBE 7.2.4	*If field measurements is used, the $(\Delta f)_{max}$ is multiplied by 12 to force member to be computed using finite life*

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1	
Detail Category Constant	44.00	$x10^8$ ksi^3		
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi		
Infinite Fatigue Life Check (Faulted State):				
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1	
Finite Fatigue Life Estimate (Faulted State):				
Initially available stress cycles, N_{av}	8.10E+07	cycles	MBE Eq. 7.2.5.1-2	
No. of consumed stress cycles, N_1	0	cycles		
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1	
Remaining fatigue life, Y_{REM}	108.6	Years	MBE Eq. 7.2.5.1-4	
Future ADTT for single lane, $ADTT_{FUTURE}$	3,327	trucks/day	MBE Eq. 7.2.5.1-6	
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5	
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7	
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8	
Total faulted state remaining fatigue life, Y_{REM}	**108.6**	Years	MBE 7.2.5.1	Faulted fatigue life? **OK**
Case I or II for faulted state?	**I(b)**	I(a), I(b), II	GS 2.5	

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	64.0	Years	GS 2.5.3
Total fatigue life only in **unfaulted** state, Y_u	∞	Years	GS 2.5.3
Total fatigue life only in **faulted** state, Y_f	108.6	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**108.6**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	I(b)	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	2.06	ksi	
Controlling stress range in faulted state, Δf_{FS} =	3.76	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**108.6**	Years	
Total remaining fatigue life, N_f	**108.6**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-3** Distance from Abut **206.92** ft

Variation Desciption: **Variation 3 - Controlling Strength**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

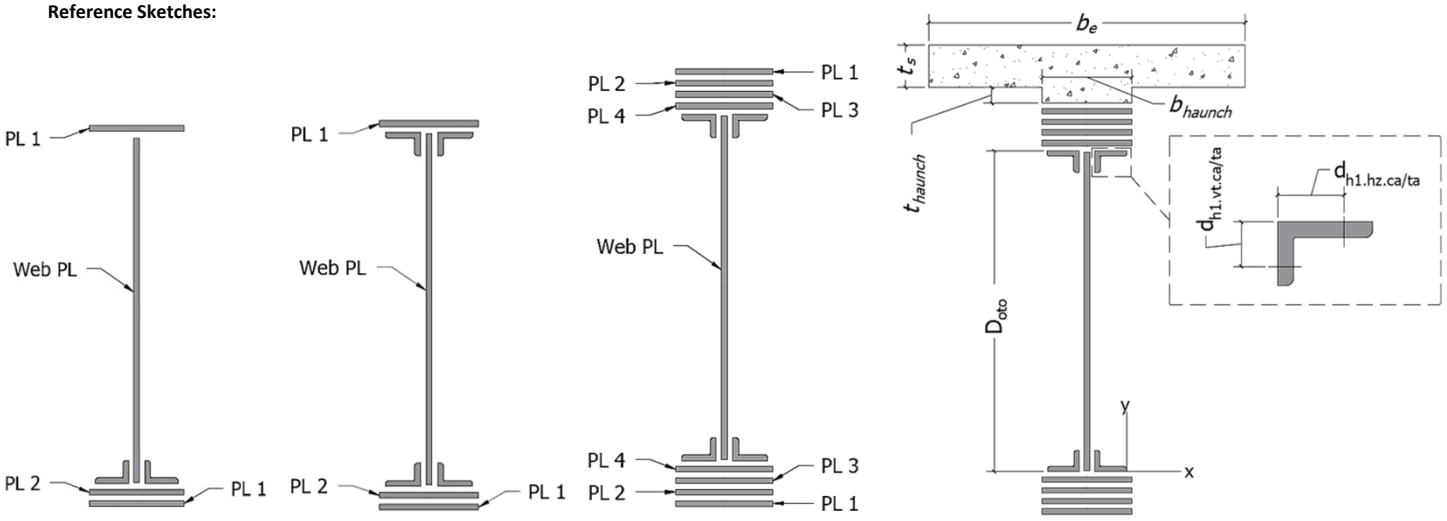
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**
Does the member meet all other provisions of Section 1.4?	**Yes**
Does the member meet all provisions of Section 1.5?	**Yes**

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**No**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**Yes**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	129.5	in	Haunch Width, b_{haunch}	**24.0**	in
Deck Slab Thickness, t_s	8.0	in	Haunch Thickness, t_{haunch}	**4.1**	in
Concrete Modulus of Elasticity, E_c	2730.4	ksi	Modular Ratio of the concrete, n	10.6	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **1** (1 to 4)

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**16.000**	0.000	0.000	0.000	in
$t_{ccp,i}$	**0.8750**	0.0000	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L6X6X1**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	11	in^2
Thickness of the angle, t_{ca}	1	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	35.4	in^4
Outer Horiz. Leg to N.A., y_{ca}	1.86	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.50**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.50**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-3** Distance from Abut **206.92** ft

Variation Desciption: **Variation 3 - Controlling Strength**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No — Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	83.50	in	Flange Angles Out-to-out Depth, D_{oto}	84.00	in
Web Thickness, t_w	0.5000	in			

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **1** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	16.000	0.000	0.000	0.000	in
$t_{tcp,i}$	0.8750	0.0000	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L6X6X1	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	11	in^2
Thickness of the angle, t_{ta}	1	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	35.4	in^4
Outer Horiz. Leg to N.A., y_{ta}	1.86	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1	holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.50	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.50	in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00	in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No — Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$ or present cycles per day	1,129	trucks/day	Current Year, $Y_{current}$	2022	year
$(ADTT_{sl})_0$ or original cycles per day	1,129	trucks/day	Span Length, L	125.00	ft
$(ADTT_{sl})_{limit}$	20,060	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
Note: Growth rate is for future growth from today on			Is this a transverse member?	No	Y or N

Unfactored Moments:

M_{DC1}	-1,475	k-ft	M_{DW}	-61	k-ft	M_{LL+IM}	-1,814	k-ft
M_{DC2}	-258	k-ft				M_{FAT+IM}	517	k-ft

$M_{FAT\ II\ +IM}$ 414 k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{G,COMP}$	-	in	$\bar{y}_{C,G,NC}$ 42.0	in
$c_{G,COMP}$	-	in	$c_{G,NC}$ 42.9	in
$A_{G,COMP}$	-	in^2	$A_{G,NC}$ 113.8	in^2
$I_{xG,COMP}$	-	in^4	$I_{xG,NC}$ 145,721.0	in^4
$S_{xG,COMP}$	-	in^3	$S_{xG,NC}$ 3,398.7	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{N,COMP}$	-	in	$\bar{y}_{N,NC}$ 42.0	in
$c_{N,COMP}$	-	in	$c_{N,NC}$ 42.9	in
$A_{N,COMP}$	-	in^2	$A_{N,NC}$ 102.0	in^2
$I_{xN,COMP}$	-	in^4	$I_{xN,NC}$ 126,760.6	in^4
$S_{xN,COMP}$	-	in^3	$S_{xN,NC}$ 2,956.5	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{AFG,COMP}$	-	in	$\bar{y}_{AFG,NC}$ 48.0	in
$c_{AFG,COMP}$	-	in	$c_{AFG,NC}$ 48.0	in
$A_{AFG,COMP}$	-	in^2	$A_{AFG,NC}$ 99.8	in^2
$I_{x,AFG,COMP}$	-	in^4	$I_{x,AFG,NC}$ 116,968.3	in^4
$S_{x\text{-}AFG,COMP}$	-	in^3	$S_{x\text{-}AFG,NC}$ 2,439.1	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{AFN,COMP}$	-	in	$\bar{y}_{AFN,NC}$ 47.8	in
$c_{AFN,COMP}$	-	in	$c_{AFN,NC}$ 47.8	in
$A_{AFN,COMP}$	-	in^2	$A_{AFN,NC}$ 89.7	in^2
$I_{x,AFN,COMP}$	-	in^4	$I_{x,AFN,NC}$ 101,432.3	in^4
$S_{x\text{-}AFN,COMP}$	-	in^3	$S_{x\text{-}AFN,NC}$ 2,119.8	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-3** Distance from Abut **206.92** ft

Variation Desciption: **Variation 3 - Controlling Strength**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.313

Number of tension CPs, N_{FL} = 1

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 4,790 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = 27.12 ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = 23.57 ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	1.95
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.33

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = - ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = - ksi GS Eq. 2.1.3-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-3** Distance from Abut **206.92** ft

Variation Desciption: **Variation 3 - Controlling Strength**

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	1.68	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	-	ksi	GS Eq. 2.1.3-1

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	1.68	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	1.69	ksi	MBE Eq. 7.2.2-1
$(\Delta f_i)_{max}$ from field measured strain (leave blank if N/A)	**6.00**	ksi	MBE 7.2.2
$(\Delta f)_{max} = \max[(\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}, (\Delta f_i)_{max}]$	**6.00**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-3** Distance from Abut **206.92** ft

Variation Desciption: **Variation 3 - Controlling Strength**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ =	3.1	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ =	-	ksi	GS Eq. 2.1.3-1
Faulted state stress range, Δf =	3.08	ksi	MBE 7.2.2
Faulted state effective stress range, $(\Delta f)_{eff}$ =	3.10	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	37.15	ksi	MBE 7.2.4 *If field measurements is used, the $(\Delta f)_{max}$ is multiplied by 12 to force member to be computed using finite life*

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	1.48E+08	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	152.6	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	5,153	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**152.6**	Years	MBE 7.2.5.1
Case I or II for faulted state?	**I(b)**	I(a), I(b), II	GS 2.5

Faulted fatigue life? **OK**

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	64.0	Years	GS 2.5.3
Total fatigue life only in **unfaulted** state, Y_u	∞	Years	GS 2.5.3
Total fatigue life only in **faulted** state, Y_f	152.6	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**152.6**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	I(b)	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	1.68	ksi	
Controlling stress range in faulted state, Δf_{FS} =	3.08	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**152.6**	Years	
Total remaining fatigue life, N_f	**152.6**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-4** Distance from Abut **86.42** ft

Variation Desciption: **Variation 4 - Controlling Fatigue**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

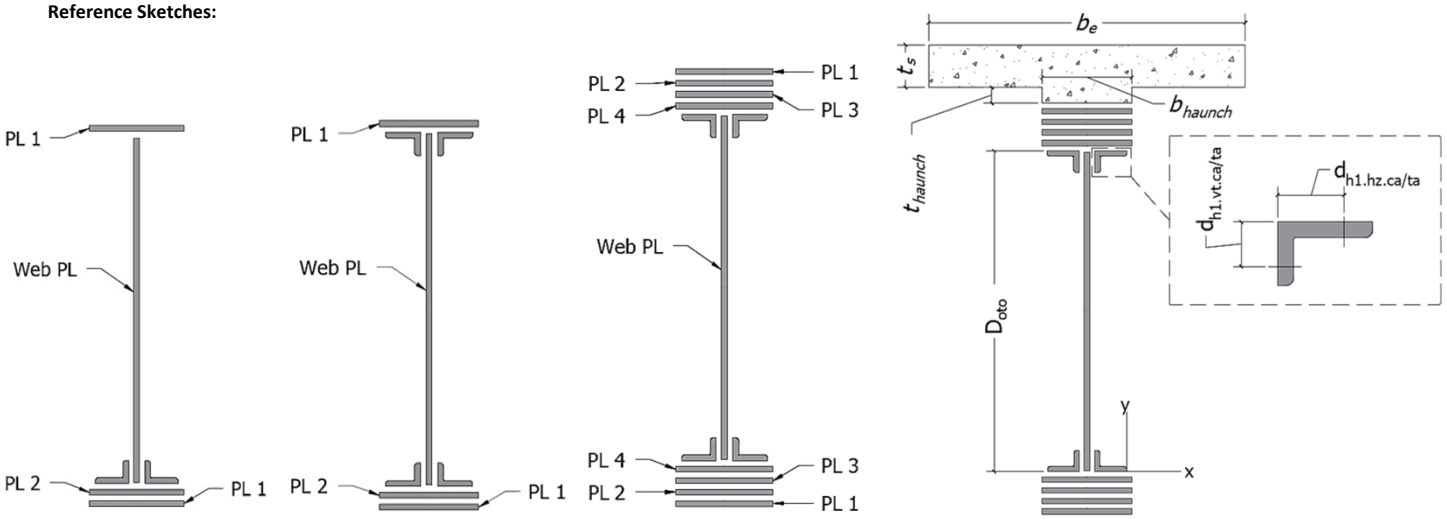
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**
Does the member meet all other provisions of Section 1.4?	**Yes**
Does the member meet all provisions of Section 1.5?	**Yes**

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**No**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**Yes**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	129.5	in	Haunch Width, b_{haunch}	**24.0**	in
Deck Slab Thickness, t_s	8.0	in	Haunch Thickness, t_{haunch}	**4.1**	in
Concrete Modulus of Elasticity, E_c	2730.4	ksi	Modular Ratio of the concrete, n	10.6	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **2** 1 to 4

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**16.000**	**16.000**	0.000	0.000	in
$t_{ccp,i}$	**0.8750**	**0.8750**	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L6X6X1**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	11	in^2
Thickness of the angle, t_{ca}	1	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	35.4	in^4
Outer Horiz. Leg to N.A., y_{ca}	1.86	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.50**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.50**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-4** Distance from Abut **86.42** ft

Variation Desciption: **Variation 4 - Controlling Fatigue**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No — Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	83.50	in	Flange Angles Out-to-out Depth, D_{oto}	84.00	in
Web Thickness, t_w	0.5000	in			

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **2** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	16.000	16.000	0.000	0.000	in
$t_{tcp,i}$	0.8750	0.8750	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L6X6X1	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	11	in^2
Thickness of the angle, t_{ta}	1	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	35.4	in^4
Outer Horiz. Leg to N.A., y_{ta}	1.86	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1	holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.50	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.50	in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00	in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No — Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$ or present cycles per day	1,129	trucks/day	Current Year, $Y_{current}$	2022	year
$(ADTT_{sl})_0$ or original cycles per day	1,129	trucks/day	Span Length, L	94.92	ft
$(ADTT_{sl})_{limit}$	20,060	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
			Is this a transverse member?	No	Y or N

Note: Growth rate is for future growth from today on

Unfactored Moments:

M_{DC1}	-1,868	k-ft	M_{DW}	-79	k-ft	M_{LL+IM}	-1,968	k-ft
M_{DC2}	-331	k-ft				M_{FAT+IM}	559	k-ft

$M_{FAT\ II\ +IM}$ 447 k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{G,COMP}$	-	in	$\bar{y}_{C,G,NC}$	42.0	in
$c_{G,COMP}$	-	in	$c_{G,NC}$	43.8	in
$A_{G,COMP}$	-	in^2	$A_{G,NC}$	141.8	in^2
$I_{xG,COMP}$	-	in^4	$I_{xG,NC}$	198,250.0	in^4
$S_{xG,COMP}$	-	in^3	$S_{xG,NC}$	4,531.4	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{N,COMP}$	-	in	$\bar{y}_{N,NC}$	42.0	in
$c_{N,COMP}$	-	in	$c_{N,NC}$	43.8	in
$A_{N,COMP}$	-	in^2	$A_{N,NC}$	126.8	in^2
$I_{xN,COMP}$	-	in^4	$I_{xN,NC}$	173,133.9	in^4
$S_{xN,COMP}$	-	in^3	$S_{xN,NC}$	3,957.3	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFG,COMP}$	-	in	$\bar{y}_{AFG,NC}$	46.7	in
$c_{AFG,COMP}$	-	in	$c_{AFG,NC}$	47.6	in
$A_{AFG,COMP}$	-	in^2	$A_{AFG,NC}$	127.8	in^2
$I_{x,AFG,COMP}$	-	in^4	$I_{x,AFG,NC}$	169,107.3	in^4
$S_{x\text{-}AFG,COMP}$	-	in^3	$S_{x\text{-}AFG,NC}$	3,551.1	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFN,COMP}$	-	in	$\bar{y}_{AFN,NC}$	46.7	in
$c_{AFN,COMP}$	-	in	$c_{AFN,NC}$	47.6	in
$A_{AFN,COMP}$	-	in^2	$A_{AFN,NC}$	114.4	in^2
$I_{x,AFN,COMP}$	-	in^4	$I_{x,AFN,NC}$	147,441.5	in^4
$S_{x\text{-}AFN,COMP}$	-	in^3	$S_{x\text{-}AFN,NC}$	3,100.5	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-4** Distance from Abut **86.42** ft

Variation Desciption: **Variation 4 - Controlling Fatigue**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.375

Number of tension CPs, N_{FL} = 2

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 5,580 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = 21.59 ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = 18.85 ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	2.45
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.66

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = - ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = - ksi GS Eq. 2.1.3-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-4** Distance from Abut **86.42** ft

Variation Desciption: **Variation 4 - Controlling Fatigue**

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	1.36	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	-	ksi	GS Eq. 2.1.3-1

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.00		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	1.36	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	1.36	ksi	MBE Eq. 7.2.2-1
$(\Delta f_i)_{max}$ from field measured strain (leave blank if N/A)	**6.00**	ksi	MBE 7.2.2
$(\Delta f)_{max} = \max[(\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}, (\Delta f_i)_{max}]$	**6.00**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-4** Distance from Abut **86.42** ft

Variation Desciption: **Variation 4 - Controlling Fatigue**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ = 2.4 ksi GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ = - ksi GS Eq. 2.1.3-1

Faulted state stress range, Δf =	2.38	ksi	MBE 7.2.2	
Faulted state effective stress range, $(\Delta f)_{eff}$ =	2.39	ksi	MBE Eq. 7.2.2-1	
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	28.70	ksi	MBE 7.2.4	*If field measurements is used, the $(\Delta f)_{max}$ is multiplied by 12 to force member to be computed using finite life*

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1	
Detail Category Constant	44.00	$x10^8$ ksi^3		
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi		
Infinite Fatigue Life Check (Faulted State):				
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1	
Finite Fatigue Life Estimate (Faulted State):				
Initially available stress cycles, N_{av}	3.22E+08	cycles	MBE Eq. 7.2.5.1-2	
No. of consumed stress cycles, N_1	0	cycles		
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1	
Remaining fatigue life, Y_{REM}	217.8	Years	MBE Eq. 7.2.5.1-4	
Future ADTT for single lane, $ADTT_{FUTURE}$	9,856	trucks/day	MBE Eq. 7.2.5.1-6	
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5	
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7	
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8	
Total faulted state remaining fatigue life, Y_{REM}	**217.8**	Years	MBE 7.2.5.1	Faulted fatigue life? **OK**
Case I or II for faulted state?	**I(b)**	I(a), I(b), II	GS 2.5	

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	64.0	Years	GS 2.5.3
Total fatigue life only in **unfaulted** state, Y_u	∞	Years	GS 2.5.3
Total fatigue life only in **faulted** state, Y_f	217.8	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**217.8**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	I(b)	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	1.36	ksi	
Controlling stress range in faulted state, Δf_{FS} =	2.38	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**217.8**	Years	
Total remaining fatigue life, N_f	**217.8**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-4** Distance from Abut **211.42** ft

Variation Desciption: **Variation 4 - Controlling Strength**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

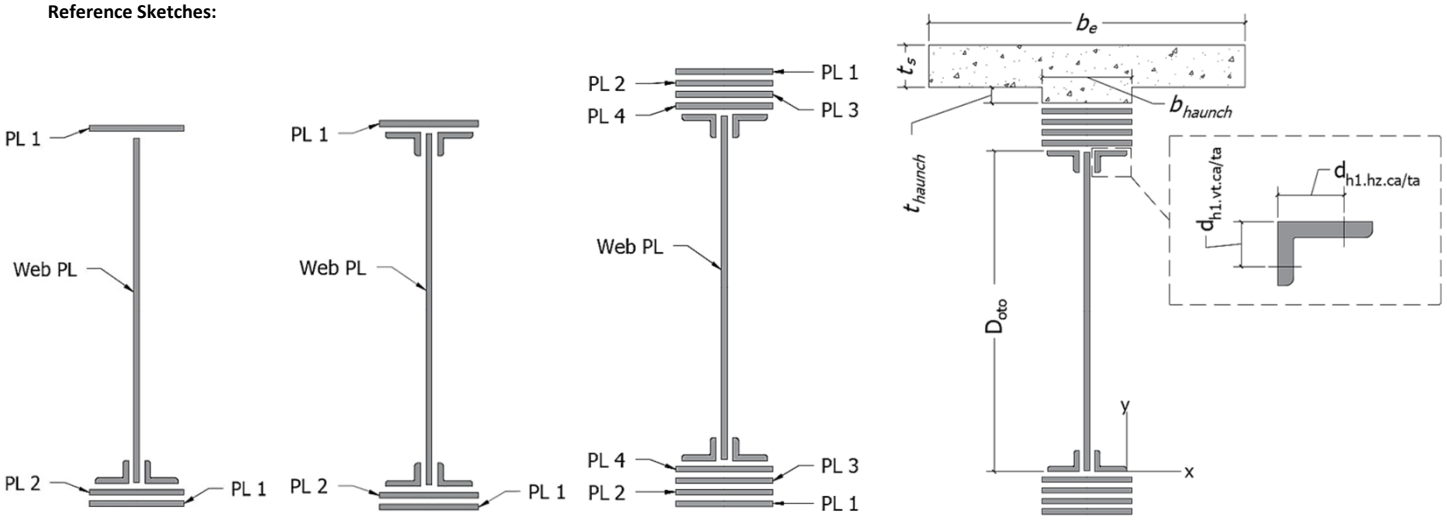
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**
Does the member meet all other provisions of Section 1.4?	**Yes**
Does the member meet all provisions of Section 1.5?	**Yes**

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**No**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**Yes**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	129.5	in	Haunch Width, b_{haunch}	**24.0**	in
Deck Slab Thickness, t_s	8.0	in	Haunch Thickness, t_{haunch}	**4.1**	in
Concrete Modulus of Elasticity, E_c	2730.4	ksi	Modular Ratio of the concrete, n	10.6	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **2** 1 to 4

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**16.000**	**16.000**	0.000	0.000	in
$t_{ccp,i}$	**0.8750**	**0.8750**	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L6X6X1**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	11	in^2
Thickness of the angle, t_{ca}	1	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	35.4	in^4
Outer Horiz. Leg to N.A., y_{ca}	1.86	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.50**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.50**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-4** Distance from Abut **211.42** ft

Variation Desciption: **Variation 4 - Controlling Strength**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No — Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	83.50	in	Flange Angles Out-to-out Depth, D_{oto}	84.00	in
Web Thickness, t_w	0.5000	in			

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **2** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	16.000	16.000	0.000	0.000	in
$t_{tcp,i}$	0.8750	0.8750	0.0000	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L6X6X1	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	11	in^2
Thickness of the angle, t_{ta}	1	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	35.4	in^4
Outer Horiz. Leg to N.A., y_{ta}	1.86	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1	holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.50	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.50	in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00	in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No — Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$ or present cycles per day	1,129	trucks/day	Current Year, $Y_{current}$	2022	year
$(ADTT_{sl})_0$ or original cycles per day	1,129	trucks/day	Span Length, L	125.00	ft
$(ADTT_{sl})_{limit}$	20,060	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
			Is this a transverse member?	No	Y or N

Note: Growth rate is for future growth from today on

Unfactored Moments:

M_{DC1}	-1,978	k-ft	M_{DW}	-85	k-ft	M_{LL+IM}	-2,232	k-ft
M_{DC2}	-358	k-ft				M_{FAT+IM}	536	k-ft

$M_{FAT\ II\ +IM}$ 429 k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{G,COMP}$	-	in	$\bar{y}_{C,G,NC}$	42.0	in
$c_{G,COMP}$	-	in	$c_{G,NC}$	43.8	in
$A_{G,COMP}$	-	in^2	$A_{G,NC}$	141.8	in^2
$I_{xG,COMP}$	-	in^4	$I_{xG,NC}$	198,250.0	in^4
$S_{xG,COMP}$	-	in^3	$S_{xG,NC}$	4,531.4	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{N,COMP}$	-	in	$\bar{y}_{N,NC}$	42.0	in
$c_{N,COMP}$	-	in	$c_{N,NC}$	43.8	in
$A_{N,COMP}$	-	in^2	$A_{N,NC}$	126.8	in^2
$I_{xN,COMP}$	-	in^4	$I_{xN,NC}$	173,133.9	in^4
$S_{xN,COMP}$	-	in^3	$S_{xN,NC}$	3,957.3	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFG,COMP}$	-	in	$\bar{y}_{AFG,NC}$	46.7	in
$c_{AFG,COMP}$	-	in	$c_{AFG,NC}$	47.6	in
$A_{AFG,COMP}$	-	in^2	$A_{AFG,NC}$	127.8	in^2
$I_{x,AFG,COMP}$	-	in^4	$I_{x,AFG,NC}$	169,107.3	in^4
$S_{x\text{-}AFG,COMP}$	-	in^3	$S_{x\text{-}AFG,NC}$	3,551.1	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite			Noncomposite	
$\bar{y}_{AFN,COMP}$	-	in	$\bar{y}_{AFN,NC}$	46.7	in
$c_{AFN,COMP}$	-	in	$c_{AFN,NC}$	47.6	in
$A_{AFN,COMP}$	-	in^2	$A_{AFN,NC}$	114.4	in^2
$I_{x,AFN,COMP}$	-	in^4	$I_{x,AFN,NC}$	147,441.5	in^4
$S_{x\text{-}AFN,COMP}$	-	in^3	$S_{x\text{-}AFN,NC}$	3,100.5	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-4** Distance from Abut **211.42** ft

Variation Desciption: **Variation 4 - Controlling Strength**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.375

Number of tension CPs, N_{FL} = 2

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 6,141 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = 23.77 ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = 20.75 ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	2.22
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.51

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = - ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = - ksi GS Eq. 2.1.3-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-4** Distance from Abut **211.42** ft

Variation Desciption: **Variation 4 - Controlling Strength**

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	1.30	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	-	ksi	GS Eq. 2.1.3-1

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	1.30	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	1.31	ksi	MBE Eq. 7.2.2-1
$(\Delta f_i)_{max}$ from field measured strain (leave blank if N/A)	**6.00**	ksi	MBE 7.2.2
$(\Delta f)_{max} = \max[(\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}, (\Delta f_i)_{max}]$	**6.00**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-4** Distance from Abut **211.42** ft

Variation Desciption: **Variation 4 - Controlling Strength**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ = 2.3 ksi GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ = - ksi GS Eq. 2.1.3-1

Faulted state stress range, Δf =	2.28	ksi	MBE 7.2.2	
Faulted state effective stress range, $(\Delta f)_{eff}$ =	2.30	ksi	MBE Eq. 7.2.2-1	
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	27.55	ksi	MBE 7.2.4	*If field measurements is used, the $(\Delta f)_{max}$ is multiplied by 12 to force member to be computed using finite life*

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1	
Detail Category Constant	44.00	$x10^8$ ksi^3		
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi		
Infinite Fatigue Life Check (Faulted State):				
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1	
Finite Fatigue Life Estimate (Faulted State):				
Initially available stress cycles, N_{av}	3.64E+08	cycles	MBE Eq. 7.2.5.1-2	
No. of consumed stress cycles, N_1	0	cycles		
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1	
Remaining fatigue life, Y_{REM}	228.7	Years	MBE Eq. 7.2.5.1-4	
Future ADTT for single lane, $ADTT_{FUTURE}$	10,993	trucks/day	MBE Eq. 7.2.5.1-6	
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5	
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7	
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8	
Total faulted state remaining fatigue life, Y_{REM}	**228.7**	Years	MBE 7.2.5.1	Faulted fatigue life? **OK**
Case I or II for faulted state?	**I(b)**	I(a), I(b), II	GS 2.5	

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	64.0	Years	GS 2.5.3
Total fatigue life only in **unfaulted** state, Y_u	∞	Years	GS 2.5.3
Total fatigue life only in **faulted** state, Y_f	228.7	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**228.7**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	I(b)	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	1.30	ksi	
Controlling stress range in faulted state, Δf_{FS} =	2.28	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**228.7**	Years	
Total remaining fatigue life, N_f	**228.7**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-5** Distance from Abut **94.92** ft

Variation Desciption: **Variation 5 - Controlling Fatigue**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

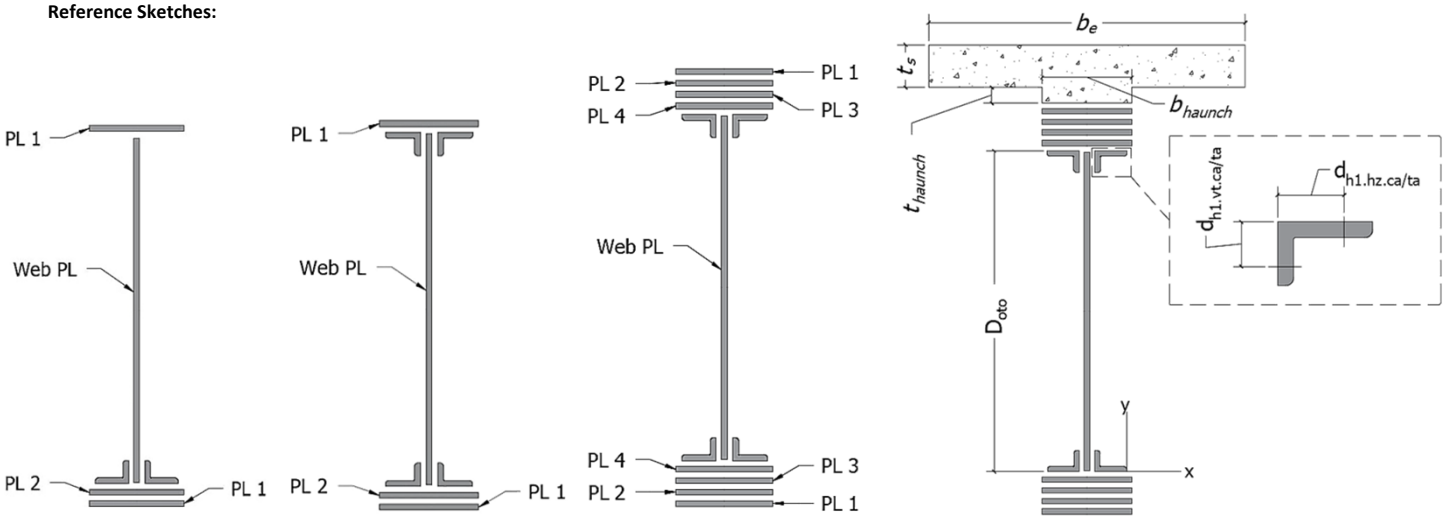
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**
Does the member meet all other provisions of Section 1.4?	**Yes**
Does the member meet all provisions of Section 1.5?	**Yes**

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0**	ksi	Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0**	ksi	Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**No**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**Yes**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	129.5	in	Haunch Width, b_{haunch}	**24.0**	in
Deck Slab Thickness, t_s	8.0	in	Haunch Thickness, t_{haunch}	**4.1**	in
Concrete Modulus of Elasticity, E_c	2730.4	ksi	Modular Ratio of the concrete, n	10.6	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **3** 1 to 4

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**16.000**	**16.000**	**16.000**	0.000	in
$t_{ccp,i}$	**0.8750**	**0.8750**	**0.7500**	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L6X6X1**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	11	in^2
Thickness of the angle, t_{ca}	1	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	35.4	in^4
Outer Horiz. Leg to N.A., y_{ca}	1.86	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.50**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.50**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-5** Distance from Abut **94.92** ft

Variation Desciption: **Variation 5 - Controlling Fatigue**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No — Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	83.50	in	Flange Angles Out-to-out Depth, D_{oto}	84.00 in
Web Thickness, t_w	0.5000	in		

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **3** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	16.000	16.000	16.000	0.000	in
$t_{tcp,i}$	0.8750	0.8750	0.7500	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L6X6X1	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	11	in^2
Thickness of the angle, t_{ta}	1	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	35.4	in^4
Outer Horiz. Leg to N.A., y_{ta}	1.86	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1 holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.50	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.50 in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00 in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No — Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$ or present cycles per day	1,129	trucks/day	Current Year, $Y_{current}$	2022 year
$(ADTT_{sl})_0$ or original cycles per day	1,129	trucks/day	Span Length, L	125.00 ft
$(ADTT_{sl})_{limit}$	20,060	trucks/day	Number of striped lanes, n_L	2 lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1 cycles
			Is this a transverse member?	No Y or N

Note: Growth rate is for future growth from today on

Unfactored Moments:

M_{DC1}	-2,928	k-ft	M_{DW}	-127	k-ft	M_{LL+IM}	-2,938	k-ft
M_{DC2}	-536	k-ft				M_{FAT+IM}	614	k-ft

$M_{FAT\ II\ +IM}$ 491 k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{G,COMP}$	-	in	$\bar{y}_{C,G,NC}$ 42.0	in
$c_{G,COMP}$	-	in	$c_{G,NC}$ 44.5	in
$A_{G,COMP}$	-	in^2	$A_{G,NC}$ 165.8	in^2
$I_{xG,COMP}$	-	in^4	$I_{xG,NC}$ 244,979.5	in^4
$S_{xG,COMP}$	-	in^3	$S_{xG,NC}$ 5,505.2	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{N,COMP}$	-	in	$\bar{y}_{N,NC}$ 42.0	in
$c_{N,COMP}$	-	in	$c_{N,NC}$ 44.5	in
$A_{N,COMP}$	-	in^2	$A_{N,NC}$ 147.9	in^2
$I_{xN,COMP}$	-	in^4	$I_{xN,NC}$ 214,387.3	in^4
$S_{xN,COMP}$	-	in^3	$S_{xN,NC}$ 4,817.7	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{AFG,COMP}$	-	in	$\bar{y}_{AFG,NC}$ 46.1	in
$c_{AFG,COMP}$	-	in	$c_{AFG,NC}$ 47.7	in
$A_{AFG,COMP}$	-	in^2	$A_{AFG,NC}$ 151.8	in^2
$I_{x,AFG,COMP}$	-	in^4	$I_{x,AFG,NC}$ 215,290.0	in^4
$S_{x\text{-}AFG,COMP}$	-	in^3	$S_{x\text{-}AFG,NC}$ 4,514.4	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite	
$\bar{y}_{AFN,COMP}$	-	in	$\bar{y}_{AFN,NC}$ 46.0	in
$c_{AFN,COMP}$	-	in	$c_{AFN,NC}$ 47.6	in
$A_{AFN,COMP}$	-	in^2	$A_{AFN,NC}$ 135.6	in^2
$I_{x,AFN,COMP}$	-	in^4	$I_{x,AFN,NC}$ 188,202.9	in^4
$S_{x\text{-}AFN,COMP}$	-	in^3	$S_{x\text{-}AFN,NC}$ 3,950.4	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-5** Distance from Abut **94.92** ft

Variation Desciption: **Variation 5 - Controlling Fatigue**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No — Optional FCP override: "Override" or blank

(This is based on the year built; "No" if prior to 1978) (This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95 — Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.438

Number of tension CPs, N_{FL} = 3

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 8,548 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = 25.97 ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = 22.72 ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	2.03
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.38

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = - ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = - ksi GS Eq. 2.1.3-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-5** Distance from Abut **94.92** ft

Variation Desciption: **Variation 5 - Controlling Fatigue**

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	1.22	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	-	ksi	GS Eq. 2.1.3-1

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	1.22	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	1.23	ksi	MBE Eq. 7.2.2-1
$(\Delta f_i)_{max}$ from field measured strain (leave blank if N/A)	**6.00**	ksi	MBE 7.2.2
$(\Delta f)_{max} = \max[(\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}, (\Delta f_i)_{max}]$	**6.00**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-5** Distance from Abut **94.92** ft

Variation Desciption: **Variation 5 - Controlling Fatigue**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ =	2.1	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ =	-	ksi	GS Eq. 2.1.3-1
Faulted state stress range, Δf =	2.15	ksi	MBE 7.2.2
Faulted state effective stress range, $(\Delta f)_{eff}$ =	2.16	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	25.92	ksi	MBE 7.2.4 *If field measurements is used, the $(\Delta f)_{max}$ is multiplied by 12 to force member to be computed using finite life*

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	4.37E+08	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	245.4	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	12,977	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**245.4**	Years	MBE 7.2.5.1
Case I or II for faulted state?	**I(b)**	I(a), I(b), II	GS 2.5

Faulted fatigue life? **OK**

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	64.0	Years	GS 2.5.3
Total fatigue life only in **unfaulted** state, Y_u	∞	Years	GS 2.5.3
Total fatigue life only in **faulted** state, Y_f	245.4	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**245.4**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	I(b)	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	1.22	ksi	
Controlling stress range in faulted state, Δf_{FS} =	2.15	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**245.4**	Years	
Total remaining fatigue life, N_f	**245.4**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-5** Distance from Abut **219.92** ft

Variation Desciption: **Variation 5 - Controlling Strength**

Assumptions:

1. Controlling fatigue detail is the fastener. 2. Deck reinforcement is ignored. 3. Maximum of two holes in each leg of the angles.

4. Outermost cover plate in tension is the failed component.

General Requirements (GS 1.4 and 1.5)

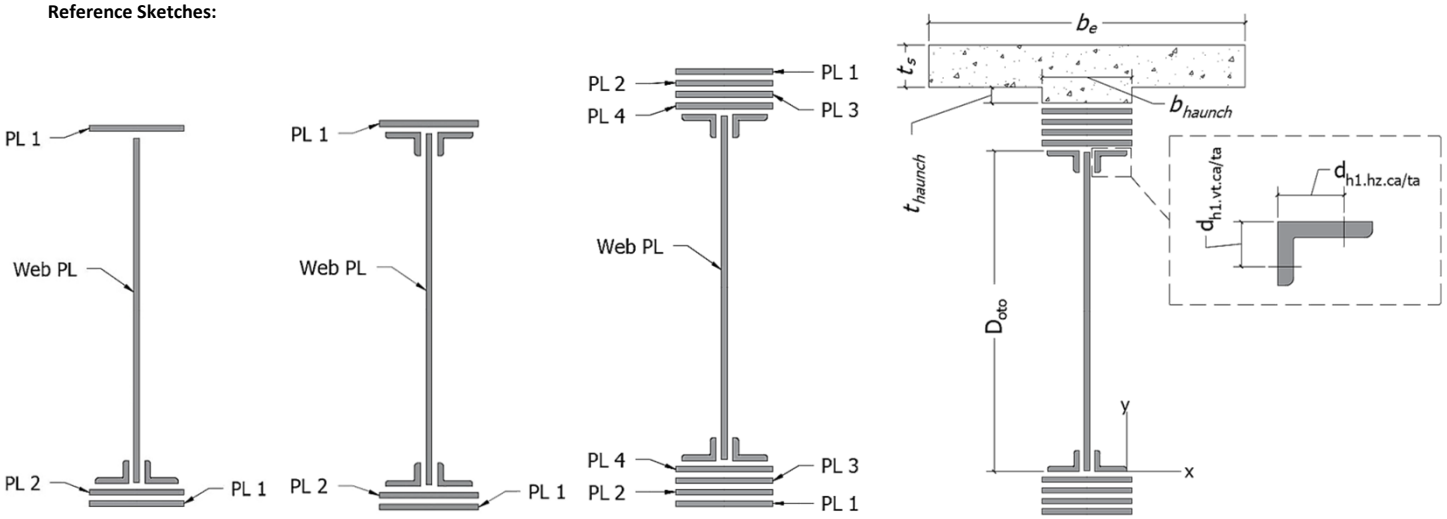
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**
Does the member meet all other provisions of Section 1.4?	**Yes**
Does the member meet all provisions of Section 1.5?	**Yes**

Member Cross Section Inputs

General:

Steel yield strength, F_y	**33.0** ksi		Fastener type	**Rivet**	Bolt or Rivet
Steel tensile strength, F_u	**66.0** ksi		Are holes punched full size?	**No**	Yes or No
Is the girder composite with the deck?	**No**	Yes or No	Fastener diameter, d_{fast}	**0.8750**	in
Include haunch in section properties?	**Yes**	Yes or No	Fastener hole diameter, d_{hole}	0.9375	in
Is this for a negative moment region?	**Yes**	Yes or No	Is compression flange welded to web?	**No**	Yes or No

Reference Sketches:



Concrete Deck Properties:

Effective Slab Width, b_e	129.5	in	Haunch Width, b_{haunch}	**24.0**	in
Deck Slab Thickness, t_s	8.0	in	Haunch Thickness, t_{haunch}	**4.1**	in
Concrete Modulus of Elasticity, E_c	2730.4	ksi	Modular Ratio of the concrete, n	10.6	

Compression Flange Plate Dimensions (in):

No. of Comp. Flange Cover Plates, N_{ccp} **3** 1 to 4

Plate(i):	1	2	3	4	
$b_{ccp,i}$	**16.000**	**16.000**	**16.000**	0.000	in
$t_{ccp,i}$	**0.8750**	**0.8750**	**0.7500**	0.0000	in

Note: Plate 1 is always the outer-most CP. See Ref sketchs.

Compression Flange Angle Properties:

Select the size of the angles	**L6X6X1**	
Select the orientation of the long leg	**Vert**	V or H
Gross area of a single angle, $A_{ca.g}$	11	in^2
Thickness of the angle, t_{ca}	1	in
Moment of Inertia about horiz. axis, $I_{xx.ca}$	35.4	in^4
Outer Horiz. Leg to N.A., y_{ca}	1.86	in

Compression Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ca}$	**1**	holes	Holes in Horz Angle Leg, $N_{holes.hz.ca}$	**1**	holes
Distance to Hole 1, $d_{h1.vt.ca}$	**4.50**	in	Distance to Hole 1, $d_{h1.hz.ca}$	**4.50**	in
Distance to Hole 2, $d_{h2.vt.ca}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ca}$	0.00	in

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-5** Distance from Abut **219.92** ft

Variation Desciption: **Variation 5 - Controlling Strength**

Additional Compression Flange Fastener Holes:

Are there additional fasteners in the compression flange plate(s)? **No** Yes or No — Holes in Comp Flange, $N_{holes.cf}$ 0 holes

Web Plate Dimensions:

Web Plate Depth, D_w	83.50	in	Flange Angles Out-to-out Depth, D_{oto}	84.00	in
Web Thickness, t_w	0.5000	in			

Tension Flange Plate Dimensions (in):

No. of Tension Flange Cover Plates, N_{tcp} **3** 1 to 4

Plate(i):	1	2	3	4	
$b_{tcp,i}$	16.000	16.000	16.000	0.000	in
$t_{tcp,i}$	0.8750	0.8750	0.7500	0.0000	in

Note: Plate 1 is always the outer-most CP, see Ref Sketches

Tension Flange Angle Properties:

Select the size of the angles	L6X6X1	
Select the orientation of the long leg	Vert	V or H
Gross area of a single angle, $A_{ta.g}$	11	in^2
Thickness of the angle, t_{ta}	1	in
Moment of Inertia about horiz. axis, $I_{xx.ta}$	35.4	in^4
Outer Horiz. Leg to N.A., y_{ta}	1.86	in

Tension Flange Angle Fastener Holes:

Holes in Vert Angle Leg, $N_{holes.vt.ta}$	1	holes	Holes in Horz Angle Leg, $N_{holes.hz.ta}$	1	holes
Distance to Hole 1, $d_{h1.vt.ta}$	4.50	in	Distance to Hole 1, $d_{h1.hz.ta}$	4.50	in
Distance to Hole 2, $d_{h2.vt.ta}$	0.00	in	Distance to Hole 2, $d_{h2.hz.ta}$	0.00	in

Additional Tension Flange Fastener Holes:

Are there additional fasteners in the tension flange plate(s)? **No** Yes or No — Holes in Tension Flange, $N_{holes.tf}$ 0 holes

Fatigue Variables:

$(ADTT_{sl})_{present}$ or present cycles per day	1,129	trucks/day	Current Year, $Y_{current}$	2022	year
$(ADTT_{sl})_0$ or original cycles per day	1,129	trucks/day	Span Length, L	125.00	ft
$(ADTT_{sl})_{limit}$	20,060	trucks/day	Number of striped lanes, n_L	2	lanes
Year Built, Y_{built}	1958	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cylces per Truck, n	1	cycles
			Is this a transverse member?	No	Y or N

Note: Growth rate is for future growth from today on

Unfactored Moments:

M_{DC1}	-3,060	k-ft	M_{DW}	-136	k-ft	M_{LL+IM}	-3,240	k-ft
M_{DC2}	-572	k-ft				M_{FAT+IM}	586	k-ft

$M_{FAT\ II\ +IM}$ 469 k-ft

Note: Enter positive moment values only. Moments are taken about the centroid of the section under consideration.

Unfaulted Member Section Properties:

Assumed no failed components

Gross Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite		
$\bar{y}_{G,COMP}$	-	in	$\bar{y}_{C,G,NC}$	42.0	in
$c_{G,COMP}$	-	in	$c_{G,NC}$	44.5	in
$A_{G,COMP}$	-	in^2	$A_{G,NC}$	165.8	in^2
$I_{xG,COMP}$	-	in^4	$I_{xG,NC}$	244,979.5	in^4
$S_{xG,COMP}$	-	in^3	$S_{xG,NC}$	5,505.2	in^3

Net Section Properties: Unfaulted (composite if applicable)

	Composite		Noncomposite		
$\bar{y}_{N,COMP}$	-	in	$\bar{y}_{N,NC}$	42.0	in
$c_{N,COMP}$	-	in	$c_{N,NC}$	44.5	in
$A_{N,COMP}$	-	in^2	$A_{N,NC}$	147.9	in^2
$I_{xN,COMP}$	-	in^4	$I_{xN,NC}$	214,387.3	in^4
$S_{xN,COMP}$	-	in^3	$S_{xN,NC}$	4,817.7	in^3

Faulted Member Section Properties:

Assumed failed component is Tension Cover PL 1 (outer-most cover plate)

Gross Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite		
$\bar{y}_{AFG,COMP}$	-	in	$\bar{y}_{AFG,NC}$	46.1	in
$c_{AFG,COMP}$	-	in	$c_{AFG,NC}$	47.7	in
$A_{AFG,COMP}$	-	in^2	$A_{AFG,NC}$	151.8	in^2
$I_{x,AFG,COMP}$	-	in^4	$I_{x,AFG,NC}$	215,290.0	in^4
$S_{x\text{-}AFG,COMP}$	-	in^3	$S_{x\text{-}AFG,NC}$	4,514.4	in^3

Net Section Properties: Faulted (composite if applicable)

	Composite		Noncomposite		
$\bar{y}_{AFN,COMP}$	-	in	$\bar{y}_{AFN,NC}$	46.0	in
$c_{AFN,COMP}$	-	in	$c_{AFN,NC}$	47.6	in
$A_{AFN,COMP}$	-	in^2	$A_{AFN,NC}$	135.6	in^2
$I_{x,AFN,COMP}$	-	in^4	$I_{x,AFN,NC}$	188,202.9	in^4
$S_{x\text{-}AFN,COMP}$	-	in^3	$S_{x\text{-}AFN,NC}$	3,950.4	in^3

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-5** Distance from Abut **219.92** ft

Variation Desciption: **Variation 5 - Controlling Strength**

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override: "Override" or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Redundancy II Load Factors (GS Table 1.7.1-1 and LRFD Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD 6.5.4.2):

Tension, Yield on Gross Section, ϕ_y 0.95

Tension, Fracture on Net Section, ϕ_u 0.80

Cover Plate Adjustment Factor (GS 2.1.2 & 2.1.3)

Fatigue Adjustment Factors (GS Eq. 2.1.2-3 & Eq. 2.1.3-3):

CP Adjustment Factor, β_{AF} = 1.438

Number of tension CPs, N_{FL} = 3

Strength Capacity Check (GS 2.1 & 2.3)

Redundancy II Factored Moment:

$M_u = \gamma_{DC}(M_{DC1} + M_{DC2}) + \gamma_{DW}M_{DW} + \gamma_{LL}M_{LL+IM}$ = 9,206 k-ft GS Eq. 1.7.1-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u$ = 52.80 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y$ = 31.35 ksi GS Eq. 2.3-1

Factored Stress in the Faulted State: (*Note:* β_{AF} = 1.0)

Noncomposite Section:

$f_{AFN} = \beta_{AF}(M_u / S_{x\text{-}AFN})$ = 27.97 ksi GS Eq. 2.1.2-1

$f_{AFG} = \beta_{AF}(M_u / S_{x\text{-}AFG})$ = 24.47 ksi GS Eq. 2.1.2-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	OK	OK or NG	GS Eq. 2.3-2	1.89
$f_{AFG} \le f_{u,g}$?	OK	OK or NG	GS Eq. 2.3-1	1.28

Composite Section:

$f_{AFN} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFN,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFN,COMP}$ = - ksi GS Eq. 2.1.3-1

$f_{AFG} = \gamma_{DC}(M_{DC1}+M_{DC2})/S_{x\text{-}AFG,NC} + (\gamma_{DW}M_{DW} + \beta_{AF}(\gamma_{LL}M_{LL+IM}))/S_{x\text{-}AFG,COMP}$ = - ksi GS Eq. 2.1.3-2

Strength Criteria Check:				Ratio
$f_{AFN} \le f_{u,n}$?	-	OK or NG	GS Eq. 2.3-2	-
$f_{AFG} \le f_{u,g}$?	-	OK or NG	GS Eq. 2.3-1	-

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-5** Distance from Abut **219.92** ft

Variation Desciption: **Variation 5 - Controlling Strength**

Fatigue Life Estimate (GS 2.5)

Unfactored Fatigue Stress in the Unfaulted State:

Noncomposite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,NC} =$	1.17	ksi	GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = M_{FAT+IM} / S_{xN,COMP} =$	-	ksi	GS Eq. 2.1.3-1

Effective Fatigue Stress Range & Max Fatigue Stress Range in Unfaulted State:

$R_p =$	1.01		MBE 7.2.2.1
Unfaulted state stress range, $\Delta f =$	1.17	ksi	MBE 7.2.2
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	1.18	ksi	MBE Eq. 7.2.2-1
$(\Delta f_i)_{max}$ from field measured strain (leave blank if N/A)	**6.00**	ksi	MBE 7.2.2
$(\Delta f)_{max} = \max[(\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}, (\Delta f_i)_{max}]$	**6.00**	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-1
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.0	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.1-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Unfaulted fatigue life? **OK**

Internal Redundancy of Built-up Member: Flexural

Cross Section Label: **XSec-5** Distance from Abut **219.92** ft

Variation Desciption: **Variation 5 - Controlling Strength**

Effective Fatigue Stress Range & Max Fatigue Stress Range in Faulted State:

Noncomposite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM} / S_{x\text{-}AFN})$ = 2.0 ksi GS Eq. 2.1.2-1

Composite Section:

$f_{AFN} = \theta_{AF}(M_{FAT+IM}) / S_{x\text{-}AFN,COMP}$ = - ksi GS Eq. 2.1.3-1

Faulted state stress range, Δf =	2.05	ksi	MBE 7.2.2	
Faulted state effective stress range, $(\Delta f)_{eff}$ =	2.06	ksi	MBE Eq. 7.2.2-1	
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	24.74	ksi	MBE 7.2.4	*If field measurements is used, the $(\Delta f)_{max}$ is multiplied by 12 to force member to be computed using finite life*

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-1	
Detail Category Constant	44.00	$x10^8$ ksi^3		
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.0	ksi		
Infinite Fatigue Life Check (Faulted State):				
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1	
Finite Fatigue Life Estimate (Faulted State):				
Initially available stress cycles, N_{av}	5.02E+08	cycles	MBE Eq. 7.2.5.1-2	
No. of consumed stress cycles, N_1	0	cycles		
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1	
Remaining fatigue life, Y_{REM}	258.3	Years	MBE Eq. 7.2.5.1-4	
Future ADTT for single lane, $ADTT_{FUTURE}$	14,747	trucks/day	MBE Eq. 7.2.5.1-6	
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5	
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7	
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8	
Total faulted state remaining fatigue life, Y_{REM}	**258.3**	Years	MBE 7.2.5.1	Faulted fatigue life? **OK**
Case I or II for faulted state?	**I(b)**	I(a), I(b), II	GS 2.5	

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, N_U	64.0	Years	GS 2.5.3
Total fatigue life only in **unfaulted** state, Y_u	∞	Years	GS 2.5.3
Total fatigue life only in **faulted** state, Y_f	258.3	Years	GS 2.5.3
Total remaining fatigue life, $N_f = Y_f(1-N_u/Y_u)$	**258.3**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.1 & 2.3
Fatigue case =	I(b)	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	1.17	ksi	
Controlling stress range in faulted state, Δf_{FS} =	2.05	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**258.3**	Years	
Total remaining fatigue life, N_f	**258.3**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

VOLUME III: Evaluation of the Redundancy Status of Structure 062-65-T4020: Wabash River Memorial Bridge

EXECUTIVE SUMMARY

Introduction

The Wabash River Memorial Bridge (Asset #062-65-T4020) is a truss bridge that spans the Wabash River and crosses the state line between Indiana and Illinois. Built in 1956 near Mount Vernon, Indiana, the bridge consists of six approach spans on each side of a three-span continuous through-arch truss main river crossing. The main truss spans contain riveted built-up members. Rehabilitations and repairs, primarily addressing deck and railing, have been completed throughout the life of the bridge. For this report, the evaluation for internal redundancy for axially loaded tension members was completed for the three interior truss spans, but the girder approach spans and the tie arch members were not included.

Findings

The bridge was evaluated using the analysis procedure for axially loaded tension members outlined in the *AASHTO Guide Specifications for Internal Redundancy of Mechanically-Fastened Built-Up Steel Members*, utilizing the latest interims added in 2022 (AASHTO, 2018/2022b) (IRM Guide Specification). The IRM Guide Specification provides a methodology for determining if a member that is currently labeled as a Non-Redundant Steel Tension Member (NSTM), formerly known as Fracture Critical Members (FCM), contains adequate internal redundancy to be relabeled as an Internally Redundant Member (IRM). The IRM Guide Specification also provides requirements for determining the scope and frequency of inspections for IRMs. The process outlined in the IRM Guide Specification is a multi-step evaluation that first determines eligibility for internal redundancy evaluation, followed by strength and fatigue analysis of the member. Eligibility is validated based on original and rehabilitation plans, current load ratings, and inspection reports. The strength capacity checks included examination of the yield on the gross section and the fracture of net section of the member in a faulted state. The fatigue checks included the validation of the fatigue life of the member in both the unfaulted and faulted states. Using this data, the maximum interval for special inspections was determined.

The National Steel Bridge Alliance and Purdue University developed a spreadsheet tool to complete the calculations as outlined in the IRM Guide Specification for determining internal redundancy of a specific axially loaded tension member (NSBA, 2020). The spreadsheet also calculates the maximum interval for special inspections, as defined in the IRM Guide Specification. The spreadsheet was primarily used as-is; however, slight modifications were required to incorporate some of the structure's unique details. Maximum unfactored axial loads due to dead, live, and fatigue loads were obtained from an existing Midas Civil model, used for load rating, on file with INDOT. For efficiency, an Excel Macro was developed in combination with the NSBA spreadsheet to evaluate each truss member included in the current NSTM/FC inspection and eligible IRM evaluation (NSBA, 2020). The IRM evaluation was completed for thirty-four members of one half the truss. The bridge was symmetric about the centerline of the center arch span. Thus, the evaluation of the thirty-four members was extrapolated to similar members within the other half of the bridge and along the other truss line. Where section loss was noted in the inspection reports, an analysis of the affected member was duplicated with an area equivalent to the section loss subtracted from the member area.

Implementation

The evaluation demonstrated that 53% of the eligible NSTM truss can be reclassified as internally redundant members and are eligible to be inspected using a special inspection at a frequency of 10 years. The remaining evaluated truss members did not pass the checks due to failing the IRM specific strength checks in the faulted state for both the gross and net sections per the IRM Guide Specification criteria.

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1. BACKGROUND

The Fracture Critical Member (FCM) label has been used on bridge members that have "a steel primary member or portion thereof subject to tension whose failure would probably cause a portion of or the entire bridge to collapse" (Lloyd, 2020). Once a bridge has been classified as having FCMs, the structure has been required to have an in-depth arm's length inspection completed at regular intervals not to exceed 24 months throughout its service life. Today, these members are referred to as nonredundant steel tension members (NSTMs).

Recent research around redundancy of steel members provides updated guidance regarding when a member should be classified as an NSTM. Based on this research, "internal member redundancy" may now be explicitly considered and is applicable to mechanically-fastened built-up members, meaning a member that is comprised of multiple individual components joined using mechanical fasteners. The research focused on mechanically fastened built-up members and culminated in the creation of the *AASHTO Guide Specifications for Internal Redundancy of Mechanically-Fastened Built-Up Steel Members* (AASHTO, 2018/2022b). (Please note that throughout this report, this guide specification will be referred to as the IRM Guide Specification (AASHTO, 2018/2022b)). The intent of the IRM Guide Specification is to provide a codified methodology "on how to establish whether adequate internal redundancy exists in a mechanically-fastened built-up steel member." Included in the IRM Guide Specification is a methodology for determining the maximum frequency between special inspections. In the context of the IRM Guide Specifications, a special inspection is defined as:

> *…an inspection of sufficient depth to reliably detect severed or fractured components and other conditions deemed important in a member identified as an IRM. To meet the objectives of the Special Inspection for IRMs, it is understood that special access equipment may be required for some bridges, while for others it may be possible to reliably detect broken components from the ground using normal visual inspection techniques.*

Note that the scope and intervals for routine safety inspections (e.g., inspection for general deck condition, etc.) remain in place for the bridge, and NSTM (formerly FCM) hands-on inspections remain the same for members still classified as NSTMs. A Special IRM Inspection only replaces the NSTM designation and inspection requirements for members that are found to be reclassified as internally redundant.

The analysis described in this report uses the IRM Guide Specifications (AASHTO, 2018/2022b), the *AASHTO Manual for Bridge Evaluation, 3rd Edition* (AASHTO, 2018/2022c), and the *AASHTO LRFD Bridge Design Specifications, 9th Edition* (AASHTO, 2020) to evaluate if members of the 062-65-T4020 Wabash River Memorial Bridge currently classified as NSTMs may be *reclassified* as IRMs. With the adoption of the new National Bridge Inspection Standards found in 23 CFR Part 650 that became law on June 6 of 2022 (DOT FHWA, 2022), once a member, or portion thereof, has been determined to be an Internally Redundant Member (IRM), the NSTM label can be removed and replaced with the IRM designation. Per the CFRs, members that are determined to have system or internal redundancy using an approved methodology in accordance with Section 650.313(f)(1)(i) of the NBIS shall then be inspected at a frequency determined using a "nationally recognized method." The IRM Guide Specification (AASHTO, 2018/2022b) is a nationally recognized method and thus was used to determine the correct inspection frequency for the IRMs. Additionally, the law replaced the Fracture Critical designation with the term nonredundant steel tension member (NSTM).

2. BRIDGE DETAILS

The structure discussed in this report, 062-65-T4020 Wabash River Memorial Bridge, is owned by the Indiana Department of Transportation (INDOT). It was originally built in 1956 but has had multiple rehabilitation and repairs since its original construction. The work performed on the bridge includes the following.

- 1956: Originally built
- 1987: Deck patching, deck reconstruction, railing replacement and bridge deck joint replacement
- 1993: Superstructure cleaning and painting
- 2009: Deck replacement (new deck and overlay), new Type PF-1 deck railing, new deck expansion joints, superstructure cleaning and painting
- 2012: Miscellaneous work involved installing detection loops and cameras
- 2024: Scheduled for rehabilitation: deck patching, joint repairs, surface sealing, replacement of rivets with section loss greater than 50%, cleaning and painting the lower chord/lower chord gusset plates/connections/vertical and diagonal members, and spot painting other members exhibiting rust, evaluation of gusset plates for potential strengthening (07/10/2024)

The bridge crosses the Indiana-Illinois state line between White County Illinois and Posey County Indiana. The bridge carries an estimated average daily traffic (ADT) of over 4,200 vehicles (based on traffic count data from 2021). The structure consists of six steel girder approach spans on each side of three steel through truss main spans. Several of the truss members are currently labeled as NSTMs and are on a 24-month NSTM inspection frequency. An elevation view of the main truss spans taken during the 2022 routine and fracture critical inspections is shown in Figure 2.1.

The approach spans consist of four riveted built-up girders and do not have any fracture critical members



Figure 2.1 Wabash Memorial Bridge elevation view.

due to load-path redundancy. The floor beams in the truss spans are built up I-sections made of WTs welded to a web plate. The floor beams are not eligible to be evaluated for internal redundancy because they are not built-up mechanically fastened members.

The most recent fracture critical and routine inspections were performed in 2022. Thus, the evaluation performed shall use 2022 as the "current year" for consumed and remaining fatigue life calculations. The condition of the superstructure as reported in the inspection varied slightly below the deck and above the deck. Below the deck, the structure was found to be in generally satisfactory to fair condition. The NSTMs and components were described in the inspection report as predominantly sound and did not indicate cracking was found. Many of the chord components and rivet heads exhibited areas of corrosion, delamination, pitting, and minor to moderate section loss. Above the deck, the NSTMs appear predominantly sound and in good physical condition. They did not exhibit any widespread structurally detrimental deterioration or any evidence of cracking. The overall superstructure had a condition rating of 5. These minor issues were not significant enough to require load posting, and no other issues were observed that would disqualify the members from being evaluated using the IRM Guide Specification (AASHTO, 2018/2022b).

The load rating of this structure was performed by Michael Baker in 2020 using MIDAS Civil, AASHTO Ware BrR 6.8.4.3002, and Excel spreadsheets. The truss system utilized the MIDAS Civil model and spreadsheets for calculating loads. The model utilized the LFR rating method with HS20 design load. The rating of the bridge was controlled by gusset plate L6′ south truss, horizontal shear for HS20-44 design ratings. Relevant construction plans related to the truss members (spans 7–9) from the original construction in 1956 and the reconstruction in 2009 can be found in Appendix E. All remaining bridge related documents including original bridge plans, rehabilitation plans, inspection reports and load ratings can be found in the INDOT BIAS/ERMS database.

2.1 Geometric Information

The analysis of the 062-65-T4020 Bridge focused on the three through-arch truss main spans. The three truss spans measure 284′-0″ for the two outer spans and 441′-0″ for the middle truss span. The approach girder spans were not labeled fracture critical and thus were not evaluated for internal redundancy. The north and south trusses are spaced at 34′-6″ center-to-center. At original construction, the bridge was built with a clear roadway of 26′-0″. After the deck reconstruction in 2009, the clear roadway is 30′-3″. The bridge has no skew and is on a tangent alignment. The superstructure carries two 12′ lanes with 3′-1½″ shoulders on each side. The typical sections of the deck and superstructure geometry taken from the 2004 reconstruction plans are shown in Figure 2.2 and Figure 2.3.

The current list of NSTMs includes the lower chords, tie girders, upper chords in tension, diagonals in tension, vertical chords (hangers) in tension, and the transverse floor beams. The IRM evaluation included only the upper, lower, diagonal, and vertical chords. Each truss is symmetric about the centerline of the main span with full symmetry between the two trusses. Thus, the evaluation of one quarter of the bridge is sufficient for analyzing both trusses. A summary of the member section variations can be found in Figure 2.4, and the specific members associated with each section variation is listed in Appendix A. Additionally, truss member sizes can be found in the construction plans in Appendix E.

2.2 Loads

A MIDAS Civil 2D truss model was provided by INDOT. The dead and live loads were applied to a single truss line to obtain the unfactored axial loads of each truss member. Live loads were obtained from HL-93 and the AASHTO fatigue truck loads. The dead loads applied on the truss consisted of the DC1, DC2, and DW loads. The following lists describes the dead loads.

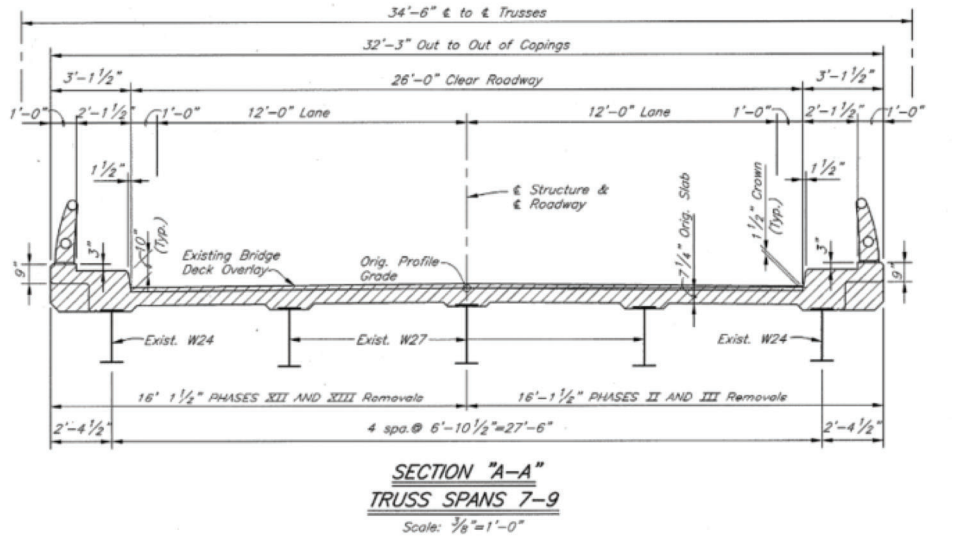


Figure 2.2 Typical section at truss spans based on original 1956 construction.

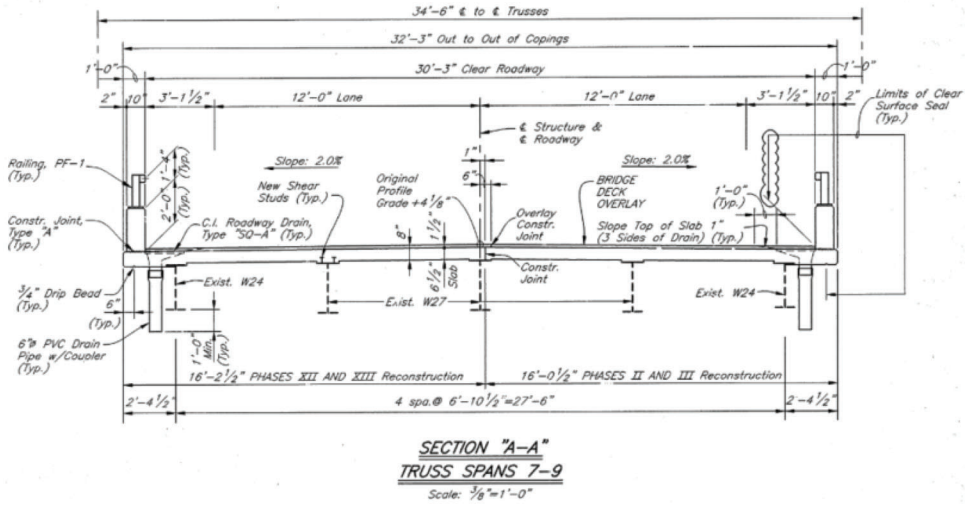


Figure 2.3 Typical section at truss spans after 2009 deck reconstruction.

Section Variation	Box?	Built-up I-section?	Channel Size	Angle Size	Steel yield strength, F_y	Steel tensile strength, F_u	Width	Thickness	Hand Hole Width	Distance to Hole 1	No. of full depth flange plates	Depth PL-0	Thickness PL-0	Dist to Hole 1, PL-0
#	Yes or No	Yes or No	Size	Size	ksi	ksi	in	in	in	in	0 to 3	in	in	in
Sect 1	Yes	No	C18x45.8	-	33	60	17	0.375	7.5	2.500	-	-	-	-
Sect 2	Yes	No	C18x51.9	-	50	70	17	0.375	7.5	2.500	-	-	-	-
Sect 3	Yes	No	C15x40	-	33	60	17	0.375	7.5	2.000	-	-	-	-
Sect 4	Yes	No	C15x33.9	-	33	60	17	0.375	7.5	2.000	-	-	-	-
Sect 5	Yes	No	C15x33.9	-	50	70	17	0.375	7.5	2.000	-	-	-	-
Sect 6	Yes	No	C12x30	-	50	70	17	0.375	7.5	1.750	-	-	-	-
Sect 7	Yes	No	C12x25	-	33	60	17	0.375	7.5	1.750	-	-	-	-
Sect 8	Yes	No	C12x20.7	-	33	60	17	0.375	7.5	1.750	-	-	-	-
Sect 9	No	Yes	-	L6x3.5x13.9	33	60	-	-	-	-	1	11	0.188	1.933
Sect 10	No	Yes	-	L6x3.5x13.9	33	60	-	-	-	-	1	11	0.313	1.933
Sect 11	Yes	No	-	L4x4x7/16	33	60	16	0.375	7.5	2.219	1	20	0.688	2.219
Sect 12	Yes	No	-	L4x4x7/16	33	60	16	0.375	7.5	2.219	1	20	0.625	2.219
Sect 13	Yes	No	-	L4x4x7/16	50	70	16	0.375	7.5	2.219	1	20	0.500	2.219
Sect 14	Yes	No	-	L4x4x3/8	33	60	16	0.375	7.5	2.188	1	20	0.375	2.188
Sect 15	Yes	No	-	L4x4x3/8	33	60	16	0.375	7.5	2.188	1	20	0.500	2.188

Figure 2.4 Truss member section variations.

	Detail/Parameter	Value	Unit	Source/Reference
Material Properties	Concrete Compressive Strength, f'_c	4	ksi	Class "C" Concrete (2004 Reconstruction Plans)
	Weight of Concrete (without reinforcing), w_c	0.12	kcf	Class "C" Concrete (2004 Reconstruction Plans)
	Weight of Concrete (with reinforcing), $w_{c\ reinf}$	0.125	kcf	Class "C" Concrete (2004 Reconstruction Plans)
	Concrete Modulus of Elasticity, E_c	2731	ksi	AASHTO LRFD BDS Eq 5.4.2.4-1
	Steel Minimum Yield Strength CS, F_y	33	ksi	1956 Plans - Carbon Steel A7-49T
	Steel Minimum Tensile Strength CS, F_u	66	ksi	1956 Plans - Carbon Steel A7-49T
	Steel Minimum Yield Strength AS, F_y	50	ksi	1956 Plans - Low-Alloy Steel A242-49T
	Steel Minimum Tensile Strength AS, F_u	70	ksi	1956 Plans - Low-Alloy Steel A242-49T
Traffic - For Information Only	Original ADT	2600	veh/day	INDOT's online database for vehicle counts (1988)
	Original truck percentage	14	%	INDOT's online database for vehicle counts
	Biodirectional factor	55	%	AASHTO LRFD BDS C3.6.1.4.2
	Fraction of Truck Traffic in a Single Lane, p	1		AASHTO LRFD BDS Table 3.6.1.4.2-1
	Original average daily truck traffic in a single lane	200	veh/day	AASHTO LRFD BDS Eq 3.6.1.4.2-1
	Present ADT	4233	veh/day	INDOT's online database for vehicle counts (2021)
	Present Truck Percentage	14	%	INDOT's online database for vehicle counts (2021)
	Current average daily truck traffic in a single lane	326	veh/day	AASHTO LRFD BDS Eq 3.6.1.4.2-1
Additional Traffic Data	Maximum ADT	20000	veh/day	AAHSTO LRFD BDS C3.6.1.4.2
	Expected Growth Rate	1.0	%	INDOT 2020 Growth Rate data
	Max limit for ADTT in a single lane	2800	veh/day	AAHSTO LRFD BDS C3.6.1.4.2
	Number of Striped Lanes, n_L	1	lanes	2022 Inspection Report
	Stress-Range Estimate Partial Load Factor, R_s	1.0		MBE Table 7.2.2.1-1
	Number of Stress-Range Cycles per Truck, n	1.0		AAHSTO LRFD BDS Table 6.6.1.2.5-2
	Resistance Factor for Evaluation - Minimum Life, R_R	1.0		MBE Table 7.2.5.1-1

Figure 2.5 Additional details/parameters.

- DC1 (placed prior to deck hardening and acting on the noncomposite section).
  - Self-weight of the truss, incorporating additional self-weight and a weight allowance for stiffeners and connection components.
  - Floor beam and stringer self-weight.
  - Deck and haunch self-weight.
- DC2 (placed after deck hardening and acting on the long-term composite section).
  - Loads due to self-weight of the concrete barrier.
- DW (wearing surfaces and utilities acting on the long-term composite section).
  - Weight of the overlay.

Because the loads obtained from the 2D model were unfactored, live load impact, multiple presence effects, and live load distribution factors were applied where pertinent. The live load distribution factor calculations can be found in Appendix D, along with material properties and associated loading data. Per the IRM Guide Specifications (AASHTO, 2018/2022b), Equation 1.7.2-1 provides the basic load combination to obtain the total factored tensile load in an axially loaded tension member when evaluating internal redundancy in the faulted state. Load factors for the internal redundancy load combination are found in Table 1.7.1-1 of the IRM Guide Specification. Article 2.2.1 outlines the process for calculating stresses in the faulted state due to axial tension for multi-component truss members.

2.3 Additional Details

Figure 2.5 lists additional details/parameters needed to complete the IRM. This information can also be found in Appendix D with detailed calculations and loading information used for the IRM evaluation.

3. IRM ANALYSIS/EVALUATION

Per AASHTO BDS 6.6.2.2, only members that are subject to net tensile stress under the Strength I load combination shall be designated as an NSTM (AASHTO, 2020). To verify the list of NSTMs as provided in the plan sets and inspection reports, the Strength I load combination was calculated for each member using the dead and live loads obtained from the MIDAS model. When compared to the existing NSTM list for inspection, it was found that member L14-U15 on the current list is not subject to net tensile stress under the Strength I limit state and does not need to be classified as an NSTM. Similarly, the members between L12-L16 were not on the list but are in fact subject to net tensile stress and thus were included in the list of members evaluated for internal redundancy. These four members were added to the evaluation results and recommendations contained herein.

Additionally, AASHTO BDS 6.6.1.2.1 dictates "in regions where the unfactored permanent loads produce compression, fatigue shall be considered only if the compressive stress is less than the maximum live load tensile stress caused by the Fatigue I load combination" (AASHTO, 2020). Thus, the Fatigue I load combination was calculated for each member using the tensile component of the fatigue load and compared to the unfactored dead load to determine if the member should be considered for fatigue. It was found that members L2-U3, L12-L13, and L13-L14 did not need to be considered for fatigue evaluation. The calculations identifying which members qualify as NSTMs and whether the members should be considered for fatigue can be found in Appendix D.

After the NSTMs were identified, the IRM evaluation consisted of sequential checks, as required in the IRM Guide Specifications (AASHTO, 2018/2022b), to

determine if the members satisfied the requirements of internal redundancy. If a member failed any of the required strength checks, then the member cannot be defined as an IRM and must remain an NSTM. The process to confirm internal redundancy of the axially loaded tension members is split into three steps in the spreadsheet: screening criteria, strength capacity checks, and fatigue life estimates.

3.1 Evaluation Requirements

The screening criteria for axially loaded tension members are defined in Sections 1.4 and 1.6 of the IRM Guide Specifications (AASHTO, 2018/2022b). The screening criteria included checks that could be verified with basic knowledge of the bridge found in inspection reports and bridge plans. A more detailed analysis of the screening criteria will be discussed further in Section 5.2.

3.2 Strength Capacity Check

After the screening requirements were met, the strength capacity of the member in the faulted state was checked. The IRM Guide Specification (AASHTO, 2018/2022b) defines a faulted state as "the condition during which an individual component of the built-up member was assumed to have severed." The factored axial stress in the faulted state was calculated for each member using the appropriate provisions of the IRM Guide Specification. The stresses on the net and gross sections are calculated per the IRM Guide Specification Eq. 2.2.1-1 and 2.2.1-2, respectively, using the net and gross sections as prescribed in Section 2.2.1 and Table 2.2.1-1 (AASHTO, 2018/2022b). Multiple faulted section scenarios were considered, each scenario representing failure of a different component in the built-up member. The strength capacity was checked using the controlling case of the various scenarios. The factored resistance was calculated using the material properties and the resistance factors specified in *AASHTO LRFD Bridge Design Specifications* Section 6.5.4.2 (AASHTO, 2020). Both yield on gross section and fracture of net section in the faulted state were checked to validate the strength adequacy of the member.

3.3 Fatigue Life in Unfaulted and Faulted State

For the truss members that met the strength capacity requirements, the next step was determining the fatigue life estimate in the unfaulted state. The unfaulted state stress range was taken as the fatigue truck live load (the range between the maximum and minimum fatigue load created by the fatigue truck) plus a 15% dynamic load allowance, divided by the net area of the member and factored for the Fatigue II load combination. The effective stress range was then calculated by multiplying the calculated stress range by the multiple presence factor, R_p, and the stress-range estimate partial load factor, R_s (AASHTO, 2018/2022c). The *AASHTO LRFD Bridge Design Specifications* sets the maximum stress range to 2.2 times the effective stress range, where 2.2 is the ratio between the Fatigue I and Fatigue II load factors. The constant amplitude fatigue limit, correlated with the respective fatigue category (i.e., Category D for this case), was then compared to the maximum calculated fatigue stress range. If the constant amplitude fatigue limit was greater than the calculated maximum fatigue stress range, the member has infinite life in the unfaulted state. Per Section 4 of this report, L2-U3 and L12-L14 did not need to be considered for fatigue evaluation. For the remaining truss members evaluated in this analysis, all but L4-L6 met the infinite life criteria in the unfaulted state. For L4-L6, additional calculations were completed using the historical, current, and predicted ADT data to determine whether remaining fatigue life existed and how many remaining years, if any.

A similar process was completed to evaluate the fatigue life in the faulted state. For the faulted state, an individual component was assumed to have been severed and was subtracted from the net area of the member. For the faulted state, the fatigue category was updated to Category C fatigue detail based on Table 2.5-1 of the IRM Guide Specification (AASHTO, 2018/2022b). The total remaining fatigue life was determined using the calculated total remaining unfaulted and faulted state fatigue lives in correlation with the number of accumulated years in unfaulted state, as found in Equation 2.5.3-1 of the IRM Guide Specification (AASHTO, 2018/2022b).

3.4 Maximum Interval for Special Inspections

Section 3 of the IRM Guide Specifications (AASHTO, 2018/2022b) provides guidance for determining the maximum interval between special inspections for identifying large cracks or completely severed components in IRMs. This method incorporates the estimated remaining fatigue life and a level of conservatism (as indicated by the case number classification) for the faulted state to estimate the maximum interval for special inspections. The depth of inspection and equipment used should be based off the ability to reliably detect severed components in a member identified as an IRM.

4. DISCUSSION OF RESULTS AND IMPLEMENTATION

4.1 Methodology

The Wabash River Memorial Bridge was evaluated using the steps described above as specified in the IRM Guide Specifications (AASHTO, 2018/2022b). A spreadsheet, IRM Evaluator (NSBA, 2020), created by the National Steel Bridge Alliance (NSBA) in collaboration with the S-BRITE Center at Purdue University, was used as a tool to evaluate the members currently labeled as NSTMs. This spreadsheet was tested and vetted by NSBA and S-BRITE staff to

assure accuracy of the tool. As stated before, the spreadsheet was primarily used as-is, but some minor modifications were made to incorporate some of the structure's unique details. For efficiency, an Excel Macro was also developed to interface with the IRM Evaluator spreadsheet in an iterative process to evaluate each truss member in the current fracture critical inspection and eligible for evaluation. The Excel Macro automated the process in which general bridge and member specific data were input into the spreadsheet to obtain the strength capacity, estimated fatigue life, and maximum interval for special inspections for each member. A process diagram is shown in Figure 4.1.

This method minimized the risk of human error, increased efficiency, and allowed for many members to be evaluated in a short period of time. The IRM evaluation was completed for thirty-four members of one quarter of the bridge. The bridge was symmetric about the centerline of the arch span and was consistent in design to the other truss. Thus, the evaluation of the thirty-four members was extrapolated to similar members on the other half of the truss and along the other truss line. An image taken during the 2016 inspection showing a south elevation view of the truss members is shown in Figure 4.2 to aid in the visualization of the symmetry of the overall structure.

4.2 Screening Criteria

The screening criteria included in Article 1.4 and 1.6 of the IRM Guide Specification were checked and verified, with the following results.

- A traditional fracture-critical member inspection was performed within the past 24 months (2022). All NSTM truss chords below the deck were deemed in generally satisfactory to fair condition and above the deck were deemed in mostly good condition.
- Below the deck, the NSTMs did not exhibit any structurally detrimental cracking. Areas of corrosion, delamination, and minor section loss were noted, but did not affect the load rating of the bridge.
- Above the deck, the NSTMs did not exhibit any structurally detrimental deterioration or cracking. Some areas of light rust were noted.
- The inspection report did not reveal severe corrosion, impact damage or other forms of damage in the members being evaluated.
- All members were found to be multi-component members with no individual component exceeding 40% of the gross area of the entire member. The area removed by hand holes were not included in the gross and net areas.
- All components were fastened together with rivets and were assumed to satisfy all strength, stitch and sealing requirements in effect at the time of design.

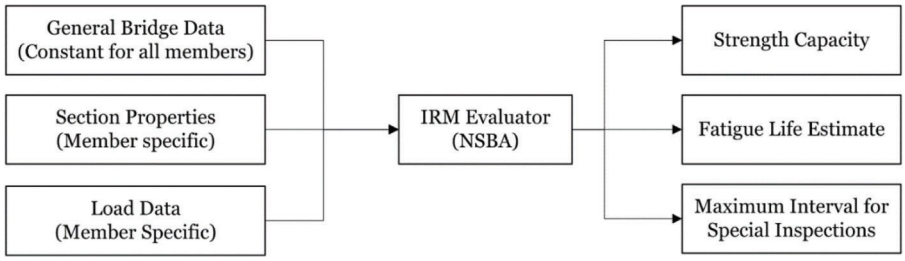


Figure 4.1 Process diagram for Excel Macro utilized for IRM Evaluator.



Figure 4.2 South elevation view of truss members.

Span	Member	Member Type	Angle Size	Channel Size	Passes Screening Criteria?	Passes Strength Check? (Faulted)	Fracture on Net, Strength Ratio	Yield on Gross, Strength Ratio
#	Member ID	Type	Size	Size	Yes or No	Yes or No	Less than 1 = NG	Less than 1 = NG
7	L2-L3	Lower Chord	L4x4x7/16		YES	NO	0.75	0.82
7	L3-L4	Lower Chord	L4x4x7/16		YES	NO	0.75	0.82
7	U7-U8	Upper Chord	L4x4x7/16		YES	NO	0.74	0.81
7	U8-U9	Upper Chord	L4x4x7/16		YES	NO	0.74	0.81
8	U9-U10	Upper Chord	L4x4x7/16		YES	NO	0.68	0.98
8	U10-U11	Upper Chord	L4x4x7/16		YES	NO	0.68	0.98
8	L14-L15	Middle Chord		C15x40	YES	NO	0.41	0.60
8	L15-L16	Middle Chord		C15x40	YES	NO	0.41	0.60
7	U1-L2	Diagonal		C12x25	YES	NO	0.58	0.85
7	L4-U5	Diagonal		C15x33.9	YES	NO	0.52	0.76
7	L6-U7	Diagonal		C15x33.9	YES	NO	0.37	0.70
7	L8-U9	Diagonal		C18x51.9	YES	NO	0.30	0.56
8	U9-L10	Diagonal		C15x33.9	YES	NO	0.53	0.78
8	U11-L12	Diagonal		C15x33.9	YES	NO	0.42	0.79
8	U13-L14	Diagonal		C12x30	YES	NO	0.44	0.83
8	U15-L16	Diagonal		C12x20.7	YES	NO	0.69	1.00

Figure 4.3 Members not passing IRM checks.

4.3 Summary of Results

Using the above prescribed methods, 53% of the NSTMs satisfied the requirements and were adequate in strength and fatigue to be recategorized as IRMs. Each member that did not pass failed due to the strength check, failing both the net section and gross section strength checks in the *faulted* state. (*Note there are no strength issues with these members in the unfaulted state.*) The specific members failing the strength criteria are summarized in Figure 4.3. The members specified in Figure 4.3 are for only half the truss length, as the bridge is symmetric about the center of the arch as stated.

For the truss members determined to be internally redundant, the maximum special inspection interval was calculated to be 10 years. Where section loss was noted in the 2020 load rating calculations, an equivalent area to the section loss was manually removed from the member's section area to verify if the loss of section had any impact on the results. No impact was found in the members exhibiting section loss. It is also worth noting that there were no areas of section loss that were severe enough to require a load posting and thus did not prohibit any members from IRM evaluation based on Section 1.4 of the IRM Guide Specifications.

The results of the evaluation can be found in table form in Appendix A as well as graphical form using the elevation view in Appendix B. The maximum loads and variable parameters needed for the evaluation of the truss members can be found in Appendix C. A specific breakdown of the of the proposed inspection frequency and descriptions can be found in Appendix G, which contains the proposed inspection plan for the bridge. The IRM analysis for the member controlling each member section variation (see Figure 2.4) can be found in Appendix F.

5. CONCLUSIONS

Presently (2023), the Wabash River Memorial Bridge is classified as having NSTMs; hence it is subjected to hands-on and arms-length field inspections every 2 years. During this evaluation process it was determined that several of the NSTMs possess internal redundancy and may be reclassified as IRMs using the procedures defined in the AASHTO IRM Guide Specification (AASHTO, 2018/2022b).

The loads applied on the bridge for the evaluation included the dead and HL-93 live loads using the Redundancy II load factors as specified in Table 1.7.1-1 of the IRM Guide Specification (AASHTO, 2018/2022b) and the fatigue truck live loads factored using Table 3.4.1-1 of the *AASHTO LRFD Bridge Design Specification* (AASHTO, 2020). The loads were applied to the truss members using a 2D MIDAS Civil model to determine the maximum loads in each member along the bridge. An NSBA spreadsheet (NSBA, 2020) was then utilized to determine the strength capacity of the faulted member, fatigue life of the member in both the unfaulted and faulted states, and maximum interval for special inspections.

Approximately 47% of the truss members did not pass the IRM evaluation. These failing members were due to not passing the strength checks, failing both the net section and gross section strength checks in the faulted state. The passing members obtained a maximum special inspection interval of 10 years. A specific breakdown of the proposed inspection frequency and descriptions can be found in Appendix G, which contains the proposed inspection plan for the bridge.

APPENDICES

Appendix 3A. Summary Table of Results

Appendix 3B. Graphical Summary of Results

Appendix 3C. Summary of Variable Loads and Parameters

Appendix 3D. Material Properties and Load Calculations

Appendix 3E. Historical Plan Sets—Original 1956 Construction (1952)

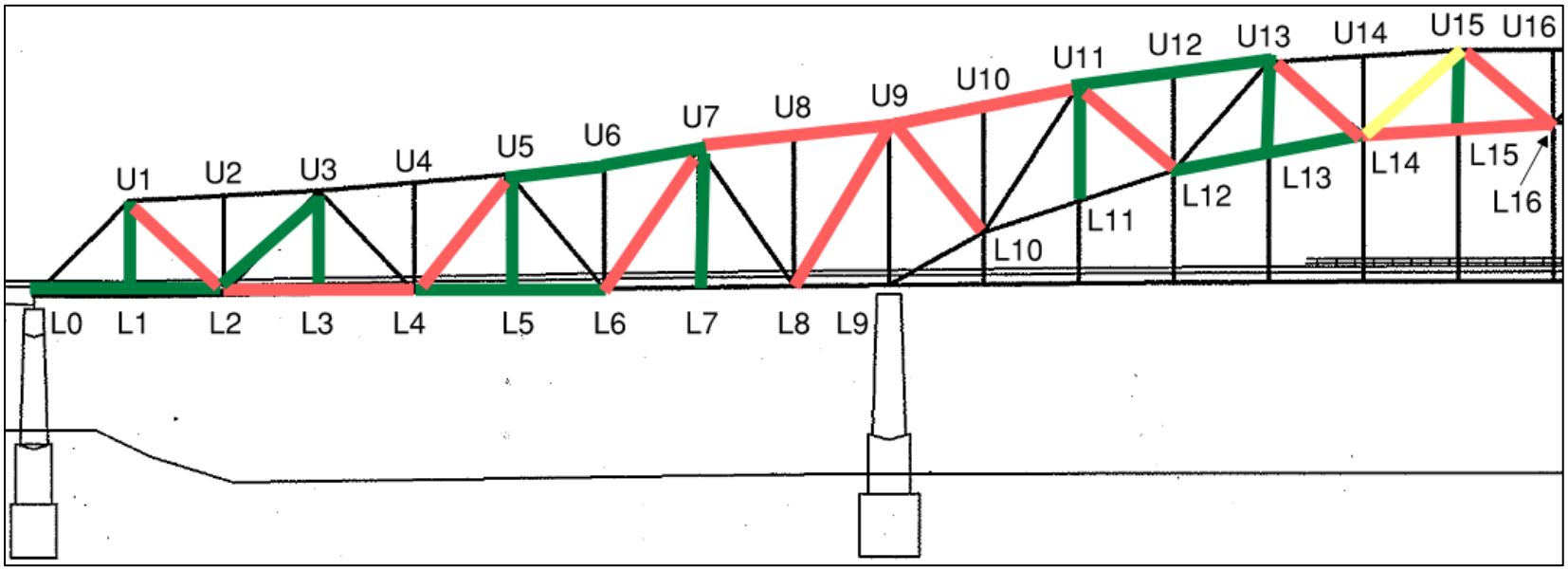
Appendix 3F. NSBA Spreadsheet Calculations for Controlling Members

Appendix 3G. NSTM/IRM Inspection Plan for Structure 062-65-T4020: Wabash River Memorial Bridge

Appendix 3A. Summary Table of Results

Span	Section	Section Variation	Screening Criteria Met	Strength Check	Fracture on Net, Strength Ratio	Yield on Gross, Strength Ratio	Fatigue Case	Effective Unfaulted Stress Range, Δf_{UFS}	Effective Faulted Stress Range, Δf_{FS}	Total Unfaulted Fatigue Life	Total Faulted Fatigue Life	Total Remaining Fatigue Life, N_f	Maximum Interval	Notes
#	Member ID	#	OK or NG	OK or NG	Less than 1 = NG	Less than 1 = NG	I(a), I(b), II	ksi	ksi	Years	Years	Years	Years	
7	L0-L1	Sect 14	OK	OK	1.19	1.34	I(b)	1.71	5.08	∞	129.7	129.7	10	
7	L1-L2	Sect 14	OK	OK	1.19	1.34	I(b)	1.71	5.08	∞	129.7	129.7	10	
7	L2-L3	Sect 12	OK	NG	0.75	0.82	-	-	-	-	-	-	-	
7	L3-L4	Sect 12	OK	NG	0.75	0.82	-	-	-	-	-	-	-	
7	L3'-L4'-South	Sect 12-SL	OK	NG	0.75	0.82	-	-	-	-	-	-	-	L3-L4 Assume 20% section loss for web plate thickness (.125" of .625" PL)
7	L4-L5	Sect 14	OK	OK	1.08	1.21	II	3.14	9.35	246.7	35.4	25.9	10	
7	L4'-L5'-South	Sect 14-SL	OK	OK	1.08	1.21	II	3.43	9.35	222.8	35.4	24.9	10	L4-L5 Apply 17% section loss to btm flange area, loss of 0.0625" of 0.375"
7	L5-L6	Sect 14	OK	OK	1.08	1.21	II	3.14	9.35	246.7	35.4	25.9	10	
7	U5-U6	Sect 15	OK	OK	2.61	2.94	I(b)	2.30	7.97	∞	52.3	52.3	10	
7	U6-U7	Sect 15	OK	OK	2.61	2.94	I(b)	2.30	7.97	∞	52.3	52.3	10	
7	U6'-U7'-North	Sect 15-SL	OK	OK	2.61	2.94	I(b)	2.36	7.97	∞	52.3	52.3	10	U6-U7 Assume 5% loss for btm flange area, Use 2.7885 in^2
7	U7-U8	Sect 11	OK	NG	0.74	0.81	-	-	-	-	-	-	-	
7	U8-U9	Sect 11	OK	NG	0.74	0.81	-	-	-	-	-	-	-	
8	U9-U10	Sect 13	OK	NG	0.68	0.98	-	-	-	-	-	-	-	
8	U10-U11	Sect 13	OK	NG	0.68	0.98	-	-	-	-	-	-	-	
8	U11-U12	Sect 15	OK	OK	2.05	2.31	I(b)	2.40	8.32	∞	46.1	46.1	10	
8	U12-U13	Sect 15	OK	OK	2.05	2.31	I(b)	2.40	8.32	∞	46.1	46.1	10	
7	U1-L1	Sect 10	OK	OK	5.61	4.00	I(b)	1.56	5.35	∞	118.7	118.7	10	Depth set manually to 17"-6" = 11" to account for loss of area for handholes
7	U3-L3	Sect 10	OK	OK	5.56	3.97	I(b)	1.56	5.35	∞	118.7	118.7	10	Depth set manually to 17"-6" = 11" to account for loss of area for handholes
7	U5-L5	Sect 10	OK	OK	5.59	3.99	I(b)	1.56	5.35	∞	118.7	118.7	10	Depth set manually to 17"-6" = 11" to account for loss of area for handholes
7	U7-L7	Sect 10	OK	OK	5.56	3.97	I(b)	1.56	5.35	∞	118.7	118.7	10	Depth set manually to 17"-6" = 11" to account for loss of area for handholes
8	U11-L11	Sect 9	OK	OK	5.28	3.76	I(b)	1.68	8.48	∞	44.0	44.0	10	Depth set manually to 17"-6" = 11" to account for loss of area for handholes
8	U13-L13	Sect 9	OK	OK	5.33	3.80	I(b)	1.68	8.49	∞	43.9	43.9	10	Depth set manually to 17"-6" = 11" to account for loss of area for handholes
8	U15-L15	Sect 10	OK	OK	5.33	3.80	I(b)	1.57	5.37	∞	115.6	115.6	10	Depth set manually to 17"-6" = 11" to account for loss of area for handholes
8	L12-L13	Sect 1	OK	OK	5.93	8.64	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Added to evaluation (LRFD 6.6.2.2), not considered for fatigue (LRFD 6.6.1.2)
8	L13-L14	Sect 1	OK	OK	5.93	8.64	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Added to evaluation (LRFD 6.6.2.2), not considered for fatigue (LRFD 6.6.1.2)
8	L14-L15	Sect 3	OK	NG	0.41	0.60	-	-	-	-	-	-	-	Added to evaluation per LRFD BDS 6.6.2.2
8	L15-L16	Sect 3	OK	NG	0.41	0.60	-	-	-	-	-	-	-	Added to evaluation per LRFD BDS 6.6.2.2
7	U1-L2	Sect 7	OK	NG	0.58	0.85	-	-	-	-	-	-	-	
7	L2-U3	Sect 7	OK	OK	3.68	5.35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not considered for fatigue (LRFD 6.6.1.2)
7	L2'-U3'-South	Sect 7-SL	OK	OK	3.68	5.35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	L2-U3 Use 12% section loss for one of the channels (.25" of 0.387"), See L2-U3
7	L4-U5	Sect 4	OK	NG	0.52	0.76	-	-	-	-	-	-	-	
7	L4-U5-South	Sect 4-SL	OK	NG	0.52	0.76	-	-	-	-	-	-	-	L4-U5 Use 7% section loss for C15x33.9
7	L6-U7	Sect 5	OK	NG	0.37	0.70	-	-	-	-	-	-	-	
7	L8-U9	Sect 2	OK	NG	0.30	0.56	-	-	-	-	-	-	-	
8	U9-L10	Sect 4	OK	NG	0.53	0.78	-	-	-	-	-	-	-	
8	U11-L12	Sect 5	OK	NG	0.42	0.79	-	-	-	-	-	-	-	
8	U13-L14	Sect 6	OK	NG	0.44	0.83	-	-	-	-	-	-	-	
8	U15-L16	Sect 8	OK	NG	0.69	1.00	-	-	-	-	-	-	-	

Appendix 3B. Graphical Summary of Results



= Eligible members that pass IRM requirement checks and can be reclassified as IRMs

= Eligible members that do not pass IRM required strength check and should remain NSTMs

= Member formerly classified as NSTM but is in net compression (Strength I) and should not be NSTM per AASHTO BDS 6.6.2.2

Appendix 3C. Summary of Variable Loads and Parameters

Span	Member	Member Type	P_{DC}	P_{DW}	P_{LL+IM}	P_{FAT+IM}	Steel yield strength, F_y	Steel tensile strength, F_u	Screening Criteria Met	Strength Check	Notes
#	Member ID	Type	k	k	k	k	ksi	ksi	OK or NG	OK or NG	
7	L0-L1	Lower Chord	235.47	22.45	165.05	58.03	33	60	OK	OK	
7	L1-L2	Lower Chord	235.47	22.45	165.05	58.03	33	60	OK	OK	
7	L2-L3	Lower Chord	384.98	37.84	312.18	113.48	33	60	OK	NG	
7	L3-L4	Lower Chord	384.98	37.84	312.18	113.48	33	60	OK	NG	
7	L3'-L4'-South	Lower Chord	384.98	37.84	312.18	113.48	33	60	OK	NG	L3-L4 Assume 20% section loss for web plate thickness (.125" of .625" PL)
7	L4-L5	Lower Chord	170.58	18.87	257.98	106.83	33	60	OK	OK	
7	L4'-L5'-South	Lower Chord	170.58	18.87	257.98	106.83	33	60	OK	OK	L4-L5 Apply 17% section loss to btm flange area, loss of 0.0625" of 0.375"
7	L5-L6	Lower Chord	170.58	18.87	257.98	106.83	33	60	OK	OK	
7	U5-U6	Upper Chord	30.44	-0.53	143.97	91.01	33	60	OK	OK	
7	U6-U7	Upper Chord	30.44	-0.53	143.97	91.01	33	60	OK	OK	
7	U6'-U7'-North	Upper Chord	30.44	-0.53	143.97	91.01	33	60	OK	OK	U6-U7 Assume 5% loss for btm flange area, Use 2.7885 in^2
7	U7-U8	Upper Chord	536.98	45.42	198.26	51.31	33	60	OK	NG	
7	U8-U9	Upper Chord	536.98	45.42	198.26	51.31	33	60	OK	NG	
8	U9-U10	Upper Chord	674.24	59.24	246.26	55.41	50	70	OK	NG	
8	U10-U11	Upper Chord	674.24	59.24	246.26	55.41	50	70	OK	NG	
8	U11-U12	Upper Chord	58.96	8.22	159.74	95.00	33	60	OK	OK	
8	U12-U13	Upper Chord	58.96	8.22	159.74	95.00	33	60	OK	OK	
7	U1-L1	Vertical	78.27	8.93	102.25	34.63	33	60	OK	OK	Depth set manually to 17"-6" = 11" to account for loss of area for handholes
7	U3-L3	Vertical	80.06	8.93	102.24	34.63	33	60	OK	OK	Depth set manually to 17"-6" = 11" to account for loss of area for handholes
7	U5-L5	Vertical	78.90	8.93	102.24	34.63	33	60	OK	OK	Depth set manually to 17"-6" = 11" to account for loss of area for handholes
7	U7-L7	Vertical	80.20	8.93	102.24	34.63	33	60	OK	OK	Depth set manually to 17"-6" = 11" to account for loss of area for handholes
8	U11-L11	Vertical	91.46	9.02	102.72	34.72	33	60	OK	OK	Depth set manually to 17"-6" = 11" to account for loss of area for handholes
8	U13-L13	Vertical	89.21	9.01	102.76	34.76	33	60	OK	OK	Depth set manually to 17"-6" = 11" to account for loss of area for handholes
8	U15-L15	Vertical	88.94	9.00	102.80	34.78	33	60	OK	OK	Depth set manually to 17"-6" = 11" to account for loss of area for handholes
8	L12-L13	Middle Chord	-152.39	-12.75	158.30	83.37	33	60	OK	OK	Added to evaluation (LRFD 6.6.2.2), not considered for fatigue (LRFD 6.6.1.2)
8	L13-L14	Middle Chord	-152.39	-12.75	158.31	83.37	33	60	OK	OK	Added to evaluation (LRFD 6.6.2.2), not considered for fatigue (LRFD 6.6.1.2)
8	L14-L15	Middle Chord	288.42	24.58	200.96	73.01	33	60	OK	NG	Added to evaluation per LRFD BDS 6.6.2.2
8	L15-L16	Middle Chord	288.43	24.58	200.96	73.01	33	60	OK	NG	Added to evaluation per LRFD BDS 6.6.2.2
7	U1-L2	Diagonal	175.58	17.25	166.18	63.62	33	60	OK	NG	
7	L2-U3	Diagonal	-35.61	-4.55	80.87	63.51	33	60	OK	OK	Not considered for fatigue (LRFD 6.6.1.2)
7	L2'-U3'-South	Diagonal	-35.61	-4.55	80.87	63.51	33	60	OK	OK	L2-U3 Use 12% section loss for one of the channels (.25" of 0.387")
7	L4-U5	Diagonal	229.60	20.32	155.89	66.57	33	60	OK	NG	
7	L4-U5-South	Diagonal	229.60	20.32	155.89	66.57	33	60	OK	NG	L4-U5 Use 7% section loss for C15x33.9
7	L6-U7	Diagonal	425.21	38.28	216.20	69.14	50	70	OK	NG	
7	L8-U9	Diagonal	560.16	49.45	251.80	70.26	50	70	OK	NG	
8	U9-L10	Diagonal	226.79	17.55	155.30	58.93	33	60	OK	NG	
8	U11-L12	Diagonal	385.81	31.98	190.59	61.94	50	70	OK	NG	
8	U13-L14	Diagonal	344.21	28.89	200.39	72.67	50	70	OK	NG	
8	U15-L16	Diagonal	117.68	9.84	167.05	81.49	33	60	OK	NG	

Appendix 3D. Material Properties and Load Calculations

MEMBERS FOR EVALUATION

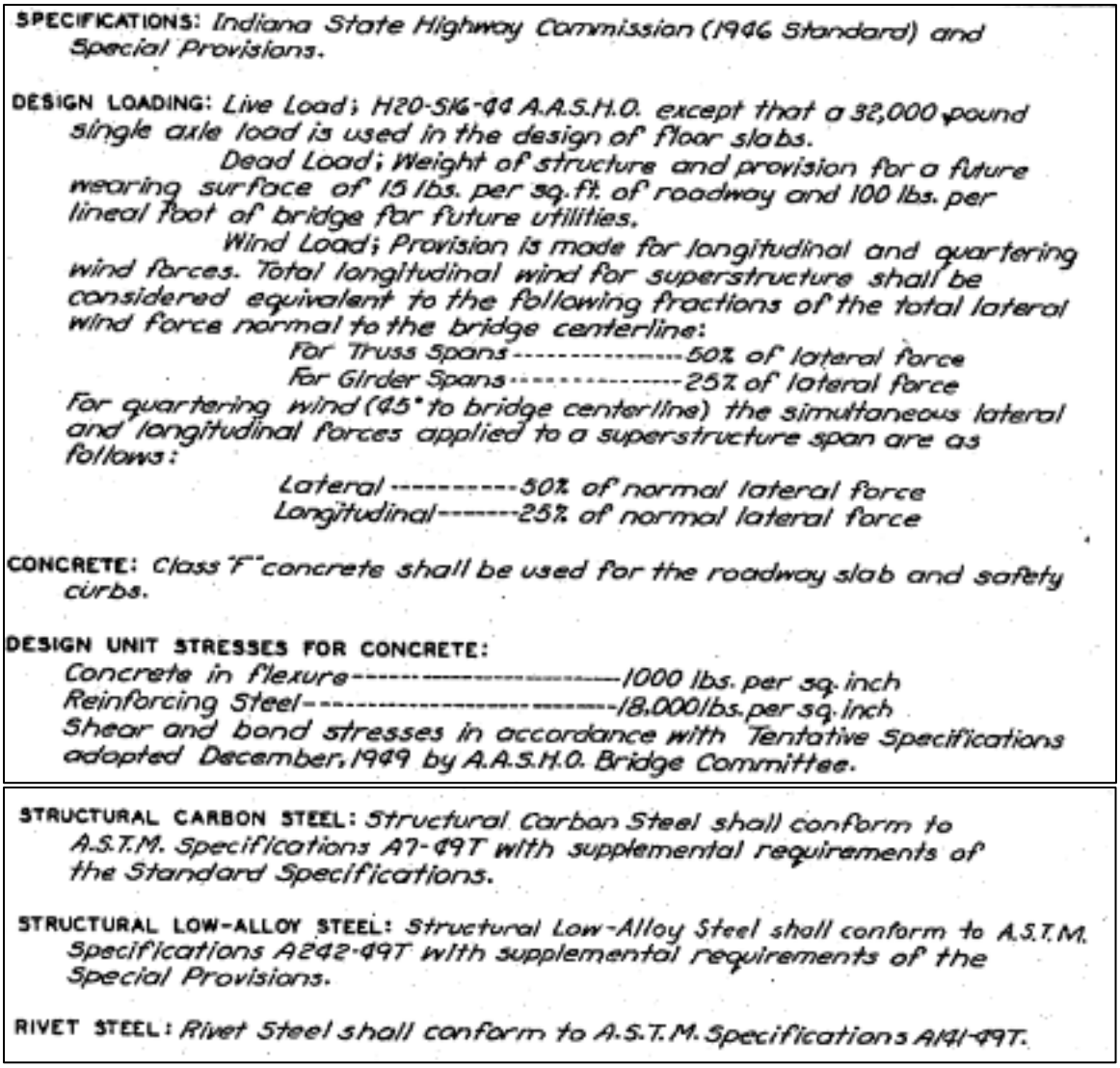
- Truss members (hangers and ties not included in evaluation) that are subject to net tensile stress under Strength Load Combination I (BDS 6.6.2.2). See table below.
- Approach spans (girders) are not fracture critical.
- Floor beams are spaced greater than 14 feet o.c., but are rolled WTs welded to web plates, so not eligible for evaluation as built-up members using mechanical fasteners.
- Truss members were considered for fatigue only where unfactored permanent loads produced compressive loads less than the maximum live load tensile stress from Fatigue I load combination (BDS 6.6.1.2). See table below.

Member ID	Location	P_{DC}	P_{DW}	$P_{DC} + P_{DW}$	HL93	Fatigue (Range)	Fatigue I (Tension)	Strength I DL	Strength I LL	Strength I - Comb	Tension Member?	Consider for Fatigue?
L0-L1	Bottom Chord	235.5	22.4	257.9	165.1	58.0	88.1	328.0	288.8	616.8	Tension	Yes
L1-L2	Bottom Chord	235.5	22.4	257.9	165.1	58.0	88.1	328.0	288.8	616.8	Tension	Yes
L2-L3	Bottom Chord	385.0	37.8	422.8	312.2	113.5	160.9	538.0	546.3	1084.3	Tension	Yes
L3-L4	Bottom Chord	385.0	37.8	422.8	312.2	113.5	160.9	538.0	546.3	1084.3	Tension	Yes
L4-L5	Bottom Chord	170.6	18.9	189.4	258.0	106.8	131.6	241.5	451.5	693.0	Tension	Yes
L5-L6	Bottom Chord	170.6	18.9	189.4	258.0	106.8	131.6	241.5	451.5	693.0	Tension	Yes
L6-L7	Bottom Chord	-270.6	-21.3	-291.9	96.8	71.2	58.7	-370.3	169.4	-200.9		
L7-L8	Bottom Chord	-270.6	-21.3	-291.9	96.8	71.2	58.7	-370.3	169.4	-200.9		
L8-L9	Bottom Chord	-808.9	-69.7	-878.6	2.5	43.6	1.9	-1115.6	4.4	-1111.2		
U1-U2	Top Chord	-359.8	-34.8	-394.6	60.9	94.7	26.0	-501.9	106.6	-395.4		
U2-U3	Top Chord	-359.8	-34.8	-394.6	60.9	94.7	26.0	-501.9	106.6	-395.4		
U3-U4	Top Chord	-314.7	-31.8	-346.6	110.6	114.7	47.3	-441.2	193.6	-247.6		
U4-U5	Top Chord	-314.7	-31.8	-346.6	110.6	114.7	47.3	-441.2	193.6	-247.6		
U5-U6	Top Chord	30.4	-0.5	29.9	144.0	91.0	61.6	37.2	251.9	289.2	Tension	Yes
U6-U7	Top Chord	30.4	-0.5	29.9	144.0	91.0	61.6	37.2	251.9	289.2	Tension	Yes
U7-U8	Top Chord	537.0	45.4	582.4	198.3	51.3	69.3	739.4	347.0	1086.3	Tension	Yes
U8-U9	Top Chord	537.0	45.4	582.4	198.3	51.3	69.3	739.4	347.0	1086.3	Tension	Yes
U9-U10	Top Chord	674.2	59.2	733.5	246.3	55.4	78.1	931.7	430.9	1362.6	Tension	Yes
U10-U11	Top Chord	674.2	59.2	733.5	246.3	55.4	78.1	931.7	430.9	1362.6	Tension	Yes
U11-U12	Top Chord	59.0	8.2	67.2	159.7	95.0	67.4	86.0	279.6	365.6	Tension	Yes
U12-U13	Top Chord	59.0	8.2	67.2	159.7	95.0	67.4	86.0	279.6	365.6	Tension	Yes
U13-U14	Top Chord	-529.1	-41.3	-570.4	112.8	126.2	48.6	-723.3	197.4	-525.9		
U14-U15	Top Chord	-529.1	-41.3	-570.4	112.8	126.2	48.6	-723.3	197.4	-525.9		
U15-U16	Top Chord	-785.9	-63.1	-849.0	85.5	130.1	24.8	-1077.1	149.6	-927.5		
U1-L1	Vertical	78.3	8.9	87.2	102.2	34.6	60.6	111.2	178.9	290.2	Tension	Yes
U2-L2	Vertical	-11.4	0.0	-11.4	0.0	0.0	0.0	-14.3	0.0	-14.3		
U3-L3	Vertical	80.1	8.9	89.0	102.2	34.6	60.6	113.5	178.9	292.4	Tension	Yes
U4-L4	Vertical	-11.5	0.0	-11.5	0.0	0.0	0.0	-14.4	0.0	-14.4		
U5-L5	Vertical	78.9	8.9	87.8	102.2	34.6	60.6	112.0	178.9	290.9	Tension	Yes
U6-L6	Vertical	-12.9	0.0	-12.9	0.0	0.0	0.0	-16.1	0.0	-16.1		
U7-L7	Vertical	80.2	8.9	89.1	102.2	34.6	60.6	113.6	178.9	292.6	Tension	Yes
U8-L8	Vertical	-14.4	0.0	-14.4	0.0	0.0	0.0	-18.0	0.0	-18.0		
U9-L9	Vertical	-638.0	-52.1	-690.1	25.0	60.5	12.6	-875.6	43.7	-831.9		
U10-L10	Vertical	-14.1	0.0	-14.1	0.0	0.0	0.0	-17.6	0.0	-17.6		
U11-L11	Vertical	91.5	9.0	100.5	102.7	34.7	60.7	127.9	179.8	307.6	Tension	Yes
U12-L12	Vertical	-12.8	0.0	-12.8	0.0	0.0	0.0	-16.0	0.0	-16.0		
U13-L13	Vertical	89.2	9.0	98.2	102.8	34.8	60.8	125.0	179.8	304.9	Tension	Yes
U14-L14	Vertical	-14.2	0.0	-14.2	0.0	0.0	0.0	-17.8	0.0	-17.8		
U15-L15	Vertical	88.9	9.0	97.9	102.8	34.8	60.8	124.7	179.9	304.6	Tension	Yes
U16-L16	Vertical	-14.2	0.0	-14.2	0.0	0.0	0.0	-17.7	0.0	-17.7		
L9-L10	Middle Chord	-1385.7	-114.9	-1500.6	63.7	110.8	29.4	-1904.5	111.5	-1793.0		
L10-L11	Middle Chord	-786.4	-65.9	-852.3	87.3	88.0	31.8	-1081.8	152.8	-929.0		
L11-L12	Middle Chord	-786.4	-65.9	-852.3	87.3	88.0	31.8	-1081.9	152.8	-929.1		
L12-L13	Middle Chord	-152.4	-12.7	-165.1	158.3	83.4	76.8	-209.6	277.0	67.4	Tension	No
L13-L14	Middle Chord	-152.4	-12.8	-165.1	158.3	83.4	76.8	-209.6	277.0	67.4	Tension	No
L14-L15	Middle Chord	288.4	24.6	313.0	201.0	73.0	106.4	397.4	351.7	749.1	Tension	Yes
L15-L16	Middle Chord	288.4	24.6	313.0	201.0	73.0	106.4	397.4	351.7	749.1	Tension	Yes

L0-U1	Diagonal	-333.0	-32.0	-365.1	44.9	82.8	19.2	-464.4	78.6	-385.8		
U1-L2	Diagonal	175.6	17.3	192.8	166.2	63.6	93.7	245.3	290.8	536.2	Tension	Yes
L2-U3	Diagonal	-35.6	-4.5	-40.2	80.9	63.5	39.0	-51.3	141.5	90.2	Tension	No
U3-L4	Diagonal	-101.3	-8.9	-110.3	68.5	61.8	43.3	-140.1	119.9	-20.1		
L4-U5	Diagonal	229.6	20.3	249.9	155.9	66.6	87.3	317.5	272.8	590.3	Tension	Yes
U5-L6	Diagonal	-310.2	-28.6	-338.9	18.5	64.3	12.9	-430.8	32.4	-398.3		
L6-U7	Diagonal	425.2	38.3	463.5	216.2	69.1	114.5	588.9	378.3	967.3	Tension	Yes
U7-L8	Diagonal	-446.2	-40.9	-487.1	1.8	65.0	1.2	-619.1	3.1	-616.0		
L8-U9	Diagonal	560.2	49.5	609.6	251.8	70.3	122.8	774.4	440.6	1215.0	Tension	Yes
U9-L10	Diagonal	226.8	17.6	244.3	155.3	58.9	88.6	309.8	271.8	581.6	Tension	Yes
L10-U11	Diagonal	-575.0	-47.9	-622.9	4.8	75.8	3.0	-790.6	8.5	-782.1		
U11-L12	Diagonal	385.8	32.0	417.8	190.6	61.9	103.9	530.2	333.5	863.8	Tension	Yes
L12-U13	Diagonal	-471.7	-40.0	-511.6	37.8	80.4	21.7	-649.5	66.2	-583.4		
U13-L14	Diagonal	344.2	28.9	373.1	200.4	72.7	105.8	473.6	350.7	824.3	Tension	Yes
L14-U15	Diagonal	-218.3	-18.7	-237.0	99.6	83.9	54.0	-300.9	174.2	-126.7		
U15-L16	Diagonal	117.7	9.8	127.5	167.0	81.5	87.8	161.9	292.3	454.2	Tension	Yes

MATERIAL PROPERTIES

From 1952 Original Construction Plans:



SPECIFICATIONS: Indiana State Highway Commission (1946 Standard) and Special Provisions.

DESIGN LOADING: Live Load; H20-S16-44 A.A.S.H.O. except that a 32,000 pound single axle load is used in the design of floor slabs.

Dead Load; Weight of structure and provision for a future wearing surface of 15 lbs. per sq. ft. of roadway and 100 lbs. per lineal foot of bridge for future utilities.

Wind Load; Provision is made for longitudinal and quartering wind forces. Total longitudinal wind for superstructure shall be considered equivalent to the following fractions of the total lateral wind force normal to the bridge centerline:

For Truss Spans ---------- 50% of lateral force
For Girder Spans ---------- 25% of lateral force

For quartering wind (45° to bridge centerline) the simultaneous lateral and longitudinal forces applied to a superstructure span are as follows:

Lateral ---------- 50% of normal lateral force
Longitudinal ------- 25% of normal lateral force

CONCRETE: Class "F" concrete shall be used for the roadway slab and safety curbs.

DESIGN UNIT STRESSES FOR CONCRETE:

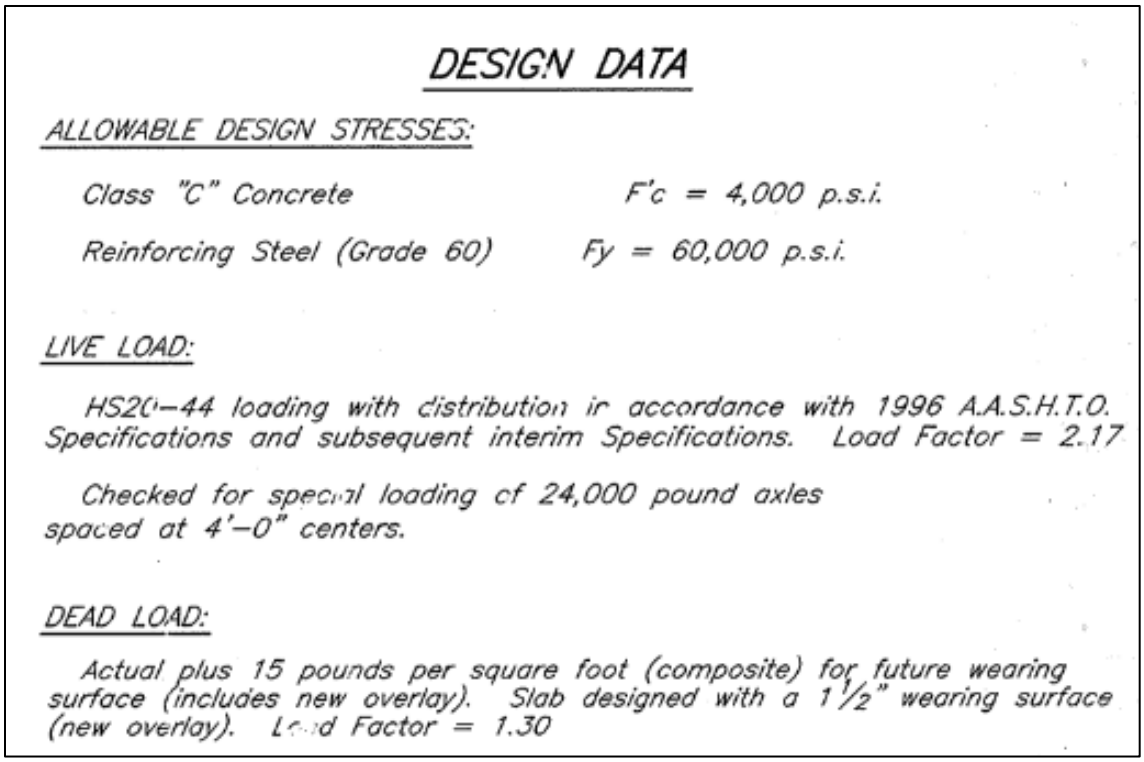
Concrete in flexure ---------- 1000 lbs. per sq. inch
Reinforcing Steel ---------- 18,000 lbs. per sq. inch
Shear and bond stresses in accordance with Tentative Specifications adopted December, 1949 by A.A.S.H.O. Bridge Committee.

STRUCTURAL CARBON STEEL: Structural Carbon Steel shall conform to A.S.T.M. Specifications A7-49T with supplemental requirements of the Standard Specifications.

STRUCTURAL LOW-ALLOY STEEL: Structural Low-Alloy Steel shall conform to A.S.T.M. Specifications A242-49T with supplemental requirements of the Special Provisions.

RIVET STEEL: Rivet Steel shall conform to A.S.T.M. Specifications A141-49T.

From 2004 Rehabilitation Plans:



DESIGN DATA

ALLOWABLE DESIGN STRESSES:

Class "C" Concrete F'c = 4,000 p.s.i.

Reinforcing Steel (Grade 60) Fy = 60,000 p.s.i.

LIVE LOAD:

HS20-44 loading with distribution in accordance with 1996 A.A.S.H.T.O. Specifications and subsequent interim Specifications. Load Factor = 2.17

Checked for special loading of 24,000 pound axles spaced at 4'-0" centers.

DEAD LOAD:

Actual plus 15 pounds per square foot (composite) for future wearing surface (includes new overlay). Slab designed with a 1 1/2" wearing surface (new overlay). Load Factor = 1.30

Concrete:

f'_c = 4 ksi (Class "C" Concrete)
w_{c_reinf} = 0.125 kcf (with reinforcing)
w_c = 0.120 kcf (without reinforcing)
K_1 = 1.0

$E_c = 120{,}000\, K_1\, w_c^{2.0}\, f'^{0.33}_c = 2{,}730.4$ ksi [AASHTO LRFD BDS Eq 5.4.2.4-1]

Steel:

Carbon-Steel (A7-49T)
F_y = 33 ksi
F_u = 66 ksi

Low-Allow Steel (A242-49T)
F_y = 50 ksi
F_u = 70 ksi

TRAFFIC DATA
Two lanes total, one lane in each direction (55% directional factor)

Original Data *(1988 INDOT data used as it was the oldest data available, assume 14% truck)*

ADT_o	= 2600	vehicles per day (INDOT Database)
$truck_{per}$	= 14%	fraction of trucks in traffic
Directional adj	= 55%	AASHTO LRFD BDS C3.6.1.4.2
$p_{,\ 1\ lane}$	= 1.0	AASHTO LRFD BDS Tb 3.6.1.4.2-1
ADTT	= ADT_o x $truck_{per}$	
	= 364	
$ADTT_{SL_o}$	= p x ADTT x direction adj	AASHTO LRFD BDS 3.6.1.4.2-1
	= 200.2	orig avg daily truck traffic single lane

Present Data (2021 Data)

ADT	= 4233	From INDOT Database
% trucks	= 14%	From INDOT Database
Directional adj	= 55%	AASHTO LRFD BDS C3.6.1.4.2
$p_{,\ 1\ lane}$	= 1.0	AASHTO LRFD BDS Tb 3.6.1.4.2-1
ADTT	= ADT_o x $truck_{per}$	
	= 592.62	
$ADTT_{SL_o}$	= p x ADTT x direction adj	AASHTO LRFD BDS 3.6.1.4.2-1
	= 325.9	orig avg daily truck traffic single lane

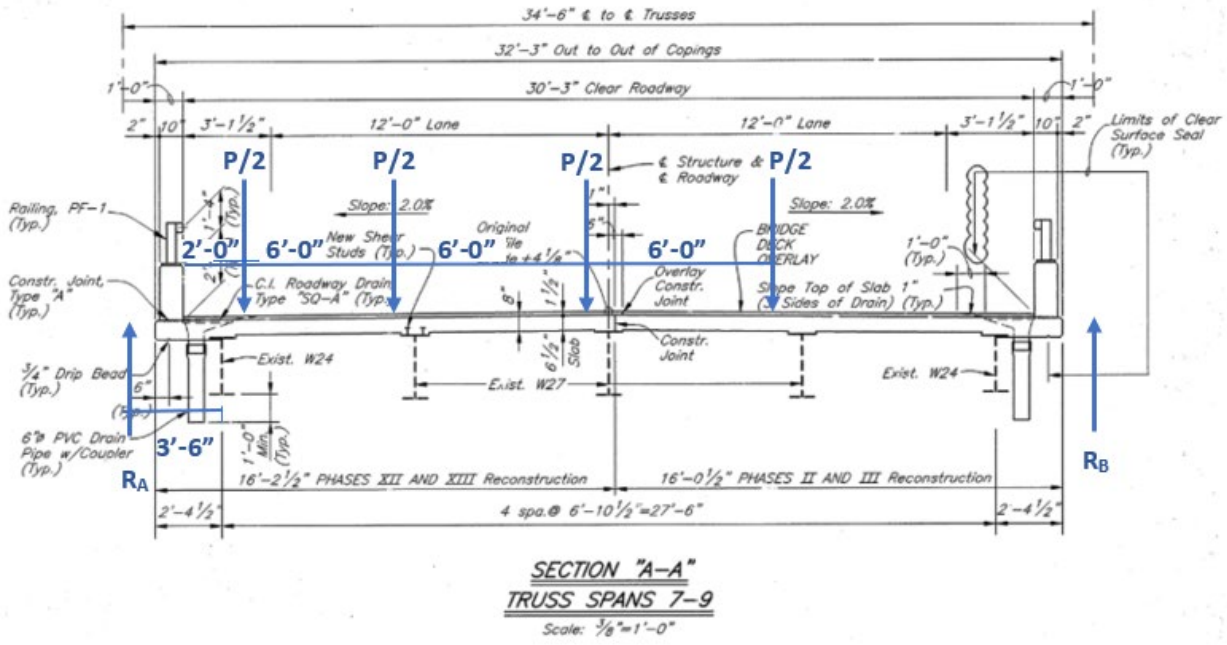
Per AASHTO LRFD BDS C3.6.1.4.22, limit of 20,000 vehicles per lane per day under normal conditions. Thus,

Max ADTT limit in a single lane = 20,000 veh/day/lane x 14% = 2,800 veh/day

Additional Parameters

g	= 1.0%	Estimated expected annual growth rate per INDOT Traffic Adjustment Factors (https://www.in.gov/indot/files/INDOT_Factors_2021_revised-20220603.pdf)
n_L	= 1	number of striped lanes
R_S	= 1.0	MBE Tb 7.2.2.1-1, using simplified, LRFD Design
R_R	= 1.0	MBE Tb 7.2.5.1-1, detail category D and Minimum Life
n	= 1.0	AASHTO LRFD Tb 6.6.1.2.5.2, using Trusses

LIVE LOAD CALCULATIONS

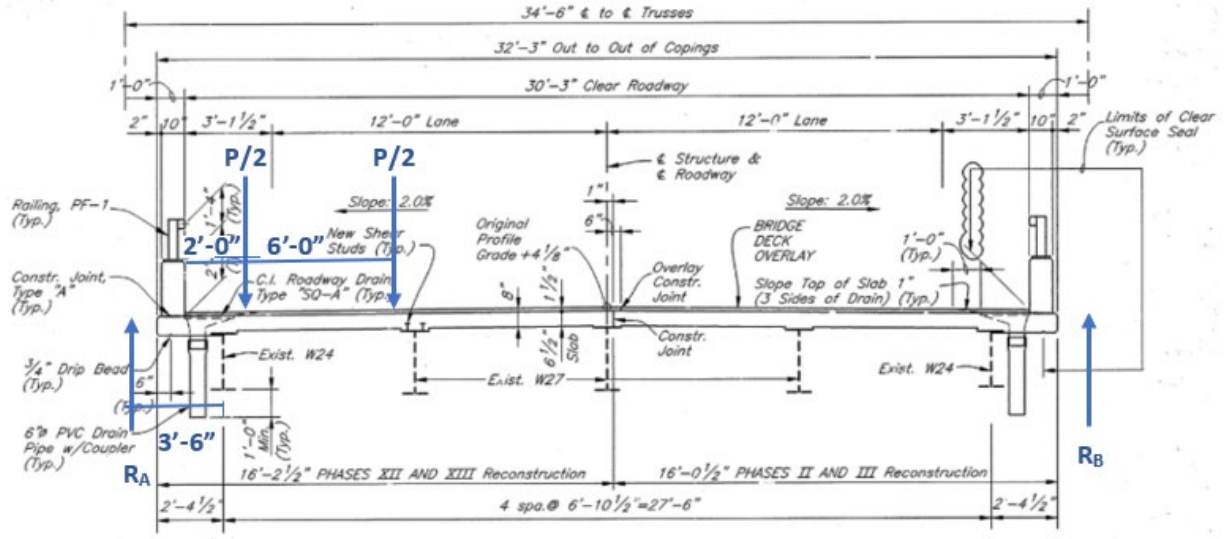


SECTION "A–A"
TRUSS SPANS 7–9
Scale: 3/8"=1'-0"

$\Sigma M_{@B} = 0 = (12.375')(P/2) + (18.375')(P/2) + (24.375')(P/2) + (30.375')(P/2) - (34.5')R_A$

$\rightarrow R_A = 1.239$, where m = 1.0

$DF_{\text{two lane}}$ = 1.239



SECTION "A–A"
TRUSS SPANS 7–9
Scale: 3/8"=1'-0"

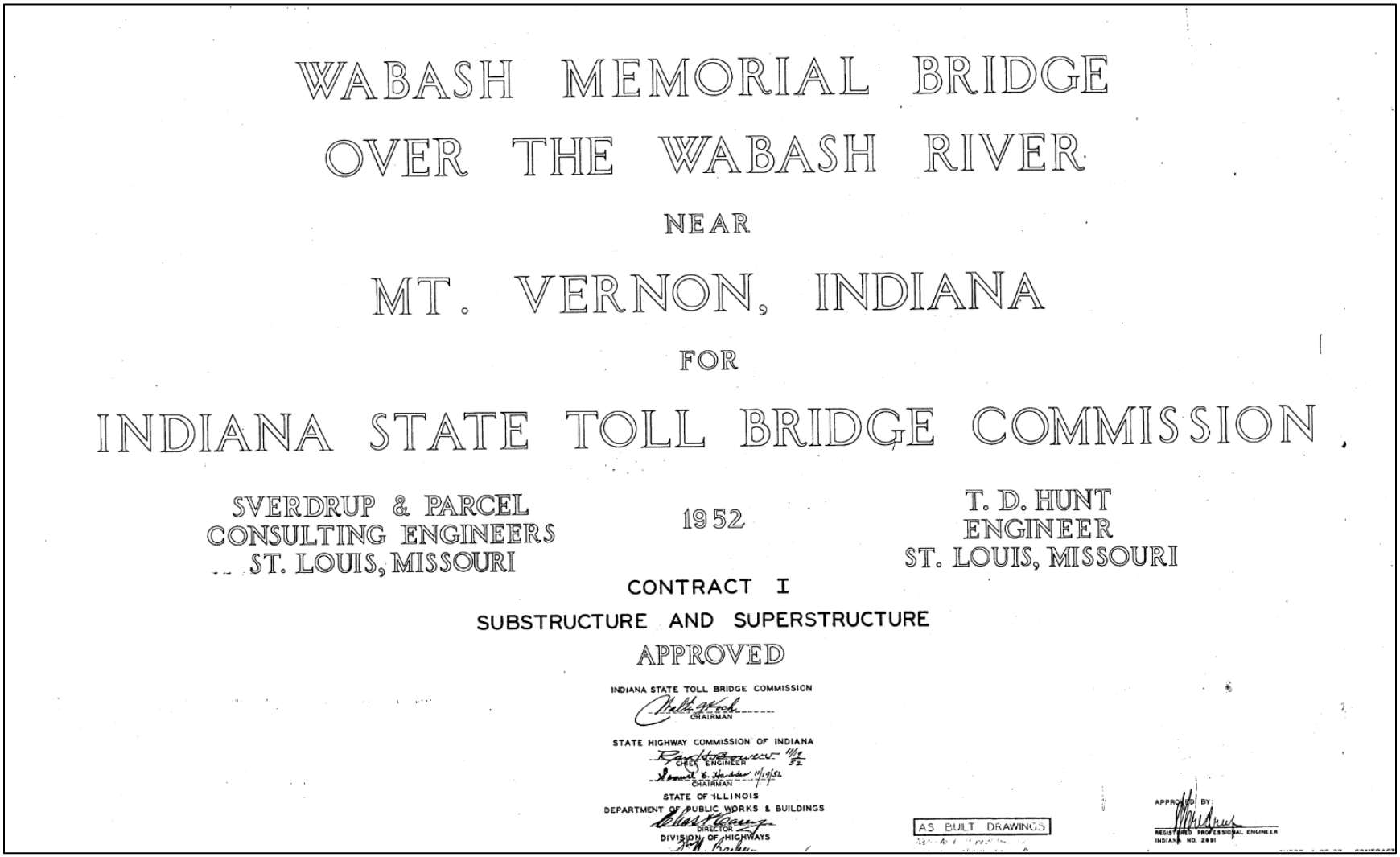
$\Sigma M_{@B} = 0 = (24.375')(P/2) + (30.375')(P/2) - (34.5')R_A$

$\rightarrow R_A = 0.793$, where m = 1.0

$DF_{\text{one lane}}$ = 0.793

Note: m = 1.0 for fatigue limit state per LRFD BDS 3.6.1.1.2

Appendix 3E. Historical Plan Sets—Original 1956 Construction (1952)



WABASH MEMORIAL BRIDGE
OVER THE WABASH RIVER
NEAR
MT. VERNON, INDIANA
FOR
INDIANA STATE TOLL BRIDGE COMMISSION

SVERDRUP & PARCEL
CONSULTING ENGINEERS
ST. LOUIS, MISSOURI

1952

T. D. HUNT
ENGINEER
ST. LOUIS, MISSOURI

CONTRACT I
SUBSTRUCTURE AND SUPERSTRUCTURE
APPROVED

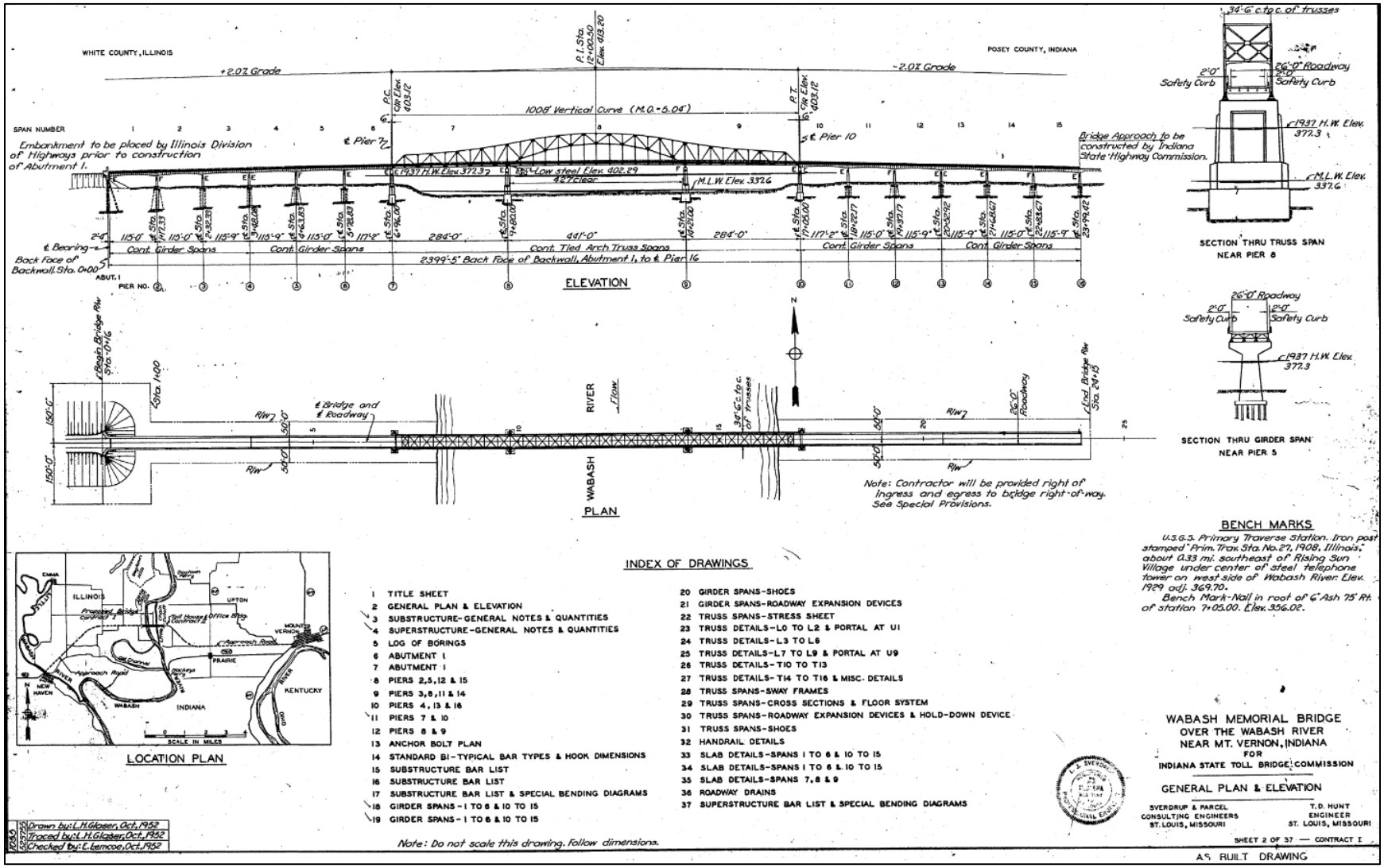
INDIANA STATE TOLL BRIDGE COMMISSION
CHAIRMAN

STATE HIGHWAY COMMISSION OF INDIANA
CHIEF ENGINEER 11/4/52
CHAIRMAN 11/19/52

STATE OF ILLINOIS
DEPARTMENT OF PUBLIC WORKS & BUILDINGS
DIRECTOR
DIVISION OF HIGHWAYS

AS BUILT DRAWINGS

APPROVED BY:
REGISTERED PROFESSIONAL ENGINEER
INDIANA NO. 2881



INDEX OF DRAWINGS

1 TITLE SHEET
2 GENERAL PLAN & ELEVATION
3 SUBSTRUCTURE-GENERAL NOTES & QUANTITIES
4 SUPERSTRUCTURE-GENERAL NOTES & QUANTITIES
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6 ABUTMENT 1
7 ABUTMENT 1
8 PIERS 2,5,12 & 15
9 PIERS 3,8,11 & 14
10 PIERS 4, 13 & 16
11 PIERS 7 & 10
12 PIERS 8 & 9
13 ANCHOR BOLT PLAN
14 STANDARD BI-TYPICAL BAR TYPES & HOOK DIMENSIONS
15 SUBSTRUCTURE BAR LIST
16 SUBSTRUCTURE BAR LIST
17 SUBSTRUCTURE BAR LIST & SPECIAL BENDING DIAGRAMS
18 GIRDER SPANS-1 TO 6 & 10 TO 15
19 GIRDER SPANS-1 TO 6 & 10 TO 15
20 GIRDER SPANS-SHOES
21 GIRDER SPANS-ROADWAY EXPANSION DEVICES
22 TRUSS SPANS-STRESS SHEET
23 TRUSS DETAILS-L0 TO L2 & PORTAL AT U1
24 TRUSS DETAILS-L3 TO L6
25 TRUSS DETAILS-L7 TO L9 & PORTAL AT U9
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27 TRUSS DETAILS-T14 TO T16 & MISC. DETAILS
28 TRUSS SPANS-SWAY FRAMES
29 TRUSS SPANS-CROSS SECTIONS & FLOOR SYSTEM
30 TRUSS SPANS-ROADWAY EXPANSION DEVICES & HOLD-DOWN DEVICE
31 TRUSS SPANS-SHOES
32 HANDRAIL DETAILS
33 SLAB DETAILS-SPANS 1 TO 6 & 10 TO 15
34 SLAB DETAILS-SPANS 1 TO 6 & 10 TO 15
35 SLAB DETAILS-SPANS 7, 8 & 9
36 ROADWAY DRAINS
37 SUPERSTRUCTURE BAR LIST & SPECIAL BENDING DIAGRAMS

BENCH MARKS

U.S.G.S. Primary Traverse Station. Iron post stamped "Prim. Trav. Sta. No. 27, 1908, Illinois," about 0.33 mi. southeast of Rising Sun Village under center of steel telephone tower on west side of Wabash River. Elev. 1929 adj. 369.70.

Bench Mark-Nail in root of 6" Ash 75' Rt. of station 7+05.00. Elev. 356.02.

Note: Do not scale this drawing. Follow dimensions.

Drawn by: L.H. Glaser, Oct., 1952
Traced by: L.H. Glaser, Oct., 1952
Checked by: C. Lemcoe, Oct., 1952

WABASH MEMORIAL BRIDGE
OVER THE WABASH RIVER
NEAR MT. VERNON, INDIANA
FOR
INDIANA STATE TOLL BRIDGE COMMISSION

GENERAL PLAN & ELEVATION

SVERDRUP & PARCEL CONSULTING ENGINEERS ST. LOUIS, MISSOURI

T.D. HUNT ENGINEER ST. LOUIS, MISSOURI

SHEET 2 OF 37 — CONTRACT I

AS BUILT DRAWING

SUPERSTRUCTURE GENERAL NOTES

SPECIFICATIONS: Indiana State Highway Commission (1946 Standard) and Special Provisions.

DESIGN LOADING: Live Load; H20-S16-44 A.A.S.H.O. except that a 32,000 pound single axle load is used in the design of floor slabs.
Dead Load; Weight of structure and provision for a future wearing surface of 15 lbs. per sq. ft. of roadway and 100 lbs. per lineal foot of bridge for future utilities.
Wind Load; Provision is made for longitudinal and quartering wind forces. Total longitudinal wind for superstructure shall be considered equivalent to the following fractions of the total lateral wind force normal to the bridge centerline:
For Truss Spans ---------- 50% of lateral force
For Girder Spans ---------- 25% of lateral force
For quartering wind (45° to bridge centerline) the simultaneous lateral and longitudinal forces applied to a superstructure span are as follows:
Lateral ---------- 50% of normal lateral force
Longitudinal -------- 25% of normal lateral force

CONCRETE: Class "F" concrete shall be used for the roadway slab and safety curbs.

DESIGN UNIT STRESSES FOR CONCRETE:
Concrete in Flexure ---------- 1000 lbs. per sq. inch
Reinforcing Steel ---------- 18,000 lbs. per sq. inch
Shear and bond stresses in accordance with Tentative Specifications adopted December, 1949 by A.A.S.H.O. Bridge Committee.

REINFORCEMENT: Surface deformations for all reinforcing steel shall conform to A.S.T.M. Specifications A305-49. All dimensions to reinforcing steel on detail drawings are to centerline of bar, except where the clear distance is noted from the face of concrete. All reinforcing steel shall be lapped a minimum of 30 bar diameters, unless otherwise shown or noted.

BEVELED EDGES: All exposed edges of concrete on slabs and safety curbs shall be beveled ¾ inch unless otherwise shown or noted.

CONSTRUCTION JOINTS: Construction joints shall be made only at locations shown on the plans. Provide substantial keys at all construction joints.

EXPANSION JOINT MATERIAL: The cost of copper flashing, preformed bituminous joint filler and asphaltic filler shall be included in the unit price bid for "Class F Concrete".

ROADWAY WEARING SURFACE: The roadway slab includes ½ monolithic wearing surface.

STRUCTURAL CARBON STEEL: Structural Carbon Steel shall conform to A.S.T.M. Specifications A7-49T with supplemental requirements of the Standard Specifications.

STRUCTURAL LOW-ALLOY STEEL: Structural Low-Alloy Steel shall conform to A.S.T.M. Specifications A242-49T with supplemental requirements of the Special Provisions.

RIVET STEEL: Rivet Steel shall conform to A.S.T.M. Specifications A141-49T.

FABRICATION: Fabrication shall be in accordance with the requirements of the Standard Specifications for Structural Steel for Structures except as noted in the Special Provisions.

ERECTION: For notes on erection of truss spans, see Sheet 22.

WELDING: All welding shall be in accordance with the current "Specifications for Welded Highway and Railway Bridges" of the American Welding Society.

PAINT: All structural steel shall be given one shop coat of red lead, one field coat of brown tinted red lead, and two field coats of aluminum paint. See Special Provisions.

SHOES: All finished surfaces shall be coated with white lead and tallow before leaving the shop.
Lead Plates shall be commercial Grade Sheet Lead.
All pilot and driving nuts shall be furnished by the contractor at his own expense.

TABLE OF ESTIMATED QUANTITIES

Item	Structural Steel Lbs.	Structural Low-Alloy Steel Lbs.	Pipe Handrail Lin. Ft.	Class "F" Concrete Cu. Yds.	Steel Reinforcement Lbs.	Cast Iron Roadway Drains Lbs.	8" W.I. Downspouts Lin. Ft.
Girder Spans 1 to 6 & 10 to 15	1,803,000	———	2780	1245	290,560	2368	92
Truss Spans 7, 8, & 9	2,445,000	681,000	2016	823	182,450	1776	54
Total	4,248,000	681,000	4796	2068	473,010	4144	146

Note: The weight of "Structural Steel" shown includes all Structural Carbon Steel, Cast Steel, Forged Steel, and Lead Plates, which are not specifically included in other payment items. See Special Provisions.

Drawn by: E. Lemcoe, Oct., 1952
Traced by: L.H. Glosen, Nov., 1952
Checked by: A.E. Fisher, Nov., 1952

L. L. SVERDRUP — REGISTERED — INDIANA — PROFESSIONAL ENGINEER

WABASH MEMORIAL BRIDGE
OVER THE WABASH RIVER
NEAR MT. VERNON, INDIANA
FOR
INDIANA STATE TOLL BRIDGE COMMISSION

SUPERSTRUCTURE-GENERAL NOTES & QUANTITIE

SVERDRUP & PARCEL
CONSULTING ENGINEERS
ST. LOUIS, MISSOURI

T. D. HUNT
ENGINEER
ST. LOUIS, MISSOUR

SHEET 4 OF 37 - CONTRACT I

TABLE OF TRUSS MEMBERS AND STRESSES

Member	D.L.	L.L.	I.	Wind on Structure T or C 30#	Wind on Struct. & L.L. T or C 30#	D+I+I.	D.L.+ 30# W.	D.L.+L.L. +I+30# W.	D.L.+ 50# W.	Area in sq.in. Furnished. Eff. Gr.	Net	%	Material
L0-L1	2477	687	117	79	132	113	3656T	3964T	4397T	3798T	30.86	25.33	—	4@ 8"x6"x⅝", 1 Pl. 20"x⅝", 2 Cov. Pls. 20"x⅝"
L1-L3	4067	1127	192	114	148	176	5807T	6257T	7067T	6057T	49.66	38.42	—	4@ 8"x6"x⅝", 2 Pls. 20"x⅝", 2 Cov. Pls. 16"x⅝"
L3-L6	1777	492	161	118	159	172	3631T	3951T	4351T	3732T	32.85	25.36	69	4@ 8"x6"x⅝", 2 Pls. 20"x⅝", 2 Cov. Pls. 16"x⅝"
L3-L6							(947)	897	986	820				
L6-L8	2270C	900C	111C	125	203	183	3910C	4117C	5135C	4945C	37.82	—	69	4@ 8"x8"x⅞", 2 Pls. 20"x⅞", 2 Cov. Pls. 16"x⅝"
L8-L9	2536C	1262C	1263	275	252	1002C	1081C	1312C	1731C	58.16	—	50	A.S.	4@ 6"x4"x⅝", 2 Pls. 20"x⅝", 2 Cov. Pls. 16"x⅝"
L9-U10	1468C	326C	296C	—	—	—	1823C	—	—	—	50.16	—	53	A.S. Varies 4@ 6"x4"x⅝", 2 Pls. 14"x⅝", 2 Cov. Pls. 16"x⅝"
U10-U8	841C	223C	200C	—	—	—	1064C	—	—	—	53.16	—	72	A.S. 4@ 6"x4"x⅝", 2 Pls. 20"x⅝", 2 Cov. Pls. 16"x⅝"
U8-U6	1135C	113C	101C	—	—	—	1248C	—	—	—	33.83	—	333	4-18"@ 55.8#, 2 Cov. Pls. 17"x⅝"
L9-L6	2907	947	87	—	—	—	3987T	—	—	—	30.83	24.43	—	2-15"@ 42.9#, 2 Cov. Pls. 17"x⅝"
L6-U7	3496C	1235C	190	13	65	23	4891C	5636C	7178C	5796C	60.63	—	67	4@ 8"x6"x⅞", 2 Pls. 20"x⅞", 2 Cov. Pls. 16"x⅝"
U7-U8	3178C	1182C	166C	63	65	23	4396C	5037C	6521C	5190C	60.63	—	60.6	do
U8-U6	3290C	1232C	190C	50	90	50	4576C	5236C	6776C	5396C	60.63	—	60.6	do
U6-U7	357	807	107	79	132	79	* 1634T	1747	2067	1697	60.63	36.13	50.5	do
	(607)	907	117	—	—	—	* 1136	686	1086	916				
U7-U9	5687	1277	157	109	189	109	7110T	6277	8197	7607	2993	39.63	—	4@ 6"x6"x⅝", 2 Pls. 20"x⅝", 2 Cov. Pls. 16"x⅝"
U9-U11	7197	1667	157	88	149	88	8997	8067	9857	8617	66.61	45.93	—	A.S. 4@ 6"x6"x⅝", 2 Pls. 20"x⅝", 2 Cov. Pls. 16"x⅝"
U11-U13	307	987	87	69	115	69	* 1767	1397	2407	1857	60.63	39.13	51	4@ 6"x6"x⅝", 2 Pls. 20"x⅝", 2 Cov. Pls. 16"x⅝"
	(997)	807	76	—	—	—	* 576	17	966	496				
U13-U15	3466	1236	190	116	189	116	7336C	6586	8086	7336	62.69	—	51	4@ 8"x6"x⅝", 2 Pls. 20"x⅝", 2 Cov. Pls. 16"x⅝"
U15-U16	2126	1256	206	180	200	180	10466	9386	11826	10186	62.69	—	51	A.S. do
U1-L2	1257	897	117	—	—	—	1957	—	—	—	31.97	16.72	—	2-12"@ 25#, 2 Cov. Pls. 17"x⅝"
L2-U3	396	636	86	—	—	—	* 1236	—	—	—	21.71	16.72	109	do
	(610)	887	97	—	—	—	* 326	—	—	—				do
U3-L4	1116	636	86	—	—	—	1856	—	—	—	21.71	—	109	do
L4-U5	2387	837	107	—	—	—	3317	—	—	—	26.93	21.33	—	
U5-L6	3336	956	186	—	—	—	4816	—	—	—	30.83	—	98.5	A.S. 2-15"@ 33.9#, 2 Cov. Pls. 17"x⅝"
L6-U7	4687	1176	167	—	—	—	6397	—	—	—	30.83	21.33	—	A.S. 2-15"@ 42.9#, 2 Cov. Pls. 17"x⅝"
U7-L8	6976	1816	156	—	—	—	9136	—	—	—	33.09	—	94	A.S. 2-15"@ 50#, 2 Cov. Pls. 17"x⅝"
L8-U9	5837	1617	177	—	—	—	7817	—	—	—	31.09	29.81	—	A.S. 2-18"@ 55.8#, 2 Cov. Pls. 17"x⅝"
U9-L9	6896	166	126	123	205	133	9257	8076	9866	8896	64.81	—	—	A.S. 4@ 8"x6"x⅞", 2 Pls. 20"x⅞", 2 Cov. Pls. 16"x⅝"
U9-U10	2967	807	77	—	—	—	3937	—	—	—	26.93	21.33	—	2-15"@ 42.9#, 2 Cov. Pls. 17"x⅝"
L10-U11	6066	1806	186	—	—	—	7586	—	—	—	65.86	—	96	A.S. 2-18"@ 50#, 2 Cov. Pls. 17"x⅝"
U12-L12	4067	977	107	—	—	—	5417	—	—	—	26.93	21.33	—	A.S. 2-15"@ 33.9#, 2 Cov. Pls. 17"x⅝"
U12-U13	5996	1396	186	—	—	—	6456	—	—	—	58.78	—	86	A.S. 2-15"@ 50#, 2 Cov. Pls. 17"x⅝"
U13-L14	3397	1087	107	—	—	—	4777	—	—	—	26.71	19.71	—	A.S. 2-12"@ 30#, 2 Cov. Pls. 17"x⅝"
L14-U15	3366	1086	106	—	—	—	4726	—	—	—	26.71	—	106.5	A.S. do
U15-L16	1207	937	87	—	—	—	2117	—	—	—	19.19	16.01	—	2-12"@ 20.7#, 2 Cov. Pls. 17"x⅝"
L9-T16	6327	1627	1277	173	288	231	9037	6057	8367	7207	99.85	29.32	—	A.S. 4@ 6"x6"x⅝", 2 Pls. 20"x⅝", 2 Cov. Pls. 16"x⅝"
U9-L1	857	297	187	—	—	—	1607	—	—	—	19.68	16.00	—	4 Bulb @ 6"x3⅜"@ 13.5#, 1 Pl. 17"x⅝"
U8-L3	857	297	187	—	—	—	1627	—	—	—	19.68	16.00	—	do
U8-L5	857	297	187	—	—	—	1687	—	—	—	19.68	16.00	—	do
U7-L5	857	297	187	—	—	—	1627	—	—	—	19.68	16.00	—	do
U11-L11	1007	297	187	—	—	—	1777	—	—	—	19.68	16.00	—	do
U13-L13	997	297	187	—	—	—	1769	—	—	—	19.68	16.00	—	do
U13-L15	997	297	187	—	—	—	1769	—	—	—	19.68	16.00	—	do
L15-T16	887	297	187	—	—	—	1687	—	—	—	19.68	16.00	—	do
U17-T16	857	297	187	—	—	—	1657	—	—	—	19.68	16.00	—	4 Bulb @ 6"x3⅜"@ 13.5#, 1 Pl. 17"x⅝"
U17-T17	857	297	187	—	—	—	1657	—	—	—	19.68	16.00	—	do
L17-T17	887	297	187	—	—	—	1657	—	—	—	19.68	16.00	—	do
L14-T16	867	297	187	—	—	—	1637	—	—	—	19.68	16.00	—	do
L13-T16	887	297	187	—	—	—	1657	—	—	—	19.68	16.00	—	do
L16-T16	867	297	187	—	—	—	1637	—	—	—	19.68	16.00	—	do
U0-L2	13C	0	0	—	—	—	13C	—	—	—	19.68	—	182	do
U0-L0	13C	0	0	—	—	—	13C	—	—	—	19.68	—	160	do
U0-L6	17C	0	0	—	—	—	17C	—	—	—	23.56	—	160	4 Bulb @ 7"x3⅝"@ 17.1#, 1 Pl. 17"x⅝"
U8-L8	20C	0	0	—	—	—	20C	—	—	—	23.56	—	160	do
U10-U0	17C	0	0	—	—	—	17C	—	—	—	23.56	—	133	do
U12-U0	13C	0	0	—	—	—	13C	—	—	—	19.68	—	133	do
U14-U0	13C	0	0	—	—	—	13C	—	—	—	19.68	—	133	4 Bulb @ 6"x3⅜"@ 13.5#, 1 Pl. 17"x⅝"
U16-L16	13C	0	0	—	—	—	13C	—	—	—	19.68	—	93	do
R0***	309	109	15	413	528	483	413	377	537	358				
R9***	1679	647	91	1181	1249	1711	1807	1626	1978	1923				

Stresses are given in kips. C = Compression; T = Tension.

Allowable stresses for combination of loadings:
D.L. + I. = 100% normal unit stresses.
D.L. + 30# W. = 100% normal unit stresses.
D+L+I+30# W. = 125% normal unit stresses.
D.L.+ 50# W. = 133⅓% normal unit stresses.

* Includes reversal due to passage of live load for which 70% of the dead load is assumed effective.

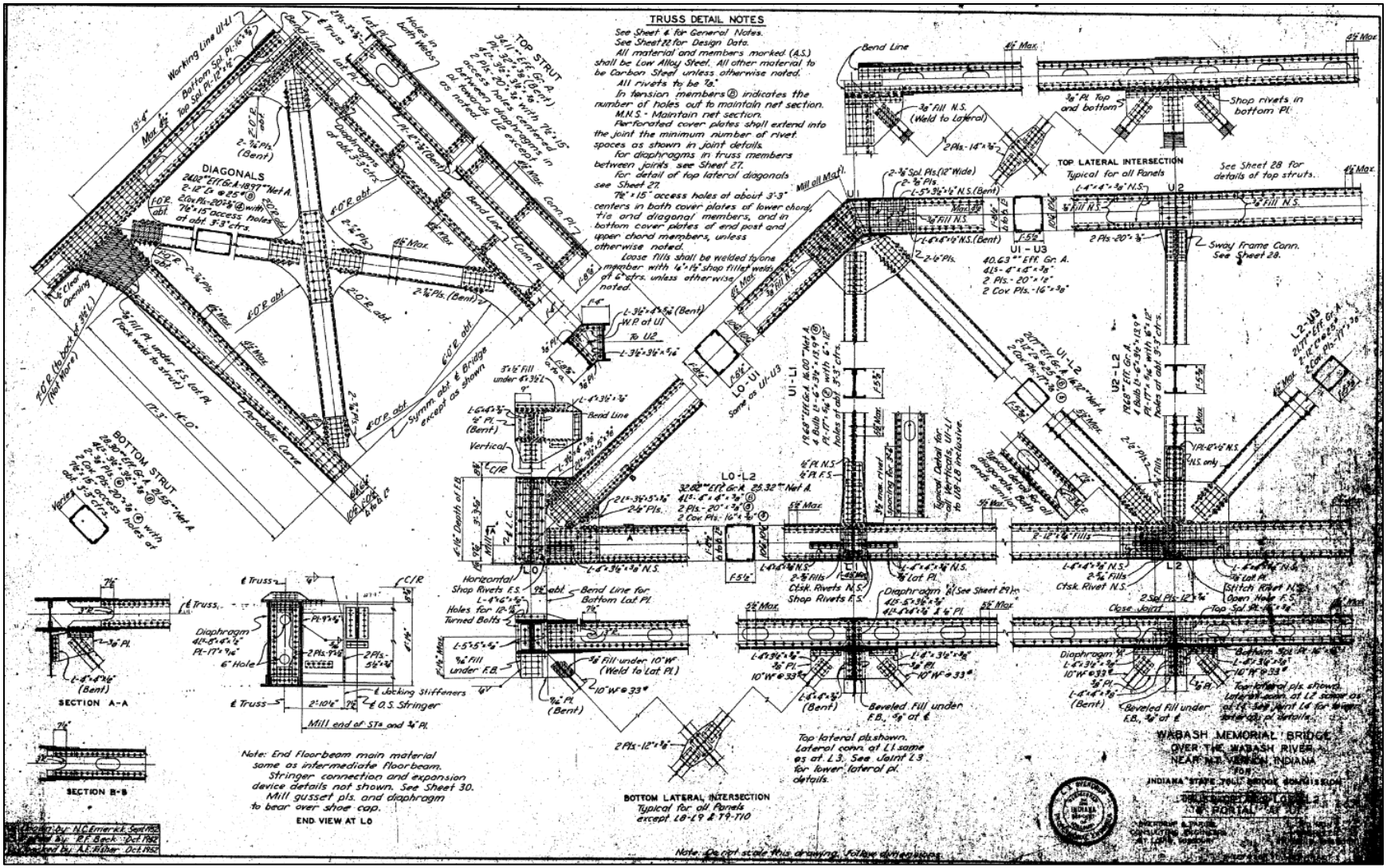
** Member proportioned for bending stresses in combination with the stresses indicated in the above table.

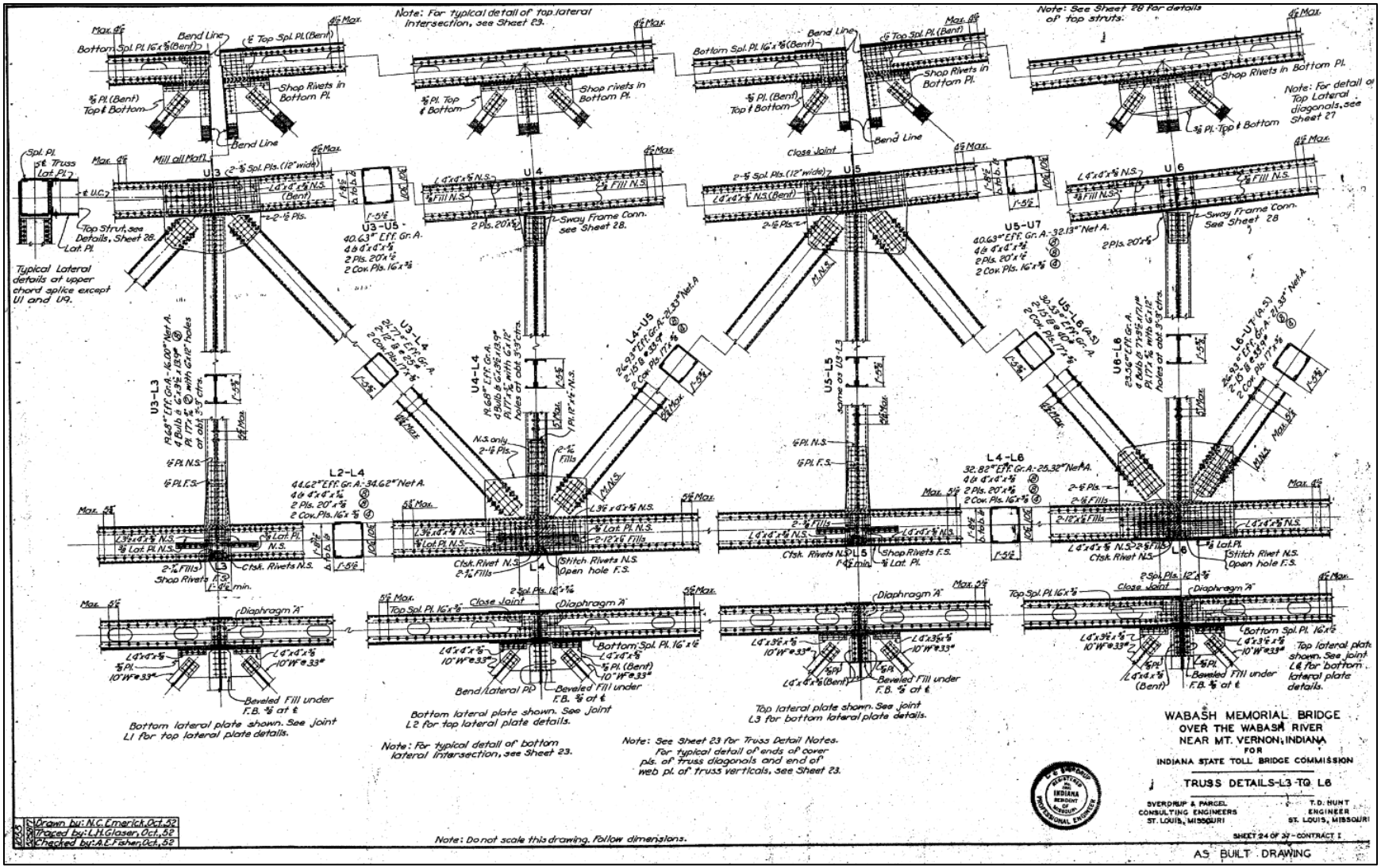
*** At & Lower Chord.

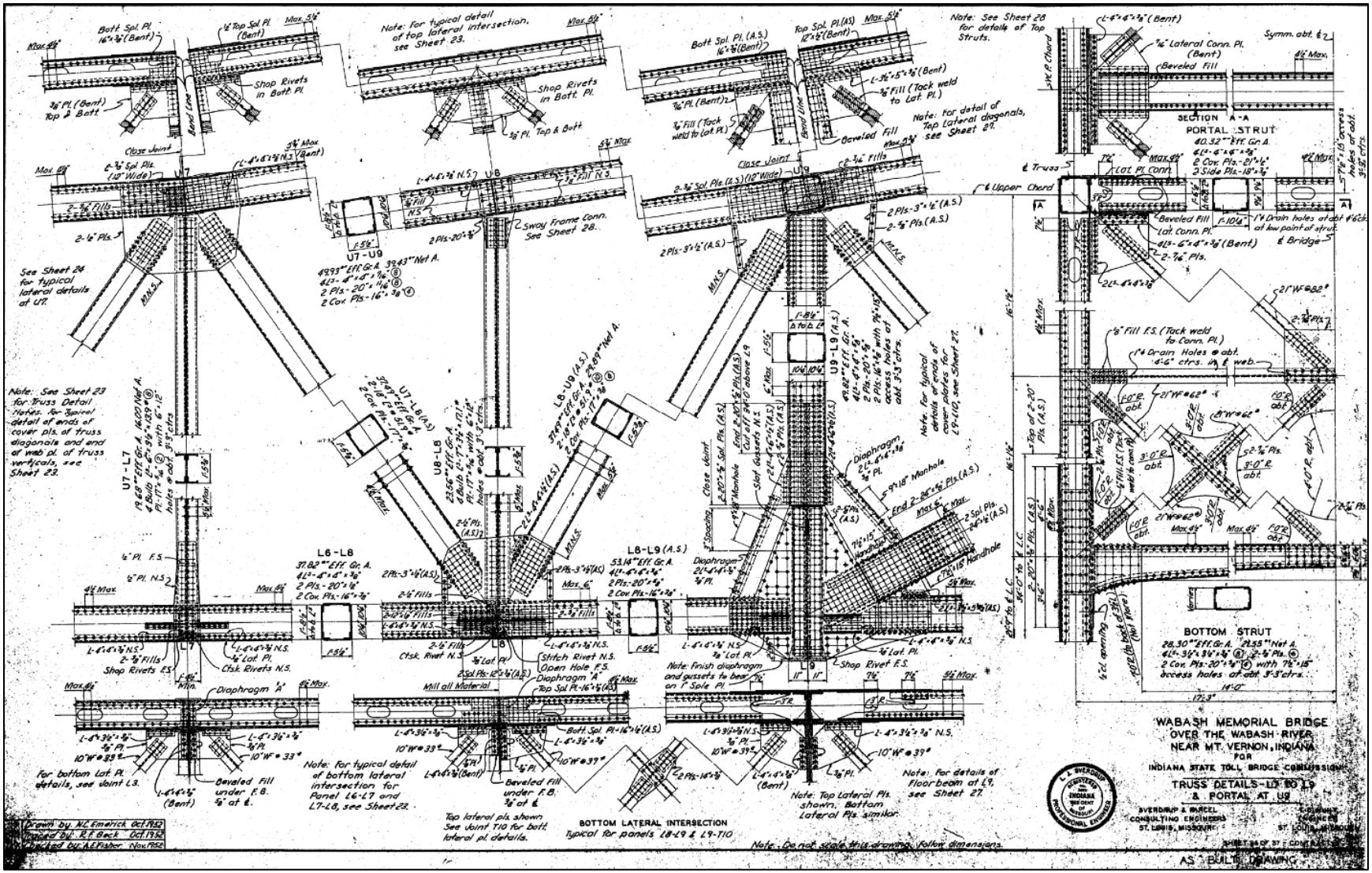
**** For reinforcement of base section, see Sheet 25.

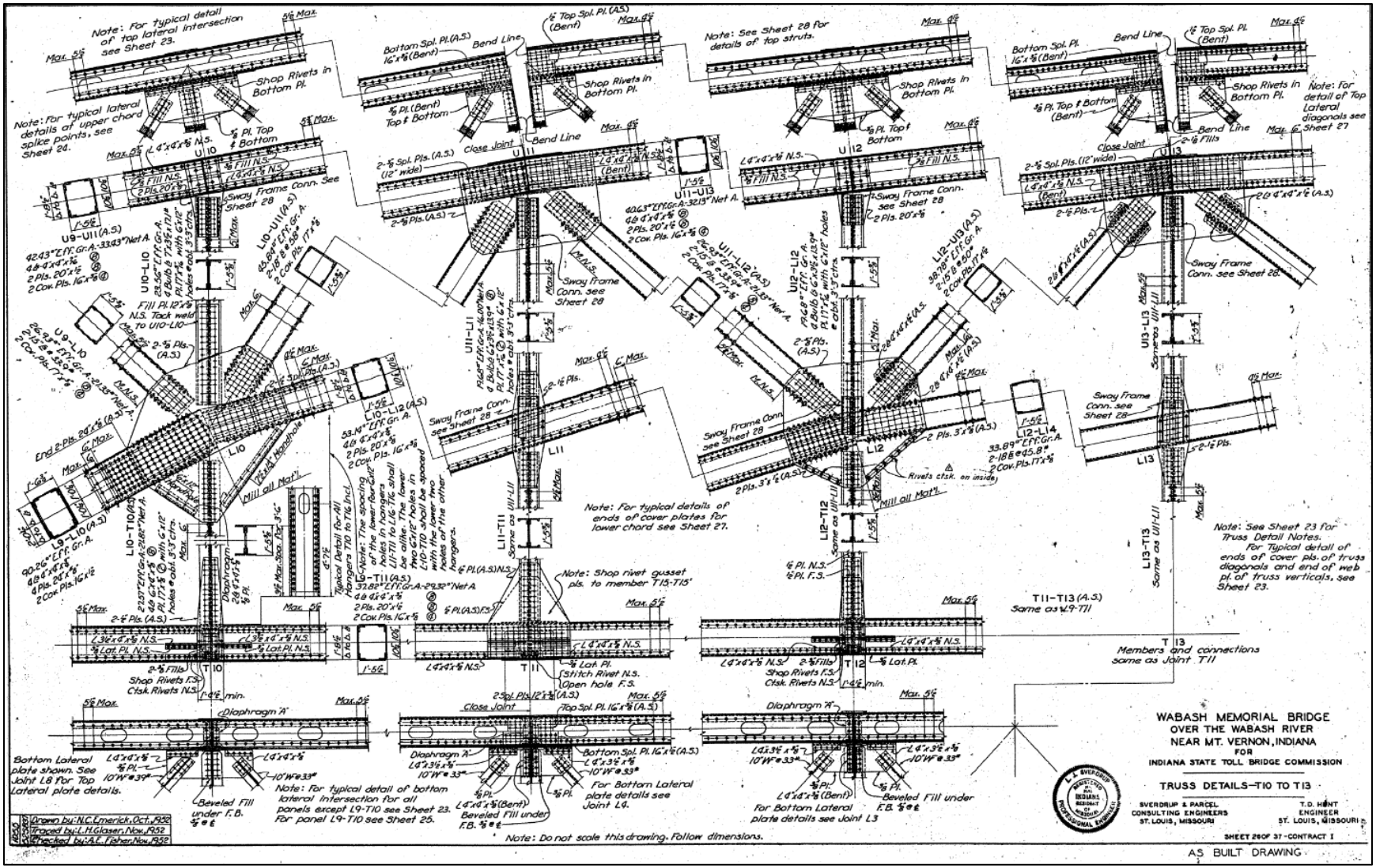
Note: All members marked A.S. shall be Low Alloy Steel. All others to be Carbon Steel.

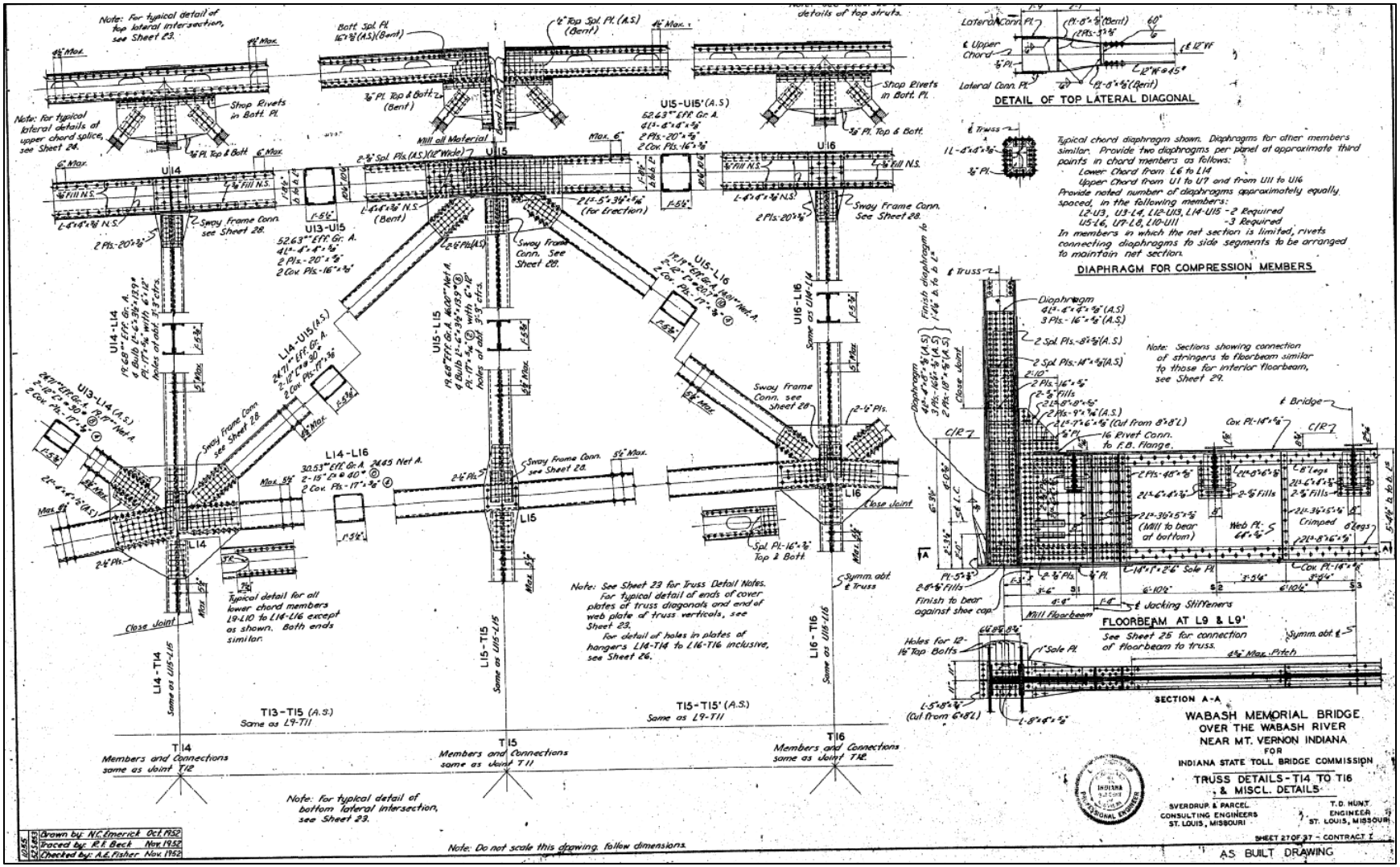
	H																	
	R9	0	.0735	.1435	.2035	.2435	.2535	.2335	.1835	.0935	0	.1135	.2135	.2835	.3235	.3335	.3035	.2335
	RD	0	.1128	.2428	.3528	.4328	.4728	.4728	.4328	.3528	.2428	.1128	0	.1128	.2428	.3528	.4328	.4728
	RD	1.000	+.8816	+.7043	+.5403	+.4044	+.3113	+.2807	+.3007	+.3613	+.4522	+.5641	+.6871	+.8113	+.9268	+1.0237	+1.0923	+1.1236

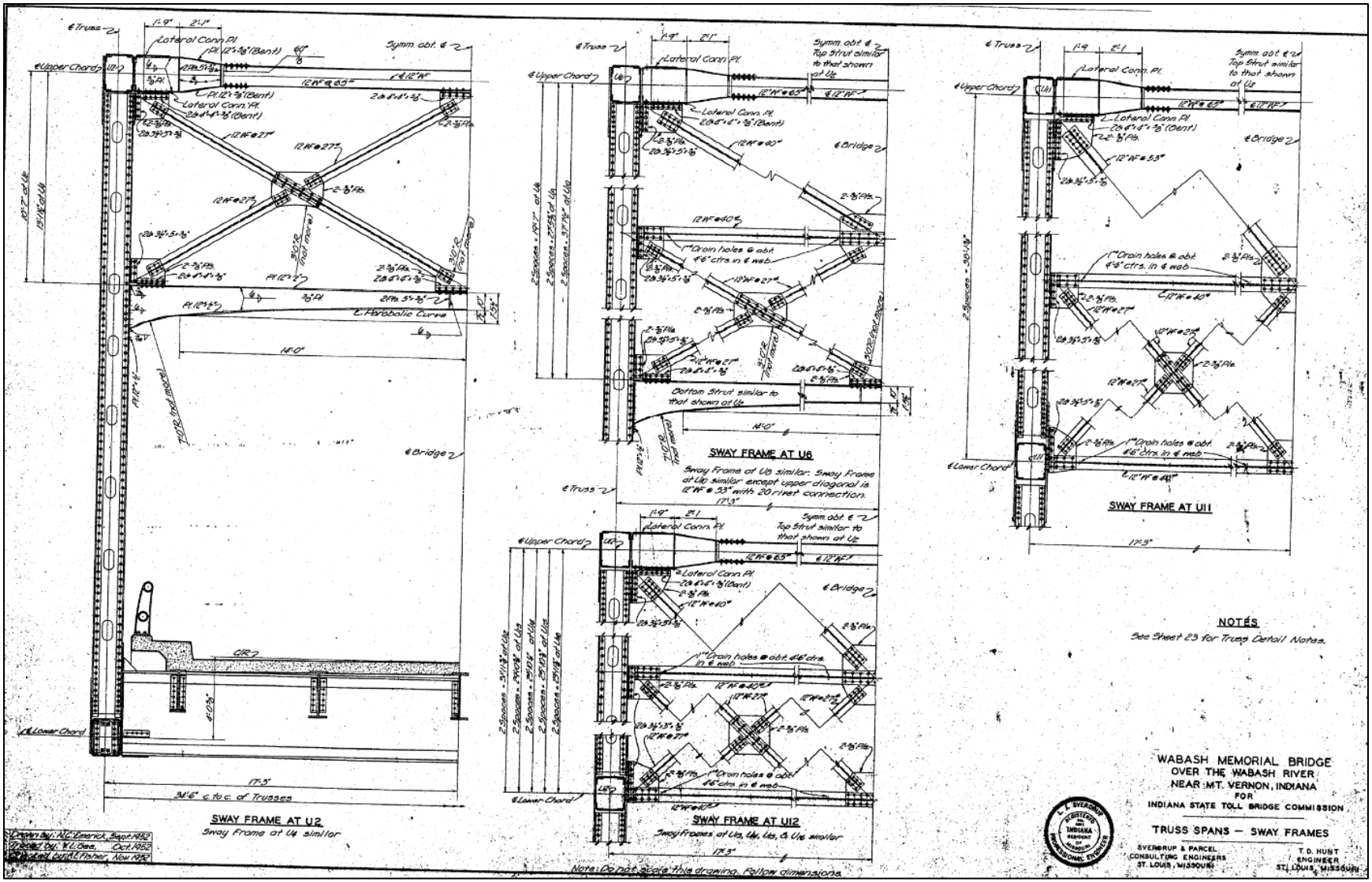

TRUSS DETAIL NOTES
See Sheet 6 for General Notes.
See Sheet 12 for Design Data.
All material and members marked (A.S.) shall be Low Alloy Steel. All other material to be Carbon Steel unless otherwise noted.
All rivets to be 7/8".
In tension members ② indicates the number of holes out to maintain net section.
M.N.S. - Maintain net section.
Perforated cover plates shall extend into the joint the minimum number of rivet spaces as shown in joint details.
For diaphragms in truss members between joints see Sheet 27.
For detail of top lateral diagonals see Sheet 27.
7/8" x 15" access holes at about 3'-3" centers in both cover plates of lower chord, tie and diagonal members, and in bottom cover plates of end post and upper chord members, unless otherwise noted.
Loose fills shall be welded to one member with 1/4" x 1 1/2" shop fillet welds at 6" ctrs. unless otherwise noted.
DIAGONALS
TOP STRUT
BOTTOM STRUT
TOP LATERAL INTERSECTION
Typical for all Panels
See Sheet 28 for details of top struts.
Sway Frame Conn. See Sheet 28.
U1 - U3
U2 - L2
U1 - L1
U1 - L2
L2 - U3
L0 - U1
L0 - L2
L1
L2
Shop rivets in bottom Pl.
Mill all Mat'l.
Typical detail for all diagonals, both ends same.
Typical detail for all verticals, U1-L1 to U8-L8 inclusive.
Diaphragm
Bend Line
Conn. Pl.
Lat. Pl.
Working Line U1-L1
Bottom Spl. Pl.
Top Spl. Pl.
Holes in both Webs
Parabolic Curve
Symm. abt. ℄ Bridge except as shown
Vertical
Horizontal
Shop Rivets F.S.
Shop Rivets A.S.
Ctsk. Rivets N.S.
Ctsk. Rivet N.S.
Close Joint
Mill end of ST. and 3/4" Pl.
Beveled Fill under F.B., 5/8" at ℄
Top lateral pls. shown. Lateral conn. at L1 same as at L3. See Joint L3 for lower lateral pl. details.
Top lateral pls. shown. Lateral conn. at L2 same as at L0. See Joint L0 for lower lateral pl. details.
SECTION A-A
SECTION B-B
END VIEW AT L0
BOTTOM LATERAL INTERSECTION
Typical for all Panels except L0-L1 & L7-L10
Note: End floorbeam main material same as intermediate floorbeam. Stringer connection and expansion device details not shown. See Sheet 30. Mill gusset pls. and diaphragm to bear over shoe cap.
Note: Do not scale this drawing. Follow dimensions.
WABASH MEMORIAL BRIDGE
OVER THE WABASH RIVER
NEAR MT. VERNON, INDIANA
FOR
INDIANA STATE TOLL BRIDGE COMMISSION
DETAILS OF TRUSS L2 - L2' AT PORTAL AT JOB
Checked By: N.C. Emerick, Sept. 1951
Drawn By: B.F. Bach, Oct. 1951
Traced By: A.F. Fisher, Oct. 1951

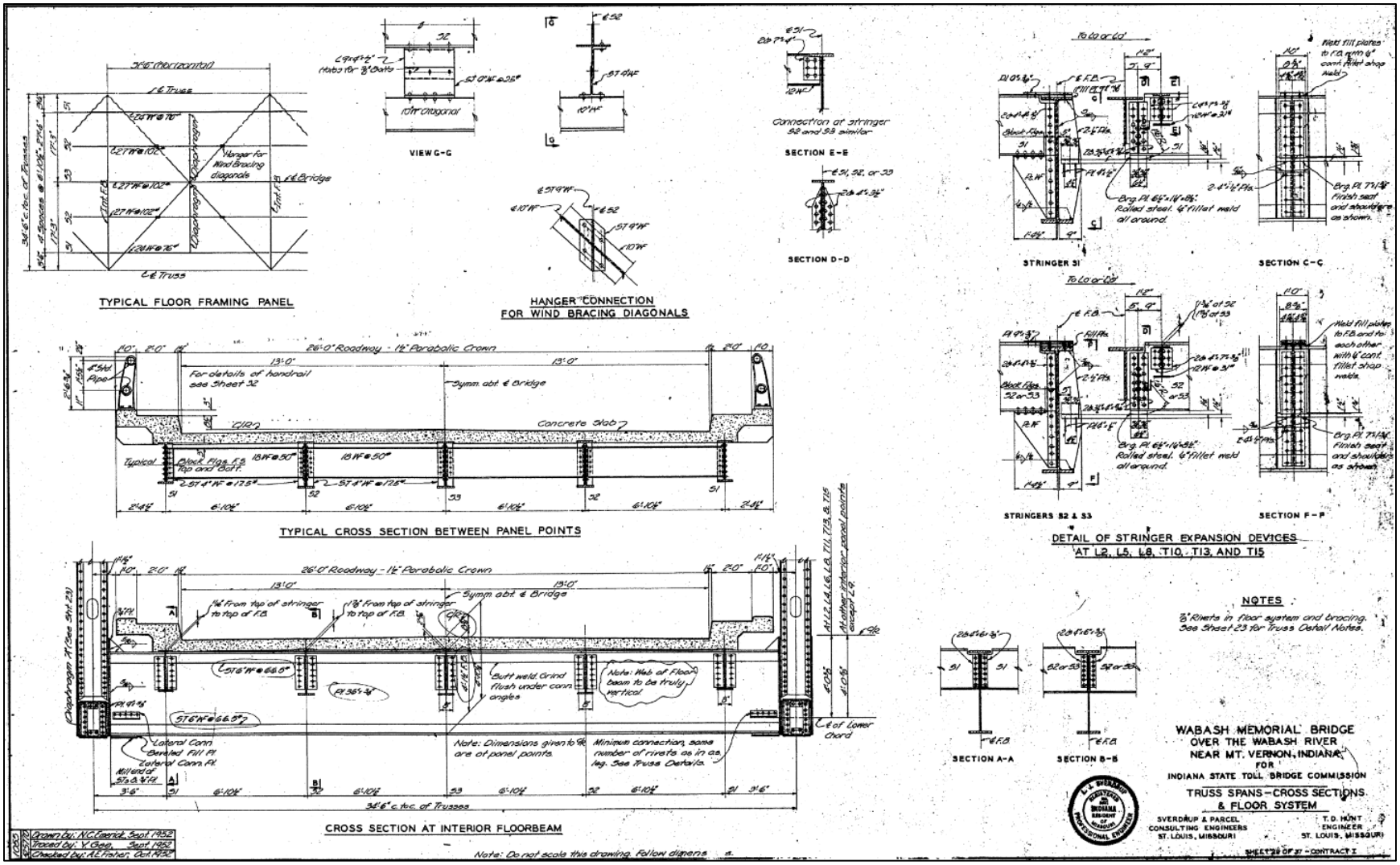

Note: For typical detail of top lateral intersection, see Sheet 23.
Note: See Sheet 28 for details of top struts.
Note: For detail of Top Lateral diagonals, see Sheet 27
Typical Lateral details at upper chord splice except U1 and U9.
Bottom lateral plate shown. See joint L1 for top lateral plate details.
Bottom lateral plate shown. See joint L2 for top lateral plate details.
Top lateral plate shown. See joint L3 for bottom lateral plate details.
Top lateral plate shown. See joint L6 for bottom lateral plate details.
Note: For typical detail of bottom lateral intersection, see Sheet 23.
Note: See Sheet 23 for Truss Detail Notes. For typical detail of ends of cover pls. of truss diagonals and end of web pl. of truss verticals, see Sheet 23.
Note: Do not scale this drawing. Follow dimensions.
Drawn by: N.C. Emerich, Oct., 52
Traced by: L.H. Glaser, Oct., 52
Checked by: A.E. Fisher, Oct., 52
WABASH MEMORIAL BRIDGE
OVER THE WABASH RIVER
NEAR MT. VERNON, INDIANA
FOR
INDIANA STATE TOLL BRIDGE COMMISSION
TRUSS DETAILS-L3 TO L6
SVERDRUP & PARCEL
CONSULTING ENGINEERS
ST. LOUIS, MISSOURI
T.D. HUNT
ENGINEER
ST. LOUIS, MISSOURI
SHEET 24 OF 32 - CONTRACT I
AS BUILT DRAWING


WABASH MEMORIAL BRIDGE
OVER THE WABASH RIVER
NEAR MT. VERNON, INDIANA
FOR
INDIANA STATE TOLL BRIDGE COMMISSION
TRUSS DETAILS-L0 TO L9
& PORTAL AT U0
SVERDRUP & PARCEL
CONSULTING ENGINEERS
ST. LOUIS, MISSOURI
AS-BUILT DRAWING
SECTION A-A
PORTAL STRUT
BOTTOM STRUT
BOTTOM LATERAL INTERSECTION
Typical for panels L8-L9 & L9-T10
Note: Do not scale this drawing. Follow dimensions.
Drawn by: N.C. Emerick Oct. 1952
Traced by: R.F. Beck Oct. 1952
Checked by: A.E. Fistor Nov. 1952


WABASH MEMORIAL BRIDGE
OVER THE WABASH RIVER
NEAR MT. VERNON, INDIANA
FOR
INDIANA STATE TOLL BRIDGE COMMISSION
TRUSS DETAILS—T10 TO T13
SVERDRUP & PARCEL
CONSULTING ENGINEERS
ST. LOUIS, MISSOURI
T. D. HUNT
ENGINEER
ST. LOUIS, MISSOURI
SHEET 26 OF 37 - CONTRACT I
Drawn by: N.C. Emerick, Oct. 1952
Traced by: L.H. Glaser, Nov. 1952
Checked by: A.E. Faber, Nov. 1952
Note: Do not scale this drawing. Follow dimensions.
AS BUILT DRAWING
T11–T13 (A.S.) Same as U9-T11
T13 Members and connections same as Joint T11


DETAIL OF TOP LATERAL DIAGONAL
DIAPHRAGM FOR COMPRESSION MEMBERS
FLOORBEAM AT L9 & L9'
See Sheet 25 for connection of floorbeam to truss.
SECTION A-A
WABASH MEMORIAL BRIDGE
OVER THE WABASH RIVER
NEAR MT. VERNON INDIANA
FOR
INDIANA STATE TOLL BRIDGE COMMISSION
TRUSS DETAILS - T14 TO T16
& MISC. DETAILS
SVERDRUP & PARCEL
CONSULTING ENGINEERS
ST. LOUIS, MISSOURI
T. D. HUNT
ENGINEER
ST. LOUIS, MISSOURI
SHEET 27 OF 37 - CONTRACT 1
AS BUILT DRAWING
Drawn by: N.C. Emerick Oct. 1952
Traced by: R.F. Beck Nov. 1952
Checked by: A.E. Fisher Nov. 1952
Note: Do not scale this drawing, follow dimensions.
T13 - T15 (A.S.)
Same as L9-T11
T15 - T15' (A.S.)
Same as L9-T11
T14
Members and Connections same as Joint T12
T15
Members and Connections same as Joint T11
T16
Members and Connections same as Joint T12
Note: For typical detail of bottom lateral intersection, see Sheet 29.
Typical detail for all lower chord members L9-L10 to L14-L16 except as shown. Both ends similar.
Note: See Sheet 23 for Truss Detail Notes.
For typical detail of ends of cover plates of truss diagonals and end of web plate of truss verticals, see Sheet 23.
For detail of holes in plates of hangers L14-T14 to L16-T16 inclusive, see Sheet 26.
Note: For typical detail of top lateral intersection, see Sheet 23.
Note: For typical detail of lateral details at upper chord splice, see Sheet 24.
Typical chord diaphragm shown. Diaphragms for other members similar. Provide two diaphragms per panel at approximate third points in chord members as follows:
Lower Chord from L6 to L14
Upper Chord from U1 to U7 and from U11 to U16
Provide noted number of diaphragms approximately equally spaced, in the following members:
L2-U3, U3-L4, L12-U13, L14-U15 - 2 Required
U5-L6, U7-L8, L10-U11 - 3 Required
In members in which the net section is limited, rivets connecting diaphragms to side segments to be arranged to maintain net section.
Note: Sections showing connection of stringers to floorbeam similar to those for interior floorbeam, see Sheet 29.
Typical details of top struts.
Mill all Material
Shop Rivets in Bott. Pl.
Sway Frame Conn. See Sheet 28.
Close Joint
Lateral Conn. Pl.
Upper Chord
Diaphragm
Web Pl.
Crimped
Finish to bear against shoe cap
Mill Floorbeam
Holes for 12-1⅛ Top Bolts
Sole Pl.
Symm. abt. ℄ Truss
Cov. Pl.
Fills
Legs
Bridge


SWAY FRAME AT U2
Sway Frame at U4 similar
SWAY FRAME AT U6
Sway Frame at U8 similar. Sway Frame at U10 similar except upper diagonal is 12"W @ 53" with 20 rivet connection.
SWAY FRAME AT U12
Sway Frames at U14, U16, U18, & U20 similar
SWAY FRAME AT U11
NOTES
See Sheet 23 for Truss Detail Notes.
WABASH MEMORIAL BRIDGE
OVER THE WABASH RIVER
NEAR MT. VERNON, INDIANA
FOR
INDIANA STATE TOLL BRIDGE COMMISSION
TRUSS SPANS — SWAY FRAMES
SVERDRUP & PARCEL
CONSULTING ENGINEERS
ST. LOUIS, MISSOURI
T. D. HUNT
ENGINEER
ST. LOUIS, MISSOURI
Note: Do not scale this drawing. Follow dimensions.


TYPICAL FLOOR FRAMING PANEL
HANGER CONNECTION FOR WIND BRACING DIAGONALS
VIEW G-G
SECTION E-E
SECTION D-D
STRINGER 31
SECTION C-C
STRINGERS 32 & 33
SECTION F-F
DETAIL OF STRINGER EXPANSION DEVICES AT L2, L5, L8, T10, T13, AND T15
TYPICAL CROSS SECTION BETWEEN PANEL POINTS
CROSS SECTION AT INTERIOR FLOORBEAM
SECTION A-A
SECTION B-B
NOTES
WABASH MEMORIAL BRIDGE
OVER THE WABASH RIVER
NEAR MT. VERNON, INDIANA
FOR
INDIANA STATE TOLL BRIDGE COMMISSION
TRUSS SPANS—CROSS SECTIONS & FLOOR SYSTEM
SVERDRUP & PARCEL CONSULTING ENGINEERS ST. LOUIS, MISSOURI
T. D. HUNT ENGINEER ST. LOUIS, MISSOURI
Note: Do not scale this drawing, follow dimens.

2009 Reconstruction (2004) Plan Set

PROJECT	DESIGNATION
BR-006-1(002)	9700670
CONTRACT	
B-25804	

STRUCTURE	TYPE	SPANS	SKEW	OVER	℄ STATION
62-65-T4020B & (62)762-65-4020B	CONTINUOUS RIVETED PLATE GIRDER, CONTINUOUS STEEL TIED ARCH-TRUSS, CONTINUOUS RIVETED PLATE GIRDER, CONTINUOUS STEEL BEAM BRIDGE	2@115'-0", 2@115'-9" 115'-0", 117'-2" 284'-0", 441'-0", 284'-0", 117'-2", 115'-0", 2@115'-9", 115'-0", 115'-9", 62'-9", 2@78'-0", 62'-7½"; 7 FOUR SPAN UNITS OF 62'-7½", 2@78'-0", 62'-7½"; 62'-7½", 2@78'-0" & 64'-3"	NONE →	WABASH RIVER	

INDEX	
SHEET NUMBER	SUBJECT
1	TITLE AND INDEX
2-12	TRAFFIC MAINTENANCE DETAILS
13-16	GENERAL PLAN EXISTING STRUCTURE
17-20	GENERAL PLAN PROPOSED STRUCTURE
21	GENERAL NOTES AND APPROACH DETAILS
22-24	ABUTMENT NO.1 DETAILS
25-26	PIERS NO.4 AND NO.13 DETAILS
27-29	PIER NO.16 DETAILS
30-31	PIERS NO.20, NO.24, NO.28, NO.32, NO.36, NO.40, NO.44 AND NO.48 DETAILS
32-34	ABUTMENT NO.52 DETAILS
35-42	STRUCTURAL STEEL DETAILS
43-44	BEARING DETAILS
45-60	FLOOR DETAILS
61-62	APPROACH SLAB DETAILS
63-65	BRIDGE SUMMARY

INDIANA DEPARTMENT OF TRANSPORTATION

BRIDGE PLANS

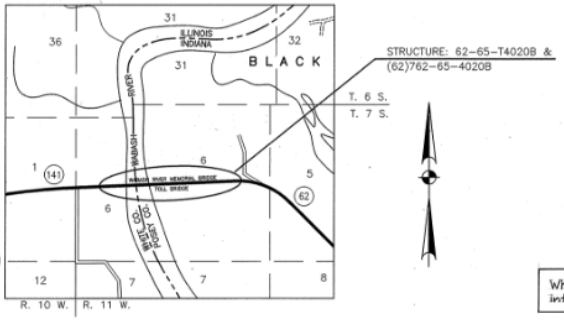
FOR SPANS OVER 20 FEET
ON STATE ROAD 62

PROJECT NO. BR-006-1(002)

DECK RECONSTRUCTION ON STRUCTURE: 62-65-T4020B & (62)762-65-4020B, (WABASH RIVER MEMORIAL TOLL BRIDGE), STATE ROAD 62 OVER WABASH RIVER LOCATED IN SECTION 6, T.7 S., R.11 W. AT R.P. 0+01, BLACK TOWNSHIP, POSEY COUNTY, INDIANA AND WHITE COUNTY, ILLINOIS.

TRAFFIC DATA		
A.A.D.T. (1999)	3700	V.P.D.
A.A.D.T. (2023)	5200	V.P.D.
D.H.V. (20)		V.P.H.
DIRECTIONAL DISTRIBUTION		%
TRUCKS	15	% A.A.D.T.
		% D.H.V.
DESIGN DATA		
POSTED SPEED	40	M.P.H.
DESIGN SPEED	40	M.P.H.
PROJECT DESIGN CRITERIA	3R (NON-FREEWAY)	
FUNCTIONAL CLASSIFICATION	MINOR ARTERIAL	
RURAL/URBAN	RURAL	
TERRAIN	LEVEL	
ACCESS CONTROL	NONE	





LOCATION IN POSEY COUNTY, INDIANA
AND WHITE COUNTY, ILLINOIS
Not to Scale

Note:
Structure 62-65-T4020 is from Abutment No. 1 to Pier No. 16.
Structure (62) 762-65-04020 is from Pier No. 16 to Abutment No. 52.

Whenever BR-006-1(002) appears, it shall be interpreted as BR-0061(008).

INDIANA DEPARTMENT OF TRANSPORTATION
STANDARD SPECIFICATIONS DATED **2006**
TO BE USED WITH THESE PLANS

REVISIONS	
DATE	SHEET NO.
07-22-05	1, 17
08-26-05	1, 4, 5, 6, 7 & 8, 9, 10, 11, 20, 21, 23, 25, 27, 30, 35, 54, 59, 60, 61, 63, 64 & 65
09-29-05	1, 12, 17, 18, 19, 35, 36, & 65
04-27-06	ADDED SHEET 54-1

8450 WESTFIELD BLVD., SUITE 300
INDIANAPOLIS, IN. 46240
317 713-4616
FAX 317 713-4616

BF&S
Butler Fairman Seufert
CONSULTING ENGINEERS

509 WEST 84TH DRIVE, SUITE G
MERRILLVILLE, IN. 46410
219 769-3333
FAX 219 756-2377

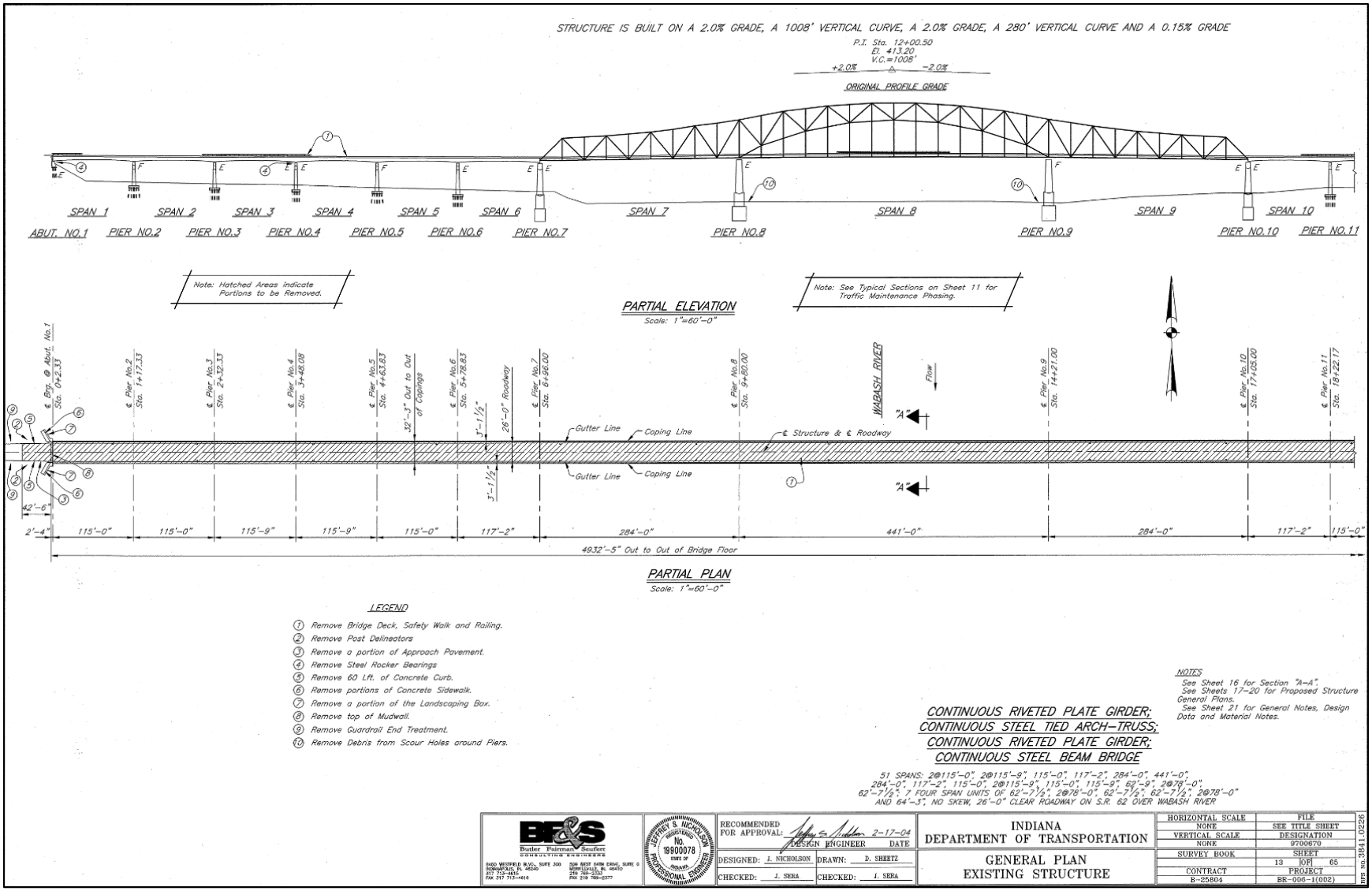
CERTIFIED BY: Jeffrey S. Nicholson 2-17-04
DESIGN ENGINEER DATE

APPROVED FOR LETTING: 8-20-04
CHIEF, DIVISION OF DESIGN DATE

JEFFREY S. NICHOLSON
No. 19900078
STATE OF INDIANA
REGISTERED PROFESSIONAL ENGINEER

BRIDGE FILE	
62-65-T4020B & (62)762-65-4020B	
DESIGNATION	
9700670	
SHEET	
1 OF 65	
CONTRACT	PROJECT
B-25804	BR-006-1(002)

3841.0226



LEGEND

1. Remove Bridge Deck, Safety Walk and Railing.
2. Remove Post Delineators
3. Remove a portion of Approach Pavement.
4. Remove Steel Rocker Bearings
5. Remove 60 Lft. of Concrete Curb.
6. Remove portions of Concrete Sidewalk.
7. Remove a portion of the Landscaping Box.
8. Remove top of Mudwall.
9. Remove Guardrail End Treatment.
10. Remove Debris from Scour Holes around Piers.

NOTES

See Sheet 16 for Section "A-A".
See Sheets 17-20 for Proposed Structure General Plans.
See Sheet 21 for General Notes, Design Data and Material Notes.

CONTINUOUS RIVETED PLATE GIRDER; CONTINUOUS STEEL TIED ARCH-TRUSS; CONTINUOUS RIVETED PLATE GIRDER; CONTINUOUS STEEL BEAM BRIDGE

51 SPANS: 2@115'-0", 2@115'-9", 115'-0", 117'-2", 284'-0", 441'-0", 284'-0", 117'-2", 115'-0", 2@115'-9", 115'-0", 115'-9", 69'-9", 2@78'-0", 62'-7½", 7 FOUR SPAN UNITS OF 62'-7½", 2@78'-0", 62'-7½", 62'-7½", 2@78'-0" AND 64'-3", NO SKEW, 26'-0" CLEAR ROADWAY ON S.R. 62 OVER WABASH RIVER

Butler Fairman & Seufert
CONSULTING ENGINEERS
8400 WESTFIELD BLVD., SUITE 300
INDIANAPOLIS, IN. 46240
317 713-4415
FAX 317 713-4616
506 WEST SIXTH DRIVE, SUITE C
MICHIGAN CITY, IN. 46360
219 769-3330
FAX 219 769-0377

JEFFREY S. NICHOLSON — REGISTERED — No. 19900078 — STATE OF INDIANA — PROFESSIONAL ENGINEER

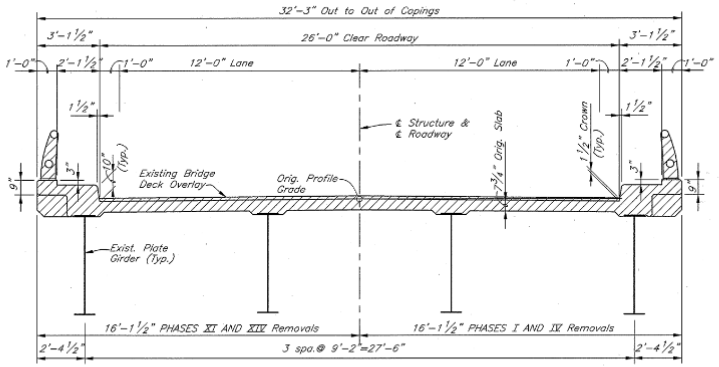
RECOMMENDED FOR APPROVAL: DESIGN ENGINEER	2-17-04 DATE	
DESIGNED: J. NICHOLSON	DRAWN: D. SHEETZ	
CHECKED: J. SERA	CHECKED: J. SERA	

INDIANA DEPARTMENT OF TRANSPORTATION

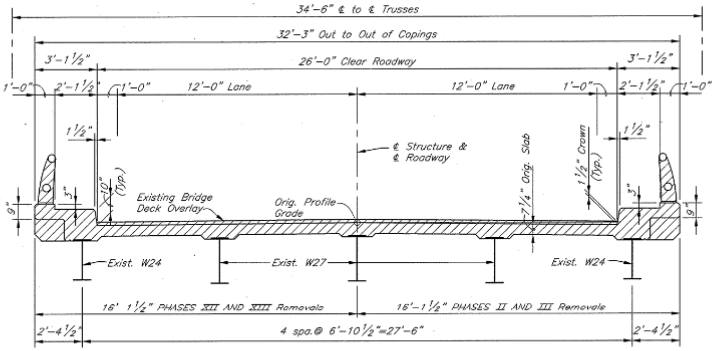
GENERAL PLAN EXISTING STRUCTURE

HORIZONTAL SCALE	FILE
NONE	SEE TITLE SHEET
VERTICAL SCALE	DESIGNATION
NONE	9700670
SURVEY BOOK	SHEET
	13 OF 65
CONTRACT	PROJECT
B-25804	BR-006-1(002)

wps 38,3841,0226

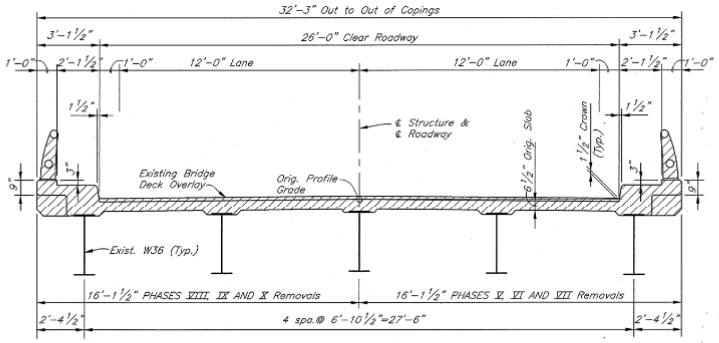


SECTION "A-A"
PLATE GIRDER APPROACH SPANS 1-6
AND SPANS 10-15
Scale: ⅜"=1'-0"



SECTION "A-A"
TRUSS SPANS 7-9
Scale: ⅜"=1'-0"

Note: Hatched Areas indicate Portions to be Removed.



SECTION "A-A"
FLOODPLAIN SPANS 16-51
Scale: ⅜"=1'-0"

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JEFFREY S. NICHOLSON
REGISTERED
No. 19900078
STATE OF INDIANA
PROFESSIONAL ENGINEER

RECOMMENDED FOR APPROVAL: Jeffrey S. Nicholson 2-17-04
DESIGN ENGINEER DATE

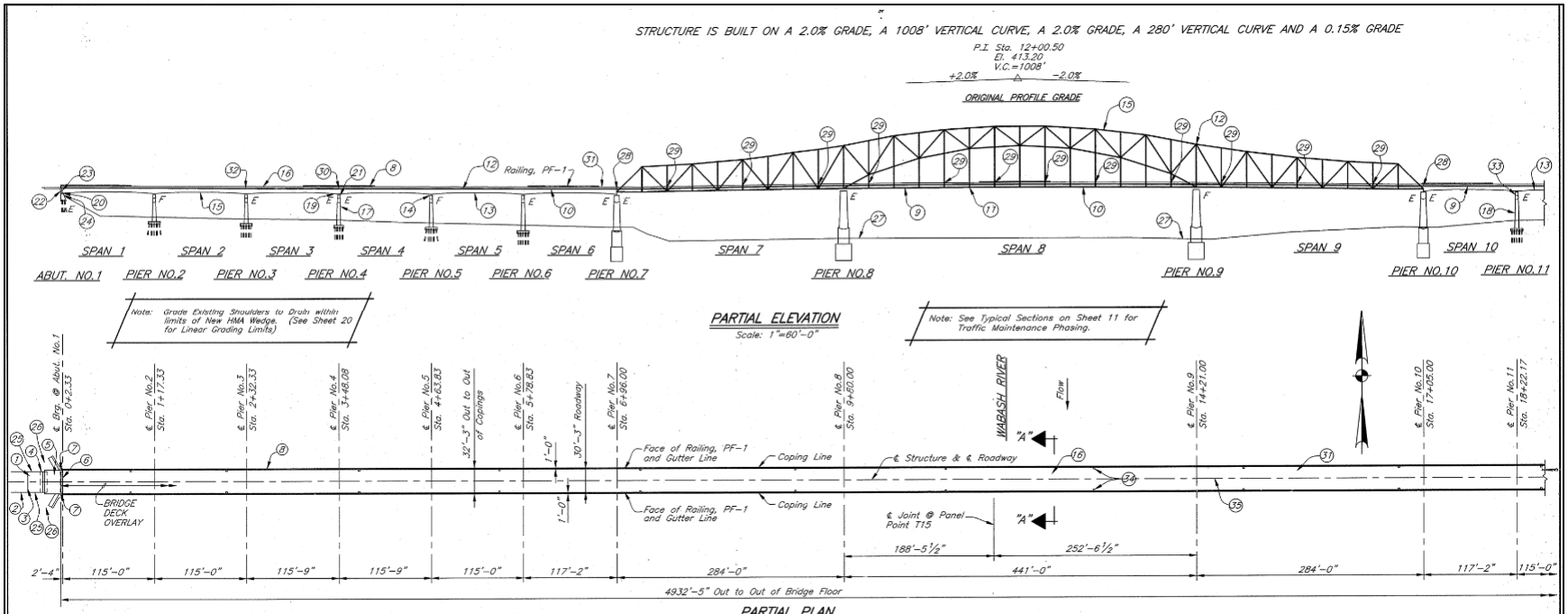
DESIGNED: J. NICHOLSON DRAWN: D. SHERTZ
CHECKED: J. SERA CHECKED: J. SERA

INDIANA
DEPARTMENT OF TRANSPORTATION

GENERAL PLAN
EXISTING STRUCTURE

HORIZONTAL SCALE	FILE
AS NOTED	SEE TITLE SHEET
VERTICAL SCALE	DESIGNATION
AS NOTED	9700670
SURVEY BOOK	SHEET
	16 JOPI 65
CONTRACT	PROJECT
B-25804	BR-006-1(002)

BFS no. 3841.00226



(1) New 20'-0" PCCP, 15" (See Standards).
(2) New HMA Wedge (See Sheet 21).
(3) Construct Transverse Pavement Joint (See Standards).
(4) Construct Terminal Joint (See Standards).
(5) New 20'-6" Concrete Approach Slab, 15" (See Sheets 61 & 62).
(6) Type 1A Joint.
(7) Install Guardrail Transition, Type TGP plus 50 Lft. of W-Beam Guardrail, 6'-3" spacing, to connect to Existing Guardrail.
(8) Construct Railing, Type PF-1.
(9) Install Shear Studs on all Girder and Stringer Top Fanges.
(10) Blast and Clean Top Flanges of all Girders and Stringers where Corrosion is present. (The Existing Paint is Lead Based).
(11) Blast, Clean and (Point) Expansion Sliding Plates at Ends of Stringers (The Existing Paint is Lead Based).
(12) Replace Missing or Deteriorated Rivets and Bolts with High Strength Bolts. (Includes Locations considered not easily Accessible)
(13) Remove Pack Rust, Clean and (Point) Cover and Splice Plate Connections in the Approach Spans where Corrosion is present. (The Existing Paint is Lead Based).
(14) Replace Missing or Damaged Anchor Bolts as Necessary.
(15) Blast, Clean, and (Point) Structural Steel for Entire Structure. (The Existing Paint is Lead Based).
(16) Reconstruct new 8" Bridge Deck (See Sheets 45-60).
(17)* Remove Patches and Delaminated Concrete from Expansion Joint Piers until Sound Concrete is Reached. Clean all Exposed Reinforcing Steel and Reface Piers with 5" of Concrete on all Faces of the Hammerheads.
(18)* Remove Deteriorated Concrete and Repoint Piers (Estimated Quantity = 50 Sft.).
(19) Install New Elastomeric Teflon Bearings.
(20) Install New Elastomeric Bearings.
(21) Sandblast and Surface Seal the Caps of all Expansion Joint Piers.
(22)* Remove Deteriorated Concrete and Repoint Abutment Mudwall (Estimated Quantity = 10 Sft.).
(23) Blast, Clean, and Surface Seal Mudwall.
(24)* Reface Abutment Cap with 5" of Concrete.
(25) Fill and Abandon Drains.
(26) Construct Riprap Drainage Turnouts to Toe of Slope. (Approx. 44 Tons of Revetment Riprap over 51 Sys. of Geotextile at each location)
(27) Place Dumped Riprap around Piers (Estimated Quantity = 285 Tons Total).
(28) Install Modular Joint.
(29) Install Expansion Joint Sealing System.
(30) Install SS Expansion Joint.
(31) Surface Seal Deck and Rail.
(32) Modify Cross Frames in Approach Spans (See Sheet 37-39).
(33) Install Lock-up Devices on Approach Structure (See Sheet 37-38).
(34) Install New C.I. Roadway Drains, Type "S0-A"
(35) Place 66 Snowplowable Raised Pavement Markers on Structure and Approaches.

* Apply Sacrificial Anodes to Rebar Exposed during Removal of Delaminated Concrete. (See Special Provisions) (Undistributed Quantity = 400 Each)

Note:
Structure 62-65-T4020 is from Abutment No. 1 to Pier No. 16.
Structure (62) 762-65-04020 is from Pier No. 16 to Abutment No. 52.

NOTES
See Sheets 13-16 for Existing Structure General Plans.
See Sheet 20 for Section "A-A".
See Sheet 21 for General Notes, Design Data and Material Notes.

CONTINUOUS RIVETED PLATE GIRDER; CONTINUOUS STEEL TIED ARCH-TRUSS; CONTINUOUS RIVETED PLATE GIRDER; CONTINUOUS STEEL BEAM BRIDGE

51 SPANS: 2@115'-0", 2@115'-9", 115'-0", 117'-2", 284'-0", 441'-0", 284'-0", 117'-2", 115'-0", 2@115'-9", 115'-0", 115'-9", 62'-9", 2@79'-0", 62'-7½", 7 FOUR SPAN UNITS OF 62'-3½", 2@78'-0", 62'-7½", 62'-7½", 2@78'-0" AND 64'-3", NO SKEW, 30'-3" CLEAR ROADWAY ON S.R. 62 OVER WABASH RIVER

REVISED 7-22-05: ADDED STRUCTURE NOTE
REVISED 9-29-05: CHANGED METALLIZE TO PAINT

Butler Fairman Seufert CONSULTING ENGINEERS
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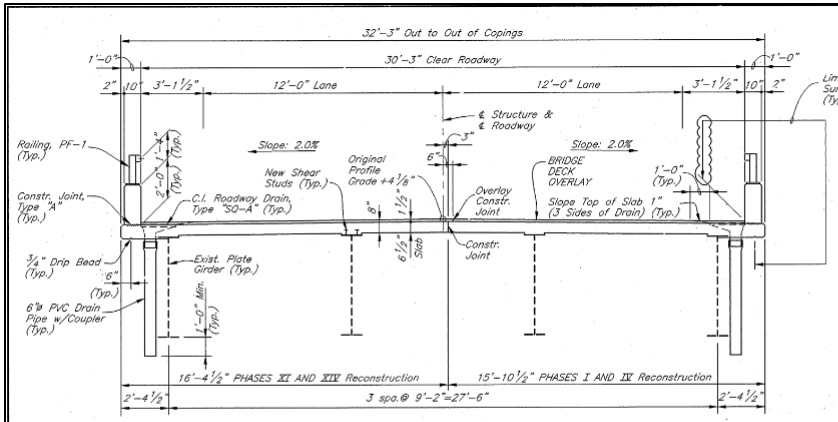
JEFFREY S. NICHOLSON, No. 19900078, STATE OF INDIANA, REGISTERED PROFESSIONAL ENGINEER

RECOMMENDED FOR APPROVAL: _____ DESIGN ENGINEER 2-17-04 DATE
DESIGNED: J. NICHOLSON DRAWN: D. SHEETZ
CHECKED: J. SERA CHECKED: J. SERA

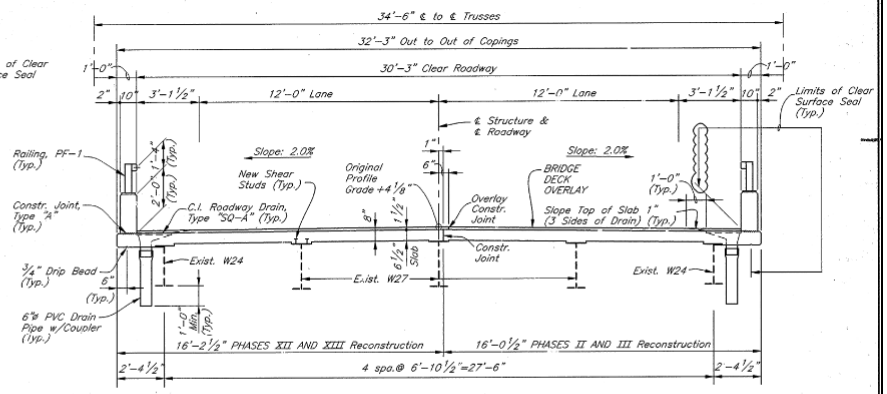
INDIANA DEPARTMENT OF TRANSPORTATION
GENERAL PLAN
PROPOSED STRUCTURE

HORIZONTAL SCALE	FILE
NONE	SEE TITLE SHEET
VERTICAL SCALE	DESIGNATION
NONE	9700670
SURVEY BOOK	SHEET
	17 OF 65
CONTRACT	PROJECT
B-25804	BR-006-1(002)

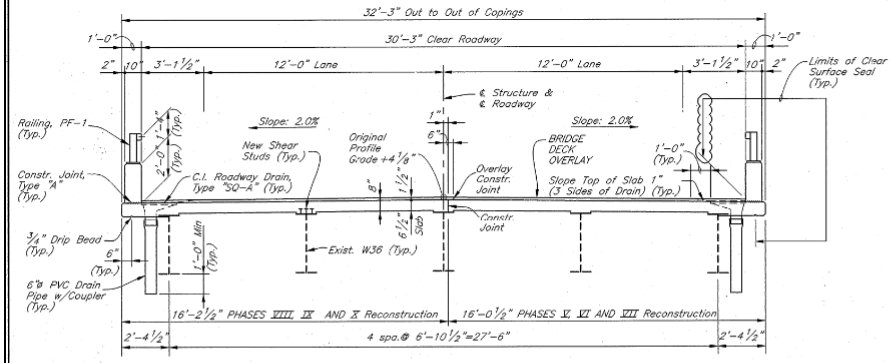
BRS NO. 3841.0226



SECTION "A-A"
PLATE GIRDER APPROACH SPANS 1-6
AND SPANS 10-15
Scale: ⅜"=1'-0"



SECTION "A-A"
TRUSS SPANS 7-9
Scale: ⅜"=1'-0"



SECTION "A-A"
FLOODPLAIN SPANS 16-51
Scale: ⅜"=1'-0"

REVISED 8-26-05: CHANGED CLEAR SURFACE SEAL LIMITS

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JEFFREY S. NICHOLSON
No. 19900078
REGISTERED
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PROFESSIONAL ENGINEER

RECOMMENDED FOR APPROVAL:	DESIGN ENGINEER	2-17-04 DATE	
DESIGNED: J. NICHOLSON	DRAWN: D. SHEETZ		
CHECKED: J. SERA	CHECKED: J. SERA		

INDIANA
DEPARTMENT OF TRANSPORTATION

GENERAL PLAN
PROPOSED STRUCTURE

HORIZONTAL SCALE	FILE
AS NOTED	SEE TITLE SHEET
VERTICAL SCALE	DESIGNATION
AS NOTED	9700670
SURVEY BOOK	SHEET
	20 OF 65
CONTRACT	PROJECT
B-25804	BR-006-1(002)

BFS no. 3841.02226

Appendix 3F. NSBA Spreadsheet Calculations for Controlling Members

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 1 (L12-L13)** Date:

Assumptions:

1. Controlling fatigue detail is the fastened connection.

General Requirements (GS 1.4 and 1.6)

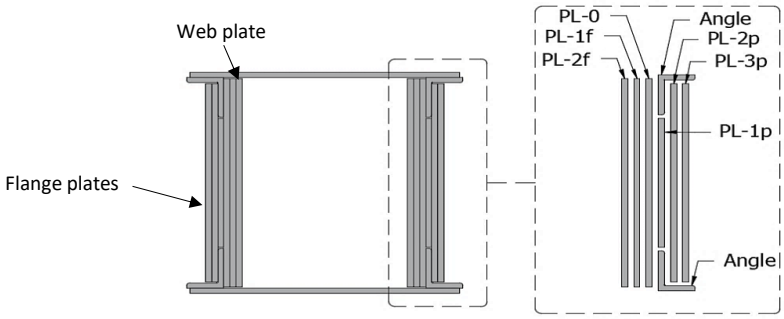
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all other provisions of Section 1.6?	**Yes**	Yes

Member Cross Section Inputs

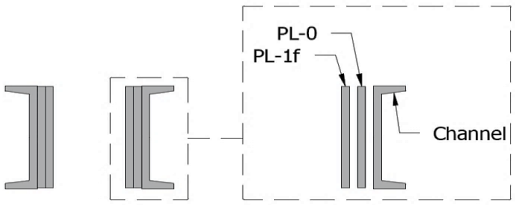
General:

Steel yield strength, F_y	**33.0**	ksi	Fastener diameter, d_{fast}	**0.8750**	in
Steel tensile strength, F_u	**60.0**	ksi	Fastener hole diameter, d_{hole}	0.9375	in
Is it a box (continuous top & bot webs)?	**Yes**	Yes or No	Are the fastener holes staggered?	**No**	Yes or No
Does the member have rolled channels?	**Yes**	Yes or No	Fastener type	**Rivet**	Bolt or Rivet
Is the member a built-up I-section?	**No**	Yes or No	Are holes punched full size?	**No**	Yes or No

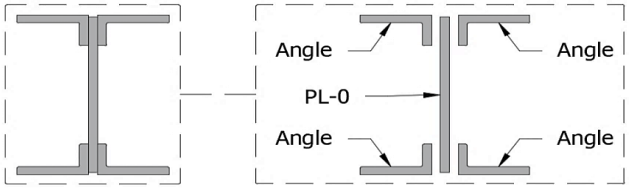
Reference sketch 1.1: Exploded view of built-up channel.



Reference sketch 1.2: Exploded view of rolled channel with additional flange plates.



Reference sketch 1.3: Exploded view of built-up I-section.



Web Plate Dimensions:	**top**	**bot**	
Web Plate Width, $b_{f.i}$	**17.000**	**17.000**	in
Web Plate Thickness, $t_{f.i}$	**0.375**	**0.375**	in
Hand Hole Width, $w_{hh.i}$	**7.500**	**7.500**	in

Fastener Location Dimensions in Web Plates:

Plate(i):	**top**	**bot**	
Holes in Web Plate, $N_{holes.i}$	**2**	**2**	holes
Distance to Hole 1, $d_{h.wp.i}$	**2.5000**	**2.5000**	in

Internal Redundancy of Built-up Member: Multi-component Axial

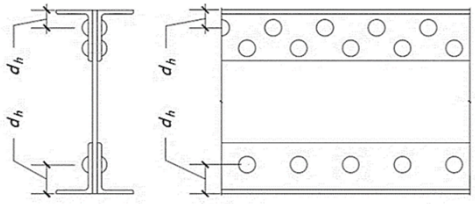
Member ID: **Sect 1 (L12-L13)** Date:

Flange Plate Dimensions (in):

Number of Full-Depth Flange Plates, $N_{fl.full}$	0	0 to 3
Number of Partial-Depth Flange Plates, $N_{fl.part}$	0	0 to 3

Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p	
$d_{fl,i}$	0.000	0.000	**0.000**	0.000	0.000	0.000	in
$t_{fl,i}$	0.0000	0.0000	**0.0000**	0.0000	0.0000	0.0000	in

Reference sketch 1.4: Distance to hole, d_h



Fastener Location Dimensions in Flange Plates:

Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p	
Holes in Flange Plate, $N_{holes.i}$	0	0	**0**	0	0	0	
Distance to Hole 1, $d_{h.fl.i}$	0.000	0.000	**0.000**	0.000	0.000	0.000	in

Angle Dimensions: (*Note: angle orientation is not important*)

Select the size of the angles		
Gross area of a single angle, $A_{agl.g}$		in^2
Thickness of the angle, t_{agl}		in
Holes in Vert Angle Leg, $N_{holes.vt.agl}$	0	holes
Holes in Horz Angle Leg, $N_{holes.hz.agl}$	0	holes

Rolled Channel Dimensions:

Select the size of the rolled channel	**C18x45.8**	
Gross area of one rolled channel, $A_{ch.g}$	13.38	in^2
Thickness of the channel flange, $t_{ch.fl}$	0.625	in
Thickness of the channel web, $t_{ch.web}$	0.5	in
Holes in the channel web, $N_{holes.ch.web}$	**0**	holes
Holes in the channel flanges, $N_{holes.ch.flange}$	**2**	holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	**326**	trucks/day	Current Year, $Y_{current}$	**2022**	year
$(ADTT_{sl})_0$	**200**	trucks/day	Span Length, L	**441.00**	ft
$(ADTT_{sl})_{limit}$	**20,000**	trucks/day	Number of striped lanes, n_L	**1**	lanes
Year Built, Y_{built}	**1956**	year	Stress-Range Estimate Partial LF, R_s	**1.00**	
Expected annual $(ADTT)_{SL}$ growth rate, g	**0.010**	MBE 7.2.5.1	No. of Stress-Range Cycles per Truck, n	**1**	cycle

Note: Growth rate is for future growth from today on

Loads:

P_{DC}	**-152**	kip	P_{LL+IM}	**158**	kip
P_{DW}	**-13**	kip	P_{FAT+IM}	**83**	kip

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override [ ] Override or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Load Factors (GS Table 1.7.1-1 and Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD A6.5.4.2):

Tension, Yield on Gross Section, ϕ_y	0.95
Tension, Fracture on Net Section, ϕ_u	0.80

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 1 (L12-L13)** Date:

Gross Area and Net Area Calculations

This section of the spreadsheet calculates faulted section areas to be used in strength limit checks and determining the controlling live load stress range in order to calculate the fatigue life in the faulted state. Due to application of the bending stress factor, Ξ_B, the controlling case may be the largest gross area plate or it may be a smaller plate positioned exterior within the section. Refer to Guide Specifications C1.6.1 for further information on "interior" and "exterior" plate positions. If there are staggered holes, the user must manually enter the controlling net area for each component, taking into account the pitch and gage of staggered hole patterns (See AASHTO LRFD 6.8.3) for strength calculations. Enter these values below under "Net (Str.)". If the holes are not staggered, the user need not manually enter net areas. **Net areas are always automatically calculated for fatigue life prediction**.

Faulted Section Scenarios:

Case 0: Assumes failure of plate PL-0

Case 1f: Assumes failure of plate PL-1f, if applicable

Case 2f: Assumes failure of plate PL-2f, if applicable

Case 2p: Assumes failure of plate PL-2p, if applicable

Case 3p: Assumes failure of plate PL-3p, if applicable

Case CH: Assumes failure of the rolled channel, if applicable

Case WP: Assumes failure of the largest net web plate, if applicable

Component	Unfaulted Areas		
	Gross	Net (Fat.)	Net (Str.)
	A_g (in^2)	A_n (in^2)	A_n (in^2)
PL-2f	0.00	0.00	
PL-1f	0.00	0.00	
PL-0	0.00	0.00	
Angles	0.00	0.00	
Channel	13.38	12.21	
PL-1p	0.00	0.00	
PL-2p	0.00	0.00	
PL-3p	0.00	0.00	
WP-top	6.38	2.86	
WP-bot	6.38	2.86	
Half Symmetry Total	**19.76**	**15.07**	
Full Member Total	**39.51**	**30.14**	

	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
Faulted Net Areas for Fatigue Life Calculations							
Half Symmetry Total	15.07	0.00	0.00	0.00	0.00	**2.86**	**13.64**
Full Member Total	30.14	0.00	0.00	0.00	0.00	**17.93**	**27.28**
Faulted Net Areas for Strength Checks							
Half Symmetry Total	15.07	0.00	0.00	0.00	0.00	**2.86**	**13.64**
Full Member Total	30.14	0.00	0.00	0.00	0.00	**17.93**	**27.28**
Faulted Gross Areas							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)
Half Symmetry Total	19.76	0.00	0.00	0.00	0.00	**6.38**	**16.57**
Full Member Total	39.51	0.00	0.00	0.00	0.00	**26.13**	**33.14**

	Area, (in^2)		Area, (in^2)		Area, (in^2)
Holes, angles	0.00	Holes, PL-3p	0.00		
Holes, PL-2f	0.00	Holes, PL-1p	0.00	Holes, Web-top	3.52
Holes, PL-1f	0.00	Holes, PL-2p	0.00	Holes, Web-bot	3.52
Holes, PL-0	0.00	Holes-channel	1.17		

Stress Amplification Factors (GS 2.2)

Stress Amplifiers (GS Table 2.2.1-1)**:**

Shear Lag Factor, Ξ_{VL}	1.20
Number of web plates, N_{web}	1
Number of flange plates, N_{fl}	1
Number of total plates, N_{AX}	2
Bending Factor, Ξ_B	1.24

40-over-fastener Rule **Required?** (GS 2.2.1.1)**:** -

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 1 (L12-L13)** Date:

Strength Capacity Check (GS 2.2 & 2.3)

Factored Load:

$P_u = \gamma_{DC} P_{DC} + \gamma_{DW} P_{DW} + \gamma_{LL} P_{LL+IM} =$ 46.3 kip GS Eq. 1.7.2-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u =$ 48.0 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y =$ 31.4 ksi GS Eq. 2.3-1

Factored Stress (Strength Limit State): (*Note:* Ξ_B & Ξ_{VL} = 1.0)

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_u / 2A_{AFN}) =$	1.54	0.00	0.00	0.00	0.00	**8.09**	**1.70**	GS Eq. 2.2.1-1
$f_{AFG} = \Xi_B \Xi_{VL} (P_u / 2A_{AFG}) =$	1.17	0.00	0.00	0.00	0.00	**3.63**	**1.40**	GS Eq. 2.2.1-2

Strength Criteria Check:

$f_{AFG} \le f_{u,g}$? 5.93 **OK** OK or NG GS Eq. 2.3-1

$f_{AFN} \le f_{u,n}$? 8.64 **OK** OK or NG GS Eq. 2.3-2

**Member L12-L13 need not be considered for fatigue per LRFD 6.6.1.2*

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 2 (L8-U9)** Date:

Assumptions:

1. Controlling fatigue detail is the fastened connection.

General Requirements (GS 1.4 and 1.6)

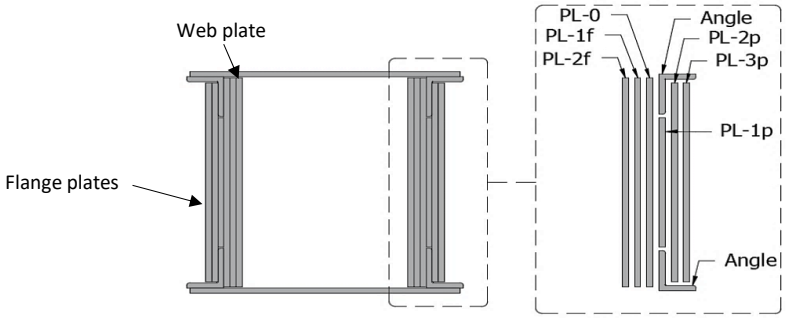
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all other provisions of Section 1.6?	**Yes**	Yes

Member Cross Section Inputs

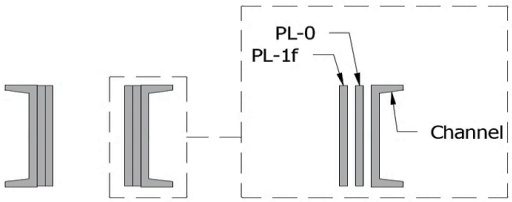
General:

Steel yield strength, F_y	**50.0**	ksi	Fastener diameter, d_{fast}	**0.8750**	in
Steel tensile strength, F_u	**70.0**	ksi	Fastener hole diameter, d_{hole}	0.9375	in
Is it a box (continuous top & bot webs)?	**Yes**	Yes or No	Are the fastener holes staggered?	**No**	Yes or No
Does the member have rolled channels?	**Yes**	Yes or No	Fastener type	**Rivet**	Bolt or Rivet
Is the member a built-up I-section?	**No**	Yes or No	Are holes punched full size?	**No**	Yes or No

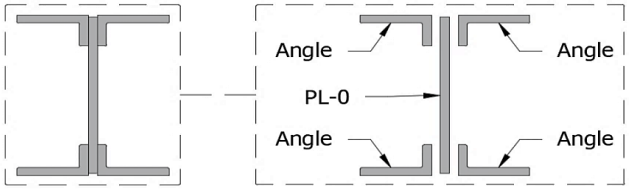
Reference sketch 1.1: Exploded view of built-up channel.



Reference sketch 1.2: Exploded view of rolled channel with additional flange plates.



Reference sketch 1.3: Exploded view of built-up I-section.



Web Plate Dimensions:	**top**	**bot**	
Web Plate Width, $b_{f.i}$	**17.000**	**17.000**	in
Web Plate Thickness, $t_{f.i}$	**0.375**	**0.375**	in
Hand Hole Width, $w_{hh.i}$	**7.500**	**7.500**	in

Fastener Location Dimensions in Web Plates: Plate(i):	**top**	**bot**	
Holes in Web Plate, $N_{holes.i}$	**2**	**2**	holes
Distance to Hole 1, $d_{h.wp.i}$	**2.5000**	**2.5000**	in

Internal Redundancy of Built-up Member: Multi-component Axial

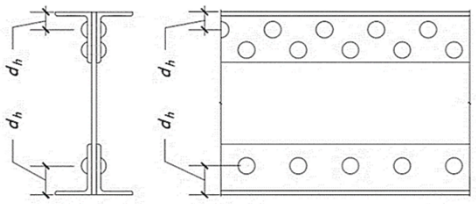
Member ID: **Sect 2 (L8-U9)** Date:

Flange Plate Dimensions (in):

Number of Full-Depth Flange Plates, $N_{fl.full}$	0	0 to 3
Number of Partial-Depth Flange Plates, $N_{fl.part}$	0	0 to 3

Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p	
$d_{fl,i}$	0.000	0.000	**0.000**	0.000	0.000	0.000	in
$t_{fl,i}$	0.0000	0.0000	**0.0000**	0.0000	0.0000	0.0000	in

Reference sketch 1.4: Distance to hole, d_h



Fastener Location Dimensions in Flange Plates:

Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p	
Holes in Flange Plate, $N_{holes.i}$	0	0	**0**	0	0	0	
Distance to Hole 1, $d_{h.fl.i}$	0.000	0.000	**0.000**	0.000	0.000	0.000	in

Angle Dimensions: (*Note: angle orientation is not important*)

Select the size of the angles		
Gross area of a single angle, $A_{agl.g}$		in^2
Thickness of the angle, t_{agl}		in
Holes in Vert Angle Leg, $N_{holes.vt.agl}$	0	holes
Holes in Horz Angle Leg, $N_{holes.hz.agl}$	0	holes

Rolled Channel Dimensions:

Select the size of the rolled channel	**C18x51.9**	
Gross area of one rolled channel, $A_{ch.g}$	15.18	in^2
Thickness of the channel flange, $t_{ch.fl}$	0.625	in
Thickness of the channel web, $t_{ch.web}$	0.625	in
Holes in the channel web, $N_{holes.ch.web}$	**0**	holes
Holes in the channel flanges, $N_{holes.ch.flange}$	**2**	holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	**326**	trucks/day	Current Year, $Y_{current}$	**2022**	year
$(ADTT_{sl})_0$	**200**	trucks/day	Span Length, L	**284.00**	ft
$(ADTT_{sl})_{limit}$	**20,000**	trucks/day	Number of striped lanes, n_L	**1**	lanes
Year Built, Y_{built}	**1956**	year	Stress-Range Estimate Partial LF, R_s	**1.00**	
Expected annual $(ADTT)_{SL}$ growth rate, g	**0.010**	MBE 7.2.5.1	No. of Stress-Range Cycles per Truck, n	**1**	cycle

Note: Growth rate is for future growth from today on

Loads:

P_{DC}	**560**	kip	P_{LL+IM}	**252**	kip
P_{DW}	**49**	kip	P_{FAT+IM}	**70**	kip

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override [ ] Override or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Load Factors (GS Table 1.7.1-1 and Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD A6.5.4.2):

Tension, Yield on Gross Section, ϕ_y	0.95
Tension, Fracture on Net Section, ϕ_u	0.80

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 2 (L8-U9)** Date:

Gross Area and Net Area Calculations

This section of the spreadsheet calculates faulted section areas to be used in strength limit checks and determining the controlling live load stress range in order to calculate the fatigue life in the faulted state. Due to application of the bending stress factor, Ξ_B, the controlling case may be the largest gross area plate or it may be a smaller plate positioned exterior within the section. Refer to Guide Specifications C1.6.1 for further information on "interior" and "exterior" plate positions. If there are staggered holes, the user must manually enter the controlling net area for each component, taking into account the pitch and gage of staggered hole patterns (See AASHTO LRFD 6.8.3) for strength calculations. Enter these values below under "Net (Str.)". If the holes are not staggered, the user need not manually enter net areas. **Net areas are always automatically calculated for fatigue life prediction**.

Faulted Section Scenarios:

Case 0: Assumes failure of plate PL-0

Case 1f: Assumes failure of plate PL-1f, if applicable

Case 2f: Assumes failure of plate PL-2f, if applicable

Case 2p: Assumes failure of plate PL-2p, if applicable

Case 3p: Assumes failure of plate PL-3p, if applicable

Case CH: Assumes failure of the rolled channel, if applicable

Case WP: Assumes failure of the largest net web plate, if applicable

Component	Unfaulted Areas			Faulted Net Areas for Fatigue Life Calculations						
	Gross	Net (Fat.)	Net (Str.)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)
	A_g (in^2)	A_n (in^2)	A_n (in^2)	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
PL-2f	0.00	0.00								
PL-1f	0.00	0.00								
PL-0	0.00	0.00								
Angles	0.00	0.00								
Channel	15.18	14.01								
PL-1p	0.00	0.00								
PL-2p	0.00	0.00								
PL-3p	0.00	0.00								
WP-top	6.38	2.86								
WP-bot	6.38	2.86								
Half Symmetry Total	**21.56**	**16.87**		16.87	0.00	0.00	0.00	0.00	**2.86**	**15.44**
Full Member Total	**43.11**	**33.74**		33.74	0.00	0.00	0.00	0.00	**19.73**	**30.88**
				Faulted Net Areas for Strength Checks						
Half Symmetry Total			**0.00**	16.87	0.00	0.00	0.00	0.00	**2.86**	**15.44**
Full Member Total			**0.00**	33.74	0.00	0.00	0.00	0.00	**19.73**	**30.88**
				Faulted Gross Areas						
				Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
				A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)
Half Symmetry Total				21.56	0.00	0.00	0.00	0.00	**6.38**	**18.37**
Full Member Total				43.11	0.00	0.00	0.00	0.00	**27.93**	**36.74**

	Area, (in^2)		Area, (in^2)		Area, (in^2)
Holes, angles	0.00	Holes, PL-3p	0.00		
Holes, PL-2f	0.00	Holes, PL-1p	0.00	Holes, Web-top	3.52
Holes, PL-1f	0.00	Holes, PL-2p	0.00	Holes, Web-bot	3.52
Holes, PL-0	0.00	Holes-channel	1.17		

Stress Amplification Factors (GS 2.2)

Stress Amplifiers (GS Table 2.2.1-1)**:**

Shear Lag Factor, Ξ_{VL}	1.20
Number of web plates, N_{web}	1
Number of flange plates, N_{fl}	1
Number of total plates, N_{AX}	2
Bending Factor, Ξ_B	1.24

40-over-fastener Rule **Required?** (GS 2.2.1.1)**:** -

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: Sect 2 (L8-U9) Date:

Strength Capacity Check (GS 2.2 & 2.3)

Factored Load:

$P_u = \gamma_{DC} P_{DC} + \gamma_{DW} P_{DW} + \gamma_{LL} P_{LL+IM} =$ 1,083.7 kip GS Eq. 1.7.2-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u =$ 56.0 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y =$ 47.5 ksi GS Eq. 2.3-1

Factored Stress (Strength Limit State): (*Note:* Ξ_B & Ξ_{VL} = 1.0)

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_u / 2A_{AFN}) =$	32.12	0.00	0.00	0.00	0.00	189.50	35.10	GS Eq. 2.2.1-1
$f_{AFG} = \Xi_B \Xi_{VL} (P_u / 2A_{AFG}) =$	25.14	0.00	0.00	0.00	0.00	85.00	29.50	GS Eq. 2.2.1-2

Strength Criteria Check:

$f_{AFG} \le f_{u,g}$? 0.30 NG OK or NG GS Eq. 2.3-1

$f_{AFN} \le f_{u,n}$? 0.56 NG OK or NG GS Eq. 2.3-2

Fatigue Life Estimate (GS 2.5)

Effective Stress Range & Max Stress Range in Unfaulted State:

$R_p =$	1.02		MBE Eq. 7.2.2.1-1
Unfaulted state stress range, $\Delta f =$	1.67	ksi	
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	1.70	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	3.74	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-2
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.00	ksi	
Resistance Factor for evaluation, R_R	1.0		MBE Table 7.2.5.2-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: Sect 2 (L8-U9) Date:

Effective Stress Range & Max Stress Range in Faulted State:

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_{FAT+IM} / 2A_{AFN}) =$	2.00	0.00	0.00	0.00	0.00	**14.63**	**2.71**	GS Eq. 2.2.1-1

40-over-fastener Rule (GS 2.2.1.1):

Load in an angle, $P_{FAT+IM-L}$	-	kip	
$f_{AFN} = P_{FAT+IM} / A_N + 0.4P_{FAT+IM-L} / I_f t_p =$	-	ksi	
Faulted state stress range, Δf =	14.63	ksi	
Faulted state effective stress range, $(\Delta f)_{eff}$ =	14.91	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	32.80	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-2
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.00	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	1.33E+06	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	10.5	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	358	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**10.5**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I(b)**	I(a), I(b), II	GS 2.5

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, NU	66.0	Years	GS 2.5.3
Total finite fatigue life only in unfaulted state, Yu	-	Years	GS 2.5.3
Total remaining fatigue life only in faulted state, Yf	-	Years	GS 2.5.3
Total remaining fatigue life, Nf = Yf(1-Nu/Yu)	**10.5**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**NG**	OK or NG	GS 2.3
Fatigue case =	-	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	-	ksi	
Controlling stress range in faulted state, Δf_{FS} =	-	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	-	Years	
Total remaining fatigue life, N_f	-	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	-	Years	GS 3

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 3 (L14-L15)** Date:

Assumptions:

1. Controlling fatigue detail is the fastened connection.

General Requirements (GS 1.4 and 1.6)

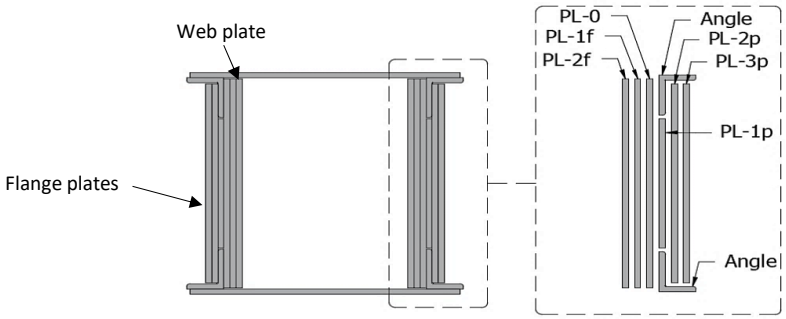
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all other provisions of Section 1.6?	**Yes**	Yes

Member Cross Section Inputs

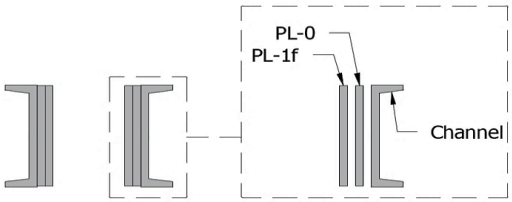
General:

Steel yield strength, F_y	**33.0**	ksi	Fastener diameter, d_{fast}	**0.8750**	in
Steel tensile strength, F_u	**60.0**	ksi	Fastener hole diameter, d_{hole}	0.9375	in
Is it a box (continuous top & bot webs)?	**Yes**	Yes or No	Are the fastener holes staggered?	**No**	Yes or No
Does the member have rolled channels?	**Yes**	Yes or No	Fastener type	**Rivet**	Bolt or Rivet
Is the member a built-up I-section?	**No**	Yes or No	Are holes punched full size?	**No**	Yes or No

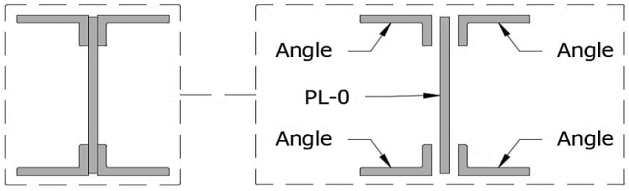
Reference sketch 1.1: Exploded view of built-up channel.



Reference sketch 1.2: Exploded view of rolled channel with additional flange plates.



Reference sketch 1.3: Exploded view of built-up I-section.



Web Plate Dimensions:	**top**	**bot**	
Web Plate Width, $b_{f.i}$	**17.000**	**17.000**	in
Web Plate Thickness, $t_{f.i}$	**0.375**	**0.375**	in
Hand Hole Width, $w_{hh.i}$	**7.500**	**7.500**	in

Fastener Location Dimensions in Web Plates: Plate(i):	**top**	**bot**	
Holes in Web Plate, $N_{holes.i}$	**2**	**2**	holes
Distance to Hole 1, $d_{h.wp.i}$	**2.0000**	**2.0000**	in

Internal Redundancy of Built-up Member: Multi-component Axial

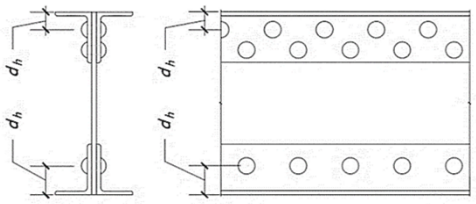
Member ID: **Sect 3 (L14-L15)** Date:

Flange Plate Dimensions (in):

Number of Full-Depth Flange Plates, $N_{fl.full}$	0	0 to 3
Number of Partial-Depth Flange Plates, $N_{fl.part}$	0	0 to 3

Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p	
$d_{fl,i}$	0.000	0.000	**0.000**	0.000	0.000	0.000	in
$t_{fl,i}$	0.0000	0.0000	**0.0000**	0.0000	0.0000	0.0000	in

Reference sketch 1.4: Distance to hole, d_h



Fastener Location Dimensions in Flange Plates:

Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p	
Holes in Flange Plate, $N_{holes.i}$	0	0	**0**	0	0	0	
Distance to Hole 1, $d_{h.fl.i}$	0.000	0.000	**0.000**	0.000	0.000	0.000	in

Angle Dimensions: (*Note: angle orientation is not important*)

Select the size of the angles		
Gross area of a single angle, $A_{agl.g}$		in^2
Thickness of the angle, t_{agl}		in
Holes in Vert Angle Leg, $N_{holes.vt.agl}$	0	holes
Holes in Horz Angle Leg, $N_{holes.hz.agl}$	0	holes

Rolled Channel Dimensions:

Select the size of the rolled channel	**C15x40**	
Gross area of one rolled channel, $A_{ch.g}$	11.8	in^2
Thickness of the channel flange, $t_{ch.fl}$	0.65	in
Thickness of the channel web, $t_{ch.web}$	0.52	in
Holes in the channel web, $N_{holes.ch.web}$	**0**	holes
Holes in the channel flanges, $N_{holes.ch.flange}$	**2**	holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	**326**	trucks/day	Current Year, $Y_{current}$	**2022**	year
$(ADTT_{sl})_0$	**200**	trucks/day	Span Length, L	**441.00**	ft
$(ADTT_{sl})_{limit}$	**20,000**	trucks/day	Number of striped lanes, n_L	**1**	lanes
Year Built, Y_{built}	**1956**	year	Stress-Range Estimate Partial LF, R_s	**1.00**	
Expected annual $(ADTT)_{SL}$ growth rate, g	**0.010**	MBE 7.2.5.1	No. of Stress-Range Cycles per Truck, n	**1**	cycle

Note: Growth rate is for future growth from today on

Loads:

P_{DC}	**288**	kip	P_{LL+IM}	**201**	kip
P_{DW}	**25**	kip	P_{FAT+IM}	**73**	kip

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override [ ] Override or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Load Factors (GS Table 1.7.1-1 and Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD A6.5.4.2):

Tension, Yield on Gross Section, ϕ_y	0.95
Tension, Fracture on Net Section, ϕ_u	0.80

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 3 (L14-L15)** Date:

Gross Area and Net Area Calculations

This section of the spreadsheet calculates faulted section areas to be used in strength limit checks and determining the controlling live load stress range in order to calculate the fatigue life in the faulted state. Due to application of the bending stress factor, Ξ_B, the controlling case may be the largest gross area plate or it may be a smaller plate positioned exterior within the section. Refer to Guide Specifications C1.6.1 for further information on "interior" and "exterior" plate positions. If there are staggered holes, the user must manually enter the controlling net area for each component, taking into account the pitch and gage of staggered hole patterns (See AASHTO LRFD 6.8.3) for strength calculations. Enter these values below under "Net (Str.)". If the holes are not staggered, the user need not manually enter net areas. **Net areas are always automatically calculated for fatigue life prediction**.

Faulted Section Scenarios:

Case 0: Assumes failure of plate PL-0

Case 1f: Assumes failure of plate PL-1f, if applicable

Case 2f: Assumes failure of plate PL-2f, if applicable

Case 2p: Assumes failure of plate PL-2p, if applicable

Case 3p: Assumes failure of plate PL-3p, if applicable

Case CH: Assumes failure of the rolled channel, if applicable

Case WP: Assumes failure of the largest net web plate, if applicable

Component	Unfaulted Areas			Faulted Net Areas for Fatigue Life Calculations						
	Gross	Net (Fat.)	Net (Str.)	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
	A_g (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)
PL-2f	0.00	0.00								
PL-1f	0.00	0.00								
PL-0	0.00	0.00								
Angles	0.00	0.00								
Channel	11.80	10.58								
PL-1p	0.00	0.00								
PL-2p	0.00	0.00								
PL-3p	0.00	0.00								
WP-top	6.38	2.86								
WP-bot	6.38	2.86								
Half Symmetry Total	**18.18**	**13.44**		13.44	0.00	0.00	0.00	0.00	**2.86**	**12.01**
Full Member Total	**36.35**	**26.88**		26.88	0.00	0.00	0.00	0.00	**16.30**	**24.02**

		Faulted Net Areas for Strength Checks						
		Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
		A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)
Half Symmetry Total	**0.00**	13.44	0.00	0.00	0.00	0.00	**2.86**	**12.01**
Full Member Total	**0.00**	26.88	0.00	0.00	0.00	0.00	**16.30**	**24.02**

	Faulted Gross Areas						
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)
Half Symmetry Total	18.18	0.00	0.00	0.00	0.00	**6.38**	**14.99**
Full Member Total	36.35	0.00	0.00	0.00	0.00	**24.55**	**29.98**

	Area, (in^2)		Area, (in^2)		Area, (in^2)
Holes, angles	0.00	Holes, PL-3p	0.00		
Holes, PL-2f	0.00	Holes, PL-1p	0.00	Holes, Web-top	3.52
Holes, PL-1f	0.00	Holes, PL-2p	0.00	Holes, Web-bot	3.52
Holes, PL-0	0.00	Holes-channel	1.22		

Stress Amplification Factors (GS 2.2)

Stress Amplifiers (GS Table 2.2.1-1)**:**

Shear Lag Factor, Ξ_{VL}	1.20
Number of web plates, N_{web}	1
Number of flange plates, N_{fl}	1
Number of total plates, N_{AX}	2
Bending Factor, Ξ_B	1.24

40-over-fastener Rule **Required?** (GS 2.2.1.1)**:** -

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 3 (L14-L15)** Date:

Strength Capacity Check (GS 2.2 & 2.3)

Factored Load:

$P_u = \gamma_{DC} P_{DC} + \gamma_{DW} P_{DW} + \gamma_{LL} P_{LL+IM} =$ 663.9 kip GS Eq. 1.7.2-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u =$ 48.0 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y =$ 31.4 ksi GS Eq. 2.3-1

Factored Stress (Strength Limit State): (*Note:* Ξ_B & Ξ_{VL} = 1.0)

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_u / 2A_{AFN}) =$	24.70	0.00	0.00	0.00	0.00	116.08	27.64	GS Eq. 2.2.1-1
$f_{AFG} = \Xi_B \Xi_{VL} (P_u / 2A_{AFG}) =$	18.26	0.00	0.00	0.00	0.00	52.07	22.15	GS Eq. 2.2.1-2

Strength Criteria Check:

$f_{AFG} \le f_{u,g}$? 0.41 NG OK or NG GS Eq. 2.3-1

$f_{AFN} \le f_{u,n}$? 0.60 NG OK or NG GS Eq. 2.3-2

Fatigue Life Estimate (GS 2.5)

Effective Stress Range & Max Stress Range in Unfaulted State:

$R_p =$	1.03		MBE Eq. 7.2.2.1-1
Unfaulted state stress range, $\Delta f =$	2.17	ksi	
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	2.24	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	4.93	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-2
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.00	ksi	
Resistance Factor for evaluation, R_R	1.0		MBE Table 7.2.5.2-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 3 (L14-L15)** Date:

Effective Stress Range & Max Stress Range in Faulted State:

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_{FAT+IM} / 2A_{AFN}) =$	2.61	0.00	0.00	0.00	0.00	**15.20**	**3.62**	GS Eq. 2.2.1-1

40-over-fastener Rule (GS 2.2.1.1):

Load in an angle, $P_{FAT+IM-L}$	-	kip	
$f_{AFN} = P_{FAT+IM} / A_N + 0.4P_{FAT+IM-L} / I_f t_p =$	-	ksi	
Faulted state stress range, Δf =	15.20	ksi	
Faulted state effective stress range, $(\Delta f)_{eff}$ =	15.66	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	34.45	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-2
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.00	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	1.15E+06	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	9.2	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	353	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**9.2**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I(b)**	I(a), I(b), II	GS 2.5

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, NU	66.0	Years	GS 2.5.3
Total finite fatigue life only in unfaulted state, Yu	-	Years	GS 2.5.3
Total remaining fatigue life only in faulted state, Yf	-	Years	GS 2.5.3
Total remaining fatigue life, Nf = Yf(1-Nu/Yu)	**9.2**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**NG**	OK or NG	GS 2.3
Fatigue case =	-	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	-	ksi	
Controlling stress range in faulted state, Δf_{FS} =	-	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	-	Years	
Total remaining fatigue life, N_f	-	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	-	Years	GS 3

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 4 (L4-U5 -SL)** Date:

Assumptions:

1. Controlling fatigue detail is the fastened connection.

General Requirements (GS 1.4 and 1.6)

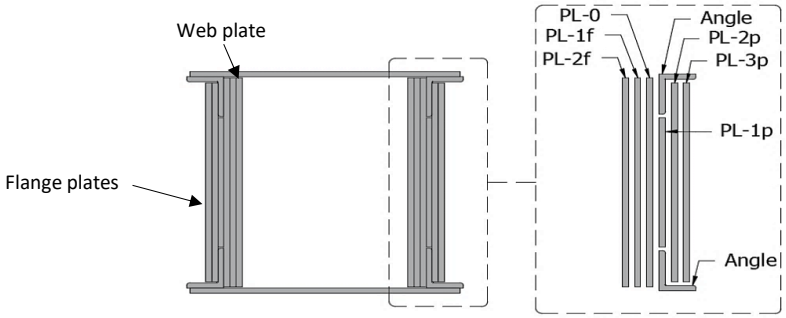
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all other provisions of Section 1.6?	**Yes**	Yes

Member Cross Section Inputs

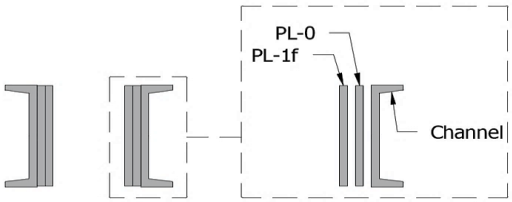
General:

Steel yield strength, F_y	**33.0**	ksi	Fastener diameter, d_{fast}	**0.8750**	in
Steel tensile strength, F_u	**60.0**	ksi	Fastener hole diameter, d_{hole}	0.9375	in
Is it a box (continuous top & bot webs)?	**Yes**	Yes or No	Are the fastener holes staggered?	**No**	Yes or No
Does the member have rolled channels?	**Yes**	Yes or No	Fastener type	**Rivet**	Bolt or Rivet
Is the member a built-up I-section?	**No**	Yes or No	Are holes punched full size?	**No**	Yes or No

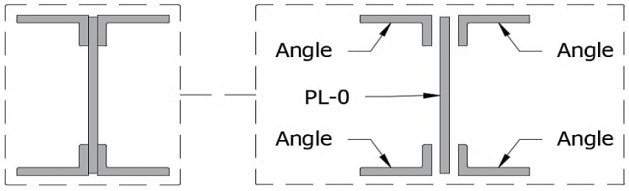
Reference sketch 1.1: Exploded view of built-up channel.



Reference sketch 1.2: Exploded view of rolled channel with additional flange plates.



Reference sketch 1.3: Exploded view of built-up I-section.



Web Plate Dimensions:	**top**	**bot**	
Web Plate Width, $b_{f.i}$	**17.000**	**17.000**	in
Web Plate Thickness, $t_{f.i}$	**0.375**	**0.375**	in
Hand Hole Width, $w_{hh.i}$	**7.500**	**7.500**	in

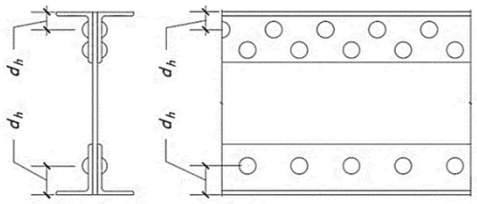
Fastener Location Dimensions in Web Plates:			
Plate(i):	**top**	**bot**	
Holes in Web Plate, $N_{holes.i}$	**2**	**2**	holes
Distance to Hole 1, $d_{h.wp.i}$	**2.0000**	**2.0000**	in

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 4 (L4-U5 -SL)** Date:

Flange Plate Dimensions (in):

Reference sketch 1.4: Distance to hole, d_h



Number of Full-Depth Flange Plates, $N_{fl.full}$			0				0 to 3
Number of Partial-Depth Flange Plates, $N_{fl.part}$			0				0 to 3
Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p	
$d_{fl,i}$	0.000	0.000	0.000	0.000	0.000	0.000	in
$t_{fl,i}$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	in

Fastener Location Dimensions in Flange Plates:

Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p	
Holes in Flange Plate, $N_{holes.i}$	0	0	0	0	0	0	
Distance to Hole 1, $d_{h.fl.i}$	0.000	0.000	0.000	0.000	0.000	0.000	in

Angle Dimensions: (*Note: angle orientation is not important*)

Select the size of the angles		
Gross area of a single angle, $A_{agl.g}$		in^2
Thickness of the angle, t_{agl}		in
Holes in Vert Angle Leg, $N_{holes.vt.agl}$	0	holes
Holes in Horz Angle Leg, $N_{holes.hz.agl}$	0	holes

Rolled Channel Dimensions:

Select the size of the rolled channel	C15x33.9-SL	
Gross area of one rolled channel, $A_{ch.g}$	9.2535	in^2
Thickness of the channel flange, $t_{ch.fl}$	0.65	in
Thickness of the channel web, $t_{ch.web}$	0.4	in
Holes in the channel web, $N_{holes.ch.web}$	0	holes
Holes in the channel flanges, $N_{holes.ch.flange}$	2	holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	326	trucks/day	Current Year, $Y_{current}$	2022	year
$(ADTT_{sl})_0$	200	trucks/day	Span Length, L	284.00	ft
$(ADTT_{sl})_{limit}$	20,000	trucks/day	Number of striped lanes, n_L	1	lanes
Year Built, Y_{built}	1956	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cycles per Truck, n	1	cycle

Note: Growth rate is for future growth from today on

Loads:

P_{DC}	230 kip	P_{LL+IM}	156 kip
P_{DW}	20 kip	P_{FAT+IM}	67 kip

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override [ ] Override or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Load Factors (GS Table 1.7.1-1 and Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD A6.5.4.2):

Tension, Yield on Gross Section, ϕ_y	0.95
Tension, Fracture on Net Section, ϕ_u	0.80

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 4 (L4-U5 -SL)** Date:

Gross Area and Net Area Calculations

This section of the spreadsheet calculates faulted section areas to be used in strength limit checks and determining the controlling live load stress range in order to calculate the fatigue life in the faulted state. Due to application of the bending stress factor, Ξ_B, the controlling case may be the largest gross area plate or it may be a smaller plate positioned exterior within the section. Refer to Guide Specifications C1.6.1 for further information on "interior" and "exterior" plate positions. If there are staggered holes, the user must manually enter the controlling net area for each component, taking into account the pitch and gage of staggered hole patterns (See AASHTO LRFD 6.8.3) for strength calculations. Enter these values below under "Net (Str.)". If the holes are not staggered, the user need not manually enter net areas. **Net areas are always automatically calculated for fatigue life prediction**.

Faulted Section Scenarios:

Case 0: Assumes failure of plate PL-0

Case 1f: Assumes failure of plate PL-1f, if applicable

Case 2f: Assumes failure of plate PL-2f, if applicable

Case 2p: Assumes failure of plate PL-2p, if applicable

Case 3p: Assumes failure of plate PL-3p, if applicable

Case CH: Assumes failure of the rolled channel, if applicable

Case WP: Assumes failure of the largest net web plate, if applicable

Component	Unfaulted Areas			Faulted Net Areas for Fatigue Life Calculations						
	Gross	Net (Fat.)	Net (Str.)	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
	A_g (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)
PL-2f	0.00	0.00								
PL-1f	0.00	0.00								
PL-0	0.00	0.00								
Angles	0.00	0.00								
Channel	9.25	8.03								
PL-1p	0.00	0.00								
PL-2p	0.00	0.00								
PL-3p	0.00	0.00								
WP-top	6.38	2.86								
WP-bot	6.38	2.86								
Half Symmetry Total	**15.63**	**10.89**		10.89	0.00	0.00	0.00	0.00	**2.86**	**9.46**
Full Member Total	**31.26**	**21.79**		21.79	0.00	0.00	0.00	0.00	**13.75**	**18.93**
				Faulted Net Areas for Strength Checks						
Half Symmetry Total			**0.00**	10.89	0.00	0.00	0.00	0.00	**2.86**	**9.46**
Full Member Total			**0.00**	21.79	0.00	0.00	0.00	0.00	**13.75**	**18.93**
				Faulted Gross Areas						
				Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
				A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)
Half Symmetry Total				15.63	0.00	0.00	0.00	0.00	**6.38**	**12.44**
Full Member Total				31.26	0.00	0.00	0.00	0.00	**22.00**	**24.88**

	Area, (in^2)		Area, (in^2)		Area, (in^2)
Holes, angles	0.00	Holes, PL-3p	0.00		
Holes, PL-2f	0.00	Holes, PL-1p	0.00	Holes, Web-top	3.52
Holes, PL-1f	0.00	Holes, PL-2p	0.00	Holes, Web-bot	3.52
Holes, PL-0	0.00	Holes-channel	1.22		

Stress Amplification Factors (GS 2.2)

Stress Amplifiers (GS Table 2.2.1-1)**:**

Shear Lag Factor, Ξ_{VL}	1.20
Number of web plates, N_{web}	1
Number of flange plates, N_{fl}	1
Number of total plates, N_{AX}	2
Bending Factor, Ξ_B	1.24

40-over-fastener Rule **Required?** (GS 2.2.1.1)**:** -

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: Sect 4 (L4-U5 -SL) Date:

Strength Capacity Check (GS 2.2 & 2.3)

Factored Load:

$P_u = \gamma_{DC} P_{DC} + \gamma_{DW} P_{DW} + \gamma_{LL} P_{LL+IM} =$ 523.3 kip GS Eq. 1.7.2-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u =$ 48.0 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y =$ 31.4 ksi GS Eq. 2.3-1

Factored Stress (Strength Limit State): (*Note:* Ξ_B & Ξ_{VL} = 1.0)

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_u / 2A_{AFN}) =$	24.02	0.00	0.00	0.00	0.00	91.50	27.64	GS Eq. 2.2.1-1
$f_{AFG} = \Xi_B \Xi_{VL} (P_u / 2A_{AFG}) =$	16.74	0.00	0.00	0.00	0.00	41.04	21.03	GS Eq. 2.2.1-2

Strength Criteria Check:

$f_{AFG} \le f_{u,g}$? 0.52 NG OK or NG GS Eq. 2.3-1

$f_{AFN} \le f_{u,n}$? 0.76 NG OK or NG GS Eq. 2.3-2

Fatigue Life Estimate (GS 2.5)

Effective Stress Range & Max Stress Range in Unfaulted State:

$R_p =$	1.02		MBE Eq. 7.2.2.1-1
Unfaulted state stress range, $\Delta f =$	2.44	ksi	
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	2.49	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	5.48	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-2
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.00	ksi	
Resistance Factor for evaluation, R_R	1.0		MBE Table 7.2.5.2-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: Sect 4 (L4-U5 -SL) Date:

Effective Stress Range & Max Stress Range in Faulted State:

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_{FAT+IM} / 2A_{AFN}) =$	2.93	0.00	0.00	0.00	0.00	**13.86**	**4.19**	GS Eq. 2.2.1-1

40-over-fastener Rule (GS 2.2.1.1):

Load in an angle, $P_{FAT+IM-L}$	-	kip	
$f_{AFN} = P_{FAT+IM} / A_N + 0.4P_{FAT+IM-L} / I_f t_p =$	-	ksi	

Faulted state stress range, Δf =	13.86	ksi	
Faulted state effective stress range, $(\Delta f)_{eff}$ =	14.13	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	31.08	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-2
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.00	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	1.56E+06	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	12.3	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	365	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8

Total faulted state remaining fatigue life, Y_{REM}	**12.3**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I(b)**	I(a), I(b), II	GS 2.5

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, NU	66.0	Years	GS 2.5.3
Total finite fatigue life only in unfaulted state, Yu	-	Years	GS 2.5.3
Total remaining fatigue life only in faulted state, Yf	-	Years	GS 2.5.3
Total remaining fatigue life, Nf = Yf(1-Nu/Yu)	**12.3**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**NG**	OK or NG	GS 2.3
Fatigue case =	-	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	-	ksi	
Controlling stress range in faulted state, Δf_{FS} =	-	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	-	Years	
Total remaining fatigue life, N_f	-	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	-	Years	GS 3

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 5 (L6-U7)** Date:

Assumptions:

1. Controlling fatigue detail is the fastened connection.

General Requirements (GS 1.4 and 1.6)

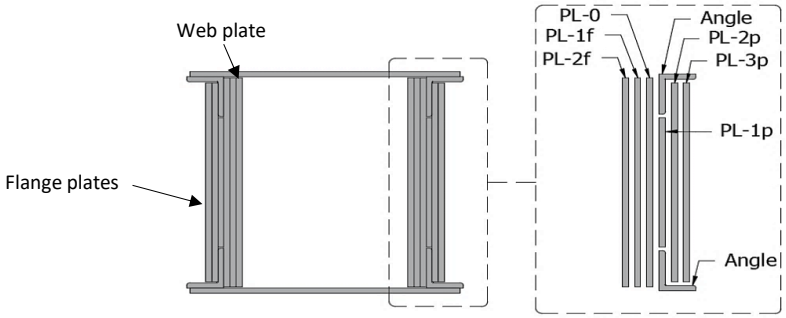
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all other provisions of Section 1.6?	**Yes**	Yes

Member Cross Section Inputs

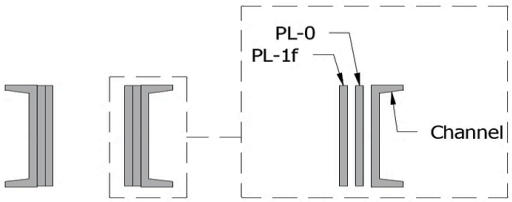
General:

Steel yield strength, F_y	**50.0**	ksi	Fastener diameter, d_{fast}	**0.8750**	in
Steel tensile strength, F_u	**70.0**	ksi	Fastener hole diameter, d_{hole}	0.9375	in
Is it a box (continuous top & bot webs)?	**Yes**	Yes or No	Are the fastener holes staggered?	**No**	Yes or No
Does the member have rolled channels?	**Yes**	Yes or No	Fastener type	**Rivet**	Bolt or Rivet
Is the member a built-up I-section?	**No**	Yes or No	Are holes punched full size?	**No**	Yes or No

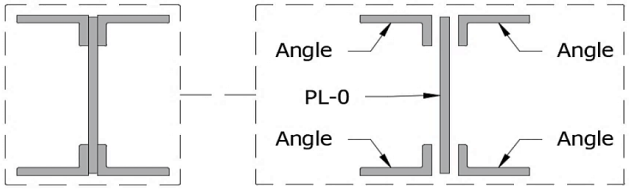
Reference sketch 1.1: Exploded view of built-up channel.



Reference sketch 1.2: Exploded view of rolled channel with additional flange plates.



Reference sketch 1.3: Exploded view of built-up I-section.



Web Plate Dimensions:	**top**	**bot**	
Web Plate Width, $b_{f.i}$	**17.000**	**17.000**	in
Web Plate Thickness, $t_{f.i}$	**0.375**	**0.375**	in
Hand Hole Width, $w_{hh.i}$	**7.500**	**7.500**	in

Fastener Location Dimensions in Web Plates: Plate(i):	**top**	**bot**	
Holes in Web Plate, $N_{holes.i}$	**2**	**2**	holes
Distance to Hole 1, $d_{h.wp.i}$	**2.0000**	**2.0000**	in

Internal Redundancy of Built-up Member: Multi-component Axial

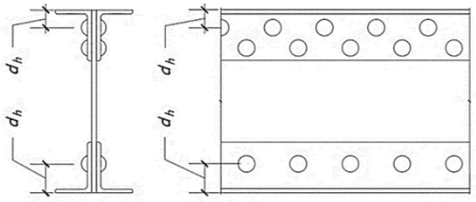
Member ID: **Sect 5 (L6-U7)** Date:

Flange Plate Dimensions (in):

Number of Full-Depth Flange Plates, $N_{fl.full}$	0	0 to 3
Number of Partial-Depth Flange Plates, $N_{fl.part}$	0	0 to 3

Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p	
$d_{fl,i}$	0.000	0.000	**0.000**	0.000	0.000	0.000	in
$t_{fl,i}$	0.0000	0.0000	**0.0000**	0.0000	0.0000	0.0000	in

Reference sketch 1.4: Distance to hole, d_h



Fastener Location Dimensions in Flange Plates:

Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p	
Holes in Flange Plate, $N_{holes.i}$	0	0	**0**	0	0	0	
Distance to Hole 1, $d_{h.fl.i}$	0.000	0.000	**0.000**	0.000	0.000	0.000	in

Angle Dimensions: (*Note: angle orientation is not important*)

Select the size of the angles		
Gross area of a single angle, $A_{agl.g}$		in^2
Thickness of the angle, t_{agl}		in
Holes in Vert Angle Leg, $N_{holes.vt.agl}$	0	holes
Holes in Horz Angle Leg, $N_{holes.hz.agl}$	0	holes

Rolled Channel Dimensions:

Select the size of the rolled channel	**C15x33.9**	
Gross area of one rolled channel, $A_{ch.g}$	9.95	in^2
Thickness of the channel flange, $t_{ch.fl}$	0.65	in
Thickness of the channel web, $t_{ch.web}$	0.4	in
Holes in the channel web, $N_{holes.ch.web}$	**0**	holes
Holes in the channel flanges, $N_{holes.ch.flange}$	**2**	holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	**326**	trucks/day	Current Year, $Y_{current}$	**2022**	year
$(ADTT_{sl})_0$	**200**	trucks/day	Span Length, L	**284.00**	ft
$(ADTT_{sl})_{limit}$	**20,000**	trucks/day	Number of striped lanes, n_L	**1**	lanes
Year Built, Y_{built}	**1956**	year	Stress-Range Estimate Partial LF, R_s	**1.00**	
Expected annual $(ADTT)_{SL}$ growth rate, g	**0.010**	MBE 7.2.5.1	No. of Stress-Range Cycles per Truck, n	**1**	cycle

Note: Growth rate is for future growth from today on

Loads:

P_{DC}	**425**	kip	P_{LL+IM}	**216**	kip
P_{DW}	**38**	kip	P_{FAT+IM}	**69**	kip

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override [ ] Override or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Load Factors (GS Table 1.7.1-1 and Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD A6.5.4.2):

Tension, Yield on Gross Section, ϕ_y	0.95
Tension, Fracture on Net Section, ϕ_u	0.80

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 5 (L6-U7)** Date:

Gross Area and Net Area Calculations

This section of the spreadsheet calculates faulted section areas to be used in strength limit checks and determining the controlling live load stress range in order to calculate the fatigue life in the faulted state. Due to application of the bending stress factor, Ξ_B, the controlling case may be the largest gross area plate or it may be a smaller plate positioned exterior within the section. Refer to Guide Specifications C1.6.1 for further information on "interior" and "exterior" plate positions. If there are staggered holes, the user must manually enter the controlling net area for each component, taking into account the pitch and gage of staggered hole patterns (See AASHTO LRFD 6.8.3) for strength calculations. Enter these values below under "Net (Str.)". If the holes are not staggered, the user need not manually enter net areas. **Net areas are always automatically calculated for fatigue life prediction**.

Faulted Section Scenarios:

Case 0: Assumes failure of plate PL-0

Case 1f: Assumes failure of plate PL-1f, if applicable

Case 2f: Assumes failure of plate PL-2f, if applicable

Case 2p: Assumes failure of plate PL-2p, if applicable

Case 3p: Assumes failure of plate PL-3p, if applicable

Case CH: Assumes failure of the rolled channel, if applicable

Case WP: Assumes failure of the largest net web plate, if applicable

Component	Unfaulted Areas			Faulted Net Areas for Fatigue Life Calculations						
	Gross	Net (Fat.)	Net (Str.)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)
	A_g (in^2)	A_n (in^2)	A_n (in^2)	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
PL-2f	0.00	0.00								
PL-1f	0.00	0.00								
PL-0	0.00	0.00								
Angles	0.00	0.00								
Channel	9.95	8.73								
PL-1p	0.00	0.00								
PL-2p	0.00	0.00								
PL-3p	0.00	0.00								
WP-top	6.38	2.86								
WP-bot	6.38	2.86								
Half Symmetry Total	**16.33**	**11.59**		11.59	0.00	0.00	0.00	0.00	**2.86**	**10.16**
Full Member Total	**32.65**	**23.18**		23.18	0.00	0.00	0.00	0.00	**14.45**	**20.32**
Faulted Net Areas for Strength Checks										
Half Symmetry Total			**0.00**	11.59	0.00	0.00	0.00	0.00	**2.86**	**10.16**
Full Member Total			**0.00**	23.18	0.00	0.00	0.00	0.00	**14.45**	**20.32**
Faulted Gross Areas										
				Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
				A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)
Half Symmetry Total				16.33	0.00	0.00	0.00	0.00	**6.38**	**13.14**
Full Member Total				32.65	0.00	0.00	0.00	0.00	**22.70**	**26.28**

	Area, (in^2)		Area, (in^2)		Area, (in^2)
Holes, angles	0.00	Holes, PL-3p	0.00		
Holes, PL-2f	0.00	Holes, PL-1p	0.00	Holes, Web-top	3.52
Holes, PL-1f	0.00	Holes, PL-2p	0.00	Holes, Web-bot	3.52
Holes, PL-0	0.00	Holes-channel	1.22		

Stress Amplification Factors (GS 2.2)

Stress Amplifiers (GS Table 2.2.1-1)**:**

Shear Lag Factor, Ξ_{VL}	1.20
Number of web plates, N_{web}	1
Number of flange plates, N_{fl}	1
Number of total plates, N_{AX}	2
Bending Factor, Ξ_B	1.24

40-over-fastener Rule **Required?** (GS 2.2.1.1)**:** -

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: Sect 5 (L6-U7) Date:

Strength Capacity Check (GS 2.2 & 2.3)

Factored Load:

$P_u = \gamma_{DC} P_{DC} + \gamma_{DW} P_{DW} + \gamma_{LL} P_{LL+IM} =$ 861.1 kip GS Eq. 1.7.2-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u =$ 56.0 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y =$ 47.5 ksi GS Eq. 2.3-1

Factored Stress (Strength Limit State): (*Note:* Ξ_B & Ξ_{VL} = 1.0)

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_u / 2A_{AFN}) =$	37.15	0.00	0.00	0.00	0.00	150.58	42.38	GS Eq. 2.2.1-1
$f_{AFG} = \Xi_B \Xi_{VL} (P_u / 2A_{AFG}) =$	26.37	0.00	0.00	0.00	0.00	67.54	32.77	GS Eq. 2.2.1-2

Strength Criteria Check:

$f_{AFG} \le f_{u,g}$? 0.37 NG OK or NG GS Eq. 2.3-1

$f_{AFN} \le f_{u,n}$? 0.70 NG OK or NG GS Eq. 2.3-2

Fatigue Life Estimate (GS 2.5)

Effective Stress Range & Max Stress Range in Unfaulted State:

$R_p =$	1.02		MBE Eq. 7.2.2.1-1
Unfaulted state stress range, $\Delta f =$	2.39	ksi	
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	2.43	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	5.35	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-2
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.00	ksi	
Resistance Factor for evaluation, R_R	1.0		MBE Table 7.2.5.2-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: Sect 5 (L6-U7) Date:

Effective Stress Range & Max Stress Range in Faulted State:

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_{FAT+IM} / 2A_{AFN}) =$	2.86	0.00	0.00	0.00	0.00	14.39	4.05	GS Eq. 2.2.1-1

40-over-fastener Rule (GS 2.2.1.1):

Load in an angle, $P_{FAT+IM-L}$	-	kip	
$f_{AFN} = P_{FAT+IM} / A_N + 0.4P_{FAT+IM-L} / I_f t_p =$	-	ksi	

Faulted state stress range, Δf =	14.39	ksi	
Faulted state effective stress range, $(\Delta f)_{eff}$ =	14.67	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	32.28	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-2
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.00	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	1.39E+06	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	11.0	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	360	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8

Total faulted state remaining fatigue life, Y_{REM}	**11.0**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I(b)**	I(a), I(b), II	GS 2.5

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, NU	66.0	Years	GS 2.5.3
Total finite fatigue life only in unfaulted state, Yu	-	Years	GS 2.5.3
Total remaining fatigue life only in faulted state, Yf	-	Years	GS 2.5.3
Total remaining fatigue life, Nf = Yf(1-Nu/Yu)	**11.0**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	NG	OK or NG	GS 2.3
Fatigue case =	-	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	-	ksi	
Controlling stress range in faulted state, Δf_{FS} =	-	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	-	Years	
Total remaining fatigue life, N_f	-	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	-	Years	GS 3

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 6 (U13-L14)** Date:

Assumptions:

1. Controlling fatigue detail is the fastened connection.

General Requirements (GS 1.4 and 1.6)

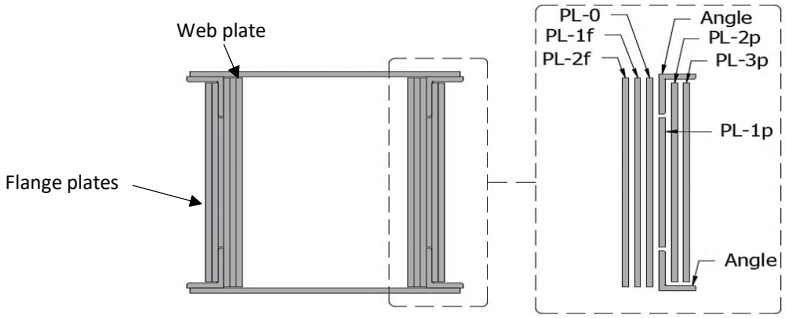
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all other provisions of Section 1.6?	**Yes**	Yes

Member Cross Section Inputs

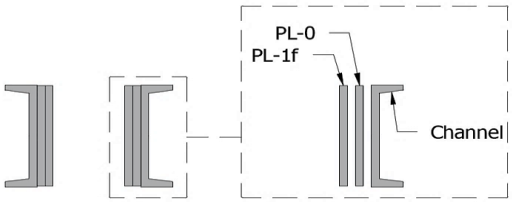
General:

Steel yield strength, F_y	**50.0**	ksi	Fastener diameter, d_{fast}	**0.8750**	in
Steel tensile strength, F_u	**70.0**	ksi	Fastener hole diameter, d_{hole}	0.9375	in
Is it a box (continuous top & bot webs)?	**Yes**	Yes or No	Are the fastener holes staggered?	**No**	Yes or No
Does the member have rolled channels?	**Yes**	Yes or No	Fastener type	**Rivet**	Bolt or Rivet
Is the member a built-up I-section?	**No**	Yes or No	Are holes punched full size?	**No**	Yes or No

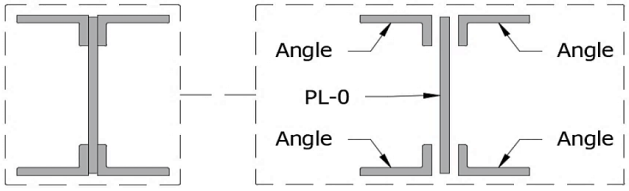
Reference sketch 1.1: Exploded view of built-up channel.



Reference sketch 1.2: Exploded view of rolled channel with additional flange plates.



Reference sketch 1.3: Exploded view of built-up I-section.



Web Plate Dimensions:	**top**	**bot**	
Web Plate Width, $b_{f.i}$	**17.000**	**17.000**	in
Web Plate Thickness, $t_{f.i}$	**0.375**	**0.375**	in
Hand Hole Width, $w_{hh.i}$	**7.500**	**7.500**	in

Fastener Location Dimensions in Web Plates: Plate(i):	**top**	**bot**	
Holes in Web Plate, $N_{holes.i}$	**2**	**2**	holes
Distance to Hole 1, $d_{h.wp.i}$	**1.7500**	**1.7500**	in

Internal Redundancy of Built-up Member: Multi-component Axial

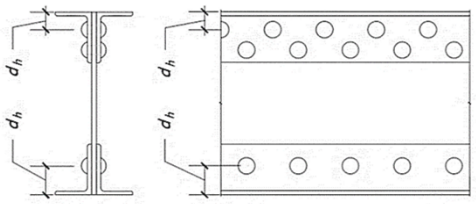
Member ID: **Sect 6 (U13-L14)** Date:

Flange Plate Dimensions (in):

Number of Full-Depth Flange Plates, $N_{fl.full}$	0	0 to 3
Number of Partial-Depth Flange Plates, $N_{fl.part}$	0	0 to 3

Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p	
$d_{fl,i}$	0.000	0.000	**0.000**	0.000	0.000	0.000	in
$t_{fl,i}$	0.0000	0.0000	**0.0000**	0.0000	0.0000	0.0000	in

Reference sketch 1.4: Distance to hole, d_h



Fastener Location Dimensions in Flange Plates:

Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p	
Holes in Flange Plate, $N_{holes.i}$	0	0	**0**	0	0	0	
Distance to Hole 1, $d_{h.fl.i}$	0.000	0.000	**0.000**	0.000	0.000	0.000	in

Angle Dimensions: (*Note: angle orientation is not important*)

Select the size of the angles		
Gross area of a single angle, $A_{agl.g}$		in^2
Thickness of the angle, t_{agl}		in
Holes in Vert Angle Leg, $N_{holes.vt.agl}$	0	holes
Holes in Horz Angle Leg, $N_{holes.hz.agl}$	0	holes

Rolled Channel Dimensions:

Select the size of the rolled channel	**C12x30**	
Gross area of one rolled channel, $A_{ch.g}$	8.81	in^2
Thickness of the channel flange, $t_{ch.fl}$	0.501	in
Thickness of the channel web, $t_{ch.web}$	0.51	in
Holes in the channel web, $N_{holes.ch.web}$	**0**	holes
Holes in the channel flanges, $N_{holes.ch.flange}$	**2**	holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	**326**	trucks/day	Current Year, $Y_{current}$	**2022**	year
$(ADTT_{sl})_0$	**200**	trucks/day	Span Length, L	**441.00**	ft
$(ADTT_{sl})_{limit}$	**20,000**	trucks/day	Number of striped lanes, n_L	**1**	lanes
Year Built, Y_{built}	**1956**	year	Stress-Range Estimate Partial LF, R_s	**1.00**	
Expected annual $(ADTT)_{SL}$ growth rate, g	**0.010**	MBE 7.2.5.1	No. of Stress-Range Cycles per Truck, n	**1**	cycle

Note: Growth rate is for future growth from today on

Loads:

P_{DC}	**344**	kip	P_{LL+IM}	**200**	kip
P_{DW}	**29**	kip	P_{FAT+IM}	**73**	kip

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override [ ] Override or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Load Factors (GS Table 1.7.1-1 and Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD A6.5.4.2):

Tension, Yield on Gross Section, ϕ_y	0.95
Tension, Fracture on Net Section, ϕ_u	0.80

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 6 (U13-L14)** Date:

Gross Area and Net Area Calculations

This section of the spreadsheet calculates faulted section areas to be used in strength limit checks and determining the controlling live load stress range in order to calculate the fatigue life in the faulted state. Due to application of the bending stress factor, Ξ_B, the controlling case may be the largest gross area plate or it may be a smaller plate positioned exterior within the section. Refer to Guide Specifications C1.6.1 for further information on "interior" and "exterior" plate positions. If there are staggered holes, the user must manually enter the controlling net area for each component, taking into account the pitch and gage of staggered hole patterns (See AASHTO LRFD 6.8.3) for strength calculations. Enter these values below under "Net (Str.)". If the holes are not staggered, the user need not manually enter net areas. **Net areas are always automatically calculated for fatigue life prediction**.

Faulted Section Scenarios:

Case 0: Assumes failure of plate PL-0

Case 1f: Assumes failure of plate PL-1f, if applicable

Case 2f: Assumes failure of plate PL-2f, if applicable

Case 2p: Assumes failure of plate PL-2p, if applicable

Case 3p: Assumes failure of plate PL-3p, if applicable

Case CH: Assumes failure of the rolled channel, if applicable

Case WP: Assumes failure of the largest net web plate, if applicable

Component	Unfaulted Areas			A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)
	Gross	Net (Fat.)	Net (Str.)	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
	A_g (in^2)	A_n (in^2)	A_n (in^2)	Faulted Net Areas for Fatigue Life Calculations						
PL-2f	0.00	0.00								
PL-1f	0.00	0.00								
PL-0	0.00	0.00								
Angles	0.00	0.00								
Channel	8.81	7.87								
PL-1p	0.00	0.00								
PL-2p	0.00	0.00								
PL-3p	0.00	0.00								
WP-top	6.38	2.86								
WP-bot	6.38	2.86								
Half Symmetry Total	**15.19**	**10.73**		10.73	0.00	0.00	0.00	0.00	**2.86**	**9.30**
Full Member Total	**30.37**	**21.46**		21.46	0.00	0.00	0.00	0.00	**13.59**	**18.60**
				Faulted Net Areas for Strength Checks						
Half Symmetry Total			**0.00**	10.73	0.00	0.00	0.00	0.00	**2.86**	**9.30**
Full Member Total			**0.00**	21.46	0.00	0.00	0.00	0.00	**13.59**	**18.60**
				Faulted Gross Areas						
				Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
				A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)
Half Symmetry Total				15.19	0.00	0.00	0.00	0.00	**6.38**	**12.00**
Full Member Total				30.37	0.00	0.00	0.00	0.00	**21.56**	**24.00**

	Area, (in^2)		Area, (in^2)		Area, (in^2)
Holes, angles	0.00	Holes, PL-3p	0.00		
Holes, PL-2f	0.00	Holes, PL-1p	0.00	Holes, Web-top	3.52
Holes, PL-1f	0.00	Holes, PL-2p	0.00	Holes, Web-bot	3.52
Holes, PL-0	0.00	Holes-channel	0.94		

Stress Amplification Factors (GS 2.2)

Stress Amplifiers (GS Table 2.2.1-1)**:**

Shear Lag Factor, Ξ_{VL}	1.20
Number of web plates, N_{web}	1
Number of flange plates, N_{fl}	1
Number of total plates, N_{AX}	2
Bending Factor, Ξ_B	1.24

40-over-fastener Rule **Required?** (GS 2.2.1.1)**:** -

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 6 (U13-L14)** Date:

Strength Capacity Check (GS 2.2 & 2.3)

Factored Load:

$P_u = \gamma_{DC} P_{DC} + \gamma_{DW} P_{DW} + \gamma_{LL} P_{LL+IM} =$ 732.5 kip GS Eq. 1.7.2-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u =$ 56.0 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y =$ 47.5 ksi GS Eq. 2.3-1

Factored Stress (Strength Limit State): (*Note:* Ξ_B & Ξ_{VL} = 1.0)

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_u / 2A_{AFN}) =$	34.14	0.00	0.00	0.00	0.00	128.09	39.38	GS Eq. 2.2.1-1
$f_{AFG} = \Xi_B \Xi_{VL} (P_u / 2A_{AFG}) =$	24.12	0.00	0.00	0.00	0.00	57.45	30.53	GS Eq. 2.2.1-2

Strength Criteria Check:

$f_{AFG} \le f_{u,g}$? 0.44 NG OK or NG GS Eq. 2.3-1

$f_{AFN} \le f_{u,n}$? 0.83 NG OK or NG GS Eq. 2.3-2

Fatigue Life Estimate (GS 2.5)

Effective Stress Range & Max Stress Range in Unfaulted State:

$R_p =$	1.03		MBE Eq. 7.2.2.1-1
Unfaulted state stress range, $\Delta f =$	2.71	ksi	
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	2.79	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	6.14	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-2
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.00	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.2-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: Sect 6 (U13-L14) Date:

Effective Stress Range & Max Stress Range in Faulted State:

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_{FAT+IM} / 2A_{AFN}) =$	3.25	0.00	0.00	0.00	0.00	15.13	4.65	GS Eq. 2.2.1-1

40-over-fastener Rule (GS 2.2.1.1):

Load in an angle, $P_{FAT+IM-L}$	-	kip	
$f_{AFN} = P_{FAT+IM} / A_N + 0.4P_{FAT+IM-L} / I_f t_p =$	-	ksi	

Faulted state stress range, Δf =	15.13	ksi	
Faulted state effective stress range, $(\Delta f)_{eff}$ =	15.58	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	34.29	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-2
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.00	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	1.16E+06	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	9.3	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	354	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8

Total faulted state remaining fatigue life, Y_{REM}	**9.3**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I(b)**	I(a), I(b), II	GS 2.5

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, NU	66.0	Years	GS 2.5.3
Total finite fatigue life only in unfaulted state, Yu	-	Years	GS 2.5.3
Total remaining fatigue life only in faulted state, Yf	-	Years	GS 2.5.3
Total remaining fatigue life, Nf = Yf(1-Nu/Yu)	**9.3**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	NG	OK or NG	GS 2.3
Fatigue case =	-	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	-	ksi	
Controlling stress range in faulted state, Δf_{FS} =	-	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	-	Years	
Total remaining fatigue life, N_f	-	Years	GS Eq. 2.5.3-1

Maximum Interval for Special Inspections = - Years GS 3

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 7 (U1-L2)- Not Passing** Date:

Assumptions:

1. Controlling fatigue detail is the fastened connection.

General Requirements (GS 1.4 and 1.6)

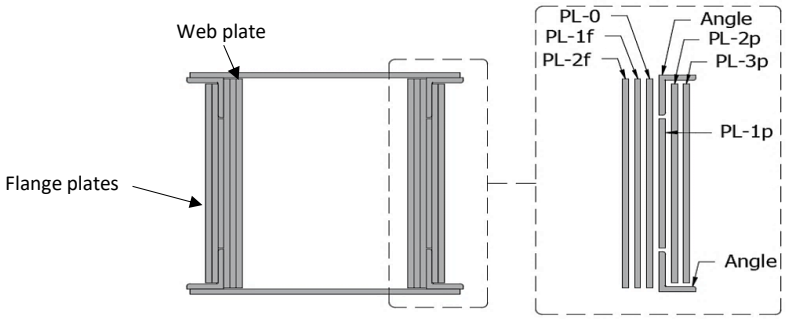
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all other provisions of Section 1.6?	**Yes**	Yes

Member Cross Section Inputs

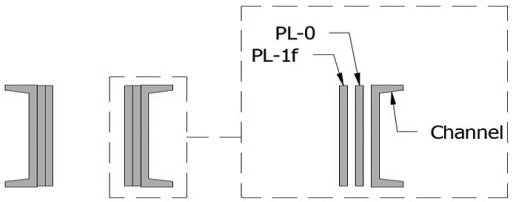
General:

Steel yield strength, F_y	**33.0**	ksi	Fastener diameter, d_{fast}	**0.8750**	in
Steel tensile strength, F_u	**60.0**	ksi	Fastener hole diameter, d_{hole}	0.9375	in
Is it a box (continuous top & bot webs)?	**Yes**	Yes or No	Are the fastener holes staggered?	**No**	Yes or No
Does the member have rolled channels?	**Yes**	Yes or No	Fastener type	**Rivet**	Bolt or Rivet
Is the member a built-up I-section?	**No**	Yes or No	Are holes punched full size?	**No**	Yes or No

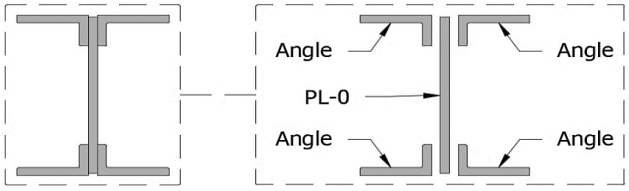
Reference sketch 1.1: Exploded view of built-up channel.



Reference sketch 1.2: Exploded view of rolled channel with additional flange plates.



Reference sketch 1.3: Exploded view of built-up I-section.



Web Plate Dimensions:	**top**	**bot**	
Web Plate Width, $b_{f.i}$	**17.000**	**17.000**	in
Web Plate Thickness, $t_{f.i}$	**0.375**	**0.375**	in
Hand Hole Width, $w_{hh.i}$	**7.500**	**7.500**	in

Fastener Location Dimensions in Web Plates:

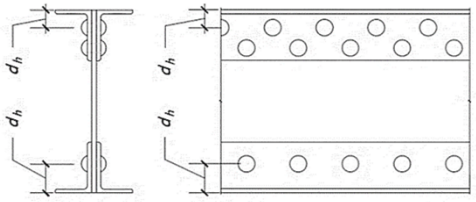
Plate(i):	**top**	**bot**	
Holes in Web Plate, $N_{holes.i}$	**2**	**2**	holes
Distance to Hole 1, $d_{h.wp.i}$	**1.7500**	**1.7500**	in

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 7 (U1-L2)- Not Passing** Date:

Flange Plate Dimensions (in):

Reference sketch 1.4: Distance to hole, d_h



Number of Full-Depth Flange Plates, $N_{fl.full}$			0				0 to 3
Number of Partial-Depth Flange Plates, $N_{fl.part}$			0				0 to 3
Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p	
$d_{fl,i}$	0.000	0.000	0.000	0.000	0.000	0.000	in
$t_{fl,i}$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	in

Fastener Location Dimensions in Flange Plates:

Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p	
Holes in Flange Plate, $N_{holes.i}$	0	0	0	0	0	0	
Distance to Hole 1, $d_{h.fl.i}$	0.000	0.000	0.000	0.000	0.000	0.000	in

Angle Dimensions: (*Note: angle orientation is not important*)

Select the size of the angles		
Gross area of a single angle, $A_{agl.g}$		in^2
Thickness of the angle, t_{agl}		in
Holes in Vert Angle Leg, $N_{holes.vt.agl}$	0	holes
Holes in Horz Angle Leg, $N_{holes.hz.agl}$	0	holes

Rolled Channel Dimensions:

Select the size of the rolled channel	C12x25	
Gross area of one rolled channel, $A_{ch.g}$	7.34	in^2
Thickness of the channel flange, $t_{ch.fl}$	0.501	in
Thickness of the channel web, $t_{ch.web}$	0.387	in
Holes in the channel web, $N_{holes.ch.web}$	0	holes
Holes in the channel flanges, $N_{holes.ch.flange}$	2	holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	326	trucks/day	Current Year, $Y_{current}$	2022	year
$(ADTT_{sl})_0$	200	trucks/day	Span Length, L	284.00	ft
$(ADTT_{sl})_{limit}$	20,000	trucks/day	Number of striped lanes, n_L	1	lanes
Year Built, Y_{built}	1956	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cycles per Truck, n	1	cycle

Note: Growth rate is for future growth from today on

Loads:

P_{DC}	176	kip	P_{LL+IM}	166	kip
P_{DW}	17	kip	P_{FAT+IM}	64	kip

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override [ ] Override or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Load Factors (GS Table 1.7.1-1 and Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD A6.5.4.2):

Tension, Yield on Gross Section, ϕ_y	0.95
Tension, Fracture on Net Section, ϕ_u	0.80

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 7 (U1-L2)- Not Passing** Date:

Gross Area and Net Area Calculations

This section of the spreadsheet calculates faulted section areas to be used in strength limit checks and determining the controlling live load stress range in order to calculate the fatigue life in the faulted state. Due to application of the bending stress factor, Ξ_B, the controlling case may be the largest gross area plate or it may be a smaller plate positioned exterior within the section. Refer to Guide Specifications C1.6.1 for further information on "interior" and "exterior" plate positions. If there are staggered holes, the user must manually enter the controlling net area for each component, taking into account the pitch and gage of staggered hole patterns (See AASHTO LRFD 6.8.3) for strength calculations. Enter these values below under "Net (Str.)". If the holes are not staggered, the user need not manually enter net areas. **Net areas are always automatically calculated for fatigue life prediction**.

Faulted Section Scenarios:

Case 0: Assumes failure of plate PL-0
Case 1f: Assumes failure of plate PL-1f, if applicable
Case 2f: Assumes failure of plate PL-2f, if applicable
Case 2p: Assumes failure of plate PL-2p, if applicable
Case 3p: Assumes failure of plate PL-3p, if applicable
Case CH: Assumes failure of the rolled channel, if applicable
Case WP: Assumes failure of the largest net web plate, if applicable

Component	Unfaulted Areas			Faulted Net Areas for Fatigue Life Calculations						
	Gross	Net (Fat.)	Net (Str.)	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
	A_g (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)
PL-2f	0.00	0.00								
PL-1f	0.00	0.00								
PL-0	0.00	0.00								
Angles	0.00	0.00								
Channel	7.34	6.40								
PL-1p	0.00	0.00								
PL-2p	0.00	0.00								
PL-3p	0.00	0.00								
WP-top	6.38	2.86								
WP-bot	6.38	2.86								
Half Symmetry Total	**13.72**	**9.26**		9.26	0.00	0.00	0.00	0.00	**2.86**	**7.83**
Full Member Total	**27.43**	**18.52**		18.52	0.00	0.00	0.00	0.00	**12.12**	**15.66**

		Faulted Net Areas for Strength Checks						
		Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
		A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)
Half Symmetry Total	**0.00**	9.26	0.00	0.00	0.00	0.00	**2.86**	**7.83**
Full Member Total	**0.00**	18.52	0.00	0.00	0.00	0.00	**12.12**	**15.66**

	Faulted Gross Areas						
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)
Half Symmetry Total	13.72	0.00	0.00	0.00	0.00	**6.38**	**10.53**
Full Member Total	27.43	0.00	0.00	0.00	0.00	**20.09**	**21.06**

	Area, (in^2)		Area, (in^2)		Area, (in^2)
Holes, angles	0.00	Holes, PL-3p	0.00		
Holes, PL-2f	0.00	Holes, PL-1p	0.00	Holes, Web-top	3.52
Holes, PL-1f	0.00	Holes, PL-2p	0.00	Holes, Web-bot	3.52
Holes, PL-0	0.00	Holes-channel	0.94		

Stress Amplification Factors (GS 2.2)

Stress Amplifiers (GS Table 2.2.1-1)**:**

Shear Lag Factor, Ξ_{VL}	1.20
Number of web plates, N_{web}	1
Number of flange plates, N_{fl}	1
Number of total plates, N_{AX}	2
Bending Factor, Ξ_B	1.24

40-over-fastener Rule **Required?** (GS 2.2.1.1)**:** -

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 7 (U1-L2)- Not Passing** Date:

Strength Capacity Check (GS 2.2 & 2.3)

Factored Load:

$P_u = \gamma_{DC} P_{DC} + \gamma_{DW} P_{DW} + \gamma_{LL} P_{LL+IM} =$ 472.8 kip GS Eq. 1.7.2-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u =$ 48.0 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y =$ 31.4 ksi GS Eq. 2.3-1

Factored Stress (Strength Limit State): (*Note:* Ξ_B & Ξ_{VL} = 1.0)

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_u / 2A_{AFN}) =$	25.53	0.00	0.00	0.00	0.00	82.67	30.19	GS Eq. 2.2.1-1
$f_{AFG} = \Xi_B \Xi_{VL} (P_u / 2A_{AFG}) =$	17.23	0.00	0.00	0.00	0.00	37.08	22.45	GS Eq. 2.2.1-2

Strength Criteria Check:

$f_{AFG} \le f_{u,g}$? 0.58 **NG** OK or NG GS Eq. 2.3-1

$f_{AFN} \le f_{u,n}$? 0.85 **NG** OK or NG GS Eq. 2.3-2

Fatigue Life Estimate (GS 2.5)

Effective Stress Range & Max Stress Range in Unfaulted State:

$R_p =$	1.02		MBE Eq. 7.2.2.1-1
Unfaulted state stress range, $\Delta f =$	2.75	ksi	
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	2.80	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	6.16	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-2
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.00	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.2-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 7 (U1-L2)- Not Passing** Date:

Effective Stress Range & Max Stress Range in Faulted State:

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_{FAT+IM} / 2A_{AFN}) =$	3.30	0.00	0.00	0.00	0.00	**13.24**	**4.84**	GS Eq. 2.2.1-1

40-over-fastener Rule (GS 2.2.1.1):

Load in an angle, $P_{FAT+IM-L}$	-	kip	
$f_{AFN} = P_{FAT+IM} / A_N + 0.4P_{FAT+IM-L} / I_f t_p =$	-	ksi	

Faulted state stress range, Δf =	13.24	ksi	
Faulted state effective stress range, $(\Delta f)_{eff}$ =	13.50	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	29.70	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-2
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.00	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	1.79E+06	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	13.9	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	371	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8

Total faulted state remaining fatigue life, Y_{REM}	**13.9**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I(b)**	I(a), I(b), II	GS 2.5

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, NU	66.0	Years	GS 2.5.3
Total finite fatigue life only in unfaulted state, Yu	-	Years	GS 2.5.3
Total remaining fatigue life only in faulted state, Yf	-	Years	GS 2.5.3
Total remaining fatigue life, Nf = Yf(1-Nu/Yu)	**13.9**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**NG**	OK or NG	GS 2.3
Fatigue case =	-	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	-	ksi	
Controlling stress range in faulted state, Δf_{FS} =	-	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	-	Years	
Total remaining fatigue life, N_f	-	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	-	Years	GS 3

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 7 (L2'-U3'-SL)- Passing** Date:

Assumptions:

1. Controlling fatigue detail is the fastened connection.

General Requirements (GS 1.4 and 1.6)

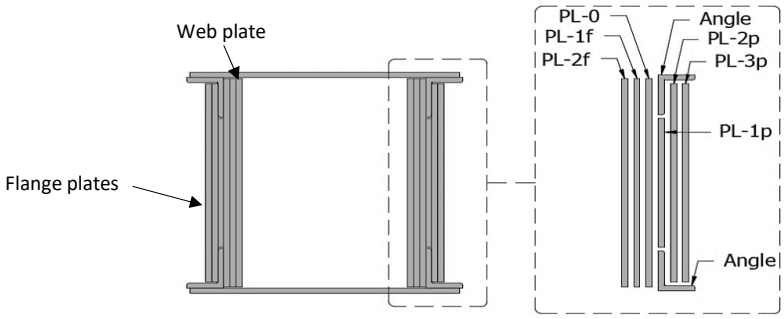
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all other provisions of Section 1.6?	**Yes**	Yes

Member Cross Section Inputs

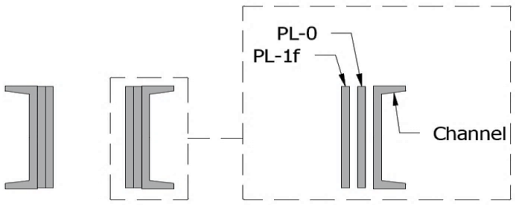
General:

Steel yield strength, F_y	**33.0**	ksi	Fastener diameter, d_{fast}	**0.8750**	in
Steel tensile strength, F_u	**60.0**	ksi	Fastener hole diameter, d_{hole}	0.9375	in
Is it a box (continuous top & bot webs)?	**Yes**	Yes or No	Are the fastener holes staggered?	**No**	Yes or No
Does the member have rolled channels?	**Yes**	Yes or No	Fastener type	**Rivet**	Bolt or Rivet
Is the member a built-up I-section?	**No**	Yes or No	Are holes punched full size?	**No**	Yes or No

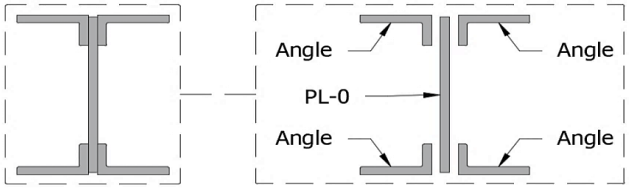
Reference sketch 1.1: Exploded view of built-up channel.



Reference sketch 1.2: Exploded view of rolled channel with additional flange plates.



Reference sketch 1.3: Exploded view of built-up I-section.



Web Plate Dimensions:	**top**	**bot**	
Web Plate Width, $b_{f.i}$	**17.000**	**17.000**	in
Web Plate Thickness, $t_{f.i}$	**0.375**	**0.375**	in
Hand Hole Width, $w_{hh.i}$	**7.500**	**7.500**	in

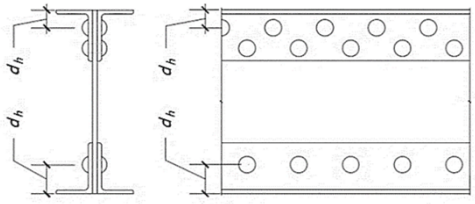
Fastener Location Dimensions in Web Plates: Plate(i):	**top**	**bot**	
Holes in Web Plate, $N_{holes.i}$	**2**	**2**	holes
Distance to Hole 1, $d_{h.wp.i}$	**1.7500**	**1.7500**	in

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 7 (L2'-U3'-SL)- Passing** Date:

Flange Plate Dimensions (in):

Reference sketch 1.4: Distance to hole, d_h



Number of Full-Depth Flange Plates, $N_{fl.full}$			0				0 to 3
Number of Partial-Depth Flange Plates, $N_{fl.part}$			0				0 to 3
Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p	
$d_{fl,i}$	0.000	0.000	0.000	0.000	0.000	0.000	in
$t_{fl,i}$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	in

Fastener Location Dimensions in Flange Plates:

Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p	
Holes in Flange Plate, $N_{holes.i}$	0	0	0	0	0	0	
Distance to Hole 1, $d_{h.fl.i}$	0.000	0.000	0.000	0.000	0.000	0.000	in

Angle Dimensions: (*Note: angle orientation is not important*)

Select the size of the angles		
Gross area of a single angle, $A_{agl.g}$		in^2
Thickness of the angle, t_{agl}		in
Holes in Vert Angle Leg, $N_{holes.vt.agl}$	0	holes
Holes in Horz Angle Leg, $N_{holes.hz.agl}$	0	holes

Rolled Channel Dimensions:

Select the size of the rolled channel	C12x25-SL	
Gross area of one rolled channel, $A_{ch.g}$	6.4592	in^2
Thickness of the channel flange, $t_{ch.fl}$	0.501	in
Thickness of the channel web, $t_{ch.web}$	0.387	in
Holes in the channel web, $N_{holes.ch.web}$	0	holes
Holes in the channel flanges, $N_{holes.ch.flange}$	2	holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	326	trucks/day	Current Year, $Y_{current}$	2022	year
$(ADTT_{sl})_0$	200	trucks/day	Span Length, L	284.00	ft
$(ADTT_{sl})_{limit}$	20,000	trucks/day	Number of striped lanes, n_L	1	lanes
Year Built, Y_{built}	1956	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cycles per Truck, n	1	cycle

Note: Growth rate is for future growth from today on

Loads:

P_{DC}	-36	kip	P_{LL+IM}	81	kip
P_{DW}	-5	kip	P_{FAT+IM}	64	kip

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override [ ] Override or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Load Factors (GS Table 1.7.1-1 and Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD A6.5.4.2):

Tension, Yield on Gross Section, ϕ_y	0.95
Tension, Fracture on Net Section, ϕ_u	0.80

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 7 (L2'-U3'-SL)- Passing** Date:

Gross Area and Net Area Calculations

This section of the spreadsheet calculates faulted section areas to be used in strength limit checks and determining the controlling live load stress range in order to calculate the fatigue life in the faulted state. Due to application of the bending stress factor, Ξ_B, the controlling case may be the largest gross area plate or it may be a smaller plate positioned exterior within the section. Refer to Guide Specifications C1.6.1 for further information on "interior" and "exterior" plate positions. If there are staggered holes, the user must manually enter the controlling net area for each component, taking into account the pitch and gage of staggered hole patterns (See AASHTO LRFD 6.8.3) for strength calculations. Enter these values below under "Net (Str.)". If the holes are not staggered, the user need not manually enter net areas. **Net areas are always automatically calculated for fatigue life prediction**.

Faulted Section Scenarios:

Case 0: Assumes failure of plate PL-0

Case 1f: Assumes failure of plate PL-1f, if applicable

Case 2f: Assumes failure of plate PL-2f, if applicable

Case 2p: Assumes failure of plate PL-2p, if applicable

Case 3p: Assumes failure of plate PL-3p, if applicable

Case CH: Assumes failure of the rolled channel, if applicable

Case WP: Assumes failure of the largest net web plate, if applicable

Component	Unfaulted Areas			Faulted Net Areas for Fatigue Life Calculations						
	Gross	Net (Fat.)	Net (Str.)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)
	A_g (in^2)	A_n (in^2)	A_n (in^2)	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
PL-2f	0.00	0.00								
PL-1f	0.00	0.00								
PL-0	0.00	0.00								
Angles	0.00	0.00								
Channel	6.46	5.52								
PL-1p	0.00	0.00								
PL-2p	0.00	0.00								
PL-3p	0.00	0.00								
WP-top	6.38	2.86								
WP-bot	6.38	2.86								
Half Symmetry Total	**12.83**	**8.38**		8.38	0.00	0.00	0.00	0.00	**2.86**	**6.95**
Full Member Total	**25.67**	**16.76**		16.76	0.00	0.00	0.00	0.00	**11.24**	**13.90**
Faulted Net Areas for Strength Checks										
Half Symmetry Total			**0.00**	8.38	0.00	0.00	0.00	0.00	**2.86**	**6.95**
Full Member Total			**0.00**	16.76	0.00	0.00	0.00	0.00	**11.24**	**13.90**
Faulted Gross Areas										
				Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
				A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)
Half Symmetry Total				12.83	0.00	0.00	0.00	0.00	**6.38**	**9.65**
Full Member Total				25.67	0.00	0.00	0.00	0.00	**19.21**	**19.29**

	Area, (in^2)		Area, (in^2)		Area, (in^2)
Holes, angles	0.00	Holes, PL-3p	0.00		
Holes, PL-2f	0.00	Holes, PL-1p	0.00	Holes, Web-top	3.52
Holes, PL-1f	0.00	Holes, PL-2p	0.00	Holes, Web-bot	3.52
Holes, PL-0	0.00	Holes-channel	0.94		

Stress Amplification Factors (GS 2.2)

Stress Amplifiers (GS Table 2.2.1-1)**:**

Shear Lag Factor, Ξ_{VL}	1.20
Number of web plates, N_{web}	1
Number of flange plates, N_{fl}	1
Number of total plates, N_{AX}	2
Bending Factor, Ξ_B	1.24

40-over-fastener Rule **Required?** (GS 2.2.1.1)**:** -

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 7 (L2'-U3'-SL)- Passing** Date:

Strength Capacity Check (GS 2.2 & 2.3)

Factored Load:

$P_u = \gamma_{DC} P_{DC} + \gamma_{DW} P_{DW} + \gamma_{LL} P_{LL+IM} =$ 74.7 kip GS Eq. 1.7.2-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u =$ 48.0 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y =$ 31.4 ksi GS Eq. 2.3-1

Factored Stress (Strength Limit State): (*Note:* Ξ_B & Ξ_{VL} = 1.0)

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_u / 2A_{AFN}) =$	4.46	0.00	0.00	0.00	0.00	13.06	5.37	GS Eq. 2.2.1-1
$f_{AFG} = \Xi_B \Xi_{VL} (P_u / 2A_{AFG}) =$	2.91	0.00	0.00	0.00	0.00	5.86	3.87	GS Eq. 2.2.1-2

Strength Criteria Check:

$f_{AFG} \le f_{u,g}$? 3.68 **OK** OK or NG GS Eq. 2.3-1

$f_{AFN} \le f_{u,n}$? 5.35 **OK** OK or NG GS Eq. 2.3-2

**Member L2-U3 need not be considered for fatigue per LRFD 6.6.1.2*

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 8 (U15-L16)** Date:

Assumptions:

1. Controlling fatigue detail is the fastened connection.

General Requirements (GS 1.4 and 1.6)

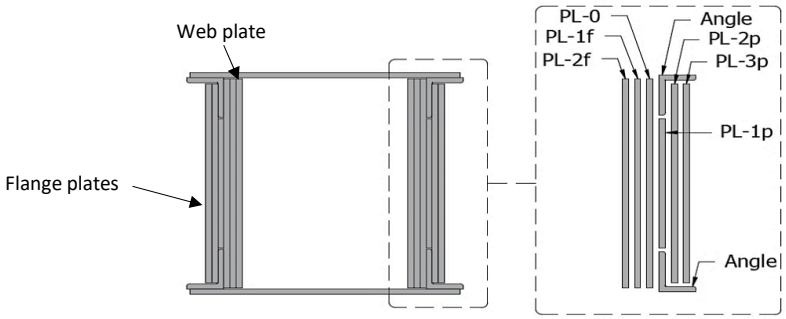
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all other provisions of Section 1.6?	**Yes**	Yes

Member Cross Section Inputs

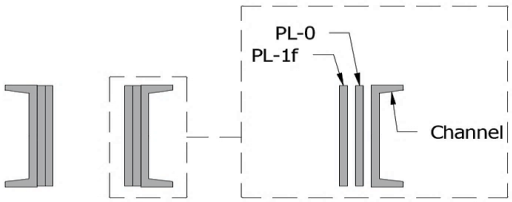
General:

Steel yield strength, F_y	**33.0**	ksi	Fastener diameter, d_{fast}	**0.8750**	in
Steel tensile strength, F_u	**60.0**	ksi	Fastener hole diameter, d_{hole}	0.9375	in
Is it a box (continuous top & bot webs)?	**Yes**	Yes or No	Are the fastener holes staggered?	**No**	Yes or No
Does the member have rolled channels?	**Yes**	Yes or No	Fastener type	**Rivet**	Bolt or Rivet
Is the member a built-up I-section?	**No**	Yes or No	Are holes punched full size?	**No**	Yes or No

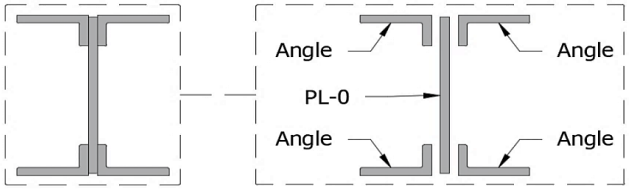
Reference sketch 1.1: Exploded view of built-up channel.



Reference sketch 1.2: Exploded view of rolled channel with additional flange plates.



Reference sketch 1.3: Exploded view of built-up I-section.



Web Plate Dimensions:	**top**	**bot**	
Web Plate Width, $b_{f.i}$	**17.000**	**17.000**	in
Web Plate Thickness, $t_{f.i}$	**0.375**	**0.375**	in
Hand Hole Width, $w_{hh.i}$	**7.500**	**7.500**	in

Fastener Location Dimensions in Web Plates: Plate(i):	**top**	**bot**	
Holes in Web Plate, $N_{holes.i}$	**2**	**2**	holes
Distance to Hole 1, $d_{h.wp.i}$	**1.7500**	**1.7500**	in

Internal Redundancy of Built-up Member: Multi-component Axial

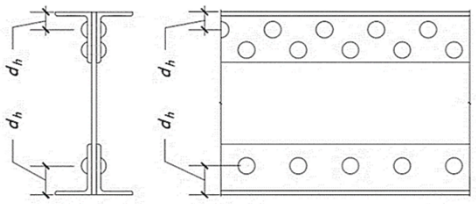
Member ID: **Sect 8 (U15-L16)** Date:

Flange Plate Dimensions (in):

Number of Full-Depth Flange Plates, $N_{fl.full}$	0	0 to 3
Number of Partial-Depth Flange Plates, $N_{fl.part}$	0	0 to 3

Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p	
$d_{fl,i}$	0.000	0.000	**0.000**	0.000	0.000	0.000	in
$t_{fl,i}$	0.0000	0.0000	**0.0000**	0.0000	0.0000	0.0000	in

Reference sketch 1.4: Distance to hole, d_h



Fastener Location Dimensions in Flange Plates:

Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p	
Holes in Flange Plate, $N_{holes.i}$	0	0	**0**	0	0	0	
Distance to Hole 1, $d_{h.fl.i}$	0.000	0.000	**0.000**	0.000	0.000	0.000	in

Angle Dimensions: (*Note: angle orientation is not important*)

Select the size of the angles		
Gross area of a single angle, $A_{agl.g}$		in^2
Thickness of the angle, t_{agl}		in
Holes in Vert Angle Leg, $N_{holes.vt.agl}$	0	holes
Holes in Horz Angle Leg, $N_{holes.hz.agl}$	0	holes

Rolled Channel Dimensions:

Select the size of the rolled channel	**C12x20.7**	
Gross area of one rolled channel, $A_{ch.g}$	6.08	in^2
Thickness of the channel flange, $t_{ch.fl}$	0.501	in
Thickness of the channel web, $t_{ch.web}$	0.282	in
Holes in the channel web, $N_{holes.ch.web}$	**0**	holes
Holes in the channel flanges, $N_{holes.ch.flange}$	**2**	holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	**326**	trucks/day	Current Year, $Y_{current}$	**2022**	year
$(ADTT_{sl})_0$	**200**	trucks/day	Span Length, L	**441.00**	ft
$(ADTT_{sl})_{limit}$	**20,000**	trucks/day	Number of striped lanes, n_L	**1**	lanes
Year Built, Y_{built}	**1956**	year	Stress-Range Estimate Partial LF, R_s	**1.00**	
Expected annual $(ADTT)_{SL}$ growth rate, g	**0.010**	MBE 7.2.5.1	No. of Stress-Range Cycles per Truck, n	**1**	cycle

Note: Growth rate is for future growth from today on

Loads:

P_{DC}	**118**	kip	P_{LL+IM}	**167**	kip
P_{DW}	**10**	kip	P_{FAT+IM}	**81**	kip

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override [ ] Override or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Load Factors (GS Table 1.7.1-1 and Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD A6.5.4.2):

Tension, Yield on Gross Section, ϕ_y	0.95
Tension, Fracture on Net Section, ϕ_u	0.80

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 8 (U15-L16)** Date:

Gross Area and Net Area Calculations

This section of the spreadsheet calculates faulted section areas to be used in strength limit checks and determining the controlling live load stress range in order to calculate the fatigue life in the faulted state. Due to application of the bending stress factor, Ξ_B, the controlling case may be the largest gross area plate or it may be a smaller plate positioned exterior within the section. Refer to Guide Specifications C1.6.1 for further information on "interior" and "exterior" plate positions. If there are staggered holes, the user must manually enter the controlling net area for each component, taking into account the pitch and gage of staggered hole patterns (See AASHTO LRFD 6.8.3) for strength calculations. Enter these values below under "Net (Str.)". If the holes are not staggered, the user need not manually enter net areas. **Net areas are always automatically calculated for fatigue life prediction**.

Faulted Section Scenarios:

Case 0: Assumes failure of plate PL-0

Case 1f: Assumes failure of plate PL-1f, if applicable

Case 2f: Assumes failure of plate PL-2f, if applicable

Case 2p: Assumes failure of plate PL-2p, if applicable

Case 3p: Assumes failure of plate PL-3p, if applicable

Case CH: Assumes failure of the rolled channel, if applicable

Case WP: Assumes failure of the largest net web plate, if applicable

Component	Unfaulted Areas			A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)
	Gross	Net (Fat.)	Net (Str.)	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
	A_g (in^2)	A_n (in^2)	A_n (in^2)	Faulted Net Areas for Fatigue Life Calculations						
PL-2f	0.00	0.00								
PL-1f	0.00	0.00								
PL-0	0.00	0.00								
Angles	0.00	0.00								
Channel	6.08	5.14								
PL-1p	0.00	0.00								
PL-2p	0.00	0.00								
PL-3p	0.00	0.00								
WP-top	6.38	2.86								
WP-bot	6.38	2.86								
Half Symmetry Total	**12.46**	**8.00**		8.00	0.00	0.00	0.00	0.00	**2.86**	**6.57**
Full Member Total	**24.91**	**16.00**		16.00	0.00	0.00	0.00	0.00	**10.86**	**13.14**
				Faulted Net Areas for Strength Checks						
Half Symmetry Total			**0.00**	8.00	0.00	0.00	0.00	0.00	**2.86**	**6.57**
Full Member Total			**0.00**	16.00	0.00	0.00	0.00	0.00	**10.86**	**13.14**
				Faulted Gross Areas						
				Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
				A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)
Half Symmetry Total				12.46	0.00	0.00	0.00	0.00	**6.38**	**9.27**
Full Member Total				24.91	0.00	0.00	0.00	0.00	**18.83**	**18.54**

	Area, (in^2)		Area, (in^2)		Area, (in^2)
Holes, angles	0.00	Holes, PL-3p	0.00		
Holes, PL-2f	0.00	Holes, PL-1p	0.00	Holes, Web-top	3.52
Holes, PL-1f	0.00	Holes, PL-2p	0.00	Holes, Web-bot	3.52
Holes, PL-0	0.00	Holes-channel	0.94		

Stress Amplification Factors (GS 2.2)

Stress Amplifiers (GS Table 2.2.1-1)**:**

Shear Lag Factor, Ξ_{VL}	1.20
Number of web plates, N_{web}	1
Number of flange plates, N_{fl}	1
Number of total plates, N_{AX}	2
Bending Factor, Ξ_B	1.24

40-over-fastener Rule **Required?** (GS 2.2.1.1)**:** -

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 8 (U15-L16)** Date:

Strength Capacity Check (GS 2.2 & 2.3)

Factored Load:

$P_u = \gamma_{DC} P_{DC} + \gamma_{DW} P_{DW} + \gamma_{LL} P_{LL+IM} =$ 398.2 kip GS Eq. 1.7.2-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u =$ 48.0 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y =$ 31.4 ksi GS Eq. 2.3-1

Factored Stress (Strength Limit State): (*Note:* Ξ_B & Ξ_{VL} = 1.0)

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_u / 2A_{AFN}) =$	24.89	0.00	0.00	0.00	0.00	69.63	30.30	GS Eq. 2.2.1-1
$f_{AFG} = \Xi_B \Xi_{VL} (P_u / 2A_{AFG}) =$	15.99	0.00	0.00	0.00	0.00	31.23	21.48	GS Eq. 2.2.1-2

Strength Criteria Check:

$f_{AFG} \le f_{u,g}$? 0.69 **OK** OK or NG GS Eq. 2.3-1

$f_{AFN} \le f_{u,n}$? 1.00 **NG** OK or NG GS Eq. 2.3-2

Fatigue Life Estimate (GS 2.5)

Effective Stress Range & Max Stress Range in Unfaulted State:

$R_p =$	1.03		MBE Eq. 7.2.2.1-1
Unfaulted state stress range, $\Delta f =$	4.07	ksi	
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	4.20	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	9.24	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-2
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.00	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.2-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	2.97E+07	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	6.311E+06	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	108.71	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	961	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**108.7**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**II**	I or II	GS 2.5

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 8 (U15-L16)** Date:

Effective Stress Range & Max Stress Range in Faulted State:

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_{FAT+IM} / 2A_{AFN}) =$	4.89	0.00	0.00	0.00	0.00	**16.96**	**7.38**	GS Eq. 2.2.1-1

40-over-fastener Rule (GS 2.2.1.1):

Load in an angle, $P_{FAT+IM-L}$	-	kip	
$f_{AFN} = P_{FAT+IM} / A_N + 0.4P_{FAT+IM-L} / I_f t_p =$	-	ksi	

Faulted state stress range, Δf =	16.96	ksi	
Faulted state effective stress range, $(\Delta f)_{eff}$ =	17.48	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	38.45	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-2
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.00	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	8.24E+05	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	6.7	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	345	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8

Total faulted state remaining fatigue life, Y_{REM}	**6.7**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**II**	I(a), I(b), II	GS 2.5

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, NU	66.0	Years	GS 2.5.3
Total finite fatigue life only in unfaulted state, Yu	-	Years	GS 2.5.3
Total remaining fatigue life only in faulted state, Yf	-	Years	GS 2.5.3
Total remaining fatigue life, Nf = Yf(1-Nu/Yu)	**#VALUE!**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**NG**	OK or NG	GS 2.3
Fatigue case =	-	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	-	ksi	
Controlling stress range in faulted state, Δf_{FS} =	-	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	-	Years	
Total remaining fatigue life, N_f	-	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	-	Years	GS 3

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 9 (U11-L11)** Date:

Assumptions:

1. Controlling fatigue detail is the fastened connection.

General Requirements (GS 1.4 and 1.6)

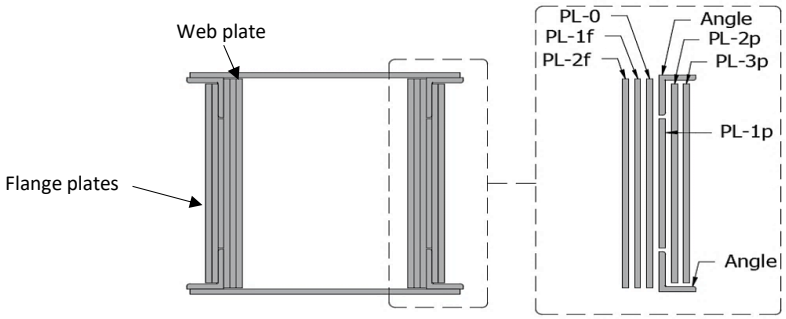
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all other provisions of Section 1.6?	**Yes**	Yes

Member Cross Section Inputs

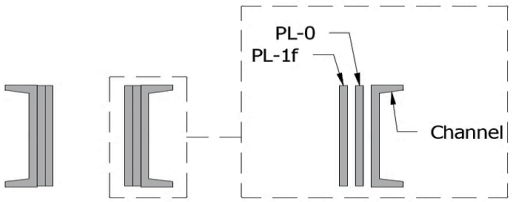
General:

Steel yield strength, F_y	**33.0**	ksi	Fastener diameter, d_{fast}	**0.8750**	in
Steel tensile strength, F_u	**60.0**	ksi	Fastener hole diameter, d_{hole}	0.9375	in
Is it a box (continuous top & bot webs)?	**No**	Yes or No	Are the fastener holes staggered?	**No**	Yes or No
Does the member have rolled channels?	**No**	Yes or No	Fastener type	**Rivet**	Bolt or Rivet
Is the member a built-up I-section?	**Yes**	Yes or No	Are holes punched full size?	**No**	Yes or No

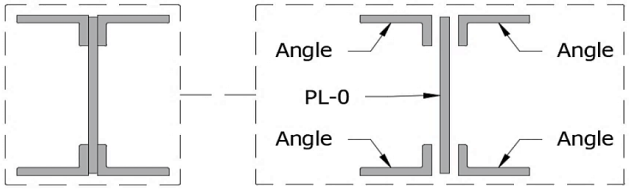
Reference sketch 1.1: Exploded view of built-up channel.



Reference sketch 1.2: Exploded view of rolled channel with additional flange plates.



Reference sketch 1.3: Exploded view of built-up I-section.



Web Plate Dimensions:	top	bot	
Web Plate Width, $b_{f.i}$	0.000	0.000	in
Web Plate Thickness, $t_{f.i}$	0.000	0.000	in
Hand Hole Width, $w_{hh.i}$	0.000	0.000	in

Fastener Location Dimensions in Web Plates:

Plate(i):	top	bot	
Holes in Web Plate, $N_{holes.i}$	0	0	holes
Distance to Hole 1, $d_{h.wp.i}$	0.0000	0.0000	in

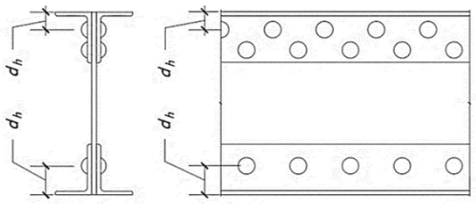
Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 9 (U11-L11)** Date:

Flange Plate Dimensions (in):

Number of Full-Depth Flange Plates, $N_{fl.full}$				1	0 to 3			
Number of Partial-Depth Flange Plates, $N_{fl.part}$				0	0 to 3			
Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p		
$d_{fl,i}$	0.000	0.000	11.000	0.000	0.000	0.000	in	
$t_{fl,i}$	0.0000	0.0000	0.1875	0.0000	0.0000	0.0000	in	

Reference sketch 1.4: Distance to hole, d_h



Fastener Location Dimensions in Flange Plates:

Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p	
Holes in Flange Plate, $N_{holes.i}$	0	0	2	0	0	0	
Distance to Hole 1, $d_{h.fl.i}$	0.000	0.000	1.933	0.000	0.000	0.000	in

Angle Dimensions: (*Note: angle orientation is not important*)

Select the size of the angles	L6x3.5x13.9	
Gross area of a single angle, $A_{agl.g}$	4.06	in^2
Thickness of the angle, t_{agl}	0.365	in
Holes in Vert Angle Leg, $N_{holes.vt.agl}$	1	holes
Holes in Horz Angle Leg, $N_{holes.hz.agl}$	0	holes

Rolled Channel Dimensions:

Select the size of the rolled channel		
Gross area of one rolled channel, $A_{ch.g}$		in^2
Thickness of the channel flange, $t_{ch.fl}$		in
Thickness of the channel web, $t_{ch.web}$		in
Holes in the channel web, $N_{holes.ch.web}$	0	holes
Holes in the channel flanges, $N_{holes.ch.flange}$	0	holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	326	trucks/day	Current Year, $Y_{current}$	2022	year
$(ADTT_{sl})_0$	200	trucks/day	Span Length, L	441.00	ft
$(ADTT_{sl})_{limit}$	20,000	trucks/day	Number of striped lanes, n_L	1	lanes
Year Built, Y_{built}	1956	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cycles per Truck, n	1	cycle

Note: Growth rate is for future growth from today on

Loads:

P_{DC}	91	kip	P_{LL+IM}	103	kip
P_{DW}	9	kip	P_{FAT+IM}	35	kip

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override [ ] Override or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Load Factors (GS Table 1.7.1-1 and Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD A6.5.4.2):

Tension, Yield on Gross Section, ϕ_y	0.95
Tension, Fracture on Net Section, ϕ_u	0.80

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 9 (U11-L11)** Date:

Gross Area and Net Area Calculations

This section of the spreadsheet calculates faulted section areas to be used in strength limit checks and determining the controlling live load stress range in order to calculate the fatigue life in the faulted state. Due to application of the bending stress factor, Ξ_B, the controlling case may be the largest gross area plate or it may be a smaller plate positioned exterior within the section. Refer to Guide Specifications C1.6.1 for further information on "interior" and "exterior" plate positions. If there are staggered holes, the user must manually enter the controlling net area for each component, taking into account the pitch and gage of staggered hole patterns (See AASHTO LRFD 6.8.3) for strength calculations. Enter these values below under "Net (Str.)". If the holes are not staggered, the user need not manually enter net areas. **Net areas are always automatically calculated for fatigue life prediction**.

Faulted Section Scenarios:

Case 0: Assumes failure of plate PL-0
Case 1f: Assumes failure of plate PL-1f, if applicable
Case 2f: Assumes failure of plate PL-2f, if applicable
Case 2p: Assumes failure of plate PL-2p, if applicable
Case 3p: Assumes failure of plate PL-3p, if applicable
Case CH: Assumes failure of the rolled channel, if applicable
Case WP: Assumes failure of the largest net web plate, if applicable

Component	Unfaulted Areas: Gross A_g (in^2)	Unfaulted Areas: Net (Fat.) A_n (in^2)	Unfaulted Areas: Net (Str.) A_n (in^2)
PL-2f	0.00	0.00	
PL-1f	0.00	0.00	
PL-0	2.06	1.71	
Angles	8.12	7.44	
Channel	0.00	0.00	
PL-1p	0.00	0.00	
PL-2p	0.00	0.00	
PL-3p	0.00	0.00	
WP-top	0.00	0.00	
WP-bot	0.00	0.00	
Half Symmetry Total	**10.18**	**9.15**	
Full Member Total	**18.30**	**16.58**	

	Faulted Net Areas for Fatigue Life Calculations: Case 0 A_n (in^2)	Case 1f A_n (in^2)	Case 2f A_n (in^2)	Case 2p A_n (in^2)	Case 3p A_n (in^2)	Case CH A_n (in^2)	Case WP A_n (in^2)
Half Symmetry Total	7.44	0.00	0.00	0.00	0.00	0.00	0.00
Full Member Total	14.87	0.00	0.00	0.00	0.00	0.00	0.00

	Faulted Net Areas for Strength Checks: Case 0 A_n (in^2)	Case 1f A_n (in^2)	Case 2f A_n (in^2)	Case 2p A_n (in^2)	Case 3p A_n (in^2)	Case CH A_n (in^2)	Case WP A_n (in^2)
Half Symmetry Total	7.44	0.00	0.00	0.00	0.00	0.00	0.00
Full Member Total	14.87	0.00	0.00	0.00	0.00	0.00	0.00

	Faulted Gross Areas: Case 0 A_g (in^2)	Case 1f A_g (in^2)	Case 2f A_g (in^2)	Case 2p A_g (in^2)	Case 3p A_g (in^2)	Case CH A_g (in^2)	Case WP A_g (in^2)
Half Symmetry Total	8.12	0.00	0.00	0.00	0.00	0.00	0.00
Full Member Total	16.24	0.00	0.00	0.00	0.00	0.00	0.00

	Area, (in^2)		Area, (in^2)		Area, (in^2)
Holes, angles	0.68	Holes, PL-3p	0.00		
Holes, PL-2f	0.00	Holes, PL-1p	0.00	Holes, Web-top	0.00
Holes, PL-1f	0.00	Holes, PL-2p	0.00	Holes, Web-bot	0.00
Holes, PL-0	0.35	Holes-channel	0.00		

Stress Amplification Factors (GS 2.2)

Stress Amplifiers (GS Table 2.2.1-1)**:**

Shear Lag Factor, Ξ_{VL}	1.20
Number of web plates, N_{web}	1
Number of flange plates, N_{fl}	1
Number of total plates, N_{AX}	2
Bending Factor, Ξ_B	1.00

40-over-fastener Rule **Required?** (GS 2.2.1.1)**:** Yes

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: Sect 9 (U11-L11) Date:

Strength Capacity Check (GS 2.2 & 2.3)

Factored Load:

$P_u = \gamma_{DC} P_{DC} + \gamma_{DW} P_{DW} + \gamma_{LL} P_{LL+IM} =$ 270.5 kip GS Eq. 1.7.2-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u =$ 48.0 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y =$ 31.4 ksi GS Eq. 2.3-1

Factored Stress (Strength Limit State): (*Note:* Ξ_B & Ξ_{VL} = 1.0)

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_u / 2A_{AFN}) =$	9.10	0.00	0.00	0.00	0.00	0.00	0.00	GS Eq. 2.2.1-1
$f_{AFG} = \Xi_B \Xi_{VL} (P_u / 2A_{AFG}) =$	8.33	0.00	0.00	0.00	0.00	0.00	0.00	GS Eq. 2.2.1-2

Strength Criteria Check:

$f_{AFG} \le f_{u,g}$? 5.28 OK OK or NG GS Eq. 2.3-1

$f_{AFN} \le f_{u,n}$? 3.76 OK OK or NG GS Eq. 2.3-2

Fatigue Life Estimate (GS 2.5)

Effective Stress Range & Max Stress Range in Unfaulted State:

$R_p =$	1.03		MBE Eq. 7.2.2.1-1
Unfaulted state stress range, $\Delta f =$	1.68	ksi	
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	1.73	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	3.80	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-2
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.00	ksi	
Resistance Factor for evaluation, R_R	1.0		MBE Table 7.2.5.2-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 9 (U11-L11)** Date:

Effective Stress Range & Max Stress Range in Faulted State:

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_{FAT+IM} / 2A_{AFN}) =$	**2.24**	0.00	0.00	0.00	0.00	0.00	0.00	GS Eq. 2.2.1-1

40-over-fastener Rule (GS 2.2.1.1):

Load in an angle, $P_{FAT+IM-L}$	6.16	kip	
$f_{AFN} = P_{FAT+IM} / A_N + 0.4P_{FAT+IM-L} / I_f t_p =$	8.48	ksi	
Faulted state stress range, Δf =	8.48	ksi	
Faulted state effective stress range, $(\Delta f)_{eff}$ =	8.73	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	19.21	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-2
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.00	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	6.60E+06	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	44.0	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	500	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**44.0**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I(b)**	I(a), I(b), II	GS 2.5

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, NU	66.0	Years	GS 2.5.3
Total finite fatigue life only in unfaulted state, Yu	∞	Years	GS 2.5.3
Total remaining fatigue life only in faulted state, Yf	44.0	Years	GS 2.5.3
Total remaining fatigue life, Nf = Yf(1-Nu/Yu)	**44.0**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.3
Fatigue case =	I(b)	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	1.68	ksi	
Controlling stress range in faulted state, Δf_{FS} =	8.48	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**44.0**	Years	
Total remaining fatigue life, N_f	**44.0**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 10 (U15-L15)** Date:

Assumptions:

1. Controlling fatigue detail is the fastened connection.

General Requirements (GS 1.4 and 1.6)

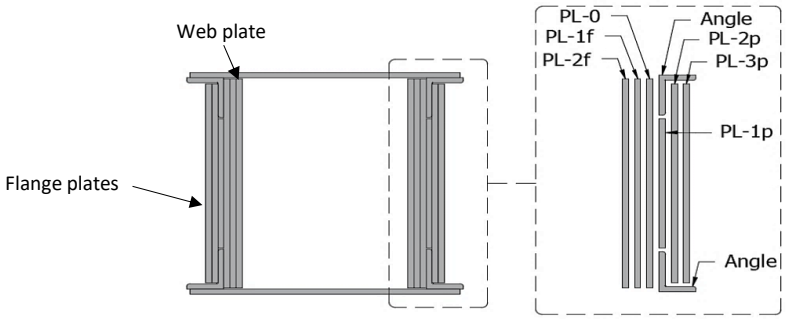
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all other provisions of Section 1.6?	**Yes**	Yes

Member Cross Section Inputs

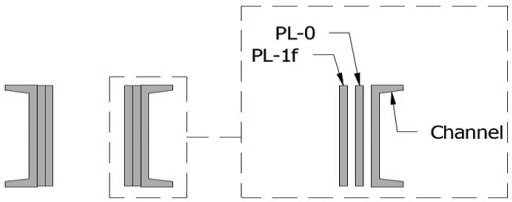
General:

Steel yield strength, F_y	**33.0**	ksi	Fastener diameter, d_{fast}	**0.8750**	in
Steel tensile strength, F_u	**60.0**	ksi	Fastener hole diameter, d_{hole}	0.9375	in
Is it a box (continuous top & bot webs)?	**No**	Yes or No	Are the fastener holes staggered?	**No**	Yes or No
Does the member have rolled channels?	**No**	Yes or No	Fastener type	**Rivet**	Bolt or Rivet
Is the member a built-up I-section?	**Yes**	Yes or No	Are holes punched full size?	**No**	Yes or No

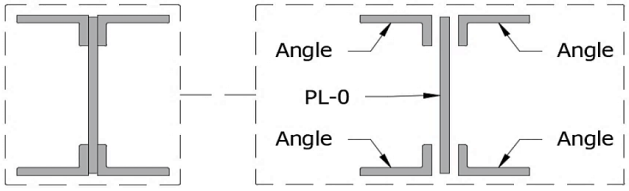
Reference sketch 1.1: Exploded view of built-up channel.



Reference sketch 1.2: Exploded view of rolled channel with additional flange plates.



Reference sketch 1.3: Exploded view of built-up I-section.



Web Plate Dimensions:	top	bot	
Web Plate Width, $b_{f.i}$	0.000	0.000	in
Web Plate Thickness, $t_{f.i}$	0.000	0.000	in
Hand Hole Width, $w_{hh.i}$	0.000	0.000	in

Fastener Location Dimensions in Web Plates:

Plate(i):	top	bot	
Holes in Web Plate, $N_{holes.i}$	0	0	holes
Distance to Hole 1, $d_{h.wp.i}$	0.0000	0.0000	in

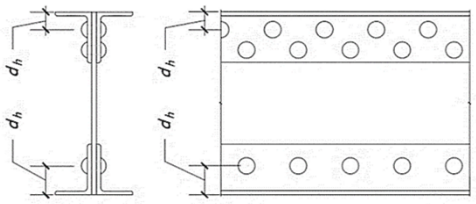
Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 10 (U15-L15)** Date:

Flange Plate Dimensions (in):

Number of Full-Depth Flange Plates, $N_{fl.full}$				1	0 to 3			
Number of Partial-Depth Flange Plates, $N_{fl.part}$				0	0 to 3			
Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p		
$d_{fl,i}$	0.000	0.000	11.000	0.000	0.000	0.000	in	
$t_{fl,i}$	0.0000	0.0000	0.3125	0.0000	0.0000	0.0000	in	

Reference sketch 1.4: Distance to hole, d_h



Fastener Location Dimensions in Flange Plates:

Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p	
Holes in Flange Plate, $N_{holes.i}$	0	0	2	0	0	0	
Distance to Hole 1, $d_{h.fl.i}$	0.000	0.000	1.933	0.000	0.000	0.000	in

Angle Dimensions: (*Note: angle orientation is not important*)

Select the size of the angles	L6x3.5x13.9	
Gross area of a single angle, $A_{agl.g}$	4.06	in^2
Thickness of the angle, t_{agl}	0.365	in
Holes in Vert Angle Leg, $N_{holes.vt.agl}$	1	holes
Holes in Horz Angle Leg, $N_{holes.hz.agl}$	0	holes

Rolled Channel Dimensions:

Select the size of the rolled channel		
Gross area of one rolled channel, $A_{ch.g}$		in^2
Thickness of the channel flange, $t_{ch.fl}$		in
Thickness of the channel web, $t_{ch.web}$		in
Holes in the channel web, $N_{holes.ch.web}$	0	holes
Holes in the channel flanges, $N_{holes.ch.flange}$	0	holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	326	trucks/day	Current Year, $Y_{current}$	2022	year
$(ADTT_{sl})_0$	200	trucks/day	Span Length, L	441.00	ft
$(ADTT_{sl})_{limit}$	20,000	trucks/day	Number of striped lanes, n_L	1	lanes
Year Built, Y_{built}	1956	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cycles per Truck, n	1	cycle

Note: Growth rate is for future growth from today on

Loads:

P_{DC}	89	kip	P_{LL+IM}	103	kip
P_{DW}	9	kip	P_{FAT+IM}	35	kip

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override [ ] Override or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Load Factors (GS Table 1.7.1-1 and Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD A6.5.4.2):

Tension, Yield on Gross Section, ϕ_y	0.95
Tension, Fracture on Net Section, ϕ_u	0.80

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 10 (U15-L15)** Date:

Gross Area and Net Area Calculations

This section of the spreadsheet calculates faulted section areas to be used in strength limit checks and determining the controlling live load stress range in order to calculate the fatigue life in the faulted state. Due to application of the bending stress factor, Ξ_B, the controlling case may be the largest gross area plate or it may be a smaller plate positioned exterior within the section. Refer to Guide Specifications C1.6.1 for further information on "interior" and "exterior" plate positions. If there are staggered holes, the user must manually enter the controlling net area for each component, taking into account the pitch and gage of staggered hole patterns (See AASHTO LRFD 6.8.3) for strength calculations. Enter these values below under "Net (Str.)". If the holes are not staggered, the user need not manually enter net areas. **Net areas are always automatically calculated for fatigue life prediction**.

Faulted Section Scenarios:

Case 0: Assumes failure of plate PL-0

Case 1f: Assumes failure of plate PL-1f, if applicable

Case 2f: Assumes failure of plate PL-2f, if applicable

Case 2p: Assumes failure of plate PL-2p, if applicable

Case 3p: Assumes failure of plate PL-3p, if applicable

Case CH: Assumes failure of the rolled channel, if applicable

Case WP: Assumes failure of the largest net web plate, if applicable

Component	Unfaulted Areas			Faulted Net Areas for Fatigue Life Calculations						
	Gross	Net (Fat.)	Net (Str.)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)
	A_g (in^2)	A_n (in^2)	A_n (in^2)	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
PL-2f	0.00	0.00								
PL-1f	0.00	0.00								
PL-0	3.44	2.85								
Angles	8.12	7.44								
Channel	0.00	0.00								
PL-1p	0.00	0.00								
PL-2p	0.00	0.00								
PL-3p	0.00	0.00								
WP-top	0.00	0.00								
WP-bot	0.00	0.00								
Half Symmetry Total	**11.56**	**10.29**		**7.44**	0.00	0.00	0.00	0.00	0.00	0.00
Full Member Total	**19.68**	**17.72**		**14.87**	0.00	0.00	0.00	0.00	0.00	0.00

	Faulted Net Areas for Strength Checks						
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
Half Symmetry Total	**7.44**	0.00	0.00	0.00	0.00	0.00	0.00
Full Member Total	**14.87**	0.00	0.00	0.00	0.00	0.00	0.00

	Faulted Gross Areas						
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)
Half Symmetry Total	**8.12**	0.00	0.00	0.00	0.00	0.00	0.00
Full Member Total	**16.24**	0.00	0.00	0.00	0.00	0.00	0.00

	Area, (in^2)		Area, (in^2)		Area, (in^2)
Holes, angles	0.68	Holes, PL-3p	0.00		
Holes, PL-2f	0.00	Holes, PL-1p	0.00	Holes, Web-top	0.00
Holes, PL-1f	0.00	Holes, PL-2p	0.00	Holes, Web-bot	0.00
Holes, PL-0	0.59	Holes-channel	0.00		

Stress Amplification Factors (GS 2.2)

Stress Amplifiers (GS Table 2.2.1-1)**:**

Shear Lag Factor, Ξ_{VL}	1.20
Number of web plates, N_{web}	1
Number of flange plates, N_{fl}	1
Number of total plates, N_{AX}	2
Bending Factor, Ξ_B	1.00

40-over-fastener Rule **Required?** (GS 2.2.1.1)**:** Yes

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: Sect 10 (U15-L15) Date:

Strength Capacity Check (GS 2.2 & 2.3)

Factored Load:

$P_u = \gamma_{DC} P_{DC} + \gamma_{DW} P_{DW} + \gamma_{LL} P_{LL+IM} =$ 267.7 kip GS Eq. 1.7.2-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u =$ 48.0 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y =$ 31.4 ksi GS Eq. 2.3-1

Factored Stress (Strength Limit State): (*Note:* Ξ_B & Ξ_{VL} = 1.0)

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_u / 2A_{AFN}) =$	9.00	0.00	0.00	0.00	0.00	0.00	0.00	GS Eq. 2.2.1-1
$f_{AFG} = \Xi_B \Xi_{VL} (P_u / 2A_{AFG}) =$	8.24	0.00	0.00	0.00	0.00	0.00	0.00	GS Eq. 2.2.1-2

Strength Criteria Check:

$f_{AFG} \le f_{u,g}$? 5.33 OK OK or NG GS Eq. 2.3-1

$f_{AFN} \le f_{u,n}$? 3.80 OK OK or NG GS Eq. 2.3-2

Fatigue Life Estimate (GS 2.5)

Effective Stress Range & Max Stress Range in Unfaulted State:

$R_p =$	1.03		MBE Eq. 7.2.2.1-1
Unfaulted state stress range, $\Delta f =$	1.57	ksi	
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	1.62	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	3.56	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-2
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.00	ksi	
Resistance Factor for evaluation, R_R	1.0		MBE Table 7.2.5.2-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 10 (U15-L15)** Date:

Effective Stress Range & Max Stress Range in Faulted State:

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_{FAT+IM} / 2A_{AFN}) =$	**2.25**	0.00	0.00	0.00	0.00	0.00	0.00	GS Eq. 2.2.1-1

40-over-fastener Rule (GS 2.2.1.1):

Load in an angle, $P_{FAT+IM-L}$	5.74	kip	
$f_{AFN} = P_{FAT+IM} / A_N + 0.4P_{FAT+IM-L} / I_f t_p =$	5.37	ksi	
Faulted state stress range, Δf =	5.37	ksi	
Faulted state effective stress range, $(\Delta f)_{eff}$ =	5.54	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	12.18	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-2
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.00	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	2.59E+07	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	115.6	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	1,019	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**115.6**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I(b)**	I(a), I(b), II	GS 2.5

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, NU	66.0	Years	GS 2.5.3
Total finite fatigue life only in unfaulted state, Yu	∞	Years	GS 2.5.3
Total remaining fatigue life only in faulted state, Yf	115.6	Years	GS 2.5.3
Total remaining fatigue life, Nf = Yf(1-Nu/Yu)	**115.6**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.3
Fatigue case =	I(b)	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	1.57	ksi	
Controlling stress range in faulted state, Δf_{FS} =	5.37	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**115.6**	Years	
Total remaining fatigue life, N_f	**115.6**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 11 (U7-U8)** Date:

Assumptions:

1. Controlling fatigue detail is the fastened connection.

General Requirements (GS 1.4 and 1.6)

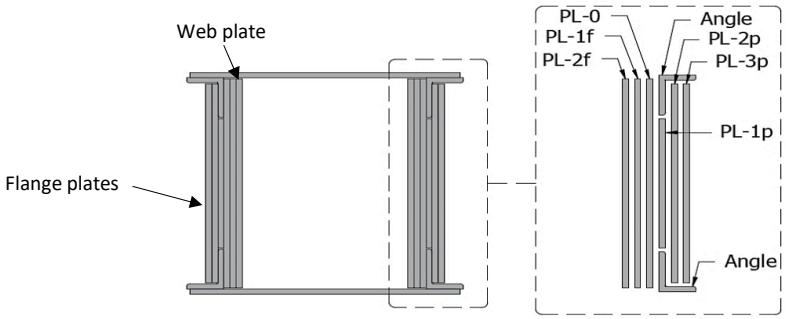
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all other provisions of Section 1.6?	**Yes**	Yes

Member Cross Section Inputs

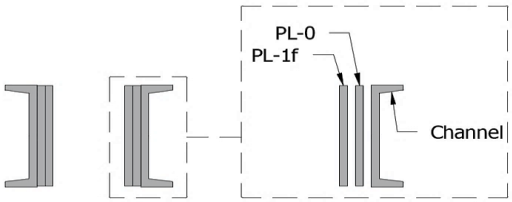
General:

Steel yield strength, F_y	**33.0**	ksi	Fastener diameter, d_{fast}	**0.8750**	in
Steel tensile strength, F_u	**60.0**	ksi	Fastener hole diameter, d_{hole}	0.9375	in
Is it a box (continuous top & bot webs)?	**Yes**	Yes or No	Are the fastener holes staggered?	**No**	Yes or No
Does the member have rolled channels?	**No**	Yes or No	Fastener type	**Rivet**	Bolt or Rivet
Is the member a built-up I-section?	**No**	Yes or No	Are holes punched full size?	**No**	Yes or No

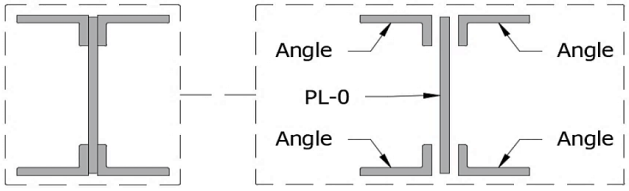
Reference sketch 1.1: Exploded view of built-up channel.



Reference sketch 1.2: Exploded view of rolled channel with additional flange plates.



Reference sketch 1.3: Exploded view of built-up I-section.



Web Plate Dimensions:	**top**	**bot**	
Web Plate Width, $b_{f.i}$	**16.000**	**16.000**	in
Web Plate Thickness, $t_{f.i}$	**0.375**	**0.375**	in
Hand Hole Width, $w_{hh.i}$	**7.500**	**7.500**	in

Fastener Location Dimensions in Web Plates: Plate(i):	**top**	**bot**	
Holes in Web Plate, $N_{holes.i}$	**2**	**2**	holes
Distance to Hole 1, $d_{h.wp.i}$	**2.2188**	**2.2188**	in

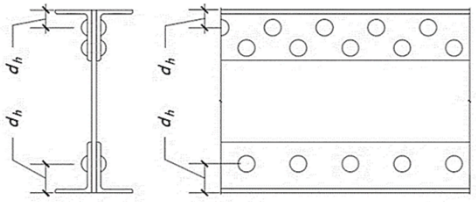
Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 11 (U7-U8)** Date:

Flange Plate Dimensions (in):

Number of Full-Depth Flange Plates, $N_{fl.full}$				1	0 to 3			
Number of Partial-Depth Flange Plates, $N_{fl.part}$				0	0 to 3			
Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p		
$d_{fl,i}$	0.000	0.000	20.000	0.000	0.000	0.000	in	
$t_{fl,i}$	0.0000	0.0000	0.6875	0.0000	0.0000	0.0000	in	

Reference sketch 1.4: Distance to hole, d_h



Fastener Location Dimensions in Flange Plates:

Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p	
Holes in Flange Plate, $N_{holes.i}$	0	0	2	0	0	0	
Distance to Hole 1, $d_{h.fl.i}$	0.000	0.000	2.219	0.000	0.000	0.000	in

Angle Dimensions: (*Note: angle orientation is not important*)

Select the size of the angles	L4x4x7/16	
Gross area of a single angle, $A_{agl.g}$	3.3	in^2
Thickness of the angle, t_{agl}	0.4375	in
Holes in Vert Angle Leg, $N_{holes.vt.agl}$	1	holes
Holes in Horz Angle Leg, $N_{holes.hz.agl}$	1	holes

Rolled Channel Dimensions:

Select the size of the rolled channel		
Gross area of one rolled channel, $A_{ch.g}$		in^2
Thickness of the channel flange, $t_{ch.fl}$		in
Thickness of the channel web, $t_{ch.web}$		in
Holes in the channel web, $N_{holes.ch.web}$	0	holes
Holes in the channel flanges, $N_{holes.ch.flange}$	0	holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	326	trucks/day	Current Year, $Y_{current}$	2022	year
$(ADTT_{sl})_0$	200	trucks/day	Span Length, L	284.00	ft
$(ADTT_{sl})_{limit}$	20,000	trucks/day	Number of striped lanes, n_L	1	lanes
Year Built, Y_{built}	1956	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cycles per Truck, n	1	cycle

Note: Growth rate is for future growth from today on

Loads:

P_{DC}	537	kip	P_{LL+IM}	198	kip
P_{DW}	45	kip	P_{FAT+IM}	51	kip

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override [ ] Override or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Load Factors (GS Table 1.7.1-1 and Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD A6.5.4.2):

Tension, Yield on Gross Section, ϕ_y	0.95
Tension, Fracture on Net Section, ϕ_u	0.80

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 11 (U7-U8)** Date:

Gross Area and Net Area Calculations

This section of the spreadsheet calculates faulted section areas to be used in strength limit checks and determining the controlling live load stress range in order to calculate the fatigue life in the faulted state. Due to application of the bending stress factor, Ξ_B, the controlling case may be the largest gross area plate or it may be a smaller plate positioned exterior within the section. Refer to Guide Specifications C1.6.1 for further information on "interior" and "exterior" plate positions. If there are staggered holes, the user must manually enter the controlling net area for each component, taking into account the pitch and gage of staggered hole patterns (See AASHTO LRFD 6.8.3) for strength calculations. Enter these values below under "Net (Str.)". If the holes are not staggered, the user need not manually enter net areas. **Net areas are always automatically calculated for fatigue life prediction**.

Faulted Section Scenarios:

Case 0: Assumes failure of plate PL-0

Case 1f: Assumes failure of plate PL-1f, if applicable

Case 2f: Assumes failure of plate PL-2f, if applicable

Case 2p: Assumes failure of plate PL-2p, if applicable

Case 3p: Assumes failure of plate PL-3p, if applicable

Case CH: Assumes failure of the rolled channel, if applicable

Case WP: Assumes failure of the largest net web plate, if applicable

Component	Unfaulted Areas								
	Gross	Net (Fat.)	Net (Str.)						
	A_g (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2) Case 0	A_n (in^2) Case 1f	A_n (in^2) Case 2f	A_n (in^2) Case 2p	A_n (in^2) Case 3p	A_n (in^2) Case CH	A_n (in^2) Case WP
PL-2f	0.00	0.00		Faulted Net Areas for Fatigue Life Calculations						
PL-1f	0.00	0.00								
PL-0	13.75	12.46								
Angles	6.60	4.96								
Channel	0.00	0.00								
PL-1p	0.00	0.00								
PL-2p	0.00	0.00								
PL-3p	0.00	0.00								
WP-top	6.00	2.48								
WP-bot	6.00	2.48								
Half Symmetry Total	**26.35**	**19.90**		**7.44**	0.00	0.00	0.00	0.00	0.00	**18.66**
Full Member Total	**52.70**	**39.81**		**27.35**	0.00	0.00	0.00	0.00	0.00	**37.33**
				Faulted Net Areas for Strength Checks						
Half Symmetry Total			**0.00**	**7.44**	0.00	0.00	0.00	0.00	0.00	**18.66**
Full Member Total			**0.00**	**27.35**	0.00	0.00	0.00	0.00	0.00	**37.33**
				Faulted Gross Areas						
				Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
				A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)
Half Symmetry Total				**12.60**	0.00	0.00	0.00	0.00	0.00	**23.35**
Full Member Total				**38.95**	0.00	0.00	0.00	0.00	0.00	**46.70**

	Area, (in^2)		Area, (in^2)		Area, (in^2)
Holes, angles	1.64	Holes, PL-3p	0.00		
Holes, PL-2f	0.00	Holes, PL-1p	0.00	Holes, Web-top	3.52
Holes, PL-1f	0.00	Holes, PL-2p	0.00	Holes, Web-bot	3.52
Holes, PL-0	1.29	Holes-channel	0.00		

Stress Amplification Factors (GS 2.2)

Stress Amplifiers (GS Table 2.2.1-1)**:**

Shear Lag Factor, Ξ_{VL}	1.20
Number of web plates, N_{web}	1
Number of flange plates, N_{fl}	1
Number of total plates, N_{AX}	2
Bending Factor, Ξ_B	1.24

40-over-fastener Rule **Required?** (GS 2.2.1.1)**:** No

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: Sect 11 (U7-U8) Date:

Strength Capacity Check (GS 2.2 & 2.3)

Factored Load:

$P_u = \gamma_{DC} P_{DC} + \gamma_{DW} P_{DW} + \gamma_{LL} P_{LL+IM} =$ 971.7 kip GS Eq. 1.7.2-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u =$ 48.0 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y =$ 31.4 ksi GS Eq. 2.3-1

Factored Stress (Strength Limit State): (*Note:* Ξ_B & Ξ_{VL} = 1.0)

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_u / 2A_{AFN}) =$	65.27	0.00	0.00	0.00	0.00	0.00	26.03	GS Eq. 2.2.1-1
$f_{AFG} = \Xi_B \Xi_{VL} (P_u / 2A_{AFG}) =$	38.56	0.00	0.00	0.00	0.00	0.00	20.81	GS Eq. 2.2.1-2

Strength Criteria Check:

$f_{AFG} \le f_{u,g}$? 0.74 NG OK or NG GS Eq. 2.3-1

$f_{AFN} \le f_{u,n}$? 0.81 NG OK or NG GS Eq. 2.3-2

Fatigue Life Estimate (GS 2.5)

Effective Stress Range & Max Stress Range in Unfaulted State:

$R_p =$ 1.02 MBE Eq. 7.2.2.1-1

Unfaulted state stress range, $\Delta f =$ 1.03 ksi

Unfaulted state effective stress range, $(\Delta f)_{eff} =$ 1.05 ksi MBE Eq. 7.2.2-1

$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$ 2.31 ksi MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category D GS Table 2.5-2

Detail Category Constant 22.00 $x10^8$ ksi^3

Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$ 7.00 ksi

Resistance Factor for evaluation, R_R **1.0** MBE Table 7.2.5.2-1

Infinite Fatigue Life Check (Unfaulted State):

Is $(\Delta f)_{max} \le (\Delta f)_{TH}$? Yes Yes or No MBE Eq. 7.2.4-1

Finite Fatigue Life Estimate (Unfaulted State):

Initially available stress cycles, N_{av} - cycles MBE Eq. 7.2.5.1-2

No. of consumed stress cycles, N_1 - cycles MBE Eq. 7.2.5.1-3

$N_{av} > N_1$? - Yes or No MBE Eq. 7.2.5.1-1

Remaining fatigue life, Y_{REM} - Years MBE Eq. 7.2.5.1-4

Future ADTT for single lane, $ADTT_{FUTURE}$ - trucks/day MBE Eq. 7.2.5.1-6

$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$? - Yes or No MBE Eq. 7.2.5.1-5

$(Y_{ADTT})_{LIMIT} =$ - Years MBE Eq. 7.2.5.1-7

Remaining fatigue life, Y_{REM} - Years MBE Eq. 7.2.5.1-8

Total unfaulted state remaining fatigue life, Y_{REM} **Infinite** Years MBE 7.2.5.1

Case I or II for unfaulted state? **I** I or II GS 2.5

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 11 (U7-U8)** Date:

Effective Stress Range & Max Stress Range in Faulted State:

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_{FAT+IM} / 2A_{AFN}) =$	4.10	0.00	0.00	0.00	0.00	0.00	1.64	GS Eq. 2.2.1-1

40-over-fastener Rule (GS 2.2.1.1):

Load in an angle, $P_{FAT+IM-L}$	N.A.	kip	
$f_{AFN} = P_{FAT+IM} / A_N + 0.4P_{FAT+IM-L} / I_f t_p =$	0.00	ksi	
Faulted state stress range, Δf =	4.10	ksi	
Faulted state effective stress range, $(\Delta f)_{eff}$ =	4.18	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	9.20	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-2
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.00	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I(a)**	I(a), I(b), II	GS 2.5

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, NU	66.0	Years	GS 2.5.3
Total finite fatigue life only in unfaulted state, Yu	-	Years	GS 2.5.3
Total remaining fatigue life only in faulted state, Yf	-	Years	GS 2.5.3
Total remaining fatigue life, Nf = Yf(1-Nu/Yu)	**Infinite**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**NG**	OK or NG	GS 2.3
Fatigue case =	-	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	-	ksi	
Controlling stress range in faulted state, Δf_{FS} =	-	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	-	Years	
Total remaining fatigue life, N_f	-	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	-	Years	GS 3

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 12 (L3-L4)** Date:

Assumptions:

1. Controlling fatigue detail is the fastened connection.

General Requirements (GS 1.4 and 1.6)

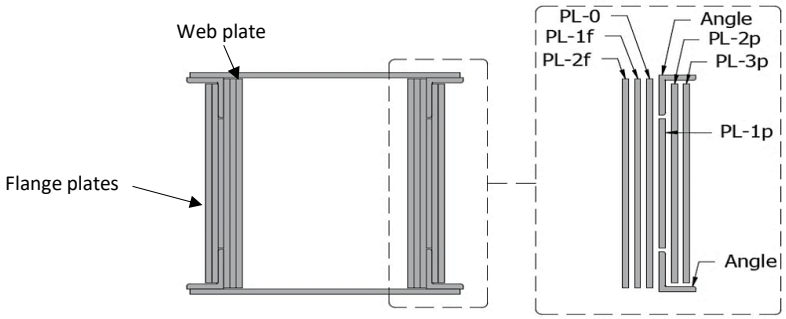
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all other provisions of Section 1.6?	**Yes**	Yes

Member Cross Section Inputs

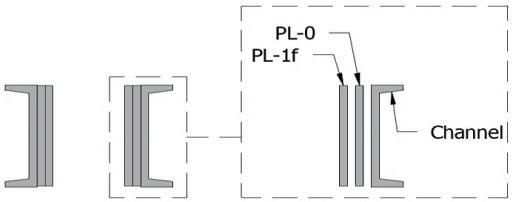
General:

Steel yield strength, F_y	**33.0**	ksi	Fastener diameter, d_{fast}	**0.8750**	in
Steel tensile strength, F_u	**60.0**	ksi	Fastener hole diameter, d_{hole}	0.9375	in
Is it a box (continuous top & bot webs)?	**Yes**	Yes or No	Are the fastener holes staggered?	**No**	Yes or No
Does the member have rolled channels?	**No**	Yes or No	Fastener type	**Rivet**	Bolt or Rivet
Is the member a built-up I-section?	**No**	Yes or No	Are holes punched full size?	**No**	Yes or No

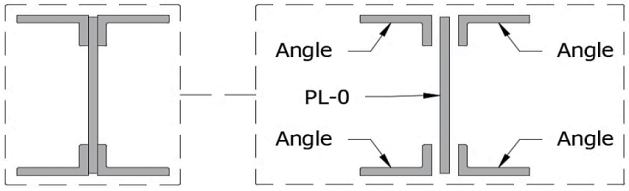
Reference sketch 1.1: Exploded view of built-up channel.



Reference sketch 1.2: Exploded view of rolled channel with additional flange plates.



Reference sketch 1.3: Exploded view of built-up I-section.



Web Plate Dimensions:	**top**	**bot**	
Web Plate Width, $b_{f.i}$	**16.000**	**16.000**	in
Web Plate Thickness, $t_{f.i}$	**0.375**	**0.375**	in
Hand Hole Width, $w_{hh.i}$	**7.500**	**7.500**	in

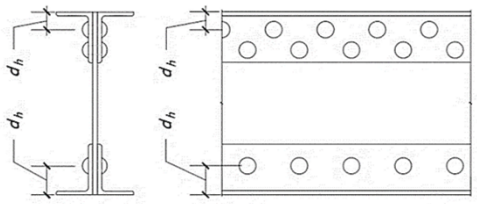
Fastener Location Dimensions in Web Plates: Plate(i):	**top**	**bot**	
Holes in Web Plate, $N_{holes.i}$	**2**	**2**	holes
Distance to Hole 1, $d_{h.wp.i}$	**2.2188**	**2.2188**	in

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 12 (L3-L4)** Date:

Flange Plate Dimensions (in):

Reference sketch 1.4: Distance to hole, d_h



Number of Full-Depth Flange Plates, $N_{fl.full}$				1	0 to 3			
Number of Partial-Depth Flange Plates, $N_{fl.part}$				0	0 to 3			
Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p		
$d_{fl,i}$	0.000	0.000	20.000	0.000	0.000	0.000	in	
$t_{fl,i}$	0.0000	0.0000	0.6250	0.0000	0.0000	0.0000	in	

Fastener Location Dimensions in Flange Plates:

Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p	
Holes in Flange Plate, $N_{holes.i}$	0	0	2	0	0	0	
Distance to Hole 1, $d_{h.fl.i}$	0.000	0.000	2.219	0.000	0.000	0.000	in

Angle Dimensions: (*Note: angle orientation is not important*)

Select the size of the angles	L4x4x7/16	
Gross area of a single angle, $A_{agl.g}$	3.3	in^2
Thickness of the angle, t_{agl}	0.4375	in
Holes in Vert Angle Leg, $N_{holes.vt.agl}$	1	holes
Holes in Horz Angle Leg, $N_{holes.hz.agl}$	1	holes

Rolled Channel Dimensions:

Select the size of the rolled channel		
Gross area of one rolled channel, $A_{ch.g}$		in^2
Thickness of the channel flange, $t_{ch.fl}$		in
Thickness of the channel web, $t_{ch.web}$		in
Holes in the channel web, $N_{holes.ch.web}$	0	holes
Holes in the channel flanges, $N_{holes.ch.flange}$	0	holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	326	trucks/day	Current Year, $Y_{current}$	2022	year
$(ADTT_{sl})_0$	200	trucks/day	Span Length, L	284.00	ft
$(ADTT_{sl})_{limit}$	20,000	trucks/day	Number of striped lanes, n_L	1	lanes
Year Built, Y_{built}	1956	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cycles per Truck, n	1	cycle

Note: Growth rate is for future growth from today on

Loads:

P_{DC}	385	kip	P_{LL+IM}	312	kip
P_{DW}	38	kip	P_{FAT+IM}	113	kip

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override Override or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Load Factors (GS Table 1.7.1-1 and Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD A6.5.4.2):

Tension, Yield on Gross Section, ϕ_y	0.95
Tension, Fracture on Net Section, ϕ_u	0.80

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 12 (L3-L4)** Date:

Gross Area and Net Area Calculations

This section of the spreadsheet calculates faulted section areas to be used in strength limit checks and determining the controlling live load stress range in order to calculate the fatigue life in the faulted state. Due to application of the bending stress factor, Ξ_B, the controlling case may be the largest gross area plate or it may be a smaller plate positioned exterior within the section. Refer to Guide Specifications C1.6.1 for further information on "interior" and "exterior" plate positions. If there are staggered holes, the user must manually enter the controlling net area for each component, taking into account the pitch and gage of staggered hole patterns (See AASHTO LRFD 6.8.3) for strength calculations. Enter these values below under "Net (Str.)". If the holes are not staggered, the user need not manually enter net areas. **Net areas are always automatically calculated for fatigue life prediction**.

Faulted Section Scenarios:

Case 0: Assumes failure of plate PL-0

Case 1f: Assumes failure of plate PL-1f, if applicable

Case 2f: Assumes failure of plate PL-2f, if applicable

Case 2p: Assumes failure of plate PL-2p, if applicable

Case 3p: Assumes failure of plate PL-3p, if applicable

Case CH: Assumes failure of the rolled channel, if applicable

Case WP: Assumes failure of the largest net web plate, if applicable

Component	Unfaulted Areas			A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)
	Gross	Net (Fat.)	Net (Str.)	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
	A_g (in^2)	A_n (in^2)	A_n (in^2)	Faulted Net Areas for Fatigue Life Calculations						
PL-2f	0.00	0.00								
PL-1f	0.00	0.00								
PL-0	12.50	11.33								
Angles	6.60	4.96								
Channel	0.00	0.00								
PL-1p	0.00	0.00								
PL-2p	0.00	0.00								
PL-3p	0.00	0.00								
WP-top	6.00	2.48								
WP-bot	6.00	2.48								
Half Symmetry Total	**25.10**	**18.77**		**7.44**	0.00	0.00	0.00	0.00	0.00	**17.53**
Full Member Total	**50.20**	**37.54**		**26.22**	0.00	0.00	0.00	0.00	0.00	**35.06**
				Faulted Net Areas for Strength Checks						
Half Symmetry Total			**0.00**	**7.44**	0.00	0.00	0.00	0.00	0.00	**17.53**
Full Member Total			**0.00**	**26.22**	0.00	0.00	0.00	0.00	0.00	**35.06**
				Faulted Gross Areas						
				Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
				A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)
Half Symmetry Total				**12.60**	0.00	0.00	0.00	0.00	0.00	**22.10**
Full Member Total				**37.70**	0.00	0.00	0.00	0.00	0.00	**44.20**

	Area, (in^2)		Area, (in^2)		Area, (in^2)
Holes, angles	1.64	Holes, PL-3p	0.00		
Holes, PL-2f	0.00	Holes, PL-1p	0.00	Holes, Web-top	3.52
Holes, PL-1f	0.00	Holes, PL-2p	0.00	Holes, Web-bot	3.52
Holes, PL-0	1.17	Holes-channel	0.00		

Stress Amplification Factors (GS 2.2)

Stress Amplifiers (GS Table 2.2.1-1)**:**

Shear Lag Factor, Ξ_{VL}	1.20
Number of web plates, N_{web}	1
Number of flange plates, N_{fl}	1
Number of total plates, N_{AX}	2
Bending Factor, Ξ_B	1.24

40-over-fastener Rule **Required?** (GS 2.2.1.1)**:** No

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: Sect 12 (L3-L4) Date:

Strength Capacity Check (GS 2.2 & 2.3)

Factored Load:

$P_u = \gamma_{DC} P_{DC} + \gamma_{DW} P_{DW} + \gamma_{LL} P_{LL+IM} =$ 958.3 kip GS Eq. 1.7.2-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u =$ 48.0 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y =$ 31.4 ksi GS Eq. 2.3-1

Factored Stress (Strength Limit State): (*Note:* Ξ_B & Ξ_{VL} = 1.0)

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_u / 2A_{AFN}) =$	64.37	0.00	0.00	0.00	0.00	0.00	27.33	GS Eq. 2.2.1-1
$f_{AFG} = \Xi_B \Xi_{VL} (P_u / 2A_{AFG}) =$	38.03	0.00	0.00	0.00	0.00	0.00	21.68	GS Eq. 2.2.1-2

Strength Criteria Check:

$f_{AFG} \le f_{u,g}$? 0.75 NG OK or NG GS Eq. 2.3-1

$f_{AFN} \le f_{u,n}$? 0.82 NG OK or NG GS Eq. 2.3-2

Fatigue Life Estimate (GS 2.5)

Effective Stress Range & Max Stress Range in Unfaulted State:

$R_p =$ 1.02 MBE Eq. 7.2.2.1-1

Unfaulted state stress range, $\Delta f =$ 2.42 ksi

Unfaulted state effective stress range, $(\Delta f)_{eff} =$ 2.47 ksi MBE Eq. 7.2.2-1

$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$ 5.42 ksi MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category D GS Table 2.5-2

Detail Category Constant 22.00 $x10^8$ ksi^3

Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$ 7.00 ksi

Resistance Factor for evaluation, R_R **1.0** MBE Table 7.2.5.2-1

Infinite Fatigue Life Check (Unfaulted State):

Is $(\Delta f)_{max} \le (\Delta f)_{TH}$? Yes Yes or No MBE Eq. 7.2.4-1

Finite Fatigue Life Estimate (Unfaulted State):

Initially available stress cycles, N_{av} - cycles MBE Eq. 7.2.5.1-2

No. of consumed stress cycles, N_1 - cycles MBE Eq. 7.2.5.1-3

$N_{av} > N_1$? - Yes or No MBE Eq. 7.2.5.1-1

Remaining fatigue life, Y_{REM} - Years MBE Eq. 7.2.5.1-4

Future ADTT for single lane, $ADTT_{FUTURE}$ - trucks/day MBE Eq. 7.2.5.1-6

$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$? - Yes or No MBE Eq. 7.2.5.1-5

$(Y_{ADTT})_{LIMIT} =$ - Years MBE Eq. 7.2.5.1-7

Remaining fatigue life, Y_{REM} - Years MBE Eq. 7.2.5.1-8

Total unfaulted state remaining fatigue life, Y_{REM} **Infinite** Years MBE 7.2.5.1

Case I or II for unfaulted state? **I** I or II GS 2.5

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 12 (L3-L4)** Date:

Effective Stress Range & Max Stress Range in Faulted State:

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_{FAT+IM} / 2A_{AFN}) =$	9.07	0.00	0.00	0.00	0.00	0.00	3.85	GS Eq. 2.2.1-1

40-over-fastener Rule (GS 2.2.1.1):

Load in an angle, $P_{FAT+IM-L}$	N.A.	kip	
$f_{AFN} = P_{FAT+IM} / A_N + 0.4P_{FAT+IM-L} / I_f t_p =$	0.00	ksi	
Faulted state stress range, Δf =	9.07	ksi	
Faulted state effective stress range, $(\Delta f)_{eff}$ =	9.25	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	20.35	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-2
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.00	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	5.56E+06	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	38.2	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	472	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**38.2**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I(b)**	I(a), I(b), II	GS 2.5

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, NU	66.0	Years	GS 2.5.3
Total finite fatigue life only in unfaulted state, Yu	-	Years	GS 2.5.3
Total remaining fatigue life only in faulted state, Yf	-	Years	GS 2.5.3
Total remaining fatigue life, Nf = Yf(1-Nu/Yu)	**38.2**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	NG	OK or NG	GS 2.3
Fatigue case =	-	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	-	ksi	
Controlling stress range in faulted state, Δf_{FS} =	-	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	-	Years	
Total remaining fatigue life, N_f	-	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	-	Years	GS 3

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 13 (U9-U10)** Date:

Assumptions:

1. Controlling fatigue detail is the fastened connection.

General Requirements (GS 1.4 and 1.6)

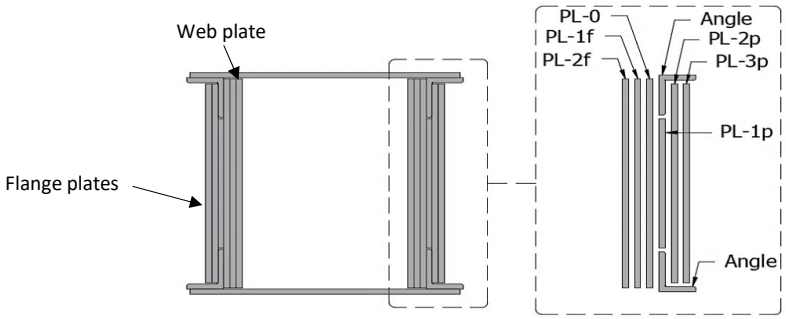
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all other provisions of Section 1.6?	**Yes**	Yes

Member Cross Section Inputs

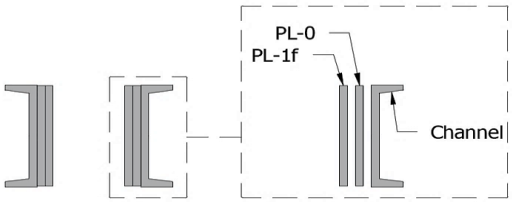
General:

Steel yield strength, F_y	**50.0**	ksi	Fastener diameter, d_{fast}	**0.8750**	in
Steel tensile strength, F_u	**70.0**	ksi	Fastener hole diameter, d_{hole}	0.9375	in
Is it a box (continuous top & bot webs)?	**Yes**	Yes or No	Are the fastener holes staggered?	**No**	Yes or No
Does the member have rolled channels?	**No**	Yes or No	Fastener type	**Rivet**	Bolt or Rivet
Is the member a built-up I-section?	**No**	Yes or No	Are holes punched full size?	**No**	Yes or No

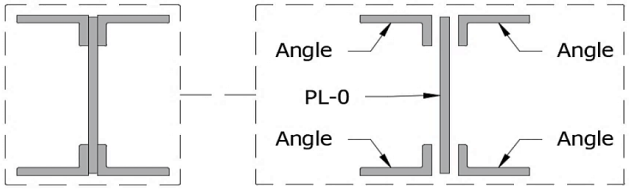
Reference sketch 1.1: Exploded view of built-up channel.



Reference sketch 1.2: Exploded view of rolled channel with additional flange plates.



Reference sketch 1.3: Exploded view of built-up I-section.



Web Plate Dimensions:	**top**	**bot**	
Web Plate Width, $b_{f.i}$	**16.000**	**16.000**	in
Web Plate Thickness, $t_{f.i}$	**0.375**	**0.375**	in
Hand Hole Width, $w_{hh.i}$	**7.500**	**7.500**	in

Fastener Location Dimensions in Web Plates: Plate(i):	**top**	**bot**	
Holes in Web Plate, $N_{holes.i}$	**2**	**2**	holes
Distance to Hole 1, $d_{h.wp.i}$	**2.2188**	**2.2188**	in

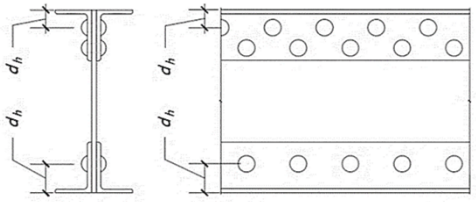
Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 13 (U9-U10)** Date:

Flange Plate Dimensions (in):

Number of Full-Depth Flange Plates, $N_{fl.full}$			1				0 to 3	
Number of Partial-Depth Flange Plates, $N_{fl.part}$			0				0 to 3	
Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p		
$d_{fl,i}$	0.000	0.000	20.000	0.000	0.000	0.000	in	
$t_{fl,i}$	0.0000	0.0000	0.5000	0.0000	0.0000	0.0000	in	

Reference sketch 1.4: Distance to hole, d_h



Fastener Location Dimensions in Flange Plates:

Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p	
Holes in Flange Plate, $N_{holes.i}$	0	0	2	0	0	0	
Distance to Hole 1, $d_{h.fl.i}$	0.000	0.000	2.219	0.000	0.000	0.000	in

Angle Dimensions: (*Note: angle orientation is not important*)

Select the size of the angles	L4x4x7/16	
Gross area of a single angle, $A_{agl.g}$	3.3	in^2
Thickness of the angle, t_{agl}	0.4375	in
Holes in Vert Angle Leg, $N_{holes.vt.agl}$	1	holes
Holes in Horz Angle Leg, $N_{holes.hz.agl}$	1	holes

Rolled Channel Dimensions:

Select the size of the rolled channel		
Gross area of one rolled channel, $A_{ch.g}$		in^2
Thickness of the channel flange, $t_{ch.fl}$		in
Thickness of the channel web, $t_{ch.web}$		in
Holes in the channel web, $N_{holes.ch.web}$	0	holes
Holes in the channel flanges, $N_{holes.ch.flange}$	0	holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	326	trucks/day	Current Year, $Y_{current}$	2022	year
$(ADTT_{sl})_0$	200	trucks/day	Span Length, L	441.00	ft
$(ADTT_{sl})_{limit}$	20,000	trucks/day	Number of striped lanes, n_L	1	lanes
Year Built, Y_{built}	1956	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cycles per Truck, n	1	cycle

Note: Growth rate is for future growth from today on

Loads:

P_{DC}	674	kip	P_{LL+IM}	246	kip
P_{DW}	59	kip	P_{FAT+IM}	55	kip

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override [ ] Override or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Load Factors (GS Table 1.7.1-1 and Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD A6.5.4.2):

Tension, Yield on Gross Section, ϕ_y	0.95
Tension, Fracture on Net Section, ϕ_u	0.80

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 13 (U9-U10)** Date:

Gross Area and Net Area Calculations

This section of the spreadsheet calculates faulted section areas to be used in strength limit checks and determining the controlling live load stress range in order to calculate the fatigue life in the faulted state. Due to application of the bending stress factor, Ξ_B, the controlling case may be the largest gross area plate or it may be a smaller plate positioned exterior within the section. Refer to Guide Specifications C1.6.1 for further information on "interior" and "exterior" plate positions. If there are staggered holes, the user must manually enter the controlling net area for each component, taking into account the pitch and gage of staggered hole patterns (See AASHTO LRFD 6.8.3) for strength calculations. Enter these values below under "Net (Str.)". If the holes are not staggered, the user need not manually enter net areas. **Net areas are always automatically calculated for fatigue life prediction**.

Faulted Section Scenarios:

Case 0: Assumes failure of plate PL-0

Case 1f: Assumes failure of plate PL-1f, if applicable

Case 2f: Assumes failure of plate PL-2f, if applicable

Case 2p: Assumes failure of plate PL-2p, if applicable

Case 3p: Assumes failure of plate PL-3p, if applicable

Case CH: Assumes failure of the rolled channel, if applicable

Case WP: Assumes failure of the largest net web plate, if applicable

Component	Unfaulted Areas			Faulted Net Areas for Fatigue Life Calculations						
	Gross	Net (Fat.)	Net (Str.)	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
	A_g (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)
PL-2f	0.00	0.00								
PL-1f	0.00	0.00								
PL-0	10.00	9.06								
Angles	6.60	4.96								
Channel	0.00	0.00								
PL-1p	0.00	0.00								
PL-2p	0.00	0.00								
PL-3p	0.00	0.00								
WP-top	6.00	2.48								
WP-bot	6.00	2.48								
Half Symmetry Total	**22.60**	**16.51**		**7.44**	0.00	0.00	0.00	0.00	0.00	**15.26**
Full Member Total	**45.20**	**33.01**		**23.95**	0.00	0.00	0.00	0.00	0.00	**30.53**

	Faulted Net Areas for Strength Checks						
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)
Half Symmetry Total	**7.44**	0.00	0.00	0.00	0.00	0.00	**15.26**
Full Member Total	**23.95**	0.00	0.00	0.00	0.00	0.00	**30.53**

	Faulted Gross Areas						
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)
Half Symmetry Total	**12.60**	0.00	0.00	0.00	0.00	0.00	**19.60**
Full Member Total	**35.20**	0.00	0.00	0.00	0.00	0.00	**39.20**

	Area, (in^2)		Area, (in^2)		Area, (in^2)
Holes, angles	1.64	Holes, PL-3p	0.00		
Holes, PL-2f	0.00	Holes, PL-1p	0.00	Holes, Web-top	3.52
Holes, PL-1f	0.00	Holes, PL-2p	0.00	Holes, Web-bot	3.52
Holes, PL-0	0.94	Holes-channel	0.00		

Stress Amplification Factors (GS 2.2)

Stress Amplifiers (GS Table 2.2.1-1)**:**

Shear Lag Factor, Ξ_{VL}	1.20
Number of web plates, N_{web}	1
Number of flange plates, N_{fl}	1
Number of total plates, N_{AX}	2
Bending Factor, Ξ_B	1.24

40-over-fastener Rule **Required?** (GS 2.2.1.1)**:** No

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: Sect 13 (U9-U10) Date:

Strength Capacity Check (GS 2.2 & 2.3)

Factored Load:

$P_u = \gamma_{DC} P_{DC} + \gamma_{DW} P_{DW} + \gamma_{LL} P_{LL+IM} =$ 1,218.8 kip GS Eq. 1.7.2-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u =$ 56.0 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y =$ 47.5 ksi GS Eq. 2.3-1

Factored Stress (Strength Limit State): (*Note:* Ξ_B & Ξ_{VL} = 1.0)

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_u / 2A_{AFN}) =$	81.87	0.00	0.00	0.00	0.00	0.00	39.92	GS Eq. 2.2.1-1
$f_{AFG} = \Xi_B \Xi_{VL} (P_u / 2A_{AFG}) =$	48.37	0.00	0.00	0.00	0.00	0.00	31.09	GS Eq. 2.2.1-2

Strength Criteria Check:

$f_{AFG} \le f_{u,g}$? 0.68 NG OK or NG GS Eq. 2.3-1

$f_{AFN} \le f_{u,n}$? 0.98 NG OK or NG GS Eq. 2.3-2

Fatigue Life Estimate (GS 2.5)

Effective Stress Range & Max Stress Range in Unfaulted State:

$R_p =$ 1.03 MBE Eq. 7.2.2.1-1

Unfaulted state stress range, $\Delta f =$ 1.34 ksi

Unfaulted state effective stress range, $(\Delta f)_{eff} =$ 1.38 ksi MBE Eq. 7.2.2-1

$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$ 3.04 ksi MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category D GS Table 2.5-2

Detail Category Constant 22.00 $x10^8$ ksi^3

Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$ 7.00 ksi

Resistance Factor for evaluation, R_R **1.0** MBE Table 7.2.5.2-1

Infinite Fatigue Life Check (Unfaulted State):

Is $(\Delta f)_{max} \le (\Delta f)_{TH}$? Yes Yes or No MBE Eq. 7.2.4-1

Finite Fatigue Life Estimate (Unfaulted State):

Initially available stress cycles, N_{av} - cycles MBE Eq. 7.2.5.1-2

No. of consumed stress cycles, N_1 - cycles MBE Eq. 7.2.5.1-3

$N_{av} > N_1$? - Yes or No MBE Eq. 7.2.5.1-1

Remaining fatigue life, Y_{REM} - Years MBE Eq. 7.2.5.1-4

Future ADTT for single lane, $ADTT_{FUTURE}$ - trucks/day MBE Eq. 7.2.5.1-6

$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$? - Yes or No MBE Eq. 7.2.5.1-5

$(Y_{ADTT})_{LIMIT} =$ - Years MBE Eq. 7.2.5.1-7

Remaining fatigue life, Y_{REM} - Years MBE Eq. 7.2.5.1-8

Total unfaulted state remaining fatigue life, Y_{REM} **Infinite** Years MBE 7.2.5.1

Case I or II for unfaulted state? **I** I or II GS 2.5

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 13 (U9-U10)** Date:

Effective Stress Range & Max Stress Range in Faulted State:

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_{FAT+IM} / 2A_{AFN}) =$	**4.43**	0.00	0.00	0.00	0.00	0.00	**2.16**	GS Eq. 2.2.1-1

40-over-fastener Rule (GS 2.2.1.1):

Load in an angle, $P_{FAT+IM-L}$	N.A.	kip	
$f_{AFN} = P_{FAT+IM} / A_N + 0.4P_{FAT+IM-L} / I_f t_p =$	0.00	ksi	
Faulted state stress range, Δf =	4.43	ksi	
Faulted state effective stress range, $(\Delta f)_{eff}$ =	4.56	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	10.04	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-2
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.00	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	4.63E+07	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	158.7	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	1,565	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**158.7**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I(b)**	I(a), I(b), II	GS 2.5

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, NU	66.0	Years	GS 2.5.3
Total finite fatigue life only in unfaulted state, Yu	-	Years	GS 2.5.3
Total remaining fatigue life only in faulted state, Yf	-	Years	GS 2.5.3
Total remaining fatigue life, Nf = Yf(1-Nu/Yu)	**158.7**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**NG**	OK or NG	GS 2.3
Fatigue case =	-	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	-	ksi	
Controlling stress range in faulted state, Δf_{FS} =	-	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	-	Years	
Total remaining fatigue life, N_f	-	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	-	Years	GS 3

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 14 (L4'-L5' South)** Date:

Assumptions:

1. Controlling fatigue detail is the fastened connection.

General Requirements (GS 1.4 and 1.6)

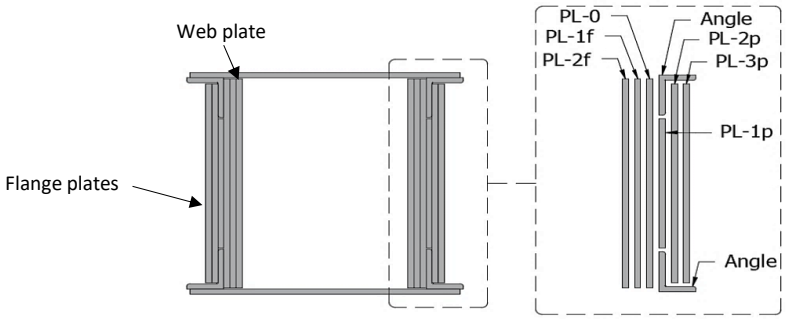
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all other provisions of Section 1.6?	**Yes**	Yes

Member Cross Section Inputs

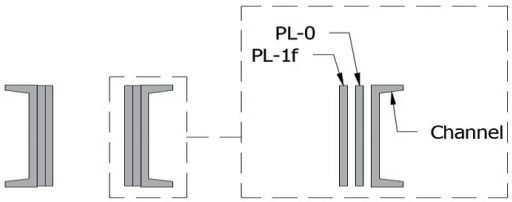
General:

Steel yield strength, F_y	**33.0**	ksi	Fastener diameter, d_{fast}	**0.8750**	in
Steel tensile strength, F_u	**60.0**	ksi	Fastener hole diameter, d_{hole}	0.9375	in
Is it a box (continuous top & bot webs)?	**Yes**	Yes or No	Are the fastener holes staggered?	**No**	Yes or No
Does the member have rolled channels?	**No**	Yes or No	Fastener type	**Rivet**	Bolt or Rivet
Is the member a built-up I-section?	**No**	Yes or No	Are holes punched full size?	**No**	Yes or No

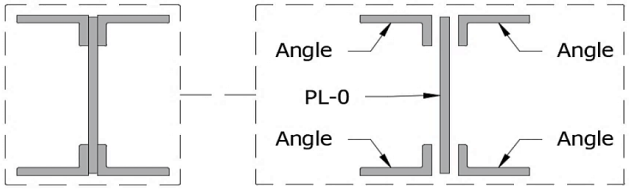
Reference sketch 1.1: Exploded view of built-up channel.



Reference sketch 1.2: Exploded view of rolled channel with additional flange plates.



Reference sketch 1.3: Exploded view of built-up I-section.



Web Plate Dimensions:	**top**	**bot**	
Web Plate Width, $b_{f.i}$	**16.000**	**16.000**	in
Web Plate Thickness, $t_{f.i}$	**0.375**	**0.375**	in
Hand Hole Width, $w_{hh.i}$	**7.500**	**7.500**	in

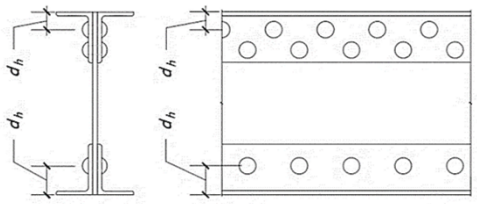
Fastener Location Dimensions in Web Plates: Plate(i):	**top**	**bot**	
Holes in Web Plate, $N_{holes.i}$	**2**	**2**	holes
Distance to Hole 1, $d_{h.wp.i}$	**2.1875**	**2.1875**	in

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 14 (L4'-L5' South)** Date:

Flange Plate Dimensions (in):

Reference sketch 1.4: Distance to hole, d_h



Number of Full-Depth Flange Plates, $N_{fl.full}$			1				0 to 3
Number of Partial-Depth Flange Plates, $N_{fl.part}$			0				0 to 3
Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p	
$d_{fl,i}$	0.000	0.000	20.000	0.000	0.000	0.000	in
$t_{fl,i}$	0.0000	0.0000	0.3125	0.0000	0.0000	0.0000	in

Fastener Location Dimensions in Flange Plates:

Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p	
Holes in Flange Plate, $N_{holes.i}$	0	0	2	0	0	0	
Distance to Hole 1, $d_{h.fl.i}$	0.000	0.000	2.188	0.000	0.000	0.000	in

Angle Dimensions: (*Note: angle orientation is not important*)

Select the size of the angles	L4x4x3/8	
Gross area of a single angle, $A_{agl.g}$	2.86	in^2
Thickness of the angle, t_{agl}	0.375	in
Holes in Vert Angle Leg, $N_{holes.vt.agl}$	1	holes
Holes in Horz Angle Leg, $N_{holes.hz.agl}$	1	holes

Rolled Channel Dimensions:

Select the size of the rolled channel		
Gross area of one rolled channel, $A_{ch.g}$		in^2
Thickness of the channel flange, $t_{ch.fl}$		in
Thickness of the channel web, $t_{ch.web}$		in
Holes in the channel web, $N_{holes.ch.web}$	0	holes
Holes in the channel flanges, $N_{holes.ch.flange}$	0	holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	326	trucks/day	Current Year, $Y_{current}$	2022	year
$(ADTT_{sl})_0$	200	trucks/day	Span Length, L	284.00	ft
$(ADTT_{sl})_{limit}$	20,000	trucks/day	Number of striped lanes, n_L	1	lanes
Year Built, Y_{built}	1956	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cycles per Truck, n	1	cycle

Note: Growth rate is for future growth from today on

Loads:

P_{DC}	171	kip	P_{LL+IM}	258	kip
P_{DW}	19	kip	P_{FAT+IM}	107	kip

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override [ ] Override or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Load Factors (GS Table 1.7.1-1 and Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD A6.5.4.2):

Tension, Yield on Gross Section, ϕ_y	0.95
Tension, Fracture on Net Section, ϕ_u	0.80

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 14 (L4'-L5' South)** Date:

Gross Area and Net Area Calculations

This section of the spreadsheet calculates faulted section areas to be used in strength limit checks and determining the controlling live load stress range in order to calculate the fatigue life in the faulted state. Due to application of the bending stress factor, Ξ_B, the controlling case may be the largest gross area plate or it may be a smaller plate positioned exterior within the section. Refer to Guide Specifications C1.6.1 for further information on "interior" and "exterior" plate positions. If there are staggered holes, the user must manually enter the controlling net area for each component, taking into account the pitch and gage of staggered hole patterns (See AASHTO LRFD 6.8.3) for strength calculations. Enter these values below under "Net (Str.)". If the holes are not staggered, the user need not manually enter net areas. **Net areas are always automatically calculated for fatigue life prediction**.

Faulted Section Scenarios:

Case 0: Assumes failure of plate PL-0

Case 1f: Assumes failure of plate PL-1f, if applicable

Case 2f: Assumes failure of plate PL-2f, if applicable

Case 2p: Assumes failure of plate PL-2p, if applicable

Case 3p: Assumes failure of plate PL-3p, if applicable

Case CH: Assumes failure of the rolled channel, if applicable

Case WP: Assumes failure of the largest net web plate, if applicable

Component	Unfaulted Areas			A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)
	Gross	Net (Fat.)	Net (Str.)	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
	A_g (in^2)	A_n (in^2)	A_n (in^2)	Faulted Net Areas for Fatigue Life Calculations						
PL-2f	0.00	0.00								
PL-1f	0.00	0.00								
PL-0	6.25	5.66								
Angles	5.72	4.31								
Channel	0.00	0.00								
PL-1p	0.00	0.00								
PL-2p	0.00	0.00								
PL-3p	0.00	0.00								
WP-top	6.00	2.48								
WP-bot	6.00	2.48								
Half Symmetry Total	**17.97**	**12.46**		**6.80**	0.00	0.00	0.00	0.00	0.00	**11.22**
Full Member Total	**35.94**	**24.92**		**19.26**	0.00	0.00	0.00	0.00	0.00	**22.44**
				Faulted Net Areas for Strength Checks						
Half Symmetry Total			**0.00**	**6.80**	0.00	0.00	0.00	0.00	0.00	**11.22**
Full Member Total			**0.00**	**19.26**	0.00	0.00	0.00	0.00	0.00	**22.44**
				Faulted Gross Areas						
				Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP
				A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)
Half Symmetry Total				**11.72**	0.00	0.00	0.00	0.00	0.00	**14.97**
Full Member Total				**29.69**	0.00	0.00	0.00	0.00	0.00	**29.94**

	Area, (in^2)		Area, (in^2)		Area, (in^2)
Holes, angles	1.41	Holes, PL-3p	0.00		
Holes, PL-2f	0.00	Holes, PL-1p	0.00	Holes, Web-top	3.52
Holes, PL-1f	0.00	Holes, PL-2p	0.00	Holes, Web-bot	3.52
Holes, PL-0	0.59	Holes-channel	0.00		

Stress Amplification Factors (GS 2.2)

Stress Amplifiers (GS Table 2.2.1-1)**:**

Shear Lag Factor, Ξ_{VL}	1.20
Number of web plates, N_{web}	1
Number of flange plates, N_{fl}	1
Number of total plates, N_{AX}	2
Bending Factor, Ξ_B	1.24

40-over-fastener Rule **Required?** (GS 2.2.1.1)**:** No

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 14 (L4'-L5' South)** Date:

Strength Capacity Check (GS 2.2 & 2.3)

Factored Load:

$P_u = \gamma_{DC} P_{DC} + \gamma_{DW} P_{DW} + \gamma_{LL} P_{LL+IM} =$ 606.7 kip GS Eq. 1.7.2-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u =$ 48.0 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y =$ 31.4 ksi GS Eq. 2.3-1

Factored Stress (Strength Limit State): (*Note:* Ξ_B & Ξ_{VL} = 1.0)

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_u / 2A_{AFN}) =$	44.62	0.00	0.00	0.00	0.00	0.00	27.04	GS Eq. 2.2.1-1
$f_{AFG} = \Xi_B \Xi_{VL} (P_u / 2A_{AFG}) =$	25.88	0.00	0.00	0.00	0.00	0.00	20.26	GS Eq. 2.2.1-2

Strength Criteria Check:

$f_{AFG} \le f_{u,g}$? 1.08 **OK** OK or NG GS Eq. 2.3-1

$f_{AFN} \le f_{u,n}$? 1.21 **OK** OK or NG GS Eq. 2.3-2

Fatigue Life Estimate (GS 2.5)

Effective Stress Range & Max Stress Range in Unfaulted State:

$R_p =$	1.02		MBE Eq. 7.2.2.1-1
Unfaulted state stress range, $\Delta f =$	3.43	ksi	
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	3.50	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	7.69	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-2
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.00	ksi	
Resistance Factor for evaluation, R_R	1.0		MBE Table 7.2.5.2-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	5.15E+07	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	6.311E+06	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	156.81	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	1,552	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**156.8**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**II**	I or II	GS 2.5

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 14 (L4'-L5' South)** Date:

Effective Stress Range & Max Stress Range in Faulted State:

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_{FAT+IM} / 2A_{AFN}) =$	**9.35**	0.00	0.00	0.00	0.00	0.00	**5.67**	GS Eq. 2.2.1-1

40-over-fastener Rule (GS 2.2.1.1):

Load in an angle, $P_{FAT+IM-L}$	N.A.	kip	
$f_{AFN} = P_{FAT+IM} / A_N + 0.4P_{FAT+IM-L} / I_f t_p =$	0.00	ksi	
Faulted state stress range, Δf =	9.35	ksi	
Faulted state effective stress range, $(\Delta f)_{eff}$ =	9.54	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	20.98	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-2
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.00	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	5.07E+06	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	35.4	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	459	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**35.4**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**II**	I(a), I(b), II	GS 2.5

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, NU	66.0	Years	GS 2.5.3
Total finite fatigue life only in unfaulted state, Yu	222.8	Years	GS 2.5.3
Total remaining fatigue life only in faulted state, Yf	35.4	Years	GS 2.5.3
Total remaining fatigue life, Nf = Yf(1-Nu/Yu)	**24.9**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.3
Fatigue case =	II	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	3.43	ksi	
Controlling stress range in faulted state, Δf_{FS} =	9.35	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**35.4**	Years	
Total remaining fatigue life, N_f	**24.9**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 15 (U11-U12)** Date:

Assumptions:

1. Controlling fatigue detail is the fastened connection.

General Requirements (GS 1.4 and 1.6)

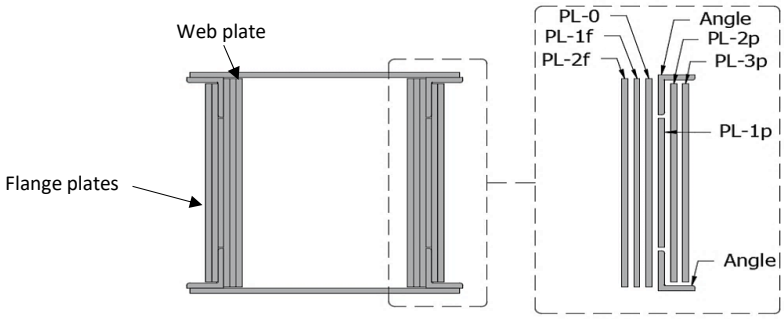
Does the member exhibit severe corrosion, impact damage, or other forms of significant damage?	**No**	No
Does the member meet all other provisions of Section 1.4?	**Yes**	Yes
Does the member meet all other provisions of Section 1.6?	**Yes**	Yes

Member Cross Section Inputs

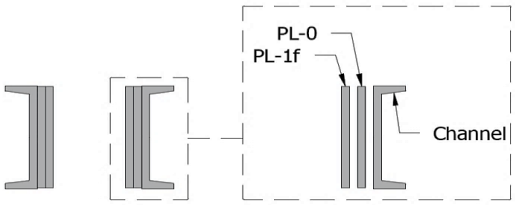
General:

Steel yield strength, F_y	**33.0**	ksi	Fastener diameter, d_{fast}	**0.8750**	in
Steel tensile strength, F_u	**60.0**	ksi	Fastener hole diameter, d_{hole}	0.9375	in
Is it a box (continuous top & bot webs)?	**Yes**	Yes or No	Are the fastener holes staggered?	**No**	Yes or No
Does the member have rolled channels?	**No**	Yes or No	Fastener type	**Rivet**	Bolt or Rivet
Is the member a built-up I-section?	**No**	Yes or No	Are holes punched full size?	**No**	Yes or No

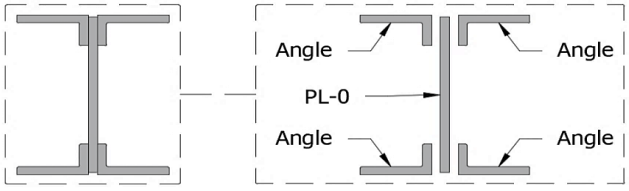
Reference sketch 1.1: Exploded view of built-up channel.



Reference sketch 1.2: Exploded view of rolled channel with additional flange plates.



Reference sketch 1.3: Exploded view of built-up I-section.



Web Plate Dimensions:	**top**	**bot**	
Web Plate Width, $b_{f.i}$	**16.000**	**16.000**	in
Web Plate Thickness, $t_{f.i}$	**0.375**	**0.375**	in
Hand Hole Width, $w_{hh.i}$	**7.500**	**7.500**	in

Fastener Location Dimensions in Web Plates: Plate(i):	**top**	**bot**	
Holes in Web Plate, $N_{holes.i}$	**2**	**2**	holes
Distance to Hole 1, $d_{h.wp.i}$	**2.1875**	**2.1875**	in

Internal Redundancy of Built-up Member: Multi-component Axial

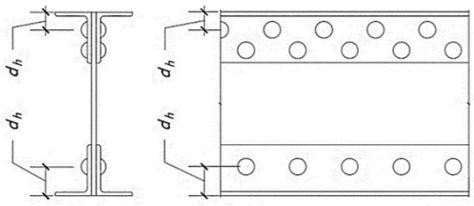
Member ID: **Sect 15 (U11-U12)** Date:

Flange Plate Dimensions (in):

Number of Full-Depth Flange Plates, $N_{fl.full}$	1	0 to 3
Number of Partial-Depth Flange Plates, $N_{fl.part}$	0	0 to 3

Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p	
$d_{fl,i}$	0.000	0.000	20.000	0.000	0.000	0.000	in
$t_{fl,i}$	0.0000	0.0000	0.5000	0.0000	0.0000	0.0000	in

Reference sketch 1.4: Distance to hole, d_h



Fastener Location Dimensions in Flange Plates:

Plate(i):	PL-2f	PL-1f	PL-0	PL-1p	PL-2p	PL-3p	
Holes in Flange Plate, $N_{holes.i}$	0	0	2	0	0	0	
Distance to Hole 1, $d_{h.fl.i}$	0.000	0.000	2.188	0.000	0.000	0.000	in

Angle Dimensions: (*Note: angle orientation is not important*)

Select the size of the angles	L4x4x3/8	
Gross area of a single angle, $A_{agl.g}$	2.86	in^2
Thickness of the angle, t_{agl}	0.375	in
Holes in Vert Angle Leg, $N_{holes.vt.agl}$	1	holes
Holes in Horz Angle Leg, $N_{holes.hz.agl}$	1	holes

Rolled Channel Dimensions:

Select the size of the rolled channel		
Gross area of one rolled channel, $A_{ch.g}$		in^2
Thickness of the channel flange, $t_{ch.fl}$		in
Thickness of the channel web, $t_{ch.web}$		in
Holes in the channel web, $N_{holes.ch.web}$	0	holes
Holes in the channel flanges, $N_{holes.ch.flange}$	0	holes

Fatigue Variables:

$(ADTT_{sl})_{present}$	326	trucks/day	Current Year, $Y_{current}$	2022	year
$(ADTT_{sl})_0$	200	trucks/day	Span Length, L	441.00	ft
$(ADTT_{sl})_{limit}$	20,000	trucks/day	Number of striped lanes, n_L	1	lanes
Year Built, Y_{built}	1956	year	Stress-Range Estimate Partial LF, R_s	1.00	
Expected annual $(ADTT)_{SL}$ growth rate, g	0.010	MBE 7.2.5.1	No. of Stress-Range Cycles per Truck, n	1	cycle

Note: Growth rate is for future growth from today on

Loads:

P_{DC}	59	kip	P_{LL+IM}	160	kip
P_{DW}	8	kip	P_{FAT+IM}	95	kip

Load and Resistance Factors (GS 1.7)

Member fabricated to AWS D1.5 FCP? No

(This is based on the year built; "No" if prior to 1978)

Optional FCP override [ ] Override or blank

(This is optional for cases where a bridge newer than 1978 does not meet FCP)

Load Factors (GS Table 1.7.1-1 and Table 3.4.1-1):

Permanent Dead Loads, γ_{DC}	1.15
Wearing Surface and Utility DL, γ_{DW}	1.25
Design Live Load, γ_{LL}	1.50
Fatigue I Load (infinite), γ_{FAT1}	1.75
Fatigue II Load (finite), γ_{FAT2}	0.80

Fatigue Constants (AASHTO LRFD 6.6.1.2.5):

Fatigue Category:	A (x 10^8) ksi^3	$(\Delta F)_{TH}$ ksi
B	120.0	16.0
C	44.0	10.0
D	22.0	7.0
E'	3.9	2.6

Resistance Factors (AASHTO LRFD A6.5.4.2):

Tension, Yield on Gross Section, ϕ_y	0.95
Tension, Fracture on Net Section, ϕ_u	0.80

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 15 (U11-U12)** Date:

Gross Area and Net Area Calculations

This section of the spreadsheet calculates faulted section areas to be used in strength limit checks and determining the controlling live load stress range in order to calculate the fatigue life in the faulted state. Due to application of the bending stress factor, Ξ_B, the controlling case may be the largest gross area plate or it may be a smaller plate positioned exterior within the section. Refer to Guide Specifications C1.6.1 for further information on "interior" and "exterior" plate positions. If there are staggered holes, the user must manually enter the controlling net area for each component, taking into account the pitch and gage of staggered hole patterns (See AASHTO LRFD 6.8.3) for strength calculations. Enter these values below under "Net (Str.)". If the holes are not staggered, the user need not manually enter net areas. **Net areas are always automatically calculated for fatigue life prediction**.

Faulted Section Scenarios:

Case 0: Assumes failure of plate PL-0

Case 1f: Assumes failure of plate PL-1f, if applicable

Case 2f: Assumes failure of plate PL-2f, if applicable

Case 2p: Assumes failure of plate PL-2p, if applicable

Case 3p: Assumes failure of plate PL-3p, if applicable

Case CH: Assumes failure of the rolled channel, if applicable

Case WP: Assumes failure of the largest net web plate, if applicable

Component	Unfaulted Areas												
	Gross	Net (Fat.)	Net (Str.)										
	A_g (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)	A_n (in^2)				
				Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP			
				Faulted Net Areas for Fatigue Life Calculations									
PL-2f	0.00	0.00											
PL-1f	0.00	0.00											
PL-0	10.00	9.06											
Angles	5.72	4.31											
Channel	0.00	0.00											
PL-1p	0.00	0.00											
PL-2p	0.00	0.00											
PL-3p	0.00	0.00											
WP-top	6.00	2.48											
WP-bot	6.00	2.48											
Half Symmetry Total	**21.72**	**15.86**		**6.80**	0.00	0.00	0.00	0.00	0.00	**14.62**			
Full Member Total	**43.44**	**31.72**		**22.66**	0.00	0.00	0.00	0.00	0.00	**29.24**			
				Faulted Net Areas for Strength Checks									
Half Symmetry Total			**0.00**	**6.80**	0.00	0.00	0.00	0.00	0.00	**14.62**			
Full Member Total			**0.00**	**22.66**	0.00	0.00	0.00	0.00	0.00	**29.24**			
				Faulted Gross Areas									
				Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP			
				A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)	A_g (in^2)			
Half Symmetry Total				**11.72**	0.00	0.00	0.00	0.00	0.00	**18.72**			
Full Member Total				**33.44**	0.00	0.00	0.00	0.00	0.00	**37.44**			

	Area, (in^2)		Area, (in^2)		Area, (in^2)
Holes, angles	1.41	Holes, PL-3p	0.00		
Holes, PL-2f	0.00	Holes, PL-1p	0.00	Holes, Web-top	3.52
Holes, PL-1f	0.00	Holes, PL-2p	0.00	Holes, Web-bot	3.52
Holes, PL-0	0.94	Holes-channel	0.00		

Stress Amplification Factors (GS 2.2)

Stress Amplifiers (GS Table 2.2.1-1)**:**

Shear Lag Factor, Ξ_{VL}	1.20
Number of web plates, N_{web}	1
Number of flange plates, N_{fl}	1
Number of total plates, N_{AX}	2
Bending Factor, Ξ_B	1.24

40-over-fastener Rule **Required?** (GS 2.2.1.1)**:** No

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 15 (U11-U12)** Date:

Strength Capacity Check (GS 2.2 & 2.3)

Factored Load:

$P_u = \gamma_{DC} P_{DC} + \gamma_{DW} P_{DW} + \gamma_{LL} P_{LL+IM} =$ 317.7 kip GS Eq. 1.7.2-1

Factored Resistance:

$f_{u,n} = \varphi_u F_u =$ 48.0 ksi GS Eq. 2.3-2

$f_{u,g} = \varphi_y F_y =$ 31.4 ksi GS Eq. 2.3-1

Factored Stress (Strength Limit State): (*Note:* Ξ_B & Ξ_{VL} = 1.0)

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_u / 2A_{AFN}) =$	23.37	0.00	0.00	0.00	0.00	0.00	10.87	GS Eq. 2.2.1-1
$f_{AFG} = \Xi_B \Xi_{VL} (P_u / 2A_{AFG}) =$	13.55	0.00	0.00	0.00	0.00	0.00	8.49	GS Eq. 2.2.1-2

Strength Criteria Check:

$f_{AFG} \le f_{u,g}$? 2.05 **OK** OK or NG GS Eq. 2.3-1

$f_{AFN} \le f_{u,n}$? 2.31 **OK** OK or NG GS Eq. 2.3-2

Fatigue Life Estimate (GS 2.5)

Effective Stress Range & Max Stress Range in Unfaulted State:

$R_p =$	1.03		MBE Eq. 7.2.2.1-1
Unfaulted state stress range, $\Delta f =$	2.40	ksi	
Unfaulted state effective stress range, $(\Delta f)_{eff} =$	2.47	ksi	MBE Eq. 7.2.2-1
$(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	5.43	ksi	MBE 7.2.4

Fatigue Life Estimate in the Unfaulted State:

Fatigue Category	D		GS Table 2.5-2
Detail Category Constant	22.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	7.00	ksi	
Resistance Factor for evaluation, R_R	**1.0**		MBE Table 7.2.5.2-1
Infinite Fatigue Life Check (Unfaulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	Yes	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Unfaulted State):			
Initially available stress cycles, N_{av}	-	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	-	cycles	MBE Eq. 7.2.5.1-3
$N_{av} > N_1$?	-	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	-	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	-	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT} =$	-	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	-	Years	MBE Eq. 7.2.5.1-8
Total unfaulted state remaining fatigue life, Y_{REM}	**Infinite**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I**	I or II	GS 2.5

Internal Redundancy of Built-up Member: Multi-component Axial

Member ID: **Sect 15 (U11-U12)** Date:

Effective Stress Range & Max Stress Range in Faulted State:

	Factored Stresses in Faulted Condition							
	Case 0	Case 1f	Case 2f	Case 2p	Case 3p	Case CH	Case WP	
	ksi	ksi	ksi	ksi	ksi	ksi	ksi	
$f_{AFN} = \Xi_B \Xi_{VL} (P_{FAT+IM} / 2A_{AFN}) =$	**8.32**	0.00	0.00	0.00	0.00	0.00	**3.87**	GS Eq. 2.2.1-1

40-over-fastener Rule (GS 2.2.1.1):

Load in an angle, $P_{FAT+IM-L}$	N.A.	kip	
$f_{AFN} = P_{FAT+IM} / A_N + 0.4P_{FAT+IM-L} / I_f t_p =$	0.00	ksi	
Faulted state stress range, Δf =	8.32	ksi	
Faulted state effective stress range, $(\Delta f)_{eff}$ =	8.57	ksi	MBE Eq. 7.2.2-1
Faulted state, $(\Delta f)_{max} = (\gamma_{FAT1}/\gamma_{FAT2})(\Delta f)_{eff} \approx 2.2(\Delta f)_{eff}$	18.85	ksi	MBE 7.2.4

Fatigue Life Estimate in the Faulted State:

Fatigue Category	C		GS Table 2.5-2
Detail Category Constant	44.00	$x10^8$ ksi^3	
Constant Amplitude Fatigue Limit, $(\Delta F)_{TH}$	10.00	ksi	
Infinite Fatigue Life Check (Faulted State):			
Is $(\Delta f)_{max} \le (\Delta f)_{TH}$?	No	Yes or No	MBE Eq. 7.2.4-1
Finite Fatigue Life Estimate (Faulted State):			
Initially available stress cycles, N_{av}	6.99E+06	cycles	MBE Eq. 7.2.5.1-2
No. of consumed stress cycles, N_1	0	cycles	
$N_{av} > N_1$?	Yes	Yes or No	MBE Eq. 7.2.5.1-1
Remaining fatigue life, Y_{REM}	46.1	Years	MBE Eq. 7.2.5.1-4
Future ADTT for single lane, $ADTT_{FUTURE}$	511	trucks/day	MBE Eq. 7.2.5.1-6
$(ADTT_{SL})_{FUTURE} \le (ADTT_{SL})_{LIMIT}$?	Yes	Yes or No	MBE Eq. 7.2.5.1-5
$(Y_{ADTT})_{LIMIT}$ =	N.A.	Years	MBE Eq. 7.2.5.1-7
Remaining fatigue life, Y_{REM}	N.A.	Years	MBE Eq. 7.2.5.1-8
Total faulted state remaining fatigue life, Y_{REM}	**46.1**	Years	MBE 7.2.5.1
Case I or II for unfaulted state?	**I(b)**	I(a), I(b), II	GS 2.5

Total Remaining Fatigue Life:

No. of accumulated years in unfaulted state, NU	66.0	Years	GS 2.5.3
Total finite fatigue life only in unfaulted state, Yu	∞	Years	GS 2.5.3
Total finite fatigue life only in faulted state, Yf	46.1	Years	GS 2.5.3
Total remaining fatigue life, Nf = Yf(1-Nu/Yu)	**46.1**	Years	GS Eq. 2.5.3-1

Summary of Results

Strength check =	**OK**	OK or NG	GS 2.3
Fatigue case =	I(b)	I(a), I(b), II	GS 2.5
Stress range in unfaulted state, Δf_{UFS} =	2.40	ksi	
Controlling stress range in faulted state, Δf_{FS} =	8.32	ksi	
Controlling faulted state remaining fatigue life, Y_{REM}	**46.1**	Years	
Total remaining fatigue life, N_f	**46.1**	Years	GS Eq. 2.5.3-1
Maximum Interval for Special Inspections =	**10.0**	Years	GS 3

Appendix 3G. NSTM/IRM Inspection Plan for Structure 062-65-T4020: Wabash River Memorial Bridge

1. INTRODUCTION

This document was prepared as an appendix to the report titled "*Evaluation of the Redundancy Status of Structure 062-65-T4020: Wabash River Memorial Bridge"*, but also serves as standalone documentation for the proposed inspection plan for the NSTMs and IRMs of the Wabash River Memorial Bridge. The Wabash River Memorial Bridge (Asset #062-65-T4020) is a truss bridge that spans over the Wabash River, crossing the state line between Indiana and Illinois. Built in 1956 near Mount Vernon, Indiana, the bridge consists of six continuous girder approach spans on each side of three continuous arch through truss main spans. The main truss spans are riveted built-up axially tension members. Rehabilitations and repairs, primarily addressing deck and railing, have been completed throughout its lifetime. The evaluation for internal redundancy for axially loaded tension members was completed for the three truss spans; the girder approach spans and the tie arch members were not included. The National Bridge Inventory details are shown in Table 3G-1.

Table 3G-1. *Bridge details*

Attribute (NBI Code)	**Value**
Bridge Name	Wabash River Memorial Bridge (62-065-T4020)
Structure Number (8)	21869
State Name (1)	Indiana
County Name (3)	129 - Posey County
Features Intersected (6A)	Wabash River, Herman Island
Facility Carried by Structure (7)	SR 62
Location (9)	00.00 @ State Line
Latitude (16)	37.94387
Longitude (17)	-88.03618
Year Built (27)	1956
Main Span Material (43A)	4 - Steel Continuous
Main Span Design (43B)	12 - Arch - Thru
Number of Spans in Main Unit (45)	3
Number of Approach Spans (46)	48
Bridge Posting Code (70)	5 - Equal to or above legal loads

Prior to the internal redundancy evaluation, several truss members were classified as non-redundant steel tension members (NSTMs) and were subjected to an arm's length field inspection at a maximum interval not to exceed 2 years.

The bridge was evaluated using the analysis procedure for axially loaded tension members outlined in the AASHTO Guide Specifications for Internal Redundancy of Mechanically-Fastened Built-Up Steel Members adopted in 2018 (AASHTO, 2018a) (IRM Guide Specification). The IRM Guide Specifications provide guidance on determining if a member

that is currently labeled as a non-redundant steel tension member (NSTM), formerly known as fracture critical members (FCM), contains adequate internal redundancy to be relabeled as an internally redundant member (IRM). Included in the IRM Guide Specification (AASHTO, 2018a) is a methodology for determining the maximum frequency between Special Inspections. In the context of the IRM Guide Specifications, a Special Inspection is defined as:

> *…an inspection of sufficient depth to reliably detect severed or fractured components and other conditions deemed important in a member identified as an IRM. To meet the objectives of the Special Inspection for IRMs, it is understood that special access equipment may be required for some bridges, while for others it may be possible to reliably detect broken components from the ground using normal visual inspection techniques.*

Note that scope and intervals utilized for routine safety inspections (e.g., general deck condition, etc.) are not affected.

The evaluation demonstrated that 53% of the eligible truss members over the Wabash River can be reclassified as internally redundant members and are eligible to receive a Special Inspection at a frequency of 10 years.

2. INSPECTION SCOPE AND FREQUENCY

The truss members that are not reclassified as IRMs should continue to be inspected as NSTMs, which includes an arm's length field inspection every 2 years. The most recent NSTM inspection was conducted in 2022, and the next NSTM inspection is scheduled for 2024. The members that should remain NSTMs and be inspected as such every 2 years are shown in Table 3G-2. The bridge is symmetric about the centerline of the arch, so the Member IDs listed in Table 3G-2 correlate to four different locations along both truss lines.

Table 3G-2. *Members not passing IRM checks*

Span	Member	Member Type	Angle Size	Channel Size	Passes Screening Criteria?	Passes Strength Check? (Faulted)	Fracture on Net, Strength Ratio	Yield on Gross, Strength Ratio
#	Member ID	Type	Size	Size	Yes or No	Yes or No	Less than 1 = NG	Less than 1 = NG
7	L2-L3	Lower Chord	L4x4x7/16		YES	NO	0.75	0.82
7	L3-L4	Lower Chord	L4x4x7/16		YES	NO	0.75	0.82
7	U7-U8	Upper Chord	L4x4x7/16		YES	NO	0.74	0.81
7	U8-U9	Upper Chord	L4x4x7/16		YES	NO	0.74	0.81
8	U9-U10	Upper Chord	L4x4x7/16		YES	NO	0.68	0.98
8	U10-U11	Upper Chord	L4x4x7/16		YES	NO	0.68	0.98
8	L14-L15	Middle Chord		C15x40	YES	NO	0.41	0.60
8	L15-L16	Middle Chord		C15x40	YES	NO	0.41	0.60
7	U1-L2	Diagonal		C12x25	YES	NO	0.58	0.85
7	L4-U5	Diagonal		C15x33.9	YES	NO	0.52	0.76
7	L6-U7	Diagonal		C15x33.9	YES	NO	0.37	0.70
7	L8-U9	Diagonal		C18x51.9	YES	NO	0.30	0.56
8	U9-L10	Diagonal		C15x33.9	YES	NO	0.53	0.78
8	U11-L12	Diagonal		C15x33.9	YES	NO	0.42	0.79
8	U13-L14	Diagonal		C12x30	YES	NO	0.44	0.83
8	U15-L16	Diagonal		C12x20.7	YES	NO	0.69	1.00

Table 3G-3. Members passing IRM checks

Span	Member	Member Type	Angle Size	Channel Size	Passes Screening Criteria?	Passes Strength Check? (Faulted)	Fracture on Net, Strength Ratio	Yield on Gross, Strength Ratio
#	Member ID	Type	Size	Size	Yes or No	Yes or No	Less than 1 = NG	Less than 1 = NG
7	L0-L1	Lower Chord	L4x4x3/8	-	YES	YES	1.19	1.34
7	L1-L2	Lower Chord	L4x4x3/8	-	YES	YES	1.19	1.34
7	L4-L5	Lower Chord	L4x4x3/8		YES	YES	1.08	1.21
7	L5-L6	Lower Chord	L4x4x3/8		YES	YES	1.08	1.21
7	U5-U6	Upper Chord	L4x4x3/8		YES	YES	2.61	2.94
7	U6-U7	Upper Chord	L4x4x3/8		YES	YES	2.61	2.94
8	U11-U12	Upper Chord	L4x4x3/8	-	YES	YES	2.05	2.31
8	U12-U13	Upper Chord	L4x4x3/8	-	YES	YES	2.05	2.31
7	U1-L1	Vertical	L6x3.5x13.9	-	YES	YES	5.61	4.00
7	U3-L3	Vertical	L6x3.5x13.9	-	YES	YES	5.56	3.97
7	U5-L5	Vertical	L6x3.5x13.9	-	YES	YES	5.59	3.99
7	U7-L7	Vertical	L6x3.5x13.9	-	YES	YES	5.56	3.97
8	U11-L11	Vertical	L6x3.5x13.9	-	YES	YES	5.28	3.76
8	U13-L13	Vertical	L6x3.5x13.9	-	YES	YES	5.33	3.80
8	U15-L15	Vertical	L6x3.5x13.9	-	YES	YES	5.33	3.80
8	L12-L13	Middle Chord	-	C18x45.8	YES	YES	5.93	8.64
8	L13-L14	Middle Chord	-	C18x45.8	YES	YES	5.93	8.64
7	L2-U3	Diagonal		C12x25	YES	YES	3.68	5.35

The truss members that can reclassified may be inspected as IRMs during a Special Inspection conducted every 10 years beginning in 2022 (the year of the most recent NSTM inspection). The purpose of the Special Inspection is to identify if an individual component of the member has failed. The IRM Guide Specifications requires that the Special Inspection scope be sufficient to reliably detect such damage as well as any other change or condition of the member that would affect the performance or eligibility of the member to remain classified as an IRM.

The following figure graphically displays the members to be inspected as NSTMs (red) and IRMs (green). L14-U15, shown in yellow, was formerly classified as an NSTM, but in the current analysis was found to be in net compression under the Strength I load combination and should no longer be classified as an NSTM, per AASTHO BDS 6.6.2.2. Again, the bridge is symmetric about the centerline of the arch (member U16-L16), so the figure below represents both halves of both trusses (north and south).

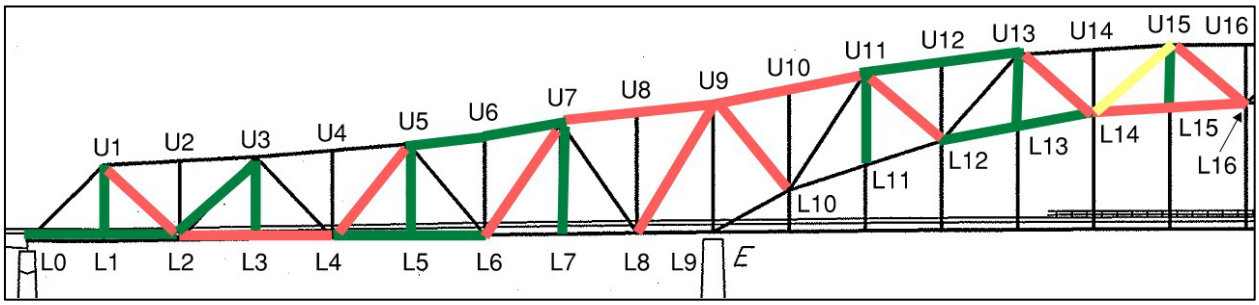


Figure 3G-1. Truss members identified as IRM (green) or that remain NSTMs (red).

3. FUTURE INSPECTIONS AND EVALUATIONS

The current (2023) inspections scheduled for this bridge include Fracture Critical, Routine, and Underwater inspections. Following this evaluation, an additional Special Inspection would be added to inspect the IRM members. The Special (IRM) Inspection was determined to have an inspection interval of ten years, which remains valid provided the bridge conditions remain unchanged. All members except for L4-L6 have infinite life in the unfaulted state and could remain on the 10-year inspection interval until bridge conditions warrant additional evaluations to determine an updated frequency.

Additionally, the Fracture Critical Inspection should be relabeled as an NSTM Inspection and the members to be inspected would be updated as shown in Figure 3G-1. Assuming current bridge conditions remained unchanged, the timeline of these inspections is provided in Table 3.G.3. Items that could affect the given schedule include, but are not limited to, change in live loads due to changes in traffic patterns or uses and changes in condition of structure, such as corrosion significant to require load posting, cracking, or damage due to vehicle impact in primary members.

Table 3G-4. *Proposed schedule of various inspections*

Inspection Type	Frequency	Yr of Last Insp	2023	2024	2025	2026	2027	2028	2029	2030
Routine	**24 months**	**2022**	No	Yes	No	Yes	No	Yes	No	Yes
NSTM	**24 months**	**2022**	No	Yes	No	Yes	No	Yes	No	Yes
Special (IRM)	**10 years**	**N/A**	No	No	No	No	No	No	No	No
Underwater	**60 months**	**2021**	No	No	No	Yes	No	No	No	No

Inspection Type	Frequency	continued...	2031	2032	2033	2034	2035	2036	2037	2038
Routine	**24 months**	**-**	No	Yes	No	Yes	No	Yes	No	Yes
NSTM	**24 months**	**-**	No	Yes	No	Yes	No	Yes	No	Yes
Special (IRM)	**10 years**	**-**	No	Yes	No	No	No	No	No	No
Underwater	**60 months**	**-**	Yes	No	No	No	No	Yes	No	No

VOLUME IV: Analytical Evaluation of the After-Fracture System Performance of Steel I-Girder Bridge: I-74-170-04684 Over Whitewater River, Simple-Span Truss Bridge: SR 1 001-68-03408 Over the Mississinewa River, and Two-Span Truss Bridge: Matthew E. Welsh Memorial Bridge, Mauckport (135-31-06504 B) in the State of Indiana

EXECUTIVE SUMMARY

In this report, three bridges from the existing INDOT inventory were evaluated because one of the structural members that had been identified as a Non-Redundant Steel Tension Member (NSTM) was assumed to have completely failed. The cause of failure was not important in the analysis, but it was generally assumed to be caused by a brittle fracture. The sudden loss of the complete cross section also included the compression flange for flexural members that had been evaluated.

The bridges were evaluated using the system analysis procedures defined in the *AASHTO Guide Specifications for Analysis and Identification of Fracture Critical Members and System Redundant Members* (AASHTO, 2018/2022a). The overall evaluation used a reliability-based approach, and all load combinations were in accordance with the AASHTO Guide Specifications (AASHTO, 2018/2022a). Using this procedure, the failed member may be reclassified from being a Non-Redundant Steel Tension Member (NSTM), formerly known as Fracture Critical Members (FCM), or re-classified as a System Redundant Member (SRM) according to the mechanics-based failure criteria and serviceability-based criteria stipulated in the guide specifications (AASHTO, 2018/2022a). The criteria ensured that the structure had adequate strength and stability to avoid partial or total collapse and to allow traffic to continue safely in the presence of a totally fractured NSTM. Note that the objective was not to suggest that the damage be left in place, but rather to demonstrate that the bridge was safe until the fracture was detected. A bridge that meets the AASHTO Guide Specifications satisfies the objectives contained in the June 20, 2012, FHWA memo titled *Clarification of Requirements for Fracture Critical Members*. Additionally, the law replaced the fracture critical designation with the term Non-Redundant Steel Tension Member (NSTM).

This current study utilized a 3D, non-linear, detailed Finite Element (FE) analysis methodology based on the guide specifications (AASHTO, 2018/2022a). All models were performed using the FE solver ABAQUS 2022. The performance criteria described included both strength and serviceability limits specifically developed to ensure the safety of the traveling public. The methodology was benchmarked against the full-scale testing explained in NCHRP Report 883 *Fracture-Critical System Analysis for Steel Bridges* (Connor et al., 2017) providing confidence in the results. Specifically, the twin-tub girder modeling approach was benchmarked to three full-scale experiments performed at the University of Texas, Austin (Mouras, 2008), the detailed FE study presented in NCHRP Project 12-87a (Connor et al., 2017) and Korkmaz et al. (2018). Finally, the evaluation methodology used for this report closely followed the methodology described in *Evaluation of the Fracture Critical Status of Ramp TH over Interstate 43/894 in Milwaukee, Wisconsin* (Connor & Korkmaz, 2016) as described in the report dated April 19, 2016, and *Analytical Evaluation of the After-Fracture System Performance of Typical Steel Twin-Tub Girder Bridges in the State of Wisconsin Phase I and Phase II* (Korkmaz et al., 2018; 2019).

In summary, the results of the analysis show that members in two of the bridges evaluated, specifically 74-170-04684 over the Whitewater River and Matthew E. Welsh Memorial Bridge, Mauckport (135-31-06504 B), failed to satisfy the specified criteria outlined in the AASHTO Guide Specifications that allowed them to be reclassified as SRMs. However, the SR 1 001-68-03408 over the Mississinewa River partially met the requirements according to the failure criteria defined in the guide specifications (AASHTO, 2018/2022a). As a result, certain components of the SR 1 bridge over the Mississinewa River do not need to be classified as NSTMs and may be reclassified as SRMs. The details of the analysis for all three bridges are presented in this report.

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1. BACKGROUND

The concepts associated with the term "Fracture Critical (FC)" that is referred to as "Non-Redundant Steel Tension Members (NSTMs)" today was developed in the mid-1970s. Interestingly, there is little evidence that FC in-service inspection contributes significantly to the improved overall reliability (Connor et al., 2005). FC inspection practices were initiated to help identify fatigue cracking that was prevalent in earlier vintage bridges. Once initiated, fatigue cracks often continue to grow until they present a risk of brittle fracture. The rationale for FC in-service inspection was to improve the likelihood that these cracks would be found at an early stage, i.e., before they present a fracture risk. Further, the maximum allowable interval between FC inspections (24 months) specified in the Code of Federal Regulations (CFRs) was not developed using any quantitative engineering-based criteria, nor has it been shown to be the most appropriate interval. Rather, it was based on the opinion that it was the "right" interval.

There are a number of case studies reported in the literature where full-depth fractures have been observed in two I-girder bridges, as shown in Table 1.1. Interestingly, in all cases, the bridge remained standing, and in most cases, continued to carry service loads (see Table 1.1) even though after-fracture system performance was not a consideration in design. Thus, in all cases, the bridges, several of which were non-composite, were capable of redistributing loads through system performance.

The same results have also been shown through full-scale testing. The tests, one at the University of Texas, Austin (UT) (Mouras, 2008) on a simple span twin-tub girder bridge and the other conducted by Purdue University (Connor et al., 2017) on a simple span truss bridge, have demonstrated the significant reserve capacity of two bridges traditionally classified as FC. In particular, the UT tests (Mouras, 2008) showed that the twin-tub girder bridge possessed a tremendous amount of reserve capacity, carrying loads that far exceeded the original design loads even in the faulted state. Other work performed by Purdue University researchers for NCHRP Project 12-87a (Connor et al., 2017) and the previous redundancy evaluation study for twin-tub girder bridges (Connor & Korkmaz, 2016; Korkmaz et al., 2018) has shown that steel girder bridges often possess significant reserve capacity even when one girder is completely severed.

TABLE 1.1
List of FC bridges where fractures have been observed in main members

Bridge	Type of Failure	Structural Type	Span Length	Conditions After Fracture
Lafayette St. Minneapolis, MN	Full-depth I-girder fracture	2-Girder Cont. span	362 ft.	Some sagging, carried traffic
US 422 over Schuylkill River Pottstown, PA	Partial-depth I-girder fracture	2-Girder Cont. span	150 ft.	No perceptible deflection, carried traffic
Neville Island over Ohio River, Pittsburgh, PA	Full-depth I-girder fracture	2-Girder Cont. span	300 ft.	No perceptible deflection, carried traffic
Hoan Bridge Milwaukee, WI	Multiple full-depth I-girder fractures	3-Girder Cont. span	217 ft.	Considerable deflection, carried light traffic for a brief period
Dan Ryan Expressway Chicago, IL	Full-depth box girder fracture	Cross Girder	40 ft.	Some deflection, still carried traffic
Diefenbaker Bridge, Prince Albert, Canada	Full-depth I-girder fracture	2-Girder Cont. span	150 ft.	No perceptible deflection, carried traffic
I-40 over Rio Grande, NM	Simulated full-depth I-girder fracture	2-Girder Cont. span	163 ft.	Testing demonstrated considerable load capacity after simulated fracture

2. FINITE ELEMENT MODEL

Detailed 3D FE analysis is the most suitable analysis tool to adequately evaluate the redundancy of the bridges. The approach utilized follows the same overall procedures defined in the AASHTO Guide Specifications (AASHTO, 2018/2022a) and NCHRP Report 883 (Connor et al., 2017). The individual steps to the analysis are summarized below and explained in detail in the following chapters. The corresponding sections of the AASHTO Guide Specifications (AASHTO, 2018/2022a) are also cited.

1. Select an adequate FEA tool (AASHTO, 2018/2022a, Section 3.1.1).
2. Construct a 3D FE Model (AASHTO, 2018/2022a, Section 3.1.2).
3. Define geometry, meshes, and material models of superstructure steel (AASHTO, 2018/2022a, Sections 4.1, 5.1, 5.2, and 5.2.1).
4. Define geometry, meshes, and material models of slab and barriers (AASHTO, 2018/2022a, Sections 4.1, 4.2, 4.2.1, 4.2.2, 5.1, and 5.3).
5. Model connections among steelwork components (AASHTO, 2018/2022a, Section 6.3).
6. Model interaction between slab and steelwork (AASHTO, 2018/2022a, Sections 6.1 and 6.2).
7. Define substructure behavior (AASHTO, 2018/2022a, Section 7.2).
8. Identify FCMs (AASHTO, 2018/2022a, Section 3.1.3).
9. Apply Redundancy I and II load combinations (AASHTO, 2018/2022a, Sections 3.2 to 3.4 and 7.1).
10. Evaluate strength criteria (AASHTO, 2018/2022a, Sections 8.2 and 8.2.1).
11. Evaluate serviceability criteria (AASHTO, 2018/2022a, Section 8.3).

2.1 Select an Adequate FEA Tool

A fully calibrated 3D detailed finite element analysis methodology was developed in NCHRP Project 12-87a (Connor et al., 2017) and Korkmaz et al. (2018) and served as the bases for the procedure defined in the guide specifications (AASHTO, 2018/2022a). The bridges used in the calibration process were the Neville Island Bridge (Connor et al., 2017), Hoan Bridge (Connor et al., 2017), three University of Texas Twin Tub Girder Bridge experiments (Korkmaz et al., 2018), Milton Madison Bridge (Connor et al., 2017), White River Bridge (Connor et al., 2017), and Dan Ryan Expressway Transit Structure (Connor et al., 2017). In this project, ABAQUS 2022 was utilized. The software is capable of modeling three-dimensional geometry, material nonlinearity, geometric nonlinearity, material features (density, damping, field variable dependent properties), kinematic constraints, contact (friction and hard), and boundary conditions (AASHTO, 2018/2022a, Section 3.1.1).

2.2 Construct a 3D FE Model

The finite element analysis was performed in two parts. The first portion was performed using implicit static analysis for the construction sequence. In this step, the dead load effects from steel and from the wet concrete prior to curing were considered. The wet concrete was modeled by assigning very low stiffness to the concrete and rebar. The deck was "hardened" in the FE model by increasing the stiffness of the concrete and rebar. Dynamic implicit (if convergency is achievable) or explicit analysis was then used for the second portion, which includes importing the results from the static analysis, simulating the fracture, and evaluating the performance of the bridge after fracture under the Redundancy I and Redundancy II load combinations. A quasi-static analysis was used so that inertial effects are neglected. Note that the dynamic effects due to free vibration after the fracture were included through a dynamic amplification factor, D_{AR}. In the models, the minimum specified time increment to stabilize the explicit analyses was determined according to the mass and element size, and it was set to 5 E-6. The shorter time increments significantly reduce the oscillations (noise) in the result output. Kinetic energy was used to validate whether the quasi-static analysis successfully progressed in the explicit model. In these analyses, it was always less than 1% of the whole model strain energy (AASHTO, 2018/2022a, Section 3.1.2).

2.3 Models of Superstructure Steelwork

Figure 2.1 illustrates the steel components of the I-girder system. The steel I-girders, diaphragms, floor beams and stringers were defined using 4-node shell elements (S4R) with finite membrane strains and a minimum of 5 Simpson thickness integration points. These are general purpose reduced integration elements with hourglass control. At least five elements were used along the depth of the web and at least four elements were used across the width of the flange to obtain accurate estimates of possible buckling behavior. The maximum element aspect ratio was 5 and the corner angles were between 60 and 120 degrees (AASHTO, 2018/2022a, Section 5.2). As seen in Figure 2.2, separate welded cover plates have been assigned into the shell elements of the top and bottom flanges.

The von Mises yield surface, an associated flow rule, and kinematic hardening were also used to assign the steel material multiaxial behavior. The yield and ultimate stresses were assigned based on the material specified on the design plans. For example, ASTM A7 Grade structural steel has an assumed yield stress of 33 ksi and tensile stress of 66 ksi. Ultimate stress was conservatively set to correspond with a strain of 0.05. The elastic modulus was assumed to be 29,000 ksi and Poisson's ratio was set equal to 0.3 (AASHTO, 2018/2022a, Section 4.1).

The material models did not have the effect of strain rate on steel tensile and compressive strength. The time-dependent behaviors of steel sections, such as corrosion, were not included in the FE models. The effect of temperature was not considered. Residual stress and section imperfection were not included in the models.

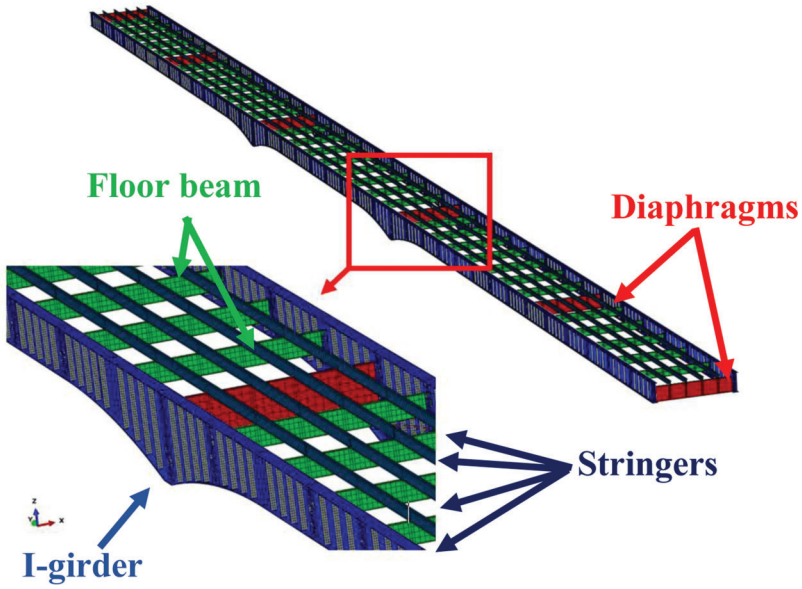


Figure 2.1 Shell model (S4R) of I-74-170-04684 bridge I-girder system.

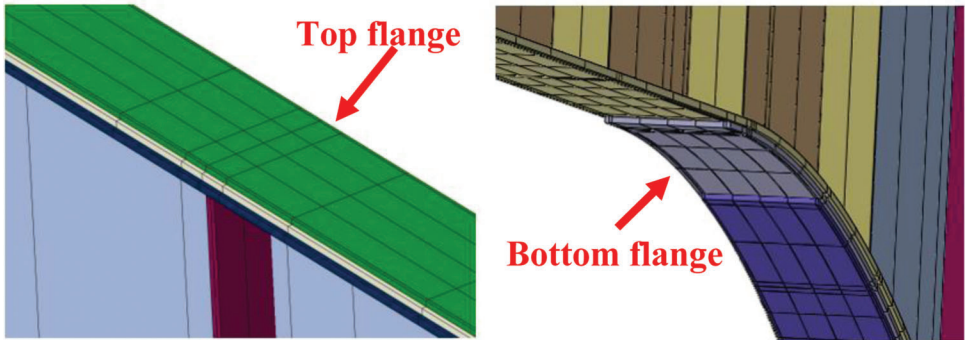


Figure 2.2 Welded cover plates in the shell elements.

In order to simplify the models, some of the bridge details were neglected, including access holes in the diaphragms, plate thickness transition sections, vertical elevation differences, horizontal slope in alignment, and camber in plate sections.

All lateral braces were modeled using traditional Timoshenko beam elements (B31). In Figure 2.3, the blue and red colors show lateral brace locations. The length of the beam elements was around 6 inches and a minimum of three elements were used along the length of the member (AASHTO, 2018/2022a, Section 5.2.1).

Transverse and longitudinal stiffeners were also defined using four-node linear shell elements (S4R) with reduced integration as shown in Figure 2.4. The longitudinal stiffeners increased the buckling capacity of the girders significantly.

The steel components of the truss system were defined using quadratic Timoshenko beam elements (B32) or 4-node shell elements (S4R). The beam elements are appropriate for simulating I-beams and box sections in order to correctly model the effects of torsion and bending. Shell elements are used as well to investigate localized effects when the beam elements reach a high degree of plasticity while remaining within the limit specified by the guide specifications. To evaluate the precision of the beam elements in distributing loads among the structural members next to a fractured component, the Milton Madison Bridge experiment (Connor et al., 2017), conducted by Purdue University on a simple span truss bridge, was also benchmarked by the current research team (see Figure 2.5).

A comparison among the experimental results from the Purdue experiment (Connor et al., 2017), and the results from FEA is presented in Table 2.1. The after-fracture stress computed by FEA is between 0.91 and 1.10 times the experimental values, which implies that all results are within 10%. Therefore, it is concluded that the FEA methodology developed herein can be reliable utilized to perform a redundancy study with beam elements. The FEA numerical results were close to experiment outcomes; hence, FEM was successfully benchmarked to the experiment.

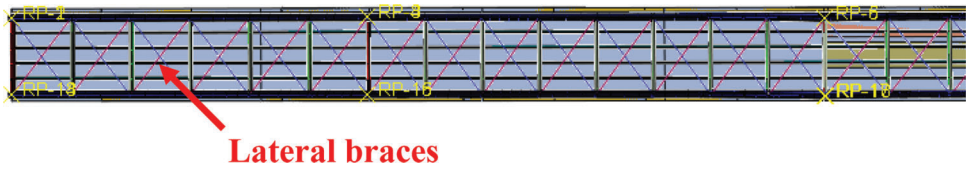


Figure 2.3 Bottom view of lateral braces.

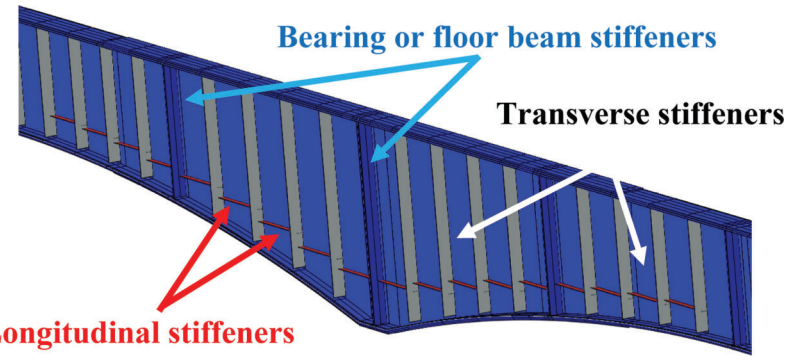


Figure 2.4 Transverse and longitudinal stiffeners.

When there was a significant amount of plasticity found in the beam elements, the shell elements (shown in Figure 2.6) were used as well to evaluate the strength of the structural component. This was done to make confident that the analysis appropriately estimated the behavior.

2.4 Models of Slab and Barriers

The reinforced concrete deck was defined using four-node linear shell elements (S4R) with reduced integration, finite membrane strains, and a minimum of five (5) Simpson thickness integration points. The transverse and lateral reinforcement in the concrete deck was modeled as a part of the reinforced concrete shell section. The section orientation followed the radius of the curvature of the structure. The minimum required number of integration points and element sizes were verified through convergence. The nominal shear capacity of the slab was also analyzed explicitly. The element aspect ratio was set to approximately 1. The use of shell elements to characterize the behavior of the composite deck was verified in NCHRP Project 12-87a (Connor et al., 2017). Using shell elements to model the composite deck greatly improves the efficiency of the model without compromising the fidelity (AASHTO, 2018/2022a, Section 5.3.2).

The concrete parapet and haunches were defined using eight-node solid elements (C3D8R) with reduced integration (shown in Figure 2.7). At least four elements were used through the depth of the exterior parapet to ensure accurate flexural performance. The element aspect ratio was set to approximately 1. The transverse and lateral reinforcement in the concrete parapets was modeled using 2-node linear truss elements (T3D2) (AASHTO, 2018/2022a, Section 5.3.1).

The concrete damage plasticity material model in ABAQUS was utilized. The compressive behavior of the concrete was assigned according to the empirical stress-strain curve proposed by Popovics (1973). The tensile strength and tensile stiffness were calculated in accordance with the fracture energy principles and empirical models noted in FIB Model Code 2010 (Du Béton, 2012) (AASHTO, 2018/2022a, Section 4.2). Both of these approaches are well documented in the literature and well established. These material models have also been used in FEA of other reinforced concrete components and confirmed with experimental data.

2.5 Connection Among Steelwork Components

The equivalent stiffness per connection was determined based on the shear stiffness of the bolts and the bearing stiffness of the plates based on the formulation in Eurocode 3 (European Committee for Standardization, 2005). This is a well-accepted approach to estimating the stiffness of a connection. Serial spring summations were used to calculate equivalent stiffness per connection, and the total equivalent stiffness for multiple bolts was obtained by multiplying one fastener stiffness by the number of fasteners as a parallel spring summation. Exterior fasteners are assumed to carry higher load than interior bolts according to the stiffness of each fastener and its location within the connections. In other words, for stiffer fasteners, the ratio of the load carried by exterior fasteners to interior fasteners is higher. The eccentricity of the single shear connection was defined inside the beam element and hence the effects of eccentricity were indirectly included in the connection model. While the stiffness of the connection is not a typical design concern, when modeling system behavior, the stiffness of the connection must be

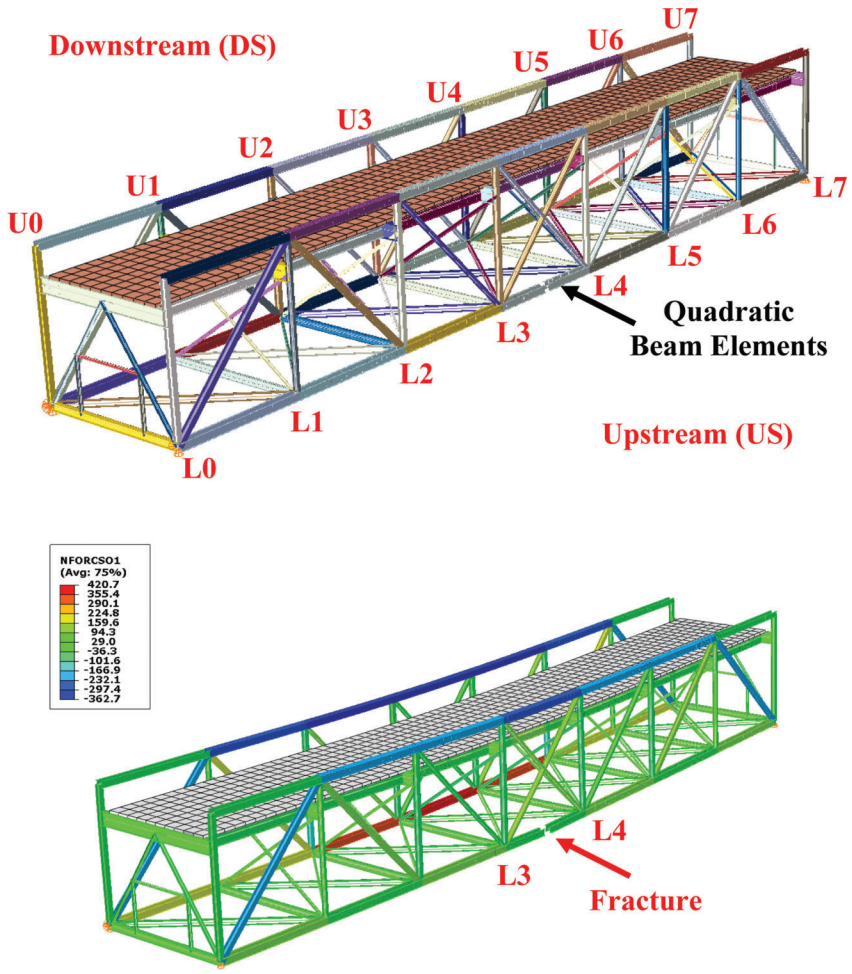


Figure 2.5 FE model of Milton Madison Bridge.

TABLE 2.1
Comparison of experimental (Exp.) stress with results from FEA

Members	Experimental After-Fracture Stress (ksi) Dead + Sand Load	FEA After-Fracture Stress (ksi) Dead + Sand Load	Ratio FEA/EXP
L4US-L3US Fractured Member (Upstream)	–	–	–
U4US-U3US (Upstream)	-9.98	-10.20	1.02
L4DS-L3DS (Downstream)	11.75	12.14	1.03
U4DS-U3DS (Downstream)	-10.66	-11.77	1.10
L4DS-L5DS (Downstream)	11.11	12.08	1.09
L4US-U3DS (Upstream)	10.09	10.44	1.03
U4US-U4DS (Floor beam)	3.32	3.02	0.91

included. The behavior was assumed to be elastic-perfectly plastic. The maximum recommended deformation was set to 2.5 times of the displacement at the start of yielding or 0.18 times the diameter of the bolt. This approach was also benchmarked against experimental connection failure behavior published in NCHRP

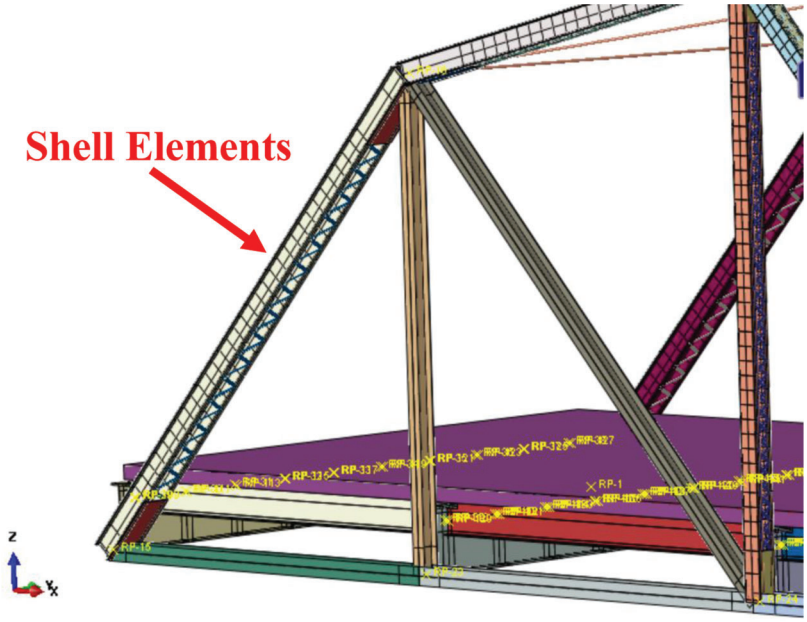


Figure 2.6 Truss model with shell elements.

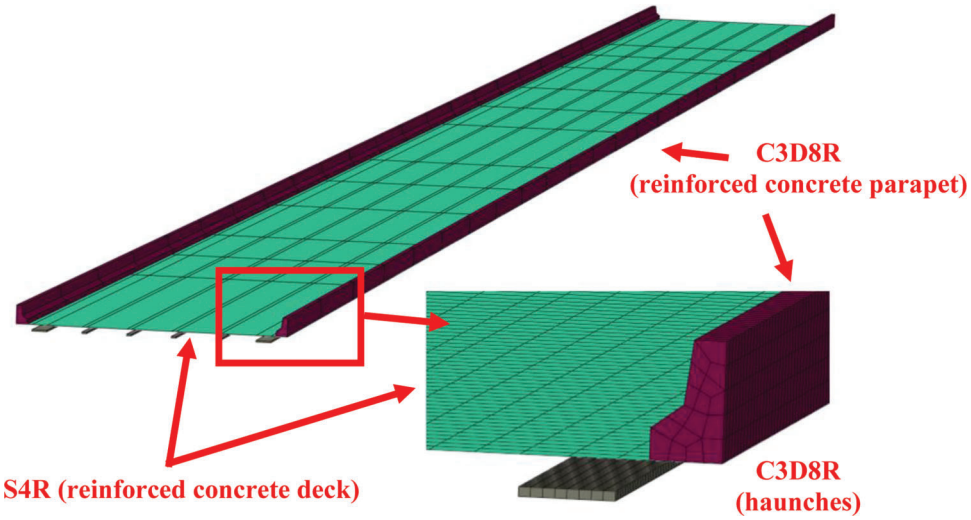


Figure 2.7 Finite element mesh of deck and parapet.

12-84, Appendix C (Ocel, 2013). These experiments focused on gusset plate behavior following the collapse of the I-35W bridge (AASHTO, 2018/2022a, Section 6.3).

In Figure 2.8, braces with connections are shown in detail. The eccentricity of single bracing components significantly reduces the buckling capacity and stiffness of the brace. The eccentricity of each brace was specified in the section definition within the FE model as shown in Figure 2.9. The approach with an eccentricity was benchmarked and verified according to the experiments published by Wang (2013).

Figure 2.10 shows the connections between the stringers and floor beams. Stringers were placed atop floor beams and were unrestrained by uplift. The connector element was utilized to specify what behavior was purposed. In addition, it is essential to note that there was a discontinuity between the stringers after a couple of floor beams, as shown in Figure 2.11. This effect was also considered during the analysis.

Gusset-plate connections for steel truss bridges were defined using the kinematic coupling constraint. Coupling constraints enable distribute the motion in terms of the translation and rotation between the surfaces. By applying this constraint in a regular sense, load transmission can be adjusted through weight factors of the resultants of the forces and moments at the coupling nodes. For traditional bolted or welded connections, it is a common distribution tool in FEA. The influence area in Figure 2.12 has been defined in accordance with the connection and the approximate effective surface area of the gusset plates.

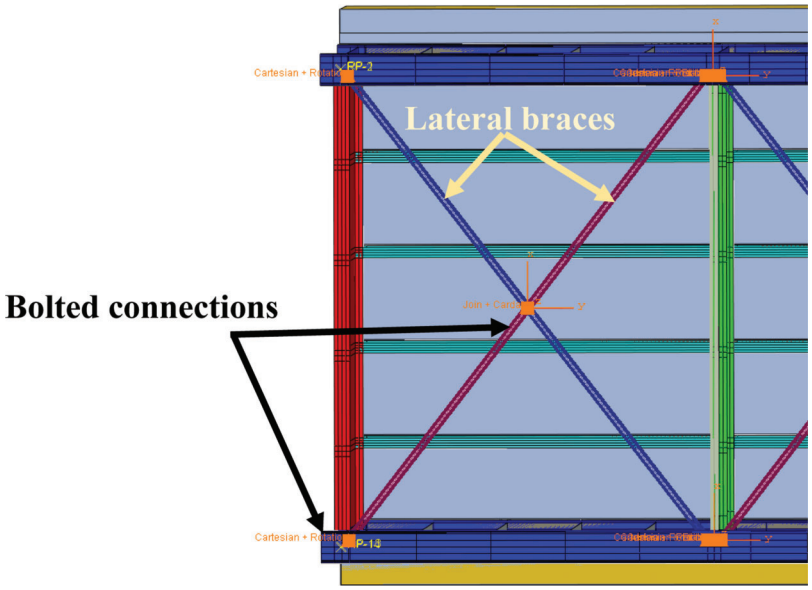


Figure 2.8 FE model details of braces with connections (plan view).

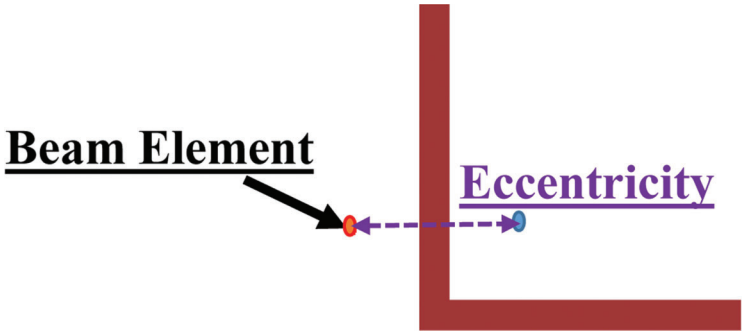


Figure 2.9 Eccentricity in the beam element used for single bracing components.

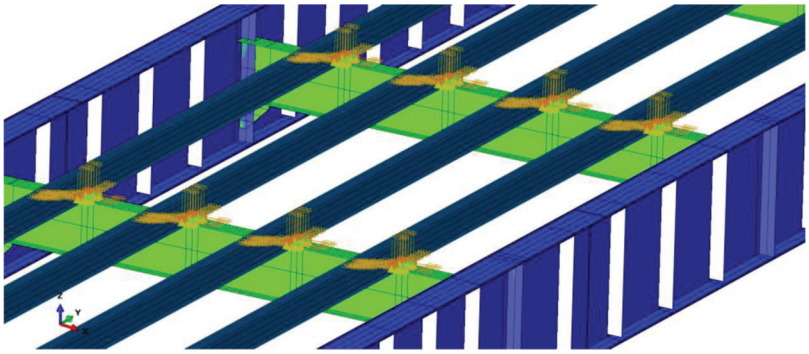


Figure 2.10 Stringer floor beam connection.

The identical method is used to define The floor beam to stringer connection in one of the truss bridges (shown in Figure 2.13).

2.6 Model Interaction Between Slab and Steelwork

Friction (based on isotropic Coulomb friction) and hard contact interaction behavior was defined between the surfaces at expansion joints in the parapets (when present) and between the bottom of the deck haunches and the top surface of the top flanges. The interaction model between the haunch of the concrete deck and the top flange of the stringers is shown in Figure 2.14. In general, the mesh density was similar to the one utilized for the steel elements. At the locations in contact with steelwork (e.g., slab haunches), the mesh

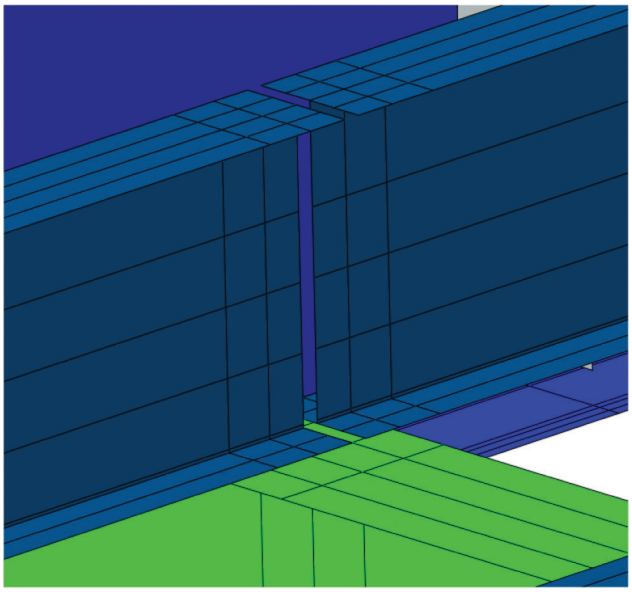


Figure 2.11 Stringer discontinuity.

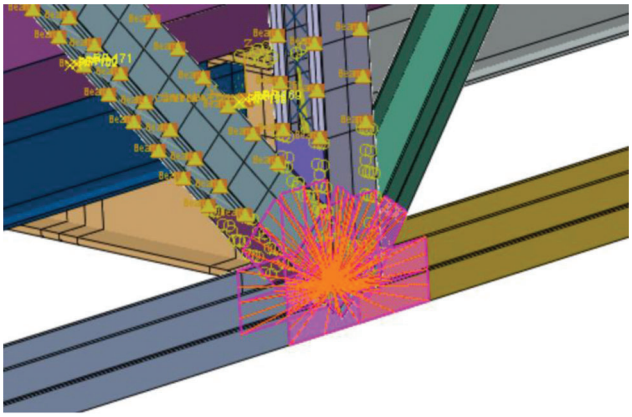


Figure 2.12 Gusset-plate connection.

density of the concrete was higher than the mesh density of the steelwork to ensure proper enforcement of the contact interaction and minimize penetrations between the element surfaces. Haunches were modeled with additional superimposed layers of shell elements. According to Lai et al. (2014), the Coulomb friction coefficient and shear stress limit carried by the interface are 0.55 and 0.06 ksi, respectively (AASHTO, 2018/2022a, Section 6.1).

The tensile and shear behavior of shear studs is critical in the load transfer between the steel members and the concrete slab in composite steel bridges, and they help provide additional load paths after the failure of a primary steel member. The methodology developed by Korkmaz (AASHTO, 2018/2022a; Korkmaz et al., 2018) to implement shear, tensile, and combined shear and tensile behavior of shear studs in finite element models of steel bridges was applied in this report (AASHTO, 2018/2022a, Section 6.2). This methodology was benchmarked to the second full-scale UT twin-tub girder experiment (Mouras, 2008).

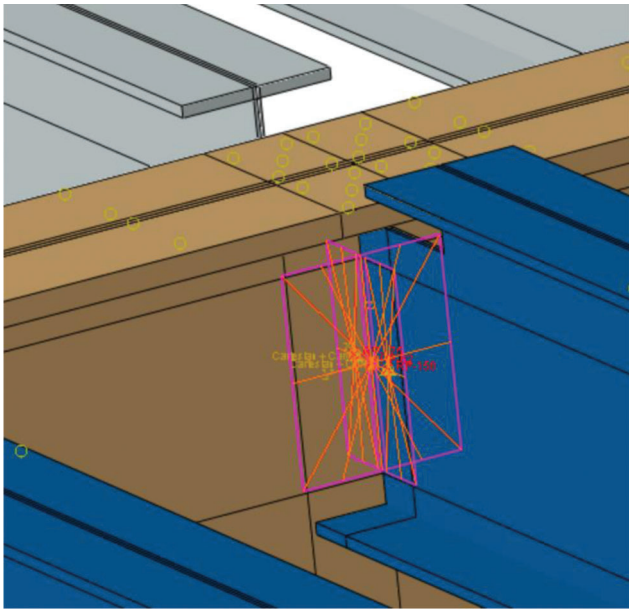


Figure 2.13 Bolted stringer floor beam connection.

To implement shear stud behavior in finite element models of composite steel bridges, it is necessary to use connector elements (shown in Figure 2.15). These elements are basically multi-dimensional springs for which coupled force-displacement curves can be assigned, which allow the engineer to characterize the stiffness, capacity, and ductility of the shear stud group at discrete locations. Linear or nonlinear force-displacement curves need to be assigned for each relative motion component. In ABAQUS, the axial and interfacial shear interaction between the shear studs and the concrete deck was defined using CONN3D2 connector elements and mesh independent fasteners (shown in Figure 2.16) were used as stud connections to transfer load from the girder to the deck (Korkmaz, 2018).

2.7 Substructure Behavior

Connector elements were used to describe boundary conditions. Infinite stiffness was defined only to resist gravity loads; hence, uplift was allowed. One of the bearing supports was fixed to avoid overturning rotation (Z axis) and longitudinal and transverse translation (X and Y axes), however longitudinal and transverse rotations (X and Y axes) were allowed. Others supports were conservatively allowed to move in all horizontal directions and rotate around all axes (AASHTO, 2018/2022a, Section 7.2).

2.8 Identification of NSTMs

In continuous spans of girder bridges, member failure was assumed in both an end span and at least one interior span at the most critical location. The positive moment region of each span was assumed as the most critical location. Since end spans are continuous at only one end, they are required to be

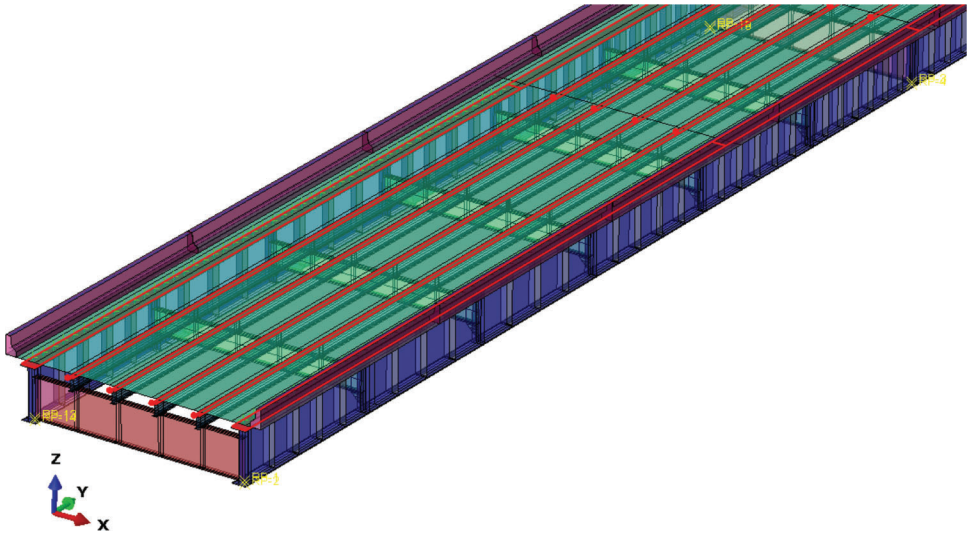


Figure 2.14 Interaction between deck haunches and top flanges.

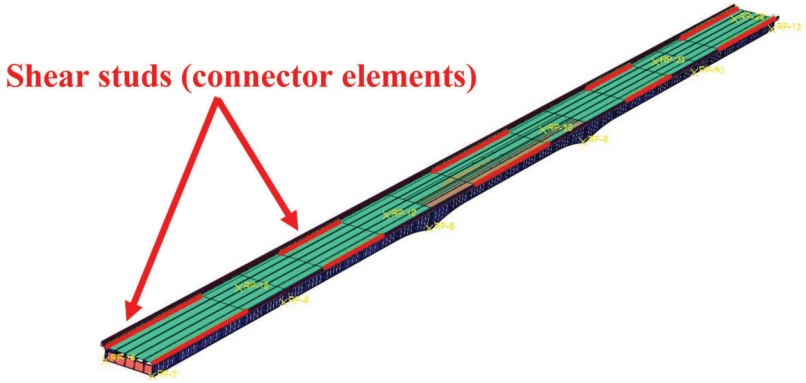


Figure 2.15 Shear studs and connector elements.

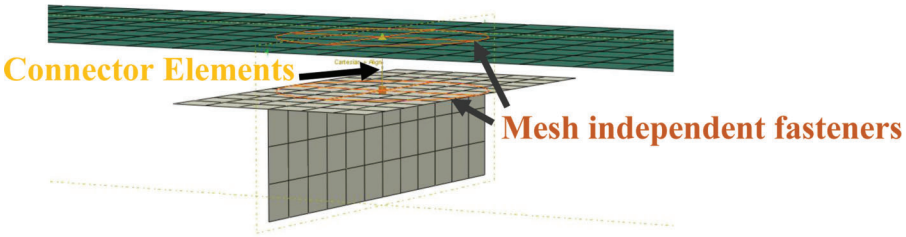


Figure 2.16 Connector elements and mesh independent fasteners.

evaluated in addition to at least one interior span. For steel girder bridges, failure of the outer girder results in the most critical condition. The damage scenario that was considered included a complete full-depth fracture (including the top flanges) of one of the I-girders. Multiple fracture scenarios were used to identify the most critical location.

Member failure was assumed in tension cords at the bottom only for simple span truss bridges and at both the bottom and top cords for continuous truss bridges. If these members can be classified as redundant, additional member failure was checked in diagonals and hangers

2.9 Load Models for the Redundancy I and II Load Combinations

The Redundancy I load combination is intended to describe the loading condition of the structure at the instant the failure of the member occurs. This load case evaluates the bridge's ability to immediately survive a sudden brittle fracture. The load factors developed for Redundancy I correspond to a target reliability factor of 2.5 in the faulted state. Note, this load combination is not intended to produce the fracture but rather to represent the average maximum load (particularly live load) that may be on the bridge at the time of the fracture.

This level of reliability ensures with high confidence that the bridge will survive the initial fracture (AASHTO, 2018/2022a, Section 3.4). While vehicles may occasionally be positioned outside of the normal travel lanes, it was deemed to be unrealistic to position vehicles outside of the striped lane for the Redundancy I load case regardless of the number of normal travel lanes carried by the bridge (Connor et al., 2017). The number of lanes used in the analysis for this load combination thus corresponded to the number of striped lanes. Thus, if only one lane is shown on the design plans, only one lane should be used regardless of the width of the bridge. The number of loaded lanes should be no greater than two for cases where the bridge is striped for two or more lanes. If a bridge had two lanes of traffic, two lane load combinations were separately used for the redundancy analysis. The first load combination considered loading in only the exterior lane load with a higher multiple presence factor, and the second considered loading in both lanes. The live load was positioned in the center of the striped lane(s).

The second case is referred to as the Redundancy II load combination. The Redundancy II load combination is intended to evaluate the structure at a level of live load that could be expected between the instant the failure occurs and the time the damage is discovered. This interval is assumed to be between 5 and 50 years. The target reliability factor is 2.5 for Redundancy II. (AASHTO, 2018/2022a, Section 3.4). For the Redundancy II load combination, the HL-93 load(s) was positioned transversely, such that the load effects were maximized in the faulted state regardless of the lane striping. It was deemed realistic to consider loading outside the striped lanes (i.e., two full lanes of HL-93 on a bridge striped for a single lane) for the longer interval between when the fracture occurs and when it is discovered. For Redundancy II, loading up to the maximum number of lanes that fit on the bridge was used. Additional analyses with less than the maximum number of lanes with higher multiple presence factors were also performed. The approach is based on AASHTO LRFD (Lai et al., 2014) lane configuration for bridges.

The resulting load combinations for the evaluations of existing structures is as follows:

$$\textit{Redundancy I}\text{: } (1+D_{AR})[1.15(DC)+1.25(DW)+1.0(LL)]$$

(AASHTO, 2018/2022a, Table 3.4-1)

$$\textit{Redundancy II}\text{: } 1.15(DC)+1.25(DW)+1.50(1+\mathrm{IM})(\mathrm{LL})$$

(AASHTO, 2018/2022a, Table 3.4-2)

In the above equations, DC is the dead load, DW is the future wearing surface/utilities load, LL is the live load, IM is the impact modifier, and D_{AR} is the dynamic amplification factor due to the sudden fracture. This dynamic amplification factor is calculated as the ratio of the peak stress in a given member in free vibration following the sudden fracture to the stress in that member after the structure comes to rest. In the Redundancy I load combination; the dynamic amplification factor is applied to both the dead and live loads. To avoid the need for complex dynamic analyses during future evaluations, the guide specifications (AASHTO, 2018/2022a) include a simplified procedure that utilizes a tabulated value for the dynamic amplification factor of 0.4 for continuous span I-girder bridges (AASHTO, 2018/2022a, Table 3.3.1-1).

To maximize the load effects on the remaining intact components in the faulted state, the centroid of the HS-20 component of the HL-93 loading was positioned longitudinally coincident with the location of the faulted member. Additionally, a fixed axle spacing of 14 feet was conservatively used. This is consistent with typical approaches to positioning live load longitudinally. Multiple presence factors were applied according to *AASHTO LRFD Bridge Design Specification* (Lai et al., 2014). The transverse position of the live loads is discussed in Section 2.10.

2.10 Minimum Strength Requirements

Once the analysis has been completed, it is necessary to establish whether the structure has adequate capacity (i.e., redundancy) in the faulted state. The minimum strength performance requirements are described in Section 8.2 of the guide specifications (AASHTO, 2018/2022a).

2.10.1 Steel Components

Four basic strength criteria for primary steel components must be met when the bridge is subjected to the Redundancy I and II load combinations. These failure criteria are as follows.

1. The average strain across a component of a cross section (e.g., a flange) must be less than the smaller of five times the yield strain or 0.01. The objective of this criterion is to limit the redistribution of forces to other components while the structure remains in service. This criterion is intended to prevent the placement of excessive demands on the intact components.
2. The maximum strain anywhere in a primary component should not exceed the ultimate strain, which is conservatively limited to 0.05.
3. The compression stress must remain below the critical buckling stress of the component in cases where the FEA does not account for the buckling mode. It is noted that the analysis conducted in this study is capable of capturing local and global buckling and hence, this limit was not explicitly checked.
4. The system must demonstrate a reserve margin of at least 15% of the applied live load in the Redundancy I and II load combinations. In other words, the system must be able to support 1.15 times the expected live load. This requirement ensures the load versus displacement curve is still on the ascending branch. This requirement is not specific to the steel components alone, but rather to the entire bridge as a system.

2.10.2 Reinforced Concrete

The nominal compressive strength of concrete may be exceeded in the analysis. This is acceptable in the barriers or haunches if the system is able to sustain the factored loads. Concrete crushing in the aforementioned regions is not expected to result in a reduction of strength based on the results of this analysis and in-situ performance of bridges where tension members have failed. However, if concrete crushing or deck reinforcement yielding takes place over at least 50% span length of the slab or if concrete crushing results in a flat or negative slope of the load-deflection curve, the structure should not be considered redundant. In these cases, passage of traffic and environmental conditions will rapidly deteriorate the slab to a point where system capacity may be further reduced. In other words, if the portion of the slab where a compressive strain of 0.003 has been exceeded is large enough to compromise the overall load carrying capacity of the system or if significant hinging occurs, the structure should not be considered as sufficiently redundant.

2.10.3 Substructure

In addition to checking the strength of the superstructure, the substructure must also be evaluated. Although the substructure may not be explicitly included in the finite element model in all load combinations, the displacements and reaction forces at support locations are checked in the analysis. In this evaluation, the capacity of the bearings, as provided in the design plans, was compared to the forces and displacements obtained from the FEA of the faulted bridge. Conservatively, only one support per bridge was assigned as a hinge and all other boundary conditions were defined as rollers; therefore, the predicted horizontal displacements at the bearings are maximized after fracture occurred.

2.11 Performance Criteria Serviceability Requirements

There are several minimum serviceability requirements for the bridge in the faulted state per the guide specifications. Overall, the criteria help to ensure that the structure is not expected to experience any overall stability problems if the results of the analysis comply with these requirements. According to Section 8.3 of the guide specifications (AASHTO, 2018/2022a), the minimum serviceability criteria for the Redundancy I and II load combinations are explained as follows.

1. *The change in the maximum vertical deflections of the superstructure should not exceed L/50.* The deflection change is defined as the difference between before fracture and after fracture displacement under Redundancy II factored dead loads. A load factor of 1.05 is applied and the limit is taken as L/50. This value represents the level of distortion that motorists can navigate without experiencing a decrease in safety. *Uplift at supports beneath a joint in the deck should not exceed 3.5 inches.* The Redundancy II factored deadloads are used for this check.
2. *Horizontal translation at supports should not result in the bridge falling off a support.* Transverse and longitudinal displacements at support locations should be considered as a member may lose support, particularly at supports that allow for expansion, in the faulted state. Hence, it should be verified that the predicted horizontal displacements can be accommodated by the existing support. This criterion simply requires that the structure does not fall off a support, either due to a bearing tipping over or a girder moving completely off of a pier or abutment.

3. I-74-170-04684 (I-74 OVER WHITEWATER RIVER)

In this section, the structural redundancy of the I-74-170-04684 over Whitewater River (Figure 3.1) owned by INDOT was evaluated for the case where one of the two I-girders fails due to an assumed sudden full-depth fracture. The I-girders are currently labeled as NSTMs and are on a 24-month NSTM inspection frequency. The bridges were evaluated using the system analysis procedures under guide specifications (AASHTO, 2018/2022a). In continuous spans of girder bridges, member failure was assumed in an end span (span C/G) and at mid interior span (span E) at the most critical location.

In summary, the analysis has concluded that the bridge analyzed in the project (I-74-170-04684) does not possess considerable reserve strength in the faulted state. Additional details regarding the reasons for this conclusion will follow.

3.1 Background, Geometry, and Loading

It was originally built in 1962 but has had multiple rehabilitations since its original construction. The work performed on the bridge includes the following.

- The bridge received a deck overlay in 1979.
- The deck was replaced in 1995.

The structure consists of five main spans, where the bridge is symmetric about the midspan. The primary girders are spaced at 30′-0″ center-to-center. The deck has a clear roadway width of 33′-4″ and out-to-out coping of 36′-4″. The bridge has no skew and is on a tangent alignment. Each superstructure carries two 12′ lanes with 4′-8″ shoulders. The twin bridges are identical and symmetric about the median centerline; thus, the findings of this evaluation apply to both structures. Table 3.1 provides details related to the geometry and material properties associated with the structure.

3.2 Results for Full Girder Fracture in Span C or F

The assumed fracture was located at a distance of 0.45L (L: 142 ft.) from the first pier (Pier 2 or 11) in the end span. Under both the Redundancy I and II load combinations, the bridge's torsional stiffness is insuffi-



Figure 3.1 I-74-170-04684 over Whitewater River.

cient to provide stability after the full-depth fracture assignment. This resulted in only the cantilever section of fractured girder carrying the load, with insufficient load-transfer to the intact girder. Finally, buckling (in span D) occurred between the Pier 3 and Splice 2, as demonstrated in the Figure 3.2. This failure was followed by deck crushing and excessive cracking. These failures cause the slope of the load-deflection curve to be flat and then negative, indicating that the bridge is collapsing (i.e., an unstable response).

3.3 Results for Full Girder Fracture in Span E

The assumed fracture was located at a distance of 0.48L (L: 220 ft.) from the Pier 4 in the mid span. Under both the Redundancy I and II load combinations, the bridge's torsional stiffness is insufficient to provide stability after the full-depth fracture assignment. This resulted in only the cantilever section of fractured girder carrying the load, with insufficient load-transfer to the intact girder. Finally, buckling (in spans D and F) occurred in the girder between the piers and the field splice location, as demonstrated in Figure 3.3, This failure was followed by deck crushing and excessive cracking. These failures cause the slope of the load-deflection curve to be flat and then negative, indicating that the bridge is collapsing, again indicating an unstable response.

3.4 Summary

Analytical models were developed to evaluate the structural redundancy of the typical I-girder bridge over Whitewater River (Structure ID I-74-170-04684) in the State of Indiana. The girders are presently classified as Non-Redundant Steel Tension Members. A full depth fracture, including web, top flange, and the bottom flange, was simulated in the exterior and mid spans. The analysis determined that the bridge *does not satisfy* the performance requirements included in the guide specifications (AASHTO, 2018/2022a) for both the Redundancy I and Redundancy II load combinations. Therefore, the girders must remain classified as Non-Redundant Steel Tension Members.

TABLE 3.1
The bridge geometry and material properties

Bridge Details	
Bridge Name	I-74-170-04684
Span Lengths	142 - 180 - 220 - 180 - 142 ft. (5 spans)
	Span IDs: C - D - E - F - G
Number of Main Girders/Spacing Between	2/30 ft.
Number of Stringers/Spacing Between	4/6 ft.
Girder Details	
Girder Steel	ASTM A7 and A373
Top Flange	Varies, 21 in. to 24 in. wide
	Varies, 1.0 in. to 3.5 in. thick
	Up to 3 welded plates
Web	Varies, 84 in. to 150 in. tall
	Varies, 0.5 in. to 0.625 in. thick
Bottom Flange	Varies, 22 in. to 24 in. wide
	Varies, 1.0 in. to 3.5 in. thick
	Up to 3 welded plates
Stiffener Details	
Transverse Stiffeners	10.0 in. width 0.375 in. thick
Bearing Stiffeners	11.0 in. width 2.0 in. thick (haunch)
	10.0 in. width 1.875 in. thick (interior piers and floor beams)
	10.0 in. width 0.875 in. thick (exterior piers)
Longitudinal Stiffeners on Web	4.5 in. width 0.375 in. thick
Stringer Details	
Section Type	W18 × 60
Continuity	2–3 floor beam spacing
Diaphragm Details	
Exterior Piers	Flange: 12 in. wide, 0.75 in. thick
	Web: 72 in. tall, 0.5 in. thick
Interior Piers	Flange: 12 in. wide, 0.75 in. thick
	Web: 72 in. tall, 0.5 in. thick
Mid Piers (Haunch)	Flange: 12 in. wide, 0.75 in. thick
	Web: 72 in. tall, 0.625 in. thick
Floor Beam Details	
Section Type	W36 × 160
Deck Details	
Concrete Material Strength	4 ksi
Composite Deck	36′-4″ wide, 8.0 in. thick
	2.4 in. haunch thick (from bot. surface of top flange to bot. surface of deck)
Transverse Reinforcement	No. 5 rebars with 8.0 in. spacing (top)
	No. 5 rebars with 8.0 in. spacing (bottom)
Longitudinal Reinforcement	No. 4 and No. 7 rebars with 12.0 in. spacing (top)
	No. 5 rebars with 12.0 in. spacing (bottom)
Girder Shear Studs	6 in. height. Longitudinal spacing 24 in. three 0.875-in. diameter shear studs spaced equally in the transverse direction
	6 in. edge distance
Stringer Shear Studs	No shear studs over stringers
Parapet Type	2′-9″ tall, 1′-6″ wide
Load Details	
Number of Lane	Two traffic lanes
Future Wearing Surface	Included in deck thickness

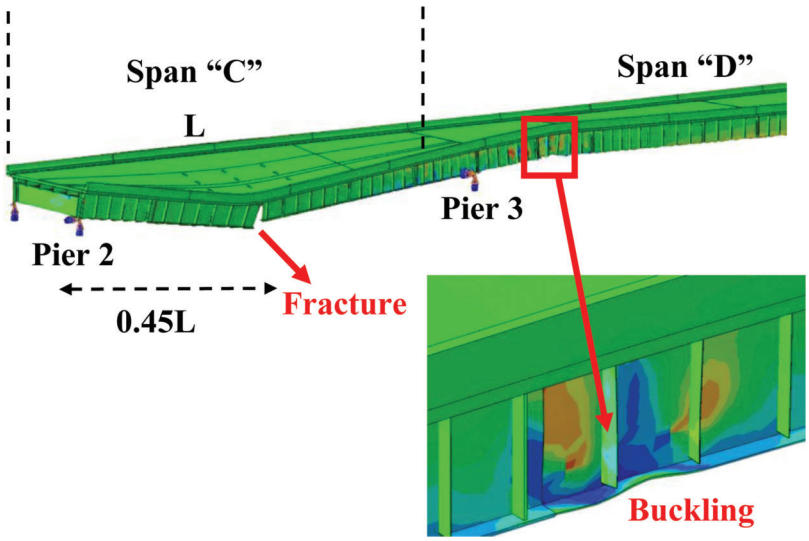


Figure 3.2 Girder failure "buckling" with full girder fracture in span C.

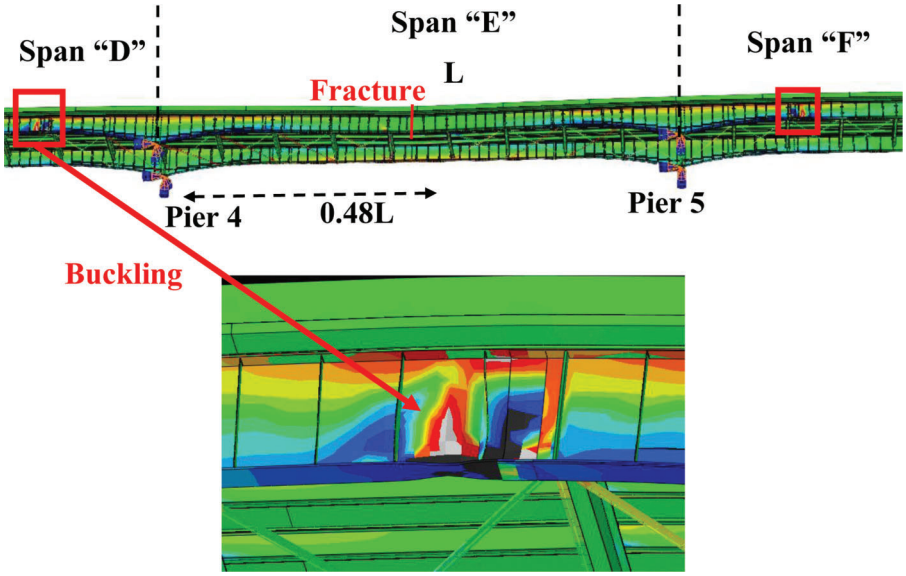


Figure 3.3 Girder failure "buckling" with full girder fracture in span E.

4. SR 1 001-68-03408 OVER THE MISSISSINEWA RIVER

In this section, the structural redundancy of the simple-span truss bridge SR 1 001-68-03408 over the Mississinewa River (Figure 4.1) owned by INDOT was evaluated for the case where one of the lower chords, diagonals, and verticals fails due to an assumed sudden full-depth fracture. The members are currently labeled as NSTMs and are on a 24-month NSTM inspection frequency. The bridges were evaluated using the system analysis procedures under guide specifications (AASHTO, 2018/2022a).

The analysis has concluded that the bridge possesses considerable reserve strength in the faulted state after the assumed fracture and that the following members need no longer be classified as NSTMs.

- Verticals: L1-U1, L2-U2, L3-U3, L4-U4, L5-U5, L6-U6
- Diagonals: U2-L3, U3-L4, L3-U4, L4-U5
- Lower chords: L2-L3, L3-L4, L4-L5

However, the diagonals (U1-L2, L5-U6), and lower chords (L0-L1, L1-L2, L5-L6, L6-L7) should continue to be classified as NSTMs.

4.1 Background, Geometry, and Loading

The bridge (Figure 4.2) was originally built in 1941 but has had multiple rehabilitations since its original construction. The work performed on the bridge includes the following.

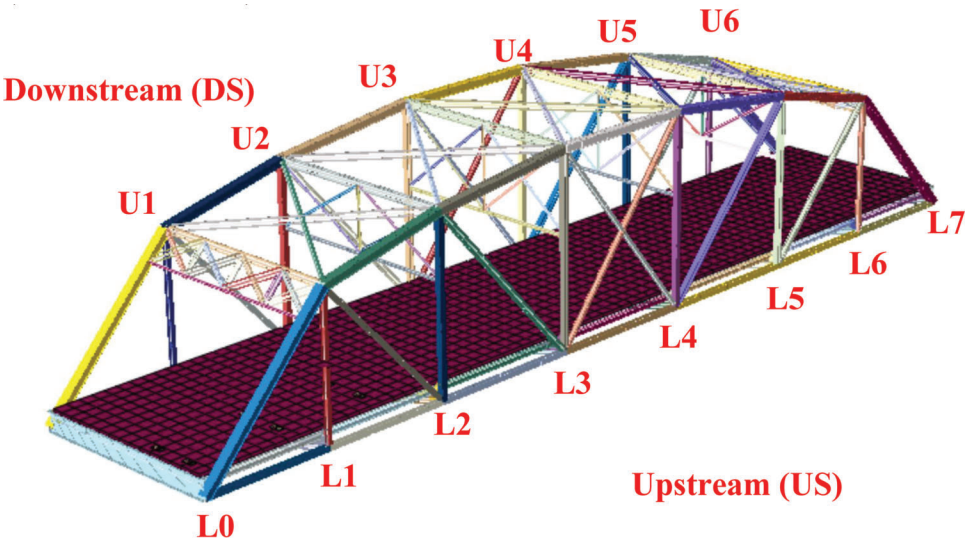


Figure 4.1 FE model of SR 1 001-68-03408 over the Mississinewa River.



Figure 4.2 SR 1 001-68-03408 over the Mississinewa River.

- Rehab A: The verticals U2L2 and U4L4 were replaced and associated sway frames in 1977.
- Rehab B: The deck was replaced in 1979, and shear connectors were added.
- Rehab C: The deck was replaced in 2008.

According to 2021 routine inspection report, the structure is in satisfactory condition. Only moderate surface corrosion on the areas of truss including bearings, end posts, and lower connections were observed.

The structure consists of two identical simple span truss bridges, where the each of them is symmetric about the midspan. The primary span length is 150′. The deck has a clear roadway width of 28′ and out-to-out coping of 29′. The upper chords were 20′ to 23′ vertically compared to lower chords, and vertical clear over bridge roadway is approximately 15′. Each superstructure carries two 12′ lanes with 2′-6″ shoulders. The twin bridges are identical and symmetric about the median centerline; thus, the findings of this evaluation apply to both structures. Table 4.1 provides details related to the geometry and material properties associated with the structure.

To verify the FE model's accuracy, design plan calculations and the results from the BrR model are compared. Axial stiffness is eliminated from the connector elements attaching the stringers to the floor beam in the FE model during the construction sequence, so as to prevent the stringers from being a part of tension chord and reducing the stresses of the lower chords. Once the construction sequence is completed, these connector elements become axially effective, allowing the stringers to carry the live loads axially. As shown in Table 4.2, the axial loads in the lower chords of all three models for dead load are reasonably close. However, the tensile loads imposed by live loads are considerably less in the FE model. The FE model behavior is more likely to actual behavior than that predicted by BrR and design plan calculations.

TABLE 4.1
The bridge geometry and material properties

Bridge Details	
Bridge Name	SR 1 001-68-03408
Span Length	150 ft.
The Superstructure Width	30 ft.–6.5 in.
Truss Height	22 ft. to 29 ft. 9 in.
Number of Panels/Spacing Btw	7/20 to 23 ft.
Number of Stringers/Spacing Btw	10/3 ft.
Structural Steel	Fy = 33 ksi, Fu = 66 ksi
Upper Chord Details	
L0-U1, U6-L7	2C12 × 35–P18 × 7/16
U1-U2, U5-U6	2C12 × 30–P18 × 7/16
U2-U3, U4-U5	2C12 × 30–P18 × 7/16
U3-U4	2C12 × 30–P18 × 7/16
Lower Chord Details	
L0-L1, L1-L2, L5-L6, L6-L7	W10 × 54
L2-L3, L4-L5	W10 × 72
L3-L4	W10 × 77
Vertical Details	
L1-U1, L6-U6	W10 × 33
L2-U2, L5-U5	2C10 × 15.3–P10.5 × 3/8
L3-U3, L4-U4	2C10 × 15.3
Diagonal Details	
U1-L2, L5-U6	W10 × 41
U2-L3, L4-U5	2C10 × 15.3
U3-L4, L3-U4	W10 × 21
Stringer Details	
Section Type	W18 × 48–W18 × 50
Floor Beam Details	
Section Type	W36 × 150–W36 × 170–W36 × 182
Deck Details	
Concrete Material Strength	4 ksi
Deck	29 wide, 8.0 in. thick
Load Details	
Number of Lane	Two traffic lanes
Future Wearing Surface	Included in deck thickness

4.2 Results for Evaluating the Fracture of Diagonal Members

The assumed fracture was located at each of the diagonals—U1-L2, U2-L3, U3-L4, L3-U4, L4-U5, L5-U6.

In the beam model of U1-L2 and L5-U6 fractures, excessive moments were found in remaining truss members. As a result, the model was improved by including shell elements in the process of checking the plasticity of the components. The truss structure is not able to support the shear force that the U1-L2 (L5-U6) diagonal was carrying before the fracture of this member. This results in excessive distortion and moment in adjacent truss members and connections. There were additional moments observed in L0-U1, U1-L1, L1-L1, L1-L2, and U1-U2. Under both the Redundancy I and II load combinations, excessive yielding on L0-U1 (gray area in Figure 4.3) member cause the bridge is collapsing.

However, subsequent analysis in which other diagonals were assumed to have failed showed that the truss was capable of redistributing the force carried by these members. Specifically, the structure has adequate redundancy after assumed failures in each of U2-L3, U3-L4, L3-U4, and L4-U5 for both Redundancy I and Redundancy II load combinations as the criteria for the strength and displacement requirements discussed above were met. The analysis demonstrated the following and a summary of the redundancy evaluation is shown in Table 4.3.

- Max localized plastic strain is 0.002 which is less than $5\varepsilon_y$ or 1% in the truss bridge (as shown in Figure 4.4).
- Crushing does not occur in the concrete deck.
- The maximum vertical deflection change (difference between before fracture and after fracture stages) is significantly lower than L/50 (36.0 inches) and the maximum change in cross-slope is below 5%.

4.3 Results for Evaluating the Fracture of Vertical Members

An assumed fracture was located at each of the verticals—L1-U1, L2-U2, L3-U3, L4-U4, L5-U5, L6-U6—individually. The truss structure is able to redistribute the tension force that the respective vertical was carrying before the fracture. While there were additional moments observed in lower chords, they were within acceptable levels and excessive yield was not observed. Under both the Redundancy I and II load combinations, a small amount of yielding on tension chords is observed in Figure 4.5.

For both Redundancy I and Redundancy II, the structure has adequate redundancy after the fracture of one vertical using the criteria for the strength and displacement requirements discussed above. The following were observed.

- Max localized plastic strain is 0.001 which is less than $5\varepsilon_y$ or 1% in the truss bridge (as shown in Figure 4.6).
- Crushing does not occur in the concrete deck.
- The maximum vertical deflection change (difference between before fracture and after fracture stages) is lower than L/50 (36.0 inches) and the maximum change in cross-slope is below 5%.

Summary of the redundancy evaluation is shown in Table 4.4.

4.4 Results for Evaluating the Fracture of Lower Chord Members

The assumed fracture was located at each of the lower chords—L0-L1, L1-L2, L2-L3, L3-L4, L4-L5,

TABLE 4.2
Comparison of loads of design plan and BrR model with FE model

Member	DL Force (kips)			Plan LL Force (kip)		BrR LL Force (kip)		FEA LL Force (kip)	
	Plan	BrR	FEA	Compression	Tension	Compression	Tension	Compression	Tension
Upper Chords									
L0-U1 U6-L7	-203.52	-204.19	-203.22	-143.52	–	-165.56	–	-163.71	–
U1-U2 U5-U6	-195.91	-196.27	-195.47	-123.08	–	-157.98	–	-156.43	–
U2-U3 U4-U5	-216.33	-216.45	-214.18	-135.75	–	-172.94	–	-169.81	–
U3-U4	-214.41	-219.57	-215.83	-134.56	–	-170.92	–	-165.48	–
Lower Chords									
L0-L1 L6-L7	136.85	139.44	132.03	–	86.06	–		–	94.52
L1-L2 L5-L6	136.85	137.36	125.94	–	86.06	–	111.36	–	82.57
L2-L3 L4-L5	190.52	190.96	177.22	–	119.7	–	153.70	–	113.64
L3-L4	214.41	209.98	195.04	–	129.67	–	162.18	–	121.52
Verticals									
L1-U1 L6-U6	46.04	41.85	38.69	–	141.56	–	71.82	–	67.42
L2-U2 L5-U5	-9.13	-13.17	-13.43	-72.73	81.56	-43.80	47.37	-31.48	31.77
L3-U3 L4-U4	18.79	16.32	14.99	-53.06	102.76	-13.93	35.50	-12.14	30.94
Diagonals									
U1-L2 L5-U6	79.95	79.69	81.17	–	78.22	-23.83	82.94	–	76.88
U2-L3 L4-U5	36.59	36.22	35.52	-73.39	111.17	-42.88	66.70	-31.79	55.47
U3-L4 L3-U4	0.00	7.76	7.49	–	93.96	-23.46	33.44	-13.23	23.09

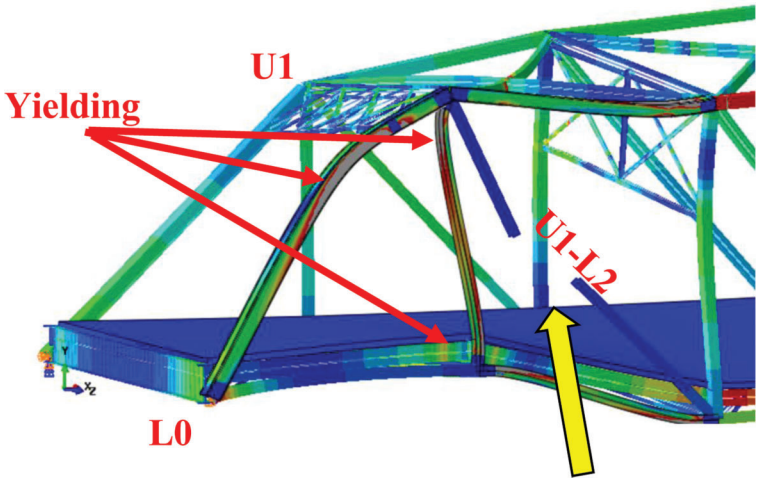


Figure 4.3 Excessive yielding (five times deformed shape).

L5-L6, L6-L7—individually. The longitudinally boundary condition is not following the fractures at L0-L1, L1-L2, L5-L6, and L6-L7 (illustrated in Figure 4.7) and as a result, the horizontal displacement at the boundary condition exceeded 6 inches following the member failure. The support is modeled as a free roller support.

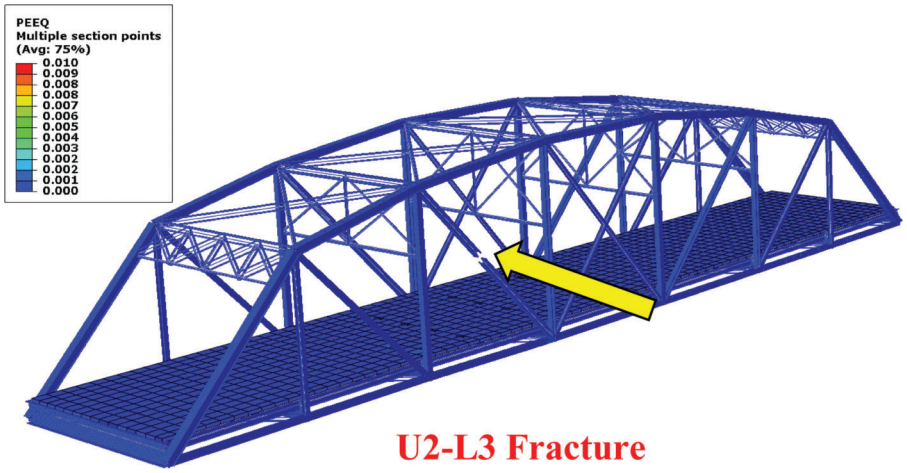


Figure 4.4 Less than 1% plastic equivalent strain in primary steel members when cracked at U2-L3, U3-L4, L3-U4, and L4-U5 applied in Redundancy I or Redundancy II.

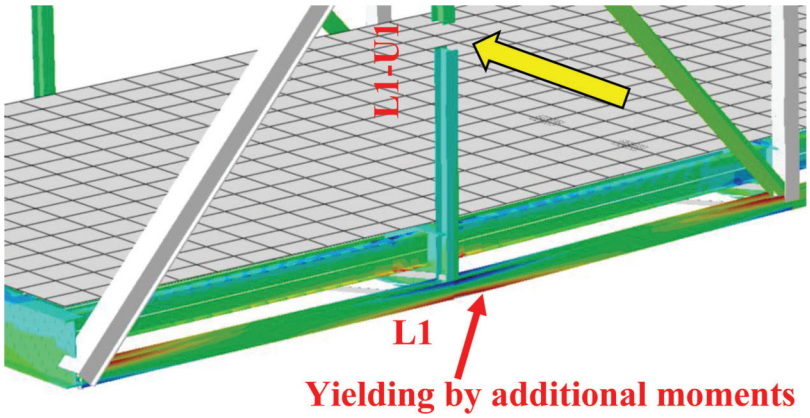


Figure 4.5 Lower chord yielding.

TABLE 4.3
Summary of redundancy evaluation in diagonals

Fracture Locations		Result	Acceptable?
Diagonals	U1-L2	Excessive yielding on L0-U1 (U6-L7).	NO
	L5-U6	Strain larger is than $5\varepsilon_y$ or 1%. Failure strain was reached.	
	U2-L3	No component has strain larger than $5\varepsilon_y$ or 1%. Failure strain was not reached	YES
	U3-L4	anywhere.	
	L4-U3	No concrete crushing.	
	L5-U4	Maximum deflection change is lower than L/50 (36.0 in).	
		Maximum additional cross-slope is less than 5%.	
		No uplift.	

Note:
The analysis showed that the structure is capable of resisting an additional 15% of the applied factored live load.
The horizontal displacement changes at support locations were lower than 6 in.
Shear capacity of the deck is checked.

Although the opposite side were assigned as a pin support, determining the capacity and rigidity of the bearing was challenging and the basic "pin and roller" approach was used to be conservative.

However, following the occurrence of fractures in L2-L3, L3-L4, and L4-L5, the load transferred from the lower tension member to the first stringer via the floor beam in the closest distance to the broken component.

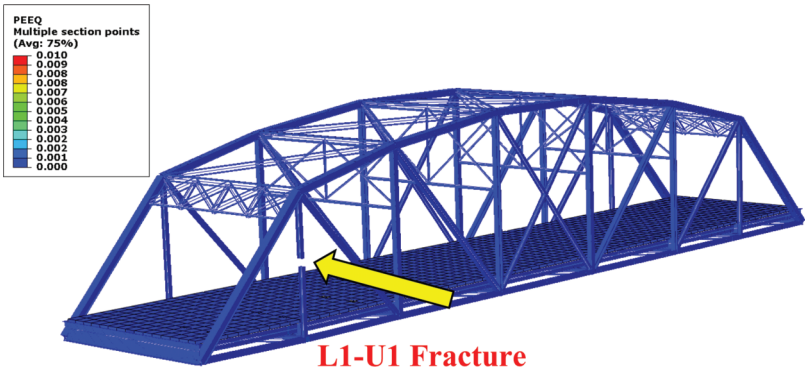


Figure 4.6 Less than 1% plastic equivalent strain in primary steel members when cracked at L1-U1, L2-U2, L3-U3, L4-U4, L5-U5, and L6-U6 applied in Redundancy I or Redundancy II.

TABLE 4.4
Summary of redundancy evaluation in verticals

Fracture Locations		Result	Acceptable?
Verticals	L1-U1	No component has strain larger than $5\varepsilon_y$ or 1%. Failure strain	YES
	L2-U2	was not reached anywhere.	
	L3-U3	No concrete crushing.	
	L4-U4	Maximum deflection change is lower than L/50 (36.0 in).	
	L5-U5	Maximum additional cross-slope is less than 5%.	
	L6-U6	No uplift.	

Note:
Shear capacity of the deck is checked.
The analysis showed that the structure is capable of resisting an additional 15% of the applied factored live load.
The horizontal displacement changes at support locations were lower than 6 in.

A significant plastic strain was detected during the analysis where components were modeled using only beam elements. However, to further study the behavior, the model fidelity was upgraded using a complete shell model to better examine the local behavior and local stresses. The study revealed the location of the concentrated high-stress areas after the model was upgraded with shell elements. A close examination of the stresses found that the floor beam plastic strain was maxing out at 0.007 (shown in Figure 4.8). However, this is less than 1% limit per the guide specifications. As a consequence, it was found that the truss structure can redistribute the tension force carried by the L2-L3, L3-L4, and L4-L5 lower chords prior to the fracture under the Redundancy I and II load combinations. A summary of the redundancy evaluation is shown in Table 4.5.

4.5 Summary

Analytical models were developed to evaluate the structural redundancy of the simple-span truss bridge SR 1 001-68-03408 over the Mississinewa River in the State of Indiana. The blue members represented in Figure 4.9 are upper compression members and not NSTMs. Green indicates that the tension member has passed redundancy verification and no longer need to be classified as NSTMs. Tension members marked by red colors must remain classified as NSTMs.

In summary, according to the analysis, thirteen components meet the performance criteria outlined in the guide specifications (AASHTO, 2018/2022a) for both Redundancy I and Redundancy II load combinations; however, six components do not meet the criteria.

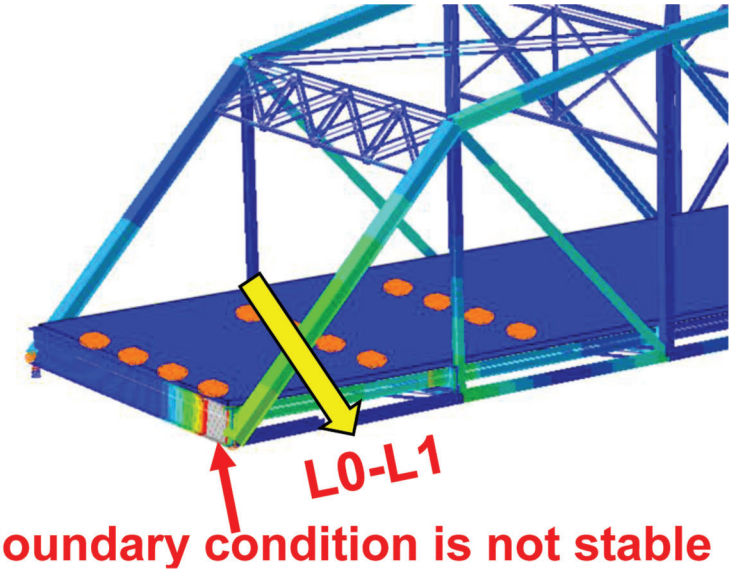


Figure 4.7 Unstable boundary condition after L1-L2, L2-L3, L5-L6, and L6-L7 fracture.

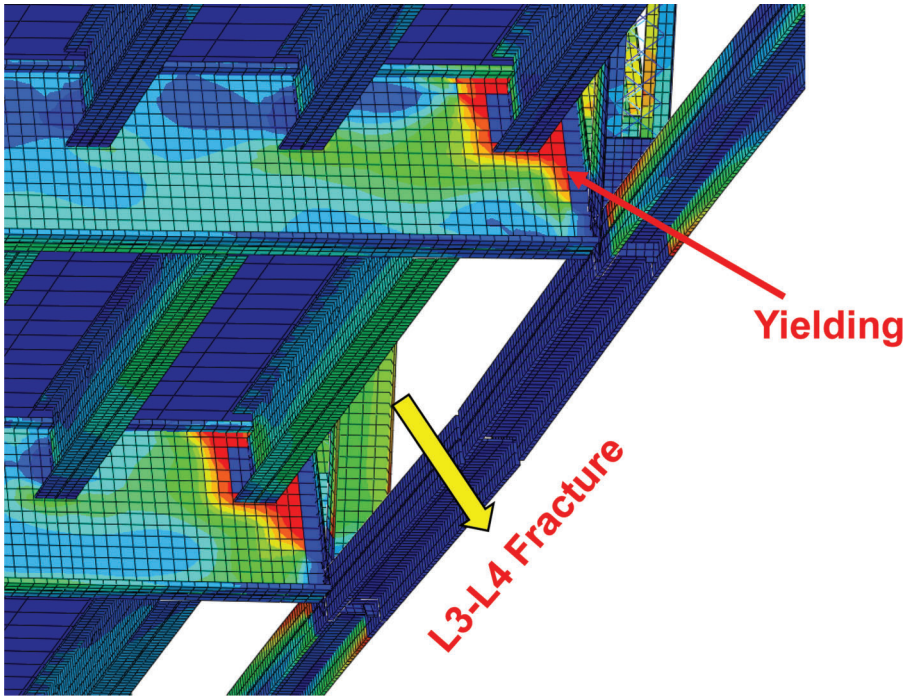


Figure 4.8 The floor beam yielding after L1-L2, L2-L3, L5-L6, and L6-L7 fracture.

TABLE 4.5
Summary of redundancy evaluation in lower chords

Fracture Locations		Result	Acceptable?
Lower Chords	L0-L1 L1-L2 L5-L6 L6-L7	The horizontal displacement changes at support locations are higher than 6 in.	NO
	L2-L3 L3-L4 L4-L5	Max plastic strain on the floor beam is 0.007 which strain smaller than $5\varepsilon_y$ or 1%. Failure strain was not reached anywhere. No concrete crushing. Maximum deflection change is lower than L/50 (36.0 in). Maximum additional cross-slope is less than 5%. No uplift. Max horizontal displacement changes at support locations is 4.68 in., which is lower than 6 in.	YES

Notes:
The analysis showed that the structure is capable of resisting an additional 15% of the applied factored live load.
Stringer to floor beam connection is checked.
Shear capacity of the deck is checked.

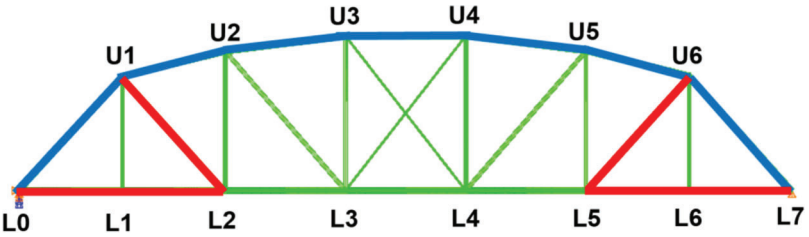


Figure 4.9 SR 1 001-68-03408 over the Mississinewa River evaluation results.

5. MATTHEW E. WELSH MEMORIAL BRIDGE, MAUCKPORT (135-31-06504 B)

In this section, the structural redundancy of the two-span continuous through truss Matthew E. Welsh Memorial Bridge, Mauckport carrying SR 135 EB and WB over the Ohio River (135-31-06504 B) owned by INDOT was evaluated (Figure 5.1) for the case where an individual tension lower chord, and upper chord tension member is assumed to have failed. The bridges were evaluated using the system analysis procedures under guide specifications (AASHTO, 2018/2022a). It is noted that modeling of this bridge is very complex and challenging with respect to implementing the AASHTO Guide Specification methodology. This is in part due to the limited guidance provided in that Specification regarding the level of checking required for such truss bridges. For example, details regarding connection modeling, failure modes etc., are all very complex checks to make in the context of the nonlinear FEA that is required is not fully defined in the specification. Thus, a considerable amount of time was spent modeling, analyzing, and evaluating this one very large bridge by the authors to ensure a reliable model was developed.

In summary, the analysis shows that the failure of the chord members results in significant damage, yielding and/or buckling into other members under the redundancy load combinations. Based on the complexity of the connections, the challenges with modeling the floor system, and the observed significant damage that resulted following assumed failure of the upper and lower tension chords, it was decided not to continue evaluations for hanger and diagonal failures. While such an analysis could be performed, the time and effort required exceeds that available in the current project. Hence, failure of the hangers and diagonals member could not explicitly be considered in the current project. Therefore, the members are currently labeled as NSTMs and are on a 24-month NSTM inspection frequency and must remain classified as such. Nevertheless, additional details of the efforts are summarized below.

5.1 Background, Geometry, and Loading

The bridge (Figure 5.2) was originally completed in 1967 but has had multiple rehabilitations since its original construction. The work performed on the bridge includes the following.

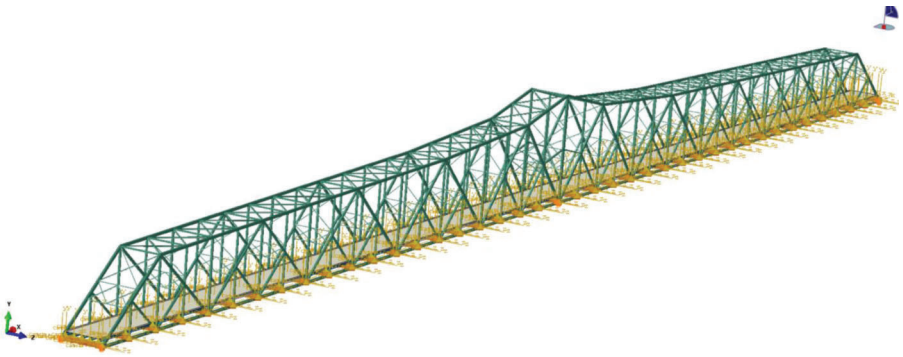


Figure 5.1 FE model of Matthew E. Welsh Memorial Bridge.

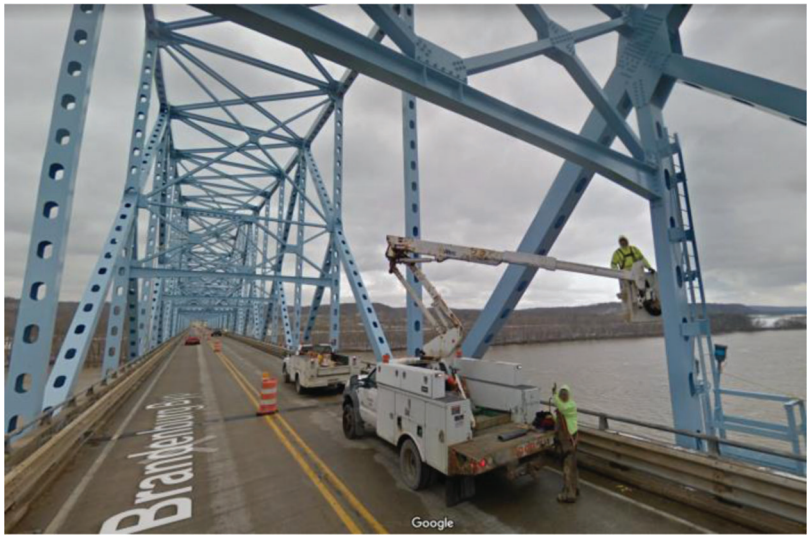


Figure 5.2 Matthew E. Welsh Memorial Bridge, Mauckport (135-31-06504 B).

- *Rehab A:* All spans have a latex concrete wearing surface. The reinforced concrete deck contains epoxy coated reinforcement. Surface milling and bridge deck overlay. The retrofits were completed in 1997.

The structure consists of the two-span continuous through truss bridge, where it is symmetric about the midspan. The primary span length is 1,450′. A continuous steel truss contains twenty panels per span. The five longitudinal stringers that support the non-composite reinforced concrete superstructure are attached to floor beams that connect the trusses at each panel point. The stringers have breaks in continuity every four panel points. Table 5.1 to Table 5.7 provide details related to the geometry and material properties associated with the structure.

5.2 Results for Lower Chord Fracture

The presumed fracture was located at one of the lower chords (L5-L6) in order to examine the typical behavior associated with fractures of lower chords (shown in Figure 5.3).

Excessive plastic strain was observed on the hangers, posts, and diagonals next to the area of the fracture location in the L5-L6 failure model; consequently, the L0-U1 compression member was subjected to buckling. The truss structure is not able to support the tension force that the was carried by the lower chords before the fracture. The failure resulted in a considerable amount of torsion/twisting as can be seen in the figure. It is also crucial to acknowledge that in this particular bridge, the stringers are simply sitting on the floor beam and thus lack the capability to carry the tensile force that the lower chords sustained prior to their failure. As a result, the stringers and deck do little in terms of providing torsional stiffness. Under both the Redundancy I and II load combinations, lower chord member fracture causes the bridge to fail the redundancy criteria by a significant margin.

5.3 Results for Upper Chord Fracture

The presumed fracture was located at one of the upper chords (U18-U19) in order to examine the typical behavior associated with fractures of upper chords (shown in Figure 5.4).

TABLE 5.1
The bridge geometry and material properties

Bridge Details	
Bridge Name	Matthew E. Welsh Memorial Bridge
Span Length	1,450 ft. (725 ft.–725 ft.) Continuous span
The Superstructure Width	36 ft.–6.0 in.
Truss Height	U20: 100 ft. height
Number of Panels/Spacing Between	Each span: 20/36 ft. 3 in.
Number of Stringers/Spacing Between	5/7 ft. 4.5 in.
Structural Steel	A441-63T structural low-alloy steel (AS) A514-64 high-yield strength, quenched and tempered steel (QT) A36-62T structural carbon steel Figure (CS)
Lower Chord Details	
Table 5.2	
Upper Chord Details	
Table 5.3	
Diagonal Details	
Table 5.4	
Hangers Details	
Table 5.5	
Post Details	
Table 5.6	
Sub-Diagonals and Struts Details	
Table 5.7	
Stringer Details	
Section Type	Flanges: 10 in. wide, 0.64 in. thick Web: 26.7 in. deep, 0.46 in. thick CS material
Floor Beam Details	
Section Type	Flanges: varies 12 to 16 in. wide, 1 to 2 in. thick Web: varies 50 to 52 in. deep, 0.3125 to 0.5625 in. thick CS material
Deck Details	
Concrete Material Strength	3 ksi
Deck	33 ft.–9.0 in. wide, 8.5 in. thick
Load Details	
Number of Lane	Two traffic lanes
Future Wearing Surface	Included in deck thickness

TABLE 5.2
Lower chord sections (all units inch or inch^2)

Points		Properties				Plates				Cover Plates				Extra Plate				Holes
Start	End	Material	Section	Area	Net Area	No.	W	t	Area	No.	W	t	Area	No.	W	t	Area	Type
L0	L1	AS	Box	64.25	55.25	2	28	1	56	2	20	0.375	15	0	0	0	0	B
L1	L2	AS	Box	64.25	55.25	2	28	1	56	2	20	0.375	15	0	0	0	0	B
L2	L3	QT	Box	50.25	43.5	2	28	0.75	42	2	20	0.375	15	0	0	0	0	B
L3	L4	QT	Box	50.25	43.5	2	28	0.75	42	2	20	0.375	15	0	0	0	0	B
L4	L5	QT	Box	74	63.88	2	28	1.125	63	2	20	0.5	20	0	0	0	0	B
L5	L6	QT	Box	74	63.88	2	28	1.125	63	2	20	0.5	20	0	0	0	0	B
L6	L7	QT	Box	74	63.88	2	28	1.125	63	2	20	0.5	20	0	0	0	0	B
L7	L8	QT	Box	74	63.88	2	28	1.125	63	2	20	0.5	20	0	0	0	0	B
L8	L9	QT	Box	65.63	56.63	2	28	1	56	2	20	0.438	17.5	0	0	0	0	B
L9	L10	QT	Box	65.63	56.63	2	28	1	56	2	20	0.438	17.5	0	0	0	0	B
L10	L11	QT	Box	65.63	56.63	2	28	1	56	2	20	0.438	17.5	0	0	0	0	B
L11	L12	QT	Box	65.63	56.63	2	28	1	56	2	20	0.438	17.5	0	0	0	0	B
L12	L13	AS	Box	51.69	44.38	2	28	0.563	31.5	2	20.25	0.5	20.25	1	19.88	0.5	9.94	A
L13	L14	AS	Box	51.69	44.38	2	28	0.563	31.5	2	20.25	0.5	20.25	1	19.88	0.5	9.94	A
L14	L15	AS	Box	51.69	44.38	2	28	0.563	31.5	2	20.25	0.5	20.25	1	19.88	0.5	9.94	A
L15	L16	AS	Box	51.69	44.38	2	28	0.563	31.5	2	20.25	0.5	20.25	1	19.88	0.5	9.94	A
L16	L17	QT	Box	82.75	–	2	28	1	56	2	20	0.625	25	1	19	0.75	14.25	A
L17	L18	QT	Box	82.75	–	2	28	1	56	2	20	0.625	25	1	19	0.75	14.25	A
L18	L19	QT	Box	82.75	–	2	28	1	56	2	20	0.625	25	1	19	0.75	14.25	A
L19	L20	QT	Box	82.75	–	2	28	1	56	2	20	0.625	25	1	19	0.75	14.25	A
L40	L39	AS	Box	64.25	55.25	2	28	1	56	2	20	0.375	15	0	0	0	0	B
L39	L38	AS	Box	64.25	55.25	2	28	1	56	2	20	0.375	15	0	0	0	0	B
L38	L37	QT	Box	50.25	43.5	2	28	0.75	42	2	20	0.375	15	0	0	0	0	B
L37	L36	QT	Box	50.25	43.5	2	28	0.75	42	2	20	0.375	15	0	0	0	0	B
L36	L35	QT	Box	74	63.88	2	28	1.125	63	2	20	0.5	20	0	0	0	0	B
L35	L34	QT	Box	74	63.88	2	28	1.125	63	2	20	0.5	20	0	0	0	0	B
L34	L33	QT	Box	74	63.88	2	28	1.125	63	2	20	0.5	20	0	0	0	0	B
L33	L32	QT	Box	74	63.88	2	28	1.125	63	2	20	0.5	20	0	0	0	0	B
L32	L31	QT	Box	65.63	56.63	2	28	1	56	2	20	0.438	17.5	0	0	0	0	B
L31	L30	QT	Box	65.63	56.63	2	28	1	56	2	20	0.438	17.5	0	0	0	0	B
L30	L29	QT	Box	65.63	56.63	2	28	1	56	2	20	0.438	17.5	0	0	0	0	B
L29	L28	QT	Box	65.63	56.63	2	28	1	56	2	20	0.438	17.5	0	0	0	0	B
L28	L27	AS	Box	51.69	44.38	2	28	0.563	31.5	2	20.25	0.5	20.25	1	19.88	0.5	9.94	A
L27	L26	AS	Box	51.69	44.38	2	28	0.563	31.5	2	20.25	0.5	20.25	1	19.88	0.5	9.94	A
L26	L25	AS	Box	51.69	44.38	2	28	0.563	31.5	2	20.25	0.5	20.25	1	19.88	0.5	9.94	A
L25	L24	AS	Box	51.69	44.38	2	28	0.563	31.5	2	20.25	0.5	20.25	1	19.88	0.5	9.94	A
L24	L23	QT	Box	82.75	–	2	28	1	56	2	20	0.625	25	1	19	0.75	14.25	A
L23	L22	QT	Box	82.75	–	2	28	1	56	2	20	0.625	25	1	19	0.75	14.25	A
L22	L21	QT	Box	82.75	–	2	28	1	56	2	20	0.625	25	1	19	0.75	14.25	A
L21	L20	QT	Box	82.75	–	2	28	1	56	2	20	0.625	25	1	19	0.75	14.25	A

TABLE 5.3
Upper chord sections (all units inch or inch^2)

Points		Properties				Plates				Cover Plates				Extra Plate				Holes
Start	End	Material	Section	Design Area	Net Area	No.	W	t	Area	No.	W	t	Area	No.	W	t	Area	Type
U2	U3	QT	Box	72.53	–	2	28	0.813	45.5	2	20	0.625	25	1	19.38	0.75	14.53	A
U3	U4	QT	Box	72.53	–	2	28	0.813	45.5	2	20	0.625	25	1	19.38	0.75	14.53	A
U4	U5	QT	Box	72.53	–	2	28	0.813	45.5	2	20	0.625	25	1	19.38	0.75	14.53	A
U5	U6	QT	Box	72.53	–	2	28	0.813	45.5	2	20	0.625	25	1	19.38	0.75	14.53	A
U6	U7	QT	Box	83.94	–	2	28	1	56	2	20	0.625	25	1	19	0.813	15.44	A
U7	U8	QT	Box	83.94	–	2	28	1	56	2	20	0.625	25	1	19	0.813	15.44	A
U8	U9	QT	Box	83.94	–	2	28	1	56	2	20	0.625	25	1	19	0.813	15.44	A
U9	U10	QT	Box	83.94	–	2	28	1	56	2	20	0.625	25	1	19	0.813	15.44	A
U10	U11	AS	Box	74.45	–	2	28	0.938	52.5	2	20	0.5	20	1	19.13	0.625	11.95	A
U11	U12	AS	Box	74.45	–	2	28	0.938	52.5	2	20	0.5	20	1	19.13	0.625	11.95	A
U12	U13	AS	Box	74.45	–	2	28	0.938	52.5	2	20	0.5	20	1	19.13	0.625	11.95	A
U13	U14	AS	Box	74.45	–	2	28	0.938	52.5	2	20	0.5	20	1	19.13	0.625	11.95	A
U14	U15	AS	Box	60	52.12	2	28	0.875	49	2	20	0.5	20	0	0	0	0	B
U15	U16	AS	Box	60	52.12	2	28	0.875	49	2	20	0.5	20	0	0	0	0	B
U16	U17	AS	Box	60	52.12	2	28	0.875	49	2	20	0.5	20	0	0	0	0	B
U17	U18	AS	Box	60	52.12	2	28	0.875	49	2	20	0.5	20	0	0	0	0	B
U18	U19	QT	Box	102	87.38	2	28	1.625	91	2	20	0.5	20	0	0	0	0	B
U19	U20	QT	Box	102	87.38	2	28	1.625	91	2	20	0.5	20	0	0	0	0	B
U38	U37	QT	Box	72.53	–	2	28	0.813	45.5	2	20	0.625	25	1	19.38	0.75	14.53	A
U37	U36	QT	Box	72.53	–	2	28	0.813	45.5	2	20	0.625	25	1	19.38	0.75	14.53	A
U36	U35	QT	Box	72.53	–	2	28	0.813	45.5	2	20	0.625	25	1	19.38	0.75	14.53	A
U35	U34	QT	Box	72.53	–	2	28	0.813	45.5	2	20	0.625	25	1	19.38	0.75	14.53	A
U34	U33	QT	Box	83.94	–	2	28	1	56	2	20	0.625	25	1	19	0.813	15.44	A
U33	U32	QT	Box	83.94	–	2	28	1	56	2	20	0.625	25	1	19	0.813	15.44	A
U32	U31	QT	Box	83.94	–	2	28	1	56	2	20	0.625	25	1	19	0.813	15.44	A
U31	U30	QT	Box	83.94	–	2	28	1	56	2	20	0.625	25	1	19	0.813	15.44	A
U30	U29	AS	Box	74.45	–	2	28	0.938	52.5	2	20	0.5	20	1	19.13	0.625	11.95	A
U29	U28	AS	Box	74.45	–	2	28	0.938	52.5	2	20	0.5	20	1	19.13	0.625	11.95	A
U28	U27	AS	Box	74.45	–	2	28	0.938	52.5	2	20	0.5	20	1	19.13	0.625	11.95	A
U27	U26	AS	Box	74.45	–	2	28	0.938	52.5	2	20	0.5	20	1	19.13	0.625	11.95	A
U26	U25	AS	Box	60	52.12	2	28	0.875	49	2	20	0.5	20	0	0	0	0	B
U25	U24	AS	Box	60	52.12	2	28	0.875	49	2	20	0.5	20	0	0	0	0	B
U24	U23	AS	Box	60	52.12	2	28	0.875	49	2	20	0.5	20	0	0	0	0	B
U23	U22	AS	Box	60	52.12	2	28	0.875	49	2	20	0.5	20	0	0	0	0	B
U22	U21	QT	Box	102	87.38	2	28	1.625	91	2	20	0.5	20	0	0	0	0	B
U21	U20	QT	Box	102	87.38	2	28	1.625	91	2	20	0.5	20	0	0	0	0	B

TABLE 5.4
Diagonal sections (all units inch or inch^2)

Points		Properties				Plates				Cover Plates				Extra Plate				Holes
Start	End	Material	Section	Design Area	Net Area	No.	W	t	Area	No.	W	t	Area	No.	W	t	Area	Type
L0	M1	QT	Box	97.88	–	2	28	1.313	73.5	2	20	0.813	32.5	0	0	0	0	C
M1	U2	QT	Box	97.88	–	2	28	1.313	73.5	2	20	0.813	32.5	0	0	0	0	C
U2	M3	AS	Box	55.5	45.38	2	21	1.125	47.25	2	20	0.375	15	0	0	0	0	B
M3	L4	AS	Box	45.01	37.13	2	21	0.875	36.75	2	20	0.375	15	0	0	0	0	B
L4	M5	AS	Box	43.76	–	2	18	0.938	33.75	2	20	0.5	20	0	0	0	0	A
M5	U6	AS	Box	34.76	–	2	18	0.688	24.75	2	20	0.5	20	0	0	0	0	A
U6	M7	CS	Box	28.76	23.14	2	16	0.625	20	2	20	0.438	17.5	0	0	0	0	A
M7	L8	CS	Box	28.76	23.14	2	16	0.625	20	2	20	0.438	17.5	0	0	0	0	A
L8	M9	AS	Box	24.19	20.25	2	18	0.438	15.75	2	20.25	0.375	15.19	0	0	0	0	B
M9	U10	AS	Box	30.75	25.13	2	18	0.625	22.5	2	20	0.375	15	0	0	0	0	B
U10	M11	AS	Box	61	–	2	24	1.063	51	2	20	0.5	20	0	0	0	0	A
M11	L12	AS	Box	67	–	2	24	1.188	57	2	20	0.5	20	0	0	0	0	A
L12	M13	QT	Box	38.25	32.63	2	24	0.625	30	2	20	0.375	15	0	0	0	0	B
M13	U14	QT	Box	41.25	35.07	2	24	0.688	33	2	20	0.375	15	0	0	0	0	B
U14	M15	QT	Box	75.5	–	2	24	1.313	63	2	20	0.625	25	0	0	0	0	A
M15	L16	QT	Box	81.5	–	2	24	1.438	69	2	20	0.625	25	0	0	0	0	A
L16	M17	QT	Box	57.62	48.62	2	24	1	48	2	20	0.438	17.5	0	0	0	0	B
M17	U18	QT	Box	60.62	51.06	2	24	1.063	51	2	20	0.438	17.5	0	0	0	0	B
U18	M19	AS	Box	89.75	–	2	28	1.313	73.5	2	20	0.813	32.5	0	0	0	0	A
M19	L20	QT	Box	89.75	–	2	28	1.313	73.5	2	20	0.813	32.5	0	0	0	0	A
L40	M39	QT	Box	97.88	–	2	28	1.313	73.5	2	20	0.813	32.5	0	0	0	0	C
M39	U38	QT	Box	97.88	–	2	28	1.313	73.5	2	20	0.813	32.5	0	0	0	0	C
U38	M37	AS	Box	55.5	45.38	2	21	1.125	47.25	2	20	0.375	15	0	0	0	0	B
M37	L36	AS	Box	45.01	37.13	2	21	0.875	36.75	2	20	0.375	15	0	0	0	0	B
L36	M35	AS	Box	43.76	–	2	18	0.938	33.75	2	20	0.5	20	0	0	0	0	A
M35	U34	AS	Box	34.76	–	2	18	0.688	24.75	2	20	0.5	20	0	0	0	0	A
U34	M33	CS	Box	28.76	23.14	2	16	0.625	20	2	20	0.438	17.5	0	0	0	0	A
M33	L32	CS	Box	28.76	23.14	2	16	0.625	20	2	20	0.438	17.5	0	0	0	0	A
L32	M31	AS	Box	24.19	20.25	2	18	0.438	15.75	2	20.25	0.375	15.19	0	0	0	0	B
M31	U30	AS	Box	30.75	25.13	2	18	0.625	22.5	2	20	0.375	15	0	0	0	0	B
U30	M29	AS	Box	61	–	2	24	1.063	51	2	20	0.5	20	0	0	0	0	A
M29	L28	AS	Box	67	–	2	24	1.188	57	2	20	0.5	20	0	0	0	0	A
L28	M27	QT	Box	38.25	32.63	2	24	0.625	30	2	20	0.375	15	0	0	0	0	B
M27	U26	QT	Box	41.25	35.07	2	24	0.688	33	2	20	0.375	15	0	0	0	0	B
U26	M25	QT	Box	75.5	–	2	24	1.313	63	2	20	0.625	25	0	0	0	0	A
M25	L24	QT	Box	81.5	–	2	24	1.438	69	2	20	0.625	25	0	0	0	0	A
L24	M23	QT	Box	57.62	48.62	2	24	1	48	2	20	0.438	17.5	0	0	0	0	B
M23	U22	QT	Box	60.62	51.06	2	24	1.063	51	2	20	0.438	17.5	0	0	0	0	B
U22	M21	AS	Box	89.75	–	2	28	1.313	73.5	2	20	0.813	32.5	0	0	0	0	A
M21	L20	QT	Box	89.75	–	2	28	1.313	73.5	2	20	0.813	32.5	0	0	0	0	A

TABLE 5.5
Hanger sections (all units inch or inch^2)

Points		Properties				Plates				Cover Plates				Extra Plate				Holes
Start	End	Material	Section	Design Area	Net Area	No.	W	t	Area	No.	W	t	Area	No.	W	t	Area	Type
M1	L1	CS	Box	17.44	15.75	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	B
M3	L3	CS	Box	17.44	15.75	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	B
M5	L5	CS	Box	17.44	15.75	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	B
M7	L7	CS	Box	17.44	15.75	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	B
M9	L9	CS	Box	17.44	15.75	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	B
M11	L11	CS	Box	17.44	15.75	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	B
M13	L13	CS	Box	17.44	15.75	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	B
M15	L15	CS	Box	17.44	15.75	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	B
M17	L17	CS	Box	17.44	15.75	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	B
M19	L19	CS	Box	17.44	15.75	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	B
U2	L2	CS	Box	25.32	21.42	2	15	0.563	16.88	2	20.25	0.375	15.19	0	0	0	0	B
U6	L6	CS	Box	25.32	21.42	2	15	0.563	16.88	2	20.25	0.375	15.19	0	0	0	0	B
U10	L10	CS	Box	25.32	21.42	2	15	0.563	16.88	2	20.25	0.375	15.19	0	0	0	0	B
U14	L14	CS	Box	25.32	21.42	2	15	0.563	16.88	2	20.25	0.375	15.19	0	0	0	0	B
U18	L18	CS	Box	25.32	21.42	2	15	0.563	16.88	2	20.25	0.375	15.19	0	0	0	0	B
M39	L39	CS	Box	17.44	15.75	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	B
M37	L37	CS	Box	17.44	15.75	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	B
M35	L35	CS	Box	17.44	15.75	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	B
M33	L33	CS	Box	17.44	15.75	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	B
M31	L31	CS	Box	17.44	15.75	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	B
M29	L29	CS	Box	17.44	15.75	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	B
M27	L27	CS	Box	17.44	15.75	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	B
M25	L25	CS	Box	17.44	15.75	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	B
M23	L23	CS	Box	17.44	15.75	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	B
M21	L21	CS	Box	17.44	15.75	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	B
U38	L38	CS	Box	25.32	21.42	2	15	0.563	16.88	2	20.25	0.375	15.19	0	0	0	0	B
U34	L34	CS	Box	25.32	21.42	2	15	0.563	16.88	2	20.25	0.375	15.19	0	0	0	0	B
U30	L30	CS	Box	25.32	21.42	2	15	0.563	16.88	2	20.25	0.375	15.19	0	0	0	0	B
U26	L26	CS	Box	25.32	21.42	2	15	0.563	16.88	2	20.25	0.375	15.19	0	0	0	0	B
U22	L22	CS	Box	25.32	21.42	2	15	0.563	16.88	2	20.25	0.375	15.19	0	0	0	0	B

TABLE 5.6
Post sections (all units inch or inch^2)

Points		Properties				Plates				Cover Plates				Extra Plate				Holes
Start	End	Material	Section	Design Area	Net Area	No.	W	t	Area	No.	W	t	Area	No.	W	t	Area	Type
U3	M3	CS	Box	16.69	–	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	A
U5	M5	CS	Box	16.69	–	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	A
U7	M7	CS	Box	16.69	–	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	A
U9	M9	CS	Box	16.69	–	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	A
U11	M11	CS	Box	16.69	–	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	A
U13	M13	CS	Box	16.69	–	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	A
U15	M15	CS	Box	16.69	–	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	A
U17	M17	CS	Box	16.69	–	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	A
U19	M19	CS	Box	16.69	–	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	A
U4	L4	CS	Box	25.69	–	2	18	0.5	18	2	20.25	0.375	15.19	0	0	0	0	A
U8	L8	CS	Box	25.69	–	2	18	0.5	18	2	20.25	0.375	15.19	0	0	0	0	A
U12	L12	CS	Box	25.69	–	2	18	0.5	18	2	20.25	0.375	15.19	0	0	0	0	A
U16	L16	CS	Box	25.69	–	2	18	0.5	18	2	20.25	0.375	15.19	0	0	0	0	A
U20	L20	QT	Box	75.5	–	2	24	1.313	63	2	20	0.625	25	0	0	0	0	A
U37	M37	CS	Box	16.69	–	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	A
U35	M35	CS	Box	16.69	–	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	A
U33	M33	CS	Box	16.69	–	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	A
U31	M31	CS	Box	16.69	–	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	A
U29	M29	CS	Box	16.69	–	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	A
U27	M27	CS	Box	16.69	–	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	A
U25	M25	CS	Box	16.69	–	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	A
U23	M23	CS	Box	16.69	–	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	A
U21	M21	CS	Box	16.69	–	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	A
U36	L36	CS	Box	25.69	–	2	18	0.5	18	2	20.25	0.375	15.19	0	0	0	0	A
U32	L32	CS	Box	25.69	–	2	18	0.5	18	2	20.25	0.375	15.19	0	0	0	0	A
U28	L28	CS	Box	25.69	–	2	18	0.5	18	2	20.25	0.375	15.19	0	0	0	0	A
U24	L24	CS	Box	25.69	–	2	18	0.5	18	2	20.25	0.375	15.19	0	0	0	0	A

TABLE 5.7
Sub-diagonals and struts sections (all units inch or inch^2)

Points		Properties				Plates				Cover Plates				Extra Plate				Holes
Start	End	Material	Section	Design Area	Net Area	No.	W	t	Area	No.	W	t	Area	No.	W	t	Area	Type
M1	L2	CS	Box	20.82	–	2	15	0.438	13.13	2	20.25	0.375	15.19	0	0	0	0	A
L2	M3	CS	Box	20.82	–	2	15	0.438	13.13	2	20.25	0.375	15.19	0	0	0	0	A
M5	L6	CS	Box	20.82	–	2	15	0.438	13.13	2	20.25	0.375	15.19	0	0	0	0	A
L6	M7	CS	Box	20.82	–	2	15	0.438	13.13	2	20.25	0.375	15.19	0	0	0	0	A
M9	L10	CS	Box	20.82	–	2	15	0.438	13.13	2	20.25	0.375	15.19	0	0	0	0	A
L10	M11	CS	Box	20.82	–	2	15	0.438	13.13	2	20.25	0.375	15.19	0	0	0	0	A
M13	L14	CS	Box	20.82	–	2	15	0.438	13.13	2	20.25	0.375	15.19	0	0	0	0	A
L14	M15	CS	Box	20.82	–	2	15	0.438	13.13	2	20.25	0.375	15.19	0	0	0	0	A
M17	L18	CS	Box	20.82	–	2	15	0.438	13.13	2	20.25	0.375	15.19	0	0	0	0	A
L18	M19	CS	Box	20.82	–	2	15	0.438	13.13	2	20.25	0.375	15.19	0	0	0	0	A
M39	L38	CS	Box	20.82	–	2	15	0.438	13.13	2	20.25	0.375	15.19	0	0	0	0	A
L38	M37	CS	Box	20.82	–	2	15	0.438	13.13	2	20.25	0.375	15.19	0	0	0	0	A
M35	L34	CS	Box	20.82	–	2	15	0.438	13.13	2	20.25	0.375	15.19	0	0	0	0	A
L34	M33	CS	Box	20.82	–	2	15	0.438	13.13	2	20.25	0.375	15.19	0	0	0	0	A
M31	L30	CS	Box	20.82	–	2	15	0.438	13.13	2	20.25	0.375	15.19	0	0	0	0	A
L30	M29	CS	Box	20.82	–	2	15	0.438	13.13	2	20.25	0.375	15.19	0	0	0	0	A
M27	L26	CS	Box	20.82	–	2	15	0.438	13.13	2	20.25	0.375	15.19	0	0	0	0	A
L26	M25	CS	Box	20.82	–	2	15	0.438	13.13	2	20.25	0.375	15.19	0	0	0	0	A
M23	L22	CS	Box	20.82	–	2	15	0.438	13.13	2	20.25	0.375	15.19	0	0	0	0	A
L22	M21	CS	Box	20.82	–	2	15	0.438	13.13	2	20.25	0.375	15.19	0	0	0	0	A
M19	M20	CS	Box	16.69	–	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	A
M21	M20	CS	Box	16.69	–	2	12	0.375	9	2	20.25	0.375	15.19	0	0	0	0	A

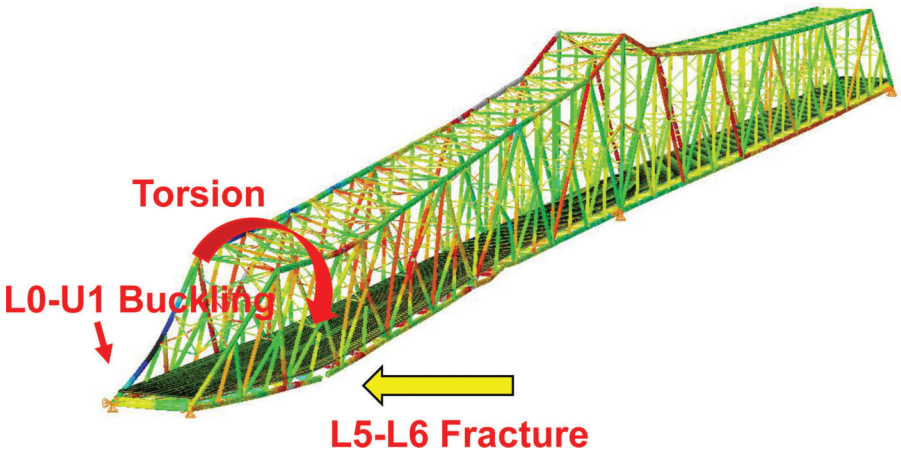


Figure 5.3 The behavior after typical lower chord fracture.

Following the failure, excessive plastic strain was observed on L20-U20 hanger; consequently, the compression member was buckled. The truss structure is not able to redistribute the tension force that the was carrying by the upper chords before the fracture. The degree of torsion following the fracturing of the upper chord prompted the lateral system to apply a significant amount of force on the hanger. Similar to the results of evaluating the lower tension chords, under both the Redundancy I and II load combinations, upper tension chord member fractures evaluated causes the bridge to fail the redundancy criteria by a significant margin.

5.4 Summary

Analytical models were developed to evaluate the structural redundancy of the two-span continuous through truss Matthew E. Welsh Memorial Bridge, Mauckport carrying SR 135 EB and WB over the Ohio River (135-31-06504 B) in the State of Indiana. The tension members are presently classified as Non-Redundant Steel Tension Members and should remain as such. A full depth fracture on the box members was simulated in the lower and upper chords. The analysis determined that the bridge does not satisfy the

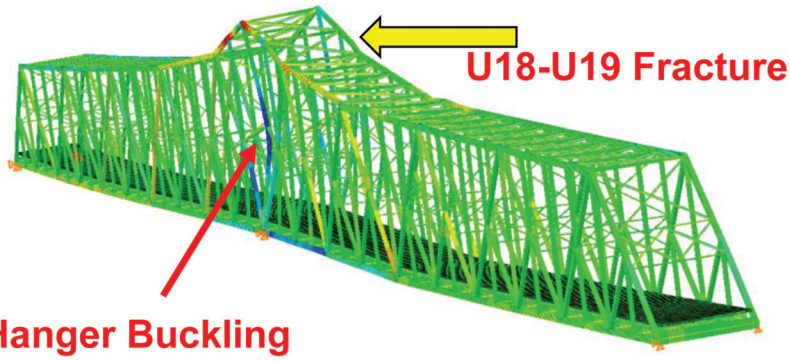


Figure 5.4 The behavior after typical upper chord fracture.

performance requirements included in the guide specifications (AASHTO, 2018/2022a) for both the Redundancy I and Redundancy II load combinations. As stated, the excessive damage that follow failure of the tension chords strongly suggests that failure of a vertical or diagonal would also result in significant damage indicating these members should remain classified as NSTMs. Due to the limited project resources, it is not possible to fully evaluate these members using the AASHTO Guide Specifications at this time. Therefore, all of the truss components presently classified as NSTMs should remain classified as NSTMs.

6. CONCLUSION

In this report, an I-girder bridge (74-170-04684 over Whitewater River), a twin simple span bridge (the SR 1 001-68-03408 over the Mississinewa River) and a two-span continuous truss bridge (Matthew E. Welsh Memorial Bridge, Mauckport, 135-31-06504 B) in INDOT's existing inventory were evaluated for the case where one of the tension members fails due to brittle fracture. The evaluation was completed using finite element models. The models included the reinforced concrete deck, shear studs, and all steel components of the super structure. The models also considered the stages of construction. A conservative approach was used to address the dynamic amplification of the bridge immediately following fracture. The fracture was assumed to be full-depth and resulted in complete failure of the cross section.

The bridges were evaluated using the system analysis procedures developed at Purdue University under NCHRP Report 883 (Connor et al., 2017) and explained in AASHTO Guide Specifications (AASHTO, 2018/2022a). The loading was established using a reliability-based approach to achieve a target reliability index of 2.5, similar to the current *AASHTO LRFD Bridge Design Specifications* (AASHTO, 2020). Two load combinations were considered. The Redundancy I load combination evaluates the ability of the bridge to immediately survive a sudden brittle fracture, and the Redundancy II load combination evaluates the ability of the bridge to carry live load during the interval between when the fracture occurs and when it is discovered. A dynamic amplification factor of 1.4 was used in the Redundancy I load case to simulate the dynamic loading effects of fracture. The failure criteria described include both strength and serviceability limits specifically developed to ensure the safety of the traveling public.

The analysis has concluded that the bridges 74-170-04684 over Whitewater River and Matthew E. Welsh Memorial Bridge, Mauckport (135-31-06504 B) analyzed in the project do not possess considerable reserve strength in the faulted state. Thirteen components of SR 1 001-68-03408 Bridge over the Mississinewa River meet the performance criteria outlined in the guide specifications.

Volume V: Suggested Procedures for Re-classifying Nonredundant Steel Tension Members as Internally Redundant Members

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1. INTRODUCTION

The purpose of this document is to outline the evaluation process for reclassifying Non-Redundant Steel Tension Members (NSTMs) as Internally Redundant Members (IRMs) in Indiana. It is intended to serve as a starting point for INDOT when developing their procedures to be applicable statewide for this process. Bridges with NSTMs are required to have an in-depth arm's length inspection of the NSTMs completed at regular intervals. However, in June of 2022, 23 CFR Part 650 (DOT FHWA, 2022) permitted owners to utilize internal member redundancy in mechanically fastened built-up members to set inspection scope and interval using a "national recognize method." INDOT has selected the *AASHTO Guide Specifications for Internal Redundancy of Mechanically-Fastened Built-Up Steel Members* (AASHTO, 2018/2022b) as the method for such evaluations. Further, the National Bridge Inspection Standards found in 23 CFR Part 650 (DOT FHWA, 2022) state that once a member, or portion thereof, has been classified as an Internally Redundant Member (IRM), the NSTM label can be removed and replaced with the IRM designation. However, specific written procedures must be developed for these members that address future inspection procedures and a documented set of criteria that will be used to determine if and when IRMs should be reclassified as NSTMs and hence, be subjected to the associated inspection requirements. The written procedures contained herein layout a suggested approach for classifying existing members as IRMs. These procedures are also illustrated in the flow chart found in Appendix A of this report, which is based upon the IRM evaluation procedures found in IRM Guide Specification. Further factors that should be considered when evaluating if an IRM should be reclassified as an NSTM are also provided.

2. IRM EVALUATION PROCESS

After a bridge with mechanically-fastened built-up NSTMs has been selected for evaluation, the IRM Guide Specification shall be used to determine if the NSTMs can be reclassified as IRMs. Note that per AASHTO BDS 6.6.2.2, only nonredundant steel members that are subject to net tensile stress under the Strength I load combination shall be designated as an NSTM (AASHTO, 2020). All members and sections being evaluated shall satisfy the general requirements of Article 1.4 of the IRM Guide Specification. The conditions set in Article 1.4 include specific factors that would preclude primary tension members from evaluation including, but not limited to, fatigue cracking, significant corrosion, and impact damage, etc. Additional requirements are included in Article 1.5 for flexural members and Article 1.6 for axially loaded tension members. These requirements shall apply to the as-built unfaulted state of the member. If a member or section does not satisfy any one of the screening requirements, it shall remain classified as an NSTM. If all screening criteria are met, the member or section may be moved forward for further evaluation.

Article 1.4 also requires the built-up member to meet all applicable strength requirements as well as possess positive remaining fatigue life in the unfaulted state. Thus, in cases where *calculations* indicate that the fatigue life has been exhausted in the unfaulted state, the member shall remain classified as an NSTM. However, in such cases where calculations indicate insufficient remaining fatigue life, INDOT may elect to collect field measurements to produce stress-range histograms to obtain a more accurate estimate of the existing fatigue damage and subsequent remaining life. When such a decision is made, INDOT's processes to be used for field instrumentation and field data analysis are discussed in Section 4 of this document. It is suggested INDOT summarize what is contained in Section 4 and include these processes in the document to be used statewide for completeness.

Once it is established that the member possesses adequate remaining fatigue life, the next step is to evaluate the strength in the *faulted* state to determine if the member has sufficient capacity. The required load to be applied in the faulted state shall be calculated according to Article 1.7 of the IRM Guide Specification. Using the calculated loads, factored stresses are calculated per Articles 2.1 and 2.2, and the performance of the faulted member shall be evaluated using the provisions of Article 2.3.

If it is found the member satisfies the requirements of Article 2.3, the remaining fatigue life of the faulted member is next evaluated to establish the in-service inspection interval as described in Section 3 of this document.

3. IRM INSPECTION REQUIREMENTS

For members determined to satisfy the internal redundancy strength requirements of the IRM Guide Specification as outlined above, Article 3 of the IRM Guide Specifications (AASHTO, 2018/2022b) will be used for determining the maximum interval between special inspections. The scope of the special inspections will be such that it is capable of reliably identifying large cracks or completely severed components in IRMs. This may require special access (such as a snooper or rope access) depending on the member and overall bridge geometry. The details associated with the access for each bridge will be documented as part of the IRM inspection plan for each bridge on a case-by-case basis as determined by INDOT.

While the special inspection is focused on detection of broken components as noted above, other reportable conditions (corrosion, impact damage, etc.) found on an IRM member will also be documented and reported for use as needed in evaluating if the member needs to be reclassified as an NSTM per Article 3.2 of the IRM Guide Specifications (AASHTO, 2018/2022b). Specifically, "*Any changes in the condition of the structural*

member that would justify a more frequent interval and/or a different level of rigor for the special inspections for IRMs" will be evaluated to determine if the member may remain classified as an IRM. The basic screening criteria found in the IRM Guide Specifications will be reevaluated each time a member is inspected to ensure the member may be classified as an IRM.

4. FIELD INSTRUMENTATION (OPTIONAL)

If after an initial fatigue evaluation of the bridge, it is found that the calculated stress ranges generated from the AASHTO fatigue truck prevent all or a portion of the bridge from having sufficient remaining fatigue life to be relabeled as IRMs, INDOT may consider field instrumentation to develop in-situ stress-range histograms. Again, it is noted that additionally, both the strength in the faulted state and the Article 1 criteria of the IRM Guide Specifications will be verified to pass before instrumenting the bridge.

Stress-range histograms will be developed to estimate the remaining fatigue life as prescribed in Article C7.2.2.2 of *The Manual for Bridge Evaluation* (MBE) (AASHTO, 2018/2022c) as well as other documents. The MBE prescribes that for infinite life checks, maximum stress range should be taken as the greater of the maximum stress range found during field instrumentation or 2.2 times the effective stress range.

The measured stress-range histograms will be used to calculate the remaining fatigue life at locations where strain gages were not installed by scaling the calculated force ranges from the initial evaluation process. INDOT will increase the maximum scaling ratio by an additional factor (suggested to be 10%) to account for the variation of load applications, load distributions, etc., that may occur at locations with no instrumentation.

5. FACTORS TO CONSIDER FOR RECLASSIFICATION AS AN NSTM, CHANGES IN INSPECTION SCOPE, OR INTERVAL

A critical part of managing IRMs is the identification of factors that must be documented during subsequent inspection which may, if detected, result in the IRM being reclassified as an NSTM. In some cases, these could be documented using a simple checklist while others may require some calculation and/or engineering judgement at times. The following multi-step process provides a suggested road map to be used for each bridge as part of an overall policy.

5.1 Step 1

After each inspection, INDOT will consult the table prepared for the given bridge which governs the intervals of the special inspections. Other required inspections will also be included in the table for completeness. This table accounts for the consumption of remaining fatigue life that occurs (assuming finite life in the unfaulted stated) over the life of the bridge. A typical example as presented in Figure 5.1, will be developed for each bridge, and will be kept as part of the permanent bridge inspection file. In the example below it is assumed the bridge includes pin and hanger details, which require different inspection intervals and scope.

In the example table, it is assumed there are no changes in condition that would independently require members being reclassified from IRM to NSTM, or other general changes in condition. In the example cited, the bridge may remain on the 120-month IRM special inspection interval until 2049. At that time due to consumption of fatigue life, the special inspection interval will be shortened to 24 months. Note, only the *interval* is shortened, as the scope need only be consistent with the special inspection strategies for IRMs since the member is still classified as an IRM. The only change is shortening of the interval.

5.2 Step 2

For each bridge, a clear statement of the required access equipment, special emphasis areas, required NDT, etc., will be developed in order to achieve the objectives of the special inspection for the given member as part of the inspection plan. Also, components or areas that should be inspected using different strategies, for example UT of pins, will be clearly documented and highlighted on the inspection plan for each bridge. This process is similar to what is commonly done for NSTM inspection and routine inspections. As noted, the special inspections for IRMs have the objective of reliably detecting broken components and not very small cracks. In many cases, this will require access equipment in order for the inspector to be up close to the member in order to reliably detect a broken component. In other cases, this may be possible from the ground. Regardless, the specific strategy will be documented as part of the procedures associated with the scope of the special inspection for each structure. Should changes in condition be observed that warrant changes in access, the need for NDT, etc., this will be evaluated following each inspection and the inspection plan updated accordingly.

5.3 Step 3

After each inspection is completed (both routine and special IRM inspection), the findings will be reviewed and INDOT will determine if the bridge may remain on the inspection schedule developed during the initial IRM evaluation (a typical example schedule was shown in Figure 5.1) or if intervals should be shortened. In some cases, changes in condition may warrant all or a portion of the members classified as IRMs to be inspected at intervals consistent with those strategies for NSTMs. In such cases, the members or portions thereof will be clearly identified on the inspection plan and communicated to the inspectors. Further the need for

Inspection Type		Frequency	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
	Routine	24 months	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
	NSTM	24 months	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
	Special (IRM)	10 years	N/A	N/A	No	No	No	No	No	No	No	No	Yes	No	No	No	No	No
	Underwater	60 months	No	No	Yes	No	No	No	No	Yes	No	No	No	No	Yes	No	No	No
	Special (Pin and Hangers)	60 months	No	No	Yes	No	No	No	No	Yes	No	No	No	No	Yes	No	No	No

Inspection Type		Frequency	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051
	Routine	24 months	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
	NSTM	24 months	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
	Special (IRM)	10 years	No	No	No	No	Yes	No	No	No	No	No	No	No	Yes	No	Yes
	Underwater	60 months	No	Yes	No	No	No	No	Yes	No	No	No	No	Yes	No	No	No
	Special (Pin and Hangers)	60 months	No	Yes	No	No	No	No	Yes	No	No	No	No	Yes	No	No	No

Figure 5.1 Example inspection interval and scope table.

Inspection Type	Routine	Special (IRM)	Routine	Routine
Inspection Date	6/2020	6/2022	6/2022	6/2024
Are there active fatigue cracking ?	Yes (No)	Yes (No)	Yes (No)	Yes (No)
Is there any impact damage?	Yes (No)	Yes (No)	Yes (No)	Yes (No)
Is there any fire damage?	Yes (No)	Yes (No)	Yes (No)	(Yes) No
Is there any corrosion resulting in section loss resulting in load capacity reduction	Yes (No)	Yes (No)	Yes (No)	Yes (No)
Is there any change in a member affecting the bridge's load posting?	Yes (No)	Yes (No)	Yes (No)	Yes (No)
Is there any deck deterioration affecting composite action?	Yes (No)	Yes (No)	Yes (No)	Yes (No)
Repairs or retrofits affecting fracture performance since last inspection?	Yes (No)	Yes (No)	Yes (No)	Yes (No)
Are there any changes to the live loads warranting fatigue life recalculation?	Yes (No)	Yes (No)	Yes (No)	Yes (No)
Are there any other condtions influencing the performance of the bridge?	Yes (No)	Yes (No)	Yes (No)	Yes (No)
Any "Yes" factors would trigger re-evaluation	Good	Good	Good	Re-evaluation

Figure 5.2 Example IRM inspection checklist.

changes in how members are accessed will also be considered during this process. The following factors will be considered during each IRM revaluation:

- the presence of active fatigue cracks including out-of-plane distortion cracks,
- impact damage,
- fire damage,
- corrosion resulting in section loss that would result in a reduction in load capacity of the member (i.e., a load rating is required),
- deck deterioration or deck repairs that may alter assumed level of composite action for plate girder type bridges,
- repairs or retrofits that may create uncertainty in the fatigue and or fracture performance of the given IRM,
- changes in live loading that would warrant a recalculation of remaining fatigue life in the unfaulted and faulted state, and
- other changes in condition that would influence the performance of the bridge overall (e.g., settlement).

A simple check list could be developed for each bridge that includes the above items and others deemed important may be added. An illustrative example of such a checklist can be seen in Figure 5.2. Following each inspection and based on the results of the check list, INDOT will then determine if a revaluation is required or not.

5.4 Step 4

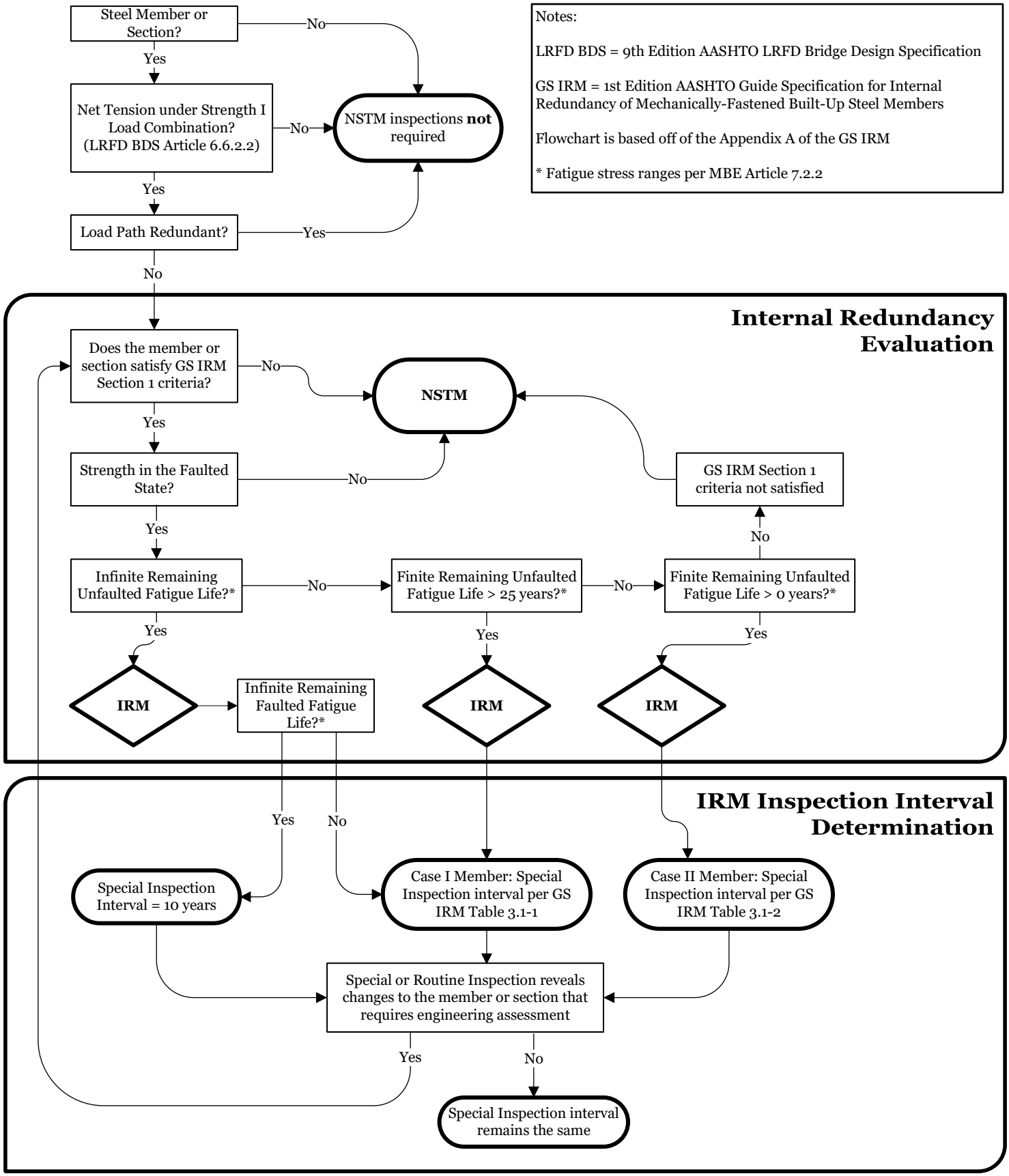
Depending on the outcome of steps 1 through 3, do the following.

- Update the inspection table illustrated in Figure 5.2, if required.
- Revise the inspection plan (including access, interval, and scope) for the bridge or specific member that need to be relabeled as NSTMs.

APPENDICES

Appendix 5A. INDOT IRM Evaluation Procedure Flowchart

Appendix 5A. INDOT IRM Evaluation Procedure Flowchart



Volume VI: Suggested Procedures for Re-classifying Nonredundant Steel Tension Members as System Redundant Members

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1. INTRODUCTION

The purpose of this document is to outline the evaluation process for reclassifying Non-Redundant Steel Tension Members (NSTMs) as System Redundant Members (SRMs) in Indiana. It is intended to serve as a starting point for INDOT when developing their procedures to be applicable statewide for this process. Bridges with NSTMs are required to have an in-depth arm's length inspection of the NSTMs completed at regular intervals. However, on June 20, 2012, FHWA released a memo titled *Clarification of Requirements for Fracture Critical Members* introducing "a new member classification, a System Redundant Member (SRM), which is a non-load-path-redundant member that gains its redundancy by system behavior." This memo was then replaced by the May 9th, 2022, FHWA memo titled *Inspection of Nonredundant Steel Tension Members* in which an update to 23 CFR part 650 Subpart C, National Bridge Inspection Standards (NBIS) was referenced (DOT FHWA, 2022). The law replaced the Fracture Critical (FC) designation with the term Non-Redundant Steel Tension Member (NSTM). Members determined to contain such system redundancy using the method prescribed in the *AASHTO Guide Specifications for the Analysis and Identification of Fracture Critical Members and System Redundant Members* (SRM Guide Specification) are allowed to have the NSTM label removed and re-classified as SRMs (AASHTO, 2018/2022a). Additionally, SRMs do not need to be subject to inspection protocols that apply to NSTMs. The written procedures contained herein layout a suggested approach for classifying existing members as SRMs. Further factors that should be considered when evaluating if an SRM should be reclassified as an NSTM are also provided.

2. SRM EVALUATION PROCESS

After a bridge with NSTMs has been selected for evaluation, the SRM Guide Specification shall be used to determine if the NSTMs can be reclassified as SRMs. All section references in this report are referencing the SRM Guide Specification (AASHTO, 2018/2022a). The first step of the evaluation process is the construction of a 3D finite element model using an adequate FEA tool as prescribed in Section 3.1.1. Some of the software requirements among others include the ability to model three-dimensional geometry, to model effects of material nonlinearity, to define a variety of boundary conditions, to allow time-dependent input and much more. The specific geometry meshes, and materials models need to be selected for both the superstructure steelwork and concrete slab and barriers using Sections 4 and 5 (AASHTO, 2018/2022a). Section 6 provides guidance on modeling the connections between steelwork components and interactions between slab and steelwork (AASHTO, 2018/2022a). Additionally, proper application of load and boundary conditions is discussed in Section 7 (AASHTO, 2018/2022a). Once the baseline model is constructed, the individual NSTM members should be analyzed using both the Redundancy I and Redundancy II load combinations as described in Sections 3 and 7 (AASHTO, 2018/2022a). Following the above-described analysis, the structure is to be evaluated in the faulted state for both strength and serviceability requirements described in Section 8 (AASHTO, 2018/2022a). The comparison of results with performance criteria will dictate if the member can be relabeled an SRM or must remain an NSTM. The procedures for INDOT's approach to classifying existing members as SRMs are also illustrated by the flow chart found in Appendix A of this report, which is based upon the SRM evaluation procedures found in the SRM Guide Specification.

3. SRM INSPECTION REQUIREMENTS

Any members that are determined to be relabeled as SRMs need not be subject to inspection protocols that apply to NSTMs (arms' length in depth inspections). However, future inspection strategies should be dependent on the overall assessment of the structure. Should a given inspection identify conditions that warrant member being reclassified as an NSTM, this shall be clearly identified in the file for the given bridge and the future inspections altered as appropriate. The factors affecting this decision should include, but not be limited to, presence of fatigue cracks, repairs/retrofits, impact damage, corrosion, age, traffic history, overall condition of the bridge, etc. Changes to the bridge that would cause any of the screening criteria found in Section 2 of the SRM Guide Specification that would disqualify the bridge from being considered for SRM analysis must be corrected if SRM label is to remain (AASHTO, 2018/2022a). If the issues are not corrected, the members must revert to being NSTMs.

4. FACTORS TO CONSIDER FOR RECLASSIFICATION AS AN NSTM

A critical part of managing SRMs is the identification of factors that must be documented during subsequent inspections which may, if detected, result in the SRM being reconsidered for reclassified as an NSTM. In some cases, these factors could be documented using a simple checklist while others may require some calculation and/or engineering judgement at times. The following multi-step process will be used for each bridge.

Each bridge containing SRMs is to be inspected as prescribed in the inspection plan. The inspection plan may follow and include strategies consistent with routine inspections for load path redundant members, special inspections for unique members such as pin and hangers or internally redundant members, as well included required underwater inspections. Each inspection requires unique access and scope to accurately assess the condition of the specific member being inspected. Should changes in condition be observed

Inspection Type	Routine	Routine	Routine
Inspection Date	6/2020	6/2022	6/2024
Are there active fatigue cracking ?	Yes (No)	Yes (No)	Yes (No)
Repairs or retrofits affecting fracture performance since last inspection?	Yes (No)	Yes (No)	Yes (No)
Is there any impact damage?	Yes (No)	Yes (No)	(Yes) No
Is there any fire damage?	Yes (No)	Yes (No)	Yes (No)
Is there any change in a member affecting the bridge's load posting?	Yes (No)	Yes (No)	Yes (No)
Is there any deck deterioration affecting composite action?	Yes (No)	Yes (No)	Yes (No)
Are there any changes to the live loads warranting strength recalculation?	Yes (No)	Yes (No)	Yes (No)
Are there any other condtions influencing the performance of the bridge?	Yes (No)	Yes (No)	Yes (No)
Any "Yes" factors would trigger re-evaluation	Good	Good	Re-evaluation

Figure 4.1 Example SRM inspection checklist.

during any inspections of the bridge that warrant changes in access, the need for NDT, etc., this will be evaluated following each inspection and the inspection plan updated accordingly.

4.1 Step 1

A simple checklist of factors will be developed for each bridge containing SRMs. This checklist will outline specific quantitative and qualitative factors that would trigger the re-evaluation of an SRM. These factors will be unique to each bridge but might include some of the following.

- The presence of active fatigue cracks including out-of-plane distortion cracks,
- repairs or retrofits that may create uncertainty in the fracture performance of the given SRM,
- impact damage,
- fire damage,
- change in load carrying capacity of a member (i.e., a load posting is required),
- deck deterioration or deck repairs that may alter assumed level of composite action for plate girder type bridges,
- changes in live loading that would warrant a recalculation of strength in the unfaulted and faulted state, and
- other changes in condition that would influence the performance of the bridge overall (e.g., settlement).

An example of such a checklist can be seen in Figure 4.1.

4.2 Step 2

After each inspection is completed, the findings will be reviewed, and the checklist developed in Step 1 will be filled out. In some cases, changes in condition may warrant all or a portion of the members classified as SRMs to be inspected at intervals and scope consistent with those strategies for NSTMs. In such cases, the members or portions thereof will be reclassified as NSTMs and clearly identified on the inspection plan and communicated to the inspectors. In some cases, repairs may need to be made to maintain a given members SRM classification (e.g., adequate repair of impact damage). In some rare cases, the FEA model may need to be rerun. Should changes in condition be observed that warrant changes in access, the need for NDT, etc., this will be evaluated following each inspection and the inspection plan updated accordingly.

4.3 Step 3

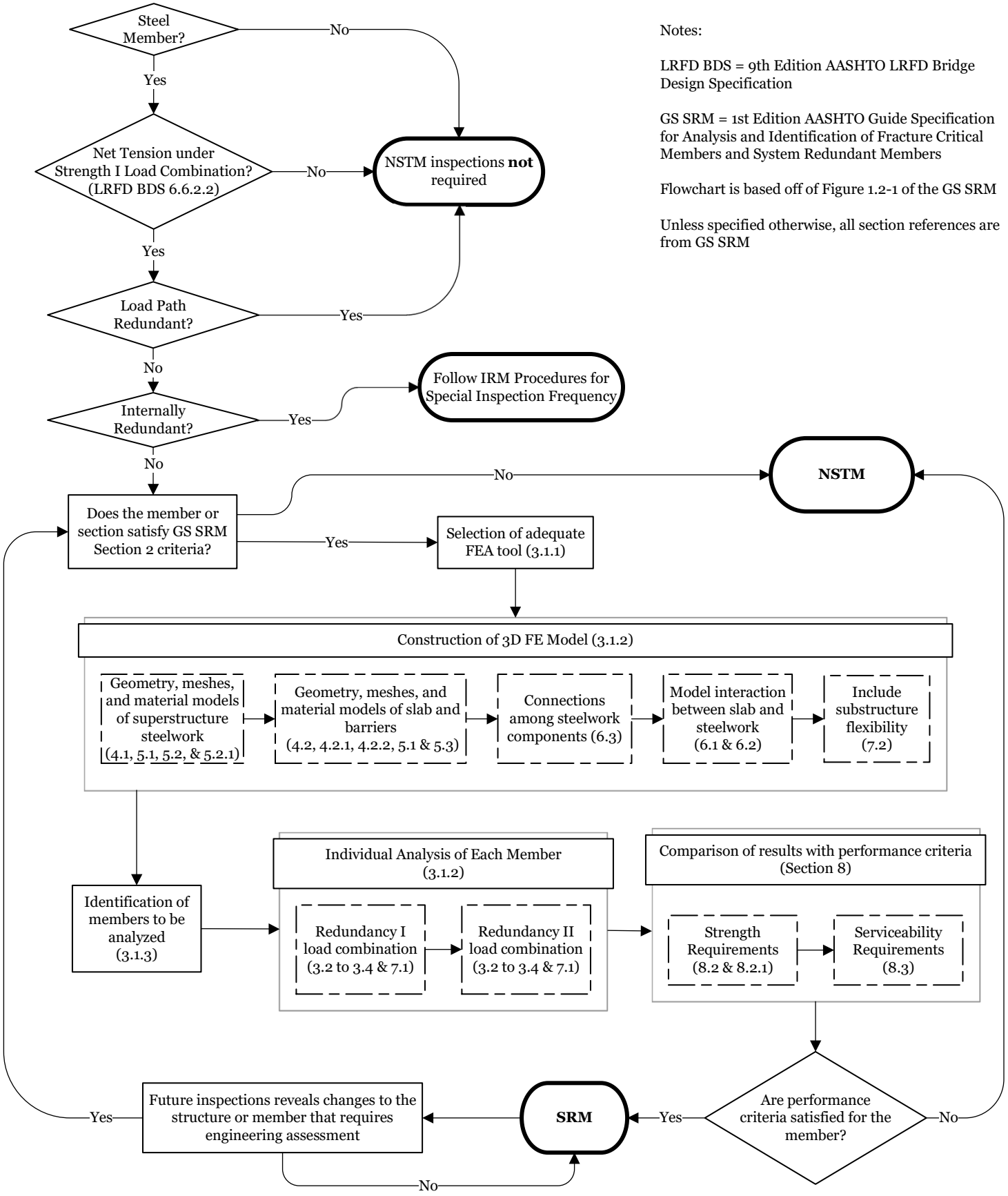
Depending on the outcomes of steps 1 through 2, do the following.

- Revise the inspection plan (including access, interval, and scope) for the bridge or specific member that needs to be relabeled as NSTMs;
- repair member/members that have a defect identified in the checklist; and
- complete an SRM evaluation using an updated FEA model for the member or bridge in question.

APPENDICES

Appendix 6A. INDOT SRM Evaluation Procedure Flowchart

Appendix 6A. INDOT SRM Evaluation Procedure Flowchart



Notes:

LRFD BDS = 9th Edition AASHTO LRFD Bridge Design Specification

GS SRM = 1st Edition AASHTO Guide Specification for Analysis and Identification of Fracture Critical Members and System Redundant Members

Flowchart is based off of Figure 1.2-1 of the GS SRM

Unless specified otherwise, all section references are from GS SRM

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About the Joint Transportation Research Program (JTRP)

On March 11, 1937, the Indiana Legislature passed an act which authorized the Indiana State Highway Commission to cooperate with and assist Purdue University in developing the best methods of improving and maintaining the highways of the state and the respective counties thereof. That collaborative effort was called the Joint Highway Research Project (JHRP). In 1997 the collaborative venture was renamed as the Joint Transportation Research Program (JTRP) to reflect the state and national efforts to integrate the management and operation of various transportation modes.

The first studies of JHRP were concerned with Test Road No. 1—evaluation of the weathering characteristics of stabilized materials. After World War II, the JHRP program grew substantially and was regularly producing technical reports. Over 1,600 technical reports are now available, published as part of the JHRP and subsequently JTRP collaborative venture between Purdue University and what is now the Indiana Department of Transportation.

Free online access to all reports is provided through a unique collaboration between JTRP and Purdue Libraries. These are available at http://docs.lib.purdue.edu/jtrp.

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