Evaluation of Finger Plate and Flat Plate Connection Design

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Report

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Construction and Materials

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This project investigates the cause(s) of premature deterioration of MoDOT finger plate and flat plate expansion devices under high traffic volumes and then uses that information to design new Load and Resistance Factor Design (LRFD) finger plate and flat plate designs that are intended to last 40 years or more with minimal maintenance.
To fully evaluate the expansion devices, a literature review and survey of current expansion devices used by transportation departments across the United States was conducted. The failure of the finger plate expansion devices were found to be contributed primarily to fatigue failure of the weld between the finger plate and the support beam beneath it as well as vertical misalignment due to poor construction. The flat plate expansion device was found to perform inadequately if the bridge span experiences rotation causing a gap between the sliding flat plate and the support angle or if construction of the device is deficient.
Experimental testing was conducted on the finger plate device on Eastbound Blanchette Bridge on Highway I-70 in St. Louis and the flat plate device on Route 350 passing over Highway I-435 in Kansas City. The results were also used to validate Finite Element Models (FEMs) of the current expansion device designs. Testing of the finger devices found that dynamic impact in the finger device is generally between 40% and 70% and could be as much as 160% and the effect of misalignment of the fingers can results in 30% additional stresses. Testing of the flat plate device revealed significant stresses build in the sliding plate due to the differential movements of the abutment and bridge span.
A robust finger plate device was designed to accommodate bridges which require large expansion lengths on high large volume routes. In addition suggestions for improvements of the existing finger plate device design were made for use on routes with lower traffic volumes. Repair and replacement best practices and details were also developed as part of this project.</td></tr>
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ABSTRACT

The objective of this project is to learn the causes of premature deterioration of MoDOT finger plate and flat plate expansion devices under high traffic volumes and then use that information to design new Load and Resistance Factor Design (LRFD) finger plate and flat plate expansion devices that are intended to last 40 years or more with minimal maintenance. In addition, repair and retrofit best practices and details were developed as part of this project.

To fully evaluate the expansion devices, a literature review and survey of current expansion devices used by transportation departments across the United States was conducted. The failure of the finger plate expansion devices were found to be contributed primarily to fatigue failure of the weld between the finger plate and the support beam beneath it as well as vertical misalignment due to poor construction. The flat plate expansion device was found to perform inadequately if the bridge span experiences rotation causing a gap between the sliding flat plate and the support angle or if construction of the device is deficient.

Experimental testing was conducted on the finger plate device on East-bound Blanchette Bridge on Highway I-70 in St. Louis and the flat plate expansion device on Route 350 passing over Highway I-435 in Kansas City. The test results showed dynamic impact in the finger plate device is generally between 40% and 70% and could be as much as 160% and the effect of misalignment of the fingers can result in an increase in stress of up to 30%. The results were used to validate Finite Element Models (FEMs) of the current expansion device designs. The FEM models showed high stresses in the weld between the finger plate and support beam concentrated over the stiffener location.

Testing of the flat plate device showed that significant stresses build in the sliding plate due to the differential movements of the abutment and bridge span. Misalignment at time of construction is a likely cause of additional stress in the flat plate devices.

The new robust finger plate expansion device was designed and evaluated with the FEM models. The new finger plate expansion device is intended for use on high volume or important routes as an alternate to Modular Expansion Device Systems and the current standard finger plate design. In addition, improvements for the existing finger plate expansion device design are recommended for use on lower volume routes with lower traffic volumes. The existing flat plate expansion device designs were modified to include adjustability of the device prior to concrete placement. Repair and retrofit best practices and details that can be implemented without concrete deck removal were developed for existing expansion devices. The new designs accommodate a wide variety of superstructure sizes, configurations, 4 to 16 inches of movement, and 0 to 60 degree skews when used with steel girders. New finger plate expansion devices and existing finger plate expansion device modifications were developed using infinite fatigue life criteria to exceed a design life of 40 years.

1 INTRODUCTION

Over the life cycle of a bridge, the structure will experience thermal expansion and contraction based on the ambient conditions of the surrounding area. If clearance is not given for these effects, internal stresses in members of the structure can develop [1]. To account for these undesired effects, expansion devices are placed throughout the span of the bridge. The purpose of expansion devices is to span the gap between conjoining spans or units at both abutment and pier locations [2]. The selection of the proper expansion device is based on the range of movement required to span the opening of the device throughout the worst case thermal expansion and contraction. The devices analyzed through this project were the finger plate and flat plate expansion devices.

Although these devices help accommodate the dynamic conditions a bridge deck experiences, there has been a problem with the structural integrity of devices placed throughout Missouri. The failure of an expansion device is not only devastating for the structural integrity of a bridge, but causes major safety concerns to any vehicles driving over the devices. Expansion devices which are poorly constructed or exposed to high volumes of truck traffic are likely to have the quickest failure rate. The failure mechanisms of both the finger plate and flat expansion devices will be discussed in detail in Section 5.

The purpose of this project was to determine the characteristics responsible for the premature deterioration of MoDOT finger plate and flat plate expansion devices under high traffic volumes and develop new Load and Resistance Factor Design (LFRD) parameters for finger plate and flat plate expansion devices that are intended to last 40 years or more with minimal required maintenance. Additionally, best practices and details for repair and retrofit were developed as part of the project. Designs for new or modified finger plate expansion devices accommodating large traffic volumes on a wide variety of superstructure, sizes, configurations, and skews was developed. The new designs encompass 4 to 16 inches of device movement and skew angles from 0 to 60 degrees.

Investigation into the failure mechanisms of the finger plate and flat plate expansion devices was accomplished by conducting a literary review and survey of expansion devices currently implemented by other DOT's. In addition, field testing evaluated both a finger plate and flat plate expansion device. A finger plate expansion device on the East-bound Blanchette Bridge on Interstate 70 over the Missouri River in St. Louis, MO and a flat plate expansion device on Route 350 over Interstate 435 in Kansas City, MO were tested. The test results showed dynamic impact in the finger plate device is generally between 40% and 70% and could be as much as 160% and the effect of misalignment of the fingers can result in an increase in stress of up to 30%.

Finite Element Models (FEM) were constructed to determine stress concentrations throughout each of the expansion devices and to evaluate the new and retrofitted expansion devices. The results of the field testing were used to validate the FEM models. The testing and FEM models showed that the cause for premature deterioration of the finger plate expansion device was fatigue failure of the weld between the finger plate and the support beam beneath it as well as vertical misalignment due to poor construction. The flat plate expansion device was found to perform inadequately if the bridge span experiences rotation or misalignment due to poor construction causing a gap between the sliding flat plate and the support.

A new robust finger plate expansion device was designed for use in high traffic areas or important routes. The finger plate expansion device was designed to meet Strength and Fatigue loading with similar factors prescribed for Modular Expansion Joint Systems. The dynamic loading factor was increased to 100% based on the testing results and in keeping with the Department's current design practice for modular expansion joints. The new finger plate device utilizes a bolted connection to the supporting structure which is supported on dual steel support beams. The new device is fully adjustable to ensure alignment prior to concrete placement. The existing finger plate expansion device designs were modified to include a bolted connection to a wider support beam and adjustability of the device prior to concrete placement was improved. The existing flat plate expansion device designs were modified to include adjustability of the device prior to concrete placement. Additionally, it is recommended to include a closure pour near any new finger plate or flat plate expansion device to allow the deflection and rotation of the spans to occur prior to setting the final expansion device alignment. Repair and retrofit details for the existing finger plate expansion devices were developed to be implemented without removal of the concrete deck. They include additional support beam stiffeners where needed and a bolted connection of the finger plate to the support beam on the open side. If the back weld of the finger plate is already broken isolated plug welds will need to be added.

2 BACKGROUND

Expansion devices are mechanisms which can be vital in the preservation of the structural integrity of a bridge. However, the premature deterioration of expansion devices is a nationwide problem in the United States. These devices are specifically used to accommodate the movement of the bridge deck due to thermal expansion or contraction without compromising the bridge. If the thermal contraction of the bridge deck is restrained, cracking of the deck can occur when the tensile strength of the deck reinforcement is exceeded by developed tensile stress. When expansion of the deck is restrained, concrete crushing and distortion can occur. Although it may seem the failure of these expansion devices is due to the material of the device itself that is not always the case. Failure of expansion devices can also be due to improper installation leading to unexpected stress risers, lack of appropriate maintenance leading to premature deterioration, and poor design [3].

Several surveys have been conducted regarding current expansion device designs. Caicedo et. al (2011) surveyed the existing expansion devices in South Carolina to determine which device was the most durable. The survey found open devices, such as finger plate expansion devices, performed the best based on their degradation models. The survey also showed the best practices to install expansion devices. Expansion devices should be installed during periods of average ambient temperatures to allow for adequate expansion and contraction limits. The concrete poured around the support system of the device should be of good quality and cured properly [8].

Palle et. al (2011) conducted a survey for the Kentucky Transportation Center. The survey showed that the longest operable life of devices with openings from three to five inches was the finger plate expansion device at an average range of 25 to 50 years. On a performance rating scale from 0 to 5 (5 being the best score) the finger plate expansion device scored an average rating of 4.0. Jointless bridges were found to have the best performance of any of the inspected bridges. The survey also suggested a main source of the problems with the expansion devices is the water runoff causing deterioration of substructure bridge elements. It was recommended that the expansion devices employ troughs, gutters, and redundant seals to remedy this problem [9].

2.1 Finger Plate Issues

A survey of existing literature found several common issues with finger plate expansion devices. A major factor for a finger plate expansion device to function properly is the proper alignment and installation of the device. Any deviations from the proper design due to rotation of the expansion device from installation can cause the finger plate itself to be misaligned with one another vertically and horizontally. The fingers of the finger plate may also be closer to each other on one end of the expansion device than the other if improperly aligned [2]. These misalignments can overstress the finger plates leading to bending or fracture during the expected service life [3].

The vertical misalignment of the finger plate expansion device, as seen in Figure 2-1, can lead to the entire load being applied to only one side of the device. This will lead to higher stresses in the device and the possibility of premature deterioration. Misalignment can also lead to the finger being broken off by snowplows. When an oncoming snowplow comes in contact with a finger plate expansion device any vertically misaligned finger has the chance of being struck by the blade of the snowplow. This can cause several fingers to be removed leaving a large void in the finger plate expansion device. To fix the vertical misalignment of finger plates the fingers are sometimes heated and bent to prevent the extension of the fingers past the roadway surface [2].

Figure 2-1: Vertical misalignment of finger plate expansion device [2]

The placement of concrete underneath and around the finger plate will determine if the installation of the expansion device is adequate. Brown (2011) suggests many voids are created between the surface of the finger plate and the concrete bridge deck if constructed inadequately. Voids and poor bondage of the two materials will prevent the device from acting as a composite section creating rotation and stress on the expansion device [3].

Drainage troughs can be used beneath finger plate expansion devices to prevent debris, such as salt, from deteriorating the substructure of the bridge. The maintenance of the troughs is important, or the trough will cause more structural problems for the expansion device. Excess debris in the troughs can prevent the flow of water through the drain sometimes causing leaks in the trough [2]. Although troughs present their own set of problems Purvis (2003) recommends using drainage trough beneath expansion devices to prevent deterioration of the substructure [4].

Studies have been conducted on the finger plates to determine if the design of the devices are adequate under the dynamic loading of vehicles. Zi and Zhu (2014) suggest that the moment induced on the expansion device is greatest not when the load is at the furthest point along the finger, but when the load is removed from the finger causing it to spring upward due to asymmetric vibration. It was suggested from their study that the traditional design procedures for anchorage bolts are inadequate once asymmetric vibration of the finger plates is considered [5]. Due to the behavior of dynamic loads the device will experience a greater effect during loading than that of a static load. Yoda and Ayashi (2008) suggest the main reason for the observed damages of the finger plate expansion device is due to dynamic loading and recommend that in-situ testing be conducted to establish the dynamic effects of vehicle loads on the finger plate devices [6].

2.2 Flat Plate Expansion Device Issues

Flat plate expansion devices are affected by installation problems similar to those for the finger plate expansion devices. Any misalignment of the flat plate from the supporting angle of the conjoining span, as seen in Figure 2-2, will cause undesired stresses to develop in the flat plate. If a gap is present in the contact surface interface the flat plate may bend under repeated traffic loads [3]. Fu and Zhang (2010) conducted a study on the Tydings Bridge in Maryland and determined the flat plate acted as a cantilever due to a gap between the plate and support. This gap was caused by poor construction and thermal movement and lead to high stresses along the longitudinal weld of the flat plate [7]. Figure 2-3 shows an example of a fatigue failure of a weld on a flat plate device. The stresses and misalignment of the flat plate devices may eventually lead to the flat plate coming loose from the bridge (either from failure in the welds or from failure in the anchors or concrete holding the device to the bridge) causing a slapping effect once a vehicle drives across the device.

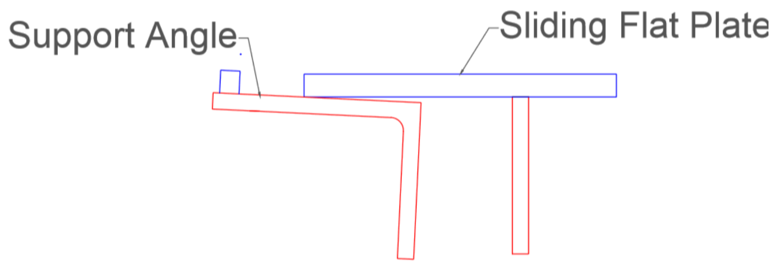


Figure 2-2: Misalignment of flat plate expansion devices due to improper support angle installation

Figure 2-3: Example of fatigue failure of a weld on the top plate of a flat plate expansion device [7]

3 SURVEY TO STATE DEPARTMENTS OF TRANSPORTATION

A survey was sent out to all transportation departments inquiring if the state currently used finger plate or flat plate expansion devices. The survey primarily focused on criteria such as construction procedures and failure pattern of the expansion devices in their areas. Of the 50 states, 22 responded to the survey. Seven states indicated they do not use finger plate or flat plate expansion devices on their bridges.

Of the fifteen states which use finger plate and flat plate expansion devices, seven provided standard details and twelve states indicated the use of LRFD specifications for their design. Drainage troughs were said to be used by 13 states and a majority of states do not flush the troughs on a frequent basis. Eight states (53%) indicated the expansion devices in their area are installed before the deck slab is poured, while five states (33%) install their devices after the deck slab is poured. For a closure pour between the device and deck slab, 11 states used regular deck concrete with one state (Rhode Island) using high strength concrete. Specific installation procedures received in the survey, as well as all survey responses from the 15 states can be found in Appendix A.

3.1 Finger Plate Survey Results

Twelve of the fifteen states indicated they use finger plate expansion devices. The allowable range of movement of these expansion devices ranged from 2.5 inches to 12 inches with an average movement of around 8.5 inches. Eight states (61%) use expansion devices with a bolted connection and three states (23%) use a welded connection to attach the finger plate to the support beam. One state (Texas) uses bolted and welded connections evenly. The preference for bolted connections indicated that this connection likely performs better.

46% of the states design for an expansion device anchored into the deck slab using anchorage straps and/or a device which is bolted to the girders of the bridge. 33% of the states used a design which is anchored by a steel angle with welded shear studs. Three other anchorage methods were provided, and can be found at question 13 in Appendix A. The approximate cost per linear foot of the finger plate expansion devices ranged from $400/lf to $2100/lf with an average cost of about $1450/lf.

The expected design life for the states' finger plate expansion devices ranged from 20 to more than 40 years. Two states indicated a design life between 20 and 30 years, two states indicated a design life between 30 and 40 years, and eight states indicated a design life of greater than 40 years. Nine states (75%) reported a design life of their expansion device to be the same as the design life of a bridge deck. Of the twelve states, 69% have replaced an expansion device before the end of the device's design life. The percentage of finger plate expansion devices which experience a shorter than desired service life ranged from 1% to 40% with an average of 12%.

Several typical mechanisms of damage were provided on the survey. Figure 3-1 shows the mechanisms of damage and the percentage noticed by the surveyed states. The major damage mechanism shown was debris being captured in the drainage trough beneath the finger plate device. While this is not a structural deficiency in the design of the finger plate devices it may have a significant effect on how the device will perform. The repair cost per linear foot of the finger plate expansion devices ranged from $500/lf to $2,000/lf. The typical repair/rehab procedures/techniques for the finger plate expansion devices can be found at question 21 in Appendix A.

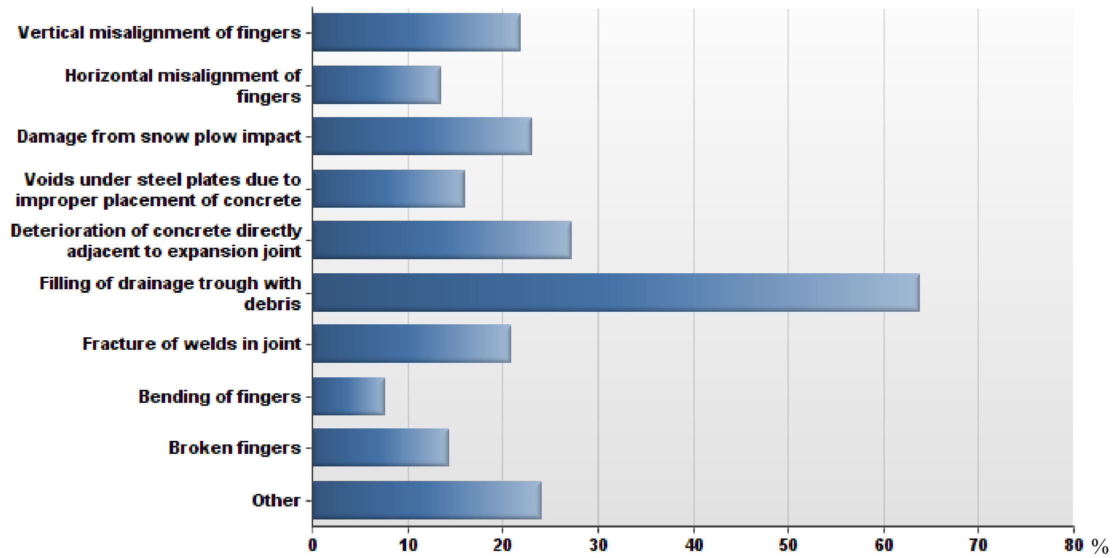


Figure 3-1: Mechanisms of damage for finger plate expansion devices

3.2 Flat Plate Survey Results

Five states who took the survey use flat plate expansion devices in their areas. Only three of the states use flat plate expansion devices in new construction. The lack of use of flat plate expansion devices indicates that most other states have found their performance unacceptable and have elected to use other expansion device types. The allowable range of the movement ranged from 1 to 6 inches with an average range of movement of approximately 3 inches. For flat plate expansion devices with movements greater than 4 inches the approximate skew range was 20 to 30 degrees. Two states indicated their flat plate expansion devices were anchored into the deck slab from the girder using either anchorage straps and/or bolts. Three states reported using steel angle anchors with welded shear studs to anchor their devices.

Of the states with flat plate expansion devices, three of five states reported having the same design life for both their devices and bridge decks, while two states did not have the same design life. Three of four of the states have had to replace their expansion device while one has not had to replace any devices. The percentage of flat plate expansion devices which experienced a shorter than desired service life ranged from 15% to 30% with an average of 22%.

The mechanisms of damage occurring in flat plate expansion devices can be seen in Figure 3-2. The mechanism of damage with highest probability was reported as the deterioration of concrete directly adjacent to the expansion devices. The repair cost per linear foot of a damaged flat plate expansion device was estimated by one state to be between $500/lf and $1,000/lf. One state reported the standard cost is to completely replace the device. The typical repair/rehab procedures/techniques for replacement of flat plate expansion devices were requested and can be found at question 31 in Appendix A.

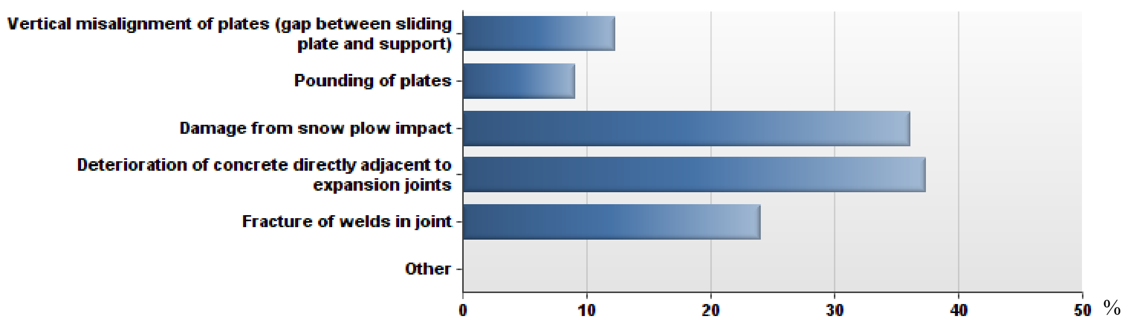


Figure 3-2: Mechanisms of damage for flat plate expansion devices

4 CURRENT EXPANSION DEVICES IN THE FIELD

4.1 MoDOT Finger Plate Expansion Devices

Finger plate expansion devices employ finger-like cutouts on conjoining bridge spans interweaving with one another to allow safe passage of vehicles. A typical finger plate cutout pattern can be seen in Figure 4-1. MoDOT requires a range of movement of 4 inches or greater to use this type of expansion device. The range of movement needed for a structure is dependent on the expansion/contraction length of the structure. The longer the structure the more it will thermally expand or contract.

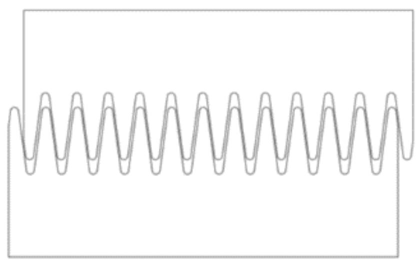


Figure 4-1: Typical finger plate cutout pattern

The finger plate of the expansion device is attached to a support beam, typically a W14x43 for MoDOT design, by a weld at the top of the W-section flange. Anchorage straps are used to anchor the expansion device to the concrete bridge deck. These straps resist the rotation the expansion device experiences when loaded by traffic and gives a more rigid connection between the two materials. The loading of the finger plate creates a large amount of shear and moment on the attached support beam. To ensure the loading does not fail the support beam, shear stiffeners are welded in the web of the support beam. The stiffeners increase the stiffness of the outstanding flanges of the rolled beam to resist deformation of the finger plate and flange of the support beam parallel with the direction of traffic. A plan view of the current finger plate expansion device MoDOT typically uses is shown in Figure 4-2. The key components of this current standard design are the finger plate itself, the finger plate to flange welds, the stiffeners and the strap plates that tie the joint into the deck. The current design has very little structural redundancy and is completely dependent on brittle welded connections and fixity into the adjacent concrete to maintain its structural integrity.

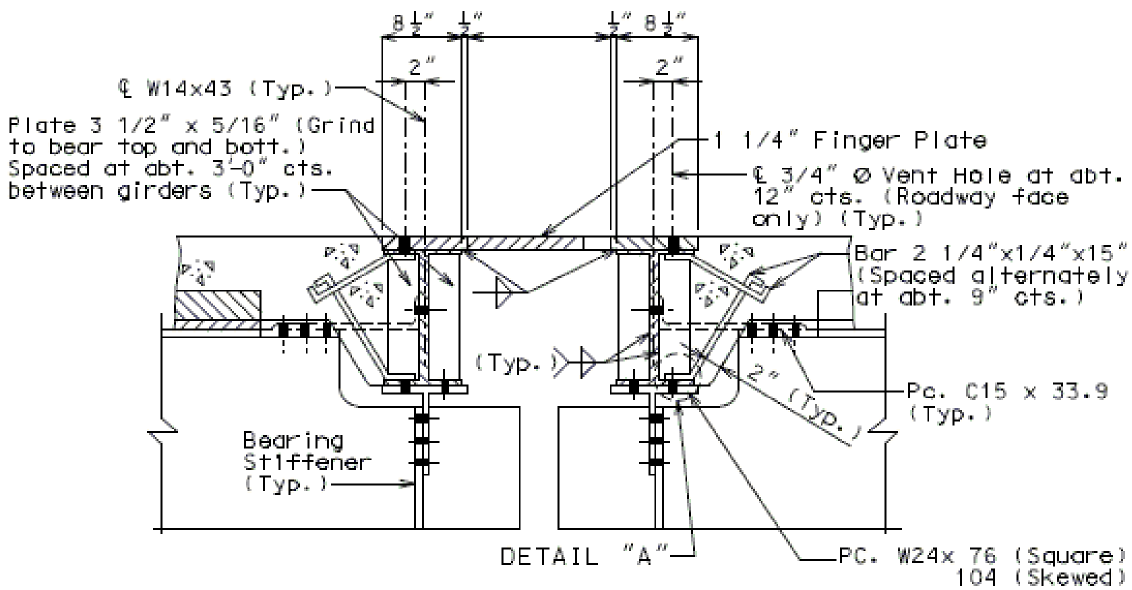


Figure 4-2: Cross-section of typical MoDOT finger plate expansion device

4.2 MoDOT Flat Plate Expansion Devices

The typical MoDOT flat plate expansion device accounts for thermal expansion and contraction by employing a design which allows a flat plate to slide across an angle attached to the conjoining span. Flat plate devices are typically used on bridges with a range of movement of up to 4 inches and can be used on a bridge of any skew. The bridge deck and expansion device are designed at a specific angle to allow for thermal movement while meeting the roadway path specifications.

As previously stated the flat plate expansion devices use a sliding flat plate resting on a conjoining steel angle to allow bridge movement. The sliding steel plate is welded perpendicularly to a vertical plate which is attached to an angle as seen in Figure 4-3. This angle is attached to the bridge girders running along the span. The support angle, the sliding plate, and the vertical plate of the device are anchored into the concrete bridge deck by shear stud connections. This provides a solid connection between the flat plate device and the deck to resist traffic loads. The shear studs are placed along the support angle, sliding plate, and vertical plate at a spacing of 9 inches on each side. The shear studs are placed at different angles to resist stresses in multiple directions as seen in the typical cross-sectional view of MoDOT's flat plate expansion device in Figure 4-3. This device requires good alignment at time of construction and consistent support and contact between the support angle and the sliding plate to maintain its structural integrity and performance.

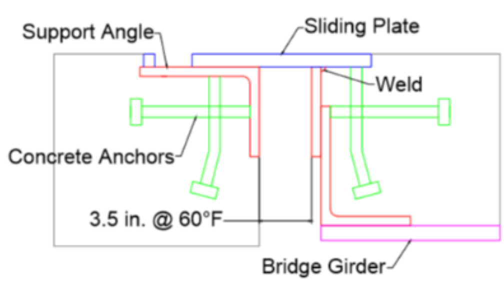


Figure 4-3: Cross-section of typical MoDOT flat plate expansion device

5 FAILURE MECHANISMS

5.1 Finger Plate Expansion Device

A review of expansion device failures in Missouri found that the bridges with the highest failure rate of finger plate expansion devices are steel bridges, while fewer problems have been reported with the expansion devices used on prestressed concrete bridges. The finger plate expansion device experiences the most damage when exposed to colder temperatures. Since bridge spans will contract when temperatures are cooler, the maximum opening in the device will occur at these times. Damage has also been seen in finger plate expansion devices if the devices are exposed to larger amounts of truck traffic, typically the right driving lane of a multiple lane road [10].

Not only do the environmental conditions of a finger plate expansion device seem to have an effect on the structural integrity, the superstructure has an effect as well. Damage to the expansion device tends to occur on the more flexible side of two conjoining spans. An example of this would be a device between a truss span and a plate girder span. The plate girder side of the device will be more flexible, therefore it will experience more stress and damage than the truss span. This is likely due to the rotation of the plate girder span elevating the fingers on that side leading to more load applied to those fingers. Damage has also been found to be greater in expansion devices when the web stiffener spacing along the finger plate support beam is larger [10].

Drainage troughs are used on finger plate expansion devices to collect debris from the roadway which has slipped through the fingers of the device. These troughs are helpful to prevent the exposure of the substructure to chlorides. These troughs need periodic cleaning and if this standard is not met the expansion device will sustain unwanted side effects. If debris is allowed to remain in the trough the expansion device will not be able to contract to its designed spacing during warmer temperature. This causes stresses to develop in the device which may lead to failure. Drainage troughs are a major benefit to have attached to a finger plate, but are often not properly maintained and cause unnecessary damage. It is noted that MoDOT's current finger plate expansion device standards do not include the installation of a drainage trough so this failure mechanism is not experienced currently for the majority of MoDOT's expansion devices.

The initial sign of a typical failure for a finger plate expansion device is the cracking of the weld attaching the finger plate to the support beam as seen in Figure 5-1. The device begins to degrade quickly once the crack is initiated. The continuous vehicle loadings applied to the device will gradually weaken the weld until the front weld fractures. After failure of the front weld, failure of the back weld and anchorage straps is likely. Furthermore, this failure can occur with little warning.

Figure 5-1: Fractured support weld on finger plate expansion device

There are several factors which can contribute to the initial cracking of the weld [10]. One main cause for the fracture occurs because of the high stress perpendicular to the weld coming from the eccentric wheel load. Additionally, there is a stress concentration at the stiffener to flange weld locations. To look at the stress associated with wheel loadings on a typical finger plate expansion device, HDR Engineering performed a calculation on the East-bound Boone Bridge on Interstate 64 in Chesterfield, MO. The calculation showed the largest portion of the overall stress in the finger plate expansion device was the stress perpendicular to the weld at 14.1 ksi. The vertical stress on the weld from the load was found to be 4.8 ksi, and the stress parallel to the weld (longitudinal flexural bending) contributed only 1.1 ksi [11]. FEM analysis of the finger plate expansion device also supported these findings of high perpendicular stress as detailed in Section 8. Repeated application of these high levels of stress perpendicular to the throat of the weld can cause the front weld to fracture prematurely and lead to progressive failure of the expansion device by fracturing the back weld and the strap plates.

Additional stresses leading to fracture can occur due to the misalignment of the fingers. Figure 5-2 shows the wearing pattern of a finger plate expansion device with fingers bent out of plane. It can be seen that the tips of the fingers on the right side of the device do not exhibit the same amount of wear. The fingers which experiences more wear, and therefore more stress, are the fingers which are higher during loading. The out-of-plane alignment of the fingers can be caused from several factors such as poor construction or the flexibility of the adjacent span and rotation of the device itself. Experimental results of the finger plate testing showed that misalignment can increase stress on average by 30% as detailed in Section 7.1.1.

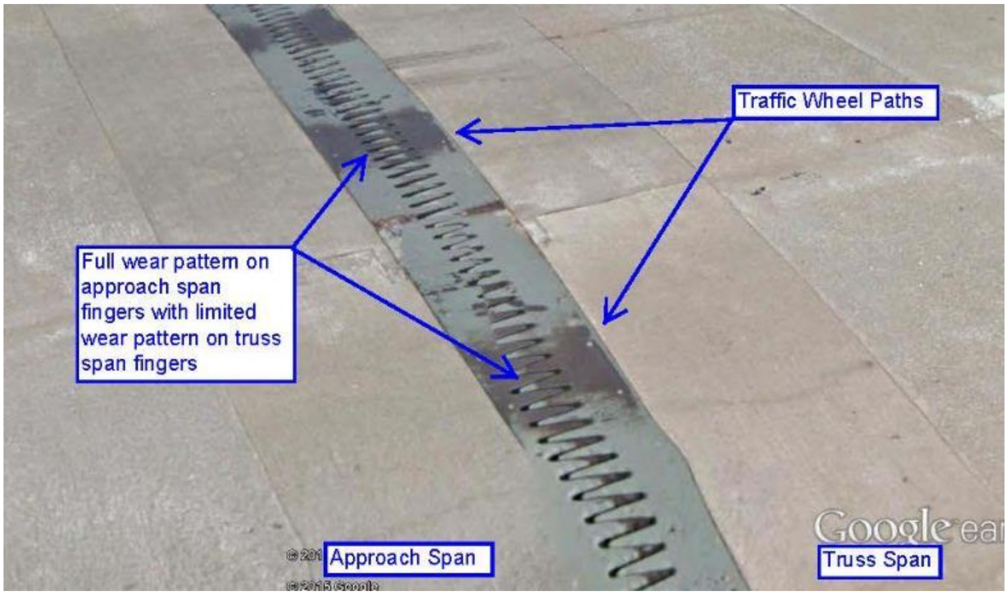


Figure 5-2: Wearing pattern of misaligned finger plate expansion device

Another factor to the premature deterioration of a finger plate expansion device comes from when a finger is loaded dynamically from the wheel of a truck. The "bouncing" of a truck as it drives over the device will increase the load applied to the device. In addition, the finger will experience asymmetric vibration based upon the duration and wheel load. This vibration will cause the finger to bounce back above the initial position of the finger. Experimental testing found that dynamic loading caused between 40% and 70% more stress in the device as detailed in Section 7.1.2.

5.2 Flat Plate Expansion Device

There have only been a few mechanisms of failure reported for flat plate expansion devices in Missouri. However, the damage patterns for the flat plate devices have been found to occur in both steel and prestressed bridges. The damage is amplified if the device is placed with a high skew and has a large amount of truck traffic. The damage typically begins when the sliding plate loosens and begins to slap the supporting angle beneath it. This slapping effect can be heard by drivers as each vehicle passes over the device. Once the plate is loose the concrete surrounding the flat plate expansion device begins to deteriorate as well [10].

Errors during the construction of the device and the rotation of the span are the main contributors to the failure of the flat plate expansion devices. If the device is constructed so the support angle and the sliding plate are not parallel, the sliding plate will be put under a large amount of stress at the connection between the bridge deck and the sliding plate. A device which has a large amount of span rotation will have problems similar to those of a device which is poorly constructed. The rotation of a span can create a gap between the sliding plate and the support angle, and will likely cause the device to be overstressed at the connection. This will eventually lead to failure of the flat plate device.

Experimental testing of the flat plate device showed the misalignment of the device as well as the high stresses incurred due to the differential movement of the bridge span and abutment as detailed in Section 7.2.

5.3 Possible Design Improvements

To combat the issues found to be associated with finger plate and flat plate expansion devices, research was done to look into possible improvements to the current designs. The fracture shown in Figure 5-1 occurs because of the high stress perpendicular to the weld coming from the eccentric wheel load. In addition, there is a concentration of stress at the stiffener to flange connection location. Bolting of the plates rather than welding can reduce the stress concentration, increase the fatigue resistance and prevent failure of the expansion device. Additional adjustment of the device to correct misalignment can also reduce the stress concentration. In addition, the inclusion of more stiffeners to help distribute the stress and stiffen the outstanding flange of the support beam will improve the expansion device behavior.

A major issue for the current MoDOT standard finger plate expansion device is the reliance on the concrete deck to restrain rotation of the device. The anchorage is non-redundant and if the concrete surrounding the expansion device deteriorates or is improperly placed the deck loses torsional resistance leading to additional stresses on the device. Asymmetric bending can also lead to the development of additional stresses on the concrete anchors.

In order to combat the rotation of the expansion device, one possible solution is to provide independent support of the finger plate expansion device. To implement this system a second support beam is placed a certain distance behind the expansion device support beam to create a coupling effect and provide a more redundant path for the load to follow. The expansion device in this connection is designed independent of the slab and the support beams resist the torsion instead of the concrete deck. Figure 5-3 shows an example of a finger plate expansion device for Iowa DOT which uses a two support beam system. The full penetration weld between the finger plate and the support plates is also a notable difference between MoDOT's standard detail and the Iowa DOT detail. The size of this weld and the support plate and its direction of applied stress are all an improvement for fatigue resistance. The Iowa DOT detail is fully adjustable with the use of shims between the support plates and the support beams.

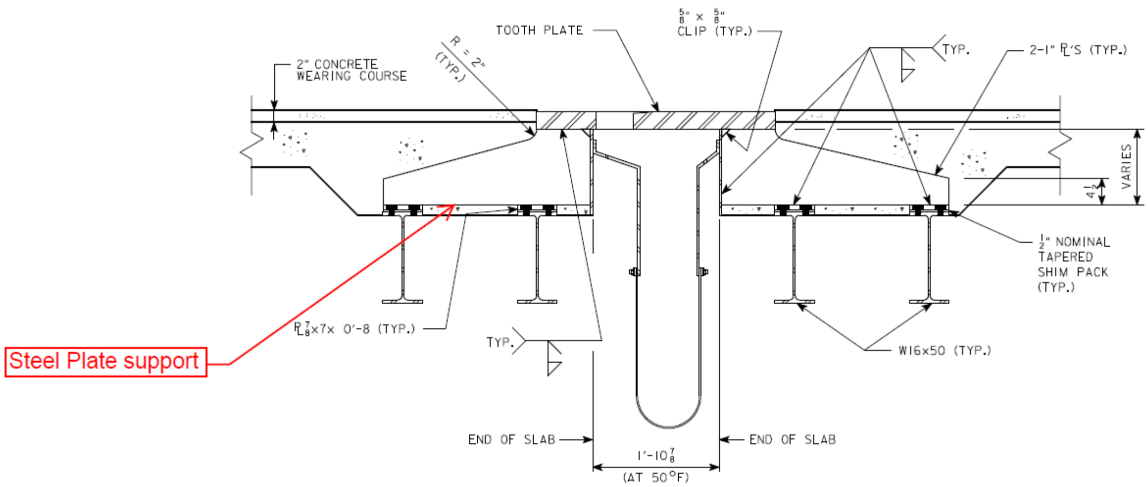


Figure 5-3: Cross-section of IaDOT finger plate expansion device

Another way to increase the durability of the expansion devices would be to increase the anchorage strength of the system. Anchorage can be embedded deeper or spaced closer together in the concrete deck to improve the connectivity at the deck slab and expansion device interface. An example of this type of connection is the typical KDOT finger plate expansion device, as seen in Figure 5-4. KDOT uses bent support rods to get a deeper penetration into the concrete deck and increase torsional resistance. It can also be seen the rods are bolted directly to the finger plate to make a stronger connection between the finger plate and the concrete deck. This also allows for the finger plate to be removed with greater ease. The KDOT detail is fully adjustable with the use of the horizontal and vertical slotted holes between the support plates and the support beam connections.

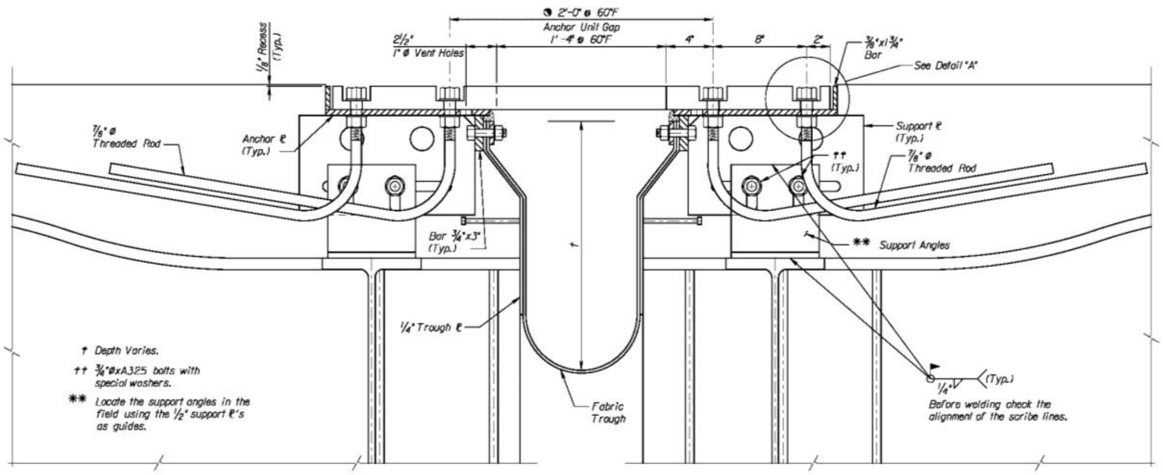


Figure 5-4: Cross-section view of typical KDOT finger plate expansion device

A final improvement to the current designs of expansion devices would be to utilize closure pours with a more workable concrete mixture that will increase consolidation under and around the expansion device. The improved consolidation under the expansion device will improve the connectivity between the device and the slab. The closure pour would be applicable for both finger plate and flat plate expansion devices. The implementation of a closure pour at expansion devices after all rotation of the adjacent spans has taken place will allow contractor and inspection staff the ability to confirm proper alignment, opening width and consolidation of concrete adjacent to the joint. These improvements in construction and installed geometry can have significant impacts on the longevity and overall performance of the finger plate and flat plate expansion devices.

Flat plate expansion devices can see additional stresses if the sliding plate does not bear evenly on the support angle. The increased stresses will cause the plate to act as a cantilever or be stressed under bridge movements and lead to fatigue failures. The increased stresses induced in the plate can cause the weld attaching the sliding plate to fracture. The use of another attachment method, such as a bolted connection, instead of a weld between the sliding plate and the vertical plate would improve the fatigue resistance to truck loadings. However, the use of a bolted design would require increased sliding plate thickness and may be cost prohibitive.

Since the construction of the flat plate expansion devices is vital to the performance of the device, increasing the adjustability of the device prior to placing concrete would improve performance. To see the most benefits of the increased adjustability a closure pour would be necessary. A closure pour would require stopping the bridge deck placement a set distance away from the expansion device. Once the flat plate expansion device is leveled at the correct position the final section of the bridge deck can be poured around the device.

6 EXPERIMENTAL TESTING

6.1 Finger Plate Test Procedures

To determine the strains and deflections induced on a finger plate expansion device, field testing was conducted on the East-bound Blanchette Bridge in St. Louis, MO. To conduct the experiment twelve strain gages, three accelerometers, and two LVDTs were attached to the finger plate in various locations. The locations for each strain gage, accelerometer, and LVDT can be seen in Figure 6-1, Figure 6-2, and Figure 6-3, respectively. Instrumentation was attached to both the plate girder and the truss sides of the device to see the difference in reactions of each side under loading.

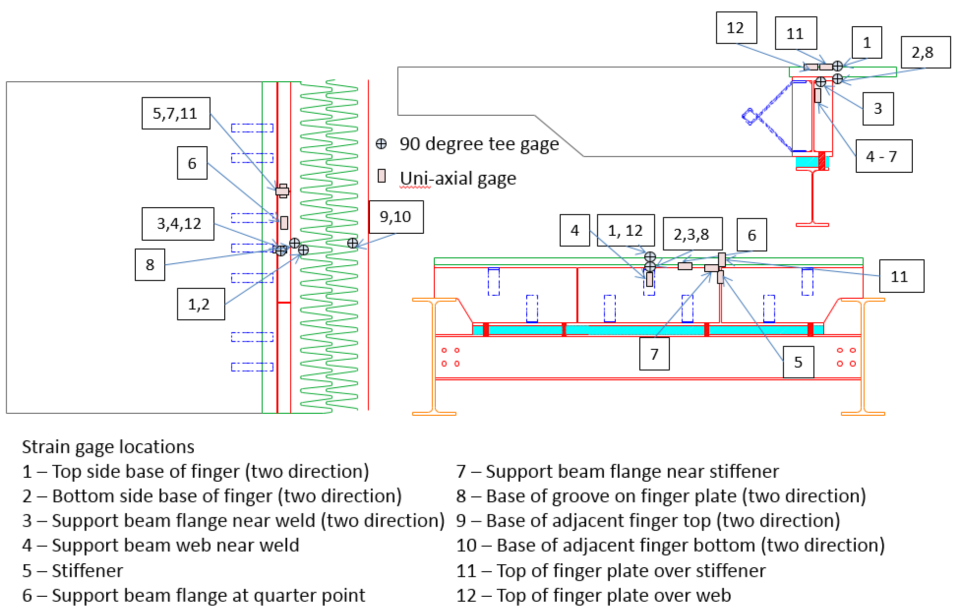


Figure 6-1: Location of strain gages on Blanchette Bridge finger plate expansion device

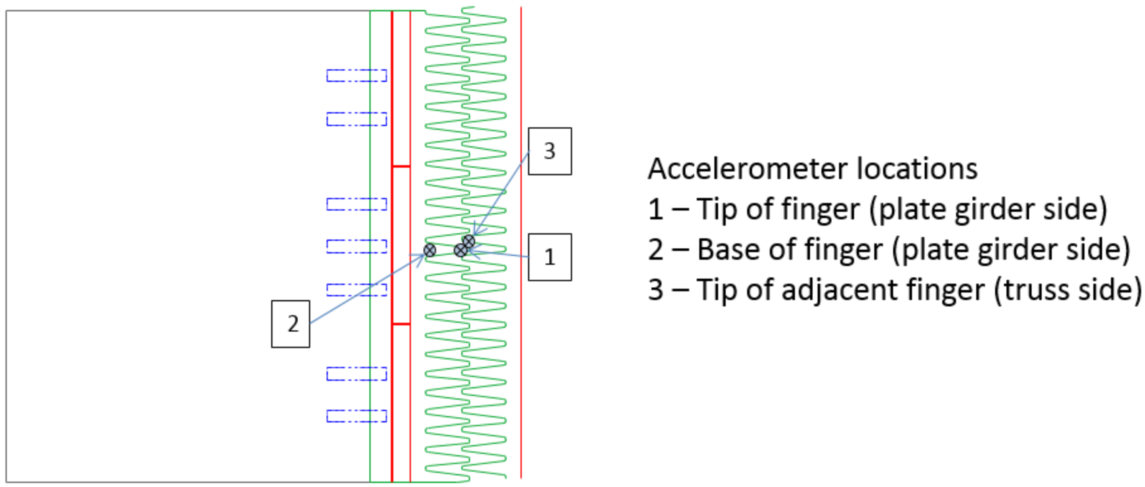


Figure 6-2: Location of accelerometers on Blanchette Bridge finger plate expansion device

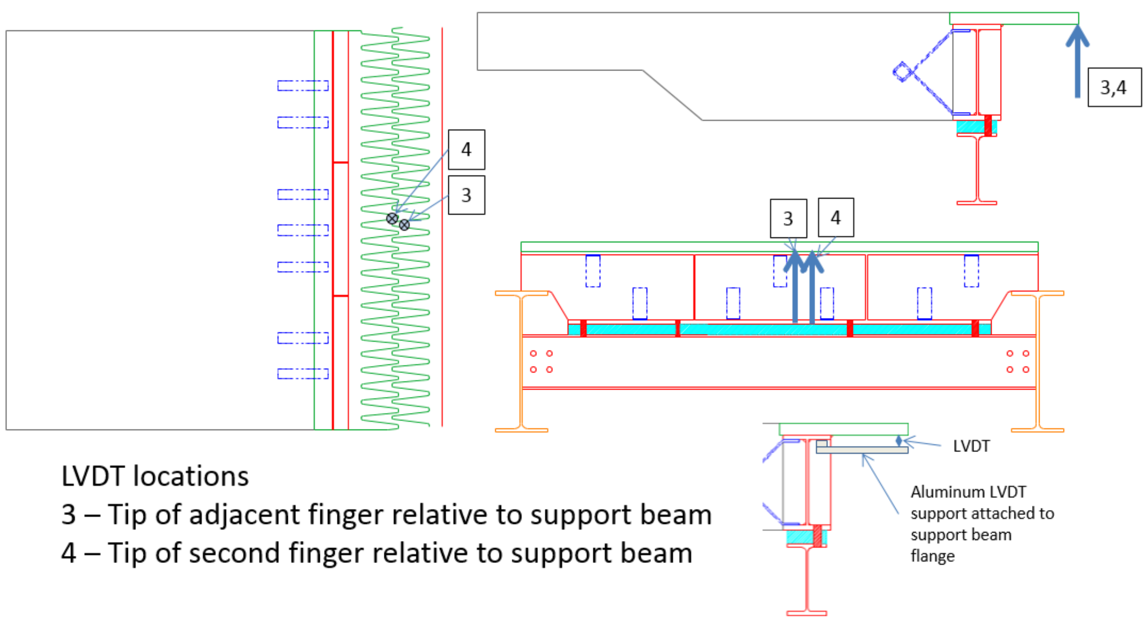


Figure 6-3: Location of LVDTs on Blanchette Bridge finger plate expansion device

Two types of strain gages were used for the experiment, uniaxial gages and 90 degree tee gages. The uniaxial gages measured the strain over a length of 3mm in a single direction, while the 90 degree tee gages measured the strain in directions perpendicular to one another. Four strain gages were attached to the top of the finger plate as can be seen in Figure 6-4. The remaining strain gages were attached beneath the finger plate and the support beam as seen in Figure 6-5. The strain gages 1 through 7 had an accuracy of 1 με and gages 8 through 12 had an accuracy of 5με.

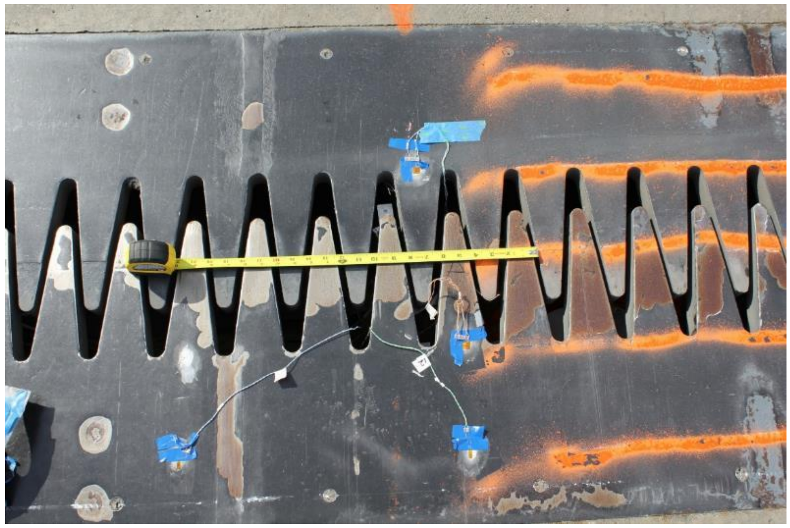


Figure 6-4: Strain gage locations on top side of finger plate expansion device on Blanchette Bridge

Figure 6-5: Strain gage locations on underside of finger plate expansion device on Blanchette Bridge

The location of the attached strain gages were based on maximum stresses from preliminary FEM models. Strain gages 1 and 2 measured the bending stresses which developed in the fingers on the plate girder side of the expansion device while strain gages 9 and 10 measured the bending stress on the truss side, as seen in Figure 6-6. Strain gage 8 was placed at the radius of a finger for bending stresses at the stress concentration. Strain gages 3 and 4 were located near the welds on the flange and web of the support beam, respectively, to determine how much stress is transferred through each weld. Strain gage 5 was placed on a stiffener while strain gages 6, and 7 were placed along the support beam flange to monitor the reduction in strain along the flange. Strain gage 11 and 12 were attached on the top side of the finger plate above the web of the support beam to find an indication of how stresses are transferred through the finger plate when the wheel loading was directly above the support beam.

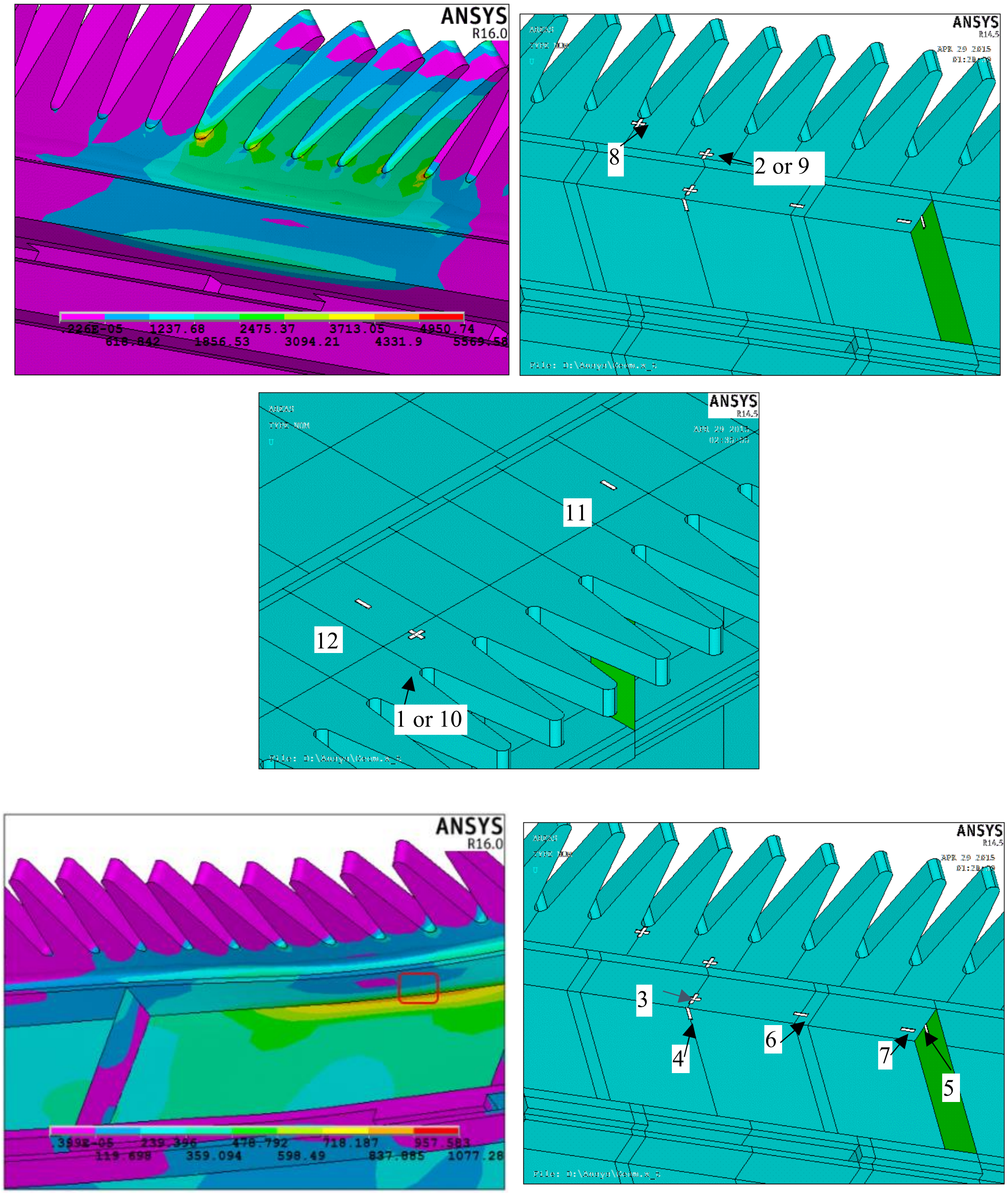


Figure 6-6: Strain gage locations based on preliminary FEM analysis

The test runs consisted of three different types of tests; static, elevated static, and dynamic. For the static tests the front tire of the rear axle of a dump truck was placed in five different locations across the finger plate expansion device. The front tire of the rear axle weighed 10,500 pounds while the back rear tire applied a load of 9,500 pounds. It can be seen in Figure 6-7 that 11 different wheel positions were tested. Positions 1 through 5 were tested using the front rear wheel of the truck, and positions 6 through 10 were tested to recorded values when the back rear wheel was at each position. Position 0 was taken to determine if any strains were present as a truck approaches the expansion device, but has not yet driven onto the finger plate. Position 1 and 2 were taken when the truck initially loads the plate and when the truck applies a load at the finger plate cutouts, respectively. These values were important in determining how the expansion device behaves when only the truss side of the device is loaded. Position 3 was taken when the weight of the wheel from the front axle is ideally distributed evenly between the plate girder and truss side of the expansion device. This position was vital in determining the strains the expansion device will experience when it is loaded with the maximum amount of moment from the truck load. Positions 4 and 5 were taken to determine how the expansion device would behave when the load transitioned from the truss side of the device to the more flexible plate girder side. Figure 6-8 shows the wheel position locations used during the testing.

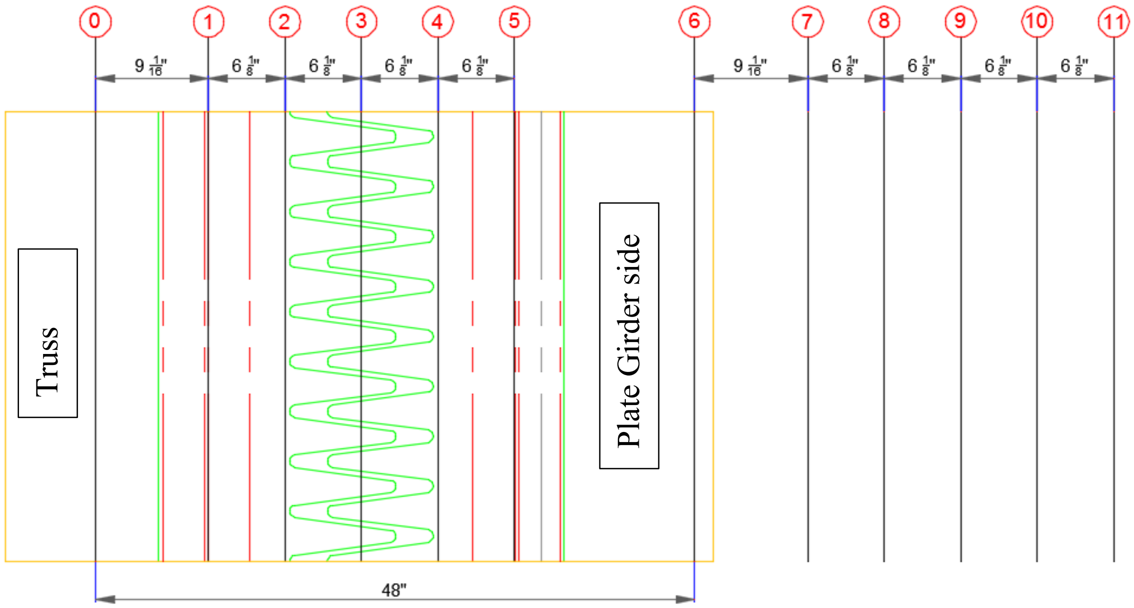


Figure 6-7: Wheel position diagram for static and elevated static tests (based on location of front rear wheel)

Figure 6-8: Wheel position locations during static test for front rear tire

The purpose of conducting tests at positions 6 through 10 was to determine how the expansion device behaved with the front rear wheel applying a load approximately 4 feet in front of the back rear wheel. Not only was this wheel a different weight, but the strain in the device may have varied with the front rear wheel being so close to the device at these positions. At each of the wheel positions three data files were recorded to minimize the effect of background traffic and the averages of the three was used in data processing procedures.

Once the static tests were complete a 0.25 in. thick plywood finger plate cutout was placed on the plate girder side of the finger plate device. The plywood was used to simulate the misalignment some expansion devices experience. The elevated static tests were conducted using the same procedure and reasoning in each of the eleven locations as the static tests.

The final tests performed were dynamic load tests where the loaded dump truck was driven across the finger plate expansion device at varying speeds. Tests were conducted with the weighted truck at an approximately slow speed (lower than 5 mph), 20 mph, 30 mph, and 40 mph. Three runs were conducted at the slow speed to simulate static loading and two runs were conducted at each of the other speeds. The varying speeds of the truck allowed for an insight into how the expansion device reacted with dynamic loading being applied at greater intensities.

6.2 Flat Plate Test Procedures

A test setup similar to the finger plate expansion device was conducted on a flat plate expansion device of the bridge on Route 350 passing over Interstate 435 in Kansas City, MO. This particular flat plate device is placed at a 30 degree skew between an abutment and a steel girder span. Investigation of this expansion device showed approximately a ¾" gap between the sliding plate and the abutment angle as depicted in Figure 2-2. The flat plate test consisted of eight strain gages, three accelerometers, and three LVDTs. The layout for each strain gage, accelerometer, and LVDT can be seen in Figure 6-9, Figure 6-10, and Figure 6-11, respectively.

Strain gages 1 and 2 were located on top and bottom of the sliding plate on the abutment side of the expansion device, respectively, to determine the strains and moments induced by the bending of the plate. Strain gages 3 and 4 were placed on top and bottom of the sliding plate at the plate girder side, respectively, for indications of how much moment is induced on the weld attaching the sliding plate and vertical plate. Strain gages 5 and 8 were attached vertically on the abutment side support angle and plate girder side vertical plate of the expansion device, respectively, to measure any compressive strains developing from the wheel loading. The location of strain gage 9 was intended to measure the amount of strain present in the sliding plate directly in the middle of the expansion gap as the truck was loading the plate. Since the flat plate is a continuous entity strain gages 6 and 7 were placed in the middle of the expansion gap on bottom and top of the sliding plate to determine if any strains were present in the sliding plate at the bridge stringer location (approximately 5.5 feet away from the wheel loading), respectively. Gages 1 through 5 had an accuracy of 1 $\mu\varepsilon$ and gages 6 through 9 had an accuracy of 5 $\mu\varepsilon$.

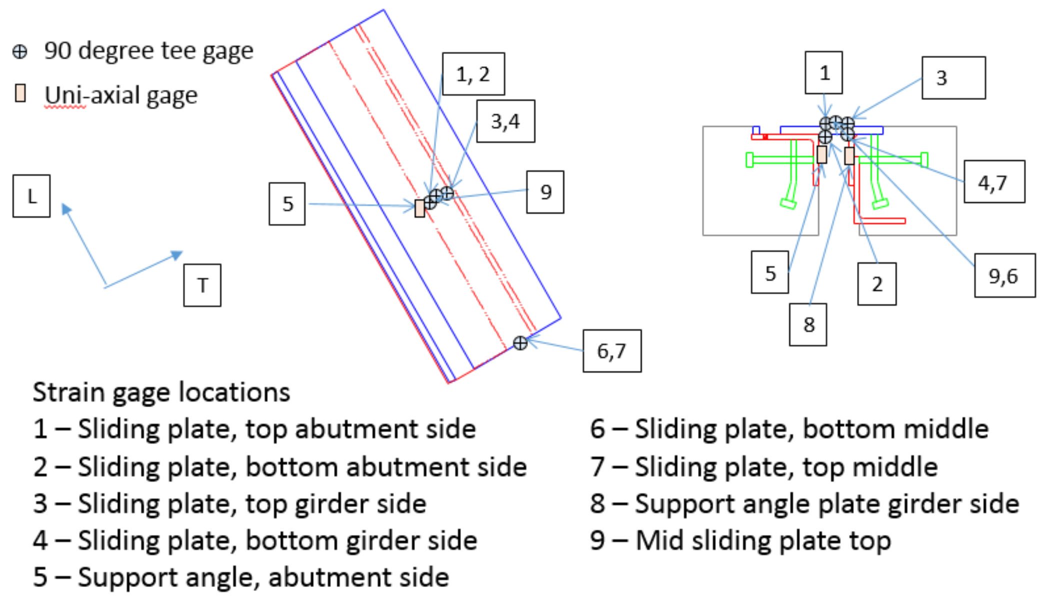


Figure 6-9: Location of strain gages used for testing on flat plate expansion device

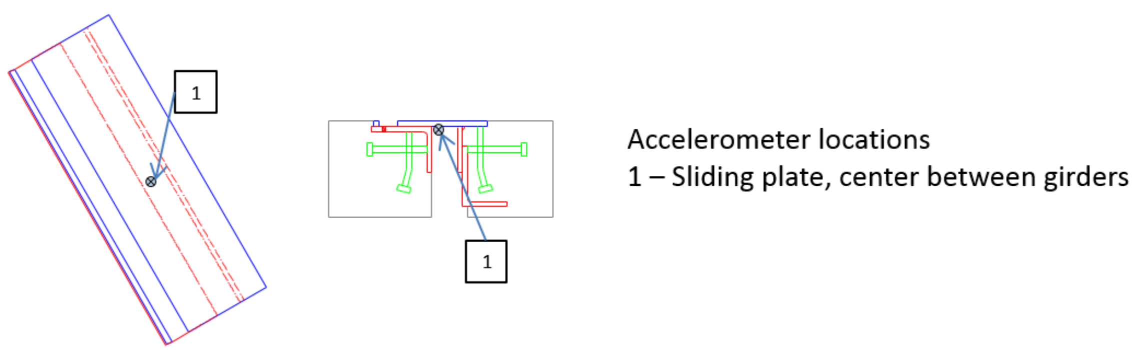


Figure 6-10: Location of accelerometer used for testing on flat plate expansion device

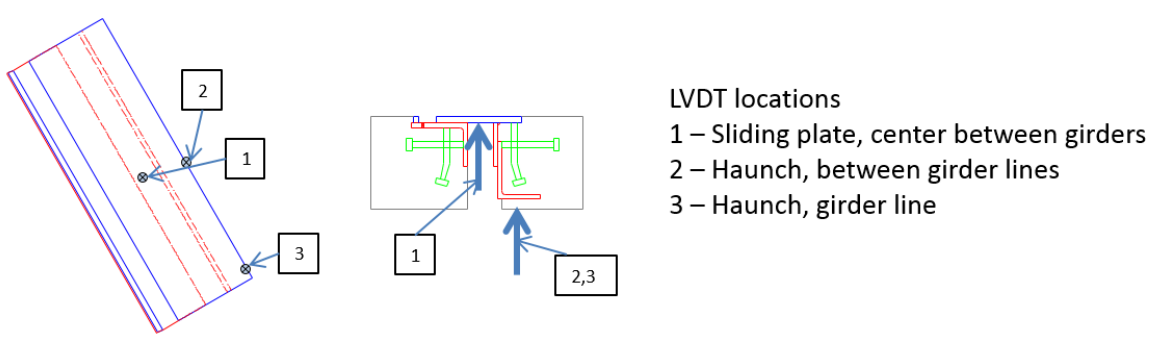


Figure 6-11: Location of LVDTs used for testing of flat plate expansion device

Of the three LVDTs, two were placed on the haunch of the bridge at the midspan between the stringers and at the stringer location. Another (LVDT 1) was placed in the middle of the sliding plate. The location of these LVDTs helped to detect the movement of the bridge deck between girders relative to one another. The true deflection of the deck could then be determined. The LVDTs had a stroke of 0.1 in. and an accuracy of 0.00005 in.

The flat plate testing was conducted in the same manner as the finger plate test with the exception of the elevated static test. Static tests were performed at each of the locations as seen in Figure 6-12. Five different points along the flat plate were determined to be ideal locations for testing of each truck axle. Positions 0 through 4 represent the front axle of the truck, positions 5 through 9 represent the front rear axle of the truck, and positions 10 through 14 represent the back rear axle of the truck for a total of fifteen static tests.

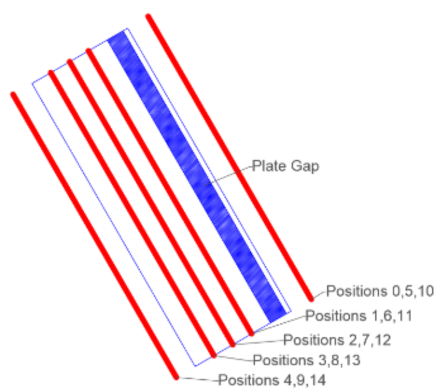


Figure 6-12: Wheel positions for static tests of flat plate expansion device

Based on the skew for this particular bridge, the loading of the flat plate expansion device was not as simple as a square bridge. As seen in Figure 6-13, when the driver’s side back rear wheel is loading the flat plate expansion device the front rear wheel on the passenger’s side is applying a load to the expansion device. Figure 6-14 also depicts the locations on the sliding plate used during the static testing of the expansion device. The uneven loading between the two points on the flat plate make the processing of the flat plate data more complicated overall. A view of the configuration of several of the strain gages used on the sliding plate can be seen in Figure 6-15 and the LVDTs in Figure 6-16.

Due to space limitations allowing the test truck to get to speed dynamic tests were performed at only a slow speed and 20 mph. Each run was conducted three times. The average values from each test of the three speeds were used in data processing procedures.

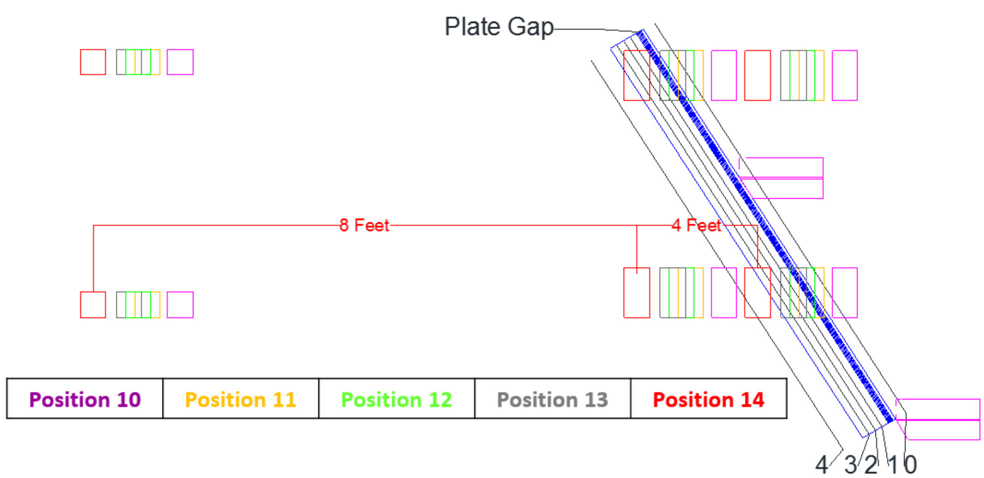


Figure 6-13: Wheel position locations for positions 10 through 14

Figure 6-14: Wheel position locations of static test for front rear tire

Figure 6-15: Strain gage arrangement attached to sliding plate

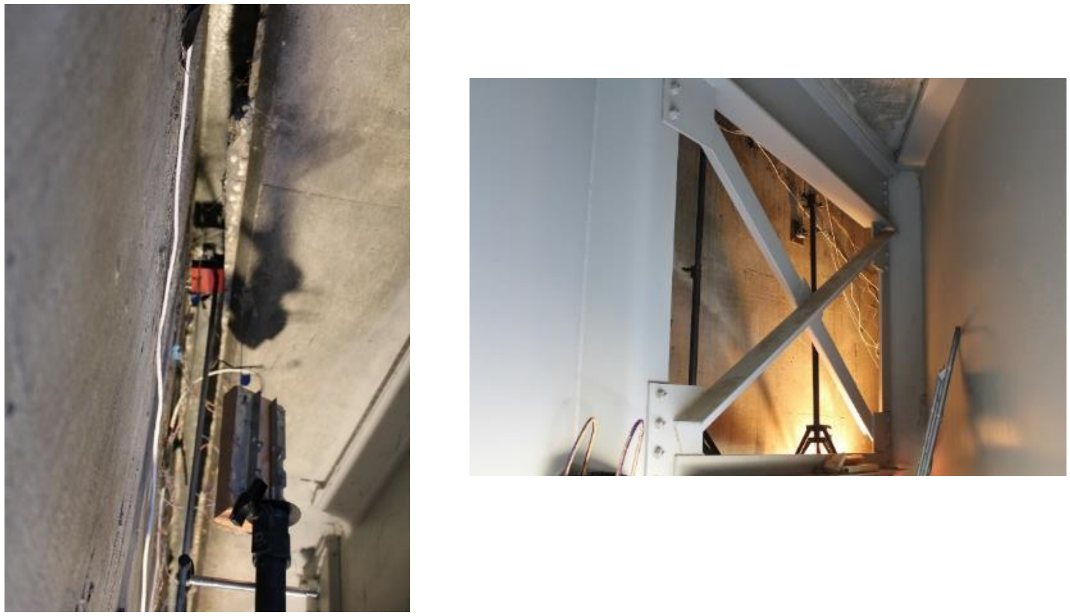


Figure 6-16: LVDT instrumentation for flat plate test

7 TEST RESULTS

7.1 Finger Plate Test Results

Both the static and dynamic test data acquired from the finger plate expansion device test on the Blanchette were used to identify and validate potential stress concentrations leading to the fatigue failure of the expansion device. All data obtained from finger plate testing can be found in Appendix B.

7.1.1 Static Test

The static test consisted of recordings taken when the rear axle of a weighted truck was located at 11 different wheel locations along the expansion device as described in Section 6.1. Unfortunately, readings from the LVDTs and accelerometers did not provide useful data. Twelve strain gages recorded values for each wheel position. The values presented are the average of three recordings to account for the different levels of background traffic along the bridge. The strain values are plotted with respect to these wheel positions to determine how the expansion device reacted in the transverse and longitudinal direction. The transverse direction is defined as the direction transverse to the device (parallel to the fingers) while longitudinal direction is considered as the direction along the device (perpendicular to the fingers).

A complete set of strain results for each wheel position is available in Appendix B. In general the highest strain readings were recorded when the wheel was in the middle of the expansion device (position 3 or 9). Figure 7-1 shows the highest level of strain recorded was 125 με which corresponds to roughly 4 ksi located at the top side of the base of the finger when the wheel load was in the middle of the device (Gage 1T). Gage

2T located on the bottom side of the finger base also had a high level of strain (100 με) due to the bending of the finger.

Gages on the support beam flange (3T, 6, 7) recorded strains of about 70 με in the transverse direction. The vertical gage on the support beam web (4) recorded a maximum value of 50 με while the vertical gage on the stiffener (5) showed strains of 70 με. These values indicate that the support beam and stiffener see stresses of around 2 ksi due to the wheel loading.

To simulate vertical misalignment of a fingerplate expansion device a 0.25" plywood fingerplate cutout was placed on top of the plate girder side of the expansion device. Clear correlations were found between the elevated and static tests. Figure 7-2 shows the strain values for strain gage 2 at each of the 11 wheel positions during the test. Strain gage 2 was located on the underside of the finger plate at the base of a finger. During the elevated static test the value for wheel position 3 was approximately 2.3 times greater than the static value. Comparisons between the maximum strain values of both the static and elevated static tests at each strain gage can be seen in Figure 7-1.

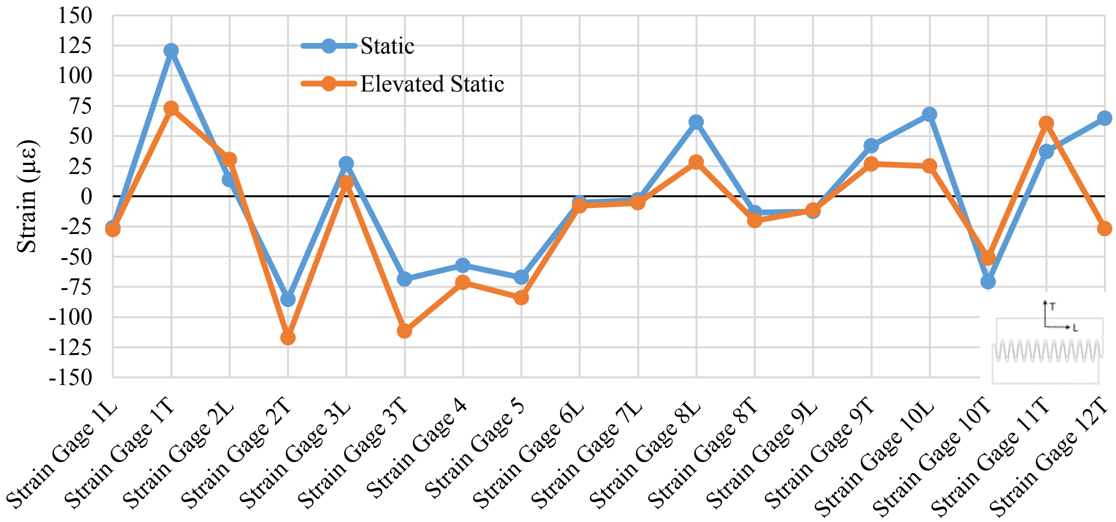


Figure 7-1: Maximum strain readings from static tests

Table 7-1 shows the increase in strain of the elevated static test vs. the strain of the static test. Gages 9-12 were on the truss side of the expansion device and did not have the elevated profile applied therefore their strains were less. Gage 1T did not receive a reading from wheel position 3 in the elevated test, therefore its value is from wheel position 2 and is lower. The average increase in strain from the gages on the plate girder side was about 30%. Therefore it can be expected that the stresses in the finger might be as much as 2.3 times the stresses found assuming proper alignment of the fingers. Stresses in the rest of the expansion device (support beam) could increase about 30% due to the misalignment. From the results between the static and elevated static tests it is apparent proper alignment of the two sides of the finger plate device is necessary to ensure each side of the expansion device is contributing to the wheel loads.

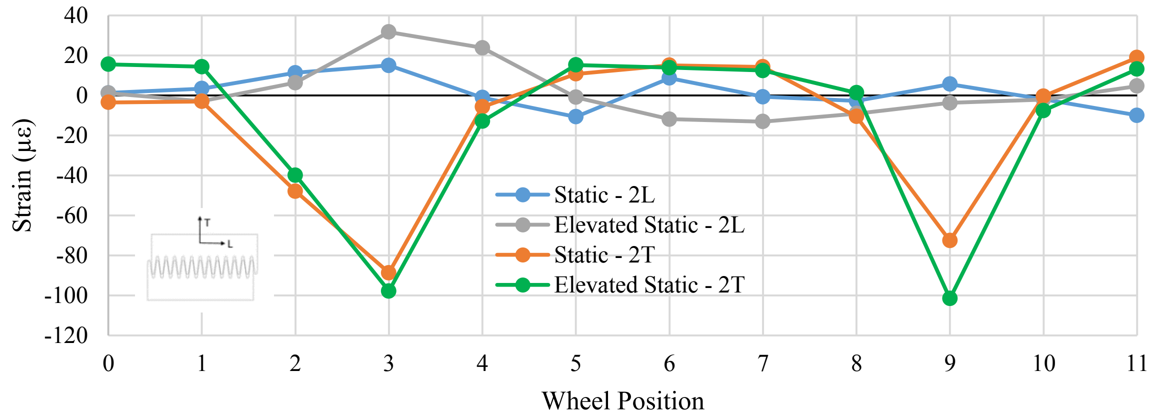


Figure 7-2: Static and elevated static data for strain gage 2 from Blanchette Bridge test

Table 7-1: Percent difference in static and elevated static strains from Blanchette Bridge test

	Strain Gage 1L	**Strain Gage 1T**	**Strain Gage 2L**	**Strain Gage 2T**	**Strain Gage 3L**	**Strain Gage 3T**	**Strain Gage 4**	**Strain Gage 5**	**Strain Gage 6L**
Static (με)	-26.05	120.57	13.69	-85.24	26.93	-68.54	-57.26	-67.17	-5.21
Elevated Static (με)	-27.56	72.81	30.57	-117.11	11.25	-111.6	-71.38	-84.00	-7.85
% increase	5.8	-39.6	123.4	37.4	-58.2	62.9	24.7	25.1	50.6
	Strain Gage 7L	**Strain Gage 8L**	**Strain Gage 8T**	**Strain Gage 9L**	**Strain Gage 9T**	**Strain Gage 10L**	**Strain Gage 10T**	**Strain Gage 11T**	**Strain Gage 12T**
Static (με)	-2.94	61.49	-13.40	-12.56	41.91	67.81	-70.67	37.24	64.61
Elevated Static (με)	-5.32	28.30	-20.24	-11.44	26.85	25.06	-51.09	60.37	-26.72
% increase	81.2	-54.0	51.0	-8.9	-35.9	-63.0	-27.7	62.1	-141.4

In addition to the overall picture of strain and stress distribution provided by the test data, the results of individual gages show areas of stress concentration as predicted by the preliminary FEM analysis. The most critical location – the weld between the support beam flange and finger plate could not be instrumented. However, gages along the support beam flange do indicate the distribution of stress due to the wheel load. The support beam beneath the finger plate was found to have high stresses when loaded by the wheel. Figure 7-3 shows a stress along the support beam flange. The source of this stress is the bending stress from the fingerplate being transferred through the expansion device. The strain values obtained from the gages along the support beam flange (3L, 6, and 7) can be seen in Figure 7-4. The strains indicate that the longitudinal stresses die out quickly as the location moves away from the wheel load. Gage 4 shows the high level of vertical strain (70με) in the support beam flange under the wheel load as seen in Figure 7-5.

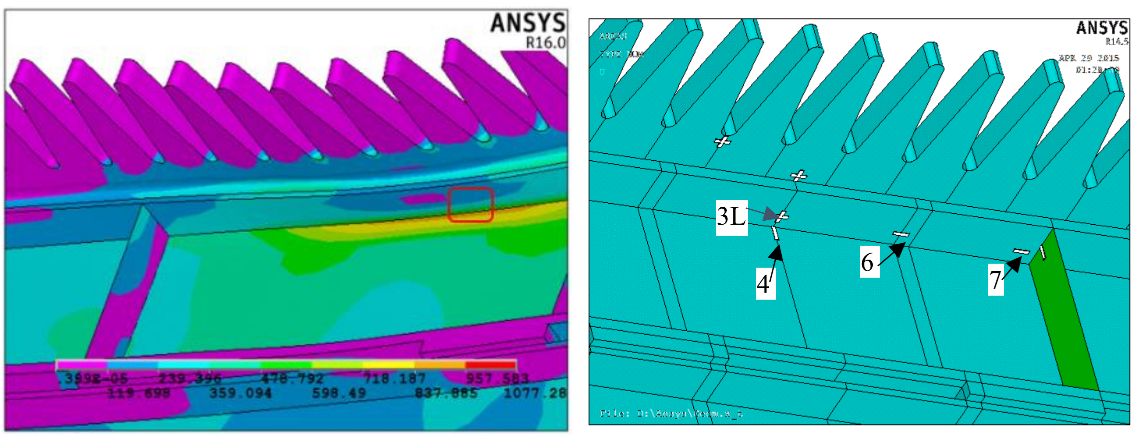


Figure 7-3: Stress concentration located at support beam web

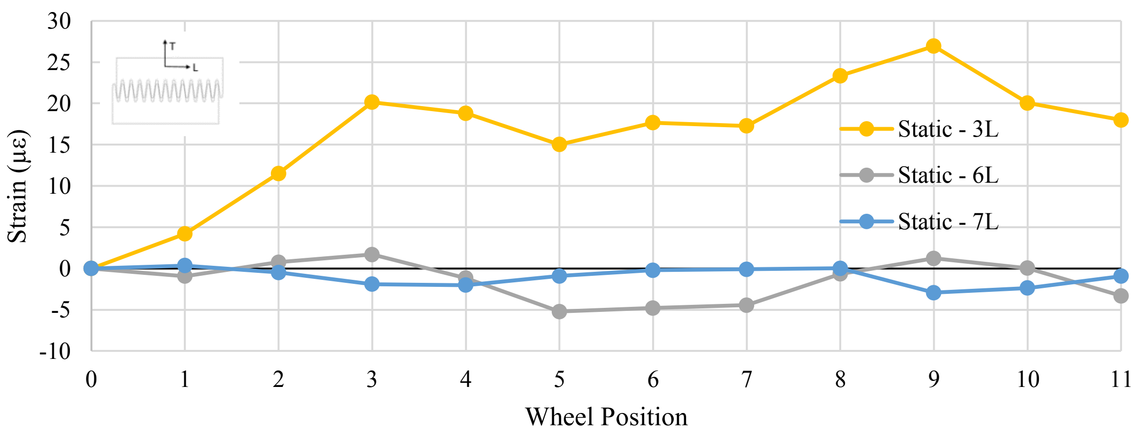


Figure 7-4: Static data for strain gages 3L, 6 and 7 from Blanchette Bridge test

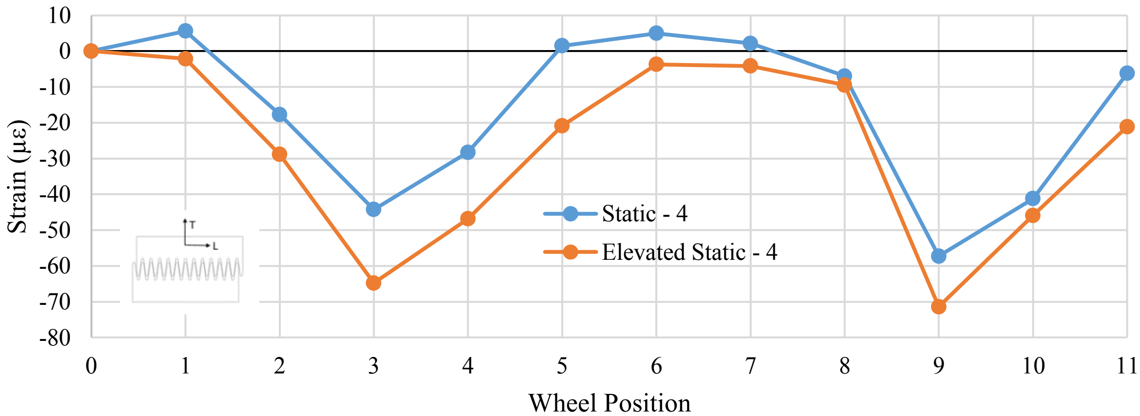


Figure 7-5: Static and elevated static data for strain gage 4T from Blanchette Bridge test

Figure 7-6 shows the prediction of a high amount of stress present in the radius of the fingers of the fingerplate when the expansion device is loaded due to the differential bending of loaded and unloaded fingers. Strain gage 8L, located at the radius of a finger, yielded a maximum strain in the longitudinal direction of 60.07 με corresponding to a stress of about 1.8 ksi as seen in Figure 7-7.

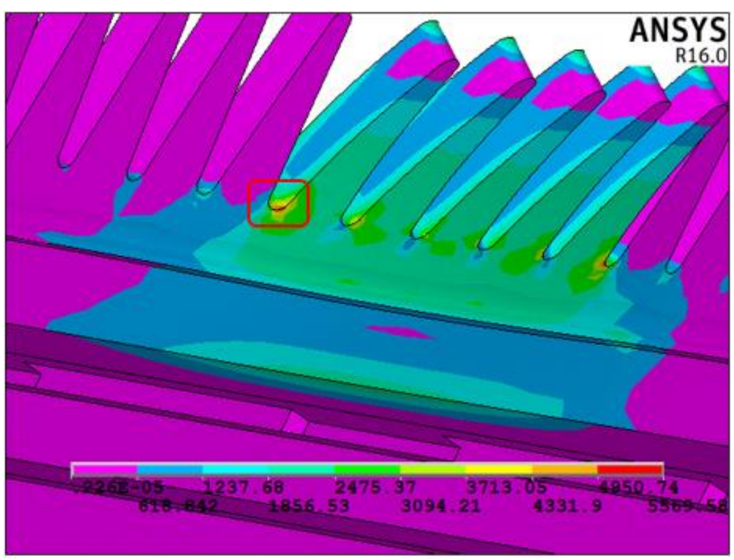


Figure 7-6: Stress concentration at radius of finger for the fingerplate expansion device (Von Mises stress (ksi))

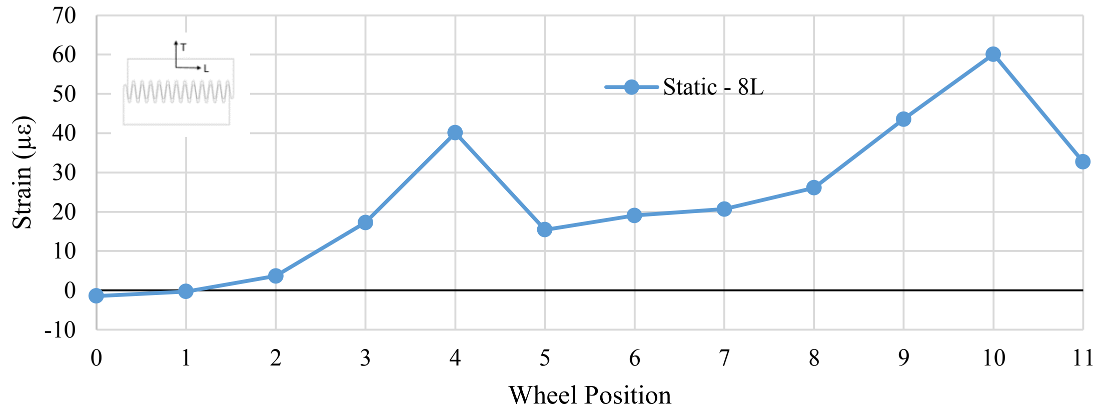


Figure 7-7: Static data for strain gage 8L from Blanchette Bridge Test

7.1.2 Dynamic Tests

The dynamic test consisted of 4 test runs of the weighted truck at a slow speed, 20 mph, 30 mph, and 40 mph. The strain gage placement was the same as the static and elevated static tests. However, each run of the truck at the dynamic speeds resulted in a slightly different wheel path and therefore some differences in the strain readings.

The data collected from the dynamic tests were interpreted as peaks for each of the strain gages caused by each of the axles of the truck crossing over the expansion device. A typical plot of the dynamic data for a single strain gage can be seen in Figure 7-8. The peaks from each of the strain gages was extracted and plotted in Figure 7-9 along with the maximum values found for the static test.

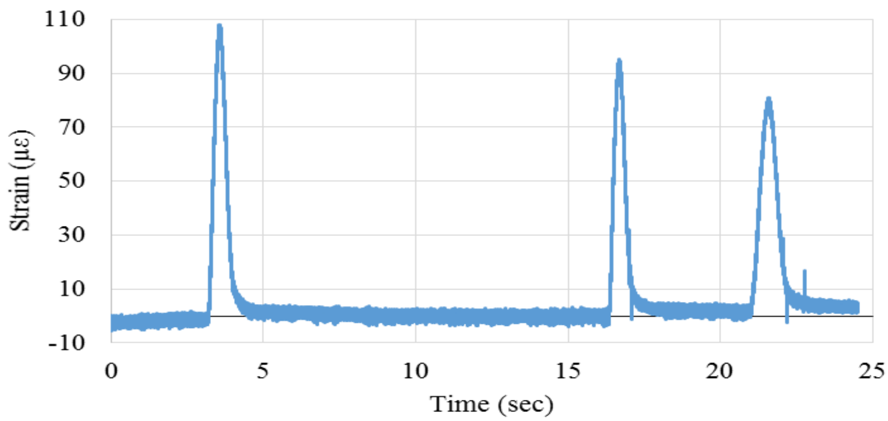


Figure 7-8: Strain gage 1T for dynamic test at slow speed for Blanchette Bridge

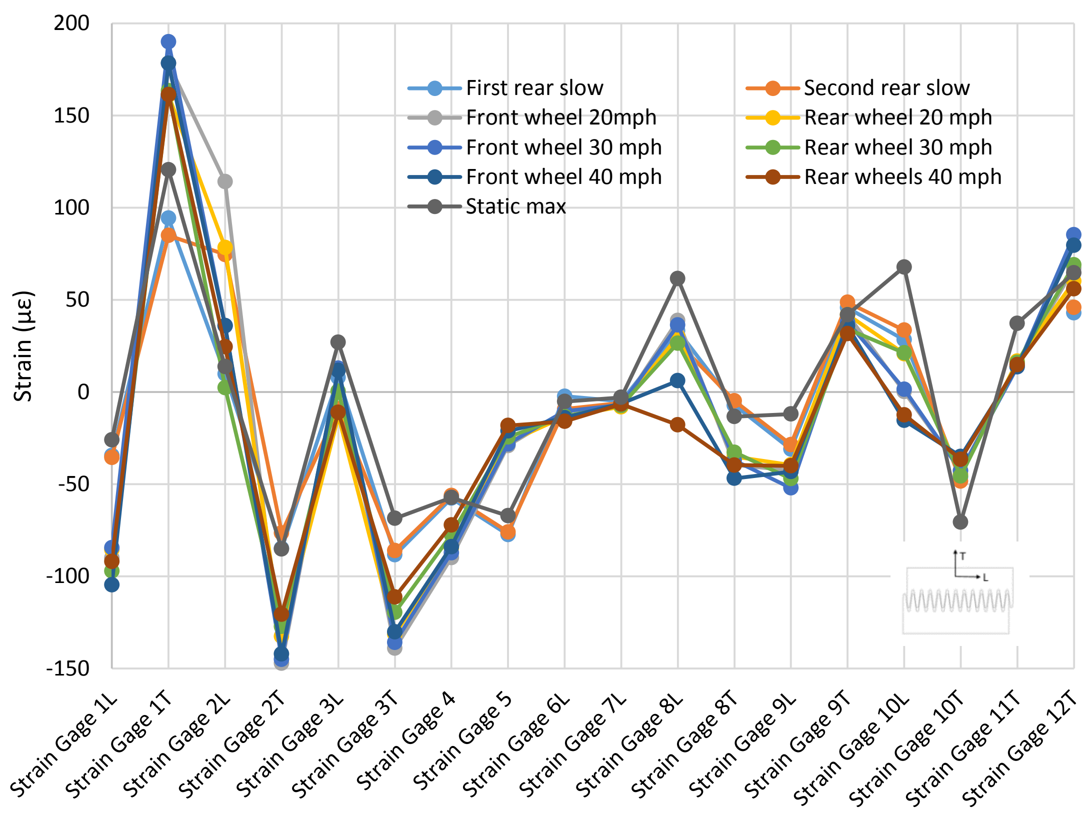


Figure 7-9: Peak strain values at each strain gage for dynamic tests on Blanchette Bridge

In general the strains recorded at the 20mph, 30mph, and 40 mph speeds showed little difference as can be seen in Figure 7-10. Therefore, the level of stress in the expansion device does not seem to depend on the speed of the truck, but rather the simple fact that the truck is moving and bouncing as it drives along the road. If the values for the dynamic runs (20mph, 30mph, and 40mph) are averaged and compared to the values for the slow/static run then Figure 7-11 and Table 7-2 show that on average the dynamic strain was 40% greater than the static reading. The greatest differences occurred in gages 1T and 2T which capture the bending of the fingers and showed a 70% increase in dynamic strain. However for gages 1L, 6L, and 8T dynamic strain increases of nearly 160% were measured although the actual difference in strain was only about 20 με. For the gages on the support beam a 38% increase in strain was found. Based on the results of the dynamic tests an increased impact factor is recommended for design.

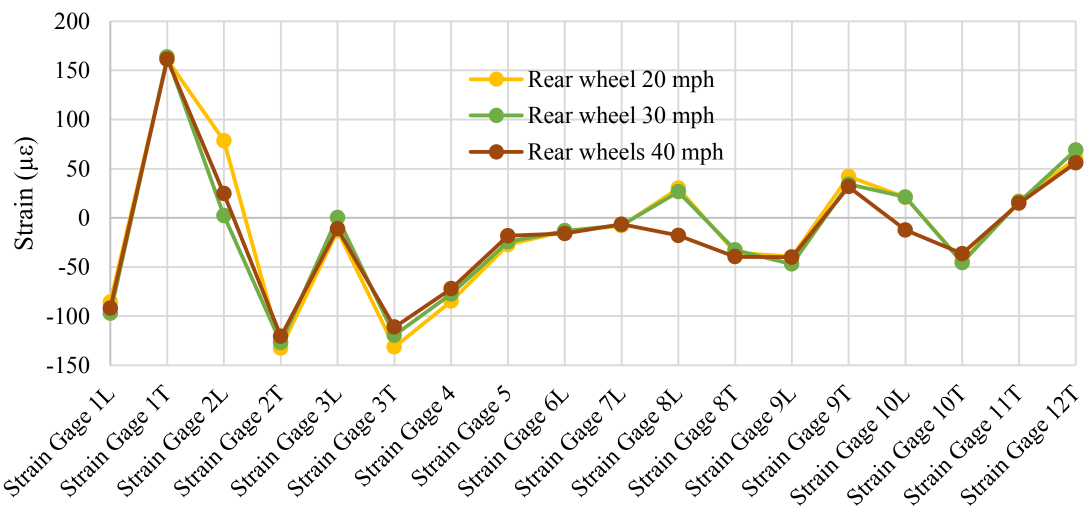


Figure 7-10: Variation of strain at different truck speeds for rear wheels

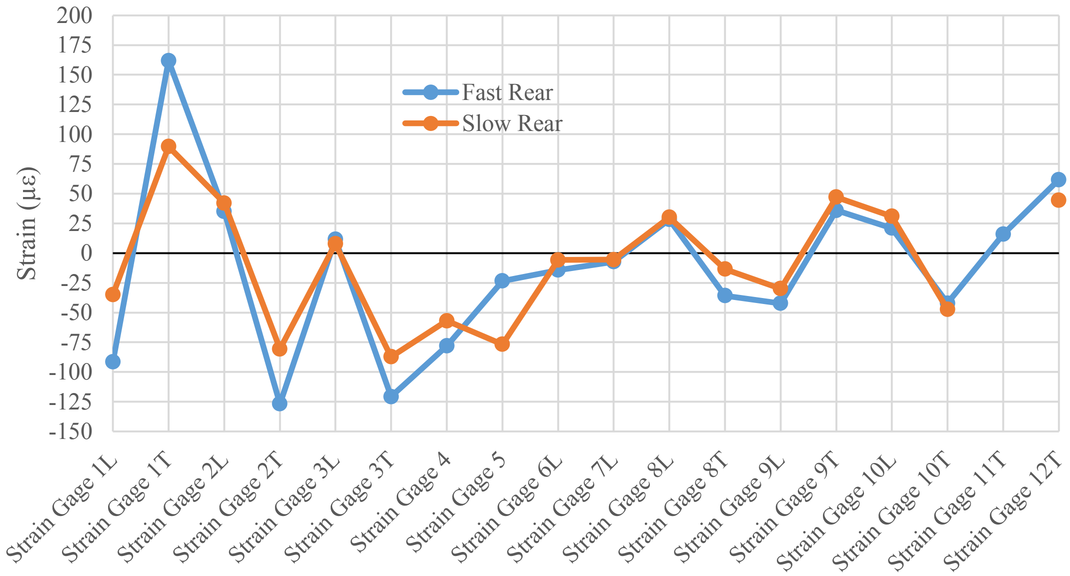


Figure 7-11: Comparison of dynamic versus static strains

Table 7-2: Static and dynamic strain data

	Strain Gage 1L	**Strain Gage 1T**	**Strain Gage 2L**	**Strain Gage 2T**	**Strain Gage 3L**	**Strain Gage 3T**	**Strain Gage 4**	**Strain Gage 5**	**Strain Gage 6L**
Fast Speed (με)	-91.53	161.92	35.07	-126.7	11.71	-120.7	-78.10	-23.36	-14.25
Slow Speed (με)	-34.98	89.58	42.18	-80.63	7.82	-87.18	-56.93	-76.68	-5.84
% increase	161.65	80.75	-16.84	57.21	49.63	38.45	37.20	-69.53	144.15
	Strain Gage 7L	**Strain Gage 8L**	**Strain Gage 8T**	**Strain Gage 9L**	**Strain Gage 9T**	**Strain Gage 10L**	**Strain Gage 10T**	**Strain Gage 11T**	**Strain Gage 12T**
Fast Speed (με)	-7.32	28.32	-35.83	-42.25	35.91	20.94	-42.19	15.86	61.71
Slow Speed (με)	-5.48	30.09	-13.40	-29.84	47.13	30.92	-47.38	-	44.37
% increase	33.67	-5.90	167.40	41.60	-23.81	-32.27	-10.95	-	39.08

7.2 Flat Plate Test Results

Static and dynamic test data was obtained to offer insight to the premature deterioration of flat plate expansion devices. Data obtained from the flat plate testing can be found in Appendix B.

7.2.1 *Static Test*

Static testing for the flat plate expansion device was conducted in a similar manner to the finger plate, but with 14 wheel position locations across the expansion device as described in Section 6.2. Nine strain gages recorded values for each position; however multiple strain gages malfunctioned or gave inconsistent results. Three separate tests at each wheel position were recorded and averaged to obtain steady values. The strain values were interpreted in the transverse and longitudinal direction with transverse being the direction perpendicular to the plate gap and longitudinal being the direction parallel with the plate gap. As discussed in Section 6.2, this particular bridge is skewed, therefore the wheel loadings from the entire axle were not directly loading the sliding plate at the same time for each wheel position.

In general the maximum strain values were found at wheel position 14 when the 2nd rear wheel was located on the plate girder side haunch and the truck was almost entirely on the bridge. The strain values of strain gages 7T and 9T, located in the middle of the top side of the sliding plate, and gage 6T, located in the middle bottom side of the sliding plate for each wheel position can be found in Figure 7-12. As seen in the figure the strain almost continually increases as the truck moves onto the bridge. The strain is in compression for the top side gages (7T and 9T), and in tension for the bottom side gage (6T) indicating bending of the plate at the truck loads the bridge. This is likely caused by the differential movement between the bridge span and abutment as recorded by the LVDTs discussed next. The maximum strain value found at wheel position 14 was at strain gage 9T, located between the bridge stringers and directly under the wheel path, was approximately 131.87 με, or 3.82 ksi. Strain gage 7T, located at the bridge stringer location, produced a strain of 56.35 με, or 1.63 ksi.

Gages 6L, 7L, and 9L oriented in the longitudinal direction (parallel) to the expansion device showed much smaller values of strains (at most -40 με) and did not show a clear trend in strain as the truck moved on the bridge or as the wheel loaded the expansion device as seen in Figure 7-13. However the highest readings were at wheel position 7 when the front rear tire was directly over the device. This is likely due to the fact that the expansion device gap was only about 3 in. and it was difficult to load the plate directly with the wheel.

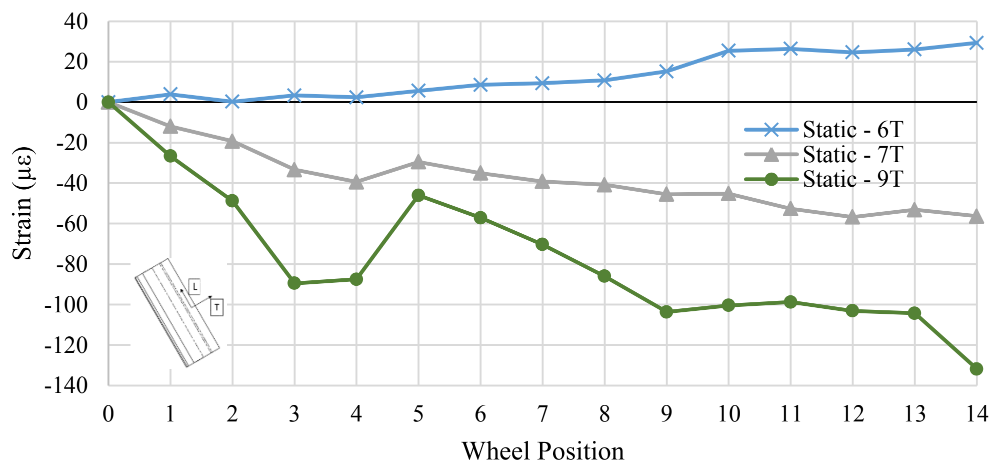


Figure 7-12: Static data for strain gage 6T, 7T, and 9T for Route 350 over I-435 bridge test

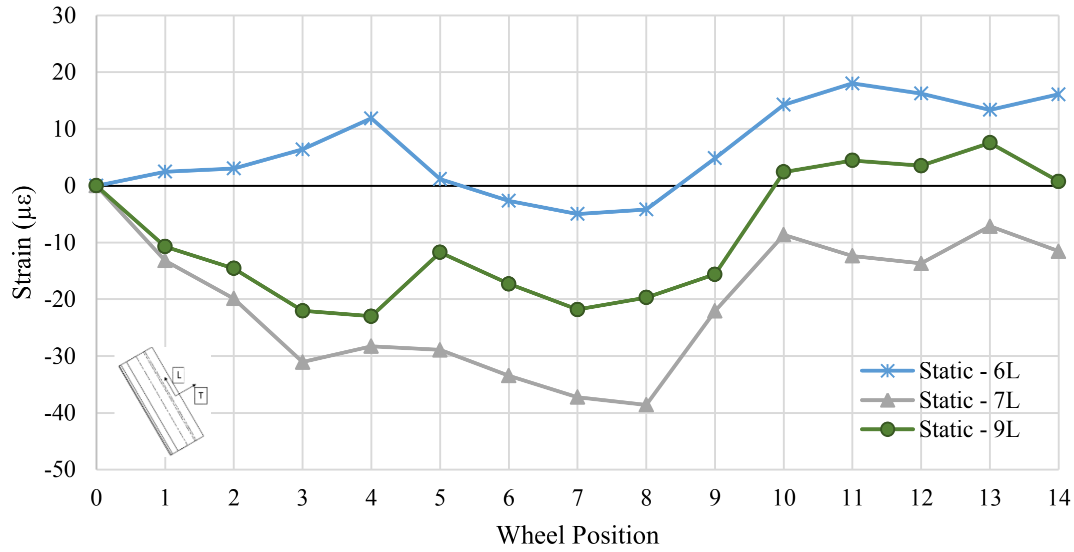


Figure 7-13: Static data for strain gage 6L, 7L, and 9L for Route 350 over I-435 bridge test

Gages located on the support angles (5 and 8) showed small values of compressive strain (approximately 12με or 0.25 ksi) due to the loading of the expansion device as seen in Figure 7-14.

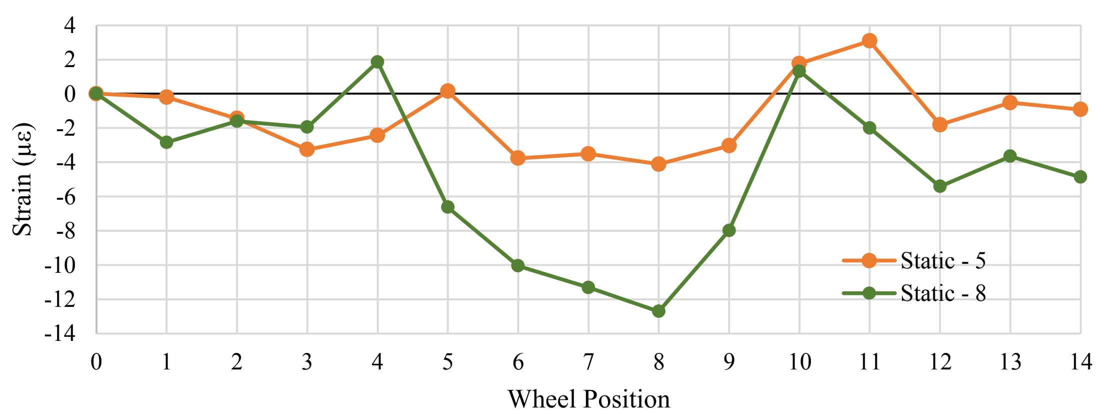


Figure 7-14: Static data for strain gage 5 and 8 for Route 350 over I-435 bridge test

The LVDTs attached to the haunch and sliding plate give a clear indication of the amount of bending the expansion device is under during loading. LVDT 1 and 2 were attached to the sliding plate and haunch (respectively) between the bridge stringers.

LVDT 3 was on the haunch at the stringer line. Figure 7-15 shows the deflections of LVDT 2 were significantly higher, 217%, than those of LVDTs 1 and 3. This is because as the wheels load the bridge span the haunch is deflected between the stringers. The deflection in the haunch at the stringer location (3) and the deflection measured in the sliding plate itself (1) were both much less. The deflection in the LVDTs also show the influence when the wheel was directly over the haunch (wheel position 4) and increasing deflections as the truck moves onto the bridge. The maximum deflection of LVDT 2 was 0.0234 inches at wheel position 14. The deflection of LVDTs 1 and 3 reached a maximum of about 0.007 in.

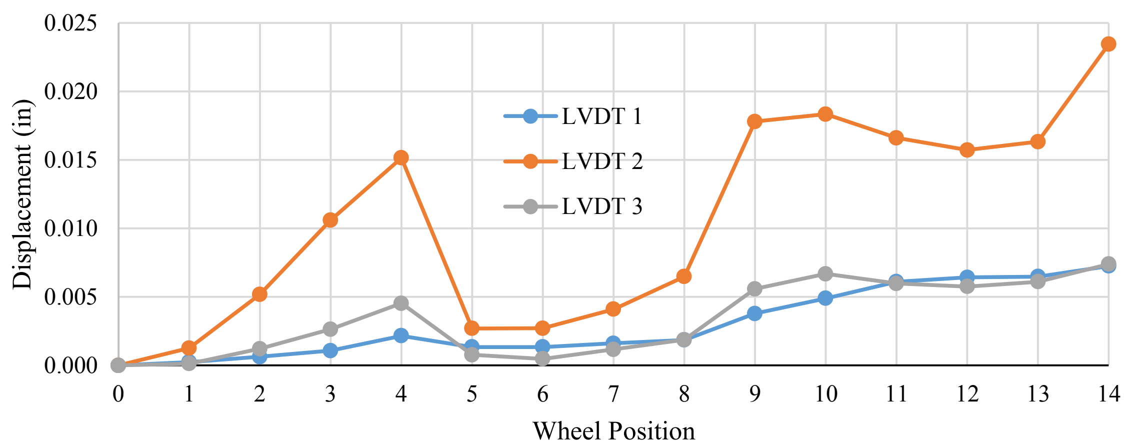


Figure 7-15: Static data for all LVDTs from Route 350 over I-435 bridge test

7.2.2 Dynamic Tests

Two dynamic tests were conducted at a slow speed and 20 mph to determine the effects of dynamic loading on the flat plate expansion device. Unfortunately, 20mph was the maximum speed of the truck due to limited run up distance. Figure 7-16 shows the peak values of each strain gage for each axle at the slow speed and 20 mph during the dynamic tests. Unlike the finger plate results, there is no clear trend between the slow and dynamic readings. This is likely due to the short width of the expansion device making it difficult for the truck to "bounce" right at the device and give a dynamic reaction, and the high skew of the device causing different tires to cross the device at different times. Furthermore, the values from the static test do not compare as well to the values for the dynamic readings, although the general trend in the strains is the same. This is likely due to the fact that the static test only measures a few wheel positions while the dynamic test is able to account for all wheel positions. Furthermore, the line up with the tires and gages is different in each run.

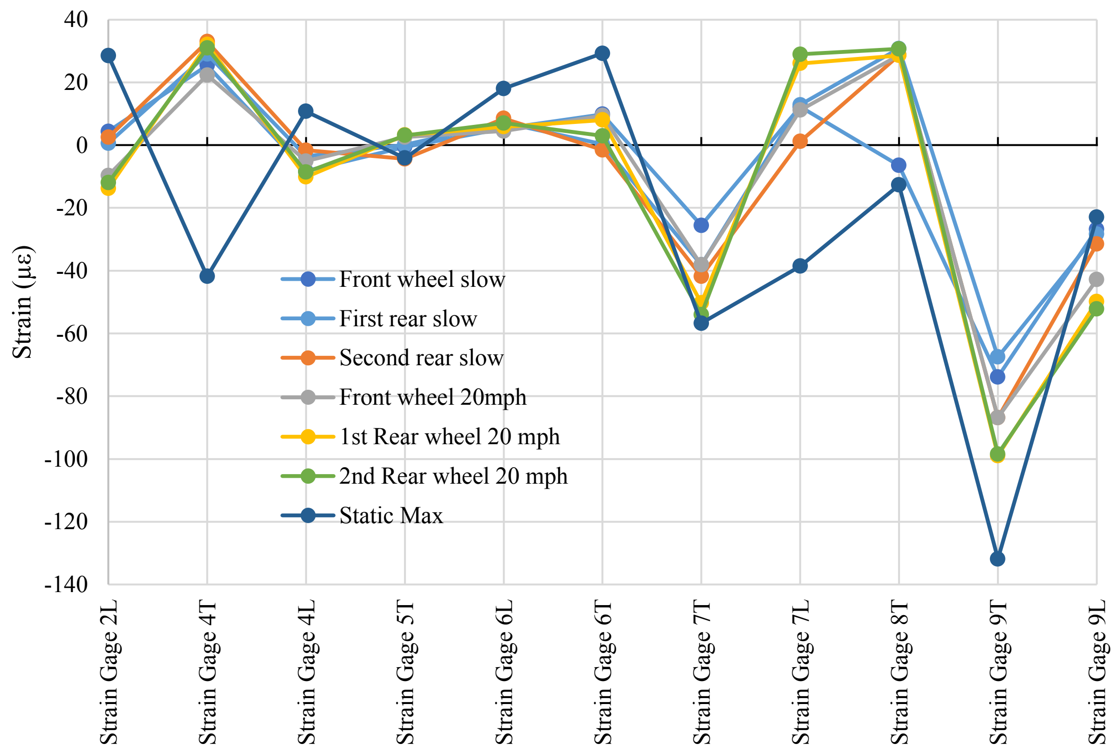


Figure 7-16: Dynamic data for all strain gages from Route 350 over I-435 bridge test

The LVDTs behaved in a similar way to the strain gages since the static maximum deflection at LVDT 2 of 0.0234 inches exceeded the maximum dynamic deflection of 0.0193 inches in the 2^{nd} rear wheel at the slow speed. As seen in Figure

7-17, there was a clear correlation in deflection across the three LVDTs with LVDT 2 consistently having the highest deflections.

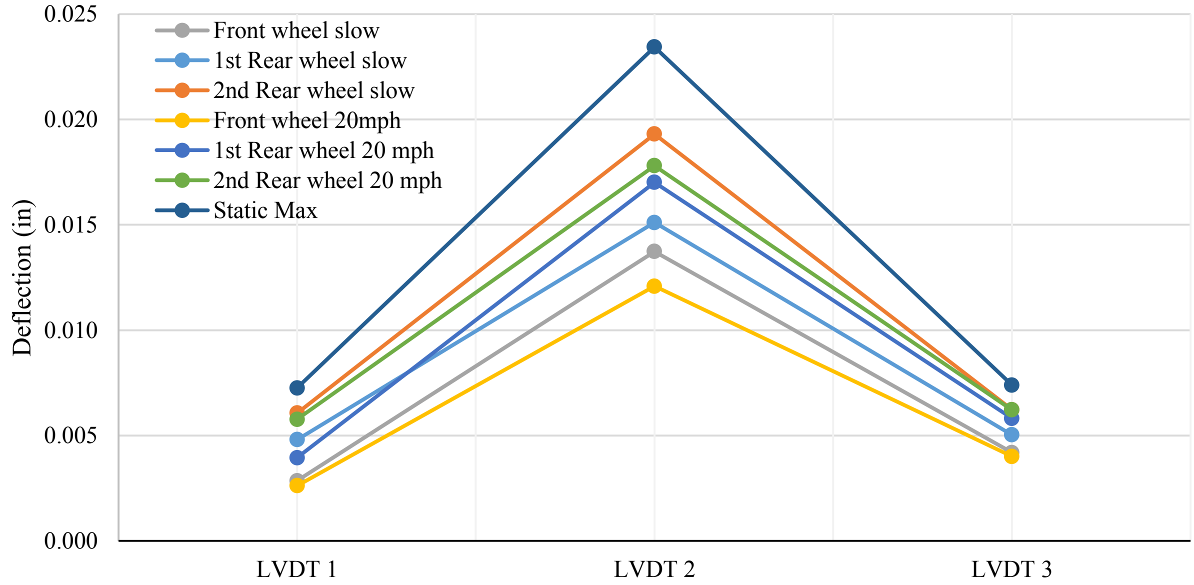
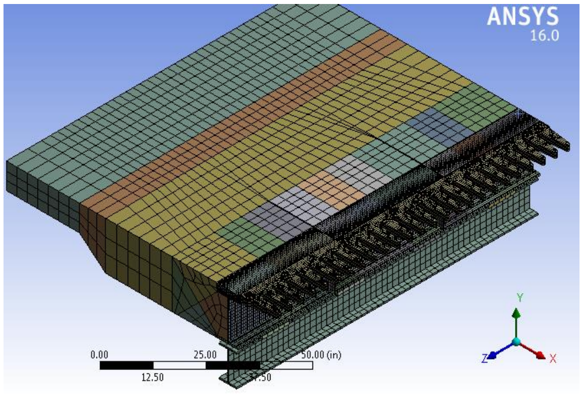


Figure 7-17: Dynamic data for all LVDTs from Route 350 over I-435 bridge test

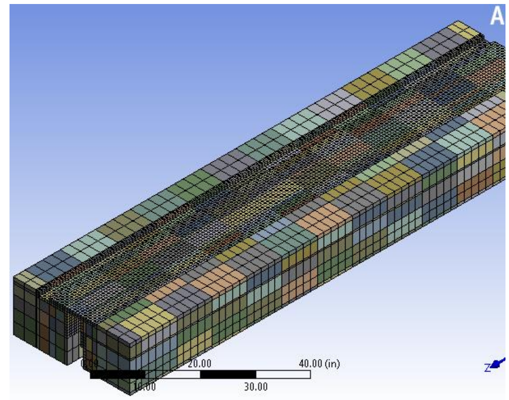
8 FEM ANALYSIS

Finite element models for the finger plate and flat plate expansion devices were created using the finite element code ANSYS 16. The models consisted of the main steel elements, a concrete block representing the bridge deck, steel reinforcements, and anchorage bolts and straps. For the modeling of the concrete block, SOLID65 concrete elements were used. SOLID65 is an 8-node brick element that supports concrete cracking behavior. For the steel parts, i.e., all plates, beams, angles and welds, 8-node SOLID185 elements were used. Link elements, LINK180 and/or BEAM186, were used to model the steel reinforcement and the anchor straps.

In order to simulate the contact between the expansion device parts, surface-to-surface contact pairs were used. ANSYS contact pairs consists of contact elements (CONTA174) and target elements (TARGE170). Coulomb friction model with a coefficient of friction 0.2 was used. ANSYS Pretension elements were used to apply the clamping force, which was applied in the mid-section of the bolt shank. The solution was manipulated in two steps; in the first step the clamping loads are applied and locked, while in the second step the wheel loads are applied. A nonlinear analysis mechanism was used, in which the total load applied to a finite element model is divided into a series of load increments and Newton-Raphson equilibrium iterations provide convergence at the end of each load increment. Material non-linearity was included: isotropic hardening plasticity was used for all steel elements, while brittle damage conjugated with damages plasticity model was used for the concrete. Figure 8-1 shows overall views for both the finger plate and the flat plate models.



Finger Plate Model



Flat Plate Model

Figure 8-1: Overall view of FEM models of existing expansion devices

8.1 Finger Plate Model

For the finger plate model, an 8-ft long single span of the supporting beam (representing a section from stringer to stringer) was considered as shown in Figure 8-1. A 6.5 feet section of the concrete deck transverse to the expansion device was modeled. The model has two fixed supports at the ends of the supporting beam and concrete block. A moving load routine was used to simulate the movement of the truck wheel. The wheel load was 10,500 lbs uniformly distributed over the tire contact area of 20 in. by 10 in. to represent the actual wheel load used in the field experiments. It is important to note that the design wheel load would be larger when all LRFD factors are applied.

The results of the ANSYS model were compared to the strains recorded during static testing, and in general good agreements were found as shown in Table 8-1. Details of the comparison for each strain gage can be found in Appendix C. The largest discrepancies were in gages with low values of strain. As the accuracy of the experimental strain is only about 5 $\mu\varepsilon$, most of the error comes from the variation of the experimental strain.

Table 8-1: Comparison of experimental and FEM model strains for wheel location 3

Strain Gage	**1L**	**1T**	**2L**	**2T**	**3L**	**3T**	**4T**	**5T**	**6L**
Experimental (με)	-14.95	125.84	14.92	-88.73	15.04	-68.34	-35.77	-69.69	-1.79
FEM (με)	-27.24	117.82	25.56	-111.60	17.13	-73.95	-40.36	-76.29	-2.61
Strain Gage	**7L**	**8L**	**8T**	**9L**	**9T**	**10L**	**10T**	**11T**	**12T**
Experimental (με)	-1.88	17.26	-17.01	13.61	-71.28	34.06	-118.2	-	47.25
FEM (με)	-1.96	17.87	-20.54	25.56	-111.60	-27.25	117.82	-	62.08

Once the model was verified with the experimental data, further analyses were undertaken to examine the possible failure modes of the expansion device. The model was loaded with one wheel load at the center. Analysis of the existing expansion device design found several locations of stress concentrations. An overall view of the stress contours is given in Figure 8-2. This view shows the stress concentration between the support beam flange and web when the wheel is located between the stiffeners.

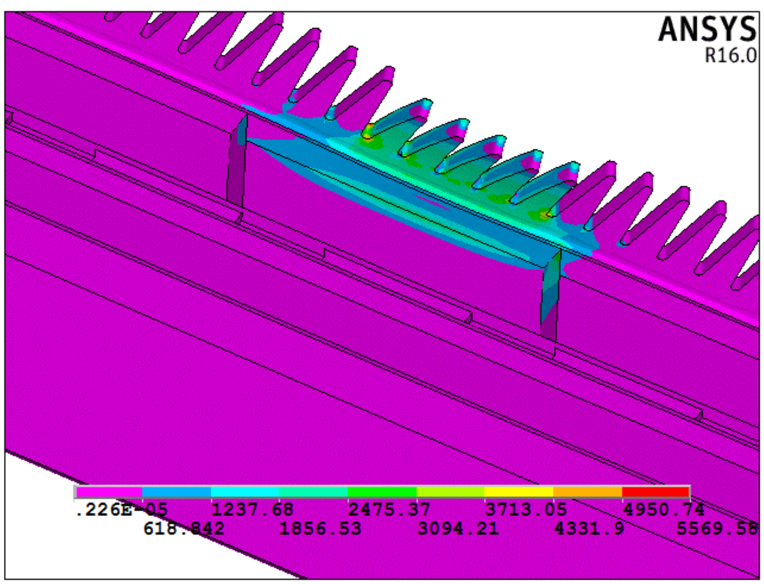


Figure 8-2: Stress contours (Von Mises - psi) in finger plate and support beam

As the weld between the finger plate device and support beam has been found to be the initiating point of failure, a detailed look at the stresses along the weld was undertaken. As seen in Figure 8-3, there is a peak value of stress of approximately 5 ksi above the stiffener location. When the wheel is moved directly above the stiffener location, this peak becomes even greater. It is concluded that this location is consistent with the reported signs of first cracking in the weld from field observations.

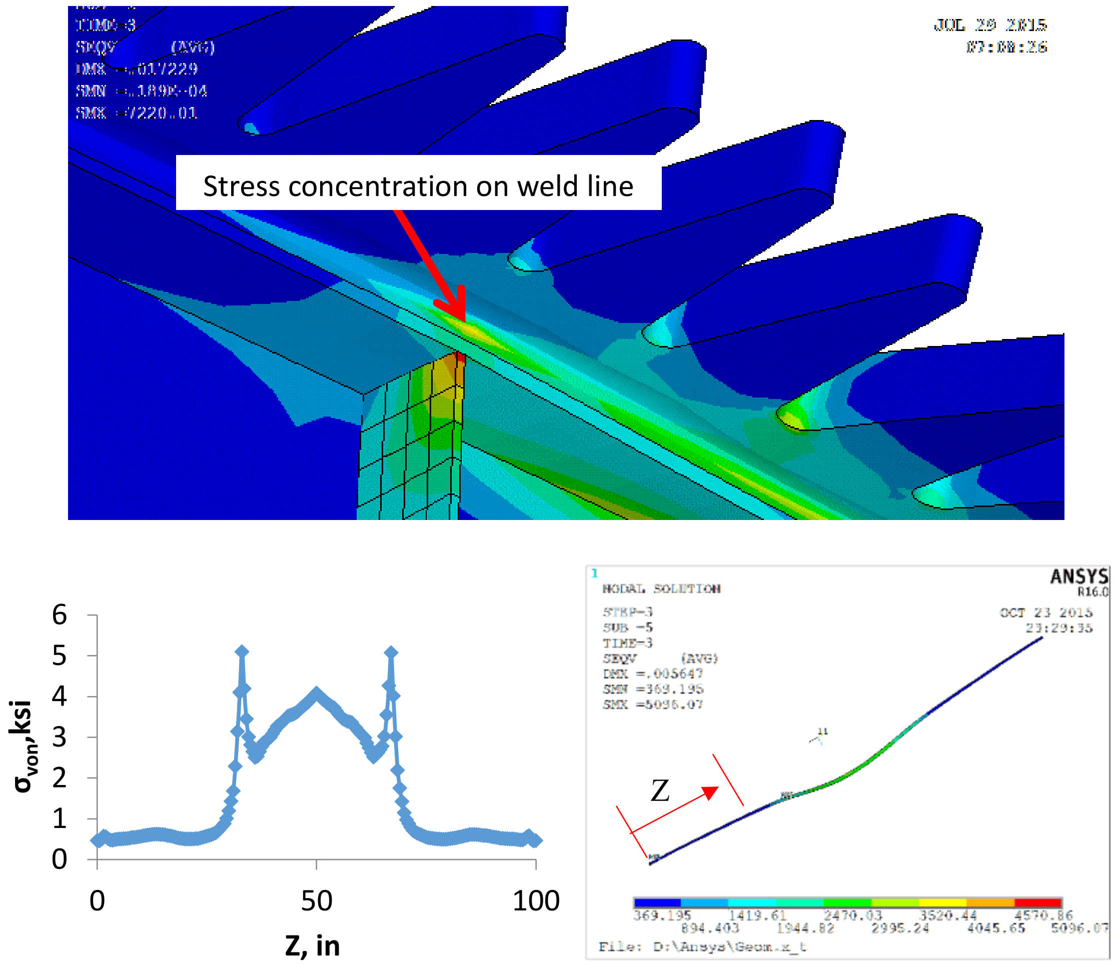


Figure 8-3: Stress concentration in weld above stiffener location

The weld line resultant force per unit length for the Blanchette Bridge under a 10.5 kip wheel load reached 1.014 kip/in. Hand calculations of the force in the weld indicate that the major portion of the force comes from the transverse direction (perpendicular to the weld) of about 0.96 kip/in. The FEM analysis confirmed this behavior, but the value was smaller due to the assumption in the hand calculation that the stress transfer between the finger plate and support beam was perfect.

Other areas of high stress in the model included the hidden backside weld between the finger plate and support beam as shown in Figure 8-4. The stresses along this weld are not as great as the front side weld, but would increase significantly if the front side weld fractures. The back side of the weld is the next likely area of failure after the front side cracks.

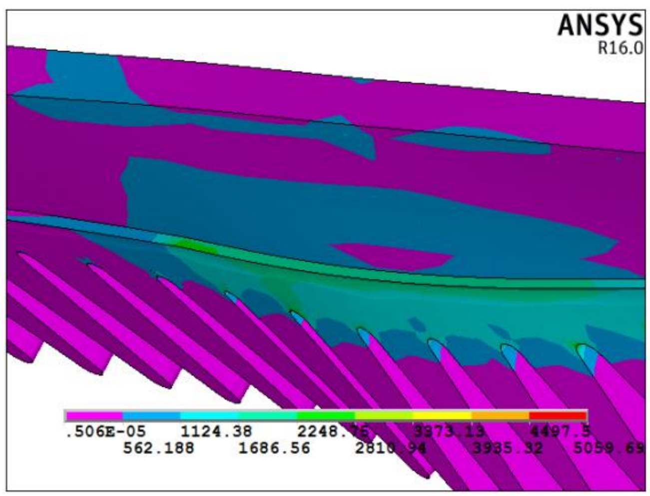


Figure 8-4: Stresses contours (Von Mises - psi) in back side weld between finger plate and support beam

The radius of the finger cutout also shows high stresses of about 5.56 ksi due to differential bending in the fingers when one finger is loaded by the wheel and the next finger is not as depicted in Figure 8-5. Analysis of the effect of the radius size showed that increasing the radius transitioned the effective stress across the loaded portion of the finger plate. The effective stress was increased across the base of the finger due to a reduced finger width, but was reduced at the cutout due to less stress concentration. For the 4-inch finger width the optimum radius was found to be approximately 0.6 inches.

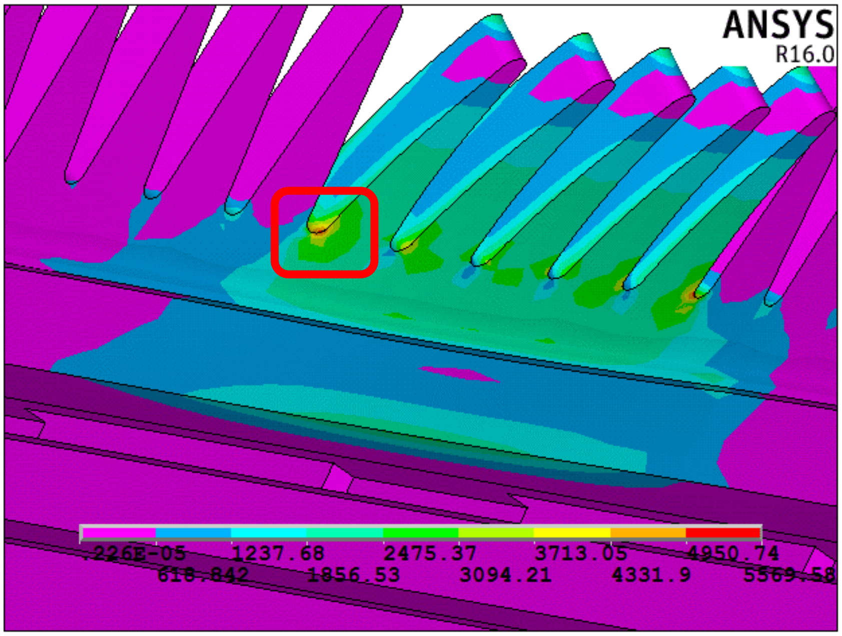


Figure 8-5: Stresses contours (Von Mises - psi) in radius of finger cutout

The location where the anchor strap attaches to the support beam was also found to be a location of higher stress as shown in Figure 8-6.

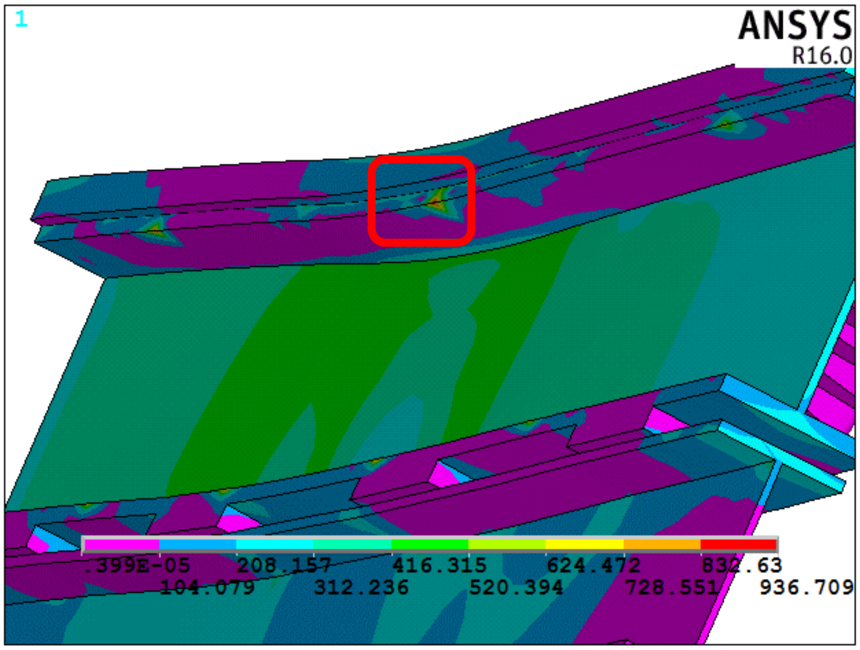


Figure 8-6: Stresses contours (Von Mises - psi) along back side of support beam

Additional analysis was undertaken to examine the effect of possible deterioration in the concrete. A model with no concrete elements increased the transverse stress in the weld by approximately 3.4 times. This indicates that the concrete is an integral part of resisting loads in the expansion device. Furthermore, an additional model was run by removing the shear compatibility between the concrete and steel which replicates the situation where there are sufficient voids in the concrete next to the steel so they are not able to share load, Table 8-2. It was found in this case that the strains in the longitudinal direction along the support beam and finger plate increased by about 50% since the concrete is not able to participate in the bending of the support beam and finger plate between the stiffeners.

Table 8-2: Effect of shear compatibility

	Strain gage 1L	**Strain gage 1T**
Experimental (με)	15	125.8
Full Model (με)	27.245	117.82
No shear compatibility (με)	43.006	116.22

The effect of adding stiffeners to the expansion device was also analyzed. It was found that a critical situation always exists when the wheel is located over the stiffener regardless of the number of stiffeners. The addition of two stiffeners between the existing stiffeners in the Blanchette Bridge reduced the average Von Mises stress over the weld line over the effective length by approximately 60% when the wheel was directly above a stiffener as shown in Figure 8-7. Figure 8-8 shows the stresses in the weld line when the wheel is in the center between the bridge stringers, which is the worst case for the three stiffener option.

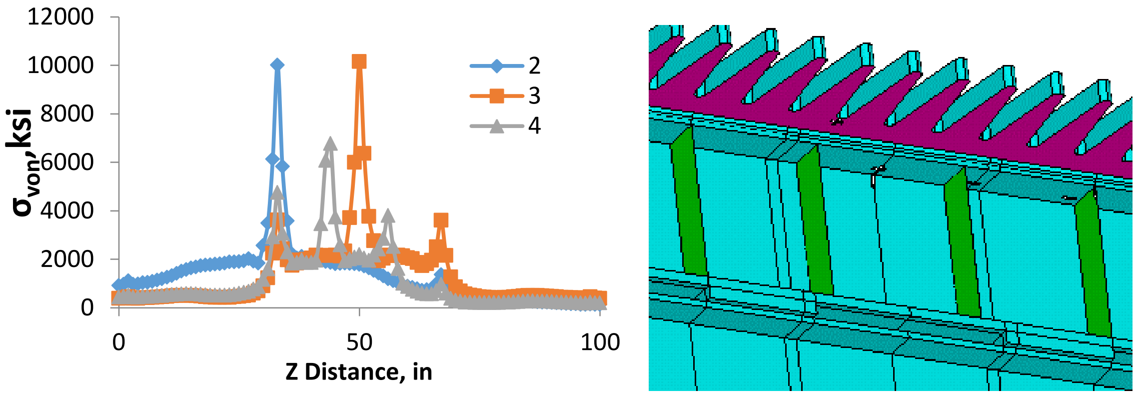


Figure 8-7: Von Mises stress distribution for wheel located over the stiffener for 2, 3, and 4 stiffener cases

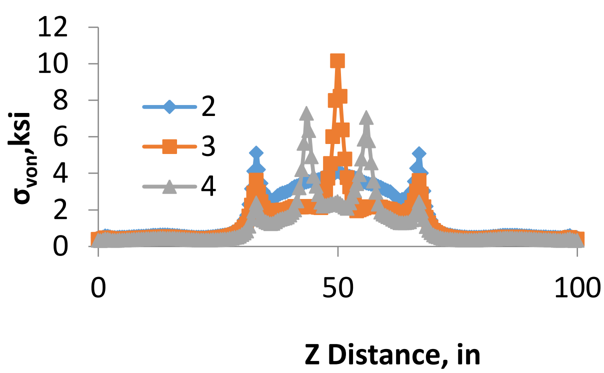


Figure 8-8: Von Mises stress distribution for in center between bridge stringers for 2, 3, and 4 stiffener cases

8.2 Flat Plate Model

For the flat plate model, a single span of the supporting beam with 9.5 feet length was considered as shown in Figure 8-1. In the bridge longitudinal direction, a portion of the concrete deck 30 inches wide was modeled. The model has two fixed supports at the ends of the supporting beam and concrete block. The abutment side of the expansion device was supported along its length while the bridge side was allowed to deflect between the end supports. A moving load routine was used to simulate the movement of the truck wheel with a wheel load of 10.5 kips. From site observation, it was found that there are some geometric differences between the plans and the built structure (namely the rotation of the support angle as discussed in Section 6.2), which would be expected to cause some differences between the FEM model and field strain measurements. The results of the FE model were compared to the strains recorded during static testing, and some strain readings have good agreement as shown in Table 8-3. It can be observed that the top strain gages have the best match, which may be due to the better installation due to the ease of access, compared with the lower gages. The largest discrepancies were in gages with low values of strain. As the accuracy of the field strain measurements is only about 5 $\mu\varepsilon$, most of the error comes from the variation of the experimental strain. Figure 8-9 shows the Von Mises stress contours in the flat plate expansion device. As expected, the highest stresses occur in the middle of the sliding plate. Furthermore, earlier versions of the model showed that allowing the span between the stringers to deflect as the truck moves onto the bridge was an important element in replicating the experimental strains. Therefore, the global movements of the bridge affect the stresses developed in the flat plate expansion device.

Table 8-3: Experimental strain vs FEM model strain per strain gage for wheel location 7

Strain Gage	6L	7L	7T	8	9L	9T
Experimental (microstrain)	-6.28	-47.4	-39.3	-19.5	-25.38	-78.41
FEM (microstrain)	-5.9	-23	-25.1	-11.3	-24.1	-72.3

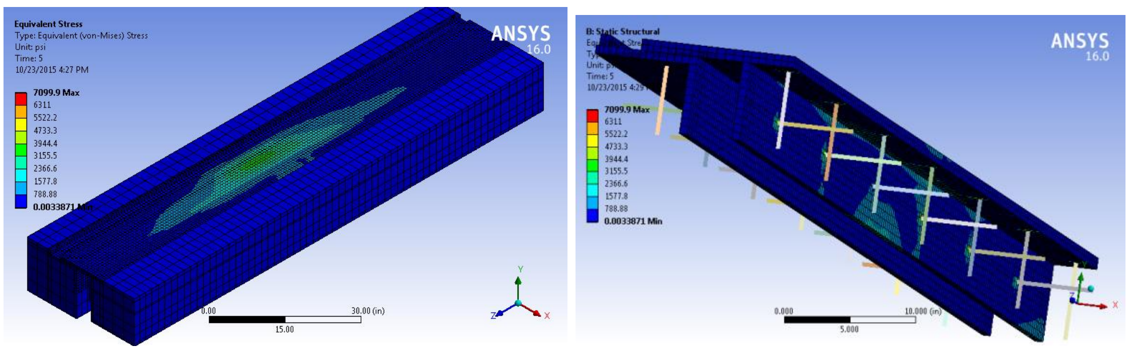


Figure 8-9: Stress contours (Von Mises – psi) in flat plate expansion device

9 FINGER PLATE DESIGNS

Based on the results of the analysis of the failure modes of the existing finger plate expansion devices and the results of testing and FEM analysis, new finger plate expansion device designs have been developed. Two designs were developed based on the usage conditions of the expansion device. A robust finger plate expansion device design was developed for use in high traffic areas and on major bridges where maintenance would be difficult or costly. This design gives the best possible performance of the expansion device but does so at a high cost. The modified finger plate expansion device design is intended for lower traffic volumes and allows an improved finger plate option at a lower cost. However, the long-term performance of the expansion device may not be as superior. In addition, a retrofit design for in service finger plate expansion devices was developed to repair and improve the performance of existing expansion devices.

To make the best use of the new finger plate and modified finger plate designs we propose a modification to the expansion device selection process to include the information in Table 9-1. The robust finger plate design should be used in locations with a Passenger Car Equivalent (PCE) of 20,000 vehicles per day or greater with an average PCE factor (Truck/Car ratio) for Missouri of 2.0. The robust finger plate design should also be used at crossings of the Missouri and Mississippi Rivers, major lake crossings and in bridges with expansion lengths that exceed the recommended range for the modified finger plate design and elsewhere at the discretion of the Structural Project Manager. The modified finger plate design could be used in all other situations. Similar to the current procedure, both the robust finger plate and the modified finger plate should be used at locations where expansion movement exceeds the limitations of strip seal expansion devices.

Table 9-1: Expansion device type selection

Expansion device Type	Allowable Movement	Allowable Skew
Preformed Compression Seal	0" – 2"	≤20°
Strip Seal	2" – 4"	≤ 45°
Flat Plate	0" – 4"	> 45°
Modified Finger Plate (Type A)	4" – 8½"	≤60°
Robust Finger Plate (Type B) (Steel Girders)	4" – 16"	≤ 60°
Robust Finger Plate (Type B) (Concrete Girders)	4" – 16"	≤20°
Modular Joints	4" – 28"	

Note: Temperature ranges considered in the design of the Modified Finger Plate and the Robust Finger Plate conform to EPG 751.13; Steel Girders: 60° rise and 90° fall from nominal 60° setting temperature; Concrete Girders: 50° rise and 70° fall from nominal 60° setting temperature

9.1 Robust Finger Plate Connection Design

MoDOT has observed numerous failures of the finger plate connection to the supporting beam. The primary mode of failure is fatigue of the welded joints. Observations of misalignment between opposite sides of the finger plate expansion devices have been made by MoDOT and our study team. Some expansion devices have been misaligned vertically while others have fingers on one side of the expansion device at a different angle than the opposite side. This misalignment prevents sharing of the wheel loads between the sides of the finger plate expansion device and increases the fatigue stress carried by the welded connections. The current finger plate expansion device design has limited adjustability during installation. The current design has no adjustability longitudinally or transversely. Vertical adjustment is achieved with shims between the bottom of the support beam and the WT attached to the girder. This shim plate could allow for very limited rotational adjustability if tapered shims were used. Additionally, the current finger plate expansion device design has no allowance for resetting the expansion devices if a wearing surface overlay is placed on the bridge. Current practice is to taper the overlay to the height of the original expansion device. This reduces the overlay thickness near the expansion devices and reduces the durability of the overlay.

To address the issues noted with the current finger plate expansion device designs we propose new finger plate expansion device standards be adopted for use on high volume and important routes as noted in Table 9-1. This design could be utilized by MoDOT as a bid alternate to modular expansion joint systems to obtain competition between expansion devices with similar performance characteristics. The new finger plate expansion devices will utilize a support structure embedded in the concrete deck with a bolted finger plate attachment to improve fatigue performance. The support structure uses dual support points that are adjustable in all three directions. Individual adjustment of the spread supports will allow straightforward rotational alignment of the opposing finger plates. Additionally, the majority of the deck concrete should be placed prior to setting the finger plate expansion device. A slab block out approximately five feet back from the expansion device should be placed after all deck pours are complete on both sides of the expansion device to avoid misalignment of the expansion device caused by girder rotations. Placement of the expansion device near the end of construction coupled with the adjustability of the expansion device will allow the device to be placed more accurately than the current design. The contractor should establish the roadway profile over the device after the adjacent concrete has been placed, including any adjustments necessary due to haunching corrections. The top surface of the device should be adjusted so that it is as close as possible to the adjusted profile but no more than 1/16” out of alignment. The opposite sides of the device should be aligned vertically so that they are also as close as possible to the same horizontal plane but no more than 1/16” different. The opposite sides of the device should be aligned transversely to maintain the expected kerf gap and should also be within 1/16” of the plan dimension. The device should be aligned along the bridge to sit on the dual support beams and the finger gap should be adjusted to the temperature at the time the device is set. After the device is set MoDOT construction personnel should check the alignment and placement of the device prior to field welding the bent plate supports to the top of the support beams. The 1/16” tolerances noted are tight and have been suggested to ensure close attention is paid to alignment and gap setting at time of construction due to the expensive nature of repairs. Final definition of construction tolerance should be investigated and adjusted upon implementation with MoDOT construction personnel for practicality.

The bolted design will allow the finger plate to be removed, shimmed and reattached during any overlay operation. The new finger plate expansion device designs can be seen in Figures 9-1 through 9-3. These details show the expansion device applied to an intermediate bent that is square to the alignment between two steel girder spans with a cast in place slab. Prestressed concrete deck panels can be used with these details but should not be placed in the area of the thickened slab. The expansion devices can also be skewed up to 60° by lengthening the support plates. The finger plate attachment bolts should be aligned to the direction of expansion. These details can also be modified to apply to prestressed concrete girder spans by elimination of the top flange of the girder within the thickened portion of the slab and by inclusion of formed holes in the web of the girder for the passage of the reinforcing cage. The need to pass the reinforcing cage through the web of the girder limits the skew angle that can be accommodated to 20°.

The use of recessed bolts in the finger plate increases the minimum plate thickness. This increased plate thickness will allow the use of straight finger geometry instead of tapered fingers used on the current standards. Straight fingers minimize the opening of the expansion device and provide increased safety for motorcycles during cold temperatures when the opening is greatest. Straight fingers also accommodate similar expansion lengths when the expansion device must be skewed. The finger plate thickness was designed for infinite life fatigue and the additional adjustment capacity of the expansion devices will prevent snags by snow plows reducing and/or eliminating the finger failure seen on older finger plate expansion devices with straight fingers. Table 9-3 shows the minimum finger thickness for a range of expansion lengths and two kerf widths between adjacent fingers. The concrete girder expansion lengths shown for the thickest plates are likely not practical but are included for comparison. The expansion device system is supported on a dual beam system for either steel or concrete girders which allows the formation of a support couple to resist the loads from the finger plate expansion device. This dual beam system should also be used to support the device under the overhang of the external girder by placement of support brackets. The optimal support beam size for a range of girder spacing and skews is shown in Table 9-2. Since the expansion device design is based on a tributary area loading, the placement of the devices can be phased if required. Similar to other expansion device types, the designer should avoid placing the phasing details in a permanent wheel path if possible. Since the expansion device support structure relies on the dual support beams, temporary support of the device may be needed if an adjacent girder is not going to be erected in the current phase and the deck and the device will overhang an interior girder. Phase lines at joint locations should be offset to align with edge of girder if possible to allow for installation of crossbeams in subsequent phases. An optional collection trough can be readily added to the expansion device if the expansion device is in an area where open drainage is not acceptable. Cover plates can be added if the expansion device is used in an area that needs protection for bicyclists, pedestrians and ADA guidelines.

Table 9-2: Support beams for robust finger plate expansion device

	Girder Spacing, ft.					
Skew, deg.	7	8	9	10	11	12
0	W18x50	W18x50	W18x50	W21x55	W21x62	W21x68
15	W18x50	W18x50	W18x50	W21x55	W21x62	W24x68
30	W18x50	W18x50	W21x55	W21x62	W24x68	W24x76
45	W18x50	W21x55	W21x68	W21x83	W24x84	W27x84
50	W18x55	W21x62	W24x68	W24x84	W27x84	W30x90
55	W21x55	W21x68	W24x76	W27x84	W30x108	W30x116
60	W21x68	W24x76	W27x84	W30x108	W30x124	W27x146

Since expansion devices are often placed at the interface between bridge units it is likely for one side of the device to be anchored to a concrete girder or end bent while the other side is anchored to a steel girder. A minimum 1/16” gap between adjacent fingers should be maintained at all temperatures. Finger plates with a 1/8” kerf can accommodate a differential movement of 1/16” which equates to a bridge width of 63 feet. Finger plates with a ¼” kerf can accommodate a differential movement of 3/16” equating to a bridge width of 189 feet. Bridges wider than 189 feet should use an alternate expansion device such as a swivel version of a modular expansion device. Additionally, expansion devices in curved bridges with unguided bearings or bearings guided along the chord could experience differential movements which do not allow the designer to align the fingers to be coincident with movement from all directions. These movements should be limited to the tolerances of the selected kerf and the teeth should be oriented to bisect the chords or directions of movement from both sides of the joint. If the movements exceed the tolerances the bearings should be guided tangentially and guide systems sufficient to resist thermal forces to restrain movement provided by the designer. At end bents or intermediate bents with one side fixed the fingers should be skewed to the direction of movement.

Table 9-3: Expansion length limits

Finger Plate Thickness	Expansion Lengths with 1/8” Kerf		Expansion Lengths with 1/4” Kerf	
	Steel Girders	Concrete Girders	Steel Girders	Concrete Girders
3”	1001’ – 1130’	1351’ – 1530’	931’ – 1060’	1271’ – 1440’
2¾”	861’ – 1000’	1151’ – 1350’	801’ – 930’	1151’ – 1270’
2½”	741’ – 860’	981’ – 1150’	691’ – 800’	981’ – 1090’
2¼”	621’ – 740’	841’ – 980’	591’ – 690’	841’ – 950’
2”	531’ – 620’	721’ – 840’	481’ – 590’	721’ – 800’
1¾”	≤ 530’	≤ 720’	≤ 480’	≤ 660’

The new finger plate expansion devices were designed to the following criteria:

- Straight fingers with a 1” radius throat and a 1/8” kerf during manufacture resulting in a 1¾” wide finger or a ¼” kerf resulting in a 1½” wide finger.
- 1½” minimum gap at minimum expansion device opening and 1½” minimum finger overlap during maximum expansion device opening.

- The finger thickness was designed based on Strength loading using the AASHTO LRFD load factors and multi-presence factors and the following information:
    - Increase impact to 100%.
    - Design load is the design tandem with 25 kips / axle (12.5 kips / wheel).
    - Each wheel is applied to a 10" x 20" area placed at the tip of the fingers on one side of the expansion device so that the centroid of the load is 5" from the tip of the fingers.
    - Assume the entire wheel load is taken by one side of the expansion device.
    - Design moment is taken at the beginning of the finger throat (1" away from the extreme throat).
    - Disregard plastic capacity of the finger and limit the moment capacity to first yield.
    - A practical maximum finger thickness of 3" works for a total factored movement of 16" which equates to a bridge expansion length of 1130 feet if steel girders and a 1/8" kerf are used.
- The selected finger thickness was checked for infinite life Fatigue loading using the AASHTO LRFD load factors and the following information:
    - Increase impact to 100%.
    - Fatigue load is the HL-93 truck with the heavy axle assumed to be a tandem with 16 kips / axle (8 kips / wheel) in accordance with the fatigue design of orthotropic decks as shown in AASHTO Fig. 3.6.1.4.1-1 and also in accordance with the fatigue design for Modular Bridge Joints as shown in AASHTO 14.5.6.9.4.
    - Each wheel is applied to a 10" x 20" area center placed at the tip of the fingers on one side of the expansion device so that the centroid of the load is 5" from the tip of the fingers.
    - Assume the load is shared between both sides of the finger plate expansion device proportional to the overlap at 30°F, a conservative assumption for the normal use of the expansion device.
    - Consider the throat of the finger to be a Class B material with Δ_{TH} = 16 ksi.
- The finger plate attachment bolts were designed as a couple with the near bolt in compression and the far bolt in tension; designed for both Strength and Fatigue.
- The anchor plate and support plate system was designed for both Strength and Fatigue using conservative assumptions. This design was verified by FEM modeling.

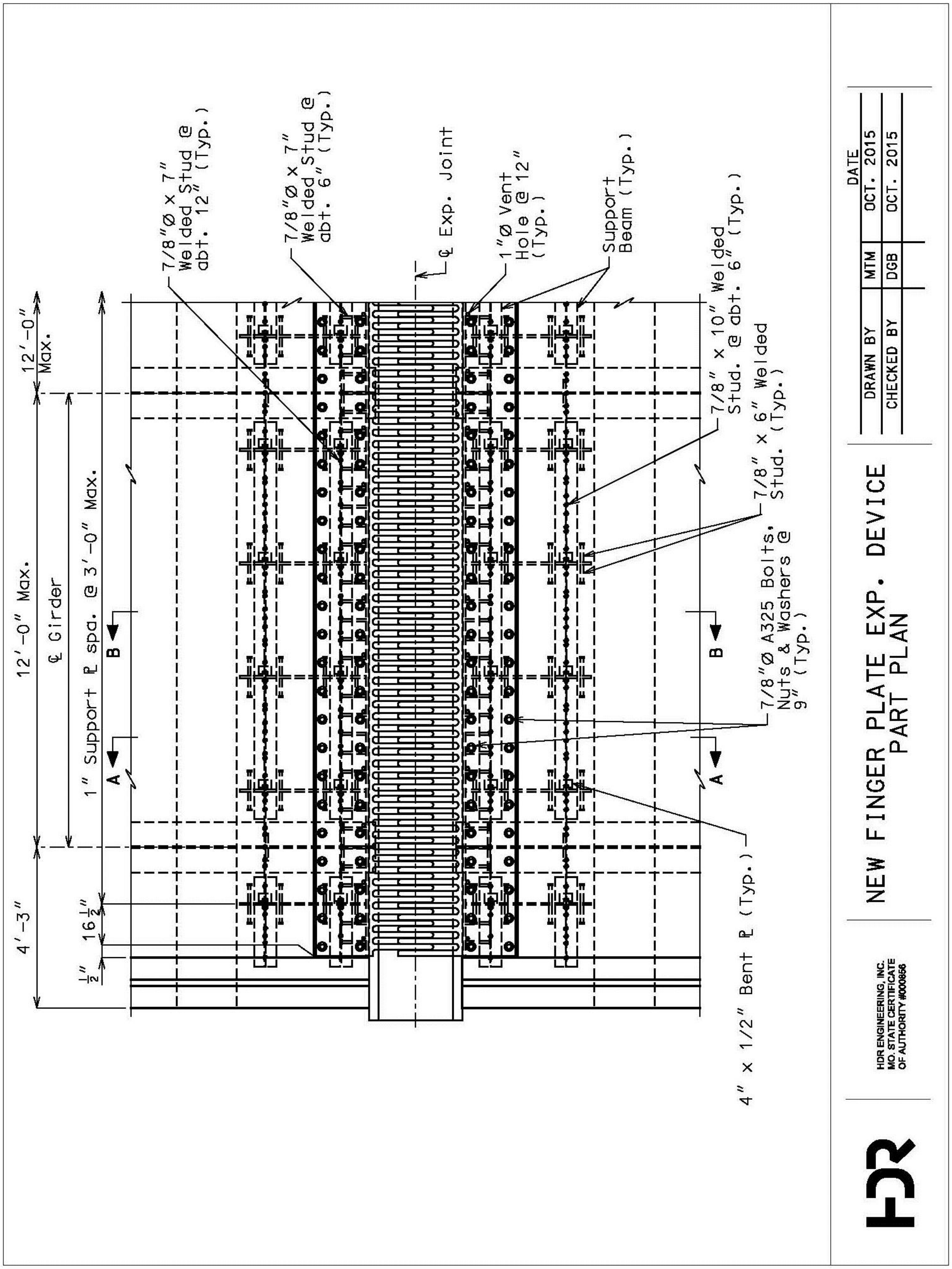


Figure 9-1: Part plan of proposed robust finger plate expansion device

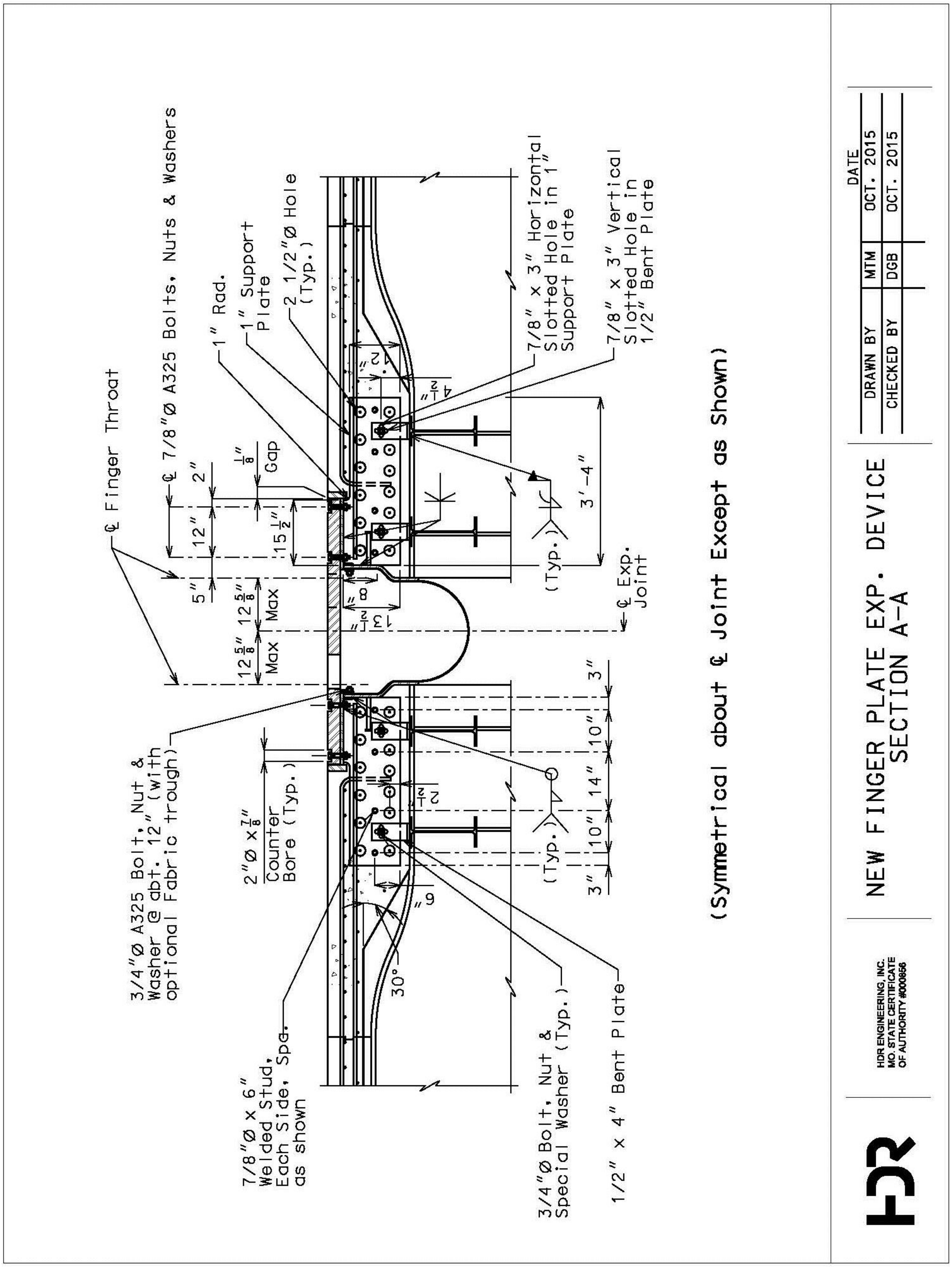


Figure 9-2: Section of proposed robust finger plate expansion device

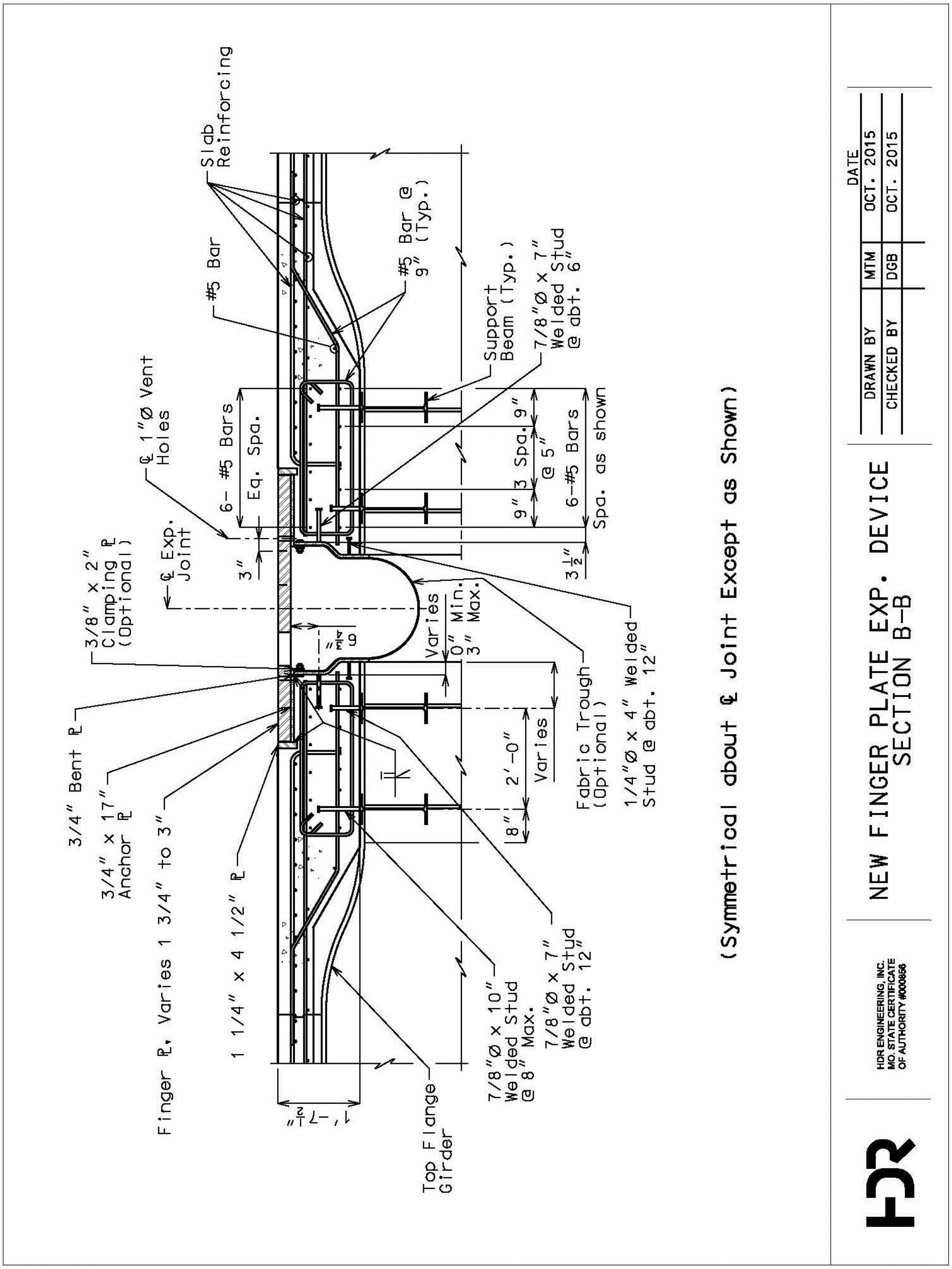


Figure 9-3: Section of proposed robust finger plate expansion device

9.1.1 *FEM Analysis of Robust Finger Plate Connection Design*

In order to evaluate if the new expansion device design will behave as desired, detailed FEM analyses was conducted of the design. The model consisted of a 36 in width of one side of the finger plate expansion device. The load applied to the expansion device was 52.5 kips (12.5 kip design load times an impact factor of 100%, a live load factor of 1.75, and a multi-presence factor of 1.20) located over a 10 in. by 20 in. area at the center of the model beginning from the fingertip. The multi-presence factor is needed in the design of the dual support beams and was included in expansion device design for compatibility. The inclusion of the factor is conservative for the expansion device design. Other modeling assumptions were similar to those made in the Blanchette model. In order to understand the contributions of different design elements, three cases were analyzed: (1) steel only (no concrete and no rebars), (2) with bonded steel reinforcing bars (bars fixed to and extending through the vertical support plate), and (3) with unbounded steel bars (bars not attached to the vertical support plate), see Figure 9-4.

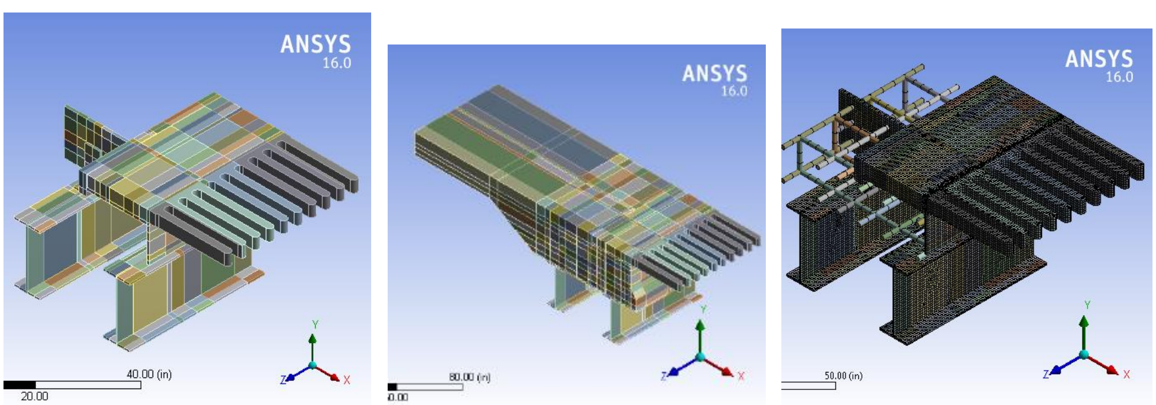


Figure 9-4: Three cases for model of robust finger plate expansion device design

Figure 9-5 show the stress contours of different parts of the model. It can be seen that the critical stress concentration is found at the location of the bolts between the finger plate and support plate, the weld between the horizontal and vertical support plates, and the reinforcing bars to vertical plate intersection points. Table 9-44 shows comparison between stresses at these critical locations shown in Figure 9-6. The existence of concrete reduces the stresses on the embedded steel plates, for example at location 5 the stress value was dropped from 25 ksi to 9.55 ksi. This shows that the concrete slab is acting to restrain the expansion device. If it is assumed that the steel reinforcing bars are perfectly bonded to the vertical support plate, the stress at the bolt location drops to -2.78 ksi, indicating that almost all the stress can be transferred to the concrete. This can also be seen in locations 10 and 11, which depict the force transmitted by the angles. The actual condition is likely to be somewhere between these bounds. The concrete is also effective at reducing the stresses in the front of the anchor plate T. In this location the stress reduced from -5.8 ksi to about 1.2 ksi indicating that the concrete transfers the compressive stress resulting from the rotation of the expansion device.

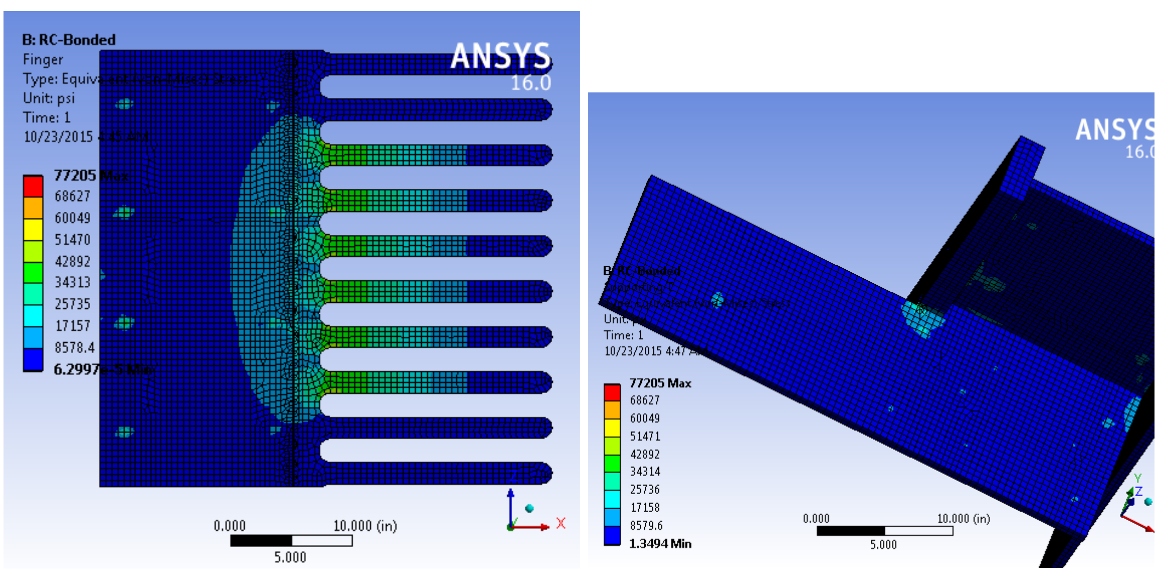


Figure 9-5: Stress contours for robust finger plate expansion device design

Table 9-4: Stress at key locations in robust finger plate expansion device design

Location	Description	Type	No concrete	Bonded steel bars	UnBonded steel bars
1	Front of the support plate T	Stress, σ_y (ksi)	-5.28	1.34	1.11
2	Back of the support plate T	Stress, σ_y (ksi)	3.27	3.83	4.04
3	Support plate Maximum	Stress, σ_y (ksi)	6.05	5.55	5.36
4	Critical finger plate bolt location	Stress, σ_{von} (ksi)	22.43	21.43	22.9
5	Critical support plate bolt location	Stress, σ_y (ksi)	25	-2.78	9.55
6	Steel rebar to support plate critical points (Bottom)	Stress, σ_y (ksi)	25	-8.09	2.15
7	Steel rebar to support plate critical points (Top)	Stress, σ_y (ksi)	-	15	9.3
8	Anchor to support plate critical points (Sec I)	Stress, σ_y (ksi)	-51.76	-2.68	-9.82
9	Anchor to support plate critical points (Sec II)	Stress, σ_y (ksi)	-	6.56	4.98
10	Vertical Force Transmitted by Angle I	Force (kip)	53.25	11.72	15.68
11	Vertical Force Transmitted by Angle II	Force (kip)	-105.6	-0.37	0.68

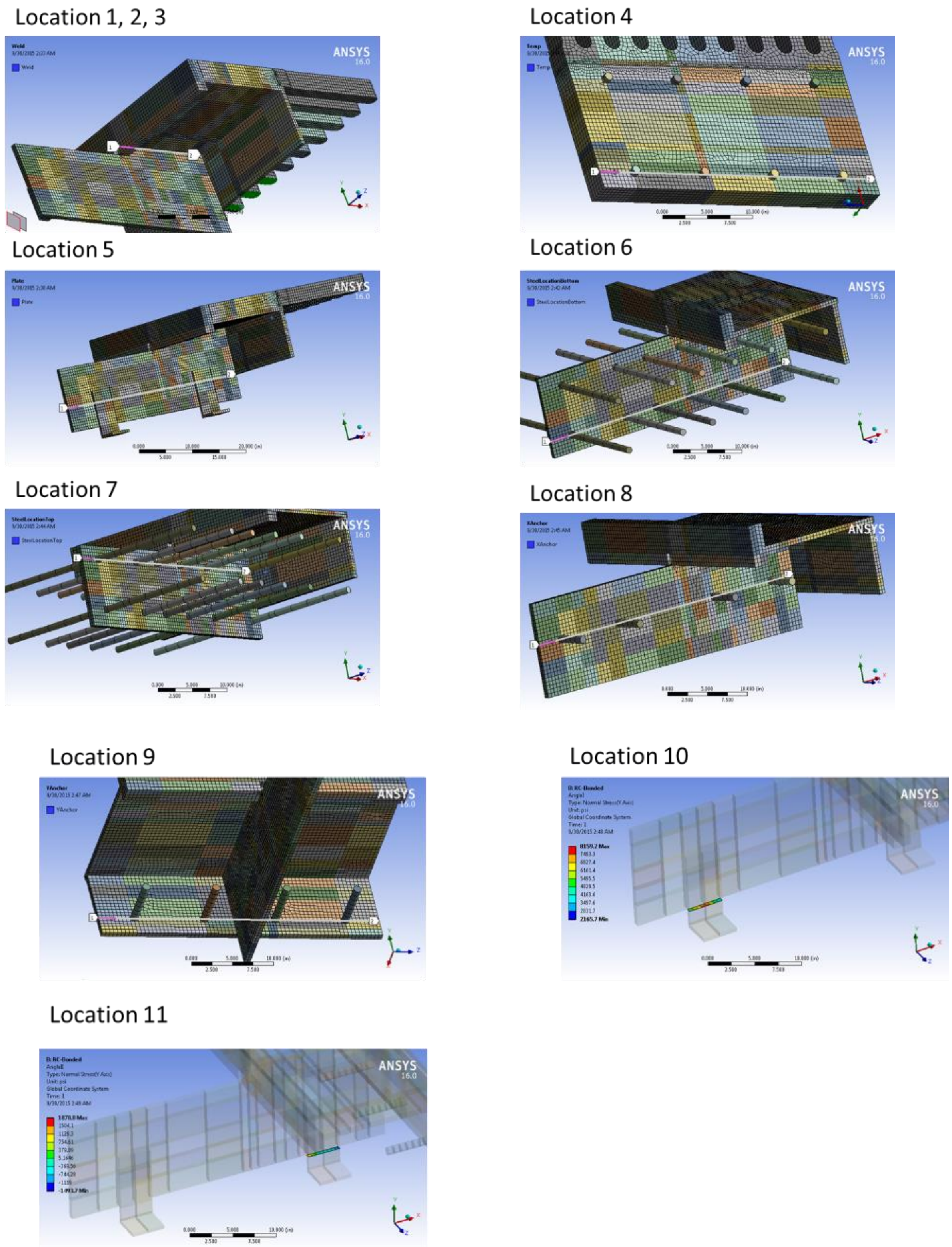


Figure 9-6: Key locations for FEM analysis

9.2 *Modified Finger Plate Expansion Device Design*

The modified finger plate expansion device design is based largely on the current finger plate design, but with a few modifications to help improve performance. We recommend modifications to the current MoDOT finger plate expansion device details including a thicker finger plate, a larger support beam for steel girders, changing the welded connection to a bolted connection, increased expansion device alignment adjustability, and a tighter support beam stiffener spacing of 12" for steel girders. We recommend changing the support of the finger plate for concrete girders to a series of support plates with dual anchorage into the girder and the concrete end diaphragm. In addition to these changes we recommend the final alignment of the expansion device should not be set until the majority of the deck concrete has been placed by leaving a block out at the expansion device. After the final alignment is set, concrete should be placed in the block out to complete the bridge deck and stabilize the expansion device. Prior to placement of the block out concrete, the expansion device should be adjusted by the contractor and checked by MoDOT construction personnel similar to the procedure outlined for the robust finger plate device.

As part of the modified finger plate expansion device details we recommend replacement of the welded connection between the finger plate and support beam with a bolted connection that will provide greater fatigue resistance. The top flange welds between the support beams and the finger plate will be replaced with a series of counterbored 7/8" diameter bolts with nuts welded to the underside of the top flange of the support beams. To help facilitate this connection change on steel girders, the support beam shall be increased in size from a W14x43 to a W18x130 rolled section and the finger plate itself shall be increased to a minimum thickness of 1¾" to allow for the recessed bolt holes. The W18x130 rolled section has a larger flange width which allows for the bolts to be spaced at a greater distance away from the centerline of the support beam which in turn reduces the stress at the bolt lines. This reduced stress allows for the bolts to be spaced further apart along the expansion device. The support beam size was designed to carry LRFD loading for infinite fatigue life with a 10'-6" girder spacing on a 60° skew. To further reduce the stress that the bolted connection between the finger plate and the support beam undergoes, the stiffener spacing will be reduced to 12". By decreasing the stiffener spacing the flanges will experience less rotation and result in a reduction in stress. The connection to concrete girders should be changed to replace the welded attachment to the support angle with a bolted attachment to a wider support plate. For a 1¾" finger plate with 12" stiffener spacing, 7/8" diameter bolts spaced 7" along the bridge and 9" across the support beam the expansion device can accommodate total movements of 8½" and skews up to 60 degrees. This equates to a 605 foot expansion length for a steel girder bridge or 819 foot expansion length for a concrete girder bridge. Expansion device movements exceeding 8½" will need to be accommodated with a different expansion device system such as the proposed robust finger plate expansion device or a modular expansion joint system.

Increased expansion device alignment adjustment for steel girders will be provided through the addition of a series of slotted holes and bolted connections and threaded support rods. Proper alignment of opposing finger plates is crucial to ensure the applied wheel loads are shared across the expansion device. The piece of C15x33.9 used in the current MoDOT standard details is replaced by a ½" bent plate which will be field drilled to make the connection to the steel girders allowing for alignment parallel and transverse to traffic. Similarly, the opposite end of the bent plate connected to the support beam will consist of four 13/16” x 1½” vertically slotted holes allowing for vertical adjustment. The addition of threaded support rods will facilitate rotational adjustment but will require an increase in the depth of the web coping. This threaded rod connection will be present on both sides of the expansion device between the support beam and the piece of W18x130 bolted to the support stiffeners. Longitudinal adjustment will be accommodated with slotted holes in the bottom flange of the support beam and transverse adjustment will be accommodated with slotted holes in the top of the piece of W18x130. Examples of these modifications applied to steel girders at an intermediate bent are shown in Figures 9-7 and 9-8.

Increased expansion device alignment adjustment in concrete girders can be accomplished by raising the support plate away from the top of the girder and adding a nut to the top and bottom of the support plate. This will allow vertical and rotational adjustment. Slotted holes in the top of the girder or concrete diaphragm as well as slotted holes in the bottom of the support plate will allow longitudinal adjustment. Transverse adjustment would be limited to the placement of the anchorage bolts in the slotted holes in the girder similar to the current standard designs. Welded studs between the support plates would continue to be utilized to provide additional support. Examples of these modifications applied to concrete girders at an intermediate bent are shown in Figures 9-9 and 9-10.

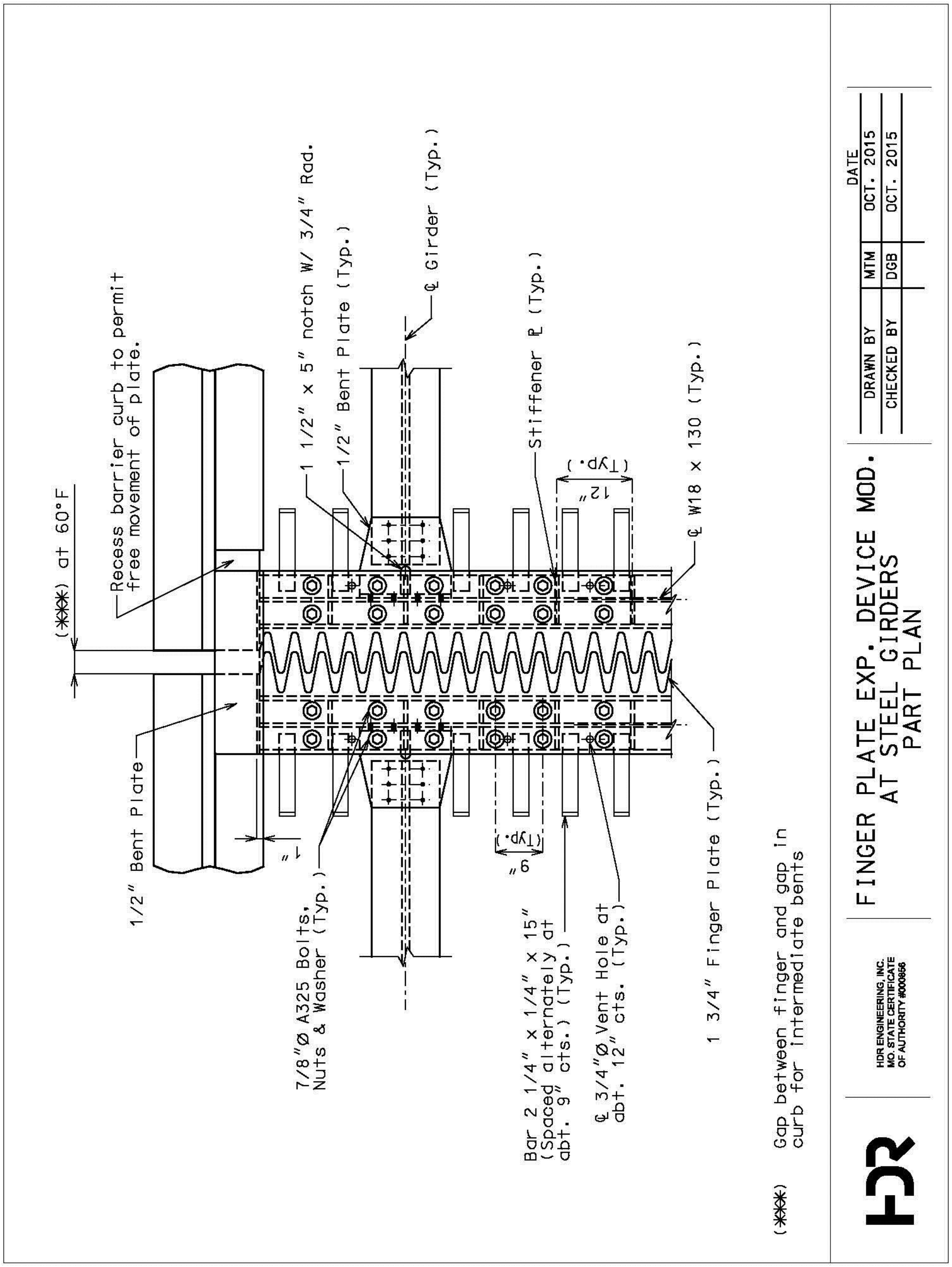


Figure 9-7: Plan of modified finger plate expansion device for steel girders

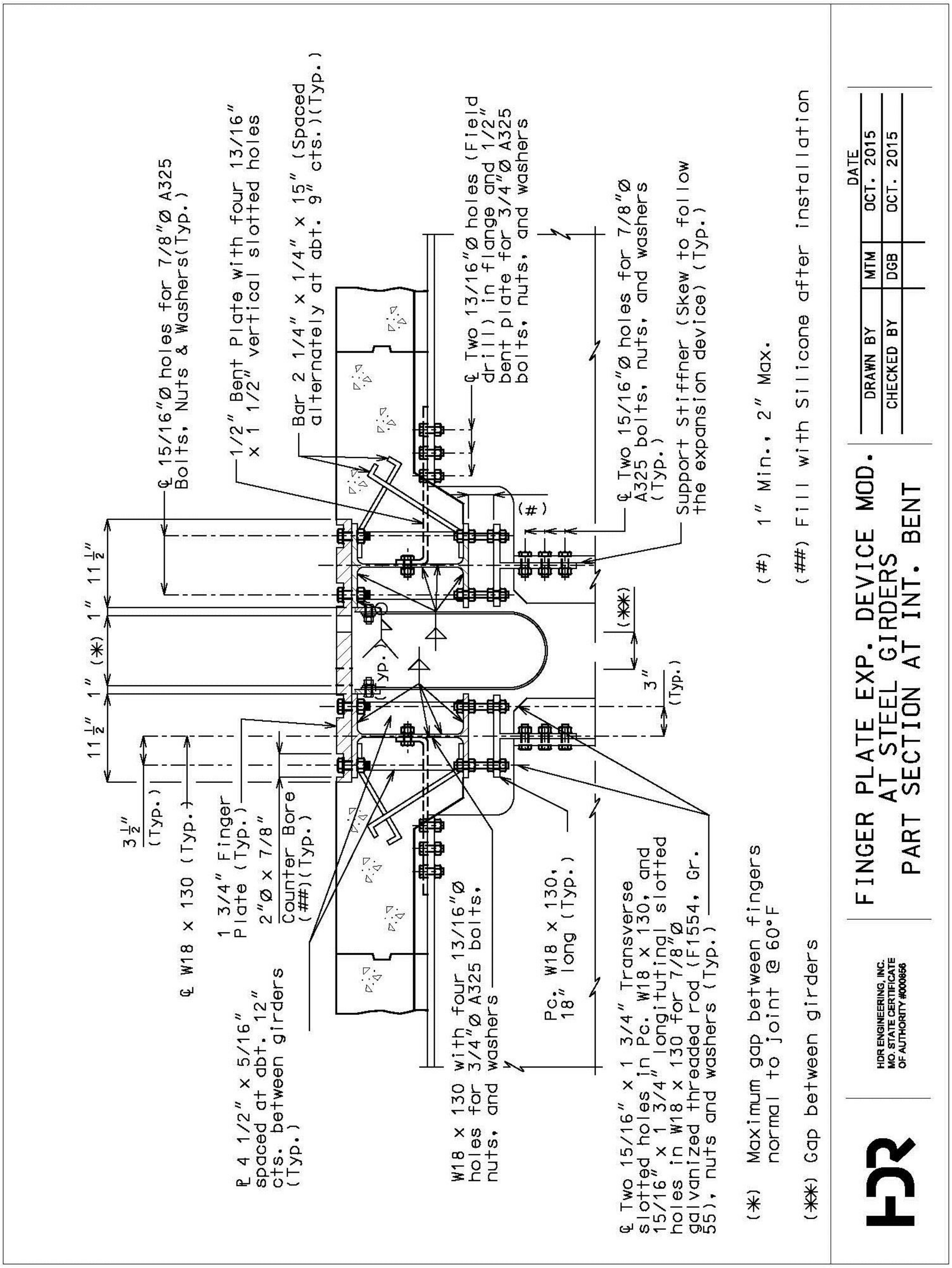


Figure 9-8: Section of modified finger plate expansion device for steel girders

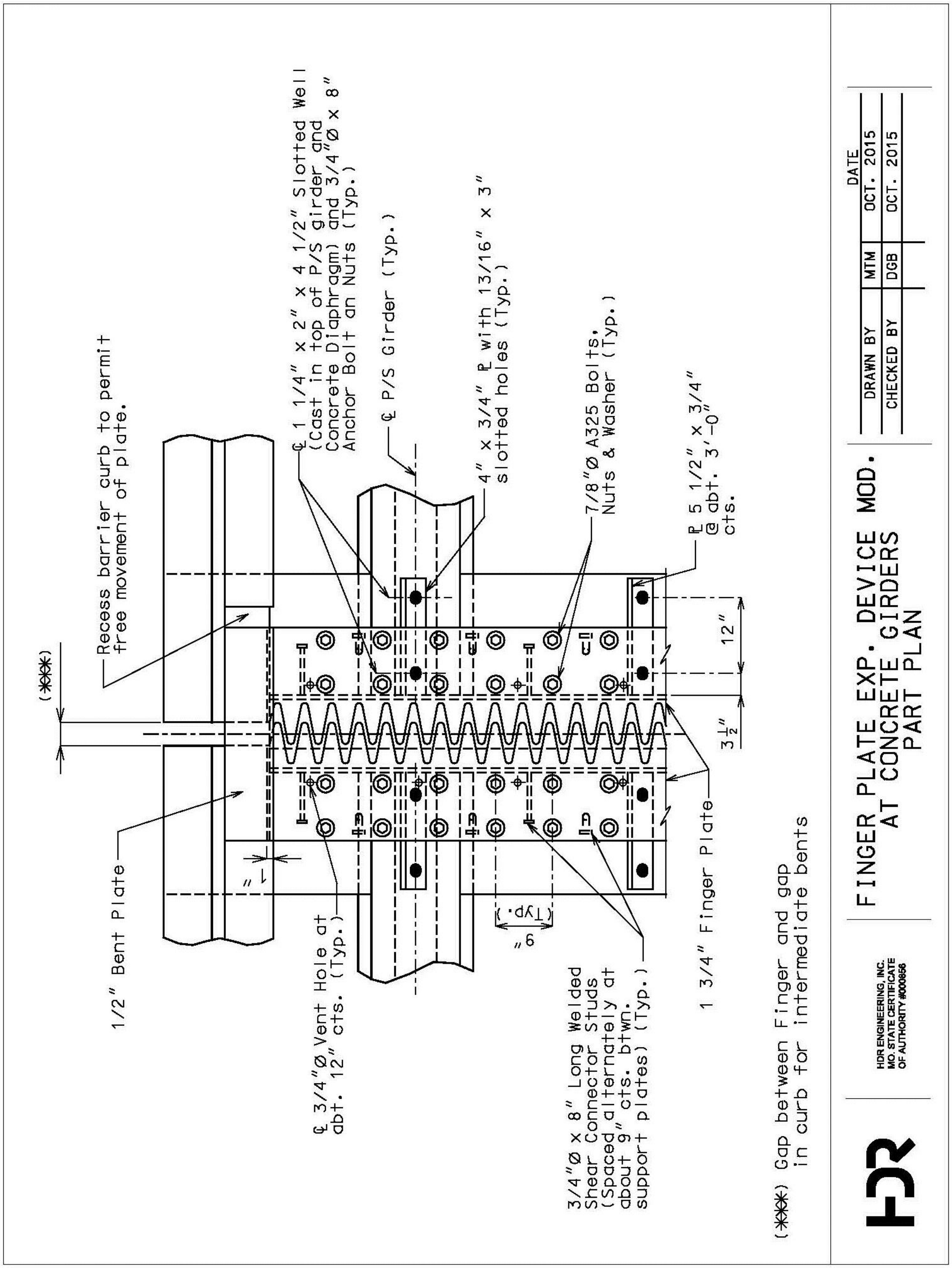


Figure 9-9: Plan of modified finger plate expansion device for concrete girders

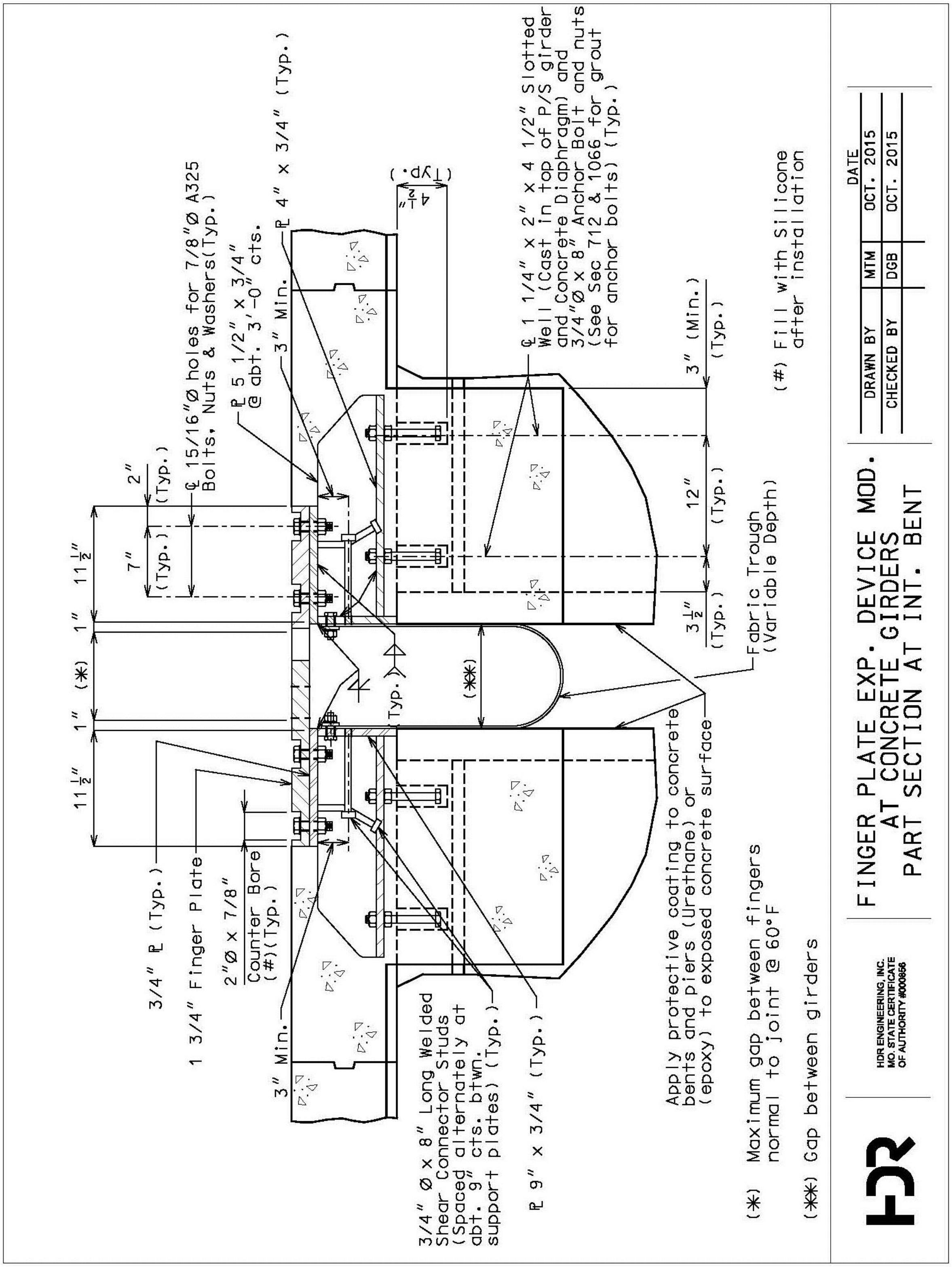


Figure 9-10: Section of modified finger plate expansion device for concrete girders

9.3 Finger Plate Expansion Device Retrofit Design

MoDOT has had several instances of finger plate expansion device failure and has applied a variety of repair methods. Most of the repair methods include replacing the weld between the finger plate and the support beam. We propose to modify the connection to a bolted design that will have increase fatigue resistance. 1" diameter tension control bolts should be applied to the front side of the support beam at spacing no greater than 4½". Tension control bolts have a rounded head that should eliminate issues with passage of vehicles, especially snow plows. To improve the ride-ability of this repair option these bolts should be placed in a shallow recess bored into the top of the finger plate. The recess will reduce the protrusion of the bolt head above the finger plate and prevent snagging on the short vertical side of the bolt head. Tension control bolts have a splined end and are tightened from one side with use of a special wrench that holds the bolt while turning the nut. The splined end is calibrated to shear off when the bolt reaches full tension. The fully tensioned bolts will provide pre-compression of the finger plate to the support beam and replace the front side weld while reducing the load carried by the back side weld. Since these bolts cannot prevent uplift of the back side of the finger plate they will not eliminate the tensile stress in the back side weld but will reduce the stress below the infinite life fatigue range. Since the bolts cannot prevent uplift of the back side of the finger plate, this method will work best in situations where the back side weld has not broken. If the back side weld has broken, 1¼" holes should be drilled and plug welds should be placed to hold the back edge of the finger in contact with the support beam.

The proposed bolted connection will carry more load on the front half of the support beam flange. To maintain stability of the expansion device additional stiffeners should be placed along the support beam. The existing standard details place the stiffeners at about 3’-0” centers. The preferred stiffener spacing is 12” with a maximum spacing of 18”. Details of the proposed retrofits are shown in Figures 9-11 and 9-12. The bolt spacing near the stiffeners is limited to 4½” to provide clearance to install the adjacent bolts. The capacity of the 1” diameter bolts at 4½” spacing limits the applicability of this retrofit option to finger plate expansion devices with 10½” fingers measured from the edge of the support beam flange. Failures in finger plate expansion devices with fingers longer than 10½” should be temporarily repaired using existing methods and scheduled for replacement.

As noted above, the retrofit uses tension control bolts which must be installed with special tooling. This tooling requires more clearance than standard tools and will limit the placement of the bolts. A practical test of this retrofit option will be performed on an active bridge near Springfield, MO in the near future. Additionally, personnel at the University of Missouri plan to create a full size model of a section of finger plate expansion device and test this retrofit option in the lab. The laboratory testing was not part of the original scope of the project and is scheduled for next spring after the submittal of the final report.

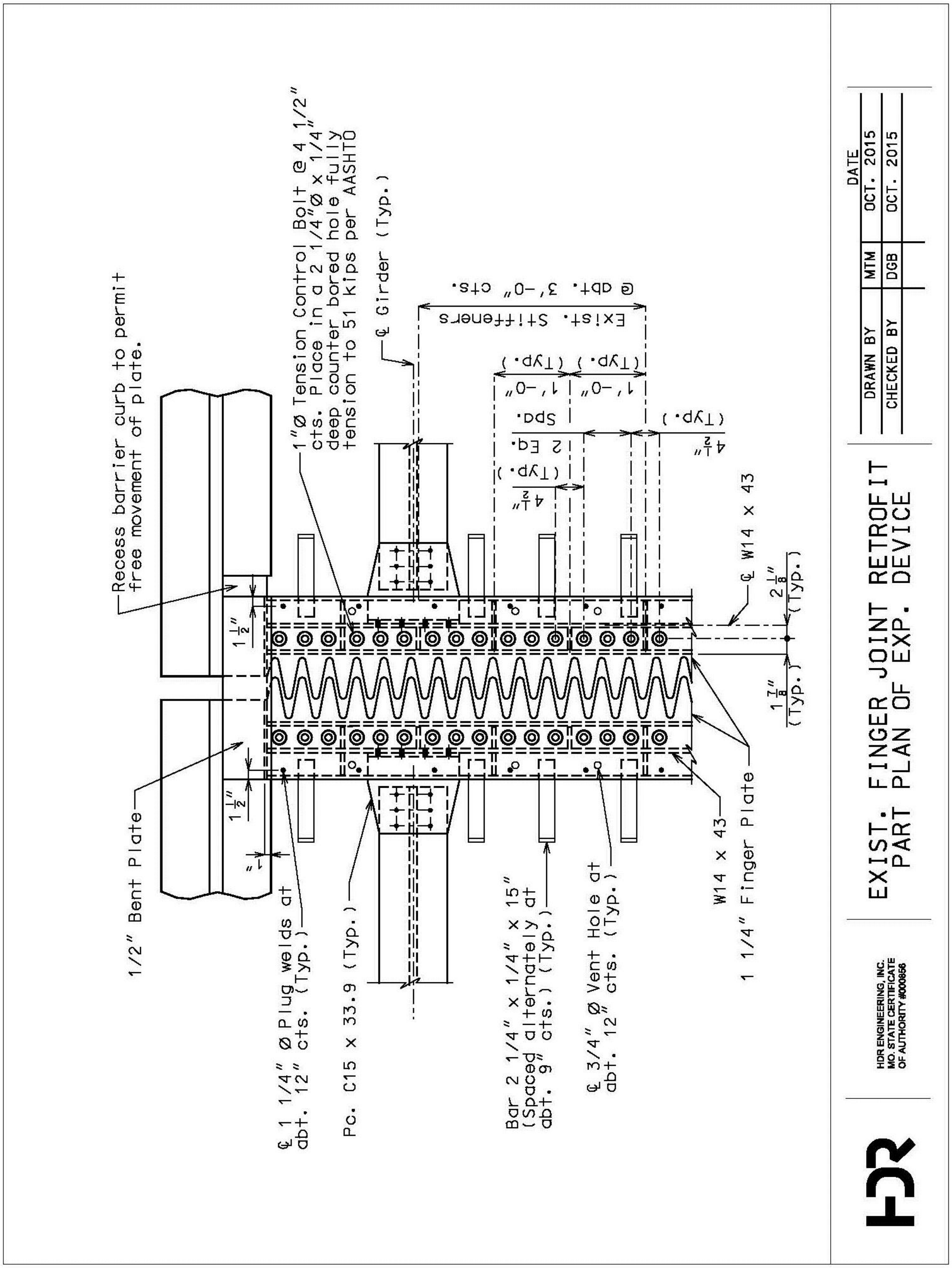


Figure 9-11: Plan of retrofit finger plate expansion device

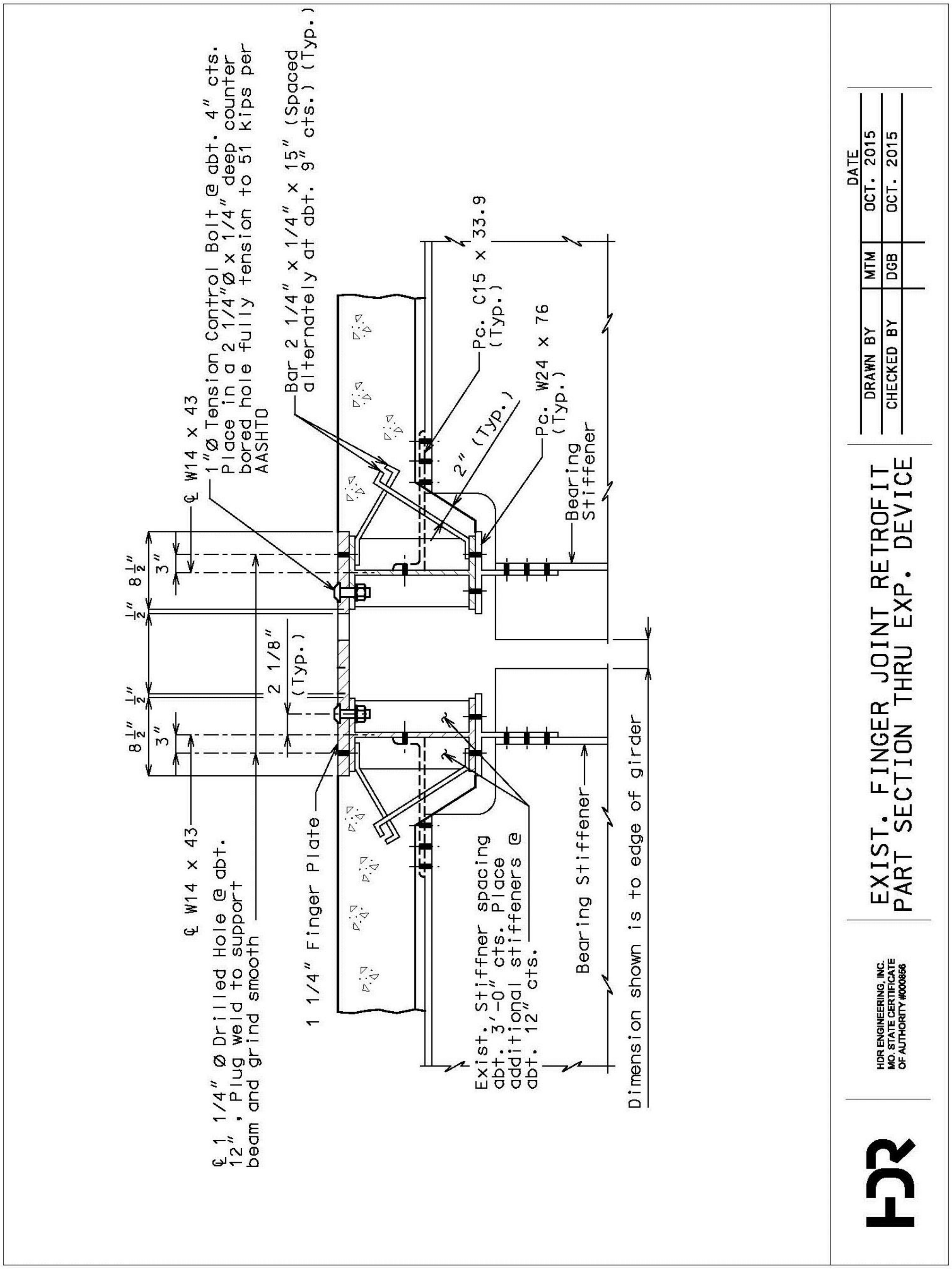


Figure 9-12: Section of retrofit finger plate expansion device

9.3.1 FEM model of finger plate retrofit design

In order to understand the effect of the retrofit changes the model of the Blanchette Bridge expansion device was modified to include the possible retrofit changes. The wheel load was increased to the design wheel load of 52.5 kips. An image of the stress contours under the retrofit bolts is shown in **Error! Reference source not found.**13. Analysis of the model with the bolts and the assumption that the back weld between the finger plate and support beam is fractured showed significant stress (86 ksi) in the support beam flange at the stiffener location as shown in **Error! Reference source not found.**14. This is because the support beam flange is required to carry twist caused by the load at the tip of the fingers. Due to the lack of the back side weld the back of the finger plate also lifts off the support beam as shown in **Error! Reference source not found.**15. These results indicated the need to attach the back of the support plate to the support beam.

In the case where the back side weld is still intact, the maximum von misses stress in the support beam flange reduces from 34.4 ksi to 18.565 ksi and the joint performs well.

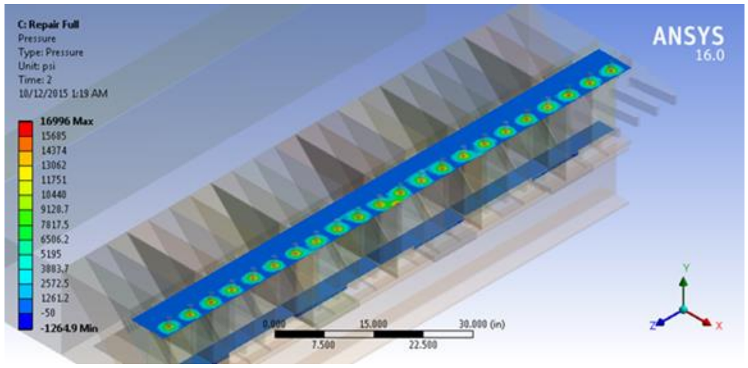


Figure 9-13: Stress concentration at bolt locations

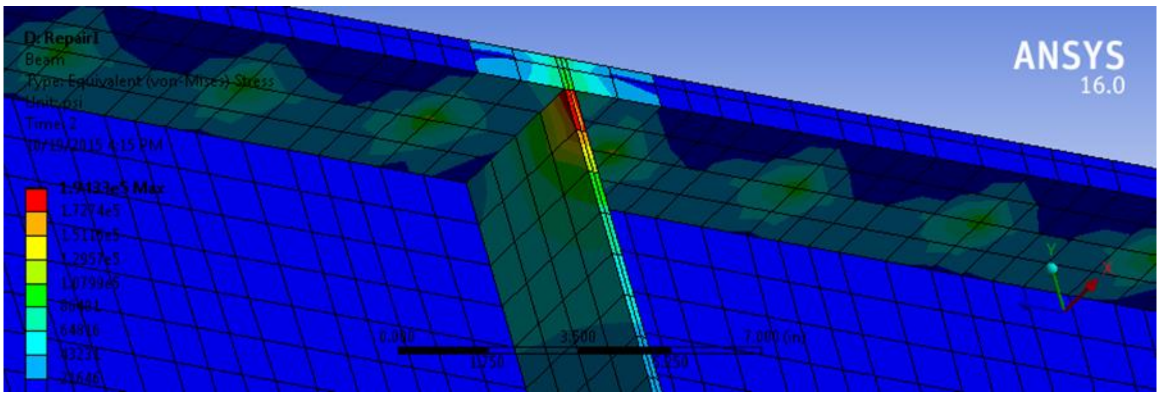


Figure 9-14: Stress in support beam flange above stiffener

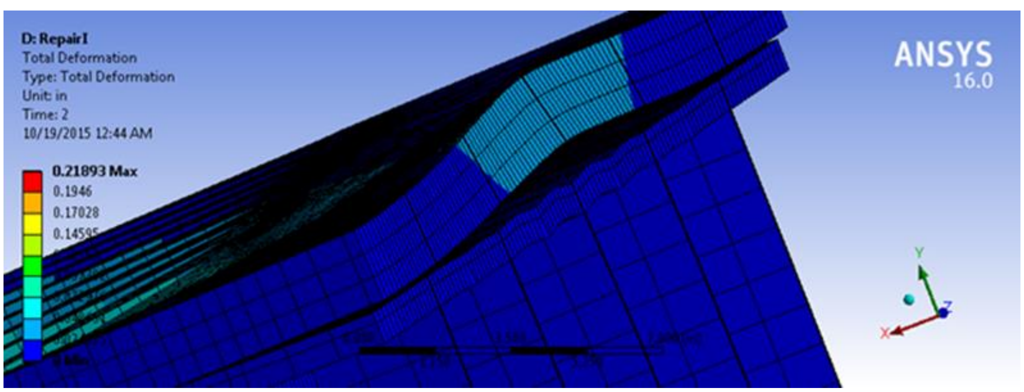


Figure 9-15: Pull up of back side of finger plate

10 FLAT PLATE DESIGNS

Researchers evaluated the causes for deterioration of the existing flat plate connections and possible design improvements. The primary cause of failure is overstress due to stress concentrations caused by misalignment of the expansion device during construction. It was determined that the best solution would be a robust design with the sliding plate bolted to a support structure similar to the KDOT sliding plate expansion device shown in Figure 10-1. From past experience with these expansion devices they are known to be almost as expensive as the robust finger plate expansion device proposed in section 9.1 and will not be an economical solution to mid-range bridge movements. Therefore, the proposed flat plate expansion device keeps most of the current detailing at the deck surface but provides increased adjustment during installation to maintain proper alignment.

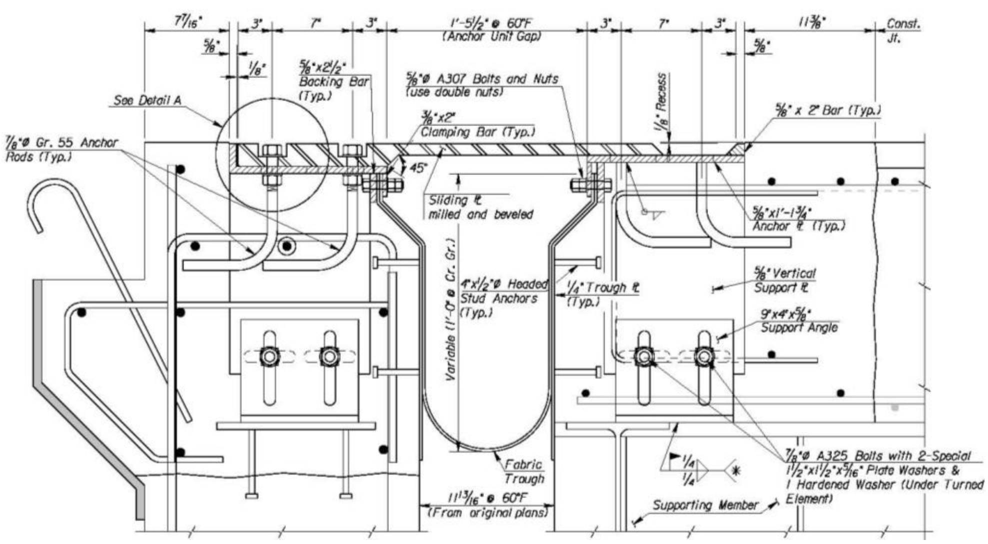


Figure 10-1: Kansas DOT sliding plate expansion device standard detail

10.1 New Flat Plate Expansion Device Design

To address the misalignment of the flat plate expansion devices during construction additional adjustability is needed. In addition, the region of the deck near the expansion device should not be placed monolithically with the remainder of the deck but rather a block out near the expansion device should be made. While the block out will create a cold joint in the bridge deck it will allow the rotation of the span to occur prior to setting the expansion device. The properly aligned expansion device will provide additional durability for the bridge as a whole and offsets the durability concern of including a cold joint.

The intent of the modified flat plate detail is to provide additional adjustability to maintain the alignment of the expansion device prior to a closure pour of the concrete deck. Currently the expansion device can be adjusted longitudinally and vertically. The new detail maintains these adjustments while also providing transverse and rotational adjustment capability to maintain parallelism between the support angle and the sliding plate. Modifications required to add this adjustability include the removal of the two lower support angles and the addition of a leveling apparatus that connects to the top flanges of the girders. Prior to placement of the block out concrete, the contractor should align the expansion device in a similar manner to the robust finger plate devices noted previously and the alignment should be verified by MoDOT construction personnel. It can be seen in Figures 10-2 and 10-3 that the leveling apparatus is comprised of a set of welded plates with slotted bolt holes and two rows of threaded rods. Vertical, longitudinal and transverse adjustment is provided by a series of slotted holes in the new welded plate supports and in the 6” vertical plate and the vertical leg of the support angle.

The threaded rods can be adjusted prior to the closure pour to provide rotational adjustments, ensuring that the flat plate will bear adequately on the support angle. This will eliminate out of plane stresses along the top plate weld that are currently present when the concrete sets with the expansion device in the improper position.

Taking a closer look at the proposed leveling apparatus, it can be seen that it consists of two ½" thick plates welded together perpendicularly in the shape of a "T". The top of the "T" is connected to either the support angle or the vertical 6" plate through the use of ¾" diameter machine bolts and nuts. The support angle and vertical plate will be slotted horizontally, while the new ½" thick plate forming the top of the "T" will be slotted vertically. Welded on to the stem of the "T" will be four ½" thick plates with slotted holes parallel to traffic for 3/4" diameter threaded rods and nuts. The leveling apparatus will be present at each girder on both sides of the expansion device. While the new support detail is shown attached to steel girders in Figures 10-2 and 10-3 it can be made compatible with prestressed concrete girders by modifying the "T" plates to an "L" shape and using an embedded attachment to the top flange similar to the current details for prestressed concrete girders. The "T" shape support can also be modified for use at end bent locations by embedding the threaded rods into the backwall at the upper construction joint.

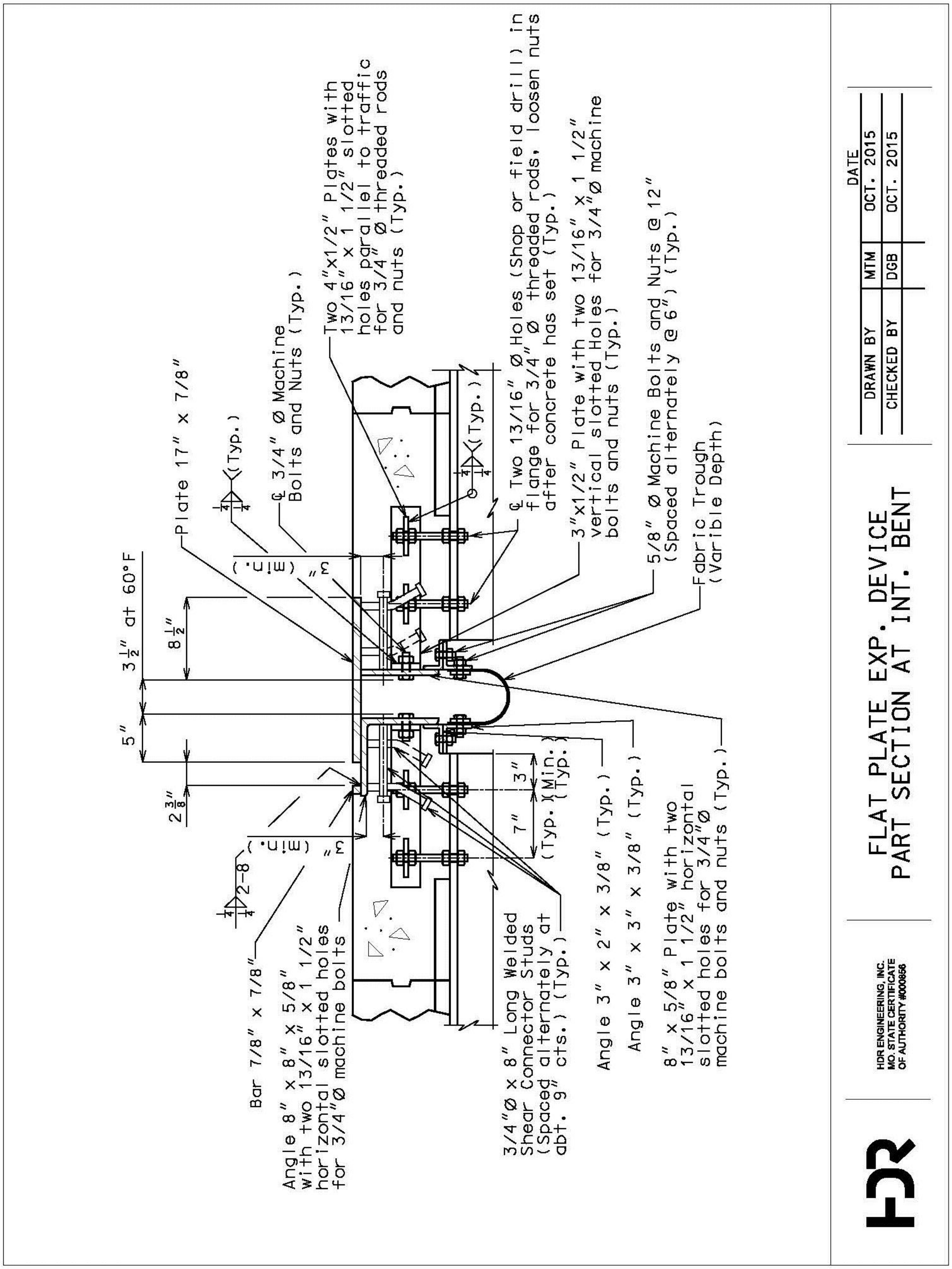


Figure 10-2: Part section of proposed flat plate expansion device

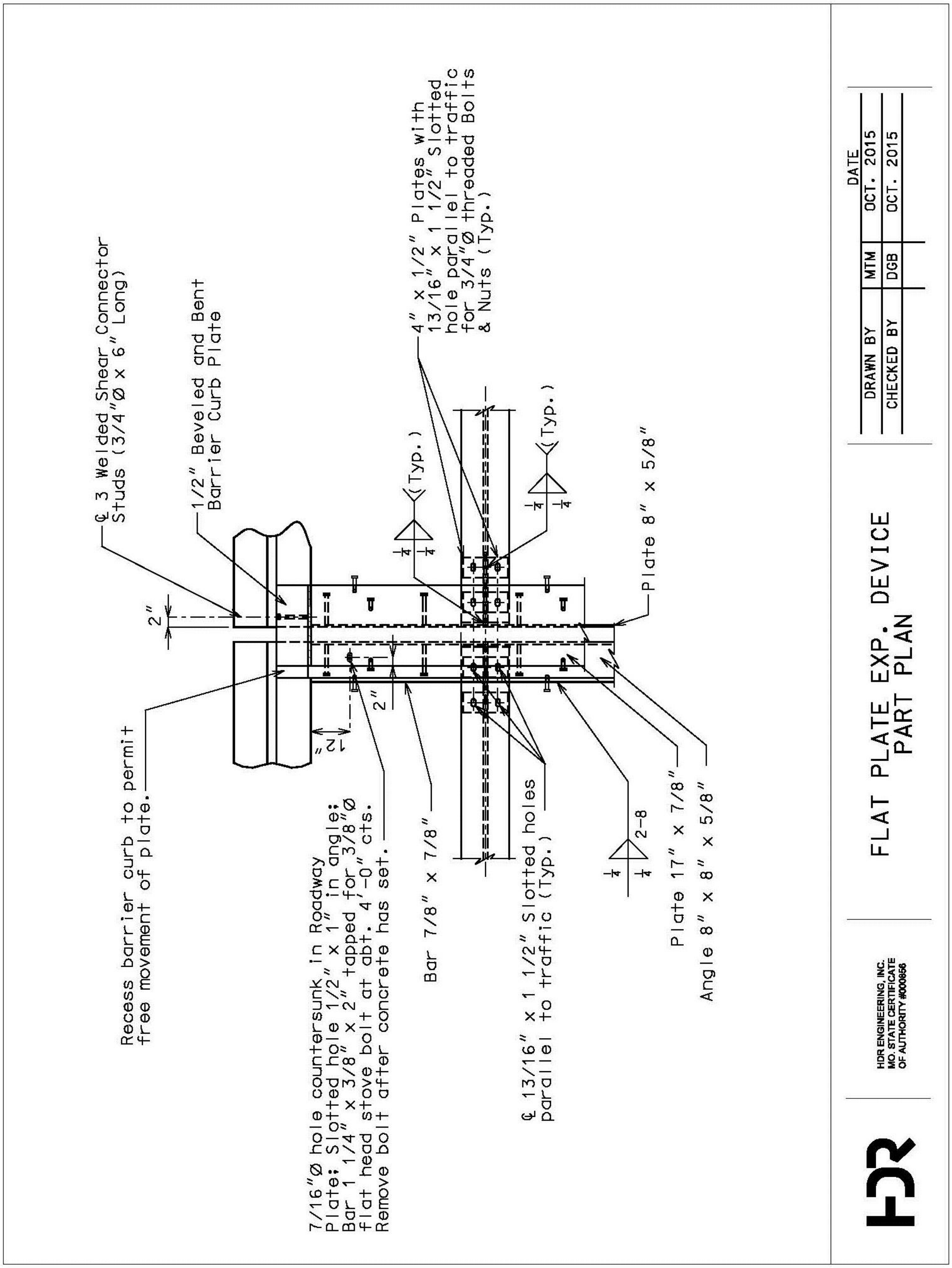


Figure 10-3: Part plan of proposed flat plate expansion device

11 CONCLUSIONS

This project evaluated causes of premature deterioration of MoDOT finger plate and flat plate expansion devices and then used that information to design new Load and Resistance Factor Design (LRFD) finger plate and flat plate expansion devices that are intended to last 40 years or more with minimal maintenance. In addition, repair and retrofit best practices and details were developed.

The main contributions to the failure of the finger plate expansion devices were found to be fatigue failure of the weld between the finger plate and the support beam as well as vertical misalignment due to poor construction. The dynamic impact of truck traffic was also found to be a contributing factor. The failures of flat plate expansion devices were generally initiated by misalignment of the sliding plate and support angle due to rotation in the bridge span or poor alignment during construction.

Experimental testing was conducted on the finger plate device on East-bound Blanchette Bridge on Highway I-70 in St. Louis and the flat plate expansion device on Route 350 passing over Highway I-435 in Kansas City. The test results showed dynamic impact in the finger plate device is generally between 40% and 70% and could be as much as 160% and the effect of misalignment of the fingers can result in an increase in stress of up to 30%. Based on these findings it was recommended to increase the Dynamic Load Allowance for expansion devices from 75% recommended in AASHTO to 100%. The results were used to validate Finite Element Models (FEMs) of the current expansion device designs. The FEM models showed high stresses in the weld between the finger plate and support beam concentrated over the stiffener location and a significant reduction of those stresses if additional stiffeners are added. Testing of the flat plate device showed that significant stresses build in the sliding plate due to the differential movements of the abutment and bridge span.

The new robust finger plate expansion device was designed for LRFD loading and infinite life fatigue and an increase Dynamic Load Allowance of 100%. The elements of the expansion device were sized to accommodate a maximum expansion movement of 16” and can be utilized with girder spacing up to 12’-0” and 60° skews for steel girders or 20° skews for concrete girders. The devices were conservatively designed using classical analysis methods and the designs were verified with the FEM models. The new finger plate expansion device is intended for use on high volume or important routes as an alternate to Modular Expansion Device Systems for bridge widths up to 189 feet. A Modular Expansion Device System should be used for bridges wider than 189 feet.

Improvements for the existing finger plate expansion device design are also recommended for use on lower volume routes with lower traffic volumes. The modifications to the existing finger plate standards were designed for LRFD loading with an increased Dynamic Load Allowance of 100% similar to the robust finger plate expansion device. The modifications to the existing standards can be used with expansion lengths up to 8½” and girder spacing of 10’-6” and 60° skews. The existing flat plate expansion device designs were modified to include adjustability of the device prior to concrete placement. Flat plate expansion devices can continue to be used with all MoDOT standard girder spacing and skews up to 60°. Repair and retrofit best practices and details consisting of a bolted design with a rounded head on the expansion gap side that can be implemented without concrete deck removal were developed for existing finger plate expansion devices.

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11. Bridge A4017 Finger Plate Repair Options. HDR Engineering.

Appendix A – Finger Plate and Flat Plate Expansion Device Survey

1) States that Responded to Survey (22)

Kansas, New Mexico, Tennessee, Hawaii, North Dakota, Illinois, Alabama, Vermont, Florida, Montana, Alaska, South Dakota, New York, Iowa, Michigan, Nevada, Maryland (SHA), Maryland (MDTA), Minnesota, Rhode Island, Pennsylvania, Arkansas

2) States that do not use finger or flat plate expansion devices (6)

New Mexico, Tennessee, Hawaii, South Dakota, New York, Minnesota

3) States which use standards detail for finger and flat plate expansion devices (7):
Kansas, Maryland (SHA), Maryland (MDTA), Illinois, Alabama, Pennsylvania, Arkansas

Standard Finger or Flat Plate expansion device details:
Kansas
http://ut1.qualtrics.com/WRQualtricsControlPanel/File.php?Filename=Chapter+14+Devices+and+Bearings.pdf&Size=129063&Type=application%2Fpdf&F=F_8jrHKJXNkaKVtel

Maryland
http://ut1.qualtrics.com/WRQualtricsControlPanel/File.php?Filename=10_Super-Roadway-Devices.pdf&Size=4268346&Type=application%2Fpdf&F=F_73d1Mo33pG274nX

http://apps.roads.maryland.gov/BusinessWithSHA/bizStdsSpecs/obd/BridgeStandards/index.asp

http://apps.roads.maryland.gov/BusinessWithSHA/bizStdsSpecs/obd/BridgeStandards/Bridge_Standards/10_Super-Roadway-Devices2853/PDF/SS321a_1.pdf

Illinois
http://www.idot.illinois.gov/Assets/uploads/files/Doing-Business/Manuals-Guides-&-Handbooks/Highways/Bridges/Bridge%20Manual%202012.pdf

Pennsylvania
ftp://ftp.dot.state.pa.us/public/Bureaus/BOPD/Bridge/2014/BC/BC762M.pdf

Arkansas
https://missouri.qualtrics.com/CP/File.php?F=F_5nWYPK6hr9nBi2p

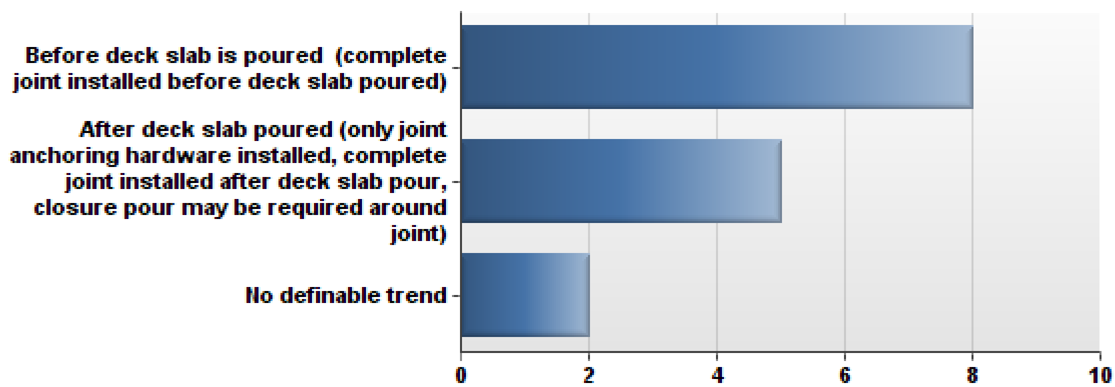
4) States which use LRFD specifications for finger and flat plate expansion devices (12)
Alaska, Florida, Illinois, Iowa, Kansas, Maryland (SHA), Michigan, North Dakota, Rhode Island, Texas, Pennsylvania, Arkansas

5) States that use a proprietary finger or flat plate expansion device design
None – one state indicated that they had in the past

6) States using a drainage trough below open expansion devices (13) – How often are troughs flushed?:
Alabama – Assumed to be flushed during inspection cycles unless report between cycles indicates debris needs removed.
Florida – When reported as being needed during routine inspection.
Illinois – Unknown.
Iowa – Very infrequently.
Kansas – Never.
Maryland (SHA) – Rarely, Annually, Typically only when other work is being performed on the bridge.
Maryland (MDTA) – No response
Montana – Seldom.
North Dakota – Never.
Rhode Island – Rarely if ever.
Texas – We have used with and without troughs.
Pennsylvania – the performance target is yearly
Arkansas – almost never

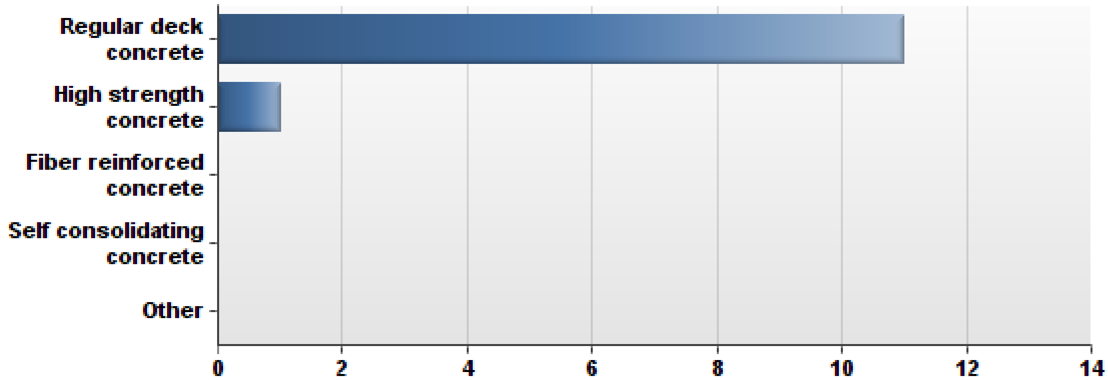
Expansion Device Installation process

7) When is finger or flat plate device installed?



Before deck slab is poured (8)
Alabama, Illinois, Iowa, Kansas, Maryland (SHA), North Dakota, Pennsylvania, Arkansas
After deck slab poured (only device anchoring hardware installed, complete device installed after deck slab pour, closure pour may be required around device (5)
Alaska, Florida, Maryland (MDTA), Montana, Rhode Island
No definable trend (2)
Michigan, Texas

8) Type of concrete material used for closure pour between device and deck slab



Regular deck concrete for closure pours (11)
Alabama, Alaska, Florida, Illinois, Kansas, Maryland, Michigan, Montana, Texas, Pennsylvania, Arkansas
High strength concrete for closure pours (1)
Rhode Island

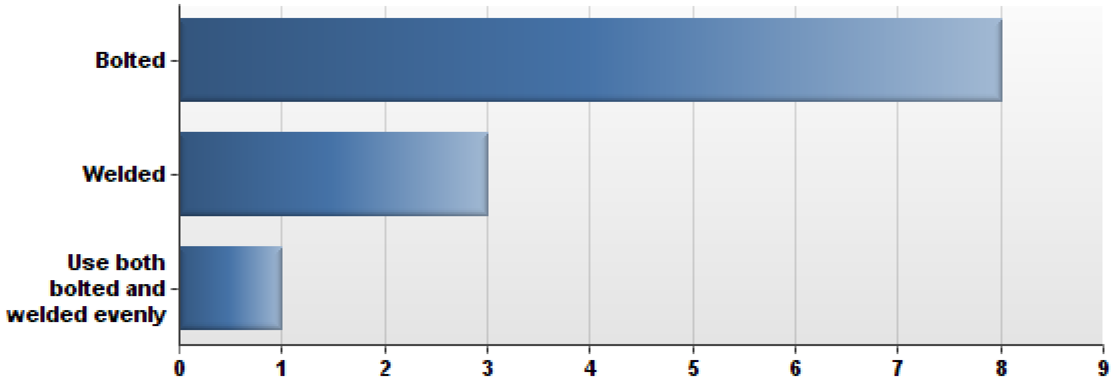
9) Specific installation procedures for finger plate or flat plate expansion devices:
Illinois – Device opening is based on procedure outlined in Article 520.04 of our Standard Specifications for Road and Bridge Construction
Kansas – Pour concrete around device from low elevation to high on both sides and in all lanes.
North Dakota – The deck side of the device is installed with the deck but the abutment side is placed with a cap that is placed on top of the abutment.
Arkansas - Finger device adjusted for grade & temperature prior to closure pours. Hand pack concrete under device armor.

Finger Plate Expansion Devices
10) States which use finger plate expansion devices (12)
Alabama, Florida, Illinois, Iowa, Maryland (SHA),Maryland (MDTA), Montana, North Dakota, Rhode Island, Texas, Pennsylvania, Arkansas

11) Allowable range of movement for your finger plate expansion devices:

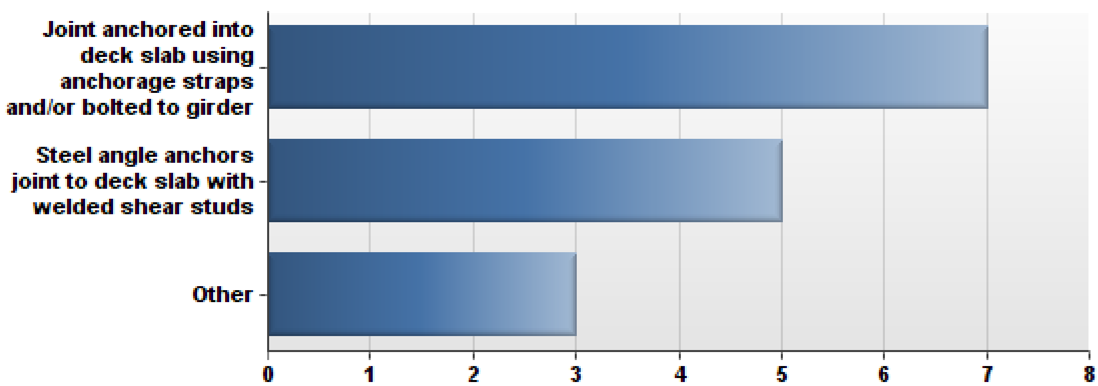
Alabama	2.5"– 6"
Florida	LRFD 14.5.3.2
Illinois	4" – 12"
Iowa	+/-4" to +/-10"
Maryland	Finger lengths are designed as part of standard to accommodate the needed movement.
Montana	4" – 9"
Rhode Island	Minimum 6"
Pennsylvania	Minimum is 5 in., a maximum is in the vicinity of 26 in., typical is 12 in.
Arkansas	4.5 to 6.5 in.

12) Type of connection between finger plate and support device



States using bolted connection (8):
Alabama, Florida, Illinois, Iowa, Kansas, Maryland (SHA), Maryland (MDTA), Montana
States using welded connection (3):
North Dakota, Rhode Island, Pennsylvania
State using both bolted and welded connections evenly (1):
Texas

13) Type of anchorage methods of finger plate device to bridge

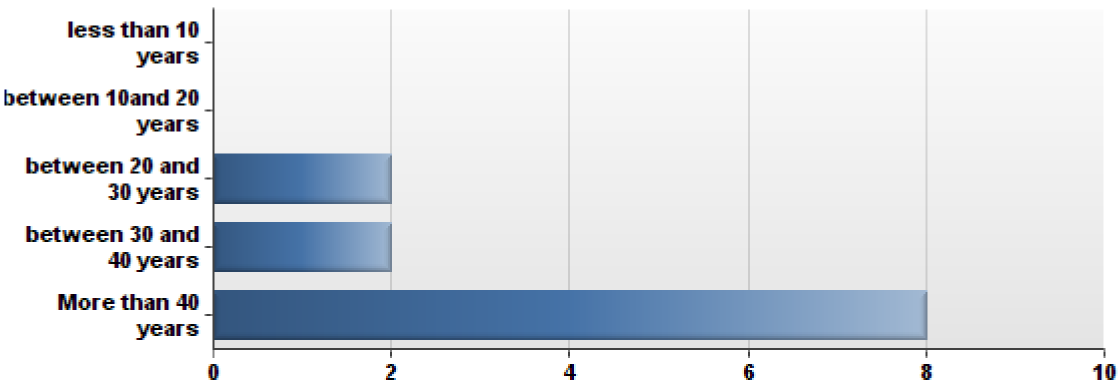


States using devices with anchorage straps and/or bolted to the girder (7)
Alabama, Iowa, Maryland (MDTA), Montana, North Dakota, Rhode Island, Pennsylvania
States using steel angle anchors with welded shear studs (5)
Florida, Kansas, Maryland (SHA), Texas, Pennsylvania
States using other anchorage methods (3)
Illinois – Device and trough plates connected to deck with welded shear studs. Stools connected to beam diaphragms with bolts.
Arkansas - Steel channels bolted to girder via welded connection plates and anchored to slab with studs. Finger plates also anchored to slab with studs.

14) Approximate cost (per linear foot) of finger plate expansion devices (includes material cost and labor):

Florida	$850-$1,500/foot
Illinois	$2,000/foot
Iowa	$2,000/foot
Kansas	$900-$1,500/foot
North Dakota	$2,000/foot
Rhode Island	$400/foot
Arkansas	$800/LF
Pennsylvania	$2100/LF

15) Expected design life for finger plate expansion devices



States with expected design life of 20-30 years (2)
Iowa, Kansas
States with expected design life of 30-40 years (2)
Maryland (SHA), Montana
States with expected design life of more than 40 years (8)
Alabama, Florida, Illinois, Maryland (MDTA), North Dakota, Rhode Island, Arkansas, Pennsylvania

16) States with the same design life for expansion device as bridge deck

States which **have** same design life for expansion device and bridge (9) 75%
Alabama, Florida, Kansas, Maryland (SHA), Maryland (MDTA), Montana, North Dakota, Arkansas, Pennsylvania
States which **do not have** same design life for expansion device and bridge (3) 25%
Illinois, Iowa, Rhode Island

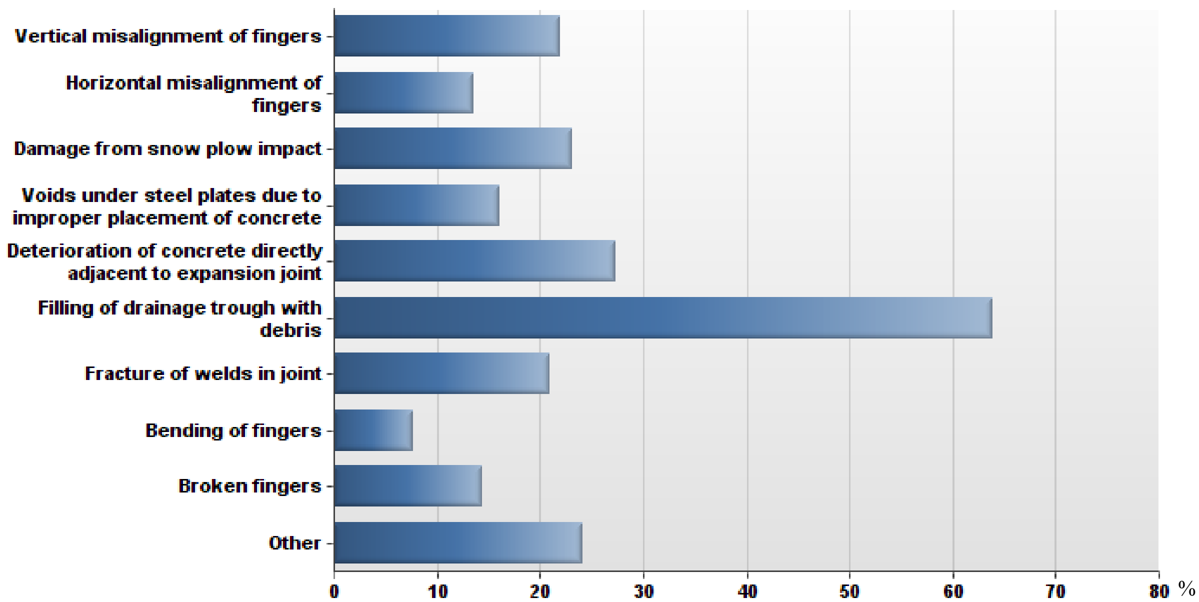
17) State which have had to replace expansion device before end of design life
States which **have** replaced expansion device before end of design life (9) 69%
Florida, Illinois, Kansas, Maryland (MDTA), Montana, North Dakota, Rhode Island, Texas, Arkansas
States which **have not** replaced expansion device before end of design life (4) 31%
Alabama, Iowa, Maryland (SHA), Pennsylvania

18) Percentage of finger plate devices which experience a shorter than desired life:

Average answer =12%

Florida	12%
Illinois	5%
Kansas	11%
Maryland (MDTA)	1%
Montana	9%
North Dakota	30%
Rhode Island	40%
Arkansas	8%

19) Mechanisms of damage that have been noticed:



*Other mechanism of damage: Bolts that hold the finger plate in place failed.

	Vertical Misalign (%)	Horz. Misalign (%)	Snow Plow (%)	Voids (%)	Deterioration (%)	Filling of trough (%)	Fracture (%)	Bending (%)	Broken (%)	Other (%)
Alabama						30				
Florida	20	20		45	40	50	15	10	10	
Illinois	25		25		10	50			2	
Iowa	5	5	10		40	70				
Kansas	8	42	11	25	13	85	2	5	43	
Maryland	10	10	10	10	11	75	1		5	
Maryland	29	30	50		19	100	40	3	15	
Montana	0	0	5	6	40	100	5	0	0	
North Dakota	71					7	18			24
Rhode Island	61	0	81	0	81	81	81		29	
Texas				25	31	5	31			
Pennsylvania	5		5		4	85	10			
Arkansas	5	0	10	0	10	90	5	20	10	

20) Repair cost (per linear foot) of finger plate expansion devices:

Florida	$400-$800
Illinois	$3,000/trough to clean, $400/ft for trough replacement
Kansas	>$1,000
North Dakota	$2,000
Arkansas	$500

21) Typical repair/rehab procedure/techniques for replacement of finger plate devices:

Florida – Reinstall achors/Remove and replace device/ reweld fingers and reinforce with cover plate.

Illinois – Self-explanatory.

Iowa – Is no typical repair

Kansas – Trough replacement is common.

Maryland (MDTA) – Unbolting and ensuring the plates are not bowed, replacing bolts that are not torqued.

Maryland (SHA) – Our finger devices are made of components. Typically we replace the finger component.

Montana – Reuse or replace in-kind-with additional anchors. Small movement < 5" may be replaced with strip seal, larger movements with modular device.

North Dakota – Replace with newer version.

Rhode Island – Breakout anchorage, replace finger plates and anchorage, recast HS concrete.

Texas – Replacement would require full-depth concrete deck repair.

Pennslyvania - 1. Removal of concrete anchoring the device. 2. Removal of bolts and welds anchoring tooth dam to the primary structural members. 3. Perform any necessary modifications to structural members to accommodate the new finger device. 4. Install the device ensuring proper device opening. 5. Place concrete in blockout region.

Arkansas - Adding stiffeners under fingers / Welding cracks / Removing the trough between beams and leaving only over bearings.

Flat Plate Expansion Devices
22) States which use flat plate expansion devices (5)
Alaska, Kansas, Maryland (MDTA), Michigan, Montana

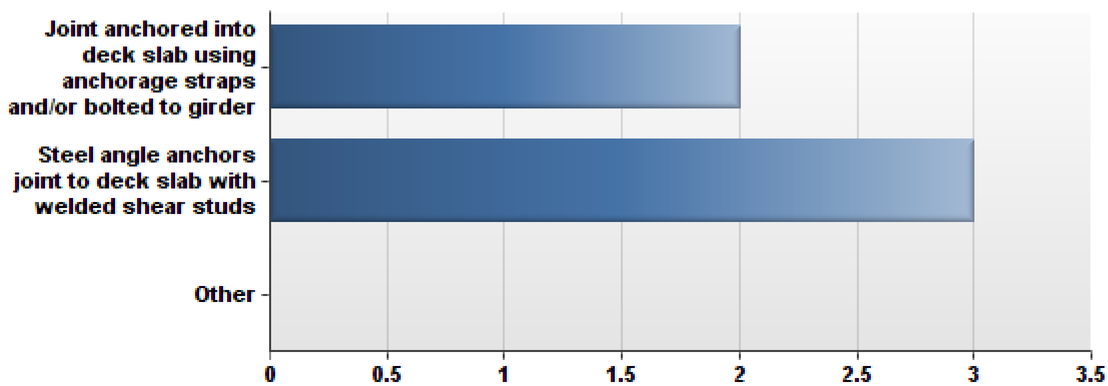
23) Typical allowable range of movement for flat plate devices:

Alaska	4”
Kansas	4”– 6”
Maryland (MDTA)	2” (only on older bridges, have been replaced with glands)
Michigan	1” – 4”
Montana	2”– 5”(don’t use for new construction)

24) Approximate skew range (degrees) for flat plate devices greater than 4 inches:

Alaska	Limit skew to 30 degrees without approval
Kansas	20 degress

25) Most common anchorage method of device to the bridge for flat plate expansion device

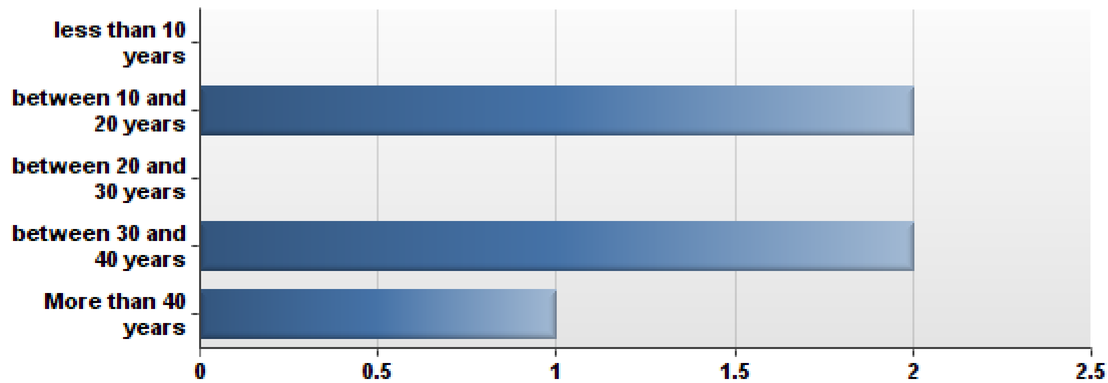


States using devices with anchorage straps and/or bolted to the girder (2)
Maryland (MDTA), Montana
States using steel angle anchors with welded shear studs (3)
Alaska, Kansas, Michigan

26) Approximate cost (per linear foot) of flat plate expansion devices:

Kansas	$900-$1,200
Michigan	$150-$200

27) Expected design life for flat plate expansion devices



States with expected design life of 10-20 years (2)
Alaska, Michigan
States with expected design life of 30-40 years (2)
Kansas, Montana
States with expected design life of more than 40 years (1)
Maryland (MDTA)

28) States with the same design life for expansion device as bridge deck (3) 60%
Kansas, Maryland (MDTA), Montana
States which do not have same design life for expansion device and bridge (2) 40%
Alaska, Michigan

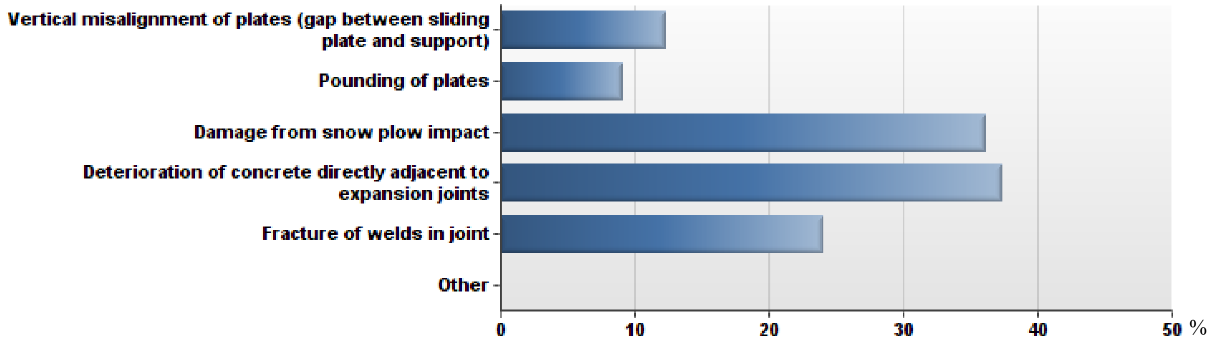
29) States which have had to replace flat plate expansion devices before end of design life (3) 75%
Alaska, Michigan, Montana
State which has not replaced expansion device before end of design life (1) 25%
Kansas

30) Percentage of flat plate devices which experience a shorter than desired life:

Average answer = 22%

Alaska	25%
Maryland (MDTA)	20%
Michigan	30%
Montana	15%

31) Mechanisms of damage for flat plate devices



	Vertical misaglin. (%)	Pounding (%)	Snow Plow (%)	Deterioration (%)	Fracture (%)
Alaska	25		75	50	50
Maryland	10	2	0	10	10
Michigan	9	10	50	39	30
Montana	5	15	19	50	6

31) Repair cost (per linear foot) of flat plate expansion devices:

Alaska – Unknown but estimated to be $500/lf – $1,000/lf (welding, traffic control, chipping, etc.)

Michigan – Typically just replace device.

32) Typical repair/rehab procedure/techniques for replacement of flat plate devices:

Alaska – Remove plate, grind old weld areas smooth, install new plate with continuous fillet and intermitent plug welds.

Kansas – Again through fabric replacement

Maryland (MDTA) – Remove broken section and weld new angle in with straps in concrete.

Montana – Reuse existing plates and add additional anchors along with additional concrete reinforcment. Replace device with strip seal.

Appendix B – Test Results Figures and Tables

Finger Plate Test Results

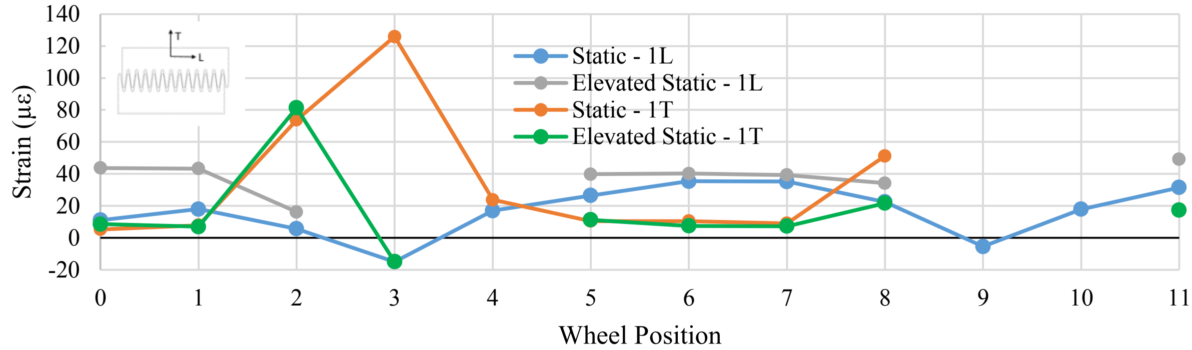


Figure B-1: Static and elevated static data for strain gage 1 from Blanchette Bridge test

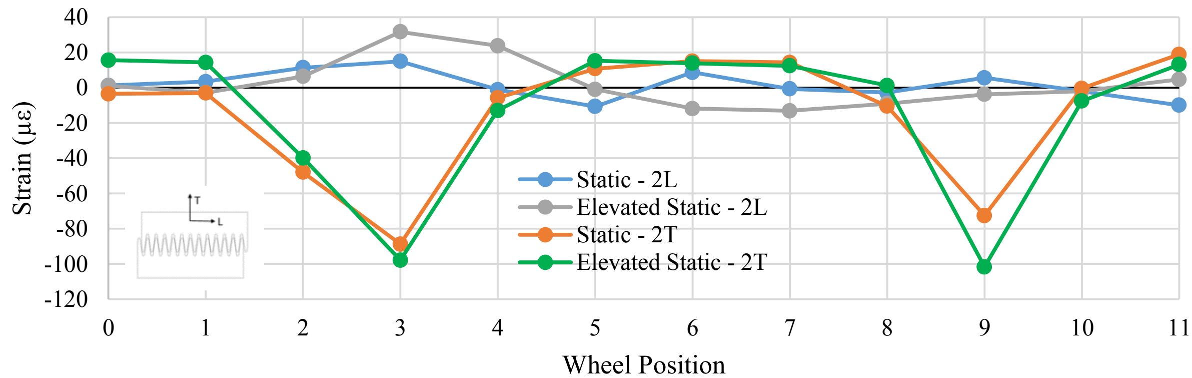


Figure B-2: Static and elevated static data for strain gage 2 from Blanchette Bridge test

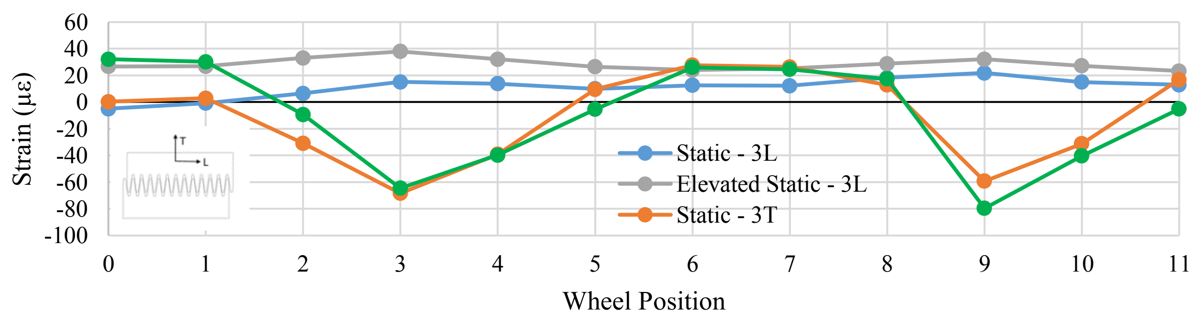


Figure B-3: Static and elevated static data for strain gage 3 from Blanchette Bridge test

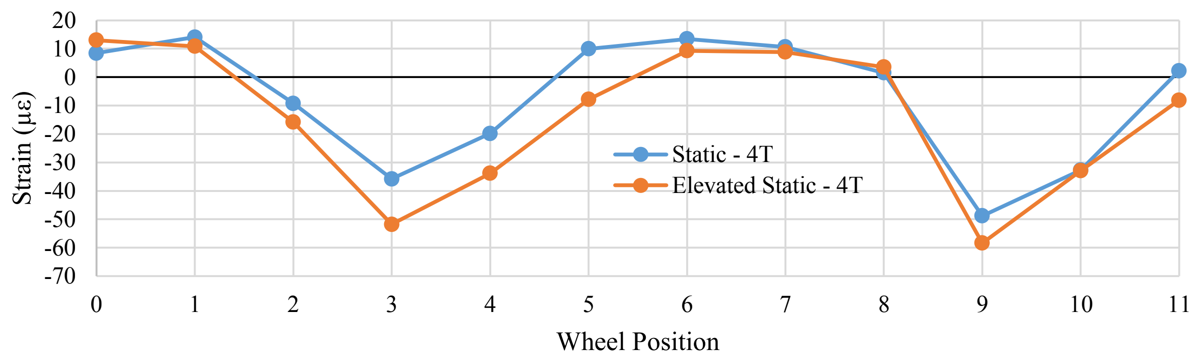


Figure B-4: Static and elevated static data for strain gage 4 from Blanchette Bridge test

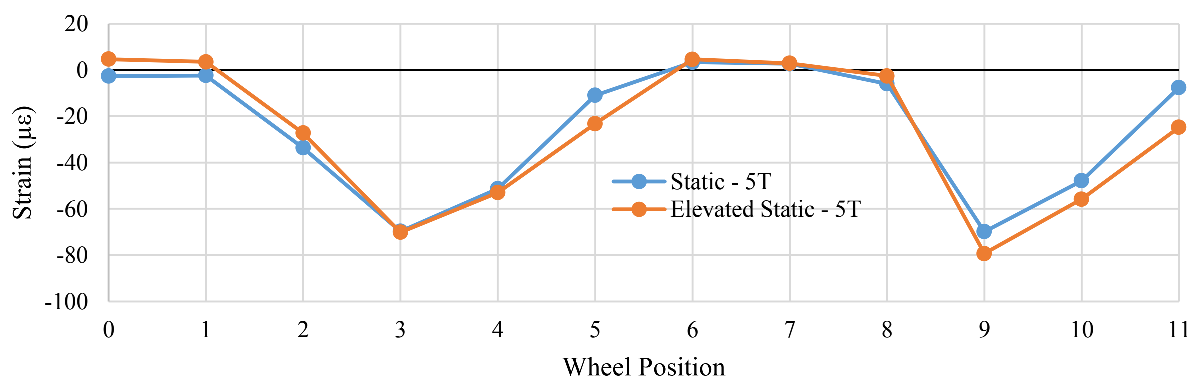


Figure B-5: Static and elevated static data for strain gage 5 from Blanchette Bridge test

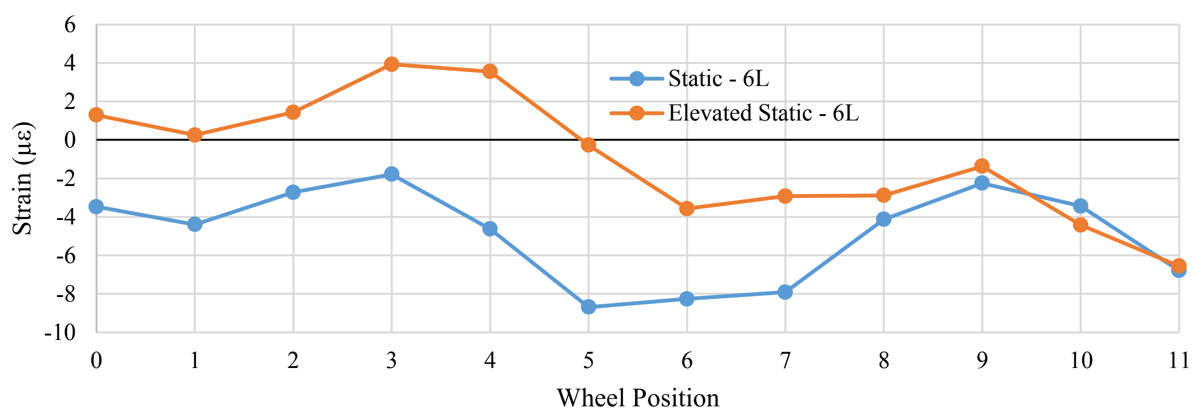


Figure B-6: Static and elevated static data for strain gage 6 from Blanchette Bridge test

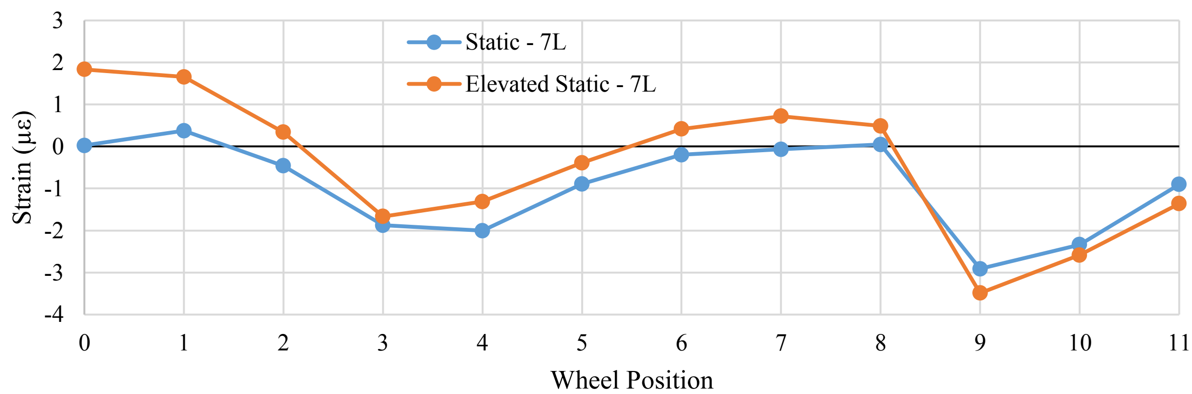


Figure B-7: Static and elevated static data for strain gage 7 from Blanchette Bridge test

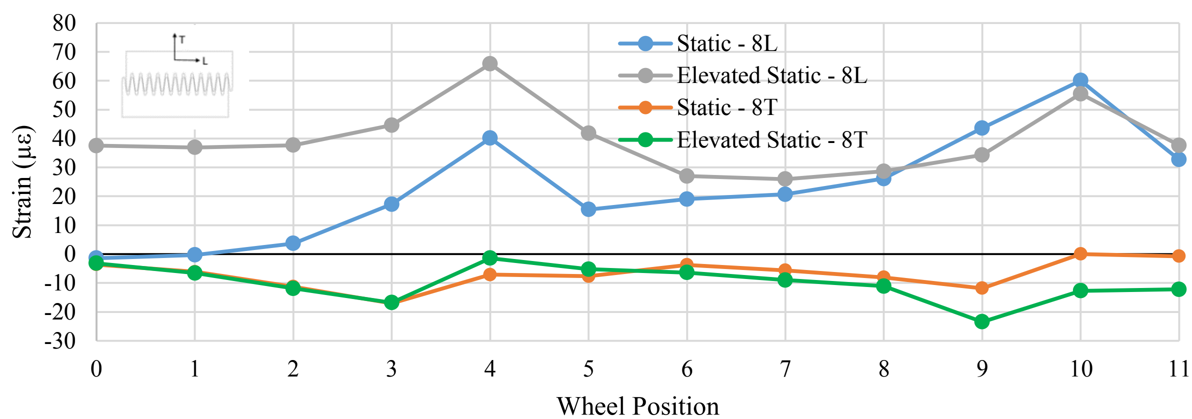


Figure B-8: Static and elevated static data for strain gage 8 from Blanchette Bridge test

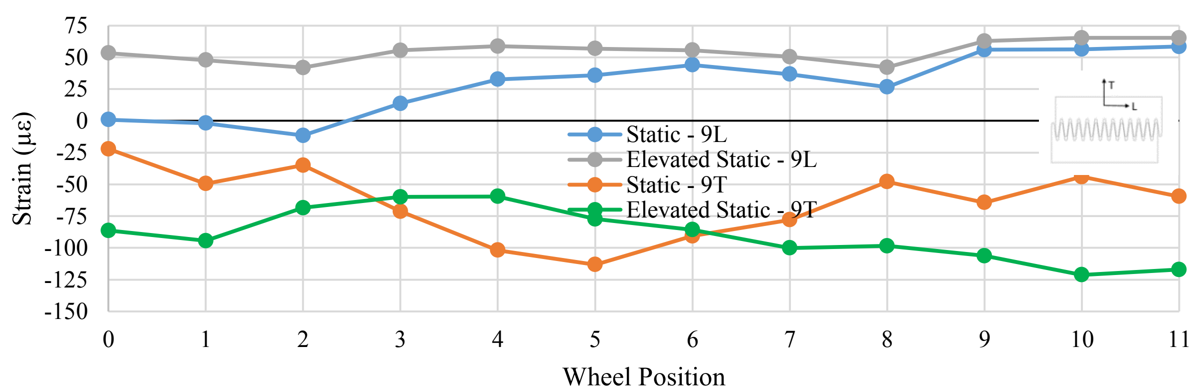


Figure B-9: Static and elevated static data for strain gage 9 from Blanchette Bridge test

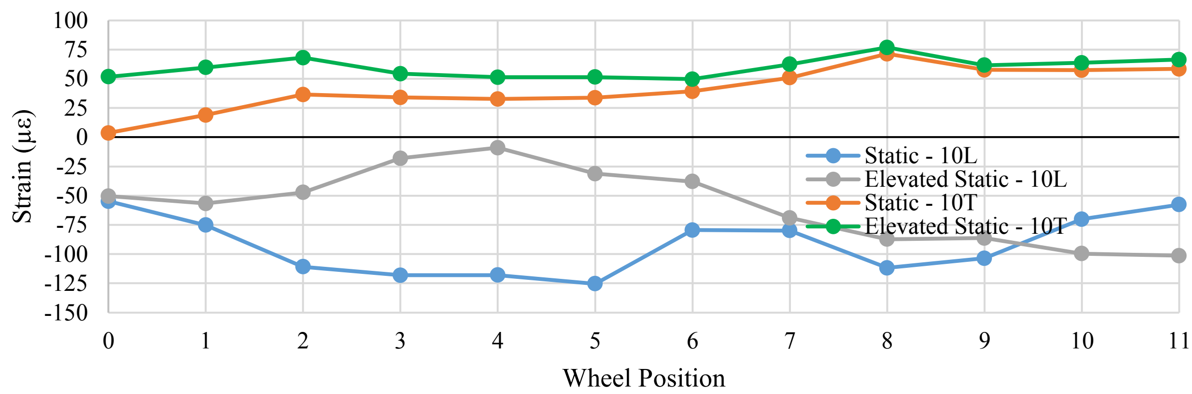


Figure B-10: Static and elevated static data for strain gage 10 from Blanchette Bridge test

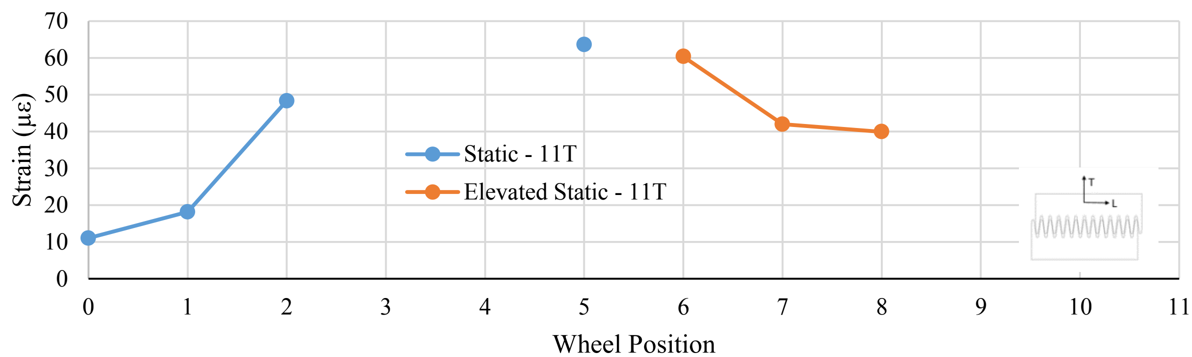


Figure B-11: Static and elevated static data for strain gage 11 from Blanchette Bridge test

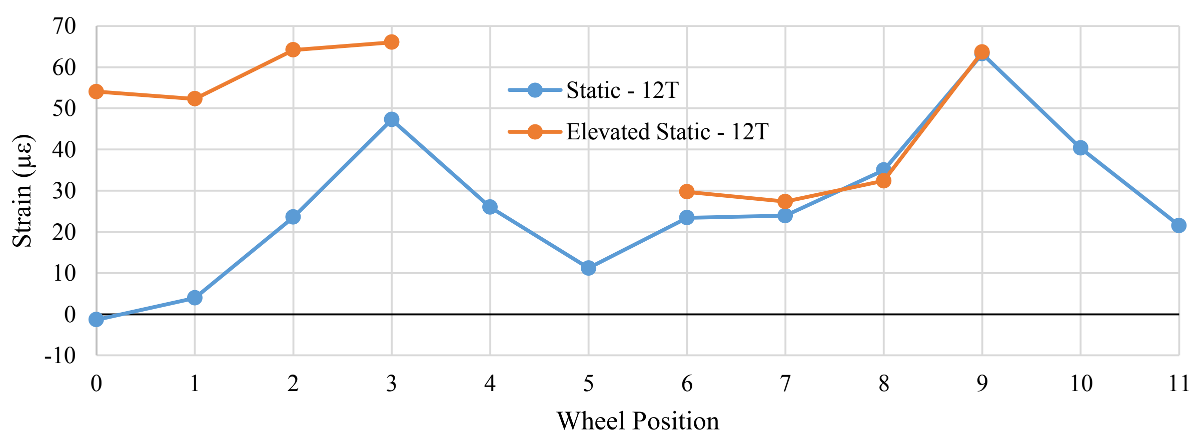


Figure B-12: Static and elevated static data for strain gage 12 from Blanchette Bridge test

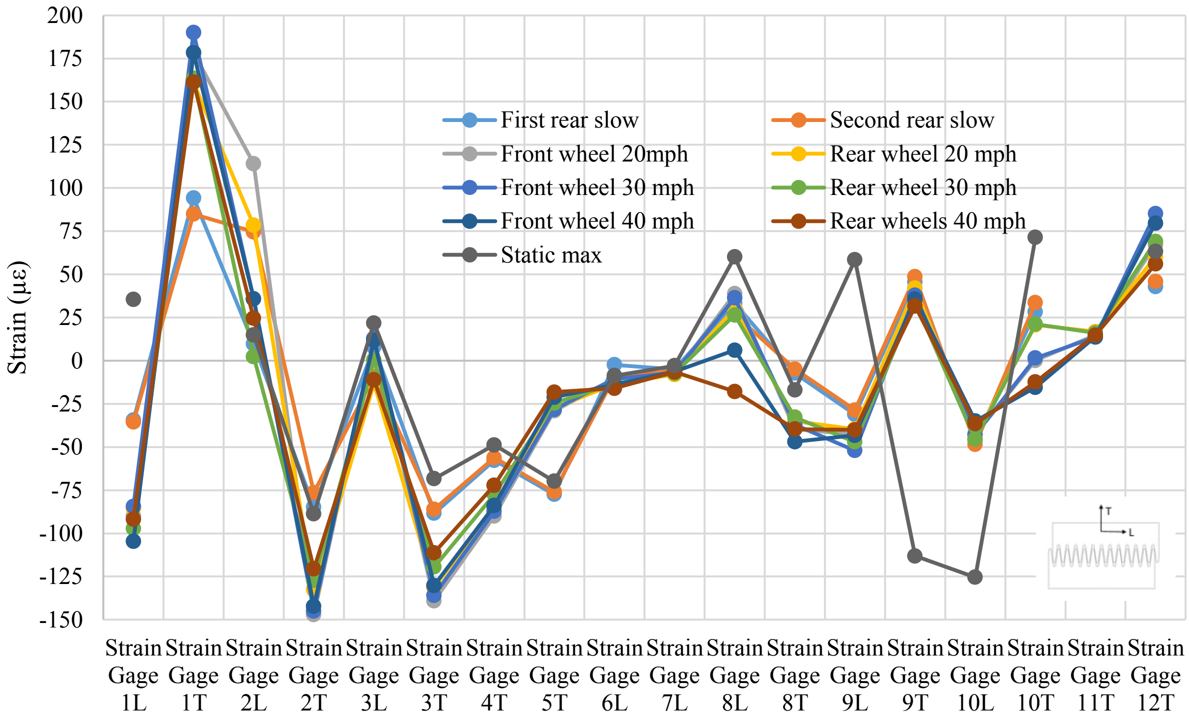


Figure B-13: Peak strains for each dynamic run conducted on Blanchette Bridge test

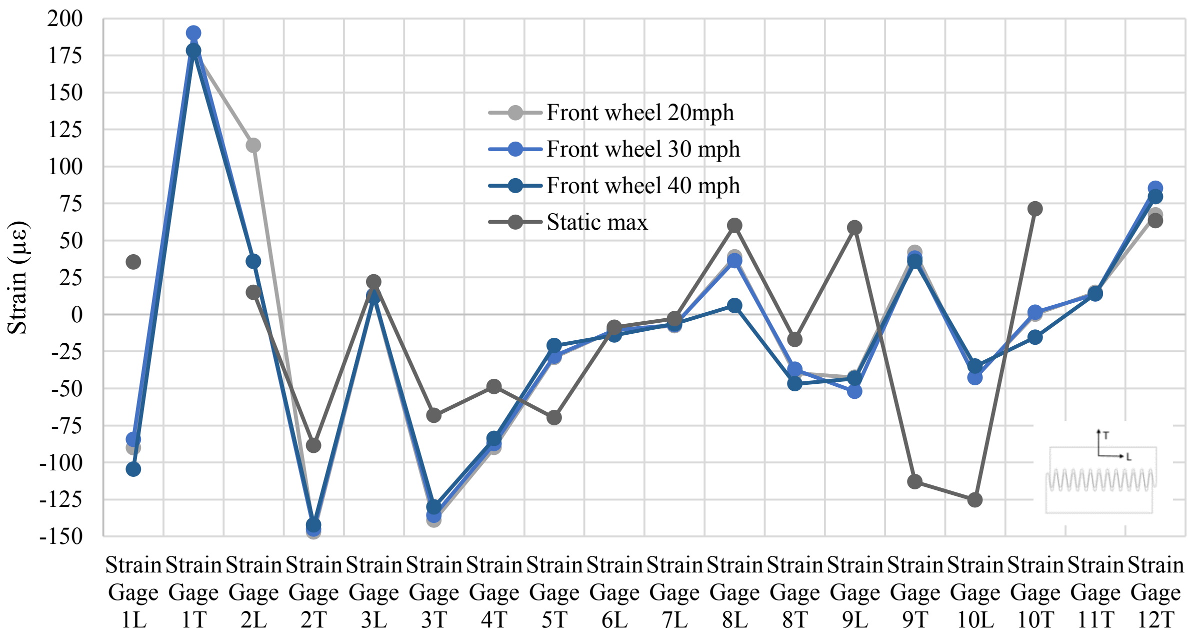


Figure B-14: Peak strains of front wheel for dynamic runs conducted on Blanchette Bridge

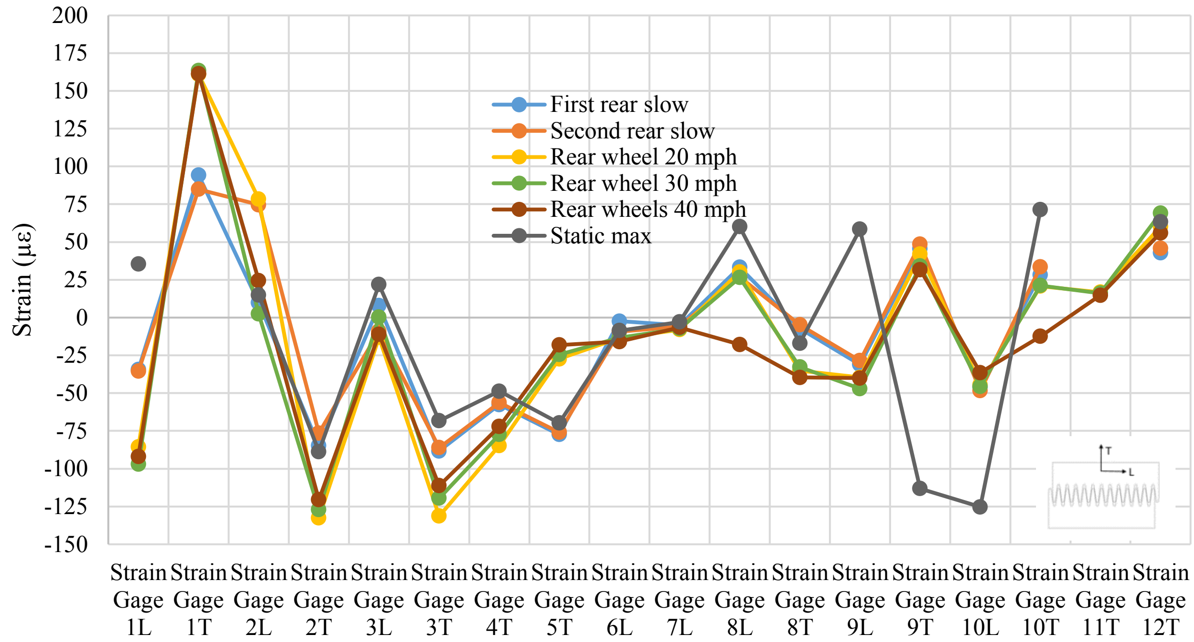


Figure B-15: Peak strains of rear wheel(s) for dynamic runs conducted on Blanchette Bridge

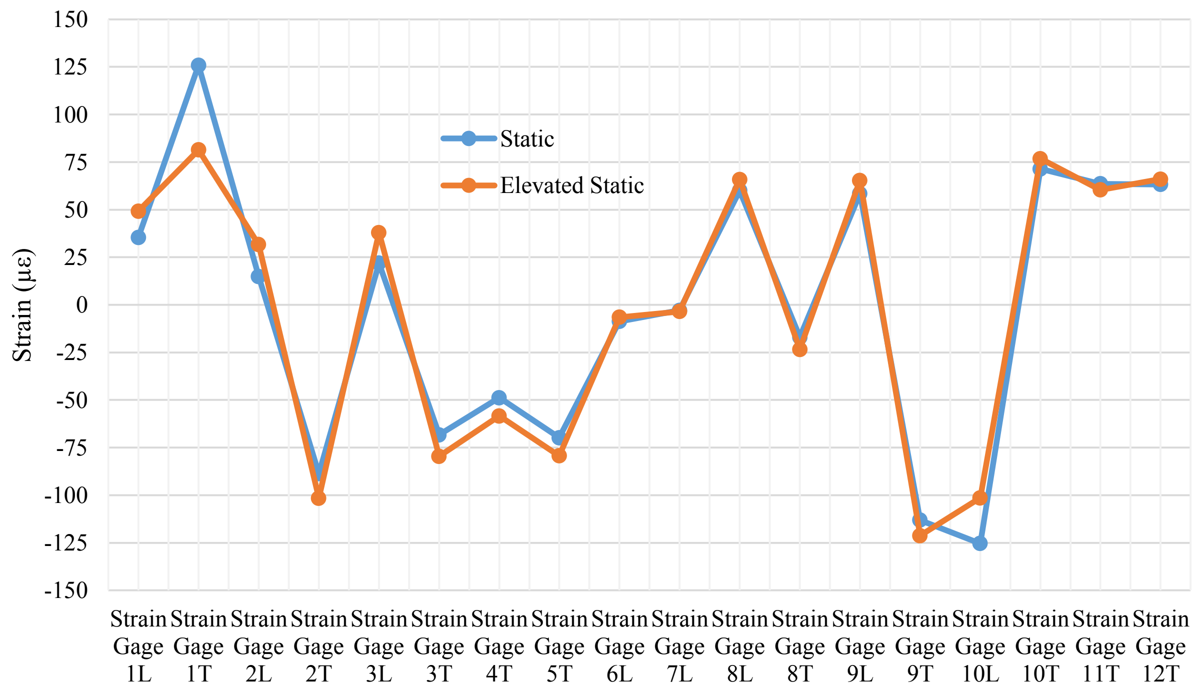


Figure B-16: Maximum strains of static vs. elevated static for Blanchette Bridge test

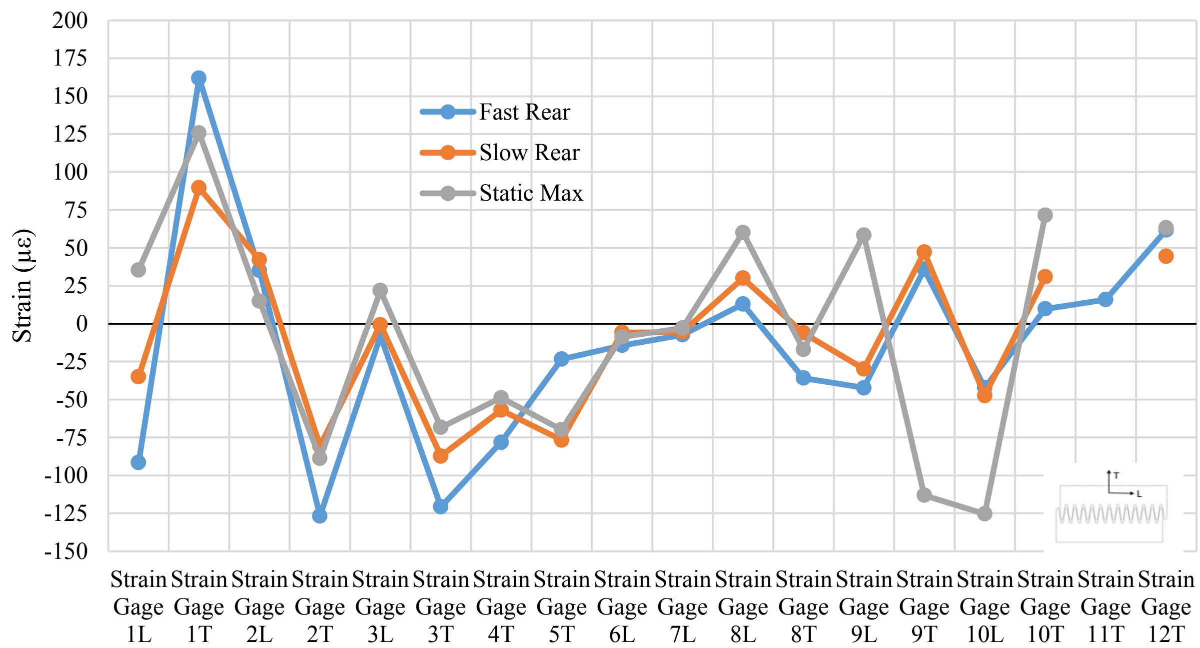


Figure B-17: Strain comparison of average maximum strains for fast and slow speeds from Blanchette Bridge test

Table B-1: Percent difference in static and elevated static strains from Blanchette Bridge test

	Strain Gage 1L	**Strain Gage 1T**	**Strain Gage 2L**	**Strain Gage 2T**	**Strain Gage 3L**	**Strain Gage 3T**	**Strain Gage 4**	**Strain Gage 5**	**Strain Gage 6L**
Static (με)	-26.05	120.57	13.69	-85.24	26.93	-68.54	-57.26	-67.17	-5.21
Elevated Static (με)	-27.56	72.81	30.57	-117.11	11.25	-111.66	-71.38	-84.00	-7.85
% increase	5.8	-39.6	123.4	37.4	-58.2	62.9	24.7	25.1	50.6
	Strain Gage 7L	**Strain Gage 8L**	**Strain Gage 8T**	**Strain Gage 9L**	**Strain Gage 9T**	**Strain Gage 10L**	**Strain Gage 10T**	**Strain Gage 11T**	**Strain Gage 12T**
Static (με)	-2.94	61.49	-13.40	-12.56	41.91	67.81	-70.67	37.24	64.61
Elevated Static (με)	-5.32	28.30	-20.24	-11.44	26.85	25.06	-51.09	60.37	-26.72
% increase	81.2	-54.0	51.0	-8.9	-35.9	-63.0	-27.7	62.1	-141.4

Table B-2: Percent difference of average maximum strains for fast and slow speeds from Blanchette Bridge test

	Strain Gage 1L	Strain Gage 1T	Strain Gage 2L	Strain Gage 2T	Strain Gage 3L	Strain Gage 3T	Strain Gage 4	Strain Gage 5	Strain Gage 6L
Fast Speed (με)	-91.53	161.92	35.07	-126.76	11.71	-120.70	-78.10	-23.36	-14.25
Slow Speed (με)	-34.98	89.58	42.18	-80.63	7.82	-87.18	-56.93	-76.68	-5.84
% increase	161.65	80.75	-16.84	57.21	49.63	38.45	37.20	-69.53	144.15
	Strain Gage 7L	**Strain Gage 8L**	**Strain Gage 8T**	**Strain Gage 9L**	**Strain Gage 9T**	**Strain Gage 10L**	**Strain Gage 10T**	**Strain Gage 11T**	**Strain Gage 12T**
Fast Speed (με)	-7.32	28.32	-35.83	-42.25	35.91	20.94	-42.19	15.86	61.71
Slow Speed (με)	-5.48	30.09	-13.40	-29.84	47.13	30.92	-47.38	-	44.37
% increase	33.67	-5.90	167.40	41.60	-23.81	-32.27	-10.95	-	39.08

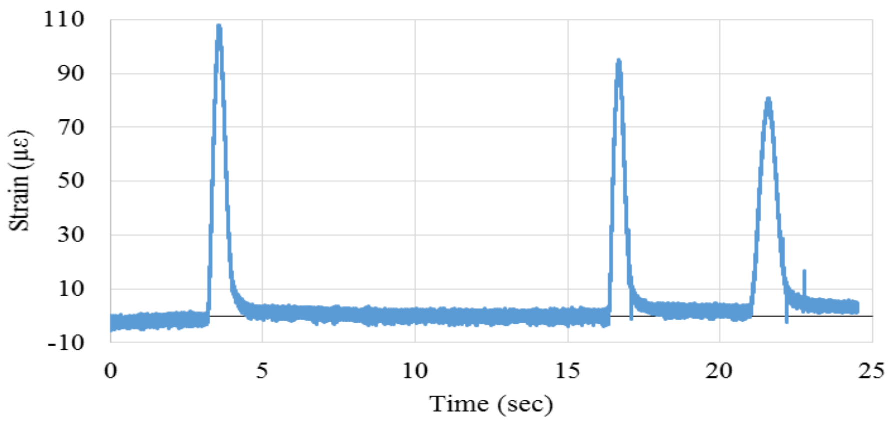


Figure B-18: Strain gage 1T for dynamic test at slow speed for Banchette Bridge test

Flat Plate Test Results

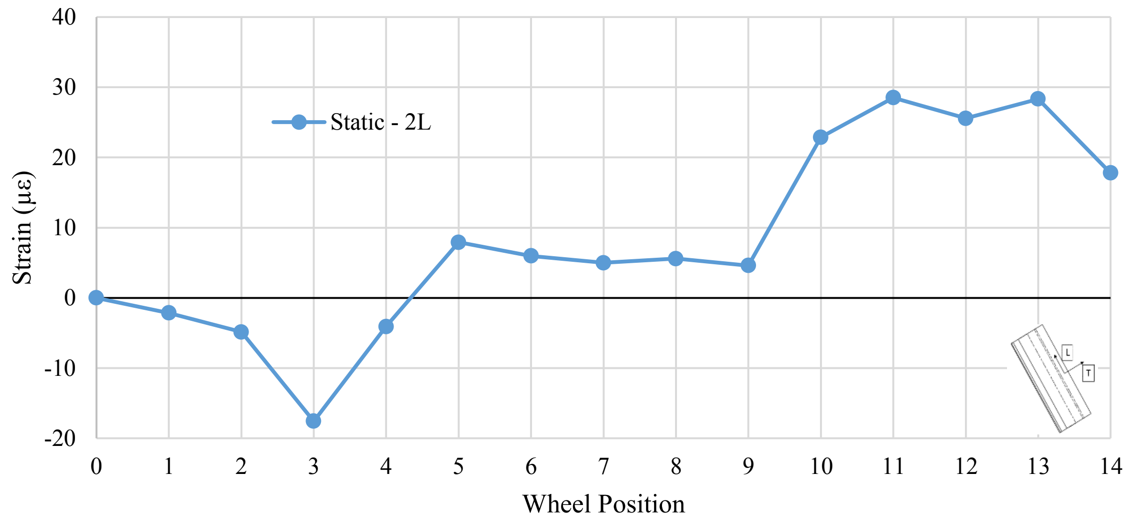


Figure B-19: Static data for strain gage 2L from Route 350 over I-435 bridge test

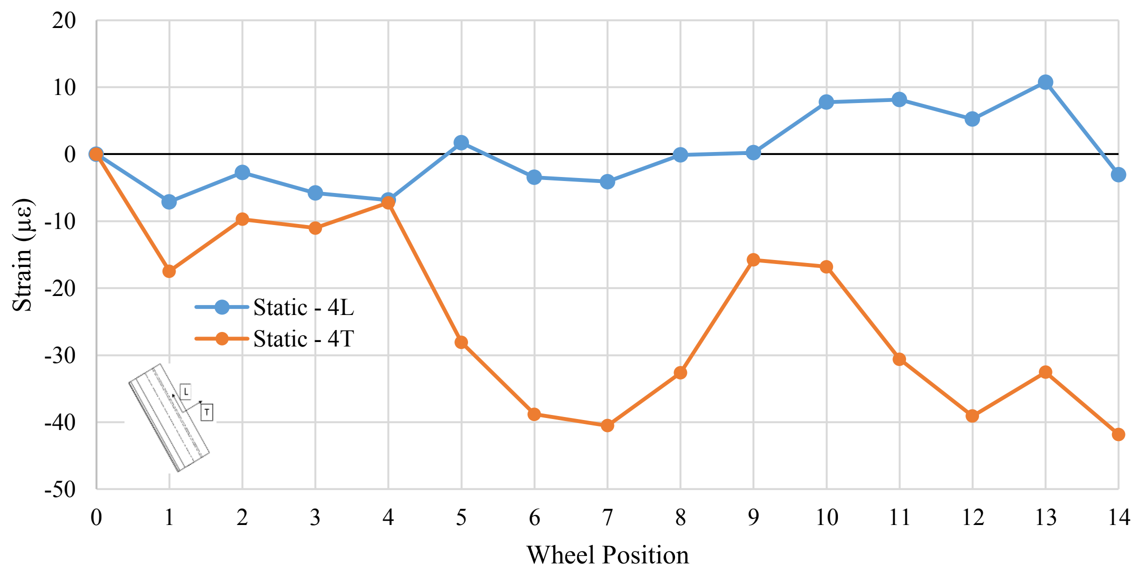


Figure B-20: Static data for strain gage 4 from Route 350 over I-435 bridge test

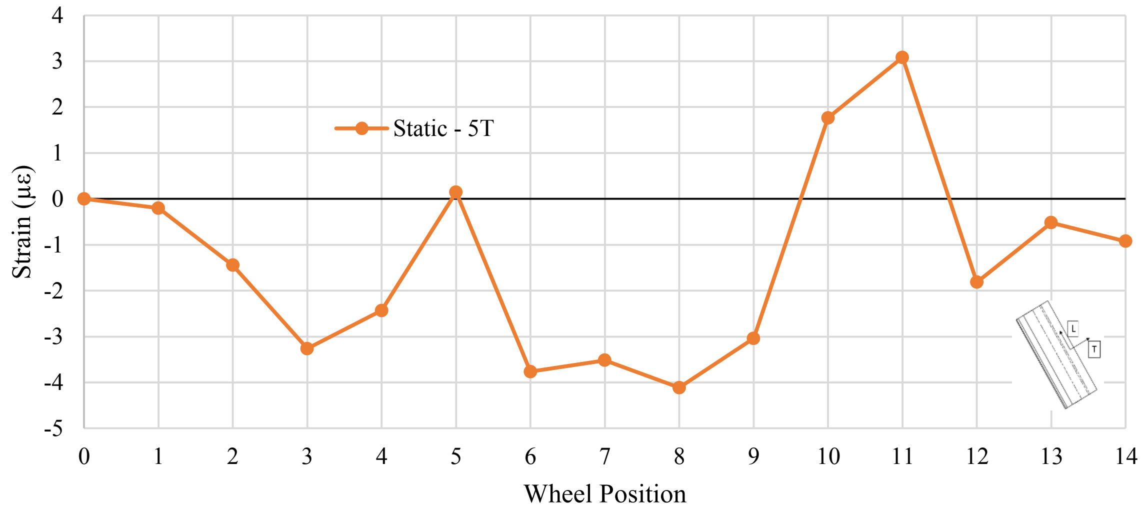


Figure B-21: Static data for strain gage 5T from Route 350 over I-435 bridge test

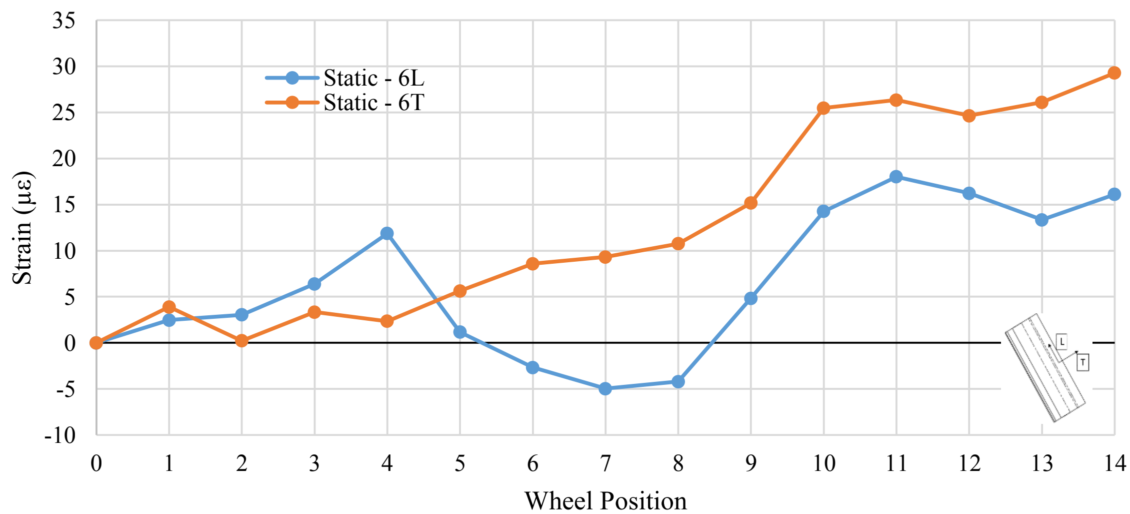


Figure B-22: Static data for strain gage 6 from Route 350 over I-435 bridge test

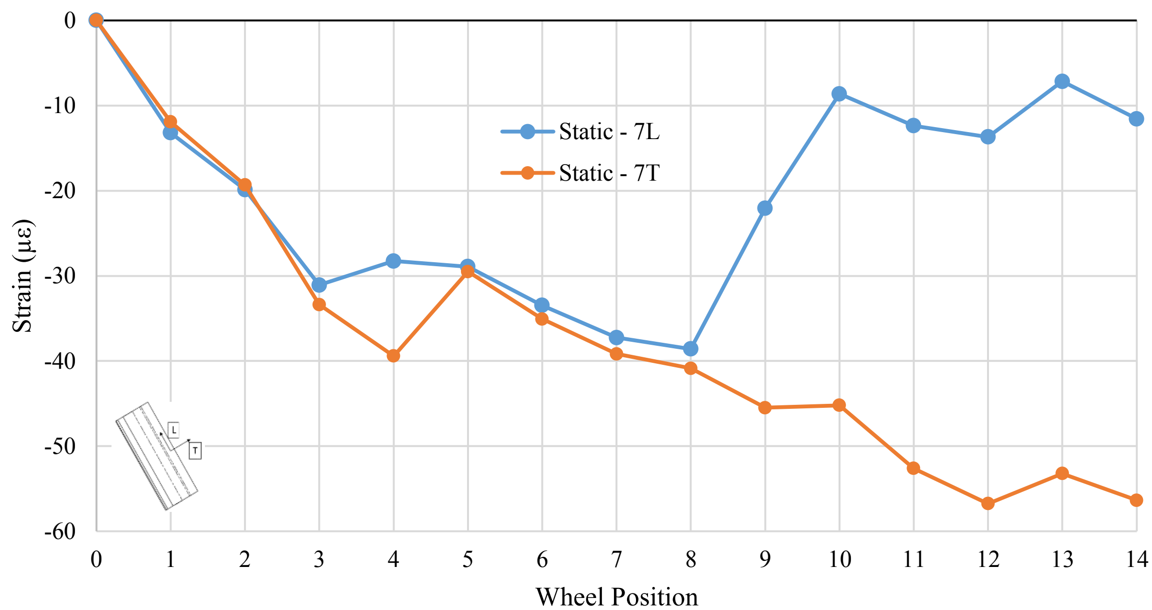


Figure B-23: Static data for strain gage 7 from Route 350 over I-435 bridge test

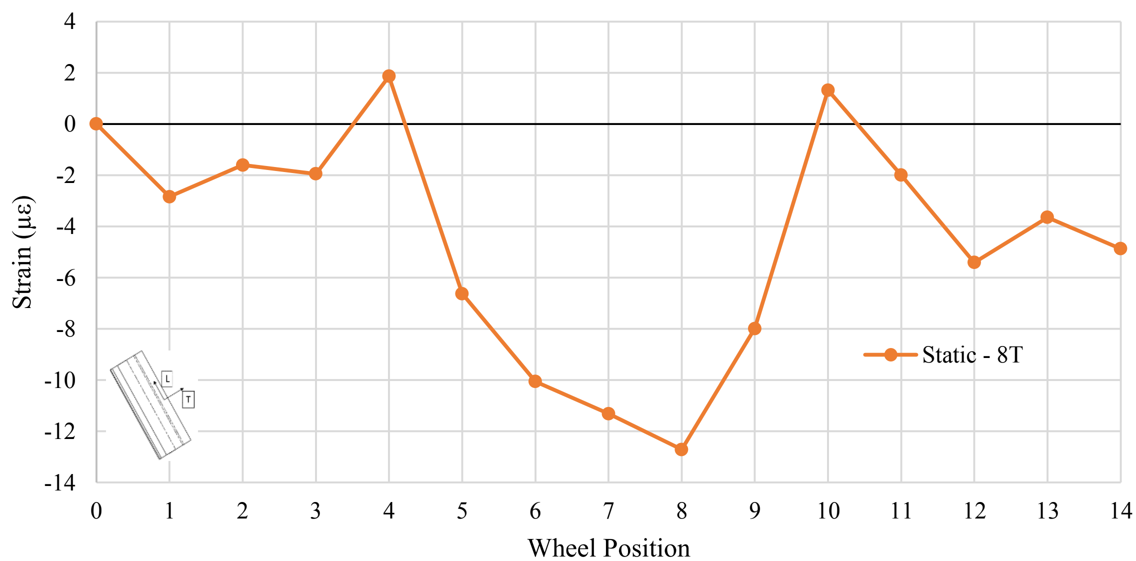


Figure B-24: Static data for strain gage 8T from Route 350 over I-435 bridge test

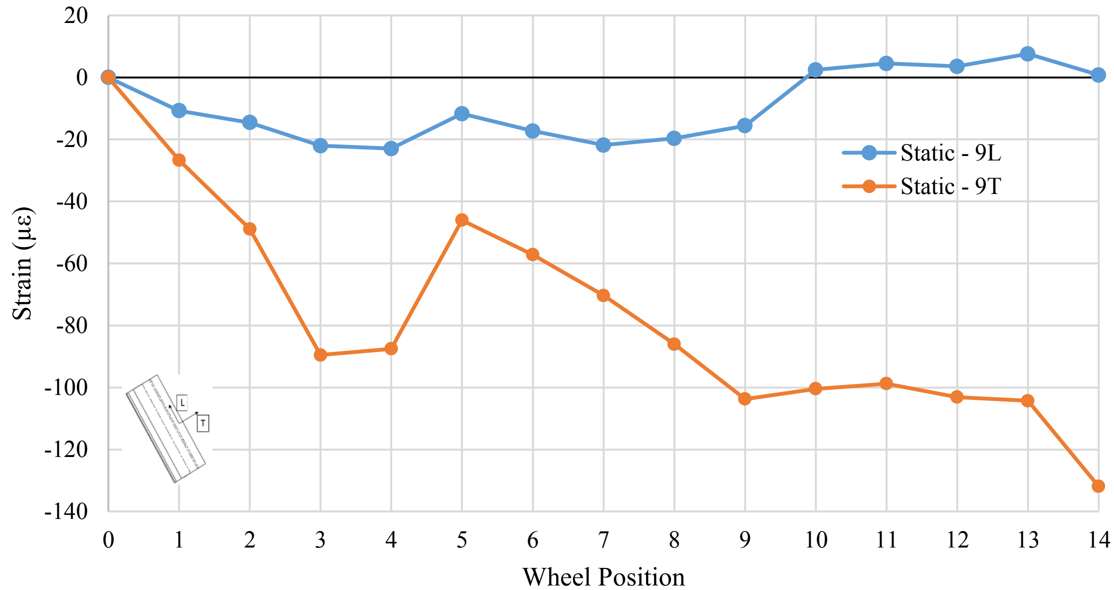


Figure B-25: Static data for strain gage 9 from Route 350 over I-435 bridge test

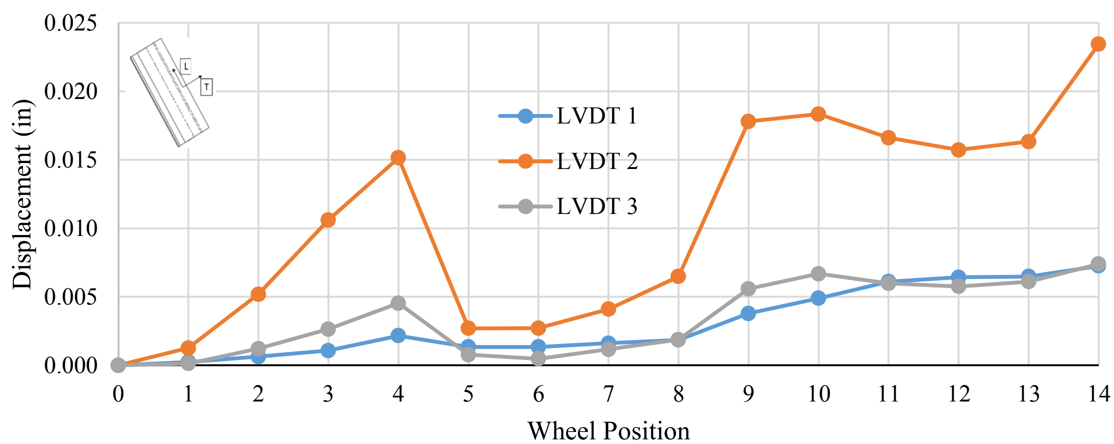


Figure B-26: Static data for all LVDTs from Route 350 over I-435 bridge test

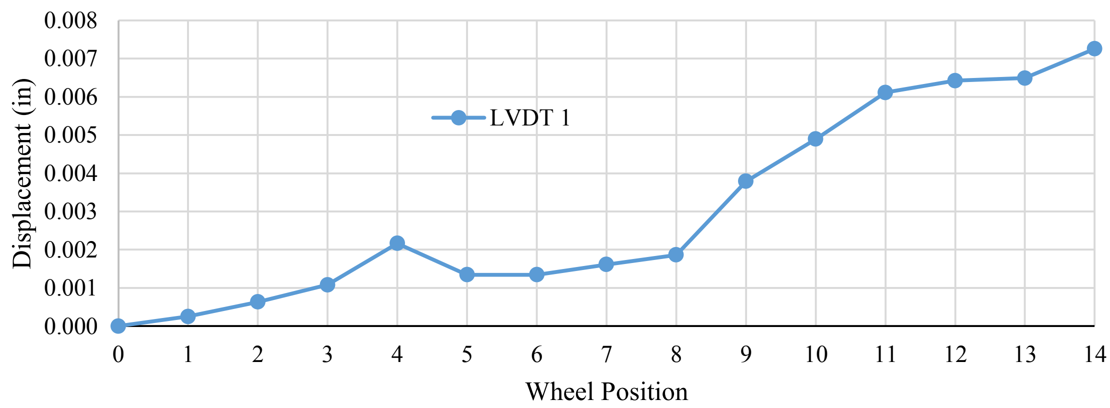


Figure B-27: Static data for LVDT 1 from Route 350 over I-435 bridge test

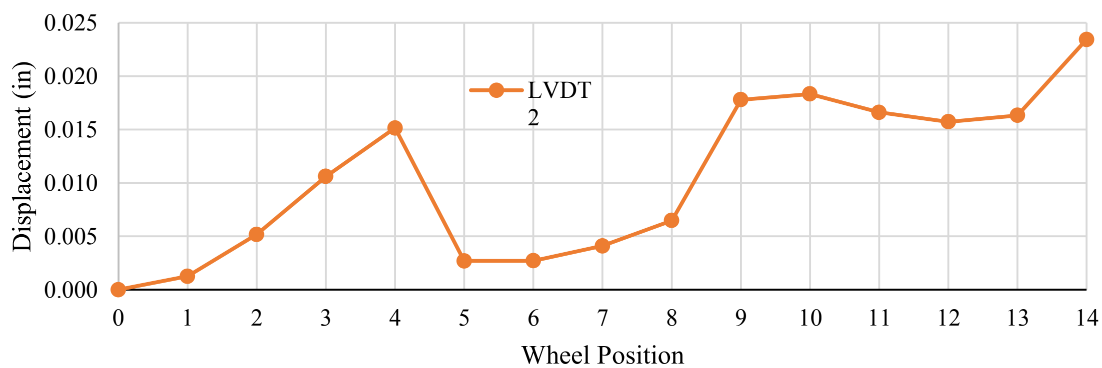


Figure B-28: Static data for LVDT 2 from Route 350 over I-435 bridge test

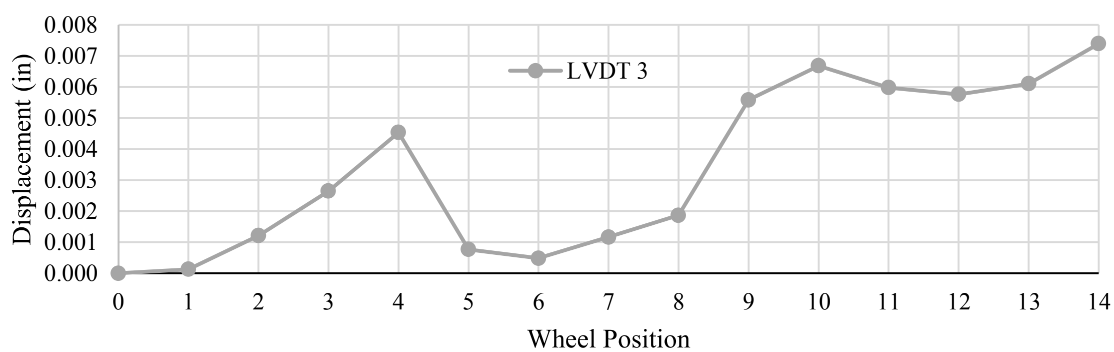


Figure B-29: Static data for LVDT 3 from Route 350 over I-435 bridge test

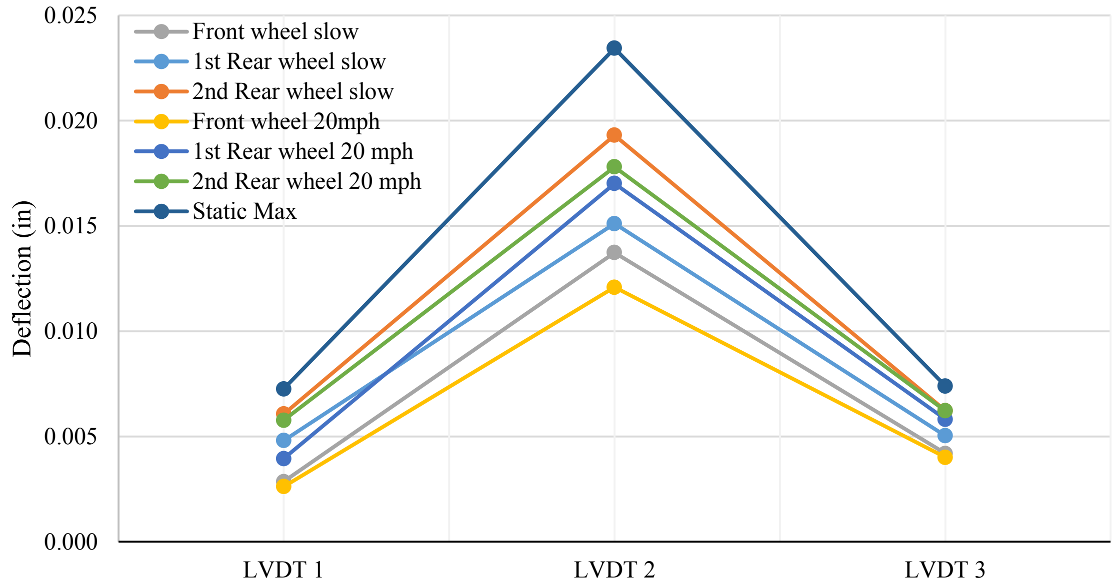


Figure B-30: Dynamic data for all LVDTs from Route 350 over I-435 bridge test

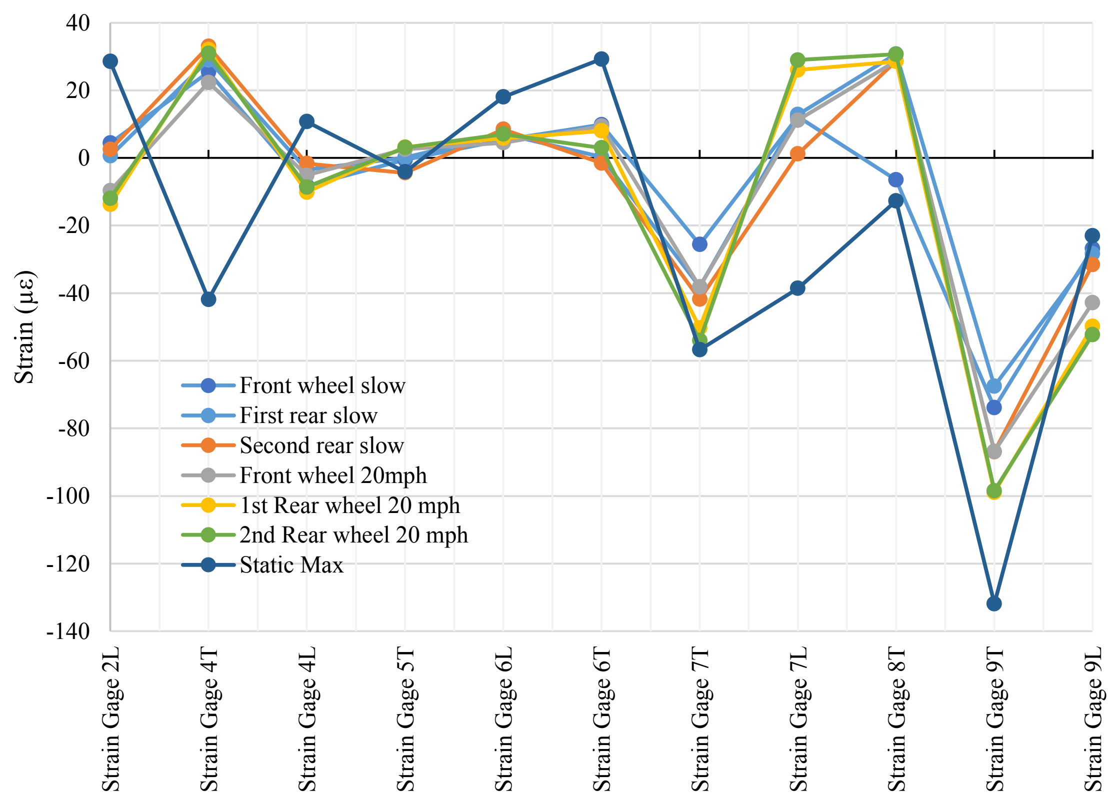


Figure B-31: Dynamic data for all strain gages from Route 350 over I-435 bridge test

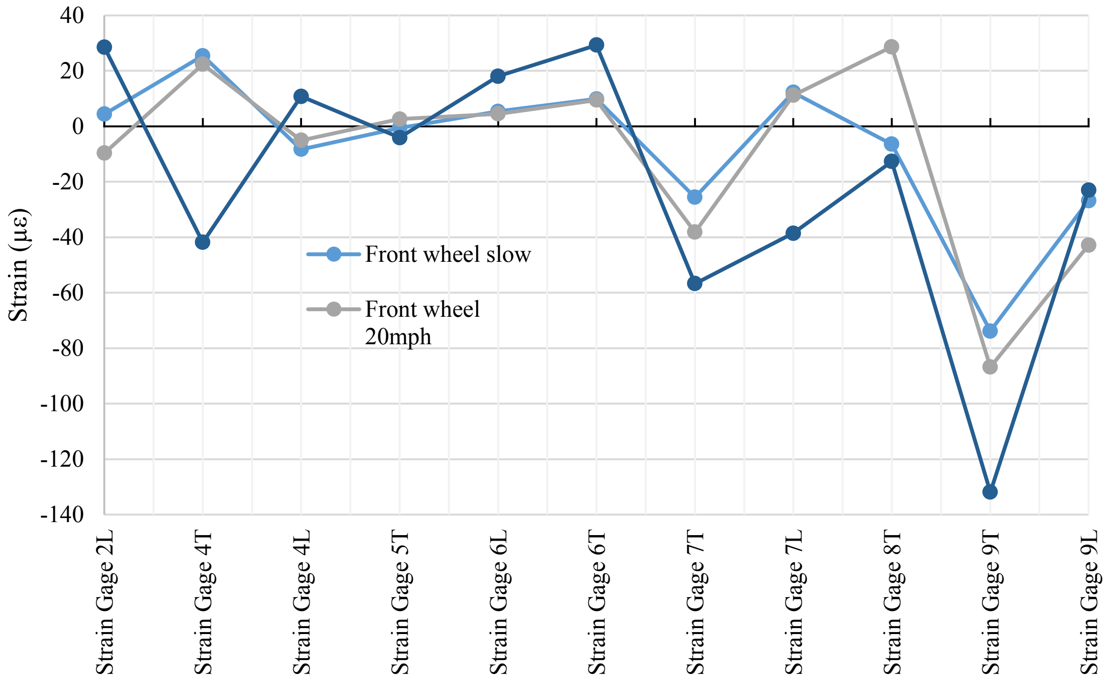


Figure B-32: Dynamic data for front wheel from Route 350 over I-435 bridge test

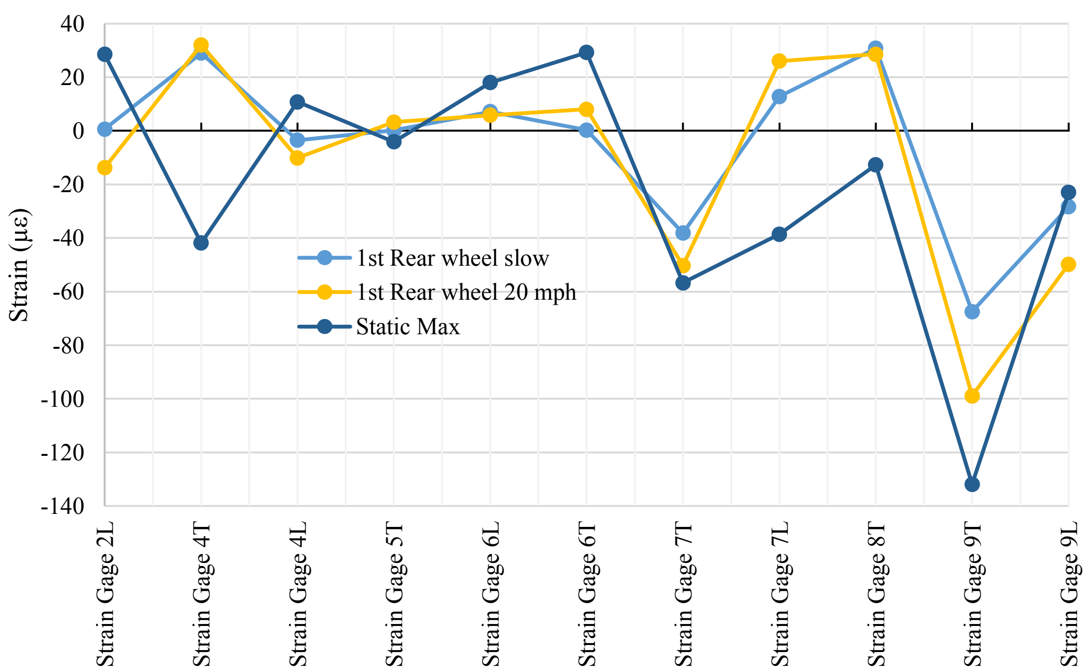


Figure B-33: Dynamic data for 1st rear wheel from Route 350 over I-435 bridge test

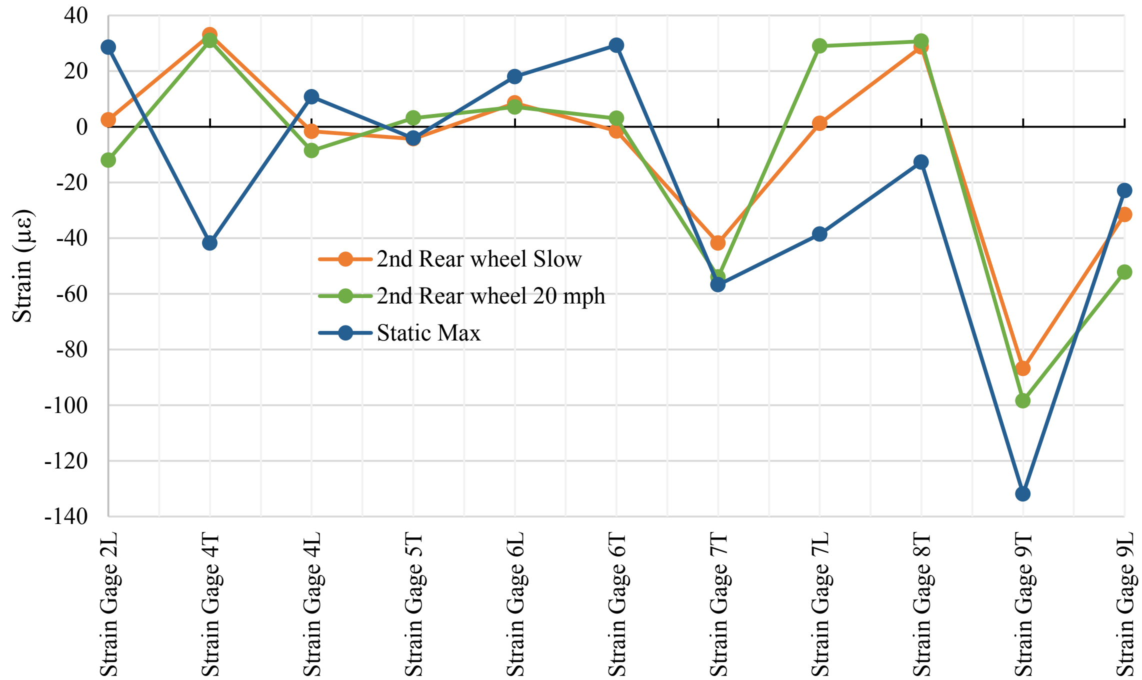


Figure B-34: Dynamic data for 2nd rear wheel from Route 350 over I-435 bridge test

Appendix C- FEM vs. Experimental Strain Comparisons

Finger Plate

Figure C-1: FEM vs. Experimental comparison of strain gage 1L for Blanchette Bridge test

Figure C-2: FEM vs. Experimental comparison of strain gage 1T for Blanchette Bridge test

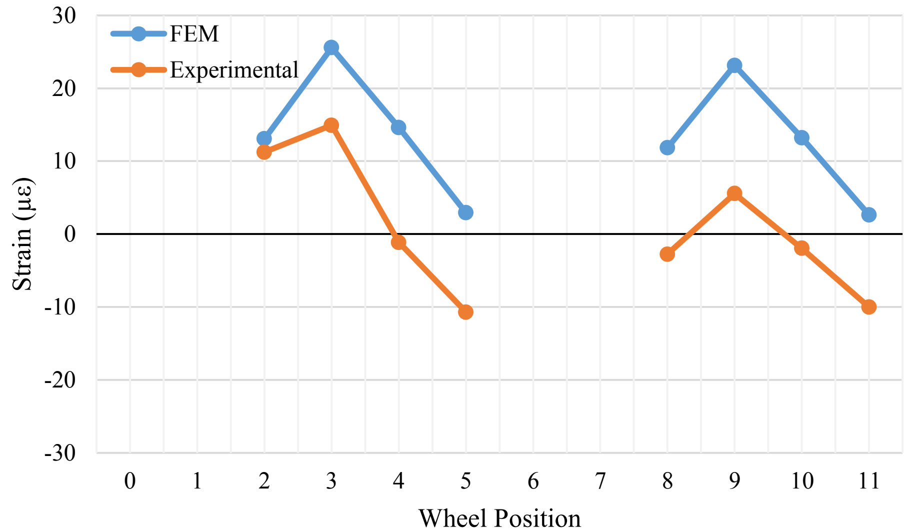


Figure C-3: FEM vs. Experimental comparison of strain gage 2L for Blanchette Bridge test

Figure C-4: FEM vs. Experimental comparison of strain gage 2T for Blanchette Bridge test

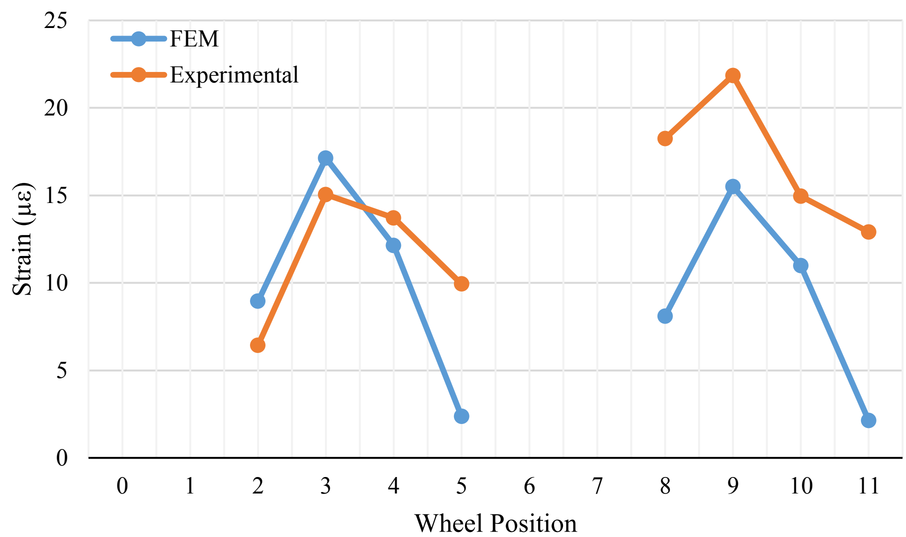


Figure C-5: FEM vs. Experimental comparison of strain gage 3L for Blanchette Bridge test

Figure C-6: FEM vs. Experimental comparison of strain gage 3T for Blanchette Bridge test

Figure C-7: FEM vs. Experimental comparison of strain gage 4 for Blanchette Bridge test

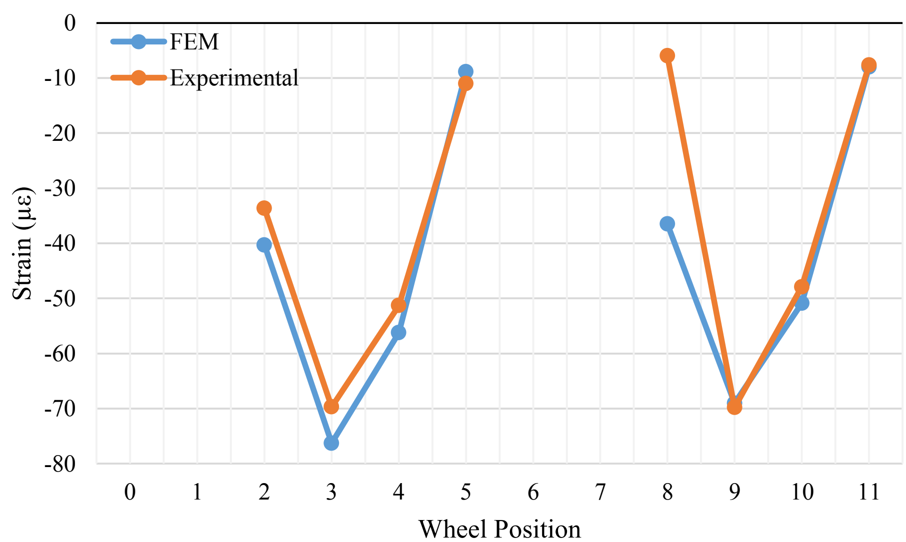


Figure C-8: FEM vs. Experimental comparison of strain gage 5 for Blanchette Bridge test

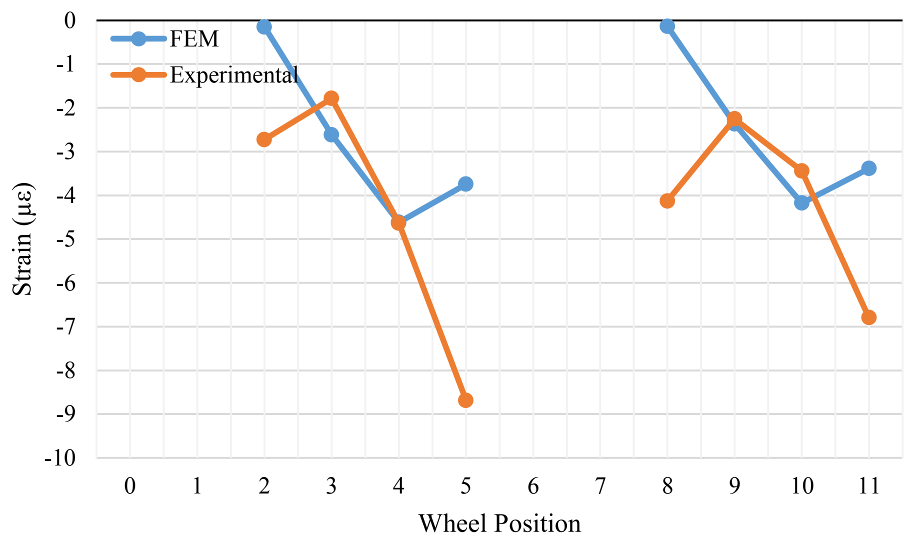


Figure C-9: FEM vs. Experimental comparison of strain gage 6 for Blanchette Bridge test

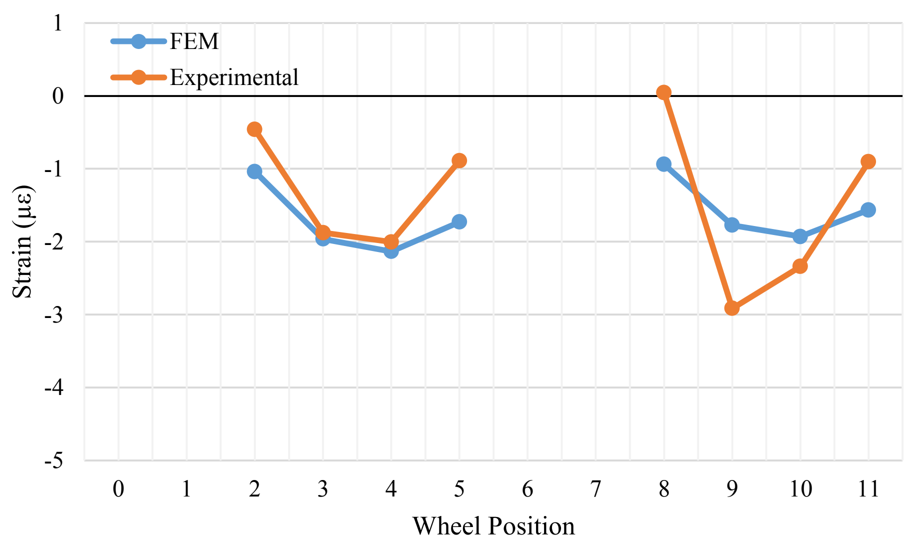


Figure C-10: FEM vs. Experimental comparison of strain gage 7L for Blanchette Bridge test

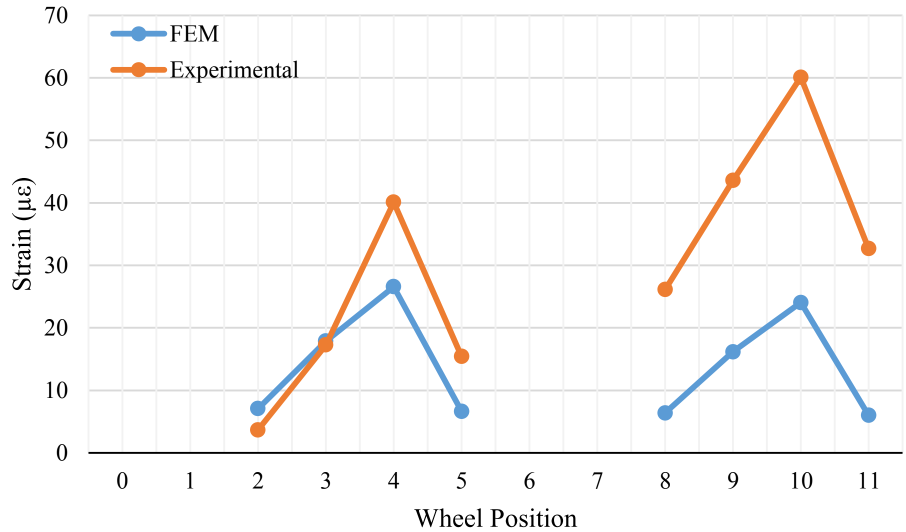


Figure C-11: FEM vs. Experimental comparison of strain gage 8L for Blanchette Bridge test

Figure C-12: FEM vs. Experimental comparison of strain gage 8T for Blanchette Bridge test

Figure C-13: FEM vs. Experimental comparison of strain gage 9L for Blanchette Bridge test

Figure C-14: FEM vs. Experimental comparison of strain gage 9T for Blanchette Bridge test

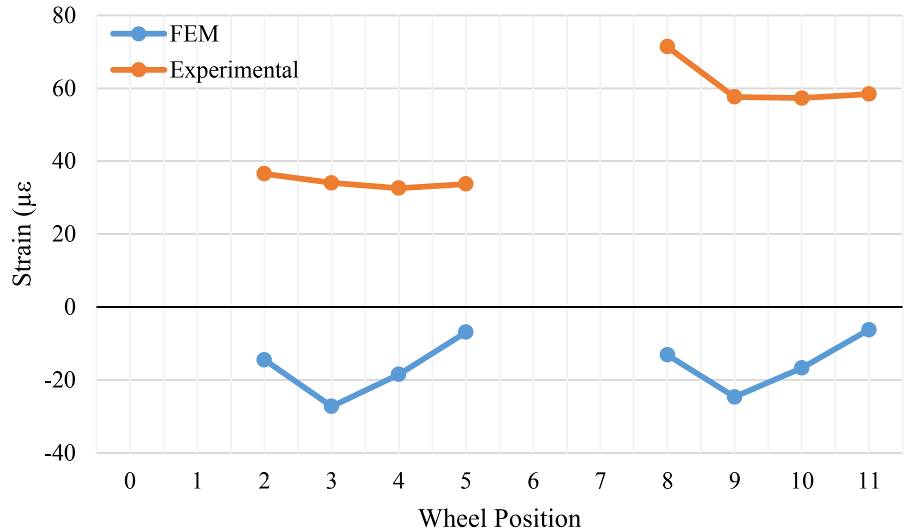


Figure C-15: FEM vs. Experimental comparison of strain gage 10L for Blanchette Bridge test

Figure C-16: FEM vs. Experimental comparison of strain gage 10T for Blanchette Bridge test

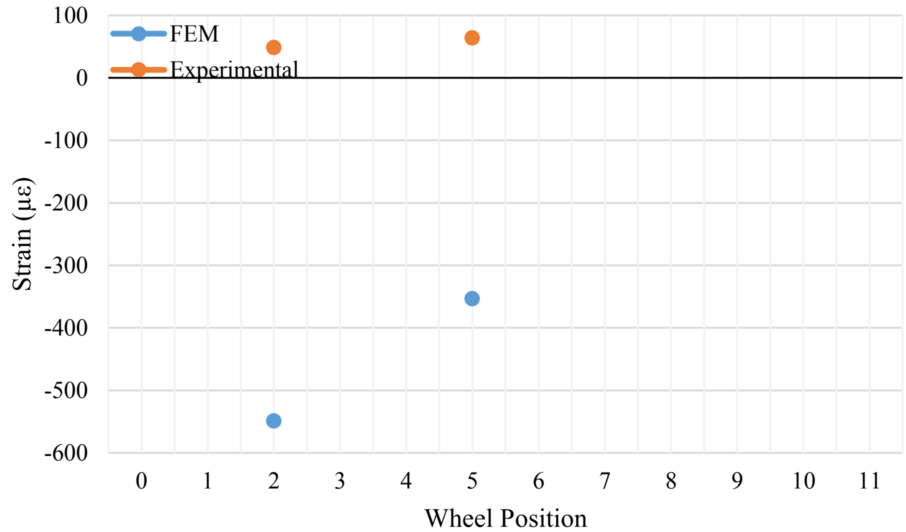


Figure C-17: FEM vs. Experimental comparison of strain gage 11T for Blanchette Bridge test

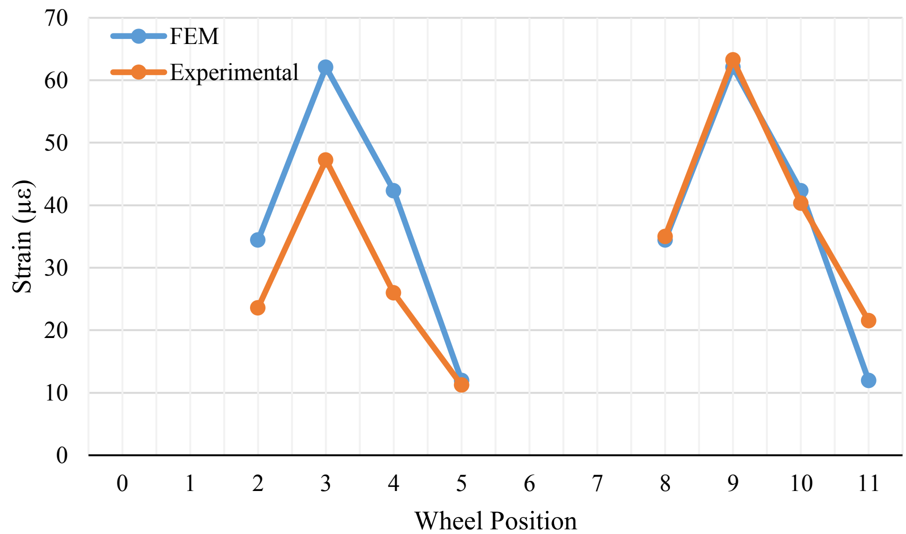


Figure C-18: FEM vs. Experimental comparison of strain gage 12T for Blanchette Bridge test

Flat Plate

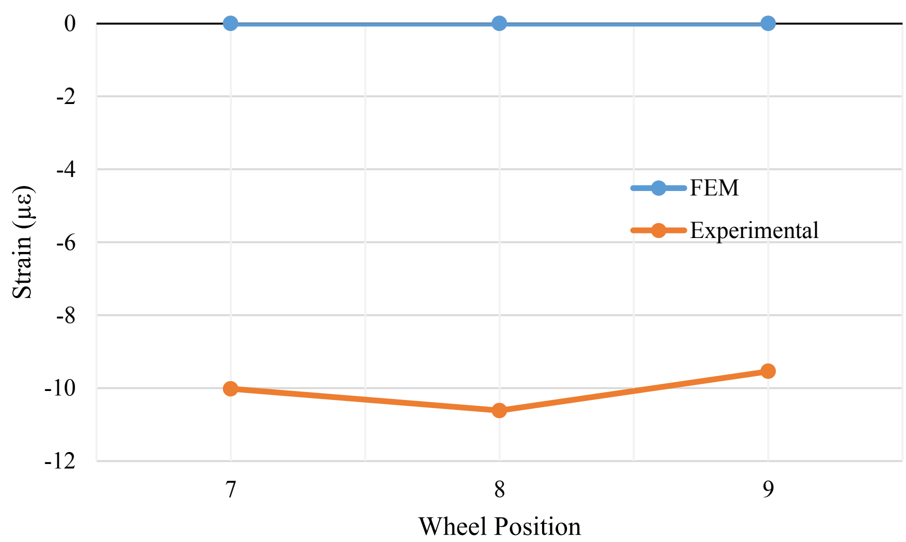


Figure C-19: FEM vs. Experimental comparison of strain gage 5T for Route 350 over I-435 test

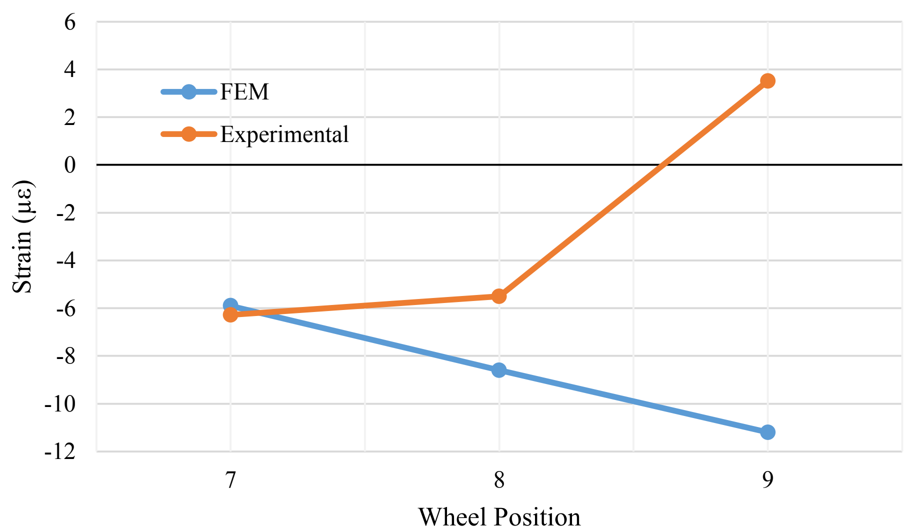


Figure C-20: FEM vs. Experimental comparison of strain gage 6L for Route 350 over I-435 test

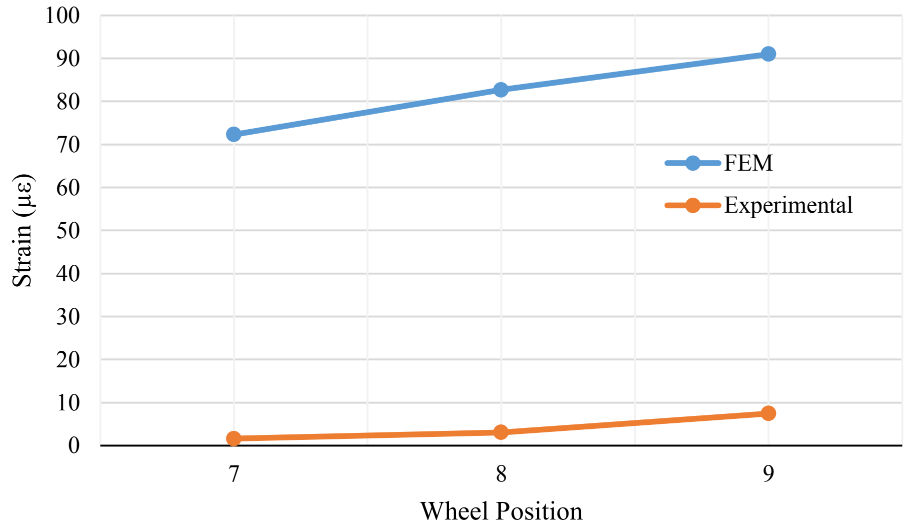


Figure C-21: FEM vs. Experimental comparison of strain gage 6T for Route 350 over I-435 test

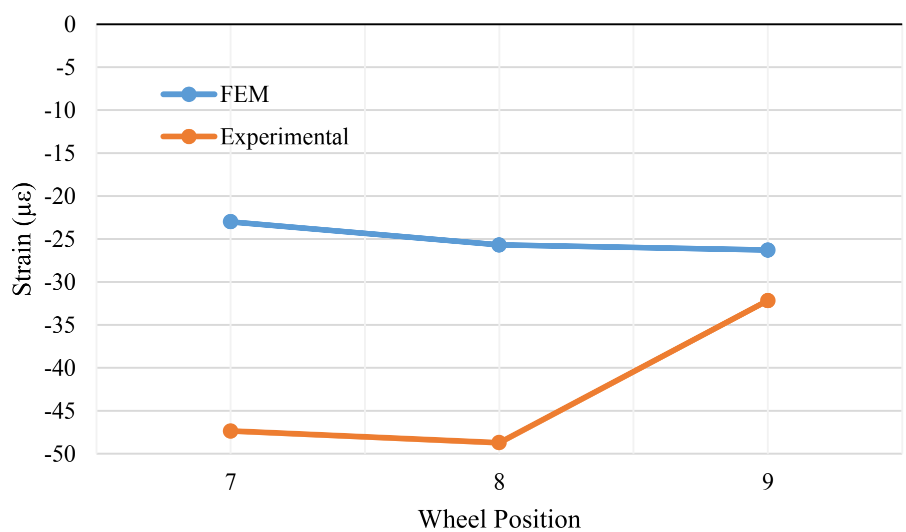


Figure C-22: FEM vs. Experimental comparison of strain gage 7L for Route 350 over I-435 test

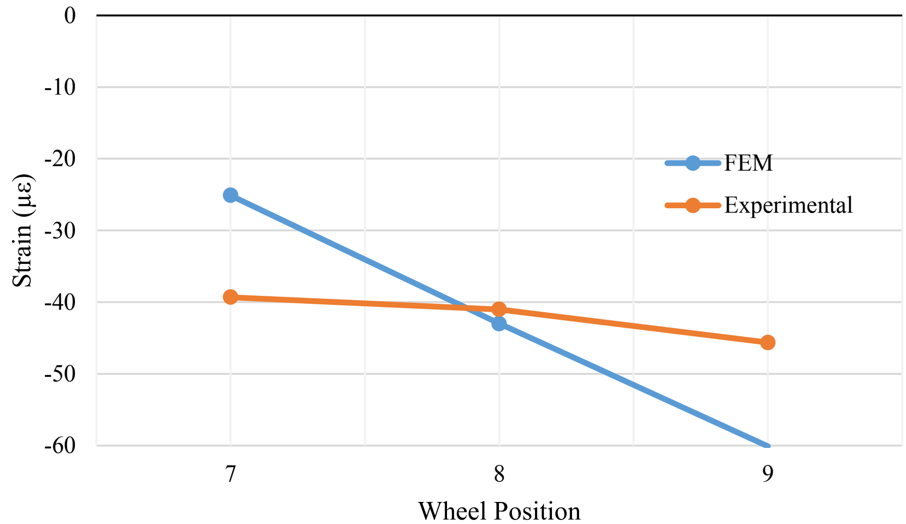


Figure C-23: FEM vs. Experimental comparison of strain gage 7T for Route 350 over I-435 test

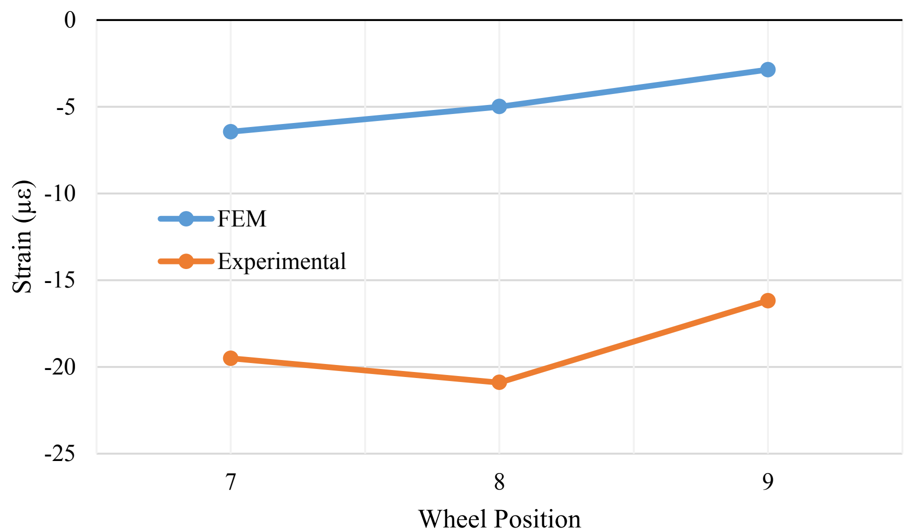


Figure C-24: FEM vs. Experimental comparison of strain gage 8L for Route 350 over I-435 test

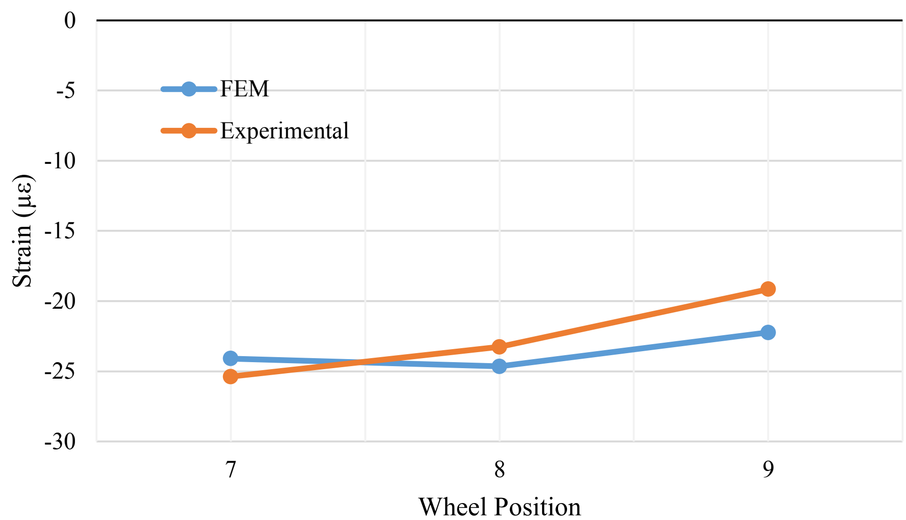


Figure C-25: FEM vs. Experimental comparison of strain gage 9L for Route 350 over I-435 test

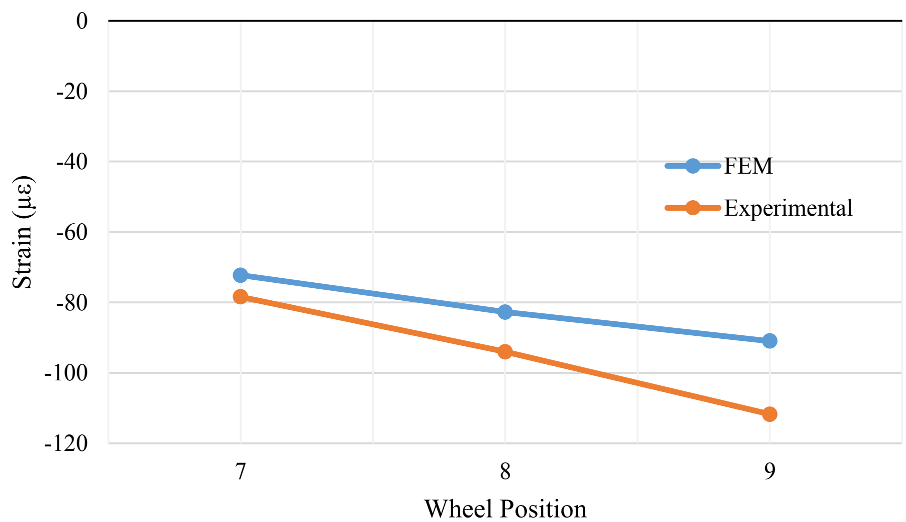


Figure C-26: FEM vs. Experimental comparison of strain gage 9T for Route 350 over I-435 test

Appendix D – Design Calculations and Specifications

Robust Finger Plate Expansion Device Design

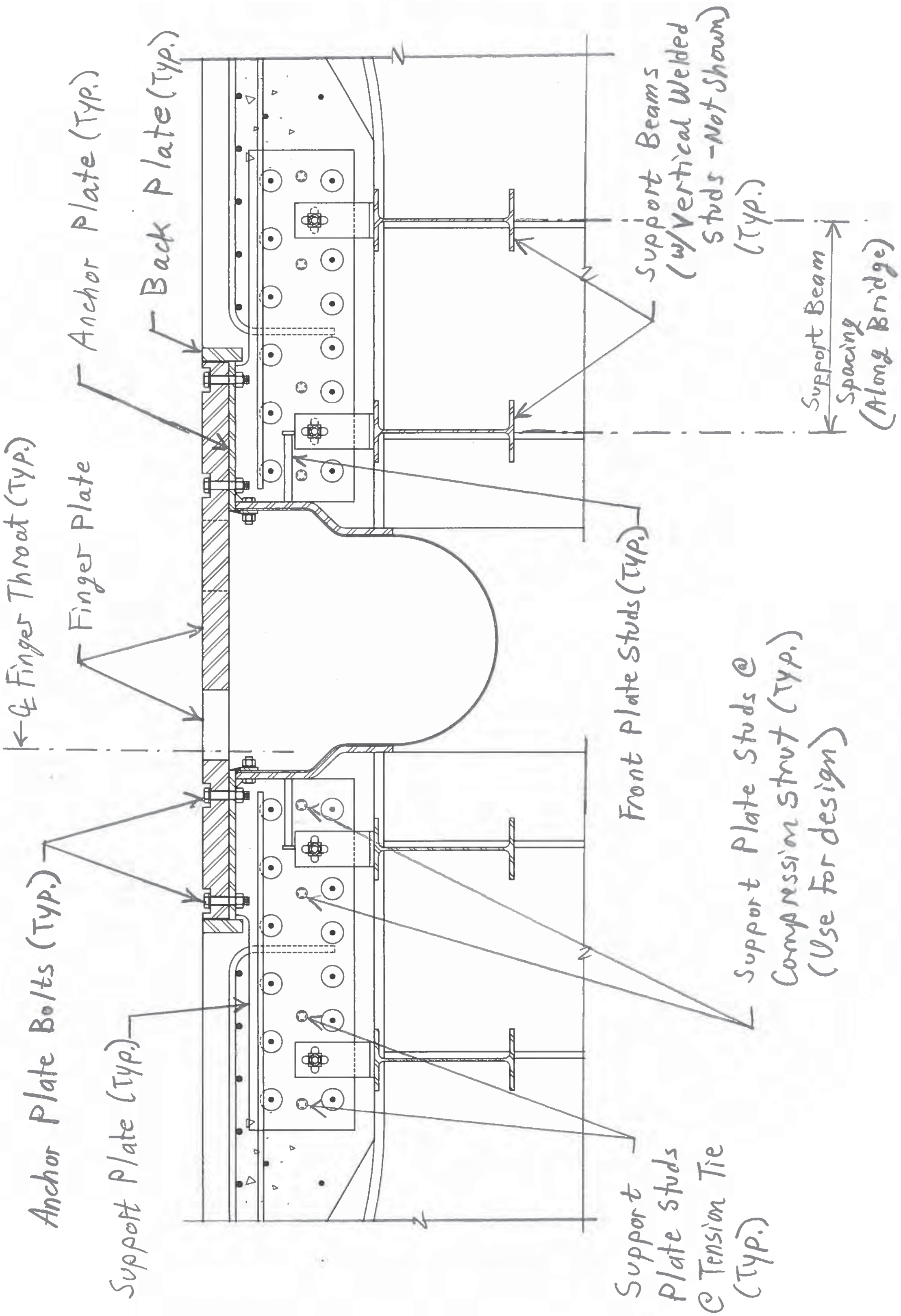
Codes referenced:

AASHTO LRFD Bridge Design Specifications, 7th Ed. 2014

PCI Design Handbook, Precast and Prestressed Concrete, 6th Ed.

ACI 318-11, Building Code Requirements for Structural Concrete

Project:	MoDOT Finger Plate	Computed:	DGB	Date:	10/1/2015
Subject:	Robust Design	Checked:	MTW	Date:	12/10/2015
Task:		Page:	1	of:	ROBUST
Job #:	244663	No:			



MoDOT Robust Finger Plate Expansion Device Design for Steel Girders

Calculation Notes:

1.0 - Finger Plate Design for Strength Moment and Shear and Fatigue Stress
2.0 - Anchorage Bolt Design for Strength and Fatigue
3.0 - Support Beam Stud Design for Strength and Fatigue
4.0 - Back Edge PL Design for Strength Moment and Shear and Fatigue Stress
5.0 - Front PL Stud Design for Strength and Fatigue
6.0 - Support PL Design for Strength Moment and Fatigue Stress
7.0 - Support PL Stud Design for Strength and Fatigue

General Parameters:

Temp. Rise* - Steel:	60°F	
Temp. Fall* - Steel:	90°F	
* - Based on 60°F setting temperature		
α_{Steel}:	0.0000065	in/in/°F
Min. Overlap @ Open:	1 1/2 in.	
Axle Load - Strength:	25 kips	
Tire - Across Bridge:	20 in.	
Tire - Along Bridge:	10 in.	
LL Factor:	1.75	
Multi-Presence Factor:	1.20	
Impact:	200%	

Temp. Rise* - Concrete:	50°F	
Temp. Fall* - Concrete:	70°F	
$\alpha_{Concrete}$:	0.0000060	in/in/°F
Min. Gap @ Close:	1 1/2 in.	
Axle Load - Fatigue:	16 kips	
Tire - Across Bridge:	20 in.	
Tire - Along Bridge:	10 in.	
LL Factor:	1.50	
Multi-Presence Factor:	1.00	
Impact:	200%	
Finger PL Fat. Category:	B	
Finger PL Δ_{TH}:	16.0 ksi	
Edge & Support PL Fat. Category:	B	
Edge & Support PL Δ_{TH}:	16.0 ksi	

Allowable Fatigue Stress per AASHTO Table 6.6.1.2.5-3

Finger Plate Steel, F_y:	50 ksi	
Steel Moment of Inertia, E_s:	29,000 ksi	
Concrete Strength, f'_c:	4 ksi	
Concrete Moment of Inertia, E_c:	3,834 ksi	AASHTO 5.4.2.4
Headed Stud Steel, F_y:	50 ksi	
Headed Stud Steel, F_u:	60 ksi	
Reinf. Steel, F_y:	60 ksi	
Resistance Factor, ϕ_f:	1.00	AASHTO 6.5.4.2
Resistance Factor, ϕ_v:	1.00	AASHTO 6.5.4.2
Resistance Factor, ϕ_t:	0.80	AASHTO 6.5.4.2
Resistance Factor, ϕ_t:	0.75	PCI 6.5.2
Resistance Factor, ϕ_{sc}:	0.85	AASHTO 6.5.4.2
Resistance Factor, $\phi_{Pullout}$:	0.75	ACI 318 D.4.4
Headed Stud Fat. Category:	C	(Full Joint Penetration weld w/o NDT or Grinding)
Headed Stud Δ_{TH}:	10.0 ksi	
Assumed Δ for Headed Stud Width:	1/2 in.	

MoDOT Robust Finger Plate Expansion Device Design for Steel Girders (Cont.)

Design ID	Expansion Length (ft)	Bridge Type Steel or Concrete (S or C)	Finger Plate Thickness (in)	Throat Radius (in)	Finger Kerf (in)	CL of Throat to First Bolt (in)	Anchor Bolt Spa. Along (in)	Anchor Bolt Spa. Across (in)	Bolt Size (in)	Bolt Grade	CL of Throat to First Stud (in)	Anchor Studs Along (in)	Anchor Studs Across (in)	Anchor Stud Size (in)
1	1130	S	3	1	1/8	5	12	9	7/8	A325	11 1/8	24	8	7/8
2	1000	S	2 3/4	1	1/8	5	10	9	7/8	A325	11 1/8	24	8	7/8
3	860	S	2 1/2	1	1/8	5	9	9	7/8	A325	11 1/8	24	8	7/8
4	740	S	2 1/4	1	1/8	5	8	9	7/8	A325	11 1/8	24	9	7/8
5	620	S	2	1	1/8	5	8	10	7/8	A325	11 1/8	24	9	7/8
6	530	S	1 3/4	1	1/8	5	8	12	7/8	A325	11 1/8	24	10	7/8
7	470	S	1 3/4	1	1/8	5	8	12	7/8	A325	11 1/8	24	10	7/8
8	430	S	1 3/4	1	1/8	5	8	12	7/8	A325	11 1/8	24	10	7/8
9	400	S	1 3/4	1	1/8	5	8	12	7/8	A325	11 1/8	24	12	7/8

Design ID	Back Edge PL Width (in)	Back Edge PL Height (in)	CL of Throat to CL Front PL (in)	CL of Back Bolt Edge of PL (in)	Support PL Spacing (in)	Support PL Thickness (in)	Support PL Connect. (in)	CL Throat to CL Support PL (in)	Front Studs Across (in)	Front Stud Size (in)	Support PL Stud Size (in)	Number Support Plate Studs
1	1 1/4	4	2 7/8	2	36	1	14 1/2	11 3/8	6	7/8	7/8	4
2	1 1/4	4	2 7/8	2	36	1	12 1/2	9 3/8	6	7/8	7/8	4
3	1 1/4	4	2 7/8	2	36	1	11 1/2	8 3/8	6	7/8	7/8	4
4	1 1/4	4	2 7/8	2	36	1	10 1/2	7 3/8	6	7/8	7/8	4
5	1 1/4	4	2 7/8	2	36	1	10 1/2	7 3/8	6	7/8	7/8	4
6	1 1/4	4	2 7/8	2	36	3/4	10 1/2	7 3/8	6	7/8	7/8	4
7	1 1/4	4	2 3/4	2	36	3/4	10 1/2	7 3/8	6	7/8	7/8	4
8	1 1/4	4	2 3/4	2	36	3/4	10 1/2	7 3/8	6	7/8	7/8	4
9	1 1/4	4	2 3/4	2	36	3/4	10 1/2	7 3/8	6	7/8	7/8	4

MoDOT Robust Finger Plate Expansion Device Design for Steel Girders (Cont.)

Design ID	Joint Geometry							
	Finger Width (in)	CL - CL Fingers (in)	$\Delta_{Cont.}$ (in)	$\Delta_{Exp.}$ (in)	$\Delta_{Tot..}$ (in)	Overlap @ 60°F (in)	Gap @ 60°F (in)	Finger Length (in)
1	1 3/4	3 3/4	9 5/8	6 3/8	16	11 1/8	7 7/8	19
2	1 3/4	3 3/4	8 1/2	5 5/8	14 1/8	10	7 1/8	17 1/8
3	1 3/4	3 3/4	7 1/4	4 7/8	12 1/8	8 3/4	6 3/8	15 1/8
4	1 3/4	3 3/4	6 1/4	4 1/4	10 1/2	7 3/4	5 3/4	13 1/2
5	1 3/4	3 3/4	5 1/4	3 1/2	8 3/4	6 3/4	5	11 3/4
6	1 3/4	3 3/4	4 1/2	3	7 1/2	6	4 1/2	10 1/2
7	1 3/4	3 3/4	4	2 3/4	6 3/4	5 1/2	4 1/4	9 3/4
8	1 3/4	3 3/4	3 5/8	2 1/2	6 1/8	5 1/8	4	9 1/8
9	1 3/4	3 3/4	3 3/8	2 1/4	5 5/8	4 7/8	3 3/4	8 5/8

Assume straight finger geometry.

MoDOT Robust Finger Plate Expansion Device Design for Steel Girders (Cont.)

	1.0 - Strength Design at Base of Finger								
Design ID	Load / Finger (kips)	Factored Load (kips)	Moment Arm (in)	S-Finger (in^3)	Applied Moment (kip-in)	Applied Stress (ksi)	Less Than $\phi_f F_y$?	Nominal Shear, Vn (kips)	Less Than $\phi_v V_n$?
1	2.34	9.83	13.00	2.625	127.79	48.68	**OK**	152.3	**OK**
2	2.34	9.83	11.13	2.206	109.36	49.57	**OK**	139.6	**OK**
3	2.34	9.83	9.13	1.823	89.70	49.20	**OK**	126.9	**OK**
4	2.34	9.83	7.50	1.477	73.73	49.92	**OK**	114.2	**OK**
5	2.34	9.83	5.75	1.167	56.52	48.43	**OK**	101.5	**OK**
6	2.23	9.37	4.75	0.893	44.51	49.84	**OK**	88.8	**OK**
7	2.05	8.61	4.38	0.893	37.67	42.18	**OK**	88.8	**OK**
8	1.90	7.98	4.06	0.893	32.42	36.30	**OK**	88.8	**OK**
9	1.79	7.52	3.81	0.893	28.67	32.11	**OK**	88.8	**OK**

Assume 100% of wheel load taken by one side of the finger joint; Value of "C" in V_n = 1.00.

Assume only the length of finger is loaded if finger length is less than longitudinal tire length.

	1.0 - Strength Design at Base of Throat								
Design ID	Load / Finger (kips)	Factored Load (kips)	Moment Arm (in)	S-Finger (in^3)	Applied Moment (kip-in)	Applied Stress (ksi)	Less Than $\phi_f F_y$?	Nominal Shear, Vn (kips)	Less Than $\phi_v V_n$?
1	2.34	9.83	14.00	5.625	137.62	24.47	**OK**	326.3	**OK**
2	2.34	9.83	12.13	4.727	119.19	25.21	**OK**	299.1	**OK**
3	2.34	9.83	10.13	3.906	99.53	25.48	**OK**	271.9	**OK**
4	2.34	9.83	8.50	3.164	83.56	26.41	**OK**	244.7	**OK**
5	2.34	9.83	6.75	2.500	66.35	26.54	**OK**	217.5	**OK**
6	2.34	9.83	5.50	1.914	54.07	28.25	**OK**	190.3	**OK**
7	2.29	9.62	4.88	1.914	46.90	24.50	**OK**	190.3	**OK**
8	2.14	8.99	4.56	1.914	41.02	21.43	**OK**	190.3	**OK**
9	2.02	8.48	4.31	1.914	36.57	19.11	**OK**	190.3	**OK**

Assume 100% of wheel load taken by one side of the finger joint; Value of "C" in V_n = 1.00.

Assume only the length of finger is loaded if finger length is less than longitudinal tire length.

MoDOT Robust Finger Plate Expansion Device Design for Steel Girders (Cont.)

Design ID	Overlap at 90°F (in)	Shared Load / Finger (kips)	Un-Shared Load / Finger (kips)	Factored Shared Load (kips)	Factored Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	S-Finger (in^3)	Applied Moment (kip-in)	Applied Stress (ksi)	Less Than Δ_{TH}?
	1.0 - Fatigue Design at Base Finger @ 90 Degrees										
1	13.77	0.75	0.00	2.25	0.00	13.00	0.00	2.625	29.25	11.14	**OK**
2	12.34	0.75	0.00	2.25	0.00	11.13	0.00	2.206	25.04	11.35	**OK**
3	10.76	0.75	0.00	2.25	0.00	9.13	0.00	1.823	20.54	11.27	**OK**
4	9.48	0.71	0.08	2.13	0.24	7.76	2.76	1.477	17.19	11.64	**OK**
5	8.20	0.62	0.27	1.86	0.81	6.65	1.65	1.167	13.71	11.75	**OK**
6	7.24	0.54	0.41	1.62	1.23	5.88	0.88	0.893	10.61	11.88	**OK**
7	6.60	0.50	0.47	1.50	1.41	5.45	0.58	0.893	8.99	10.07	**OK**
8	6.13	0.46	0.45	1.38	1.35	5.06	0.50	0.893	7.66	8.58	**OK**
9	5.81	0.44	0.42	1.32	1.26	4.72	0.41	0.893	6.75	7.56	**OK**

Assumes equal load sharing to adjacent fingers in regions of finger overlap.

Design ID	Overlap at 80°F (in)	Shared Load / Finger (kips)	Un-Shared Load / Finger (kips)	Factored Shared Load (kips)	Factored Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	S-Finger (in^3)	Applied Moment (kip-in)	Applied Stress (ksi)	Less Than Δ_{TH}?
	1.0 - Fatigue Design at Base Finger @ 80 Degrees										
1	12.89	0.75	0.00	2.25	0.00	13.00	0.00	2.625	29.25	11.14	**OK**
2	11.56	0.75	0.00	2.25	0.00	11.13	0.00	2.206	25.04	11.35	**OK**
3	10.09	0.75	0.00	2.25	0.00	9.13	0.00	1.823	20.54	11.27	**OK**
4	8.90	0.67	0.17	2.01	0.51	8.05	3.05	1.477	17.74	12.01	**OK**
5	7.72	0.58	0.34	1.74	1.02	6.89	1.89	1.167	13.92	11.93	**OK**
6	6.83	0.51	0.48	1.53	1.44	6.09	1.09	0.893	10.89	12.19	**OK**
7	6.23	0.47	0.53	1.41	1.59	5.64	0.76	0.893	9.16	10.26	**OK**
8	5.80	0.44	0.50	1.32	1.50	5.23	0.66	0.893	7.89	8.84	**OK**
9	5.50	0.41	0.47	1.23	1.41	4.88	0.56	0.893	6.79	7.60	**OK**

Assumes equal load sharing to opposite fingers in regions of finger overlap.

Perform a parametric analysis of the fatigue performance of the fingers at various temperatures.

MoDOT Robust Finger Plate Expansion Device Design for Steel Girders (Cont.)

Design ID	1.0 - Fatigue Design at Base Finger @ 70 Degrees										
	Overlap at 70°F (in)	Shared Load / Finger (kips)	Un-Shared Load / Finger (kips)	Factored Shared Load (kips)	Factored Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	S-Finger (in^3)	Applied Moment (kip-in)	Applied Stress (ksi)	Less Than Δ_{TH} ?
1	12.01	0.75	0.00	2.25	0.00	13.00	0.00	2.625	29.25	11.14	**OK**
2	10.78	0.75	0.00	2.25	0.00	11.13	0.00	2.206	25.04	11.35	**OK**
3	9.42	0.71	0.09	2.13	0.27	9.42	4.42	1.823	21.26	11.66	**OK**
4	8.33	0.62	0.25	1.86	0.75	8.34	3.34	1.477	18.02	12.20	**OK**
5	7.23	0.54	0.42	1.62	1.26	7.14	2.14	1.167	14.26	12.22	**OK**
6	6.41	0.48	0.54	1.44	1.62	6.30	1.30	0.893	11.18	12.52	**OK**
7	5.87	0.44	0.58	1.32	1.74	5.82	0.94	0.893	9.32	10.44	**OK**
8	5.46	0.41	0.55	1.23	1.65	5.40	0.83	0.893	8.01	8.97	**OK**
9	5.19	0.39	0.52	1.17	1.56	5.03	0.72	0.893	7.01	7.85	**OK**

Assumes equal load sharing to adjacent fingers in regions of finger overlap.

Design ID	1.0 - Fatigue Design at Base Finger @ 60 Degrees										
	Overlap at 60°F (in)	Shared Load / Finger (kips)	Un-Shared Load / Finger (kips)	Factored Shared Load (kips)	Factored Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	S-Finger (in^3)	Applied Moment (kip-in)	Applied Stress (ksi)	Less Than Δ_{TH} ?
1	11.13	0.75	0.00	2.25	0.00	13.00	0.00	2.625	29.25	11.14	**OK**
2	10.00	0.75	0.00	2.25	0.00	11.13	0.00	2.206	25.04	11.35	**OK**
3	8.75	0.66	0.19	1.98	0.57	9.75	4.75	1.823	22.01	12.07	**OK**
4	7.75	0.58	0.34	1.74	1.02	8.63	3.63	1.477	18.72	12.67	**OK**
5	6.75	0.51	0.49	1.53	1.47	7.38	2.38	1.167	14.79	12.67	**OK**
6	6.00	0.45	0.60	1.35	1.80	6.50	1.50	0.893	11.48	12.86	**OK**
7	5.50	0.41	0.64	1.23	1.92	6.00	1.13	0.893	9.55	10.69	**OK**
8	5.13	0.38	0.60	1.14	1.80	5.56	1.00	0.893	8.14	9.12	**OK**
9	4.88	0.37	0.56	1.11	1.68	5.19	0.87	0.893	7.22	8.09	**OK**

Assumes equal load sharing to opposite fingers in regions of finger overlap.

MoDOT Robust Finger Plate Expansion Device Design for Steel Girders (Cont.)

Design ID	Overlap at 50°F (in)	Shared Load / Finger (kips)	Un-Shared Load / Finger (kips)	Factored Shared Load (kips)	Factored Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	S-Finger (in^3)	Applied Moment (kip-in)	Applied Stress (ksi)	Less Than Δ_{TH}?
	1.0 - Fatigue Design at Base Finger @ 50 Degrees										
1	10.24	0.75	0.00	2.25	0.00	13.00	0.00	2.625	29.25	11.14	**OK**
2	9.22	0.69	0.12	2.07	0.36	11.52	6.52	2.206	26.19	11.87	**OK**
3	8.08	0.61	0.29	1.83	0.87	10.09	5.09	1.823	22.89	12.56	**OK**
4	7.17	0.54	0.42	1.62	1.26	8.92	3.92	1.477	19.39	13.13	**OK**
5	6.27	0.47	0.56	1.41	1.68	7.62	2.62	1.167	15.15	12.98	**OK**
6	5.59	0.42	0.66	1.26	1.98	6.71	1.71	0.893	11.84	13.26	**OK**
7	5.13	0.38	0.69	1.14	2.07	6.19	1.31	0.893	9.77	10.94	**OK**
8	4.79	0.36	0.65	1.08	1.95	5.73	1.17	0.893	8.47	9.48	**OK**
9	4.56	0.34	0.61	1.02	1.83	5.35	1.03	0.893	7.34	8.22	**OK**

Assumes equal load sharing to adjacent fingers in regions of finger overlap.

Design ID	Overlap at 40°F (in)	Shared Load / Finger (kips)	Un-Shared Load / Finger (kips)	Factored Shared Load (kips)	Factored Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	S-Finger (in^3)	Applied Moment (kip-in)	Applied Stress (ksi)	Less Than Δ_{TH}?
	1.0 - Fatigue Design at Base Finger @ 40 Degrees										
1	9.36	0.70	0.10	2.10	0.30	13.32	8.32	2.625	30.47	11.61	**OK**
2	8.44	0.63	0.23	1.89	0.69	11.91	6.91	2.206	27.28	12.37	**OK**
3	7.41	0.56	0.39	1.68	1.17	10.42	5.42	1.823	23.85	13.08	**OK**
4	6.60	0.50	0.51	1.50	1.53	9.20	4.20	1.477	20.23	13.70	**OK**
5	5.78	0.43	0.63	1.29	1.89	7.86	2.86	1.167	15.54	13.32	**OK**
6	5.17	0.39	0.72	1.17	2.16	6.92	1.92	0.893	12.24	13.71	**OK**
7	4.77	0.36	0.75	1.08	2.25	6.37	1.49	0.893	10.23	11.46	**OK**
8	4.45	0.33	0.70	0.99	2.10	5.90	1.34	0.893	8.66	9.70	**OK**
9	4.25	0.32	0.66	0.96	1.98	5.50	1.19	0.893	7.64	8.56	**OK**

Assumes equal load sharing to opposite fingers in regions of finger overlap.

MoDOT Robust Finger Plate Expansion Device Design for Steel Girders (Cont.)

Design ID	1.0 - Fatigue Design at Base Finger @ 30 Degrees										
	Overlap at 30°F (in)	Shared Load / Finger (kips)	Un-Shared Load / Finger (kips)	Factored Shared Load (kips)	Factored Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	S-Finger (in^3)	Applied Moment (kip-in)	Applied Stress (ksi)	Less Than Δ_{TH}?
1	8.48	0.64	0.23	1.92	0.69	13.76	8.76	2.625	32.46	12.37	**OK**
2	7.66	0.57	0.35	1.71	1.05	12.30	7.30	2.206	28.70	13.01	**OK**
3	6.74	0.51	0.49	1.53	1.47	10.76	5.76	1.823	24.93	13.68	**OK**
4	6.02	0.45	0.60	1.35	1.80	9.49	4.49	1.477	20.89	14.14	**OK**
5	5.30	0.40	0.71	1.20	2.13	8.10	3.10	1.167	16.32	13.98	**OK**
6	4.76	0.36	0.79	1.08	2.37	7.12	2.12	0.893	12.71	14.23	**OK**
7	4.40	0.33	0.80	0.99	2.40	6.55	1.68	0.893	10.52	11.78	**OK**
8	4.12	0.31	0.75	0.93	2.25	6.07	1.50	0.893	9.02	10.10	**OK**
9	3.94	0.30	0.70	0.90	2.10	5.66	1.34	0.893	7.91	8.86	**OK**

Assumes equal load sharing to adjacent fingers in regions of finger overlap.

Design ID	1.0 - Fatigue Design at Base Finger @ 20 Degrees										
	Overlap at 20°F (in)	Shared Load / Finger (kips)	Un-Shared Load / Finger (kips)	Factored Shared Load (kips)	Factored Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	S-Finger (in^3)	Applied Moment (kip-in)	Applied Stress (ksi)	Less Than Δ_{TH}?
1	7.60	0.57	0.36	1.71	1.08	14.20	9.20	2.625	34.22	13.04	**OK**
2	6.88	0.52	0.47	1.56	1.41	12.69	7.69	2.206	30.64	13.89	**OK**
3	6.07	0.46	0.59	1.38	1.77	11.09	6.09	1.823	26.08	14.31	**OK**
4	5.44	0.41	0.68	1.23	2.04	9.78	4.78	1.477	21.78	14.75	**OK**
5	4.82	0.36	0.78	1.08	2.34	8.34	3.34	1.167	16.82	14.41	**OK**
6	4.35	0.33	0.85	0.99	2.55	7.33	2.33	0.893	13.20	14.78	**OK**
7	4.03	0.30	0.86	0.90	2.58	6.74	1.86	0.893	10.86	12.16	**OK**
8	3.78	0.28	0.80	0.84	2.40	6.24	1.67	0.893	9.25	10.36	**OK**
9	3.63	0.27	0.75	0.81	2.25	5.81	1.50	0.893	8.08	9.05	**OK**

Assumes equal load sharing to opposite fingers in regions of finger overlap.

Finger plate design is controlled by Strength instead of Fatigue for all temperatures down to 0°. Use 50° for all remaining calculations as a expected median point of the temperature range.

MoDOT Robust Finger Plate Expansion Device Design for Steel Girders (Cont.)

Design ID	2.0 - Strength Design of Anchor Plate Bolts: Trib. Load per Bolt Line (kips)	Factor Trib. Load per Bolt Line (kips)	Moment Arm (in)	Applied Bolt Tension (kips)	Allowable Bolt Tension (kips)	Bolt Pre-Tension (kips)	Less Than Allowable ?
1	5.63	23.65	18.00	35.48	43.87	39	**OK**
2	5.63	23.65	16.13	38.15	43.87	39	**OK**
3	5.63	23.65	14.13	37.13	43.87	39	**OK**
4	5.63	23.65	12.50	36.95	43.87	39	**OK**
5	6.25	26.25	10.75	35.27	43.87	39	**OK**
6	7.50	31.50	9.50	37.41	43.87	39	**OK**
7	7.50	31.50	8.75	34.45	43.87	39	**OK**
8	7.50	31.50	8.13	32.01	43.87	39	**OK**
9	7.50	31.50	7.63	30.04	43.87	39	**OK**

Assumes 100% of wheel load taken by one side of the finger joint and the point of support is the first bolt in the couple.

$\phi_t T_n = \phi_t\, 0.76\, A_b\, F_{ub}$ AASHTO Eq. 6.13.2.10.2-1

Min. Tension AASHTO C6.13.2.8

Design ID	2.0 - Fatigue Design of Anchor Plate Bolts @ 50 Degrees: Overlap at 50°F (in)	Shared Load / Bolt Line (kips)	Un-Shared Load / Bolt Line (kips)	Factored Shared Load (kips)	Factored Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	Applied Moment (kip-in)	Applied Stress (ksi)	Fatigue Threshold $\Delta_{TH.}$ (ksi)	Less Than Δ_{TH} ?
1	10.24	1.80	0.00	5.40	0.00	18.00	0.00	97.20	13.5	31.0	**OK**
2	9.22	1.66	0.28	4.98	0.84	16.52	11.52	91.95	15.3	31.0	**OK**
3	8.08	1.45	0.69	4.35	2.07	15.09	10.09	86.53	16.0	31.0	**OK**
4	7.17	1.29	1.02	3.87	3.06	13.92	8.92	81.17	16.9	31.0	**OK**
5	6.27	1.25	1.49	3.75	4.47	12.62	7.62	81.39	16.9	31.0	**OK**
6	5.59	1.34	2.12	4.02	6.36	11.71	6.71	89.75	18.7	31.0	**OK**
7	5.13	1.23	2.34	3.69	7.02	11.19	6.19	84.74	17.6	31.0	**OK**
8	4.79	1.15	2.50	3.45	7.50	10.73	5.73	79.99	16.6	31.0	**OK**
9	4.56	1.09	2.61	3.27	7.83	10.35	5.35	75.74	15.7	31.0	**OK**

Fatigue Threshold
AASHTO Table 6.6.1.2.5-3

Assumes equal load sharing to opposite fingers in regions of finger overlap and the point of support is the first bolt in the couple.

MoDOT Robust Finger Plate Expansion Device Design for Steel Girders (Cont.)

	3.0 - Strength Design of Support Beam Studs						
Design ID	Trib. Load per Stud Line (kips)	Factor Trib. Load per Stud Line (kips)	Moment Arm (in)	Applied Stud Tension (kips)	Allowable Stud Tension (kips)	Allowable Stud Pullout (kips)	Less Than Allowable ?
1	5.00	21.00	24.13	21.11	27.06	21.21	**OK**
2	5.00	21.00	22.25	19.47	27.06	21.21	**OK**
3	5.00	21.00	20.25	17.72	27.06	21.21	**OK**
4	5.63	23.65	18.63	18.36	27.06	21.21	**OK**
5	5.63	23.65	16.88	16.63	27.06	21.21	**OK**
6	6.25	26.25	15.63	17.10	27.06	21.21	**OK**
7	6.25	26.25	14.88	16.28	27.06	21.21	**OK**
8	6.25	26.25	14.25	15.59	27.06	21.21	**OK**
9	7.50	31.50	13.75	18.05	27.06	21.21	**OK**

Load is carried as a couple between the front and back support beams. Designed for the back tension stud only.

Allowable Stud Tension PCI 6.5.2

Allowable Stud Pullout ACI 318 D.5.3.1

	3.0 - Fatigue Design of Support Beam Studs @ 50 Degrees										
Design ID	Overlap at 50°F (in)	Shared Load / Stud Line (kips)	Un-Shared Load / Stud Line (kips)	Factored Shared Load (kips)	Factored Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	Applied Moment (kip-in)	Applied Stress (ksi)	Fatigue Threshold $\Delta_{TH.}$ (ksi)	Less Than Δ_{TH} ?
1	10.24	1.60	0.00	4.80	0.00	24.13	0.00	115.82	8.0	10.0	**OK**
2	9.22	1.48	0.25	4.44	0.75	22.64	17.64	113.75	7.9	10.0	**OK**
3	8.08	1.29	0.61	3.87	1.83	21.21	16.21	111.75	7.7	10.0	**OK**
4	7.17	1.29	1.02	3.87	3.06	20.04	15.04	123.58	8.6	10.0	**OK**
5	6.27	1.13	1.34	3.39	4.02	18.74	13.74	118.76	8.2	10.0	**OK**
6	5.59	1.12	1.76	3.36	5.28	17.83	12.83	127.65	8.8	10.0	**OK**
7	5.13	1.03	1.95	3.09	5.85	17.31	12.31	125.50	8.7	10.0	**OK**
8	4.79	0.96	2.08	2.88	6.24	16.86	11.86	122.56	8.5	10.0	**OK**
9	4.56	1.09	2.61	3.27	7.83	16.47	11.47	143.67	10.0	10.0	**OK**

Assumes equal load sharing to opposite fingers in regions of finger overlap. Designed for the back tension stud only.

MoDOT Robust Finger Plate Expansion Device Design for Steel Girders (Cont.)

LTB Check and Mn per AASHTO 6.12.2.2.7; Vn per AASHTO 6.12.1.2.3 & 6.10.9.2

Design ID	Loaded Width (in)	Couple Depth (in)	Moment Arm (in)	Tension Load (kips)	Uniform Load (kips/in)	Factored Load (kips/in)	Applied Mom., M_u (kip-in)	S-Plate (in^3)	LTB Check (?)	Nominal Mom., M_n (kip-in)	Less Than $\phi_f M_n$?	Factored Shear, V_u (kips)	Nominal Shear, V_n (kips)	Less Than $\phi_v V_n$?
	4.0 - Strength Design of Back Edge PL													
1	36	16.88	15.88	11.76	0.327	1.373	222.43	3.333	**OK**	246.05	**OK**	24.71	145.0	**OK**
2	36	14.88	14.00	11.76	0.327	1.373	222.43	3.333	**OK**	246.05	**OK**	24.71	145.0	**OK**
3	36	13.88	12.00	10.81	0.300	1.260	204.12	3.333	**OK**	246.05	**OK**	22.68	145.0	**OK**
4	34 3/4	12.88	10.38	10.07	0.290	1.218	197.08	3.333	**OK**	246.05	**OK**	21.16	145.0	**OK**
5	34 3/4	12.88	8.63	8.38	0.241	1.012	163.75	3.333	**OK**	246.05	**OK**	17.58	145.0	**OK**
6	34 3/4	12.88	7.38	7.16	0.206	0.865	139.96	3.333	**OK**	246.05	**OK**	15.03	145.0	**OK**
7	35	13.00	6.50	6.25	0.179	0.752	121.73	3.333	**OK**	246.05	**OK**	13.16	145.0	**OK**
8	35	13.00	5.88	5.65	0.161	0.676	109.43	3.333	**OK**	246.05	**OK**	11.83	145.0	**OK**
9	35	13.00	5.38	5.17	0.148	0.622	100.69	3.333	**OK**	246.05	**OK**	10.89	145.0	**OK**

Assume 30° load path past the front edge plate; Load is carried as a couple between the front edge and back plate.

Assume load is carried by back edge only w/o help from anchor PL, Back Edge is simply supported; Value of "C_b" in M_n = 1.00; Value of "C" in V_n = 1.00.

Design ID	Overlap at 50°F (in)	Shared Load (kips)	Un-Shared Load (kips)	Factored Shared Load (kips)	Factored Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	Factored Tension Load (kips)	Uniform Load (kips/in)	Applied Moment (kip-in)	Applied Stress (ksi)	Fatigue Threshold $\Delta_{TH.}$ (ksi)	Less Than Δ_{TH} ?
	4.0 - Fatigue Design of Back Edge PL @ 50 Degrees												
1	10.24	4.00	0.00	12.00	0.00	15.88	0.00	11.29	0.314	50.87	15.3	16.0	**OK**
2	9.22	3.69	0.62	11.07	1.86	14.39	9.39	11.88	0.330	53.46	16.0	16.0	**OK**
3	8.08	3.23	1.54	9.69	4.62	12.96	7.96	11.70	0.325	52.65	15.8	16.0	**OK**
4	7.17	2.87	2.26	8.61	6.78	11.79	6.79	11.46	0.330	53.40	16.0	16.0	**OK**
5	6.27	2.51	2.98	7.53	8.94	10.49	5.49	9.94	0.286	46.28	13.9	16.0	**OK**
6	5.59	2.24	3.53	6.72	10.59	9.58	4.58	8.76	0.252	40.77	12.2	16.0	**OK**
7	5.13	2.05	3.90	6.15	11.70	8.94	3.94	7.78	0.222	35.94	10.8	16.0	**OK**
8	4.79	1.92	4.17	5.76	12.51	8.48	3.48	7.11	0.203	32.86	9.9	16.0	**OK**
9	4.56	1.82	4.35	5.46	13.05	8.10	3.10	6.51	0.186	30.11	9.0	16.0	**OK**

Assumes equal load sharing to opposite fingers in regions of finger overlap.

MoDOT Robust Finger Plate Expansion Device Design for Steel Girders (Cont.)

Design ID	Compress Load (kips)	Loaded Width (in)	Stud Spacing (in)	Shear Load / Stud (kips)	Factored Load / Stud (kips)	Stud Cap. Q_n (kips)	Factored Cap. Q_r (kips)	Less Than Q_r ?
	5.0 - Strength Design of Front PL Studs							
1	24.26	20.0	6.00	7.28	15.29	36.08	30.67	**OK**
2	24.26	20.0	6.00	7.28	15.29	36.08	30.67	**OK**
3	23.31	20.0	6.00	6.99	14.68	36.08	30.67	**OK**
4	22.57	20.0	6.00	6.77	14.22	36.08	30.67	**OK**
5	20.88	20.0	6.00	6.26	13.15	36.08	30.67	**OK**
6	19.66	20.0	6.00	5.90	12.39	36.08	30.67	**OK**
7	18.75	20.0	6.00	5.63	11.82	36.08	30.67	**OK**
8	18.15	20.0	6.00	5.45	11.45	36.08	30.67	**OK**
9	17.67	20.0	6.00	5.30	11.13	36.08	30.67	**OK**

$f_{sc}\ Q_n = Q_r$ per AASHTO 6.10.10.4.1

Assume load is carried as a couple between the front edge bearing on concrete and the back plate. Assume 50% of the load is transferred directly into the concrete through bearing of the anchorage plate and the other 50% is carried through the front edge plate into the concrete by the studs.

Design ID	Factored Couple Load (kips)	Factored Direct Load (kips)	Factored Compress Load (kips)	Loaded Width (in)	Stud Spacing (in)	Factored Shear Load / Stud (kips)	Stud Cap. Z_r (kips)	Less Than Z_r ?
	5.0 - Fatigue Design of Front PL Studs @ 50 Degrees							
1	11.29	12.00	23.29	20.0	6.00	3.49	4.21	**OK**
2	11.88	12.93	24.81	20.0	6.00	3.72	4.21	**OK**
3	11.70	14.31	26.01	20.0	6.00	3.90	4.21	**OK**
4	11.46	15.39	26.85	20.0	6.00	4.03	4.21	**OK**
5	9.94	16.47	26.41	20.0	6.00	3.96	4.21	**OK**
6	8.76	17.31	26.07	20.0	6.00	3.91	4.21	**OK**
7	7.78	17.85	25.63	20.0	6.00	3.84	4.21	**OK**
8	7.11	18.27	25.38	20.0	6.00	3.81	4.21	**OK**
9	6.51	18.51	25.02	20.0	6.00	3.75	4.21	**OK**

Z_r per AASHTO 6.10.10.2

Assumes equal load sharing to opposite fingers in regions of finger overlap.

MoDOT Robust Finger Plate Expansion Device Design for Steel Girders (Cont.)

Design ID	6.0 - Strength Design of Support PL @ Connection					
	Factored Load (kips)	Moment Arm (in)	Applied Moment (kip-in)	S (in^3)	Applied Stress (ksi)	Less Than $\phi_f F_y$?
1	52.50	24.38	1279.95	35.04	36.53	**OK**
2	52.50	20.50	1076.25	26.04	41.33	**OK**
3	52.50	17.50	918.75	22.04	41.69	**OK**
4	52.50	14.88	781.20	18.38	42.50	**OK**
5	52.50	13.13	689.33	18.38	37.50	**OK**
6	52.50	11.88	623.70	13.78	45.26	**OK**
7	52.50	11.13	584.33	13.78	42.40	**OK**
8	52.50	10.50	551.25	13.78	40.00	**OK**
9	52.50	10.00	525.00	13.78	38.10	**OK**

Assume load is centered on support plate and not shared to adjacent support plates.

Design ID	6.0 - Fatigue Design of Support PL Connection @ 50 Degrees										
	Overlap at 50°F (in)	Shared Load (kips)	Un-Shared Load (kips)	Factored Shared Load (kips)	Factored Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	Applied Moment (kip-in)	Applied Stress (ksi)	Fatigue Threshold $\Delta_{TH.}$ (ksi)	Less Than Δ_{TH} ?
1	10.24	4.00	0.00	12.00	0.00	24.38	0.00	292.56	8.3	16.0	**OK**
2	9.22	3.69	0.62	11.07	1.86	20.89	15.89	260.81	10.0	16.0	**OK**
3	8.08	3.23	1.54	9.69	4.62	18.46	13.46	241.06	10.9	16.0	**OK**
4	7.17	2.87	2.26	8.61	6.78	16.29	11.29	216.80	11.8	16.0	**OK**
5	6.27	2.51	2.98	7.53	8.94	14.99	9.99	202.19	11.0	16.0	**OK**
6	5.59	2.24	3.53	6.72	10.59	14.08	9.08	190.77	13.8	16.0	**OK**
7	5.13	2.05	3.90	6.15	11.70	13.56	8.56	183.55	13.3	16.0	**OK**
8	4.79	1.92	4.17	5.76	12.51	13.11	8.11	176.97	12.8	16.0	**OK**
9	4.56	1.82	4.35	5.46	13.05	12.72	7.72	170.20	12.4	16.0	**OK**

Assumes equal load sharing to opposite fingers in regions of finger overlap.

MoDOT Robust Finger Plate Expansion Device Design for Steel Girders (Cont.)

	7.0 - Strength Design of Support PL Studs						
Design ID	Factored Load (kips)	Moment Arm (in)	Compress Load (kips)	Factored Load / Stud (kips)	Stud Cap. Q_n (kips)	Factored Cap. Q_r (kips)	Less Than Q_r ?
1	52.50	24.13	105.28	13.16	36.08	30.67	**OK**
2	52.50	22.25	101.17	12.65	36.08	30.67	**OK**
3	52.50	20.25	96.80	12.10	36.08	30.67	**OK**
4	52.50	18.63	93.25	11.66	36.08	30.67	**OK**
5	52.50	16.88	89.43	11.18	36.08	30.67	**OK**
6	52.50	15.63	86.69	10.84	36.08	30.67	**OK**
7	52.50	14.88	85.05	10.63	36.08	30.67	**OK**
8	52.50	14.25	83.67	10.46	36.08	30.67	**OK**
9	52.50	13.75	82.58	10.32	36.08	30.67	**OK**

$f_{sc}\,Q_n = Q_r$ per AASHTO 6.10.10.4.1

Final Resultant - Use the parameters from "Design ID 1" as standard layout for all expansion devices using this configuration.

Assume load is centered on support plate and not shared to adjacent support plates. The load is carried through the studs at the front and back support beams. The thrust load at the front support beam controls. Assume 50% of load is carried directly into the concrete by bearing of the anchor plate and the other 50% is carried by the shear studs.

	7.0 - Fatigue Design of Support PL Studs @ 50 Degrees										
Design ID	Overlap at 50°F (in)	Shared Load (kips)	Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	Applied Moment (kip-in)	Compress Load (kips)	Factored Compress Load (kips)	Load per Stud (kips)	Stud Cap. Z_r (kips)	Less Than Z_r ?
1	10.24	4	0	24.13	0	96.52	8.02	24.06	3.01	4.21	**OK**
2	9.22	3.69	0.62	22.64	17.64	94.48	8.25	24.75	3.09	4.21	**OK**
3	8.08	3.23	1.54	21.21	16.21	93.47	8.66	25.98	3.25	4.21	**OK**
4	7.17	2.87	2.26	20.04	15.04	91.51	8.94	26.82	3.35	4.21	**OK**
5	6.27	2.51	2.98	18.74	13.74	87.98	9.16	27.48	3.44	4.21	**OK**
6	5.59	2.24	3.53	17.83	12.83	85.23	9.32	27.96	3.50	4.21	**OK**
7	5.13	2.05	3.9	17.31	12.31	83.49	9.43	28.29	3.54	4.21	**OK**
8	4.79	1.92	4.17	16.86	11.86	81.83	9.50	28.5	3.56	4.21	**OK**
9	4.56	1.82	4.35	16.47	11.47	79.87	9.50	28.5	3.56	4.21	**OK**

Z_r per AASHTO 6.10.10.2

Assume load is shared to opposite fingers in regions of overlap.

MoDOT Robust Finger Plate Expansion Device Design for Concrete Girders

Calculation Notes:

1.0 - Finger Plate Design for Strength Moment and Shear and Fatigue Stress
2.0 - Anchorage Bolt Design for Strength and Fatigue
3.0 - Support Beam Stud Design for Strength and Fatigue
4.0 - Back Edge PL Design for Strength Moment and Shear and Fatigue Stress
5.0 - Front PL Stud Design for Strength and Fatigue
6.0 - Support PL Design for Strength Moment and Fatigue Stress
7.0 - Support PL Stud Design for Strength and Fatigue

General Parameters:

Temp. Rise* - Steel:	60°F	Temp. Rise* - Concrete:	50°F	Finger Plate Steel, F_y:	50 ksi	
Temp. Fall* - Steel:	90°F	Temp. Fall* - Concrete:	70°F	Steel Moment of Inertia, E_s:	29,000 ksi	
* - Based on 60°F setting temperature				Concrete Strength, f'_c:	4 ksi	
				Concrete Moment of Inertia, E_c:	3,834 ksi	AASHTO 5.4.2.4
α_{Steel}:	0.0000065 in/in/°F	$\alpha_{Concrete}$:	0.0000060 in/in/°F	Headed Stud Steel, F_y:	50 ksi	
Min. Overlap @ Open:	1 1/2 in.	Min. Gap @ Close:	1 1/2 in.	Headed Stud Steel, F_u:	60 ksi	
				Reinf. Steel, F_y:	60 ksi	
Axle Load - Strength:	25 kips	Axle Load - Fatigue:	16 kips	Resistance Factor, ϕ_f:	1.00	AASHTO 6.5.4.2
Tire - Across Bridge:	20 in.	Tire - Across Bridge:	20 in.	Resistance Factor, ϕ_v:	1.00	AASHTO 6.5.4.2
Tire - Along Bridge:	10 in.	Tire - Along Bridge:	10 in.	Resistance Factor, ϕ_t:	0.80	AASHTO 6.5.4.2
LL Factor:	1.75	LL Factor:	1.50	Resistance Factor, ϕ_t:	0.75	PCI 6.5.2
Multi-Presence Factor:	1.20	Multi-Presence Factor:	1.00	Resistance Factor, ϕ_{sc}:	0.85	AASHTO 6.5.4.2
Impact:	200%	Impact:	200%	Resistance Factor, $\phi_{Pullout}$:	0.75	ACI 318 D.4.4
				Headed Stud Fat. Category:	C	(Full Joint Penetration weld w/o NDT or Grinding)
		Finger PL Fat. Category:	B	Headed Stud Δ_{TH}:	10.0 ksi	
		Finger PL Δ_{TH}:	16.0 ksi	Assumed Δ for Headed Stud Width:	1/2 in.	
		Edge & Support PL Fat. Category:	B			
		Edge & Support PL Δ_{TH}:	16.0 ksi			

Allowable Fatigue Stress per AASHTO Table 6.6.1.2.5-3

MoDOT Robust Finger Plate Expansion Device Design for Concrete Girders (Cont.)

Design ID	Expansion Length (ft)	Bridge Type Steel or Concrete (S or C)	Finger Plate Thickness (in)	Throat Radius (in)	Finger Kerf (in)	CL of Throat to First Bolt (in)	Anchor Bolt Spa. Along (in)	Anchor Bolt Spa. Across (in)	Bolt Size (in)	Bolt Grade	CL of Throat to First Stud (in)	Anchor Studs Along (in)	Anchor Studs Across (in)	Anchor Stud Size (in)
1	1530	C	3	1	1/8	5	12	9	7/8	A325	11 1/8	24	8	7/8
2	1350	C	2 3/4	1	1/8	5	11	9	7/8	A325	11 1/8	24	8	7/8
3	1150	C	2 1/2	1	1/8	5	9	9	7/8	A325	11 1/8	24	8	7/8
4	980	C	2 1/4	1	1/8	5	8	9	7/8	A325	11 1/8	24	9	7/8
5	840	C	2	1	1/8	5	8	10	7/8	A325	11 1/8	24	9	7/8
6	720	C	1 3/4	1	1/8	5	8	12	7/8	A325	11 1/8	24	10	7/8
7	630	C	1 3/4	1	1/8	5	8	12	7/8	A325	11 1/8	24	10	7/8
8	570	C	1 3/4	1	1/8	5	8	12	7/8	A325	11 1/8	24	10	7/8
9	520	C	1 3/4	1	1/8	5	8	12	7/8	A325	11 1/8	24	12	7/8

Design ID	Back Edge PL Width (in)	Back Edge PL Height (in)	CL of Throat to CL Front PL (in)	CL of Back Bolt Edge of PL (in)	Support PL Spacing (in)	Support PL Thickness (in)	Support PL Connect. (in)	CL Throat to CL Support PL (in)	Front Studs Across (in)	Front Stud Size (in)	Support PL Stud Size (in)	Number Support Plate Studs
1	1 1/4	4	2 7/8	2	36	1	14 1/2	11 3/8	6	7/8	7/8	4
2	1 1/4	4	2 7/8	2	36	1	12 1/2	9 3/8	6	7/8	7/8	4
3	1 1/4	4	2 7/8	2	36	1	11 1/2	8 3/8	6	7/8	7/8	4
4	1 1/4	4	2 7/8	2	36	1	10 1/2	7 3/8	6	7/8	7/8	4
5	1 1/4	4	2 7/8	2	36	1	10 1/2	7 3/8	6	7/8	7/8	4
6	1 1/4	4	2 7/8	2	36	3/4	10 1/2	7 3/8	6	7/8	7/8	4
7	1 1/4	4	2 3/4	2	36	3/4	10 1/2	7 3/8	6	7/8	7/8	4
8	1 1/4	4	2 3/4	2	36	3/4	10 1/2	7 3/8	6	7/8	7/8	4
9	1 1/4	4	2 3/4	2	36	3/4	10 1/2	7 3/8	6	7/8	7/8	4

MoDOT Robust Finger Plate Expansion Device Design for Concrete Girders (Cont.)

Design ID	Joint Geometry							
	Finger Width (in)	CL - CL Fingers (in)	$\Delta_{Cont.}$ (in)	$\Delta_{Exp.}$ (in)	$\Delta_{Tot..}$ (in)	Overlap @ 60°F (in)	Gap @ 60°F (in)	Finger Length (in)
1	1 3/4	3 3/4	9 3/8	6 5/8	16	10 7/8	8 1/8	19
2	1 3/4	3 3/4	8 1/4	5 7/8	14 1/8	9 3/4	7 3/8	17 1/8
3	1 3/4	3 3/4	7	5	12	8 1/2	6 1/2	15
4	1 3/4	3 3/4	6	4 1/4	10 1/4	7 1/2	5 3/4	13 1/4
5	1 3/4	3 3/4	5 1/8	3 3/4	8 7/8	6 5/8	5 1/4	11 7/8
6	1 3/4	3 3/4	4 3/8	3 1/8	7 1/2	5 7/8	4 5/8	10 1/2
7	1 3/4	3 3/4	3 7/8	2 3/4	6 5/8	5 3/8	4 1/4	9 5/8
8	1 3/4	3 3/4	3 1/2	2 1/2	6	5	4	9
9	1 3/4	3 3/4	3 1/4	2 1/4	5 1/2	4 3/4	3 3/4	8 1/2

Assume straight finger geometry.

MoDOT Robust Finger Plate Expansion Device Design for Concrete Girders (Cont.)

Design ID	1.0 - Strength Design at Base of Finger								
	Load / Finger (kips)	Factored Load (kips)	Moment Arm (in)	S-Finger (in^3)	Applied Moment (kip-in)	Applied Stress (ksi)	Less Than $\phi_f F_y$?	Nominal Shear, Vn (kips)	Less Than $\phi_v V_n$?
1	2.34	9.83	13.00	2.625	127.79	48.68	**OK**	152.3	**OK**
2	2.34	9.83	11.13	2.206	109.36	49.57	**OK**	139.6	**OK**
3	2.34	9.83	9.00	1.823	88.47	48.53	**OK**	126.9	**OK**
4	2.34	9.83	7.25	1.477	71.27	48.25	**OK**	114.2	**OK**
5	2.34	9.83	5.88	1.167	57.75	49.49	**OK**	101.5	**OK**
6	2.23	9.37	4.75	0.893	44.51	49.84	**OK**	88.8	**OK**
7	2.02	8.48	4.31	0.893	36.57	40.95	**OK**	88.8	**OK**
8	1.88	7.90	4.00	0.893	31.60	35.39	**OK**	88.8	**OK**
9	1.76	7.39	3.75	0.893	27.71	31.03	**OK**	88.8	**OK**

Assume 100% of wheel load taken by one side of the finger joint; Value of "C" in V_n = 1.00.

Assume only the length of finger is loaded if finger length is less than longitudinal tire length.

Design ID	1.0 - Strength Design at Base of Throat								
	Load / Finger (kips)	Factored Load (kips)	Moment Arm (in)	S-Finger (in^3)	Applied Moment (kip-in)	Applied Stress (ksi)	Less Than $\phi_f F_y$?	Nominal Shear, Vn (kips)	Less Than $\phi_v V_n$?
1	2.34	9.83	14.00	5.625	137.62	24.47	**OK**	326.3	**OK**
2	2.34	9.83	12.13	4.727	119.19	25.21	**OK**	299.1	**OK**
3	2.34	9.83	10.00	3.906	98.30	25.17	**OK**	271.9	**OK**
4	2.34	9.83	8.25	3.164	81.10	25.63	**OK**	244.7	**OK**
5	2.34	9.83	6.88	2.500	67.58	27.03	**OK**	217.5	**OK**
6	2.34	9.83	5.50	1.914	54.07	28.25	**OK**	190.3	**OK**
7	2.26	9.49	4.81	1.914	45.67	23.86	**OK**	190.3	**OK**
8	2.11	8.86	4.50	1.914	39.87	20.83	**OK**	190.3	**OK**
9	1.99	8.36	4.25	1.914	35.53	18.56	**OK**	190.3	**OK**

Assume 100% of wheel load taken by one side of the finger joint; Value of "C" in V_n = 1.00.

Assume only the length of finger is loaded if finger length is less than longitudinal tire length.

MoDOT Robust Finger Plate Expansion Device Design for Concrete Girders (Cont.)

Design ID	1.0 - Fatigue Design at Base Finger @ 90 Degrees										
	Overlap at **90°F** (in)	Shared Load / Finger (kips)	Un-Shared Load / Finger (kips)	Factored Shared Load (kips)	Factored Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	S-Finger (in^3)	Applied Moment (kip-in)	Applied Stress (ksi)	Less Than Δ_{TH}?
1	14.18	0.75	0.00	2.25	0.00	13.00	0.00	2.625	29.25	11.14	**OK**
2	12.67	0.75	0.00	2.25	0.00	11.13	0.00	2.206	25.04	11.35	**OK**
3	10.98	0.75	0.00	2.25	0.00	9.00	0.00	1.823	20.25	11.11	**OK**
4	9.62	0.72	0.06	2.16	0.18	7.44	2.44	1.477	16.51	11.18	**OK**
5	8.44	0.63	0.23	1.89	0.69	6.66	1.66	1.167	13.73	11.77	**OK**
6	7.43	0.56	0.39	1.68	1.17	5.79	0.79	0.893	10.65	11.93	**OK**
7	6.74	0.51	0.43	1.53	1.29	5.26	0.44	0.893	8.62	9.65	**OK**
8	6.23	0.47	0.42	1.41	1.26	4.89	0.39	0.893	7.39	8.28	**OK**
9	5.87	0.44	0.39	1.32	1.17	4.57	0.32	0.893	6.41	7.18	**OK**

Assumes equal load sharing to adjacent fingers in regions of finger overlap.

Perform a parametric analysis of the fatigue performance of the fingers at various temperatures.

Design ID	1.0 - Fatigue Design at Base Finger @ 80 Degrees										
	Overlap at **80°F** (in)	Shared Load / Finger (kips)	Un-Shared Load / Finger (kips)	Factored Shared Load (kips)	Factored Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	S-Finger (in^3)	Applied Moment (kip-in)	Applied Stress (ksi)	Less Than Δ_{TH}?
1	13.08	0.75	0.00	2.25	0.00	13.00	0.00	2.625	29.25	11.14	**OK**
2	11.69	0.75	0.00	2.25	0.00	11.13	0.00	2.206	25.04	11.35	**OK**
3	10.16	0.75	0.00	2.25	0.00	9.00	0.00	1.823	20.25	11.11	**OK**
4	8.91	0.67	0.16	2.01	0.48	7.80	2.80	1.477	17.02	11.52	**OK**
5	7.83	0.59	0.33	1.77	0.99	6.96	1.96	1.167	14.26	12.22	**OK**
6	6.91	0.52	0.46	1.56	1.38	6.05	1.05	0.893	10.89	12.19	**OK**
7	6.28	0.47	0.50	1.41	1.50	5.49	0.67	0.893	8.75	9.80	**OK**
8	5.82	0.44	0.48	1.32	1.44	5.09	0.59	0.893	7.57	8.48	**OK**
9	5.50	0.41	0.45	1.23	1.35	4.75	0.50	0.893	6.52	7.30	**OK**

Assumes equal load sharing to opposite fingers in regions of finger overlap.

MoDOT Robust Finger Plate Expansion Device Design for Concrete Girders (Cont.)

Design ID	1.0 - Fatigue Design at Base Finger @ 70 Degrees										
	Overlap at **70°F** (in)	Shared Load / Finger (kips)	Un-Shared Load / Finger (kips)	Factored Shared Load (kips)	Factored Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	S-Finger (in^3)	Applied Moment (kip-in)	Applied Stress (ksi)	Less Than Δ_{TH}?
1	11.98	0.75	0.00	2.25	0.00	13.00	0.00	2.625	29.25	11.14	**OK**
2	10.72	0.75	0.00	2.25	0.00	11.13	0.00	2.206	25.04	11.35	**OK**
3	9.33	0.70	0.10	2.10	0.30	9.34	4.34	1.823	20.92	11.48	**OK**
4	8.21	0.62	0.27	1.86	0.81	8.15	3.15	1.477	17.71	11.99	**OK**
5	7.23	0.54	0.42	1.62	1.26	7.26	2.26	1.167	14.61	12.52	**OK**
6	6.39	0.48	0.54	1.44	1.62	6.31	1.31	0.893	11.21	12.55	**OK**
7	5.83	0.44	0.57	1.32	1.71	5.71	0.90	0.893	9.08	10.17	**OK**
8	5.41	0.41	0.54	1.23	1.62	5.30	0.80	0.893	7.82	8.76	**OK**
9	5.12	0.38	0.51	1.14	1.53	4.94	0.69	0.893	6.69	7.49	**OK**

Assumes equal load sharing to adjacent fingers in regions of finger overlap.

Design ID	1.0 - Fatigue Design at Base Finger @ 60 Degrees										
	Overlap at **60°F** (in)	Shared Load / Finger (kips)	Un-Shared Load / Finger (kips)	Factored Shared Load (kips)	Factored Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	S-Finger (in^3)	Applied Moment (kip-in)	Applied Stress (ksi)	Less Than Δ_{TH}?
1	10.88	0.75	0.00	2.25	0.00	13.00	0.00	2.625	29.25	11.14	**OK**
2	9.75	0.73	0.04	2.19	0.12	11.25	6.25	2.206	25.39	11.51	**OK**
3	8.50	0.64	0.23	1.92	0.69	9.75	4.75	1.823	22.00	12.07	**OK**
4	7.50	0.56	0.38	1.68	1.14	8.50	3.50	1.477	18.27	12.37	**OK**
5	6.63	0.50	0.51	1.50	1.53	7.56	2.56	1.167	15.26	13.08	**OK**
6	5.88	0.44	0.62	1.32	1.86	6.56	1.56	0.893	11.56	12.95	**OK**
7	5.38	0.40	0.64	1.20	1.92	5.94	1.12	0.893	9.28	10.39	**OK**
8	5.00	0.38	0.60	1.14	1.80	5.50	1.00	0.893	8.07	9.04	**OK**
9	4.75	0.36	0.56	1.08	1.68	5.13	0.88	0.893	7.02	7.86	**OK**

Assumes equal load sharing to opposite fingers in regions of finger overlap.

MoDOT Robust Finger Plate Expansion Device Design for Concrete Girders (Cont.)

Design ID	1.0 - Fatigue Design at Base Finger @ 50 Degrees										
	Overlap at 50°F (in)	Shared Load / Finger (kips)	Un-Shared Load / Finger (kips)	Factored Shared Load (kips)	Factored Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	S-Finger (in^3)	Applied Moment (kip-in)	Applied Stress (ksi)	Less Than Δ_{TH}?
1	9.77	0.73	0.03	2.19	0.09	13.12	8.12	2.625	29.46	11.22	**OK**
2	8.78	0.66	0.18	1.98	0.54	11.74	6.74	2.206	26.88	12.18	**OK**
3	7.67	0.58	0.35	1.74	1.05	10.17	5.17	1.823	23.12	12.68	**OK**
4	6.79	0.51	0.48	1.53	1.44	8.86	3.86	1.477	19.11	12.94	**OK**
5	6.02	0.45	0.60	1.35	1.80	7.87	2.87	1.167	15.79	13.53	**OK**
6	5.36	0.40	0.70	1.20	2.10	6.82	1.82	0.893	12.01	13.45	**OK**
7	4.92	0.37	0.71	1.11	2.13	6.17	1.35	0.893	9.72	10.88	**OK**
8	4.59	0.34	0.66	1.02	1.98	5.71	1.21	0.893	8.22	9.20	**OK**
9	4.38	0.33	0.62	0.99	1.86	5.31	1.06	0.893	7.23	8.10	**OK**

Assumes equal load sharing to adjacent fingers in regions of finger overlap.

Design ID	1.0 - Fatigue Design at Base Finger @ 40 Degrees										
	Overlap at 40°F (in)	Shared Load / Finger (kips)	Un-Shared Load / Finger (kips)	Factored Shared Load (kips)	Factored Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	S-Finger (in^3)	Applied Moment (kip-in)	Applied Stress (ksi)	Less Than Δ_{TH}?
1	8.67	0.65	0.20	1.95	0.60	13.67	8.67	2.625	31.86	12.14	**OK**
2	7.81	0.59	0.33	1.77	0.99	12.22	7.22	2.206	28.78	13.05	**OK**
3	6.84	0.51	0.47	1.53	1.41	10.58	5.58	1.823	24.06	13.20	**OK**
4	6.09	0.46	0.59	1.38	1.77	9.21	4.21	1.477	20.16	13.65	**OK**
5	5.42	0.41	0.69	1.23	2.07	8.17	3.17	1.167	16.61	14.23	**OK**
6	4.84	0.36	0.77	1.08	2.31	7.08	2.08	0.893	12.45	13.94	**OK**
7	4.47	0.34	0.77	1.02	2.31	6.39	1.58	0.893	10.17	11.39	**OK**
8	4.18	0.31	0.72	0.93	2.16	5.91	1.41	0.893	8.54	9.56	**OK**
9	4.00	0.30	0.68	0.90	2.04	5.50	1.25	0.893	7.50	8.40	**OK**

Assumes equal load sharing to opposite fingers in regions of finger overlap.

MoDOT Robust Finger Plate Expansion Device Design for Concrete Girders (Cont.)

Design ID	1.0 - Fatigue Design at Base Finger @ 30 Degrees										
	Overlap at 30°F (in)	Shared Load / Finger (kips)	Un-Shared Load / Finger (kips)	Factored Shared Load (kips)	Factored Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	S-Finger (in^3)	Applied Moment (kip-in)	Applied Stress (ksi)	Less Than Δ_{TH}?
1	7.57	0.57	0.36	1.71	1.08	14.22	9.22	2.625	34.27	13.06	**OK**
2	6.83	0.51	0.48	1.53	1.44	12.71	7.71	2.206	30.55	13.85	**OK**
3	6.02	0.45	0.60	1.35	1.80	10.99	5.99	1.823	25.62	14.05	**OK**
4	5.38	0.40	0.69	1.20	2.07	9.56	4.56	1.477	20.91	14.16	**OK**
5	4.81	0.36	0.78	1.08	2.34	8.47	3.47	1.167	17.27	14.80	**OK**
6	4.32	0.32	0.85	0.96	2.55	7.34	2.34	0.893	13.01	14.57	**OK**
7	4.01	0.30	0.84	0.90	2.52	6.62	1.81	0.893	10.52	11.78	**OK**
8	3.77	0.28	0.78	0.84	2.34	6.12	1.62	0.893	8.93	10.00	**OK**
9	3.63	0.27	0.73	0.81	2.19	5.69	1.44	0.893	7.76	8.69	**OK**

Assumes equal load sharing to adjacent fingers in regions of finger overlap.

Design ID	1.0 - Fatigue Design at Base Finger @ 20 Degrees										
	Overlap at 20°F (in)	Shared Load / Finger (kips)	Un-Shared Load / Finger (kips)	Factored Shared Load (kips)	Factored Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	S-Finger (in^3)	Applied Moment (kip-in)	Applied Stress (ksi)	Less Than Δ_{TH}?
1	6.47	0.49	0.53	1.47	1.59	14.77	9.77	2.625	37.25	14.19	**OK**
2	5.86	0.44	0.62	1.32	1.86	13.20	8.20	2.206	32.68	14.81	**OK**
3	5.19	0.39	0.72	1.17	2.16	11.41	6.41	1.823	27.20	14.92	**OK**
4	4.68	0.35	0.80	1.05	2.40	9.91	4.91	1.477	22.19	15.02	**OK**
5	4.21	0.32	0.87	0.96	2.61	8.77	3.77	1.167	18.26	15.65	**OK**
6	3.80	0.29	0.93	0.87	2.79	7.60	2.60	0.893	13.87	15.53	**OK**
7	3.56	0.27	0.91	0.81	2.73	6.85	2.03	0.893	11.09	12.42	**OK**
8	3.36	0.25	0.85	0.75	2.55	6.32	1.82	0.893	9.38	10.50	**OK**
9	3.25	0.24	0.79	0.72	2.37	5.88	1.63	0.893	8.10	9.07	**OK**

Assumes equal load sharing to opposite fingers in regions of finger overlap.

Finger plate design is controlled by Strength instead of Fatigue for all temperatures down to 0°. Use 50° for all remaining calculations as a expected median point of the temperature range.

MoDOT Robust Finger Plate Expansion Device Design for Concrete Girders (Cont.)

Design ID	2.0 - Strength Design of Anchor Plate Bolts Trib. Load per Bolt Line (kips)	Factor Trib. Load per Bolt Line (kips)	Moment Arm (in)	Applied Bolt Tension (kips)	Allowable Bolt Tension (kips)	Bolt Pre-Tension (kips)	Less Than Allowable ?
1	5.63	23.65	18.00	35.48	43.87	39	**OK**
2	5.63	23.65	16.13	34.68	43.87	39	**OK**
3	5.63	23.65	14.00	36.79	43.87	39	**OK**
4	5.63	23.65	12.25	36.21	43.87	39	**OK**
5	6.25	26.25	10.88	35.70	43.87	39	**OK**
6	7.50	31.50	9.50	37.41	43.87	39	**OK**
7	7.50	31.50	8.63	33.98	43.87	39	**OK**
8	7.50	31.50	8.00	31.50	43.87	39	**OK**
9	7.50	31.50	7.50	29.53	43.87	39	**OK**

Assumes 100% of wheel load taken by one side of the finger joint and the point of support is the first bolt in the couple.

$\phi_t T_n = \phi_t 0.76 A_b F_{ub}$ AASHTO Eq. 6.13.2.10.2-1

Min. Tension AASHTO C6.13.2.8

Design ID	2.0 - Fatigue Design of Anchor Plate Bolts @ 50 Degrees Overlap at 50°F (in)	Shared Load / Bolt Line (kips)	Un-Shared Load / Bolt Line (kips)	Factored Shared Load (kips)	Factored Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	Applied Moment (kip-in)	Applied Stress (ksi)	Fatigue Threshold $\Delta_{TH.}$ (ksi)	Less Than Δ_{TH} ?
1	9.77	1.76	0.08	5.28	0.24	18.12	13.12	98.82	13.7	31.0	**OK**
2	8.78	1.58	0.44	4.74	1.32	16.74	11.74	94.84	14.3	31.0	**OK**
3	7.67	1.38	0.84	4.14	2.52	15.17	10.17	88.43	16.3	31.0	**OK**
4	6.79	1.22	1.16	3.66	3.48	13.86	8.86	81.56	17.0	31.0	**OK**
5	6.02	1.20	1.59	3.60	4.77	12.87	7.87	83.87	17.4	31.0	**OK**
6	5.36	1.29	2.23	3.87	6.69	11.82	6.82	91.37	19.0	31.0	**OK**
7	4.92	1.18	2.44	3.54	7.32	11.17	6.17	84.71	17.6	31.0	**OK**
8	4.59	1.10	2.60	3.30	7.80	10.71	5.71	79.88	16.6	31.0	**OK**
9	4.38	1.05	2.70	3.15	8.10	10.31	5.31	75.49	15.7	31.0	**OK**

Fatigue Threshold

AASHTO Table 6.6.1.2.5-3

Assumes equal load sharing to opposite fingers in regions of finger overlap and the point of support is the first bolt in the couple.

MoDOT Robust Finger Plate Expansion Device Design for Concrete Girders (Cont.)

Design ID	3.0 - Strength Design of Support Beam Studs						
	Trib. Load per Stud Line (kips)	Factor Trib. Load per Stud Line (kips)	Moment Arm (in)	Applied Stud Tension (kips)	Allowable Stud Tension (kips)	Allowable Stud Pullout (kips)	Less Than Allowable ?
1	5.00	21.00	24.13	21.11	27.06	21.21	**OK**
2	5.00	21.00	22.25	19.47	27.06	21.21	**OK**
3	5.00	21.00	20.13	17.61	27.06	21.21	**OK**
4	5.63	23.65	18.38	18.11	27.06	21.21	**OK**
5	5.63	23.65	17.00	16.75	27.06	21.21	**OK**
6	6.25	26.25	15.63	17.10	27.06	21.21	**OK**
7	6.25	26.25	14.75	16.13	27.06	21.21	**OK**
8	6.25	26.25	14.13	15.45	27.06	21.21	**OK**
9	7.50	31.50	13.63	17.89	27.06	21.21	**OK**

Load is carried as a couple between the front and back support beams. Designed for the back tension stud only.

Allowable Stud Tension PCI 6.5.2

Allowable Stud Pullout ACI 318 D.5.3.1

Design ID	3.0 - Fatigue Design of Support Beam Studs @ 50 Degrees										
	Overlap at 50°F (in)	Shared Load / Stud Line (kips)	Un-Shared Load / Stud Line (kips)	Factored Shared Load (kips)	Factored Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	Applied Moment (kip-in)	Applied Stress (ksi)	Fatigue Threshold $\Delta_{TH.}$ (ksi)	Less Than Δ_{TH}?
1	9.77	1.56	0.07	4.68	0.21	24.24	19.24	117.48	8.1	10.0	**OK**
2	8.78	1.40	0.39	4.20	1.17	22.86	17.86	116.91	8.1	10.0	**OK**
3	7.67	1.23	0.75	3.69	2.25	21.29	16.29	115.21	8.0	10.0	**OK**
4	6.79	1.22	1.16	3.66	3.48	19.98	14.98	125.26	8.7	10.0	**OK**
5	6.02	1.08	1.43	3.24	4.29	18.99	13.99	121.54	8.4	10.0	**OK**
6	5.36	1.07	1.86	3.21	5.58	17.95	12.95	129.88	9.0	10.0	**OK**
7	4.92	0.98	2.03	2.94	6.09	17.29	12.29	125.68	8.7	10.0	**OK**
8	4.59	0.92	2.16	2.76	6.48	16.83	11.83	123.11	8.5	10.0	**OK**
9	4.38	1.05	2.70	3.15	8.10	16.44	11.44	144.45	10.0	10.0	**OK**

Assumes equal load sharing to opposite fingers in regions of finger overlap. Designed for the back tension stud only.

MoDOT Robust Finger Plate Expansion Device Design for Concrete Girders (Cont.)

LTB Check and Mn per AASHTO 6.12.2.2.7; Vn per AASHTO 6.12.1.2.3 & 6.10.9.2

Design ID	4.0 - Strength Design of Back Edge PL													
	Loaded Width (in)	Couple Depth (in)	Moment Arm (in)	Tension Load (kips)	Uniform Load (kips/in)	Factored Load (kips/in)	Applied Mom., M_u (kip-in)	S-Plate (in^3)	LTB Check (?)	Nominal Mom., M_n (kip-in)	Less Than $\phi_f M_n$?	Factored Shear, V_u (kips)	Nominal Shear, V_n (kips)	Less Than $\phi_v V_n$?
1	36	16.88	15.88	11.76	0.327	1.373	222.43	3.333	**OK**	246.05	**OK**	24.71	145.0	**OK**
2	36	15.88	14.00	11.02	0.306	1.285	208.17	3.333	**OK**	246.05	**OK**	23.13	145.0	**OK**
3	36	13.88	11.88	10.7	0.297	1.247	202.01	3.333	**OK**	246.05	**OK**	22.45	145.0	**OK**
4	34 3/4	12.88	10.13	9.83	0.283	1.189	192.39	3.333	**OK**	246.05	**OK**	20.66	145.0	**OK**
5	34 3/4	12.88	8.75	8.49	0.244	1.025	165.85	3.333	**OK**	246.05	**OK**	17.81	145.0	**OK**
6	34 3/4	12.88	7.38	7.16	0.206	0.865	139.96	3.333	**OK**	246.05	**OK**	15.03	145.0	**OK**
7	35	13.00	6.38	6.13	0.175	0.735	118.98	3.333	**OK**	246.05	**OK**	12.86	145.0	**OK**
8	35	13.00	5.75	5.53	0.158	0.664	107.49	3.333	**OK**	246.05	**OK**	11.62	145.0	**OK**
9	35	13.00	5.25	5.05	0.144	0.605	97.93	3.333	**OK**	246.05	**OK**	10.59	145.0	**OK**

Assume 30° load path past the front edge plate; Load is carried as a couple between the front edge and back plate.

Assume load is carried by back edge only w/o help from anchor PL, Back Edge is simply supported; Value of "C_b" in M_n = 1.00; Value of "C" in V_n = 1.00.

Design ID	4.0 - Fatigue Design of Back Edge PL @ 50 Degrees												
	Overlap at 50°F (in)	Shared Load (kips)	Un-Shared Load (kips)	Factored Shared Load (kips)	Factored Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	Factored Tension Load (kips)	Uniform Load (kips/in)	Applied Moment (kip-in)	Applied Stress (ksi)	Fatigue Threshold $\Delta_{TH.}$ (ksi)	Less Than Δ_{TH} ?
1	9.77	3.91	0.18	11.73	0.54	15.99	10.99	11.46	0.318	51.52	15.5	16.0	**OK**
2	8.78	3.51	0.98	10.53	2.94	14.61	9.61	11.47	0.319	51.68	15.5	16.0	**OK**
3	7.67	3.07	1.86	9.21	5.58	13.04	8.04	11.88	0.330	53.46	16.0	16.0	**OK**
4	6.79	2.72	2.57	8.16	7.71	11.73	6.73	11.46	0.330	53.40	16.0	16.0	**OK**
5	6.02	2.41	3.18	7.23	9.54	10.74	5.74	10.28	0.296	47.89	14.4	16.0	**OK**
6	5.36	2.14	3.71	6.42	11.13	9.70	4.70	8.90	0.256	41.42	12.4	16.0	**OK**
7	4.92	1.97	4.06	5.91	12.18	8.92	3.92	7.73	0.221	35.77	10.7	16.0	**OK**
8	4.59	1.84	4.33	5.52	12.99	8.46	3.46	7.05	0.201	32.54	9.8	16.0	**OK**
9	4.38	1.75	4.50	5.25	13.50	8.06	3.06	6.43	0.184	29.79	8.9	16.0	**OK**

Assumes equal load sharing to opposite fingers in regions of finger overlap.

MoDOT Robust Finger Plate Expansion Device Design for Concrete Girders (Cont.)

	5.0 - Strength Design of Front PL Studs							
Design ID	Compress Load (kips)	Loaded Width (in)	Stud Spacing (in)	Shear Load / Stud (kips)	Factored Load / Stud (kips)	Stud Cap. Q_n (kips)	Factored Cap. Q_r (kips)	Less Than Q_r ?
1	24.26	20.0	6.00	7.28	15.29	36.08	30.67	**OK**
2	23.52	20.0	6.00	7.06	14.83	36.08	30.67	**OK**
3	23.20	20.0	6.00	6.96	14.62	36.08	30.67	**OK**
4	22.33	20.0	6.00	6.70	14.07	36.08	30.67	**OK**
5	20.99	20.0	6.00	6.30	13.23	36.08	30.67	**OK**
6	19.66	20.0	6.00	5.90	12.39	36.08	30.67	**OK**
7	18.63	20.0	6.00	5.59	11.74	36.08	30.67	**OK**
8	18.03	20.0	6.00	5.41	11.36	36.08	30.67	**OK**
9	17.55	20.0	6.00	5.27	11.07	36.08	30.67	**OK**

$f_{sc}\ Q_n = Q_r$ per AASHTO 6.10.10.4.1

Assume load is carried as a couple between the front edge bearing on concrete and the back plate. Assume 50% of the load is transferred directly into the concrete through bearing of the anchorage plate and the other 50% is carried through the front edge plate into the concrete by the studs.

	5.0 - Fatigue Design of Front PL Studs @ 50 Degrees							
Design ID	Factored Couple Load (kips)	Factored Direct Load (kips)	Factored Compress Load (kips)	Loaded Width (in)	Stud Spacing (in)	Factored Shear Load / Stud (kips)	Stud Cap. Z_r (kips)	Less Than Z_r ?
1	11.46	12.27	23.73	20.0	6.00	3.56	4.21	**OK**
2	11.47	13.47	24.94	20.0	6.00	3.74	4.21	**OK**
3	11.88	14.79	26.67	20.0	6.00	4.00	4.21	**OK**
4	11.46	15.87	27.33	20.0	6.00	4.10	4.21	**OK**
5	10.28	16.77	27.05	20.0	6.00	4.06	4.21	**OK**
6	8.90	17.55	26.45	20.0	6.00	3.97	4.21	**OK**
7	7.73	18.09	25.82	20.0	6.00	3.87	4.21	**OK**
8	7.05	18.51	25.56	20.0	6.00	3.83	4.21	**OK**
9	6.43	18.75	25.18	20.0	6.00	3.78	4.21	**OK**

Z_r per AASHTO 6.10.10.2

Assumes equal load sharing to opposite fingers in regions of finger overlap.

MoDOT Robust Finger Plate Expansion Device Design for Concrete Girders (Cont.)

	6.0 - Strength Design of Support PL @ Connection					
Design ID	Factored Load (kips)	Moment Arm (in)	Applied Moment (kip-in)	S (in^3)	Applied Stress (ksi)	Less Than $\phi_f F_y$?
1	52.50	24.38	1279.95	35.04	36.53	**OK**
2	52.50	20.50	1076.25	26.04	41.33	**OK**
3	52.50	17.38	912.45	22.04	41.40	**OK**
4	52.50	14.63	768.08	18.38	41.79	**OK**
5	52.50	13.25	695.63	18.38	37.85	**OK**
6	52.50	11.88	623.70	13.78	45.26	**OK**
7	52.50	11.00	577.50	13.78	41.91	**OK**
8	52.50	10.38	544.95	13.78	39.55	**OK**
9	52.50	9.88	518.70	13.78	37.64	**OK**

Assume load is centered on support plate and not shared to adjacent support plates.

	6.0 - Fatigue Design of Support PL Connection @ 50 Degrees										
Design ID	Overlap at 50°F (in)	Shared Load (kips)	Un-Shared Load (kips)	Factored Shared Load (kips)	Factored Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	Applied Moment (kip-in)	Applied Stress (ksi)	Fatigue Threshold $\Delta_{TH.}$ (ksi)	Less Than Δ_{TH} ?
1	9.77	3.91	0.18	11.73	0.54	24.49	19.49	297.79	8.5	16.0	**OK**
2	8.78	3.51	0.98	10.53	2.94	21.11	16.11	269.65	10.4	16.0	**OK**
3	7.67	3.07	1.86	9.21	5.58	18.54	13.54	246.31	11.2	16.0	**OK**
4	6.79	2.72	2.57	8.16	7.71	16.23	11.23	219.02	11.9	16.0	**OK**
5	6.02	2.41	3.18	7.23	9.54	15.24	10.24	207.87	11.3	16.0	**OK**
6	5.36	2.14	3.71	6.42	11.13	14.20	9.20	193.56	14.0	16.0	**OK**
7	4.92	1.97	4.06	5.91	12.18	13.54	8.54	184.04	13.4	16.0	**OK**
8	4.59	1.84	4.33	5.52	12.99	13.08	8.08	177.16	12.9	16.0	**OK**
9	4.38	1.75	4.50	5.25	13.50	12.69	7.69	170.44	12.4	16.0	**OK**

Assumes equal load sharing to opposite fingers in regions of finger overlap.

MoDOT Robust Finger Plate Expansion Device Design for Concrete Girders (Cont.)

Design ID	7.0 - Strength Design of Support PL Studs Factored Load (kips)	Moment Arm (in)	Compress Load (kips)	Factored Load / Stud (kips)	Stud Cap. Q_n (kips)	Factored Cap. Q_r (kips)	Less Than Q_r ?
1	52.50	24.13	105.28	13.16	36.08	30.67	**OK**
2	52.50	22.25	101.17	12.65	36.08	30.67	**OK**
3	52.50	20.13	96.53	12.07	36.08	30.67	**OK**
4	52.50	18.38	92.71	11.59	36.08	30.67	**OK**
5	52.50	17.00	89.69	11.21	36.08	30.67	**OK**
6	52.50	15.63	86.69	10.84	36.08	30.67	**OK**
7	52.50	14.75	84.77	10.60	36.08	30.67	**OK**
8	52.50	14.13	83.41	10.43	36.08	30.67	**OK**
9	52.50	13.63	82.32	10.29	36.08	30.67	**OK**

$f_{sc}\,Q_n = Q_r$ per AASHTO 6.10.10.4.1

Final Resultant - Use the parameters from "Design ID 1" as standard layout for all expansion devices using this configuration.

Assume load is centered on support plate and not shared to adjacent support plates. The load is carried through the studs at the front and back support beams. The thrust load at the front support beam controls. Assume 50% of load is carried directly into the concrete by bearing of the anchor plate and the other 50% is carried by the shear studs.

Design ID	7.0 - Fatigue Design of Support PL Studs @ 50 Degrees Overlap at 50°F (in)	Shared Load (kips)	Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	Applied Moment (kip-in)	Compress Load (kips)	Factored Compress Load (kips)	Load per Stud (kips)	Stud Cap. Z_r (kips)	Less Than Z_r ?
1	9.77	3.91	0.18	24.24	19.24	98.24	8.18	24.54	3.07	4.21	**OK**
2	8.78	3.51	0.98	22.86	17.86	97.74	8.56	25.68	3.21	4.21	**OK**
3	7.67	3.07	1.86	21.29	16.29	95.66	8.92	26.76	3.35	4.21	**OK**
4	6.79	2.72	2.57	19.98	14.98	92.84	9.16	27.48	3.44	4.21	**OK**
5	6.02	2.41	3.18	18.99	13.99	90.25	9.35	28.05	3.51	4.21	**OK**
6	5.36	2.14	3.71	17.95	12.95	86.46	9.45	28.35	3.54	4.21	**OK**
7	4.92	1.97	4.06	17.29	12.29	83.96	9.53	28.59	3.57	4.21	**OK**
8	4.59	1.84	4.33	16.83	11.83	82.19	9.59	28.77	3.60	4.21	**OK**
9	4.38	1.75	4.5	16.44	11.44	80.25	9.59	28.77	3.60	4.21	**OK**

Z_r per AASHTO 6.10.10.2

Assume load is shared to opposite fingers in regions of overlap.

Project:	MoDOT Finger Plate	Computed:	DGB	Date:	10/1/2015
Subject:	Robust Design	Checked:	MTW	Date:	12/10/2015
Task:	Tension studs	Page:	30	of:	ROBUST
Job #:	244663	No:			

Anchorage Pullout   ACI 318 D.5.3.1

$N_{pn} = \Psi_{c,p} N_p$

$\Psi_{c,p} = 1.0$ For cracked concrete (Conservative Assumption)   ACI 318 D.5.3.6

$N_p = 8 A_{brg} f'_c$ ACI 318 D.5.3.4

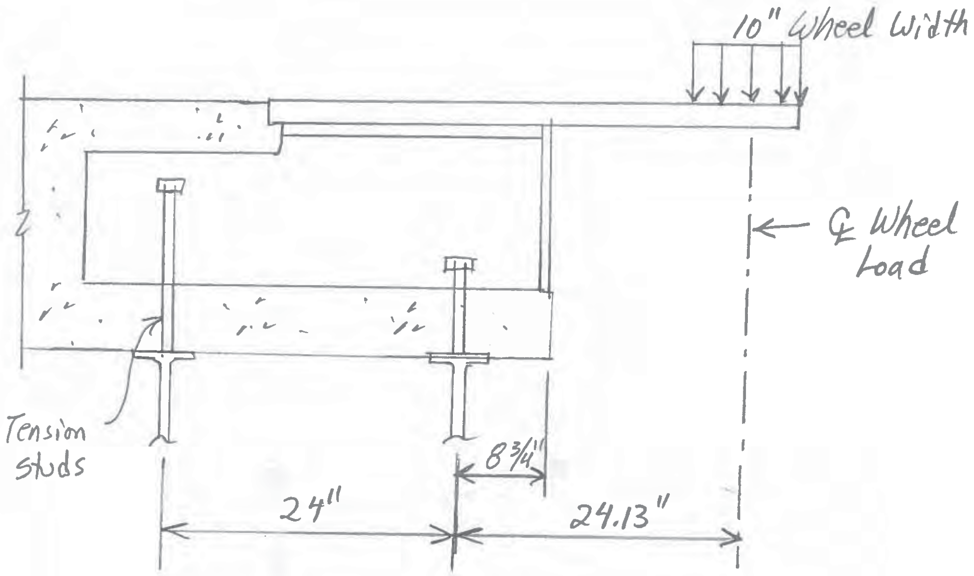
$A_{brg} = [(7/8"\phi + 1/2" \text{head})^2 - (7/8"\phi)^2] \frac{\pi}{4} = 0.884 in^2$

$N_p = (8)(0.884 in^2)(4000 psi) = 28288 lbs$

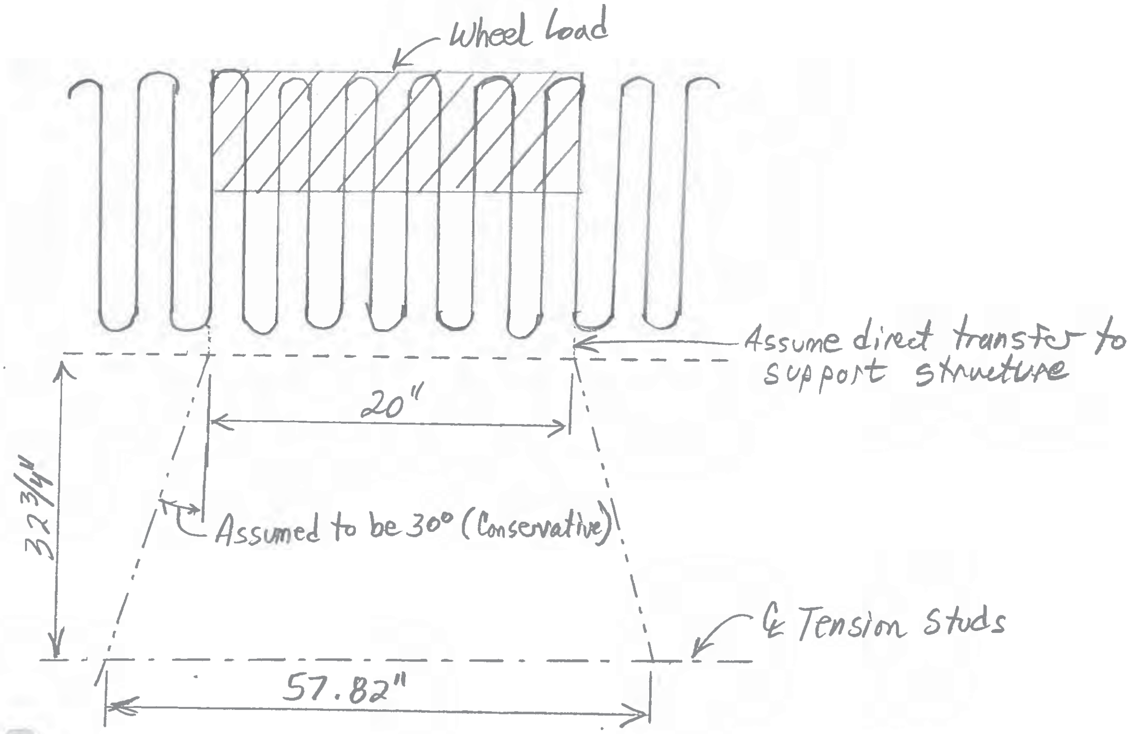
$\phi N_{pn} = (0.75)(1.0)(28.3 kips) = 21.2 kips$

Project:	MoDOT Finger Plate	Computed:	DGB	Date:	10/1/2015
Subject:	Robust Design	Checked:	MTW	Date:	12/10/2015
Task:	Tension studs	Page:	31	of:	ROBUST
Job #:	244663	No:			

Concrete Break out

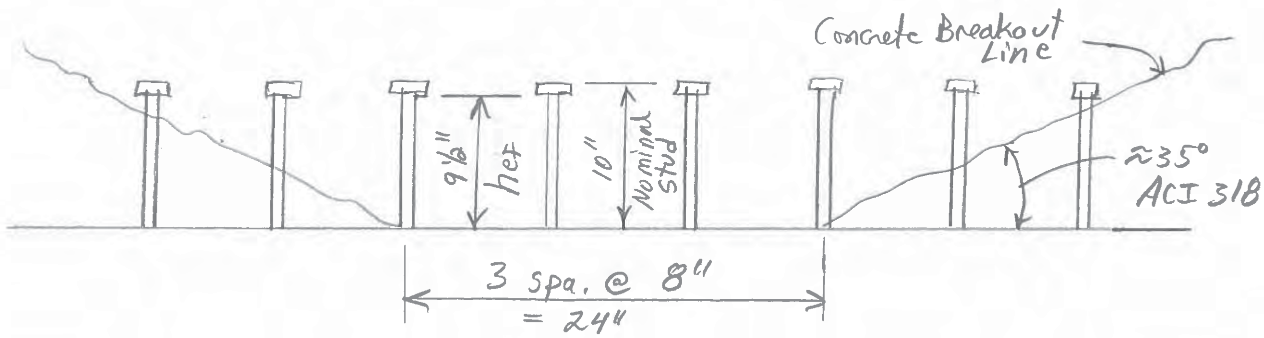


SECTION



Concrete Breakout (Cont.)

Consider a group of anchors supporting a wheel load.



24" < 57.82" Conservative Assumption to determine the number of active studs for each wheel

Studs must have 1.5 h_{ef} clear on all sides to reach full capacity. Consider a wheel load will be at least 12" away from a 16" barrier. Therefore no edge reduction will be needed.

$$N_{cbg} = \frac{A_{Nc}}{A_{Nco}} \Psi_{ec,N} \Psi_{ed,N} \Psi_{c,N} \Psi_{cp,N} N_b$$ ACI 318 D.5.2.1

$$A_{Nc} = (1.5h_{ef} + S_1 + S_1 + S_1 + 1.5h_{ef})(1.5h_{ef} + 1.5h_{ef})$$

$$= [(1.5)(9\tfrac{1}{2}")(2) + (8")(3)][(1.5)(9\tfrac{1}{2}")(2)] = 1496.25\ in^2$$

$$A_{Nco} = 9h_{ef}^2 = (9)(9\tfrac{1}{2}")^2 = 812.25\ in^2$$

$$\Psi_{ec,N} = \frac{1}{1 + \frac{2e'_N}{3h_{ef}}}$$

ACI 318 D.5.2.4
Consider e'_N to be ½ of a stud spacing ⇒ 4"

$$= \frac{1}{1 + \frac{(2)(4")}{(3)(9\tfrac{1}{2}")}} = 0.781$$

Concrete Breakout (Cont.)

$\Psi_{ed,N} = 1.0$ ACI 318 D.5.2.5

$\Psi_{c,N} = 1.25$ (Cast in Place) ACI 318 D.5.2.6

$\Psi_{cp,N} = 1.0$ (Cast in Place) ACI 318 D.5.2.7

$N_b = k_c \lambda_a \sqrt{f'_c}\, h_{ef}^{1.5}$ ACI 318 D.5.2.2

$k_c = 24$

$\lambda_a = 1.0 \lambda$ ACI 318 D.3.6

$\lambda = 1.0$ Normal weight Concrete ACI 318 8.6.1

$N_b = (24)(1.0)\sqrt{4000\text{psi}}\,(9\tfrac{1}{2}")^{1.5} = 44\,445 \text{ lbs}$

$N_{cbg} = \dfrac{1496.25 \text{ in}^2}{812.25 \text{ in}^2}(0.781)(1.0)(1.25)(1.0)(44.4 \text{ kips}) = \underline{79.8 \text{ kips}}$

Applied Load: 1 wheel from a design tandem axel.

Factored wheel load $= (1.75)(1.20)(200\%)(12.5 \text{ kips}) = 52.5 \text{ kips}$

Max. moment arm to first support beam $= 24.13"$ ← Spreadsheet Calcs

Stud spacing along the bridge $= 24"$

Applied Load $= \dfrac{24.13"}{24"}(52.5 \text{ kips}) = 52.8 \text{ kips}$

$\phi N_{cbg} = (0.75)(79.8 \text{ kips}) = 59.8 \text{ kips} > 52.8 \text{ kips}$ ok

Robust Finger Plate Design with Increased Kerf

Codes referenced:

AASHTO LRFD Bridge Design Specifications, 7th Ed. 2014

MoDOT Finger Plate Expansion Device Design for Steel Girders with 1/4" Kerf

Calculation Notes:

1.0 - Finger Plate Design for Strength Moment and Shear and Fatigue Stress

Anchorage is the same as with a 1/8" kerf and is not checked in this calculation.

General Parameters:

Temp. Rise* - Steel:	**60°F**	Temp. Rise* - Concrete:	**50°F**	Finger Plate Steel, F_y:	**50 ksi**	
Temp. Fall* - Steel:	**90°F**	Temp. Fall* - Concrete:	**70°F**			

* - Based on 60°F setting temperature

α_{Steel}:	**0.0000065** in/in/°F	$\alpha_{Concrete}$:	**0.0000060** in/in/°F			
Min. Overlap @ Open:	**1 1/2 in.**	Min. Gap @ Close:	**1 1/2 in.**			
Axle Load - Strength:	**25 kips**	Axle Load - Fatigue:	**16 kips**	Resistance Factor, ϕ_f:	**1.00**	AASHTO 6.5.4.2
Tire - Across Bridge:	**20 in.**	Tire - Across Bridge:	**20 in.**	Resistance Factor, ϕ_v:	**1.00**	AASHTO 6.5.4.2
Tire - Along Bridge:	**10 in.**	Tire - Along Bridge:	**10 in.**			
LL Factor:	**1.75**	LL Factor:	**1.50**			
Multi-Presence Factor:	**1.20**	Multi-Presence Factor:	**1.00**			
Impact:	**200%**	Impact:	**200%**			
		Finger PL Fat. Category:	**B**			
		Finger PL Δ_{TH}:	16.0 ksi			

MoDOT Finger Plate Expansion Device Design for Steel Girders with 1/4" Kerf (Cont.)

Design ID	Max. Expansion Length (ft)	Bridge Type Steel or Concrete (S or C)	Finger Plate Thickness (in)	Throat Radius (in)	Finger Kerf (in)
1	1060	S	3	1	1/4
2	930	S	2 3/4	1	1/4
3	800	S	2 1/2	1	1/4
4	690	S	2 1/4	1	1/4
5	590	S	2	1	1/4
6	480	S	1 3/4	1	1/4

Updated values

Design ID	Joint Geometry							
	Finger Width (in)	CL - CL Fingers (in)	$\Delta_{Cont.}$ (in)	$\Delta_{Exp.}$ (in)	$\Delta_{Tot..}$ (in)	Overlap @ 60°F (in)	Gap @ 60°F (in)	Finger Length (in)
1	1 1/2	3 1/2	9	6	15	10 1/2	7 1/2	18
2	1 1/2	3 1/2	7 7/8	5 1/4	13 1/8	9 3/8	6 3/4	16 1/8
3	1 1/2	3 1/2	6 3/4	4 1/2	11 1/4	8 1/4	6	14 1/4
4	1 1/2	3 1/2	5 7/8	4	9 7/8	7 3/8	5 1/2	12 7/8
5	1 1/2	3 1/2	5	3 3/8	8 3/8	6 1/2	4 7/8	11 3/8
6	1 1/2	3 1/2	4 1/8	2 3/4	6 7/8	5 5/8	4 1/4	9 7/8

Assume straight finger geometry.

MoDOT Finger Plate Expansion Device Design for Steel Girders with 1/4" Kerf (Cont.)

Design ID	1.0 - Strength Design at Base of Finger								
	Load / Finger (kips)	Factored Load (kips)	Moment Arm (in)	S-Finger (in^3)	Applied Moment (kip-in)	Applied Stress (ksi)	Less Than $\phi_f F_y$?	Nominal Shear, Vn (kips)	Less Than $\phi_v V_n$?
1	2.19	9.20	12.00	2.250	110.40	49.07	**OK**	130.5	**OK**
2	2.19	9.20	10.13	1.891	93.15	49.26	**OK**	119.6	**OK**
3	2.19	9.20	8.25	1.563	75.90	48.56	**OK**	108.8	**OK**
4	2.19	9.20	6.88	1.266	63.25	49.96	**OK**	97.9	**OK**
5	2.19	9.20	5.38	1.000	49.45	49.45	**OK**	87.0	**OK**
6	1.94	8.15	4.44	0.766	36.17	47.22	**OK**	76.1	**OK**

Assume 100% of wheel load taken by one side of the finger joint; Value of "C" in V_n = 1.00.

Assume only the length of finger is loaded if finger length is less than longitudinal tire length.

Design ID	1.0 - Strength Design at Base of Throat								
	Load / Finger (kips)	Factored Load (kips)	Moment Arm (in)	S-Finger (in^3)	Applied Moment (kip-in)	Applied Stress (ksi)	Less Than $\phi_f F_y$?	Nominal Shear, Vn (kips)	Less Than $\phi_v V_n$?
1	2.19	9.20	13.00	5.250	119.60	22.78	**OK**	304.5	**OK**
2	2.19	9.2	11.13	4.411	102.35	23.20	**OK**	279.1	**OK**
3	2.19	9.2	9.25	3.646	85.10	23.34	**OK**	253.8	**OK**
4	2.19	9.2	7.88	2.953	72.45	24.53	**OK**	228.4	**OK**
5	2.19	9.2	6.38	2.333	58.65	25.14	**OK**	203.0	**OK**
6	2.16	9.07	4.94	1.786	44.78	25.07	**OK**	177.6	**OK**

Assume 100% of wheel load taken by one side of the finger joint; Value of "C" in V_n = 1.00.

Assume only the length of finger is loaded if finger length is less than longitudinal tire length.

MoDOT Finger Plate Expansion Device Design for Steel Girders with 1/4" Kerf (Cont.)

Design ID	1.0 - Fatigue Design at Base Finger @ 50 Degrees										
	Overlap at 50°F (in)	Shared Load / Finger (kips)	Un-Shared Load / Finger (kips)	Factored Shared Load (kips)	Factored Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	S-Finger (in^3)	Applied Moment (kip-in)	Applied Stress (ksi)	Less Than Δ_{TH} ?
1	9.67	0.68	0.05	2.04	0.15	12.17	7.17	2.250	25.90	11.51	**OK**
2	8.65	0.61	0.19	1.83	0.57	10.80	5.80	1.891	23.07	12.20	**OK**
3	7.63	0.53	0.33	1.59	0.99	9.44	4.44	1.563	19.41	12.42	**OK**
4	6.84	0.48	0.44	1.44	1.32	8.46	3.46	1.266	16.75	13.23	**OK**
5	6.04	0.42	0.55	1.26	1.65	7.36	2.36	1.000	13.17	13.17	**OK**
6	5.25	0.37	0.65	1.11	1.95	6.25	1.31	0.766	9.49	12.39	**OK**

Assumes equal load sharing to adjacent fingers in regions of finger overlap.

MoDOT Finger Plate Expansion Device Design for Concrete Girders with 1/4" Kerf

Calculation Notes:

1.0 - Finger Plate Design for Strength Moment and Shear and Fatigue Stress

Anchorage is the same as with a 1/8" kerf and is not checked in this calculation.

General Parameters:

Temp. Rise* - Steel:	**60°F**	Temp. Rise* - Concrete:	**50°F**	Finger Plate Steel, F_y:	**50 ksi**	
Temp. Fall* - Steel:	**90°F**	Temp. Fall* - Concrete:	**70°F**			

* - Based on 60°F setting temperature

α_{Steel}:	**0.0000065** in/in/°F	$\alpha_{Concrete}$:	**0.0000060** in/in/°F			
Min. Overlap @ Open:	**1 1/2 in.**	Min. Gap @ Close:	**1 1/2 in.**			
Axle Load - Strength:	**25 kips**	Axle Load - Fatigue:	**16 kips**	Resistance Factor, ϕ_f:	**1.00**	AASHTO 6.5.4.2
Tire - Across Bridge:	**20 in.**	Tire - Across Bridge:	**20 in.**	Resistance Factor, ϕ_v:	**1.00**	AASHTO 6.5.4.2
Tire - Along Bridge:	**10 in.**	Tire - Along Bridge:	**10 in.**			
LL Factor:	**1.75**	LL Factor:	**1.50**			
Multi-Presence Factor:	**1.20**	Multi-Presence Factor:	**1.00**			
Impact:	**200%**	Impact:	**200%**			
		Finger PL Fat. Category:	**B**			
		Finger PL Δ_{TH}:	16.0 ksi			

MoDOT Finger Plate Expansion Device Design for Concrete Girders with 1/4" Kerf (Cont.)

Design ID	Max. Expansion Length (ft)	Bridge Type Steel or Concrete (S or C)	Finger Plate Thickness (in)	Throat Radius (in)	Finger Kerf (in)
1	1440	C	3	1	1/4
2	1270	C	2 3/4	1	1/4
3	1090	C	2 1/2	1	1/4
4	950	C	2 1/4	1	1/4
5	800	C	2	1	1/4
6	660	C	1 3/4	1	1/4

Updated values

Design ID	Joint Geometry							
	Finger Width (in)	CL - CL Fingers (in)	$\Delta_{Cont.}$ (in)	$\Delta_{Exp.}$ (in)	$\Delta_{Tot.}$ (in)	Overlap @ 60°F (in)	Gap @ 60°F (in)	Finger Length (in)
1	1 1/2	3 1/2	8 3/4	6 1/4	15	10 1/4	7 3/4	18
2	1 1/2	3 1/2	7 3/4	5 1/2	13 1/4	9 1/4	7	16 1/4
3	1 1/2	3 1/2	6 5/8	4 3/4	11 3/8	8 1/8	6 1/4	14 3/8
4	1 1/2	3 1/2	5 3/4	4 1/8	9 7/8	7 1/4	5 5/8	12 7/8
5	1 1/2	3 1/2	4 7/8	3 1/2	8 3/8	6 3/8	5	11 3/8
6	1 1/2	3 1/2	4	2 7/8	6 7/8	5 1/2	4 3/8	9 7/8

Assume straight finger geometry.

MoDOT Finger Plate Expansion Device Design for Concrete Girders with 1/4" Kerf (Cont.)

Design ID	1.0 - Strength Design at Base of Finger								
	Load / Finger (kips)	Factored Load (kips)	Moment Arm (in)	S-Finger (in^3)	Applied Moment (kip-in)	Applied Stress (ksi)	Less Than $\phi_f F_y$?	Nominal Shear, Vn (kips)	Less Than $\phi_v V_n$?
1	2.19	9.20	12.00	2.250	110.40	49.07	**OK**	130.5	**OK**
2	2.19	9.20	10.25	1.891	94.30	49.87	**OK**	119.6	**OK**
3	2.19	9.20	8.38	1.563	77.05	49.30	**OK**	108.8	**OK**
4	2.19	9.20	6.88	1.266	63.25	49.96	**OK**	97.9	**OK**
5	2.19	9.20	5.38	1.000	49.45	49.45	**OK**	87.0	**OK**
6	1.94	8.15	4.44	0.766	36.17	47.22	**OK**	76.1	**OK**

Assume 100% of wheel load taken by one side of the finger joint; Value of "C" in V_n = 1.00.

Assume only the length of finger is loaded if finger length is less than longitudinal tire length.

Design ID	1.0 - Strength Design at Base of Throat								
	Load / Finger (kips)	Factored Load (kips)	Moment Arm (in)	S-Finger (in^3)	Applied Moment (kip-in)	Applied Stress (ksi)	Less Than $\phi_f F_y$?	Nominal Shear, Vn (kips)	Less Than $\phi_v V_n$?
1	2.19	9.20	13.00	5.250	119.60	22.78	**OK**	304.5	**OK**
2	2.19	9.2	11.25	4.411	103.50	23.46	**OK**	279.1	**OK**
3	2.19	9.2	9.38	3.646	86.25	23.66	**OK**	253.8	**OK**
4	2.19	9.2	7.88	2.953	72.45	24.53	**OK**	228.4	**OK**
5	2.19	9.2	6.38	2.333	58.65	25.14	**OK**	203.0	**OK**
6	2.16	9.07	4.94	1.786	44.78	25.07	**OK**	177.6	**OK**

Assume 100% of wheel load taken by one side of the finger joint; Value of "C" in V_n = 1.00.

Assume only the length of finger is loaded if finger length is less than longitudinal tire length.

Project:	MoDOT Finger Plate	Computed:	DGB	Date:	12/1/2015
Subject:	Robust Design	Checked:	MTW	Date:	12/10/2015
Task:	Increased Kerf	Page:	8	of:	KERF
Job #:	244663	No:			

MoDOT Finger Plate Expansion Device Design for Concrete Girders with 1/4" Kerf (Cont.)

Design ID	1.0 - Fatigue Design at Base Finger @ 50 Degrees										
	Overlap at 50°F (in)	Shared Load / Finger (kips)	Un-Shared Load / Finger (kips)	Factored Shared Load (kips)	Factored Un-Shared Load (kips)	Shared Moment Arm (in)	Un-Shared Moment Arm (in)	S-Finger (in^3)	Applied Moment (kip-in)	Applied Stress (ksi)	Less Than Δ_{TH} ?
1	9.21	0.64	0.11	1.92	0.33	12.40	7.40	2.250	26.25	11.67	**OK**
2	8.34	0.58	0.23	1.74	0.69	11.08	6.08	1.891	23.47	12.41	**OK**
3	7.34	0.51	0.37	1.53	1.11	9.71	4.71	1.563	20.08	12.85	**OK**
4	6.57	0.46	0.48	1.38	1.44	8.59	3.59	1.266	17.02	13.44	**OK**
5	5.80	0.41	0.59	1.23	1.77	7.48	2.48	1.000	13.59	13.59	**OK**
6	5.02	0.35	0.68	1.05	2.04	6.37	1.43	0.766	9.61	12.55	**OK**

Assumes equal load sharing to adjacent fingers in regions of finger overlap.

Limiting Bridge Width for Specified Kerf

- Consider the case of a concrete superstructure of abutment on one side of the exp. device and a steel girder superstructure on the other side.

- Find maximum bridge that can be accomodated.

$[(\text{Exp. Width})(90°F\text{-Fall})(0.0000065\ in/in/°F) - (\text{Exp. Width})(70°F\text{-Fall})(0.000006\ in/in/°F)](12''/Ft)$

- Maintain a minimum gap of 1/16"
- For a 1/8" nominal kerf allow 1/16" of differential movement.
- For a 1/4" nominal kerf allow 3/16" of differential movement.

$$\text{Exp. Width} = \frac{1/16''}{[(90°)(0.0000065) - (70°)(0.000006)](12''/Ft)} = 31.5'$$

Maximum Roadway Width (1/8" Kerf) = (31.5')(2) = 63'-0"

For a 3/16" movement → $\text{Exp. Width} = (31.5')\left[\frac{3/16''}{1/16''}\right] = 94.5'$

Maximum Roadway Width (1/4" Kerf) = (94.5')(2) = 189'-0"

Robust Finger Plate Expansion Device Design

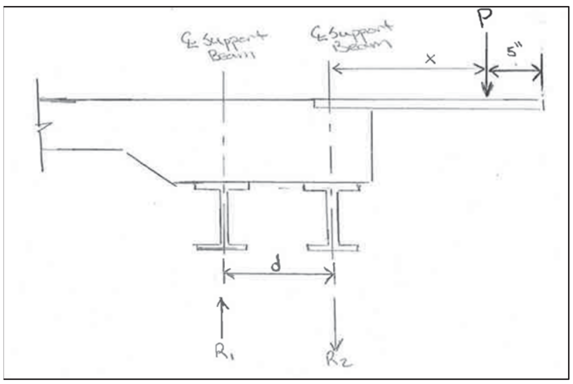
Support Beams

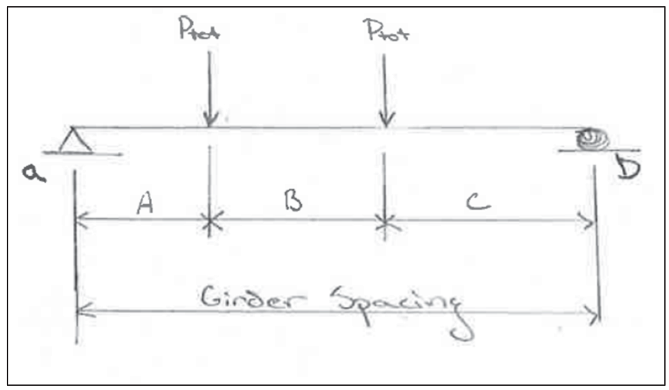
Codes referenced:

AASHTO LRFD Bridge Design Specifications, 7th Ed. 2014

SUPPORT BEAM DESIGN CALCULATIONS: NOTES AND METHODOLOGY

-The basic idea for the finger joint design is to use a dual support beam under each side of the finger joint.
This eliminates the torque in a single support beam by creating a couple between the front beam and the rear beam.
The front beam takes significantly more compresson than the rear beam takes tension since it has to have a compression component of the couple and the vertical reaction of the applied wheel load.
-For STR: consider a tandem wheel load (12.5 kips) applied to one side of the joint only.
Load Factor = 1.75, Impact = 100%, Multi-presence = 1.20
-For FATIGUE: consider an equivalent tandem for an HL-93 wheel load (8 kips) applied to both sides of the joint.
Load Factor = 1.5, Impact = 100%, Multi-presence = 1.00 (Assume 40 degrees for distribution of load across joint sides).
Assume a Detail Category B for fatigue threshold (16 ksi).





Design Procedure, Equations and AASHTO references used throughout support beam evaluation

1) Calculate factored load being applied to finger plate; each wheel is applied to a 10" x 20" area placed at the tip of the fingers on one side of the joint so that the centroid of the load is 5" from the tip of the fingers

P = (multi precense factor)(IM factor)(LL factor)(tandem wheel load)

2) Determine moment couple between support beams

$M_{couple} = P(x)$

3) Determine load, P_{tot}, being applied to the front support beam

$R_1 = M_{couple}/d$

$P_{tot} = R_2 = P + R_1$

4) Calculate Dead Load Moment, $M_{u,D}$

$M_{u,D}$ = (DC factor)(W_{finger} + W_{slab} + $W_{support\_beam}$)(L)^2/8

with L = A + B + C (varies depending bridge skew)

SUPPORT BEAM DESIGN CALCULATIONS: NOTES AND METHODOLOGY

5) Calculate Maximum Live Load Moment, $M_{u,L}$ (Lengths A, B and C have been optimized for max moment)

Reaction at support b produces max LL moment since distance A < distance C

$R_b = P_{tot}((2)(A)+(B))/L$

$M_{u,L} = R_b(C)$

6) Determine the Ultimate Moment, M_u, and stress, f_{bu}, applied to front support beam

$M_u = M_{u,D} + M_{u,L}$

$f_{bu} = M_u/S_x$

with S_x *= elastic section modulus of support beam*

7) Check the Compression-Flange Flexural Resistance based on AASHTO Guidelines

The nominal flexural resistance of the compression flange shall be taken as the smaller of the local buckling resistance detrmined in AASHTO Article 6.10.8.2.2, and the lateral torsional buckling resistance specified in AASHTO Article 6.10.8.2.3

Ref. AASHTO LRFD Bridge Design Specs. 6.10.8.2.2 Local Buckling Resistance

The local buckling resistance of the compression flange shall be taken as:

If $\lambda_f \le \lambda_{pf}$ then:

$F_{nc} = R_b R_h F_{yc}$ *(AASHTO Eq. 6.10.8.2.2-1)*

Otherwise:

$F_{nc} = [1-(1-F_{yr}/R_h F_{yc})(\lambda_f-\lambda_{pf}/\lambda_{rf}-\lambda_{pf})]R_b R_h F_{yc}$ *(AASHTO Eq. 6.10.8.2.2-2)*

with:

$\lambda_f = b_{fc}/2t_{fc}$ *(AASHTO Eq. 6.10.8.2.2-3)*

$\lambda_{pf} = 0.38(E/F_{yc})^{1/2}$ *(AASHTO Eq. 6.10.8.2.2-4)*

$\lambda_{rf} = 0.56(E/F_{yr})^{1/2}$ *(AASHTO Eq. 6.10.8.2.2-5)*

F_{yr} *= smaller of* $0.7F_{yc}$ *and* F_{yw}*, but not less than* $0.5F_{yc}$

Rh = 1.0 (for our case) *(Ref. AASHTO Article 6.10.1.10.1)*

Rb = 1.0 (for our case) *(Ref. AASHTO Article 6.10.1.10.2)*

SUPPORT BEAM DESIGN CALCULATIONS: NOTES AND METHODOLOGY

Ref. AASHTO LRFD Bridge Design Specs. 6.10.8.2.3 Lateral Torsional Buckling Resistance

For unbraced lengths in which the member is prismatic, the lateral torsional buckling resistance of the compression flange shall be taken as:

If $L_b \leq L_p$, then:

$F_{nc} = R_b R_h F_{yc}$ (AASHTO Eq. 6.10.8.2.3-1)

If $L_p < L_b \leq L_r$, then:

$F_{nc} = C_b [1-(1-F_{yr}/R_h F_{yc})(L_b - L_p/L_r - L_p)]R_b R_h F_{yc} \leq R_b R_h F_{yc}$ (AASHTO Eq. 6.10.8.2.3-2)

If $L_b > L_r$, then:

$F_{nc} = F_{cr} \leq R_b R_h F_{yc}$ (AASHTO Eq. 6.10.8.2.3-3)

with:

L_b = unbraced length

$L_p = 1.0 r_t (E/F_{yc})^{1/2}$ (AASHTO Eq. 6.10.8.2.3-4)

$L_r = \pi r_t (E/F_{yr})^{1/2}$ (AASHTO Eq. 6.10.8.2.3-5)

$C_b = 1.0$ (for our case) (AASHTO Eq. 6.10.8.2.3-6)

$F_{cr} = C_b R_b \pi^2 E/(L_b/r_t)^2$ (AASHTO Eq. 6.10.8.2.3-8)

$r_t = b_{fc}/(12(1+(D_c t_w/3b_{fc} t_{fc}))^{1/2}$ (AASHTO Eq. 6.10.8.2.3-9)

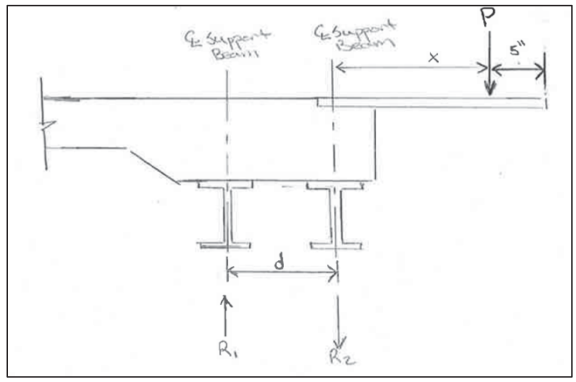
8) Check $f_{bu} \leq F_{nc}$ (for STR); Check $f_{Fat} \leq \Delta_{TH}$ (for FATIGUE)

9) The following design spreadsheets will follow the methodology presented above to determine an optimized matrix of potential support beams to be utilized in HDR's proposed robust finger plate expansion device to MoDOT. The spreadsheets will perform the necessary design checks and create individual support beam tables based on W-Section sizes (W16 through W30). This is done through utilizing a series of index functions within the spreadsheets.
These individual support beam tables can then be combined as deemed fit based on the most economic and efficient beam sizes for a given girder spacing and skew angle. Girder spacings were investigated at 1 foot increments in the range of 7 to 12 feet. Skew angles investigated were 0, 15, 30, 45, 50, 55 and 60 degrees.

SUPPORT BEAM DESIGN CALCULATIONS: NOTES AND METHODOLOGY

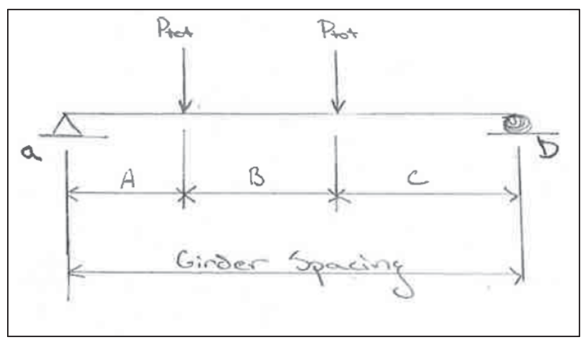
Support Beam Design STR Calculations - Parameters for 19" Finger Length

Parameters		Loading	
Fy (ksi)	50	tandem wheel load (kips)	12.5
E (ksi)	29000	DC STR Factor	1.25
d (in)	24.000	LL STR Factor	1.75
x (in)	24.125	IM Factor	2.00
t_{slab} (in)	19.500	Multi-presence Factor	1.20
w_{slab} (in)	34.000	P (kips)	52.5
t_{plate} (in)	3.000	M_{couple} (kip-in)	1267
l_{plate} (in)	27.500	R_1 (kips)	52.8
γ_c (kcf)	0.145	R_2 (kips)	105.3
γ_s (kcf)	0.49	P_{tot} (kips)	105
W_{finger} (k/ft)	0.281		
W_{slab} (k/ft)	0.668		



Support Beam Design FATIGUE Calculations - Parameters for 19" Finger Length

Parameters		Loading	
Fy (ksi)	50	tandem wheel load (kips)	4
E (ksi)	29000	DC STR Factor	0
d (in)	24.000	LL STR Factor	1.5
x (in)	24.125	IM Factor	2.00
		Multi-presence Factor	1.00
		P (kips)	12
		M_{couple} (kip-in)	290
		R_1 (kips)	12.1
		R_2 (kips)	24.1
		P_{tot} (kips)	24



Assume Detail Category B for Fatigue Threshold (16 ksi)

SUPPORT BEAM DESIGN CALCULATIONS: NOTES AND METHODOLOGY

Support Beam Design Summary

Optimized Support Beam Design Table for STR

Girder Spacing (ft)	Skew (Degrees)						
	0	15	30	45	50	55	60
7	W18x50	W18x50	W18x50	W18x50	W18x55	W21x55	W21x68
8	W18x50	W18x50	W18x50	W21x55	W21x62	W21x68	W24x76
9	W18x50	W18x50	W21x55	W21x68	W24x68	W24x76	W27x84
10	W21x55	W21x55	W21x62	W21x83	W24x84	W27x84	W30x108
11	W21x62	W21x62	W24x68	W24x84	W27x84	W30x108	W30x124
12	W21x68	W24x68	W24x76	W27x84	W30x90	W30x116	W27x146

Optimized Support Beam Design Table for FATIGUE

Girder Spacing (ft)	Skew (Degrees)						
	0	15	30	45	50	55	60
7	W18x50	W18x50	W18x50	W18x50	W18x50	W18x50	W18x50
8	W18x50	W18x50	W18x50	W18x50	W18x50	W18x55	W21x62
9	W18x50	W18x50	W18x50	W18x50	W21x55	W21x62	W21x68
10	W18x50	W18x50	W18x50	W21x55	W21x62	W21x68	W24x76
11	W18x50	W18x50	W18x55	W21x62	W21x68	W24x76	W24x84
12	W18x55	W18x55	W21x55	W24x68	W24x76	W24x84	W30x90

NOTE: STR CONTROLS SUPPORT BEAM DESIGN

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 0°

		Skew	0°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W16	W16x57	7	0.50	4.00	2.50	75.2	7.7	188.0	195.7	25.5	45.3	OK
		8	1.00	4.00	3.00	79.0	10.1	236.9	246.9	32.1	43.8	OK
		9	1.50	4.00	3.50	81.9	12.7	286.6	299.3	39.0	42.4	OK
		10	2.00	4.00	4.00	84.2	15.7	336.9	352.6	45.9	40.9	NO GOOD
		11	2.50	4.00	4.50	86.1	19.0	387.6	406.6	52.9	39.5	NO GOOD
		12	3.00	4.00	5.00	87.7	22.6	438.6	461.3	60.0	38.0	NO GOOD
	W16x67	7	0.50	4.00	2.50	75.2	7.8	188.0	195.8	20.1	48.5	OK
		8	1.00	4.00	3.00	79.0	10.2	236.9	247.0	25.3	47.6	OK
		9	1.50	4.00	3.50	81.9	12.9	286.6	299.4	30.7	46.6	OK
		10	2.00	4.00	4.00	84.2	15.9	336.9	352.7	36.2	45.6	OK
		11	2.50	4.00	4.50	86.1	19.2	387.6	406.8	41.7	44.6	OK
		12	3.00	4.00	5.00	87.7	22.8	438.6	461.5	47.3	43.6	NO GOOD
	W16x77	7	0.50	4.00	2.50	75.2	7.9	188.0	195.8	17.5	48.6	OK
		8	1.00	4.00	3.00	79.0	10.3	236.9	247.1	22.1	47.6	OK
		9	1.50	4.00	3.50	81.9	13.0	286.6	299.6	26.8	46.7	OK
		10	2.00	4.00	4.00	84.2	16.0	336.9	352.9	31.6	45.7	OK
		11	2.50	4.00	4.50	86.1	19.4	387.6	407.0	36.4	44.7	OK
		12	3.00	4.00	5.00	87.7	23.1	438.6	461.7	41.3	43.7	OK
	W16x89	7	0.50	4.00	2.50	75.2	7.9	188.0	195.9	15.2	48.7	OK
		8	1.00	4.00	3.00	79.0	10.4	236.9	247.2	19.1	47.7	OK
		9	1.50	4.00	3.50	81.9	13.1	286.6	299.7	23.2	46.7	OK
		10	2.00	4.00	4.00	84.2	16.2	336.9	353.1	27.3	45.8	OK
		11	2.50	4.00	4.50	86.1	19.6	387.6	407.2	31.5	44.8	OK
		12	3.00	4.00	5.00	87.7	23.3	438.6	462.0	35.8	43.8	OK
	W16x100	7	0.50	4.00	2.50	75.2	8.0	188.0	196.0	13.4	48.7	OK
		8	1.00	4.00	3.00	79.0	10.5	236.9	247.3	17.0	47.7	OK
		9	1.50	4.00	3.50	81.9	13.3	286.6	299.8	20.6	46.7	OK
		10	2.00	4.00	4.00	84.2	16.4	336.9	353.3	24.2	45.8	OK
		11	2.50	4.00	4.50	86.1	19.8	387.6	407.4	27.9	44.8	OK
		12	3.00	4.00	5.00	87.7	23.6	438.6	462.2	31.7	43.9	OK

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 15°

		Skew	15°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	f_{bu}<F_{nc}
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W16	W16x57	7	0.52	4.14	2.59	75.2	8.2	194.6	202.9	26.4	44.9	OK
		8	1.04	4.14	3.11	79.0	10.8	245.2	256.0	33.3	43.4	OK
		9	1.55	4.14	3.62	81.9	13.6	296.7	310.3	40.4	41.9	OK
		10	2.07	4.14	4.14	84.2	16.8	348.8	365.6	47.6	40.4	NO GOOD
		11	2.59	4.14	4.66	86.1	20.4	401.3	421.6	54.9	38.9	NO GOOD
		12	3.11	4.14	5.18	87.7	24.2	454.1	478.4	62.3	37.4	NO GOOD
	W16x67	7	0.52	4.14	2.59	75.2	8.3	194.6	203.0	20.8	48.3	OK
		8	1.04	4.14	3.11	79.0	10.9	245.2	256.1	26.3	47.3	OK
		9	1.55	4.14	3.62	81.9	13.8	296.7	310.5	31.8	46.3	OK
		10	2.07	4.14	4.14	84.2	17.0	348.8	365.8	37.5	45.2	OK
		11	2.59	4.14	4.66	86.1	20.6	401.3	421.8	43.3	44.2	OK
		12	3.11	4.14	5.18	87.7	24.5	454.1	478.6	49.1	43.2	NO GOOD
	W16x77	7	0.52	4.14	2.59	75.2	8.4	194.6	203.0	18.2	48.4	OK
		8	1.04	4.14	3.11	79.0	11.0	245.2	256.2	22.9	47.4	OK
		9	1.55	4.14	3.62	81.9	13.9	296.7	310.6	27.8	46.3	OK
		10	2.07	4.14	4.14	84.2	17.2	348.8	365.9	32.8	45.3	OK
		11	2.59	4.14	4.66	86.1	20.8	401.3	422.0	37.8	44.3	OK
		12	3.11	4.14	5.18	87.7	24.7	454.1	478.8	42.9	43.3	OK
	W16x89	7	0.52	4.14	2.59	75.2	8.5	194.6	203.1	15.7	48.4	OK
		8	1.04	4.14	3.11	79.0	11.1	245.2	256.3	19.8	47.4	OK
		9	1.55	4.14	3.62	81.9	14.1	296.7	310.8	24.1	46.4	OK
		10	2.07	4.14	4.14	84.2	17.4	348.8	366.1	28.3	45.4	OK
		11	2.59	4.14	4.66	86.1	21.0	401.3	422.3	32.7	44.4	OK
		12	3.11	4.14	5.18	87.7	25.0	454.1	479.1	37.1	43.4	OK
	W16x100	7	0.52	4.14	2.59	75.2	8.6	194.6	203.2	13.9	48.4	OK
		8	1.04	4.14	3.11	79.0	11.2	245.2	256.5	17.6	47.4	OK
		9	1.55	4.14	3.62	81.9	14.2	296.7	310.9	21.3	46.4	OK
		10	2.07	4.14	4.14	84.2	17.6	348.8	366.3	25.1	45.4	OK
		11	2.59	4.14	4.66	86.1	21.2	401.3	422.5	29.0	44.4	OK
		12	3.11	4.14	5.18	87.7	25.3	454.1	479.4	32.9	43.4	OK

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 30°

		Skew	30°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W16	W16x57	7	0.58	4.62	2.89	75.2	10.3	217.1	227.3	29.6	43.7	OK
		8	1.15	4.62	3.46	79.0	13.4	273.5	286.9	37.3	42.0	OK
		9	1.73	4.62	4.04	81.9	17.0	330.9	347.9	45.3	40.4	NO GOOD
		10	2.31	4.62	4.62	84.2	20.9	389.0	409.9	53.4	38.7	NO GOOD
		11	2.89	4.62	5.20	86.1	25.3	447.6	472.9	61.5	37.0	NO GOOD
		12	3.46	4.62	5.77	87.7	30.2	506.5	536.7	69.8	35.3	NO GOOD
	W16x67	7	0.58	4.62	2.89	75.2	10.4	217.1	227.4	23.3	47.5	OK
		8	1.15	4.62	3.46	79.0	13.5	273.5	287.0	29.4	46.3	OK
		9	1.73	4.62	4.04	81.9	17.1	330.9	348.0	35.7	45.2	OK
		10	2.31	4.62	4.62	84.2	21.2	389.0	410.1	42.1	44.1	OK
		11	2.89	4.62	5.20	86.1	25.6	447.6	473.2	48.5	42.9	NO GOOD
		12	3.46	4.62	5.77	87.7	30.5	506.5	537.0	55.1	41.8	NO GOOD
	W16x77	7	0.58	4.62	2.89	75.2	10.5	217.1	227.5	20.4	47.6	OK
		8	1.15	4.62	3.46	79.0	13.7	273.5	287.2	25.7	46.4	OK
		9	1.73	4.62	4.04	81.9	17.3	330.9	348.2	31.2	45.3	OK
		10	2.31	4.62	4.62	84.2	21.4	389.0	410.4	36.7	44.2	OK
		11	2.89	4.62	5.20	86.1	25.8	447.6	473.4	42.4	43.0	OK
		12	3.46	4.62	5.77	87.7	30.8	506.5	537.3	48.1	41.9	NO GOOD
	W16x89	7	0.58	4.62	2.89	75.2	10.6	217.1	227.7	17.6	47.6	OK
		8	1.15	4.62	3.46	79.0	13.8	273.5	287.3	22.2	46.5	OK
		9	1.73	4.62	4.04	81.9	17.5	330.9	348.4	27.0	45.4	OK
		10	2.31	4.62	4.62	84.2	21.6	389.0	410.6	31.8	44.3	OK
		11	2.89	4.62	5.20	86.1	26.1	447.6	473.7	36.7	43.2	OK
		12	3.46	4.62	5.77	87.7	31.1	506.5	537.6	41.6	42.0	OK
	W16x100	7	0.58	4.62	2.89	75.2	10.7	217.1	227.8	15.6	47.6	OK
		8	1.15	4.62	3.46	79.0	14.0	273.5	287.5	19.7	46.5	OK
		9	1.73	4.62	4.04	81.9	17.7	330.9	348.6	23.9	45.4	OK
		10	2.31	4.62	4.62	84.2	21.8	389.0	410.8	28.2	44.3	OK
		11	2.89	4.62	5.20	86.1	26.4	447.6	474.0	32.5	43.2	OK
		12	3.46	4.62	5.77	87.7	31.5	506.5	537.9	36.9	42.1	OK

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 45°

		Skew	45									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	f_{bu}<F_{nc}
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W16	W16x57	7	0.71	5.66	3.54	75.2	15.4	265.9	281.2	36.6	41.1	OK
		8	1.41	5.66	4.24	79.0	20.1	335.0	355.1	46.2	39.0	NO GOOD
		9	2.12	5.66	4.95	81.9	25.4	405.3	430.7	56.1	37.0	NO GOOD
		10	2.83	5.66	5.66	84.2	31.4	476.4	507.8	66.1	34.7	NO GOOD
		11	3.54	5.66	6.36	86.1	38.0	548.1	586.2	76.3	28.7	NO GOOD
		12	4.24	5.66	7.07	87.7	45.2	620.3	665.6	86.6	24.1	NO GOOD
	W16x67	7	0.71	5.66	3.54	75.2	15.5	265.9	281.4	28.9	45.7	OK
		8	1.41	5.66	4.24	79.0	20.3	335.0	355.3	36.4	44.3	OK
		9	2.12	5.66	4.95	81.9	25.7	405.3	431.0	44.2	42.9	NO GOOD
		10	2.83	5.66	5.66	84.2	31.7	476.4	508.1	52.1	41.5	NO GOOD
		11	3.54	5.66	6.36	86.1	38.4	548.1	586.5	60.2	40.1	NO GOOD
		12	4.24	5.66	7.07	87.7	45.7	620.3	666.0	68.3	38.7	NO GOOD
	W16x77	7	0.71	5.66	3.54	75.2	15.7	265.9	281.6	25.2	45.8	OK
		8	1.41	5.66	4.24	79.0	20.5	335.0	355.5	31.8	44.4	OK
		9	2.12	5.66	4.95	81.9	26.0	405.3	431.2	38.6	43.0	OK
		10	2.83	5.66	5.66	84.2	32.0	476.4	508.5	45.5	41.6	NO GOOD
		11	3.54	5.66	6.36	86.1	38.8	548.1	586.9	52.6	40.3	NO GOOD
		12	4.24	5.66	7.07	87.7	46.1	620.3	666.5	59.7	38.9	NO GOOD
	W16x89	7	0.71	5.66	3.54	75.2	15.9	265.9	281.7	21.8	45.9	OK
		8	1.41	5.66	4.24	79.0	20.7	335.0	355.7	27.5	44.5	OK
		9	2.12	5.66	4.95	81.9	26.3	405.3	431.5	33.4	43.1	OK
		10	2.83	5.66	5.66	84.2	32.4	476.4	508.8	39.4	41.8	OK
		11	3.54	5.66	6.36	86.1	39.2	548.1	587.4	45.5	40.4	NO GOOD
		12	4.24	5.66	7.07	87.7	46.7	620.3	667.0	51.6	39.0	NO GOOD
	W16x100	7	0.71	5.66	3.54	75.2	16.1	265.9	281.9	19.3	45.9	OK
		8	1.41	5.66	4.24	79.0	21.0	335.0	355.9	24.4	44.5	OK
		9	2.12	5.66	4.95	81.9	26.5	405.3	431.8	29.6	43.1	OK
		10	2.83	5.66	5.66	84.2	32.8	476.4	509.2	34.9	41.8	OK
		11	3.54	5.66	6.36	86.1	39.6	548.1	587.8	40.3	40.4	OK
		12	4.24	5.66	7.07	87.7	47.2	620.3	667.5	45.8	39.0	NO GOOD

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 50°

		Skew	50°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	f_{bu}<F_{nc}
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W16	W16x57	7	0.78	6.22	3.89	75.2	18.6	292.5	311.1	40.5	39.6	NO GOOD
		8	1.56	6.22	4.67	79.0	24.3	368.5	392.8	51.1	37.4	NO GOOD
		9	2.33	6.22	5.45	81.9	30.8	445.8	476.6	62.0	35.1	NO GOOD
		10	3.11	6.22	6.22	84.2	38.0	524.1	562.1	73.2	28.7	NO GOOD
		11	3.89	6.22	7.00	86.1	46.0	603.0	649.0	84.5	23.7	NO GOOD
		12	4.67	6.22	7.78	87.7	54.7	682.4	737.1	95.9	19.9	NO GOOD
	W16x67	7	0.78	6.22	3.89	75.2	18.8	292.5	311.3	31.9	44.7	OK
		8	1.56	6.22	4.67	79.0	24.6	368.5	393.1	40.3	43.2	OK
		9	2.33	6.22	5.45	81.9	31.1	445.8	476.9	48.9	41.6	NO GOOD
		10	3.11	6.22	6.22	84.2	38.4	524.1	562.5	57.7	40.1	NO GOOD
		11	3.89	6.22	7.00	86.1	46.5	603.0	649.5	66.6	38.6	NO GOOD
		12	4.67	6.22	7.78	87.7	55.3	682.4	737.7	75.7	37.0	NO GOOD
	W16x77	7	0.78	6.22	3.89	75.2	19.0	292.5	311.5	27.9	44.8	OK
		8	1.56	6.22	4.67	79.0	24.8	368.5	393.3	35.2	43.3	OK
		9	2.33	6.22	5.45	81.9	31.4	445.8	477.2	42.7	41.8	NO GOOD
		10	3.11	6.22	6.22	84.2	38.8	524.1	562.9	50.4	40.3	NO GOOD
		11	3.89	6.22	7.00	86.1	46.9	603.0	649.9	58.2	38.7	NO GOOD
		12	4.67	6.22	7.78	87.7	55.8	682.4	738.2	66.1	37.2	NO GOOD
	W16x89	7	0.78	6.22	3.89	75.2	19.2	292.5	311.7	24.1	44.9	OK
		8	1.56	6.22	4.67	79.0	25.1	368.5	393.6	30.5	43.4	OK
		9	2.33	6.22	5.45	81.9	31.8	445.8	477.6	37.0	41.9	OK
		10	3.11	6.22	6.22	84.2	39.2	524.1	563.3	43.6	40.4	NO GOOD
		11	3.89	6.22	7.00	86.1	47.5	603.0	650.5	50.4	38.9	NO GOOD
		12	4.67	6.22	7.78	87.7	56.5	682.4	738.9	57.2	37.4	NO GOOD
	W16x100	7	0.78	6.22	3.89	75.2	19.4	292.5	311.9	21.4	44.9	OK
		8	1.56	6.22	4.67	79.0	25.4	368.5	393.9	27.0	43.4	OK
		9	2.33	6.22	5.45	81.9	32.1	445.8	477.9	32.8	41.9	OK
		10	3.11	6.22	6.22	84.2	39.6	524.1	563.7	38.7	40.4	OK
		11	3.89	6.22	7.00	86.1	48.0	603.0	651.0	44.6	38.9	NO GOOD
		12	4.67	6.22	7.78	87.7	57.1	682.4	739.5	50.7	37.4	NO GOOD

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 55°

		Skew	55°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W16	W16x57	7	0.87	6.97	4.36	75.2	23.4	327.7	351.1	45.7	37.7	NO GOOD
		8	1.74	6.97	5.23	79.0	30.6	413.0	443.5	57.7	35.2	NO GOOD
		9	2.62	6.97	6.10	81.9	38.7	499.6	538.3	70.1	28.2	NO GOOD
		10	3.49	6.97	6.97	84.2	47.7	587.3	635.1	82.7	22.8	NO GOOD
		11	4.36	6.97	7.85	86.1	57.8	675.8	733.5	95.5	18.9	NO GOOD
		12	5.23	6.97	8.72	87.7	68.8	764.7	833.5	108.5	15.8	NO GOOD
	W16x67	7	0.87	6.97	4.36	75.2	23.6	327.7	351.4	36.0	43.4	OK
		8	1.74	6.97	5.23	79.0	30.9	413.0	443.8	45.5	41.7	NO GOOD
		9	2.62	6.97	6.10	81.9	39.1	499.6	538.7	55.3	40.0	NO GOOD
		10	3.49	6.97	6.97	84.2	48.2	587.3	635.5	65.2	38.3	NO GOOD
		11	4.36	6.97	7.85	86.1	58.3	675.8	734.1	75.3	36.5	NO GOOD
		12	5.23	6.97	8.72	87.7	69.4	764.7	834.2	85.6	34.4	NO GOOD
	W16x77	7	0.87	6.97	4.36	75.2	23.9	327.7	351.6	31.5	43.5	OK
		8	1.74	6.97	5.23	79.0	31.2	413.0	444.1	39.8	41.8	OK
		9	2.62	6.97	6.10	81.9	39.4	499.6	539.1	48.3	40.1	NO GOOD
		10	3.49	6.97	6.97	84.2	48.7	587.3	636.0	57.0	38.4	NO GOOD
		11	4.36	6.97	7.85	86.1	58.9	675.8	734.7	65.8	36.7	NO GOOD
		12	5.23	6.97	8.72	87.7	70.1	764.7	834.9	74.8	35.0	NO GOOD
	W16x89	7	0.87	6.97	4.36	75.2	24.1	327.7	351.9	27.2	43.6	OK
		8	1.74	6.97	5.23	79.0	31.5	413.0	444.5	34.4	42.0	OK
		9	2.62	6.97	6.10	81.9	39.9	499.6	539.5	41.8	40.3	NO GOOD
		10	3.49	6.97	6.97	84.2	49.3	587.3	636.6	49.3	38.6	NO GOOD
		11	4.36	6.97	7.85	86.1	59.6	675.8	735.4	56.9	36.9	NO GOOD
		12	5.23	6.97	8.72	87.7	70.9	764.7	835.7	64.7	35.2	NO GOOD
	W16x100	7	0.87	6.97	4.36	75.2	24.4	327.7	352.1	24.1	43.7	OK
		8	1.74	6.97	5.23	79.0	31.9	413.0	444.8	30.5	42.0	OK
		9	2.62	6.97	6.10	81.9	40.3	499.6	540.0	37.0	40.3	OK
		10	3.49	6.97	6.97	84.2	49.8	587.3	637.1	43.7	38.6	NO GOOD
		11	4.36	6.97	7.85	86.1	60.2	675.8	736.0	50.5	36.9	NO GOOD
		12	5.23	6.97	8.72	87.7	71.7	764.7	836.4	57.4	35.2	NO GOOD

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 60°

		Skew	60°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W16	W16x57	7	1.00	8.00	5.00	75.2	30.8	376.0	406.8	52.9	35.1	NO GOOD
		8	2.00	8.00	6.00	79.0	40.2	473.7	513.9	66.9	27.1	NO GOOD
		9	3.00	8.00	7.00	81.9	50.9	573.2	624.1	81.2	21.4	NO GOOD
		10	4.00	8.00	8.00	84.2	62.8	673.8	736.6	95.9	17.3	NO GOOD
		11	5.00	8.00	9.00	86.1	76.0	775.2	851.2	110.8	14.3	NO GOOD
		12	6.00	8.00	10.00	87.7	90.5	877.3	967.8	126.0	12.0	NO GOOD
	W16x67	7	1.00	8.00	5.00	75.2	31.1	376.0	407.1	41.8	41.6	NO GOOD
		8	2.00	8.00	6.00	79.0	40.6	473.7	514.3	52.8	39.7	NO GOOD
		9	3.00	8.00	7.00	81.9	51.4	573.2	624.6	64.1	37.7	NO GOOD
		10	4.00	8.00	8.00	84.2	63.5	673.8	737.2	75.6	35.7	NO GOOD
		11	5.00	8.00	9.00	86.1	76.8	775.2	852.0	87.4	31.1	NO GOOD
		12	6.00	8.00	10.00	87.7	91.4	877.3	968.7	99.3	26.1	NO GOOD
	W16x77	7	1.00	8.00	5.00	75.2	31.4	376.0	407.4	36.5	41.8	OK
		8	2.00	8.00	6.00	79.0	41.0	473.7	514.7	46.1	39.8	NO GOOD
		9	3.00	8.00	7.00	81.9	51.9	573.2	625.1	56.0	37.9	NO GOOD
		10	4.00	8.00	8.00	84.2	64.1	673.8	737.8	66.1	35.9	NO GOOD
		11	5.00	8.00	9.00	86.1	77.5	775.2	852.7	76.4	31.7	NO GOOD
		12	6.00	8.00	10.00	87.7	92.3	877.3	969.6	86.8	26.6	NO GOOD
	W16x89	7	1.00	8.00	5.00	75.2	31.8	376.0	407.7	31.6	41.9	OK
		8	2.00	8.00	6.00	79.0	41.5	473.7	515.2	39.9	40.0	OK
		9	3.00	8.00	7.00	81.9	52.5	573.2	625.7	48.4	38.0	NO GOOD
		10	4.00	8.00	8.00	84.2	64.8	673.8	738.6	57.2	36.1	NO GOOD
		11	5.00	8.00	9.00	86.1	78.4	775.2	853.6	66.1	32.3	NO GOOD
		12	6.00	8.00	10.00	87.7	93.4	877.3	970.6	75.1	27.2	NO GOOD
	W16x100	7	1.00	8.00	5.00	75.2	32.1	376.0	408.1	28.0	41.9	OK
		8	2.00	8.00	6.00	79.0	41.9	473.7	515.7	35.4	40.0	OK
		9	3.00	8.00	7.00	81.9	53.1	573.2	626.2	42.9	38.1	NO GOOD
		10	4.00	8.00	8.00	84.2	65.5	673.8	739.3	50.7	36.1	NO GOOD
		11	5.00	8.00	9.00	86.1	79.3	775.2	854.5	58.6	32.4	NO GOOD
		12	6.00	8.00	10.00	87.7	94.4	877.3	971.6	66.6	27.2	NO GOOD

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 0°

		Skew	0°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W18	W18x50	7	0.50	4.00	2.50	75.2	7.6	188.0	195.6	26.4	45.7	OK
		8	1.00	4.00	3.00	79.0	10.0	236.9	246.8	33.3	44.3	OK
		9	1.50	4.00	3.50	81.9	12.6	286.6	299.2	40.4	42.9	OK
		10	2.00	4.00	4.00	84.2	15.6	336.9	352.5	47.6	41.5	NO GOOD
		11	2.50	4.00	4.50	86.1	18.9	387.6	406.5	54.9	40.1	NO GOOD
		12	3.00	4.00	5.00	87.7	22.5	438.6	461.1	62.2	38.7	NO GOOD
	W18x55	7	0.50	4.00	2.50	75.2	7.7	188.0	195.7	23.9	45.8	OK
		8	1.00	4.00	3.00	79.0	10.0	236.9	246.9	30.1	44.4	OK
		9	1.50	4.00	3.50	81.9	12.7	286.6	299.3	36.5	43.0	OK
		10	2.00	4.00	4.00	84.2	15.7	336.9	352.6	43.0	41.6	NO GOOD
		11	2.50	4.00	4.50	86.1	19.0	387.6	406.6	49.6	40.2	NO GOOD
		12	3.00	4.00	5.00	87.7	22.6	438.6	461.2	56.3	38.8	NO GOOD
	W18x60	7	0.50	4.00	2.50	75.2	7.7	188.0	195.7	21.7	45.8	OK
		8	1.00	4.00	3.00	79.0	10.1	236.9	246.9	27.4	44.5	OK
		9	1.50	4.00	3.50	81.9	12.8	286.6	299.3	33.3	43.1	OK
		10	2.00	4.00	4.00	84.2	15.8	336.9	352.6	39.2	41.7	OK
		11	2.50	4.00	4.50	86.1	19.1	387.6	406.7	45.2	40.3	NO GOOD
		12	3.00	4.00	5.00	87.7	22.7	438.6	461.3	51.3	39.0	NO GOOD
	W18x65	7	0.50	4.00	2.50	75.2	7.8	188.0	195.7	20.1	45.9	OK
		8	1.00	4.00	3.00	79.0	10.1	236.9	247.0	25.3	44.5	OK
		9	1.50	4.00	3.50	81.9	12.8	286.6	299.4	30.7	43.1	OK
		10	2.00	4.00	4.00	84.2	15.8	336.9	352.7	36.2	41.8	OK
		11	2.50	4.00	4.50	86.1	19.2	387.6	406.8	41.7	40.4	NO GOOD
		12	3.00	4.00	5.00	87.7	22.8	438.6	461.4	47.3	39.0	NO GOOD
	W18x71	7	0.50	4.00	2.50	75.2	7.8	188.0	195.8	18.5	45.9	OK
		8	1.00	4.00	3.00	79.0	10.2	236.9	247.1	23.3	44.6	OK
		9	1.50	4.00	3.50	81.9	12.9	286.6	299.5	28.3	43.2	OK
		10	2.00	4.00	4.00	84.2	15.9	336.9	352.8	33.3	41.8	OK
		11	2.50	4.00	4.50	86.1	19.3	387.6	406.9	38.4	40.5	OK
		12	3.00	4.00	5.00	87.7	22.9	438.6	461.6	43.6	39.1	NO GOOD
	W18x76	7	0.50	4.00	2.50	75.2	7.8	188.0	195.8	16.1	49.0	OK
		8	1.00	4.00	3.00	79.0	10.2	236.9	247.1	20.3	48.1	OK
		9	1.50	4.00	3.50	81.9	13.0	286.6	299.5	24.6	47.2	OK
		10	2.00	4.00	4.00	84.2	16.0	336.9	352.9	29.0	46.2	OK
		11	2.50	4.00	4.50	86.1	19.4	387.6	407.0	33.4	45.3	OK
		12	3.00	4.00	5.00	87.7	23.0	438.6	461.7	37.9	44.4	OK
	W18x86	7	0.50	4.00	2.50	75.2	7.9	188.0	195.9	14.2	49.1	OK
		8	1.00	4.00	3.00	79.0	10.3	236.9	247.2	17.9	48.2	OK
		9	1.50	4.00	3.50	81.9	13.1	286.6	299.7	21.7	47.2	OK
		10	2.00	4.00	4.00	84.2	16.2	336.9	353.0	25.5	46.3	OK
		11	2.50	4.00	4.50	86.1	19.6	387.6	407.2	29.4	45.4	OK
		12	3.00	4.00	5.00	87.7	23.3	438.6	461.9	33.4	44.5	OK
	W18x97	7	0.50	4.00	2.50	75.2	8.0	188.0	196.0	12.5	49.1	OK
		8	1.00	4.00	3.00	79.0	10.5	236.9	247.3	15.8	48.2	OK
		9	1.50	4.00	3.50	81.9	13.2	286.6	299.8	19.1	47.3	OK
		10	2.00	4.00	4.00	84.2	16.3	336.9	353.2	22.5	46.3	OK
		11	2.50	4.00	4.50	86.1	19.8	387.6	407.4	26.0	45.4	OK
		12	3.00	4.00	5.00	87.7	23.5	438.6	462.2	29.5	44.5	OK
	W18x106	7	0.50	4.00	2.50	75.2	8.1	188.0	196.1	11.5	49.1	OK
		8	1.00	4.00	3.00	79.0	10.5	236.9	247.4	14.6	48.2	OK
		9	1.50	4.00	3.50	81.9	13.3	286.6	299.9	17.6	47.3	OK
		10	2.00	4.00	4.00	84.2	16.5	336.9	353.3	20.8	46.4	OK
		11	2.50	4.00	4.50	86.1	19.9	387.6	407.5	24.0	45.5	OK
		12	3.00	4.00	5.00	87.7	23.7	438.6	462.4	27.2	44.6	OK

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 15°

		Skew	15°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W18	W18x50	7	0.52	4.14	2.59	75.2	8.2	194.6	202.8	27.4	45.4	OK
		8	1.04	4.14	3.11	79.0	10.7	245.2	255.9	34.5	43.9	OK
		9	1.55	4.14	3.62	81.9	13.5	296.7	310.2	41.9	42.5	OK
		10	2.07	4.14	4.14	84.2	16.7	348.8	365.5	49.3	41.0	NO GOOD
		11	2.59	4.14	4.66	86.1	20.2	401.3	421.5	56.9	39.6	NO GOOD
		12	3.11	4.14	5.18	87.7	24.1	454.1	478.2	64.5	38.2	NO GOOD
	W18x55	7	0.52	4.14	2.59	75.2	8.2	194.6	202.9	24.8	45.4	OK
		8	1.04	4.14	3.11	79.0	10.8	245.2	256.0	31.2	44.0	OK
		9	1.55	4.14	3.62	81.9	13.6	296.7	310.3	37.9	42.5	OK
		10	2.07	4.14	4.14	84.2	16.8	348.8	365.6	44.6	41.1	NO GOOD
		11	2.59	4.14	4.66	86.1	20.3	401.3	421.6	51.5	39.7	NO GOOD
		12	3.11	4.14	5.18	87.7	24.2	454.1	478.3	58.4	38.2	NO GOOD
	W18x60	7	0.52	4.14	2.59	75.2	8.3	194.6	202.9	22.5	45.5	OK
		8	1.04	4.14	3.11	79.0	10.8	245.2	256.0	28.4	44.1	OK
		9	1.55	4.14	3.62	81.9	13.7	296.7	310.4	34.5	42.6	OK
		10	2.07	4.14	4.14	84.2	16.9	348.8	365.6	40.6	41.2	OK
		11	2.59	4.14	4.66	86.1	20.4	401.3	421.7	46.9	39.8	NO GOOD
		12	3.11	4.14	5.18	87.7	24.3	454.1	478.4	53.2	38.4	NO GOOD
	W18x65	7	0.52	4.14	2.59	75.2	8.3	194.6	202.9	20.8	45.5	OK
		8	1.04	4.14	3.11	79.0	10.9	245.2	256.1	26.3	44.1	OK
		9	1.55	4.14	3.62	81.9	13.7	296.7	310.4	31.8	42.7	OK
		10	2.07	4.14	4.14	84.2	17.0	348.8	365.7	37.5	41.3	OK
		11	2.59	4.14	4.66	86.1	20.5	401.3	421.8	43.3	39.9	NO GOOD
		12	3.11	4.14	5.18	87.7	24.4	454.1	478.5	49.1	38.4	NO GOOD
	W18x71	7	0.52	4.14	2.59	75.2	8.4	194.6	203.0	19.2	45.6	OK
		8	1.04	4.14	3.11	79.0	10.9	245.2	256.1	24.2	44.2	OK
		9	1.55	4.14	3.62	81.9	13.8	296.7	310.5	29.3	42.8	OK
		10	2.07	4.14	4.14	84.2	17.1	348.8	365.8	34.6	41.3	OK
		11	2.59	4.14	4.66	86.1	20.7	401.3	421.9	39.9	39.9	OK
		12	3.11	4.14	5.18	87.7	24.6	454.1	478.7	45.2	38.5	NO GOOD
	W18x76	7	0.52	4.14	2.59	75.2	8.4	194.6	203.0	16.7	48.8	OK
		8	1.04	4.14	3.11	79.0	11.0	245.2	256.2	21.1	47.8	OK
		9	1.55	4.14	3.62	81.9	13.9	296.7	310.6	25.5	46.9	OK
		10	2.07	4.14	4.14	84.2	17.2	348.8	365.9	30.1	45.9	OK
		11	2.59	4.14	4.66	86.1	20.8	401.3	422.0	34.7	45.0	OK
		12	3.11	4.14	5.18	87.7	24.7	454.1	478.8	39.4	44.0	OK
	W18x86	7	0.52	4.14	2.59	75.2	8.5	194.6	203.1	14.7	48.8	OK
		8	1.04	4.14	3.11	79.0	11.1	245.2	256.3	18.5	47.9	OK
		9	1.55	4.14	3.62	81.9	14.0	296.7	310.7	22.5	47.0	OK
		10	2.07	4.14	4.14	84.2	17.3	348.8	366.1	26.5	46.0	OK
		11	2.59	4.14	4.66	86.1	21.0	401.3	422.2	30.5	45.1	OK
		12	3.11	4.14	5.18	87.7	24.9	454.1	479.1	34.6	44.1	OK
	W18x97	7	0.52	4.14	2.59	75.2	8.6	194.6	203.2	13.0	48.8	OK
		8	1.04	4.14	3.11	79.0	11.2	245.2	256.4	16.4	47.9	OK
		9	1.55	4.14	3.62	81.9	14.2	296.7	310.9	19.8	47.0	OK
		10	2.07	4.14	4.14	84.2	17.5	348.8	366.3	23.4	46.0	OK
		11	2.59	4.14	4.66	86.1	21.2	401.3	422.5	27.0	45.1	OK
		12	3.11	4.14	5.18	87.7	25.2	454.1	479.3	30.6	44.1	OK
	W18x106	7	0.52	4.14	2.59	75.2	8.7	194.6	203.3	12.0	48.9	OK
		8	1.04	4.14	3.11	79.0	11.3	245.2	256.5	15.1	48.0	OK
		9	1.55	4.14	3.62	81.9	14.3	296.7	311.0	18.3	47.0	OK
		10	2.07	4.14	4.14	84.2	17.7	348.8	366.4	21.6	46.1	OK
		11	2.59	4.14	4.66	86.1	21.4	401.3	422.6	24.9	45.2	OK
		12	3.11	4.14	5.18	87.7	25.4	454.1	479.5	28.2	44.2	OK

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 30°

		Skew	30°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W18	W18x50	7	0.58	4.62	2.89	75.2	10.2	217.1	227.3	30.7	44.2	OK
		8	1.15	4.62	3.46	79.0	13.3	273.5	286.8	38.7	42.6	OK
		9	1.73	4.62	4.04	81.9	16.8	330.9	347.8	46.9	41.0	NO GOOD
		10	2.31	4.62	4.62	84.2	20.8	389.0	409.8	55.3	39.4	NO GOOD
		11	2.89	4.62	5.20	86.1	25.2	447.6	472.7	63.8	37.8	NO GOOD
		12	3.46	4.62	5.77	87.7	30.0	506.5	536.4	72.4	36.2	NO GOOD
	W18x55	7	0.58	4.62	2.89	75.2	10.2	217.1	227.3	27.7	44.3	OK
		8	1.15	4.62	3.46	79.0	13.4	273.5	286.9	35.0	42.7	OK
		9	1.73	4.62	4.04	81.9	16.9	330.9	347.8	42.5	41.1	NO GOOD
		10	2.31	4.62	4.62	84.2	20.9	389.0	409.9	50.0	39.5	NO GOOD
		11	2.89	4.62	5.20	86.1	25.3	447.6	472.9	57.7	37.9	NO GOOD
		12	3.46	4.62	5.77	87.7	30.1	506.5	536.6	65.5	36.3	NO GOOD
	W18x60	7	0.58	4.62	2.89	75.2	10.3	217.1	227.4	25.3	44.3	OK
		8	1.15	4.62	3.46	79.0	13.4	273.5	287.0	31.9	42.8	OK
		9	1.73	4.62	4.04	81.9	17.0	330.9	347.9	38.7	41.2	OK
		10	2.31	4.62	4.62	84.2	21.0	389.0	410.0	45.6	39.6	NO GOOD
		11	2.89	4.62	5.20	86.1	25.4	447.6	473.0	52.6	38.0	NO GOOD
		12	3.46	4.62	5.77	87.7	30.3	506.5	536.7	59.6	36.4	NO GOOD
	W18x65	7	0.58	4.62	2.89	75.2	10.3	217.1	227.4	23.3	44.4	OK
		8	1.15	4.62	3.46	79.0	13.5	273.5	287.0	29.4	42.8	OK
		9	1.73	4.62	4.04	81.9	17.1	330.9	348.0	35.7	41.2	OK
		10	2.31	4.62	4.62	84.2	21.1	389.0	410.1	42.1	39.6	NO GOOD
		11	2.89	4.62	5.20	86.1	25.5	447.6	473.1	48.5	38.1	NO GOOD
		12	3.46	4.62	5.77	87.7	30.4	506.5	536.9	55.1	36.5	NO GOOD
	W18x71	7	0.58	4.62	2.89	75.2	10.4	217.1	227.5	21.5	44.4	OK
		8	1.15	4.62	3.46	79.0	13.6	273.5	287.1	27.1	42.9	OK
		9	1.73	4.62	4.04	81.9	17.2	330.9	348.1	32.9	41.3	OK
		10	2.31	4.62	4.62	84.2	21.2	389.0	410.2	38.8	39.7	OK
		11	2.89	4.62	5.20	86.1	25.7	447.6	473.3	44.7	38.2	NO GOOD
		12	3.46	4.62	5.77	87.7	30.6	506.5	537.1	50.7	36.6	NO GOOD
	W18x76	7	0.58	4.62	2.89	75.2	10.5	217.1	227.5	18.7	48.0	OK
		8	1.15	4.62	3.46	79.0	13.7	273.5	287.2	23.6	46.9	OK
		9	1.73	4.62	4.04	81.9	17.3	330.9	348.2	28.6	45.9	OK
		10	2.31	4.62	4.62	84.2	21.3	389.0	410.3	33.7	44.8	OK
		11	2.89	4.62	5.20	86.1	25.8	447.6	473.4	38.9	43.8	OK
		12	3.46	4.62	5.77	87.7	30.7	506.5	537.2	44.2	42.7	NO GOOD
	W18x86	7	0.58	4.62	2.89	75.2	10.6	217.1	227.6	16.5	48.1	OK
		8	1.15	4.62	3.46	79.0	13.8	273.5	287.3	20.8	47.0	OK
		9	1.73	4.62	4.04	81.9	17.5	330.9	348.4	25.2	46.0	OK
		10	2.31	4.62	4.62	84.2	21.5	389.0	410.5	29.7	44.9	OK
		11	2.89	4.62	5.20	86.1	26.1	447.6	473.6	34.2	43.9	OK
		12	3.46	4.62	5.77	87.7	31.0	506.5	537.5	38.9	42.8	OK
	W18x97	7	0.58	4.62	2.89	75.2	10.7	217.1	227.7	14.5	48.1	OK
		8	1.15	4.62	3.46	79.0	13.9	273.5	287.4	18.3	47.0	OK
		9	1.73	4.62	4.04	81.9	17.6	330.9	348.6	22.2	46.0	OK
		10	2.31	4.62	4.62	84.2	21.8	389.0	410.8	26.2	44.9	OK
		11	2.89	4.62	5.20	86.1	26.4	447.6	473.9	30.2	43.9	OK
		12	3.46	4.62	5.77	87.7	31.4	506.5	537.9	34.3	42.8	OK
	W18x106	7	0.58	4.62	2.89	75.2	10.8	217.1	227.8	13.4	48.1	OK
		8	1.15	4.62	3.46	79.0	14.1	273.5	287.6	16.9	47.1	OK
		9	1.73	4.62	4.04	81.9	17.8	330.9	348.7	20.5	46.1	OK
		10	2.31	4.62	4.62	84.2	22.0	389.0	411.0	24.2	45.0	OK
		11	2.89	4.62	5.20	86.1	26.6	447.6	474.1	27.9	44.0	OK
		12	3.46	4.62	5.77	87.7	31.6	506.5	538.1	31.7	42.9	OK

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 45°

		Skew	45									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W18	W18x50	7	0.71	5.66	3.54	75.2	15.3	265.9	281.1	37.9	41.7	OK
		8	1.41	5.66	4.24	79.0	20.0	335.0	354.9	47.9	39.7	NO GOOD
		9	2.12	5.66	4.95	81.9	25.3	405.3	430.6	58.1	37.7	NO GOOD
		10	2.83	5.66	5.66	84.2	31.2	476.4	507.6	68.5	35.8	NO GOOD
		11	3.54	5.66	6.36	86.1	37.7	548.1	585.9	79.1	31.2	NO GOOD
		12	4.24	5.66	7.07	87.7	44.9	620.3	665.3	89.8	26.2	NO GOOD
	W18x55	7	0.71	5.66	3.54	75.2	15.4	265.9	281.2	34.3	41.7	OK
		8	1.41	5.66	4.24	79.0	20.1	335.0	355.0	43.3	39.8	NO GOOD
		9	2.12	5.66	4.95	81.9	25.4	405.3	430.7	52.6	37.8	NO GOOD
		10	2.83	5.66	5.66	84.2	31.4	476.4	507.8	62.0	35.9	NO GOOD
		11	3.54	5.66	6.36	86.1	37.9	548.1	586.1	71.5	31.5	NO GOOD
		12	4.24	5.66	7.07	87.7	45.2	620.3	665.5	81.2	26.5	NO GOOD
	W18x60	7	0.71	5.66	3.54	75.2	15.4	265.9	281.3	31.3	41.8	OK
		8	1.41	5.66	4.24	79.0	20.2	335.0	355.1	39.5	39.9	OK
		9	2.12	5.66	4.95	81.9	25.5	405.3	430.8	47.9	38.0	NO GOOD
		10	2.83	5.66	5.66	84.2	31.5	476.4	507.9	56.4	36.0	NO GOOD
		11	3.54	5.66	6.36	86.1	38.1	548.1	586.3	65.1	32.0	NO GOOD
		12	4.24	5.66	7.07	87.7	45.4	620.3	665.7	74.0	26.9	NO GOOD
	W18x65	7	0.71	5.66	3.54	75.2	15.5	265.9	281.4	28.9	41.9	OK
		8	1.41	5.66	4.24	79.0	20.3	335.0	355.2	36.4	40.0	OK
		9	2.12	5.66	4.95	81.9	25.7	405.3	430.9	44.2	38.0	NO GOOD
		10	2.83	5.66	5.66	84.2	31.7	476.4	508.1	52.1	36.1	NO GOOD
		11	3.54	5.66	6.36	86.1	38.3	548.1	586.5	60.2	32.2	NO GOOD
		12	4.24	5.66	7.07	87.7	45.6	620.3	665.9	68.3	27.1	NO GOOD
	W18x71	7	0.71	5.66	3.54	75.2	15.6	265.9	281.5	26.6	42.0	OK
		8	1.41	5.66	4.24	79.0	20.4	335.0	355.4	33.6	40.0	OK
		9	2.12	5.66	4.95	81.9	25.8	405.3	431.1	40.7	38.1	NO GOOD
		10	2.83	5.66	5.66	84.2	31.9	476.4	508.3	48.0	36.2	NO GOOD
		11	3.54	5.66	6.36	86.1	38.5	548.1	586.7	55.4	32.6	NO GOOD
		12	4.24	5.66	7.07	87.7	45.9	620.3	666.2	62.9	27.4	NO GOOD
	W18x76	7	0.71	5.66	3.54	75.2	15.7	265.9	281.5	23.1	46.3	OK
		8	1.41	5.66	4.24	79.0	20.5	335.0	355.5	29.2	45.0	OK
		9	2.12	5.66	4.95	81.9	25.9	405.3	431.2	35.4	43.7	OK
		10	2.83	5.66	5.66	84.2	32.0	476.4	508.4	41.8	42.4	OK
		11	3.54	5.66	6.36	86.1	38.7	548.1	586.9	48.2	41.1	NO GOOD
		12	4.24	5.66	7.07	87.7	46.1	620.3	666.4	54.8	39.8	NO GOOD
	W18x86	7	0.71	5.66	3.54	75.2	15.8	265.9	281.7	20.4	46.4	OK
		8	1.41	5.66	4.24	79.0	20.7	335.0	355.7	25.7	45.1	OK
		9	2.12	5.66	4.95	81.9	26.2	405.3	431.5	31.2	43.8	OK
		10	2.83	5.66	5.66	84.2	32.3	476.4	508.7	36.8	42.6	OK
		11	3.54	5.66	6.36	86.1	39.1	548.1	587.3	42.5	41.3	NO GOOD
		12	4.24	5.66	7.07	87.7	46.5	620.3	666.9	48.2	40.0	NO GOOD
	W18x97	7	0.71	5.66	3.54	75.2	16.0	265.9	281.9	18.0	46.4	OK
		8	1.41	5.66	4.24	79.0	20.9	335.0	355.9	22.7	45.1	OK
		9	2.12	5.66	4.95	81.9	26.5	405.3	431.7	27.6	43.9	OK
		10	2.83	5.66	5.66	84.2	32.7	476.4	509.1	32.5	42.6	OK
		11	3.54	5.66	6.36	86.1	39.5	548.1	587.7	37.5	41.3	OK
		12	4.24	5.66	7.07	87.7	47.0	620.3	667.4	42.6	40.0	NO GOOD
	W18x106	7	0.71	5.66	3.54	75.2	16.1	265.9	282.0	16.6	46.5	OK
		8	1.41	5.66	4.24	79.0	21.1	335.0	356.1	20.9	45.2	OK
		9	2.12	5.66	4.95	81.9	26.7	405.3	432.0	25.4	44.0	OK
		10	2.83	5.66	5.66	84.2	32.9	476.4	509.4	30.0	42.7	OK
		11	3.54	5.66	6.36	86.1	39.9	548.1	588.0	34.6	41.4	OK
		12	4.24	5.66	7.07	87.7	47.4	620.3	667.8	39.3	40.1	OK

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 50°

		Skew	50°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W18	W18x50	7	0.78	6.22	3.89	75.2	18.5	292.5	311.0	42.0	40.3	NO GOOD
		8	1.56	6.22	4.67	79.0	24.2	368.5	392.7	53.0	38.1	NO GOOD
		9	2.33	6.22	5.45	81.9	30.6	445.8	476.4	64.3	36.0	NO GOOD
		10	3.11	6.22	6.22	84.2	37.8	524.1	561.8	75.8	31.2	NO GOOD
		11	3.89	6.22	7.00	86.1	45.7	603.0	648.7	87.6	25.8	NO GOOD
		12	4.67	6.22	7.78	87.7	54.4	682.4	736.8	99.5	21.7	NO GOOD
	W18x55	7	0.78	6.22	3.89	75.2	18.6	292.5	311.0	38.0	40.4	OK
		8	1.56	6.22	4.67	79.0	24.3	368.5	392.8	47.9	38.2	NO GOOD
		9	2.33	6.22	5.45	81.9	30.7	445.8	476.6	58.2	36.1	NO GOOD
		10	3.11	6.22	6.22	84.2	37.9	524.1	562.0	68.6	31.5	NO GOOD
		11	3.89	6.22	7.00	86.1	45.9	603.0	648.9	79.2	26.1	NO GOOD
		12	4.67	6.22	7.78	87.7	54.6	682.4	737.0	90.0	21.9	NO GOOD
	W18x60	7	0.78	6.22	3.89	75.2	18.7	292.5	311.1	34.6	40.5	OK
		8	1.56	6.22	4.67	79.0	24.4	368.5	392.9	43.7	38.3	NO GOOD
		9	2.33	6.22	5.45	81.9	30.9	445.8	476.7	53.0	36.2	NO GOOD
		10	3.11	6.22	6.22	84.2	38.1	524.1	562.2	62.5	32.0	NO GOOD
		11	3.89	6.22	7.00	86.1	46.1	603.0	649.1	72.1	26.5	NO GOOD
		12	4.67	6.22	7.78	87.7	54.9	682.4	737.3	81.9	22.2	NO GOOD
	W18x65	7	0.78	6.22	3.89	75.2	18.8	292.5	311.2	31.9	40.5	OK
		8	1.56	6.22	4.67	79.0	24.5	368.5	393.0	40.3	38.4	NO GOOD
		9	2.33	6.22	5.45	81.9	31.0	445.8	476.9	48.9	36.3	NO GOOD
		10	3.11	6.22	6.22	84.2	38.3	524.1	562.4	57.7	32.2	NO GOOD
		11	3.89	6.22	7.00	86.1	46.4	603.0	649.4	66.6	26.6	NO GOOD
		12	4.67	6.22	7.78	87.7	55.2	682.4	737.6	75.6	22.4	NO GOOD
	W18x71	7	0.78	6.22	3.89	75.2	18.9	292.5	311.3	29.4	40.6	OK
		8	1.56	6.22	4.67	79.0	24.7	368.5	393.2	37.1	38.5	OK
		9	2.33	6.22	5.45	81.9	31.2	445.8	477.1	45.1	36.4	NO GOOD
		10	3.11	6.22	6.22	84.2	38.5	524.1	562.6	53.2	32.6	NO GOOD
		11	3.89	6.22	7.00	86.1	46.6	603.0	649.6	61.4	26.9	NO GOOD
		12	4.67	6.22	7.78	87.7	55.5	682.4	737.9	69.7	22.6	NO GOOD
	W18x76	7	0.78	6.22	3.89	75.2	19.0	292.5	311.4	25.6	45.4	OK
		8	1.56	6.22	4.67	79.0	24.8	368.5	393.3	32.3	44.0	OK
		9	2.33	6.22	5.45	81.9	31.4	445.8	477.2	39.2	42.6	OK
		10	3.11	6.22	6.22	84.2	38.7	524.1	562.8	46.3	41.1	NO GOOD
		11	3.89	6.22	7.00	86.1	46.9	603.0	649.9	53.4	39.7	NO GOOD
		12	4.67	6.22	7.78	87.7	55.8	682.4	738.2	60.7	38.3	NO GOOD
	W18x86	7	0.78	6.22	3.89	75.2	19.2	292.5	311.6	22.5	45.5	OK
		8	1.56	6.22	4.67	79.0	25.0	368.5	393.5	28.4	44.1	OK
		9	2.33	6.22	5.45	81.9	31.7	445.8	477.5	34.5	42.7	OK
		10	3.11	6.22	6.22	84.2	39.1	524.1	563.2	40.7	41.3	OK
		11	3.89	6.22	7.00	86.1	47.3	603.0	650.3	47.0	39.9	NO GOOD
		12	4.67	6.22	7.78	87.7	56.3	682.4	738.7	53.4	38.4	NO GOOD
	W18x97	7	0.78	6.22	3.89	75.2	19.4	292.5	311.8	19.9	45.5	OK
		8	1.56	6.22	4.67	79.0	25.3	368.5	393.8	25.1	44.1	OK
		9	2.33	6.22	5.45	81.9	32.0	445.8	477.9	30.5	42.7	OK
		10	3.11	6.22	6.22	84.2	39.5	524.1	563.6	36.0	41.3	OK
		11	3.89	6.22	7.00	86.1	47.8	603.0	650.8	41.5	39.9	NO GOOD
		12	4.67	6.22	7.78	87.7	56.9	682.4	739.3	47.2	38.5	NO GOOD
	W18x106	7	0.78	6.22	3.89	75.2	19.5	292.5	312.0	18.4	45.6	OK
		8	1.56	6.22	4.67	79.0	25.5	368.5	394.0	23.2	44.2	OK
		9	2.33	6.22	5.45	81.9	32.3	445.8	478.1	28.1	42.8	OK
		10	3.11	6.22	6.22	84.2	39.9	524.1	564.0	33.2	41.4	OK
		11	3.89	6.22	7.00	86.1	48.2	603.0	651.2	38.3	40.0	OK
		12	4.67	6.22	7.78	87.7	57.4	682.4	739.8	43.5	38.6	NO GOOD

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 55°

		Skew	55°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W18	W18x50	7	0.87	6.97	4.36	75.2	23.2	327.7	351.0	47.4	38.5	NO GOOD
		8	1.74	6.97	5.23	79.0	30.3	413.0	443.3	59.8	36.0	NO GOOD
		9	2.62	6.97	6.10	81.9	38.4	499.6	538.0	72.6	30.7	NO GOOD
		10	3.49	6.97	6.97	84.2	47.4	587.3	634.7	85.7	24.9	NO GOOD
		11	4.36	6.97	7.85	86.1	57.4	675.8	733.1	99.0	20.5	NO GOOD
		12	5.23	6.97	8.72	87.7	68.3	764.7	833.0	112.4	17.3	NO GOOD
	W18x55	7	0.87	6.97	4.36	75.2	23.3	327.7	351.1	42.9	38.5	NO GOOD
		8	1.74	6.97	5.23	79.0	30.5	413.0	443.5	54.1	36.1	NO GOOD
		9	2.62	6.97	6.10	81.9	38.6	499.6	538.2	65.7	31.0	NO GOOD
		10	3.49	6.97	6.97	84.2	47.7	587.3	635.0	77.5	25.1	NO GOOD
		11	4.36	6.97	7.85	86.1	57.7	675.8	733.4	89.5	20.7	NO GOOD
		12	5.23	6.97	8.72	87.7	68.6	764.7	833.4	101.7	17.4	NO GOOD
	W18x60	7	0.87	6.97	4.36	75.2	23.5	327.7	351.2	39.0	38.7	NO GOOD
		8	1.74	6.97	5.23	79.0	30.6	413.0	443.6	49.3	36.3	NO GOOD
		9	2.62	6.97	6.10	81.9	38.8	499.6	538.4	59.8	31.5	NO GOOD
		10	3.49	6.97	6.97	84.2	47.9	587.3	635.2	70.6	25.5	NO GOOD
		11	4.36	6.97	7.85	86.1	57.9	675.8	733.7	81.5	21.1	NO GOOD
		12	5.23	6.97	8.72	87.7	69.0	764.7	833.7	92.6	17.7	NO GOOD
	W18x65	7	0.87	6.97	4.36	75.2	23.6	327.7	351.3	36.0	38.7	OK
		8	1.74	6.97	5.23	79.0	30.8	413.0	443.8	45.5	36.3	NO GOOD
		9	2.62	6.97	6.10	81.9	39.0	499.6	538.6	55.2	31.7	NO GOOD
		10	3.49	6.97	6.97	84.2	48.1	587.3	635.5	65.2	25.7	NO GOOD
		11	4.36	6.97	7.85	86.1	58.2	675.8	734.0	75.3	21.2	NO GOOD
		12	5.23	6.97	8.72	87.7	69.3	764.7	834.0	85.5	17.8	NO GOOD
	W18x71	7	0.87	6.97	4.36	75.2	23.7	327.7	351.5	33.2	38.8	OK
		8	1.74	6.97	5.23	79.0	31.0	413.0	443.9	41.9	36.5	NO GOOD
		9	2.62	6.97	6.10	81.9	39.2	499.6	538.8	50.9	32.1	NO GOOD
		10	3.49	6.97	6.97	84.2	48.4	587.3	635.7	60.1	26.0	NO GOOD
		11	4.36	6.97	7.85	86.1	58.6	675.8	734.3	69.4	21.5	NO GOOD
		12	5.23	6.97	8.72	87.7	69.7	764.7	834.5	78.8	18.0	NO GOOD
	W18x76	7	0.87	6.97	4.36	75.2	23.8	327.7	351.6	28.9	44.2	OK
		8	1.74	6.97	5.23	79.0	31.1	413.0	444.1	36.5	42.6	OK
		9	2.62	6.97	6.10	81.9	39.4	499.6	539.0	44.3	41.0	NO GOOD
		10	3.49	6.97	6.97	84.2	48.6	587.3	636.0	52.3	39.4	NO GOOD
		11	4.36	6.97	7.85	86.1	58.9	675.8	734.6	60.4	37.8	NO GOOD
		12	5.23	6.97	8.72	87.7	70.1	764.7	834.8	68.6	36.2	NO GOOD
	W18x86	7	0.87	6.97	4.36	75.2	24.1	327.7	351.8	25.4	44.3	OK
		8	1.74	6.97	5.23	79.0	31.4	413.0	444.4	32.1	42.7	OK
		9	2.62	6.97	6.10	81.9	39.8	499.6	539.4	39.0	41.1	OK
		10	3.49	6.97	6.97	84.2	49.1	587.3	636.4	46.0	39.6	NO GOOD
		11	4.36	6.97	7.85	86.1	59.4	675.8	735.2	53.1	38.0	NO GOOD
		12	5.23	6.97	8.72	87.7	70.7	764.7	835.5	60.4	36.4	NO GOOD
	W18x97	7	0.87	6.97	4.36	75.2	24.3	327.7	352.1	22.5	44.3	OK
		8	1.74	6.97	5.23	79.0	31.8	413.0	444.7	28.4	42.7	OK
		9	2.62	6.97	6.10	81.9	40.2	499.6	539.8	34.5	41.2	OK
		10	3.49	6.97	6.97	84.2	49.6	587.3	637.0	40.7	39.6	NO GOOD
		11	4.36	6.97	7.85	86.1	60.1	675.8	735.8	47.0	38.0	NO GOOD
		12	5.23	6.97	8.72	87.7	71.5	764.7	836.2	53.4	36.4	NO GOOD
	W18x106	7	0.87	6.97	4.36	75.2	24.5	327.7	352.3	20.7	44.4	OK
		8	1.74	6.97	5.23	79.0	32.0	413.0	445.0	26.2	42.9	OK
		9	2.62	6.97	6.10	81.9	40.6	499.6	540.2	31.8	41.3	OK
		10	3.49	6.97	6.97	84.2	50.1	587.3	637.4	37.5	39.7	OK
		11	4.36	6.97	7.85	86.1	60.6	675.8	736.3	43.3	38.1	NO GOOD
		12	5.23	6.97	8.72	87.7	72.1	764.7	836.9	49.2	36.6	NO GOOD

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 60°

		Skew	60°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W18	W18x50	7	1.00	8.00	5.00	75.2	30.6	376.0	406.6	54.9	36.0	NO GOOD
		8	2.00	8.00	6.00	79.0	39.9	473.7	513.7	69.3	29.5	NO GOOD
		9	3.00	8.00	7.00	81.9	50.5	573.2	623.7	84.2	23.3	NO GOOD
		10	4.00	8.00	8.00	84.2	62.4	673.8	736.1	99.4	18.9	NO GOOD
		11	5.00	8.00	9.00	86.1	75.5	775.2	850.7	114.8	15.6	NO GOOD
		12	6.00	8.00	10.00	87.7	89.8	877.3	967.1	130.5	13.1	NO GOOD
	W18x55	7	1.00	8.00	5.00	75.2	30.7	376.0	406.7	49.6	36.1	NO GOOD
		8	2.00	8.00	6.00	79.0	40.1	473.7	513.9	62.7	29.8	NO GOOD
		9	3.00	8.00	7.00	81.9	50.8	573.2	623.9	76.2	23.6	NO GOOD
		10	4.00	8.00	8.00	84.2	62.7	673.8	736.5	89.9	19.1	NO GOOD
		11	5.00	8.00	9.00	86.1	75.9	775.2	851.1	103.9	15.8	NO GOOD
		12	6.00	8.00	10.00	87.7	90.3	877.3	967.6	118.1	13.2	NO GOOD
	W18x60	7	1.00	8.00	5.00	75.2	30.9	376.0	406.9	45.2	36.2	NO GOOD
		8	2.00	8.00	6.00	79.0	40.3	473.7	514.1	57.1	30.3	NO GOOD
		9	3.00	8.00	7.00	81.9	51.0	573.2	624.2	69.4	23.9	NO GOOD
		10	4.00	8.00	8.00	84.2	63.0	673.8	736.8	81.9	19.4	NO GOOD
		11	5.00	8.00	9.00	86.1	76.3	775.2	851.5	94.6	16.0	NO GOOD
		12	6.00	8.00	10.00	87.7	90.7	877.3	968.0	107.6	13.5	NO GOOD
	W18x65	7	1.00	8.00	5.00	75.2	31.0	376.0	407.0	41.7	36.3	NO GOOD
		8	2.00	8.00	6.00	79.0	40.5	473.7	514.3	52.7	30.5	NO GOOD
		9	3.00	8.00	7.00	81.9	51.3	573.2	624.5	64.0	24.1	NO GOOD
		10	4.00	8.00	8.00	84.2	63.3	673.8	737.1	75.6	19.5	NO GOOD
		11	5.00	8.00	9.00	86.1	76.6	775.2	851.8	87.4	16.1	NO GOOD
		12	6.00	8.00	10.00	87.7	91.2	877.3	968.5	99.3	13.5	NO GOOD
	W18x71	7	1.00	8.00	5.00	75.2	31.2	376.0	407.2	38.5	36.4	NO GOOD
		8	2.00	8.00	6.00	79.0	40.8	473.7	514.5	48.6	30.8	NO GOOD
		9	3.00	8.00	7.00	81.9	51.6	573.2	624.8	59.0	24.4	NO GOOD
		10	4.00	8.00	8.00	84.2	63.7	673.8	737.5	69.7	19.7	NO GOOD
		11	5.00	8.00	9.00	86.1	77.1	775.2	852.3	80.5	16.3	NO GOOD
		12	6.00	8.00	10.00	87.7	91.7	877.3	969.0	91.6	13.7	NO GOOD
	W18x76	7	1.00	8.00	5.00	75.2	31.4	376.0	407.3	33.5	42.6	OK
		8	2.00	8.00	6.00	79.0	41.0	473.7	514.7	42.3	40.7	NO GOOD
		9	3.00	8.00	7.00	81.9	51.9	573.2	625.0	51.4	38.9	NO GOOD
		10	4.00	8.00	8.00	84.2	64.0	673.8	737.8	60.6	37.0	NO GOOD
		11	5.00	8.00	9.00	86.1	77.5	775.2	852.7	70.1	35.2	NO GOOD
		12	6.00	8.00	10.00	87.7	92.2	877.3	969.5	79.7	30.0	NO GOOD
	W18x86	7	1.00	8.00	5.00	75.2	31.7	376.0	407.7	29.5	42.7	OK
		8	2.00	8.00	6.00	79.0	41.4	473.7	515.1	37.2	40.9	OK
		9	3.00	8.00	7.00	81.9	52.4	573.2	625.5	45.2	39.0	NO GOOD
		10	4.00	8.00	8.00	84.2	64.6	673.8	738.4	53.4	37.2	NO GOOD
		11	5.00	8.00	9.00	86.1	78.2	775.2	853.4	61.7	35.4	NO GOOD
		12	6.00	8.00	10.00	87.7	93.1	877.3	970.4	70.1	30.6	NO GOOD
	W18x97	7	1.00	8.00	5.00	75.2	32.0	376.0	408.0	26.0	42.7	OK
		8	2.00	8.00	6.00	79.0	41.8	473.7	515.5	32.9	40.9	OK
		9	3.00	8.00	7.00	81.9	52.9	573.2	626.1	40.0	39.1	NO GOOD
		10	4.00	8.00	8.00	84.2	65.3	673.8	739.1	47.2	37.2	NO GOOD
		11	5.00	8.00	9.00	86.1	79.1	775.2	854.2	54.5	35.4	NO GOOD
		12	6.00	8.00	10.00	87.7	94.1	877.3	971.4	62.0	30.7	NO GOOD
	W18x106	7	1.00	8.00	5.00	75.2	32.3	376.0	408.3	24.0	42.8	OK
		8	2.00	8.00	6.00	79.0	42.2	473.7	515.9	30.3	41.0	OK
		9	3.00	8.00	7.00	81.9	53.4	573.2	626.5	36.9	39.2	OK
		10	4.00	8.00	8.00	84.2	65.9	673.8	739.6	43.5	37.4	NO GOOD
		11	5.00	8.00	9.00	86.1	79.7	775.2	854.9	50.3	35.6	NO GOOD
		12	6.00	8.00	10.00	87.7	94.9	877.3	972.2	57.2	31.2	NO GOOD

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 0°

		Skew	0°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W21	W21x55	7	0.50	4.00	2.50	75.2	7.7	188.0	195.7	21.3	46.4	OK
		8	1.00	4.00	3.00	79.0	10.0	236.9	246.9	26.9	45.1	OK
		9	1.50	4.00	3.50	81.9	12.7	286.6	299.3	32.6	43.8	OK
		10	2.00	4.00	4.00	84.2	15.7	336.9	352.6	38.5	42.5	OK
		11	2.50	4.00	4.50	86.1	19.0	387.6	406.6	44.4	41.2	NO GOOD
		12	3.00	4.00	5.00	87.7	22.6	438.6	461.2	50.3	39.9	NO GOOD
	W21x62	7	0.50	4.00	2.50	75.2	7.7	188.0	195.7	18.5	46.5	OK
		8	1.00	4.00	3.00	79.0	10.1	236.9	247.0	23.3	45.2	OK
		9	1.50	4.00	3.50	81.9	12.8	286.6	299.4	28.3	43.9	OK
		10	2.00	4.00	4.00	84.2	15.8	336.9	352.7	33.3	42.6	OK
		11	2.50	4.00	4.50	86.1	19.1	387.6	406.7	38.4	41.4	OK
		12	3.00	4.00	5.00	87.7	22.7	438.6	461.4	43.6	40.1	NO GOOD
	W21x68	7	0.50	4.00	2.50	75.2	7.8	188.0	195.8	16.8	46.6	OK
		8	1.00	4.00	3.00	79.0	10.2	236.9	247.0	21.2	45.3	OK
		9	1.50	4.00	3.50	81.9	12.9	286.6	299.4	25.7	44.0	OK
		10	2.00	4.00	4.00	84.2	15.9	336.9	352.8	30.2	42.7	OK
		11	2.50	4.00	4.50	86.1	19.2	387.6	406.8	34.9	41.5	OK
		12	3.00	4.00	5.00	87.7	22.9	438.6	461.5	39.6	40.2	OK
	W21x73	7	0.50	4.00	2.50	75.2	7.8	188.0	195.8	15.6	46.6	OK
		8	1.00	4.00	3.00	79.0	10.2	236.9	247.1	19.6	45.3	OK
		9	1.50	4.00	3.50	81.9	12.9	286.6	299.5	23.8	44.1	OK
		10	2.00	4.00	4.00	84.2	16.0	336.9	352.8	28.0	42.8	OK
		11	2.50	4.00	4.50	86.1	19.3	387.6	406.9	32.3	41.6	OK
		12	3.00	4.00	5.00	87.7	23.0	438.6	461.6	36.7	40.3	OK
	W21x83	7	0.50	4.00	2.50	75.2	7.9	188.0	195.9	13.7	46.7	OK
		8	1.00	4.00	3.00	79.0	10.3	236.9	247.2	17.3	45.4	OK
		9	1.50	4.00	3.50	81.9	13.1	286.6	299.6	21.0	44.2	OK
		10	2.00	4.00	4.00	84.2	16.1	336.9	353.0	24.8	42.9	OK
		11	2.50	4.00	4.50	86.1	19.5	387.6	407.1	28.6	41.7	OK
		12	3.00	4.00	5.00	87.7	23.2	438.6	461.8	32.4	40.4	OK
	W21x93	7	0.50	4.00	2.50	75.2	8.0	188.0	196.0	12.2	46.7	OK
		8	1.00	4.00	3.00	79.0	10.4	236.9	247.3	15.5	45.5	OK
		9	1.50	4.00	3.50	81.9	13.2	286.6	299.8	18.7	44.2	OK
		10	2.00	4.00	4.00	84.2	16.3	336.9	353.1	22.1	43.0	OK
		11	2.50	4.00	4.50	86.1	19.7	387.6	407.3	25.5	41.8	OK
		12	3.00	4.00	5.00	87.7	23.4	438.6	462.1	28.9	40.5	OK
	W21x101	7	0.50	4.00	2.50	75.2	8.0	188.0	196.0	10.4	49.7	OK
		8	1.00	4.00	3.00	79.0	10.5	236.9	247.4	13.1	48.8	OK
		9	1.50	4.00	3.50	81.9	13.3	286.6	299.9	15.9	48.0	OK
		10	2.00	4.00	4.00	84.2	16.4	336.9	353.3	18.7	47.2	OK
		11	2.50	4.00	4.50	86.1	19.8	387.6	407.4	21.5	46.4	OK
		12	3.00	4.00	5.00	87.7	23.6	438.6	462.2	24.4	45.5	OK
	W21x111	7	0.50	4.00	2.50	75.2	8.1	188.0	196.1	9.5	49.7	OK
		8	1.00	4.00	3.00	79.0	10.6	236.9	247.5	11.9	48.8	OK
		9	1.50	4.00	3.50	81.9	13.4	286.6	300.0	14.5	48.0	OK
		10	2.00	4.00	4.00	84.2	16.6	336.9	353.4	17.0	47.2	OK
		11	2.50	4.00	4.50	86.1	20.0	387.6	407.6	19.6	46.4	OK
		12	3.00	4.00	5.00	87.7	23.8	438.6	462.5	22.3	45.5	OK
	W21x122	7	0.50	4.00	2.50	75.2	8.2	188.0	196.2	8.6	49.7	OK
		8	1.00	4.00	3.00	79.0	10.7	236.9	247.6	10.9	48.9	OK
		9	1.50	4.00	3.50	81.9	13.5	286.6	300.1	13.2	48.1	OK
		10	2.00	4.00	4.00	84.2	16.7	336.9	353.6	15.5	47.3	OK
		11	2.50	4.00	4.50	86.1	20.2	387.6	407.8	17.9	46.4	OK
		12	3.00	4.00	5.00	87.7	24.1	438.6	462.7	20.3	45.6	OK
	W21x132	7	0.50	4.00	2.50	75.2	8.3	188.0	196.3	8.0	49.7	OK
		8	1.00	4.00	3.00	79.0	10.8	236.9	247.7	10.1	48.9	OK
		9	1.50	4.00	3.50	81.9	13.7	286.6	300.3	12.2	48.1	OK
		10	2.00	4.00	4.00	84.2	16.9	336.9	353.8	14.4	47.3	OK
		11	2.50	4.00	4.50	86.1	20.4	387.6	408.0	16.6	46.4	OK
		12	3.00	4.00	5.00	87.7	24.3	438.6	462.9	18.8	45.6	OK

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 15°

		Skew	15°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W21	W21x55	7	0.52	4.14	2.59	75.2	8.2	194.6	202.9	22.1	46.0	OK
		8	1.04	4.14	3.11	79.0	10.8	245.2	256.0	27.9	44.7	OK
		9	1.55	4.14	3.62	81.9	13.6	296.7	310.3	33.9	43.4	OK
		10	2.07	4.14	4.14	84.2	16.8	348.8	365.6	39.9	42.0	OK
		11	2.59	4.14	4.66	86.1	20.3	401.3	421.6	46.0	40.7	NO GOOD
		12	3.11	4.14	5.18	87.7	24.2	454.1	478.3	52.2	39.3	NO GOOD
	W21x62	7	0.52	4.14	2.59	75.2	8.3	194.6	202.9	19.2	46.2	OK
		8	1.04	4.14	3.11	79.0	10.8	245.2	256.0	24.2	44.8	OK
		9	1.55	4.14	3.62	81.9	13.7	296.7	310.4	29.3	43.5	OK
		10	2.07	4.14	4.14	84.2	16.9	348.8	365.7	34.6	42.2	OK
		11	2.59	4.14	4.66	86.1	20.5	401.3	421.7	39.8	40.9	OK
		12	3.11	4.14	5.18	87.7	24.4	454.1	478.5	45.2	39.5	NO GOOD
	W21x68	7	0.52	4.14	2.59	75.2	8.3	194.6	203.0	17.4	46.2	OK
		8	1.04	4.14	3.11	79.0	10.9	245.2	256.1	22.0	44.9	OK
		9	1.55	4.14	3.62	81.9	13.8	296.7	310.5	26.6	43.6	OK
		10	2.07	4.14	4.14	84.2	17.0	348.8	365.8	31.4	42.3	OK
		11	2.59	4.14	4.66	86.1	20.6	401.3	421.9	36.2	41.0	OK
		12	3.11	4.14	5.18	87.7	24.5	454.1	478.6	41.0	39.7	NO GOOD
	W21x73	7	0.52	4.14	2.59	75.2	8.4	194.6	203.0	16.1	46.3	OK
		8	1.04	4.14	3.11	79.0	10.9	245.2	256.2	20.4	45.0	OK
		9	1.55	4.14	3.62	81.9	13.9	296.7	310.5	24.7	43.7	OK
		10	2.07	4.14	4.14	84.2	17.1	348.8	365.9	29.1	42.4	OK
		11	2.59	4.14	4.66	86.1	20.7	401.3	422.0	33.5	41.1	OK
		12	3.11	4.14	5.18	87.7	24.6	454.1	478.7	38.0	39.8	OK
	W21x83	7	0.52	4.14	2.59	75.2	8.5	194.6	203.1	14.3	46.4	OK
		8	1.04	4.14	3.11	79.0	11.1	245.2	256.3	18.0	45.1	OK
		9	1.55	4.14	3.62	81.9	14.0	296.7	310.7	21.8	43.8	OK
		10	2.07	4.14	4.14	84.2	17.3	348.8	366.0	25.7	42.5	OK
		11	2.59	4.14	4.66	86.1	20.9	401.3	422.2	29.6	41.2	OK
		12	3.11	4.14	5.18	87.7	24.9	454.1	479.0	33.6	39.9	OK
	W21x93	7	0.52	4.14	2.59	75.2	8.5	194.6	203.2	12.7	46.4	OK
		8	1.04	4.14	3.11	79.0	11.2	245.2	256.4	16.0	45.1	OK
		9	1.55	4.14	3.62	81.9	14.1	296.7	310.8	19.4	43.8	OK
		10	2.07	4.14	4.14	84.2	17.4	348.8	366.2	22.9	42.6	OK
		11	2.59	4.14	4.66	86.1	21.1	401.3	422.4	26.4	41.3	OK
		12	3.11	4.14	5.18	87.7	25.1	454.1	479.2	30.0	40.0	OK
	W21x101	7	0.52	4.14	2.59	75.2	8.6	194.6	203.2	10.7	49.5	OK
		8	1.04	4.14	3.11	79.0	11.2	245.2	256.5	13.6	48.6	OK
		9	1.55	4.14	3.62	81.9	14.2	296.7	310.9	16.4	47.8	OK
		10	2.07	4.14	4.14	84.2	17.6	348.8	366.3	19.4	46.9	OK
		11	2.59	4.14	4.66	86.1	21.3	401.3	422.5	22.3	46.0	OK
		12	3.11	4.14	5.18	87.7	25.3	454.1	479.4	25.3	45.2	OK
	W21x111	7	0.52	4.14	2.59	75.2	8.7	194.6	203.3	9.8	49.5	OK
		8	1.04	4.14	3.11	79.0	11.4	245.2	256.6	12.4	48.6	OK
		9	1.55	4.14	3.62	81.9	14.4	296.7	311.1	15.0	47.8	OK
		10	2.07	4.14	4.14	84.2	17.7	348.8	366.5	17.7	46.9	OK
		11	2.59	4.14	4.66	86.1	21.5	401.3	422.7	20.4	46.0	OK
		12	3.11	4.14	5.18	87.7	25.5	454.1	479.7	23.1	45.2	OK
	W21x122	7	0.52	4.14	2.59	75.2	8.8	194.6	203.4	8.9	49.5	OK
		8	1.04	4.14	3.11	79.0	11.5	245.2	256.7	11.3	48.7	OK
		9	1.55	4.14	3.62	81.9	14.5	296.7	311.2	13.7	47.8	OK
		10	2.07	4.14	4.14	84.2	17.9	348.8	366.7	16.1	47.0	OK
		11	2.59	4.14	4.66	86.1	21.7	401.3	423.0	18.6	46.1	OK
		12	3.11	4.14	5.18	87.7	25.8	454.1	479.9	21.1	45.3	OK
	W21x132	7	0.52	4.14	2.59	75.2	8.9	194.6	203.5	8.3	49.5	OK
		8	1.04	4.14	3.11	79.0	11.6	245.2	256.8	10.4	48.7	OK
		9	1.55	4.14	3.62	81.9	14.7	296.7	311.3	12.7	47.8	OK
		10	2.07	4.14	4.14	84.2	18.1	348.8	366.9	14.9	47.0	OK
		11	2.59	4.14	4.66	86.1	21.9	401.3	423.2	17.2	46.1	OK
		12	3.11	4.14	5.18	87.7	26.1	454.1	480.2	19.5	45.3	OK

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 30°

		Skew	30°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W21	W21x55	7	0.58	4.62	2.89	75.2	10.2	217.1	227.3	24.8	45.0	OK
		8	1.15	4.62	3.46	79.0	13.4	273.5	286.9	31.3	43.5	OK
		9	1.73	4.62	4.04	81.9	16.9	330.9	347.8	37.9	42.0	OK
		10	2.31	4.62	4.62	84.2	20.9	389.0	409.9	44.7	40.5	NO GOOD
		11	2.89	4.62	5.20	86.1	25.3	447.6	472.9	51.6	39.0	NO GOOD
		12	3.46	4.62	5.77	87.7	30.1	506.5	536.6	58.5	37.5	NO GOOD
	W21x62	7	0.58	4.62	2.89	75.2	10.3	217.1	227.4	21.5	45.1	OK
		8	1.15	4.62	3.46	79.0	13.5	273.5	287.0	27.1	43.6	OK
		9	1.73	4.62	4.04	81.9	17.0	330.9	348.0	32.9	42.1	OK
		10	2.31	4.62	4.62	84.2	21.0	389.0	410.0	38.7	40.7	OK
		11	2.89	4.62	5.20	86.1	25.5	447.6	473.0	44.7	39.2	NO GOOD
		12	3.46	4.62	5.77	87.7	30.3	506.5	536.8	50.7	37.7	NO GOOD
	W21x68	7	0.58	4.62	2.89	75.2	10.4	217.1	227.4	19.5	45.2	OK
		8	1.15	4.62	3.46	79.0	13.6	273.5	287.1	24.6	43.7	OK
		9	1.73	4.62	4.04	81.9	17.2	330.9	348.1	29.8	42.2	OK
		10	2.31	4.62	4.62	84.2	21.2	389.0	410.2	35.2	40.8	OK
		11	2.89	4.62	5.20	86.1	25.6	447.6	473.2	40.6	39.3	NO GOOD
		12	3.46	4.62	5.77	87.7	30.5	506.5	537.0	46.0	37.8	NO GOOD
	W21x73	7	0.58	4.62	2.89	75.2	10.4	217.1	227.5	18.1	45.2	OK
		8	1.15	4.62	3.46	79.0	13.6	273.5	287.1	22.8	43.8	OK
		9	1.73	4.62	4.04	81.9	17.2	330.9	348.1	27.7	42.3	OK
		10	2.31	4.62	4.62	84.2	21.3	389.0	410.3	32.6	40.9	OK
		11	2.89	4.62	5.20	86.1	25.7	447.6	473.3	37.6	39.4	OK
		12	3.46	4.62	5.77	87.7	30.6	506.5	537.1	42.7	37.9	NO GOOD
	W21x83	7	0.58	4.62	2.89	75.2	10.5	217.1	227.6	16.0	45.3	OK
		8	1.15	4.62	3.46	79.0	13.8	273.5	287.3	20.2	43.9	OK
		9	1.73	4.62	4.04	81.9	17.4	330.9	348.3	24.4	42.4	OK
		10	2.31	4.62	4.62	84.2	21.5	389.0	410.5	28.8	41.0	OK
		11	2.89	4.62	5.20	86.1	26.0	447.6	473.6	33.2	39.5	OK
		12	3.46	4.62	5.77	87.7	30.9	506.5	537.4	37.7	38.1	OK
	W21x93	7	0.58	4.62	2.89	75.2	10.6	217.1	227.7	14.2	45.4	OK
		8	1.15	4.62	3.46	79.0	13.9	273.5	287.4	18.0	43.9	OK
		9	1.73	4.62	4.04	81.9	17.6	330.9	348.5	21.8	42.5	OK
		10	2.31	4.62	4.62	84.2	21.7	389.0	410.7	25.7	41.1	OK
		11	2.89	4.62	5.20	86.1	26.3	447.6	473.8	29.6	39.6	OK
		12	3.46	4.62	5.77	87.7	31.2	506.5	537.7	33.6	38.2	OK
	W21x101	7	0.58	4.62	2.89	75.2	10.7	217.1	227.8	12.0	48.8	OK
		8	1.15	4.62	3.46	79.0	14.0	273.5	287.5	15.2	47.8	OK
		9	1.73	4.62	4.04	81.9	17.7	330.9	348.6	18.4	46.9	OK
		10	2.31	4.62	4.62	84.2	21.9	389.0	410.9	21.7	45.9	OK
		11	2.89	4.62	5.20	86.1	26.5	447.6	474.0	25.1	45.0	OK
		12	3.46	4.62	5.77	87.7	31.5	506.5	538.0	28.4	44.0	OK
	W21x111	7	0.58	4.62	2.89	75.2	10.8	217.1	227.9	11.0	48.8	OK
		8	1.15	4.62	3.46	79.0	14.1	273.5	287.6	13.9	47.8	OK
		9	1.73	4.62	4.04	81.9	17.9	330.9	348.8	16.8	46.9	OK
		10	2.31	4.62	4.62	84.2	22.1	389.0	411.1	19.8	45.9	OK
		11	2.89	4.62	5.20	86.1	26.7	447.6	474.3	22.9	45.0	OK
		12	3.46	4.62	5.77	87.7	31.8	506.5	538.3	25.9	44.0	OK
	W21x122	7	0.58	4.62	2.89	75.2	10.9	217.1	228.0	10.0	48.8	OK
		8	1.15	4.62	3.46	79.0	14.3	273.5	287.8	12.6	47.9	OK
		9	1.73	4.62	4.04	81.9	18.1	330.9	349.0	15.3	46.9	OK
		10	2.31	4.62	4.62	84.2	22.3	389.0	411.3	18.1	46.0	OK
		11	2.89	4.62	5.20	86.1	27.0	447.6	474.5	20.9	45.0	OK
		12	3.46	4.62	5.77	87.7	32.1	506.5	538.6	23.7	44.1	OK
	W21x132	7	0.58	4.62	2.89	75.2	11.0	217.1	228.1	9.3	48.8	OK
		8	1.15	4.62	3.46	79.0	14.4	273.5	287.9	11.7	47.9	OK
		9	1.73	4.62	4.04	81.9	18.2	330.9	349.1	14.2	46.9	OK
		10	2.31	4.62	4.62	84.2	22.5	389.0	411.5	16.7	46.0	OK
		11	2.89	4.62	5.20	86.1	27.2	447.6	474.8	19.3	45.1	OK
		12	3.46	4.62	5.77	87.7	32.4	506.5	538.9	21.9	44.1	OK

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 45°

		Skew	45									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W21	W21x55	7	0.71	5.66	3.54	75.2	15.4	265.9	281.2	30.7	42.6	OK
		8	1.41	5.66	4.24	79.0	20.1	335.0	355.0	38.7	40.8	OK
		9	2.12	5.66	4.95	81.9	25.4	405.3	430.7	47.0	38.9	NO GOOD
		10	2.83	5.66	5.66	84.2	31.4	476.4	507.8	55.4	37.1	NO GOOD
		11	3.54	5.66	6.36	86.1	37.9	548.1	586.1	63.9	35.3	NO GOOD
		12	4.24	5.66	7.07	87.7	45.2	620.3	665.5	72.6	30.2	NO GOOD
	W21x62	7	0.71	5.66	3.54	75.2	15.5	265.9	281.3	26.6	42.8	OK
		8	1.41	5.66	4.24	79.0	20.2	335.0	355.2	33.6	41.0	OK
		9	2.12	5.66	4.95	81.9	25.6	405.3	430.9	40.7	39.1	NO GOOD
		10	2.83	5.66	5.66	84.2	31.6	476.4	508.0	48.0	37.3	NO GOOD
		11	3.54	5.66	6.36	86.1	38.2	548.1	586.3	55.4	35.5	NO GOOD
		12	4.24	5.66	7.07	87.7	45.5	620.3	665.8	62.9	31.0	NO GOOD
	W21x68	7	0.71	5.66	3.54	75.2	15.6	265.9	281.4	24.1	42.9	OK
		8	1.41	5.66	4.24	79.0	20.3	335.0	355.3	30.5	41.1	OK
		9	2.12	5.66	4.95	81.9	25.7	405.3	431.0	36.9	39.3	OK
		10	2.83	5.66	5.66	84.2	31.8	476.4	508.2	43.6	37.5	NO GOOD
		11	3.54	5.66	6.36	86.1	38.4	548.1	586.6	50.3	35.7	NO GOOD
		12	4.24	5.66	7.07	87.7	45.7	620.3	666.1	57.1	31.5	NO GOOD
	W21x73	7	0.71	5.66	3.54	75.2	15.6	265.9	281.5	22.4	42.9	OK
		8	1.41	5.66	4.24	79.0	20.4	335.0	355.4	28.2	41.2	OK
		9	2.12	5.66	4.95	81.9	25.9	405.3	431.1	34.3	39.4	OK
		10	2.83	5.66	5.66	84.2	31.9	476.4	508.3	40.4	37.6	NO GOOD
		11	3.54	5.66	6.36	86.1	38.6	548.1	586.8	46.6	35.8	NO GOOD
		12	4.24	5.66	7.07	87.7	46.0	620.3	666.3	53.0	31.9	NO GOOD
	W21x83	7	0.71	5.66	3.54	75.2	15.8	265.9	281.6	19.8	43.0	OK
		8	1.41	5.66	4.24	79.0	20.6	335.0	355.6	25.0	41.3	OK
		9	2.12	5.66	4.95	81.9	26.1	405.3	431.4	30.3	39.5	OK
		10	2.83	5.66	5.66	84.2	32.2	476.4	508.6	35.7	37.7	OK
		11	3.54	5.66	6.36	86.1	39.0	548.1	587.1	41.2	36.0	NO GOOD
		12	4.24	5.66	7.07	87.7	46.4	620.3	666.7	46.8	32.3	NO GOOD
	W21x93	7	0.71	5.66	3.54	75.2	15.9	265.9	281.8	17.6	43.1	OK
		8	1.41	5.66	4.24	79.0	20.8	335.0	355.8	22.2	41.4	OK
		9	2.12	5.66	4.95	81.9	26.4	405.3	431.6	27.0	39.6	OK
		10	2.83	5.66	5.66	84.2	32.5	476.4	509.0	31.8	37.8	OK
		11	3.54	5.66	6.36	86.1	39.4	548.1	587.5	36.7	36.1	NO GOOD
		12	4.24	5.66	7.07	87.7	46.9	620.3	667.2	41.7	32.8	NO GOOD
	W21x101	7	0.71	5.66	3.54	75.2	16.1	265.9	281.9	14.9	47.3	OK
		8	1.41	5.66	4.24	79.0	21.0	335.0	356.0	18.8	46.1	OK
		9	2.12	5.66	4.95	81.9	26.6	405.3	431.8	22.8	44.9	OK
		10	2.83	5.66	5.66	84.2	32.8	476.4	509.2	26.9	43.8	OK
		11	3.54	5.66	6.36	86.1	39.7	548.1	587.8	31.1	42.6	OK
		12	4.24	5.66	7.07	87.7	47.2	620.3	667.5	35.3	41.4	OK
	W21x111	7	0.71	5.66	3.54	75.2	16.2	265.9	282.1	13.6	47.3	OK
		8	1.41	5.66	4.24	79.0	21.2	335.0	356.2	17.2	46.1	OK
		9	2.12	5.66	4.95	81.9	26.8	405.3	432.1	20.8	44.9	OK
		10	2.83	5.66	5.66	84.2	33.1	476.4	509.5	24.6	43.8	OK
		11	3.54	5.66	6.36	86.1	40.1	548.1	588.2	28.3	42.6	OK
		12	4.24	5.66	7.07	87.7	47.7	620.3	668.0	32.2	41.4	OK
	W21x122	7	0.71	5.66	3.54	75.2	16.4	265.9	282.2	12.4	47.3	OK
		8	1.41	5.66	4.24	79.0	21.4	335.0	356.4	15.7	46.2	OK
		9	2.12	5.66	4.95	81.9	27.1	405.3	432.4	19.0	45.0	OK
		10	2.83	5.66	5.66	84.2	33.4	476.4	509.9	22.4	43.9	OK
		11	3.54	5.66	6.36	86.1	40.5	548.1	588.6	25.9	42.7	OK
		12	4.24	5.66	7.07	87.7	48.2	620.3	668.5	29.4	41.6	OK
	W21x132	7	0.71	5.66	3.54	75.2	16.5	265.9	282.4	11.5	47.3	OK
		8	1.41	5.66	4.24	79.0	21.6	335.0	356.6	14.5	46.2	OK
		9	2.12	5.66	4.95	81.9	27.3	405.3	432.6	17.6	45.0	OK
		10	2.83	5.66	5.66	84.2	33.8	476.4	510.2	20.8	43.9	OK
		11	3.54	5.66	6.36	86.1	40.9	548.1	589.0	24.0	42.7	OK
		12	4.24	5.66	7.07	87.7	48.6	620.3	668.9	27.2	41.6	OK

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 50°

		Skew	50°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W21	W21x55	7	0.78	6.22	3.89	75.2	18.6	292.5	311.0	33.9	41.3	OK
		8	1.56	6.22	4.67	79.0	24.3	368.5	392.8	42.8	39.3	NO GOOD
		9	2.33	6.22	5.45	81.9	30.7	445.8	476.6	52.0	37.3	NO GOOD
		10	3.11	6.22	6.22	84.2	37.9	524.1	562.0	61.3	35.3	NO GOOD
		11	3.89	6.22	7.00	86.1	45.9	603.0	648.9	70.8	29.7	NO GOOD
		12	4.67	6.22	7.78	87.7	54.6	682.4	737.0	80.4	24.9	NO GOOD
	W21x62	7	0.78	6.22	3.89	75.2	18.7	292.5	311.2	29.4	41.5	OK
		8	1.56	6.22	4.67	79.0	24.5	368.5	392.9	37.1	39.5	OK
		9	2.33	6.22	5.45	81.9	30.9	445.8	476.8	45.1	37.5	NO GOOD
		10	3.11	6.22	6.22	84.2	38.2	524.1	562.3	53.1	35.5	NO GOOD
		11	3.89	6.22	7.00	86.1	46.2	603.0	649.2	61.3	30.5	NO GOOD
		12	4.67	6.22	7.78	87.7	55.0	682.4	737.4	69.7	25.6	NO GOOD
	W21x68	7	0.78	6.22	3.89	75.2	18.8	292.5	311.3	26.7	41.6	OK
		8	1.56	6.22	4.67	79.0	24.6	368.5	393.1	33.7	39.6	OK
		9	2.33	6.22	5.45	81.9	31.1	445.8	477.0	40.9	37.7	NO GOOD
		10	3.11	6.22	6.22	84.2	38.4	524.1	562.5	48.2	35.7	NO GOOD
		11	3.89	6.22	7.00	86.1	46.5	603.0	649.5	55.7	31.0	NO GOOD
		12	4.67	6.22	7.78	87.7	55.3	682.4	737.7	63.2	26.0	NO GOOD
	W21x73	7	0.78	6.22	3.89	75.2	18.9	292.5	311.4	24.7	41.7	OK
		8	1.56	6.22	4.67	79.0	24.7	368.5	393.2	31.2	39.7	OK
		9	2.33	6.22	5.45	81.9	31.3	445.8	477.1	37.9	37.8	NO GOOD
		10	3.11	6.22	6.22	84.2	38.6	524.1	562.7	44.7	35.8	NO GOOD
		11	3.89	6.22	7.00	86.1	46.7	603.0	649.7	51.6	31.3	NO GOOD
		12	4.67	6.22	7.78	87.7	55.6	682.4	738.0	58.7	26.3	NO GOOD
	W21x83	7	0.78	6.22	3.89	75.2	19.1	292.5	311.6	21.9	41.8	OK
		8	1.56	6.22	4.67	79.0	25.0	368.5	393.5	27.6	39.8	OK
		9	2.33	6.22	5.45	81.9	31.6	445.8	477.4	33.5	37.9	OK
		10	3.11	6.22	6.22	84.2	39.0	524.1	563.1	39.5	35.9	NO GOOD
		11	3.89	6.22	7.00	86.1	47.2	603.0	650.2	45.6	31.8	NO GOOD
		12	4.67	6.22	7.78	87.7	56.2	682.4	738.6	51.8	26.7	NO GOOD
	W21x93	7	0.78	6.22	3.89	75.2	19.3	292.5	311.8	19.5	41.9	OK
		8	1.56	6.22	4.67	79.0	25.2	368.5	393.7	24.6	40.0	OK
		9	2.33	6.22	5.45	81.9	31.9	445.8	477.7	29.9	38.0	OK
		10	3.11	6.22	6.22	84.2	39.4	524.1	563.5	35.2	36.1	OK
		11	3.89	6.22	7.00	86.1	47.6	603.0	650.6	40.7	32.2	NO GOOD
		12	4.67	6.22	7.78	87.7	56.7	682.4	739.1	46.2	27.1	NO GOOD
	W21x101	7	0.78	6.22	3.89	75.2	19.4	292.5	311.9	16.5	46.5	OK
		8	1.56	6.22	4.67	79.0	25.4	368.5	393.9	20.8	45.2	OK
		9	2.33	6.22	5.45	81.9	32.1	445.8	478.0	25.3	43.9	OK
		10	3.11	6.22	6.22	84.2	39.7	524.1	563.8	29.8	42.6	OK
		11	3.89	6.22	7.00	86.1	48.0	603.0	651.0	34.4	41.3	OK
		12	4.67	6.22	7.78	87.7	57.1	682.4	739.5	39.1	40.0	OK
	W21x111	7	0.78	6.22	3.89	75.2	19.6	292.5	312.1	15.0	46.5	OK
		8	1.56	6.22	4.67	79.0	25.6	368.5	394.1	19.0	45.2	OK
		9	2.33	6.22	5.45	81.9	32.4	445.8	478.3	23.0	43.9	OK
		10	3.11	6.22	6.22	84.2	40.1	524.1	564.1	27.2	42.6	OK
		11	3.89	6.22	7.00	86.1	48.5	603.0	651.5	31.4	41.3	OK
		12	4.67	6.22	7.78	87.7	57.7	682.4	740.1	35.7	40.0	OK
	W21x122	7	0.78	6.22	3.89	75.2	19.8	292.5	312.3	13.7	46.5	OK
		8	1.56	6.22	4.67	79.0	25.9	368.5	394.4	17.3	45.3	OK
		9	2.33	6.22	5.45	81.9	32.8	445.8	478.6	21.0	44.0	OK
		10	3.11	6.22	6.22	84.2	40.5	524.1	564.6	24.8	42.7	OK
		11	3.89	6.22	7.00	86.1	49.0	603.0	652.0	28.7	41.4	OK
		12	4.67	6.22	7.78	87.7	58.3	682.4	740.7	32.6	40.2	OK
	W21x132	7	0.78	6.22	3.89	75.2	20.0	292.5	312.5	12.7	46.5	OK
		8	1.56	6.22	4.67	79.0	26.1	368.5	394.6	16.1	45.3	OK
		9	2.33	6.22	5.45	81.9	33.1	445.8	478.9	19.5	44.0	OK
		10	3.11	6.22	6.22	84.2	40.9	524.1	564.9	23.0	42.7	OK
		11	3.89	6.22	7.00	86.1	49.4	603.0	652.4	26.5	41.4	OK
		12	4.67	6.22	7.78	87.7	58.8	682.4	741.2	30.2	40.2	OK

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 55°

		Skew	55°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W21	W21x55	7	0.87	6.97	4.36	75.2	23.3	327.7	351.1	38.3	39.6	OK
		8	1.74	6.97	5.23	79.0	30.5	413.0	443.5	48.4	37.3	NO GOOD
		9	2.62	6.97	6.10	81.9	38.6	499.6	538.2	58.7	35.1	NO GOOD
		10	3.49	6.97	6.97	84.2	47.7	587.3	635.0	69.3	28.6	NO GOOD
		11	4.36	6.97	7.85	86.1	57.7	675.8	733.4	80.0	23.6	NO GOOD
		12	5.23	6.97	8.72	87.7	68.6	764.7	833.4	90.9	19.9	NO GOOD
	W21x62	7	0.87	6.97	4.36	75.2	23.5	327.7	351.3	33.2	39.8	OK
		8	1.74	6.97	5.23	79.0	30.7	413.0	443.7	41.9	37.6	NO GOOD
		9	2.62	6.97	6.10	81.9	38.9	499.6	538.5	50.9	35.4	NO GOOD
		10	3.49	6.97	6.97	84.2	48.0	587.3	635.3	60.0	29.4	NO GOOD
		11	4.36	6.97	7.85	86.1	58.1	675.8	733.8	69.3	24.3	NO GOOD
		12	5.23	6.97	8.72	87.7	69.1	764.7	833.8	78.8	20.4	NO GOOD
	W21x68	7	0.87	6.97	4.36	75.2	23.7	327.7	351.4	30.1	39.9	OK
		8	1.74	6.97	5.23	79.0	30.9	413.0	443.9	38.0	37.7	NO GOOD
		9	2.62	6.97	6.10	81.9	39.1	499.6	538.7	46.2	35.5	NO GOOD
		10	3.49	6.97	6.97	84.2	48.3	587.3	635.6	54.5	29.8	NO GOOD
		11	4.36	6.97	7.85	86.1	58.4	675.8	734.2	62.9	24.6	NO GOOD
		12	5.23	6.97	8.72	87.7	69.5	764.7	834.3	71.5	20.7	NO GOOD
	W21x73	7	0.87	6.97	4.36	75.2	23.8	327.7	351.5	27.9	40.0	OK
		8	1.74	6.97	5.23	79.0	31.0	413.0	444.0	35.3	37.8	OK
		9	2.62	6.97	6.10	81.9	39.3	499.6	538.9	42.8	35.6	NO GOOD
		10	3.49	6.97	6.97	84.2	48.5	587.3	635.8	50.5	30.2	NO GOOD
		11	4.36	6.97	7.85	86.1	58.7	675.8	734.4	58.4	24.9	NO GOOD
		12	5.23	6.97	8.72	87.7	69.9	764.7	834.6	66.3	21.0	NO GOOD
	W21x83	7	0.87	6.97	4.36	75.2	24.0	327.7	351.7	24.7	40.2	OK
		8	1.74	6.97	5.23	79.0	31.3	413.0	444.3	31.2	38.0	OK
		9	2.62	6.97	6.10	81.9	39.7	499.6	539.3	37.8	35.8	NO GOOD
		10	3.49	6.97	6.97	84.2	49.0	587.3	636.3	44.7	30.6	NO GOOD
		11	4.36	6.97	7.85	86.1	59.3	675.8	735.0	51.6	25.3	NO GOOD
		12	5.23	6.97	8.72	87.7	70.5	764.7	835.3	58.6	21.3	NO GOOD
	W21x93	7	0.87	6.97	4.36	75.2	24.2	327.7	352.0	22.0	40.3	OK
		8	1.74	6.97	5.23	79.0	31.7	413.0	444.6	27.8	38.1	OK
		9	2.62	6.97	6.10	81.9	40.1	499.6	539.7	33.7	35.9	OK
		10	3.49	6.97	6.97	84.2	49.5	587.3	636.8	39.8	31.1	NO GOOD
		11	4.36	6.97	7.85	86.1	59.8	675.8	735.6	46.0	25.7	NO GOOD
		12	5.23	6.97	8.72	87.7	71.2	764.7	836.0	52.2	21.6	NO GOOD
	W21x101	7	0.87	6.97	4.36	75.2	24.4	327.7	352.2	18.6	45.4	OK
		8	1.74	6.97	5.23	79.0	31.9	413.0	444.9	23.5	43.9	OK
		9	2.62	6.97	6.10	81.9	40.4	499.6	540.0	28.5	42.5	OK
		10	3.49	6.97	6.97	84.2	49.8	587.3	637.2	33.7	41.0	OK
		11	4.36	6.97	7.85	86.1	60.3	675.8	736.1	38.9	39.6	OK
		12	5.23	6.97	8.72	87.7	71.8	764.7	836.5	44.2	38.2	NO GOOD
	W21x111	7	0.87	6.97	4.36	75.2	24.7	327.7	352.4	17.0	45.4	OK
		8	1.74	6.97	5.23	79.0	32.2	413.0	445.2	21.5	43.9	OK
		9	2.62	6.97	6.10	81.9	40.8	499.6	540.4	26.0	42.5	OK
		10	3.49	6.97	6.97	84.2	50.3	587.3	637.6	30.7	41.0	OK
		11	4.36	6.97	7.85	86.1	60.9	675.8	736.6	35.5	39.6	OK
		12	5.23	6.97	8.72	87.7	72.4	764.7	837.2	40.3	38.2	NO GOOD
	W21x122	7	0.87	6.97	4.36	75.2	24.9	327.7	352.7	15.5	45.5	OK
		8	1.74	6.97	5.23	79.0	32.5	413.0	445.5	19.6	44.0	OK
		9	2.62	6.97	6.10	81.9	41.2	499.6	540.8	23.8	42.6	OK
		10	3.49	6.97	6.97	84.2	50.8	587.3	638.2	28.1	41.2	OK
		11	4.36	6.97	7.85	86.1	61.5	675.8	737.3	32.4	39.7	OK
		12	5.23	6.97	8.72	87.7	73.2	764.7	837.9	36.8	38.3	OK
	W21x132	7	0.87	6.97	4.36	75.2	25.1	327.7	352.9	14.4	45.5	OK
		8	1.74	6.97	5.23	79.0	32.8	413.0	445.8	18.1	44.0	OK
		9	2.62	6.97	6.10	81.9	41.6	499.6	541.2	22.0	42.6	OK
		10	3.49	6.97	6.97	84.2	51.3	587.3	638.6	26.0	41.2	OK
		11	4.36	6.97	7.85	86.1	62.1	675.8	737.8	30.0	39.8	OK
		12	5.23	6.97	8.72	87.7	73.9	764.7	838.6	34.1	38.3	OK

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 60°

		Skew	60°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W21	W21x55	7	1.00	8.00	5.00	75.2	30.7	376.0	406.7	44.4	37.3	NO GOOD
		8	2.00	8.00	6.00	79.0	40.1	473.7	513.9	56.1	33.9	NO GOOD
		9	3.00	8.00	7.00	81.9	50.8	573.2	623.9	68.1	26.8	NO GOOD
		10	4.00	8.00	8.00	84.2	62.7	673.8	736.5	80.3	21.7	NO GOOD
		11	5.00	8.00	9.00	86.1	75.9	775.2	851.1	92.8	18.0	NO GOOD
		12	6.00	8.00	10.00	87.7	90.3	877.3	967.6	105.6	15.1	NO GOOD
	W21x62	7	1.00	8.00	5.00	75.2	30.9	376.0	406.9	38.4	37.5	NO GOOD
		8	2.00	8.00	6.00	79.0	40.4	473.7	514.1	48.6	34.9	NO GOOD
		9	3.00	8.00	7.00	81.9	51.1	573.2	624.3	59.0	27.5	NO GOOD
		10	4.00	8.00	8.00	84.2	63.1	673.8	736.9	69.6	22.3	NO GOOD
		11	5.00	8.00	9.00	86.1	76.4	775.2	851.6	80.5	18.4	NO GOOD
		12	6.00	8.00	10.00	87.7	90.9	877.3	968.2	91.5	15.5	NO GOOD
	W21x68	7	1.00	8.00	5.00	75.2	31.1	376.0	407.1	34.9	37.7	OK
		8	2.00	8.00	6.00	79.0	40.7	473.7	514.4	44.1	35.1	NO GOOD
		9	3.00	8.00	7.00	81.9	51.5	573.2	624.6	53.5	28.0	NO GOOD
		10	4.00	8.00	8.00	84.2	63.5	673.8	737.3	63.2	22.7	NO GOOD
		11	5.00	8.00	9.00	86.1	76.9	775.2	852.1	73.0	18.7	NO GOOD
		12	6.00	8.00	10.00	87.7	91.5	877.3	968.7	83.0	15.7	NO GOOD
	W21x73	7	1.00	8.00	5.00	75.2	31.3	376.0	407.3	32.4	37.8	OK
		8	2.00	8.00	6.00	79.0	40.9	473.7	514.6	40.9	35.2	NO GOOD
		9	3.00	8.00	7.00	81.9	51.7	573.2	624.9	49.7	28.3	NO GOOD
		10	4.00	8.00	8.00	84.2	63.8	673.8	737.6	58.6	22.9	NO GOOD
		11	5.00	8.00	9.00	86.1	77.2	775.2	852.4	67.7	19.0	NO GOOD
		12	6.00	8.00	10.00	87.7	91.9	877.3	969.2	77.0	15.9	NO GOOD
	W21x83	7	1.00	8.00	5.00	75.2	31.6	376.0	407.6	28.6	37.9	OK
		8	2.00	8.00	6.00	79.0	41.3	473.7	515.0	36.1	35.4	NO GOOD
		9	3.00	8.00	7.00	81.9	52.2	573.2	625.4	43.9	28.8	NO GOOD
		10	4.00	8.00	8.00	84.2	64.5	673.8	738.2	51.8	23.3	NO GOOD
		11	5.00	8.00	9.00	86.1	78.0	775.2	853.2	59.9	19.2	NO GOOD
		12	6.00	8.00	10.00	87.7	92.8	877.3	970.1	68.1	16.2	NO GOOD
	W21x93	7	1.00	8.00	5.00	75.2	31.9	376.0	407.9	25.5	38.0	OK
		8	2.00	8.00	6.00	79.0	41.7	473.7	515.4	32.2	35.5	OK
		9	3.00	8.00	7.00	81.9	52.7	573.2	625.9	39.1	29.1	NO GOOD
		10	4.00	8.00	8.00	84.2	65.1	673.8	738.8	46.2	23.6	NO GOOD
		11	5.00	8.00	9.00	86.1	78.8	775.2	853.9	53.4	19.5	NO GOOD
		12	6.00	8.00	10.00	87.7	93.7	877.3	971.0	60.7	16.4	NO GOOD
	W21x101	7	1.00	8.00	5.00	75.2	32.1	376.0	408.1	21.6	43.9	OK
		8	2.00	8.00	6.00	79.0	42.0	473.7	515.7	27.3	42.2	OK
		9	3.00	8.00	7.00	81.9	53.1	573.2	626.3	33.1	40.6	OK
		10	4.00	8.00	8.00	84.2	65.6	673.8	739.3	39.1	38.9	NO GOOD
		11	5.00	8.00	9.00	86.1	79.4	775.2	854.6	45.2	37.3	NO GOOD
		12	6.00	8.00	10.00	87.7	94.4	877.3	971.7	51.4	35.6	NO GOOD
	W21x111	7	1.00	8.00	5.00	75.2	32.4	376.0	408.4	19.7	43.9	OK
		8	2.00	8.00	6.00	79.0	42.4	473.7	516.1	24.9	42.2	OK
		9	3.00	8.00	7.00	81.9	53.6	573.2	626.8	30.2	40.6	OK
		10	4.00	8.00	8.00	84.2	66.2	673.8	740.0	35.7	38.9	OK
		11	5.00	8.00	9.00	86.1	80.1	775.2	855.3	41.2	37.3	NO GOOD
		12	6.00	8.00	10.00	87.7	95.3	877.3	972.6	46.9	35.6	NO GOOD
	W21x122	7	1.00	8.00	5.00	75.2	32.8	376.0	408.8	18.0	44.0	OK
		8	2.00	8.00	6.00	79.0	42.8	473.7	516.5	22.7	42.3	OK
		9	3.00	8.00	7.00	81.9	54.2	573.2	627.3	27.6	40.7	OK
		10	4.00	8.00	8.00	84.2	66.9	673.8	740.6	32.6	39.1	OK
		11	5.00	8.00	9.00	86.1	80.9	775.2	856.1	37.6	37.4	NO GOOD
		12	6.00	8.00	10.00	87.7	96.3	877.3	973.6	42.8	35.8	NO GOOD
	W21x132	7	1.00	8.00	5.00	75.2	33.1	376.0	409.1	16.6	44.0	OK
		8	2.00	8.00	6.00	79.0	43.2	473.7	516.9	21.0	42.4	OK
		9	3.00	8.00	7.00	81.9	54.7	573.2	627.8	25.5	40.7	OK
		10	4.00	8.00	8.00	84.2	67.5	673.8	741.3	30.2	39.1	OK
		11	5.00	8.00	9.00	86.1	81.7	775.2	856.9	34.9	37.4	OK
		12	6.00	8.00	10.00	87.7	97.2	877.3	974.5	39.6	35.8	NO GOOD

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 0°

		Skew	0°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W24	W24x55	7	0.50	4.00	2.50	75.2	7.7	188.0	195.7	20.6	44.3	OK
		8	1.00	4.00	3.00	79.0	10.0	236.9	246.9	26.0	42.7	OK
		9	1.50	4.00	3.50	81.9	12.7	286.6	299.3	31.5	41.1	OK
		10	2.00	4.00	4.00	84.2	15.7	336.9	352.6	37.1	39.5	OK
		11	2.50	4.00	4.50	86.1	19.0	387.6	406.6	42.8	37.9	NO GOOD
		12	3.00	4.00	5.00	87.7	22.6	438.6	461.2	48.5	36.3	NO GOOD
	W24x62	7	0.50	4.00	2.50	75.2	7.7	188.0	195.7	17.9	44.4	OK
		8	1.00	4.00	3.00	79.0	10.1	236.9	247.0	22.6	42.9	OK
		9	1.50	4.00	3.50	81.9	12.8	286.6	299.4	27.4	41.3	OK
		10	2.00	4.00	4.00	84.2	15.8	336.9	352.7	32.3	39.7	OK
		11	2.50	4.00	4.50	86.1	19.1	387.6	406.7	37.3	38.1	OK
		12	3.00	4.00	5.00	87.7	22.7	438.6	461.4	42.3	36.6	NO GOOD
	W24x68	7	0.50	4.00	2.50	75.2	7.8	188.0	195.8	15.3	47.1	OK
		8	1.00	4.00	3.00	79.0	10.2	236.9	247.0	19.2	45.9	OK
		9	1.50	4.00	3.50	81.9	12.9	286.6	299.4	23.3	44.7	OK
		10	2.00	4.00	4.00	84.2	15.9	336.9	352.8	27.5	43.5	OK
		11	2.50	4.00	4.50	86.1	19.2	387.6	406.8	31.7	42.3	OK
		12	3.00	4.00	5.00	87.7	22.9	438.6	461.5	36.0	41.1	OK
	W24x76	7	0.50	4.00	2.50	75.2	7.8	188.0	195.8	13.4	47.2	OK
		8	1.00	4.00	3.00	79.0	10.2	236.9	247.1	16.8	46.0	OK
		9	1.50	4.00	3.50	81.9	13.0	286.6	299.5	20.4	44.8	OK
		10	2.00	4.00	4.00	84.2	16.0	336.9	352.9	24.1	43.7	OK
		11	2.50	4.00	4.50	86.1	19.4	387.6	407.0	27.7	42.5	OK
		12	3.00	4.00	5.00	87.7	23.0	438.6	461.7	31.5	41.3	OK
	W24x84	7	0.50	4.00	2.50	75.2	7.9	188.0	195.9	12.0	47.3	OK
		8	1.00	4.00	3.00	79.0	10.3	236.9	247.2	15.1	46.1	OK
		9	1.50	4.00	3.50	81.9	13.1	286.6	299.6	18.3	44.9	OK
		10	2.00	4.00	4.00	84.2	16.1	336.9	353.0	21.6	43.8	OK
		11	2.50	4.00	4.50	86.1	19.5	387.6	407.1	24.9	42.6	OK
		12	3.00	4.00	5.00	87.7	23.2	438.6	461.9	28.3	41.4	OK
	W24x94	7	0.50	4.00	2.50	75.2	8.0	188.0	196.0	10.6	47.4	OK
		8	1.00	4.00	3.00	79.0	10.4	236.9	247.3	13.4	46.2	OK
		9	1.50	4.00	3.50	81.9	13.2	286.6	299.8	16.2	45.0	OK
		10	2.00	4.00	4.00	84.2	16.3	336.9	353.2	19.1	43.9	OK
		11	2.50	4.00	4.50	86.1	19.7	387.6	407.3	22.0	42.7	OK
		12	3.00	4.00	5.00	87.7	23.5	438.6	462.1	25.0	41.6	OK
	W24x103	7	0.50	4.00	2.50	75.2	8.0	188.0	196.0	9.6	47.3	OK
		8	1.00	4.00	3.00	79.0	10.5	236.9	247.4	12.1	46.2	OK
		9	1.50	4.00	3.50	81.9	13.3	286.6	299.9	14.7	45.0	OK
		10	2.00	4.00	4.00	84.2	16.4	336.9	353.3	17.3	43.8	OK
		11	2.50	4.00	4.50	86.1	19.9	387.6	407.5	20.0	42.7	OK
		12	3.00	4.00	5.00	87.7	23.7	438.6	462.3	22.6	41.5	OK
	W24x104	7	0.50	4.00	2.50	75.2	8.1	188.0	196.0	9.1	49.8	OK
		8	1.00	4.00	3.00	79.0	10.5	236.9	247.4	11.5	49.0	OK
		9	1.50	4.00	3.50	81.9	13.3	286.6	299.9	13.9	48.2	OK
		10	2.00	4.00	4.00	84.2	16.4	336.9	353.3	16.4	47.4	OK
		11	2.50	4.00	4.50	86.1	19.9	387.6	407.5	19.0	46.6	OK
		12	3.00	4.00	5.00	87.7	23.7	438.6	462.3	21.5	45.8	OK
	W24x117	7	0.50	4.00	2.50	75.2	8.2	188.0	196.1	8.1	49.8	OK
		8	1.00	4.00	3.00	79.0	10.7	236.9	247.5	10.2	49.0	OK
		9	1.50	4.00	3.50	81.9	13.5	286.6	300.1	12.4	48.2	OK
		10	2.00	4.00	4.00	84.2	16.6	336.9	353.5	14.6	47.4	OK
		11	2.50	4.00	4.50	86.1	20.1	387.6	407.7	16.8	46.6	OK
		12	3.00	4.00	5.00	87.7	24.0	438.6	462.6	19.1	45.8	OK
	W24x131	7	0.50	4.00	2.50	75.2	8.3	188.0	196.3	7.2	49.9	OK
		8	1.00	4.00	3.00	79.0	10.8	236.9	247.7	9.0	49.1	OK
		9	1.50	4.00	3.50	81.9	13.7	286.6	300.2	11.0	48.3	OK
		10	2.00	4.00	4.00	84.2	16.9	336.9	353.7	12.9	47.5	OK
		11	2.50	4.00	4.50	86.1	20.4	387.6	408.0	14.9	46.7	OK
		12	3.00	4.00	5.00	87.7	24.3	438.6	462.9	16.9	45.9	OK
	W24x146	7	0.50	4.00	2.50	75.2	8.4	188.0	196.4	6.4	49.9	OK
		8	1.00	4.00	3.00	79.0	10.9	236.9	247.8	8.0	49.1	OK
		9	1.50	4.00	3.50	81.9	13.9	286.6	300.4	9.7	48.3	OK
		10	2.00	4.00	4.00	84.2	17.1	336.9	354.0	11.4	47.6	OK
		11	2.50	4.00	4.50	86.1	20.7	387.6	408.3	13.2	46.8	OK
		12	3.00	4.00	5.00	87.7	24.6	438.6	463.3	15.0	46.0	OK

HDR

Project:	MoDOT Finger/Flat Plate Eval	Computed:	MTW	Date:	11/4/2015
Subject:	New Finger Plate Design	Checked:	DGB	Date:	12/3/2015
Task:	Support Beam Design	Page:	28	of:	SUPPORT
Job #:	244663	No:			

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 15°

		Skew	15°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W24	W24x55	7	0.52	4.14	2.59	75.2	8.2	194.6	202.9	21.4	43.9	OK
		8	1.04	4.14	3.11	79.0	10.8	245.2	256.0	26.9	42.2	OK
		9	1.55	4.14	3.62	81.9	13.6	296.7	310.3	32.7	40.6	OK
		10	2.07	4.14	4.14	84.2	16.8	348.8	365.6	38.5	38.9	OK
		11	2.59	4.14	4.66	86.1	20.3	401.3	421.6	44.4	37.3	NO GOOD
		12	3.11	4.14	5.18	87.7	24.2	454.1	478.3	50.3	35.6	NO GOOD
	W24x62	7	0.52	4.14	2.59	75.2	8.3	194.6	202.9	18.6	44.0	OK
		8	1.04	4.14	3.11	79.0	10.8	245.2	256.0	23.5	42.4	OK
		9	1.55	4.14	3.62	81.9	13.7	296.7	310.4	28.4	40.8	OK
		10	2.07	4.14	4.14	84.2	16.9	348.8	365.7	33.5	39.2	OK
		11	2.59	4.14	4.66	86.1	20.5	401.3	421.7	38.6	37.5	NO GOOD
		12	3.11	4.14	5.18	87.7	24.4	454.1	478.5	43.8	35.9	NO GOOD
	W24x68	7	0.52	4.14	2.59	75.2	8.3	194.6	203.0	15.8	46.8	OK
		8	1.04	4.14	3.11	79.0	10.9	245.2	256.1	20.0	45.6	OK
		9	1.55	4.14	3.62	81.9	13.8	296.7	310.5	24.2	44.3	OK
		10	2.07	4.14	4.14	84.2	17.0	348.8	365.8	28.5	43.1	OK
		11	2.59	4.14	4.66	86.1	20.6	401.3	421.9	32.9	41.9	OK
		12	3.11	4.14	5.18	87.7	24.5	454.1	478.6	37.3	40.6	OK
	W24x76	7	0.52	4.14	2.59	75.2	8.4	194.6	203.0	13.8	46.9	OK
		8	1.04	4.14	3.11	79.0	11.0	245.2	256.2	17.5	45.7	OK
		9	1.55	4.14	3.62	81.9	13.9	296.7	310.6	21.2	44.5	OK
		10	2.07	4.14	4.14	84.2	17.2	348.8	365.9	24.9	43.2	OK
		11	2.59	4.14	4.66	86.1	20.8	401.3	422.0	28.8	42.0	OK
		12	3.11	4.14	5.18	87.7	24.7	454.1	478.8	32.6	40.8	OK
	W24x84	7	0.52	4.14	2.59	75.2	8.5	194.6	203.1	12.4	47.0	OK
		8	1.04	4.14	3.11	79.0	11.1	245.2	256.3	15.7	45.8	OK
		9	1.55	4.14	3.62	81.9	14.0	296.7	310.7	19.0	44.6	OK
		10	2.07	4.14	4.14	84.2	17.3	348.8	366.0	22.4	43.4	OK
		11	2.59	4.14	4.66	86.1	20.9	401.3	422.2	25.8	42.2	OK
		12	3.11	4.14	5.18	87.7	24.9	454.1	479.0	29.3	40.9	OK
	W24x94	7	0.52	4.14	2.59	75.2	8.6	194.6	203.2	11.0	47.1	OK
		8	1.04	4.14	3.11	79.0	11.2	245.2	256.4	13.9	45.9	OK
		9	1.55	4.14	3.62	81.9	14.1	296.7	310.8	16.8	44.7	OK
		10	2.07	4.14	4.14	84.2	17.5	348.8	366.2	19.8	43.5	OK
		11	2.59	4.14	4.66	86.1	21.1	401.3	422.4	22.8	42.3	OK
		12	3.11	4.14	5.18	87.7	25.1	454.1	479.2	25.9	41.1	OK
	W24x103	7	0.52	4.14	2.59	75.2	8.6	194.6	203.2	10.0	47.0	OK
		8	1.04	4.14	3.11	79.0	11.3	245.2	256.5	12.6	45.8	OK
		9	1.55	4.14	3.62	81.9	14.3	296.7	310.9	15.2	44.6	OK
		10	2.07	4.14	4.14	84.2	17.6	348.8	366.4	17.9	43.4	OK
		11	2.59	4.14	4.66	86.1	21.3	401.3	422.6	20.7	42.2	OK
		12	3.11	4.14	5.18	87.7	25.4	454.1	479.5	23.5	41.0	OK
	W24x104	7	0.52	4.14	2.59	75.2	8.6	194.6	203.3	9.5	49.6	OK
		8	1.04	4.14	3.11	79.0	11.3	245.2	256.5	11.9	48.8	OK
		9	1.55	4.14	3.62	81.9	14.3	296.7	311.0	14.5	48.0	OK
		10	2.07	4.14	4.14	84.2	17.6	348.8	366.4	17.0	47.1	OK
		11	2.59	4.14	4.66	86.1	21.3	401.3	422.6	19.7	46.3	OK
		12	3.11	4.14	5.18	87.7	25.4	454.1	479.5	22.3	45.5	OK
	W24x117	7	0.52	4.14	2.59	75.2	8.7	194.6	203.4	8.4	49.6	OK
		8	1.04	4.14	3.11	79.0	11.4	245.2	256.6	10.6	48.8	OK
		9	1.55	4.14	3.62	81.9	14.5	296.7	311.1	12.8	48.0	OK
		10	2.07	4.14	4.14	84.2	17.8	348.8	366.6	15.1	47.2	OK
		11	2.59	4.14	4.66	86.1	21.6	401.3	422.9	17.4	46.3	OK
		12	3.11	4.14	5.18	87.7	25.7	454.1	479.8	19.8	45.5	OK
	W24x131	7	0.52	4.14	2.59	75.2	8.9	194.6	203.5	7.4	49.7	OK
		8	1.04	4.14	3.11	79.0	11.6	245.2	256.8	9.4	48.9	OK
		9	1.55	4.14	3.62	81.9	14.6	296.7	311.3	11.4	48.1	OK
		10	2.07	4.14	4.14	84.2	18.1	348.8	366.8	13.4	47.2	OK
		11	2.59	4.14	4.66	86.1	21.9	401.3	423.1	15.4	46.4	OK
		12	3.11	4.14	5.18	87.7	26.0	454.1	480.1	17.5	45.6	OK
	W24x146	7	0.52	4.14	2.59	75.2	9.0	194.6	203.6	6.6	49.7	OK
		8	1.04	4.14	3.11	79.0	11.7	245.2	256.9	8.3	48.9	OK
		9	1.55	4.14	3.62	81.9	14.8	296.7	311.5	10.1	48.1	OK
		10	2.07	4.14	4.14	84.2	18.3	348.8	367.1	11.9	47.3	OK
		11	2.59	4.14	4.66	86.1	22.2	401.3	423.4	13.7	46.5	OK
		12	3.11	4.14	5.18	87.7	26.4	454.1	480.5	15.5	45.6	OK

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 30°

		Skew	30°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W24	W24x55	7	0.58	4.62	2.89	75.2	10.2	217.1	227.3	23.9	42.5	OK
		8	1.15	4.62	3.46	79.0	13.4	273.5	286.9	30.2	40.7	OK
		9	1.73	4.62	4.04	81.9	16.9	330.9	347.8	36.6	38.8	OK
		10	2.31	4.62	4.62	84.2	20.9	389.0	409.9	43.1	37.0	NO GOOD
		11	2.89	4.62	5.20	86.1	25.3	447.6	472.9	49.8	35.2	NO GOOD
		12	3.46	4.62	5.77	87.7	30.1	506.5	536.6	56.5	29.9	NO GOOD
	W24x62	7	0.58	4.62	2.89	75.2	10.3	217.1	227.4	20.8	42.7	OK
		8	1.15	4.62	3.46	79.0	13.5	273.5	287.0	26.3	40.9	OK
		9	1.73	4.62	4.04	81.9	17.0	330.9	348.0	31.9	39.1	OK
		10	2.31	4.62	4.62	84.2	21.0	389.0	410.0	37.6	37.3	NO GOOD
		11	2.89	4.62	5.20	86.1	25.5	447.6	473.0	43.3	35.5	NO GOOD
		12	3.46	4.62	5.77	87.7	30.3	506.5	536.8	49.2	30.8	NO GOOD
	W24x68	7	0.58	4.62	2.89	75.2	10.4	217.1	227.4	17.7	45.8	OK
		8	1.15	4.62	3.46	79.0	13.6	273.5	287.1	22.4	44.4	OK
		9	1.73	4.62	4.04	81.9	17.2	330.9	348.1	27.1	43.0	OK
		10	2.31	4.62	4.62	84.2	21.2	389.0	410.2	32.0	41.7	OK
		11	2.89	4.62	5.20	86.1	25.6	447.6	473.2	36.9	40.3	OK
		12	3.46	4.62	5.77	87.7	30.5	506.5	537.0	41.8	38.9	NO GOOD
	W24x76	7	0.58	4.62	2.89	75.2	10.5	217.1	227.5	15.5	45.9	OK
		8	1.15	4.62	3.46	79.0	13.7	273.5	287.2	19.6	44.6	OK
		9	1.73	4.62	4.04	81.9	17.3	330.9	348.2	23.7	43.2	OK
		10	2.31	4.62	4.62	84.2	21.3	389.0	410.3	28.0	41.8	OK
		11	2.89	4.62	5.20	86.1	25.8	447.6	473.4	32.3	40.5	OK
		12	3.46	4.62	5.77	87.7	30.7	506.5	537.2	36.6	39.1	OK
	W24x84	7	0.58	4.62	2.89	75.2	10.5	217.1	227.6	13.9	46.0	OK
		8	1.15	4.62	3.46	79.0	13.8	273.5	287.3	17.6	44.7	OK
		9	1.73	4.62	4.04	81.9	17.4	330.9	348.3	21.3	43.3	OK
		10	2.31	4.62	4.62	84.2	21.5	389.0	410.5	25.1	42.0	OK
		11	2.89	4.62	5.20	86.1	26.0	447.6	473.6	29.0	40.6	OK
		12	3.46	4.62	5.77	87.7	31.0	506.5	537.5	32.9	39.3	OK
	W24x94	7	0.58	4.62	2.89	75.2	10.6	217.1	227.7	12.3	46.1	OK
		8	1.15	4.62	3.46	79.0	13.9	273.5	287.4	15.5	44.8	OK
		9	1.73	4.62	4.04	81.9	17.6	330.9	348.5	18.8	43.4	OK
		10	2.31	4.62	4.62	84.2	21.7	389.0	410.7	22.2	42.1	OK
		11	2.89	4.62	5.20	86.1	26.3	447.6	473.8	25.6	40.8	OK
		12	3.46	4.62	5.77	87.7	31.3	506.5	537.8	29.1	39.4	OK
	W24x103	7	0.58	4.62	2.89	75.2	10.7	217.1	227.8	11.2	46.1	OK
		8	1.15	4.62	3.46	79.0	14.0	273.5	287.5	14.1	44.7	OK
		9	1.73	4.62	4.04	81.9	17.7	330.9	348.7	17.1	43.4	OK
		10	2.31	4.62	4.62	84.2	21.9	389.0	410.9	20.1	42.0	OK
		11	2.89	4.62	5.20	86.1	26.5	447.6	474.1	23.2	40.7	OK
		12	3.46	4.62	5.77	87.7	31.5	506.5	538.0	26.4	39.4	OK
	W24x104	7	0.58	4.62	2.89	75.2	10.7	217.1	227.8	10.6	49.0	OK
		8	1.15	4.62	3.46	79.0	14.0	273.5	287.5	13.4	48.0	OK
		9	1.73	4.62	4.04	81.9	17.8	330.9	348.7	16.2	47.1	OK
		10	2.31	4.62	4.62	84.2	21.9	389.0	410.9	19.1	46.2	OK
		11	2.89	4.62	5.20	86.1	26.5	447.6	474.1	22.1	45.2	OK
		12	3.46	4.62	5.77	87.7	31.6	506.5	538.1	25.0	44.3	OK
	W24x117	7	0.58	4.62	2.89	75.2	10.9	217.1	227.9	9.4	49.0	OK
		8	1.15	4.62	3.46	79.0	14.2	273.5	287.7	11.9	48.0	OK
		9	1.73	4.62	4.04	81.9	18.0	330.9	348.9	14.4	47.1	OK
		10	2.31	4.62	4.62	84.2	22.2	389.0	411.2	17.0	46.2	OK
		11	2.89	4.62	5.20	86.1	26.9	447.6	474.4	19.6	45.3	OK
		12	3.46	4.62	5.77	87.7	32.0	506.5	538.5	22.2	44.3	OK
	W24x131	7	0.58	4.62	2.89	75.2	11.0	217.1	228.1	8.3	49.0	OK
		8	1.15	4.62	3.46	79.0	14.4	273.5	287.9	10.5	48.1	OK
		9	1.73	4.62	4.04	81.9	18.2	330.9	349.1	12.7	47.2	OK
		10	2.31	4.62	4.62	84.2	22.5	389.0	411.5	15.0	46.3	OK
		11	2.89	4.62	5.20	86.1	27.2	447.6	474.8	17.3	45.4	OK
		12	3.46	4.62	5.77	87.7	32.4	506.5	538.9	19.7	44.5	OK
	W24x146	7	0.58	4.62	2.89	75.2	11.2	217.1	228.2	7.4	49.1	OK
		8	1.15	4.62	3.46	79.0	14.6	273.5	288.1	9.3	48.2	OK
		9	1.73	4.62	4.04	81.9	18.5	330.9	349.4	11.3	47.2	OK
		10	2.31	4.62	4.62	84.2	22.8	389.0	411.8	13.3	46.3	OK
		11	2.89	4.62	5.20	86.1	27.6	447.6	475.1	15.4	45.4	OK
		12	3.46	4.62	5.77	87.7	32.8	506.5	539.3	17.4	44.5	OK

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 45°

		Skew	45									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W24	W24x55	7	0.71	5.66	3.54	75.2	15.4	265.9	281.2	29.6	39.6	OK
		8	1.41	5.66	4.24	79.0	20.1	335.0	355.0	37.4	37.4	NO GOOD
		9	2.12	5.66	4.95	81.9	25.4	405.3	430.7	45.3	35.1	NO GOOD
		10	2.83	5.66	5.66	84.2	31.4	476.4	507.8	53.4	28.7	NO GOOD
		11	3.54	5.66	6.36	86.1	37.9	548.1	586.1	61.7	23.7	NO GOOD
		12	4.24	5.66	7.07	87.7	45.2	620.3	665.5	70.1	19.9	NO GOOD
	W24x62	7	0.71	5.66	3.54	75.2	15.5	265.9	281.3	25.8	39.9	OK
		8	1.41	5.66	4.24	79.0	20.2	335.0	355.2	32.5	37.6	OK
		9	2.12	5.66	4.95	81.9	25.6	405.3	430.9	39.5	35.4	NO GOOD
		10	2.83	5.66	5.66	84.2	31.6	476.4	508.0	46.5	29.6	NO GOOD
		11	3.54	5.66	6.36	86.1	38.2	548.1	586.3	53.7	24.4	NO GOOD
		12	4.24	5.66	7.07	87.7	45.5	620.3	665.8	61.0	20.5	NO GOOD
	W24x68	7	0.71	5.66	3.54	75.2	15.6	265.9	281.4	21.9	43.6	OK
		8	1.41	5.66	4.24	79.0	20.3	335.0	355.3	27.7	41.9	OK
		9	2.12	5.66	4.95	81.9	25.7	405.3	431.0	33.6	40.3	OK
		10	2.83	5.66	5.66	84.2	31.8	476.4	508.2	39.6	38.6	NO GOOD
		11	3.54	5.66	6.36	86.1	38.4	548.1	586.6	45.7	36.9	NO GOOD
		12	4.24	5.66	7.07	87.7	45.7	620.3	666.1	51.9	35.2	NO GOOD
	W24x76	7	0.71	5.66	3.54	75.2	15.7	265.9	281.5	19.2	43.8	OK
		8	1.41	5.66	4.24	79.0	20.5	335.0	355.5	24.2	42.1	OK
		9	2.12	5.66	4.95	81.9	25.9	405.3	431.2	29.4	40.4	OK
		10	2.83	5.66	5.66	84.2	32.0	476.4	508.4	34.7	38.8	OK
		11	3.54	5.66	6.36	86.1	38.7	548.1	586.9	40.0	37.1	NO GOOD
		12	4.24	5.66	7.07	87.7	46.1	620.3	666.4	45.4	35.4	NO GOOD
	W24x84	7	0.71	5.66	3.54	75.2	15.8	265.9	281.7	17.2	43.9	OK
		8	1.41	5.66	4.24	79.0	20.6	335.0	355.6	21.8	42.2	OK
		9	2.12	5.66	4.95	81.9	26.1	405.3	431.4	26.4	40.6	OK
		10	2.83	5.66	5.66	84.2	32.3	476.4	508.7	31.1	38.9	OK
		11	3.54	5.66	6.36	86.1	39.0	548.1	587.2	35.9	37.3	OK
		12	4.24	5.66	7.07	87.7	46.5	620.3	666.8	40.8	35.6	NO GOOD
	W24x94	7	0.71	5.66	3.54	75.2	16.0	265.9	281.8	15.2	44.0	OK
		8	1.41	5.66	4.24	79.0	20.8	335.0	355.8	19.2	42.4	OK
		9	2.12	5.66	4.95	81.9	26.4	405.3	431.7	23.3	40.7	OK
		10	2.83	5.66	5.66	84.2	32.6	476.4	509.0	27.5	39.1	OK
		11	3.54	5.66	6.36	86.1	39.4	548.1	587.6	31.8	37.5	OK
		12	4.24	5.66	7.07	87.7	46.9	620.3	667.2	36.1	35.8	NO GOOD
	W24x103	7	0.71	5.66	3.54	75.2	16.1	265.9	282.0	13.8	44.0	OK
		8	1.41	5.66	4.24	79.0	21.0	335.0	356.0	17.4	42.3	OK
		9	2.12	5.66	4.95	81.9	26.6	405.3	431.9	21.2	40.7	OK
		10	2.83	5.66	5.66	84.2	32.9	476.4	509.3	24.9	39.0	OK
		11	3.54	5.66	6.36	86.1	39.8	548.1	587.9	28.8	37.4	OK
		12	4.24	5.66	7.07	87.7	47.3	620.3	667.6	32.7	35.8	OK
	W24x104	7	0.71	5.66	3.54	75.2	16.1	265.9	282.0	13.1	47.5	OK
		8	1.41	5.66	4.24	79.0	21.0	335.0	356.0	16.6	46.4	OK
		9	2.12	5.66	4.95	81.9	26.6	405.3	431.9	20.1	45.2	OK
		10	2.83	5.66	5.66	84.2	32.9	476.4	509.3	23.7	44.1	OK
		11	3.54	5.66	6.36	86.1	39.8	548.1	587.9	27.3	43.0	OK
		12	4.24	5.66	7.07	87.7	47.4	620.3	667.7	31.1	41.8	OK
	W24x117	7	0.71	5.66	3.54	75.2	16.3	265.9	282.2	11.6	47.5	OK
		8	1.41	5.66	4.24	79.0	21.3	335.0	356.3	14.7	46.4	OK
		9	2.12	5.66	4.95	81.9	27.0	405.3	432.2	17.8	45.2	OK
		10	2.83	5.66	5.66	84.2	33.3	476.4	509.7	21.0	44.1	OK
		11	3.54	5.66	6.36	86.1	40.3	548.1	588.4	24.3	43.0	OK
		12	4.24	5.66	7.07	87.7	47.9	620.3	668.3	27.6	41.8	OK
	W24x131	7	0.71	5.66	3.54	75.2	16.5	265.9	282.4	10.3	47.6	OK
		8	1.41	5.66	4.24	79.0	21.6	335.0	356.6	13.0	46.5	OK
		9	2.12	5.66	4.95	81.9	27.3	405.3	432.6	15.8	45.4	OK
		10	2.83	5.66	5.66	84.2	33.7	476.4	510.1	18.6	44.2	OK
		11	3.54	5.66	6.36	86.1	40.8	548.1	589.0	21.5	43.1	OK
		12	4.24	5.66	7.07	87.7	48.6	620.3	668.9	24.4	42.0	OK
	W24x146	7	0.71	5.66	3.54	75.2	16.8	265.9	282.6	9.1	47.6	OK
		8	1.41	5.66	4.24	79.0	21.9	335.0	356.9	11.5	46.5	OK
		9	2.12	5.66	4.95	81.9	27.7	405.3	433.0	14.0	45.4	OK
		10	2.83	5.66	5.66	84.2	34.2	476.4	510.6	16.5	44.3	OK
		11	3.54	5.66	6.36	86.1	41.4	548.1	589.5	19.1	43.2	OK
		12	4.24	5.66	7.07	87.7	49.2	620.3	669.6	21.7	42.1	OK

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 50°

		Skew	50°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W24	W24x55	7	0.78	6.22	3.89	75.2	18.6	292.5	311.0	32.7	38.0	OK
		8	1.56	6.22	4.67	79.0	24.3	368.5	392.8	41.3	35.6	NO GOOD
		9	2.33	6.22	5.45	81.9	30.7	445.8	476.6	50.2	29.2	NO GOOD
		10	3.11	6.22	6.22	84.2	37.9	524.1	562.0	59.2	23.7	NO GOOD
		11	3.89	6.22	7.00	86.1	45.9	603.0	648.9	68.3	19.6	NO GOOD
		12	4.67	6.22	7.78	87.7	54.6	682.4	737.0	77.6	16.4	NO GOOD
	W24x62	7	0.78	6.22	3.89	75.2	18.7	292.5	311.2	28.5	38.3	OK
		8	1.56	6.22	4.67	79.0	24.5	368.5	392.9	36.0	35.9	NO GOOD
		9	2.33	6.22	5.45	81.9	30.9	445.8	476.8	43.7	30.2	NO GOOD
		10	3.11	6.22	6.22	84.2	38.2	524.1	562.3	51.5	24.4	NO GOOD
		11	3.89	6.22	7.00	86.1	46.2	603.0	649.2	59.5	20.2	NO GOOD
		12	4.67	6.22	7.78	87.7	55.0	682.4	737.4	67.5	17.0	NO GOOD
	W24x68	7	0.78	6.22	3.89	75.2	18.8	292.5	311.3	24.3	42.5	OK
		8	1.56	6.22	4.67	79.0	24.6	368.5	393.1	30.6	40.6	OK
		9	2.33	6.22	5.45	81.9	31.1	445.8	477.0	37.2	38.7	OK
		10	3.11	6.22	6.22	84.2	38.4	524.1	562.5	43.8	36.9	NO GOOD
		11	3.89	6.22	7.00	86.1	46.5	603.0	649.5	50.6	35.0	NO GOOD
		12	4.67	6.22	7.78	87.7	55.3	682.4	737.7	57.5	29.5	NO GOOD
	W24x76	7	0.78	6.22	3.89	75.2	19.0	292.5	311.4	21.2	42.6	OK
		8	1.56	6.22	4.67	79.0	24.8	368.5	393.3	26.8	40.8	OK
		9	2.33	6.22	5.45	81.9	31.4	445.8	477.2	32.5	38.9	OK
		10	3.11	6.22	6.22	84.2	38.7	524.1	562.8	38.4	37.1	NO GOOD
		11	3.89	6.22	7.00	86.1	46.9	603.0	649.9	44.3	35.3	NO GOOD
		12	4.67	6.22	7.78	87.7	55.8	682.4	738.2	50.3	30.2	NO GOOD
	W24x84	7	0.78	6.22	3.89	75.2	19.1	292.5	311.6	19.1	42.7	OK
		8	1.56	6.22	4.67	79.0	25.0	368.5	393.5	24.1	40.9	OK
		9	2.33	6.22	5.45	81.9	31.6	445.8	477.5	29.2	39.1	OK
		10	3.11	6.22	6.22	84.2	39.0	524.1	563.1	34.5	37.3	OK
		11	3.89	6.22	7.00	86.1	47.2	603.0	650.2	39.8	35.5	NO GOOD
		12	4.67	6.22	7.78	87.7	56.2	682.4	738.6	45.2	30.8	NO GOOD
	W24x94	7	0.78	6.22	3.89	75.2	19.3	292.5	311.8	16.9	42.9	OK
		8	1.56	6.22	4.67	79.0	25.2	368.5	393.7	21.3	41.1	OK
		9	2.33	6.22	5.45	81.9	31.9	445.8	477.8	25.8	39.3	OK
		10	3.11	6.22	6.22	84.2	39.4	524.1	563.5	30.5	37.5	OK
		11	3.89	6.22	7.00	86.1	47.7	603.0	650.7	35.2	35.7	OK
		12	4.67	6.22	7.78	87.7	56.8	682.4	739.2	40.0	31.4	NO GOOD
	W24x103	7	0.78	6.22	3.89	75.2	19.5	292.5	311.9	15.3	42.8	OK
		8	1.56	6.22	4.67	79.0	25.4	368.5	393.9	19.3	41.0	OK
		9	2.33	6.22	5.45	81.9	32.2	445.8	478.0	23.4	39.2	OK
		10	3.11	6.22	6.22	84.2	39.8	524.1	563.8	27.6	37.4	OK
		11	3.89	6.22	7.00	86.1	48.1	603.0	651.1	31.9	35.6	OK
		12	4.67	6.22	7.78	87.7	57.3	682.4	739.7	36.2	31.2	NO GOOD
	W24x104	7	0.78	6.22	3.89	75.2	19.5	292.5	312.0	14.5	46.7	OK
		8	1.56	6.22	4.67	79.0	25.5	368.5	394.0	18.3	45.5	OK
		9	2.33	6.22	5.45	81.9	32.2	445.8	478.1	22.2	44.2	OK
		10	3.11	6.22	6.22	84.2	39.8	524.1	563.9	26.2	43.0	OK
		11	3.89	6.22	7.00	86.1	48.2	603.0	651.1	30.3	41.7	OK
		12	4.67	6.22	7.78	87.7	57.3	682.4	739.7	34.4	40.5	OK
	W24x117	7	0.78	6.22	3.89	75.2	19.7	292.5	312.2	12.9	46.7	OK
		8	1.56	6.22	4.67	79.0	25.8	368.5	394.3	16.3	45.5	OK
		9	2.33	6.22	5.45	81.9	32.6	445.8	478.5	19.7	44.2	OK
		10	3.11	6.22	6.22	84.2	40.3	524.1	564.4	23.3	43.0	OK
		11	3.89	6.22	7.00	86.1	48.7	603.0	651.7	26.9	41.7	OK
		12	4.67	6.22	7.78	87.7	58.0	682.4	740.4	30.5	40.5	OK
	W24x131	7	0.78	6.22	3.89	75.2	20.0	292.5	312.5	11.4	46.8	OK
		8	1.56	6.22	4.67	79.0	26.1	368.5	394.6	14.4	45.6	OK
		9	2.33	6.22	5.45	81.9	33.1	445.8	478.9	17.5	44.3	OK
		10	3.11	6.22	6.22	84.2	40.8	524.1	564.9	20.6	43.1	OK
		11	3.89	6.22	7.00	86.1	49.4	603.0	652.4	23.8	41.9	OK
		12	4.67	6.22	7.78	87.7	58.8	682.4	741.2	27.0	40.6	OK
	W24x146	7	0.78	6.22	3.89	75.2	20.3	292.5	312.7	10.1	46.9	OK
		8	1.56	6.22	4.67	79.0	26.5	368.5	395.0	12.8	45.6	OK
		9	2.33	6.22	5.45	81.9	33.5	445.8	479.4	15.5	44.4	OK
		10	3.11	6.22	6.22	84.2	41.4	524.1	565.5	18.3	43.2	OK
		11	3.89	6.22	7.00	86.1	50.1	603.0	653.1	21.1	41.9	OK
		12	4.67	6.22	7.78	87.7	59.6	682.4	742.0	24.0	40.7	OK

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 55°

		Skew	55°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W24	W24x55	7	0.87	6.97	4.36	75.2	23.3	327.7	351.1	37.0	35.9	NO GOOD
		8	1.74	6.97	5.23	79.0	30.5	413.0	443.5	46.7	29.5	NO GOOD
		9	2.62	6.97	6.10	81.9	38.6	499.6	538.2	56.7	23.3	NO GOOD
		10	3.49	6.97	6.97	84.2	47.7	587.3	635.0	66.8	18.9	NO GOOD
		11	4.36	6.97	7.85	86.1	57.7	675.8	733.4	77.2	15.6	NO GOOD
		12	5.23	6.97	8.72	87.7	68.6	764.7	833.4	87.7	13.1	NO GOOD
	W24x62	7	0.87	6.97	4.36	75.2	23.5	327.7	351.3	32.2	36.2	OK
		8	1.74	6.97	5.23	79.0	30.7	413.0	443.7	40.6	30.4	NO GOOD
		9	2.62	6.97	6.10	81.9	38.9	499.6	538.5	49.3	24.0	NO GOOD
		10	3.49	6.97	6.97	84.2	48.0	587.3	635.3	58.2	19.4	NO GOOD
		11	4.36	6.97	7.85	86.1	58.1	675.8	733.8	67.2	16.1	NO GOOD
		12	5.23	6.97	8.72	87.7	69.1	764.7	833.8	76.4	13.5	NO GOOD
	W24x68	7	0.87	6.97	4.36	75.2	23.7	327.7	351.4	27.4	40.9	OK
		8	1.74	6.97	5.23	79.0	30.9	413.0	443.9	34.6	38.8	OK
		9	2.62	6.97	6.10	81.9	39.1	499.6	538.7	42.0	36.7	NO GOOD
		10	3.49	6.97	6.97	84.2	48.3	587.3	635.6	49.5	33.8	NO GOOD
		11	4.36	6.97	7.85	86.1	58.4	675.8	734.2	57.2	27.9	NO GOOD
		12	5.23	6.97	8.72	87.7	69.5	764.7	834.3	65.0	23.5	NO GOOD
	W24x76	7	0.87	6.97	4.36	75.2	23.8	327.7	351.6	24.0	41.1	OK
		8	1.74	6.97	5.23	79.0	31.1	413.0	444.1	30.3	39.0	OK
		9	2.62	6.97	6.10	81.9	39.4	499.6	539.0	36.8	37.0	OK
		10	3.49	6.97	6.97	84.2	48.6	587.3	636.0	43.4	34.7	NO GOOD
		11	4.36	6.97	7.85	86.1	58.9	675.8	734.6	50.1	28.7	NO GOOD
		12	5.23	6.97	8.72	87.7	70.1	764.7	834.8	56.9	24.1	NO GOOD
	W24x84	7	0.87	6.97	4.36	75.2	24.0	327.7	351.8	21.5	41.2	OK
		8	1.74	6.97	5.23	79.0	31.4	413.0	444.3	27.2	39.2	OK
		9	2.62	6.97	6.10	81.9	39.7	499.6	539.3	33.0	37.1	OK
		10	3.49	6.97	6.97	84.2	49.0	587.3	636.4	39.0	35.1	NO GOOD
		11	4.36	6.97	7.85	86.1	59.3	675.8	735.1	45.0	29.2	NO GOOD
		12	5.23	6.97	8.72	87.7	70.6	764.7	835.3	51.1	24.5	NO GOOD
	W24x94	7	0.87	6.97	4.36	75.2	24.3	327.7	352.0	19.0	41.3	OK
		8	1.74	6.97	5.23	79.0	31.7	413.0	444.6	24.0	39.3	OK
		9	2.62	6.97	6.10	81.9	40.1	499.6	539.7	29.2	37.3	OK
		10	3.49	6.97	6.97	84.2	49.5	587.3	636.8	34.4	35.3	OK
		11	4.36	6.97	7.85	86.1	59.9	675.8	735.7	39.8	29.8	NO GOOD
		12	5.23	6.97	8.72	87.7	71.3	764.7	836.0	45.2	25.0	NO GOOD
	W24x103	7	0.87	6.97	4.36	75.2	24.5	327.7	352.2	17.3	41.3	OK
		8	1.74	6.97	5.23	79.0	32.0	413.0	444.9	21.8	39.3	OK
		9	2.62	6.97	6.10	81.9	40.4	499.6	540.1	26.5	37.2	OK
		10	3.49	6.97	6.97	84.2	49.9	587.3	637.3	31.2	35.2	OK
		11	4.36	6.97	7.85	86.1	60.4	675.8	736.2	36.1	29.6	NO GOOD
		12	5.23	6.97	8.72	87.7	71.9	764.7	836.6	41.0	24.8	NO GOOD
	W24x104	7	0.87	6.97	4.36	75.2	24.5	327.7	352.2	16.4	45.6	OK
		8	1.74	6.97	5.23	79.0	32.0	413.0	444.9	20.7	44.2	OK
		9	2.62	6.97	6.10	81.9	40.5	499.6	540.1	25.1	42.8	OK
		10	3.49	6.97	6.97	84.2	50.0	587.3	637.3	29.6	41.4	OK
		11	4.36	6.97	7.85	86.1	60.5	675.8	736.2	34.2	40.0	OK
		12	5.23	6.97	8.72	87.7	72.0	764.7	836.7	38.9	38.6	NO GOOD
	W24x117	7	0.87	6.97	4.36	75.2	24.8	327.7	352.5	14.5	45.7	OK
		8	1.74	6.97	5.23	79.0	32.4	413.0	445.3	18.4	44.3	OK
		9	2.62	6.97	6.10	81.9	41.0	499.6	540.6	22.3	42.9	OK
		10	3.49	6.97	6.97	84.2	50.6	587.3	637.9	26.3	41.5	OK
		11	4.36	6.97	7.85	86.1	61.2	675.8	737.0	30.4	40.1	OK
		12	5.23	6.97	8.72	87.7	72.9	764.7	837.6	34.5	38.7	OK
	W24x131	7	0.87	6.97	4.36	75.2	25.1	327.7	352.9	12.9	45.8	OK
		8	1.74	6.97	5.23	79.0	32.8	413.0	445.8	16.3	44.4	OK
		9	2.62	6.97	6.10	81.9	41.5	499.6	541.2	19.7	43.0	OK
		10	3.49	6.97	6.97	84.2	51.3	587.3	638.6	23.3	41.6	OK
		11	4.36	6.97	7.85	86.1	62.0	675.8	737.8	26.9	40.2	OK
		12	5.23	6.97	8.72	87.7	73.8	764.7	838.6	30.6	38.9	OK
	W24x146	7	0.87	6.97	4.36	75.2	25.5	327.7	353.2	11.4	45.8	OK
		8	1.74	6.97	5.23	79.0	33.3	413.0	446.2	14.4	44.4	OK
		9	2.62	6.97	6.10	81.9	42.1	499.6	541.7	17.5	43.1	OK
		10	3.49	6.97	6.97	84.2	52.0	587.3	639.3	20.7	41.7	OK
		11	4.36	6.97	7.85	86.1	62.9	675.8	738.6	23.9	40.3	OK
		12	5.23	6.97	8.72	87.7	74.8	764.7	839.6	27.2	38.9	OK

Project:	MoDOT Finger/Flat Plate Eval	Computed:	MTW	Date:	11/4/2015
Subject:	New Finger Plate Design	Checked:	DGB	Date:	12/3/2015
Task:	Support Beam Design	Page:	33	of:	SUPPORT
Job #:	244663	No:			

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 60°

		Skew	60°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	f_{bu}<F_{nc}
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W24	W24x55	7	1.00	8.00	5.00	75.2	30.7	376.0	406.7	42.8	29.2	NO GOOD
		8	2.00	8.00	6.00	79.0	40.1	473.7	513.9	54.1	22.4	NO GOOD
		9	3.00	8.00	7.00	81.9	50.8	573.2	623.9	65.7	17.7	NO GOOD
		10	4.00	8.00	8.00	84.2	62.7	673.8	736.5	77.5	14.3	NO GOOD
		11	5.00	8.00	9.00	86.1	75.9	775.2	851.1	89.6	11.8	NO GOOD
		12	6.00	8.00	10.00	87.7	90.3	877.3	967.6	101.9	10.0	NO GOOD
	W24x62	7	1.00	8.00	5.00	75.2	30.9	376.0	406.9	37.3	30.2	NO GOOD
		8	2.00	8.00	6.00	79.0	40.4	473.7	514.1	47.1	23.1	NO GOOD
		9	3.00	8.00	7.00	81.9	51.1	573.2	624.3	57.2	18.2	NO GOOD
		10	4.00	8.00	8.00	84.2	63.1	673.8	736.9	67.5	14.8	NO GOOD
		11	5.00	8.00	9.00	86.1	76.4	775.2	851.6	78.0	12.2	NO GOOD
		12	6.00	8.00	10.00	87.7	90.9	877.3	968.2	88.7	10.3	NO GOOD
	W24x68	7	1.00	8.00	5.00	75.2	31.1	376.0	407.1	31.7	38.7	OK
		8	2.00	8.00	6.00	79.0	40.7	473.7	514.4	40.1	36.4	NO GOOD
		9	3.00	8.00	7.00	81.9	51.5	573.2	624.6	48.7	31.7	NO GOOD
		10	4.00	8.00	8.00	84.2	63.5	673.8	737.3	57.4	25.7	NO GOOD
		11	5.00	8.00	9.00	86.1	76.9	775.2	852.1	66.4	21.2	NO GOOD
		12	6.00	8.00	10.00	87.7	91.5	877.3	968.7	75.5	17.8	NO GOOD
	W24x76	7	1.00	8.00	5.00	75.2	31.4	376.0	407.3	27.8	38.9	OK
		8	2.00	8.00	6.00	79.0	41.0	473.7	514.7	35.1	36.6	OK
		9	3.00	8.00	7.00	81.9	51.9	573.2	625.0	42.6	32.5	NO GOOD
		10	4.00	8.00	8.00	84.2	64.0	673.8	737.8	50.3	26.3	NO GOOD
		11	5.00	8.00	9.00	86.1	77.5	775.2	852.7	58.1	21.8	NO GOOD
		12	6.00	8.00	10.00	87.7	92.2	877.3	969.5	66.1	18.3	NO GOOD
	W24x84	7	1.00	8.00	5.00	75.2	31.6	376.0	407.6	25.0	39.1	OK
		8	2.00	8.00	6.00	79.0	41.3	473.7	515.0	31.5	36.8	OK
		9	3.00	8.00	7.00	81.9	52.3	573.2	625.4	38.3	33.2	NO GOOD
		10	4.00	8.00	8.00	84.2	64.5	673.8	738.3	45.2	26.9	NO GOOD
		11	5.00	8.00	9.00	86.1	78.1	775.2	853.3	52.2	22.2	NO GOOD
		12	6.00	8.00	10.00	87.7	92.9	877.3	970.2	59.4	18.7	NO GOOD
	W24x94	7	1.00	8.00	5.00	75.2	31.9	376.0	407.9	22.0	39.3	OK
		8	2.00	8.00	6.00	79.0	41.7	473.7	515.4	27.9	37.0	OK
		9	3.00	8.00	7.00	81.9	52.8	573.2	625.9	33.8	33.8	NO GOOD
		10	4.00	8.00	8.00	84.2	65.1	673.8	738.9	39.9	27.4	NO GOOD
		11	5.00	8.00	9.00	86.1	78.8	775.2	854.0	46.2	22.6	NO GOOD
		12	6.00	8.00	10.00	87.7	93.8	877.3	971.1	52.5	19.0	NO GOOD
	W24x103	7	1.00	8.00	5.00	75.2	32.2	376.0	408.2	20.0	39.2	OK
		8	2.00	8.00	6.00	79.0	42.1	473.7	515.8	25.3	36.9	OK
		9	3.00	8.00	7.00	81.9	53.2	573.2	626.4	30.7	33.5	OK
		10	4.00	8.00	8.00	84.2	65.7	673.8	739.5	36.2	27.2	NO GOOD
		11	5.00	8.00	9.00	86.1	79.5	775.2	854.7	41.9	22.5	NO GOOD
		12	6.00	8.00	10.00	87.7	94.6	877.3	971.9	47.6	18.9	NO GOOD
	W24x104	7	1.00	8.00	5.00	75.2	32.2	376.0	408.2	19.0	44.2	OK
		8	2.00	8.00	6.00	79.0	42.1	473.7	515.8	24.0	42.6	OK
		9	3.00	8.00	7.00	81.9	53.3	573.2	626.4	29.1	41.0	OK
		10	4.00	8.00	8.00	84.2	65.8	673.8	739.5	34.4	39.4	OK
		11	5.00	8.00	9.00	86.1	79.6	775.2	854.8	39.8	37.8	NO GOOD
		12	6.00	8.00	10.00	87.7	94.7	877.3	972.0	45.2	36.2	NO GOOD
	W24x117	7	1.00	8.00	5.00	75.2	32.6	376.0	408.6	16.8	44.2	OK
		8	2.00	8.00	6.00	79.0	42.6	473.7	516.3	21.3	42.6	OK
		9	3.00	8.00	7.00	81.9	53.9	573.2	627.1	25.9	41.0	OK
		10	4.00	8.00	8.00	84.2	66.6	673.8	740.3	30.5	39.4	OK
		11	5.00	8.00	9.00	86.1	80.6	775.2	855.8	35.3	37.8	OK
		12	6.00	8.00	10.00	87.7	95.9	877.3	973.2	40.1	36.2	NO GOOD
	W24x131	7	1.00	8.00	5.00	75.2	33.1	376.0	409.0	14.9	44.3	OK
		8	2.00	8.00	6.00	79.0	43.2	473.7	516.9	18.9	42.8	OK
		9	3.00	8.00	7.00	81.9	54.6	573.2	627.8	22.9	41.2	OK
		10	4.00	8.00	8.00	84.2	67.5	673.8	741.2	27.0	39.6	OK
		11	5.00	8.00	9.00	86.1	81.6	775.2	856.8	31.3	38.0	OK
		12	6.00	8.00	10.00	87.7	97.1	877.3	974.4	35.5	36.4	OK
	W24x146	7	1.00	8.00	5.00	75.2	33.5	376.0	409.5	13.2	44.4	OK
		8	2.00	8.00	6.00	79.0	43.8	473.7	517.5	16.7	42.8	OK
		9	3.00	8.00	7.00	81.9	55.4	573.2	628.6	20.3	41.2	OK
		10	4.00	8.00	8.00	84.2	68.4	673.8	742.1	24.0	39.7	OK
		11	5.00	8.00	9.00	86.1	82.8	775.2	858.0	27.8	38.1	OK
		12	6.00	8.00	10.00	87.7	98.5	877.3	975.8	31.6	36.5	OK

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 0°

		Skew	0°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W27	**W27x84**	7	0.50	4.00	2.50	75.2	7.9	188.0	195.9	11.0	47.9	OK
		8	1.00	4.00	3.00	79.0	10.3	236.9	247.2	13.9	46.9	OK
		9	1.50	4.00	3.50	81.9	13.1	286.6	299.6	16.9	45.8	OK
		10	2.00	4.00	4.00	84.2	16.1	336.9	353.0	19.9	44.7	OK
		11	2.50	4.00	4.50	86.1	19.5	387.6	407.1	22.9	43.6	OK
		12	3.00	4.00	5.00	87.7	23.2	438.6	461.9	26.0	42.6	OK
	W27x94	7	0.50	4.00	2.50	75.2	8.0	188.0	196.0	9.7	48.0	OK
		8	1.00	4.00	3.00	79.0	10.4	236.9	247.3	12.2	46.9	OK
		9	1.50	4.00	3.50	81.9	13.2	286.6	299.8	14.8	45.9	OK
		10	2.00	4.00	4.00	84.2	16.3	336.9	353.2	17.4	44.8	OK
		11	2.50	4.00	4.50	86.1	19.7	387.6	407.3	20.1	43.8	OK
		12	3.00	4.00	5.00	87.7	23.5	438.6	462.1	22.8	42.7	OK
	W27x114	7	0.50	4.00	2.50	75.2	8.1	188.0	196.1	7.9	48.1	OK
		8	1.00	4.00	3.00	79.0	10.6	236.9	247.5	9.9	47.1	OK
		9	1.50	4.00	3.50	81.9	13.4	286.6	300.0	12.0	46.1	OK
		10	2.00	4.00	4.00	84.2	16.6	336.9	353.5	14.2	45.0	OK
		11	2.50	4.00	4.50	86.1	20.1	387.6	407.7	16.4	44.0	OK
		12	3.00	4.00	5.00	87.7	23.9	438.6	462.5	18.6	42.9	OK
	W27x129	7	0.50	4.00	2.50	75.2	8.2	188.0	196.2	6.8	48.1	OK
		8	1.00	4.00	3.00	79.0	10.8	236.9	247.6	8.6	47.1	OK
		9	1.50	4.00	3.50	81.9	13.6	286.6	300.2	10.4	46.0	OK
		10	2.00	4.00	4.00	84.2	16.8	336.9	353.7	12.3	45.0	OK
		11	2.50	4.00	4.50	86.1	20.4	387.6	408.0	14.2	44.0	OK
		12	3.00	4.00	5.00	87.7	24.2	438.6	462.9	16.1	42.9	OK
	W27x146	7	0.50	4.00	2.50	75.2	8.4	188.0	196.4	5.7	50.0	OK
		8	1.00	4.00	3.00	79.0	10.9	236.9	247.8	7.2	49.6	OK
		9	1.50	4.00	3.50	81.9	13.9	286.6	300.4	8.7	48.9	OK
		10	2.00	4.00	4.00	84.2	17.1	336.9	354.0	10.3	48.1	OK
		11	2.50	4.00	4.50	86.1	20.7	387.6	408.3	11.8	47.4	OK
		12	3.00	4.00	5.00	87.7	24.6	438.6	463.3	13.4	46.7	OK
W30	**W30x90**	7	0.50	4.00	2.50	75.2	7.9	188.0	195.9	9.6	48.1	OK
		8	1.00	4.00	3.00	79.0	10.4	236.9	247.2	12.1	47.0	OK
		9	1.50	4.00	3.50	81.9	13.1	286.6	299.7	14.7	46.0	OK
		10	2.00	4.00	4.00	84.2	16.2	336.9	353.1	17.3	44.9	OK
		11	2.50	4.00	4.50	86.1	19.6	387.6	407.2	19.9	43.9	OK
		12	3.00	4.00	5.00	87.7	23.4	438.6	462.0	22.6	42.8	OK
	W30x108	7	0.50	4.00	2.50	75.2	8.1	188.0	196.1	7.9	48.2	OK
		8	1.00	4.00	3.00	79.0	10.6	236.9	247.4	9.9	47.2	OK
		9	1.50	4.00	3.50	81.9	13.4	286.6	299.9	12.0	46.2	OK
		10	2.00	4.00	4.00	84.2	16.5	336.9	353.4	14.2	45.2	OK
		11	2.50	4.00	4.50	86.1	20.0	387.6	407.6	16.4	44.1	OK
		12	3.00	4.00	5.00	87.7	23.8	438.6	462.4	18.6	43.1	OK
	W30x116	7	0.50	4.00	2.50	75.2	8.1	188.0	196.1	7.2	48.3	OK
		8	1.00	4.00	3.00	79.0	10.6	236.9	247.5	9.0	47.3	OK
		9	1.50	4.00	3.50	81.9	13.5	286.6	300.0	10.9	46.3	OK
		10	2.00	4.00	4.00	84.2	16.6	336.9	353.5	12.9	45.2	OK
		11	2.50	4.00	4.50	86.1	20.1	387.6	407.7	14.9	44.2	OK
		12	3.00	4.00	5.00	87.7	23.9	438.6	462.6	16.9	43.2	OK
	W30x124	7	0.50	4.00	2.50	75.2	8.2	188.0	196.2	6.6	48.3	OK
		8	1.00	4.00	3.00	79.0	10.7	236.9	247.6	8.4	47.3	OK
		9	1.50	4.00	3.50	81.9	13.6	286.6	300.1	10.1	46.3	OK
		10	2.00	4.00	4.00	84.2	16.8	336.9	353.6	12.0	45.3	OK
		11	2.50	4.00	4.50	86.1	20.3	387.6	407.9	13.8	44.3	OK
		12	3.00	4.00	5.00	87.7	24.1	438.6	462.8	15.6	43.3	OK
	W30x148	7	0.50	4.00	2.50	75.2	8.4	188.0	196.4	5.4	48.4	OK
		8	1.00	4.00	3.00	79.0	11.0	236.9	247.8	6.8	47.4	OK
		9	1.50	4.00	3.50	81.9	13.9	286.6	300.5	8.3	46.4	OK
		10	2.00	4.00	4.00	84.2	17.1	336.9	354.0	9.7	45.4	OK
		11	2.50	4.00	4.50	86.1	20.7	387.6	408.3	11.2	44.4	OK
		12	3.00	4.00	5.00	87.7	24.7	438.6	463.3	12.8	43.4	OK

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 15°

		Skew	15°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W27	W27x84	7	0.52	4.14	2.59	75.2	8.5	194.6	203.1	11.4	47.7	OK
		8	1.04	4.14	3.11	79.0	11.1	245.2	256.3	14.4	46.6	OK
		9	1.55	4.14	3.62	81.9	14.0	296.7	310.7	17.5	45.4	OK
		10	2.07	4.14	4.14	84.2	17.3	348.8	366.0	20.6	44.3	OK
		11	2.59	4.14	4.66	86.1	20.9	401.3	422.2	23.8	43.2	OK
		12	3.11	4.14	5.18	87.7	24.9	454.1	479.0	27.0	42.1	OK
	W27x94	7	0.52	4.14	2.59	75.2	8.6	194.6	203.2	10.0	47.7	OK
		8	1.04	4.14	3.11	79.0	11.2	245.2	256.4	12.7	46.6	OK
		9	1.55	4.14	3.62	81.9	14.1	296.7	310.8	15.3	45.5	OK
		10	2.07	4.14	4.14	84.2	17.5	348.8	366.2	18.1	44.4	OK
		11	2.59	4.14	4.66	86.1	21.1	401.3	422.4	20.9	43.3	OK
		12	3.11	4.14	5.18	87.7	25.1	454.1	479.2	23.7	42.2	OK
	W27x114	7	0.52	4.14	2.59	75.2	8.7	194.6	203.3	8.2	47.9	OK
		8	1.04	4.14	3.11	79.0	11.4	245.2	256.6	10.3	46.8	OK
		9	1.55	4.14	3.62	81.9	14.4	296.7	311.1	12.5	45.7	OK
		10	2.07	4.14	4.14	84.2	17.8	348.8	366.5	14.7	44.6	OK
		11	2.59	4.14	4.66	86.1	21.5	401.3	422.8	17.0	43.6	OK
		12	3.11	4.14	5.18	87.7	25.6	454.1	479.7	19.3	42.5	OK
	W27x129	7	0.52	4.14	2.59	75.2	8.8	194.6	203.5	7.1	47.9	OK
		8	1.04	4.14	3.11	79.0	11.5	245.2	256.8	8.9	46.8	OK
		9	1.55	4.14	3.62	81.9	14.6	296.7	311.3	10.8	45.7	OK
		10	2.07	4.14	4.14	84.2	18.0	348.8	366.8	12.8	44.6	OK
		11	2.59	4.14	4.66	86.1	21.8	401.3	423.1	14.7	43.6	OK
		12	3.11	4.14	5.18	87.7	26.0	454.1	480.1	16.7	42.5	OK
	W27x146	7	0.52	4.14	2.59	75.2	9.0	194.6	203.6	5.9	50.0	OK
		8	1.04	4.14	3.11	79.0	11.7	245.2	256.9	7.4	49.4	OK
		9	1.55	4.14	3.62	81.9	14.8	296.7	311.5	9.0	48.6	OK
		10	2.07	4.14	4.14	84.2	18.3	348.8	367.1	10.6	47.9	OK
		11	2.59	4.14	4.66	86.1	22.2	401.3	423.4	12.3	47.1	OK
		12	3.11	4.14	5.18	87.7	26.4	454.1	480.5	13.9	46.4	OK
W30	W30x90	7	0.52	4.14	2.59	75.2	8.5	194.6	203.1	9.9	47.8	OK
		8	1.04	4.14	3.11	79.0	11.1	245.2	256.3	12.6	46.8	OK
		9	1.55	4.14	3.62	81.9	14.1	296.7	310.8	15.2	45.7	OK
		10	2.07	4.14	4.14	84.2	17.4	348.8	366.1	17.9	44.6	OK
		11	2.59	4.14	4.66	86.1	21.0	401.3	422.3	20.7	43.5	OK
		12	3.11	4.14	5.18	87.7	25.0	454.1	479.2	23.5	42.4	OK
	W30x108	7	0.52	4.14	2.59	75.2	8.7	194.6	203.3	8.2	48.0	OK
		8	1.04	4.14	3.11	79.0	11.3	245.2	256.5	10.3	46.9	OK
		9	1.55	4.14	3.62	81.9	14.3	296.7	311.0	12.5	45.9	OK
		10	2.07	4.14	4.14	84.2	17.7	348.8	366.4	14.7	44.8	OK
		11	2.59	4.14	4.66	86.1	21.4	401.3	422.7	17.0	43.7	OK
		12	3.11	4.14	5.18	87.7	25.5	454.1	479.6	19.2	42.7	OK
	W30x116	7	0.52	4.14	2.59	75.2	8.7	194.6	203.4	7.4	48.1	OK
		8	1.04	4.14	3.11	79.0	11.4	245.2	256.6	9.4	47.0	OK
		9	1.55	4.14	3.62	81.9	14.4	296.7	311.1	11.3	45.9	OK
		10	2.07	4.14	4.14	84.2	17.8	348.8	366.6	13.4	44.9	OK
		11	2.59	4.14	4.66	86.1	21.6	401.3	422.8	15.4	43.8	OK
		12	3.11	4.14	5.18	87.7	25.7	454.1	479.8	17.5	42.8	OK
	W30x124	7	0.52	4.14	2.59	75.2	8.8	194.6	203.4	6.9	48.1	OK
		8	1.04	4.14	3.11	79.0	11.5	245.2	256.7	8.7	47.0	OK
		9	1.55	4.14	3.62	81.9	14.5	296.7	311.2	10.5	46.0	OK
		10	2.07	4.14	4.14	84.2	18.0	348.8	366.7	12.4	44.9	OK
		11	2.59	4.14	4.66	86.1	21.7	401.3	423.0	14.3	43.9	OK
		12	3.11	4.14	5.18	87.7	25.9	454.1	480.0	16.2	42.8	OK
	W30x148	7	0.52	4.14	2.59	75.2	9.0	194.6	203.6	5.6	48.2	OK
		8	1.04	4.14	3.11	79.0	11.8	245.2	257.0	7.1	47.2	OK
		9	1.55	4.14	3.62	81.9	14.9	296.7	311.6	8.6	46.1	OK
		10	2.07	4.14	4.14	84.2	18.4	348.8	367.1	10.1	45.1	OK
		11	2.59	4.14	4.66	86.1	22.2	401.3	423.5	11.7	44.1	OK
		12	3.11	4.14	5.18	87.7	26.4	454.1	480.6	13.2	43.0	OK

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 30°

		Skew	30°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	f_{bu}<F_{nc}
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W27	W27x84	7	0.58	4.62	2.89	75.2	10.5	217.1	227.6	12.8	46.8	OK
		8	1.15	4.62	3.46	79.0	13.8	273.5	287.3	16.2	45.5	OK
		9	1.73	4.62	4.04	81.9	17.4	330.9	348.3	19.6	44.3	OK
		10	2.31	4.62	4.62	84.2	21.5	389.0	410.5	23.1	43.1	OK
		11	2.89	4.62	5.20	86.1	26.0	447.6	473.6	26.7	41.8	OK
		12	3.46	4.62	5.77	87.7	31.0	506.5	537.5	30.3	40.6	OK
	W27x94	7	0.58	4.62	2.89	75.2	10.6	217.1	227.7	11.2	46.9	OK
		8	1.15	4.62	3.46	79.0	13.9	273.5	287.4	14.2	45.6	OK
		9	1.73	4.62	4.04	81.9	17.6	330.9	348.5	17.2	44.4	OK
		10	2.31	4.62	4.62	84.2	21.7	389.0	410.7	20.3	43.2	OK
		11	2.89	4.62	5.20	86.1	26.3	447.6	473.8	23.4	41.9	OK
		12	3.46	4.62	5.77	87.7	31.3	506.5	537.8	26.6	40.7	OK
	W27x114	7	0.58	4.62	2.89	75.2	10.8	217.1	227.9	9.1	47.0	OK
		8	1.15	4.62	3.46	79.0	14.2	273.5	287.7	11.5	45.8	OK
		9	1.73	4.62	4.04	81.9	17.9	330.9	348.8	14.0	44.6	OK
		10	2.31	4.62	4.62	84.2	22.1	389.0	411.1	16.5	43.4	OK
		11	2.89	4.62	5.20	86.1	26.8	447.6	474.3	19.0	42.2	OK
		12	3.46	4.62	5.77	87.7	31.9	506.5	538.4	21.6	41.0	OK
	W27x129	7	0.58	4.62	2.89	75.2	11.0	217.1	228.1	7.9	47.0	OK
		8	1.15	4.62	3.46	79.0	14.4	273.5	287.9	10.0	45.8	OK
		9	1.73	4.62	4.04	81.9	18.2	330.9	349.1	12.1	44.6	OK
		10	2.31	4.62	4.62	84.2	22.4	389.0	411.4	14.3	43.4	OK
		11	2.89	4.62	5.20	86.1	27.2	447.6	474.7	16.5	42.2	OK
		12	3.46	4.62	5.77	87.7	32.3	506.5	538.8	18.7	41.0	OK
	W27x146	7	0.58	4.62	2.89	75.2	11.2	217.1	228.2	6.6	49.5	OK
		8	1.15	4.62	3.46	79.0	14.6	273.5	288.1	8.4	48.7	OK
		9	1.73	4.62	4.04	81.9	18.5	330.9	349.4	10.1	47.8	OK
		10	2.31	4.62	4.62	84.2	22.8	389.0	411.8	11.9	47.0	OK
		11	2.89	4.62	5.20	86.1	27.6	447.6	475.1	13.8	46.2	OK
		12	3.46	4.62	5.77	87.7	32.8	506.5	539.3	15.6	45.3	OK
W30	W30x90	7	0.58	4.62	2.89	75.2	10.6	217.1	227.7	11.2	47.0	OK
		8	1.15	4.62	3.46	79.0	13.8	273.5	287.4	14.1	45.7	OK
		9	1.73	4.62	4.04	81.9	17.5	330.9	348.4	17.1	44.5	OK
		10	2.31	4.62	4.62	84.2	21.6	389.0	410.6	20.1	43.3	OK
		11	2.89	4.62	5.20	86.1	26.2	447.6	473.7	23.2	42.1	OK
		12	3.46	4.62	5.77	87.7	31.2	506.5	537.6	26.3	40.9	OK
	W30x108	7	0.58	4.62	2.89	75.2	10.8	217.1	227.9	9.1	47.1	OK
		8	1.15	4.62	3.46	79.0	14.1	273.5	287.6	11.5	45.9	OK
		9	1.73	4.62	4.04	81.9	17.8	330.9	348.7	14.0	44.8	OK
		10	2.31	4.62	4.62	84.2	22.0	389.0	411.0	16.5	43.6	OK
		11	2.89	4.62	5.20	86.1	26.6	447.6	474.2	19.0	42.4	OK
		12	3.46	4.62	5.77	87.7	31.7	506.5	538.2	21.6	41.2	OK
	W30x116	7	0.58	4.62	2.89	75.2	10.9	217.1	227.9	8.3	47.2	OK
		8	1.15	4.62	3.46	79.0	14.2	273.5	287.7	10.5	46.0	OK
		9	1.73	4.62	4.04	81.9	18.0	330.9	348.9	12.7	44.8	OK
		10	2.31	4.62	4.62	84.2	22.2	389.0	411.2	15.0	43.7	OK
		11	2.89	4.62	5.20	86.1	26.8	447.6	474.4	17.3	42.5	OK
		12	3.46	4.62	5.77	87.7	31.9	506.5	538.4	19.6	41.3	OK
	W30x124	7	0.58	4.62	2.89	75.2	10.9	217.1	228.0	7.7	47.3	OK
		8	1.15	4.62	3.46	79.0	14.3	273.5	287.8	9.7	46.1	OK
		9	1.73	4.62	4.04	81.9	18.1	330.9	349.0	11.8	44.9	OK
		10	2.31	4.62	4.62	84.2	22.3	389.0	411.3	13.9	43.7	OK
		11	2.89	4.62	5.20	86.1	27.0	447.6	474.6	16.0	42.6	OK
		12	3.46	4.62	5.77	87.7	32.2	506.5	538.7	18.2	41.4	OK
	W30x148	7	0.58	4.62	2.89	75.2	11.2	217.1	228.3	6.3	47.4	OK
		8	1.15	4.62	3.46	79.0	14.6	273.5	288.1	7.9	46.2	OK
		9	1.73	4.62	4.04	81.9	18.5	330.9	349.4	9.6	45.1	OK
		10	2.31	4.62	4.62	84.2	22.8	389.0	411.8	11.3	43.9	OK
		11	2.89	4.62	5.20	86.1	27.6	447.6	475.2	13.1	42.7	OK
		12	3.46	4.62	5.77	87.7	32.9	506.5	539.4	14.8	41.6	OK

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 45°

		Skew	45									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	f_{bu}<F_{nc}
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W27	W27x84	7	0.71	5.66	3.54	75.2	15.8	265.9	281.7	15.9	44.8	OK
		8	1.41	5.66	4.24	79.0	20.6	335.0	355.6	20.0	43.3	OK
		9	2.12	5.66	4.95	81.9	26.1	405.3	431.4	24.3	41.8	OK
		10	2.83	5.66	5.66	84.2	32.3	476.4	508.7	28.7	40.3	OK
		11	3.54	5.66	6.36	86.1	39.0	548.1	587.2	33.1	38.7	OK
		12	4.24	5.66	7.07	87.7	46.5	620.3	666.8	37.6	37.2	NO GOOD
	W27x94	7	0.71	5.66	3.54	75.2	16.0	265.9	281.8	13.9	44.9	OK
		8	1.41	5.66	4.24	79.0	20.8	335.0	355.8	17.6	43.4	OK
		9	2.12	5.66	4.95	81.9	26.4	405.3	431.7	21.3	41.9	OK
		10	2.83	5.66	5.66	84.2	32.6	476.4	509.0	25.1	40.4	OK
		11	3.54	5.66	6.36	86.1	39.4	548.1	587.6	29.0	38.9	OK
		12	4.24	5.66	7.07	87.7	46.9	620.3	667.2	32.9	37.4	OK
	W27x114	7	0.71	5.66	3.54	75.2	16.3	265.9	282.1	11.3	45.1	OK
		8	1.41	5.66	4.24	79.0	21.2	335.0	356.2	14.3	43.6	OK
		9	2.12	5.66	4.95	81.9	26.9	405.3	432.2	17.3	42.2	OK
		10	2.83	5.66	5.66	84.2	33.2	476.4	509.6	20.5	40.7	OK
		11	3.54	5.66	6.36	86.1	40.2	548.1	588.3	23.6	39.2	OK
		12	4.24	5.66	7.07	87.7	47.8	620.3	668.1	26.8	37.7	OK
	W27x129	7	0.71	5.66	3.54	75.2	16.5	265.9	282.4	9.8	45.1	OK
		8	1.41	5.66	4.24	79.0	21.5	335.0	356.5	12.4	43.6	OK
		9	2.12	5.66	4.95	81.9	27.3	405.3	432.6	15.0	42.2	OK
		10	2.83	5.66	5.66	84.2	33.7	476.4	510.1	17.7	40.7	OK
		11	3.54	5.66	6.36	86.1	40.7	548.1	588.9	20.5	39.2	OK
		12	4.24	5.66	7.07	87.7	48.5	620.3	668.8	23.3	37.7	OK
	W27x146	7	0.71	5.66	3.54	75.2	16.8	265.9	282.6	8.2	48.2	OK
		8	1.41	5.66	4.24	79.0	21.9	335.0	356.9	10.3	47.2	OK
		9	2.12	5.66	4.95	81.9	27.7	405.3	433.0	12.6	46.1	OK
		10	2.83	5.66	5.66	84.2	34.2	476.4	510.6	14.8	45.1	OK
		11	3.54	5.66	6.36	86.1	41.4	548.1	589.5	17.1	44.1	OK
		12	4.24	5.66	7.07	87.7	49.2	620.3	669.6	19.4	43.0	OK
W30	W30x90	7	0.71	5.66	3.54	75.2	15.9	265.9	281.8	13.8	45.1	OK
		8	1.41	5.66	4.24	79.0	20.8	335.0	355.7	17.4	43.6	OK
		9	2.12	5.66	4.95	81.9	26.3	405.3	431.6	21.1	42.1	OK
		10	2.83	5.66	5.66	84.2	32.4	476.4	508.9	24.9	40.6	OK
		11	3.54	5.66	6.36	86.1	39.3	548.1	587.4	28.8	39.1	OK
		12	4.24	5.66	7.07	87.7	46.7	620.3	667.1	32.7	37.6	OK
	W30x108	7	0.71	5.66	3.54	75.2	16.2	265.9	282.0	11.3	45.3	OK
		8	1.41	5.66	4.24	79.0	21.1	335.0	356.1	14.3	43.8	OK
		9	2.12	5.66	4.95	81.9	26.7	405.3	432.0	17.3	42.3	OK
		10	2.83	5.66	5.66	84.2	33.0	476.4	509.4	20.4	40.9	OK
		11	3.54	5.66	6.36	86.1	39.9	548.1	588.1	23.6	39.4	OK
		12	4.24	5.66	7.07	87.7	47.5	620.3	667.9	26.8	38.0	OK
	W30x116	7	0.71	5.66	3.54	75.2	16.3	265.9	282.2	10.3	45.3	OK
		8	1.41	5.66	4.24	79.0	21.3	335.0	356.3	13.0	43.9	OK
		9	2.12	5.66	4.95	81.9	26.9	405.3	432.2	15.8	42.5	OK
		10	2.83	5.66	5.66	84.2	33.3	476.4	509.7	18.6	41.0	OK
		11	3.54	5.66	6.36	86.1	40.2	548.1	588.4	21.5	39.6	OK
		12	4.24	5.66	7.07	87.7	47.9	620.3	668.2	24.4	38.1	OK
	W30x124	7	0.71	5.66	3.54	75.2	16.4	265.9	282.3	9.5	45.4	OK
		8	1.41	5.66	4.24	79.0	21.4	335.0	356.4	12.0	44.0	OK
		9	2.12	5.66	4.95	81.9	27.1	405.3	432.4	14.6	42.5	OK
		10	2.83	5.66	5.66	84.2	33.5	476.4	509.9	17.2	41.1	OK
		11	3.54	5.66	6.36	86.1	40.5	548.1	588.7	19.9	39.7	OK
		12	4.24	5.66	7.07	87.7	48.3	620.3	668.6	22.6	38.2	OK
	W30x148	7	0.71	5.66	3.54	75.2	16.8	265.9	282.6	7.8	45.5	OK
		8	1.41	5.66	4.24	79.0	21.9	335.0	356.9	9.8	44.1	OK
		9	2.12	5.66	4.95	81.9	27.8	405.3	433.0	11.9	42.7	OK
		10	2.83	5.66	5.66	84.2	34.3	476.4	510.7	14.1	41.3	OK
		11	3.54	5.66	6.36	86.1	41.5	548.1	589.6	16.2	39.9	OK
		12	4.24	5.66	7.07	87.7	49.3	620.3	669.7	18.4	38.5	OK

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 50°

		Skew	50°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W27	W27x84	7	0.78	6.22	3.89	75.2	19.1	292.5	311.6	17.6	43.8	OK
		8	1.56	6.22	4.67	79.0	25.0	368.5	393.5	22.2	42.1	OK
		9	2.33	6.22	5.45	81.9	31.6	445.8	477.5	26.9	40.4	OK
		10	3.11	6.22	6.22	84.2	39.0	524.1	563.1	31.7	38.7	OK
		11	3.89	6.22	7.00	86.1	47.2	603.0	650.2	36.6	37.1	OK
		12	4.67	6.22	7.78	87.7	56.2	682.4	738.6	41.6	35.4	NO GOOD
	W27x94	7	0.78	6.22	3.89	75.2	19.3	292.5	311.8	15.4	43.9	OK
		8	1.56	6.22	4.67	79.0	25.2	368.5	393.7	19.4	42.2	OK
		9	2.33	6.22	5.45	81.9	31.9	445.8	477.8	23.6	40.6	OK
		10	3.11	6.22	6.22	84.2	39.4	524.1	563.5	27.8	38.9	OK
		11	3.89	6.22	7.00	86.1	47.7	603.0	650.7	32.1	37.3	OK
		12	4.67	6.22	7.78	87.7	56.8	682.4	739.2	36.5	35.6	NO GOOD
	W27x114	7	0.78	6.22	3.89	75.2	19.7	292.5	312.1	12.5	44.1	OK
		8	1.56	6.22	4.67	79.0	25.7	368.5	394.2	15.8	42.5	OK
		9	2.33	6.22	5.45	81.9	32.5	445.8	478.4	19.2	40.8	OK
		10	3.11	6.22	6.22	84.2	40.2	524.1	564.3	22.6	39.2	OK
		11	3.89	6.22	7.00	86.1	48.6	603.0	651.6	26.2	37.6	OK
		12	4.67	6.22	7.78	87.7	57.9	682.4	740.3	29.7	36.0	OK
	W27x129	7	0.78	6.22	3.89	75.2	20.0	292.5	312.4	10.9	44.1	OK
		8	1.56	6.22	4.67	79.0	26.1	368.5	394.6	13.7	42.4	OK
		9	2.33	6.22	5.45	81.9	33.0	445.8	478.8	16.7	40.8	OK
		10	3.11	6.22	6.22	84.2	40.7	524.1	564.8	19.6	39.2	OK
		11	3.89	6.22	7.00	86.1	49.3	603.0	652.3	22.7	37.6	OK
		12	4.67	6.22	7.78	87.7	58.7	682.4	741.1	25.8	35.9	OK
	W27x146	7	0.78	6.22	3.89	75.2	20.3	292.5	312.7	9.1	47.5	OK
		8	1.56	6.22	4.67	79.0	26.5	368.5	395.0	11.4	46.3	OK
		9	2.33	6.22	5.45	81.9	33.5	445.8	479.4	13.9	45.2	OK
		10	3.11	6.22	6.22	84.2	41.4	524.1	565.5	16.4	44.1	OK
		11	3.89	6.22	7.00	86.1	50.1	603.0	653.1	18.9	42.9	OK
		12	4.67	6.22	7.78	87.7	59.6	682.4	742.0	21.5	41.8	OK
W30	W30x90	7	0.78	6.22	3.89	75.2	19.2	292.5	311.7	15.3	44.0	OK
		8	1.56	6.22	4.67	79.0	25.1	368.5	393.6	19.3	42.4	OK
		9	2.33	6.22	5.45	81.9	31.8	445.8	477.6	23.4	40.7	OK
		10	3.11	6.22	6.22	84.2	39.3	524.1	563.4	27.6	39.1	OK
		11	3.89	6.22	7.00	86.1	47.5	603.0	650.5	31.9	37.5	OK
		12	4.67	6.22	7.78	87.7	56.5	682.4	738.9	36.2	35.8	NO GOOD
	W30x108	7	0.78	6.22	3.89	75.2	19.6	292.5	312.0	12.5	44.2	OK
		8	1.56	6.22	4.67	79.0	25.6	368.5	394.1	15.8	42.6	OK
		9	2.33	6.22	5.45	81.9	32.4	445.8	478.2	19.2	41.0	OK
		10	3.11	6.22	6.22	84.2	39.9	524.1	564.0	22.6	39.4	OK
		11	3.89	6.22	7.00	86.1	48.3	603.0	651.3	26.1	37.8	OK
		12	4.67	6.22	7.78	87.7	57.5	682.4	739.9	29.7	36.2	OK
	W30x116	7	0.78	6.22	3.89	75.2	19.7	292.5	312.2	11.4	44.3	OK
		8	1.56	6.22	4.67	79.0	25.8	368.5	394.3	14.4	42.8	OK
		9	2.33	6.22	5.45	81.9	32.6	445.8	478.4	17.5	41.2	OK
		10	3.11	6.22	6.22	84.2	40.2	524.1	564.3	20.6	39.6	OK
		11	3.89	6.22	7.00	86.1	48.7	603.0	651.7	23.8	38.0	OK
		12	4.67	6.22	7.78	87.7	58.0	682.4	740.4	27.0	36.4	OK
	W30x124	7	0.78	6.22	3.89	75.2	19.9	292.5	312.3	10.6	44.4	OK
		8	1.56	6.22	4.67	79.0	26.0	368.5	394.5	13.3	42.8	OK
		9	2.33	6.22	5.45	81.9	32.8	445.8	478.7	16.2	41.2	OK
		10	3.11	6.22	6.22	84.2	40.6	524.1	564.6	19.1	39.7	OK
		11	3.89	6.22	7.00	86.1	49.1	603.0	652.1	22.0	38.1	OK
		12	4.67	6.22	7.78	87.7	58.4	682.4	740.8	25.0	36.5	OK
	W30x148	7	0.78	6.22	3.89	75.2	20.3	292.5	312.8	8.6	44.6	OK
		8	1.56	6.22	4.67	79.0	26.5	368.5	395.0	10.9	43.0	OK
		9	2.33	6.22	5.45	81.9	33.6	445.8	479.4	13.2	41.4	OK
		10	3.11	6.22	6.22	84.2	41.5	524.1	565.5	15.6	39.9	OK
		11	3.89	6.22	7.00	86.1	50.2	603.0	653.2	18.0	38.3	OK
		12	4.67	6.22	7.78	87.7	59.7	682.4	742.1	20.4	36.8	OK

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 55°

		Skew	55°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	f_{bu}<F_{nc}
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W27	W27x84	7	0.87	6.97	4.36	75.2	24.0	327.7	351.8	19.8	42.3	OK
		8	1.74	6.97	5.23	79.0	31.4	413.0	444.3	25.0	40.5	OK
		9	2.62	6.97	6.10	81.9	39.7	499.6	539.3	30.4	38.6	OK
		10	3.49	6.97	6.97	84.2	49.0	587.3	636.4	35.9	36.7	OK
		11	4.36	6.97	7.85	86.1	59.3	675.8	735.1	41.4	34.5	NO GOOD
		12	5.23	6.97	8.72	87.7	70.6	764.7	835.3	47.1	29.0	NO GOOD
	W27x94	7	0.87	6.97	4.36	75.2	24.3	327.7	352.0	17.4	42.5	OK
		8	1.74	6.97	5.23	79.0	31.7	413.0	444.6	22.0	40.6	OK
		9	2.62	6.97	6.10	81.9	40.1	499.6	539.7	26.7	38.8	OK
		10	3.49	6.97	6.97	84.2	49.5	587.3	636.8	31.4	36.9	OK
		11	4.36	6.97	7.85	86.1	59.9	675.8	735.7	36.3	35.1	NO GOOD
		12	5.23	6.97	8.72	87.7	71.3	764.7	836.0	41.3	29.6	NO GOOD
	W27x114	7	0.87	6.97	4.36	75.2	24.7	327.7	352.5	14.1	42.7	OK
		8	1.74	6.97	5.23	79.0	32.3	413.0	445.3	17.9	40.9	OK
		9	2.62	6.97	6.10	81.9	40.9	499.6	540.5	21.7	39.1	OK
		10	3.49	6.97	6.97	84.2	50.5	587.3	637.8	25.6	37.3	OK
		11	4.36	6.97	7.85	86.1	61.0	675.8	736.8	29.6	35.4	OK
		12	5.23	6.97	8.72	87.7	72.7	764.7	837.4	33.6	30.7	NO GOOD
	W27x129	7	0.87	6.97	4.36	75.2	25.1	327.7	352.8	12.3	42.7	OK
		8	1.74	6.97	5.23	79.0	32.7	413.0	445.7	15.5	40.9	OK
		9	2.62	6.97	6.10	81.9	41.4	499.6	541.1	18.8	39.1	OK
		10	3.49	6.97	6.97	84.2	51.2	587.3	638.5	22.2	37.2	OK
		11	4.36	6.97	7.85	86.1	61.9	675.8	737.7	25.7	35.4	OK
		12	5.23	6.97	8.72	87.7	73.7	764.7	838.4	29.2	30.6	OK
	W27x146	7	0.87	6.97	4.36	75.2	25.5	327.7	353.2	10.2	46.5	OK
		8	1.74	6.97	5.23	79.0	33.3	413.0	446.2	12.9	45.2	OK
		9	2.62	6.97	6.10	81.9	42.1	499.6	541.7	15.7	44.0	OK
		10	3.49	6.97	6.97	84.2	52.0	587.3	639.3	18.5	42.7	OK
		11	4.36	6.97	7.85	86.1	62.9	675.8	738.6	21.4	41.4	OK
		12	5.23	6.97	8.72	87.7	74.8	764.7	839.6	24.3	40.1	OK
W30	W30x90	7	0.87	6.97	4.36	75.2	24.2	327.7	351.9	17.2	42.6	OK
		8	1.74	6.97	5.23	79.0	31.6	413.0	444.5	21.8	40.8	OK
		9	2.62	6.97	6.10	81.9	39.9	499.6	539.6	26.4	39.0	OK
		10	3.49	6.97	6.97	84.2	49.3	587.3	636.6	31.2	37.1	OK
		11	4.36	6.97	7.85	86.1	59.7	675.8	735.4	36.0	35.3	NO GOOD
		12	5.23	6.97	8.72	87.7	71.0	764.7	835.8	40.9	30.3	NO GOOD
	W30x108	7	0.87	6.97	4.36	75.2	24.6	327.7	352.3	14.1	42.9	OK
		8	1.74	6.97	5.23	79.0	32.1	413.0	445.1	17.9	41.1	OK
		9	2.62	6.97	6.10	81.9	40.6	499.6	540.3	21.7	39.3	OK
		10	3.49	6.97	6.97	84.2	50.2	587.3	637.5	25.6	37.5	OK
		11	4.36	6.97	7.85	86.1	60.7	675.8	736.5	29.6	35.7	OK
		12	5.23	6.97	8.72	87.7	72.2	764.7	837.0	33.6	31.6	NO GOOD
	W30x116	7	0.87	6.97	4.36	75.2	24.8	327.7	352.5	12.9	43.0	OK
		8	1.74	6.97	5.23	79.0	32.4	413.0	445.3	16.2	41.2	OK
		9	2.62	6.97	6.10	81.9	40.9	499.6	540.6	19.7	39.4	OK
		10	3.49	6.97	6.97	84.2	50.5	587.3	637.9	23.3	37.7	OK
		11	4.36	6.97	7.85	86.1	61.2	675.8	736.9	26.9	35.9	OK
		12	5.23	6.97	8.72	87.7	72.8	764.7	837.5	30.5	32.1	OK
	W30x124	7	0.87	6.97	4.36	75.2	25.0	327.7	352.7	11.9	43.1	OK
		8	1.74	6.97	5.23	79.0	32.6	413.0	445.6	15.1	41.3	OK
		9	2.62	6.97	6.10	81.9	41.3	499.6	540.9	18.3	39.5	OK
		10	3.49	6.97	6.97	84.2	50.9	587.3	638.3	21.6	37.8	OK
		11	4.36	6.97	7.85	86.1	61.6	675.8	737.4	24.9	36.0	OK
		12	5.23	6.97	8.72	87.7	73.3	764.7	838.1	28.3	32.5	OK
	W30x148	7	0.87	6.97	4.36	75.2	25.5	327.7	353.3	9.7	43.2	OK
		8	1.74	6.97	5.23	79.0	33.3	413.0	446.3	12.3	41.5	OK
		9	2.62	6.97	6.10	81.9	42.2	499.6	541.8	14.9	39.8	OK
		10	3.49	6.97	6.97	84.2	52.1	587.3	639.4	17.6	38.0	OK
		11	4.36	6.97	7.85	86.1	63.0	675.8	738.8	20.3	36.3	OK
		12	5.23	6.97	8.72	87.7	75.0	764.7	839.7	23.1	33.4	OK

Support Beam Design STR Calculations: 19" Finger Length w/ Skew 60°

		Skew	60°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{bu}	F_{nc}	$f_{bu}<F_{nc}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W27	W27x84	7	1.00	8.00	5.00	75.2	31.6	376.0	407.6	23.0	40.4	OK
		8	2.00	8.00	6.00	79.0	41.3	473.7	515.0	29.0	38.3	OK
		9	3.00	8.00	7.00	81.9	52.3	573.2	625.4	35.2	36.1	OK
		10	4.00	8.00	8.00	84.2	64.5	673.8	738.3	41.6	31.7	NO GOOD
		11	5.00	8.00	9.00	86.1	78.1	775.2	853.3	48.1	26.2	NO GOOD
		12	6.00	8.00	10.00	87.7	92.9	877.3	970.2	54.7	22.0	NO GOOD
	W27x94	7	1.00	8.00	5.00	75.2	31.9	376.0	407.9	20.1	40.6	OK
		8	2.00	8.00	6.00	79.0	41.7	473.7	515.4	25.5	38.4	OK
		9	3.00	8.00	7.00	81.9	52.8	573.2	625.9	30.9	36.3	OK
		10	4.00	8.00	8.00	84.2	65.1	673.8	738.9	36.5	32.4	NO GOOD
		11	5.00	8.00	9.00	86.1	78.8	775.2	854.0	42.2	26.8	NO GOOD
		12	6.00	8.00	10.00	87.7	93.8	877.3	971.1	48.0	22.5	NO GOOD
	W27x114	7	1.00	8.00	5.00	75.2	32.5	376.0	408.5	16.4	40.8	OK
		8	2.00	8.00	6.00	79.0	42.5	473.7	516.2	20.7	38.8	OK
		9	3.00	8.00	7.00	81.9	53.8	573.2	626.9	25.2	36.7	OK
		10	4.00	8.00	8.00	84.2	66.4	673.8	740.1	29.7	33.6	OK
		11	5.00	8.00	9.00	86.1	80.3	775.2	855.5	34.3	27.8	NO GOOD
		12	6.00	8.00	10.00	87.7	95.6	877.3	972.9	39.0	23.3	NO GOOD
	W27x129	7	1.00	8.00	5.00	75.2	33.0	376.0	409.0	14.2	40.8	OK
		8	2.00	8.00	6.00	79.0	43.1	473.7	516.8	18.0	38.7	OK
		9	3.00	8.00	7.00	81.9	54.5	573.2	627.7	21.8	36.6	OK
		10	4.00	8.00	8.00	84.2	67.3	673.8	741.1	25.8	33.5	OK
		11	5.00	8.00	9.00	86.1	81.5	775.2	856.7	29.8	27.7	NO GOOD
		12	6.00	8.00	10.00	87.7	97.0	877.3	974.2	33.9	23.3	NO GOOD
	W27x146	7	1.00	8.00	5.00	75.2	33.5	376.0	409.5	11.9	45.2	OK
		8	2.00	8.00	6.00	79.0	43.8	473.7	517.5	15.0	43.7	OK
		9	3.00	8.00	7.00	81.9	55.4	573.2	628.6	18.2	42.3	OK
		10	4.00	8.00	8.00	84.2	68.4	673.8	742.1	21.5	40.8	OK
		11	5.00	8.00	9.00	86.1	82.8	775.2	858.0	24.9	39.3	OK
		12	6.00	8.00	10.00	87.7	98.5	877.3	975.8	28.3	37.9	OK
W30	W30x90	7	1.00	8.00	5.00	75.2	31.8	376.0	407.8	20.0	40.7	OK
		8	2.00	8.00	6.00	79.0	41.5	473.7	515.3	25.2	38.7	OK
		9	3.00	8.00	7.00	81.9	52.6	573.2	625.7	30.6	36.6	OK
		10	4.00	8.00	8.00	84.2	64.9	673.8	738.6	36.2	33.2	NO GOOD
		11	5.00	8.00	9.00	86.1	78.5	775.2	853.7	41.8	27.4	NO GOOD
		12	6.00	8.00	10.00	87.7	93.4	877.3	970.7	47.5	23.1	NO GOOD
	W30x108	7	1.00	8.00	5.00	75.2	32.4	376.0	408.3	16.4	41.0	OK
		8	2.00	8.00	6.00	79.0	42.3	473.7	516.0	20.7	39.0	OK
		9	3.00	8.00	7.00	81.9	53.5	573.2	626.6	25.1	36.9	OK
		10	4.00	8.00	8.00	84.2	66.0	673.8	739.8	29.7	34.5	OK
		11	5.00	8.00	9.00	86.1	79.9	775.2	855.1	34.3	28.5	NO GOOD
		12	6.00	8.00	10.00	87.7	95.1	877.3	972.3	39.0	24.0	NO GOOD
	W30x116	7	1.00	8.00	5.00	75.2	32.6	376.0	408.6	14.9	41.2	OK
		8	2.00	8.00	6.00	79.0	42.6	473.7	516.3	18.8	39.1	OK
		9	3.00	8.00	7.00	81.9	53.9	573.2	627.0	22.9	37.1	OK
		10	4.00	8.00	8.00	84.2	66.5	673.8	740.3	27.0	35.0	OK
		11	5.00	8.00	9.00	86.1	80.5	775.2	855.7	31.2	29.1	NO GOOD
		12	6.00	8.00	10.00	87.7	95.8	877.3	973.1	35.5	24.4	NO GOOD
	W30x124	7	1.00	8.00	5.00	75.2	32.8	376.0	408.8	13.8	41.3	OK
		8	2.00	8.00	6.00	79.0	42.9	473.7	516.6	17.5	39.2	OK
		9	3.00	8.00	7.00	81.9	54.3	573.2	627.4	21.2	37.2	OK
		10	4.00	8.00	8.00	84.2	67.0	673.8	740.8	25.0	35.2	OK
		11	5.00	8.00	9.00	86.1	81.1	775.2	856.3	28.9	29.4	OK
		12	6.00	8.00	10.00	87.7	96.5	877.3	973.8	32.9	24.7	NO GOOD
	W30x148	7	1.00	8.00	5.00	75.2	33.6	376.0	409.6	11.3	41.4	OK
		8	2.00	8.00	6.00	79.0	43.9	473.7	517.6	14.2	39.4	OK
		9	3.00	8.00	7.00	81.9	55.5	573.2	628.7	17.3	37.4	OK
		10	4.00	8.00	8.00	84.2	68.5	673.8	742.3	20.4	35.4	OK
		11	5.00	8.00	9.00	86.1	82.9	775.2	858.1	23.6	30.2	OK
		12	6.00	8.00	10.00	87.7	98.7	877.3	975.9	26.9	25.4	NO GOOD

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 0°

		Skew	0°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W16	W16x57	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	5.6	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	7.0	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	8.5	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	10.0	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	11.5	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	13.0	16.0	OK
	W16x67	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	4.4	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	5.6	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	6.7	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	7.9	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	9.1	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	10.3	16.0	OK
	W16x77	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	3.8	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	4.8	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	5.9	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	6.9	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	7.9	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	9.0	16.0	OK
	W16x89	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	3.3	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	4.2	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	5.1	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	6.0	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	6.9	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	7.8	16.0	OK
	W16x100	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	2.9	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	3.7	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	4.5	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	5.3	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	6.1	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	6.9	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 15°

		Skew	15°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W16	W16x57	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	5.8	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	7.3	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	8.8	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	10.4	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	11.9	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	13.5	16.0	OK
	W16x67	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	4.6	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	5.7	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	7.0	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	8.2	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	9.4	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	10.6	16.0	OK
	W16x77	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	4.0	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	5.0	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	6.1	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	7.1	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	8.2	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	9.3	16.0	OK
	W16x89	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	3.4	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	4.3	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	5.3	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	6.2	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	7.1	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	8.0	16.0	OK
	W16x100	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	3.1	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	3.8	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	4.7	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	5.5	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	6.3	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	7.1	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 30°

		Skew	30°										
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$	
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check	
W16	W16x57	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	6.5	16.0	OK	
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	8.1	16.0	OK	
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	9.8	16.0	OK	
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	11.6	16.0	OK	
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	13.3	16.0	OK	
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	15.1	16.0	OK	
	W16x67	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	5.1	16.0	OK	
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	6.4	16.0	OK	
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	7.8	16.0	OK	
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	9.1	16.0	OK	
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	10.5	16.0	OK	
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	11.9	16.0	OK	
	W16x77	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	4.4	16.0	OK	
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	5.6	16.0	OK	
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	6.8	16.0	OK	
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	8.0	16.0	OK	
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	9.2	16.0	OK	
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	10.4	16.0	OK	
	W16x89	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	3.8	16.0	OK	
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	4.8	16.0	OK	
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	5.9	16.0	OK	
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	6.9	16.0	OK	
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	7.9	16.0	OK	
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	9.0	16.0	OK	
	W16x100	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	3.4	16.0	OK	
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	4.3	16.0	OK	
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	5.2	16.0	OK	
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	6.1	16.0	OK	
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	7.0	16.0	OK	
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	7.9	16.0	OK	

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 45°

		Skew	45°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W16	W16x57	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	7.9	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	10.0	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	12.1	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	14.2	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	16.3	16.0	NO GOOD
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	18.5	16.0	NO GOOD
	W16x67	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	6.2	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	7.9	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	9.5	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	11.2	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	12.9	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	14.5	16.0	OK
	W16x77	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	5.4	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	6.9	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	8.3	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	9.8	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	11.2	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	12.7	16.0	OK
	W16x89	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	4.7	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	5.9	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	7.2	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	8.4	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	9.7	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	11.0	16.0	OK
	W16x100	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	4.2	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	5.3	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	6.4	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	7.5	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	8.6	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	9.7	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 50°

		Skew	50°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W16	W16x57	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	8.7	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	11.0	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	13.3	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	15.6	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	17.9	16.0	NO GOOD
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	20.3	16.0	NO GOOD
	W16x67	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	6.9	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	8.6	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	10.5	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	12.3	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	14.1	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	16.0	16.0	OK
	W16x77	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	6.0	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	7.5	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	9.1	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	10.7	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	12.3	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	14.0	16.0	OK
	W16x89	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	5.2	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	6.5	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	7.9	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	9.3	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	10.7	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	12.1	16.0	OK
	W16x100	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	4.6	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	5.8	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	7.0	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	8.2	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	9.5	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	10.7	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 55°

		Skew	55°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W16	W16x57	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	9.8	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	12.3	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	14.9	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	17.5	16.0	NO GOOD
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	20.1	16.0	NO GOOD
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	22.8	16.0	NO GOOD
	W16x67	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	7.7	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	9.7	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	11.7	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	13.8	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	15.8	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	17.9	16.0	NO GOOD
	W16x77	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	6.7	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	8.5	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	10.2	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	12.0	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	13.8	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	15.7	16.0	OK
	W16x89	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	5.8	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	7.3	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	8.8	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	10.4	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	12.0	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	13.5	16.0	OK
	W16x100	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	5.1	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	6.5	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	7.8	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	9.2	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	10.6	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	12.0	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 60°

		Skew	60°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W16	W16x57	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	11.2	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	14.1	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	17.1	16.0	NO GOOD
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	20.0	16.0	NO GOOD
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	23.1	16.0	NO GOOD
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	26.1	16.0	NO GOOD
	W16x67	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	8.8	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	11.1	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	13.4	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	15.8	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	18.2	16.0	NO GOOD
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	20.6	16.0	NO GOOD
	W16x77	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	7.7	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	9.7	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	11.7	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	13.8	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	15.9	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	18.0	16.0	NO GOOD
	W16x89	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	6.7	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	8.4	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	10.1	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	11.9	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	13.7	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	15.5	16.0	OK
	W16x100	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	5.9	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	7.4	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	9.0	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	10.6	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	12.2	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	13.8	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 0°

		Skew	0°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W18	W18x50	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	5.8	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	7.3	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	8.8	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	10.4	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	12.0	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	13.5	16.0	OK
	W18x55	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	5.2	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	6.6	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	8.0	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	9.4	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	10.8	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	12.2	16.0	OK
	W18x60	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	4.8	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	6.0	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	7.3	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	8.6	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	9.8	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	11.1	16.0	OK
	W18x65	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	4.4	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	5.6	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	6.7	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	7.9	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	9.1	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	10.3	16.0	OK
	W18x71	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	4.1	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	5.1	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	6.2	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	7.3	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	8.4	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	9.5	16.0	OK
	W18x76	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	3.5	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	4.4	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	5.4	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	6.3	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	7.3	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	8.2	16.0	OK
	W18x86	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	3.1	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	3.9	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	4.7	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	5.6	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	6.4	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	7.2	16.0	OK
	W18x97	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	2.7	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	3.5	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	4.2	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	4.9	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	5.7	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	6.4	16.0	OK
	W18x106	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	2.5	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	3.2	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	3.9	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	4.5	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	5.2	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	5.9	16.0	OK

Project:	MoDOT Finger/Flat Plate Eval	Computed:	MTW	Date:	11/4/2015
Subject:	New Finger Plate Design	Checked:	DGB	Date:	12/3/2015
Task:	Support Beam Design	Page:	49	of:	SUPPORT
Job #:	244663	No:			

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 15°

		Skew	15°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W18	W18x50	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	6.0	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	7.6	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	9.2	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	10.8	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	12.4	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	14.0	16.0	OK
	W18x55	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	5.4	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	6.8	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	8.3	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	9.7	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	11.2	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	12.7	16.0	OK
	W18x60	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	4.9	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	6.2	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	7.5	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	8.9	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	10.2	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	11.5	16.0	OK
	W18x65	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	4.6	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	5.7	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	7.0	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	8.2	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	9.4	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	10.6	16.0	OK
	W18x71	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	4.2	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	5.3	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	6.4	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	7.5	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	8.7	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	9.8	16.0	OK
	W18x76	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	3.7	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	4.6	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	5.6	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	6.6	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	7.5	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	8.5	16.0	OK
	W18x86	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	3.2	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	4.1	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	4.9	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	5.8	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	6.6	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	7.5	16.0	OK
	W18x97	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	2.8	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	3.6	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	4.3	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	5.1	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	5.9	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	6.6	16.0	OK
	W18x106	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	2.6	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	3.3	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	4.0	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	4.7	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	5.4	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	6.1	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 30°

		Skew	30°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W18	W18x50	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	6.7	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	8.4	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	10.2	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	12.0	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	13.8	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	15.6	16.0	OK
	W18x55	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	6.1	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	7.6	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	9.2	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	10.9	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	12.5	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	14.1	16.0	OK
	W18x60	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	5.5	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	6.9	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	8.4	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	9.9	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	11.4	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	12.9	16.0	OK
	W18x65	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	5.1	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	6.4	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	7.8	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	9.1	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	10.5	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	11.9	16.0	OK
	W18x71	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	4.7	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	5.9	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	7.1	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	8.4	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	9.7	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	10.9	16.0	OK
	W18x76	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	4.1	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	5.1	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	6.2	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	7.3	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	8.4	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	9.5	16.0	OK
	W18x86	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	3.6	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	4.5	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	5.5	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	6.4	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	7.4	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	8.4	16.0	OK
	W18x97	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	3.2	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	4.0	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	4.8	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	5.7	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	6.5	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	7.4	16.0	OK
	W18x106	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	2.9	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	3.7	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	4.4	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	5.2	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	6.0	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	6.8	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 45°

		Skew	45°										
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W18	W18x50	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	8.2	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	10.3	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	12.5	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	14.7	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	16.9	16.0	NO GOOD
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	19.1	16.0	NO GOOD
	W18x55	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	7.4	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	9.3	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	11.3	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	13.3	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	15.3	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	17.3	16.0	NO GOOD
	W18x60	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	6.8	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	8.5	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	10.3	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	12.1	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	13.9	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	15.8	16.0	OK
	W18x65	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	6.2	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	7.9	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	9.5	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	11.2	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	12.9	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	14.5	16.0	OK
	W18x71	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	5.7	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	7.2	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	8.8	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	10.3	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	11.8	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	13.4	16.0	OK
	W18x76	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	5.0	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	6.3	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	7.6	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	9.0	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	10.3	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	11.7	16.0	OK
	W18x86	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	4.4	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	5.5	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	6.7	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	7.9	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	9.1	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	10.2	16.0	OK
	W18x97	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	3.9	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	4.9	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	5.9	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	7.0	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	8.0	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	9.1	16.0	OK
	W18x106	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	3.6	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	4.5	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	5.4	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	6.4	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	7.4	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	8.3	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 50°

		Skew	50°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W18	W18x50	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	9.0	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	11.4	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	13.8	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	16.2	16.0	NO GOOD
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	18.6	16.0	NO GOOD
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	21.1	16.0	NO GOOD
	W18x55	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	8.2	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	10.3	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	12.4	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	14.6	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	16.8	16.0	NO GOOD
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	19.0	16.0	NO GOOD
	W18x60	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	7.4	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	9.4	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	11.3	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	13.3	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	15.3	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	17.3	16.0	NO GOOD
	W18x65	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	6.9	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	8.6	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	10.5	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	12.3	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	14.1	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	16.0	16.0	OK
	W18x71	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	6.3	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	8.0	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	9.6	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	11.3	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	13.0	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	14.7	16.0	OK
	W18x76	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	5.5	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	6.9	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	8.4	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	9.8	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	11.3	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	12.8	16.0	OK
	W18x86	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	4.8	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	6.1	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	7.4	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	8.7	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	10.0	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	11.3	16.0	OK
	W18x97	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	4.3	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	5.4	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	6.5	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	7.6	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	8.8	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	10.0	16.0	OK
	W18x106	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	3.9	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	5.0	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	6.0	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	7.0	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	8.1	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	9.2	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 55°

		Skew	55°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W18	W18x50	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	10.1	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	12.7	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	15.4	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	18.1	16.0	NO GOOD
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	20.8	16.0	NO GOOD
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	23.6	16.0	NO GOOD
	W18x55	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	9.1	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	11.5	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	13.9	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	16.4	16.0	NO GOOD
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	18.9	16.0	NO GOOD
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	21.3	16.0	NO GOOD
	W18x60	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	8.3	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	10.5	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	12.7	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	14.9	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	17.2	16.0	NO GOOD
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	19.4	16.0	NO GOOD
	W18x65	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	7.7	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	9.7	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	11.7	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	13.8	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	15.8	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	17.9	16.0	NO GOOD
	W18x71	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	7.1	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	8.9	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	10.8	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	12.7	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	14.6	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	16.5	16.0	NO GOOD
	W18x76	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	6.2	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	7.8	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	9.4	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	11.0	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	12.7	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	14.4	16.0	OK
	W18x86	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	5.4	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	6.8	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	8.3	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	9.7	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	11.2	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	12.6	16.0	OK
	W18x97	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	4.8	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	6.0	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	7.3	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	8.6	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	9.9	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	11.2	16.0	OK
	W18x106	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	4.4	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	5.6	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	6.7	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	7.9	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	9.1	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	10.3	16.0	OK

HDR

Project:	MoDOT Finger/Flat Plate Eval	Computed:	MTW	Date:	11/4/2015
Subject:	New Finger Plate Design	Checked:	DGB	Date:	12/3/2015
Task:	Support Beam Design	Page:	54	of:	SUPPORT
Job #:	244663	No:			

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 60°

		Skew	60°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W18	W18x50	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	11.6	16.0	OK
W18	W18x50	8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	14.6	16.0	OK
W18	W18x50	9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	17.7	16.0	NO GOOD
W18	W18x50	10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	20.8	16.0	NO GOOD
W18	W18x50	11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	23.9	16.0	NO GOOD
W18	W18x50	12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	27.1	16.0	NO GOOD
W18	W18x55	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	10.5	16.0	OK
W18	W18x55	8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	13.2	16.0	OK
W18	W18x55	9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	16.0	16.0	OK
W18	W18x55	10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	18.8	16.0	NO GOOD
W18	W18x55	11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	21.6	16.0	NO GOOD
W18	W18x55	12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	24.5	16.0	NO GOOD
W18	W18x60	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	9.5	16.0	OK
W18	W18x60	8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	12.0	16.0	OK
W18	W18x60	9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	14.6	16.0	OK
W18	W18x60	10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	17.1	16.0	NO GOOD
W18	W18x60	11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	19.7	16.0	NO GOOD
W18	W18x60	12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	22.3	16.0	NO GOOD
W18	W18x65	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	8.8	16.0	OK
W18	W18x65	8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	11.1	16.0	OK
W18	W18x65	9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	13.4	16.0	OK
W18	W18x65	10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	15.8	16.0	OK
W18	W18x65	11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	18.2	16.0	NO GOOD
W18	W18x65	12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	20.6	16.0	NO GOOD
W18	W18x71	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	8.1	16.0	OK
W18	W18x71	8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	10.2	16.0	OK
W18	W18x71	9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	12.4	16.0	OK
W18	W18x71	10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	14.6	16.0	OK
W18	W18x71	11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	16.7	16.0	NO GOOD
W18	W18x71	12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	18.9	16.0	NO GOOD
W18	W18x76	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	7.1	16.0	OK
W18	W18x76	8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	8.9	16.0	OK
W18	W18x76	9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	10.8	16.0	OK
W18	W18x76	10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	12.7	16.0	OK
W18	W18x76	11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	14.6	16.0	OK
W18	W18x76	12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	16.5	16.0	NO GOOD
W18	W18x86	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	6.2	16.0	OK
W18	W18x86	8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	7.8	16.0	OK
W18	W18x86	9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	9.5	16.0	OK
W18	W18x86	10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	11.1	16.0	OK
W18	W18x86	11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	12.8	16.0	OK
W18	W18x86	12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	14.5	16.0	OK
W18	W18x97	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	5.5	16.0	OK
W18	W18x97	8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	6.9	16.0	OK
W18	W18x97	9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	8.4	16.0	OK
W18	W18x97	10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	9.8	16.0	OK
W18	W18x97	11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	11.3	16.0	OK
W18	W18x97	12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	12.8	16.0	OK
W18	W18x106	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	5.1	16.0	OK
W18	W18x106	8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	6.4	16.0	OK
W18	W18x106	9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	7.7	16.0	OK
W18	W18x106	10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	9.1	16.0	OK
W18	W18x106	11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	10.4	16.0	OK
W18	W18x106	12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	11.8	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 0°

		Skew	0°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W21	W21x55	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	4.7	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	5.9	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	7.1	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	8.4	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	9.7	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	10.9	16.0	OK
	W21x62	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	4.1	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	5.1	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	6.2	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	7.3	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	8.4	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	9.5	16.0	OK
	W21x68	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	3.7	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	4.6	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	5.6	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	6.6	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	7.6	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	8.6	16.0	OK
	W21x73	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	3.4	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	4.3	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	5.2	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	6.1	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	7.0	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	8.0	16.0	OK
	W21x83	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	3.0	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	3.8	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	4.6	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	5.4	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	6.2	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	7.0	16.0	OK
	W21x93	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	2.7	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	3.4	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	4.1	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	4.8	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	5.5	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	6.3	16.0	OK
	W21x101	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	2.3	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	2.9	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	3.5	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	4.1	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	4.7	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	5.3	16.0	OK
	W21x111	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	2.1	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	2.6	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	3.2	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	3.7	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	4.3	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	4.8	16.0	OK
	W21x122	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	1.9	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	2.4	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	2.9	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	3.4	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	3.9	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	4.4	16.0	OK
	W21x132	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	1.7	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	2.2	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	2.7	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	3.1	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	3.6	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	4.1	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 15°

		Skew	15°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W21	W21x55	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	4.9	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	6.1	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	7.4	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	8.7	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	10.0	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	11.3	16.0	OK
	W21x62	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	4.2	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	5.3	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	6.4	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	7.5	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	8.7	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	9.8	16.0	OK
	W21x68	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	3.8	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	4.8	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	5.8	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	6.8	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	7.9	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	8.9	16.0	OK
	W21x73	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	3.5	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	4.5	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	5.4	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	6.3	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	7.3	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	8.2	16.0	OK
	W21x83	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	3.1	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	3.9	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	4.8	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	5.6	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	6.4	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	7.3	16.0	OK
	W21x93	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	2.8	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	3.5	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	4.2	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	5.0	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	5.7	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	6.5	16.0	OK
	W21x101	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	2.4	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	3.0	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	3.6	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	4.2	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	4.8	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	5.5	16.0	OK
	W21x111	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	2.1	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	2.7	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	3.3	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	3.8	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	4.4	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	5.0	16.0	OK
	W21x122	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	2.0	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	2.5	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	3.0	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	3.5	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	4.0	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	4.6	16.0	OK
	W21x132	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	1.8	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	2.3	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	2.8	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	3.2	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	3.7	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	4.2	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 30°

		Skew	30°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W21	W21x55	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	5.4	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	6.8	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	8.3	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	9.7	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	11.2	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	12.6	16.0	OK
	W21x62	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	4.7	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	5.9	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	7.1	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	8.4	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	9.7	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	10.9	16.0	OK
	W21x68	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	4.3	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	5.4	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	6.5	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	7.6	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	8.8	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	9.9	16.0	OK
	W21x73	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	3.9	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	5.0	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	6.0	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	7.1	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	8.1	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	9.2	16.0	OK
	W21x83	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	3.5	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	4.4	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	5.3	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	6.2	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	7.2	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	8.1	16.0	OK
	W21x93	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	3.1	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	3.9	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	4.7	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	5.6	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	6.4	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	7.2	16.0	OK
	W21x101	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	2.6	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	3.3	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	4.0	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	4.7	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	5.4	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	6.1	16.0	OK
	W21x111	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	2.4	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	3.0	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	3.6	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	4.3	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	4.9	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	5.6	16.0	OK
	W21x122	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	2.2	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	2.7	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	3.3	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	3.9	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	4.5	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	5.1	16.0	OK
	W21x132	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	2.0	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	2.5	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	3.1	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	3.6	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	4.2	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	4.7	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 45°

		Skew	45°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W21	W21x55	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	6.6	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	8.4	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	10.1	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	11.9	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	13.7	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	15.5	16.0	OK
	W21x62	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	5.7	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	7.2	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	8.8	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	10.3	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	11.8	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	13.4	16.0	OK
	W21x68	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	5.2	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	6.6	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	7.9	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	9.3	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	10.7	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	12.2	16.0	OK
	W21x73	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	4.8	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	6.1	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	7.4	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	8.7	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	10.0	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	11.3	16.0	OK
	W21x83	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	4.3	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	5.4	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	6.5	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	7.6	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	8.8	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	10.0	16.0	OK
	W21x93	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	3.8	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	4.8	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	5.8	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	6.8	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	7.8	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	8.9	16.0	OK
	W21x101	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	3.2	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	4.0	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	4.9	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	5.8	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	6.6	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	7.5	16.0	OK
	W21x111	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	2.9	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	3.7	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	4.5	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	5.2	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	6.0	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	6.8	16.0	OK
	W21x122	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	2.7	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	3.4	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	4.1	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	4.8	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	5.5	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	6.2	16.0	OK
	W21x132	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	2.5	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	3.1	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	3.8	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	4.4	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	5.1	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	5.8	16.0	OK

Project:	MoDOT Finger/Flat Plate Eval	Compute:	MTW	Date:	11/4/2015
Subject:	New Finger Plate Design	Checked:	DGB	Date:	12/3/2015
Task:	Support Beam Design	Page:	59	of:	SUPPORT
Job #:	244663	No:			

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 50°

		Skew	50°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W21	W21x55	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	7.3	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	9.2	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	11.1	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	13.1	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	15.0	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	17.0	16.0	NO GOOD
	W21x62	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	6.3	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	8.0	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	9.6	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	11.3	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	13.0	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	14.7	16.0	OK
	W21x68	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	5.7	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	7.2	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	8.7	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	10.3	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	11.8	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	13.4	16.0	OK
	W21x73	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	5.3	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	6.7	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	8.1	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	9.5	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	11.0	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	12.4	16.0	OK
	W21x83	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	4.7	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	5.9	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	7.2	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	8.4	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	9.7	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	10.9	16.0	OK
	W21x93	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	4.2	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	5.3	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	6.4	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	7.5	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	8.6	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	9.7	16.0	OK
	W21x101	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	3.5	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	4.5	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	5.4	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	6.3	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	7.3	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	8.2	16.0	OK
	W21x111	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	3.2	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	4.1	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	4.9	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	5.8	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	6.6	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	7.5	16.0	OK
	W21x122	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	2.9	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	3.7	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	4.5	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	5.3	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	6.1	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	6.9	16.0	OK
	W21x132	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	2.7	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	3.4	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	4.1	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	4.9	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	5.6	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	6.3	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 55°

		Skew	55°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W21	W21x55	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	8.2	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	10.3	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	12.5	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	14.6	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	16.9	16.0	NO GOOD
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	19.1	16.0	NO GOOD
	W21x62	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	7.1	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	8.9	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	10.8	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	12.7	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	14.6	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	16.5	16.0	NO GOOD
	W21x68	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	6.4	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	8.1	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	9.8	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	11.5	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	13.2	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	15.0	16.0	OK
	W21x73	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	6.0	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	7.5	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	9.1	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	10.7	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	12.3	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	13.9	16.0	OK
	W21x83	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	5.3	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	6.6	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	8.0	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	9.4	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	10.8	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	12.3	16.0	OK
	W21x93	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	4.7	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	5.9	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	7.1	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	8.4	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	9.7	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	10.9	16.0	OK
	W21x101	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	4.0	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	5.0	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	6.0	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	7.1	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	8.2	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	9.2	16.0	OK
	W21x111	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	3.6	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	4.5	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	5.5	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	6.5	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	7.4	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	8.4	16.0	OK
	W21x122	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	3.3	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	4.1	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	5.0	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	5.9	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	6.8	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	7.7	16.0	OK
	W21x132	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	3.0	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	3.8	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	4.6	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	5.5	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	6.3	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	7.1	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 60°

		Skew	60°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W21	W21x55	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	9.4	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	11.8	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	14.3	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	16.8	16.0	NO GOOD
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	19.3	16.0	NO GOOD
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	21.9	16.0	NO GOOD
	W21x62	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	8.1	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	10.2	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	12.4	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	14.6	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	16.7	16.0	NO GOOD
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	18.9	16.0	NO GOOD
	W21x68	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	7.4	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	9.3	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	11.2	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	13.2	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	15.2	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	17.2	16.0	NO GOOD
	W21x73	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	6.8	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	8.6	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	10.4	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	12.2	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	14.1	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	15.9	16.0	OK
	W21x83	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	6.0	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	7.6	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	9.2	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	10.8	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	12.4	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	14.1	16.0	OK
	W21x93	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	5.4	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	6.8	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	8.2	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	9.6	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	11.1	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	12.5	16.0	OK
	W21x101	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	4.5	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	5.7	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	6.9	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	8.1	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	9.4	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	10.6	16.0	OK
	W21x111	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	4.1	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	5.2	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	6.3	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	7.4	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	8.5	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	9.7	16.0	OK
	W21x122	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	3.8	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	4.8	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	5.8	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	6.8	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	7.8	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	8.8	16.0	OK
	W21x132	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	3.5	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	4.4	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	5.3	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	6.3	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	7.2	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	8.2	16.0	OK

Project:	MoDOT Finger/Flat Plate Eval	Computed:	MTW	Date:	11/4/2015
Subject:	New Finger Plate Design	Checked:	DGB	Date:	12/3/2015
Task:	Support Beam Design	Page:	62	of:	SUPPORT
Job #:	244663	No:			

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 0°

		Skew	0°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W24	W24x55	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	4.5	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	5.7	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	6.9	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	8.1	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	9.3	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	10.6	16.0	OK
	W24x62	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	3.9	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	5.0	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	6.0	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	7.1	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	8.1	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	9.2	16.0	OK
	W24x68	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	3.3	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	4.2	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	5.1	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	6.0	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	6.9	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	7.8	16.0	OK
	W24x76	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	2.9	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	3.7	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	4.5	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	5.3	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	6.0	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	6.8	16.0	OK
	W24x84	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	2.6	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	3.3	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	4.0	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	4.7	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	5.4	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	6.1	16.0	OK
	W24x94	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	2.3	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	2.9	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	3.5	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	4.2	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	4.8	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	5.4	16.0	OK
	W24x103	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	2.1	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	2.7	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	3.2	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	3.8	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	4.3	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	4.9	16.0	OK
	W24x104	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	2.0	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	2.5	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	3.0	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	3.6	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	4.1	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	4.7	16.0	OK
	W24x117	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	1.8	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	2.2	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	2.7	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	3.2	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	3.7	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	4.1	16.0	OK
	W24x131	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	1.6	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	2.0	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	2.4	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	2.8	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	3.2	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	3.7	16.0	OK
	W24x146	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	1.4	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	1.8	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	2.1	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	2.5	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	2.9	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	3.2	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 15°

		Skew	15°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W24	W24x55	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	4.7	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	5.9	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	7.1	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	8.4	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	9.7	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	10.9	16.0	OK
	W24x62	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	4.1	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	5.1	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	6.2	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	7.3	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	8.4	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	9.5	16.0	OK
	W24x68	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	3.5	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	4.4	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	5.3	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	6.2	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	7.1	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	8.1	16.0	OK
	W24x76	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	3.0	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	3.8	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	4.6	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	5.4	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	6.3	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	7.1	16.0	OK
	W24x84	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	2.7	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	3.4	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	4.2	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	4.9	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	5.6	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	6.4	16.0	OK
	W24x94	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	2.4	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	3.0	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	3.7	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	4.3	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	5.0	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	5.6	16.0	OK
	W24x103	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	2.2	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	2.7	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	3.3	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	3.9	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	4.5	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	5.1	16.0	OK
	W24x104	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	2.1	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	2.6	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	3.2	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	3.7	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	4.3	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	4.8	16.0	OK
	W24x117	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	1.8	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	2.3	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	2.8	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	3.3	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	3.8	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	4.3	16.0	OK
	W24x131	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	1.6	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	2.0	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	2.5	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	2.9	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	3.3	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	3.8	16.0	OK
	W24x146	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	1.4	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	1.8	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	2.2	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	2.6	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	3.0	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	3.4	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 30°

		Skew	30°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W24	W24x55	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	5.2	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	6.6	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	8.0	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	9.4	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	10.8	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	12.2	16.0	OK
	W24x62	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	4.5	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	5.7	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	6.9	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	8.1	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	9.4	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	10.6	16.0	OK
	W24x68	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	3.9	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	4.9	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	5.9	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	6.9	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	8.0	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	9.0	16.0	OK
	W24x76	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	3.4	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	4.3	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	5.2	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	6.1	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	7.0	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	7.9	16.0	OK
	W24x84	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	3.0	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	3.8	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	4.6	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	5.4	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	6.3	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	7.1	16.0	OK
	W24x94	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	2.7	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	3.4	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	4.1	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	4.8	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	5.5	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	6.3	16.0	OK
	W24x103	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	2.4	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	3.1	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	3.7	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	4.4	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	5.0	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	5.7	16.0	OK
	W24x104	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	2.3	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	2.9	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	3.5	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	4.1	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	4.8	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	5.4	16.0	OK
	W24x117	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	2.0	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	2.6	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	3.1	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	3.7	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	4.2	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	4.8	16.0	OK
	W24x131	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	1.8	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	2.3	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	2.8	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	3.2	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	3.7	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	4.2	16.0	OK
	W24x146	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	1.6	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	2.0	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	2.4	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	2.9	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	3.3	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	3.7	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 45°

		Skew	45°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W24	W24x55	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	6.4	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	8.1	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	9.8	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	11.5	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	13.2	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	14.9	16.0	OK
	W24x62	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	5.6	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	7.0	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	8.5	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	10.0	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	11.5	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	13.0	16.0	OK
	W24x68	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	4.7	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	6.0	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	7.2	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	8.5	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	9.8	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	11.0	16.0	OK
	W24x76	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	4.1	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	5.2	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	6.3	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	7.4	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	8.5	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	9.7	16.0	OK
	W24x84	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	3.7	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	4.7	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	5.7	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	6.7	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	7.7	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	8.7	16.0	OK
	W24x94	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	3.3	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	4.1	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	5.0	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	5.9	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	6.8	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	7.7	16.0	OK
	W24x103	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	3.0	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	3.8	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	4.5	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	5.3	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	6.1	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	6.9	16.0	OK
	W24x104	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	2.8	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	3.6	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	4.3	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	5.1	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	5.8	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	6.6	16.0	OK
	W24x117	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	2.5	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	3.2	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	3.8	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	4.5	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	5.2	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	5.8	16.0	OK
	W24x131	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	2.2	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	2.8	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	3.4	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	4.0	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	4.6	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	5.2	16.0	OK
	W24x146	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	2.0	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	2.5	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	3.0	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	3.5	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	4.1	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	4.6	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 50°

		Skew	50°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W24	W24x55	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	7.0	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	8.9	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	10.7	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	12.6	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	14.5	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	16.4	16.0	NO GOOD
	W24x62	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	6.1	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	7.7	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	9.3	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	11.0	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	12.6	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	14.3	16.0	OK
	W24x68	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	5.2	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	6.6	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	7.9	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	9.3	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	10.7	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	12.2	16.0	OK
	W24x76	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	4.6	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	5.7	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	6.9	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	8.2	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	9.4	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	10.6	16.0	OK
	W24x84	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	4.1	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	5.2	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	6.2	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	7.3	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	8.4	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	9.5	16.0	OK
	W24x94	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	3.6	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	4.6	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	5.5	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	6.5	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	7.5	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	8.4	16.0	OK
	W24x103	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	3.3	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	4.1	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	5.0	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	5.9	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	6.8	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	7.6	16.0	OK
	W24x104	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	3.1	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	3.9	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	4.7	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	5.6	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	6.4	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	7.3	16.0	OK
	W24x117	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	2.8	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	3.5	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	4.2	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	4.9	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	5.7	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	6.4	16.0	OK
	W24x131	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	2.4	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	3.1	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	3.7	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	4.4	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	5.0	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	5.7	16.0	OK
	W24x146	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	2.2	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	2.7	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	3.3	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	3.9	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	4.5	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	5.0	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 55°

		Skew	55°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W24	W24x55	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	7.9	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	9.9	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	12.0	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	14.1	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	16.3	16.0	NO GOOD
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	18.4	16.0	NO GOOD
	W24x62	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	6.9	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	8.6	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	10.5	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	12.3	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	14.1	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	16.0	16.0	NO GOOD
	W24x68	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	5.8	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	7.4	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	8.9	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	10.5	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	12.0	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	13.6	16.0	OK
	W24x76	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	5.1	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	6.4	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	7.8	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	9.2	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	10.5	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	11.9	16.0	OK
	W24x84	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	4.6	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	5.8	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	7.0	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	8.2	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	9.5	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	10.7	16.0	OK
	W24x94	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	4.0	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	5.1	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	6.2	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	7.3	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	8.3	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	9.4	16.0	OK
	W24x103	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	3.7	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	4.6	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	5.6	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	6.6	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	7.6	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	8.6	16.0	OK
	W24x104	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	3.5	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	4.4	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	5.3	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	6.2	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	7.2	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	8.1	16.0	OK
	W24x117	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	3.1	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	3.9	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	4.7	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	5.5	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	6.4	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	7.2	16.0	OK
	W24x131	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	2.7	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	3.4	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	4.2	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	4.9	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	5.6	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	6.4	16.0	OK
	W24x146	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	2.4	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	3.1	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	3.7	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	4.3	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	5.0	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	5.7	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 60°

		Skew	60°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W24	W24x55	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	9.0	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	11.4	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	13.8	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	16.2	16.0	NO GOOD
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	18.7	16.0	NO GOOD
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	21.1	16.0	NO GOOD
	W24x62	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	7.9	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	9.9	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	12.0	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	14.1	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	16.2	16.0	NO GOOD
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	18.4	16.0	NO GOOD
	W24x68	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	6.7	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	8.4	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	10.2	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	12.0	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	13.8	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	15.6	16.0	OK
	W24x76	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	5.9	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	7.4	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	8.9	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	10.5	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	12.1	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	13.7	16.0	OK
	W24x84	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	5.3	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	6.6	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	8.0	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	9.4	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	10.8	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	12.3	16.0	OK
	W24x94	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	4.6	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	5.9	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	7.1	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	8.3	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	9.6	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	10.8	16.0	OK
	W24x103	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	4.2	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	5.3	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	6.4	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	7.5	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	8.7	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	9.8	16.0	OK
	W24x104	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	4.0	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	5.0	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	6.1	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	7.2	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	8.2	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	9.3	16.0	OK
	W24x117	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	3.5	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	4.5	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	5.4	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	6.4	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	7.3	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	8.3	16.0	OK
	W24x131	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	3.1	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	3.9	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	4.8	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	5.6	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	6.5	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	7.3	16.0	OK
	W24x146	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	2.8	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	3.5	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	4.2	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	5.0	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	5.7	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	6.5	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 0°

		Skew	0°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W27	W27x84	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	2.4	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	3.1	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	3.7	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	4.3	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	5.0	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	5.6	16.0	OK
	W27x94	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	2.1	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	2.7	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	3.2	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	3.8	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	4.4	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	5.0	16.0	OK
	W27x114	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	1.7	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	2.2	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	2.6	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	3.1	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	3.6	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	4.0	16.0	OK
	W27x129	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	1.5	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	1.9	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	2.3	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	2.7	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	3.1	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	3.5	16.0	OK
	W27x146	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	1.2	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	1.6	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	1.9	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	2.2	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	2.6	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	2.9	16.0	OK
W30	W30x90	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	2.1	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	2.7	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	3.2	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	3.8	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	4.3	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	4.9	16.0	OK
	W30x108	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	1.7	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	2.2	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	2.6	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	3.1	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	3.6	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	4.0	16.0	OK
	W30x116	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	1.6	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	2.0	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	2.4	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	2.8	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	3.2	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	3.7	16.0	OK
	W30x124	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	1.5	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	1.8	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	2.2	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	2.6	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	3.0	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	3.4	16.0	OK
	W30x148	7	0.50	4.00	2.50	17.2	0.0	43.0	43.0	1.2	16.0	OK
		8	1.00	4.00	3.00	18.0	0.0	54.1	54.1	1.5	16.0	OK
		9	1.50	4.00	3.50	18.7	0.0	65.5	65.5	1.8	16.0	OK
		10	2.00	4.00	4.00	19.3	0.0	77.0	77.0	2.1	16.0	OK
		11	2.50	4.00	4.50	19.7	0.0	88.6	88.6	2.4	16.0	OK
		12	3.00	4.00	5.00	20.1	0.0	100.3	100.3	2.8	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 15°

		Skew	15°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W27	W27x84	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	2.5	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	3.2	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	3.8	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	4.5	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	5.2	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	5.8	16.0	OK
	W27x94	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	2.2	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	2.8	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	3.3	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	3.9	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	4.5	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	5.1	16.0	OK
	W27x114	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	1.8	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	2.2	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	2.7	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	3.2	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	3.7	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	4.2	16.0	OK
	W27x129	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	1.5	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	1.9	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	2.4	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	2.8	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	3.2	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	3.6	16.0	OK
	W27x146	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	1.3	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	1.6	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	2.0	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	2.3	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	2.7	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	3.0	16.0	OK
W30	W30x90	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	2.2	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	2.7	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	3.3	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	3.9	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	4.5	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	5.1	16.0	OK
	W30x108	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	1.8	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	2.2	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	2.7	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	3.2	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	3.7	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	4.2	16.0	OK
	W30x116	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	1.6	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	2.0	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	2.5	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	2.9	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	3.3	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	3.8	16.0	OK
	W30x124	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	1.5	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	1.9	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	2.3	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	2.7	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	3.1	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	3.5	16.0	OK
	W30x148	7	0.52	4.14	2.59	17.2	0.0	44.5	44.5	1.2	16.0	OK
		8	1.04	4.14	3.11	18.0	0.0	56.1	56.1	1.5	16.0	OK
		9	1.55	4.14	3.62	18.7	0.0	67.8	67.8	1.9	16.0	OK
		10	2.07	4.14	4.14	19.3	0.0	79.7	79.7	2.2	16.0	OK
		11	2.59	4.14	4.66	19.7	0.0	91.7	91.7	2.5	16.0	OK
		12	3.11	4.14	5.18	20.1	0.0	103.8	103.8	2.9	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 30°

		Skew	30°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W27	W27x84	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	2.8	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	3.5	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	4.3	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	5.0	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	5.8	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	6.5	16.0	OK
	W27x94	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	2.5	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	3.1	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	3.7	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	4.4	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	5.1	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	5.7	16.0	OK
	W27x114	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	2.0	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	2.5	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	3.0	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	3.6	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	4.1	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	4.6	16.0	OK
	W27x129	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	1.7	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	2.2	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	2.6	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	3.1	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	3.6	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	4.0	16.0	OK
	W27x146	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	1.4	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	1.8	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	2.2	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	2.6	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	3.0	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	3.4	16.0	OK
W30	W30x90	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	2.4	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	3.1	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	3.7	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	4.4	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	5.0	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	5.7	16.0	OK
	W30x108	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	2.0	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	2.5	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	3.0	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	3.6	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	4.1	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	4.6	16.0	OK
	W30x116	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	1.8	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	2.3	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	2.8	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	3.2	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	3.7	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	4.2	16.0	OK
	W30x124	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	1.7	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	2.1	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	2.6	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	3.0	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	3.5	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	3.9	16.0	OK
	W30x148	7	0.58	4.62	2.89	17.2	0.0	49.6	49.6	1.4	16.0	OK
		8	1.15	4.62	3.46	18.0	0.0	62.5	62.5	1.7	16.0	OK
		9	1.73	4.62	4.04	18.7	0.0	75.6	75.6	2.1	16.0	OK
		10	2.31	4.62	4.62	19.3	0.0	88.9	88.9	2.4	16.0	OK
		11	2.89	4.62	5.20	19.7	0.0	102.3	102.3	2.8	16.0	OK
		12	3.46	4.62	5.77	20.1	0.0	115.8	115.8	3.2	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 45°

		Skew	45°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W27	W27x84	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	3.4	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	4.3	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	5.2	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	6.1	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	7.1	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	8.0	16.0	OK
	W27x94	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	3.0	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	3.8	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	4.6	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	5.4	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	6.2	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	7.0	16.0	OK
	W27x114	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	2.4	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	3.1	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	3.7	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	4.4	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	5.0	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	5.7	16.0	OK
	W27x129	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	2.1	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	2.7	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	3.2	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	3.8	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	4.4	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	4.9	16.0	OK
	W27x146	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	1.8	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	2.2	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	2.7	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	3.2	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	3.6	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	4.1	16.0	OK
W30	W30x90	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	3.0	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	3.8	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	4.5	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	5.3	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	6.1	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	6.9	16.0	OK
	W30x108	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	2.4	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	3.1	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	3.7	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	4.4	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	5.0	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	5.7	16.0	OK
	W30x116	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	2.2	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	2.8	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	3.4	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	4.0	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	4.6	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	5.2	16.0	OK
	W30x124	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	2.1	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	2.6	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	3.1	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	3.7	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	4.2	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	4.8	16.0	OK
	W30x148	7	0.71	5.66	3.54	17.2	0.0	60.8	60.8	1.7	16.0	OK
		8	1.41	5.66	4.24	18.0	0.0	76.6	76.6	2.1	16.0	OK
		9	2.12	5.66	4.95	18.7	0.0	92.6	92.6	2.5	16.0	OK
		10	2.83	5.66	5.66	19.3	0.0	108.9	108.9	3.0	16.0	OK
		11	3.54	5.66	6.36	19.7	0.0	125.3	125.3	3.4	16.0	OK
		12	4.24	5.66	7.07	20.1	0.0	141.8	141.8	3.9	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 50°

		Skew	50°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W27	W27x84	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	3.8	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	4.7	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	5.7	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	6.7	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	7.8	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	8.8	16.0	OK
	W27x94	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	3.3	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	4.2	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	5.0	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	5.9	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	6.8	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	7.7	16.0	OK
	W27x114	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	2.7	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	3.4	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	4.1	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	4.8	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	5.5	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	6.3	16.0	OK
	W27x129	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	2.3	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	2.9	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	3.5	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	4.2	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	4.8	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	5.4	16.0	OK
	W27x146	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	1.9	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	2.4	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	3.0	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	3.5	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	4.0	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	4.5	16.0	OK
W30	W30x90	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	3.3	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	4.1	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	5.0	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	5.9	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	6.8	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	7.6	16.0	OK
	W30x108	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	2.7	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	3.4	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	4.1	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	4.8	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	5.5	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	6.3	16.0	OK
	W30x116	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	2.4	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	3.1	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	3.7	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	4.4	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	5.0	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	5.7	16.0	OK
	W30x124	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	2.3	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	2.8	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	3.4	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	4.0	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	4.7	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	5.3	16.0	OK
	W30x148	7	0.78	6.22	3.89	17.2	0.0	66.8	66.8	1.8	16.0	OK
		8	1.56	6.22	4.67	18.0	0.0	84.2	84.2	2.3	16.0	OK
		9	2.33	6.22	5.45	18.7	0.0	101.9	101.9	2.8	16.0	OK
		10	3.11	6.22	6.22	19.3	0.0	119.8	119.8	3.3	16.0	OK
		11	3.89	6.22	7.00	19.7	0.0	137.8	137.8	3.8	16.0	OK
		12	4.67	6.22	7.78	20.1	0.0	156.0	156.0	4.3	16.0	OK

Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 55°

		Skew	55°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W27	W27x84	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	4.2	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	5.3	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	6.4	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	7.6	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	8.7	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	9.8	16.0	OK
	W27x94	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	3.7	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	4.7	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	5.6	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	6.6	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	7.6	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	8.6	16.0	OK
	W27x114	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	3.0	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	3.8	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	4.6	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	5.4	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	6.2	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	7.0	16.0	OK
	W27x129	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	2.6	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	3.3	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	4.0	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	4.7	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	5.4	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	6.1	16.0	OK
	W27x146	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	2.2	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	2.7	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	3.3	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	3.9	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	4.5	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	5.1	16.0	OK
W30	W30x90	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	3.7	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	4.6	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	5.6	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	6.6	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	7.6	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	8.6	16.0	OK
	W30x108	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	3.0	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	3.8	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	4.6	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	5.4	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	6.2	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	7.0	16.0	OK
	W30x116	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	2.7	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	3.4	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	4.2	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	4.9	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	5.6	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	6.4	16.0	OK
	W30x124	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	2.5	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	3.2	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	3.9	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	4.5	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	5.2	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	5.9	16.0	OK
	W30x148	7	0.87	6.97	4.36	17.2	0.0	74.9	74.9	2.1	16.0	OK
		8	1.74	6.97	5.23	18.0	0.0	94.4	94.4	2.6	16.0	OK
		9	2.62	6.97	6.10	18.7	0.0	114.2	114.2	3.1	16.0	OK
		10	3.49	6.97	6.97	19.3	0.0	134.2	134.2	3.7	16.0	OK
		11	4.36	6.97	7.85	19.7	0.0	154.5	154.5	4.3	16.0	OK
		12	5.23	6.97	8.72	20.1	0.0	174.8	174.8	4.8	16.0	OK

Project:	MoDOT Finger/Flat Plate Eval	Compute:	MTW	Date:	11/4/2015
Subject:	New Finger Plate Design	Checked:	DGB	Date:	12/3/2015
Task:	Support Beam Design	Page:	75	of:	SUPPORT
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Support Beam Design FATIGUE Calculations: 19" Finger Length w/ Skew 60°

		Skew	60°									
		Gdr. Spa.	A	B	C	R_b	$M_{u,D}$	$M_{u,L}$	M_u	f_{Fat}	Δ_{TH}	$f_{Fat}<\Delta_{TH}$
		ft	ft	ft	ft	kip	kip-ft	kip-ft	kip-ft	ksi	ksi	Check
W27	W27x84	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	4.8	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	6.1	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	7.4	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	8.7	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	10.0	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	11.3	16.0	OK
	W27x94	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	4.2	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	5.3	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	6.5	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	7.6	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	8.8	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	9.9	16.0	OK
	W27x114	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	3.4	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	4.3	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	5.3	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	6.2	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	7.1	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	8.0	16.0	OK
	W27x129	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	3.0	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	3.8	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	4.6	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	5.4	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	6.2	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	7.0	16.0	OK
	W27x146	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	2.5	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	3.1	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	3.8	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	4.5	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	5.1	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	5.8	16.0	OK
W30	W30x90	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	4.2	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	5.3	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	6.4	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	7.5	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	8.7	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	9.8	16.0	OK
	W30x108	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	3.4	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	4.3	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	5.3	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	6.2	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	7.1	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	8.0	16.0	OK
	W30x116	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	3.1	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	3.9	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	4.8	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	5.6	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	6.5	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	7.3	16.0	OK
	W30x124	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	2.9	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	3.7	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	4.4	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	5.2	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	6.0	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	6.8	16.0	OK
	W30x148	7	1.00	8.00	5.00	17.2	0.0	85.9	85.9	2.4	16.0	OK
		8	2.00	8.00	6.00	18.0	0.0	108.3	108.3	3.0	16.0	OK
		9	3.00	8.00	7.00	18.7	0.0	131.0	131.0	3.6	16.0	OK
		10	4.00	8.00	8.00	19.3	0.0	154.0	154.0	4.2	16.0	OK
		11	5.00	8.00	9.00	19.7	0.0	177.2	177.2	4.9	16.0	OK
		12	6.00	8.00	10.00	20.1	0.0	200.5	200.5	5.5	16.0	OK

Modified Finger Plate Expansion Device Design

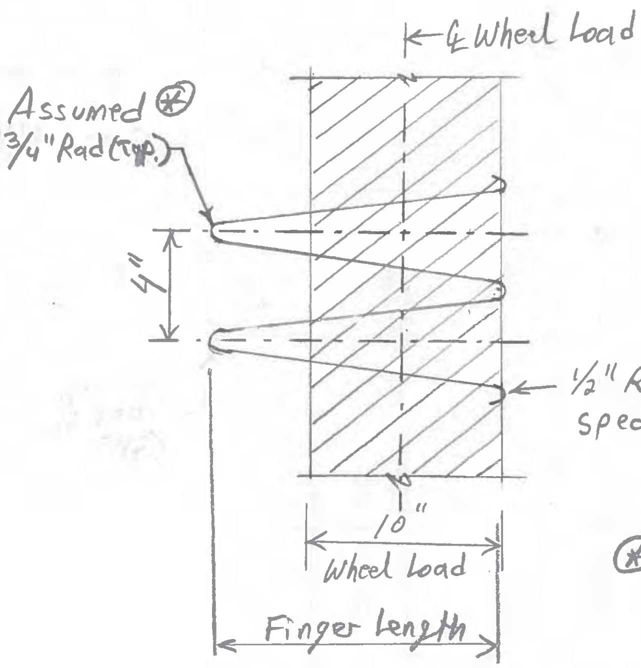
Codes referenced:

AASHTO LRFD Bridge Design Specifications, 7th Ed. 2014

MoDOT EPG 751.13, Fall 2015

Finger Plate Design

- Use 1 3/4" Grade 50 plate for the Fingers.
- Design for strength and Fatigue similar to the Robust design.
- Use a dynamic allowance of 200% in accordance with the MU Findings.
- Design for strength and Fatigue at the base of the finger instead of the extreme base of the throat.
- Design for strength assuming the opposing Fingers are slightly offset vertically resulting in no load sharing across the Fingers.
- Design for Fatigue assuming equal load sharing to opposite Fingers.
- Assume the gap can exceed 8" along the bridge and limit the gap to 2" across per EPG 751.13.6.1
- Standard plan shows ½" radius at the throat of the fingers.
- Standard plan shows fingers at 4" centers.



Tire Contact Area = 10" x 20"
AASHTO 3.6.1.2.5

Design Finger width = 4" − 3/4"(2) = 2.5"

⊛ Assume Fingers are cut from a single plate with a 1/4" kerf.

Finger Plate Design (Cont.)

- Set Max. Finger Length Based on Strength design.
- Consider the Design Tandem Loading: 2 - 25 kip axels

Load to Finger: $(4''/20'')(12.5 \text{ kips/wheel}) = 2.5 \text{ kips/Finger}$

Factored Load - P_u: $(2.5 \text{ kips/Finger})(1.75)(1.20)(200\%) = 10.5 \text{ kips/Finger}$

S-Finger: $\dfrac{(2.5'')(1\tfrac{3}{4}'')^3}{12\ (1\tfrac{3}{4}''/2)} = 1.276 \text{ in}^3$

Limit stress to First yield - $f_y = 50$ ksi

$\phi_f = 1.00$ AASHTO 6.5.4.2

$M_y = f_y S = (50 \text{ ksi})(1.276 \text{ in}^3) = 63.8 \text{ kip-in}$

Find maximum length to center of wheel

$M = P\ell \quad \therefore \quad \ell_{allow} = M_y / P_u = 63.8 \text{ kip-in} / 10.5 \text{ kips} = 6.08''$

Max. Total Finger Length:

$\tfrac{1}{2}'' + 6.08'' + 10''/2 = 11.6'' \Rightarrow 11\tfrac{1}{2}''$

- Hold a minimum of 1½" overlap at extreme opening and a minimum of 1½" gap at extreme closing.

Max. Finger movement $= 11\tfrac{1}{2}'' - 1\tfrac{1}{2}'' - 1\tfrac{1}{2}'' = 8\tfrac{1}{2}'' = \Delta_{Total}$

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Finger Plate Design (Cont.)

Set gap @ 60°F for a steel structure & concrete structure

- Temp Range Steel Structure : -30°F → 120°F
- Temp Range Concrete Structure : -10°F → 110°F

$$\text{Gap @ 60°F steel} = \frac{60°F}{150°F}(8\tfrac{1}{2}") + 1\tfrac{1}{2}" = 4.90"$$

$$\text{Gap @ 60°F Concrete} = \frac{50°F}{120°F}(8\tfrac{1}{2}") + 1\tfrac{1}{2}" = 5.04"$$

- Check Fatigue of Finger Plate:

Consider the finger plate a Category B material.

$\Delta_{TH} = 16.0$ ksi for infinite life AASHTO 6.6.1.2.5.3

Fatigue load is the HL-93 truck. Similar to the guidance given for modular joints in AASHTO 14.5.6.9.4 the design axel should be considered as an equivalent tandem.

1-32kip axel on the notional HL-93 truck ⇒ 2-16kip axels

- Consider the fatigue load to be shared by opposite sides of the expansion device @ 50°F.

$$\text{Gap @ 50°F-Concrete} = \frac{60°F}{120°F}(8\tfrac{1}{2}") + 1\tfrac{1}{2}" = 5.75"$$

Controls over steel

Finger Overlap @ 50°F = 11½" - 5.75" = 5.75"

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Finger Plate Design (Cont.)

Fatigue Load = 8 kips/wheel

$$P\text{-shared} = \left(\frac{5.75''}{10''}\right)\left(\frac{4''}{20''}\right)(50\%)(8\text{ kips}) = 0.46\text{ kips/Finger}$$

↑ shared to other side

$$P\text{-Unshared} = \left(\frac{4.25''}{10''}\right)\left(\frac{4''}{20''}\right)(8\text{ kips}) = 0.68\text{ kips/Finger}$$

Check stress at base of Finger, not at extreme throat.

Moment Arm - shared $= 11\frac{1}{2}'' - \frac{1}{2}'' - 5.75''/2 = 8.13''$

Moment Arm - Unshared $= 11\frac{1}{2}'' - \frac{1}{2}'' - 5.75 - 4.25''/2 = 3.13''$

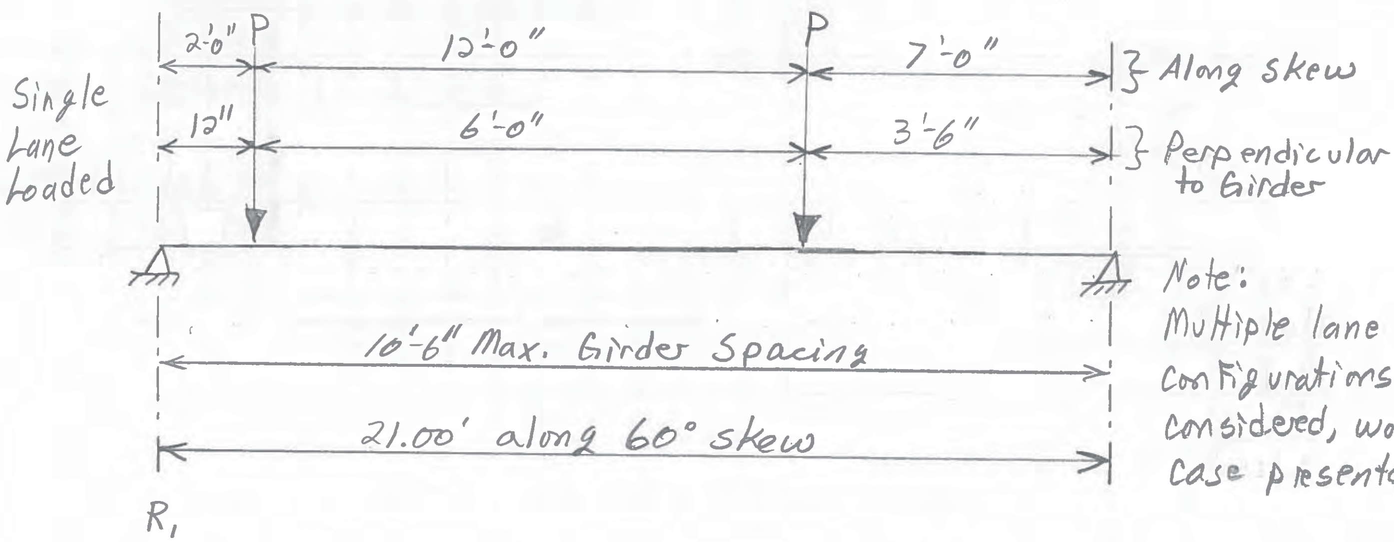
$$M_{Fat} = [(0.46\text{ kips})(8.13'') + (0.68\text{ kips})(3.13'')](1.50)(200\%) = 17.6\text{ kip-in}$$

$$f_{Fat} = \frac{17.6\text{ kip-in}}{1.276\text{ in}^3} = 13.8\text{ ksi} < 16.0\text{ ksi} - \underline{\text{OK}}$$

Use maximum Finger length of $11\frac{1}{2}''$.

Integrated Support Beam

- Consider beam simply supported between girders.
- Consider one beam size for all girder spacings and skews.
- Max. girder spacing considered = 10'-6" to match current EP6 End Diaphragm design spacing or 12'0" to match robust design.
- Max. skew considered is 60°.
- Loading is HL-93 truck with proper multi-presence Factor.
- Use 200% Impact similar to Robust design and value found from MV testing.
- Selected shape must have a minimum 10" wide Flange. to accomodate a 7" wide bolt spacing.



Note: Multiple lane configurations considered, worst case presented.

$P_1 = 32\text{ kips}/2 = 16\text{ kips/wheel line}$ } Consider whole axel for this element.

$R_1 = 16\text{ kips}\left(\frac{9.5'}{10.5'}\right) + 16\text{ kips}\left(\frac{3.5'}{10.5'}\right) = 19.81\text{ kips}$

$M_{LL} = (19.81\text{ kips})(2') + (19.81\text{ kips} - 16.0\text{ kips})(12') = 85.34\text{ k-ft}$
$= 1024\text{ k-in}$

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Integrated Support Beam (Cont.)

- Consider a W14X68 to provide a minimum 3/4" Flange thickness for attachment of a trough connection plate.

$$M_{DL} = \frac{w l^2}{8} = \frac{(0.068 \text{ kips/Ft})(21')^2}{8} = 3.75 \text{ kip-ft} = 45.0 \text{ kip-in}$$

$$M_u = (45.0 \text{ k-in})(1.25) + (1024 \text{ k-in})(1.20)(1.75)(200\%) = 4357 \text{ kip-in}$$

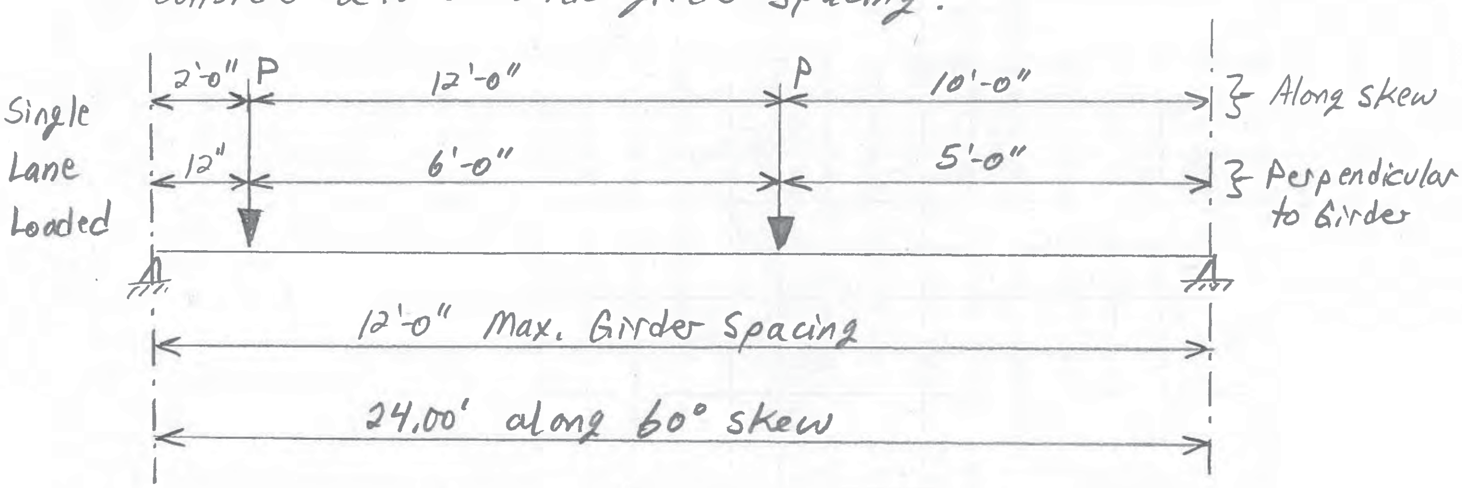
- Limit the beam to first yield - Conservative.

$M_r = \phi M_n \qquad \phi_f = 1.00 \quad \therefore \; M_r = (f_y)(S)$

- Consider all grade 50 ksi material.

$M_r = (50 \text{ ksi})(103 \text{ in}^3) = 5150 \text{ kip-in} > 4357 \text{ kip-in}$ - OK

- Consider a 12'-0" wide girder spacing.



Integrated Support Beam (Cont.)

$P = 16 \text{ kips / wheel line}$

$R_1 = 16 \text{ kips}\left(\frac{11'}{12'}\right) + 16 \text{ kips}\left(\frac{5'}{12'}\right) = 21.33 \text{ kips}$

$M_{LL} = (21.33 \text{ kips})(2') + (21.33 \text{ kips} - 16 \text{ kips})(12') = 106.6 \text{ k-ft}$
$= 1279 \text{ k-in}$

- Consider a W14X74 beam.

$M_{DL} = \frac{(0.074 \text{ kips/ft})(24.0')^2}{8} = 5.33 \text{ kip-ft} = 64.0 \text{ kip-in}$

$M_u = (64.0 \text{ kip-in})(1.25) + (1279 \text{ kip-in})(1.20)(1.75)(200\%) = 5452 \text{ kip-in}$

$M_r = \phi f_y S = (1.00)(50 \text{ ksi})(112 \text{ in}^3) = 5600 \text{ kip-in} > 5452 \text{ kip-in}$ - ok

Integrated Support Beam (Cont.)

- Check Fatigue for 10'-6" girder spacing: Consider infinite life.

$M_{Fat} = (1024 \text{ k-in})(1.50)(1.00)(200\%) = 3072 \text{ k-in}$

Bolted rolled steel shape ⇒ Category B

$\Delta_{TH} = 16.0 \text{ ksi}$ AASHTO Table 6.6.1.2.5-3

- $S_{required} = \dfrac{3072 \text{ k-in}}{16 \text{ ksi}} = 192 \text{ in}^3$

W14X132 has $S = 209 \text{ in}^3$ however, it has 14.7" Flanges and will be too wide for the detailing.

No W16 shape has an S large enough to acheive this fatigue stress.

W18X106 has $S = 204 \text{ in}^3$ with 11.2" Flanges.

- Check Fatigue for 12'0" girder spacing: Consider infinite life.

$M_{Fat} = (1279 \text{ k-in})(1.50)(1.00)(200\%) = 3837 \text{ k-in}$

- $S_{required} = \dfrac{3837 \text{ k-in}}{16 \text{ ksi}} = 240 \text{ in}^3$

W18X130 has $S = 256 \text{ in}^3$ with 11.2" Flanges.

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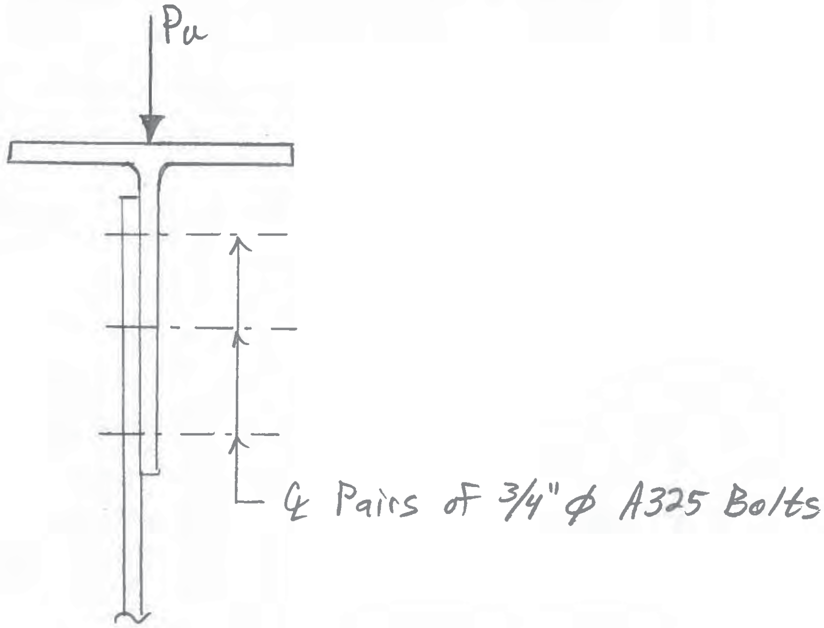
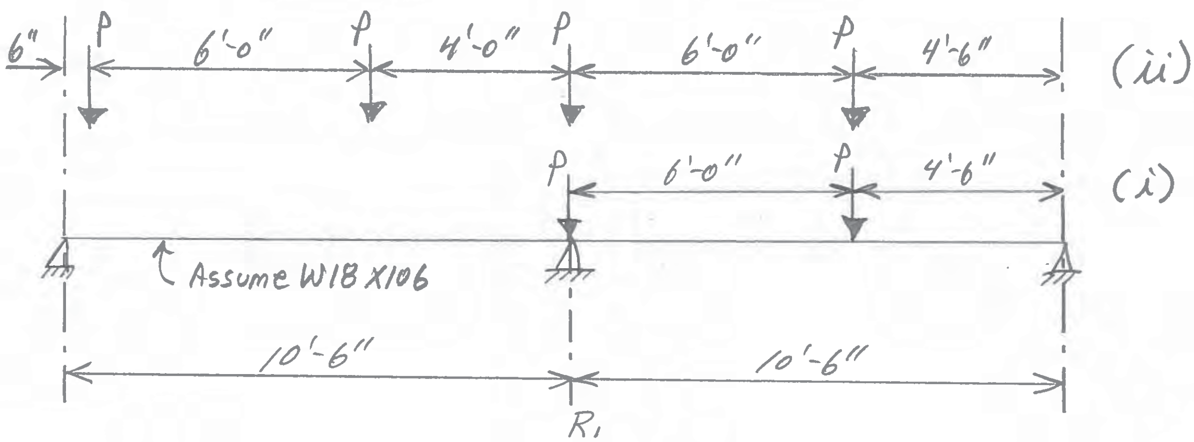
Support Piece Connection Design



• Check 10'-6" Girder Spacing:



(i) $R_1 = \left[P + P\left(\frac{4'6''}{10'6''}\right)\right](1.20) = 1.71\,P$

(ii) $R_1 = \left[P\left(\frac{6''}{10'6''}\right) + P\left(\frac{6'6''}{10'6''}\right) + P + P\left(\frac{4'6''}{10'6''}\right)\right](1.0) = 2.10\,P$ ⟸ CONTROLS

$R_1 = (2.10)(16 \text{ kips}) = 33.6 \text{ kips} = P_{LL}$

$P_{DL} = (0.106 \text{ kips/ft})(10'6'') + \left[(1\tfrac{3}{4}'')(11\tfrac{1}{2}'' + 1'' + 11\tfrac{1}{2}''/2)(1\text{ft}^2/144\text{in}^2)(10'6'')\right](0.49 \text{ kips/ft}^3)$

$= 2.25 \text{ kips}$

Support Piece Connection Design (Cont.)

$P_u = (2.25\ kips)(1.25) + (33.6\ kips)(1.75)(200\%) = 120.4\ kips$

- Include threads in the shear plane - conservative.

$R_r = \phi R_n$ AASHTO Eq. 6.13.2.2-2 $\phi_s = 0.80$ AASHTO 6.5.4.2

$R_n = 0.38\ A_b\ F_{ub}\ N_s$ AASHTO Eq. 6.13.2.7-2

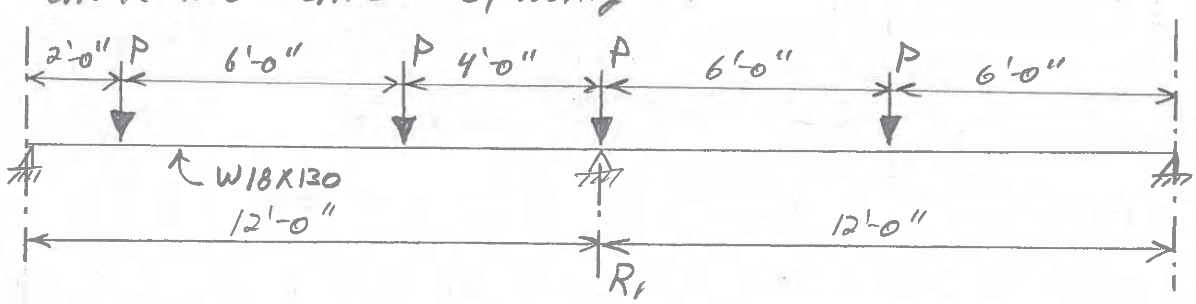
$F_{ub} = 120\ ksi$ AASHTO 6.4.3.1

$R_r = (0.80)(0.38)(3/4")^2 \frac{\pi}{4}(120 ksi)(6\ Bolts) = 96.70\ kips$ - NG

- Keep currently detailed 6 bolt pattern but increase to 7/8"ϕ.

$R_r = (0.80)(0.38)(7/8")^2 \frac{\pi}{4}(120 ksi)(6\ Bolts) = 131.6\ kips > P_u$ - ok

- Check 12'0" Girder Spacing:



$R_1 = [P(\frac{2'}{12'}) + P(\frac{8'}{12'}) + P + P(\frac{6'}{12'})](1.0) = 2.33P = (2.33)(16 kips) = 37.28\ kips = P_{LL}$

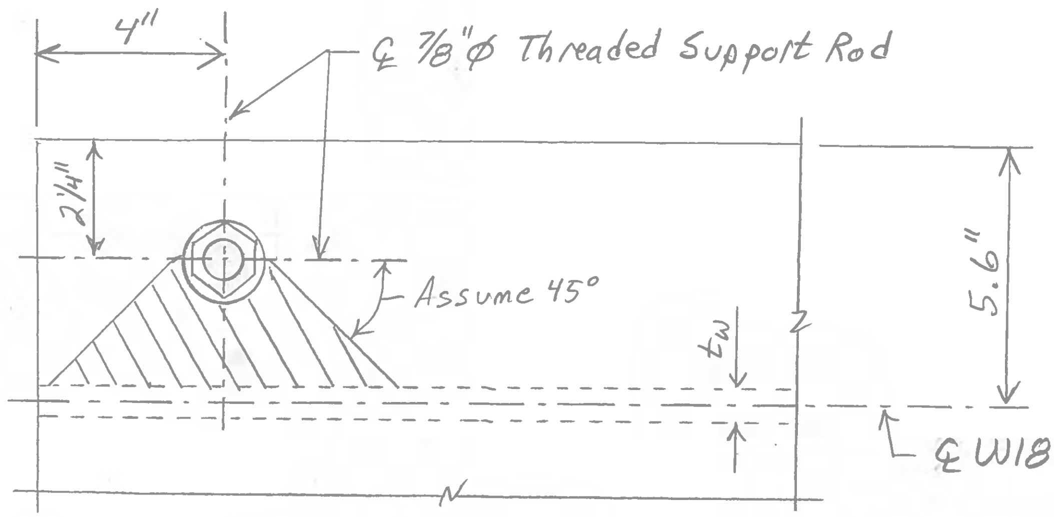
$P_{DL} = (0.130\ kips/ft)(12'0") + [(1\tfrac{3}{4}")(11\tfrac{1}{2}" + 1" + 11\tfrac{1}{2}"/2)(1ft^2/144in^2)(12'0")](0.49\ kips/ft^3) = 2.86\ kips$

$P_u = (2.86\ kips)(1.25) + (37.28\ kips)(1.75)(200\%) = 134.1\ kips$

$P_u > R_r$ ∴ Bolts are NG → Check connection to flange before adjusting the bolt pattern.

Support Beam / Support Piece Connection

- Check for local Flange yielding at threaded rod support.



- Assume load is carried equally by all 4 threaded rod supports.

$P_{u-rod} = P_{u-Support\ Piece} / 4$ Diameter of washer = 1¾"

- For 10'-6" Max. Girder Spacing:

$P_{u-rod} = 120.4\text{ kips} / 4 = 30.1\text{ kips}$

For W18 X 106: $t_w = 0.59"$ $t_f = 0.94"$

Moment Arm $= 5.6" - 0.59"/2 - 2\tfrac{1}{4}" = 3.06"$

Width at Face of web $= 3.06"(2) + 1\tfrac{3}{4}" = 7.87"$

$$S = \frac{(7.87")(0.94")^3}{(12)(0.94"/2)} = 1.159\text{ in}^3$$

Support Beam / Support Piece Connection (Cont.)

- 10'-6" Max. Girder Spacing (Cont.):

$M_u = (30.1\ \text{kips})(3.06") = 92.1\ \text{kip-in}$

$f = \dfrac{92.1\ \text{kip-in}}{1.159\ \text{in}^3} = 79.5\ \text{ksi} > 50\ \text{ksi}$ – NG

– Consider a W18X130 Support Beam: $t_w = 0.67"$ $t_f = 1.20"$

Moment Arm $= 5.6" - 0.67"/2 - 2\frac{1}{4}" = 3.02"$

Width of Face of web $= 3.02"(2) + 1\frac{3}{4}" = 7.79"$

$S = \dfrac{(7.79")(1.20")^3}{(12)\ (1.20"/2)} = 1.870\ \text{in}^3$

$M_u = (30.1\ \text{kips})(3.02") = 90.9\ \text{kip-in}$

$f = \dfrac{90.9\ \text{kip-in}}{1.870\ \text{in}^3} = 48.6\ \text{ksi} < 50\ \text{ksi}$ – OK

- For 12'-0" Max. Girder Spacing: Consider W18X130

$P_{u\text{-rod}} = 134.1\ \text{kips}/4 = 33.53\ \text{kips}$

$M_u = (33.53\ \text{kips})(3.02") = 101.3\ \text{kip-in}$

$f = \dfrac{101.3\ \text{kip-in}}{1.870\ \text{in}^3} = 54.2\ \text{ksi} > 50\ \text{ksi}$ – NG

Support Beam / Support Piece Connection (Cont.)

- 12'-0" Max. Girder Spacing (Cont.):

Consider a W18X143 : $t_w = 0.73"$ $t_f = 1.32"$

Moment Arm $= 5.6" - 0.73"/2 - 2\frac{1}{4}" = 2.99"$

Width at Face of Web $= 2.99"(2) + 1\frac{3}{4}" = 7.73"$

$$S = \frac{(7.73")(1.32")^3}{(12)(1.32"/2)} = 2.245 \text{ in}^3$$

$M_u = (33.53 \text{ kips})(2.99") = 100.3$ kip-in

$$f = \frac{100.3 \text{ kip-in}}{2.245 \text{ in}^3} = 44.7 \text{ ksi} < 50 \text{ ksi} - \underline{\text{ok}}$$

- Current detailing for End Diaphragms (EPG 751.14.5.4) is limited to 10'-6" girder spacing.

Hold to currently detailed maximum girder spacing and use a W18X130 support beam and a piece of a W18X130 for the "saddle".

Project:	MoDOT Finger Plate	Computed:	DGB	Date:	10/26/2015
Subject:	Modified Design	Checked:	MTW	Date:	12/16/2015
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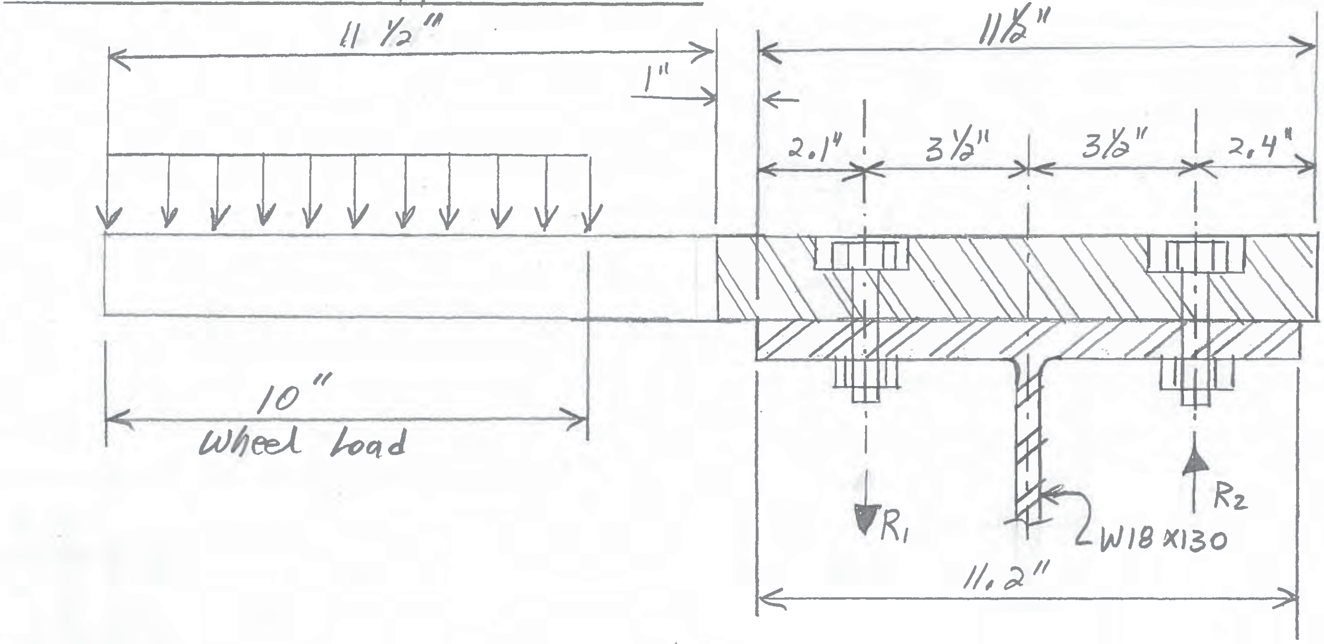
Job #:	244663	No:			

Connection to Support Beam



- 7/8" ϕ Bolts @ 9" across the bridge.

$P_u = 10.5$ kips/Finger　　　Page 2-MOD

Adjust to bolt spacing: (10.5 kips/Finger)(9"/4") = 23.63 kips/Bolt line

Moment Arm = 11 1/2" − 10/2 + 1" + 2.1" = 9.60"

M_u = (23.63 kips/Bolt)(9.60") = 226.8 kip-in/Bolt

$R_2 = \frac{226.8 \text{ kip-in/Bolt}}{7"} = 32.40$ kips/Bolt

$T_r = \phi T_n$　　AASHTO Eq. 6.13.2.2-3　　$\phi_t = 0.80$　AASHTO 6.5.4.2

$T_n = 0.76 A_b F_{ub}$　　AASHTO Eq. 6.13.2.10.2-1

$T_r = (0.80)(0.76)(7/8")^2 \frac{\pi}{4}(120\text{ ksi}) = 43.87\text{ kips} > 32.40\text{ kips}$ OK

Connection to Support Beam (Cont.)

- Check Fatigue of Connection with device @ 50°F.

P-shared = 0.46 kips/Finger
P-Unshared = 0.68 kips/Finger } Page 4-MOD

Adjust to bolt spacing:

P-Shared = (0.46 kips/Finger) (9"/4") = 1.04 kips/Bolt

P-Unshared = (0.68 kips/Finger) (9"/4") = 1.53 kips/Bolt

Momet Arm - Shared : 11 1/2" + 1" + 2.1" − 5.75"/2 = 11.73"

Moment Arm - Unshared : 11 1/2" + 1" + 2.1" − 5.75" − 4.25"/2 = 6.73"

M_{Fat} = [(1.04 kips/Bolt)(11.73") + (1.53 kips/Bolt)(6.73")] (1.50)(200%)
= 67.50 kip-in/Bolt

R_2-Fat = $\frac{67.50 \text{ kip-in}}{7"}$ = 9.64 kips/Bolt

f_{Fat} = $\frac{9.64 \text{ kips/Bolt}}{(7/8")^2 \frac{\pi}{4}}$ = 16.03 ksi

Δ_{TH} = 31.0 ksi For A325 Bolts in Tension AASHTO Table 6.6.1.2.5-3

$f_{Fat} < \Delta_{TH}$ ∴ OK

Existing Finger Plate Expansion Device Retrofit Design

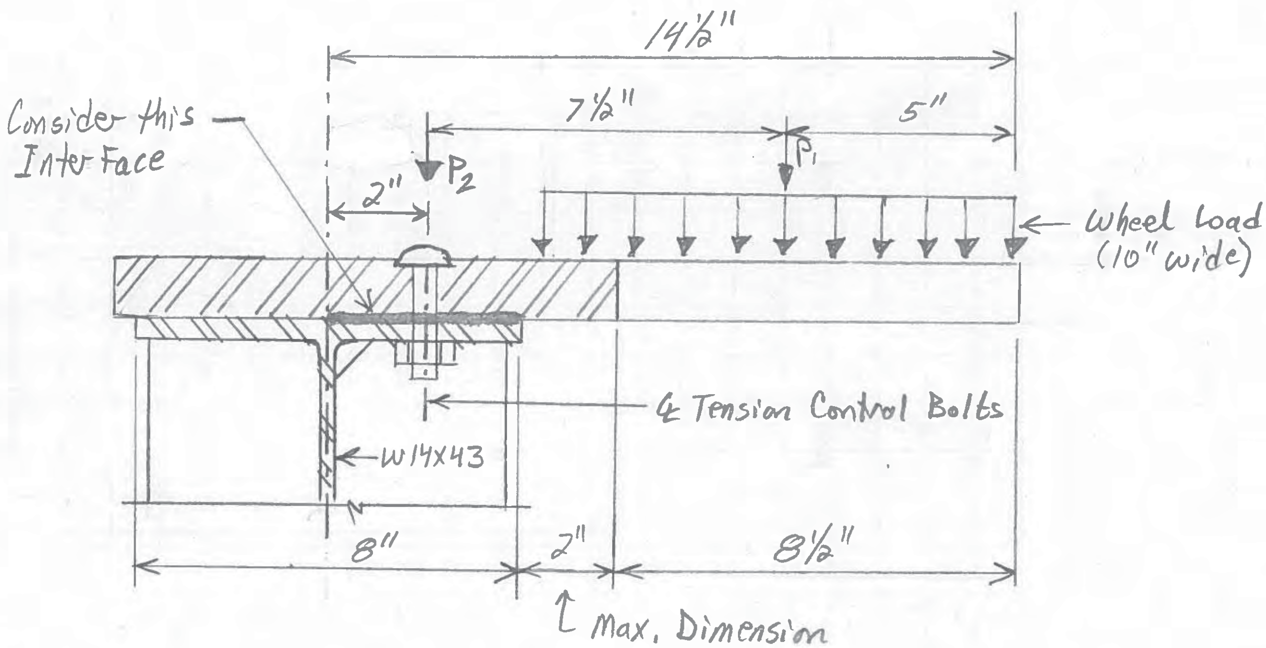
Codes referenced:

AASHTO LRFD Bridge Design Specifications, 7th Ed. 2014

Project:	MoDOT Finger Plate	Computed:	DGB	Date:	11/16/2015
Subject:	Retrofit Design	Checked:	MTW	Date:	12/17/2015
Task:		Page:	1	of:	RETROFIT
Job #:	244663	No:			

Bolted Retrofit Design

- Intermediate Bent 6 of Bridge A7024 in Greene Co. was offered for a test project for the bolted connection.
- Design a bolted connection through the front Flange.
- Apply compressive Force to the Finger Plate / Support Beam Flange interface to try to prevent uplift of the Finger Plate at the back edge.

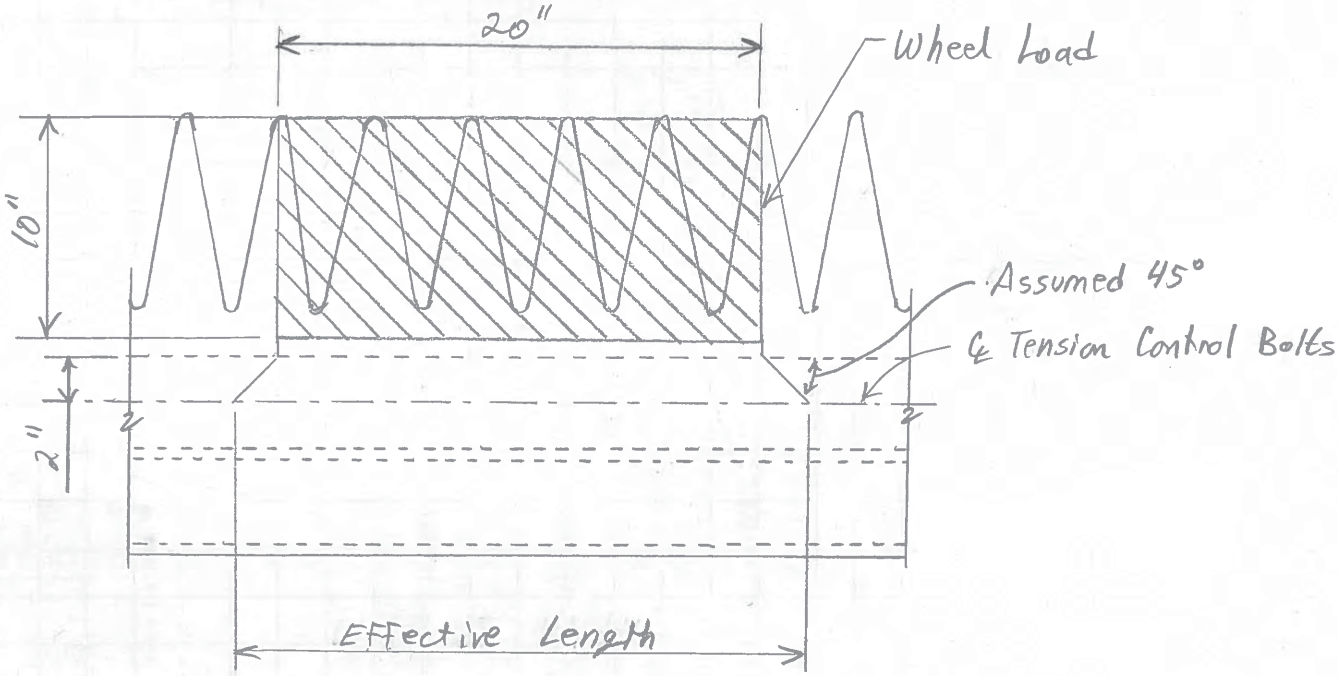


- Consider the design tandem for Strength loading
  25 kips/axel ⇒ 12.5 kips/wheel

- Balance the compressive stress of the fully tensioned bolts and the tensile stress caused by the moment applied to the designated interface.

- Consider the wheel load to be carried by one side of the expansion device.

Bolted Retrofit Design (Cont.)



Effective Length = $20'' + (2'')(\tan 45°)(2) = 24''$

Effective Width = ½ Flange Width = $8''/2 = 4''$

P_1 = Wheel Load = 12.5 kips

Find P_2 to reach a balanced stress condition:

Compressive stress on the Flange = $\frac{P}{A} = \frac{P_1 + P_2}{(24'')(4'')}$

S - Interface = $\frac{(24'')(4'')^3}{(12)(4''/2)} = 64 \text{ in}^3$

$M = (P_1)(7½'')$

Tensile stress on the Flange = $\frac{M}{S} = \frac{P_1 (7½'')}{S}$

Bolted Retrofit Design (Cont.)

$$\frac{P_1 + P_2}{(24")(4")} = \frac{P_1 (7\tfrac{1}{2}")}{S}$$

$$P_2 = \frac{P_1 (7\tfrac{1}{2}")(24")(4")}{S} - P_1$$

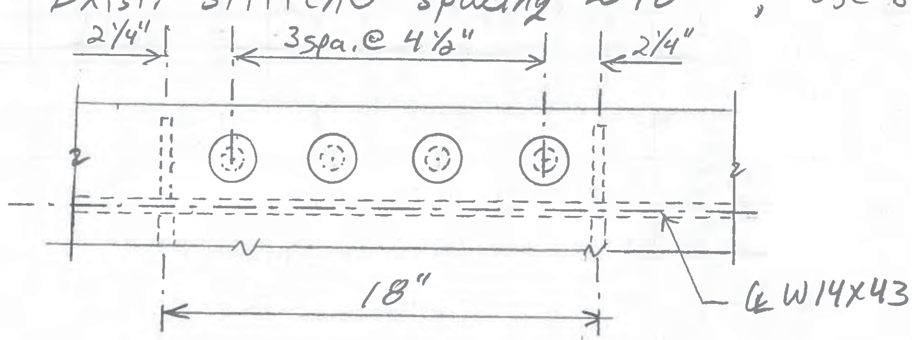
$$P_2 = \frac{(12.5\text{ kips})(7\tfrac{1}{2}")(24")(4")}{64\text{ in}^3} - 12.5\text{ kips} = 128.1\text{ kips}$$

Dynamic Load Allowance = 75% AASHTO Table 3.6.2.1-1

↑ Consider the code provisions for IM instead of the theoretical value proposed by the MU research.

$$P_u = (128.1\text{ kips})(1.75)(175\%) = 392.3\text{ kips}$$

- Exist. stiffener spacing ≈ 18", Use bolts @ 4½" cts.



Number of bolts in 24" ⇒ $\frac{24"}{4\tfrac{1}{2}"} + 1 = 6.333$ bolts

- Consider 1"φ bolts as practical maximum size to be installed in the field.

- Required clearance to the web of a stiffener to meet entering and tightening clearance on a 1"φ Tension-Control bolt is 1⅞" -ok AISC LRFD 2nd Ed. Table 8-5

Bolted Retrofit Design (Cont.)

$$\text{Load per bolt} = \frac{392.3 \text{ kips}}{6.333 \text{ bolts}} = 61.9 \text{ kips/Bolt}$$

Pre-Tension Load for 1"ϕ A325 bolts = 51 kips — AASHTO Table 6.13.2.8-1

51 kips < 61.9 kips - No Good for Full Factored Load

- 1"ϕ bolts @ 4½" cts. is the largest practical bolt size at the tightest practical spacing.

- Find the equivalent Factor of safety of 1"ϕ A325 bolts @ 4½"

$$P\text{-service} = \frac{128.1 \text{ kips}}{6.333 \text{ bolts}} = 20.2 \text{ kips}$$

$$F.O.S. = \frac{51 \text{ kips}}{20.2 \text{ kips}} = 2.5$$ ⇐ This is an adequate F.O.S. for a retrofit design - ok.

- MU will verify the stress distribution across the front Flange.

- Results of MU analysis show stress is variably distributed across the front Flange and along the support beam, therefore a reduced tensile stress still exists at the back edge weld. This weld stress was gathered and is included in the spread sheet of Page 7-RETROFIT.

- Since 1"ϕ bolts @ 4½" cts is a practical maximum for placing the bolts the 8½" long finger with a 2" offset from the edge of the Flange is the maximum Finger length that can be retrofit with this method.

Plug Weld Design – Strength

- From MV FEM analysis average vertical stress in back weld with retrofit bolts included = 6.55 ksi Page 7 – RETROFIT
- Load is applied over 54.2" – all effective bolts at wheel loading.
- Weld size is assumed to be 5/16".

Applied Load = (6.55 ksi)(54.2")(5/16") = 110.9 kips

Try 1" ∅ Plug Welds

Treat as a partial penetration weld.

$R_r = 0.6 \; \phi_{e2} \; F_{exx}$ AASHTO 6.13.3.2.3a-1

$\phi_{e2} = 0.80$ AASHTO 6.5.4.2

$F_{exx} = 70$ ksi AASHTO Welding Guide

$R_r = (0.6)(0.80)(70\text{ ksi}) = 33.6\text{ ksi}$

Area Plug Weld $= (1")^2 \frac{\pi}{4} = 0.785\text{ in}^2$

$P_{Allow} = (0.785\text{ in}^2)(33.6\text{ ksi}) = 26.38$ kips/weld

$\frac{110.9\text{ kips}}{26.38\text{ kips/weld}} = 4.20$ welds

$\frac{54.2"}{4.20\text{ welds}} = 12.90" > 12"$ spacing – OK

Plug Weld Design - Fatigue

- From MU FEM analysis average vertical stress in back weld with retrofit bolts included = 3.31 ksi Page 7-RETROFIT
- Strength load factors were included in the model but the load has been ratioed to a factored Fatigue load.
- Load is applied over 8.33" - Width of effective area around one bolt.
- Weld size is assumed to be 5/16".

Applied Fatigue Load = (3.31 ksi)(8.33")(5/16") = 8.62 Kips

Assume the plug weld is a Category C' detail.

Δ_{TH} = 12.0 ksi For infinite Fatigue life AASHTO 6.6.1.2.5-3

$P_{Allow} = (0.785\ in^2)(12.0\ ksi) = 9.42$ Kips/weld

$\frac{8.62\ \text{Kips}}{9.42\ \text{Kips/weld}} = 0.92$ welds $\frac{8.33''}{0.92\ \text{welds}} = 9.05''$ Weld Spacing

Try 1¼" Plug welds - Try to keep 12" spacing.

Area Plug Weld $= (1\tfrac{1}{4}'')^2 \frac{\pi}{4} = 1.23\ in^2$

$P_{Allow} = (1.23\ in^2)(12.0\ ksi) = 14.76$ Kips/weld

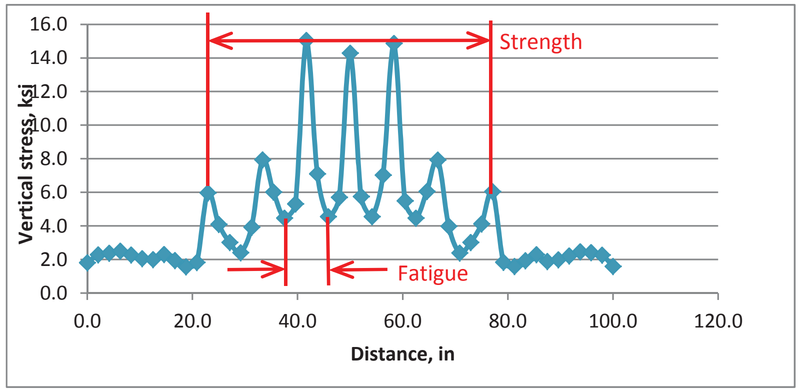
$\frac{8.62\ \text{Kips}}{14.76\ \text{Kips/weld}} = 0.584$ welds

$\frac{8.33''}{0.584\ \text{welds}} = 14.3''$ weld spacing > 12" - OK

Use 1¼" ϕ Plug Welds @ 12" cts.

Finger Plate Weld Stresses for Bridge A7024 (Greene Co.) at Pier 6

Stresses Developed by MU for Strength Design of Finger Plate Retrofit				
Front Weld		Back Weld		Average
0.0	2,174.6	0.0	1,450.4	1.8
2.1	2,296.0	2.1	2,272.5	2.3
4.2	2,463.8	4.2	2,296.0	2.4
6.3	2,717.8	6.3	2,301.7	2.5
8.3	2,551.9	8.3	2,008.8	2.3
10.4	2,310.3	10.4	1,798.2	2.1
12.5	2,293.5	12.5	1,709.5	2.0
14.6	2,454.8	14.6	2,161.4	2.3
16.7	2,197.1	16.7	1,689.4	1.9
18.8	1,830.6	18.8	1,318.6	1.6
20.8	2,242.3	20.8	1,414.5	1.8
22.9	6,551.5	22.9	5,388.6	6.0
25.0	4,237.9	25.0	3,958.3	4.1
27.1	3,304.8	27.1	2,725.2	3.0
29.2	2,720.2	29.2	2,099.5	2.4
31.3	3,744.9	31.3	4,101.6	3.9
33.3	8,041.9	33.3	7,844.8	7.9
35.4	6,394.5	35.4	5,636.1	6.0
37.5	4,308.2	37.5	4,620.8	4.5
39.6	4,815.2	39.6	5,811.6	5.3
41.7	12,184.0	41.7	17,924.0	15.1
43.8	6,471.5	43.8	7,728.4	7.1
45.8	3,857.8	45.8	5,238.9	4.5
47.9	5,256.6	47.9	6,155.5	5.7
50.0	10,241.0	50.0	18,335.0	14.3
52.1	5,304.1	52.1	6,198.9	5.8
54.2	3,858.5	54.2	5,249.8	4.6
56.3	6,469.1	56.3	7,591.5	7.0
58.3	12,192.0	58.3	17,558.0	14.9
60.4	4,813.5	60.4	6,169.3	5.5
62.5	4,315.1	62.5	4,613.4	4.5
64.6	6,404.5	64.6	5,708.7	6.1
66.7	8,060.8	66.7	7,794.6	7.9
68.8	3,748.6	68.8	4,220.2	4.0
70.8	2,716.4	70.8	2,073.7	2.4
72.9	3,301.5	72.9	2,735.5	3.0
75.0	4,263.5	75.0	3,975.0	4.1
77.1	6,588.8	77.1	5,498.5	6.0
79.2	2,240.2	79.2	1,442.7	1.8
81.3	1,839.9	81.3	1,335.1	1.6
83.3	2,186.9	83.3	1,684.8	1.9
85.4	2,436.8	85.4	2,157.9	2.3
87.5	2,058.7	87.5	1,714.2	1.9
89.6	2,169.3	89.6	1,815.0	2.0
91.7	2,414.6	91.7	2,017.4	2.2
93.8	2,641.5	93.8	2,301.3	2.5
95.8	2,525.5	95.8	2,315.0	2.4
97.9	2,232.8	97.9	2,294.6	2.3
100.0	1,711.3	100.0	1,465.2	1.6
				4.3



Length: 54.17"

Avg. Back Weld Stress Strength: 6,553.9 psi

Length: 8.33"

Avg. Back Weld Stress Fatigue: 3,305.9 psi

Stresses presented are factored for Strength design:
LL Factor= 1.75
Multi-presence Factor = 1.20
Dyamic Factor = 200%

Ratio these stresses for the Fatigue check:
LL Factor = 1.50
Multi-presence Factor = 1.00
Dyanamic Factor = 175%

- Consider the average stress over all bolts carrying load from the wheel line for the Strength check.
- Consider the maximum average stress over a single bolt for the Fatigue check.

STATE	PROJ. NO.	SHEET NO.
MO		B50

GENERAL NOTES:

Finger plate shall be cut with a machine guided gas torch from one plate. The plate from which fingers are cut may be spliced before fingers are cut. The surface of cut shall be perpendicular to the surface of the plate. The cut shall not exceed 1/8" in width. The centerline of cut shall not deviate more than 1/16" from the position of centerline of cut shown. No splicing of finger plate or finger plate assembly will be allowed after fingers are cut. The expansion device shall be fabricated and installed to the crown and grade of the roadway.

Plan dimensions are based on installation at 60°F. The expansion gap and other dimensions shall be increased or decreased 5/16" for Bent 3 and 1/2" for Bent 6 for each 10°F rise or fall in temperature at installation.

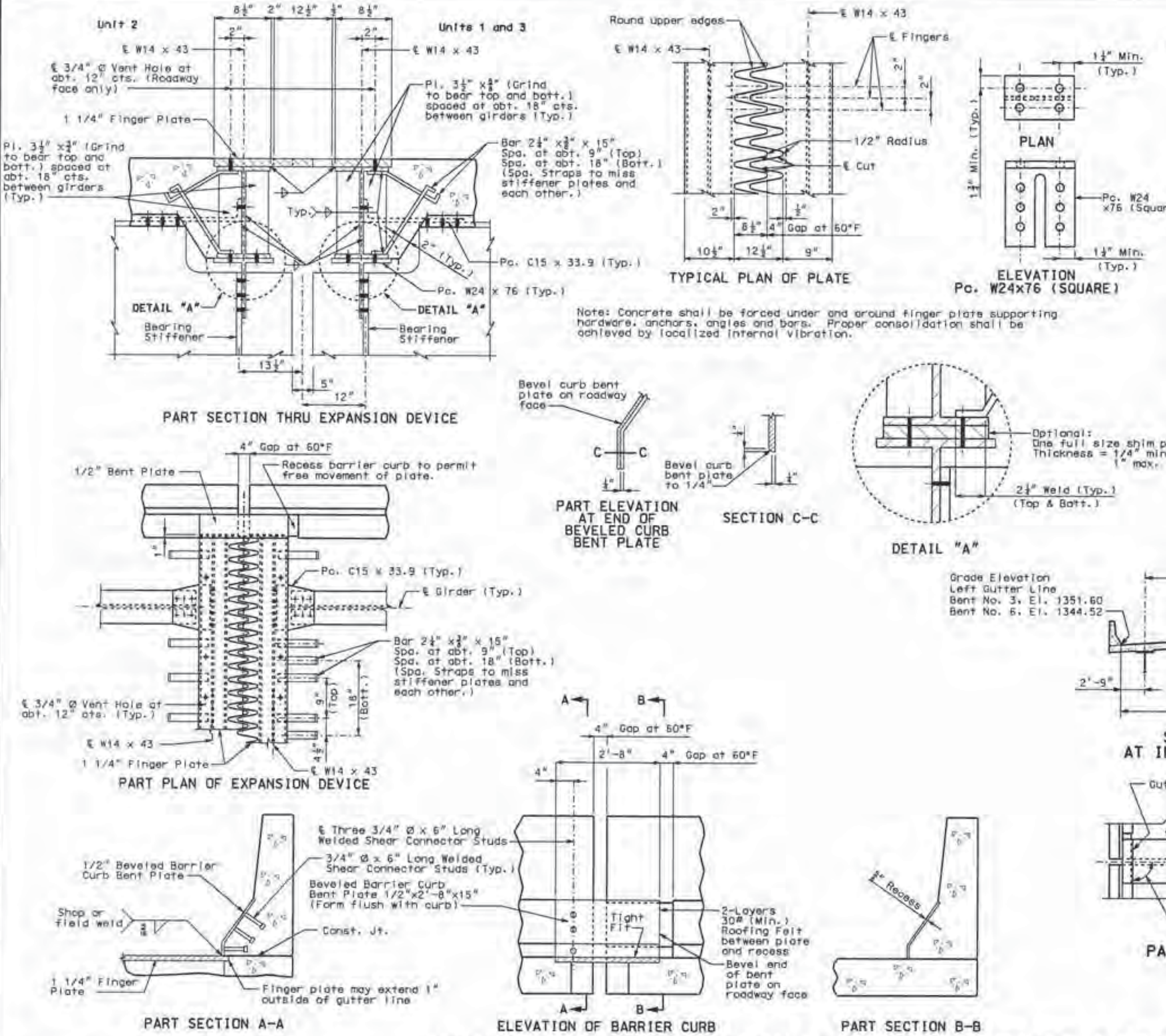
Material for the expansion device shall be ASTM A709 Grade 36 structural steel. Anchors for the expansion device shall be in accordance with Sec 1037.

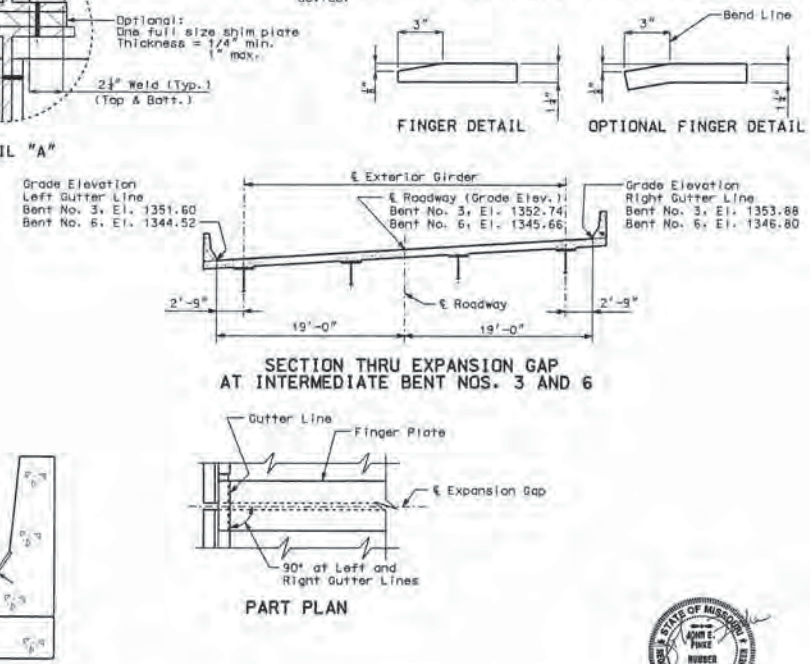
Structural steel for the expansion device and curb plate shall be coated with a minimum of two coats of inorganic zinc primer (5 mils minimum) or galvanized in accordance with ASTM A123. Anchors need not be protected from overspray.

Payment for furnishing, coating or galvanizing and installing the structural steel for the expansion device will be considered completely covered by the contract unit price for Expansion Device (Finger Plate) per lin. ft.

All holes shown for connections to be subpunched 11/16" Ø (shop or field drill) and reamed to 13/16" Ø in field.

Longitudinal reinforcing steel shall be placed so that ends shall not be more than ±1" from the web of W14x43 at the expansion device.





DETAILS OF FINGER PLATE EXPANSION DEVICE AT INT. BENT NOS. 3 AND 6

DETAILED: GJD OCT. 2005
CHECKED: FAC JAN. 2006

JACOBS CIVIL INC.
ST. LOUIS, MO.

SHEET NO. 50 OF 77

GREENE COUNTY

A7024

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