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16. Abstract

This report evaluates TxDOT criteria for the superheavy loads that trigger bridge analyses to determine whether the criteria adequately protects Texas bridges. Researchers used solid modeling calibrated with a bridge test of a 3-span continuous steel girder unit of SH 159. The bridge testing measured girder end rotations with tilt loggers and load position using a sub-foot accuracy GPS. Solid modeling was done with ANSYS 12. The calibrated model was used to conduct a parametric study. Axle distribution factors of 0.28 and 0.45 were experimentally determined for interior and exterior girders respectively. Results of the parametric study showed that the Texas superheavy load criteria are valid for this bridge type. A study of service life extension showed that operational stress level loads applied as little as 5 percent of time to a particular structure will have a significant effect on the lifetime of the structure, and that the number of fatigue load-cycles per truck cannot be assumed to be one. A graphical version of the bridge review trigger (load-length curve with existing allowances and restrictions) might serve TxDOT and heavy-haul carriers better than does the gross vehicle weight triggers. Data collected long term of load frequency and load level from a relevant bridge would help TxDOT determine what effects stress level variations have on the life of Texas bridges.

17. Key Words Bridge Analysis Load, Bridge Review Trigger, Superload, Superheavy Load, Bridge Rating, Axle Distribution Factors, Solid Modeling, Instrumentation, Steel Girder, Variable Stress Level Fatigue, Preservation of Civil Structures, Abnormal Loads, Overweight Permit, Permit Criteria, Live Load Distribution.	18. Distribution Statement No restrictions. This document is available to the public through NTIS: National Technical Information Service Alexandria, Virginia 22161 http://www.ntis.gov

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VERIFICATION OF TEXAS SUPERHEAVY LOAD CRITERIA FOR BRIDGES

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DISCLAIMER

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CHAPTER 1
INFORMATIONAL SEARCH

1.1 INTRODUCTION

The literature review included the review of published work on superheavy loads, live-load distribution and factors, fatigue of bridge structures from heavy loads, bridge modeling with finite element analysis, and other related research and guides. The discussion of literature reviewed, which follows this introduction, covers superheavy and abnormal loads. Literature reviews of these other topics are included in subsequent chapters. Most researchers studying superheavy loads are using finite element analysis, and their models and modeling techniques are often included in their published work. Most of the modeling techniques use model calibration from field measurements of strain-gage-instrumented bridge structures.

The literature review found a completed 2008 project similar to Project 0-6438. This was the only similar study found. The study was conducted by engineering consultants with Vela-VKE in Cape Town, Republic of South Africa (R.S.A), and was commissioned by the R.S.A. Department of Transport. Vela-VKE was tasked with a review of abnormal bridge load formula that had been in place since 1974. It includes a vehicle gross mass limit of 275,000 lb, or a maximum load intensity of 375 psf, and a mass limit on multiple axles using a bridge formula. The objectives of the study were to make recommendations with regard to vehicle mass limitation, vehicle-loading intensity, axle mass limitation as expressed by the bridge formula, and the applicability of the bridge formula to heavier loads.

Most of the literature on superheavy bridge loads from the United States concerns the effects of superheavy loads on bridges, and the work is usually undertaken to ensure safety and prevent overloading of bridges. Most of the superheavy bridge research has occurred since 1999 and much of it comes from four research centers. All four are department of transportation partnerships with universities.

1.2 LITERATURE ON SUPERHEAVY LOADS

The earliest literature concerning superheavy loads comes from the Republic of South Africa. In Europe and South Africa, heavy loads are known as abnormal loads. Much of the European literature on abnormal loads covers superheavy loads. In 1970, a committee was appointed to develop uniform rules for the movement of abnormal loads on roadways across South Africa. In 1974, the work of the committee was published as TRH-11 (2008), "Dimensional and Mass Limitations and other Requirements for Abnormal Vehicles." The committee currently exists and is known as the "Abnormal Loads Technical Committee." Boulet (1977) gives specifications and calculations for tractor-trailer combinations using as many as 4 tractors with both 440,000 and 880,000 lb gross combined-mass trailers. He gives a gross vehicle mass of 1,720,000 lb for a payload of 864,216 lb, the girder-type trailer, two trailer bogies and four vehicles (3 pull trucks and one push truck), with a total length of 313 ft. He also gives a simplified method for calculating the effect of these loads on bridges apparently taken from TRH-11 published 3 years earlier.

The method estimates the maximum load that can be carried on any span. It takes into account maximum shear forces and bending moment, and the critical span length. The critical span of the bridge is defined as the "approximate span of the bridge that will be most highly stressed by the load." Shear, moment, and critical span length are all found with a nomograph that relates maximum-load-per-unit-width and critical-span-length with parameters that are determined with given formulas.

Figure 1.1 shows the Goldhofer-type trailer that Boulet discusses and was in use by the South African Railways, designed and built by the French company Nicolas. The railway company had written its own specifications for haulers (tractors, tractor units), which is the focus of Boulet's paper. The guidelines in TRH-11 are "restrictive" due to road-bed foundation materials and light bridges, and the distances the abnormal loads must travel is long (up to 400 mi). Therefore, instead of using ballast on the drive axles of a single hauler to get traction, as was the practice in Europe, South African Railways used several unballasted haulers. This is still the practice today in South Africa on road routes that have become known as "super routes." Figure 1.2 shows such loads, taken from an enthusiast photo collection (Dennis Child Collection).

Duncan (1977) anticipated 2,200,000 lb loads on some South Africa highways with transporters using as many as 320 wheels. He investigated the effects of these wide and long loads on bridges and tried to extend the system developed for abnormal loads for use with the anticipated loads. Nordengen et al. (2002) discuss super routes used by abnormal loads in South Africa "during the past several decades." The routes are necessary, they say, because there are no inland waterways and the standard (narrow) rail gauge prevents most superheavy loads from being moved by rail. They argue that, in spite of the wear, cost, and inconvenience, these super routes need to remain and many need to be upgraded to accommodate the recent, even larger, loads for economic advantage. From the literature, it appears that pavement distress from abnormal loads is the biggest problem in South Africa. However, concerns over the preservation of bridges have also come about with the increasing size and frequency of heavy loads.

Roux and Kemp (2008) report on a project to review TRH-11 commissioned by the S. A. Department of Transport. The bridge formula in TRH-11 was reviewed for the first time since 1981. Engineers at Vela-VKE Consultants in Cape Town conducted the review. In TRH-11 (2008) a superload is defined as a single abnormal vehicle exceeding a gross vehicle mass of 275,000 lb, or 375 psf. Also, the gross mass of a single group of axles is limited by the bridge formula:

Allowable Load on Multi-Axle Units (lb):

$$P_A = w_E \frac{2.54}{100} (15070 + 81d) \qquad \textbf{(Eq. 1.1)}$$

where both w_E and d are in units inches. w_E is defined as the effective width of the axle group, and d is the distance between extreme (or outer) axles of the group (w_E cannot exceed the width of the span).

TRH-11 (2008) shows that a super load was first defined there in 2004. The review of the bridge formula by Vela-VKE was limited to the evaluation of the 275,000-lb load limit and 375-psf maximum loading intensity. The objective was to recommend whether these provisions can be revised or replaced, with particular regard to vehicle mass limitation, vehicle loading intensity, axle mass limitation expressed by the bridge formula, and applicability of the bridge formula to superloads. The consultants conducted a literature review and carried out a parametric study to compare the effects of abnormal vehicles loaded using the provisions of TRH-11 with abnormal design vehicles in codes of practice. The basis for the load limits in TRH-11 was not found nor was a basis found for the bridge formula. According the consultants, the bridge formula may be a lower bound of the graph of mass-versus-axle-spacing corrected for vehicle width. They find that the bridge formula accurately simulates abnormal loads on short-span bridges (spans less than 115 ft) but do not recommend extrapolating it for larger loads. They suggest an exhaustive literature review take place, and that alternative codes of practice be considered, before any changes are made to the existing provisions. The parametric study was conducted using finite element analysis, and there is discussion of the comparative analysis. However the discussion is in terms of codes of practice in use in South Africa. Also the literature Vela-VKE reviewed is unknown.

In the United States, an early study related to superheavy loads is found in Kostem (1978). He does a parametric study using computer-numerical analysis with five common overload vehicles and nine bridge configurations. The bridges are all simple span, slab-on-girder bridges, with prestressed concrete I-beams, reinforced concrete decks, and no skew. He finds that if a small amount of bridge deck damage is allowed, overload vehicles larger than those commonly permissible may be carried by these bridges.

Most of the literature on superheavy loads on bridges are from the year 1999 and later, and most are from four research centers. The Connecticut Transportation Institute is a program of the Connecticut Department of Transportation and has published some of the earliest data in papers on superloads crossing bridges because of its bridge instrumentation program. Researchers include Culmo, DeWolf, and DelGrego. The Joint Transportation Research Program is a program of the Indiana Department of Transportation and Purdue University. Researchers include Akinci, Liu, Bowman, Wood, Reisert, and Chotickai. The University of Cincinnati Infrastructure Institute is a program of the Ohio Department of Transportation and the University of Cincinnati. Researchers there include Helmicki, Hunt, Turer, and Aktan. Finally, the Louisiana Transportation Research Center is a program of the Louisiana Department of Transportation and Development, and researchers there include Grimson, Commander, Ziekl, and Lamanna.

Turer and Aktan (1999) instrumented three slab-on-steel-girder bridges and developed a calibrated finite element model of a critical span to predict the behavior of the bridges under a payload of 742,000 lb. They monitored the three bridges as the load crossed and inspected the bridges for damage. They give details of the bridges and instrumentation, and report that measurements taken while the loads crossed the bridges showed that their finite element model gave conservative predictions.

Chou et al. (1999) worked with the Tennessee Department of Transportation (TnDOT) to develop a method that would reduce the number of structural analyses of bridges performed as a result of superloads. TnDOT considers gross vehicle weights greater than 150,000 lb superloads that require structural analysis. Researchers used data from prior permits to identify cases that would not need structural analysis. The method used gross vehicle weight, axle loads, and axle spacing. They estimate that if adopted the method would reduce the number of structural analyses performed by half.

Fu and Hag-Elsafi (2000) also worked to develop an analysis procedure to evaluate overstress levels in bridge structures due to overloads. They present a method to develop live load models and associated reliability models for assessing structural safety. They also developed load factors and conducted a sensitivity analysis on their use.

Ghosen and Moses (2000) use a sensitivity analysis to show how changes in the safety criteria used to develop truck weight regulations would affect the existing bridge network. They performed detailed load capacity evaluations and reliability analyses on a representative sample of highway bridges.

Hunt and Helmicki (2002) describe the instrumentation of an Ohio bridge (WAS-339-2013) that was crossed by a superheavy load with a gross vehicle weight of 883,488 lb. The bridge is a 650-ft long, 6-span, 2-lane, steel-stringer-type bridge with a reinforced concrete deck. It was built in 1963. The Ohio Department of Transportation performed a BARS software analysis on the bridge that showed the bridge would possibly be overloaded by the superload. Researchers instrumented the bridge and used known loads on dump trucks to evaluate the condition of the bridge. The data were linearly extrapolated to estimate the effects from the superload. They also developed a finite element model using bridge plans then calibrated the model with data from field measurements. They monitored the bridge during superload crossing and inspected the bridge for damage after the load passed. Measurements showed a maximum stress of 10,000 psi on girders at mid-span. Inspection showed some transverse cracking on the deck.

Helmicki and Hunt (2004) provide more information about the experimental program of Ohio bridge WAS-339-2013 with much greater detail in this report to the Ohio Department of Transportation. Haf-Elsafi and Kunin (2004) instrumented a prestressed concrete box-beam bridge with integral abutments for superload passages after an engineering analysis resulted in recommendations of two unusual crossing methods. The bridge is a single span of 107 ft and is 11 box beams wide (42 ft). The superloads were boiler units and several were scheduled to cross this bridge structure. Both recommended crossing methods involved spreading the trailer unit load over the width of the bridge. One method was to move the load in diagonal steps, and the other was to skew the load and move it across the bridge in the skewed configuration. Analysis of data collected from four crossings showed that stresses were not high enough to cause cracking of concrete, that skewing the load had no benefit over moving the load diagonally in steps across the bridge, and that the integral abutments provided significant end fixity.

Culmo et al. (2004) introduce some of the different types of trailers available for superheavy-load transport on highways and, to a lesser extent, their effects on bridges. Discussion includes trailer layouts, simplified methods of analysis, live load distribution, and dynamic load allowance. Researchers here attribute the increasing use of highway systems by superloads to a spurred power plant building program. In this program, the next generation of power plants is being built, which uses existing natural gas pipelines. The building sites are areas where existing pipelines cross existing electric power grids. Such places are remote from rivers and heavy rail. Strain gage data from a superheavy crossing a Connecticut steel-girder bridge are presented and compared with live load stress estimates. The strain data are available from Connecticut Department of Transportation’s (CTDOT’s) webpage and were collected during a 2002 bridge crossing. The instrumentation of Connecticut bridges is discussed in DeWolf (2006) and DeWolf et al. (2009).

Wood et al. (2007) studied the long-term effects of superloads on typical steel and prestressed concrete slab-on-girder bridges. They used beam line analysis and finite element models, and heavily instrumented one prestressed concrete bridge and one steel bridge. Their results show that 500,000 lb loads on these bridges are not expected to reduce their long-term performance. Field measurements show that these bridges perform better than is predicted using design assumptions and that American Association of State Highway and Transportation Officials (AASHTO) girder distribution factors are conservative. Researchers therefore recommend using finite element models to predict bridge behavior under superheavy loads.

Akinci et al. (2008) evaluated the effects of parapets on live-load response of slab-on-girder steel bridges subjected to superheavy loads to determine whether girder distribution factors could be reduced on such bridges. They found girder distribution factors could be reduced up to 30 percent. They used 3D finite-element static analyses with SAP2000. Cases for steel bridges with continuous and discontinuous parapets were analyzed. The results of the finite element analysis were compared with strain measurements from an instrumented bridge. The strain data are available from the CTDOT webpage and were collected during a 2002 bridge crossing.

Ziehl and Lamanna (2003) and Grimson (2008) discuss the instrumentation of the Bonnet Carré spillway bridge for superheavy load crossing. Ziehl and Lamanna prepared a report for the Louisiana Transportation Research Center. Researchers give a qualitative analysis of the event due to various factors. Grimson uses the same crossing event to discuss applications of acoustic analysis for such bridge analyses.

Fu et al. (2008) studied the impact of commercial vehicle weight changes on highway bridge infrastructure. They present concepts of a new methodology for estimating cost effects of truck weight limit changes on bridges. Inadequate strength of existing bridges and increased design requirements for new bridges were found to dominate total impact cost.

Phares et al. (2008) discuss commercial equipment and analytical tools available that simplify the processes of modeling, testing, and rating bridges for superheavy load passage. Two case studies involving Iowa bridges and the Iowa Department of Transportation are presented. Bridges were instrumented with strain gages and evaluated with known loads. The bridges were then modeled with finite elements, and the models were calibrated with the measurement data. The model was then used to predict bridge response to a 640,000-lb superload. The instrumented structures were monitored as the load crossed, and the data collected were compared with the predicted response to determine the validity of their diagnostic procedure.

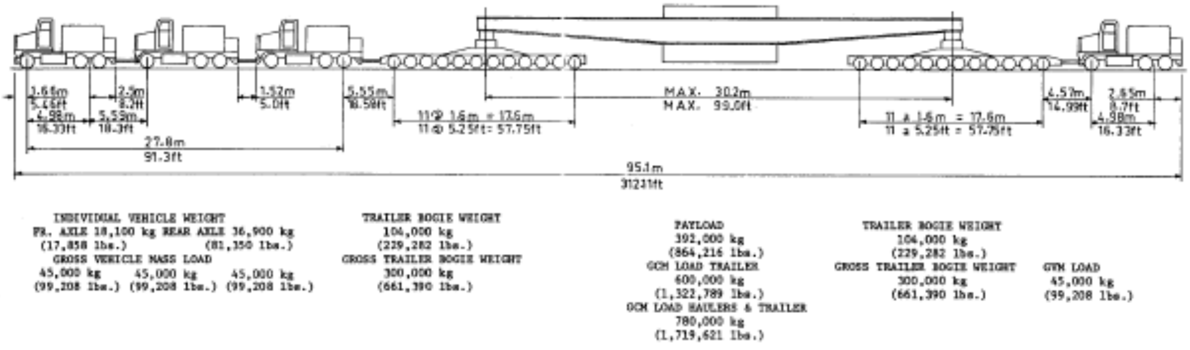


Figure 1.1. Abnormal Load Haulers and Trailer from Boulet (1977).

Figure 1.2. Tractors and Goldhofer Trailer in South Africa.

CHAPTER 2
CRITERIA AND EVALUATION METHODOLOGY

2.1 INTRODUCTION

This is a discussion of the procedures involved in permitting superheavy loads to move over bridges. Other procedures that may be involved concerning superheavy loads on pavements are not discussed. The information contained here was gathered from documents provided by the Texas Department of Transportation (TxDOT) Bridge and Motor Carrier Divisions, meetings on September 30, 2009, and October 16, 2009, with TxDOT, and from meetings during February 2010 with TxDOT bridge consultants.

2.2 PROCEDURES AND DEFINITIONS

TxDOT superheavy loads are vehicle loads defined in Title 43: Texas Administrative Code, Chapter 28, Subchapters A – K. They are defined as:

- An overdimension load that is between 200,001 and 254,300 lb total with less than 95 ft overall axle spacing.
- Or is over the maximum permitted weight on any axle or axle group.
- Or is over 254,300 lb gross weight.
- Or is over the weight limits described in §28.11(d).

The *maximum permitted weight on any axle or axle group* is defined in §28.11(d).

An *overdimension load* is defined as a vehicle, combination of vehicles, or vehicle and its load that exceeds maximum legal width, height, length, overhang, or weight as set forth by Transportation Code, Chapter 621, Subchapters B and C.

A *nondivisible load* is defined as a load that cannot be reduced to a smaller dimension without compromising the integrity of the load or requiring more than eight hours of work using appropriate equipment to dismantle.

Gross weight is defined as the unladen weight of a vehicle or combination of vehicles plus the weight of the load being transported.

Gauge is defined as the transverse spacing distance between tires on an axle, expressed in feet and measured to the nearest inch, from center-of-tire to center-of-tire on an axle equipped with only two tires, or measured to the nearest inch from the center of the dual wheels on one side of the axle to the center of the dual wheels on the opposite side of the axle.

A hauler requesting a permit to move a superheavy load must submit to TxDOT Motor Carrier Division (MCD) a loading diagram with several specified details, a map of beginning and ending points relative to a state highway, a copy of the hauler's contract to move the load, appropriate fees, and specified information about the hauler's TxDOT-approved licensed professional engineer (bridge consultant).

The MCD develops a proposed route and sends the route to the affected TxDOT districts. With the input from the districts, the proposed route is provided to the hauler who then inspects the route for suitability. When MCD has a suitable route, it develops a list of bridges and culverts along the route from graphic information software linked to a bridge inventory database (ArcMap and BRINSAP). MCD then sends a package of bridge information (which includes route, load description and diagrams, bridge list, and bridge inspection reports) to the bridge consultant. The bridge consultant then performs a structural analysis of each bridge to be crossed by the superheavy load. The bridge consultant may obtain bridge plans from TxDOT to perform the work. Once the route and load configuration are approved, TxDOT Bridge Division may ask the Texas Department of Public Safety to weigh the load prior to movement, and they may ask that TxDOT vehicles and law enforcement be present during superheavy load bridge crossing.

2.3 MEETING WITH TXDOT BRIDGE CONSULTANTS IN DALLAS

On February 9, 2010, researchers from Lamar and West Texas A&M University (WTAMU) met with TxDOT consultants and John Holt of the Bridge Division to discuss superheavy load analyses. After receiving drawings of the superheavy load vehicle from the hauler, and a bridge list from TxDOT MCD, the consultants first categorize the bridge structures into critical types. They then convert non-AASHTO axle loads to equivalent axle loads. With the equivalent axle loads, several software applications are available to evaluate the suitability of the bridges. Software mentioned included TxDOT software such as Slab49 (for evaluating load distribution) BeamColumn51, Prestress14, and AASHTO software such as BARS, BRASS, Virtis, and other TxDOT in-house guides such as the "Panak curve," a curve developed by TxDOT bridge engineer John Panak. Often a hauler will need to cross a bridge that is not easily categorized and the bridge analysis may involve issues that may be esoteric or unusual.

Therefore the analyst's experience and familiarity with Texas bridges and heavy load hauling equipment is very important. In general, they follow the overload provisions of AASHTO (1994).

2.4 MEETING WITH TXDOT BRIDGE CONSULTANTS IN HOUSTON

On February 24, 2010, researchers from Lamar met with TxDOT consultants and John Holt of the Bridge Division to discuss superheavy load analyses. The consultants use Load Factor Resistance Rating (LRFR) rather than Allowable Strength Rating (ASR) and Load Factor Rating (LFR). They use the AASHTO Manual for Bridge Evaluation (AASHTO, 2008) that contains procedures for bridge rating with both LRFR and LFR. With LRFR, lateral load distribution is determined with the lever rule, and distribution factors are applied to an axle rather than to wheel loads. They also used TxDOT software. For continuous spans, they used BeamColumn51 and for prestressed spans they used Prestress14. (For simple spans they use spreadsheets.) In their bridge sorting process, they look for, among other things, load density. Once they get load configuration drawings and a route from a hauler, they look at bridge plans and then section properties. For most structures, they look at flexural capacity. Occasionally they look at substructure elements. They also have much experience and familiarity with TxDOT bridges and bridge plans.

2.5 DISCUSSION

Live load capacity of bridge structures is limited by design loads and by bridge condition ratings. Load distribution to bridges from design trucks may be determined using load distribution factors. Influence lines for shear and moment effects may then be obtained. Generally, when overweight-truck axle and wheel configurations are different from those of design trucks, load distribution to bridge structures involves the gross weight and overall length between extreme axles, axle weight, axle spacing, wheel gauge, wheel (tire) width, and girder spacing. To analyze the effects of overweight trucks on bridges, the approach is to approximate effective width allowed by code and then determine load distribution factors for the wheels of the overweight truck. Then the influence lines for moment in the girders are compared with the influence lines of the design truck, for the particular bridge structure. Generally, an occasional load of about 75 percent of yield stress is considered acceptable by code. The effective width method used by TxDOT is an interpolation of AASHTO single lane and AASHTO dual lane distribution factors for interior beams (McLelland, n.d.). In certain instances, load distribution for wheel loads on bridges with girders spaced far apart is done by the simple beam method, where the deck between girders is assumed to act as a simple beam.

Flexural stresses in girders are usually the focus of such bridge analyses. Shear in girders, loads on columns and bent caps, and ancillary bridge components are often neglected from analysis. However the particular bridge type and bridge ratings have to be considered, and may dictate further analysis. Truss, through truss, and bridges with low dead-to-total-load ratios require extra careful consideration for analysis (Panak, 1992). Other methods of the analysis of superheavy loads on TxDOT bridges include 2D and 3D finite element analysis, and discrete element analysis.

In general, superheavy load analyses are performed by bridge engineers who are very familiar with Texas bridges. For a given route and superheavy load, bridges are sorted into passable and conditionally passable groups. If a route crosses a special, historic, or load-zoned bridge, the analyst will ask the hauler and MCD to choose another route. Problematic structures include those designed with H15 loading, through and deck truss units, and long-span plate girder units with widely spaced girders. Passable structures are usually checked for flexural load capacity. Passable structures are identifiable by type, design load, year built, bridge condition rating, and span length. Conditionally passable structures include those that have been retrofit, those with marginal rating conditions, and those with skewed, curved, or long narrow spans. The analysis of conditionally passable structures may include investigation of shear capacity in addition to flexural capacity. Substructure elements are rarely considered in superheavy analyses. Bridge crossing may involve restrictions such as having the load occupy the center of the structure, restricting the number of vehicles on the bridge while crossing, speed restrictions, and prohibiting the load from stopping on the bridge. Other restrictions may be imposed to spread the load across multiple girders, such as having the load move diagonally across a structure, or conversely, having the hauler skew the load and moving the load across the structure in the skewed position. The hauler may use several load distribution configurations along a route, which is possible by the use of outrigger-type dollies. These restrictions may allow impact factors to be neglected, along with multiple-presence factors and extreme event factors. If analysis shows that a particular load configuration causes overload in a particular bridge structure, then the TxDOT consultant may be able to reconfigure a load such that it may cross the structure without overloading it. In more extreme cases, it is also possible, with some bridge structures, to build a temporary bridge over bridge to allow the load to cross.

CHAPTER 3
SURVEY OF OTHER DOT SUPERHEAVY CRITERIA

3.1 INTRODUCTION

Researchers from WTAMU and Lamar University sent surveys to each of the 50 states by email. The purpose of the surveys was to gather information about the policies concerning the bridge analyses performed to determine the suitability of a bridge for a particular overweight load. Such overweight loads are known as superloads and superheavy loads. In retrospect, because many of the states do not have a definition for a superload, a better term for these overweight loads, for the purpose of the survey, might have been “state bridge analysis load.”

WTAMU modeled its survey forms on those used by Fu and Fu (2006). Researchers there pointed out that though they had collected from the many state departments of transportation (DOTs) information concerning bridge rating practice and policy, they had neglected to ask the states what they had used as a basis for those bridge rating practices and policies. Lamar attempted to gather information from the states concerning the basis used for bridge analysis loads since one of the objectives of Project 0-6438 is to evaluate the validity of the Texas criteria. Survey results are summarized in the text of this report. The WTAMU and Lamar survey instruments and survey responses are attached to this report as Appendix 3.1 and Appendix 3.2.

3.2 SURVEY RESULTS

WTAMU and Lamar received 42 survey responses that represent 28 states. All of the state DOTs have permit websites and most of those websites have links to the state laws that govern oversize and overweight load movement on roadways. How the particular DOT handles permit requests relative to bridge crossing is not spelled out in state laws, however. Many of the states do not define or make reference to superheavy loads. Therefore the bridge analysis loads discussed below were collected from state DOT websites and from the Specialized Carriers & Rigging Association (SC&RA) Oversize/Overweight Permit Manual (December 2009) in addition to the surveys.

The SC&RA Manual is a collection of state legislation concerning oversize and overweight vehicle movement. It does not interpret the state legislation, to make the laws more uniform or helpful to haulers. The state DOT websites, however, tend to add interpretation, perhaps to make the sites easier to use, and many make references to superheavy loads. Some that refer to superloads give a gross vehicle weight definition (Montana), and some do not (Wyoming). Some of the survey responses give gross vehicle weight definitions of superloads, and some for bridge analysis loads. In the case of Nevada, the superload gross vehicle weight definitions from state law, state DOT website and state survey appear to contradict each other. At any rate, it is clear from the collected data that the Texas bridge analysis load of 254,300 lb (for vehicles 95 ft and longer) is high compared to most of the other 49 states. The average bridge analysis load is 165,000 lb. Texas has the highest bridge analysis load.

The surveys, along with the review of state laws and prior research, show:

- State law does not provide a good indication of the criteria used by states to trigger a bridge analysis that determines whether a particular load is allowed to cross a particular bridge.
- All of the states use “operating stress level” as the basis for allowing a particular permit load to cross a particular bridge.
- Many of the states use the Federal Bridge Formula, sometimes with modifications, as a basis for permitting loads. The formula is used along with axle load limits.
- Some states use a series of load tables as a basis for permitting loads. Some of these are color coded, and each bridge in the state network is assigned to a color table or is posted.
- None of the states responding to the surveys have completed a study of the fatigue effects on bridges due to superheavy loads.
- The State of New Hampshire Department of Transportation, for a year prior to September 2009, “...review[ed] all procedures, regulations, and rules...to determine if current procedures were appropriate to protect the condition and safety of New Hampshire’s roads and bridges with regards to overweight loads.” As a result, “...a number of loads that previously would not have required, nor received, a bridge

review will now require a bridge review prior to a permit being issued." The changes became effective November 2, 2009. The state law and the succeeding changes are included in appendices. The new criteria, which is referred to as the criteria for "bridge review trigger" is discussed below.

- Many of the states have computer-assisted permitting systems and some incorporate bridge screening. At least six states use a computer-based routing and "bridge analysis" system from Bentley Systems, Inc. with the apt name "Superload." Apparently, Bentley sponsors a central permitting site, gotpermits.com (Bentley, 2011).
- Bridge screening (or filtering) is dependent upon bridge ratings or an empirical bridge load envelope. Hawaii, for example, has all of its bridges rated using LRFR. Tennessee has an empirical bridge load envelope that is used along with acceptance sampling to screen superheavy loads. (According to the Federal Highway Administration, Hawaii has just over 1100 bridges in the national database, while Texas has over 51,000.)

3.3 GRAPHICAL SURVEY RESULTS

Many states indicate that every permit load is evaluated before it is allowed to cross a particular bridge. But the evaluation process is not the same as a heavy-load triggered bridge analysis. Some states that use computer-assisted routing and bridge analysis and states that use color coded tables resist giving a bridge analysis load; therefore information for a few of the states is missing from the figures.

Figure 3.1 shows the state bridge analysis loads in a histogram. The histogram shows how the identified triggers loads are distributed. Figure 3.2 shows a bar chart of the bridge analysis loads by state with a line overlay of the average size bridge analysis load. The average bridge analysis load is 165,000 lb. Figure 3.3 shows the graph of the normal distribution of the bridge analysis load data. The standard deviation is 36.5 kip, and the Texas bridge analysis load of 254.3 kip is outside two standard deviations.

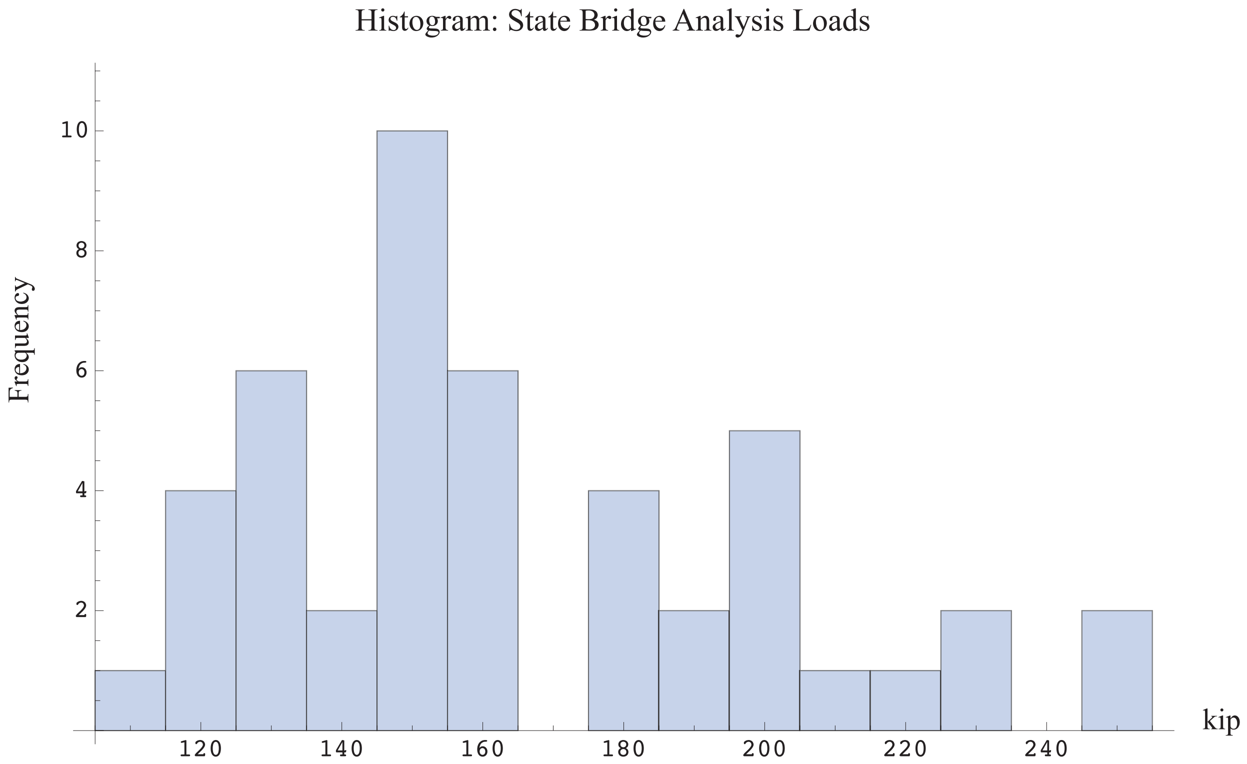


Figure 3.1. State Bridge Analysis Loads Histogram.

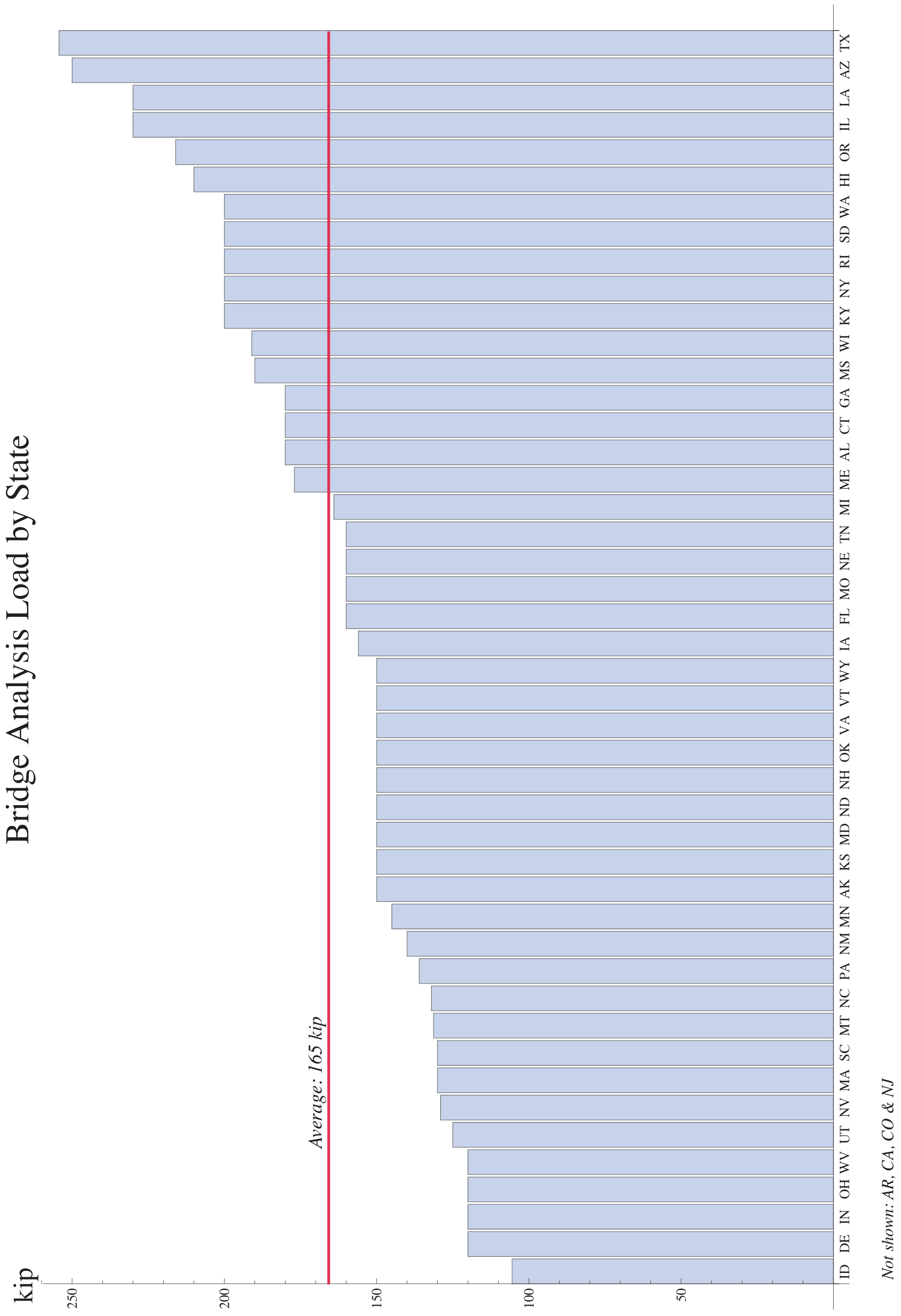
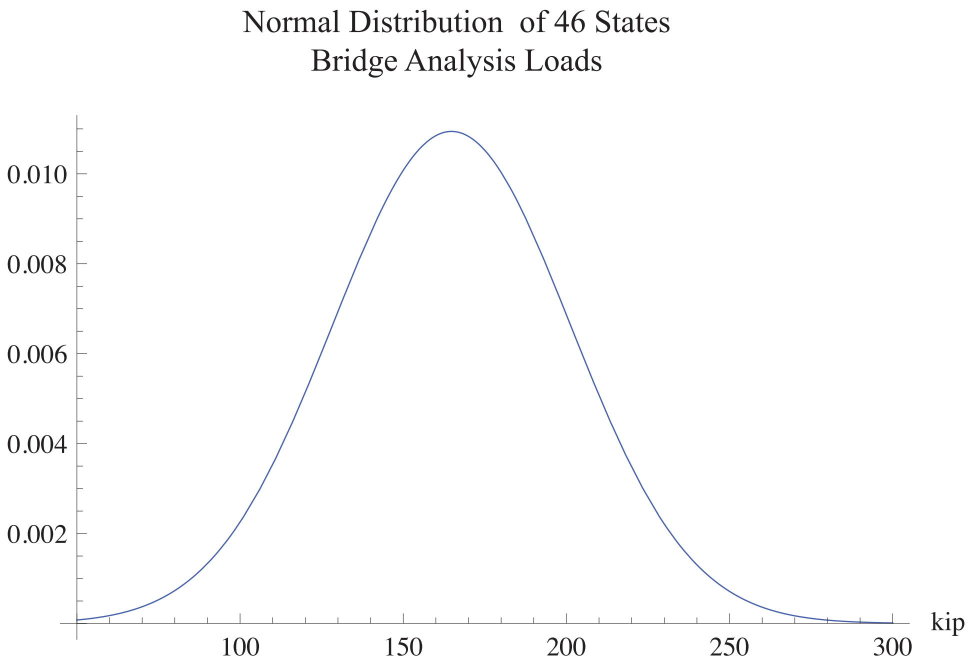


Figure 3.2. State Bridge Analysis Loads.


Normal Distribution of 46 States
Bridge Analysis Loads

Mean: 164.8 kip
Variance: 1328.9
StandardDeviation: 36.5 kip
SampleRange: 148.8 kip

Figure 3.3. Normal Distribution of State Bridge Analysis Loads.

Bridge rating is a common tool when evaluating loads; however, the formula has changed over the years and some states have adopted the latest version while other states have not. ASR, LFR, and LRFR are well known bridge load rating methods used. According to the survey responses, most states use LFR as a bridge rating method and have developed their own policies for bridge rating. The newly adopted Load Factor Resistance Design (LRFD) manual is currently being used in eight states among the states that completed the survey, while other states use combined ASR, LFR, and LRFR methods. Massachusetts uses only the ASR method for bridge rating.

Software is an important component of vehicle permitting, which decreases human error and increases efficiency. However, each DOT uses different programs. Virtis, BARS, and BRASS were found to be the most popular programs among the states. North Carolina uses an in-house program. New Mexico analyzes all bridges along routes using the software OVLOAD. South Dakota uses South Dakota Automated Permitting System, SDAPS, to analyze each bridge crossed by every overweight vehicle and is a standard part of its evaluation process.

States have not experienced fatigue or damage from superheavy loads. Iowa and New Mexico have observed some damage but are unsure of the causes. Virginia DOT is interested in analyzing the fatigue effects from very high loads and currently is developing a policy that may include such criteria.

3.4 DISCUSSION OF REVISED NEW HAMPSHIRE CRITERIA

From the review of state DOT websites for oversize and overweight vehicle loads, it was found that New Hampshire has recently reviewed and revised its criteria for heavy loads on bridges. This information is particularly relevant to TxDOT Research Project 0-6438. This information was not found during a literature review. A copy of the New Hampshire law covering oversize and overweight vehicles (OS/OW) is included in Project Technical Memoranda. The revised New Hampshire criteria (2009) are included in Appendix 3.3. According to the letter that introduces the revisions, a review of data from permit applications showed that some load combinations could damage bridges. As a result the DOT developed specific criteria for loads and axle spacing combinations that trigger a bridge review. The criteria give 18 such combinations. Along with other combinations of load and axle spacing, these 18 will be useful in the bridge modeling tasks of Project 0-6438. Included in the 18 criteria that trigger a bridge review is “Any Combination Vehicle, with 8 or more axles, exceeds 149,999 lb.” The 150,000-lb gross vehicle weight bridge analysis load is less than the average bridge analysis load. This load is the bridge analysis load with the highest frequency, as shown in Figure 3.1.

CHAPTER 4
ANALYTICAL MODELING

4.1 BRIDGE DESCRIPTION

The Brazos River Bridge consists (Figure 4.1) of six spans total. Spans 1, 2, and 6 contain 6 evenly spaced concrete girders (AASHTO Type-4) centered under an 8 in. thick concrete slab. A continuous 720 ft long steel plate girder extends across Spans 3, 4, and 5 and suspended above the girders lays an 8 in. thick concrete slab. The slab is supported by several concrete haunches with a thickness of 3 in. from the lower surface of the top flange of the steel girder to the bottom of the concrete slab. Span 4 measures 280 ft in length and maintains a web height of 84 in. throughout the entire span; Spans 3 and 5 measure 220 ft in length.

Figure 4.1. SH 159 Brazos River Bridge.

4.1.1 Plate Girder Section

The steel girders are 720 ft long and have web dimensions of 84 in. by ¾ in. thick plate. Top/bottom flange dimensions are 30 in. by $1^{3}/_{8}$ in. thick. Tapered sections at the beginning of Span 2 and at the end of Span 4 reduce the depth of webs from 84 in. to 51 in. (see Figure 4.2). The web stiffeners, located every 20 ft along the longitudinal axis, are fastened to the web; top/bottom flanges measure ¾ in. × $13^{5}/_{8}$ in. Additional web stiffeners are fastened 7½ in. and 60 in. from each end of the steel girders. The stiffeners located at the farthest end of girder measures 1½ in thick. Additional plates are located over the two central supports extending 42 ft toward the center span and 44 ft toward Spans 3 and 5. The additional plates attached to the bottom and top flanges measure 30 in wide and 1 $^{1}/_{8}$ in thick (see Figure 4.3).

Figure 4.2. Tapered End Section.

Figure 4.3. Flange Supports.

4.1.2 Slab

The concrete slab maintains a uniform thickness of 8 in. throughout the entirety of the bridge, and the bridge contains steel decking below the slab between the girders. The haunch, including the thickness of the top flange, measures 3 in. in depth throughout the continuous steel span; however the haunch reduces in thickness to $1^7/_8$ in. to compensate for the increased flange thickness near the two most central columns (i.e., between Spans 3-4 and 4-5).

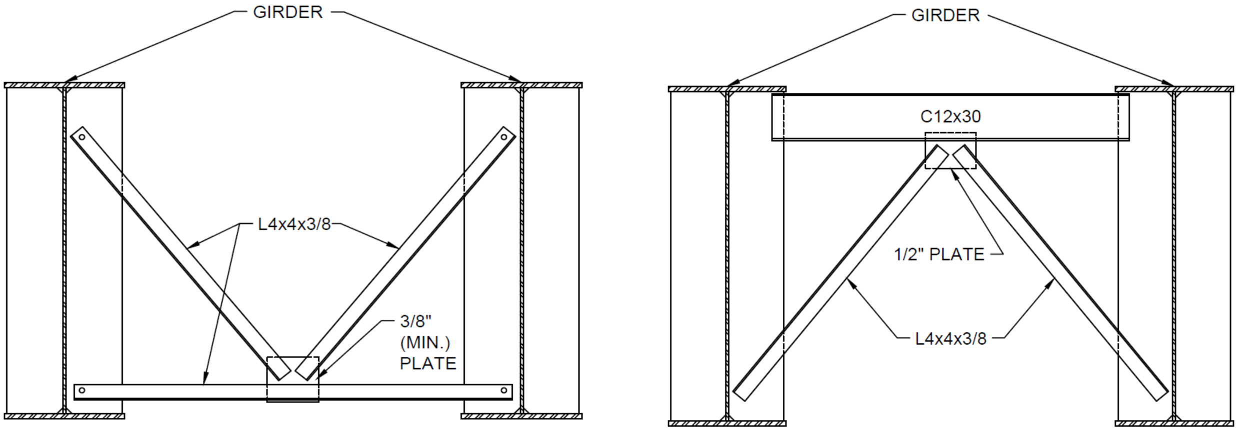
4.1.3 Diaphragms

4.1.3.1 Bearing Diaphragm

The bearing diaphragm is comprised of C12X30 channel welded to a ½ in. thick plate connected to two L4×4×3/8 angle iron segments in a "K" configuration (see Figure 4.4b). The bearing diaphragms are welded to the web stiffeners nearest the ends of the girder.

4.1.3.2 Interior Diaphragm

Interior diaphragms are welded to full section web stiffeners of Spans 3, 4, and 5. The interior diaphragm is comprised of three L4×4×3/8 angle iron segments welded to a ½ in. steel plate (see Figure 4.4a) in a "K" type configuration. Interior diaphragms are welded to the web stiffeners.



(a) Type "D"

(b) Type "B"

Figure 4.4. Diaphragms.

4.2 BRIDGE-TEST VEHICLE CONFIGURATION

The vehicles used for field testing consisted of two 10-yard TxDOT dump trucks, shown in Figure 4.5, and have a combined weight of 96.4 kips and a span of 51.5 ft. The individual vehicles are lengths of 17.75 ft with a between distance of approximately 16 ft. Figure 4.6 shows lengths and axle weights.

Figure 4.5. Two 10-Yard TxDOT Dump Trucks.

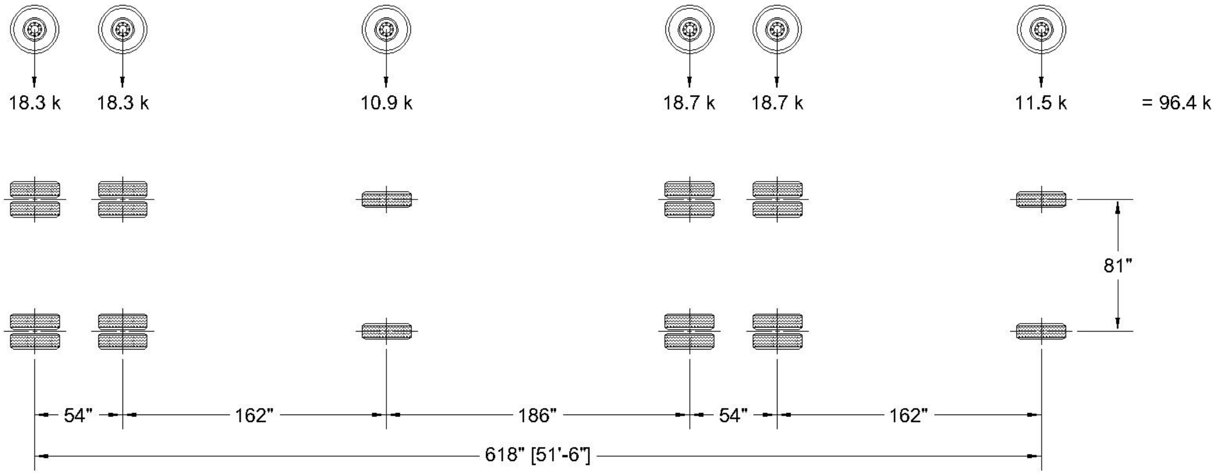


Figure 4.6. TxDOT Vehicle Configuration.

4.3 COMPUTER-AIDED BRIDGE ANALYSIS

Finite Element Analysis (FEA) is a method of analyzing and finding approximate solutions to complex systems that would otherwise require vast amounts of time and resources. ANSYS 12 was used to model the SH159 Brazos River Bridge. ANSYS is a FEA software package that is developed by ANSYS, Inc. ANSYS contains the ability to conduct a broad range of analysis types, from structural to thermal to fluid flow applications, as well as combinations of analyses. FEA uses defined points known as nodes. Nodes are points on an object that define the boundaries of the object.

The greater the number of nodes, the better defined the object and the more accurate the results. In areas of greater interest, such as areas of high stress concentrations, a greater density of nodes is desirable. This allows for greater accuracy by reducing the size of the piece being analyzed. The pattern created by the placement of the nodes defines what is known as the mesh. The structure of the mesh is imperative to an accurate solution. The most desirable mesh pattern is a mapped mesh as opposed to a free mesh. A mapped mesh consists of four sided areas, generally in an organized pattern requiring the user to construct the pattern manually. A free mesh is generated by the program itself and is made of three sided areas in a coarse unorganized manner (typically undesired due to increased error).

4.3.1 Beam Analysis

As a preliminary study, a beam analysis with a degree of freedom (DOF) of one was performed to obtain approximate locations where the maximum and minimum moments occur, as well as the vehicle location at those instances. This information is useful for 3D solid modeling.

4.3.1.1 Type of Element

BEAM4 is one of the line type elements in ANSYS and was modeled with a 3-in. mesh size. BEAM4 is a uni-axial element with tension, compression, torsion, and bending capabilities. Each node in the element has six degrees of freedom, translations in the nodal X, Y, and Z directions and rotations about the nodal X, Y, and Z axes. Stress stiffening and large deflection capabilities are included (see Figure 4.7).

4.3.1.2 Material Properties

Beam elements in ANSYS utilize simple beam theory to predict force distribution of beam structures. The preliminary beam analysis helps predict stress concentrations in the model so optimal meshing is utilized in later shell and solid element models. Additional memory limits produce problems in larger models (such as the bridge in this study). Beam elements help define critical stress concentrations so optimal meshing in solid models will produce a greater level of accuracy while avoiding system computational limits.

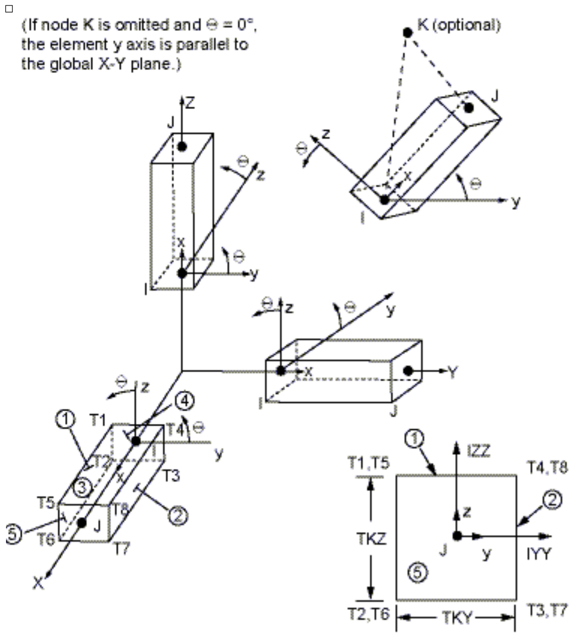


Figure 4.7. Beam 4 Element (Tickoo, 2009).

4.3.1.3 Load Application Step/Iteration

Point loads are applied to the beam model to represent the axle weights of the truck-trailer vehicle. Moving load analysis along the spans was performed by programming since ANSYS does not have a moving load analysis function. The distribution factor per axle load of one was used, and the tapered end sections were neglected to simplify the model. Two boundary conditions placed at Bent 4 and Bent 5 from the beginning of Span 3 restricts translational displacement in the X, Y, and Z directions. Two additional boundary conditions are placed at the end of the steel girder to restrict translational displacement in the Y and Z directions.

Axle loads applied at the beginning of the steel girder created a simple model producing moment data at each 6-in. segment along the beam. The load started as a single point load (representing the first steering axle) applied to the beginning of the beam, and then to the adjacent node until the front axle reached the end of the beam.

4.3.2 Beam Analysis Results

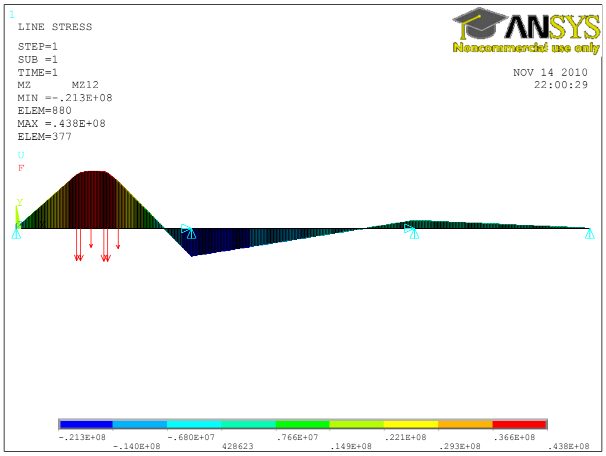
Beam elements cannot directly produce a moment diagram of a structure. However the elements produce nodal loads. Exportation of the nodal moments into a spreadsheet allowed the user to locate maximum (critical) nodal values. The user then obtained nodal moments at the critical nodes as the vehicle crossed the spans for each load step. An 'Element' table in ANSYS was generated from each nodal load and a line element plot employed to produce a moment diagram of the loaded beam.

Beam 4 elements produced moment, rotation, and translational displacement. Nodal moments where taken to produce an influence line graph. Generated ANSYS images display the moment diagram and load position of maximum moment in each span. The shaded region (Figure 4.8) displays the moment diagram, and red arrows represent the location of the vehicle at that particular time. Units used in ANSYS are lb/in and were converted in a spreadsheet to kip/ft, as displayed in the influence line graph. Table 4.1 summarizes the maximum-minimum moment-envelope results using the two 10-yard TxDOT dump trucks.

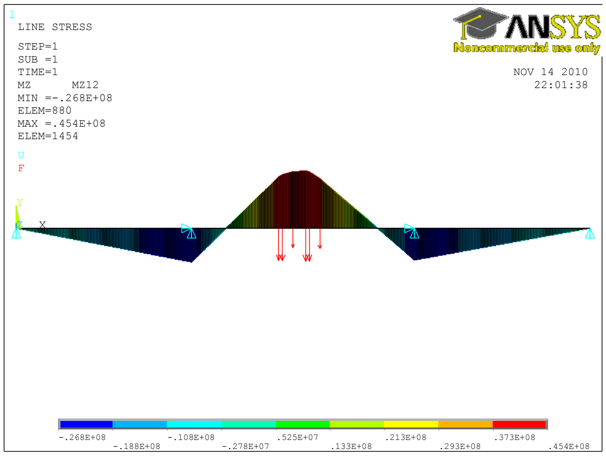
Table 4.1. Max./Min. Moment Envelope.

		Max. '+' Mom. location	Max. '-' Mom. location
		(Steering axle location)	
Span 1		94 ft - 0.43 pt (138 ft)	
	Bent 4		220 ft (356 ft)
Span 2		363 ft - 0.51 pt (381 ft)	
	Bent 5		500 ft (422 ft)
Span 3		628 ft - 0.58 pt (646 ft)	

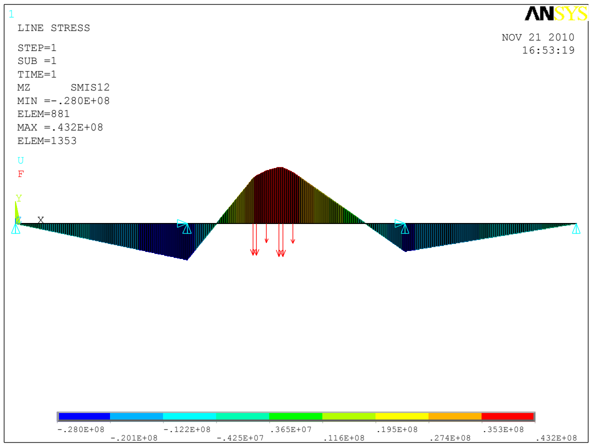
In Figures 4.9 and 4.10, influence lines for moments at 94 ft, 363 ft, and 628 ft represent the sites of maximum moments for Spans 3, 4, and 5, respectively, while influence lines for moment at 220 ft and 500 ft represent the sites of maximum negative moments for two interior supports. The moment values in the figure are meaningless since the DF of one was applied.



(a) **Maximum positive moment on Span 1.**



(b) **Maximum positive moment on Span 2.**



(c) **Maximum negative moment on Bent 4.**

Figure 4.8. Moment Diagram and Vehicle Location.

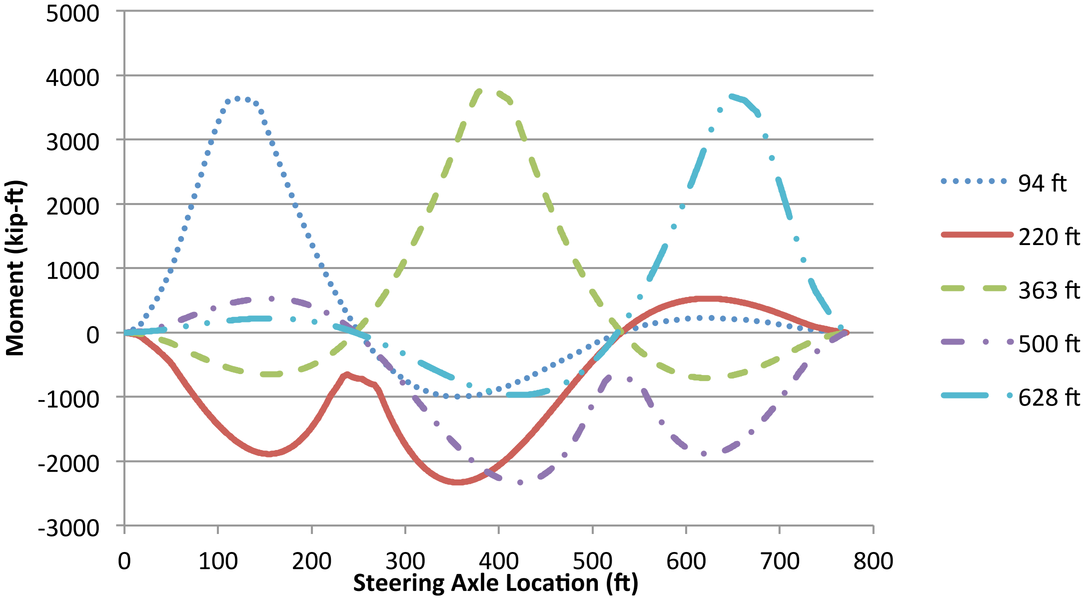


Figure 4.9. Max. Moment Envelope for Forward Moving Analysis (DF =1).

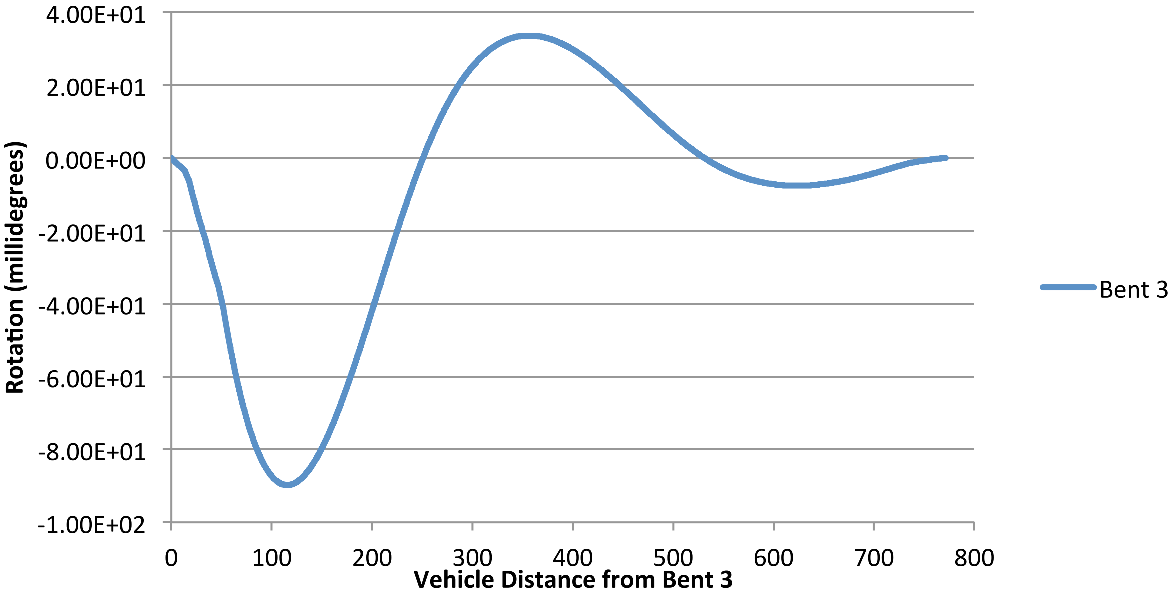


Figure 4.10. Influence Line for Rotation at Bent 3 (DF =1).

4.4 3D SOLID MODELING USING ANSYS

4.4.1 Modeling

Solid modeling (Figure 4.11) uses 3D volumes to display an exact representation of the physical specimen of the bridge. The element type used for the solid elements is known as SOLID73. This element type was selected due to its capabilities of rotational degrees of freedom. The rotational degrees of freedom aided in the comparison of the field data that were collected using tilt meters with the FEA results.

Once a single girder is modeled, ‘glued,’ ‘meshed,’ and ‘copy’ commands in ANSYS were used produced exact replicas of the original central girder geometry and meshing. An 8 in. thick slab was introduced in the model. The slab is centered on the central girder while the distance from the lower surface of the top flange measures 3 in. to the bottom of the slab. T203 type railing was modeled and placed 1.5 in. from the outer most edge of the slab.

The glue command allows the user to combine separate volumes so adjacent volumes become rigidly attached, while the line divisions of each respective volume are individually assigned to obtain mapped meshing throughout the model (drastically increasing the accuracy of the model).

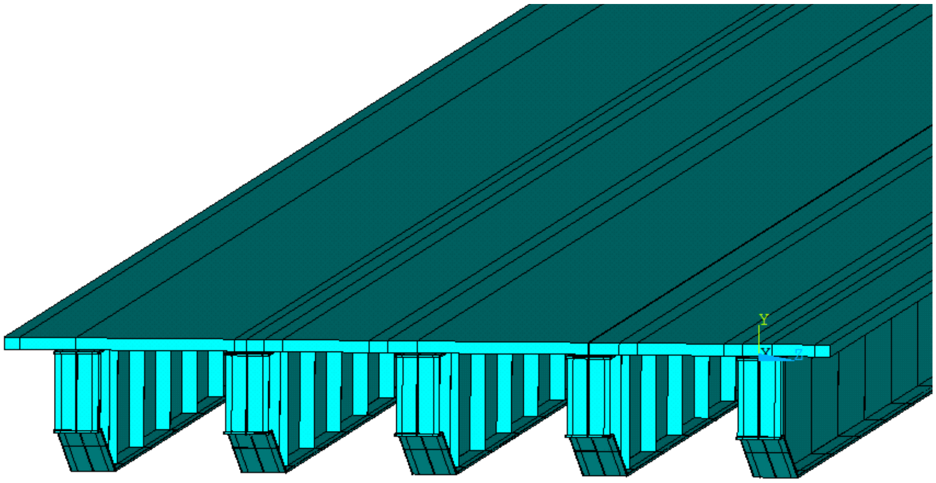


Figure 4.11. Girder and Slab Solid Model.

4.4.2 Meshing

To produce mapped meshing, line divisions throughout the girder's web must remain constant. Therefore, the girder's cross-section is divided into 18 sections to obtain the necessary geometry for mapped meshing. Additional divisions at locations of each volume intersection (i.e., web stiffeners connected to the flange and web) were produced to obtain uniform mapped meshing. Figure 4.12 shows a mapped meshing of the five steel girders.

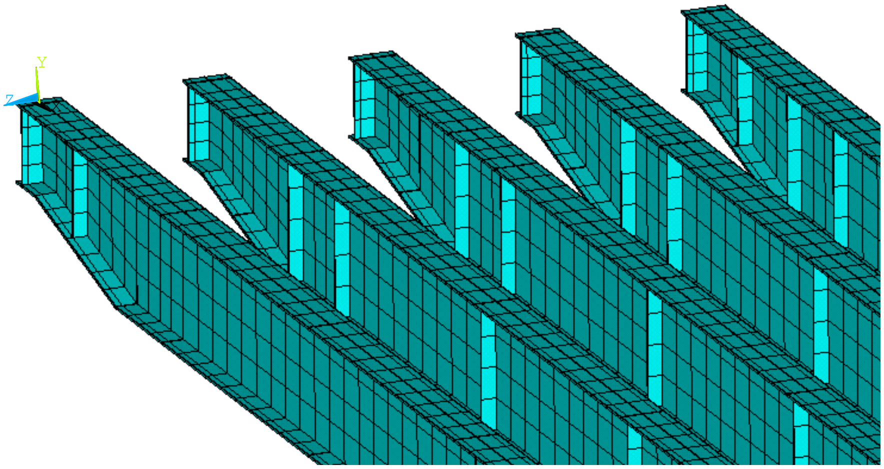


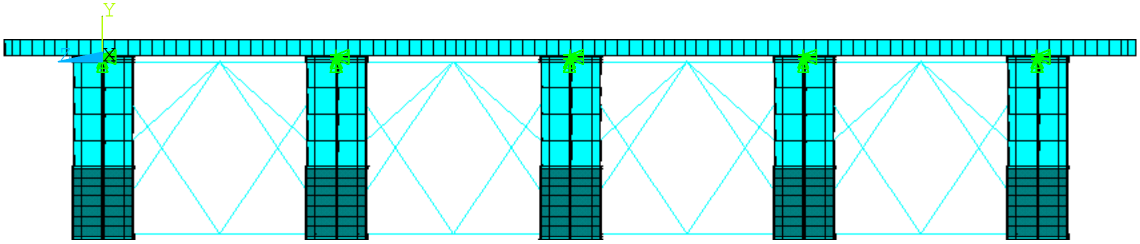
Figure 4.12. Meshed Girders.

4.4.3 Coupling

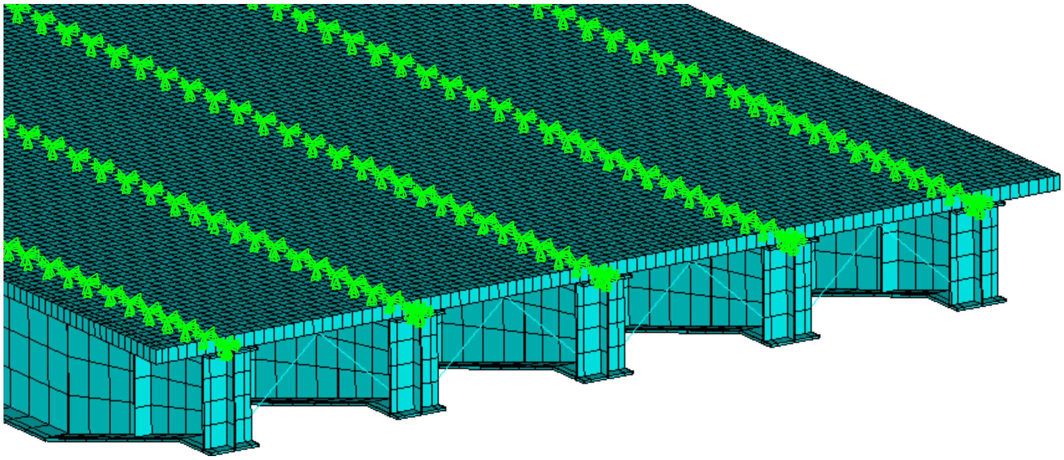
To connect the slab and girder at key points (composite action), the coupling command was used to model the shear connectors and haunches. The coupling command is used to rigidly add LINK 2 nodes in ANSYS, which are not physically attached; therefore several loops were employed to couple the girders to the slab at 1.5 to 2 ft increments in accordance with bridge details. The green objects displayed in Figures 4.13a and 4.13b show the couples.

4.4.4 Loading Conditions

Point loads were located on nodes using the positions obtained in the line analyses conducted for each vehicle configuration and corresponding to the vehicle placement and orientation from Table 4.1. Analyses were conducted using each of the five critical loading locations. Deflection, stress, and rotational data were exported to a spreadsheet for easier handling and calculations. Maximum stresses produced at stiffener support locations were not used for absolute maximum values. Figures 4.14a and 4.14b show vehicle orientations on the slab surface. Orientation 1 corresponds to data obtained in the field tests of odd numbered runs, and orientation 2 corresponds to even number runs.



(a) End View.



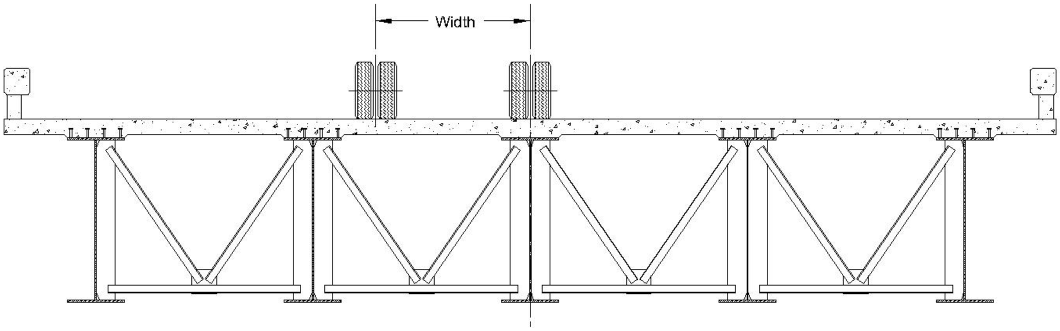
(b) Aerial View.

Figure 4.13. Girder and Slab Coupling.

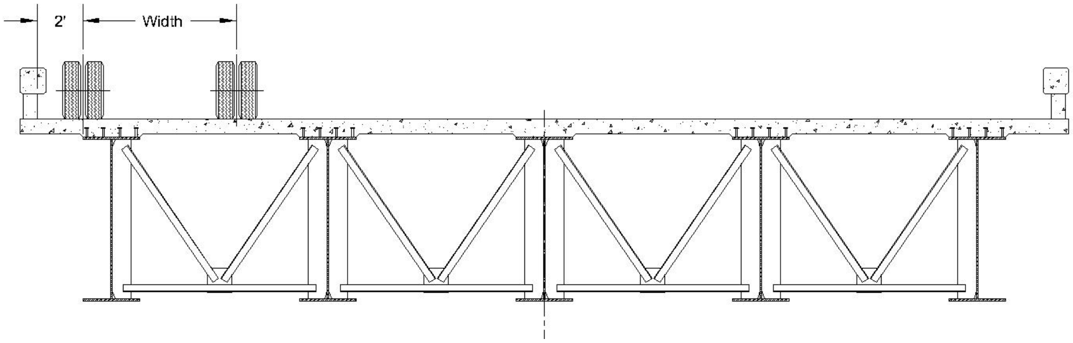
4.4.5 Girder End Rotation and Stress Data

All data were exported from ANSYS into list files, which could then be imported into a spreadsheet for further processing. Rotational data from the nodes located along the bottom center of the lower flange were used in the development of the rotational profile of the girders. All rotations used in distribution factors were taken from points on the bearing stiffeners located at bents three through six concurring with locations used to place the tilt meters in the field tests. Figure 4.15 shows the rotational magnitudes displayed on the deflected bridge section.

Stress data used in the stress-based distribution factors were taken from the bottom center of the lower flange. Figure 4.16 shows the stress magnitudes displayed on the deflected bridge section.



(a) Loading Orientation 1.



(b) Loading Orientation 2.

Figure 4.14. Loading Orientations.

4.5 RESULTS

4.5.1 Modeling Components

Table 4.2 provides the total numbers of modeling components used to construct the beam and solid model replica of the Brazos River Bridge.

Table 4.2. Modeling Components.

No. of Nodes		359,782
No. of Elements		211,696
	Solid 73	200,064
	Beam 4	592
	Couples	11,040
Approx. Analysis Run time		1 hour

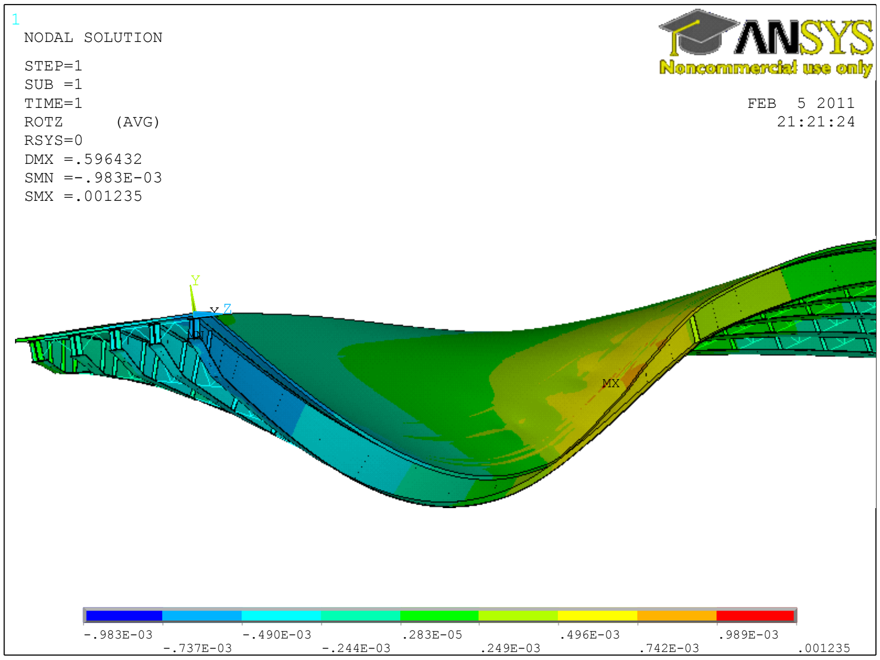


Figure 4.15. Deflected Bridge Displaying Rotational Magnitudes.

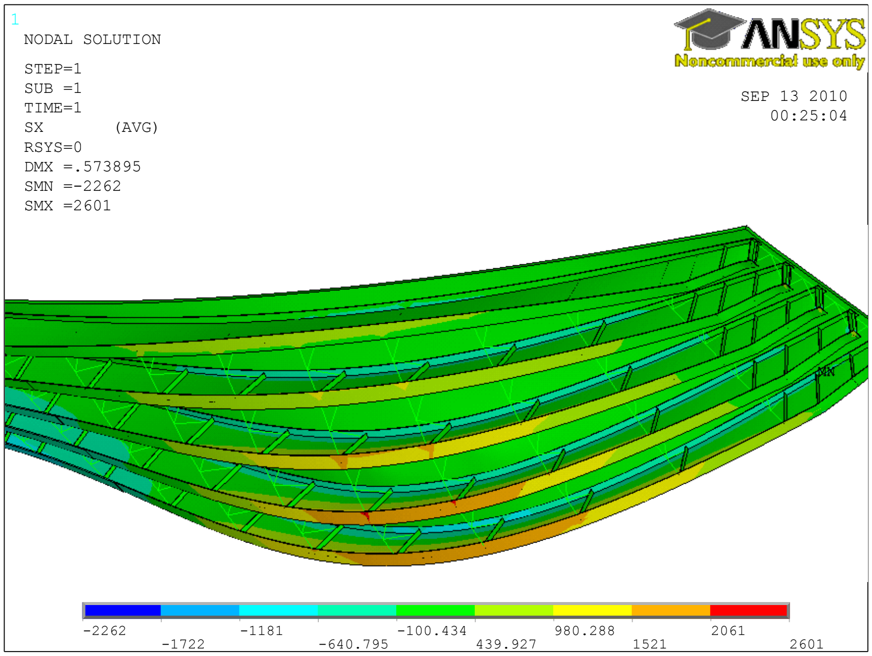


Figure 4.16. Deflected Bridge Displaying Stress Magnitudes.

4.5.2 Two-10 Yard TxDOT Dump Trucks

The following tables (Tables 4.3–4.6) show all distribution factors generated by the 3D ANSYS analysis. For most other vehicles the three critical locations mentioned above for each individual vehicle are used, but several other intermediate locations were used in this analysis for better comparison of data among the 3D analysis and that of the field tests.

Table 4.3. Loading Orientation 1 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No.				
		1	2	3	4	5
128	3	0.278	0.217	0.167	0.185	0.153
	4	0.241	0.198	0.167	0.198	0.196
381	4	0.261	0.193	0.151	0.198	0.197
	5	0.270	0.196	0.147	0.195	0.192
356	4	0.258	0.192	0.151	0.198	0.201
	5	0.258	0.195	0.137	0.193	0.189
68	3	0.291	0.224	0.140	0.200	0.145
	4	0.234	0.201	0.177	0.197	0.191
188	3	0.288	0.201	0.140	0.191	0.179
	4	0.267	0.182	0.125	0.210	0.215
408	4	0.276	0.192	0.133	0.201	0.199
	5	0.268	0.192	0.142	0.199	0.198

Table 4.4. Loading Orientation 1 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No.				
		1	2	3	4	5
128	102-108	0.217	0.247	0.242	0.172	0.121
381	362-368	0.217	0.264	0.261	0.161	0.097
356	222-228	0.252	0.252	0.228	0.168	0.100
68	50-56	0.197	0.270	0.277	0.164	0.091
188	142-148	0.182	0.254	0.267	0.178	0.120
408	362-368	0.221	0.261	0.254	0.164	0.100

Table 4.5. Loading Orientation 2 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No.				
		1	2	3	4	5
128	3	0.469	0.342	0.212	0.064	−0.087
	4	0.270	0.252	0.215	0.163	0.100
381	4	0.294	0.271	0.224	0.148	0.062
	5	0.328	0.287	0.223	0.132	0.029
356	4	0.278	0.266	0.225	0.156	0.076
	5	0.357	0.306	0.228	0.117	−0.009

Table 4.6. Loading Orientation 2 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No.				
		1	2	3	4	5
128	84-90	0.501	0.330	0.174	0.053	−0.058
381	364-370	0.576	0.355	0.161	0.019	−0.111
356	222-228	0.606	0.382	0.179	0.000	0.166

All locations used in the 3D analysis yielded different distribution factors as well as different trends. Using the influence line generated from the beam analysis (see Figure 4.10), the distribution factor is taken from the position closest to the location of maximum rotation.

Using the DF obtained from the 3D analysis, the rotational influence line obtained in the beam analysis can be adjusted and plotted against the field data and can be used for calibration of the 3D analysis. Rotational values were also taken from the 3D analysis and plotted against the field and adjusted beam lines for verification between the three.

The exterior girder distribution factor of 0.469 taken from Table 4.5 at the vehicle location of 128 ft from Bent 3 falls very close to the distribution factor, calculated from the field data (Chapter 5), of 0.45. The comparison of the three analyses is shown in Figure 4.17. The interior distribution factor was taken for girder 2 and was found to be 0.217. Figure 4.18 shows the comparison among the three analyses.

4.6 PARAMETRIC STUDY

Analyses were conducted for 19 other vehicle configurations. Vehicles were chosen based upon their qualification of criteria given by The New Hampshire OS/OW Criteria shown in Table 4.7. Some vehicles qualify for more than one of the criteria. However one vehicle was chosen to fulfill a single criterion. Field data are unavailable for the remainder of the vehicles. The results of the comparison between the field data and FEA show that the results from the current model are acceptable to proceed with further calculations. Several other vehicles were included that were not intended to fulfill any of the criteria, but were used for comparison between methods.

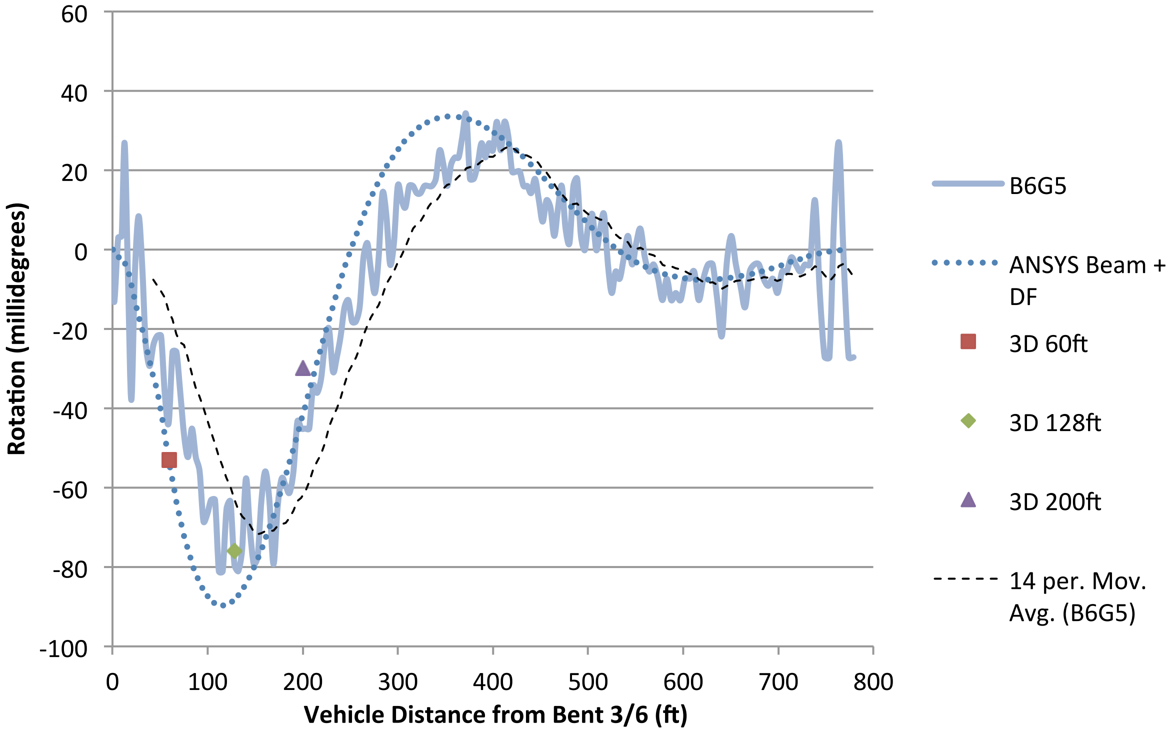


Figure 4.17. Comparison of Exterior Girder Rotation at Bent 6.

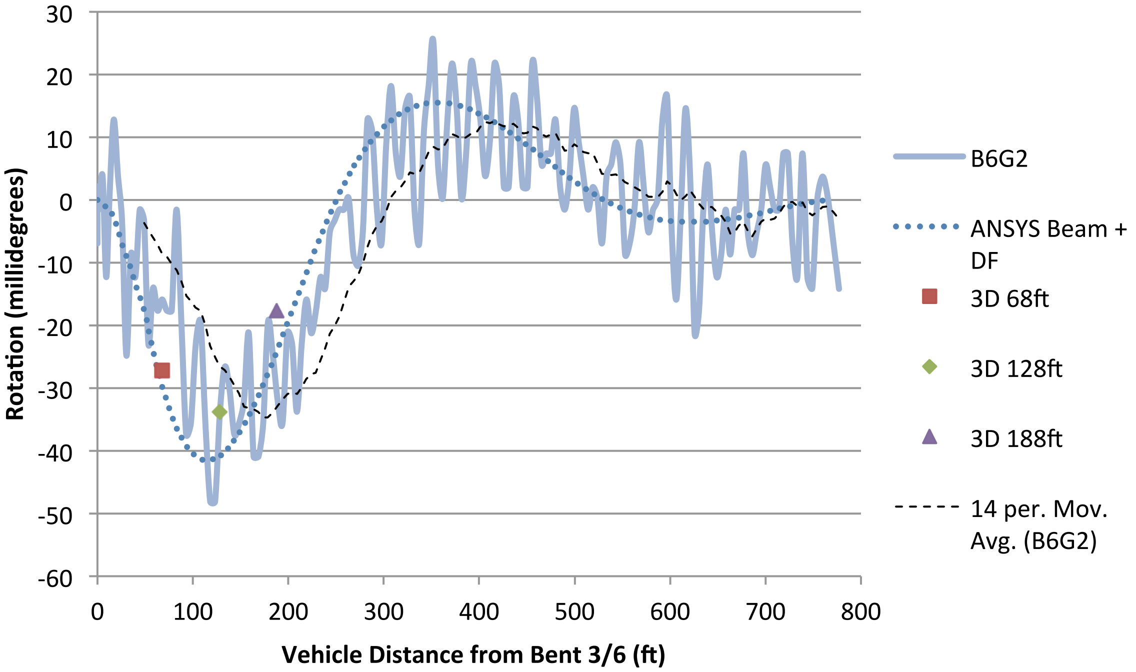


Figure 4.18. Comparison of Interior Girder Rotation at Bent 6.

Table 4.7. **NH OS/OW Bridge Review Triggers (New Hampshire DOT).**

#	Vehicle Criteria
1	Any Bridge on the proposed route has a load posting or weight restriction
2	Any axle spacing less than 4'-0"
3	Any single axle exceeds 27,500 lb (10'-0" or more to any adjacent axle)
4	Any axle of a tandem group exceeds 25,000 lb (see note 2)
5	Any axle of a tridem group exceeds 22,500 lb (see note 2)
6	Any axle of a quad group exceeds 20,000 lb (see note 2)
7	Any group of five axles (see note 2)
8	Any 2-Axle Single Unit exceeds 55,000 lb
9	Any 3-Axle Single Unit exceeds 72,500 lb
10	Any 4-Axle Single Unit exceeds 90,000 lb
11	Any 5-Axle Single Unit exceeds 100,000 lb
12	Any Single Unit, with 6 or more axles, exceeds 110,000 lb
13	Any 3-Axle combination Unit exceeds 82,500 lb
14	Any 4-Axle combination Unit exceeds 95,000 lb
15	Any 5-Axle Combination Vehicle exceeds 108,000 lb
16	Any 6-Axle Combination Vehicle exceeds 120,000 lb
17	Any 7-Axle Combination Vehicle exceeds 130,000 lb
18	Any Combination Vehicle, with 8 or more axles, exceeds 149,999 lb

(Note 2) For purposes of this table, axles together are considered a group of axles when each individual axle space in the group is less than 10'-0"

Table 4.8 shows the chosen vehicles and the criterion in which they qualify as well as the corresponding appendix (in Appendix 4.1) with all analysis data from the 3D analysis. Table 4.9 summarizes the results of parametric analysis.

Table 4.8. Vehicle Criteria and Description.

Vehicle	Criteria No.	Appendix 4.1	Notes
TxDOT	-	4C	Field Test Vehicle
HETS	-	4A	
3S2	-	4B	
2 Axle Single	8	4I	AASHTO H-20
3 Axle Combination	13	4J	AASHTO HS-25
3 Axle Single	9	4G	Ontario Evaluation Loads Level 1
4 Axle Combination	14	4K	Ontario Evaluation Loads Level 2
4 Axle Single	10	4L	Ohio Legal Loads-4F1
5 Axle Combination	15	4M	Ontario Evaluation Loads Level 3
5 Axle Group	7	4H	Michigan DOT Bridge Analysis Guide Truck No. 15
5 Axle Single	11	4N	Michigan DOT Bridge Analysis Guide Truck No. 4
6 Axle Combination	16	4O	Michigan DOT Bridge Analysis Guide Truck No. 8
7 Axle Combination	17	4P	Michigan DOT Bridge Analysis Guide Truck No. 7
7 Axle Single	12	4Q	ABRAMS Tank
8 Axle Combination	6	4F	Wisconsin Standard Permit Vehicle
10 Axle Combination	4	4R	Michigan DOT Bridge Analysis Guide Truck No. 16
11 Axle Combination	18	4S	Michigan DOT Bridge Analysis Guide Truck No. 25
3 Single Axle Combination	3	4E	AASHTO HS-20
Spacing Axle Combination	2	4D	Michigan DOT Bridge Analysis Guide Truck No. 18
Tridem Axle Single	5	4T	Michigan DOT Bridge Analysis Guide Truck No. 3

Table 4.9. Summary of Parametric Analysis.

Vehicle Type	Length (ft)	Width (ft)	GVW (kips)	Load Density (GVW/L, kip/ft)	Exterior DF		
					Rotation[1]	Stress[2]	Stress[3]
Two 10-yd trucks	51.5	6.75	96.4	1.87	0.469 (Field=0.45)	0.501	0.576
HETS	62	4.83-10.17	231.4	3.73	0.442	0.449	0.510
3S2	41	6	80	1.95	0.482	0.517	0.597
2 Axle Single	14	6.75	60	4.29	0.468	0.526	0.597
3 Axle Comb.	36	6	90	2.50	0.478	0.523	0.592
3 Axle Single	16	6.75	85.5	5.34	0.469	0.526	0.597
4 Axle Comb.	35.5	6	130.5	3.68	0.478	0.524	0.602
4 Axle Single	18	6	97.2	5.40	0.474	0.534	0.610
5 Axle Comb.	59	6	166.5	2.82	0.486	0.517	0.595
5 Axle Group	22.5	6.75	72.4	3.22	0.476	0.534	0.608
5 Axle Single	19.5	6.75	103	5.28	0.471	0.523	0.591
6 Axle Comb.	34	6	97.2	2.86	0.477	0.522	0.597
7 Axle Comb.	48.5	6	133.4	2.75	0.478	0.518	0.590
7 Axle Single	15.5	9.33	140	9.03	0.455	0.487	0.546
8 Axle Comb.	63	6	190	3.02	0.472	0.507	0.588
10 Axle Comb.	44.5	6	311.4	7.00	0.478	0.520	0.595
11 Axle Comb.	61	6	164	2.69	0.478	0.515	0.588
3 Single Axle Comb.	28	6	72	2.57	0.480	0.532	0.602
Spacing Axle Comb.	49.5	6	154	3.11	0.475	0.520	0.595
Tridem Axle Single	17	6	136	8.00	0.476	0.534	0.606

Note:

1. Rotation values were obtained on Bent 3.
2. Stress values were obtained at the location of maximum positive moment on the first span.
3. Stress values were obtained at the location of maximum positive moment on the second span.

CHAPTER 5
FIELD TESTS TO EVALUATE DISTRIBUTION AND RATING FACTORS

5.1 FEASIBILITY STUDY

This is the instrumentation *plan* to instrument and characterize bridge response to wheel loads. The instrumented structure is the three continuous-span steel girder unit of the Brazos River Bridge on SH 159 near Hempstead. The instrumentation is Geokon 8101 micro-electro-mechanical systems (MEMS) datalogging tilt meters. The measurand is beam rotation over supports, and the engineering units are radians or degrees. The wheel loads are from a study vehicle that is discussed below, and the position of the load in the longitudinal direction will be logged using a dual frequency global positioning system (GPS).

5.1.1 Tilt Instrumentation Background

To characterize the load response of a complicated structure to a particular load, it is simpler to measure displacement than it is to measure strain. This is because strain values may vary greatly from point to point, whereas displacements are smooth and characterize a large area of a structure. In the case of a bridge superstructure with a deck that acts composite with the girders, with wheel loads applied, the flexural response may be characterized with vertical displacement or angular displacement data. Vertical displacements are difficult to measure on many bridges, but the angular displacements at beam ends are easily measured. With measured end rotations, the displacements, shears, and moments in the flexural member may be obtained by using the differential equation governing beams or by using numerical methods. Tilt meters are also much easier to install than are strain gages. Also the proposed tilt meters for bridge instrumentation may be easily relocated to different members or structures for temporary use. These tilt meters include self-contained dataloggers that time stamp each measurement with a synchronized clock. This greatly simplifies data reduction and load response characterization of bridges. Project Technical Memoranda includes manufacturer datasheets for the tilt loggers. Like strain gages, MEMS tilt meters have potentially high resolution and fast response times. Therefore they also work well to measure bridge natural frequency and impact. The primary use of the tilt instrumentation in this study is to characterize the bridge response and wheel load distribution using static (pseudo-static, slow moving) wheel loads. The MEMS tilt meters proposed have a resolution of 2 arc seconds (0.5 millidegree or 9 microradians), and data will be logged once each second.

5.1.2 Preliminary Tilt Measurements

Feasibility of the particular tilt logger was investigated August 3 and August 20, 2010, using "ambient" traffic loads. On August 3, tilt measurements from Beam 2 over Bent 6 (expansion joint, southeast side of the river) were recorded one time per second using routine traffic from 5:30 to 7:30 p.m. The first hour of measurements is shown in Figure 5.1 where the tilt is shown on the ordinate axis in millidegrees (1 arc second is about equal to 0.28 millidegree). The abscissa shows time in Greenwich Mean Time. Each measurement is paired with a complete date. The dataloggers have a delayed start feature. The tilt logger was attached to the bearing stiffener. Shortly after 5:30 p.m., traffic was visually monitored and 18-wheeler crossings were recorded in a notebook. A complete record of these measurements is included in the Project Technical Memoranda.

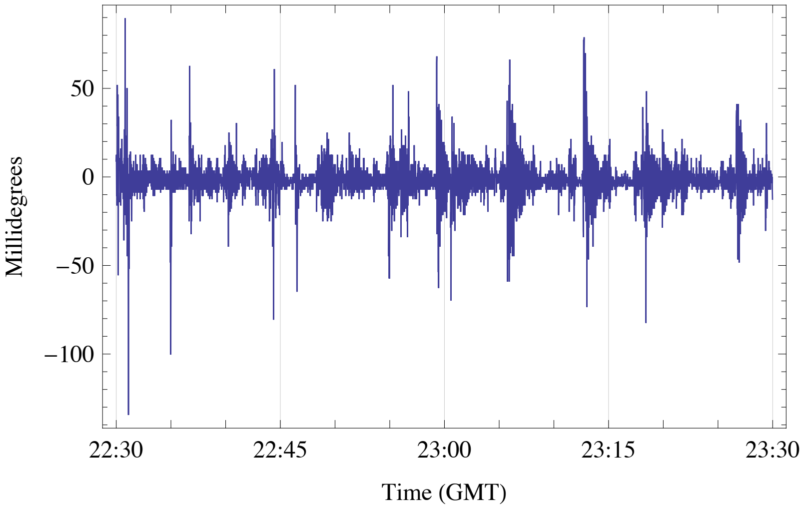


Figure 5.1. 3600 Measurements of Ambient Traffic.

Figure 5.2 shows the 4-minute interval of time in which an 18-wheeler, with an assumed AASHTO 3S2 axle configuration, crossed the bridge. This response is shown in Figure 5.1 at the 23:05 mark. Traffic was light, and this "Triple Crown" 18-wheeler was the only vehicle on the structure for several minutes. The bridge natural frequency response is evident in the attenuated shape of the tilt amplitude. With faster measurements, the steel girder unit's natural frequency may be determined.

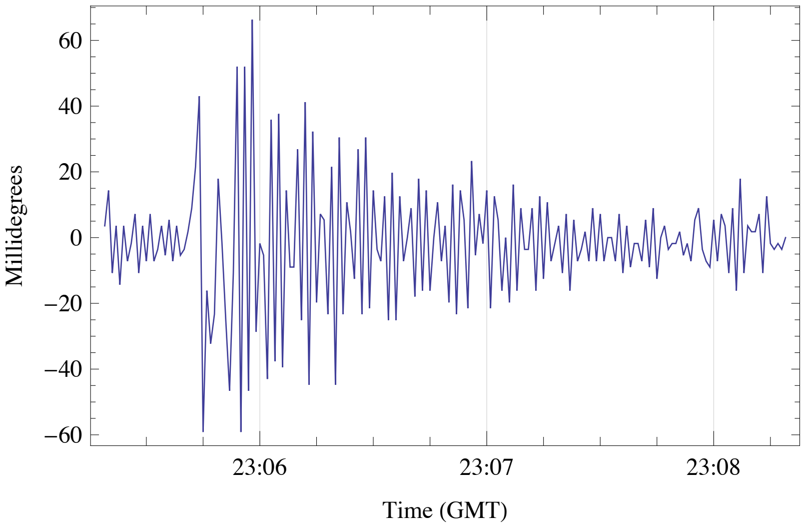


Figure 5.2. Bridge Response to 3S2 AASHTO Load.

With a speed of 65 mph, vehicles are on the steel girder unit for about 7 seconds. The truck in Figure 5.2 was moving eastbound and passed directly over the instrumented beam end. Figure 5.3 shows a short wheelbase tanker truck that passed going eastbound at about 7:12 p.m. The truck had one steering axle and a one tandem dual axle. In Figures 5.1 through 5.3, positive signs indicate end rotation such that the girder experiences downward displacement, and therefore positive moment.

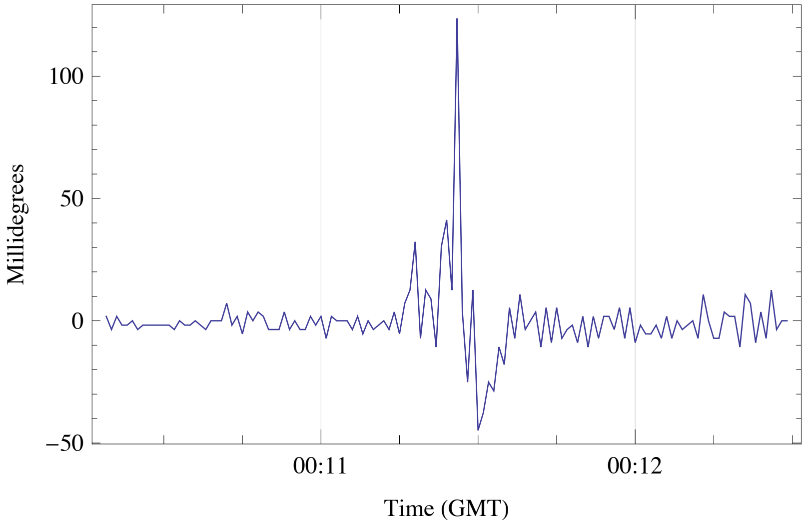


Figure 5.3. Bridge Response to Type 3 AASHTO Load.

Using girder line analysis and STAAD.Pro, the maximum end rotation at Beam 2 under a legal Type 3S2 loading was determined to be 116 millidegrees. The load position, wheel loads, and distribution factors are shown in Project Technical Memoranda. The distribution factors used are from a finite differences model.

Figure 5.4 shows a measurement from the late night or early morning of August 20. The traffic was very light, and the wind was light and variable. The response in Figure 5.4 occurred after about 8 minutes where there was no traffic on the bridge. The tilt measurements were made with a sampling rate of 20 measurements per second. The loggers used here have a 3-digit (three numbers to the right of the decimal point) readability that results in a resolution of measured angular displacement of 3 millidegrees. The tilt meter was placed on Beam 2 at Bent 6. This location and the sign convention used for beam end rotation are shown on the instrumentation plan drawings herein. Three sets of 20-samples-per-second tilt measurements were made, each for 30 minutes. The times shown on the graphs are relative to the measurement sets. They do not show time of day. The speed limit on the roadway is 65 mph. Therefore the vehicle shown in Figure 5.4 was on the steel girder unit for about 7 seconds. Figure 5.4 shows that the excitation response lasted about 1 minute 30 seconds.

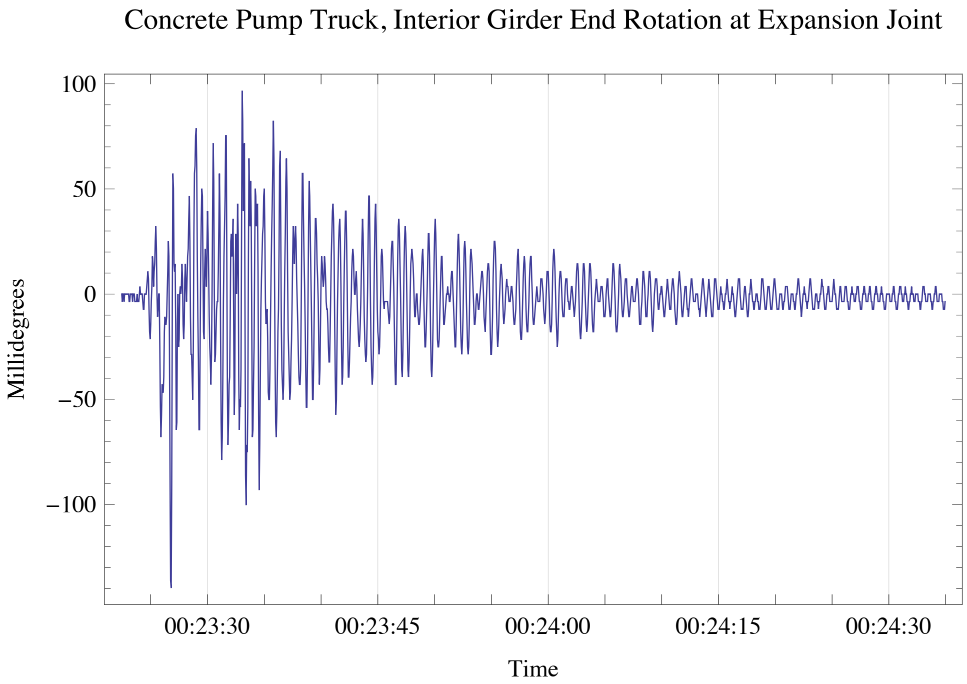
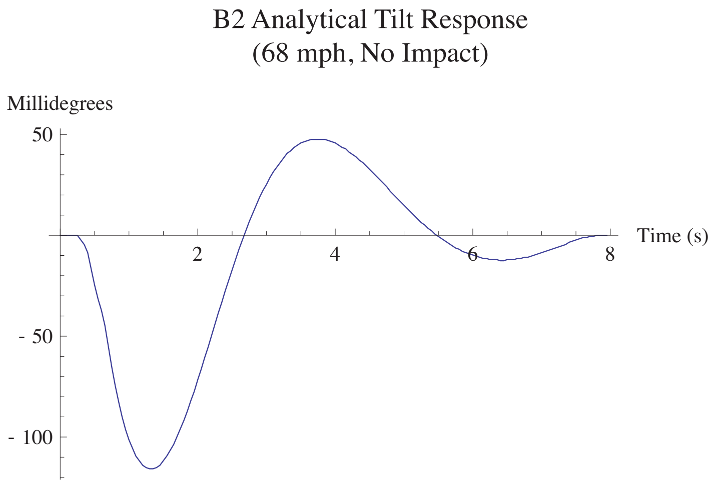


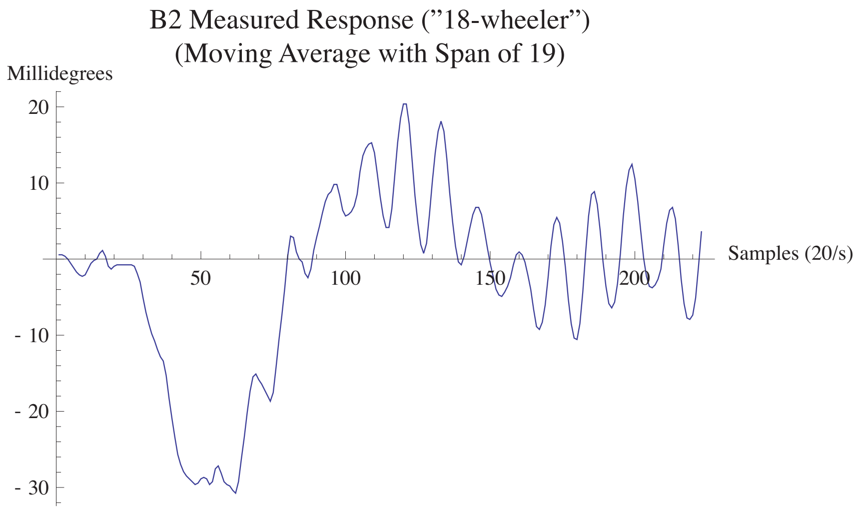
Figure 5.4. Bridge Response with 20 Samples per Second Rate.

Figure 5.5 shows a comparison of two responses at 20 samples per second with an analytical model of a moving load. The moving load is included in Project Technical Memoranda. The load was moved in 5-ft increments to simulate a 68 mph moving load recorded every 0.05 seconds (20 readings per second). The moving load was applied without a factor for impact. About 10 seconds of the measured responses are used in the comparison, and smoothing, using a moving average with a span of 19, was applied to the data.

Frequency analysis of two of the responses was done using Fourier transformations of convolutions. With the 20 samples per second rate, it is possible to identify frequency modes less that 10 Hz. Figure 5.6 shows one of the analyses; another is shown in Project Technical Memoranda. The analysis shown in Figure 5.6 is based on more than 1400 data points. The second analysis is based on a little more than 1000 data points. Based on the analysis, the fundamental frequency of the 3-continuous span unit is 1.5 Hz. These responses were chosen because they were both isolated loadings. These two responses show a truck pass over the bridge after the bridge had sat 8 or more minutes with no traffic loads. Then, once the truck passes, the bridge has several minutes with no other vehicles crossing. The wind was very light. Wind load on the structure was negligible.

In summary, these preliminary measurements show that the tilt loggers are capable of collecting engineering measurements suitable for calibrating the planned FE models.


B2 Analytical Tilt Response
(68 mph, No Impact)


B2 Measured Response ("18-wheeler")
(Moving Average with Span of 19)

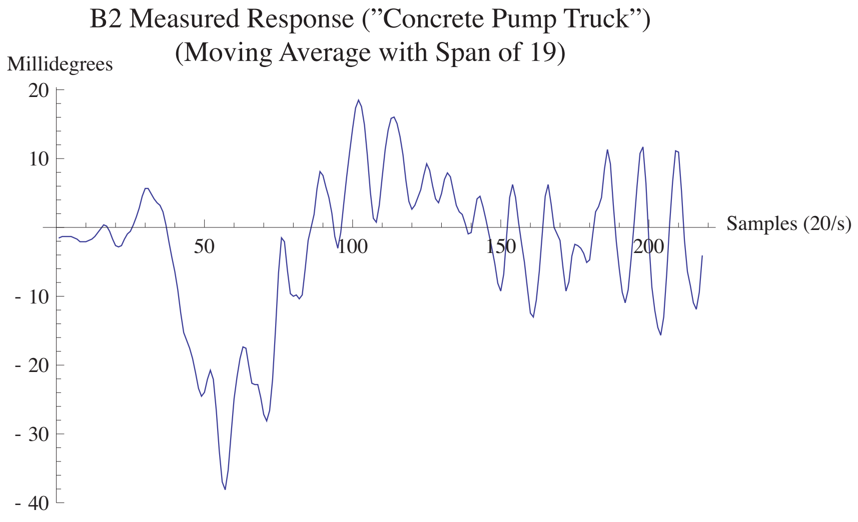
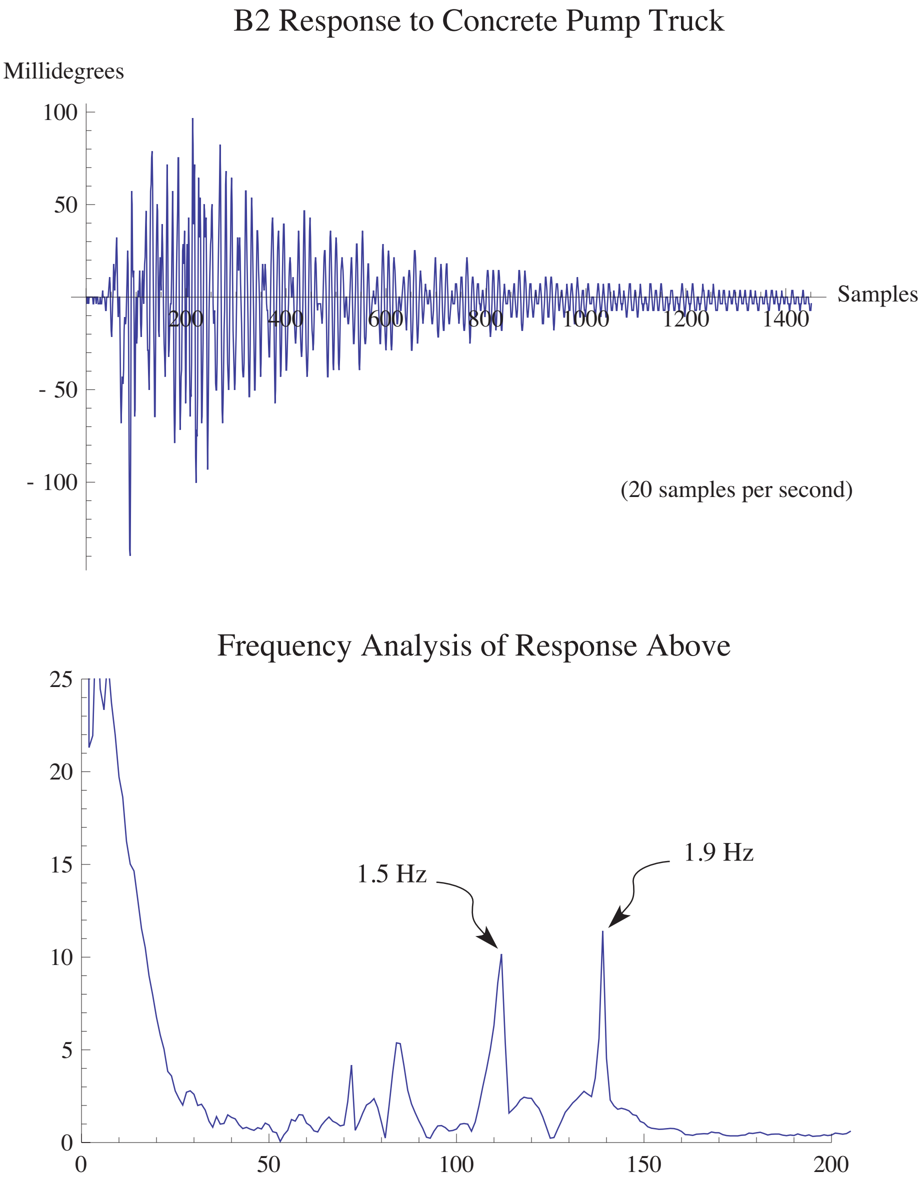

B2 Measured Response ("Concrete Pump Truck")
(Moving Average with Span of 19)

Figure 5.5. Comparison of Analytical and Measured Responses.



B2 Response to Concrete Pump Truck

Frequency Analysis of Response Above

Figure 5.6. Frequency Analysis of Responses.

5.1.3 Instrumentation *Plan*

Note that this section (5.1.3) contains details of the instrumentation *plan*. See section 5.2 for the as-instrumented conditions. Figure 5.7 shows a plan view of the study bridge along SH 159. Data collection will take place over 2 days. Instrumentation will be placed on Spans 3, 4, and 5, over Bents 3, 4, 5, and 6. Figure 5.7 shows that the continuous supports of the unit are over the Brazos River (Bents 4 and 5). Because it is more difficult to instrument the locations at Bents 4 and 5, they will be instrumented first and data collection for these locations will be schedule for the first day of measurements.

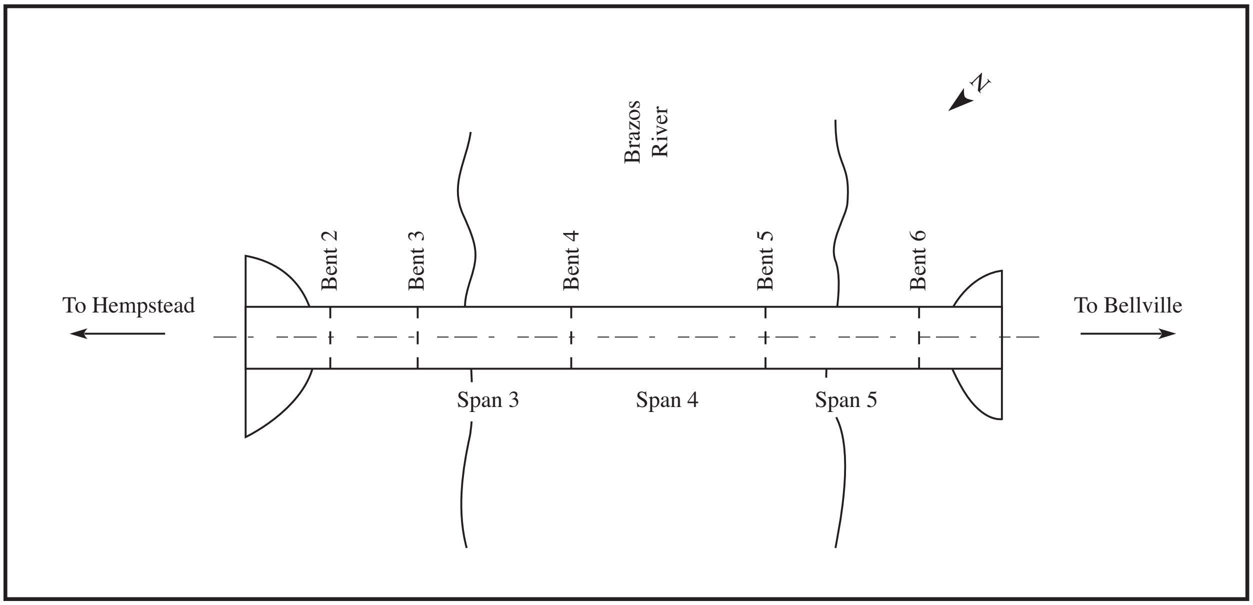


Figure 5.7. Plan View of Study Bridge.

After recording the load responses at Bents 4 and 5, and after checking to ensure the desired data are collected from these locations, the instrumentation will be moved to Bents 3 and 6 for the second day of measurements. A power generator and shelter will be set up at the west abutment to facilitate data collection. If a set of portable scales is not available from TxDOT, portable truck scales will be rented to measure the wheel loads. The axle configurations and weights will be recorded in a field notebook. Table 5.1 shows the vehicle loading sequence. The study vehicle will complete the 4-step sequence three times on each of the two data collection days. Two flaggers and a traffic control vehicle are requested to control traffic and ensure safety. These measurement operations will take place on weekdays between the hours of 9 a.m. and 2 p.m. A suggested turn around route is shown in Figure 5.8, in the event TxDOT provides a long wheelbase study vehicle.

Table 5.1. Bridge Loading Sequence.

Repeat Sequence 3 Times

Direction	Wheel Location	Vehicle Speed	Time on Structure
Northbound	Outside Wheel 2 feet from Bridge Rail	5 mph (7.3 fps)	99 s
Southbound	Outside Wheel 2 feet from Bridge Rail	5 mph (7.3 fps)	99 s
Northbound	Inside Wheel at Center Stipe	5 mph (7.3 fps)	99 s
Southbound	Inside Wheel at Center Stipe	5 mph (7.3 fps)	99 s

Lane stripes are 10 ft from the inside face of the bridge rail (10-ft wide shoulders). The 2 driving lane widths are 12 ft. The longitudinal position of the study vehicle will be recorded using a Trimble GeoXH dual frequency GPS using Trimble software. A data sheet for this GPS is included in Project Technical Memoranda. An antenna will be mounted on the study vehicle at a convenient location and the GPS unit will log position with high accuracy. These position measurements can be post-processed to give 4 in. accuracy. Additionally, researchers will hand log vehicle position at quarter points along each span with an electronic time stamp and field notebook. The instrumentation plan for days 1 and 2 are shown in Figures 5.9 and 5.10.

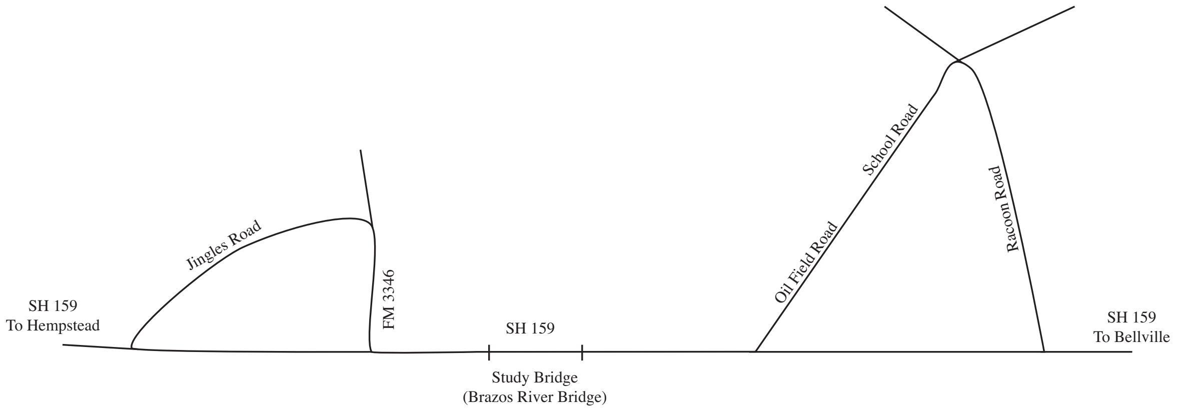


Figure 5.8. Turnarounds for Long Wheelbase Study Vehicle.

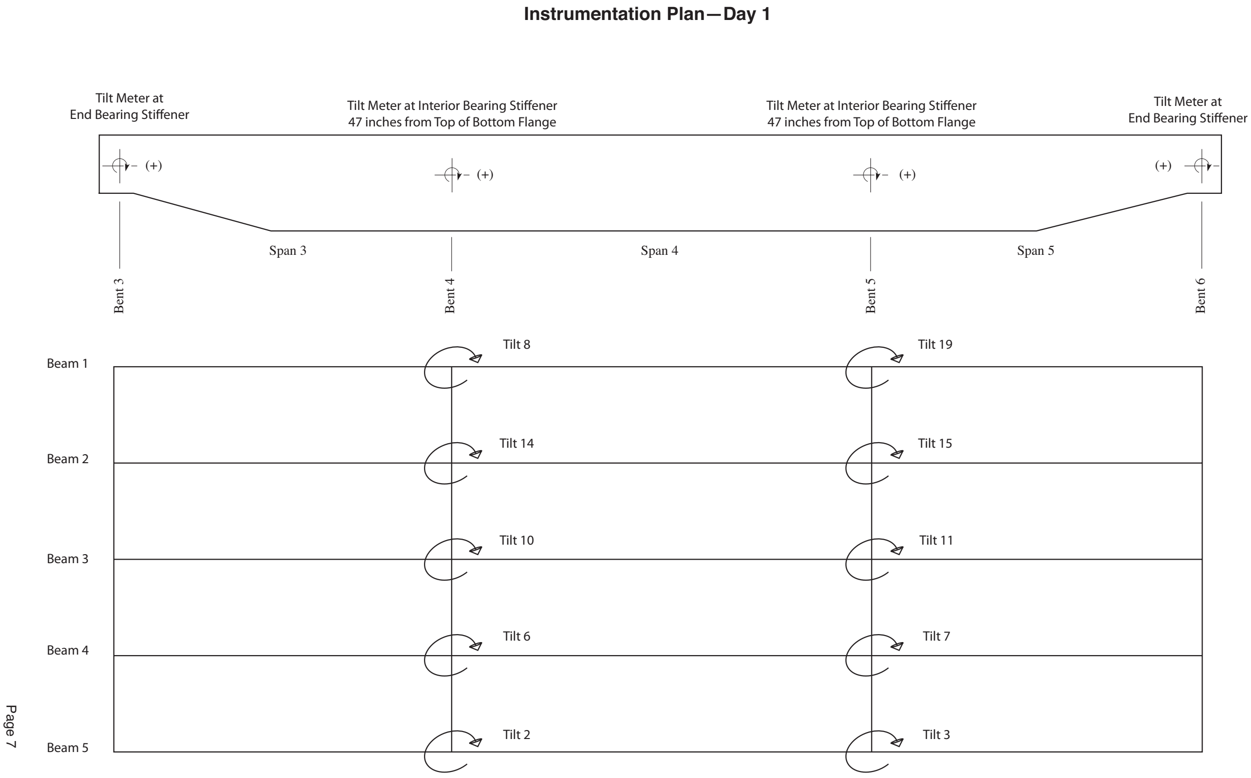


Figure 5.9. Day 1 Instrument Plan.

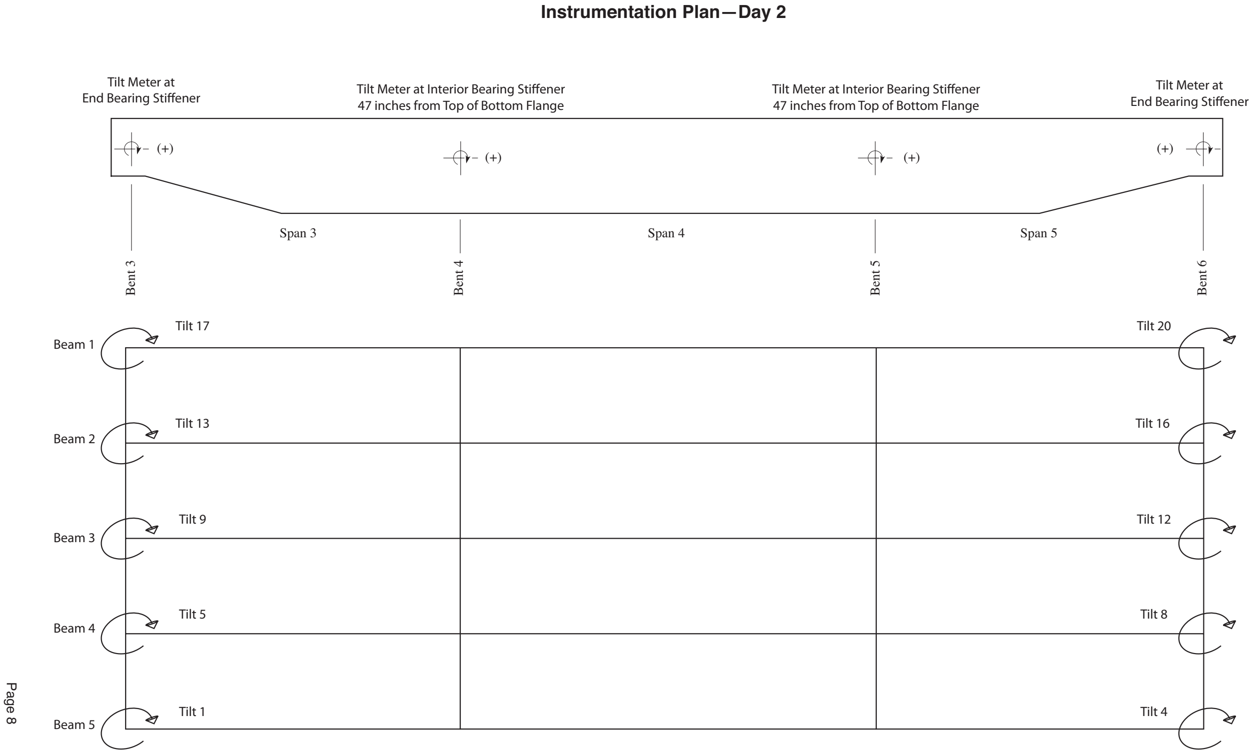


Figure 5.10. Day 2 Instrument Plan.

Researchers will wear helmets and fall protection equipment during instrumentation work. Access to Bents 4 and 5 will be from the bridge deck at the shoulder using a secured hook-type ladder. A beam clamp will be attached to the bottom flanges of the girders that will support a 5-rung section of aluminum ladder. The ladder is a "gunwale" type ladder designed to be hung. The ladder section will hang from the beam clamp at the face of the pier cap and will extend 6 ft below the top of the pier cap so that personnel can move between girder supports. A lifeline and tie off points under the superstructure will be used. No drilling or welding will be done anywhere on the structure. Instrumentation equipment will be staged at the base of the pier and will be hoisted to the top of the cap. A small motorboat will be anchored at the pier. Signage and traffic cones will be placed along the shoulder when personnel are present or working below. Researchers will have no vehicles on the bridge structure during instrumentation. A throwable life preserver will be on site.

5.2 REPORT OF INSTRUMENTATION WORK

5.2.1 Introduction

This is a report of the instrumentation work (bridge test) on the 3-span continuous steel girder unit of SH 159 (study bridge) for TxDOT Project 0-6438. The installation and measurements took place on Tuesday, October 5, and Wednesday, October 6, 2010. TxDOT provided load truck, traffic control, and aerial lift equipment and crews.

5.2.2 Results Summary

The field measurements of the study bridge were made with loggers to measure girder end rotations and load position using a sub-foot accuracy GPS with an L1/L2 antenna. The measurements took place over two consecutive days. The collected data are of good quality and were used to calibrate the analytical model of the study bridge for further analysis.

The measured axle distribution factors for exterior and interior girders were found to be:

Exterior Girder (Axle): 0.45

G5	0.45
G4	0.34
G3	0.21

Interior Girder (Axle): 0.28

G1	0.28
G2	0.28
G3	0.28
G4	0.16

For comparison, these measured axle distribution factors for interior and exterior girders are shown in Table 5.2 along with distribution factors determined using AASHTO LRFD.

Table 5.2. Comparison of Test Vehicle Axle Distribution Factors.

	Measured	AASHTO LRFD (one lane loaded)	Percent Difference
Interior Girder	0.28	0.43	53.5
Exterior Girder	0.45	0.68	51.1

By using the measured distribution factors, the analytical influence diagrams closely match the shape and magnitude of the measured girder end rotations.

5.2.3 Purpose of Bridge Testing

A study bridge was identified that would be modeled with 3D solid finite elements to evaluate the response of the structure to superheavy vehicle loads. The purpose of instrumenting and load testing the study bridge was to collect good and relevant engineering data to use in the calibration of the 3D solid model. The approach was to collect measurements of displacement of the entire structure rather than to collect measurements of strains at particular points. The load placements were based on those typically used in bridge rating with a focus on load distribution to interior and exterior girders.

5.2.4 Study Bridge, SH 159 Brazos River Bridge

Figure 5.11 shows the SH 159 Brazos River Bridge. A discussion of how this particular bridge was identified for use in TxDOT Project 0-6438 is included in the Project Technical Memoranda. The bridge has been in service less than 10 years. There are two pre-stressed-concrete-girder approach spans at the east end, and one pre-stressed-concrete-girder approach span at the west end. The main spans are a continuous 3-span steel girder unit that is 46 ft wide and 720 ft long. The main span is 280 ft. The girder spacing is 9.5 ft. It has 4-ft overhangs and a reinforced-concrete deck that is composite with the five 30-in.-wide girder flanges. The girders have webs that are 84 in. deep. Details of the unit and supports are shown in the TxDOT drawings listed in Table 5.3. These drawings were used for both modeling and instrumentation.

Figure 5.11. SH 159 Brazos River Bridge (Study Bridge).

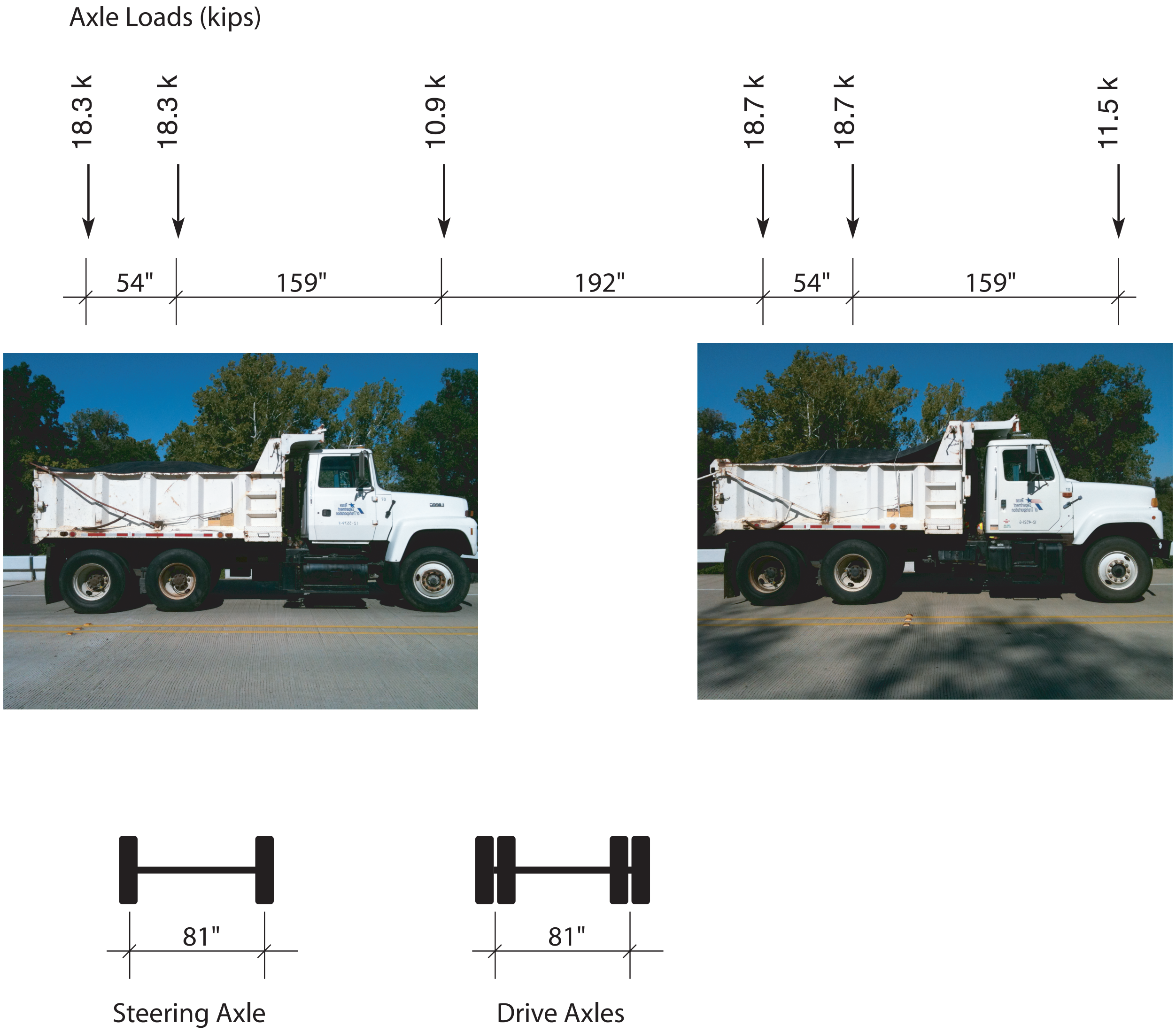
Table 5.3. SH159 Drawings and Details.

Control-Section-Job-Sheet Number	Title
0409-02-021-124	Elastomeric Bearing Details
0409-02-021-96	Framing Plans
0409-02-021-97	Framing Plans
0409-02-021-100A	720.000’ Continuous Plate Girder Unit
0409-02-021-101	720.000’ Continuous Plate Girder Unit
0409-02-021-102	720.000’ Continuous Plate Girder Unit
0409-02-021-108	Slab Plans
0409-02-021-126	Plate Girder Details
0409-02-021-127	Plate Girder Details
0409-02-021-128	Traffic Rail
0409-02-021-129	Traffic Rail

5.2.5 Bridge Test Vehicle

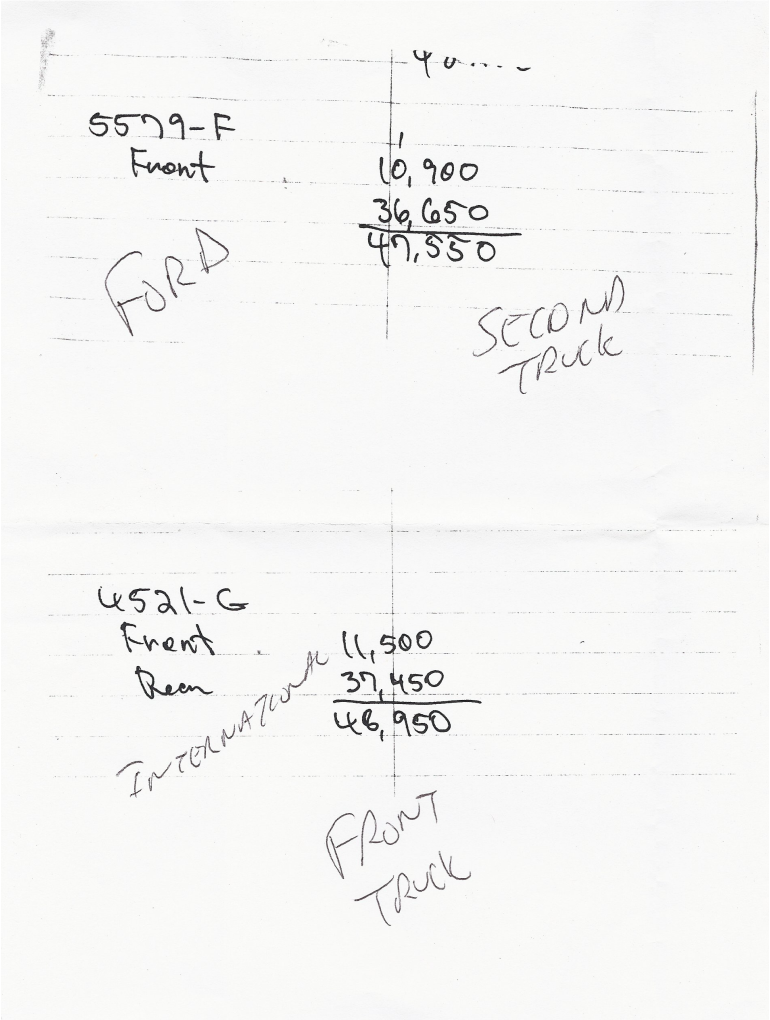
Two 10-yard dump trucks were used as a test vehicle. The lead truck weight was 48,950 lb. The follow truck weight was 47,550 lb. Each truck has a steering axle and a rear tandem axle. The driver of the follow truck was relied on to keep the follow vehicle about 16 ft behind the lead vehicle. The driver did this by sight using the lead vehicle rear axle as a reference. The driver did a good job; however there was some variation in distance and in retrospect two changes to this vehicle load configuration and procedure may produce better measurements. One change would be to connect the two vehicles to maintain a constant spacing between them. The second change would be to start and stop the vehicle runs some distance before and after the portions of the unit over which measurements are being taken to help keep the load moving at near constant velocity. The vehicles and axle loads are shown in Figure 5.12. The lead truck had an 11,500-lb steering axle and a 37,450-lb rear tandem axle. A follow truck (about 16-ft behind the lead) had a 10,900-lb steering axle and a 36,650-lb rear tandem axle. A copy of a handwritten record of the “scale ticket” is included in Figure 5.13. The vehicles were loaded with reclaimed pavement and were weighed just prior to the bridge tests. The weights were taken at a weigh station by personnel from the Texas Department of Public Safety. The same two vehicles and drivers were used for both days of testing. The lead vehicle had an L1/L2 GPS antenna attached to the cab roof. The lead vehicle steering axle was positioned directly over one of the steel girder unit’s expansion joints as a starting point for each of the test runs. See the instrumentation and procedure sections that follow for more information about load placement.

SH 159 Bridge Test
Load Vehicle



Distances in inches.
The images are inverted to match the load diagram.
Scale is 1:100

Figure 5.12. Bridge Test Vehicle.



40....

5579-F
Front

10,900
36,650
47,550

FORD

SECOND TRUCK

4521-G
Front
Rear

11,500
37,450
48,950

INTERNATIONAL

FRONT TRUCK

Figure 5.13. Handwritten Scale Ticket.

5.2.6 Instrumentation

The instrumentation consisted of 10 tilt loggers and one sub-foot accuracy GPS handheld and logger. The tilt loggers used were Geokon 8101 Unidirectional MEMS Tiltloggers. They were used to measure girder end rotations over the supports. The loggers recorded girder end rotation, and date-time stamp every one second, and they recorded temperature and a date-time stamp every two seconds. The loggers operated continuously on both days of the bridge tests. The resolution of the tilt measurements was about plus-or-minus 0.5 millidegrees (2 arc seconds). The Geokon 8101 datasheet is provided in Project Technical Memoranda. Each logger has a calibration sheet which gives gage and temperature factors. The calibration sheets are included in Project Technical Memoranda.

The position of the vehicle load was measured using a Trimble GeoXH handheld GPS with a Trimble L1/L2 Tornado external antenna. The external antenna was magnetically mounted to the roof of the cab of the lead vehicle. The GeoXH logged position every second along with a date-time stamp. The clocks of the tilt loggers were synchronized with the GeoXH. A "generic line" segment was recorded with the GPS for each run. All runs were started at one of the bridge unit's two expansion joints. The in-field accuracy of the GPS measurements was all sub-meter (most were about 25 in.). The post-processed accuracy of the position measurements using Trimble Pathfinder software was all sub-foot (typically 4 in.). The data sheet for the GeoXH and external antenna are included in Project Technical Memoranda. Position measurements were also recorded by hand with a date-time stamp application using a handheld device. The time stamps were logged as researchers walked alongside the load trucks during the runs. These hand logged position measurements are in Project Technical Memoranda.

5.2.7 Procedure, Definitions, and Instrument Locations

On both days, the procedure was to close the westbound (to Bellville) lane of the SH 159 roadway, use a snooper truck to install 10 tilt loggers on selected girders over bent caps, then collect 6 sets of live load measurements (3 with the driver side wheel on the center stripe, and 3 with the passenger side wheel on the lane stripe [wheels about 2-ft from bridge rail]). Traffic was stopped during the live-load measurements so no other traffic was on the structure. The roadway was then cleared of the lane closure; the team took a 30-minute break, then the eastbound (to Hempstead) lane was closed and another 6 sets of live load measurements were taken (3 with the driver side wheel on the center stripe and 3 with the passenger side wheel on the lane stripe [wheels about 2-ft from bridge rail]). Traffic was stopped during the live-load measurements so no other traffic was on the structure. The snooper truck was used to take down the tilt loggers. The roadway was then cleared of the lane closure.

The study bridge is shown in plan view in Figure 5.7. The eastbound lane goes to Hempstead, and the westbound lane goes to Bellville. Lane closure of the eastbound lane is shown in Figure 5.14. Figure 5.15 shows a view to the west and of the snooper truck.

Figure 5.14. Traffic Control.

Figure 5.15. Traffic Control (toward Bellville).

Figure 5.16 shows a model of the framing plan for the steel girder unit. Bents 3 and 6 support the expansion ends. Bent 3 is on the east end of the unit. The unit is fixed-supported at Bent 4. The girders are numbered consecutively 1 through 5, with girder 1 being the exterior girder in the eastbound lane. The bent and girder numbering convention shown in Figure 5.16 is used to identify the placement of tilt meters. For example, a tilt meter installed above Bent 3 on girder 5 is referred to in the sets of measurements as B3G5.

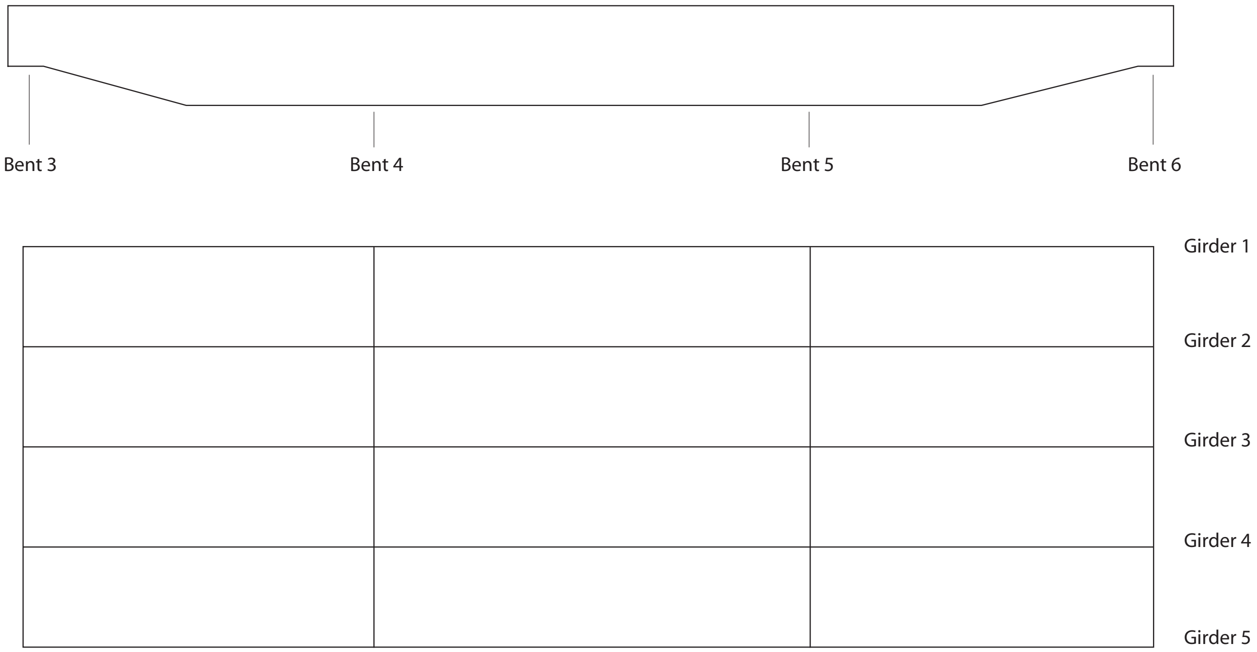


Figure 5.16. Bent and Girder Numbering.

Figure 5.17 shows a tilt logger installed on a girder. The tilt meters were installed on the bearing stiffeners (47 in. from top of bottom flange, at Bents 4 and 5, and at mid height at Bents 3 and 6) and were attached with c-clamps. The tilt meters are configured to measure girder rotation due to flexure.

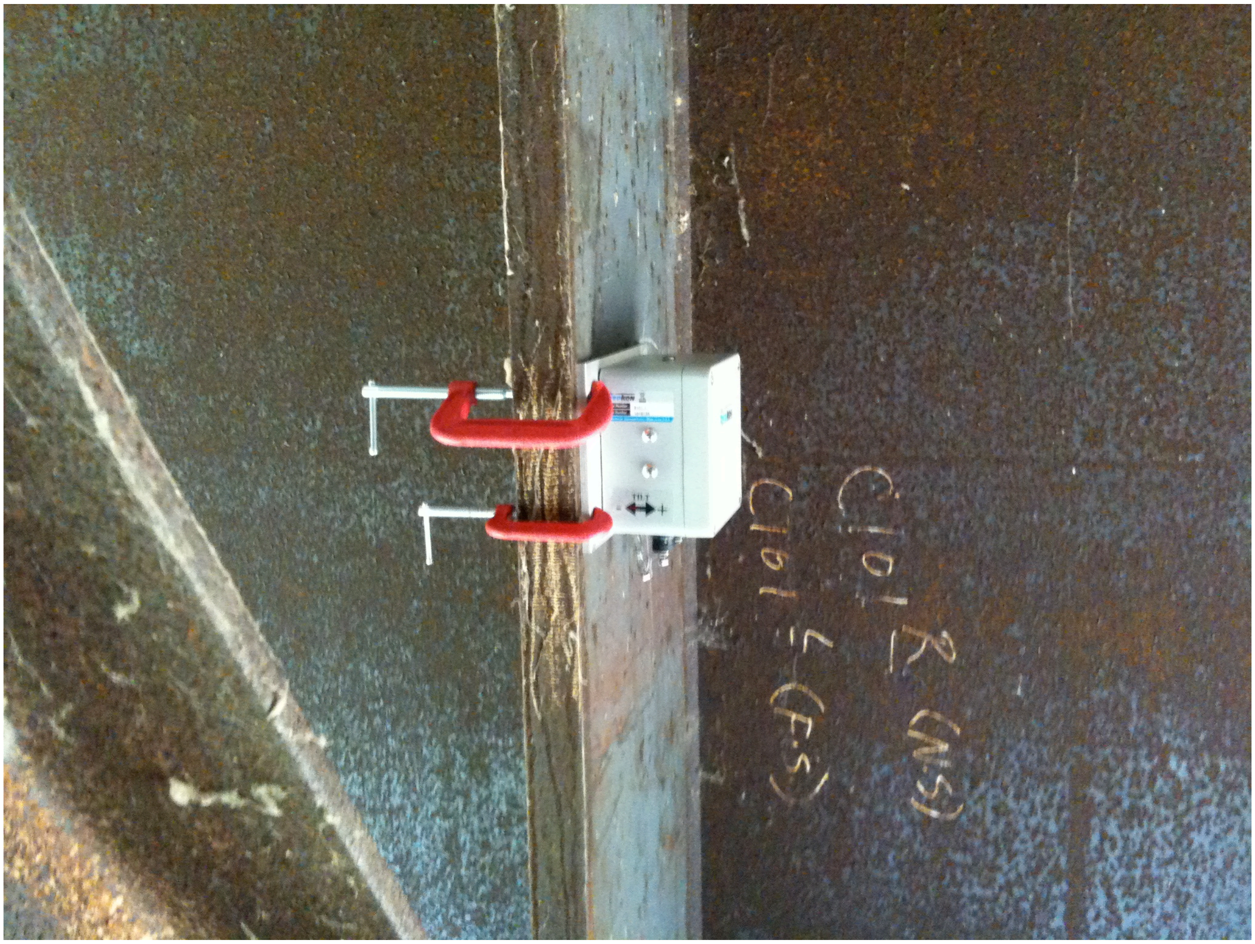


Figure 5.17. Tilt Logger Installed on Girder.

The sign convention for the tilt measurements is shown in Figures 5.18 and 5.19. Figure 5.18 shows the locations of the installed tilt meters on the first day of testing, October 5, 2010. The sign convention for the orientation shown is clockwise positive. Three runs for each of four vehicle pathways were recorded. Therefore, there were four load cases. The vehicle pathways are discussed below. Figure 5.18 includes a table describing these four load cases.

Case	Date	Runs	Load Position
1	Oct 5, 2010	1, 3 & 5	Driver Side Wheel on Center Stripe, Westbound in Westbound Lane
2	Oct 5, 2010	2, 4 & 6	Passenger Side Wheel on Lane Stripe, Eastbound in Westbound Lane
3	Oct 5, 2010	7, 9 & 11	Driver Side Wheel on Center Stripe, Eastbound in Eastbound Lane
4	Oct 5, 2010	8, 10 & 12	Passenger Side Wheel on Lane Stripe, Westbound in Eastbound Lane

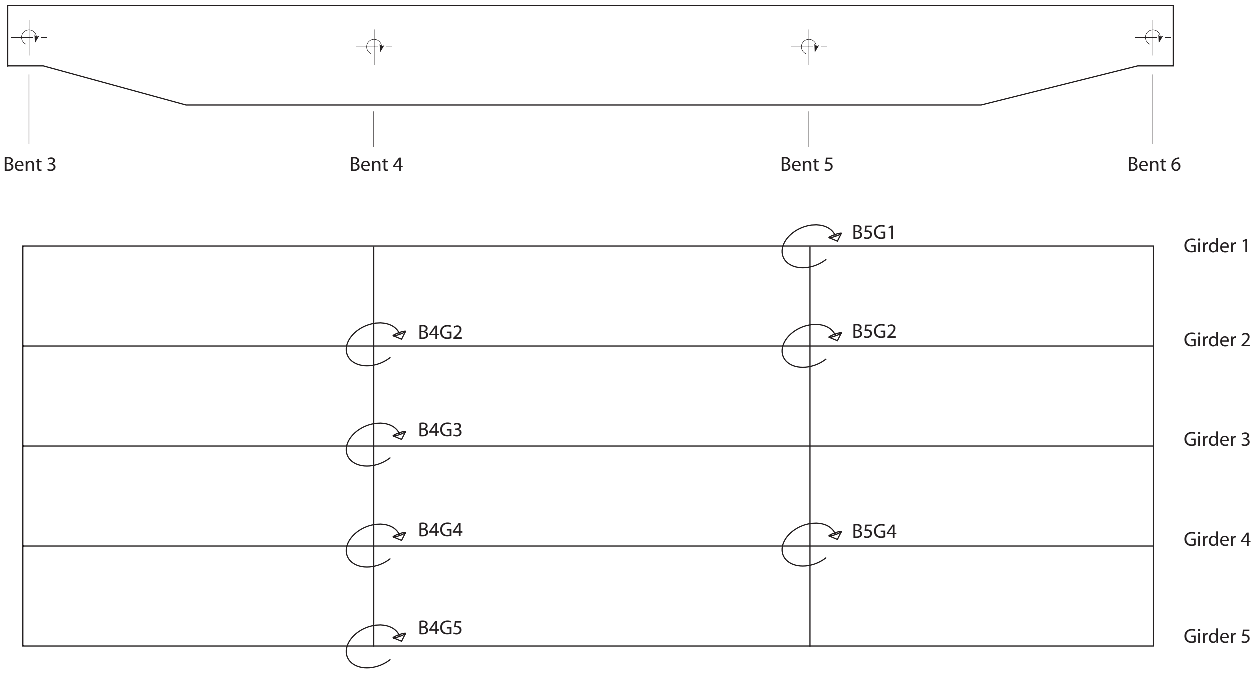


Figure 5.18. Instrument Locations and Load Cases, Oct. 5.

Figure 5.19 shows the locations of the installed tilt meters on the second day of testing, October 6, 2010. The sign convention for the girder end rotations is also shown, which here is clockwise positive. Three runs for each of four vehicle pathways were recorded. Therefore, there were another four load cases, numbered 5 through 8. These load cases are also shown in Figure 5.19. In total, there were 8 load cases, or 24 runs (12 runs each day of testing).

Case	Date	Runs	Load Position
5	Oct 6, 2010	1, 3 & 5	Driver Side Wheel on Center Stripe, Westbound in Westbound Lane
6	Oct 6, 2010	2, 4 & 6	Passenger Side Wheel on Lane Stripe, Eastbound in Westbound Lane
7	Oct 6, 2010	7, 9 & 11	Driver Side Wheel on Center Stripe, Eastbound in Eastbound Lane
8	Oct 6, 2010	8, 10 & 12	Passenger Side Wheel on Lane Stripe, Westbound in Eastbound Lane

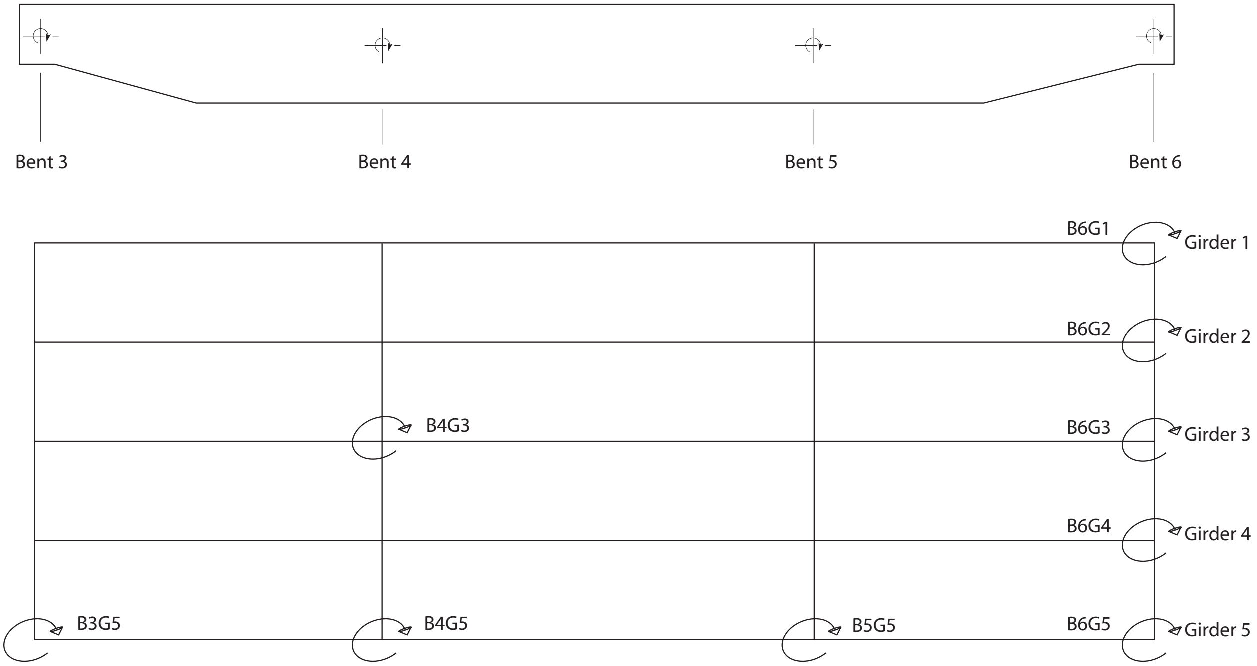


Figure 5.19. Instrument Locations and Load Cases, Oct. 6.

The load pathways were along the center stripe and along the lane stripes. The two travel lanes are 12-ft wide and have 11-ft shoulders. The trucks are shown on a center stripe in Figure 5.20, and on a lane stripe in Figure 5.21.

Figure 5.20. Load Trucks on Center Stripe (Odd Numbered Passes).

Figure 5.21. Load Trucks on Lane Stripe (Even Numbered Passes).

For both days of bridge testing, the procedure for load application was the same. With the westbound lane closed, Run 1 occurred with the driver side wheel on the center stripe. The loads would then turn around, and Run 2 was conducted with the passenger side wheel on the lane stripe. These two were repeated two more times for Runs 3 through 6. Then the eastbound lane was closed. Run 7 was then completed with the driver side wheel on the center stripe. The load vehicles then turn around, and Run 8 was completed with the passenger side wheel on the lane stripe. These two were repeated two more times for Runs 9 through 12. On the second day of testing, this same sequence was repeated. The only difference was that the tilt loggers had been installed at a different set of locations.

A functional model of the bridge is shown in Figure 5.22. Bents 4 and 5 are in inside the banks of the Brazos River. The bent and girder numbering are shown, along with the eastbound direction pointing to Hempstead. Figure 5.23 shows the driver side wheel on the center stripe and the vehicles are westbound in the westbound lane. Figure 5.24 shows the passenger side wheel on the lane stripe, and the vehicles are eastbound in the westbound lane. Figure 5.25 shows the driver side wheel on the center stripe, and the vehicles are shown eastbound in the eastbound lane. Finally, Figure 5.26 shows the passenger side wheel on the lane stripe, with the vehicles westbound in the eastbound lane.

Figure 5.22. Functional Model of Steel Girder Unit for Load Application.

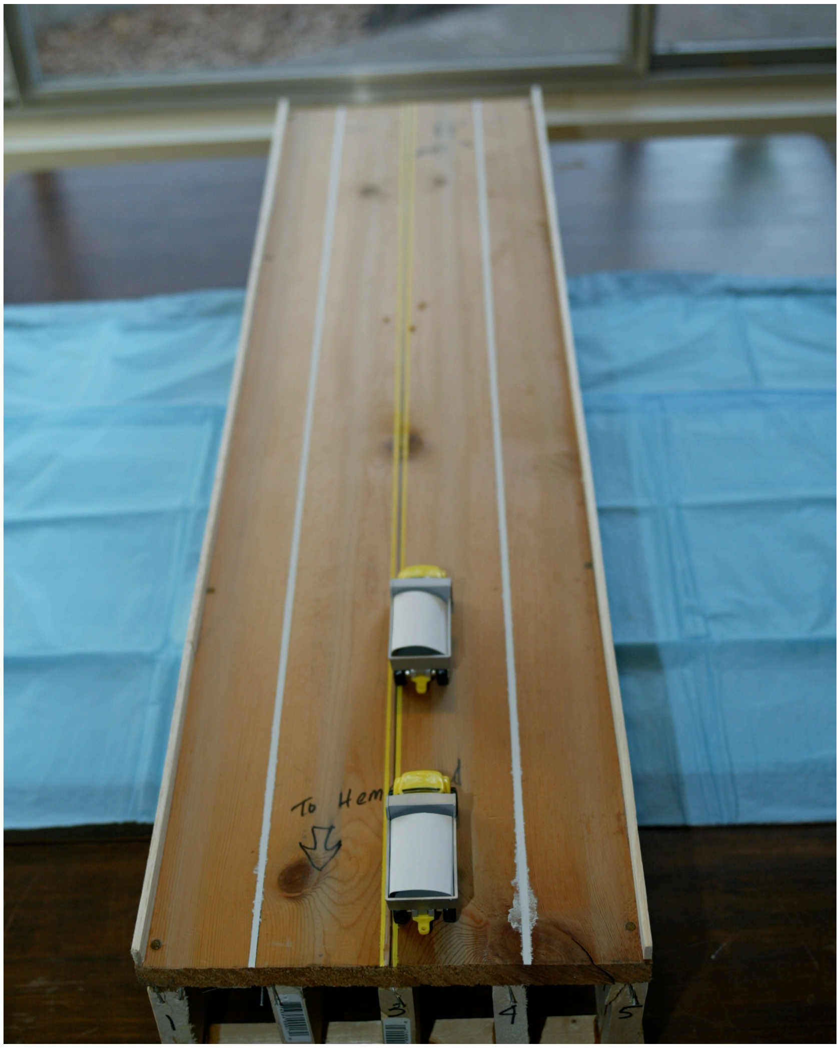


Figure 5.23. Load on Center Stripe, Westbound in Westbound Lane.

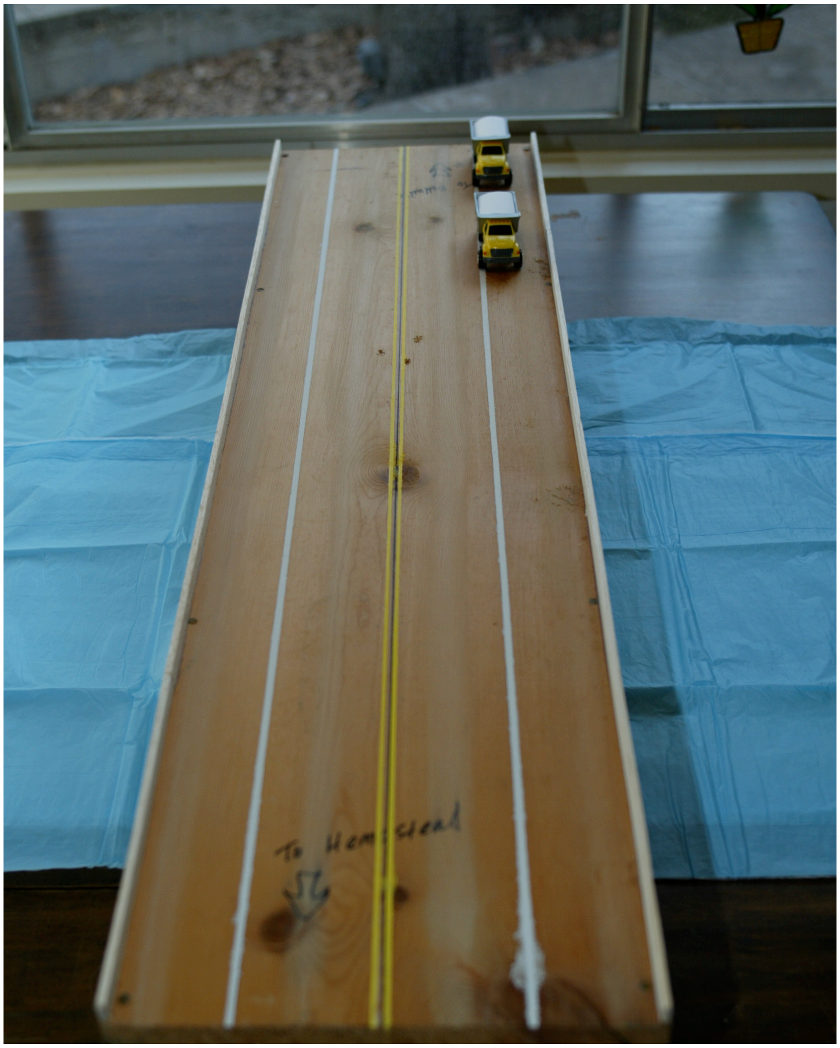


Figure 5.24. Load on Lane Stripe, Eastbound in Westbound Lane.

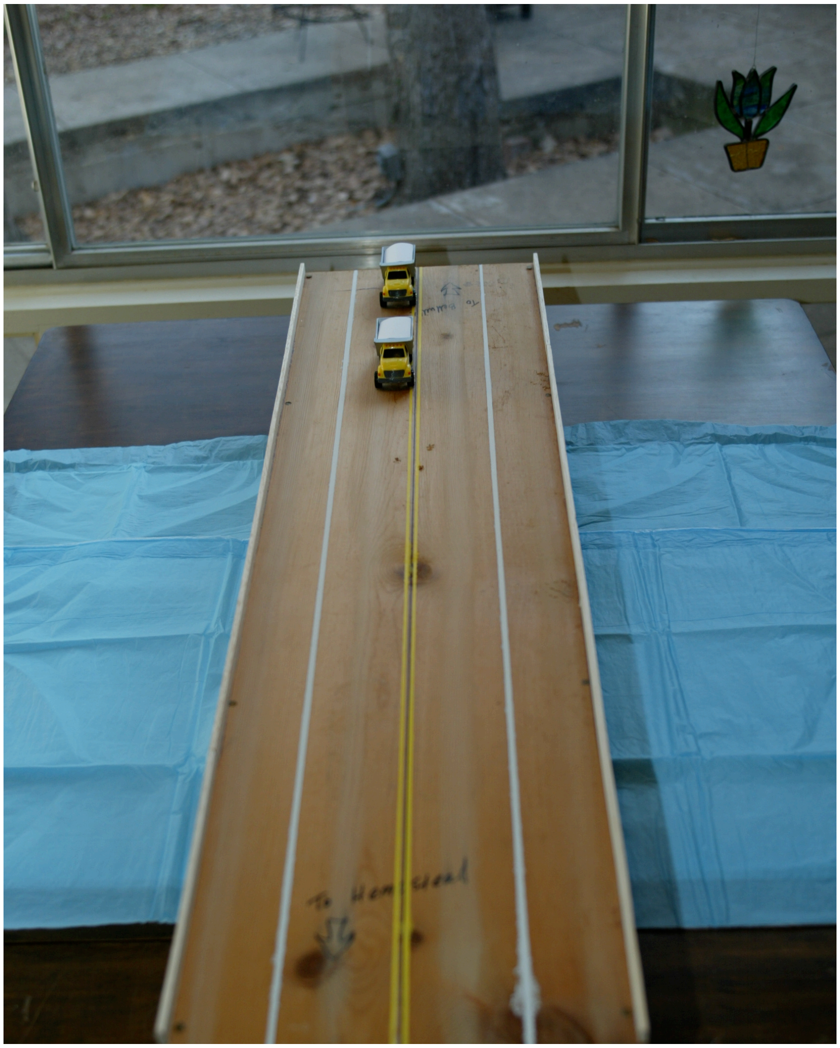


Figure 5.25. Load on Center Stripe, Eastbound in Eastbound Lane.

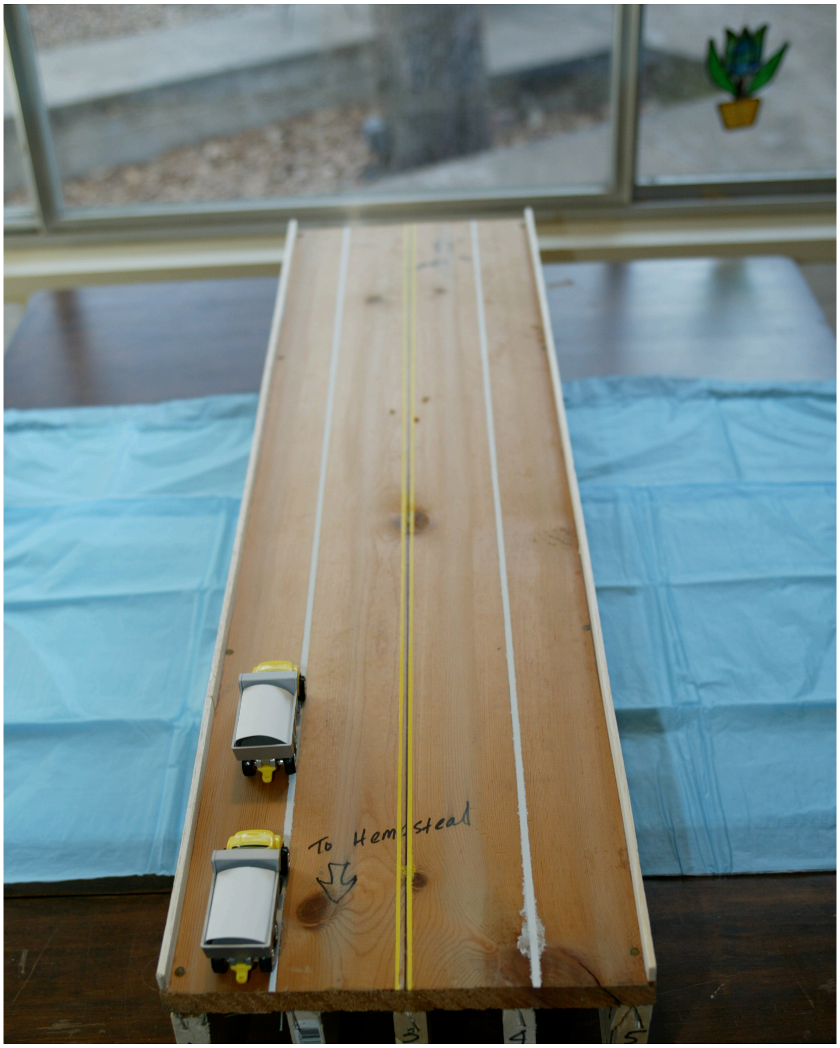


Figure 5.26. Load on Lane Stripe, Westbound in Eastbound Lane.

5.2.8 Data Collection

The tilt loggers were installed at the selected locations with their clocks synchronized with the GPS datalogger. The tilt loggers were installed with a delayed start, and all installed tilt meters began logging at the same time, with a one-measurement-per-second rate. The tilt loggers also recorded temperature information at a one-measurement-per-two-second rate. The tilt loggers recorded data continuously throughout the testing days. The GPS handheld was used to record the position of the vehicle load, the time period of the load application, and the velocity of the moving vehicle load. The GPS handheld recorded position and a date-time stamp once per second. The procedure was to position the load vehicles on the unit with the lead vehicle steering axle directly over the expansion joint of either Bent 3 or 6. When traffic was halted, the GPS handheld was set to record a line segment at the one-measurement-per-second rate. Once the run had been completed, and the trucks had turned around and had been repositioned on the unit, the recording of the line sequence was stopped, and the GPS handheld was reset to record the next line sequence of the next run.

In addition to the position measurements taken by the GPS handheld, the vehicle load position was also recorded using a handheld-device time-stamp application. These hand logged time stamps recorded the start and stop times, along with the times the steering axles passed over the interior bents. For each day, at the end of the load testing, the tilt loggers were retrieved and the data were sampled to evaluate whether the loggers functioned properly.

5.2.9 Data Reduction

The girder end rotation data were recorded as voltage. Using factors in the calibration sheets for the tilt loggers, the voltage record was converted to degrees. These angles are small, and it is convenient to convert them to millidegrees by multiplying them by 1000. The tilt meters measure changes in girder end rotation. A reading of zero would indicate no change in rotation from a referenced angle. The reference angle is the angle with no load applied and has to be determined by evaluating the data. The temperature change during the time of the measurements was not large; however the end rotations were corrected for temperature. These corrections for temperature are discussed below in the analysis section. The end rotation data were trimmed of ambient loads by using the time information recorded with the handheld GPS. These measurements were also trimmed to remove the measurements taken during the times the load vehicles were turning around to reposition on the unit. These measurements were post processed using the Trimble Pathfinder Office (PFO) software and the TxDOT Hempstead continuously operated reference station. The post-processed position measurements achieved sub-foot accuracy. The position measurements, which are latitude and longitude measurements, were then reduced to distance and velocity data. The distance measurements were calculated using a method based on the Trimble software; however two other methods are shown and discussed in the analysis section. The distance data are reported in units of feet, and the velocity data are reported in feet-per-second.

5.3 PLOTS AND TABLES OF COLLECTED DATA

The tilt loggers produced (16 tilt logger locations × 12 runs) 192 sets of girder end rotations, each over 120 measurements. For both days of testing, 12 runs took place. These 24 runs are grouped into 8 cases. The cases are shown in Table 5.4. Each case has a set of tilt logger locations and a particular load position and direction of moving load. (See Figures 5.18 and 5.19 for Instrument Setup Locations.) Table 5.4 shows that for each load case, three sets of measurements were taken.

Table 5.4. Measurements Runs by Load Case.

Case	Instrument Setup	Runs	Load Position and Application
1	Oct. 5	1, 3 & 5	Driver Side Wheel on Center Stripe, Westbound in Westbound Lane
2	Oct. 5	2, 4 & 6	Passenger Side Wheel on Lane Stripe, Eastbound in Westbound Lane
3	Oct. 5	7, 9 & 11	Driver Side Wheel on Center Stripe, Eastbound in Eastbound Lane
4	Oct. 5	8, 10 & 12	Passenger Side Wheel on Lane Stripe, Westbound in Eastbound Lane
5	Oct. 6	1, 3 & 5	Driver Side Wheel on Center Stripe, Westbound in Westbound Lane
6	Oct. 6	2, 4 & 6	Passenger Side Wheel on Lane Stripe, Eastbound in Westbound Lane
7	Oct. 6	7, 9 & 11	Driver Side Wheel on Center Stripe, Eastbound in Eastbound Lane
8	Oct. 6	8, 10 & 12	Passenger Side Wheel on Lane Stripe, Westbound in Eastbound Lane

The data collected during the testing is organized into tables. Project Technical Memoranda includes the data collected October 5 and 6, 2010, by Run. The tables give give a date-time group with a one-second resolution and one-measurement-per-second rate; post-processed longitude and latitude coordinates in decimal degrees; position of steering axle of the lead vehicle from the start point (the expansion joint at Bent 3 or Bent 6) in feet; velocity in feet-per-second, and girder end rotations in millidegrees. The end rotation data have been corrected for temperature.

Plots of the graphs from the data tables are given in Project Technical Memoranda. The plots are organized by date, domain, and case. Two domains are plotted: one set of graphs shows End Rotation vs. Time, and the second set of graphs shows End Rotation vs. Distance (from starting point, Bent 3 or Bent 6). Analysis by instrument location is included below in Section 5.4.

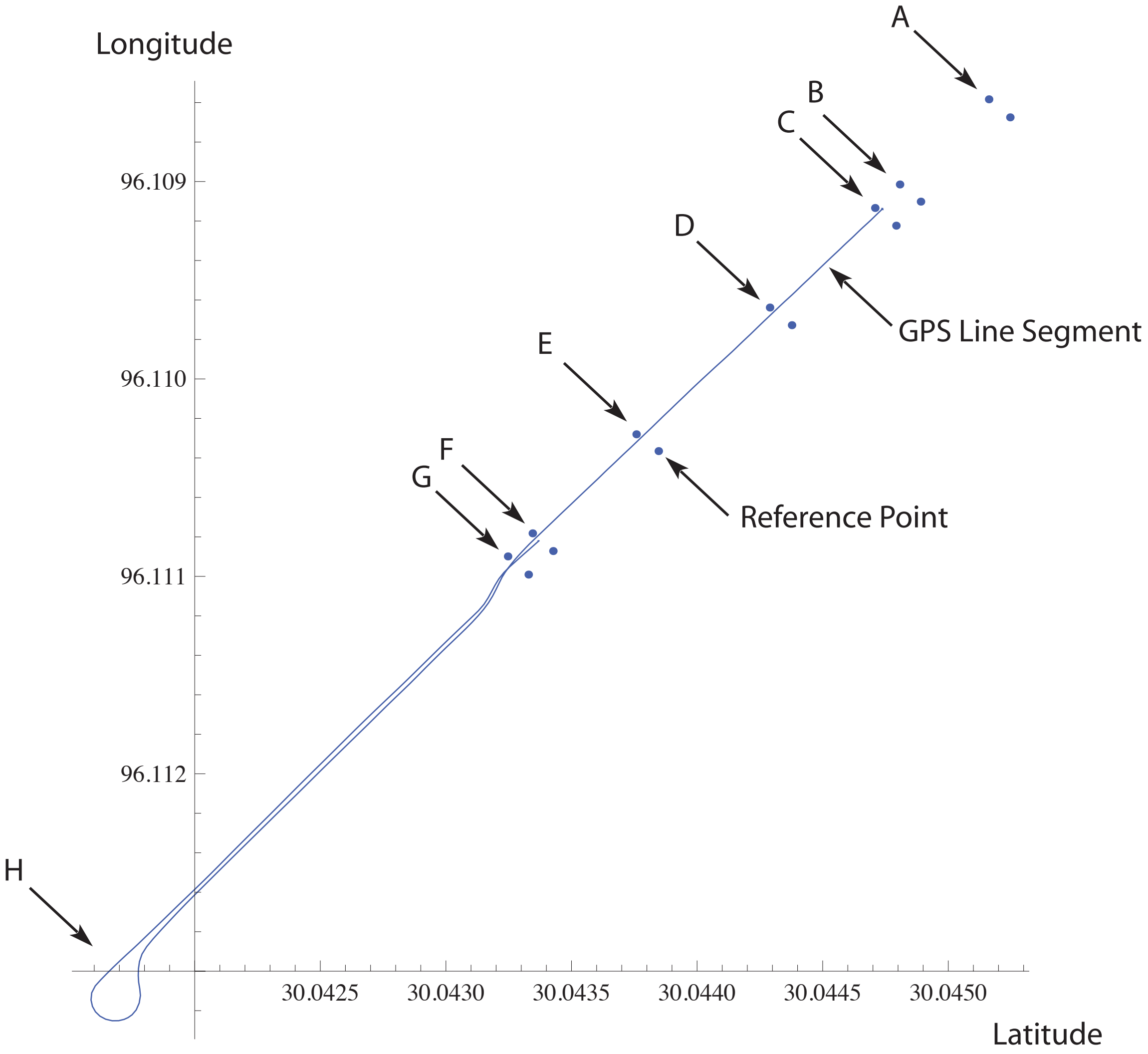
Hand entered date-time stamps were also recorded for most of the runs. The time stamps were hand entered roughly when the lead and follow truck steering axles reached marked locations along the bridge structure. The hand entered date-time stamps are shown by table in Project Technical Memoranda. These date-time stamps include a program-calculated accuracy. This is relative to an official atomic clock. For the record, all the clocks involved with the measurements were synchronized with this official clock; however each device uses a different internal or local clock. Regardless, the program-calculated accuracy of the hand entered date-time stamps are meaningless since they are hand entered. There is parallax and other human error involved. Therefore these hand-entered times are approximate.

5.4 ANALYSIS OF COLLECTED DATA

In this section, the position and beam end rotation measurements are analyzed and then compared with influence diagrams from moving load analysis performed in STAAD.Pro using beam finite elements.

5.4.1 Distance Measurements

For each measurement run, the steering axle of the lead vehicle is positioned over one of the two expansion joints. The traffic is stopped and the GPS logger is set to record a “generic line” segment. The GPS logs position once per second as the load moves across the bridge. Once the load passes over the steel girder unit and crosses the far end expansion joint, the vehicles move beyond the structure, turn around, and then reposition the front steering axle over the expansion joint to prepare for another measurement run. The GPS recording of the line segment is then stopped. Figure 5.27 shows these steps graphically.



A	Bent 1 (east abutment)
B	Ref. Line 52 ft east of Bent 3
C	Bent 3 (steel girder unit expansion joint)
D	Bent 4 (fixed support)
E	Bent 5
F	Bent 6 (steel girder unit expansion joint)
G	Ref. Line 52 ft west of Bent 6
H	Vehicle Turn Around Loop

Figure 5.27. GPS Line Segment of Run with Turnaround.

A set of reference points was taken with the GeoXH GPS unit from the bridge structure for use in trimming the line segments. The reference points were used to create transverse line segments and exported to a “background” for use with trimming the measurement runs. The reference points and an untrimmed line segment from a measurement run in shown in

Figure 5.27. The reference lines allow the measurement runs to be easily trimmed. Extra points at the start of the run are trimmed off. These occur as the vehicles wait for traffic to clear the structure. Then the many position measurements beyond 52 ft of the far end expansion joint are trimmed off. The 52-ft distance beyond the far expansion joint is the approximate distance from the lead vehicle steering axle to the follow vehicle rear tandem axle. Figure 5.28 shows the measurement run trimmed of the extra GPS position data. PFO gives the distance of this line segment as 773.7 ft. The steel girder unit is 720 ft. The measurements continue for approximately 52 ft beyond (720 + 52 = 772 ft). The line segment distance reported for each trimmed and differentially corrected line segment is used as a basis for the distance measurements. These measurements are relative to one of the expansion joints and give the distance in feet of the lead vehicle steering axle from the expansion joint (Bent 3 or 6).

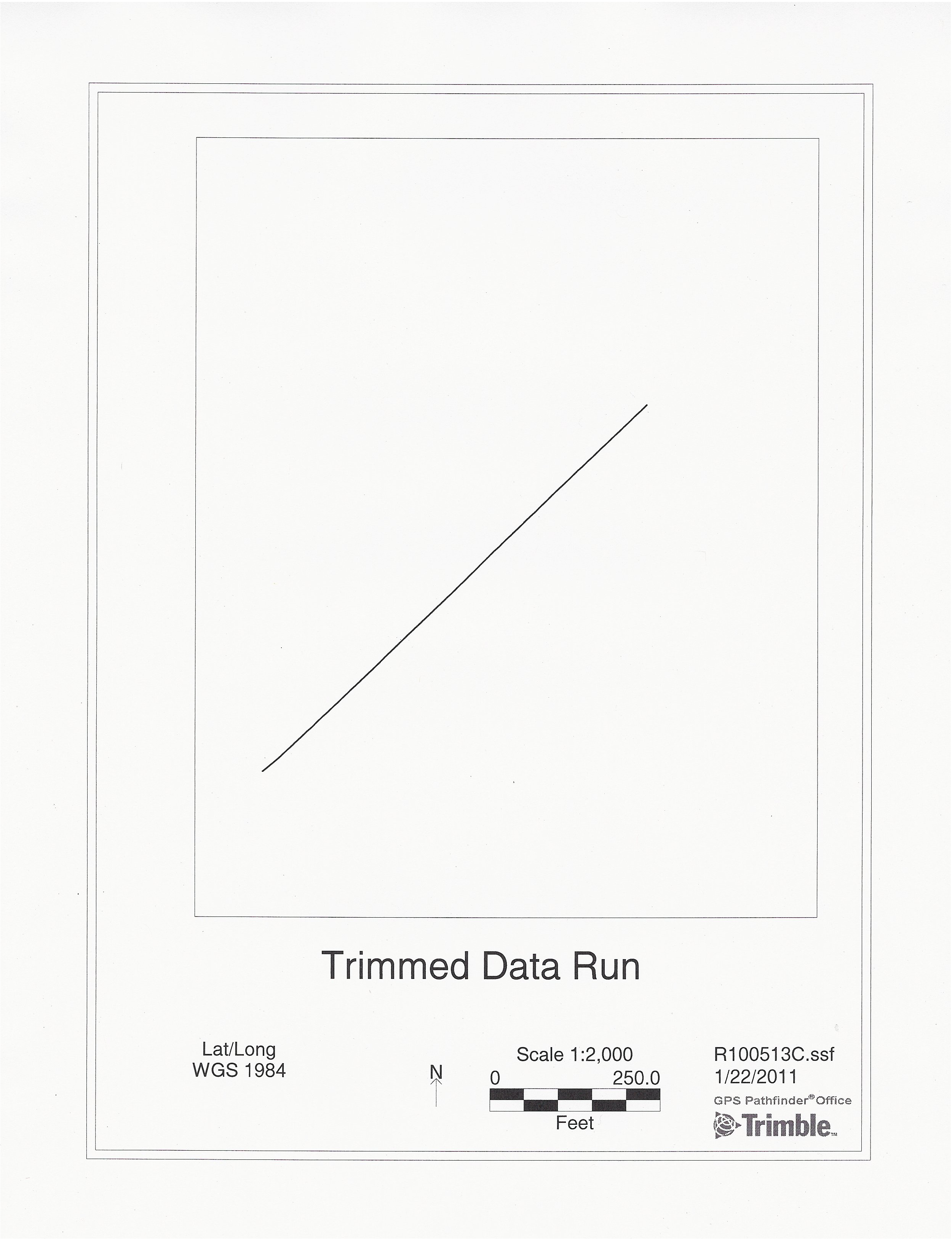


Figure 5.28. Trimmed Data Run Graph from PFO.

Two other methods of calculating distance from the collected and differentially corrected latitude and longitude points were also investigated. These methods are the Spherical Law of Cosines and the Haversine Formula. All three methods gave nearly identical results. Distance (ft) using the Spherical Law of Cosines may be found with equation 5.1. The Haversine Formula is given in equation 5.2. A plot of the three graphs of distance from start using the three different methods is given in Figure 5.29. Note that velocity (the slope of the curve) is not constant.

$$d(ft) = 20902231 ArcCos\left[Sin(lat1) * Sin(lat2) + Cos(lat1) * Cos(lat2) * Cos(lon2 - lon1)\right]$$

(Eq. 5.1)

$$\begin{aligned} R &= 20902231(ft) \\ \Delta Lat &= (Lat_2 - Lat_1) \\ \Delta Long &= (Long_2 - Long_1) \\ a &= Sin(\frac{\Delta Lat}{2})^2 + Cos(Lat_1) * Cos(Lat_2) * Sin(\frac{\Delta Long}{2})^2 \\ c &= \pi - 2ArcTan[\sqrt{a}.\sqrt{1-a}] \\ d &= R * c \end{aligned}$$

(Eq. 5.2)

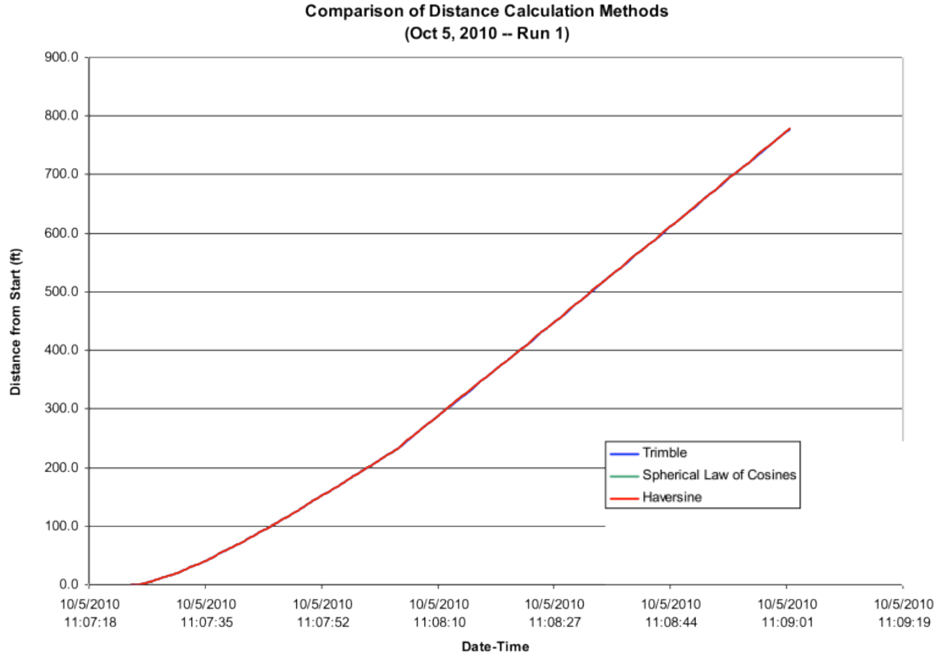


Figure 5.29. Distance Calculation Method Comparison.

5.4.2 Temperature Corrections

The air temperature changes for both days during the entire period of the measurements were only about 8°F. Incident radiation also causes thermal moment in the girders that causes small girder end rotations. During the small time periods (about 2 minutes) during which load test runs occur, no thermal effects occur. However, over longer time periods, such as between the first and last run, there are thermal effects. The tilt measurements were corrected for these temperature effects.

5.4.3 Structural Vibration

Measurements showed that a large excitation (like a 3S2 truck moving 60 mph) applied while the structure was at rest caused the structure to oscillate for about 1 minute. During the load tests, the two fully loaded 10-yard dump trucks started moving at an expansion joint and applied load to the steel girder unit. The load responses at the gages (tilt meters) typically showed large oscillations during the initial application of the load, and then, typically, an even larger vibration response at the ends of the runs when the wheel loads were removed from the steel girder unit. At the ends of the runs, the structure got more than a minute to come to rest when no loads were on it, while the traffic was stopped and the load trucks turned around. These periods where the structure had time to rest and no load was applied are helpful when analyzing the data. Ideally, with this load condition, all the tilt loggers give zero readings. Figure 5.30 shows plots of graphs from Run 12 of October 6. There were large oscillations at initial load application and at load release, and the thermal effects are apparent at the no-load period at the end of the run.

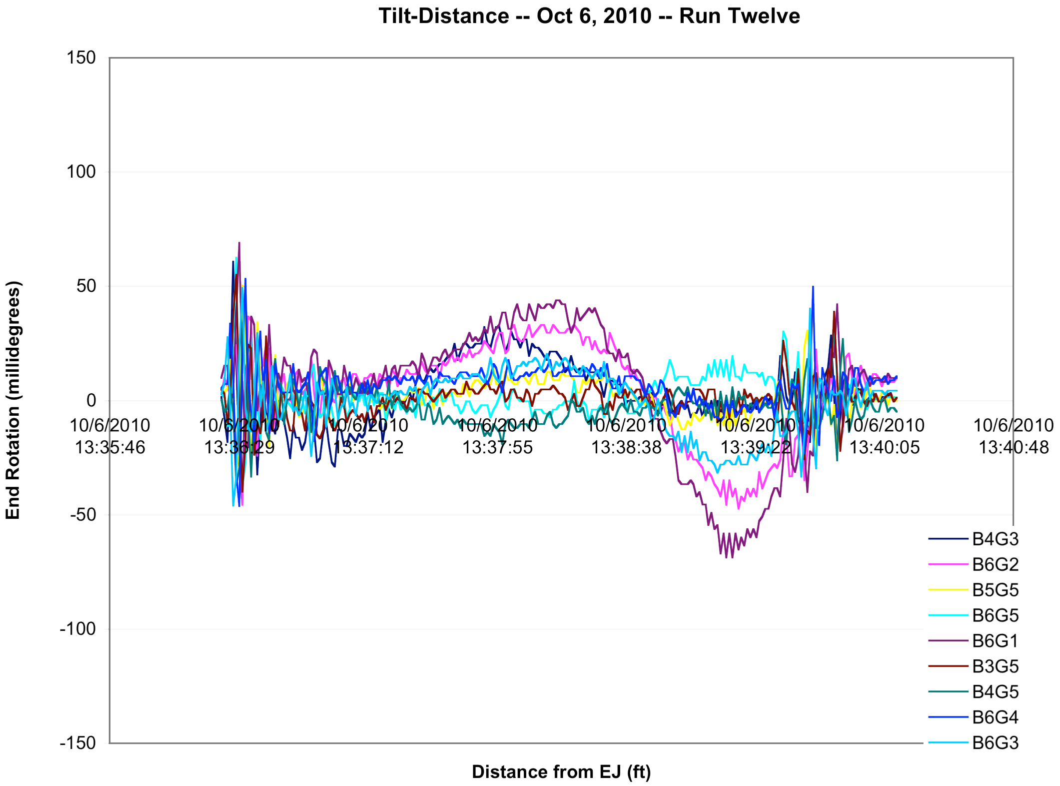


Figure 5.30. Vibration and Thermal Effects.

5.4.4 Measured Axle Load Distribution Factors

The first step taken with the analysis of the measurements was to compare the shape of the graphs. The graph shapes were compared with influence diagrams generated using a finite element model and STAAD.Pro moving load analysis. This line analysis model, the section properties, and the distribution factors used are described in Project Technical Memoranda. The shape functions matched the measured data, but the magnitudes were off. In this section, the girder end-rotation graphs will be analyzed to find the empirical lateral live-load distribution factors (axle distribution factors, or DF) for exterior and interior girders.

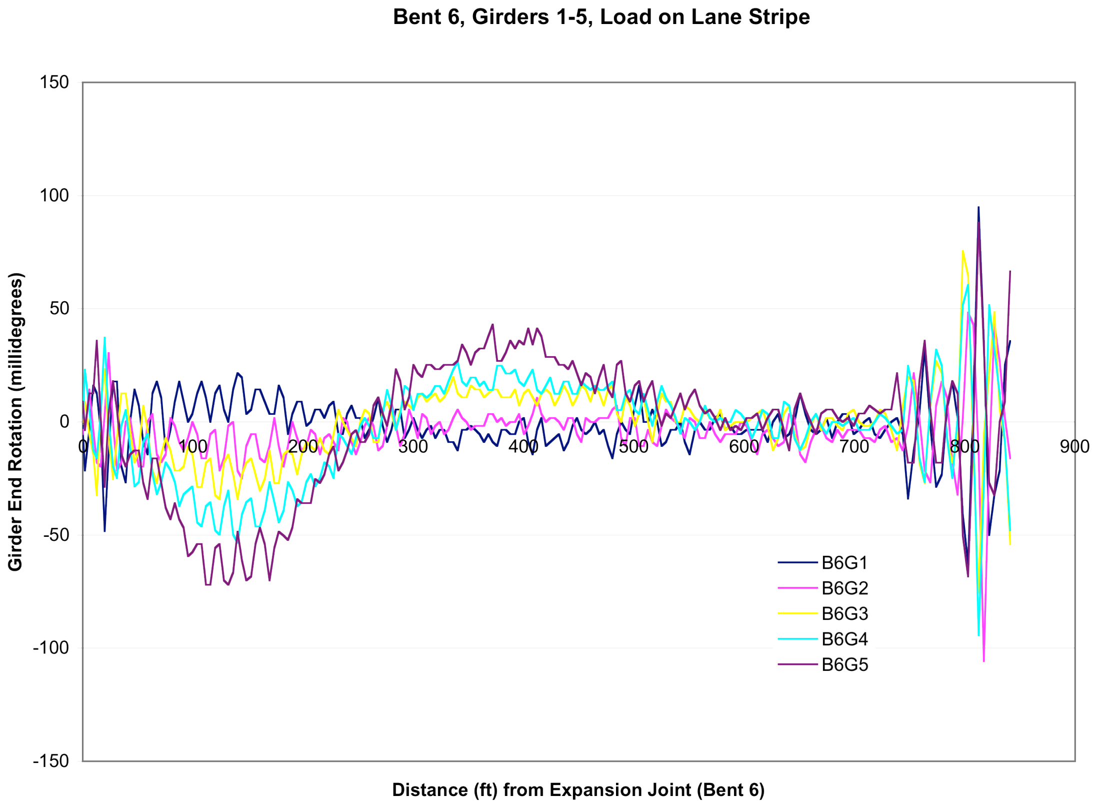


Figure 5.31. Exterior Girder Distribution Factors.

Figure 5.31 shows graphs of the end girder rotations over Bent 6 at each of the five girders. The load (Case 6) is applied about 2 ft from the bridge rail and moves from the expansion joint at Bent 6 to the far end expansion joint at Bent 3. At Bent 6, the maximum response (positive moment) occurs 140 ft from the start point. From the plot it is clear that girders 5, 4, and 3 are loaded up. The axle load distribution factors may be determined from girder end-rotation magnitudes at this 140-ft point by assuming the entire load is carried by girders 5, 4, and 3.

The axle distribution factors are then found to be:

G5	0.45
G4	0.34
G3	0.21

The observed exterior girder axle distribution factor is therefore 0.45.

A similar analysis can be used to find the axle distribution factors for the interior girder. Figure 5.32 shows graphs of the end girder rotations over Bent 6 at each of the five girders. The load (Case 7) is applied with the driver side wheel on the center stripe and moves eastbound in the eastbound lane from the expansion joint at Bent 6 to the far end expansion joint at Bent 3.

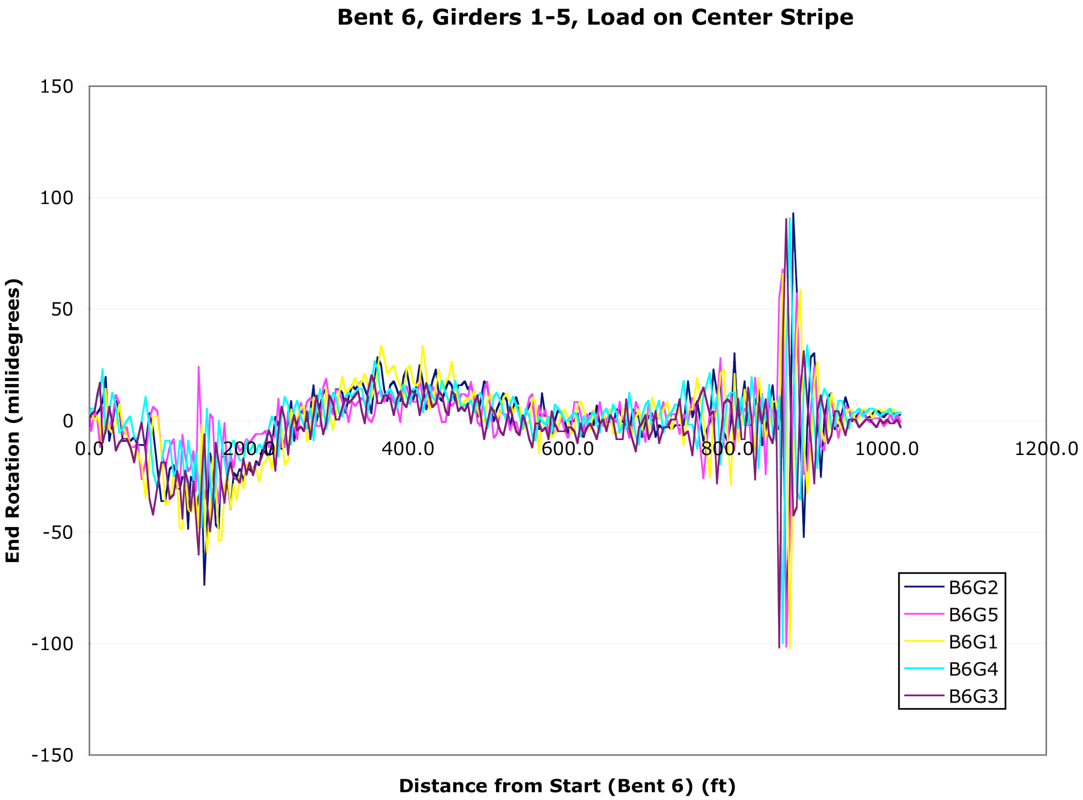


Figure 5.32. Interior Girder Distribution Factors.

Note the large oscillations that occur at the end of the run when the loads move off the steel girder unit. The plots show the attenuation of the vibration and the no-load condition at the end of the plot. This is discussed in Section 5.4.3.

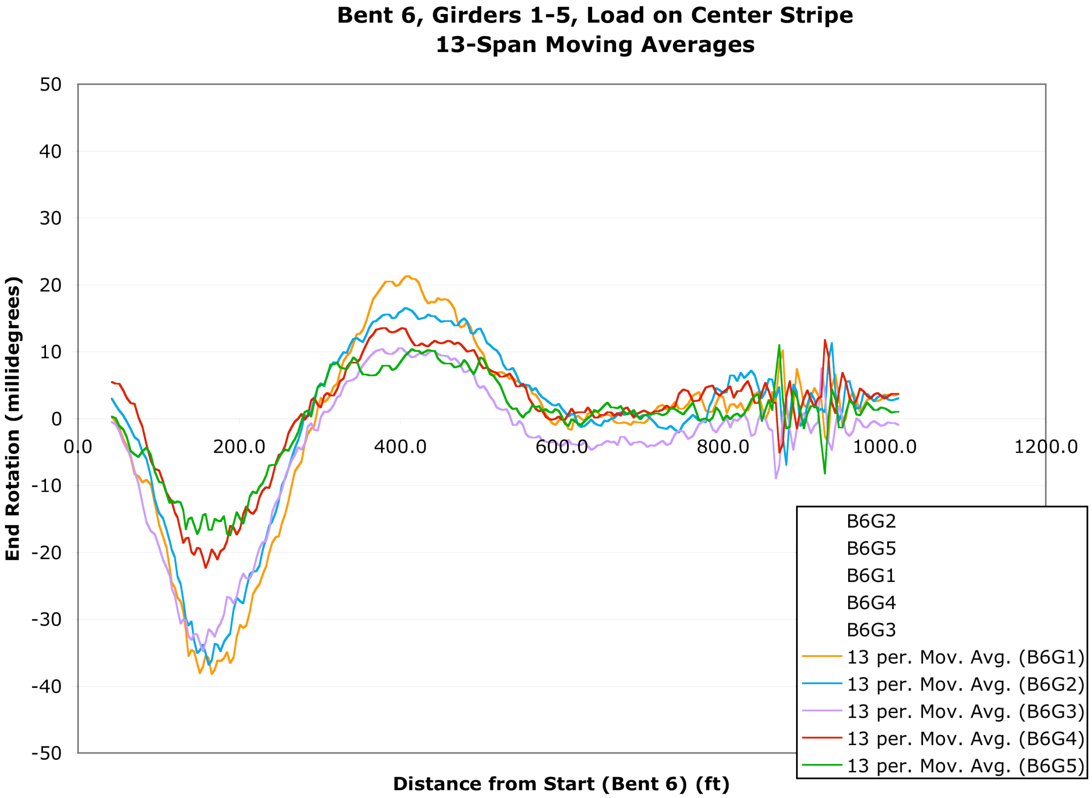


Figure 5.33. Smoothed Graphs.

In Figure 5.32, at Bent 6, the maximum response (positive moment) occurs 140 ft from the start point. The plot shows all the girders are loaded up. In this case it is easier to get the magnitudes by smoothing the graphs. Figure 5.33 shows the graphs after a 13-span moving average is applied. Note that the moving average causes the graphs to shift to the right along the horizontal axis. The location of the maximum load response must be taken from Figure 5.32. Using the magnitudes of end rotation in Figure 5.33, and neglecting the load on the far girder (G5), the distribution factors are:

G1	0.28
G2	0.28
G3	0.28
G4	0.16

The interior girder axle distribution factor is therefore 0.28.

5.5 COMPARISON OF MEASURED AND ANALYTICAL LOAD RESPONSES

From the collected data it can be shown that the steel girder response to loads is symmetric in both the longitudinal and transverse directions. The collected data also show that the measurements are repeatable. Measurements were collected from the same two girder end rotation locations both days of testing but using different tilt loggers. The graphs match very well. Apart from using moving averages to smooth the end rotation graphs, the graphs can also be averaged since three sets of measurements were made at each measurement location for each load condition. Since, in the time domain, each measurement increment is 1 second, the graphs of end rotation versus time may be reversed. The sign convention of the rotations may be changed by multiplying the millidegree readings by −1. This makes it possible to compare the measurements with other models that use a load moving in a different direction or that use a different sign convention for rotational displacements.

Figure 5.34 shows a graph of the average of three runs at Bent 4 Girder 5 (B4G5) on October 5. The averages use numerical methods and interpolation functions of the discreet data sets.

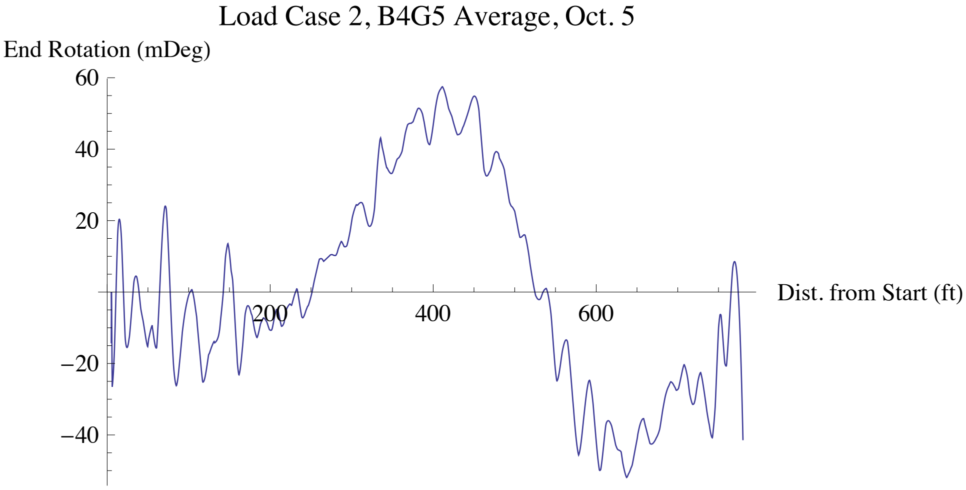


Figure 5.34. Average of 3 Runs at B4G5 from Oct. 5.

Figure 5.35 shows a graph of the average of three runs at B4G5 on October 6. Figure 5.36 shows the graphs of B4G5 from October 5 and 6 overlaid.

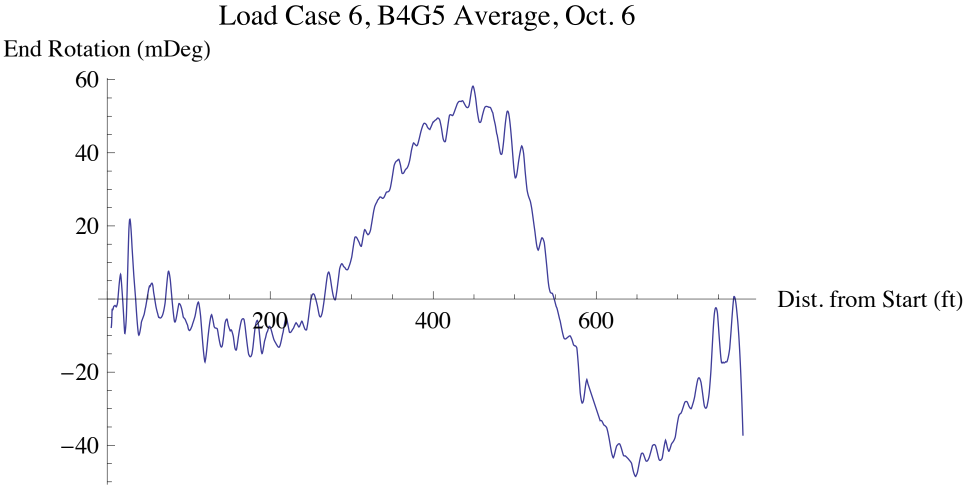


Figure 5.35. Average of 3 Runs at B4G5 from Oct. 6.

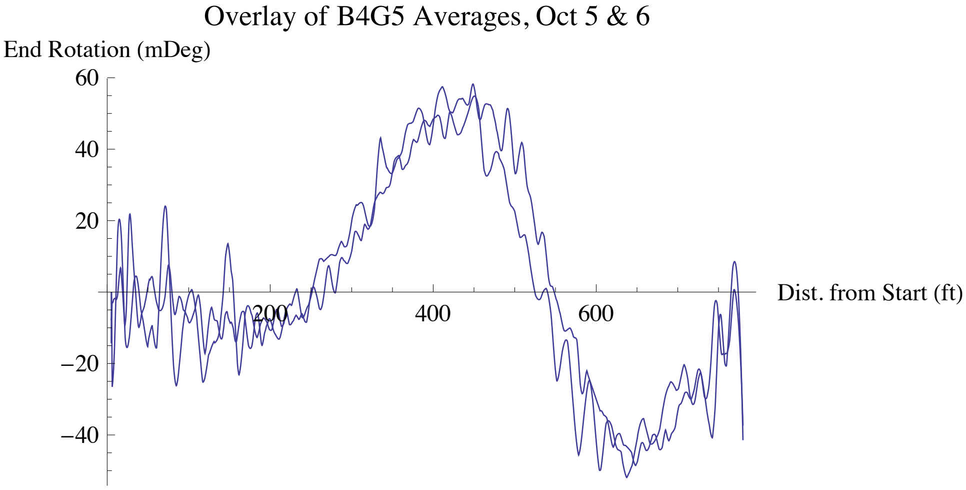


Figure 5.36. Overlay of Averaged Runs at B4G5 from Oct. 5 & 6.

In general, all the data collected are good quality and rather than averaging data at a gage location, a moving average with a span of 13 to 15 produces a shape function that closely matches analytical influence lines. Figure 5.37 shows B4G5 from Run 6 with a 15-span moving average applied.

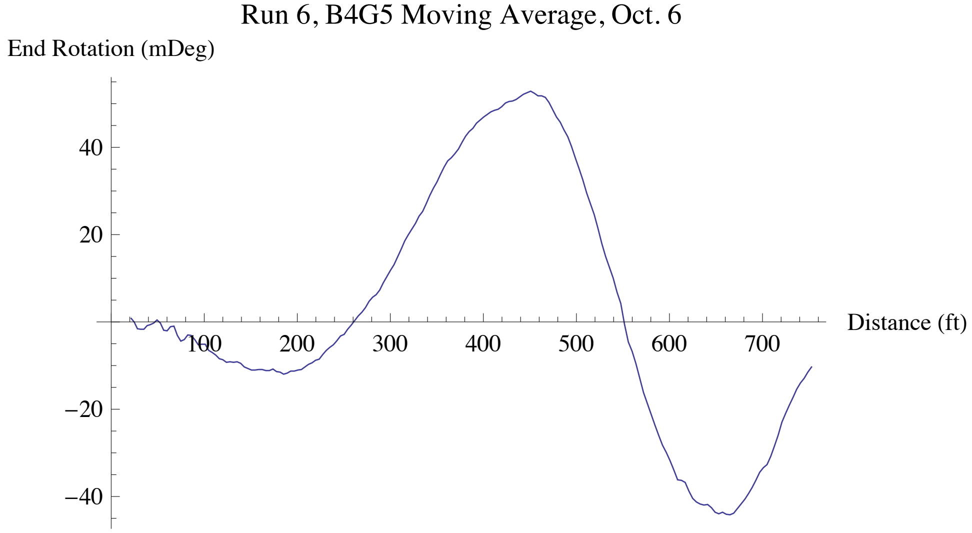


Figure 5.37. Moving Average of Run 6, B4G5 from Oct. 6.

Using the axle distribution factors determined in Section 5.4.4, the exterior and interior girder cases influence diagrams are compared with a measured response. The STAAD.Pro input for the interior and exterior girder cases is included in Project Technical Memoranda.

Figure 5.38 shows the graph of B6G5 (exterior girder) from Run 4 on October 6. The graph has been reversed and the sign changed to coincide with the load direction and sign convention of a STAAD.Pro analysis.

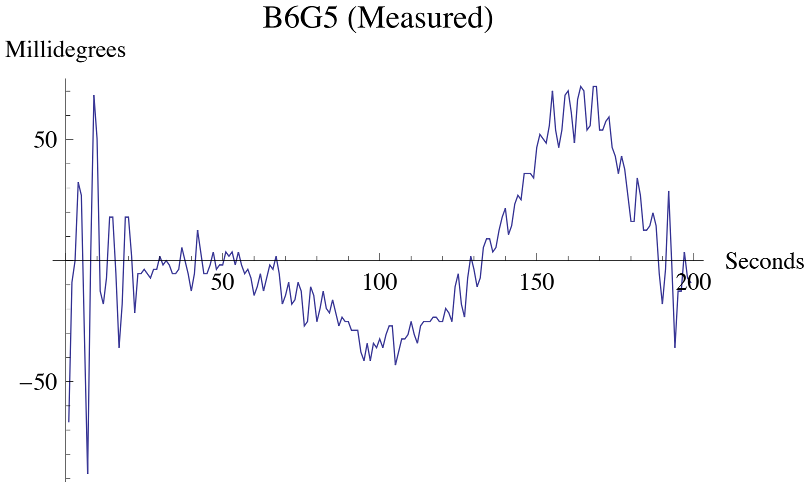


Figure 5.38. B6G5 Measured Response.

Figure 5.39 shows the analytical influence diagram of an exterior girder load condition at the girder end at Bent 6 using the measured distribution factors for the exterior girder. The moving load is applied such that the load moves at the average velocity of the measured response shown in Figure 5.38. Figure 5.40 shows the measured and analytical responses at B6G5 overlaid.

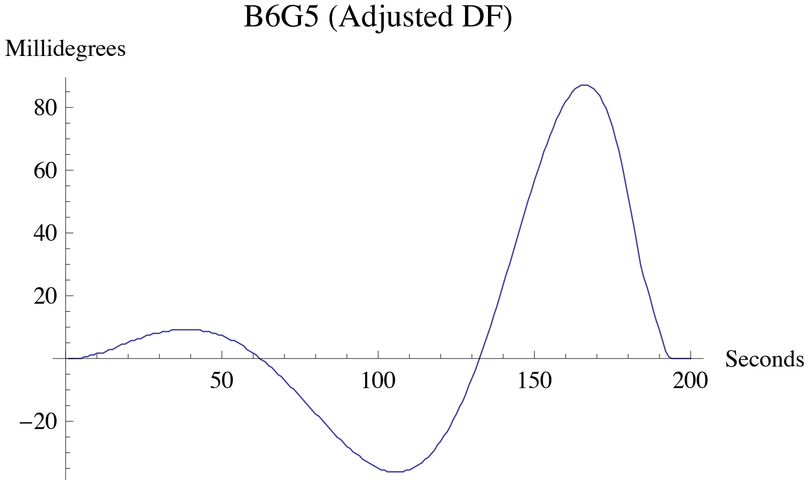


Figure 5.39. B6G5 Analytical Response, STAAD.Pro.

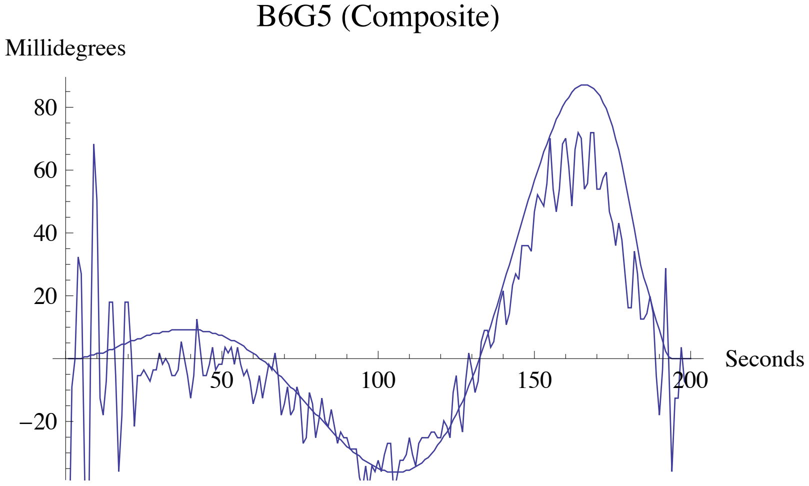


Figure 5.40. Measured and Analytical Response Overlay.

A similar analysis for an interior girder follows. Figure 5.41 shows the graph of B6G4 (interior girder) from Run 4 on October 6. The graph has been reversed and the sign changed to coincide with the load direction and sign convention of a STAAD.Pro analysis.

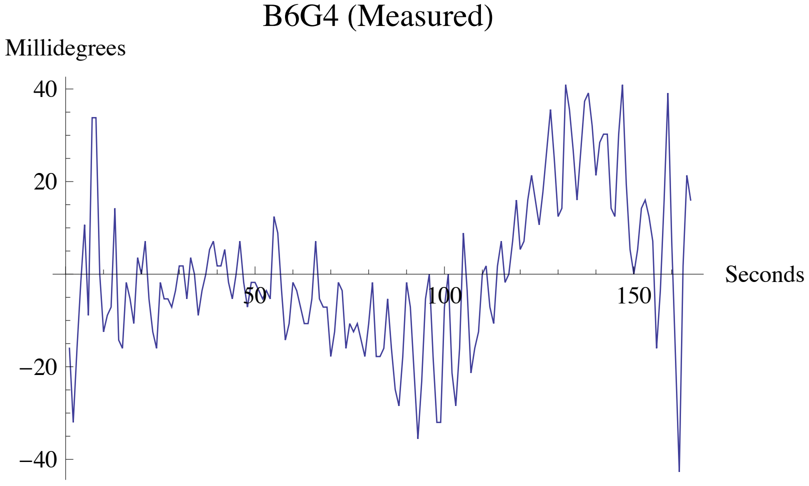


Figure 5.41. B6G4 Measured Response, Oct. 6.

Figure 5.42 shows the analytical influence diagram of an interior girder load condition at the girder end at Bent 6 using the measured distribution factors for the interior girder. The moving load is applied such that the load moves at the average velocity of the measured response shown in Figure 5.41. Figure 5.43 shows the measured and analytical responses at B6G4 overlaid.

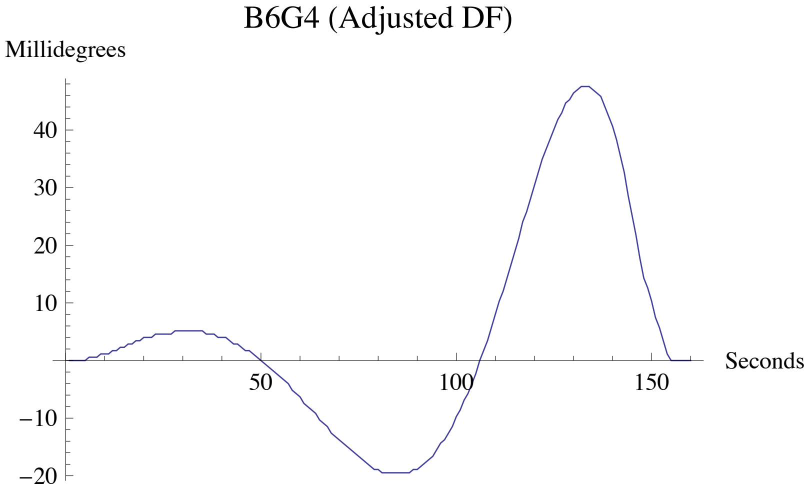


Figure 5.42. B6G4 Analytical Response, STAAD.Pro.

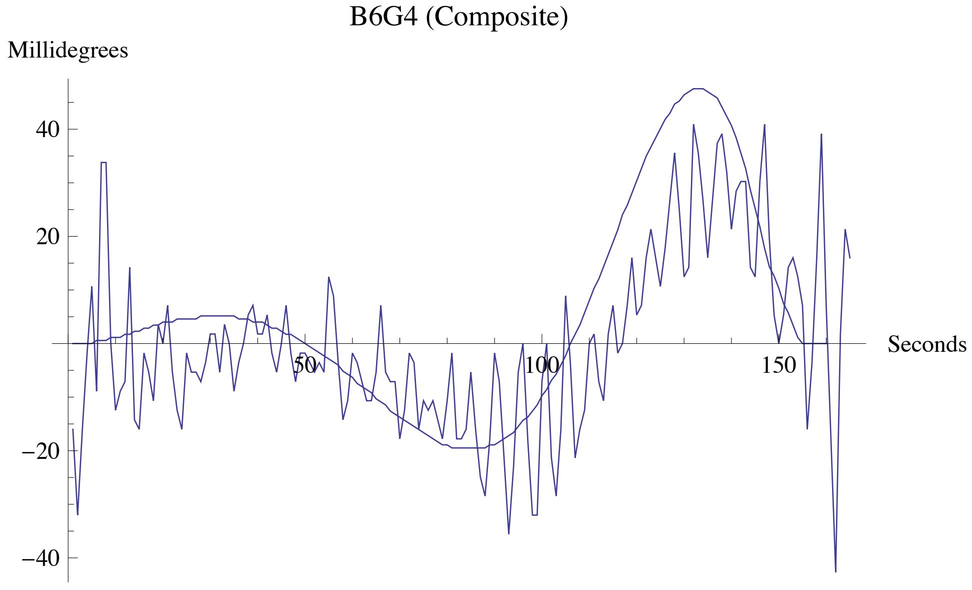


Figure 5.43. B6G4 (Interior Girder) Measured and Analytical Response Overlay.

The vehicle loads in the measured responses do not move at a constant velocity as do the analytical responses. Also the measured responses shown in Figures 5.38 and 5.41 are without temperature corrections and are not smoothed. They fit very well with the analytical graphs using the measured axle distribution factors.

5.6 SUMMARY OF FIELD TESTS

The field measurements of the study bridge were made with tilt loggers to measure girder end rotations and a sub-foot accuracy GPS with an L1/L2 antenna to measure load position. The measurements took place over two consecutive days. The collected data are good quality and were used to calibrate the analytical model of the study bridge for further analysis. The lateral distribution of live load was found to be very good for this bridge type. Axle distribution factors of 0.28 and 0.45 were experimentally determined for interior and exterior girders respectively.

CHAPTER 6

EVALUATION OF LOAD AND BRIDGE RATING FACTORS

6.1 RATING FACTOR EQUATIONS

Two methods were selected for bridge rating: the Load and Resistance Factor Rating and the Load Factor Rating. The Allowable Stress Rating method, which is based on the same general equation as the LFR calculation, was not considered, as it does not generate additional ratings that are meaningful. This is because two parameters, A_1 and A_2, are both given to be 1.0 in ASR. So all results would have a value greater than any result obtained using LFR (wherein both A_1 and $A_2 = 1.3$) given the same load effects and impact factor.

For LRFR and LFR, values for maximum moments and distribution factors were necessary for calculating girder-bending stresses due to dead loads from structural components and from wearing surfaces, and from live load (DC, DW, and LL respectively), at critical sections. Permanent loads other than dead loads were not applicable to the subject bridge. Dead load values have units of weight per girder and are distributed uniformly. Maximum moments for dead loads were hand-calculated and verified using both a spreadsheet and an analytical method. For LRFR, DC are calculated separately from DW. The LFR equation does not require separation of dead load types. The Rating Factor (RF) equations are as follows.

LRFR Equation **(Eq. 6.1)**

$$RF = \frac{C - (\gamma_{DC} \cdot DC) - (\gamma_{DW} \cdot DW) \pm (\gamma_P \cdot P)}{\gamma_L \cdot LL \cdot (1 + IM)}$$

where,

RF = Rating factor.
C = Capacity of the bridge member = $\phi_C \cdot \phi_S \cdot \phi \cdot R$ for strength limit and f_R for service limit.
70 ksi for the girder flanges of the Brazos Bridge
ϕ_C = Condition factor (0.85 ~ 1.0).
ϕ_S = System factor (0.85 ~ 1.0).
ϕ = LRFD resistance factor.
R = Nominal member resistance.
f_R = Allowable stress.
γ_{DC} = LRFD load factor for structural components and attachments = 1.25.
DC = Dead load effect due to structural components and attachments.
γ_{DW} = LRFD load factor for wearing surfaces and utilities = 150.
DW = Dead load effect due to wearing surfaces and utilities.
γ_P = LRFD load factor permanent loads other than dead loads = 0.
P = Permanent loads other than dead loads = 0.
γ_L = Evaluation live load factor = 1.15.
LL = Live load effects.
IM = Dynamic load allowance = 0 (5<mph).

LFR Equation

$$RF = \frac{C - A_1 \cdot D}{A_2 \cdot L \cdot (1 + I)}$$

(Eq. 6.2)

where,

A_1 = Factor for dead loads = 1.3.
A_2 = Factor for live load = 1.3.

6.2 CRITICAL MOMENTS

ANSYS 12, an FEA software package, was used to develop data necessary for analyzing moments on the Brazos River Bridge. Beam elements in ANSYS produce nodal loads that were then used to determine nodal moments. Influence lines consisting of nodal moments were generated along with ANSYS images displaying the moment diagram and load position of maximum moment in each span. Values of maximum moments were then used in the RF equations corresponding to three locations for a vehicle. The following is an example for the U.S. Army Heavy Equipment Transport System (HETS) vehicle:

(1) At a point approximately 0.42 of the length of Span 3 (220 ft) measured from Bent 3 0.42(220) ≈ 92 ft from Bent 3.
(2) At a point approximately 0.50 of the length of Span 4 (280 ft) measured from Bent 4, which corresponds to the middle of the steel girder portion of the bridge 220 + 0.5(280) = 360 ft from Bent 3 or 140 ft from Bent 4.
(3) At Bent 4.

For the 17 trucks (2-axle single, 6-axle combo, etc.), only location (2) in the middle of the bridge was analyzed for rating factors as this is the location where the maximum positive moment occurs for all vehicles.

6.3 RATING FACTORS

The calculated rating factors for the HETS vehicle using the DF from Appendix 4.1 are shown in Table 6.1 for the three critical moment locations on the bridge. The detailed calculation is shown in Project Technical Memoranda. The calculated rating factors for the other 18 vehicles, including the HETS, are shown in Table 6.2. In both Tables 6.1 and 6.2, the values for LFR are less than the LRFR values, reflecting the more conservative character of the LFR equation.

Figures 6.1 and 6.2 show the relationship between rating factors and load density, and rating factors and gross vehicle weight (GVW), respectively. No relationship was found in Figure 6.1 while rating factor decreases as GVW increases in Figure 6.2.

Table 6.1. Summary of HETS Rating Factors.

Location	Permit Load Rating	
	LRFR	LFR
Flexure at Span 3	4.63	4.06
Flexure at Span 4	3.85	3.37
Flexure at Bent 4	6.20	6.65

Table 6.2. Summary of Rating Factors.

Vehicle Type	Permit Load Rating	
	LRFR	LFR
HETS	3.85	3.37
2 Axle Single	10.90	9.53
3 Axle Combination	8.04	7.03
3 Axle Single	7.30	6.38
4 Axle Combination	5.34	4.67
4 Axle Single	6.76	5.91
5 Axle Combination	4.58	4.00
5 Axle Group	9.19	8.04
5 Axle Single	6.58	5.76
6 Axle Combination	5.54	4.84
7 Axle Combination	5.6.0	4.90
7 Axle Single	5.2.0	4.55
8 Axle Combination	4.27	3.74
10 Axle Combination	2.32	2.03
11 Axle Combination	4.66	4.08
3 Single Axle Combination	9.51	8.32
Spacing Axle Combination	4.77	4.17
Tridem Single	4.87	4.26

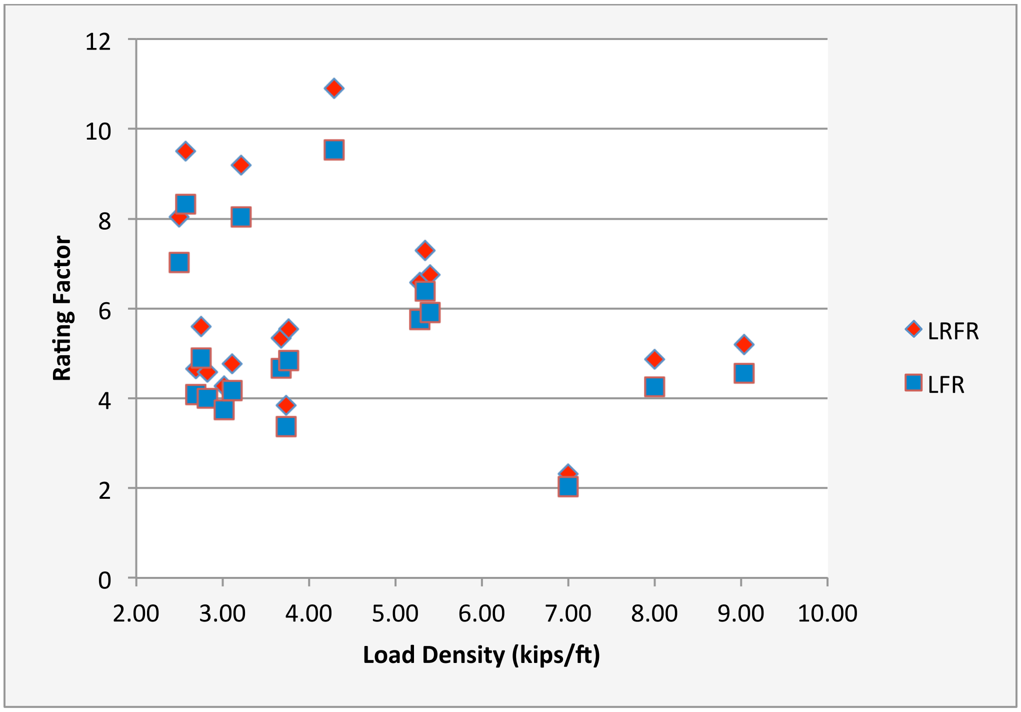


Figure 6.1. Rating Factor vs. Load Density.

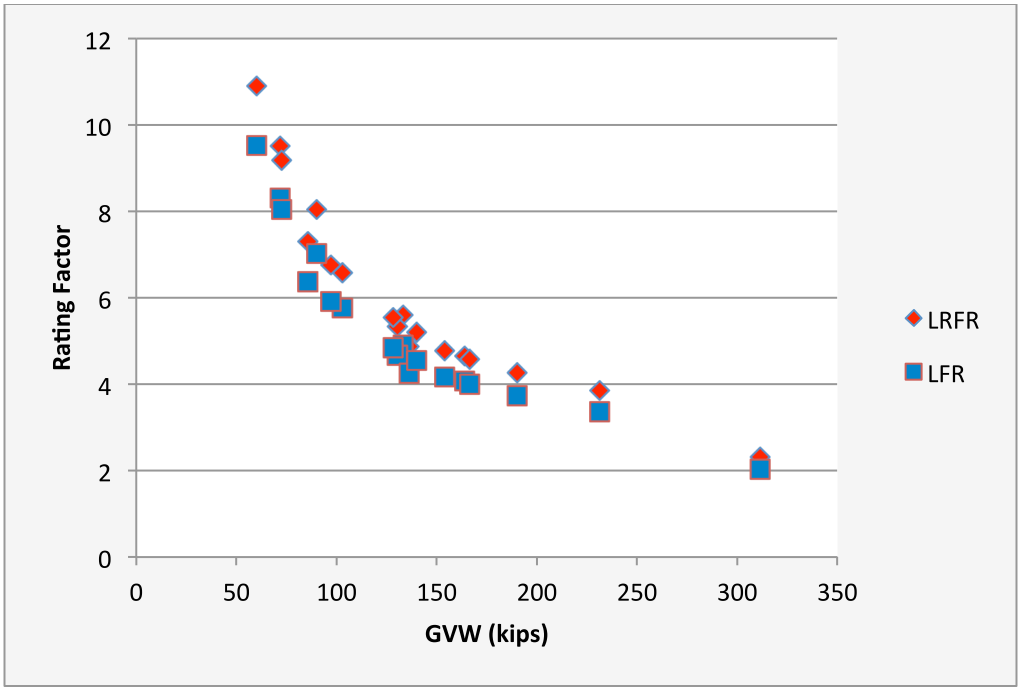


Figure 6.2. Rating Factor vs. Gross Vehicle Weight.

CHAPTER 7
ANALYSIS FOR SERVICE LIFE EXTENSION

7.1 INTRODUCTION

There are several studies in the literature concerning fatigue from overweight loads on bridges and the effects of varying stress levels on parts, along with many studies on the fatigue of metals. Most, if not all, the literature concerning fatigue from overweight loads on bridges concerns distortion induced fatigue. The AASHTO *Guide Specification for Fatigue Evaluation of Existing Steel Bridges* and the *Guide Manual for Condition Evaluation and Load and Resistance Factor Rating of Highway Bridges* have related information concerning distortion based fatigue that is more than 17 years old (Bowman, 2011). Purdue University is scheduled to complete a study (Bowman, 2011) and to give recommendations to AASHTO for a revision of these AASHTO chapters that includes consideration of variable-amplitude behavior, high-cycles and long-life behavior, weigh-in-motion, effects from superloads, actual traffic loading, and reliability-based methods, among other issues. Superloads in Indiana (Purdue University) are defined as a truck with a gross vehicle weight in excess of 108,000 lb. AASHTO has had inventory and operational stress level distinctions for bridges since at least 1970, and several states take loads that are over the operational stress level as a basis for their superload classifications.

Here in Chapter 7, the inventory and operational stress levels are used as a basis to evaluate the effects of superloads on the service lives of Texas bridges. The fatigue considered here is not distortion based, but that which occurs due to flexure in longitudinal members. (Distortion based fatigue may be controlled by using proper connection details, and the methods and approximations discussed below may be applied to connections with the limitations discussed. Several researchers have studied the effects of stress variations on connections.) A field study that would provide weigh-in-motion data (or a histogram of stress levels over a significant period) for a particular steel bridge would be very helpful. It would allow a clear picture of the stress levels Texas bridges experience, and it could be used to better estimate the service life extension available from reduced stress levels.

7.2 FATIGUE TESTING AND FATIGUE LIFE

Fatigue testing is usually performed by placing a material specimen under a known load that is then fully reversed. Each load and reversal combination is counted as one cycle, and the cyclic loading continues a certain number of cycles or until failure. Figure 7.1 shows a fatigue test loading where one cycle is identified on the graph. Stress amplitude is shown on the vertical axis, and time is shown on the horizontal axis. A series of tests are performed at varying stress levels and the number of cycles to failure is recorded. The results of the test series can be plotted on a log-log plot to get a stress-life diagram (S-N diagram). The S-N diagram plots nominal stress amplitude versus number of cycles to failure. Figure 7.2 shows a stress-life diagram. Many materials exhibit an endurance limit that is defined as the stress amplitude below which the material may be cycled infinitely. In this case the part is said to have an infinite life. The endurance limit, S_e, is shown in Figure 7.2 to be about 500 psi for this hypothetical material.

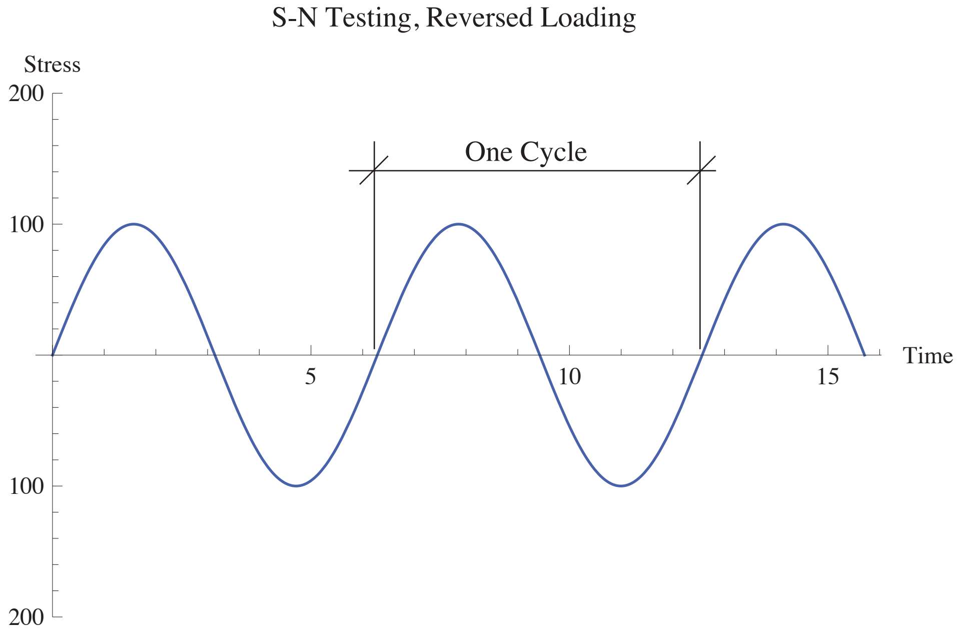


Figure 7.1. Fully Reversed Stress Used in Fatigue Life Testing.

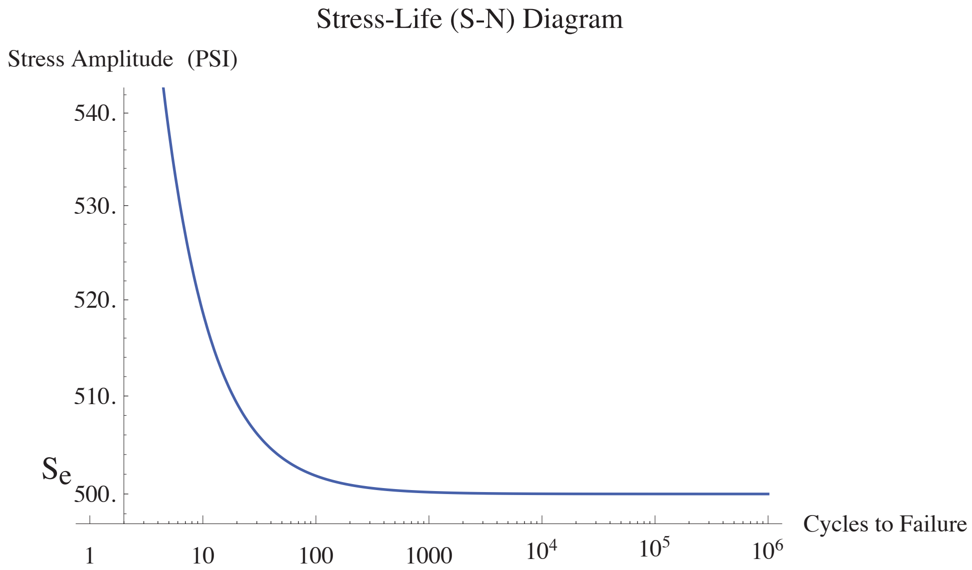


Figure 7.2. Stress-Life Diagram with Endurance Limit.

A part does not need to experience a stress reversal to develop fatigue-related cracks. Instead the part need only experience a cyclical tensile stress. Except for fatigue testing, parts are rarely subjected to fully reversed loadings. With actual fatigue loads, the mean stress the part experiences is typically non-zero and is more important than the stress amplitude (Ballantine, 1990). The mean stress is shown in Figure 7.3 and is defined below.

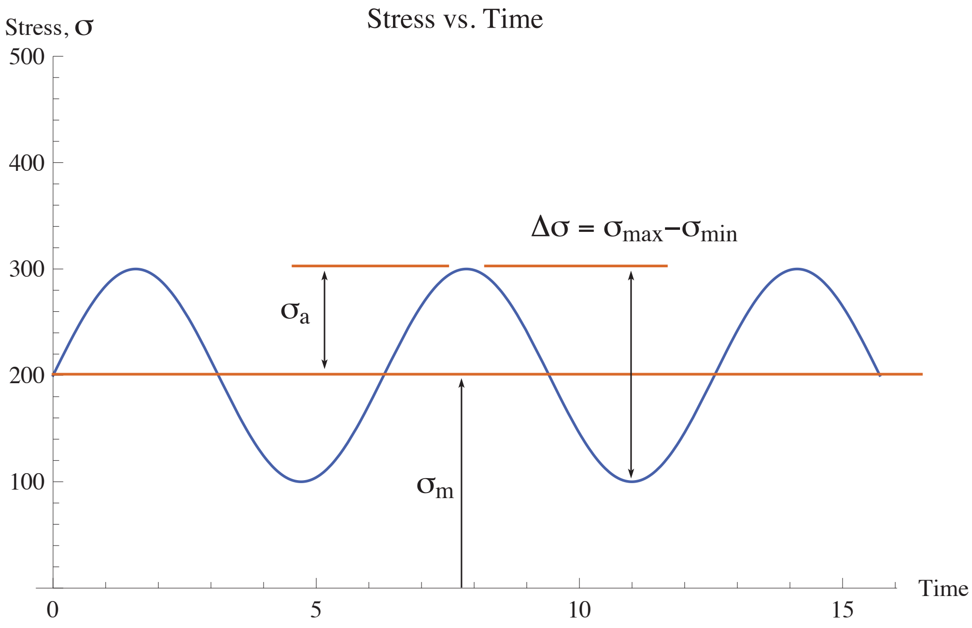


Figure 7.3. Definitions of Mean and Average Stress.

The stress range is defined as:

$$\Delta\sigma = \sigma_{max} - \sigma_{min} \qquad \textbf{(Eq. 7.1)}$$

And the stress amplitude is defined as:

$$\sigma_a = \frac{\Delta\sigma}{2} \qquad \textbf{(Eq. 7.2)}$$

Mean stress is defined as:

$$\sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2} \qquad \textbf{(Eq. 7.3)}$$

In addition, two ratios are often used. The stress ratio is defined as:

$$R = \frac{\sigma_{min}}{\sigma_{max}} \qquad \textbf{(Eq. 7.4)}$$

And the amplitude ratio is defined as:

$$A = \frac{\sigma_a}{\sigma_m} = \frac{(1 - R)}{(1 + R)} \qquad \textbf{(Eq. 7.5)}$$

Figures 7.4 through 7.6 show graphs of three combinations of the stress and amplitude ratios. In Figure 7.4, the stress ratio, R, goes to infinity, and the amplitude ratio is -1. In Figure 7.5, R is equal to zero and A is equal to one. Finally, in case three shown in Figure 7.6, R equals minus one and A goes to infinity.

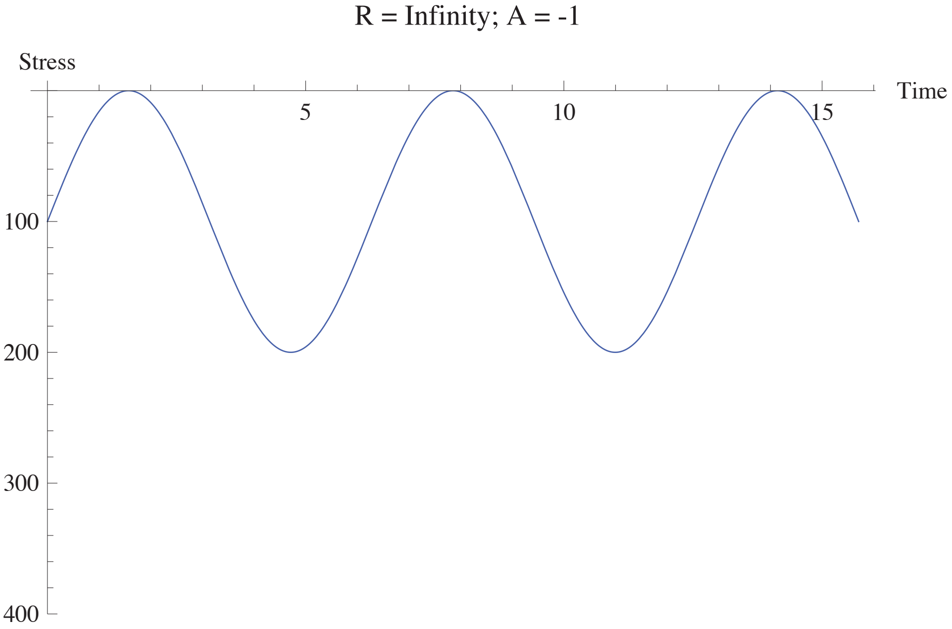


Figure 7.4. Case 1, Zero to Minimum, R Goes to Infinity and A =−1.

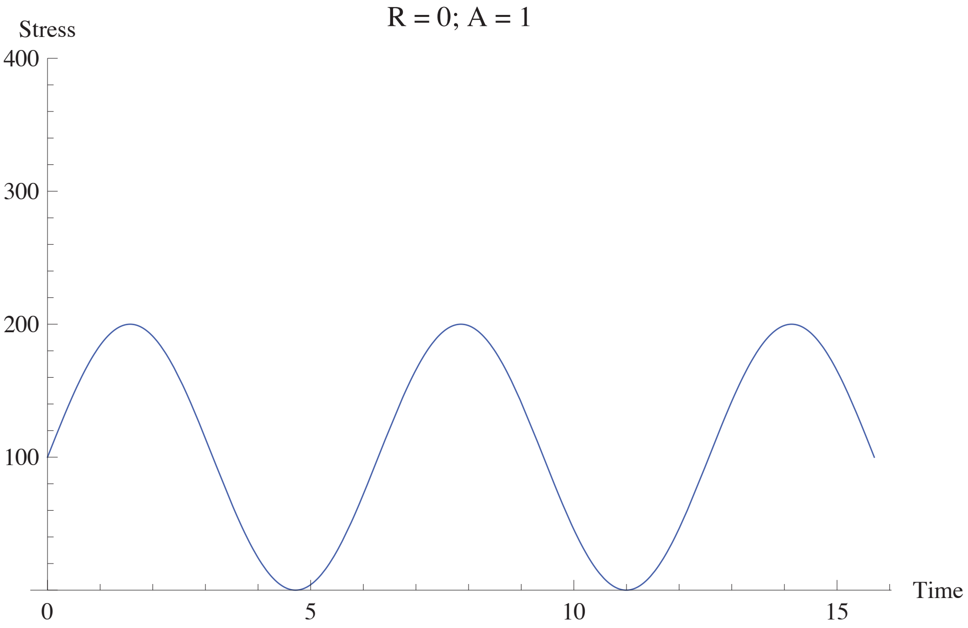


Figure 7.5. Case 2, Zero to Maximum, R=0 and A =1.

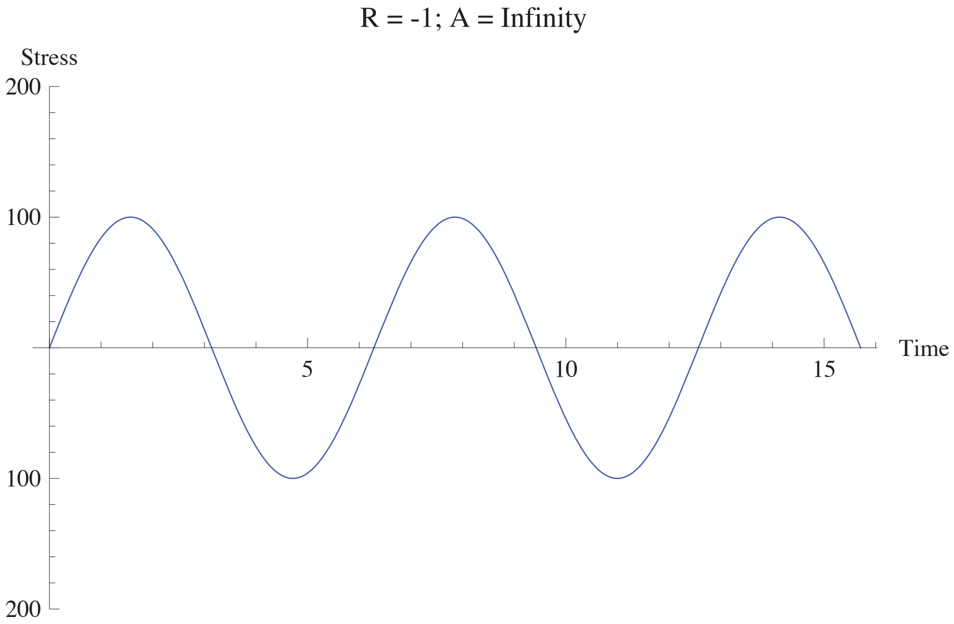


Figure 7.6. Case 3, Fully Reversed, R=−1 and A Goes to Infinity.

Most fatigue loads are similar to case two (Figure 7.5) with R < 1. For a given material, a change in mean stress causes a shift of the S-N curve. This is shown in Figure 7.7 where several S-N curves for the same material but with varying mean stresses are shown.

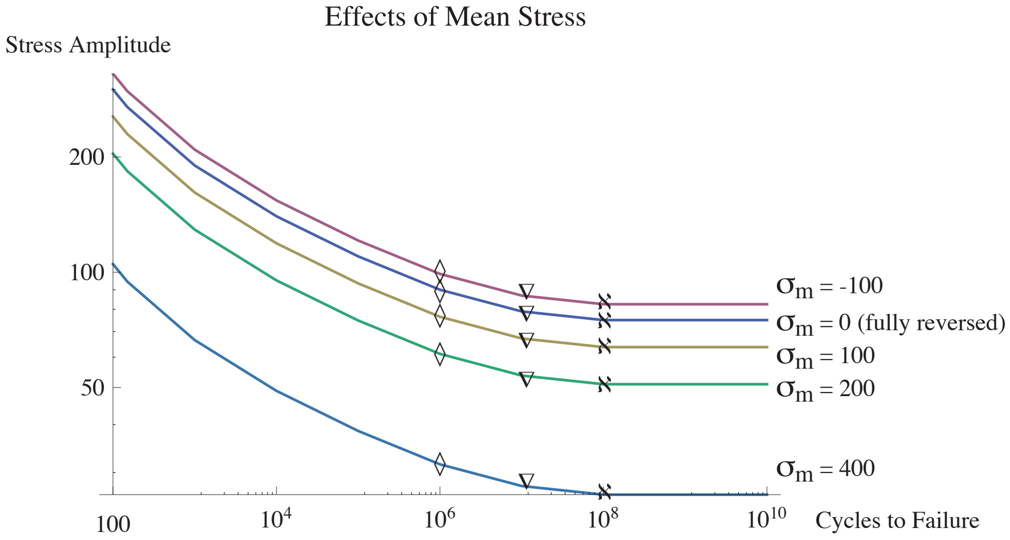


Figure 7.7. Effects of Mean Stress on the S-N Diagram.

With a set of curves like the set shown in Figure 7.7, a stress amplitude and mean stress pair can be recorded for a particular N for cycles to failure. These points can be plotted to give a constant life diagram like the one in Figure 7.8.

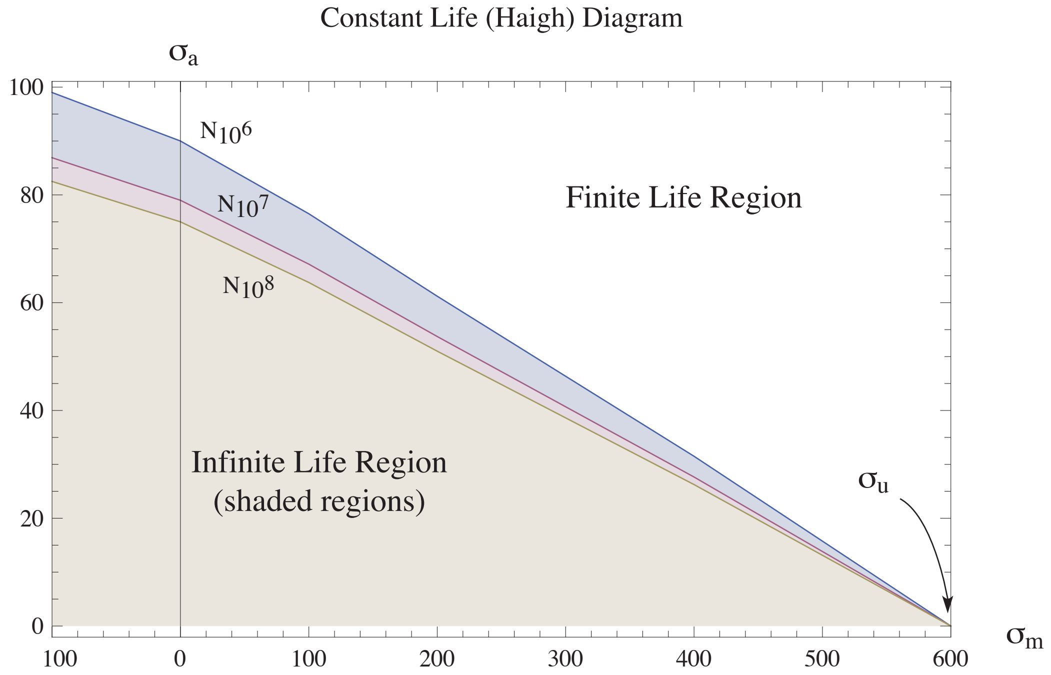


Figure 7.8. Constant Life Diagram for a Particular Material.

In the constant life diagram shown in Figure 7.8, plots of (σ_a, σ_m) pairs are shown for N of 10^6, 10^7, and 10^8 cycles to failure. The vertical axis shows the stress amplitude, and the horizontal axis shows mean stress with the final mean stress value equal to the material's ultimate stress. These curves show all the combinations of stress amplitude and mean stress available for a desired lifetime. Constant life diagrams require a significant number of tests and are seldom investigated. There are, however, several empirical relations available that work well for fatigue load cases where R is less than 1.

7.3 APPROXIMATIONS OF FATIGUE LIFE AND MEAN STRESS EFFECTS

7.3.1 Fatigue Life Approximations

An S-N curve can be approximated by a straight line when plotted on a log-log scale using the power law and the Basquin slope. Two points are needed (S_1,N_1) and (S_2,N_2) that represent the stress and number of cycles to failure at two points on the S-N curve.

Then with the power law:

$$N_1 = N_2\left(\frac{S_1}{S_2}\right)^{\frac{1}{b}} \tag{Eq. 7.6}$$

where b, the Basquin slope, is:

$$b = \frac{-\left(\log S_1 - \log S_2\right)}{\log N_2 - \log N_1} \tag{Eq. 7.7}$$

With this straight-line approximation, any N can be found for a known stress amplitude (in the range of 10^3 to 10^6 cycles, for ferrous metals). From years of fatigue studies, empirical relations between fatigue and tensile properties have been developed. The ratio of the endurance limit, S_e, to the ultimate strength, σ_u, is called the fatigue ratio:

$$FatigueRatio = \frac{S_e}{\sigma_u} \tag{Eq. 7.8}$$

For steel, the approximate endurance strength can be estimated by:

$$S'_{e,steel} \approx 0.5\sigma_u \quad ,\sigma_u < 200\,ksi \tag{Eq. 7.9}$$

Additionally, for wrought steels, the stress level corresponding to 1000 cycles can be approximated by:

$$S_{1000,steel} \approx 0.9\sigma_u \tag{Eq. 7.10}$$

Using equations (7.6) through (7.10), an approximate S-N curve for 70-ksi wrought steel may be developed like the one shown in Figure 7.9. The endurance limit is shown to be 35 ksi.

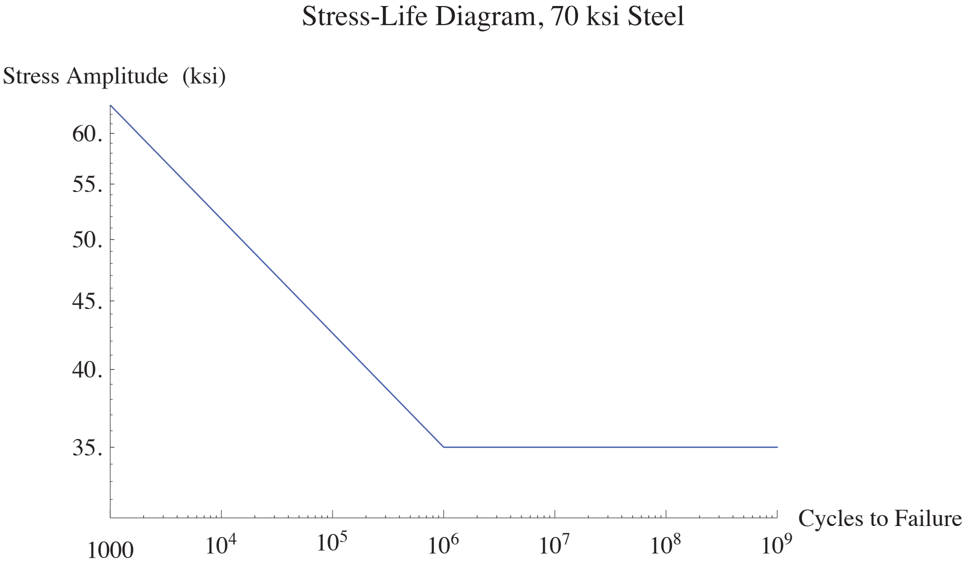


Figure 7.9. Approximate S-N Diagram for 70-ksi Steel.

Figure 7.10 shows another approximate S-N curve for the sake of comparison. Here the curve is for high performance steel (HPS) with an experimentally determined 95 ksi ultimate strength. Chen et al. (2005) performed the fatigue testing and found that the endurance limit for the HPS could be taken as 39 ksi.

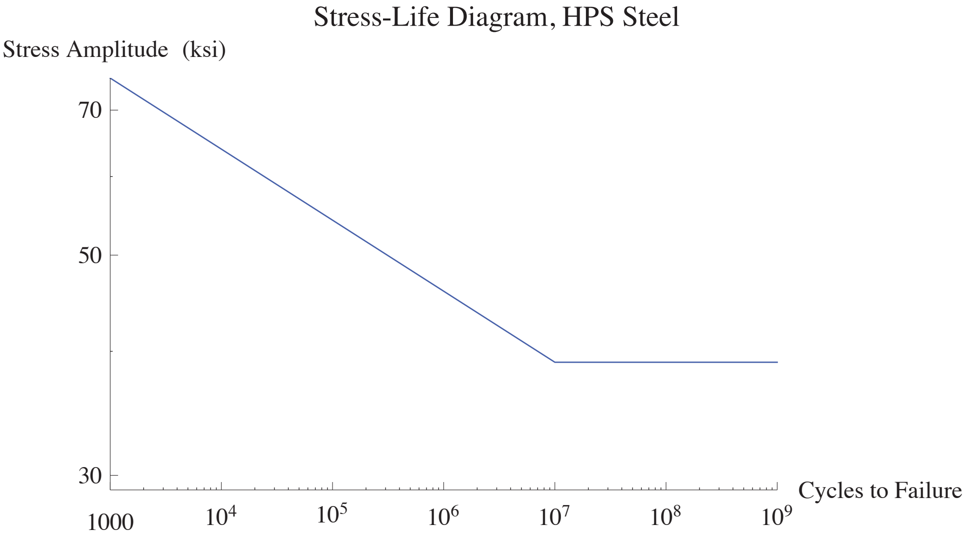


Figure 7.10. Approximate S-N Diagram, HPS Steel.

7.3.2 Approximations of Mean Stress Effects

Mean stress effects can be estimated using the empirical curves given by Goodman (1899) and Gerber (1874) or with more recent approximations given by Soderberg (1930) and by

Morrow (1960). Curves of Goodman and Gerber are shown here and they give good results when the stress ratio is less than 1.

The Goodman curve is:

$$1 = \frac{\sigma_a}{\sigma_e'} + \frac{\sigma_m}{\sigma_u} \qquad \textbf{(Eq. 7.11)}$$

where σ_e' is the effective alternating stress at failure ($\sigma_m = 0$) for a lifetime of N_f cycles, and σ_u is the ultimate stress.

Soderberg's curve is identical to Goodman's except that the yield stress is used instead of the ultimate stress. The Soderberg curve is very conservative and is not often used.

The Gerber curve is:

$$1 = \frac{\sigma_a}{\sigma_e'} + \left(\frac{\sigma_m}{\sigma_u}\right)^2 \qquad \textbf{(Eq. 7.12)}$$

where σ_e' is the effective alternating stress at failure ($\sigma_m = 0$) for a lifetime of N_f cycles, and σ_u is the ultimate stress.

Figure 7.11 shows a constant life diagram for an infinite life design based on the Goodman curve for 70 ksi steel. Equation (7.9) is used for σ_e', and equation (7.11) is solved for σ_a as a function of σ_m. Any combination of mean and alternating stress that is to the left of the curve is taken to provide an infinite life for the part.

For a finite life design, a given combination of mean and alternating stresses is taken to lie on a constant life curve. That curve is then used to solve for σ_e'. The lifetime for this stress is then determined from the S-N diagram (zero mean stress) for the given material.

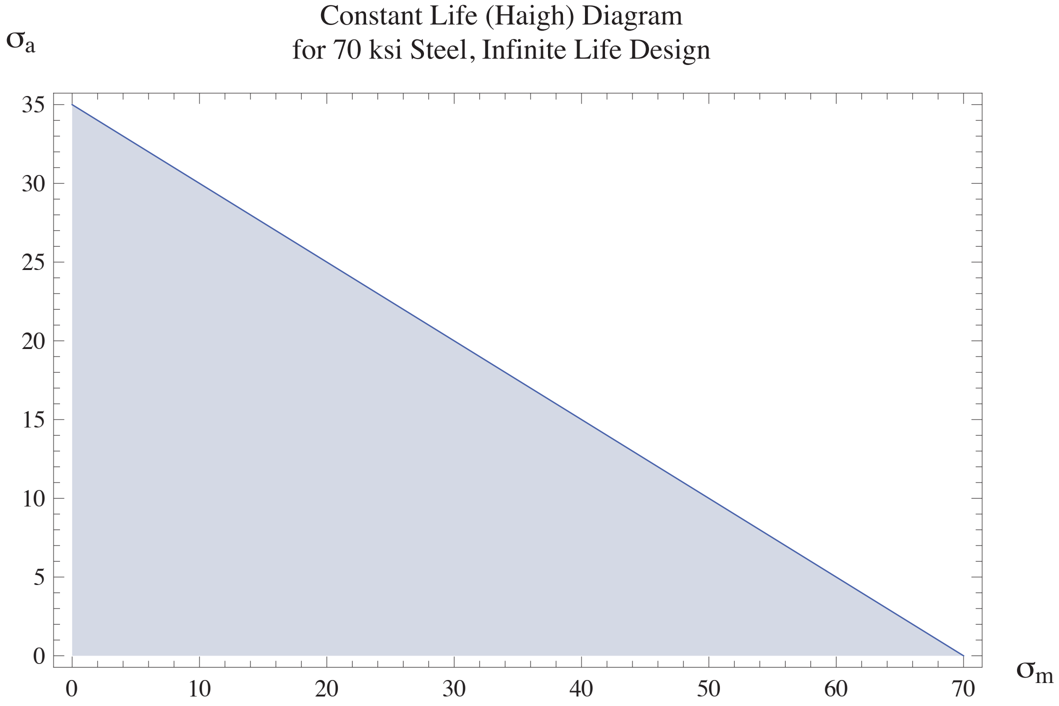


Figure 7.11. Constant Life Diagram, 70 ksi Steel.

7.3.3 Adjustments for Variations in Stress Levels

The Palmgren-Miner Rule can be used to estimate the fatigue life of a part that is subjected to variations in stress levels. The assumptions are that a body can only tolerate a certain amount of damage, D. If the body then experiences D_i from N sources (i =1 to N), then failure would occur when:

$$D = \sum_{i=1}^{N} D_i \tag{Eq. 7.13}$$

or:

$$1 = \frac{\sum_{i=1}^{N} D_i}{D} \tag{Eq. 7.14}$$

If a part is subject to n_1 cycles at stress S_1, n_2 cycles at stress S_2...n_N cycles at S_n, then from a S-N diagram for the material, the number of cycles to failure N_1, N_2 and N_N could be found, so that the fractional damage at stress level S_i will be n_i / N_i. The Palmgren-Miner rule says that failure occurs when:

$$1 = \sum_{i=1}^{N} \frac{n_i}{N_i} \tag{Eq. 7.15}$$

In the literature, it is reported that the Palmgren-Miner rule correlates very well to tests with random loading histories and should therefore be appropriate for ambient bridge loading. However the rule does not include a method to take into account the sequence of load effects and the rule implies that damage accumulation is independent of stress level (application of the Palmgren-Miner rule results in a shift of the entire original S-N curve).

7.4 APPLICATION OF APPROXIMATIONS TO TEXAS BRIDGES

Here the Palmgren-Miner rule and the Load Factor Rating method for 50 ksi steel are used to consider the effects of operational load levels on fatigue life. With a live-load-to-dead-load ratio of 3, the case of the inventory stress level is first considered.

With equations (7.1) through (7.5):

$$\Delta_\sigma = 34.6ksi$$

$$\sigma_a = 17.3ksi$$

$$\sigma_m = 5.8ksi$$

$$R = -0.5$$

$$A = 3$$

Then with equations (7.9), (7.10), and (7.11), the plot of a Haigh diagram shows that this σ_a, σ_m pair is indeed in the infinite life region of the plot. With regard to the Palmgren-Miner rule, the fractional damage at this stress level is zero for any number, n_N, of cycles. Therefore the inventory load stress levels can be neglected when the Palmgren-Miner rule is used to consider the effects of operational level loads and overloads. The case for the operational stress level, (1/1.3)*50 ksi, load is considered next.

The dead load stress level does not change in the operational level case. Consequently, the mean stress level, equation (7.3), does not change.

$$\Delta\sigma = 65.4\ ksi$$

$$\sigma_a = 32.7\ ksi$$

$$\sigma_m = 5.7\ ksi$$

$$R = -0.7$$

$$A = 5.7$$

The Goodman curve is used again, equation (7.11), but this time it is used to find the effective stress amplitude, $\sigma_e^{\prime}$, since the lifetime is finite. With σ_a, σ_m and equation (7.11),

$$\sigma_e^{\prime} = 36.9\ ksi$$

Now with equations (7.6), (7.7), (7.9), and (7.10), the following equation is determined, which can be solved for x.

$$81 * \left(\frac{1}{x}\right)^{0.0850908} = 36.907$$

Here, x = N_f = 10,278 cycles, the number of cycles to failure for the 36.9 ksi effective stress amplitude load level.

Finally, using the Palmgren-Miner rule, equation (7.15), the effects of the load level on the part using a percent time basis can be estimated. Since no fractional damage occurs with the inventory stress level, that term can be neglected in equation (7.15). If the operational load level is applied 100 percent of the time, then the lifetime of a girder (flexural loading) is 10,278 cycles. Equation (7.15) can be solved for N_f as a function of percent time applied (assuming the only other load level applied is at the inventory stress level), as shown in Figure 7.12.

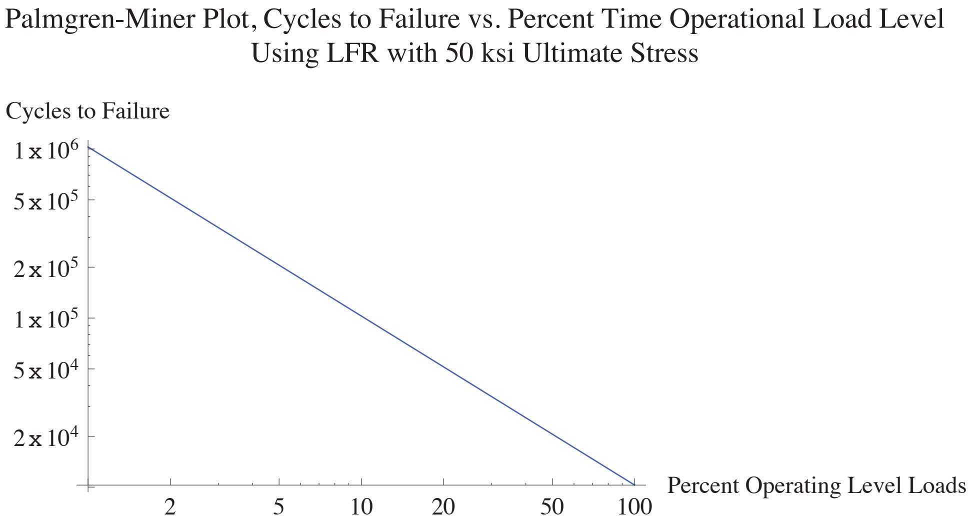


Figure 7.12. Palmgren-Miner Plot of Percent Time for Operational Load.

From the graph in Figure 7.12, it can be seen that the lifetime of the girder would be significantly reduced by the operational stress level load if applied as little as 5 percent of the time. Research shows that for various reasons this stress level is not often or easily reached. Percentage of time per stress level may be estimated using average annual truck traffic data based on weigh-in-motion studies or on Motor Carrier or Bridge Division records.

One other finding concerns the stress cycles that occur during live loading. In the literature, the number of cycles per truck load is usually taken as 1. Figure 7.13 shows the passing of a large pump truck that passed over the study bridge during the feasibility study. The bridge response was recorded at the expansion joint at an interior girder. The sample rate was 20 samples per second, and the measurand was girder end rotation in units millidegrees. The graph of girder response to the heavy loading (it was basically twice as high as any other observed response) shows that the girder actually experiences several high-stress cycles per truck passing.

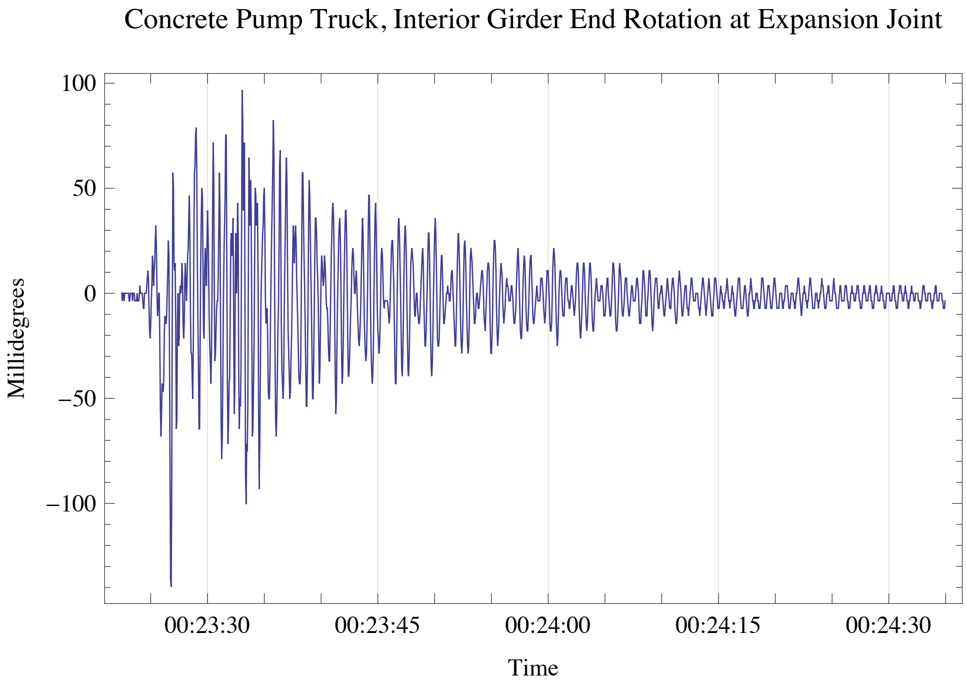


Figure 7.13. Several High Cycles due to Single Truck Load.

The graph in Figure 7.13 shows that there are 6 or more high-stress-level load cycles experienced by the girder by a single heavy truck passing over it. This is a characteristic of the particular structure that should not be overlooked. In the operational-stress-level case, applied 100 percent of time, the number of trucks passing to failure would be as few as (10,278/6) = 1713, not 10,278.

7.5 SUMMARY

In summary, the fatigue life of girders is controlled by design using the inventory stress level. There are several approximations available to evaluate the effects of fatigue and mean stress levels of higher loads. When, as in most bridge loads, the stress level varies, the Palmgren-Miner rule can be used to estimate the effects. However the rule has limitations, and researchers are working on probabilistic methods that take into account damage sequence, variations in stress levels, bridge condition ratings, and weigh-in-motion data for a particular structure. Most, if not all, of this research effort is focused on distortion-induced fatigue that occurs at connections. Work here has shown that operational stress level loads applied as little as 5 percent of time to a particular structure on an annual basis will have a significant effect on the lifetime of the structure. Also shown here is that the number of load cycles per truck cannot be assumed to be one per truck. The bridge response should be characterized by field tests since there are no models available to evaluate this analytically. It may be possible to characterize load-cycles-per-truck by bridge type.

CHAPTER 8

VERIFICATION OF SUPERHEAVY LOAD CRITERIA

8.1 INTRODUCTION

This chapter relies on the work discussed in the previous chapters to validate the superheavy load criteria and evaluation methodology. TxDOT superheavy loads are vehicle loads defined in Title 43: Texas Administrative Code, Chapter 28, Subchapters A – K. They are defined as:

- An overdimension load that is between 200,001 and 254,300 lb total with less than 95 ft overall axle spacing.
- Or is over the maximum permitted weight on any axle or axle group.
- Or is over 254,300 lb gross weight.
- Or is over the weight limits described in §28.11(d).

The *maximum permitted weight on any axle or axle group* is defined in §28.11(d).

There are other criteria that concern pavement that are not considered in this study. The criteria above for bridges identify loads that trigger a bridge review. In a bridge review, each bridge on the proposed route of the superheavy load is analyzed to determine whether the bridge has the capacity to carry the load. In other words the TxDOT bridge-review triggers are loads over 254,300 lb, or 200,001 lb if less than 95 ft overall axle spacing.

8.2 BASES OF TRIGGER LOADS

There are several approaches a transportation department may use to identify a bridge review trigger. These include the definitions of inventory and operational stress levels, empirical data, probabilistic methods, analytical modeling, and bridge rating. Bridge rating may be based on LFR or LRFR. Rating each bridge individually with probabilistic methods may not be feasible for a state with many bridges. For example, Texas has more than 50,000 highway bridges, whereas Hawaii has just over 1,100. The TxDOT bridge review trigger is based on empirical data. The superheavy load criteria are based on a review of prior permitting. The review was performed with the intent of protecting bridges that were designed using the older H15 live loading. In spite of this, the TxDOT bridge trigger is very generous compared to the triggers of other state departments of transportation. The average U.S. bridge trigger was found to be 165,000 lb, the most frequent trigger is 150,000 lb, and at least 4 states use a trigger of 120,000 lb.

In 2009, the New Hampshire DOT (NHDOT) reviewed its permitting practices, and as a result it added to its single 150,000-lb bridge trigger load 17 load and axle configurations that also trigger a bridge review. NHDOT did this because they found that these loads were capable of damaging some of their bridges. These 17 load and axle configurations were included in a parametric study used here to help verify the TxDOT superheavy load criteria.

8.3 VALIDATION OF CRITERIA

The results from solid modeling and from the parametric study show that the TxDOT criteria are valid for the bridge type used in the study. The flexural stresses determined were all very low. Stresses observed in the girders were below 15,000 psi. In the parametric study, using the Army HETS, the bridge permit load rating using LRFR was found to be 3.85. The HETS has well described and readily available axle-location and axle-load data, and with its 231,000 lb combined gross vehicle weight and with 62 ft between its extreme axles, it is by the TxDOT criteria a superheavy load. The 3.85 bridge rating shows that the load carrying capacity of the study bridge is nearly four times that of this superheavy load. That is, the load intensity could be four times greater before the stresses would reach operational stress levels.

The study bridge was constructed in 2000 and was designed using HS20 loading and high strength steel girders. Load distribution was found to be much better than the distribution assumed during design. The composite deck, bridge rails, and transverse members are all assumed to contribute to the observed improved lateral distribution of axle loads. The TxDOT superheavy load criteria was intended to protect older bridges designed using H15 loading. In the late 1980s, prior permitted loads were plotted on a load-length graph (Panak, 1992). The graph showed axle load divided by length-between-axles plus 4 ft on the vertical axis and length-between-axles plus 4 ft on the horizontal axis. A curve was fit through the points such that any point above the curve would require a bridge analysis to protect H15 designed bridges. Figure 8.1 shows a list plot of points along the curve.

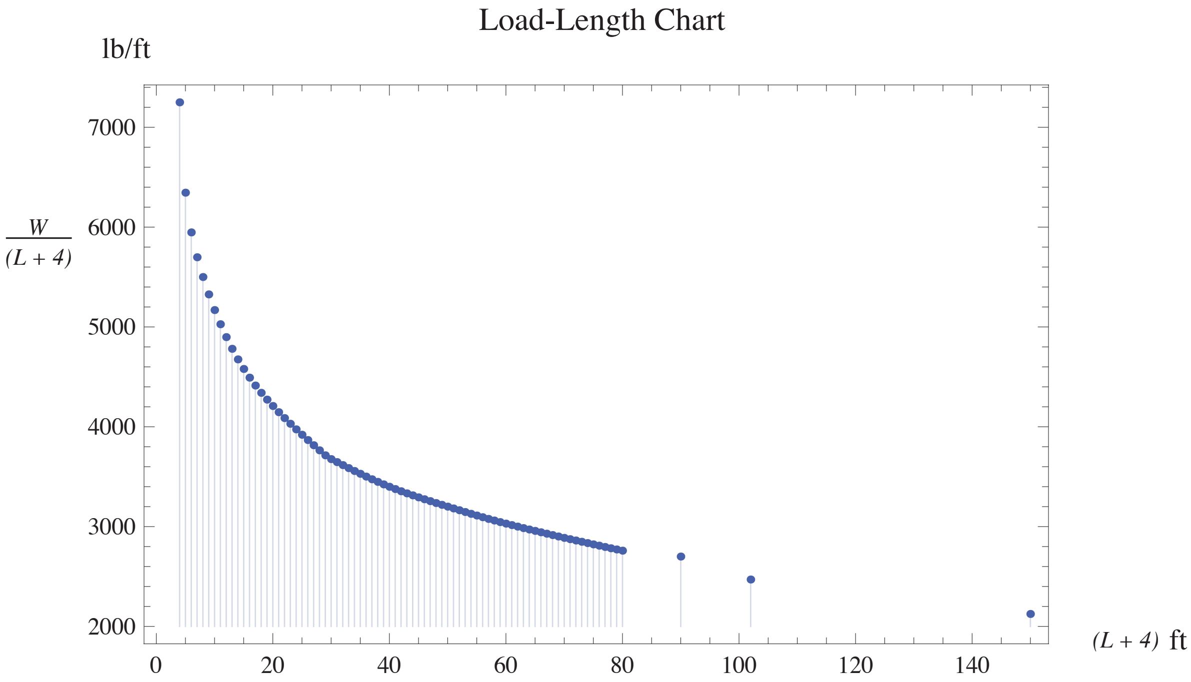


Figure 8.1. List Plot and Basis of TxDOT Superheavy Load Criteria.

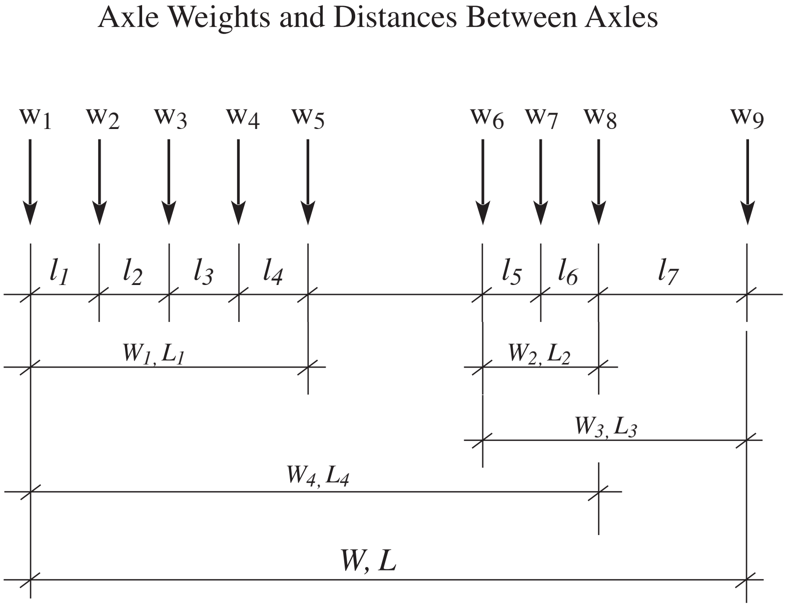


Figure 8.2. Example Vehicle Axle Weights and Distances between Axles.

Figure 8.2 shows axle weights and distances between axles for an example vehicle. If every combination of upper case W and L from Figure 8.2 are plotted on the graph in Figure 8.1, and all the points are below the curve shown in Figure 8.1, then the load is considered safe and no bridge analyses are required. This curve is for simple spans, but at any rate it was used as the basis for the superheavy load criteria. Figure 8.3 shows curve fits of the points shown in Figure 8.1.

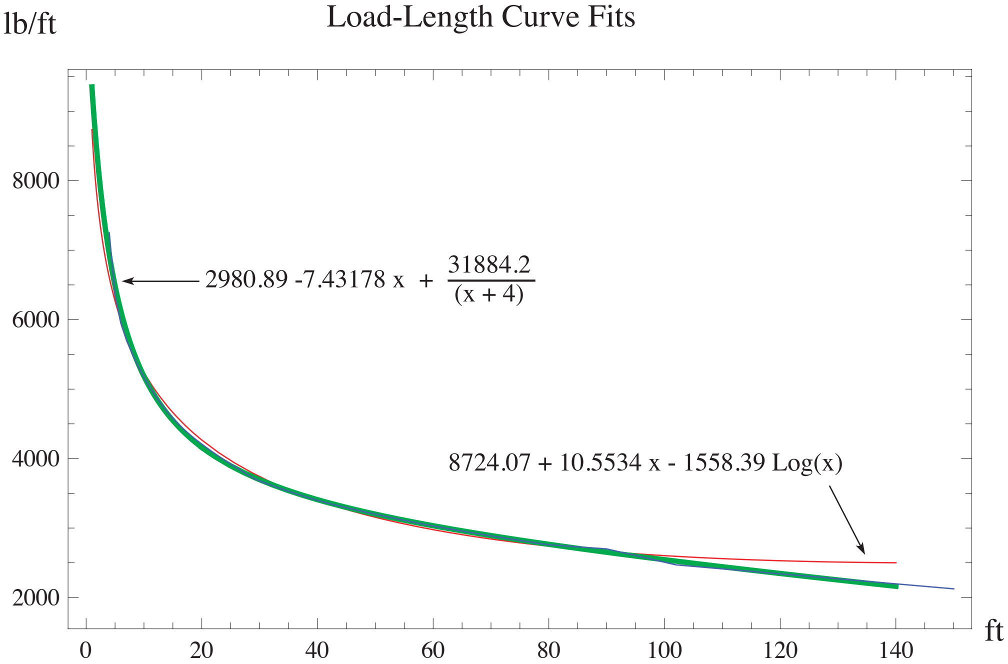
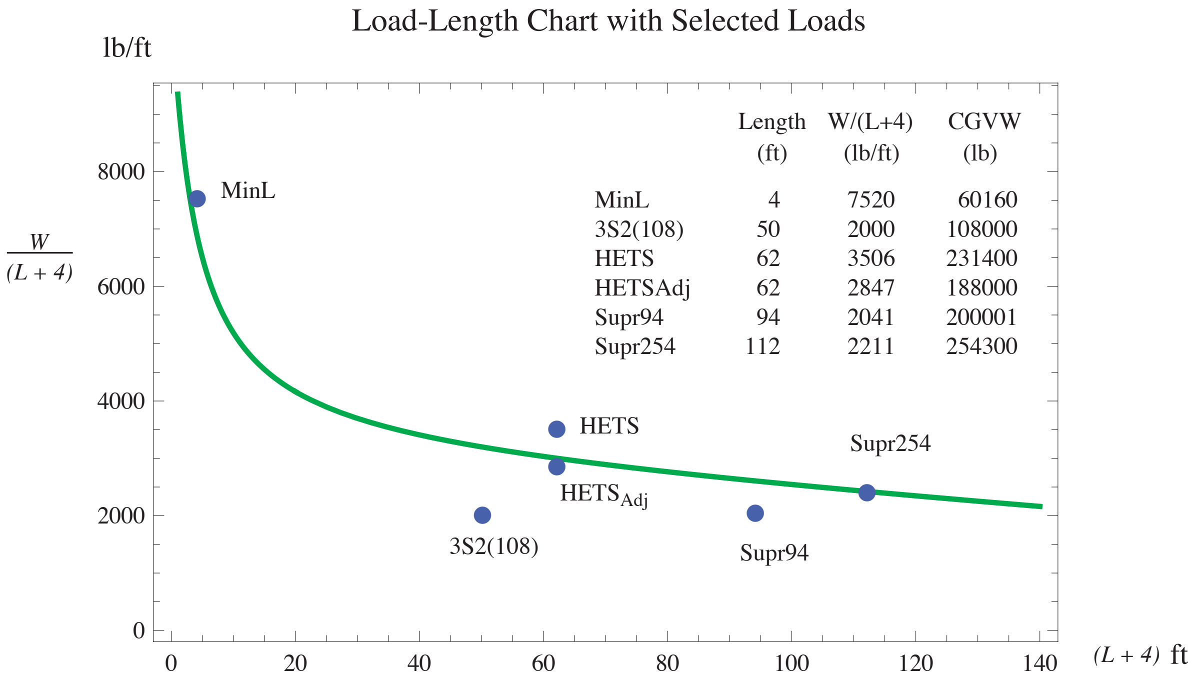


Figure 8.3. Fits of Data Points.

Figure 8.4 shows the non-linear fit along with several data points including a 254,300 lb and 94 ft superheavy load (Supr254 and Supr94) from the late 1980 TxDOT study (Panak, 1992; and, unpublished internal records provide by TxDOT to authors). Also shown are two points for the HETS. These two points are based on the extreme distances between axles (62 ft). The HETS point plotted above the curve is based on axle weights that are not adjusted for the number of tires and wider non-standard-gauge axles on the HETS. The second point, $HETS_{Adj}$, shows that the HETS plots below the curve when the axle weights are adjusted for number of tires and non-standard gauge. The axle weight reduction factors for number of tires and gauge distance greater than 6.0 ft are specified in appendices of the Texas Administrative Code (TxDOT, 2008). Although it is not shown in Figure 8.4, each point of every combination of W and L for the adjusted-axle-weight HETS falls below the curve.



Load-Length Chart with Selected Loads

	Length (ft)	W/(L+4) (lb/ft)	CGVW (lb)
MinL	4	7520	60160
3S2(108)	50	2000	108000
HETS	62	3506	231400
HETSAdj	62	2847	188000
Supr94	94	2041	200001
Supr254	112	2211	254300

Figure 8.4. Load-Length Graph with Selected Points.

8.4 POSSIBLE CHANGES TO SUPERHEAVY LOAD CRITERIA

Figure 8.5 shows the graph of load-length combinations in Figure 8.4 approximated by piecewise linear functions. Figure 8.6 shows the two regions of the graph when the TxDOT data are approximated with the two piecewise linear functions. It may be beneficial to TxDOT to replace the existing superheavy load criteria with Figure 8.6 and Figure 8.2, along with the axle and axle group restrictions of §28.11(d), and the tire and axle reduction factors. This would allow a carrier to configure loads so that they fall in the safe region without the time and expense to the carrier necessitated solely by gross vehicle weight. This could possibly reduce the number of superheavy permit requests and save TxDOT time and money while continuing to protect Texas bridges from overloads.

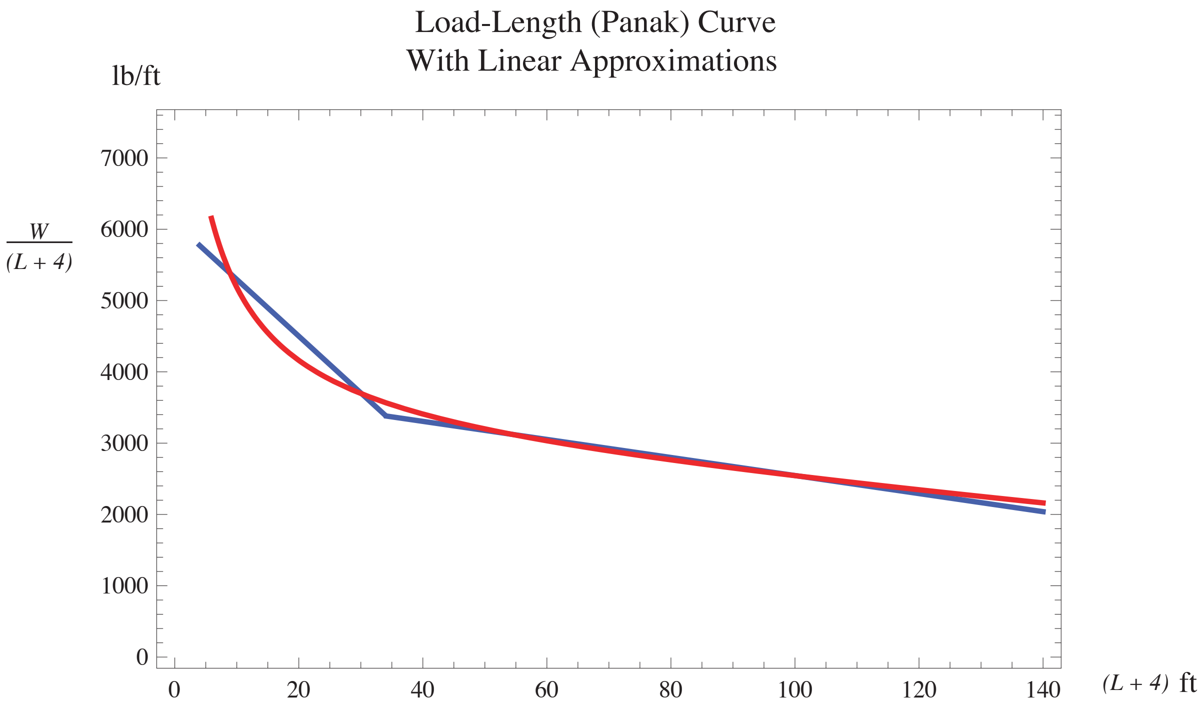


Figure 8.5. Load-Length Graph with Piecewise Linear Fits.

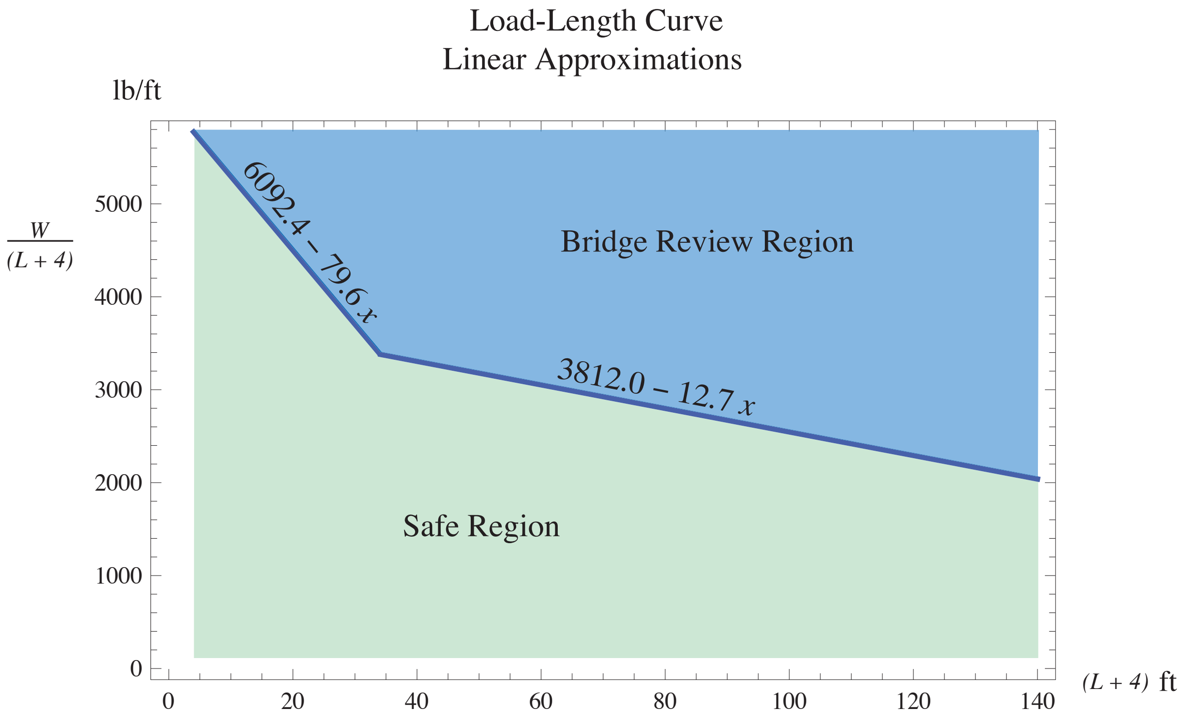


Figure 8.6. Suggested TxDOT Graphical Superheavy Load Criteria.

Specifically, if the axle and axle group restrictions of §28.11(d) are met, and using the tire and axle reduction factors for axle weights, then for each combination of L and W for a particular vehicle:

If a carrier has an (L + 4) in feet less than 34 ft, then W/(L + 4) in lb/ft should be less than 6092.4 − 79.6 x, where x = (L + 4) in feet.

If a carrier has an (L + 4) in feet equal to or greater than 34 ft, then W/(L + 4) in lb/ft should be less than 3812.0 − 12.7 x, where x = (L + 4) in feet.

If a carrier has an (L + 4) in feet greater than 140 ft, then W/(L + 4) in lb/ft should be 2000 lb/ft or less.

The 2000 lb/ft is the apparent upper limit of the TxDOT load-length curve. However there is a practical limit on load length due to horizontal curves and other factors.

8.5 OTHER RECOMMENDATIONS

The results from field measurements show that solid modeling works well for the evaluation of bridge performance. The model did not require a significant amount of calibration. Analysis with and without bridge rail (barrier) properties showed about a 5 percent difference on average. A solid model without the properties of the bridge rail is therefore a little more conservative. For other common bridge types that have composite decks, it is suggested that TxDOT use solid modeling without the field calibration step, if there is a need for such evaluations. It is also recommended that load frequency and load level data be collected (load level histogram) for a 2 or 3 year period from a bridge structure, similar to the study bridge used here, for use in evaluating the effects of stress variations on the fatigue life of Texas bridges.

8.6 SUMMARY AND CONCLUSIONS

The field-calibrated solid model and related parametric study show that the Texas superheavy load criteria are valid for this bridge type. The criteria along with a lateral load distribution that is much better than is assumed in design keep stress levels well below operating stress levels. Bridge ratings, using the distribution factors determined in the study, show that the bridge has much reserve capacity, even with short 230 kip and longer 311 kip superheavy loads applied. The parametric study shows that the criteria adequately protect this bridge type. Because the criteria are based on TxDOT's prior permitting, a graphical version of the criteria might serve TxDOT and carriers better than does the gross vehicle weight limits alone. Data collected long term of frequency and load level from a relevant bridge would help TxDOT determine what effects stress level variations have on the life of Texas bridges.

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APPENDIX 3.1

Revised New Hampshire “Superload Criteria,” (2009) State of New Hampshire, Department of Transportation, Bureau of Highway Maintenance Letter dated September 17, 2009 addressed to All Applicants for Overweight Permits.

THE STATE OF NEW HAMPSHIRE
DEPARTMENT OF TRANSPORTATION

GEORGE N. CAMPBELL, JR.
COMMISSIONER

JEFF BRILLHART, P.E.
ASSISTANT COMMISSIONER

Bureau of Highway Maintenance
September 17, 2009

To: All Applicants for Overweight Permits

Re: New Load / Axle Weight Restrictions
Effective Monday, November 2, 2009
Meeting and Discussion on Tuesday, September 29, 2009

Dear Permit Applicants:

As you may know, during the past year the New Hampshire Department of Transportation has been thoroughly reviewing all procedures, regulations, and rules that pertain to permits that allow overweight vehicles and loads to travel on New Hampshire's highways and bridges. The goal was to determine if current procedures were appropriate to protect the condition and safety of New Hampshire's roads and bridges with regards to overweight loads.

Part of this effort resulted in additional information being requested when applying for a permit to transport an overweight vehicle and load, specifically, individual axle loads, axle spacings, gross vehicle weight rating, gross combined weight rating, and various other equipment ratings. This again, was to ensure that the equipment being used to transport the overweight vehicle and load was adequate to safely complete the trip.

More recently, a review of the data from overweight permit applications determined that some combinations of equipment and loads were configured such that the resulting loads applied to the bridges and roadways could cause damage to these facilities. For this reason, the Department is revising the criteria by which a permit for transporting an overweight vehicle and load can be approved. The result is that a number of loads that previously would not have required, nor received, a bridge review will now require a bridge review prior to a permit being issued.

Criteria for specific loads and axle spacing combinations have been identified and will serve as limits for determining when a bridge review is required, as listed on the attachment. Whenever an application to transport an overweight vehicle and load is received, if it is above these limits, then a bridge review will be performed.

<u>These limits will go into effect on Monday, November 2, 2009</u>. It is recognized that many more bridge reviews will be required, in addition to those that currently undergo a bridge review. The Department also recognizes that timely reviews and responses to applications are critical to your business and operations. For this reason, additional staff has been retained to assist with this effort and to ensure that all bridge reviews will be processed in a timely manner.

That being said, the Applicant will not receive immediate approval for overweight vehicles and loads that exceed these limits. The requested information must be submitted, using current procedures, and if necessary, a bridge review will be performed. This overall process is estimated to take a minimum of 2+ hours to process, and we will endeavor to perform these reviews as quickly as possible. However, when considering the number of bridge reviews anticipated with these changes, and the complexity of some of the applications, there will be times when the bridge review cannot be completed within the ideal 2-hour time frame. Therefore, all Applicants should plan accordingly when preparing and submitting their applications.

It is recognized that these proposed changes will create some disruption in the issuance of permits for overweight vehicles and loads. However, the safety of the traveling public and the integrity of the transportation infrastructure are of critical importance. The Department is committed to working cooperatively with the trucking industry to assure that this change is implemented with minimal disruption to your activities.

The Department believes that permits will be issued for the vast majority of overweight vehicles and loads currently being submitted. However, we are very concerned with the potential damage being caused to our transportation infrastructure by the overweight vehicles and loads that currently exceed the new limits.

A meeting has been scheduled for Tuesday, September 29th, 2009 from 2:00 pm to 4:00 pm in Room 114 at the Department's offices at 7 Hazen Drive in Concord. At that time, we will discuss these changes, answer questions, and further explain the reasons that these new restrictions for permitting overweight vehicles and loads are necessary. You are invited to attend this discussion and exchange of information regarding the need for the proposed revisions.

If you have any questions, please contact Jim Gilbert, Oversize/Overweight Permit Supervisor, at (603)-271-6489.

Sincerely

(Signed)

Caleb B. Dobbins, PE
Highway Maintenance Engineer

cc: Commissioner John Barthelmes, NH Department of Safety
NHDOT Commissioner George N. Campbell, Jr., NH Department of Transportation
David J. Brillhart, Assistant Commissioner/Chief Engineer, NH Department of Transportation
Caleb Dobbins, State Maintenance Engineer, NHDOT
David Powelson, Chief, Existing Bridge Section, NHDOT

OS/OW Permit shall be submitted to Bridge Design for bridge review if:

Description of bridge review "trigger":
Any bridge on the proposed route has a load posting or weight restriction
Any axle spacing less than 4'-0"
Any single axle exceeds 27,500 pounds. (10'-0" or more to any adjacent axle)
Any axle of a tandem group exceeds 25,000 pounds. (see note 2)
Any axle of a tridem group exceeds 22,500 pounds. (see note 2)
Any axle of a quad group exceeds 20,000 pounds. (see note 2)
Any group of five axles. (see note 2)
Any 2-Axle Single Unit exceeds 55,000 pounds.
Any 3-Axle Single Unit exceeds 72,500 pounds.
Any 4-Axle Single Unit exceeds 90,000 pounds.
Any 5-Axle Single Unit exceeds 100,000 pounds.
Any Single Unit, with 6 or more axles, exceeds 110,000 pounds.
Any 3-Axle combination Unit exceeds 82,500 pounds.
Any 4-Axle combination Unit exceeds 95,000 pounds.
Any 5-Axle Combination Vehicle exceeds 108,000 pounds.
Any 6-Axle Combination Vehicle exceeds 120,000 pounds.
Any 7-Axle Combination Vehicle exceeds 130,000 pounds.
Any Combination Vehicle, with 8 or more axles, exceeds 149,999 pounds.

Note 1) RSA 266:18-c states that a vehicle or combination of vehicles shall not be driven or moved over any bridge or other structure on any way if the weight of such vehicle, or combination of vehicles and load, is greater than the capacity of the structure as shown by a sign on the right side of or overhead on the structure. It is assumed that the weight of the OS/OW permit vehicle will be in excess of the provisions of RSA 266:18-b, and therefore will exceed the posted capacity of the bridge.

Note 2) For purposes of this table, axles together are considered a group of axles (tandem, tridem, quad, etc.) when each individual axle space in the group is less than 10'-0".

Note 3) Speed of permit vehicle shall not exceed 20 miles per hour while crossing bridges (except for bridges on the interstate and turnpike system, or corridors designed to meet interstate standards...including NH101 from Manchester to Hampton, etc.).

APPENDIX 3.2

WTAMU Response Tables, Survey Instrument and Survey Responses

WTAMU Survey Result Tables, Survey Instrument and Survey Responses

Table 1 Superload Criteria and Permit

State	GVW (lbs)	Axle Weight (lbs)	Width	Height	Length	Basis for the criteria	Permit by other agencies
AL	180,000	22,000	16 ft	16 ft	150 ft	Bridge analyses over the year	Yes
AZ	250,000					Federal formula	Yes
HI	Max. 210,000 for bridge rate						
IA	Vehicles weighing over 156,000 lbs normally have 20,000 lbs axle weights	20,000			None	Federal formula	Yes
KS	150,000					State legislature	Yes
IN	200,000						Yes
MI	Based on vehicle configuration	60,000	16 ft	15 ft	150 ft	Route analysis	Yes
MA	130,000					State Regulations	No
MN	sees many overweight trucks of up to 13 axels and 256,000 lbs	20,000					Yes
MS	190,000						Yes
MO	160,000	22,400	16 ft	16 ft	150 ft	Limit in commercial zone	No
NV	250,000	60,000	17 ft in urban or 26ft in rural	19'	110ft urban or 150 ft in rural areas	Caltrans charts Administrative code	No
NM	250,000	Tandem: 46,000 Tridem: 60,000 Qua: 68,000	None	None	None	Engineering analysis, historical permit	No
NC	112,000 on 4 axle 120,000 on 6 axle 132,000 on 7 axle	Single: 25,000 Tandem: 50,000 Tridem: 60,000 Qua: 68,000	No limit	No limit	51ft from steer axle to rear axle	Operating stress level	Yes
OR	By published weight tables					Published weight tables	Yes
SD	No limit	No practical limit	Restricted by route	Restricted by route	None		Yes
VA	By chart	22,000	15 ft	15 ft	150 ft	Federal formula	Yes

Table 2 Bridge load rating method and analysis software

State	Bridge rating method	Software used for bridge rating	Software used for bridge analysis	Own policies in rating	Performed fatigue analysis
AL	ASR,LFR	BRASS BARS BRUFEM Virtis	BRASS-Girder BARS BRUFEM Virtis	Yes	No
AZ	LFR,LRFR	CONBOX CONSPAN GT STRUDL Virtis	CONBOX CONSPAN GT STRUDL Virtis	Yes	No
HI	LRFR				
IA	ASR,LFR	BARS LARS Virtis	BARS LARS Virtis	No	No
KS	LFR	BRASS-Girder Virtis	BRASS-Girder	Yes	No
IN	LFR,LRFR	BARS Virtis	BARS Virtis	No	No
MA	ASR	BRASS-CULVERT MDX STAAD Virtis	Virtis	No	No
MI	LFR,LRFR	Virtis	Virtis	Yes	No
MN	ASR,LFR,LRFR	CONBOX STADD MDX Virtis	Virtis	Yes	No
MS	ASR,LFR	BARS Virtis	BARS		
MO	ASR,LFR	BARS LARS Virtis	MoBARS LARS Virtis	No	No
NA	ASR,LFR,LRFR	BRASS-Girder MDX Sap 2000, WinBDS	Caltrans weight charts with bonus factors	Yes	No
NM	ASR,LFR	BRASS-Girder Virtis	OVLOAD (DOT own)	Yes	No
NC	ASR,LFR,LRFR	In-house software	In-house software	Yes	No
OR	LFR,LRFR	BRASS-Girder	BRASS-Girder	Yes	No
SD	ASR,LFR	BARS Virtis	BARS Virtis BridgeModeler	No	No
VA	ASR,LFR,LRFR	BARS CONSPAN DESUS Virtis	BARS DESCUS STAAD Virtis	No	No

Table 3 Evaluation of bridge after/before superload effect

State	Inspection for superload permit	Fatigue damage under superload
AL	Yes	No
AZ	No	
HI		
IA	No	No Difficult to verify if damage is caused by a superload
KS	No	No
IN	No	No
MA	Yes	No
MI	Yes	
MN	No	
MS		
MO	No	No
NA	No	No
NM	No	Had fatigue issues but not sure if it was caused by overweight vehicles
NC	No	No
OR	No	
SD	No	No
VA	No	No

Questionnaire: Superload Criteria for Bridges

West Texas A&M University is undertaking a research project in collaboration with Lamar University, TX to evaluate Superload criteria for bridges, specifically in Texas, under the authority of TxDOT (Project: 0-6438).

The number of permits for Superheavy loads crossing Texas bridges has steadily increased over the years, and compared with several other states, the criteria that establish Superheavy-load status is generous. The result is that many Texas bridges experience routine, high-stress loads that cause accelerated deterioration. In this project, bridge load and rating factors and the validity of the criteria for establishing Superheavy load status are evaluated. The purpose of the study is to validate that the Texas Superheavy load criteria and evaluation methodology adequately protects and preserves Texas bridges. Information concerning other state DOT criteria and evaluation methodologies for Superheavy load classification will be helpful to the researchers and to TxDOT.

We appreciate your responding to the following questionnaire and please return the questionnaire by email or fax, or mail by February 22, 2010: to:

Dr. Byungik Chang, Ph.D.
WTAMU Box 60767
Canyon, TX 79016
806-651-2507
806-651-5259 (fax)
bchang@wtamu.edu

Date	
State	
Organization and Division	
Name	
Position	
Email	
Fax	
Phone	

Please fill out the following questionnaire to the best of your ability. If additional space is required to adequately answer the question, please attach the information to the survey. You can double-click on the box ☐ and select the ‘Checked’☒ in appropriate boxes. If manuals are available that identify Superload criteria please attach them to this survey. If you are not sure of any question, you may leave them unanswered.

<u>Superload Permit Process and Procedures</u>

Please identify the classifications of your state issued Superload permit/permits and the criteria or provide a copy of the permit practice manual that include this information. Please identify and list each criteria checked below. Attach more sheets as required.

1.

<u>PLEASE LIST SPECIFIC VALUES FOR EACH ITEM CHECKED BELOW</u>

Minimum Limit Maximum Limit

☐ Gross vehicle weight (GVW)

☐ Axle weight

☐ Weight per inch of tire width (Steering axle)

☐ Weight per inch of tire width (Drive axle)

☐ Overall Width

☐ Overall Height

☐ Overall Length

☐ Others

2. How did your department identify criteria for superloads identified in problem 1 (what was the reasoning behind this limit? and how was the criteria established?). Additionally please specify the basis for limits on multi-axle groups.

3. What is the basis for load intensity or load-and-vehicle-length-combination limit for Superload vehicles?

4. Do agencies other than the state DOT issue Superload permits (such as local municipalities)?

☐ Yes

☐ No

Load Rating Procedures for State Bridges and Bridge evaluations

5. Has the DOT performed any kind of analysis for fatigue effects on bridges due to Superloads?

☐ Yes

☐ No

If yes, please List/Link materials associated with the above question (reports, journals, etc.).

6. What type of modeling software does your department or Agency use to analyze a bridge under Superloads (please specify which software is used)?

☐ Finite-element analysis. Specify software

☐ Grillage method. Specify software

☐ Girder line analysis. Specify software

☐ Other (specify method and software)

☐ None

7. What type of Bridge Load rating is used in your department (check all that apply)

☐ ASR

☐ LFR

☐ LRFR

☐ Other Please Specify in detail:

If more than one is used please specify which is the formula used most frequently.

8. What software do you use for bridge rating? (Check all that apply)

☐ None

☐ BRASS -Girder

☐ BARS

☐ Virtis

☐ Other (specify):

If more than one is checked, please identify the most frequently used software.

11. Do you restrict permit vehicles regarding their traveling behaviors?
☐ Position on Bridge
☐ Speed
☐ Exclusion of other vehicles on bridge
☐ Acceleration/deceleration on bridge
☐ Other (Please Specify):

12. Does your department evaluate bridges under Superload effects (i.e bridge analysis, Superload permits) in-house?
☐ Yes
☐ No

13. Do you have your (DOT) own specifications/guidelines/policies for considering bridge conditions in rating?
☐ Yes
☐ No
If Yes, please give the title of the document or provide a copy of the document if it is state specific or link access it.

Evaluations of bridges after Superload effects

14. Does your department inspect the bridge/bridges under review for pre-existing damage before the Superload permit is accepted?
☐ Yes
☐ No
If yes, please describe how the preexisting damage effected your evaluation of the bridge.

15. Was any fatigue (or damage) suffered with bridges under Superloads?
☐ Yes
☐ No
If yes, please specify what damage occurred (please specify critical location and mode of failure).

16. Was the Superload (mentioned above in question #15) permitted in your department?
☐ Yes
☐ No
If yes, could you please list data involved in the permit (e.g. GVW, dimensions, axle configuration) or provide the inventory data (Frequency/year and increasing rate, and so on).

If you have any further comments/questions relevant to this questionnaire, please list them below.

B1. Alabama

Date	2/09/2010
State	Alabama
Organization and Division	Alabama Department of Transportation
Name	Eric Christie
Position	Assistant State Maintenance Engineer - Bridges
Email	christiee@dot.state.al.us
Fax	(334) 242-6378
Phone	(334) 242-6281

Superload Permit Process and Procedures

Please identify the classifications of your state issued Superload permit/permits and the criteria or provide a copy of the permit practice manual that include this information. Please identify and list each criteria checked below. Attach more sheets as required.

1.

PLEASE LIST SPECIFIC VALUES FOR EACH ITEM CHECKED BELOW

	Minimum Limit	Maximum Limit
☒ Gross vehicle weight (GVW)		22,000 lbs
☒ Axle weight		
☐ Weight per inch of tire width (Steering axle)		
☐ Weight per inch of tire width (Drive axle)		
☒ Overall Width	16 feet	
☒ Overall Height	16 feet	
☒ Overall Length	150 feet	
☐ Others		

2. How did your department identify criteria for superloads identified in problem 1 (what was the reasoning behind this limit? and how was the criteria established?). Additionally please specify the basis for limits on multi-axle groups.

Gross vehicle weight is based on bridge analyses performed over the years.
Axle weight is based on state law.
Width, Height, and Length were established based on roadway characteristics in Alabama.

3. What is the basis for load intensity or load-and-vehicle-length-combination limit for Superload vehicles?

none

4. Do agencies other than the state DOT issue Superload permits (such as local municipalities)?

☒ Yes
☐ No

Load Rating Procedures for State Bridges and Bridge evaluations

5. Has the DOT performed any kind of analysis for fatigue effects on bridges due to Superloads?
☐ Yes
☒ No
If yes, please List/Link materials associated with the above question (reports, journals, etc.).

6. What type of modeling software does your department or Agency use to analyze a bridge under Superloads (please specify which software is used)?

☒ Finite-element analysis. Specify software	BRUFEM, Virtis (non-standard gage)
☐ Grillage method. Specify software	
☒ Girder line analysis. Specify software	Virtis, BRASS, BARS
☐ Other (specify method and software)	
☐ None	

7. What type of Bridge Load rating is used in your department (check all that apply)
☒ ASR
☒ LFR
☐ LRFR
☐ Other Please Specify in detail:
If more than one is used please specify which is the formula used most frequently.

8. What software do you use for bridge rating? (Check all that apply)
☐ None
☒ BRASS -Girder
☒ BARS
☒ Virtis
☒ Other (specify): BRUFEM
If more than one is checked, please identify the most frequently used software.

11. Do you restrict permit vehicles regarding their traveling behaviors?
☒ Position on Bridge
☒ Speed
☒ Exclusion of other vehicles on bridge
☒ Acceleration/deceleration on bridge
☐ Other (Please Specify):

12. Does your department evaluate bridges under Superload effects (i.e bridge analysis, Superload permits) in-house?
☒ Yes
☐ No

13. Do you have your (DOT) own specifications/guidelines/policies for considering bridge conditions in rating?
☒ Yes
☐ No

If Yes, please give the title of the document or provide a copy of the document if it is state specific or link access it.

Evaluations of bridges after Superload effects

14. Does your department inspect the bridge/bridges under review for pre-existing damage before the Superload permit is accepted?
☒ Yes (Sometimes)
☐ No
If yes, please describe how the preexisting damage effected your evaluation of the bridge.
If damage was present, it would be included in the rating analysis.

15. Was any fatigue (or damage) suffered with bridges under Superloads?
☐ Yes
☐ No
If yes, please specify what damage occurred (please specify critical location and mode of failure). ______

16. Was the Superload (mentioned above in question #15) permitted in your department?
☐ Yes
☐ No
If yes, could you please list data involved in the permit (e.g. GVW, dimensions, axle configuration) or provide the inventory data (Frequency/year and increasing rate, and so on).

If you have any further comments/questions relevant to this questionnaire, please list them below.

B2. Arizona

Date	2-9-10
State	Arizona
Organization and Division	Dept. of Transportation, Bridge Group, Bridge Technical Section
Name	Amin Islam
Position	Bridge Technical Section Leader
Email	mislam@azdot.gov
Fax	(602)712-3056
Phone	(602)712-8621

Superload Permit Process and Procedures

Please identify the classifications of your state issued Superload permit/permits and the criteria or provide a copy of the permit practice manual that include this information. Please identify and list each criteria checked below. Attach more sheets as required.

1.

PLEASE LIST SPECIFIC VALUES FOR EACH ITEM CHECKED BELOW

	Minimum Limit	Maximum Limit
☐ Gross vehicle weight (GVW)		
☐ Axle weight		
☐ Weight per inch of tire width (Steering axle)		
☐ Weight per inch of tire width (Drive axle)		
☐ Overall Width		
☐ Overall Height		
☐ Overall Length		
☒ Others	Please see below	Please see below

**

1. If the weight of any vehicle is 80,000 lbs or less and also comply with the Federal Bridge Gross Weight Formula (which is $W = 500\ (LN/(N-1) + 12N + 36)$), then no permit is needed unless it travels on a restricted bridge.
2. If the weight of any vehicle is more than 80,000 lbs or does not comply with the Federal Bridge Gross Weight Formula (which is $W = 500\ (LN/(N-1) + 12N + 36)$), then the weight is checked against Arizona Administrative Code Formula weight ($1.5 \times 700\ (L + 40)$) which is shown in the Charts for axle width and number of tires and Class A permit is issued if it is satisfied.
3. For any vehicle weighing more than 250,000 lbs or does not comply with Arizona Administrative Code Formula weight (which is shown in the Charts for axle width and number of tires) shall apply for class C permit and comes to the Bridge Group for analysis.

2. How did your department identify criteria for superloads identified in problem 1 (what was the reasoning behind this limit? and how was the criteria established?). Additionally please specify the basis for limits on multi-axle groups.

** Please see question no. 1

3. What is the basis for load intensity or load-and-vehicle-length-combination limit for Superload vehicle?

** Please see question no. 1

4. Do agencies other than the state DOT issue Superload permits (such as local municipalities)?

☒ Yes
☐ No

Load Rating Procedures for State Bridges and Bridge evaluations

5. Has the DOT performed any kind of analysis for fatigue effects on bridges due to Superloads

☐ Yes
☒ No

IF yes , please List/Link materials associated with the above question (reports/journals).

6. What type of modeling software does your department or Agency use to analyze a bridge under Superloads (please specify which software is used)?

☒ Finite-element analysis. Specify software CONBOX, CONSPAN, GT STRUDL
☒ Grillage method. Specify software VIRTIS
☒ Girder line analysis. Specify software VIRTIS
☒ Other (specify method and software) VIRTIS
☐ None

7. What type of Bridge Load rating is used in your department (check all that apply)

☐ ASR
☒ LFR
☒ LRFR
☐ Other Please Specify in detail:

IF more than one is used please specify which is the formula used most frequently.

8. What software do you use for bridge rating? (Check all that apply)

☐ None
☐ BRASS -Girder
☐ BARS
☒ Virtis
☒ Other (specify): CONBOX, CONSPAN, GT STRUDL

IF more than one is checked, Please identify the most frequently used software.

11. Do you restrict permit vehicles regarding their traveling behaviors?

☒ Position on Bridge
☒ Speed
☒ Exclusion of other vehicles on bridge
☒ Acceleration/deceleration on bridge
☐ Other (Please Specify):

12. Does your department evaluate bridges under Superload effects (i.e bridge analysis, Superload permits) in-house?

☒ Yes
☐ No

13. Do you have your (DOT) own specifications/guidelines/policies for considering bridge conditions in rating?
☐ Yes
☒ No
IF Yes, please give the title of the document or provide a copy of the document if it is state specific or link access it.

<u>Evaluations of bridges after Superload effects</u>

14. Does your department inspect the bridge/bridges under review for pre-existing damage before the Superload permit is accepted?
☐ Yes
☒ No
IF yes, please describe how the preexisting damage effected your evaluation of the bridge.

15. Was any fatigue (or damage) suffered with bridges under Superloads?
☐ Yes
☐ No
IF yes, please specify what damage occurred (please specify critical location and mode of

16. Was the Superload (mentioned above in question #15 permitted in your department?
☐ Yes
☐ No
IF yes, could you please list data involved in the permit (e.g. GVW, dimensions, axle configuration) or provide the inventory data (Frequency/year and increasing rate, and so on).

If you have any further comments/questions relevant to this questionnaire, please list them below.

B3. Hawaii

Paul Santo, P.E.
Bridge Design Engineer
Hawaii DOT, Bridge Design Section
601 Kamokila Blvd., Room 611
Kapolei, HI 96707
Phone: (808) 692-7611
Fax: (808) 692-7617
Email: paul.santo@hawaii.gov

First of all, we now load rate our bridges in accordance with our "Implementation Guidelines for Load and Resistance Factor Rating (LRFR) of Highway Bridges" based on the AASHTO Manual for Bridge Evaluation. In our guidelines, we rate our bridges for some "standard" single trip permit trucks with the maximum weighing about 210 kips. If the bridge in question has already been load rated with our current guidelines and the truck weight and configuration is close to the rated truck, no further analysis is performed and a decision is made based on the existing ratings. If the truck exceeds the highest weight truck already rated with rating greater than 1.0, we would analyze the bridge for this special truck. We would also perform the analysis for a bridge that has not been load rated to our current guidelines. Generally each route for permit trucks have specific bridge(s) that control whether a permit is approved or not so analysis, if any, would usually be on a limited number of bridges.

B4. Indiana

Date	2/10/2010
State	Indiana
Organization and Division	Structural Services Section, INDOT
Name	George Snyder
Position	Bridge Rehab & Load Rating Engineer
Email	gsnyder@indot.in.gov
Fax	317-233-4929
Phone	317-232-5163

Superload Permit Process and Procedures

Please identify the classifications of your state issued Superload permit/permits and the criteria or provide a copy of the permit practice manual that include this information. Please identify and list each criteria checked below. Attach more sheets as required.

1.

PLEASE LIST SPECIFIC VALUES FOR EACH ITEM CHECKED BELOW

Please see the attached Permit Manual for items 1,2 3

	Minimum Limit	Maximum Limit
☐ Gross vehicle weight (GVW)		
☐ Axle weight		
☐ Weight per inch of tire width (Steering axle)		
☐ Weight per inch of tire width (Drive axle)		
☐ Overall Width		
☐ Overall Height		
☐ Overall Length		
☐ Others		

2. How did your department identify criteria for superloads identified in problem 1 (what was the reasoning behind this limit? and how was the criteria established?). Additionally please specify the basis for limits on multi-axle groups.

3. What is the basis for load intensity or load-and-vehicle-length-combination limit for Superload vehicle?

4. Do agencies other than the state DOT issue Superload permits (such as local municipalities)?

☒ Yes
☐ No

Load Rating Procedures for State Bridges and Bridge evaluations

5. Has the DOT performed any kind of analysis for fatigue effects on bridges due to Superloads

☐ Yes

☒ No

IF yes , please List/Link materials associated with the above question (reports/journals).

6. What type of modeling software does your department or Agency use to analyze a bridge under Superloads (please specify which software is used)?

☐ Finite-element analysis. Specify software
☐ Grillage method. Specify software
☒ Girder line analysis. Specify software Virtis
☒ Other (specify method and software) BARS
☐ None

7. What type of Bridge Load rating is used in your department (check all that apply)

☐ ASR
☒ LFR
☒ LRFR
☐ Other Please Specify in detail:

IF more than one is used please specify which is the formula used most frequently. LRFR

8. What software do you use for bridge rating? (Check all that apply)

☐ None
☐ BRASS -Girder
☒ BARS
☒ Virtis
☐ Other (specify):

IF more than one is checked, Please identify the most frequently used software.

11. Do you restrict permit vehicles regarding their traveling behaviors?

☒ Position on Bridge
☒ Speed
☒ Exclusion of other vehicles on bridge
☒ Acceleration/deceleration on bridge
☒ Other (Please Specify): "Crabbing" the main trailer to distribute load to two or more lanes

12. Does your department evaluate bridges under Superload effects (i.e bridge analysis, Superload permits) in-house?

☒ Yes
☐ No

13. Do you have your (DOT) own specifications/guidelines/policies for considering bridge conditions in rating?

☐ Yes
☒ No

IF Yes, please give the title of the document or provide a copy of the document if it is state specific or link access it.

Evaluations of bridges after Superload effects

14. Does your department inspect the bridge/bridges under review for pre-existing damage before the Superload permit is accepted?

☐ Yes
☒ No
IF yes, please describe how the preexisting damage effected your evaluation of the bridge.

15. Was any fatigue (or damage) suffered with bridges under Superloads?
☐ Yes
☒ No
IF yes, please specify what damage occurred (please specify critical location and mode of failure.). ____________________

16. Was the Superload (mentioned above in question #15 permitted in your department?
☐ Yes
☐ No
IF yes, could you please list data involved in the permit (e.g. GVW, dimensions, axle configuration) or provide the inventory data (Frequency/year and increasing rate, and so on).

If you have any further comments/questions relevant to this questionnaire, please list them below.

B5. Iowa

Date	February 15, 2010
State	Iowa
Organization and Division	Iowa DOT Office of Bridges and Structures
Name	Scott Neubauer
Position	Bridge Rating Engineer
Email	scott.neubauer@dot.iowa.gov
Fax	515-239-1978
Phone	515-239-1290

Superload Permit Process and Procedures

Please identify the classifications of your state issued Superload permit/permits and the criteria or provide a copy of the permit practice manual that include this information. Please identify and list each criteria checked below. Attach more sheets as required.

1.

PLEASE LIST SPECIFIC VALUES FOR EACH ITEM CHECKED BELOW

	Minimum Limit	Maximum Limit
☐ Gross vehicle weight (GVW)	See Attached Iowa Truck Information Guide	
☐ Axle weight		
☐ Weight per inch of tire width (Steering axle)		
☐ Weight per inch of tire width (Drive axle)		
☐ Overall Width		
☐ Overall Height		
☐ Overall Length		
☐ Others		

2. How did your department identify criteria for superloads identified in problem 1 (what was the reasoning behind this limit? and how was the criteria established?). Additionally please specify the basis for limits on multi-axle groups.

Iowa does not have a Superload designation that it applies to trucks over a given dimension or size. The Federal bridge formula is used to limit axle weights on the Interstate and Primary highways and a modified formula is used for Secondary highways. The modified formula was developed to limit the number of bridges that would require posting after the change in Federal law in 1974 allowing 80,000 pound Legal truck loads.

The maximum gross axle weight for permitted loads is 20,000 pounds. Special construction equipment, self-propelled cranes, and implements of husbandry have higher axle load limits. These guidelines are shown in the attached pamphlet.

3. What is the basis for load intensity or load-and-vehicle-length-combination limit for Superload vehicle?

The 20,000 pound axle load limit is the only weight criteria. There are no length criteria. The only other criteria to be met is that the load must be indivisible.

4. Do agencies other than the state DOT issue Superload permits (such as local municipalities)?
☒ Yes
☐ No

Load Rating Procedures for State Bridges and Bridge evaluations

5. Has the DOT performed any kind of analysis for fatigue effects on bridges due to Superloads
☐ Yes
☒ No
IF yes , please List/Link materials associated with the above question (reports/journals).

6. What type of modeling software does your department or Agency use to analyze a bridge under Superloads (please specify which software is used)?
☐ Finite-element analysis. Specify software
☐ Grillage method. Specify software
☒ Girder line analysis. Specify software LARS and VIRTIS
☐ Other (specify method and software)
☐ None

7. What type of Bridge Load rating is used in your department (check all that apply)
☒ ASR
☒ LFR
☐ LRFR
☐ Other Please Specify in detail:
IF more than one is used please specify which is the formula used most frequently.
LFR is used most often.

8. What software do you use for bridge rating? (Check all that apply)
☐ None
☐ BRASS -Girder
☐ BARS
☒ Virtis
☒ Other (specify): LARS, the revised version of BARS
IF more than one is checked, Please identify the most frequently used software.
LARS is used most often.

11. Do you restrict permit vehicles regarding their traveling behaviors?

☒ Position on Bridge	Centerline when crossing bridge
☒ Speed	Cross non-interstate bridges at 5 mph
☐ Exclusion of other vehicles on bridge	
☐ Acceleration/deceleration on bridge	
☐ Other (Please Specify):	

12. Does your department evaluate bridges under Superload effects (i.e bridge analysis, Superload permits) in-house?
☒ Yes
☐ No

13. Do you have your (DOT) own specifications/guidelines/policies for considering bridge conditions in rating?
☐ Yes
☒ No
IF Yes, please give the title of the document or provide a copy of the document if it is state specific or link access it.

Evaluations of bridges after Superload effects

14. Does your department inspect the bridge/bridges under review for pre-existing damage before the Superload permit is accepted?
☐ Yes
☒ No Rely on last NBI inspection documentation.
IF yes, please describe how the preexisting damage effected your evaluation of the bridge.

15. Was any fatigue (or damage) suffered with bridges under Superloads?
☐ Yes
☒ No It is too difficult to verify if damage was caused by a Superload.
IF yes, please specify what damage occurred (please specify critical location and mode of failure.). ____

16. Was the Superload (mentioned above in question #15 permitted in your department?
☐ Yes
☐ No
IF yes, could you please list data involved in the permit (e.g. GVW, dimensions, axle configuration) or provide the inventory data (Frequency/year and increasing rate, and so on).

If you have any further comments/questions relevant to this questionnaire, please list them below.
Your survey seems to assume Superloads are not common. In Iowa, we issue 50 to 100 permits for vehicles weighing over 156,000 pounds each day. These vehicles normally have axle weights of 20,000 pounds.

B6. Kansas

Date	Feb. 11, 2010
State	Kansas
Organization and Division	Bureau of Design – Bridge Management
Name	John Culbertson
Position	Bridge Evaluation Engineer
Email	johnc@ksdot.org
Fax	(785) 296-8870
Phone	(785) 296-4434

Superload Permit Process and Procedures

Please identify the classifications of your state issued Superload permit/permits and the criteria or provide a copy of the permit practice manual that include this information. Please identify and list each criteria checked below. Attach more sheets as required.

1.

PLEASE LIST SPECIFIC VALUES FOR EACH ITEM CHECKED BELOW

	Minimum Limit	Maximum Limit
☒ Gross vehicle weight (GVW)	150,000 lb	
☒ Axle weight	Pg. 30 in “Truckin’ Through Kansas” Handbook	
☐ Weight per inch of tire width (Steering axle)		
☐ Weight per inch of tire width (Drive axle)		
☐ Overall Width		
☐ Overall Height		
☐ Overall Length		
☒ Others	Pg. 31 in “Truckin’ Through Kansas” Handbook	

2. How did your department identify criteria for superloads identified in problem 1 (what was the reasoning behind this limit? and how was the criteria established?). Additionally please specify the basis for limits on multi-axle groups.

Set in Statute by State Legislature.

3. What is the basis for load intensity or load-and-vehicle-length-combination limit for Superload vehicle?

4. Do agencies other than the state DOT issue Superload permits (such as local municipalities)?

☒ Yes
☐ No

Only on local, non-state routes.

Load Rating Procedures for State Bridges and Bridge evaluations

5. Has the DOT performed any kind of analysis for fatigue effects on bridges due to Superloads
☐ Yes
☒ No
IF yes , please List/Link materials associated with the above question (reports/journals).

6. What type of modeling software does your department or Agency use to analyze a bridge under Superloads (please specify which software is used)?
☐ Finite-element analysis. Specify software
☐ Grillage method. Specify software
☒ Girder line analysis. Specify software BRASS Girder
☐ Other (specify method and software)
☐ None

7. What type of Bridge Load rating is used in your department (check all that apply)
☐ ASR
☒ LFR
☐ LRFR
☐ Other Please Specify in detail:
IF more than one is used please specify which is the formula used most frequently.

8. What software do you use for bridge rating? (Check all that apply)
☐ None
☒ BRASS -Girder
☐ BARS
☒ Virtis
☐ Other (specify):
IF more than one is checked, Please identify the most frequently used software.
BRASS Girder

11. Do you restrict permit vehicles regarding their traveling behaviors?
☒ Position on Bridge
☒ Speed
☒ Exclusion of other vehicles on bridge
☒ Acceleration/deceleration on bridge
☐ Other (Please Specify):

12. Does your department evaluate bridges under Superload effects (i.e bridge analysis, Superload permits) in-house?
☒ Yes
☐ No

13. Do you have your (DOT) own specifications/guidelines/policies for considering bridge conditions in rating?
☒ Yes
☐ No
IF Yes, please give the title of the document or provide a copy of the document if it is state specific or link access it. KDOT Bridge Design Manual

Evaluations of bridges after Superload effects

14. Does your department inspect the bridge/bridges under review for pre-existing damage before the Superload permit is accepted?
☐ Yes
☒ No
IF yes, please describe how the preexisting damage effected your evaluation of the bridge.

15. Was any fatigue (or damage) suffered with bridges under Superloads?
☐ Yes
☒ No
IF yes, please specify what damage occurred (please specify critical location and mode of failure.). ______________________________

16. Was the Superload (mentioned above in question #15 permitted in your department?
☐ Yes
☐ No
IF yes, could you please list data involved in the permit (e.g. GVW, dimensions, axle configuration) or provide the inventory data (Frequency/year and increasing rate, and so on).

If you have any further comments/questions relevant to this questionnaire, please list them below.

B7. Massachusetts

Date	2/22/2010
State	Massachusetts
Organization and Division	Department of Transportation – Highway Division – Bridge Section
Name	Michael Taylor
Position	Assistant Ratings Engineer
Email	Michael.Taylor@state.ma.us
Fax	617-973-7575
Phone	617-973-7771

Superload Permit Process and Procedures

Please identify the classifications of your state issued Superload permit/permits and the criteria or provide a copy of the permit practice manual that include this information. Please identify and list each criteria checked below. Attach more sheets as required.

1.

PLEASE LIST SPECIFIC VALUES FOR EACH ITEM CHECKED BELOW

	Minimum Limit	Maximum Limit
☒ Gross vehicle weight (GVW)	130,000	
☐ Axle weight		
☐ Weight per inch of tire width (Steering axle)		
☐ Weight per inch of tire width (Drive axle)		
☐ Overall Width		
☐ Overall Height		
☐ Overall Length		
☐ Others		

2. How did your department identify criteria for superloads identified in problem 1 (what was the reasoning behind this limit? and how was the criteria established?). Additionally please specify the basis for limits on multi-axle groups.

State Regulations

3. What is the basis for load intensity or load-and-vehicle-length-combination limit for Superload vehicle?

4. Do agencies other than the state DOT issue Superload permits (such as local municipalities)?

☐ Yes

☒ No

Load Rating Procedures for State Bridges and Bridge evaluations

5. Has the DOT performed any kind of analysis for fatigue effects on bridges due to Superloads
☐ Yes
☒ No
IF yes , please List/Link materials associated with the above question (reports/journals).

6. What type of modeling software does your department or Agency use to analyze a bridge under Superloads (please specify which software is used)?
☐ Finite-element analysis. Specify software
☐ Grillage method. Specify software
☒ Girder line analysis. Specify software Virtis
☐ Other (specify method and software)
☐ None

7. What type of Bridge Load rating is used in your department (check all that apply)
☒ ASR
☐ LFR
☐ LRFR
☐ Other Please Specify in detail:
IF more than one is used please specify which is the formula used most frequently.

8. What software do you use for bridge rating? (Check all that apply)
☐ None
☐ BRASS -Girder
☐ BARS
☒ Virtis Most frequent
☒ Other (specify): STAAD, MDX, BRASS-CULVERT
IF more than one is checked, Please identify the most frequently used software.

11. Do you restrict permit vehicles regarding their traveling behaviors?
☒ Position on Bridge
☒ Speed
☒ Exclusion of other vehicles on bridge
☐ Acceleration/deceleration on bridge
☐ Other (Please Specify):

12. Does your department evaluate bridges under Superload effects (i.e bridge analysis, Superload permits) in-house?
☒ Yes
☐ No

13. Do you have your (DOT) own specifications/guidelines/policies for considering bridge conditions in rating?
☐ Yes

☒ No

IF Yes, please give the title of the document or provide a copy of the document if it is state specific or link access it.

Evaluations of bridges after Superload effects

14. Does your department inspect the bridge/bridges under review for pre-existing damage before the Superload permit is accepted?

☒ Yes
☐ No

IF yes, please describe how the preexisting damage effected your evaluation of the bridge.
Bridges are inspected per NBIS requirements

15. Was any fatigue (or damage) suffered with bridges under Superloads?

☐ Yes
☒ No

IF yes, please specify what damage occurred (please specify critical location and mode of failure.). ______

16. Was the Superload (mentioned above in question #15 permitted in your department?

☐ Yes
☐ No

IF yes, could you please list data involved in the permit (e.g. GVW, dimensions, axle configuration) or provide the inventory data (Frequency/year and increasing rate, and so on).

If you have any further comments/questions relevant to this questionnaire, please list them below.

B8. Michigan

Date	2/9/10
State	Michigan
Organization and Division	Department of Transportation, Bridge Operations Unit
Name	Rebecca Curtis
Position	Load Rating Engineer
Email	curtisre@michigan.gov
Fax	517-322-5664
Phone	517-322-1186

Superload Permit Process and Procedures

Please identify the classifications of your state issued Superload permit/permits and the criteria or provide a copy of the permit practice manual that include this information. Please identify and list each criteria checked below. Attach more sheets as required.

1.

PLEASE LIST SPECIFIC VALUES FOR EACH ITEM CHECKED BELOW

	Minimum Limit	Maximum Limit
☒ Gross vehicle weight (GVW)		Varies based on vehicle configuration
☒ Axle weight		60-kip
☒ Weight per inch of tire width (Steering axle)		700lb/in
☒ Weight per inch of tire width (Drive axle)		700 lb/in
☒Overall Width	16 feet	none
☒ Overall Height	15 feet	none
☒Overall Length	150 feet	none
☐ Others		

2. How did your department identify criteria for superloads identified in problem 1 (what was the reasoning behind this limit? and how was the criteria established?). Additionally please specify the basis for limits on multi-axle groups.

There is no specific criteria for multi-axle groups, superloads are checked on a vehicle-structure-route specific analysis. Please refer to Chapter 8 of our Bridge Analysis Guide for more information http://www.michigan.gov/mdot/0,1607,7-151-9625_24768_24773-132786--,00.html

3. What is the basis for load intensity or load-and-vehicle-length-combination limit for Superload vehicle?

Superloads are checked on a vehicle-structure-route specific analysis.

4. Do agencies other than the state DOT issue Superload permits (such as local municipalities)?

☒ Yes

☐No

Local Agencies are responsible for their own superload analyses and permits.

Load Rating Procedures for State Bridges and Bridge evaluations

5. Has the DOT performed any kind of analysis for fatigue effects on bridges due to Superloads
☐ Yes
☒ No
IF yes , please List/Link materials associated with the above question (reports/journals).

6. What type of modeling software does your department or Agency use to analyze a bridge under Superloads (please specify which software is used)?
☐ Finite-element analysis. Specify software
☒ Grillage method. Specify software AASHTOWare Virtis
☒ Girder line analysis. Specify software AASHTOWare Virtis
☐ Other (specify method and software)
☐ None

7. What type of Bridge Load rating is used in your department (check all that apply)
☐ ASR
☒ LFR
☒ LRFR
☐ Other Please Specify in detail:
IF more than one is used please specify which is the formula used most frequently.

8. What software do you use for bridge rating? (Check all that apply)
☐ None
☐ BRASS -Girder
☐ BARS
☒ Virtis
☐ Other (specify):
IF more than one is checked, Please identify the most frequently used software.

11. Do you restrict permit vehicles regarding their traveling behaviors?
☒ Position on Bridge
☒ Speed
☒ Exclusion of other vehicles on bridge
☐ Acceleration/deceleration on bridge
☐ Other (Please Specify):

12. Does your department evaluate bridges under Superload effects (i.e bridge analysis, Superload permits) in-house?
☒ Yes
☐ No

13. Do you have your (DOT) own specifications/guidelines/policies for considering bridge conditions in rating?
☒ Yes
☐ No
IF Yes, please give the title of the document or provide a copy of the document if it is state specific or link access it. http://www.michigan.gov/mdot/0,1607,7-151-9625_24768_24773-132786--,00.html

Evaluations of bridges after Superload effects

14. Does your department inspect the bridge/bridges under review for pre-existing damage before the Superload permit is accepted?
☒ Yes The bridge safety inspection report is reviewed before approving superloads.
☐ No
IF yes, please describe how the preexisting damage effected your evaluation of the bridge.

15. Was any fatigue (or damage) suffered with bridges under Superloads?
☐ Yes
☐ No
IF yes, please specify what damage occurred (please specify critical location and mode of failure.). I have no information regarding this question.

16. Was the Superload (mentioned above in question #15 permitted in your department?
☐ Yes
☐ No
IF yes, could you please list data involved in the permit (e.g. GVW, dimensions, axle configuration) or provide the inventory data (Frequency/year and increasing rate, and so on).

If you have any further comments/questions relevant to this questionnaire, please list them below.

B9. Minnesota

Date	February 9, 2010
State	Minnesota
Organization and Division	MnDOT, Bridge Office
Name	Lowell Johnson
Position	Bridge Rating Engineer
Email	Lowell.johnson@state.mn.us
Fax	
Phone	651 366 4552

<u>Superload Permit Process and Procedures</u>

Please identify the classifications of your state issued Superload permit/permits and the criteria or provide a copy of the permit practice manual that include this information. Please identify and list each criteria checked below. Attach more sheets as required.

1.

PLEASE LIST SPECIFIC VALUES FOR EACH ITEM CHECKED BELOW

	Minimum Limit	Maximum Limit
☐ Gross vehicle weight (GVW)		
☐ Axle weight	20000lb	23000 lb
☐ Weight per inch of tire width (Steering axle)	600	600
☐ Weight per inch of tire width (Drive axle)	600	600
☐ Overall Width		
☐ Overall Height		
☐ Overall Length		
☐ Others		

2. How did your department identify criteria for superloads identified in problem 1 (what was the reasoning behind this limit? and how was the criteria established?). Additionally please specify the basis for limits on multi-axle groups.

3. What is the basis for load intensity or load-and-vehicle-length-combination limit for Superload vehicle?

4. Do agencies other than the state DOT issue Superload permits (such as local municipalities)?

☒ Yes
☐No

All local agencies are responsible for their own regulations and permitting.

Load Rating Procedures for State Bridges and Bridge evaluations

5. Has the DOT performed any kind of analysis for fatigue effects on bridges due to Superloads
☐ Yes
☒ No
IF yes , please List/Link materials associated with the above question (reports/journals).

6. What type of modeling software does your department or Agency use to analyze a bridge under Superloads (please specify which software is used)?
☒ Finite-element analysis. Specify software Virtis
☐ Grillage method. Specify software
☐ Girder line analysis. Specify software
☐ Other (specify method and software)
☐ None

7. What type of Bridge Load rating is used in your department (check all that apply)
☒ ASR
☒ LFR
☒ LRFR
☐ Other Please Specify in detail:
IF more than one is used please specify which is the formula used most frequently. LFR

8. What software do you use for bridge rating? (Check all that apply)
☐ None
☐ BRASS -Girder
☐ BARS
☒ Virtis
☒ Other (specify): STADD MDX, CONBOX
IF more than one is checked, Please identify the most frequently used software.
Virtis most frequently

11. Do you restrict permit vehicles regarding their traveling behaviors?
☒ Position on Bridge
☒ Speed
☐ Exclusion of other vehicles on bridge
☐ Acceleration/deceleration on bridge
☐ Other (Please Specify):
Sometimes

12. Does your department evaluate bridges under Superload effects (i.e bridge analysis, Superload permits) in-house?
☒ Yes
☒ No

13. Do you have your (DOT) own specifications/guidelines/policies for considering bridge conditions in rating?
☒ Yes
☐ No
IF Yes, please give the title of the document or provide a copy of the document if it is state specific or link access it. http://www.dot.state.mn.us/bridge/manuals/LRFD/pdf/section15.pdf

Evaluations of bridges after Superload effects

14. Does your department inspect the bridge/bridges under review for pre-existing damage before the Superload permit is accepted?
☐ Yes
☒ No
IF yes, please describe how the preexisting damage effected your evaluation of the bridge.

15. Was any fatigue (or damage) suffered with bridges under Superloads?
☐ Yes
☐ No
IF yes, please specify what damage occurred (please specify critical location and mode of failure.). ____________________

16. Was the Superload (mentioned above in question #15 permitted in your department?
☐ Yes
☐ No
IF yes, could you please list data involved in the permit (e.g. GVW, dimensions, axle configuration) or provide the inventory data (Frequency/year and increasing rate, and so on).

If you have any further comments/questions relevant to this questionnaire, please list them below.
What is the definition of superload? I have heard the word used in many different contexts. We do not use the word ourselves.
Our state sees many overweight trucks of up to 13 axles and 256,000 lb .
Trucks above this are infrequent, but they usually have 8 tires / axle and their gross weights may be up to around 800,000 lb.

B10. Mississippi

SURVEY of State Bridge Rating Practices Concerning Superheavy Load

STATE OF ___Mississippi_________________

1. What type of modeling software is used to analyze bridges for use by superheavy loads?

__Finite-element analysis. Specify software __Grillage method. Specify software _XX_Girder line analysis, Bridge Analysis Rating System (BARS). Specify software __Other (specify method and software)

2. What type of bridge load ratings are used? (check all that apply) _XX_ASR _XX_LFR __LRFR __Other (please describe):
If more than one bridge rating system is used, please specify which one is used most. LFR

3. Which software is used for bridge rating? (Check all that apply) __BRASS -Girder _XX_BARS _XX_Virtis __Other (specify):
If more than one bridge rating software is used, please specify which one is used most. BARS

4. Please provide your name, title and telephone number.
Lonny Pigott
Bridge Inspection Program Manager
601-359-7200

If you have questions or comments, please include them.

B11. Missouri

Date	2/9/10
State	Missouri
Organization and Division	MoDOT / Bridge Division
Name	Chad Daniel
Position	Bridge Rating and Inventory Engineer
Email	chad.daniel@modot.mo.gov
Fax	(573) 526-5488
Phone	(573) 751-4365

Superload Permit Process and Procedures

Please identify the classifications of your state issued Superload permit/permits and the criteria or provide a copy of the permit practice manual that include this information. Please identify and list each criteria checked below. Attach more sheets as required.

1.

PLEASE LIST SPECIFIC VALUES FOR EACH ITEM CHECKED BELOW

See the 2009OSOWRegBook[1].pdf document that's attached for more information.

	Minimum Limit	Maximum Limit
☒ Gross vehicle weight (GVW)	160,000 lbs.	None
☒ Axle weight	None	22,400 lbs.
☐ Weight per inch of tire width (Steering axle)		
☐ Weight per inch of tire width (Drive axle)		
☒ Overall Width	16’	None
☒ Overall Height	16’	None
☒ Overall Length	150’	None
☐ Others		

2. How did your department identify criteria for superloads identified in problem 1 (what was the reasoning behind this limit? and how was the criteria established?). Additionally please specify the basis for limits on multi-axle groups.
Minimum is upper range for routine permits.
Axle limit was based on limit in commercial zone.

3. What is the basis for load intensity or load-and-vehicle-length-combination limit for Superload vehicle?
22,400 lbs. per axle is the only limit.

4. Do agencies other than the state DOT issue Superload permits (such as local municipalities)?

☐ Yes
☒No

Load Rating Procedures for State Bridges and Bridge evaluations

5. Has the DOT performed any kind of analysis for fatigue effects on bridges due to Superloads
☐ Yes
☒ No
IF yes , please List/Link materials associated with the above question (reports/journals).

6. What type of modeling software does your department or Agency use to analyze a bridge under Superloads (please specify which software is used)?
☐ Finite-element analysis. Specify software
☐ Grillage method. Specify software
☒ Girder line analysis. Specify software MoBARS, Virtis & LARS
☐ Other (specify method and software)
☐ None

7. What type of Bridge Load rating is used in your department (check all that apply)
☒ ASR
☒ LFR
☐ LRFR We're not using at this time, but will be using after October 2010 on specified bridges
☐ Other Please Specify in detail:
IF more than one is used please specify which is the formula used most frequently.
LFR

8. What software do you use for bridge rating? (Check all that apply)
☐ None
☐ BRASS -Girder
☒ BARS
☒ Virtis
☒ Other (specify): LARS
IF more than one is checked, Please identify the most frequently used software.
Virtis

11. Do you restrict permit vehicles regarding their traveling behaviors?
☒ Position on Bridge
☒ Speed
☒ Exclusion of other vehicles on bridge
☐ Acceleration/deceleration on bridge
☐ Other (Please Specify):

12. Does your department evaluate bridges under Superload effects (i.e bridge analysis, Superload permits) in-house?
☒ Yes

☐ No

13. Do you have your (DOT) own specifications/guidelines/policies for considering bridge conditions in rating?
☐ Yes
☒ No
IF Yes, please give the title of the document or provide a copy of the document if it is state specific or link access it.

We have no specific document or policies, but we review condition ratings, inspection notes and pictures to determine if it's safe to cross a structure with a superload.

Evaluations of bridges after Superload effects

14. Does your department inspect the bridge/bridges under review for pre-existing damage before the Superload permit is accepted?
☐ Yes
☒ No
IF yes, please describe how the preexisting damage effected your evaluation of the bridge.

15. Was any fatigue (or damage) suffered with bridges under Superloads?
☐ Yes
☒ No
IF yes, please specify what damage occurred (please specify critical location and mode of failure.). ______________________________

16. Was the Superload (mentioned above in question #15 permitted in your department?
☐ Yes
☒ No
IF yes, could you please list data involved in the permit (e.g. GVW, dimensions, axle configuration) or provide the inventory data (Frequency/year and increasing rate, and so on).

If you have any further comments/questions relevant to this questionnaire, please list them below.

B12. Nevada

Date	February 10, 2010
State	Nevada
Organization and Division	Nevada DOT, Structures Division
Name	George Klockzien
Position	Senior Engineer, Load Rating/OD Permits
Email	gklockzien@dot.state.nv.us
Fax	(775) 888-8405
Phone	(775) 888-7541

Superload Permit Process and Procedures

Please identify the classifications of your state issued Superload permit/permits and the criteria or provide a copy of the permit practice manual that include this information. Please identify and list each criteria checked below. Attach more sheets as required.

1.

PLEASE LIST SPECIFIC VALUES FOR EACH ITEM CHECKED BELOW

	Minimum Limit	Maximum Limit
☒ Gross vehicle weight (GVW)	250, 000 lbs	
☒ Axle weight		60, 000 lbs
☒ Weight per inch of tire width (Steering axle)		800 lb/inch
☒ Weight per inch of tire width (Drive axle)		800 lb/inch
☒ Overall Width	17’ in urban areas, or 26’ in rural areas	
☒ Overall Height	19’	
☒ Overall Length	110’ urban areas, or 150’ in rural areas	
☐ Others		

2. How did your department identify criteria for superloads identified in problem 1 (what was the reasoning behind this limit? and how was the criteria established?). Additionally please specify the basis for limits on multi-axle groups.

The NDOT superload criteria above were established with a 30-day application deadline to ensure adequate time for route/bridge reviews, planning and coordination by permit, bridge and district operations staff and the carrier. The thresholds are guidelines that trigger a 30-day review in those situations in which an extremely oversized or overweight vehicle/load has the potential to cause significant traffic control issues or significant damage to roadways and bridges. The 60, 000 lbs axle weight limit is based on the bonus tridem axle group. The single and larger number axle groups are based on the Caltrans color charts (purple, green and orange) with bonus factors for axle, dolly width, number of tires and maximum tire weight.

3. What is the basis for load intensity or load-and-vehicle-length-combination limit for Superload vehicle?
Nevada Administrative Code

4. Do agencies other than the state DOT issue Superload permits (such as local municipalities)?
☐ Yes
☒ No

Load Rating Procedures for State Bridges and Bridge evaluations

5. Has the DOT performed any kind of analysis for fatigue effects on bridges due to Superloads
☐ Yes
☒ No
IF yes , please List/Link materials associated with the above question (reports/journals).

6. What type of modeling software does your department or Agency use to analyze a bridge under Superloads (please specify which software is used)?
☐ Finite-element analysis. Specify software
☐ Grillage method. Specify software
☐ Girder line analysis. Specify software
☒ Other (specify method and software) Caltrans weight charts with bonus factors.
☐ None

7. What type of Bridge Load rating is used in your department (check all that apply)
☒ ASR
☒ LFR Used most frequently
☒ LRFR
☐ Other Please Specify in detail:
IF more than one is used please specify which is the formula used most frequently.

8. What software do you use for bridge rating? (Check all that apply)
☐ None
☒ BRASS -Girder Most frequently used software.
☐ BARS
☐ Virtis
☒ Other (specify): Sap 2000, WinBDS with spreadsheet, MDX for curved girder.
IF more than one is checked, Please identify the most frequently used software.

11. Do you restrict permit vehicles regarding their traveling behaviors?
☒ Position on Bridge
☒ Speed
☐ Exclusion of other vehicles on bridge
☐ Acceleration/deceleration on bridge

☒ Other (Please Specify): Re-routing, if feasible.

12. Does your department evaluate bridges under Superload effects (i.e bridge analysis, Superload permits) in-house?
☐ Yes
☒ No

13. Do you have your (DOT) own specifications/guidelines/policies for considering bridge conditions in rating?
☒ Yes NDOT Structures Manual; Chapter 28
☐ No
IF Yes, please give the title of the document or provide a copy of the document if it is state specific or link access it.

Evaluations of bridges after Superload effects

14. Does your department inspect the bridge/bridges under review for pre-existing damage before the Superload permit is accepted?
☐ Yes
☒ No
IF yes, please describe how the preexisting damage effected your evaluation of the bridge.

15. Was any fatigue (or damage) suffered with bridges under Superloads?
☐ Yes
☒ No No fatigue has been documented as specifically caused by Superloads.
IF yes, please specify what damage occurred (please specify critical location and mode of failure.).

16. Was the Superload (mentioned above in question #15 permitted in your department?
☐ Yes
☒ No N/A
IF yes, could you please list data involved in the permit (e.g. GVW, dimensions, axle configuration) or provide the inventory data (Frequency/year and increasing rate, and so on).

If you have any further comments/questions relevant to this questionnaire, please list them below.

B13. New Mexico

Date	February 15, 2010
State	New Mexico
Organization and Division	NM DOT
Name	Jeff Vigil
Position	Bridge Management Engineer
Email	jeff.vigil@state.nm.us
Fax	505-827-5339
Phone	505-827-5457

Superload Permit Process and Procedures

Please identify the classifications of your state issued Superload permit/permits and the criteria or provide a copy of the permit practice manual that include this information. Please identify and list each criteria checked below. Attach more sheets as required.

1.

PLEASE LIST SPECIFIC VALUES FOR EACH ITEM CHECKED BELOW

	Minimum Limit	Maximum Limit
☐ Gross vehicle weight (GVW)	none	
☐ Axle weight	Dependant on many variables	
☐ Weight per inch of tire width (Steering axle)	650#	
☐ Weight per inch of tire width (Drive axle)	None – based on allowable weight per axle	
☐ Overall Width	none	
☐ Overall Height	none	
☐ Overall Length	none	
☐ Others		

2. How did your department identify criteria for superloads identified in problem 1 (what was the reasoning behind this limit? and how was the criteria established?). Additionally please specify the basis for limits on multi-axle groups.

Superload – gross 250,000 or greater
Allowed on tandem – 46,000#
Allowed on tridem – 60,000#
Allowed on quad – 68,000#

Bonus factors for additional width and additional tires

Most of these limits were instituted 20-30 years ago. I have been told that a combination of engineering analysis, engineering judgement, historical permitting procedures and other factors were used to develop these limits.

The limits that are used in combination with our OVLOAD program have served New Mexico well in minimizing the negative effects that overweight loads produce on our bridges. We have made some changes to accommodate some loads (eg. trunnions).

3. What is the basis for load intensity or load-and-vehicle-length-combination limit for Superload vehicle?
All bridges on route are analyzed for moment capacity.

4. Do agencies other than the state DOT issue Superload permits (such as local municipalities)?
☐ Yes
☐No
NMDOT is only agency that issues oversize/overweight permits.

The city of Albuquerque requires an additional special use permit issued by their traffic department.

Load Rating Procedures for State Bridges and Bridge evaluations

5. Has the DOT performed any kind of analysis for fatigue effects on bridges due to Superloads
☐ Yes
☒ No
IF yes , please List/Link materials associated with the above question (reports/journals).

6. What type of modeling software does your department or Agency use to analyze a bridge under Superloads (please specify which software is used)?
☐ Finite-element analysis. Specify software
☐ Grillage method. Specify software
☐ Girder line analysis. Specify software
☐ Other (specify method and software)
OVLOAD – see question #12
☐ None

7. What type of Bridge Load rating is used in your department (check all that apply)
☒ ASR
☒ LFR
☐ LRFR
☐ Other Please Specify in detail:
IF more than one is used please specify which is the formula used most frequently.
LFR

8. What software do you use for bridge rating? (Check all that apply)
☐ None
☒ BRASS -Girder
☐ BARS
☒ Virtis

☐ Other (specify):

IF more than one is checked, Please identify the most frequently used software.
VIRTIS

11. Do you restrict permit vehicles regarding their traveling behaviors?
☒ Position on Bridge
☒ Speed
☒ Exclusion of other vehicles on bridge
☐ Acceleration/deceleration on bridge
☐ Other (Please Specify):

12. Does your department evaluate bridges under Superload effects (i.e bridge analysis, Superload permits) in-house?
☐ Yes
☐ No

Empirically – No
Analytically – Yes. All bridges on route are analyzed using department owned software (OVLOAD). Moments produced by Operating Rating vehicle are compared to moments produced by permit truck. There are some assumptions and simplifications that are made .

13. Do you have your (DOT) own specifications/guidelines/policies for considering bridge conditions in rating?
☒ Yes
☐ No

IF Yes, please give the title of the document or provide a copy of the document if it is state specific or link access it.
http://nmshtd.state.nm.us/upload/images/Maps/bridge/Bridge%20Map%20Front.pdf
Critical bridges are listed on this map.

Evaluations of bridges after Superload effects

14. Does your department inspect the bridge/bridges under review for pre-existing damage before the Superload permit is accepted?
☐ Yes
☒ No

IF yes, please describe how the preexisting damage effected your evaluation of the bridge.

15. Was any fatigue (or damage) suffered with bridges under Superloads?
☐ Yes
☐ No

IF yes, please specify what damage occurred (please specify critical location and mode of failure.). We have had fatigue issues(and out of plane bending issues) on bridges; however, we have no way of knowing if this was caused by overweight vehicles.)

16. Was the Superload (mentioned above in question #15 permitted in your department?
☐ Yes
☐ No
IF yes, could you please list data involved in the permit (e.g. GVW, dimensions, axle configuration) or provide the inventory data (Frequency/year and increasing rate, and so on).

If you have any further comments/questions relevant to this questionnaire, please list them below.

B14. North Carolina

Date	February 9, 2010
State	North Carolina
Organization and Division	North Carolina Department of Transportation Division of Highways Bridge Management Unit
Name	Don Idol
Position	Assistant State Bridge Inspection Engineer
Email	didol@ncdot.gov
Fax	(919)715-0786
Phone	(919)835-8226

Superload Permit Process and Procedures

Please identify the classifications of your state issued Superload permit/permits and the criteria or provide a copy of the permit practice manual that include this information. Please identify and list each criteria checked below. Attach more sheets as required.

1.

PLEASE LIST SPECIFIC VALUES FOR EACH ITEM CHECKED BELOW

	Minimum Limit	Maximum Limit
☒ Gross vehicle weight (GVW)	112,000 pounds on 4 axles 120,000 pounds on6 axles 132,000 pounds on 7 axles	Unlimited
☒ Axle weight	Single = 25,000 pounds Tandem = 50,000 pounds Tridem = 60,000 pounds Quad = 68,000 pounds	Single = 25,000 pounds Tandem = 50,000 pounds Tridem = 60,000 pounds Quad = 68,000 pounds
☒ Weight per inch of tire width (Steering axle)	Do not use.	Do not use.
☒ Weight per inch of tire width (Drive axle)	Do not use.	Do not use.
☒ Overall Width	Unlimited	Unlimited
☒ Overall Height	Unlimited	Unlimited
☒ Overall Length	51'-0" from steer axle to rear trailer axle	Unlimited
☐ Others		

2. How did your department identify criteria for superloads identified in problem 1 (what was the reasoning behind this limit? and how was the criteria established?). Minimum weights were based on amount of weight needed for moving most construction equipment. Maximum weights were left open in order to move as much weight as possible. Maximum stress level for "Superloads" is at the Operating Stress Level. Additionally please specify the basis for limits on

multi-axle groups. The multi-axle groups shown above for Tandem, Tridem, and Quad Axle groups give fairly equal stresses in North Carolina Bridges at the Operating Stress Level. North Carolina has a large number of short span bridges where the controlling load will be one of these groups on a single simple span.

3. What is the basis for load intensity or load-and-vehicle-length-combination limit for Superload vehicle?
NC does not use.

4. Do agencies other than the state DOT issue Superload permits (such as local municipalities)?
☒ Yes
☐ No
There are 750 municipal bridges in NC. Sometimes a municipality will need to issue an overweight permit. There are a few US Government owned bridges in NC for which they must issue overweight permits if required.

<u>Load Rating Procedures for State Bridges and Bridge evaluations</u>

5. Has the DOT performed any kind of analysis for fatigue effects on bridges due to Superloads
☐ Yes
☒ No
IF yes , please List/Link materials associated with the above question (reports/journals).

6. What type of modeling software does your department or Agency use to analyze a bridge under Superloads (please specify which software is used)?
☐ Finite-element analysis. Specify software
☐ Grillage method. Specify software
☐ Girder line analysis. Specify software
☒ Other (specify method and software) In house software. LFR for all materials except timber where we use ASR. We use ASR for rating trusses.
☐ None

7. What type of Bridge Load rating is used in your department (check all that apply)
☒ ASR Use for timber and trusses. Use 2nd most.
☒ LFR Use for all materials except timber and for trusses. Used most.
☒ LRFR Use only for new LRFD designs.
☐ Other Please Specify in detail:
IF more than one is used please specify which is the formula used most frequently.

8. What software do you use for bridge rating? (Check all that apply)
☐ None
☐ BRASS -Girder
☐ BARS
☐ Virtis
☒ Other (specify): In-house software.

IF more than one is checked, Please identify the most frequently used software.

11. Do you restrict permit vehicles regarding their traveling behaviors?
☒ Position on Bridge
☒ Speed Generally try not to use speed restriction on a bridge carrying Interstate traffic.
☒ Exclusion of other vehicles on bridge
☒ Acceleration/deceleration on bridge
☐ Other (Please Specify):

12. Does your department evaluate bridges under Superload effects (i.e bridge analysis, Superload permits) in-house?
☒ Yes
☐ No

13. Do you have your (DOT) own specifications/guidelines/policies for considering bridge conditions in rating?
☒ Yes See attachment A.
☐ No
IF Yes, please give the title of the document or provide a copy of the document if it is state specific or link access it.

Evaluations of bridges after Superload effects

14. Does your department inspect the bridge/bridges under review for pre-existing damage before the Superload permit is accepted?
☐ Yes
☒ No
IF yes, please describe how the preexisting damage effected your evaluation of the bridge.

15. Was any fatigue (or damage) suffered with bridges under Superloads?
☐ Yes
☒ No
IF yes, please specify what damage occurred (please specify critical location and mode of failure.). ____

16. Was the Superload (mentioned above in question #15 permitted in your department?
☐ Yes
☐ No
IF yes, could you please list data involved in the permit (e.g. GVW, dimensions, axle configuration) or provide the inventory data (Frequency/year and increasing rate, and so on).

If you have any further comments/questions relevant to this questionnaire, please list them below.

B15. Oregon

Date	2/8/10
State	Oregon
Organization and Division	Oregon Department of Transportation, Highway Division
Name	Bert Hartman, P.E.
Position	Bridge Program Managing Engineer
Email	Bert.h.hartman@odot.state.or.us
Fax	503-986-3407
Phone	503-986-3395

Superload Permit Process and Procedures

Please identify the classifications of your state issued Superload permit/permits and the criteria or provide a copy of the permit practice manual that include this information. Please identify and list each criteria checked below. Attach more sheets as required.

1.

PLEASE LIST SPECIFIC VALUES FOR EACH ITEM CHECKED BELOW

	Minimum Limit	Maximum Limit
☒ Gross vehicle weight (GVW)		
☒ Axle weight		
☒ Weight per inch of tire width (Steering axle)		
☒ Weight per inch of tire width (Drive axle)		
☒ Overall Width		
☐ Overall Height		
☒ Overall Length		
☐ Others		

Oregon defines a Superload as a vehicle that exceeds our published weight tables 3, 4, and 5 that are used for single trip permits. Tables 1 and 2 are for continuous trip permit vehicles.

2. How did your department identify criteria for superloads identified in problem 1 (what was the reasoning behind this limit? and how was the criteria established?). Additionally please specify the basis for limits on multi-axle groups.

Oregon defines a Superload as a vehicle that exceeds our published weight tables 3, 4, and 5 that are used for single trip permits. Tables 1 and 2 are for continuous trip permit vehicles. The tables have the loaded weights for single and groups of axles.

3. What is the basis for load intensity or load-and-vehicle-length-combination limit for Superload vehicle?

Oregon defines a Superload as a vehicle that exceeds our published weight tables 3, 4, and 5 that are used for single trip permits. Tables 1 and 2 are for continuous trip permit vehicles.

4. Do agencies other than the state DOT issue Superload permits (such as local municipalities)?
☒ Yes
☐No
Some local agencies have the capacity to review single trip permit applications, but most do not. Our larger cities and counties do maintain engineering staff that can be used for permit review.

Load Rating Procedures for State Bridges and Bridge evaluations

5. Has the DOT performed any kind of analysis for fatigue effects on bridges due to Superloads
☐ Yes
☒ No
IF yes , please List/Link materials associated with the above question (reports/journals).

6. What type of modeling software does your department or Agency use to analyze a bridge under Superloads (please specify which software is used)?
☒ Finite-element analysis. Specify software BRASS Girder
☐ Grillage method. Specify software
☐ Girder line analysis. Specify software
☐ Other (specify method and software)
☐ None

7. What type of Bridge Load rating is used in your department (check all that apply)
☐ ASR
☒ LFR
☒ LRFR
☐ Other Please Specify in detail:
IF more than one is used please specify which is the formula used most frequently.

8. What software do you use for bridge rating? (Check all that apply)
☐ None
☒ BRASS -Girder
☐ BARS
☐ Virtis
☐ Other (specify):
IF more than one is checked, Please identify the most frequently used software.

11. Do you restrict permit vehicles regarding their traveling behaviors?
☒ Position on Bridge
☒ Speed
☒ Exclusion of other vehicles on bridge
☐ Acceleration/deceleration on bridge
☐ Other (Please Specify):

12. Does your department evaluate bridges under Superload effects (i.e bridge analysis, Superload permits) in-house?

☒ Yes
☐ No

13. Do you have your (DOT) own specifications/guidelines/policies for considering bridge conditions in rating?
☒ Yes
☐ No
IF Yes, please give the title of the document or provide a copy of the document if it is state specific or link access it.

Evaluations of bridges after Superload effects

14. Does your department inspect the bridge/bridges under review for pre-existing damage before the Superload permit is accepted?
☐ Yes
☒ No
IF yes, please describe how the preexisting damage effected your evaluation of the bridge.

15. Was any fatigue (or damage) suffered with bridges under Superloads?
☐ Yes
☐ No
IF yes, please specify what damage occurred (please specify critical location and mode of failure.). ____

____

____

16. Was the Superload (mentioned above in question #15 permitted in your department?
☐ Yes
☐ No
IF yes, could you please list data involved in the permit (e.g. GVW, dimensions, axle configuration) or provide the inventory data (Frequency/year and increasing rate, and so on).

If you have any further comments/questions relevant to this questionnaire, please list them below.

B16. South Dakota

Date	2/11/2010
State	South Dakota
Organization and Division	SDDOT Office of Bridge Design
Name	Todd Thompson
Position	Bridge Management Engineer
Email	todd.thompson@state.sd.us
Fax	605.773.2614
Phone	605.773.3285

Superload Permit Process and Procedures

Please identify the classifications of your state issued Superload permit/permits and the criteria or provide a copy of the permit practice manual that include this information. Please identify and list each criteria checked below. Attach more sheets as required.

1.

PLEASE LIST SPECIFIC VALUES FOR EACH ITEM CHECKED BELOW

	Minimum Limit	Maximum Limit
☒ Gross vehicle weight (GVW)		No limit (uncapped)
☒ Axle weight		No practical max (governed by wt/in of tire width)
☒ Weight per inch of tire width (Steering axle)		600 lb/in
☒ Weight per inch of tire width (Drive axle)		600 lb/in (500 lb/in for axles with single tires)
☒ Overall Width		Restricted by route & any physical limitations of route
☒ Overall Height		Restricted by route & any physical limitations of route
☒ Overall Length		None
☐ Others		

2. How did your department identify criteria for superloads identified in problem 1 (what was the reasoning behind this limit? and how was the criteria established?). Additionally please specify the basis for limits on multi-axle groups.
Weight per inch of tier width limits were based upon pavements (not bridge needs).

3. What is the basis for load intensity or load-and-vehicle-length-combination limit for Superload vehicle?
N/A

4. Do agencies other than the state DOT issue Superload permits (such as local municipalities)?

☒ Yes
☐ No
Local transportation agencies can issue permits for their systems.

Load Rating Procedures for State Bridges and Bridge evaluations

5. Has the DOT performed any kind of analysis for fatigue effects on bridges due to Superloads
☐ Yes
☒ No
IF yes , please List/Link materials associated with the above question (reports/journals).

6. What type of modeling software does your department or Agency use to analyze a bridge under Superloads (please specify which software is used)?
☒ Finite-element analysis. Specify software VIRTIS
☐ Grillage method. Specify software
☒ Girder line analysis. Specify software BARS, VIRTIS, BridgeModeler
☐ Other (specify method and software)
☐ None

7. What type of Bridge Load rating is used in your department (check all that apply)
☒ ASR
☒ LFR
☐ LRFR
☐ Other Please Specify in detail:
IF more than one is used please specify which is the formula used most frequently.
LFR is used most frequently

8. What software do you use for bridge rating? (Check all that apply)
☐ None
☐ BRASS -Girder
☒ BARS
☒ Virtis
☐ Other (specify):
IF more than one is checked, Please identify the most frequently used software.

11. Do you restrict permit vehicles regarding their traveling behaviors?
☒ Position on Bridge
☒ Speed
☒ Exclusion of other vehicles on bridge
☐ Acceleration/deceleration on bridge
☐ Other (Please Specify):

12. Does your department evaluate bridges under Superload effects (i.e bridge analysis, Superload permits) in-house?
☒ Yes
☐ No

13. Do you have your (DOT) own specifications/guidelines/policies for considering bridge conditions in rating?
☐ Yes
☒ No
IF Yes, please give the title of the document or provide a copy of the document if it is state specific or link access it.

Evaluations of bridges after Superload effects

14. Does your department inspect the bridge/bridges under review for pre-existing damage before the Superload permit is accepted?
☐ Yes
☒ No
IF yes, please describe how the preexisting damage effected your evaluation of the bridge.

15. Was any fatigue (or damage) suffered with bridges under Superloads?
☐ Yes
☒ No
IF yes, please specify what damage occurred (please specify critical location and mode of failure.). ______________________________

16. Was the Superload (mentioned above in question #15 permitted in your department?
☐ Yes
☐ No
IF yes, could you please list data involved in the permit (e.g. GVW, dimensions, axle configuration) or provide the inventory data (Frequency/year and increasing rate, and so on).

If you have any further comments/questions relevant to this questionnaire, please list them below.

- Go to www.sdtruckinfo.com for more detail on South Dakota vehicle size & weight regulations.
- SDDOT follows Bridge Formula B (uncapped) for weight limits.
- SDAPS (SD Automated Permitting System) is utilized for analyzing every bridge to be crossed for each overweight vehicle as part of an evaluation process.
- All overweight vehicles are treated the same – “Superloads” are not considered any differently.

B17. Virginia

Date	2/10/10
State	Commonwealth of Virginia
Organization and Division	Virginia Department of Transportation (VDOT) Structure & Bridge (S&B), Central Office (CO)
Name	Prasad Nallapaneni
Position	Program Manager
Email	Prasad.Nallapaneni@VDOT.Virginia.gov
Fax	804-786-2988
Phone	804-371-2770

Superload Permit Process and Procedures

Please identify the classifications of your state issued Superload permit/permits and the criteria or provide a copy of the permit practice manual that include this information. Please identify and list each criteria checked below. Attach more sheets as required.

1.

PLEASE LIST SPECIFIC VALUES FOR EACH ITEM CHECKED BELOW

	Minimum Limit	Maximum Limit
☒ Gross vehicle weight (GVW)	by chart	N/A
☒ Axle weight	22,000 lbs	N/A
☒ Weight per inch of tire width (Steering axle)	N/A	650
☒ Weight per inch of tire width (Drive axle)	N/A	650
☒ Overall Width	N/A	15’
☒ Overall Height	N/A	15’
☒ Overall Length	N/A	150’
☐ Others		

2. How did your department identify criteria for superloads identified in problem 1 (what was the reasoning behind this limit? and how was the criteria established?). Additionally please specify the basis for limits on multi-axle groups.
The historical limits correspond with built inventory policies for clearances and the federal bridge formula for weight. The multi-axle limits are given by the charts in the attached document.

3. What is the basis for load intensity or load-and-vehicle-length-combination limit for Superload vehicle? Primarily, the Federal Bridge Formula.

4. Do agencies other than the state DOT issue Superload permits (such as local municipalities)?
☒ Yes Actually Department of Motor Vehicles (DMV) issues the permits in the Commonwealth of Virginia. VDOT Structure and Bridge Division evaluate the

vehicle's effects on the bridges along the route and provide comments to the DMV. Other divisions such as Maintenance and Security and Operations in VDOT may also be involved in the permitting process depending on the size and weight of the load. Local independent jurisdictions issue their own permits for the roads and bridges they maintain.

☐No

Load Rating Procedures for State Bridges and Bridge evaluations

5. Has the DOT performed any kind of analysis for fatigue effects on bridges due to Superloads

☐ Yes

☒ No Not yet – VDOT is interested in analyzing these effects for the permits with very high loads. Currently VDOT is developing the policy that may include such criteria.

IF yes , please List/Link materials associated with the above question (reports/journals).

6. What type of modeling software does your department or Agency use to analyze a bridge under Superloads (please specify which software is used)?

☐ Finite-element analysis. Specify software

☐ Grillage method. Specify software

☐ Girder line analysis. Specify software

☒ Other (specify method and software) VIRTIS, BARS, DESCUS, STAAD, EXCEL. Since the majority of our inventory was simple spans, as a first cut, we compare simple span moments of the permit load to the operating rated capacity of the bridge. Then we run the input files from various programs mentioned above as required, to get a refined analysis.

☐ None

7. What type of Bridge Load rating is used in your department (check all that apply)

☒ ASR

☒ LFR

☒ LRFR

☐ Other Please Specify in detail:

IF more than one is used please specify which is the formula used most frequently. VDOT is currently transitioning to LRFR. As this comes online, ASR and LFR are abandoned.

8. What software do you use for bridge rating? (Check all that apply)

☐ None

☐ BRASS -Girder

☒ BARS

☒ Virtis

☒ Other (specify): DESCUS, CON SPAN

IF more than one is checked, Please identify the most frequently used software.

In conjunction with #7, as the VIRTIS ratings come online, they control. Other software, usually BARS, is used in the absence of a VIRTIS rating.

11. Do you restrict permit vehicles regarding their traveling behaviors?
☒ Position on Bridge
☒ Speed
☒ Exclusion of other vehicles on bridge
☒ Acceleration/deceleration on bridge
☒ Other (Please Specify): See attached document

12. Does your department evaluate bridges under Superload effects (i.e bridge analysis, Superload permits) in-house?
☒ Yes VDOT do most of the analysis in-house. For a recent Superload (1.3 MM lbs.) VDOT solicited the owner of the permit to have a third party review to supplement or perform the load rating of critical bridges.
☐ No

13. Do you have your (DOT) own specifications/guidelines/policies for considering bridge conditions in rating?
☐ Yes
☒ No VDOT follows FHWA guidelines to rate the condition of a bridge. Engineering Judgment plays an important role, and the Central Office discusses with the District personnel if the bridge has NBI general condition rating of 5 or below for input.

IF Yes, please give the title of the document or provide a copy of the document if it is state specific or link access it.

Evaluations of bridges after Superload effects

14. Does your department inspect the bridge/bridges under review for pre-existing damage before the Superload permit is accepted?
☐ Yes
☒ No Since the threshold of loads is increasing day by day, we are currently developing a policy to inspect bridges pre and post move to handle 1.3Mil. # vehicle.

IF yes, please describe how the preexisting damage effected your evaluation of the bridge.

15. Was any fatigue (or damage) suffered with bridges under Superloads?
☐ Yes
☒ No To date - no damage is yet linked to Superloads.

IF yes, please specify what damage occurred (please specify critical location and mode of failure.).

16. Was the Superload (mentioned above in question #15 permitted in your department?
☐ Yes
☐ No

IF yes, could you please list data involved in the permit (e.g. GVW, dimensions, axle configuration) or provide the inventory data (Frequency/year and increasing rate, and so on).

If you have any further comments/questions relevant to this questionnaire, please list them below.
Attached in this email is a sample request of permit from Department of Motor Vehicles to verify the structural (load rating) capacity of the bridges along the specified route and the reply from the Structure and Bridge Division. VDOT S&B is responsible for identifying and evaluating all bridges on the Interstate system for a given route, so accordingly, not all of these may be listed. Also attached is the current Virgina Hauling Permit Manual.

APPENDIX 3.3

Lamar Survey Responses and Survey Instrument

Responses to Lamar University Surveys of State DOTs

Index

SURVEY -- SUPERHEAVY LOAD CRITERIA FOR HIGHWAY BRIDGES

STATE OF ALBAMA

1. What is the basis for the State's gross vehicle weight limit (the weight over which a vehicle is not eligible for a permit, and is classified as a "superheavy load")?

___By Consensus
___AASHTO H-15 Design Trucks
___AASHTO H-20 or HS-20 Design Trucks
___State Overweight Trucks
_X_Other (Please give general description):

Anything over 180,000 lbs is considered a superload in Alabama.

2. If the State has a maximum vehicle loading intensity (weight per unit length, or weight per unit area), what is the basis for the load intensity?

___Please give general description:

none

3. If the State has a bridge formula for the maximum weight on any group of two or more axles, what is the basis for the bridge formula?

___Please give general description:

Alabama uses the Federal Bridge Formula

4. If the State has completed a recent analysis of the fatigue effects of superheavy loads on its highway bridges, what fatigue model was used and what did the model show?

___Please give general description:

none

5. Please give your name, title and office telephone number:

Eric Christie
Assistant State Maintenance Engineer - Bridges
(334) 242-6281

SURVEY -- SUPERHEAVY LOAD CRITERIA FOR HIGHWAY BRIDGES

STATE OF ARIZONA

1. What is the basis for the State's gross vehicle weight limit (the weight over which a vehicle is not eligible for a permit, and is classified as a "superheavy load")?

___By Consensus
___AASHTO H-15 Design Trucks
___AASHTO H-20 or HS-20 Design Trucks
___State Overweight Trucks
__X_Other (Please give general description):

1. If the weight of any vehicle is 80,000 lbs or less and also comply with the Federal Bridge Gross Weight Formula (which is W = 500 (LN/(N-1) + 12N + 36)), then no permit is needed unless it travels on a restricted bridge.
2. If the weight of any vehicle is more than 80,000 lbs or does not comply with the Federal Bridge Gross Weight Formula (which is W = 500 (LN/(N-1) + 12N + 36)), then the weight is checked against Arizona Administrative Code Formula weight (1.5 X 700 (L + 40)) which is shown in the Charts for axle width and number of tires and Class A permit is issued if it is satisfied.
3. For any vehicle weighing more than 250,000 lbs or does not comply with Arizona Administrative Code Formula weight (which is shown in the Charts for axle width and number of tires) shall apply for class C permit and comes to the Bridge Group for analysis.

2. If the State has a maximum vehicle loading intensity (weight per unit length, or weight per unit area), what is the basis for the load intensity?

___Please give general description: N/A

3. If the State has a bridge formula for the maximum weight on any group of two or more axles, what is the basis for the bridge formula?

_X__Please give general description: Please see the answer for the question no. 1

4. If the State has completed a recent analysis of the fatigue effects of superheavy loads on its highway bridges, what fatigue model was used and what did the model show?

___Please give general description: N/A

5. Please give your name, title and office telephone number:

Amin Islam, Ph.D., PE
Bridge Technical Section Leader
Arizona DOT Bridge Group, Tel: (602)712-8621

SURVEY -- SUPERHEAVY LOAD CRITERIA FOR HIGHWAY BRIDGES

STATE OF ARKANSAS

1. What is the basis for the State's gross vehicle weight limit (the weight over which a vehicle is not eligible for a permit, and is classified as a "superheavy load")?

___By Consensus
___AASHTO H-15 Design Trucks
___AASHTO H-20 or HS-20 Design Trucks
___State Overweight Trucks
_ X Other (Please give general description): When the proposed load overstresses the bridges or pavement on the route(s)on which it is seeking to travel, it is not eligible for a permit.

2. If the State has a maximum vehicle loading intensity (weight per unit length, or weight per unit area), what is the basis for the load intensity?

___Please give general description: All vehicles are required to comply with the federal bridge formula. For certain non-articulated vehicles of special design carrying no weight other than self-weight, the maximum legal weight per axle and maximum legal gross weight isgoverned by the formula "width of tire x 650 psi".

3. If the State has a bridge formula for the maximum weight on any group of two or more axles, what is the basis for the bridge formula?

___Please give general description: We ensure all vehicles applying for overweight permits can at least bridge 80,000 pounds pursuant to the federal bridge formula. We also have set maximum weights on axle groups.

4. If the State has completed a recent analysis of the fatigue effects of superheavy loads on its highway bridges, what fatigue model was used and what did the model show?

___Please give general description: No such analysis has been conducted.

5. Please give your name, title and office telephone number:

Phil Brand, Division Head-Bridge Division, 501-569-2361

SURVEY -- SUPERHEAVY LOAD CRITERIA FOR HIGHWAY BRIDGES

STATE OF HAWAII

1. What is the basis for the State's gross vehicle weight limit (the weight over which a vehicle is not eligible for a permit, and is classified as a "superheavy load")?

___By Consensus
___AASHTO H-15 Design Trucks
___AASHTO H-20 or HS-20 Design Trucks
___State Overweight Trucks
___Other (Please give general description):

As mentioned above, we do not have a criteria for which a vehicle is not eligible for a permit. Eligibility is based on what the bridge can carry safely.

2. If the State has a maximum vehicle loading intensity (weight per unit length, or weight per unit area), what is the basis for the load intensity?

___Please give general description:

We do not have this information.

3. If the State has a bridge formula for the maximum weight on any group of two or more axles, what is the basis for the bridge formula?

___Please give general description:

We do not have this information.

4. If the State has completed a recent analysis of the fatigue effects of superheavy loads on its highway bridges, what fatigue model was used and what did the model show?

___Please give general description:

We do not have this information and have not done this.

5. Please give your name, title and office telephone number:

Paul Santo
Bridge Design Engineer
Hawaii DOT
808-692-7611

You mentioned that Hawaii does not have a superheavy load criteria. Then, does the state sometimes perform a structural analysis of a bridge to determine whether a particular vehicle load will be allowed to cross it? **Yes.**
If so, will you tell us what factors are involved in the decision to perform the analysis?
First of all, we now load rate our bridges in accordance with our "Implementation Guidelines for Load and Resistance Factor Rating (LRFR) of Highway Bridges" based on the AASHTO Manual for Bridge Evaluation. In our guidelines, we rate our bridges for some "standard" single trip permit trucks with the maximum weighing about 210 kips. If the bridge in question has already been load rated with our current guidelines and the truck weight and configuration is close to the rated truck, no further analysis is performed and a decision is made based on the existing ratings. If the truck exceeds the highest weight truck already rated with rating greater than 1.0, we would analyze the bridge for this special truck. We would also perform the analysis for a bridge that has not been load rated to our current guidelines. Generally each route for permit trucks have specific bridge(s) that control whether a permit is approved or not so analysis, if any, would usually be on a limited number of bridges.

SURVEY -- SUPERHEAVY LOAD CRITERIA FOR HIGHWAY BRIDGES

STATE OF ILLINOIS

1. What is the basis for the State's gross vehicle weight limit (the weight over which a vehicle is not eligible for a permit, and is classified as a "superheavy load")?

___By Consensus
___AASHTO H-15 Design Trucks
___AASHTO H-20 or HS-20 Design Trucks
___State Overweight Trucks
_X_Other (Please give general description):

There is no maximum gross weight limit in Illinois. A permit approval/denial is based on analysis on a per bridge basis.

2. If the State has a maximum vehicle loading intensity (weight per unit length, or weight per unit area), what is the basis for the load intensity?

___Please give general description:

Same answer as for #1. There is no maximum – based on analysis.

3. If the State has a bridge formula for the maximum weight on any group of two or more axles, what is the basis for the bridge formula?

___Please give general description:

The formula provided in the Illinois state statutes is the same as the federal bridge formula B.

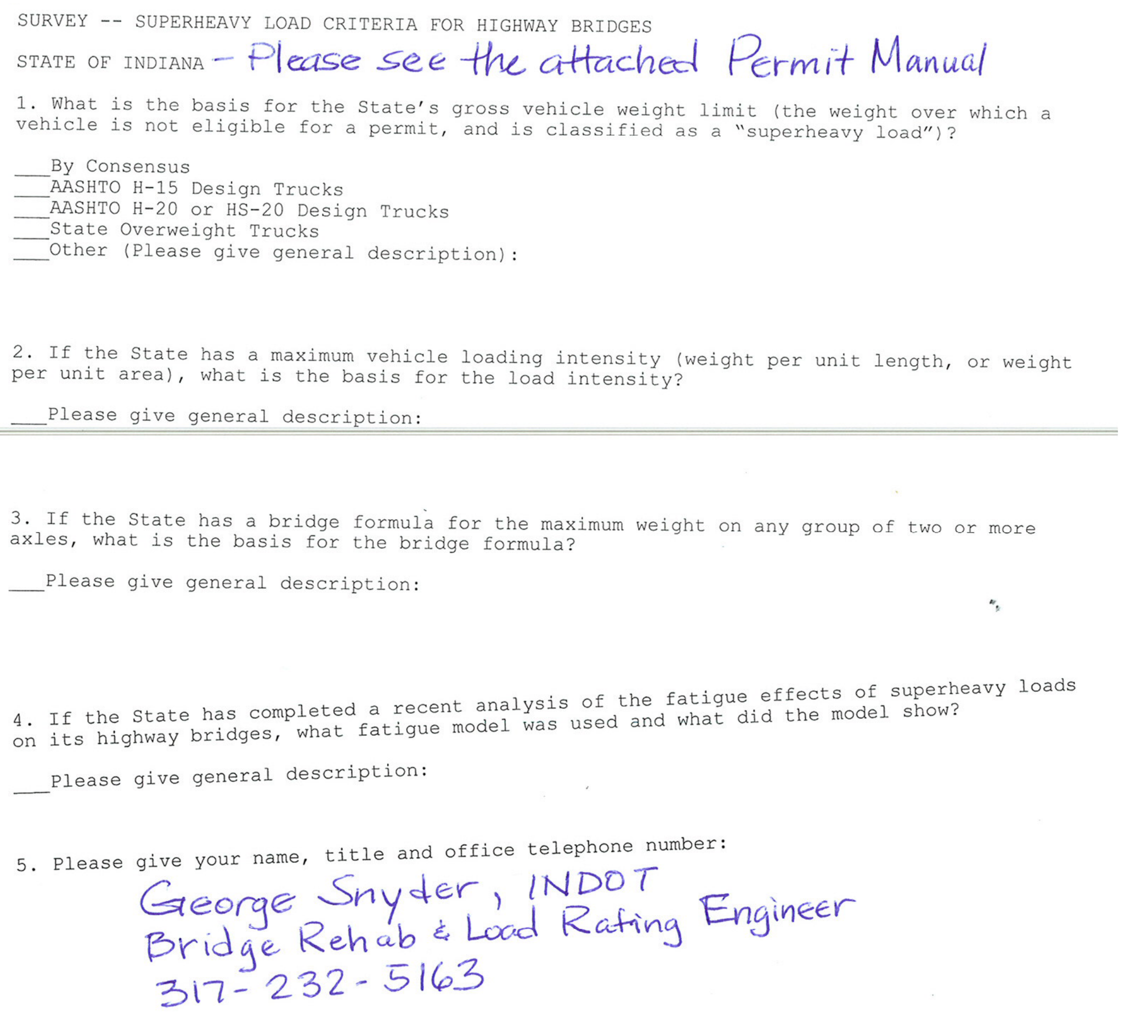
4. If the State has completed a recent analysis of the fatigue effects of superheavy loads on its highway bridges, what fatigue model was used and what did the model show?

___Please give general description:

Not applicable.

5. Please give your name, title and office telephone number:

Tim Armbrecht
Chief, Bridge Ratings and Permits Unit
(217) 782-6266



SURVEY -- SUPERHEAVY LOAD CRITERIA FOR HIGHWAY BRIDGES

STATE OF INDIANA - Please see the attached Permit Manual

1. What is the basis for the State's gross vehicle weight limit (the weight over which a vehicle is not eligible for a permit, and is classified as a "superheavy load")?

___By Consensus
___AASHTO H-15 Design Trucks
___AASHTO H-20 or HS-20 Design Trucks
___State Overweight Trucks
___Other (Please give general description):

2. If the State has a maximum vehicle loading intensity (weight per unit length, or weight per unit area), what is the basis for the load intensity?

___Please give general description:

3. If the State has a bridge formula for the maximum weight on any group of two or more axles, what is the basis for the bridge formula?

___Please give general description:

4. If the State has completed a recent analysis of the fatigue effects of superheavy loads on its highway bridges, what fatigue model was used and what did the model show?

___Please give general description:

5. Please give your name, title and office telephone number:

George Snyder, INDOT
Bridge Rehab & Load Rating Engineer
317-232-5163

OVERSIZE || OVERWEIGHT

Vehicle Permitting Handbook

Motor Carrier Services Division - Permit Unit - 5252 Decatur Blvd. - Suite R - (313) 615-7320

www.in.gov/dor

SURVEY -- SUPERHEAVY LOAD CRITERIA FOR HIGHWAY BRIDGES

STATE OF IOWA

1. What is the basis for the State's gross vehicle weight limit (the weight over which a vehicle is not eligible for a permit, and is classified as a "superheavy load")?

___By Consensus
___AASHTO H-15 Design Trucks
___AASHTO H-20 or HS-20 Design Trucks
___State Overweight Trucks
_X__Other (Please give general description): Iowa does not have a maximum gross weight limit. Our only limit is on the axle weight. Gross axle weight cannot be over 20,000 pounds. In general, trucks with indivisible loads over 80,000 pounds require a heavy load permit. Iowa doesn't have a Superheavy load category. All indivisible loads over 80,000 pounds are treated the same and have the same route analysis performed.

2. If the State has a maximum vehicle loading intensity (weight per unit length, or weight per unit area), what is the basis for the load intensity?

___Please give general description: Iowa has not limit.

3. If the State has a bridge formula for the maximum weight on any group of two or more axles, what is the basis for the bridge formula?

____Please give general description: The Federal bridge formula is used for axle weights on the Interstate and Primary highway system. The Secondary highway system has a modified bridge formula for maximum axle weights. The modification of the Federal Bridge formula is as follows:
a. 4 axles at 18 feet or more between extreme axles is allowed a gross weight of 53,000 pounds.
b. 5 axles at 32 feet or more between extreme axles is allowed a gross weight of 67,500 pounds.
c. 6 or more axles at 41 feet or more between extreme axles is allowed a gross weight of 78,000 pounds.
d. For each foot of overall length less than the above, deduct 1,000 pounds from the gross weight.

4. If the State has completed a recent analysis of the fatigue effects of superheavy loads on its highway bridges, what fatigue model was used and what did the model show?

___Please give general description: Iowa has not done a fatigue study on superheavy loads.

5. Please give your name, title and office telephone number:

Scott Neubauer
Bridge Rating Engineer
Office of Bridges and Structures
515-239-1290

I don't know all the specifics about how the modified formula was determined. I can say that it was done to prevent the need to post more of Secondary highway bridges. I have attached a copy of some documentation from 1981, when the Iowa Code was changed to mirror the change in the 1975 Federal law for Legal loads.

We have a electronic routing system that allows us to check every bridge on a specified route for every heavy load permit request. We generate maps of bridges that cannot be crossed by common heavy load configurations from 80,000 to 156,000 pounds for our permit officers to use to issue permits. This helps reduce the number of permit reviews the bridge office has to perform. All permits over 156,000 pounds are reviewed by the bridge office with our electronic routing system.

Scott Neubauer, P.E.
Bridge Rating Engineer
Iowa Department of Transportation

Federal Legislation Bridge Formula / Maximum weights

The Federal government first intervened in the matter of sizes and weights with the enactment of the Federal Aid Highway Act of 1956. This act provided extensive funding for the completion of the national system of Interstate and defense highways over the following 16 years. The act also established maximum vehicle weights permissible on highways of the Interstate System. The weight limits were 18,000 lbs. on a single axle, 32,000 lbs. on a tandem axle, and 73,280 lbs. gross vehicle weight. A "grandfather clause" was included which allowed states with limits already greater than those specified to preserve the higher limits for their portions of the Interstate System.

In 1975 Federal legislation was passed that allowed states to increase maximum weight limits permitted on the Interstate System to 20,000 lbs. on a single axle, 34,000 lbs. on a tandem axle, and up to 80,000 lbs. maximum gross weight, depending on a formula governing the number of axles and axle spacing.

State Legislation Modified Bridge Formula

Iowa laws pertaining to truck lengths, weights, and axle loads were changed substantially by legislation passed in 1980 by the Iowa State Legislature. (H.F. 747)

Maximum legal single axle loads were increased from 18,000 lbs. to 20,000 lbs. Maximum legal tandem axle loads were increased from 32,000 lbs. to 34,000 lbs. The maximum total legal gross weight was increased to 80,000 lbs. The previous Code table, which listed the maximum legal gross load vs. the out to out spacing of any group of consecutive axles, was replaced by the new formula:

$$W=500(LN/N-1 + 12N + 36)$$

The weight formula was modified, for non-interstate highways, by legislation passed in 1981 by the Iowa State Legislature. (S.F. 159) This legislation went into effect on July 1, 1981.

Comparison of Federal & Iowa Weight Table

Distance In Feet*	Federal 4 Axles	Iowa 4 Axles	Difference	Federal 5 Axles	Iowa 5 Axles	Difference	Federal 6 Axles	Iowa 6 or More Axles	Difference	Federal 7 Axles
4										
5										
6										
7										
8										
8'1"										
9										
10	48,500	45,000	3,500							
11	49,500	46,000	3,500							
12	50,000	47,000	3,000							
13	50,500	48,000	2,500	56,000	48,500	7,500				
14	51,500	49,000	2,500	57,000	49,500	7,500				
15	52,000	50,000	2,000	57,500	50,500	7,000				
16	52,500	51,000	1,500	58,000	51,500	6,500				
17	53,500	52,000	1,500	58,500	52,500	6,000	64,000	54,000	10,000	
18	54,000	53,000	1,000	59,000	53,500	5,500	65,000	55,000	10,000	
19	54,500	54,500		60,000	54,500	5,500	65,500	56,000	9,500	
20	55,500	55,500		60,500	55,500	5,000	66,000	57,000	9,000	71,500
21	56,000	56,000		61,000	56,500	4,500	66,500	58,000	8,500	72,500
22	56,500	56,500		61,500	57,500	4,000	67,000	59,000	8,000	73,000
23	57,500	57,500		62,500	58,500	4,000	68,000	60,000	8,000	73,500
24	58,000	58,000		63,000	59,500	3,500	68,500	61,000	7,500	74,000
25	58,500	58,500		63,500	60,500	3,000	69,000	62,000	7,000	74,500
26	59,500	59,500		64,000	61,500	2,500	69,500	63,000	6,500	75,000
27	60,000	60,000		65,000	62,500	2,500	70,000	64,000	6,000	76,000
28	60,500	60,500		65,500	63,500	2,000	71,000	65,000	6,000	76,500
29	61,500	61,500		66,000	64,500	1,500	71,500	66,000	5,500	77,000
30	62,000	62,000		66,500	65,500	1,000	72,000	67,000	5,000	77,500
31	62,500	62,500		67,500	66,500	1,000	72,500	68,000	4,500	78,000
32	63,500	63,500		68,000	67,500	500	73,000	69,000	4,000	78,500
33	64,000	64,000		68,500	68,500		74,000	70,000	4,000	79,500
34	64,500	64,500		69,500	69,500		74,500	71,000	3,500	80,000
35	65,500	65,500		70,000	70,000		75,000	72,000	3,000	
36	68,000	68,000		70,500	70,500		75,500	73,000	2,500	
37	68,000	68,000		71,000	71,000		76,000	74,000	2,000	
38	68,000	68,000		72,000	72,000		77,000	75,000	2,000	
39	68,000	68,000		72,500	72,500		77,500	76,000	1,500	
40	68,500	68,500		73,000	73,000		78,000	77,000	1,000	
41	69,500	69,500		73,500	73,500		78,500	78,000	500	
42	70,000	70,000		74,000	74,000		79,000	79,000		
43	70,500	70,500		75,000	75,000		80,000	80,000		
44	71,500	71,500		75,500	75,500					
45	72,000	72,000		76,000	76,000					
46	72,500	72,500		76,500	76,500					
47	73,500	73,500		77,500	77,500					
48	74,000	74,000		78,000	78,000					
49	74,500	74,500		78,500	78,500					
50	75,500	75,500		79,000	79,000					
51	76,000	76,000		80,000	80,000					
52	76,500	76,500								
53	77,500	77,500								
54	78,000	78,000								
55	78,500	78,500								
56	79,500	79,500								
57	80,000	80,000								

SINGLE BRIDGE FORMULA

Vehicle Weight Law (S.F. 159) went into effect on July 1, 1981.
80,000 lb. Total legal gross weight
20,000 lb. Single axle load
34,000 lb. Tandem axle

The weight formula was modified for non-interstate highways.
Several hundred bridges would have been posted with a single weight formula.
The change essentially eliminated legal load configurations on non-interstate highways, that are more severe than the typical rating vehicles used for posting.

The interstate formula is:

$$W = 500\left(\frac{LN}{N-1} + 12N + 36\right) \qquad \text{(Nearest 500 lbs.)}$$

Where w= weight in pounds
L= length in feet between extreme axles
N= number of axles (if N>6 then use N=6)

The non interstate formula is modified as below,

Number of axles	L (feet)	W (lbs)
4	18	53,000
5	32	67,500
6 or more	41	78,000

For each foot of L less than above deduct 1,000 pounds from W.

SURVEY -- SUPERHEAVY LOAD CRITERIA FOR HIGHWAY BRIDGES

STATE OF KANSAS

1. What is the basis for the State's gross vehicle weight limit (the weight over which a vehicle is not eligible for a permit, and is classified as a "superheavy load")?

___By Consensus
___AASHTO H-15 Design Trucks
___AASHTO H-20 or HS-20 Design Trucks
___State Overweight Trucks
_X_Other (Please give general description):

150,000 lb GVW
22k (Single, Non-Drive), 24k (Single), 45k (Tandem), 60k (Triple), 65k (Quad)
"Standard And Annual Permit Gross Vehicle Weight Table" from KTC Handbook

2. If the State has a maximum vehicle loading intensity (weight per unit length, or weight per unit area), what is the basis for the load intensity?

___Please give general description:
"Standard And Annual Permit Gross Vehicle Weight Table" from KTC Handbook

3. If the State has a bridge formula for the maximum weight on any group of two or more axles, what is the basis for the bridge formula?

___Please give general description:
Set in Statute by State Legislature

4. If the State has completed a recent analysis of the fatigue effects of superheavy loads on its highway bridges, what fatigue model was used and what did the model show?

___Please give general description:

5. Please give your name, title and office telephone number:

John Culbertson
Bridge Evaluation Engineer
johnc@ksdot.org
(785) 296-4434

All Kansas permits are available through the "Kansas Trucking Connection" by phoning (785) 271-3145. These regulations may also be found at www.truckingKS.org. Permit information and applicable permit applications may be found on the "Kansas Trucking Connection" web page.

SURVEY -- SUPERHEAVY LOAD CRITERIA FOR HIGHWAY BRIDGES

STATE OF MAINE

1. What is the basis for the State's gross vehicle weight limit (the weight over which a vehicle is not eligible for a permit, and is classified as a "superheavy load")?
___By Consensus
___AASHTO H-15 Design Trucks
___AASHTO H-20 or HS-20 Design Trucks
___State Overweight Trucks
_x__Other (Please give general description): Below are the loads that are approved without and analysis from MaineDOT 2 axle truck or special mobile equipment º 39,100 lbs 3 " " " " " º 62,100 lbs 4 axle truck º 73,000 lbs 4 axle special mobile equipment º 110,000 lbs 4 axle tractor-trailer comb. º 120,000 lbs 5 " " " " º 130,000 lbs 6 " " " " º 140,000 lbs 7 " " " " º 159,000 lbs ** 8 " " " " º 177,000 lbs ** ** Single Axle Limits: when over 159,000lbs (167,000lbs) 1st axle º 12,000lbs (20,000lbs) 2nd, 3rd, and 4th axles º 26,000lbs (26,000lbs) (combined max weight 72,000lbs) 5th, 6th, and 7th axles º 27,000lbs (27,000lbs) (combined max weight 75,000lbs) There is an additional 3% tolerance on any axle or group of axles.

2. If the State has a maximum vehicle loading intensity (weight per unit length, or weight per unit area), what is the basis for the load intensity?
___Please give general description: There is no maximum vehicle load intensity

3. If the State has a bridge formula for the maximum weight on any group of two or more axles, what is the basis for the bridge formula?
___Please give general description: We try to keep the axle weights less than 25,000 pounds.

4. If the State has completed a recent analysis of the fatigue effects of superheavy loads on its highway bridges, what fatigue model was used and what did the model show? ___Please give general description: No fatigue analysis has been completed

5. Please give your name, title and office telephone number: Ben Foster Assistant Bridge Maintenance Engineer (207) 623-6224

SURVEY -- SUPERHEAVY LOAD CRITERIA FOR HIGHWAY BRIDGES

STATE OF MASSACHUSETTS

>>1. What is the basis for the State's gross vehicle weight limit (the weight over which a vehicle is not eligible for a permit, and is classified as a "superheavy load")?

2. If the State has a maximum vehicle loading intensity (weight per unit length, or weight per unit area), what is the basis for the load intensity?

3. If the State has a bridge formula for the maximum weight on any group of two or more axles, what is the basis for the bridge formula?

4. If the State has completed a recent analysis of the fatigue effects of superheavy loads on its highway bridges, what fatigue model was used and what did the model show?

5. Please give your name, title and office telephone number:

Please find answers to your questions below as follows:

1. Other, Any vehicle in excess of 130,000 lbs will be classified as an overload.
2. MassDOT does not have any criteria as you state.
3. MassDOT does not have any formula that we go by.
4. MassDOT has not completed any fatigue analysis reviews.
5. Gregory Krikoris, P.E.
   Acting Ratings & Overload Engineer
   617-973-7778

Greg

SURVEY -- SUPERHEAVY LOAD CRITERIA FOR HIGHWAY BRIDGES

STATE OF MICHIGAN

1. What is the basis for the State's gross vehicle weight limit (the weight over which a vehicle is not eligible for a permit, and is classified as a "superheavy load")?

___By Consensus
___AASHTO H-15 Design Trucks
___AASHTO H-20 or HS-20 Design Trucks
___State Overweight Trucks
___Other (Please give general description):

Michigan has 20 vehicle definitions that are considered our routine permits. If these are exceeded then the vehicle would be considered "overweight' and require special analysis. Please see Chapter 8 of our Bridge Analysis guide for more information, http://www.michigan.gov/mdot/0,1607,7-151-9625_24768_24773-132786--,00.html

2. If the State has a maximum vehicle loading intensity (weight per unit length, or weight per unit area), what is the basis for the load intensity?

___Please give general description:
Tire pressures are limited to 700 lbs/in except for construction vehicles.

3. If the State has a bridge formula for the maximum weight on any group of two or more axles, what is the basis for the bridge formula?

___Please give general description:
A single axle is limited to 60-kips. There are no other maximums for groups of axles for overweight permits as long as the structure being crossed is capable of carrying the load.

4. If the State has completed a recent analysis of the fatigue effects of superheavy loads on its highway bridges, what fatigue model was used and what did the model show?

___Please give general description:
None that I am aware of.

5. Please give your name, title and office telephone number:

Rebecca Curtis
Load Rating Engineer
Michigan Department of Transportation
517-322-1186

SURVEY -- SUPERHEAVY LOAD CRITERIA FOR HIGHWAY BRIDGES

STATE OF MISSISSIPPI

Dr. Bourland,

The Ms Dept of Transportation has no policy limiting the weight of any vehicle. The maximum legal weight, no permits required, is a gross weight of 80,000lbs. Above that limit a permit must be applied for stating their axle weights and configurations, and also the routes to be traveled. All bridges located along that route are analyzed for that vehicle's particular weight, regardless of how much that weight is. If the bridge can carry without being overstressed, the permit is approved. Questions 1, 2, & 3 would have to be answered with "not applicable"; and, "No" would be the answer to question 4. Apologies if we are of no help with your survey.

If we can be of any other assistance feel free to contact me.

Lonny Pigott

MDOT Bridge Inspection Program Manager

601-359-7198

SURVEY -- SUPERHEAVY LOAD CRITERIA FOR HIGHWAY BRIDGES

STATE OF MISSOURI

1. What is the basis for the State's gross vehicle weight limit (the weight over which a vehicle is not eligible for a permit, and is classified as a "superheavy load")?

___By Consensus
___AASHTO H-15 Design Trucks
___AASHTO H-20 or HS-20 Design Trucks
___State Overweight Trucks
_x__Other (Please give general description): Greater than 160,000 lbs., but can be less than 160,000 pounds if it doesn't meet routine permit regulations. See the 2009OSOWRegBook[1].pdf document that's attached below.

2. If the State has a maximum vehicle loading intensity (weight per unit length, or weight per unit area), what is the basis for the load intensity?

___Please give general description: See the 2009OSOWRegBook[1].pdf document that's attached below for the answer(s) to this question.

3. If the State has a bridge formula for the maximum weight on any group of two or more axles, what is the basis for the bridge formula?

___Please give general description: We use a percentage of the Federal Bridge Formula that varies depending on the axle configuration.

4. If the State has completed a recent analysis of the fatigue effects of superheavy loads on its highway bridges, what fatigue model was used and what did the model show?

___Please give general description: We haven't recently completed an analysis of the fatigue effects of superheavy loads on our highway bridges.

5. Please give your name, title and office telephone number:

Chad Daniel, P.E.
Bridge Rating and Inventory Engineer
(573) 751-4365

SURVEY -- SUPERHEAVY LOAD CRITERIA FOR HIGHWAY BRIDGES

STATE OF NEBRASKA

1. What is the basis for the State’s gross vehicle weight limit (the weight over which a vehicle is not eligible for a permit, and is classified as a “superheavy load”)?

___By Consensus
___AASHTO H-15 Design Trucks
___AASHTO H-20 or HS-20 Design Trucks
_X__State Overweight Trucks
_X__Other (Please give general description):
Generally will not consider axles over than 20 kips (State law)

2. If the State has a maximum vehicle loading intensity (weight per unit length, or weight per unit area), what is the basis for the load intensity?

___Please give general description:
Nebraska uses the Federal bridge formula which was adopted in the state law using the axles spacing and weight

3. If the State has a bridge formula for the maximum weight on any group of two or more axles, what is the basis for the bridge formula?

___Please give general description:

We use Federal Bridge formula with some exception to some agriculture equipments which stated in state law #60-6-294 (Let me know if a copy is needed)

4. If the State has completed a recent analysis of the fatigue effects of superheavy loads on its highway bridges, what fatigue model was used and what did the model show?

___Please give general description: We have not done such analysis

5. Please give your name, title and office telephone number:

Fouad Jaber, PE
Nebraska department Of Road
Assistant State Bridge Engineer
402-479-3967

SURVEY -- SUPERHEAVY LOAD CRITERIA FOR HIGHWAY BRIDGES

STATE OF NEVADA

1. What is the basis for the State's gross vehicle weight limit (the weight over which a vehicle is not eligible for a permit, and is classified as a "superheavy load")?

___By Consensus
___AASHTO H-15 Design Trucks
___AASHTO H-20 or HS-20 Design Trucks
___State Overweight Trucks
__X_Other (Please give general description): GCW >= 250,000 lbs.

2. If the State has a maximum vehicle loading intensity (weight per unit length, or weight per unit area), what is the basis for the load intensity?

_X__Please give general description:

Overdimensional weight limits and vehicle geometric criteria are dictated by Nevada Administrative Code.

3. If the State has a bridge formula for the maximum weight on any group of two or more axles, what is the basis for the bridge formula?

_X__Please give general description:

NDOT formulas are the Caltrans color chart formulas (purple, green and orange) with bonus factors and tire weight limit (800 lb/in).

4. If the State has completed a recent analysis of the fatigue effects of superheavy loads on its highway bridges, what fatigue model was used and what did the model show?

___Please give general description:

5. Please give your name, title and office telephone number:

David A. Severns, P.E.
Asst. Chief Structures Engineer
NDOT Bridge Inventory/Inspection
775-888-7545

SURVEY -- SUPERHEAVY LOAD CRITERIA FOR HIGHWAY BRIDGES

STATE OF NEW JERSEY

1. What is the basis for the State's gross vehicle weight limit (the weight over which a vehicle is not eligible for a permit, and is classified as a "superheavy load")?
Any vehicle having a Gross Vehicle Weight 80,000 lbs or more requires a permit.

___By Consensus
___AASHTO H-15 Design Trucks
___AASHTO H-20 or HS-20 Design Trucks
_X__State Overweight Trucks
___Other (Please give general description):

2. If the State has a maximum vehicle loading intensity (weight per unit length, or weight per unit area), what is the basis for the load intensity?
Weight per inch of tire width = 800 lbs

___Please give general description:

3. If the State has a bridge formula for the maximum weight on any group of two or more axles, what is the basis for the bridge formula?

___Please give general description: Same as Federal Bridge Formula

4. If the State has completed a recent analysis of the fatigue effects of superheavy loads on its highway bridges, what fatigue model was used and what did the model show?
None
___Please give general description:

5. Please give your name, title and office telephone number:
Gregory T. Renman, Manager Structural Evaluation

SURVEY -- SUPERHEAVY LOAD CRITERIA FOR HIGHWAY BRIDGES

STATE OF NEW MEXICO

1. What is the basis for the State's gross vehicle weight limit (the weight over which a vehicle is not eligible for a permit, and is classified as a "superheavy load")?

___By Consensus
___AASHTO H-15 Design Trucks
___AASHTO H-20 or HS-20 Design Trucks
_X__State Overweight Trucks
__X_Other (Please give general description):
New Mexico DOT looks at vehicles over 140,000 GVW as superloads. Vehicles both over legal and over 140,00 GVW have to comply to the NMDOT bridge weight limit map. New Mexico uses weight factors for non standard gages. There are some exceptions with self propelled units from the limits on the NMDOT Bridge weight limit maps.

2. If the State has a maximum vehicle loading intensity (weight per unit length, or weight per unit area), what is the basis for the load intensity? Yes

The NMDOT most generally required vehicles to adhere to the NMDOT weight limit map to distribute weight. Some exceptions for self propelled units exist.

3. If the State has a bridge formula for the maximum weight on any group of two or more axles, what is the basis for the bridge formula? Don't use the bridge formula for the most part.

4. If the State has completed a recent analysis of the fatigue effects of superheavy loads on its highway bridges, what fatigue model was used and what did the model show? No analysis/study of fatigue on highway bridges.

5. Please give your name, title and office telephone number:
Jimmy D. Camp, P.E.
Engineering Support Division
Bridge, Drainage, Traffic Support & Pavement Design
New Mexico DOT
PO Box 1149, Room 224
Santa Fe, NM 87504-1149
Phone No. (505)827-5532

SURVEY -- SUPERHEAVY LOAD CRITERIA FOR HIGHWAY BRIDGES

STATE OF NORTH CAROLINA

1. What is the basis for the State's gross vehicle weight limit (the weight over which a vehicle is not eligible for a permit, and is classified as a "superheavy load")?

___By Consensus
___AASHTO H-15 Design Trucks
___AASHTO H-20 or HS-20 Design Trucks
___State Overweight Trucks
_x__Other (Please give general description):

Any vehicle larger than the following are considered "Superload".

112,000 pounds on 5 Axles
120,000 pounds on 6 Axles
132,000 pounds on 7 Axles.

A minimum of 51'-0" from steer axle to rear trailer axle.

Maximum Axle Group weights are:
    Single = 25,000 pounds
    Tandem = 50,000 pounds
    Tridem = 60,000 pounds
    Quad = 68,000 pounds

2. If the State has a maximum vehicle loading intensity (weight per unit length, or weight per unit area), what is the basis for the load intensity?

NC does not have a maximum vehicle load intensity. Permit Loads do not exceed Operating Stress Level.

3. If the State has a bridge formula for the maximum weight on any group of two or more axles, what is the basis for the bridge formula?

NC does not use a bridge formula for Permit Loads. However, maximum axle loads for the following groups are established:
Tandem = 50,000 pounds
Tridem = 60,000 pounds
Quad = 68,000 pounds

4. If the State has completed a recent analysis of the fatigue effects of superheavy loads on its highway bridges, what fatigue model was used and what did the model show?

NC has not completed a fatigue analysis for Permit Loads.
___Please give general description:

5. Please give your name, title and office telephone number:

Don Idol
Assistant State Bridge Inspection Engineer (In charge of Load Rating Group and evaluating bridges for overweight permits)
Phone: (919)835-8226

SURVEY -- SUPERHEAVY LOAD CRITERIA FOR HIGHWAY BRIDGES

STATE OF NORTH DAKOTA

1. What is the basis for the State's gross vehicle weight limit (the weight over which a vehicle is not eligible for a permit, and is classified as a "superheavy load")?

___By Consensus
___AASHTO H-15 Design Trucks
___AASHTO H-20 or HS-20 Design Trucks
___State Overweight Trucks
_X_Other (Please give general description):

> On heavy loads (loads that do not fit the Federal Bridge Formula), permit availability is determined by a bridge analysis on the actual route that is selected. It the load cannot safely cross a bridge, and a different route cannot be found, the permit is denied.

2. If the State has a maximum vehicle loading intensity (weight per unit length, or weight per unit area), what is the basis for the load intensity?

___Please give general description:

> The general rule for Highway permits is 600#/inch of wheel width for tandems but they must satisfy the FHWA bridge formula or have an analysis done on the bridges on the route prior to approval. Mobile cranes are allowed to go up to 650 #/inch but they go thru an analysis for all bridges in the state and the permit shows them which bridges are "do not cross".

3. If the State has a bridge formula for the maximum weight on any group of two or more axles, what is the basis for the bridge formula?

___Please give general description:

> The NDDOT used the FHWA Bridge Formula for permits. If a vehicle does not meet that formula, it requires a bridge analysis.

4. If the State has completed a recent analysis of the fatigue effects of superheavy loads on its highway bridges, what fatigue model was used and what did the model show?

___Please give general description:

> We have not investigated fatigue modeling or fatigue effects. If an overload cannot cross a structure without surpassing the Operating Rating of the bridge, it is not allowed to cross that structure.

5. Please give your name, title and office telephone number:

Gary L. Doerr PE
Bridge Management Section Leader
NDDOT
608 E Boulevard Ave
Bismarck, ND 58505-0700
Phone 701-328-4844
Fax 701-328-0310
gldoerr@nd.gov

SURVEY -- SUPERHEAVY LOAD CRITERIA FOR HIGHWAY BRIDGES

STATE OF OKLAHOMA

1. What is the basis for the State's gross vehicle weight limit (the weight over which a vehicle is not eligible for a permit, and is classified as a "superheavy load")?

___By Consensus
___AASHTO H-15 Design Trucks
___AASHTO H-20 or HS-20 Design Trucks
___State Overweight Trucks
_X__Other (Please give general description): Regardless of the design load, weight restrictions are based on the computed operating rating
http://www.okladot.state.ok.us/bridge/lpb/index.htm

2. If the State has a maximum vehicle loading intensity (weight per unit length, or weight per unit area), what is the basis for the load intensity?

We do not have a maximum vehicle loading intensity

N/A___Please give general description:

3. If the State has a bridge formula for the maximum weight on any group of two or more axles, what is the basis for the bridge formula?

We use the federal bridge formula for legal loads - permit loads are restricted to 20 pounds maximum___Please give general description:

4. If the State has completed a recent analysis of the fatigue effects of superheavy loads on its highway bridges, what fatigue model was used and what did the model show?

No survey

N/A___Please give general description:

5. Please give your name, title and office telephone number:
Walter (Walt) Peters, P.E.
Assistant Bridge Engineer - Operations
Oklahoma Department of Transportation
Bridge Division
200 N.E. 21st Street
Oklahoma City, OK 73105-3204
405-521-2606
405-522-0134 Fax
wpeters@odot.org

SURVEY -- SUPERHEAVY LOAD CRITERIA FOR HIGHWAY BRIDGES

STATE OF OREGON

1. What is the basis for the State's gross vehicle weight limit (the weight over which a vehicle is not eligible for a permit, and is classified as a "superheavy load")?

___By Consensus
___AASHTO H-15 Design Trucks
___AASHTO H-20 or HS-20 Design Trucks
___State Overweight Trucks
X___Other (Please give general description):

Any vehicle that exceeds weight tables 3,4, or 5 is classified as a "Superheavy Load"

2. If the State has a maximum vehicle loading intensity (weight per unit length, or weight per unit area), what is the basis for the load intensity?

___Please give general description:

Each weight table has a general description, and details the axle weights and limits for axle combinations.

3. If the State has a bridge formula for the maximum weight on any group of two or more axles, what is the basis for the bridge formula?

___Please give general description:

The weight tables have been in place for many years. Each table is different so there may have been formulas that were used in the development of the weight tables, but the formulas themselves are not used directly.

4. If the State has completed a recent analysis of the fatigue effects of superheavy loads on its highway bridges, what fatigue model was used and what did the model show?

___Please give general description:

We have not completed a recent analysis of the fatigue effects of superheave loads on highway bridges.

5. Please give your name, title and office telephone number:

Bert Hartman, P.E.
Bridge Program Unit Manager
503-986-3395

The weight tables have been in place for many years, well before I got involved with load rating. I do not know the criteria that was used.

Here is the link to the website that explains the weight tables and has links to the tables:

http://www.oregon.gov/ODOT/MCT/OD.shtml#Weight_Tables

SURVEY -- SUPERHEAVY LOAD CRITERIA FOR HIGHWAY BRIDGES

STATE OF RHODE ISLAND

1. What is the basis for the State's gross vehicle weight limit (the weight over which a vehicle is not eligible for a permit, and is classified as a "superheavy load")?

___By Consensus
___AASHTO H-15 Design Trucks
___AASHTO H-20 or HS-20 Design Trucks
___State Overweight Trucks
_X__Other (Please give general description): Trucks in excess of 200,000 lbs. are considered "Superheavy" Loads and are required to have a Structural Analysis performed by a Professional Engineering Co. for All structures along specific route.

2. If the State has a maximum vehicle loading intensity (weight per unit length, or weight per unit area), what is the basis for the load intensity?

_X__Please give general description: Loads in excess of 80,000 lbs. and/or Axle Weights greater than 22.4 kips must apply for a OS/OW Permit.

3. If the State has a bridge formula for the maximum weight on any group of two or more axles, what is the basis for the bridge formula?

_X__Please give general description: Fed FORMULA B.

4. If the State has completed a recent analysis of the fatigue effects of superheavy loads on its highway bridges, what fatigue model was used and what did the model show?

___Please give general description: Not performed to date.

5. Please give your name, title and office telephone number:

ENGINEERING REVIEW OS/OW PERMITS (RIDOT):
David Morgan
Project Manager/Bridge Engineering Section
Rhode Island Department of Transportation
2 Capitol Hill, Rm. 100
Providence, RI 02903
Phone: 401-222-2053 X4285 Fax: 401-222-1271
e-mail: dmorgan@dot.ri.gov
Website: https://www.ri.gov/DMV/OSOW/dashboard/applicant/login

SURVEY -- SUPERHEAVY LOAD CRITERIA FOR HIGHWAY BRIDGES

STATE OF TENNESSEE

Dear Sir or Madam:

Mr. Wasserman requested that I respond to your survey questions. I manage the Structure Inventory and Appraisal Office for the Tennessee DOT. In addition, my office performs all load rating and weight posting calculations and we also perform bridge analysis for heavy permit vehicles.

I will answer your survey as follows:

1. What is the basis for the State's gross vehicle weight limit (the weight over which a vehicle is not eligible for a permit, and is classified as a "superheavy load")?

ANSWER: This question is unclear to us. Tennessee does not have a fixed weight whereby a vehicle is not eligible for a permit. In addition, the term "super-heavy load" is undefined. This is not a term that we use in Tennessee, therefore, a definition of what you mean would have been helpful.

Since I am not sure exactly what information you seek with this question, I will simply explain our procedure for issuing overweight permits in Tennessee:

Tennessee has two (2) basic types of permits. One type is called an "annual" permit. As the name implies, annual permits are valid for a time period of one year. There are several classes of annual permit (for boats, mobile homes, etc.) however, for overweight loads, they are available at the 120,000 lb (60 ton) and 150,000 lb (75 ton) levels. Annual permits have certain fixed restrictions. For example, axle weights cannot exceed 20,000 lbs per axle and the vehicle cannot cross any weight posted bridge. Otherwise, movement is unrestricted.

The other type of overweight permit is a "Single-Trip" permit. As the name implies, this permit is only valid for a single trip inside a six (6) day time window. These "Single-Trip" permits may require that a bridge analysis be performed. Our software system contains a screening algorithm based upon the Federal Gross Weight formula and a permissible ratio curve that is a function of the overall gross weight of the vehicle. If the maximum axle weight ratio is less than the permissible ratio, a bridge analysis is not required and our Permit Office may simply go ahead and issue the permit. However, if the ratio exceeds the permissible ratio, our software system routes the permit request to the bridge office (i.e. my office) so that a bridge analysis may be performed. The bridge office will conduct the bridge analysis and recommend either approval or rejection of the request based upon the outcome.

Because the bridge analysis screening is algorithm based, there is no fixed weight whereby a bridge analysis is required. However, as a general rule, the majority of the permits routed to the bridge office exceed 150,000 lbs in gross vehicle weight. However, lighter vehicles are sometimes routed to the bridge office in cases where they are short (in terms of overall length) and have heavy axle weights.

For many of these permit requests, below about 300,000-400,000 lbs in gross vehicle weight (GVW), the bridge analysis may be handled in a fairly routine manner by our software system. Very heavy vehicle requests, in the 500,000 lb to 1,000,000+ lb GVW range, require special analysis and processing. Often Finite Element analysis methods are required for these permits. Perhaps this type of permit is what you mean by "super-heavy load"?

2. If the State has a maximum vehicle loading intensity (weight per unit length, or weight per unit area), what is the basis for the load intensity?
ANSWER: Tennessee does not have a maximum vehicle load intensity. However, a somewhat similar thing is achieved by means of our weight screening algorithm. Also, Tennessee does limit axle weights to a maximum of 20,000 lbs per axle except in cases of fixed axle loads for which the axle weights cannot be reduced. For example, in the case of a mobile crane which was designed with axles weights greater than 20,000 lbs and which cannot be reduced as a result.

3. If the State has a bridge formula for the maximum weight on any group of two or more axles, what is the basis for the bridge formula?
ANSWER: As noted above, the Federal Gross Weight formula is used in combination with an allowable ratio curve (as a screening tool) combined with a general limitation of 20,000 lbs per axle for most vehicles. Note that our screening method has been validated by a research project that was conducted by the University of Tennessee in Knoxville. See the attached PDF file which contains an overview of this research.

4. If the State has completed a recent analysis of the fatigue effects of superheavy loads on its highway bridges, what fatigue model was used and what did the model show?
ANSWER: To my knowledge, Tennessee has not conducted any research into the fatigue effects of overweight permit vehicles.

5. Please give your name, title and office telephone number:
Terry D. Leatherwood, P.E.
Civil Engineering Manager 1
Tennessee Department of Transportation
Structure Inventory and Appraisal Office
Suite 1200, James K. Polk Building
505 Deaderick Street
Nashville, TN 37243-0338
Tel: (615) 741-0806
Fax: (615) 532-5990
Email: Terry.D.Leatherwood@tn.gov

SURVEY -- SUPERHEAVY LOAD CRITERIA FOR HIGHWAY BRIDGES

STATE OF WASHINGTON

1. What is the basis for the State's gross vehicle weight limit (the weight over which a vehicle is not eligible for a permit, and is classified as a "superheavy load")?
___By Consensus
___AASHTO H-15 Design Trucks
___AASHTO H-20 or HS-20 Design Trucks
___State Overweight Trucks
_ X _Other (Please give general description):

There is no limit for a permit load, however, it has to meet State regulations and the bridges/roadways can carry the load.

2. If the State has a maximum vehicle loading intensity (weight per unit length, or weight per unit area), what is the basis for the load intensity? See answer to question 3.

___Please give general description:

3. If the State has a bridge formula for the maximum weight on any group of two or more axles, what is the basis for the bridge formula?

___Please give general description:

4. If the State has completed a recent analysis of the fatigue effects of superheavy loads on its highway bridges, what fatigue model was used and what did the model show? No

___Please give general description:

5. Please give your name, title and office telephone number:

Mohamad Al-Salman

(360)570-2567

We load our structures for a fictitious overload vehicle that encompasses a good percentage of our permits. Based on the rating factors of the overload vehicle, we restrict structures. We compare the permit request to the restricted list, and ensure it meets state RCW, if it meets them, then they will be approved. For cases where the permit request exceeds the limits of rated vehicle, then we will do special analysis.

SURVEY -- SUPERHEAVY LOAD CRITERIA FOR HIGHWAY BRIDGES

STATE OF WYOMING

1. What is the basis for the State's gross vehicle weight limit (the weight over which a vehicle is not eligible for a permit, and is classified as a "superheavy load")?

___By Consensus
___AASHTO H-15 Design Trucks
___AASHTO H-20 or HS-20 Design Trucks
___State Overweight Trucks
_X_Other (Please give general description):
Per State Statutes, the gross weight limit is 117,000 lbs; anything over 117,000 lbs requires a special analysis.

2. If the State has a maximum vehicle loading intensity (weight per unit length, or weight per unit area), what is the basis for the load intensity?

___Please give general description:

The State does not use a maximum vehicle loading intensity.

3. If the State has a bridge formula for the maximum weight on any group of two or more axles, what is the basis for the bridge formula?

___Please give general description:

The allowable load for any given configuration will not generate a higher bending stress in a 50' simple span than that produced by an HS20 truck, without impact, at the operating level.

If the load exceeds the above formula, we utilize a routing program that can analyze each bridge for any given truck weight and axle configuration.

4. If the State has completed a recent analysis of the fatigue effects of superheavy loads on its highway bridges, what fatigue model was used and what did the model show?

___Please give general description:

No analysis of fatigue effects has been initiated.

5. Please give your name, title and office telephone number:
Paul Cortez, P.E
Bridge Operations Engineer
Wyoming Department of Transportation
307-777-4427

SURVEY INSTRUMENT

Dear ________________,

In conjunction with work on Texas Department of Transportation Project 0-6438, Lamar University is conducting a survey concerning superheavy load criteria for highway bridges.

Please complete the following short survey and either fax or email it to me at your earliest convenience, but not later than the end of the day, Monday, February 15, 2010.

To fax the form, please send to: 409 880 8121, Attn: Mark Bourland

To email the form, please send to: mark.bourland@lamar.edu

Please call or email me if you have any questions or comments. Thank you for your help and cooperation.

Mark C. Bourland, Ph.D.
Lamar University
Assistant Professor of Civil Engineering
Phone: 409 880 8765
Email: mark.bourland@lamar.edu

SURVEY -- SUPERHEAVY LOAD CRITERIA FOR HIGHWAY BRIDGES

STATE OF ____________

1. What is the basis for the State's gross vehicle weight limit (the weight over which a vehicle is not eligible for a permit, and is classified as a "superheavy load")?

___By Consensus
___AASHTO H-15 Design Trucks
___AASHTO H-20 or HS-20 Design Trucks
___State Overweight Trucks
___Other (Please give general description):

2. If the State has a maximum vehicle loading intensity (weight per unit length, or weight per unit area), what is the basis for the load intensity?

___Please give general description:

3. If the State has a bridge formula for the maximum weight on any group of two or more axles, what is the basis for the bridge formula?

___Please give general description:

4. If the State has completed a recent analysis of the fatigue effects of superheavy loads on its highway bridges, what fatigue model was used and what did the model show?

___Please give general description:

5. Please give your name, title and office telephone number:

APPENDIX 4A: HETS

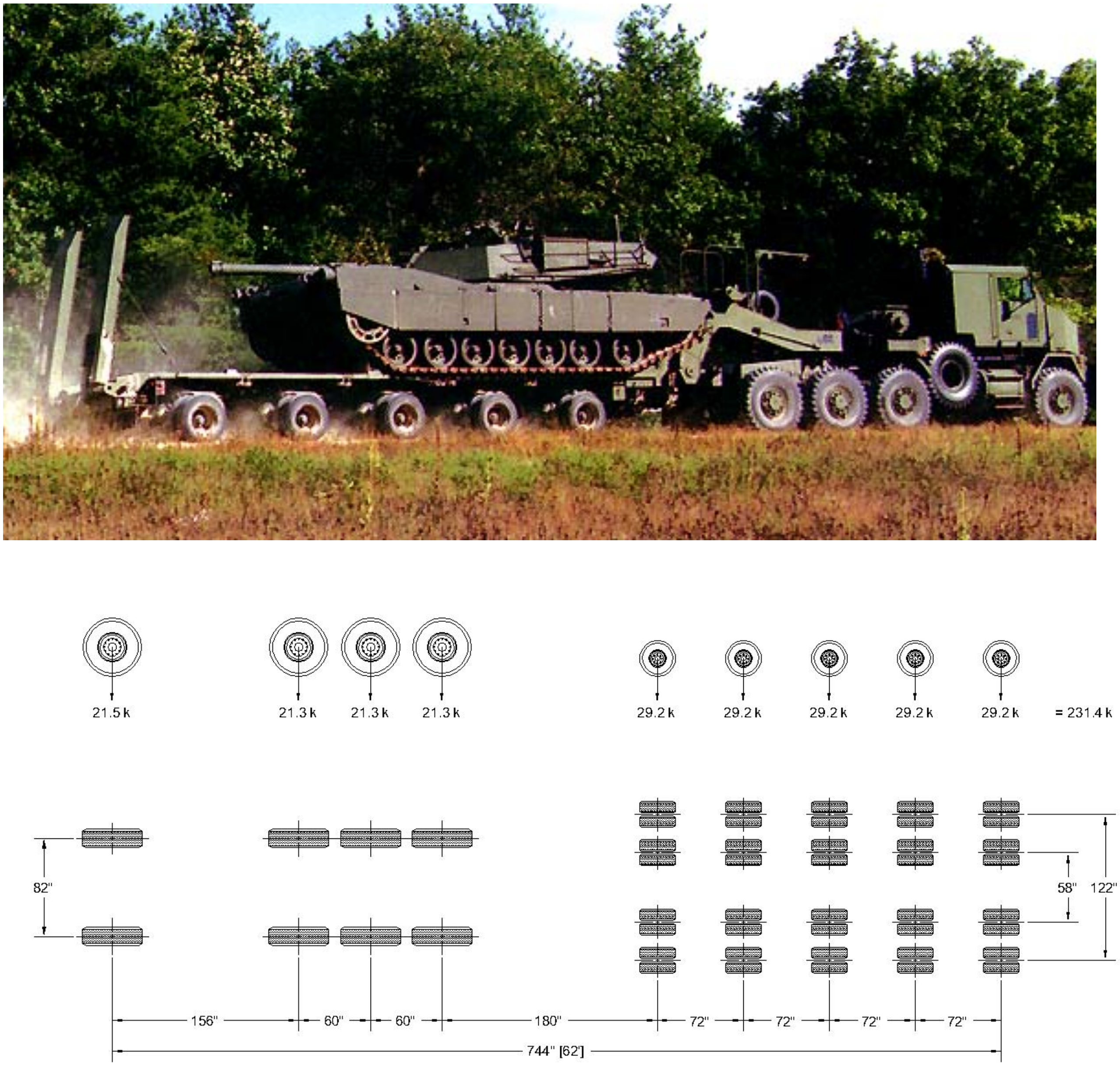


Figure 4A-1. Heavy Equipment Transport System (HETS) Loading.

Table 4A-1. HETS Loading Orientation 1 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No.				
		1	2	3	4	5
138	3	0.442	0.310	0.211	0.085	-0.048
	4	0.272	0.234	0.211	0.168	0.114
402	4	0.306	0.248	0.219	0.153	0.074
	5	0.317	0.253	0.217	0.148	0.065
362	4	0.281	0.238	0.220	0.165	0.096
	5	0.259	0.270	0.222	0.130	0.020

Table 4A-2. HETS Loading Orientation 1 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No.				
		1	2	3	4	5
138	90-96	0.449	0.326	0.180	0.071	-0.026
402	356-364	0.510	0.355	0.174	0.039	-0.079
362	222-228	0.548	0.366	0.187	0.025	-0.126

Table 4A-3. HETS Loading Orientation 2 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No.				
		1	2	3	4	5
402	4	0.263	0.193	0.161	0.193	0.189
	5	0.265	0.195	0.162	0.191	0.187

Table 4A-4. HETS Loading Orientation 2 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No.				
		1	2	3	4	5
402	362-368	0.230	0.266	0.250	0.161	0.093

APPENDIX 4B: 3S2

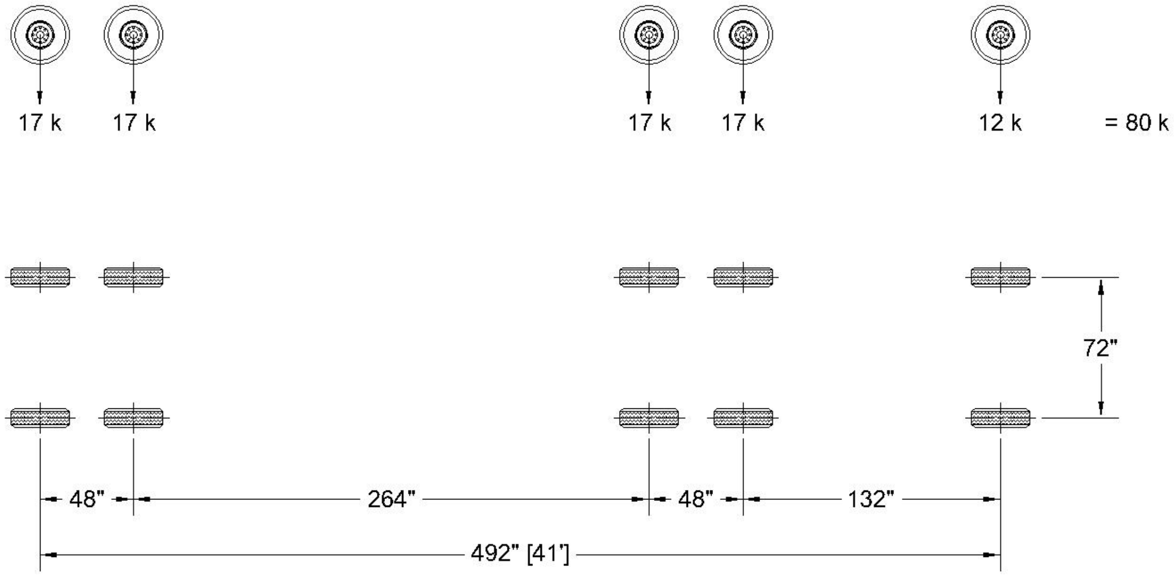


Figure 4B-1. AASHTO 3S2 (3S2) Unit Loading.

Table 4B-1. 3S2 Loading Orientation 1 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No.				
		1	2	3	4	5
114	3	0.482	0.351	0.210	0.057	-0.099
	4	0.282	0.258	0.213	0.156	0.090
377	4	0.306	0.281	0.223	0.141	0.050
	5	0.333	0.293	0.222	0.128	0.023

Table 4B-2. 3S2 Loading Orientation 1 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No.				
		1	2	3	4	5
114	92-98	0.517	0.328	0.168	0.049	-0.061
377	362-368	0.597	0.353	0.153	0.013	-0.116

Table 4B-3. 3S2 Loading Orientation 2 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No.				
		1	2	3	4	5
114	3	0.336	0.215	0.190	0.162	0.096
	4	0.258	0.191	0.189	0.192	0.171

Table 4B-4. 3S2 Loading Orientation 2 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No.				
		1	2	3	4	5
114	92-98	0.230	0.266	0.250	0.161	0.093

APPENDIX 4C: FIELD TEST TRUCK

Figure 4C-1. TxDOT Unit Loading.

Table 4C-1. TxDOT Loading Orientation 1 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No.				
		1	2	3	4	5
128	3	0.278	0.217	0.167	0.185	0.153
	4	0.241	0.198	0.167	0.198	0.196
381	4	0.261	0.193	0.151	0.198	0.197
	5	0.270	0.196	0.147	0.195	0.192
356	4	0.258	0.192	0.151	0.198	0.201
	5	0.258	0.195	0.137	0.193	0.189
68	3	0.291	0.224	0.140	0.200	0.145
	4	0.234	0.201	0.177	0.197	0.191
188	3	0.288	0.201	0.140	0.191	0.179
	4	0.267	0.182	0.125	0.210	0.215
408	4	0.276	0.192	0.133	0.201	0.199
	5	0.268	0.192	0.142	0.199	0.198

Table 4C-2. TxDOT Loading Orientation 1 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No.				
		1	2	3	4	5
128	102-108	0.217	0.247	0.242	0.172	0.121
381	362-368	0.217	0.264	0.261	0.161	0.097
356	222-228	0.252	0.252	0.228	0.168	0.100
68	50-56	0.197	0.270	0.277	0.164	0.091
188	142-148	0.182	0.254	0.267	0.178	0.120
408	362-368	0.221	0.261	0.254	0.164	0.100

Table 4C-3. TxDOT Loading Orientation 2 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No.				
		1	2	3	4	5
128	3	0.469	0.342	0.212	0.064	-0.087
	4	0.270	0.252	0.215	0.163	0.100
381	4	0.294	0.271	0.224	0.148	0.062
	5	0.328	0.287	0.223	0.132	0.029
356	4	0.278	0.266	0.225	0.156	0.076
	5	0.357	0.306	0.228	0.117	-0.009

Table 4C-4. TxDOT Loading Orientation 2 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No.				
		1	2	3	4	5
128	84-90	0.501	0.330	0.174	0.053	-0.058
381	364-370	0.576	0.355	0.161	0.019	-0.111
356	222-228	0.606	0.382	0.179	0.000	0.166

APPENDIX 4D: 11 AXLE COMBO SPACING (11ACS)

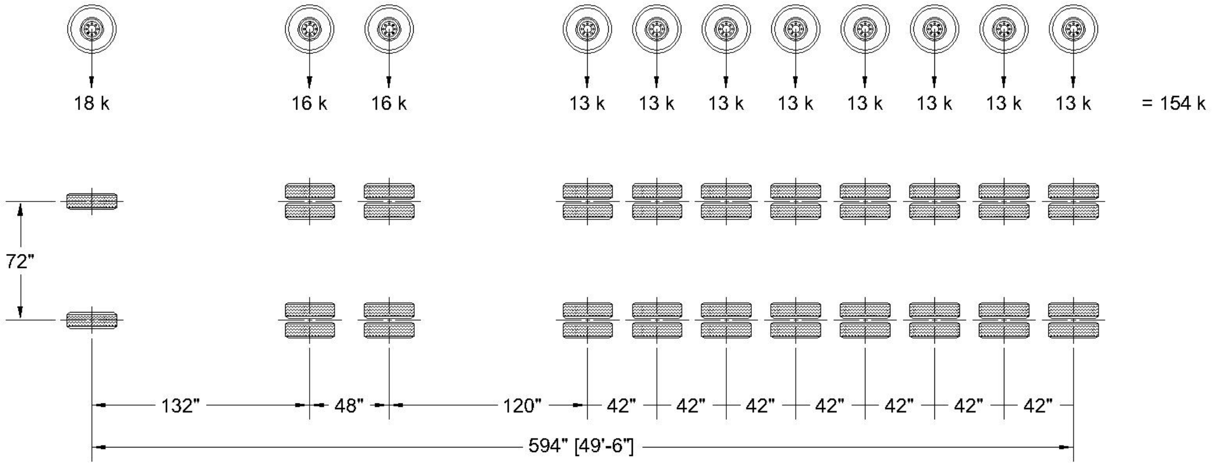


Figure 4D-1. 11 Axle Combo Spacing (11ACS) Unit Loading.

Table 4D-1. 11ACS Loading Orientation 1 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No. 1	2	3	4	5
127	3	0.270	0.216	0.168	0.187	0.159
	4	0.238	0.199	0.166	0.199	0.198
391	4	0.262	0.195	0.144	0.199	0.200
	5	0.263	0.196	0.145	0.198	0.198
355	4	0.257	0.192	0.144	0.201	0.206
	5	0.283	0.195	0.128	0.197	0.196

Table 4D-2. 11ACS Loading Orientation 1 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No. 1	2	3	4	5
127	90-96	0.206	0.248	0.255	0.170	0.120
391	362-368	0.203	0.261	0.271	0.165	0.099
355	222-228	0.243	0.195	0.128	0.197	0.196

Table 4D-3. 11ACS Loading Orientation 2 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No. 1	2	3	4	5
127	3	0.475	0.348	0.211	0.060	-0.095
	4	0.272	0.256	0.215	0.161	0.097
391	4	0.304	0.283	0.226	0.141	0.046
	5	0.315	0.287	0.224	0.137	0.037
355	4	0.274	0.271	0.227	0.155	0.073
	5	0.356	0.314	0.231	0.115	-0.016

Table 4D-4. 11ACS Loading Orientation 2 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No. 1	2	3	4	5
127	88-94	0.520	0.327	0.165	0.048	-0.060
391	362-368	0.595	0.353	0.153	0.013	-0.114
355	222-228	0.618	0.386	0.177	-0.006	-0.175

APPENDIX 4E: 3 SINGLE AXLE COMBO (3SAC)

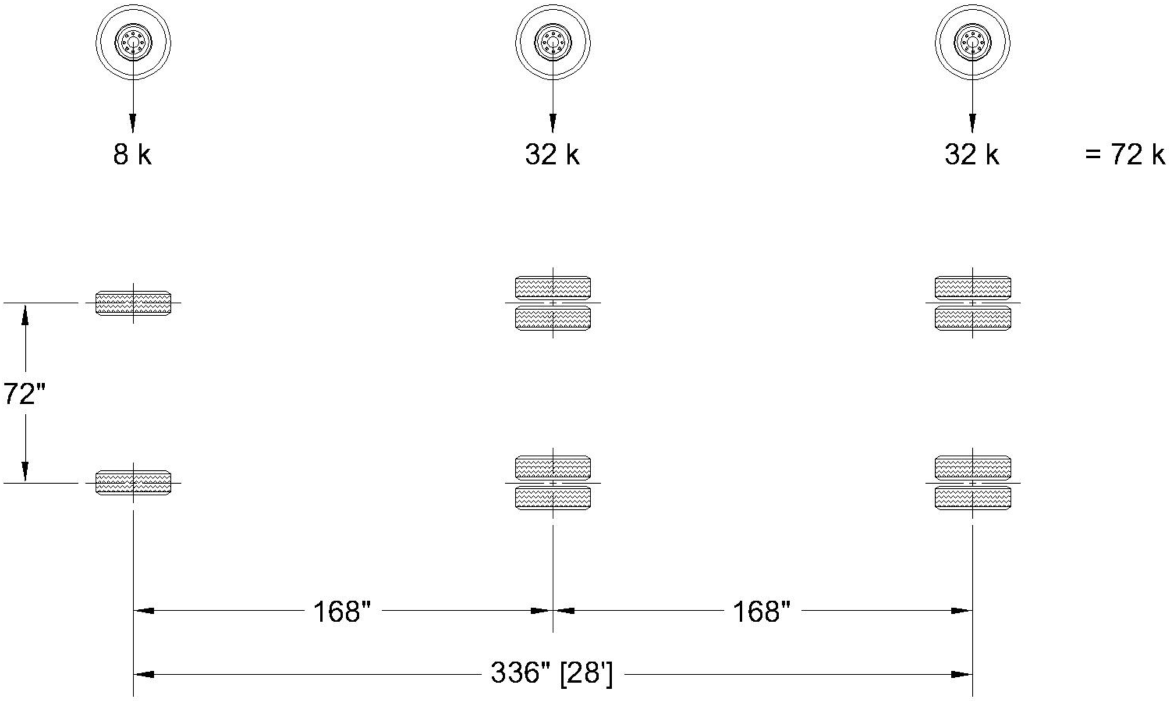


Figure 4E-1. 3 Single Axle Combo (3SAC) Unit Loading.

Table 4E-1. 3SAC Loading Orientation 1 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No. 1	2	3	4	5
112	3	0.267	0.217	0.173	0.186	0.157
	4	0.236	0.200	0.171	0.197	0.196
376	4	0.257	0.197	0.150	0.198	0.199
	5	0.263	0.199	0.147	0.196	0.196
345	4	0.260	0.189	0.140	0.203	0.208
	5	0.288	0.192	0.123	0.199	0.199

Table 4E-2. 3SAC Loading Orientation 1 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No. 1	2	3	4	5
112	90-96	0.198	0.253	0.286	0.166	0.114
376	350-356	0.192	0.268	0.289	0.158	0.093
345	222-228	0.244	0.247	0.228	0.173	0.108

Table 4E-3. 3SAC Loading Orientation 2 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No. 1	2	3	4	5
112	3	0.480	0.350	0.210	0.058	-0.097
	4	0.274	0.256	0.214	0.160	0.097
376	4	0.304	0.278	0.222	0.143	0.054
	5	0.329	0.290	0.221	0.131	0.029
345	4	0.266	0.271	0.230	0.158	0.075
	5	0.351	0.318	0.235	0.115	-0.019

Table 4E-4. 3SAC Loading Orientation 2 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No. 1	2	3	4	5
112	88-94	0.532	0.326	0.158	0.045	-0.060
376	352-358	0.602	0.348	0.145	0.013	-0.107
345	222-228	0.619	0.387	0.178	-0.006	-0.178

APPENDIX 4F: 8 AXLE COMBO (8AC)

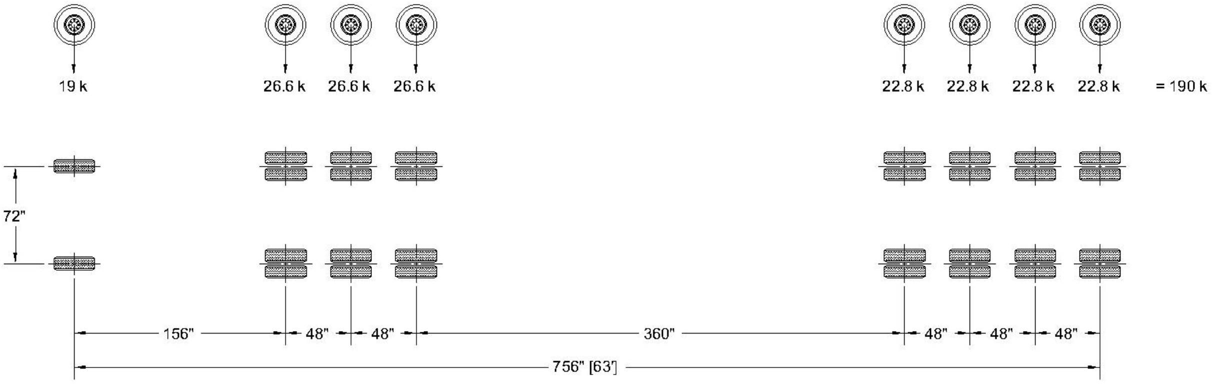


Figure 4F-1. 8 Axle Combo (8AC) Unit Loading.

Table 4F-1. 8AC Loading Orientation 1 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No. 1	2	3	4	5
141	3	0.268	0.217	0.169	0.186	0.160
	4	0.239	0.199	0.165	0.198	0.198
385	4	0.258	0.193	0.148	0.199	0.202
	5	0.268	0.195	0.144	0.197	0.197
363	4	0.257	0.193	0.146	0.200	0.205
	5	0.280	0.197	0.133	0.195	0.195

Table 4F-2. 8AC Loading Orientation 1 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No. 1	2	3	4	5
141	82-88	0.216	0.242	0.244	0.171	0.127
385	362-368	0.214	0.255	0.258	0.166	0.107
363	222-228	0.241	0.248	0.231	0.172	0.108

Table 4F-3. 8AC Loading Orientation 2 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No. 1	2	3	4	5
141	3	0.472	0.345	0.210	0.062	-0.090
	4	0.273	0.256	0.215	0.160	0.096
385	4	0.292	0.277	0.225	0.147	0.059
	5	0.327	0.294	0.226	0.130	0.023
363	4	0.279	0.271	0.226	0.153	0.071
	5	0.358	0.311	0.227	0.115	-0.011

Table 4F-4. 8AC Loading Orientation 2 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No. 1	2	3	4	5
141	84-90	0.507	0.328	0.173	0.052	-0.060
385	362-368	0.588	0.357	0.161	0.015	-0.121
363	222-228	0.616	0.384	0.176	-0.004	-0.172

APPENDIX 4G: 3 AXLE SINGLE (3AS)

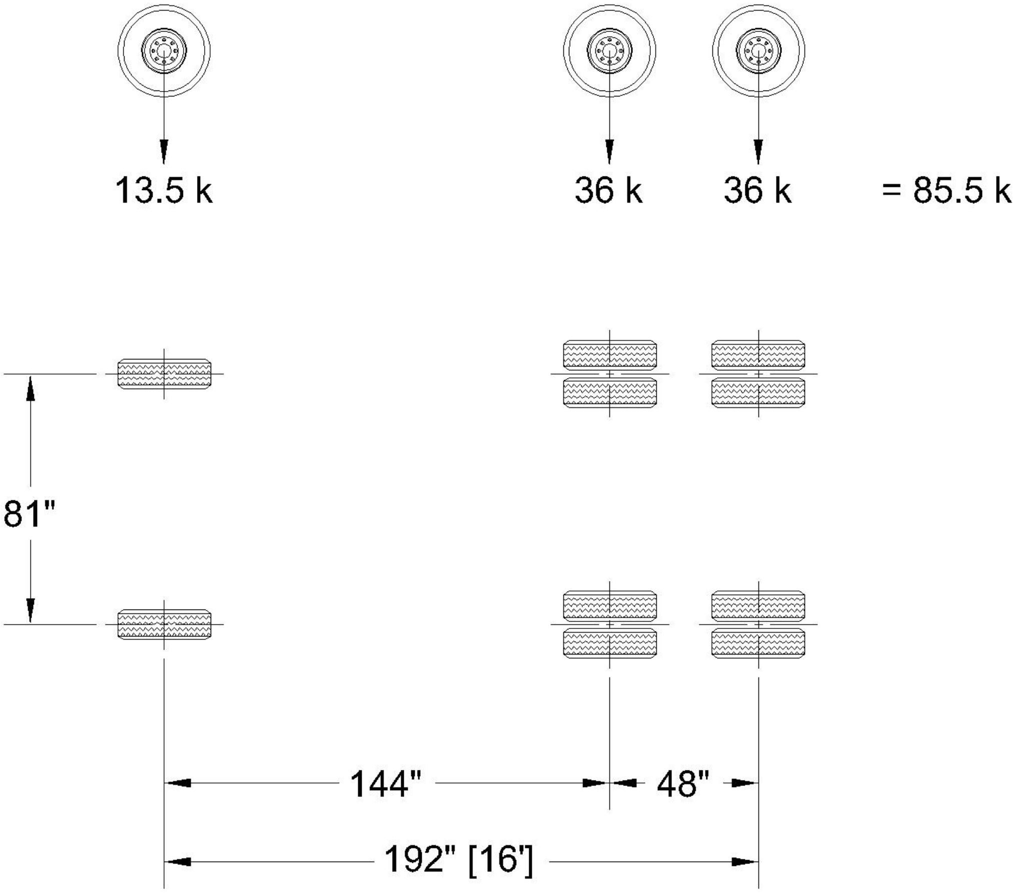


Figure 4G-1. 3 Axle Single (3AS) Unit Loading.

Table 4G-1. 3AS Loading Orientation 1 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No. 1	2	3	4	5
108	3	0.278	0.214	0.171	0.185	0.153
	4	0.240	0.197	0.170	0.198	0.195
372	4	0.266	0.195	0.139	0.201	0.199
	5	0.270	0.197	0.140	0.198	0.195
339	4	0.254	0.194	0.156	0.197	0.199
	5	0.283	0.198	0.142	0.191	0.187

Table 4G-4. 3AS Loading Orientation 1 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No. 1	2	3	4	5
108	92-98	0.197	0.264	0.275	0.158	0.106
372	354-362	0.191	0.279	0.297	0.149	0.084
339	222-228	0.254	0.251	0.225	0.168	0.101

Table 4G-1. 3AS Loading Orientation 2 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No. 1	2	3	4	5
108	3	0.469	0.344	0.214	0.064	-0.090
	4	0.270	0.252	0.215	0.163	0.100
372	4	0.297	0.276	0.226	0.146	0.056
	5	0.318	0.284	0.224	0.137	0.037
339	4	0.283	0.266	0.222	0.154	0.076
	5	0.365	0.308	0.225	0.114	-0.013

Table 4G-4. 3AS Loading Orientation 2 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No. 1	2	3	4	5
108	90-96	0.526	0.325	0.153	0.047	-0.052
372	356-364	0.597	0.349	0.139	0.014	-0.099
339	222-228	0.608	0.384	0.180	-0.001	-0.171

APPENDIX 4H: 5 AXLE SINGLE GROUP (5ASG)

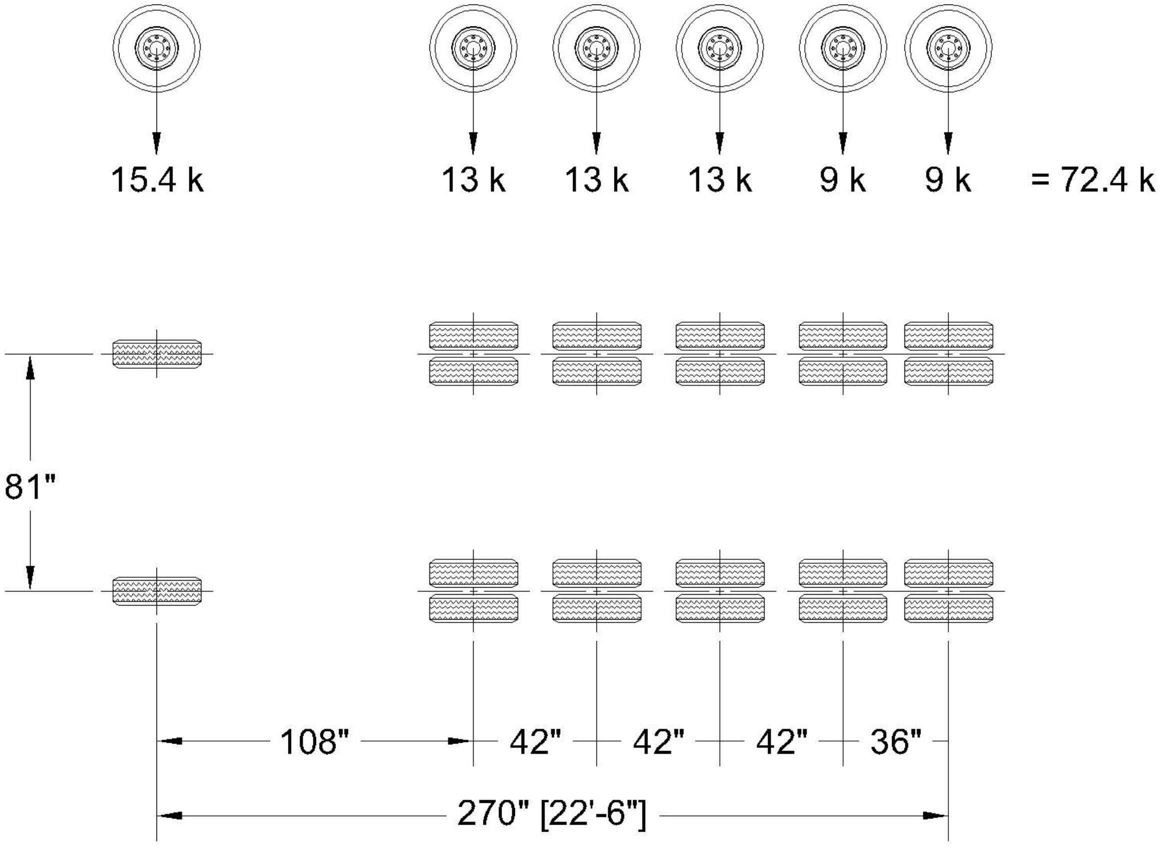


Figure 4H-1. 5 Axle Single Group (5ASG) Unit Loading.

Table 4H-1. 5ASG Loading Orientation 1 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No.				
		1	2	3	4	5
108	3	0.269	0.215	0.171	0.187	0.158
	4	0.237	0.198	0.170	0.198	0.197
372	4	0.261	0.194	0.143	0.200	0.201
	5	0.265	0.196	0.143	0.198	0.198
338	4	0.257	0.193	0.143	0.201	0.206
	5	0.285	0.196	0.126	0.197	0.196

Table 4H-2. 5ASG Loading Orientation 1 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No.				
		1	2	3	4	5
108	90-96	0.194	0.255	0.274	0.163	0.113
372	354-362	0.188	0.268	0.296	0.156	0.092
338	222-228	0.244	0.247	0.227	0.173	0.108

Table 4H-3. 5ASG Loading Orientation 2 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No.				
		1	2	3	4	5
108	3	0.476	0.349	0.212	0.059	-0.096
	4	0.272	0.255	0.215	0.161	0.097
372	4	0.298	0.281	0.226	0.144	0.051
	5	0.318	0.289	0.225	0.135	0.033
338	4	0.274	0.271	0.227	0.155	0.074
	5	0.359	0.317	0.231	0.113	-0.020

Table 4H-4. 5ASG Loading Orientation 2 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No.				
		1	2	3	4	5
108	90-96	0.534	0.323	0.155	0.045	-0.057
372	356-364	0.608	0.347	0.141	0.011	-0.107
338	222-228	0.619	0.388	0.178	-0.007	-0.178

APPENDIX 4I: 2 AXLE SINGLE (2AS)

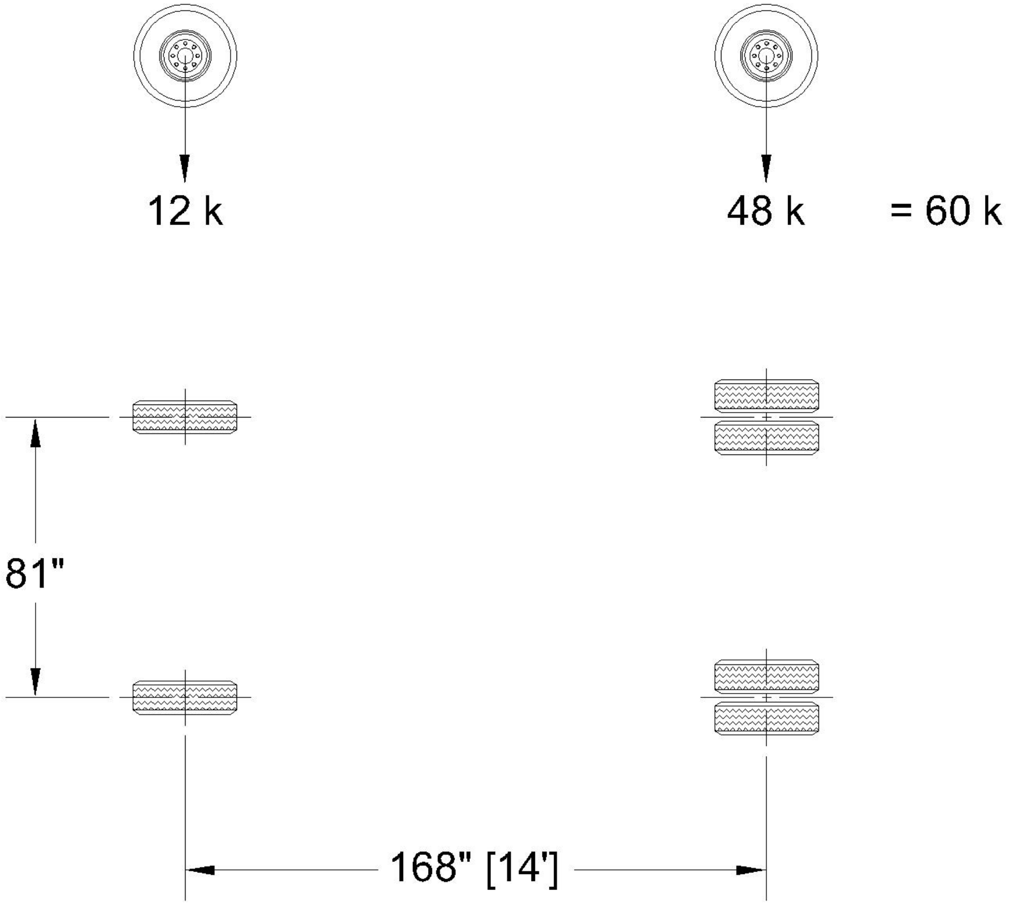


Figure 4I-1. 2 Axle Single (2AS) Unit Loading.

Table 4I-1. 2AS Loading Orientation 1 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No. 1	2	3	4	5
109	3	0.279	0.213	0.170	0.185	0.153
	4	0.241	0.196	0.169	0.198	0.196
373	4	0.264	0.195	0.146	0.199	0.197
	5	0.267	0.197	0.148	0.196	0.193
337	4	0.252	0.195	0.161	0.195	0.197
	5	0.281	0.198	0.147	0.189	0.185

Table 4I-2. 2AS Loading Orientation 1 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No. 1	2	3	4	5
109	92-98	0.197	0.264	0.276	0.158	0.106
373	362-368	0.195	0.278	0.290	0.152	0.085
337	222-228	0.254	0.251	0.226	0.168	0.100

Table 4I-3. 2AS Loading Orientation 2 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No. 1	2	3	4	5
109	3	0.468	0.344	0.214	0.064	-0.090
	4	0.269	0.252	0.216	0.163	0.100
373	4	0.298	0.277	0.225	0.145	0.054
	5	0.317	0.284	0.223	0.137	0.039
337	4	0.285	0.266	0.221	0.153	0.076
	5	0.369	0.309	0.224	0.112	-0.015

Table 4I-4. 2AS Loading Orientation 2 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No. 1	2	3	4	5
109	92-98	0.526	0.324	0.153	0.047	-0.050
373	356-364	0.597	0.349	0.139	0.014	-0.099
337	222-228	0.610	0.385	0.180	-0.002	-0.171

APPENDIX 4J: 3 AXLE COMBINATION (3AC)

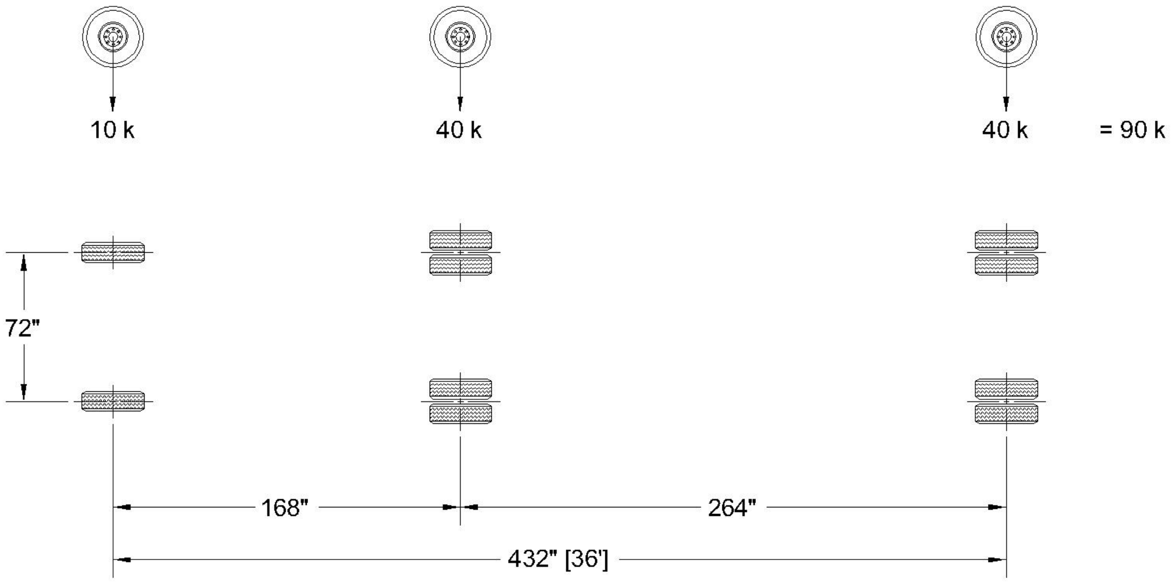


Figure 4J-1. 3 Axle Combination (3AC) Unit Loading.

Table 4J-1. 3AC Loading Orientation 1 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No. 1	2	3	4	5
114	3	0.270	0.218	0.167	0.188	0.157
	4	0.237	0.200	0.168	0.198	0.196
349	4	0.262	0.187	0.137	0.204	0.209
	5	0.290	0.189	0.119	0.201	0.201
377	4	0.257	0.202	0.144	0.198	0.199
	5	0.264	0.203	0.143	0.196	0.195

Table 4J-2. 3AC Loading Orientation 1 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No. 1	2	3	4	5
114	92-98	0.206	0.248	0.255	0.171	0.119
349	222-228	0.244	0.247	0.228	0.173	0.108
377	352-358	0.204	0.261	0.270	0.166	0.099

Table 4J-3. 3AC Loading Orientation 2 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No. 1	2	3	4	5
114	3	0.478	0.351	0.211	0.058	-0.098
	4	0.274	0.256	0.214	0.160	0.097
349	4	0.263	0.271	0.232	0.159	0.075
	5	0.346	0.317	0.237	0.117	-0.017
377	4	0.307	0.276	0.219	0.142	0.055
	5	0.336	0.290	0.219	0.128	0.026

Table 4J-4. 3AC Loading Orientation 2 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No. 1	2	3	4	5
114	96-104	0.523	0.329	0.166	0.046	-0.064
349	222-228	0.618	0.387	0.178	-0.006	-0.176
377	352-358	0.592	0.352	0.154	0.014	-0.113

APPENDIX 4K: 4 AXLE COMBINATION (4AC)

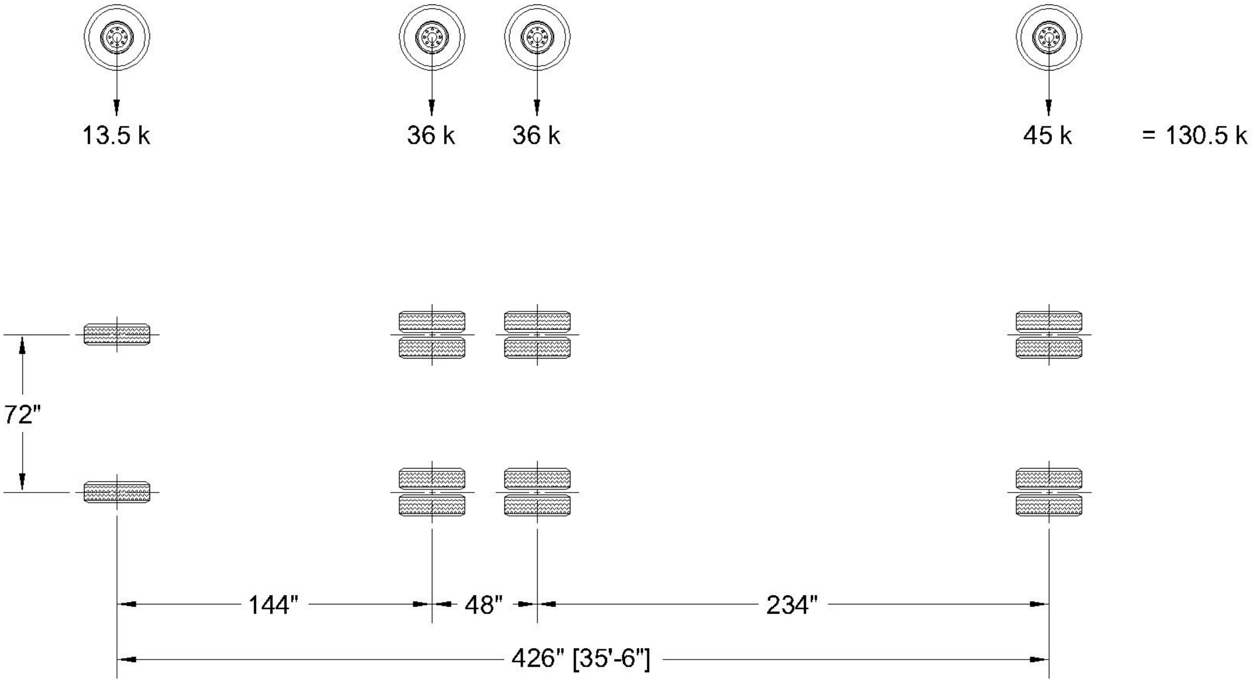


Figure 4K-1. 4 Axle Combination (4AC) Unit Loading.

Table 4K-1. 4AC Loading Orientation 1 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No. 1	2	3	4	5
114	3	0.270	0.218	0.165	0.188	0.158
	4	0.237	0.201	0.166	0.198	0.197
347	4	0.259	0.188	0.142	0.203	0.207
	5	0.288	0.190	0.125	0.199	0.198
377	4	0.259	0.202	0.139	0.200	0.200
	5	0.265	0.203	0.137	0.197	0.197

Table 4K-2. 4AC Loading Orientation 1 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No. 1	2	3	4	5
114	96-102	0.202	0.250	0.260	0.170	0.118
347	222-228	0.244	0.247	0.228	0.173	0.108
377	362-368	0.196	0.264	0.284	0.160	0.096

Table 4K-3. 4AC Loading Orientation 2 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No. 1	2	3	4	5
114	3	0.478	0.350	0.210	0.058	-0.097
	4	0.275	0.255	0.214	0.160	0.096
347	4	0.268	0.270	0.230	0.157	0.074
	5	0.351	0.316	0.235	0.116	-0.018
377	4	0.309	0.277	0.220	0.141	0.053
	5	0.332	0.289	0.219	0.130	0.029

Table 4K-4. 4AC Loading Orientation 2 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No. 1	2	3	4	5
114	92-98	0.524	0.325	0.162	0.047	-0.059
347	222-228	0.619	0.387	0.178	-0.006	-0.177
377	362-368	0.602	0.350	0.147	0.012	-0.111

APPENDIX 4L: 4 AXLE SINGLE (4AS)

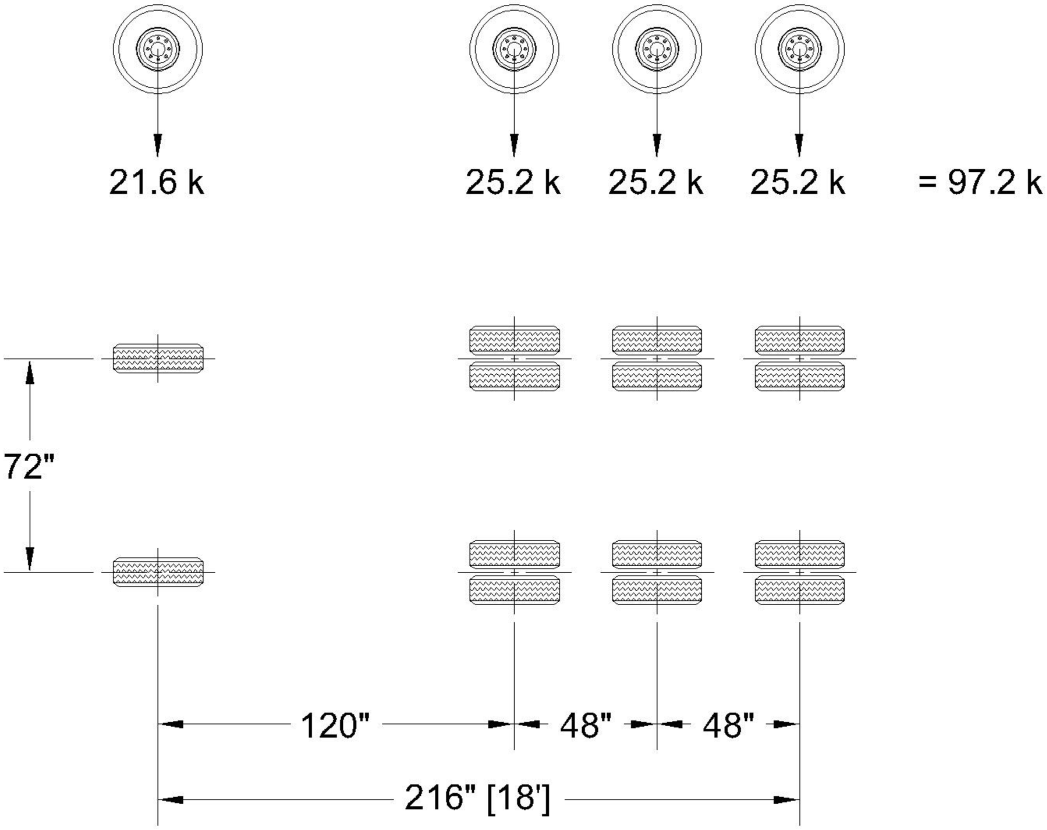


Figure 4L-1. 4 Axle Single (4AS) Unit Loading.

Table 4L-1. 4AS Loading Orientation 1 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No. 1	2	3	4	5
109	3	0.270	0.214	0.169	0.187	0.159
	4	0.238	0.198	0.168	0.198	0.197
337	4	0.255	0.193	0.148	0.200	0.204
	5	0.282	0.196	0.132	0.195	0.195
373	4	0.260	0.194	0.146	0.200	0.200
	5	0.263	0.196	0.146	0.197	0.197

Table 4L-2. 4AS Loading Orientation 1 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No. 1	2	3	4	5
109	92-98	0.193	0.255	0.277	0.163	0.112
337	222-228	0.245	0.247	0.227	0.173	0.108
373	362-368	0.187	0.270	0.296	0.156	0.091

Table 4L-3. 4AS Loading Orientation 2 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No. 1	2	3	4	5
109	3	0.474	0.349	0.213	0.060	-0.096
	4	0.271	0.255	0.215	0.161	0.097
337	4	0.275	0.271	0.226	0.155	0.073
	5	0.361	0.317	0.230	0.113	-0.020
373	4	0.299	0.282	0.226	0.143	0.050
	5	0.317	0.289	0.224	0.135	0.035

Table 4L-4. 4AS Loading Orientation 2 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No. 1	2	3	4	5
109	92-98	0.534	0.322	0.154	0.045	-0.055
337	222-228	0.619	0.388	0.178	-0.007	-0.178
373	356-364	0.610	0.346	0.139	0.011	-0.106

APPENDIX 4M: 4 AXLE COMBINATION (5AC)

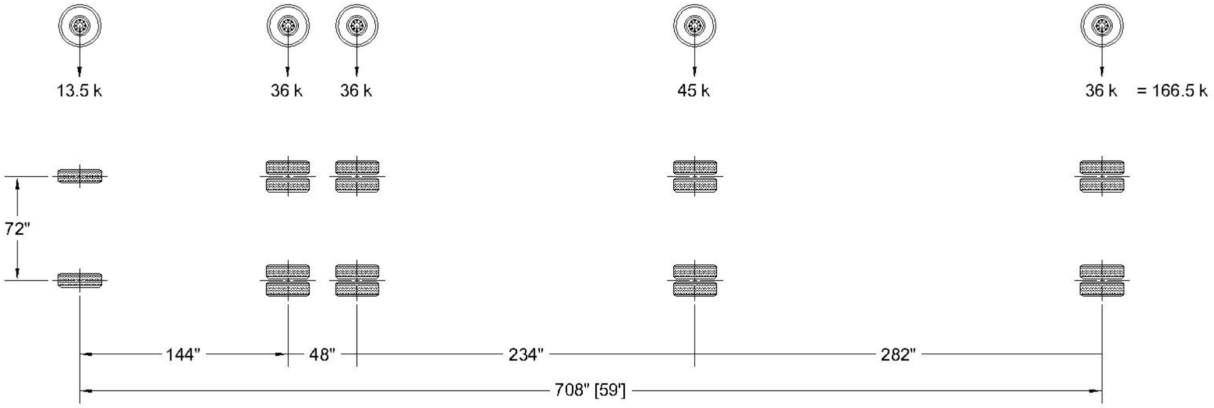


Figure 4M-1. 4 Axle Combination (5AC) Unit Loading.

Table 4M-1. 5AC Loading Orientation 1 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No. 1	2	3	4	5
118	3	0.266	0.221	0.173	0.186	0.155
	4	0.235	0.202	0.170	0.197	0.196
356	4	0.260	0.196	0.133	0.203	0.208
	5	0.284	0.201	0.120	0.198	0.197
380	4	0.257	0.199	0.145	0.199	0.201
	5	0.266	0.199	0.143	0.196	0.196

Table 4M-2. 5AC Loading Orientation 1 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No. 1	2	3	4	5
118	102-108	0.208	0.245	0.252	0.171	0.124
356	222-228	0.242	0.248	0.229	0.172	0.108
380	352-358	0.213	0.256	0.257	0.169	0.105

Table 4M-3. 5AC Loading Orientation 2 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No. 1	2	3	4	5
118	3	0.486	0.348	0.206	0.056	-0.097
	4	0.279	0.255	0.212	0.159	0.096
356	4	0.277	0.271	0.226	0.154	0.072
	5	0.359	0.312	0.227	0.114	-0.013
380	4	0.301	0.277	0.222	0.144	0.057
	5	0.333	0.293	0.222	0.129	0.024

Table 4M-4. 5AC Loading Orientation 2 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No. 1	2	3	4	5
118	84-90	0.517	0.331	0.172	0.047	-0.067
356	222-228	0.616	0.385	0.177	-0.005	-0.173
380	362-368	0.595	0.353	0.154	0.013	-0.116

APPENDIX 4N: 5 AXLE SINGLE (5AS)

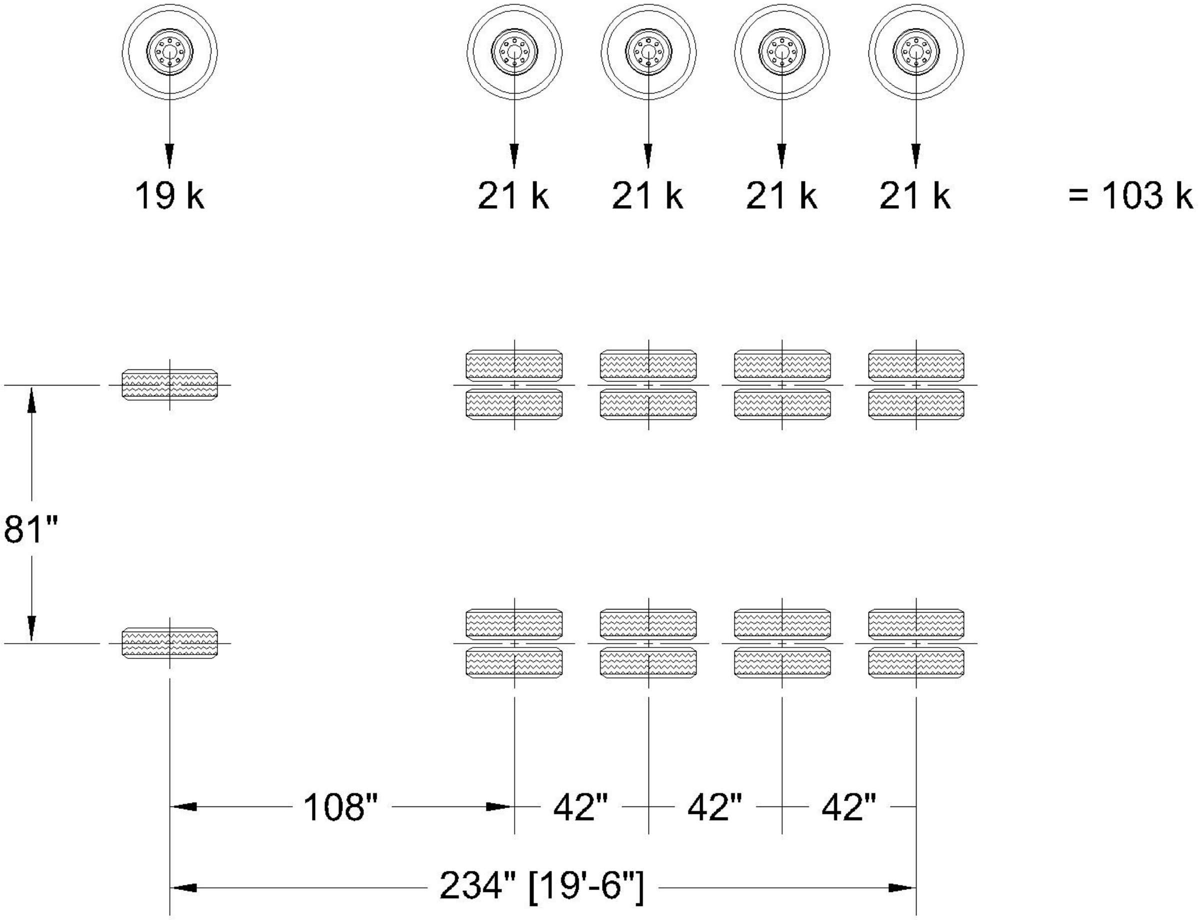


Figure 4N-1. 5 Axle Single (5AS) Unit Loading.

Table 4N-1. 5AS Loading Orientation 1 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No. 1	2	3	4	5
108	3	0.276	0.512	0.173	0.184	0.152
	4	0.239	0.198	0.171	0.197	0.194
338	4	0.259	0.193	0.154	0.200	0.202
	5	0.290	0.196	0.128	0.195	0.191
372	4	0.263	0.193	0.149	0.198	0.196
	5	0.267	0.195	0.149	0.196	0.193

Table 4N-2. 5AS Loading Orientation 1 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No. 1	2	3	4	5
108	92-98	0.200	0.262	0.271	0.160	0.108
338	222-228	0.254	0.251	0.226	0.168	0.100
372	362-368	0.197	0.276	0.286	0.154	0.087

Table 4N-3. 5AS Loading Orientation 2 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No. 1	2	3	4	5
108	3	0.471	0.344	0.212	0.063	-0.090
	4	0.272	0.252	0.215	0.162	0.100
338	4	0.276	0.266	0.225	0.156	0.077
	5	0.361	0.310	0.229	0.115	-0.015
372	4	0.298	0.275	0.225	0.145	0.055
	5	0.318	0.284	0.224	0.137	0.037

Table 4N-4. 5AS Loading Orientation 2 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No. 1	2	3	4	5
108	92-98	0.523	0.325	0.155	0.048	-0.051
338	222-228	0.609	0.385	0.180	-0.002	-0.171
372	352-358	0.591	0.349	0.143	0.016	-0.100

APPENDIX 4O: 6 AXLE COMBINATION (6AC)

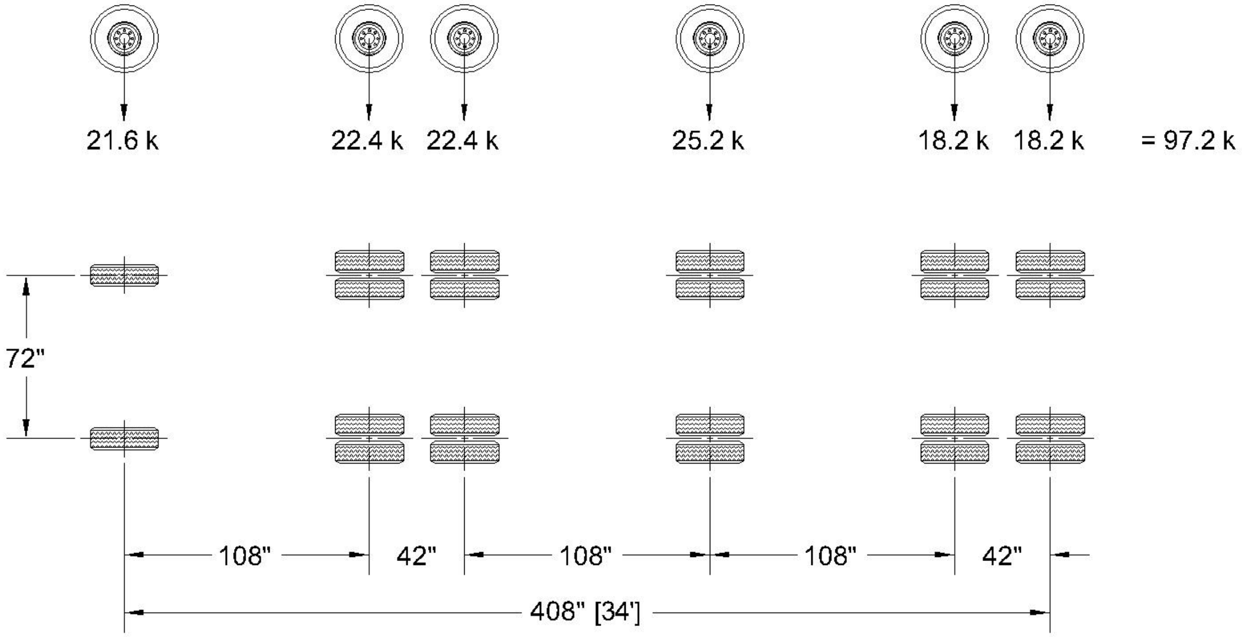


Figure 4O-1. 6 Axle Combination (6AC) Unit Loading.

Table 4O-1. 6AC Loading Orientation 1 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No. 1	2	3	4	5
116	3	0.268	0.216	0.172	0.186	0.158
	4	0.237	0.199	0.169	0.198	0.197
344	4	0.258	0.192	0.141	0.202	0.207
	5	0.286	0.195	0.124	0.198	0.197
374	4	0.259	0.197	0.145	0.199	0.200
	5	0.265	0.198	0.143	0.197	0.197

Table 4O-2. 6AC Loading Orientation 1 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No. 1	2	3	4	5
116	102-108	0.201	0.250	0.261	0.170	0.119
344	222-228	0.243	0.248	0.228	0.173	0.108
374	362-368	0.199	0.263	0.279	0.162	0.097

Table 4O-3. 6AC Loading Orientation 2 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No. 1	2	3	4	5
116	3	0.477	0.348	0.210	0.060	-0.094
	4	0.274	0.255	0.214	0.160	0.096
344	4	0.276	0.270	0.227	0.155	0.073
	5	0.360	0.315	0.230	0.113	-0.018
374	4	0.301	0.278	0.223	0.144	0.054
	5	0.326	0.290	0.223	0.132	0.029

Table 4O-4. 6AC Loading Orientation 2 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No. 1	2	3	4	5
116	92-98	0.522	0.325	0.163	0.048	-0.057
344	222-228	0.619	0.387	0.177	-0.006	-0.177
374	352-358	0.597	0.350	0.150	0.014	-0.110

APPENDIX 4P: 7 AXLE COMBINATION (7AC)

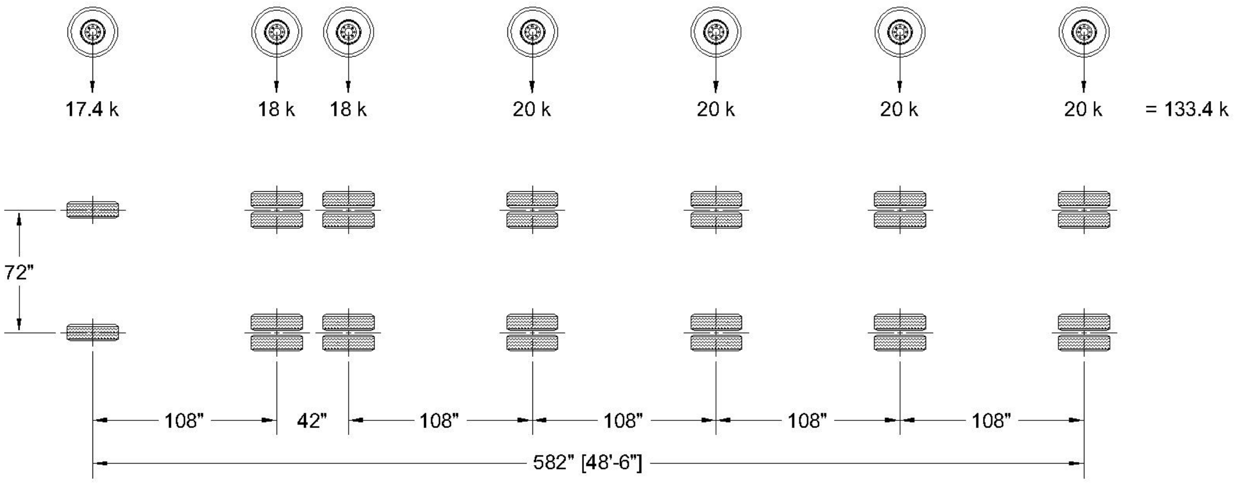


Figure 4P-1. 7 Axle Combination (7AC) Unit Loading.

Table 4P-1. 7AC Loading Orientation 1 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No.				
		1	2	3	4	5
119	3	0.269	0.216	0.171	0.187	0.158
	4	0.237	0.199	0.169	0.198	0.197
122	3	0.269	0.217	0.170	0.187	0.158
	4	0.238	0.200	0.167	0.198	0.197
351	4	0.257	0.194	0.144	0.200	0.205
	5	0.282	0.197	0.128	0.196	0.196
382	4	0.260	0.195	0.145	0.200	0.201
	5	0.265	0.197	0.143	0.197	0.197

Table 4P-2. 7AC Loading Orientation 1 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No.				
		1	2	3	4	5
119	102-108	0.208	0.245	0.251	0.173	0.124
122	102-108	0.207	0.246	0.251	0.173	0.123
351	222-228	0.243	0.248	0.229	0.173	0.108
382	362-368	0.206	0.260	0.268	0.166	0.101

Table 4P-3. 7AC Loading Orientation 2 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No.				
		1	2	3	4	5
119	3	0.477	0.350	0.211	0.059	-0.096
	4	0.272	0.256	0.215	0.161	0.097
122	3	0.478	0.347	0.210	0.059	-0.094
	4	0.276	0.255	0.214	0.160	0.096
351	4	0.279	0.270	0.225	0.154	0.072
	5	0.361	0.312	0.228	0.114	-0.015
382	4	0.300	0.279	0.224	0.144	0.053
	5	0.324	0.289	0.223	0.133	0.030

Table 4P-4. 7AC Loading Orientation 2 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No.				
		1	2	3	4	5
119	88-94	0.518	0.328	0.168	0.048	-0.062
122	92-98	0.514	0.327	0.168	0.050	-0.059
351	222-228	0.617	0.386	0.177	-0.005	-0.175
382	352-358	0.590	0.354	0.157	0.015	-0.115

APPENDIX 4Q: 7 AXLE SINGLE (7AS)

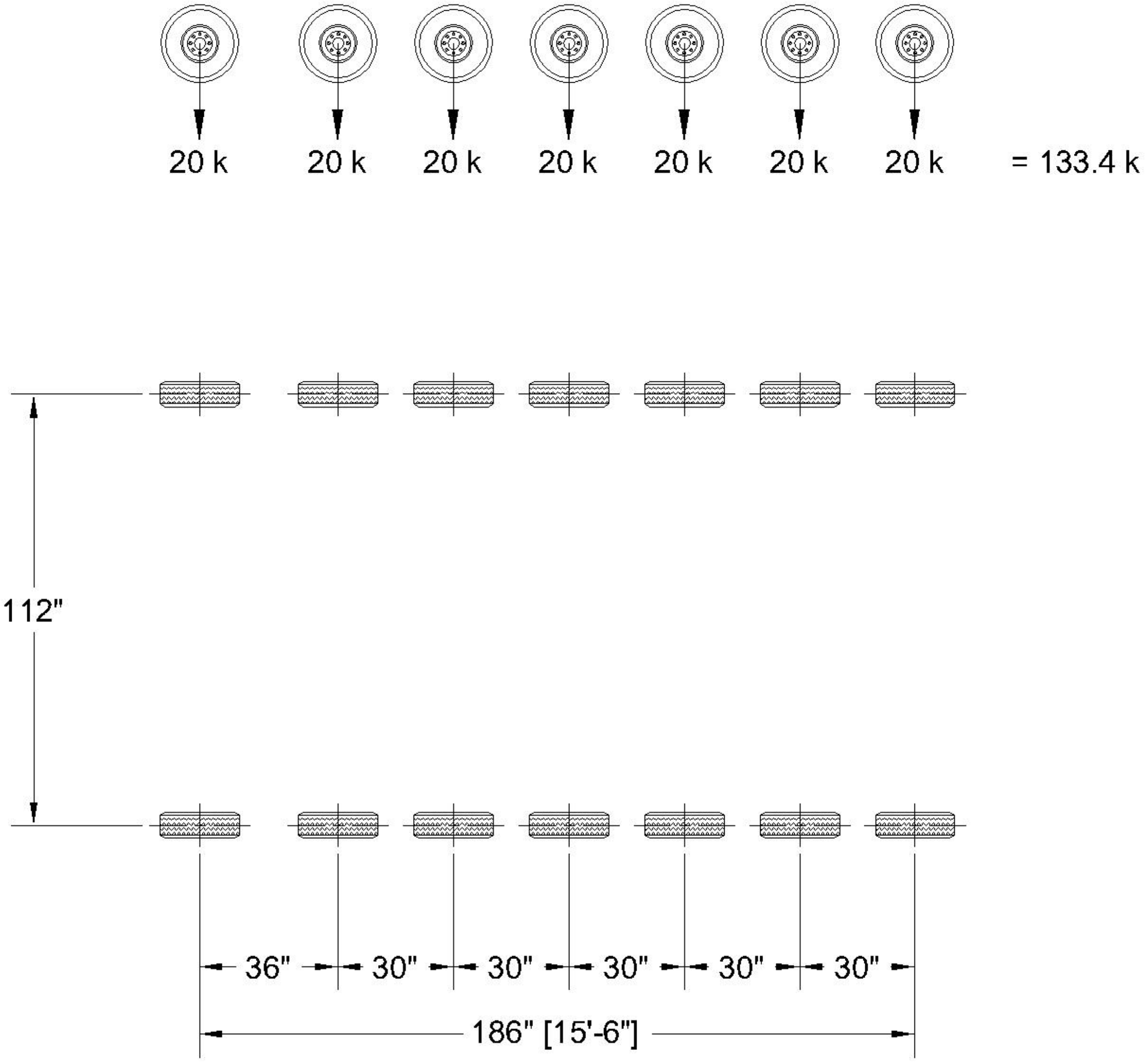


Figure 4Q-1. 7 Axle Single (7AS) Unit Loading.

Table 4Q-1. 7AS Loading Orientation 1 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No.				
		1	2	3	4	5
104	3	0.299	0.220	0.179	0.172	0.130
	4	0.245	0.197	0.177	0.194	0.186
344	4	0.266	0.186	0.160	0.196	0.192
	5	0.304	0.188	0.148	0.188	0.172
368	4	0.271	0.189	0.161	0.194	0.184
	5	0.278	0.192	0.161	0.190	0.179

Table 4Q-2. 7AS Loading Orientation 1 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No.				
		1	2	3	4	5
104	92-98	0.224	0.280	0.255	0.149	0.091
344	222-228	0.288	0.265	0.222	0.152	0.074
368	362-368	0.227	0.297	0.268	0.140	0.068

Table 4Q-3. 7AS Loading Orientation 2 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No.				
		1	2	3	4	5
104	3	0.455	0.327	0.209	0.075	-0.067
	4	0.272	0.244	0.211	0.165	0.108
344	4	0.278	0.253	0.220	0.161	0.089
	5	0.358	0.291	0.223	0.123	0.005
368	4	0.299	0.261	0.220	0.151	0.069
	5	0.318	0.270	0.218	0.142	0.051

Table 4Q-4. 7AS Loading Orientation 2 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No.				
		1	2	3	4	5
104	92-98	0.487	0.330	0.163	0.057	-0.036
344	222-228	0.574	0.373	0.185	0.014	-0.146
368	352-358	0.546	0.355	0.153	0.027	-0.082

APPENDIX 4R: 10 AXLE COMBINATION (10AC)

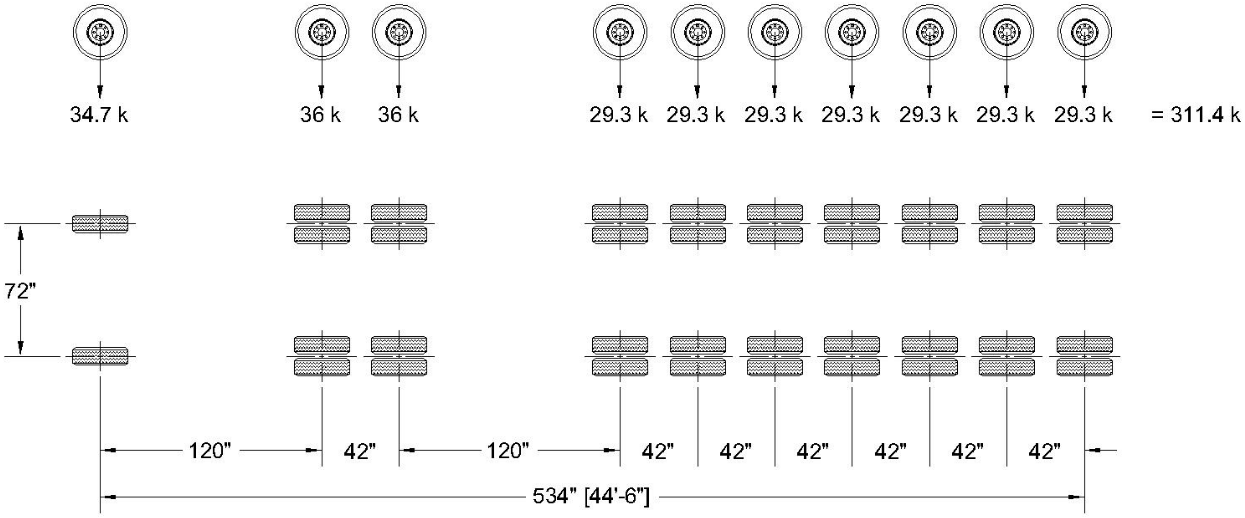


Figure 4R-1. 10 Axle Combination (10AC) Unit Loading.

Table 4R-1. 10AC Loading Orientation 1 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No. 1	2	3	4	5
125	3	0.478	0.348	0.210	0.059	-0.095
	4	0.281	0.258	0.214	0.157	0.090
378	4	0.299	0.281	0.226	0.143	0.050
	5	0.317	0.289	0.225	0.135	0.034

Table 4R-2. 10AC Loading Orientation 1 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No. 1	2	3	4	5
125	90-96	0.520	0.325	0.164	0.049	-0.058
378	352-358	0.595	0.351	0.152	0.014	-0.112

APPENDIX 4S: 11 AXLE COMBINATION (11AC)

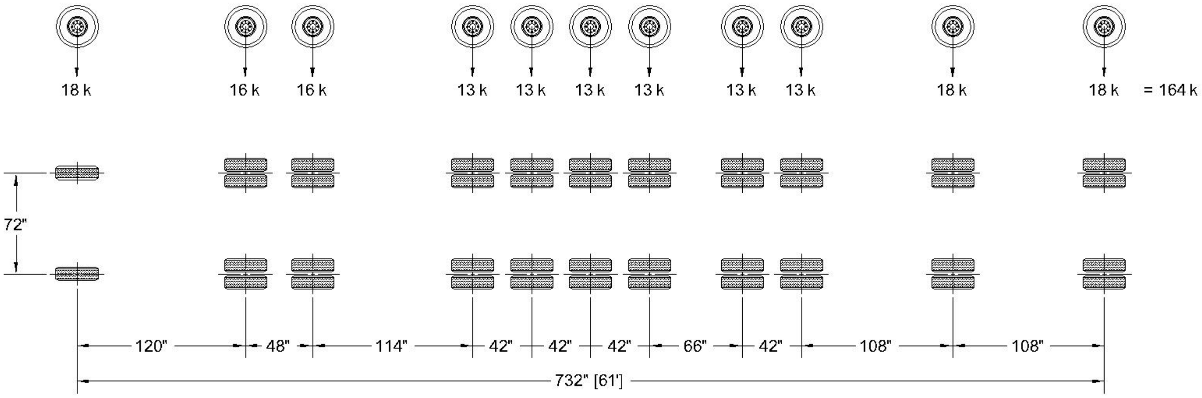


Figure 4S-1. 11 Axle Combination (11AC) Unit Loading.

Table 4S-1. 11AC Loading Orientation 1 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No. 1	2	3	4	5
127	3	0.268	0.216	0.172	0.186	0.158
	4	0.238	0.198	0.169	0.198	0.197
358	4	0.259	0.190	0.142	0.202	0.207
	5	0.284	0.193	0.128	0.198	0.197
390	4	0.262	0.194	0.142	0.201	0.202
	5	0.266	0.195	0.142	0.198	0.199

Table 4S-2. 11AC Loading Orientation 12 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No. 1	2	3	4	5
127	92-98	0.212	0.245	0.247	0.173	0.123
358	222-228	0.242	0.248	0.230	0.173	0.108
390	362-368	0.210	0.258	0.263	0.167	0.103

Table 4S-3. 11AC Loading Orientation 2 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No. 1	2	3	4	5
127	3	0.478	0.349	0.210	0.069	-0.096
	4	0.272	0.256	0.215	0.016	0.097
358	4	0.269	0.268	0.229	0.158	0.076
	5	0.353	0.311	0.233	0.117	-0.014
390	4	0.294	0.280	0.227	0.145	0.053
	5	0.319	0.291	0.225	0.134	0.031

Table 4S-4. 11AC Loading Orientation 2 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No. 1	2	3	4	5
127	88-94	0.515	0.328	0.169	0.049	-0.062
358	222-228	0.613	0.384	0.177	-0.004	-0.171
390	352-358	0.588	0.354	0.159	0.015	-0.116

APPENDIX 4T: TRIDEM AXLE SINGLE (TAC)

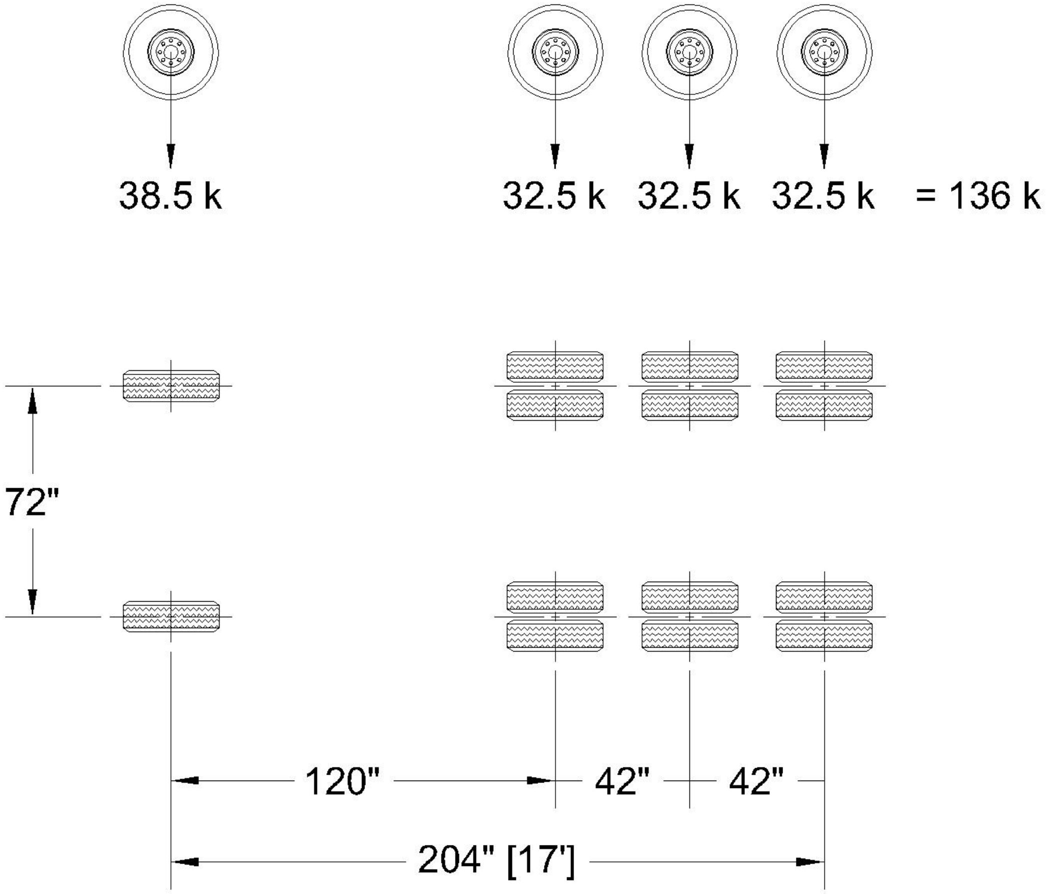


Figure 4T-1. Tridem Axle Single (TAC) Unit Loading.

Table 4T-1. TAC Loading Orientation 1 Rotational DF.

Front Axle Location (ft)	Bent No. Bearing Stiffener	Girder No. 1	2	3	4	5
108	3	0.476	0.350	0.212	0.059	-0.098
	4	0.279	0.259	0.215	0.157	0.091
370	4	0.295	0.281	0.227	0.145	0.052
	5	0.316	0.290	0.226	0.135	0.033

Table 4T-2. TAC Loading Orientation 1 Stress Based DF.

Front Axle Location (ft)	Stress Locations (ft)	Girder No. 1	2	3	4	5
108	92-98	0.534	0.322	0.154	0.045	-0.056
370	352-358	0.606	0.345	0.141	0.013	-0.105