DESIGN OF STEEL SPLICE REPAIR FOR DECAYING TIMBER PILES ON OKLAHOMA COUNTY BRIDGES

By

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DESIGN OF STEEL SPLICE REPAIR FOR DECAYING TIMBER PILES ON OKLAHOMA COUNTY BRIDGES

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Date of Degree: DECEMBER, 2012

Title of Study: DESIGN OF STEEL SPLICE REPAIR FOR DECAYING TIMBER
PILES ON OKLAHOMA COUNTY BRIDGES

Major Field: CIVIL ENGINEERING

Abstract:

Scope and Method of Study: The purpose of this project was to identify recurring structural issues on off-system bridges and design an inexpensive, simple repair to resolve the problem. After communicating with multiple sources, it was disclosed that an existing repair had been installed in the past to solve issues regarding decaying timber piles on older timber bridges. This repair had not been tested in the field, nor did it have a standard design. The repair can be described as a steel splice because it involves removing a length of decayed timber pile (from the pile cap to the ground) from under a bridge, and replacing that section with a steel member, either an H-Pile or a pipe. The steel section is then connected to the existing timber pile below grade by way of a fabricated sleeve, made up of a section of pipe that slides over the timber pile and a steel plate that is welded on top of the pipe. Field testing of this repair was conducted to determine the performance of the repair.

Findings and Conclusions: Based on the field testing results, this repair is an effective way to provide a load path from a pile cap to a foundation. The installation is simple, inexpensive, and can be completed in less than eight hours. To standardize the design of the repair and ensure a conservative capacity, design tables were created to help choose the dimensions of steel that need to be used. These sizes correspond with pipes and H-Piles that county governments typically have inexpensive access to. Included with the design tables are all design details and installation procedures.

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CHAPTER I

INTRODUCTION

Throughout the United States, bridges serve as an extremely important part of the infrastructure. As time passes and bridges age, they inevitably deteriorate and require maintenance. Unfortunately, all across the country the resources are not available to maintain the structural reliability of bridges, both on and off of State Highway systems. Oklahoma is not exempt from this issue. In fact, "Oklahoma rated first in the Nation in the percentage of bridges that are structurally deficient or functionally obsolete" (Oklahoma, 2003). In 2003, the cost of replacing all of these bridges was estimated to be $3.4 billion by the Oklahoma Department of Transportation (ODOT) (Oklahoma, 2003). Obviously, this creates situation where repairs to extend the service life of bridges are a necessity. While ODOT is responsible for many of these bridges and their maintenance, 69% are off-system bridges (Oklahoma, 2003). This means they are looked after by County, City, and Tribal governments, who generally have even less resources and expertise in bridge engineering and maintenance. These entities use what they can to keep the functionality and structural capability of their bridges up to code. It was estimated that only 15 off-system bridges are replaced each year. Again, it is reiterated that repairs to keep bridges in service are a necessity.

Bridge superstructures are constructed from steel, concrete, or timber. The typical timber pile that needs replacement has undergone approximately fifty years of exposure to the elements

(Head, 2012). Bridge inspections determine which piles are in the worst shape, and which ones need to be repaired or replaced. Typically, the inspector uses a sound test to estimate the amount of section loss in a decaying timer pile. An experienced inspector can use this sound test effectively to determine the state of decay in a timber structure (Ritter, 1992). Different agents of wood deterioration include moisture, oxygen, temperature, bacteria, fungi and insects. These are in addition to physical problems that might damage a pile such as impacts or every day wear and tear (Ritter, 1992).

OBJECTIVE

The purpose of this project is to provide County, City, and Tribal engineers with a simple, inexpensive bridge repair that utilizes readily available material and manpower. Specifically, this thesis describes a "splice" that replaces old, decayed timber piles with steel members (pipes or H-Piles). This repair is simple, cost effective, and reliable. The repair, which has been installed previously before this project on a few bridges across Oklahoma, was field tested and analyzed for the project. The final results of the project consist of installation instructions and simple design tables that have been calculated using the latest codes. These design tables and installation instructions standardize the repair, ensuring any future use of the repair will be a safe, useful improvement to the bridge superstructure.

CHAPTER II

REVIEW OF LITERATURE

INFORMATION FROM COUNTY AND STATE MEETINGS

In order to identify reoccurring structural issues in county bridges, meetings were organized with both ODOT and the Association of County Commissioners of Oklahoma (ACCO). In a meeting with Walter Peters, P.E., an assistant bridge engineer at ODOT, numerous topics regarding bridge functionality and inspection were discussed. Although most of the information gathered did not apply to the focus of the project, a few details were relevant. The substructure, rather than the deck, of a bridge is thought to be more important to the bridges rating during an inspection. This means if given the option, the piles, beams, pile caps, and abutments are highest priorities when choosing components to repair. Mr. Peters was able to mention a few common issues ODOT experienced with their bridges, but none were of the structural nature. He also referred us to a number of other sources for more information.

A second meeting was organized with ACCO in Oklahoma City. Here, Randy Robinson, P.E., Donny Head, and Jimmy Watson described common issues and the current methods used to repair county bridges. The poor condition and lack of resources was reinforced throughout the meeting, as make-shift repairs were discussed. According to ACCO, 600 county bridges are functionally obsolete and 4300 are structurally deficient. It was mentioned that timber piling used in bridges that were built as long ago as the 1930's were deteriorating all over the state.

This was especially true in conditions that provided excessive moisture, such as creeks or rivers. Donny Head explained that timber bridge components should “last” about fifty years before they need to be replaced or repaired. This figure was estimated by Mr. Head’s observations in the field throughout his career and is highly variable depending on the conditions of each bridge. While it is evident that these timber bridges will need to be replaced altogether, the resources are simply not there to replace every bridge at this time. ACCO claims that if the deck and beams are in relatively good condition, the piles can be repaired in order to extend the service life of the bridge for at least a few years.

One specific repair was mentioned in the meeting that had been used around the state previously. This repair involved removing decayed timber piles from under the bridge and splicing metal shapes, either pipe or H-Pile, under the bridge to replace the timber. In the field, this repair has been considered when 50% section loss of a pile has been estimated. It has been observed by ACCO that the timber piles do not decay or rot below grade. Because of this, the steel member can be connected to the existing timber pile that extends into the ground, thus resulting in a pile repair that does not require driving a new pile into the soil. Avoiding pile driving in the repair provides numerous benefits. The connection of the steel member to the existing pile below ground consisted of a “sleeve” of metal pipe that capped off the top of the timber pile. This cap is welded onto the new steel pile, which extends all the way to the pile cap. The repair is displayed in Figure 2.1.

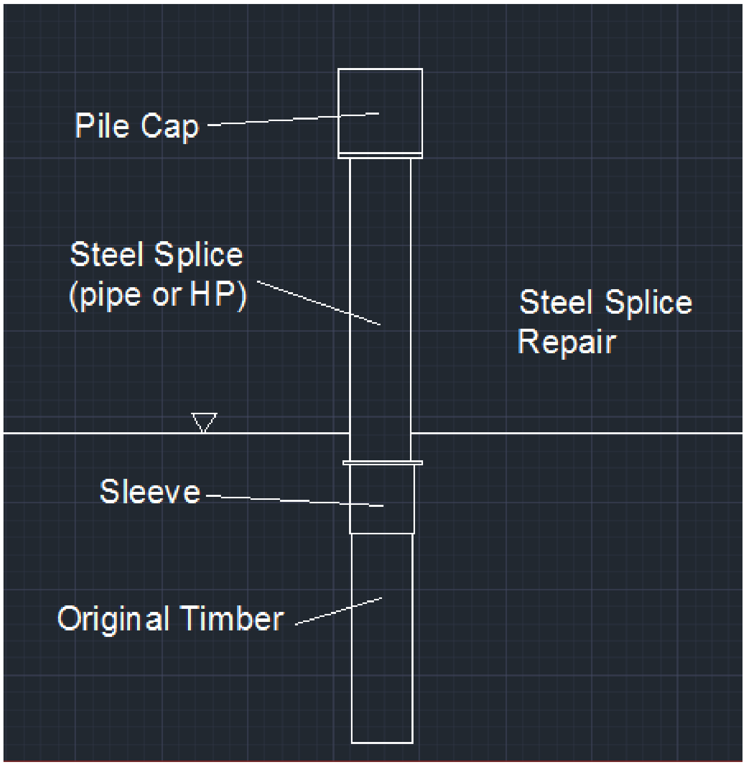


Figure 2.1 Steel Splice Repair

This repair method provided the perfect opportunity for the project. It was an idea that ACCO created that is inexpensive and easy to install. However, ACCO has not tested the repair's effectiveness of transferring load from the bridge deck to the soil. There is also no design standard for the repair.

OTHER REPAIR PROCEDURES

In order to design the best possible repair, different timber piling repairs were researched. The following are some of the more common or feasible repairs available.

Epoxy injection: Epoxy injection is repair technique that is used in both timber and concrete structures. Epoxy itself is a mixture of two agents that combine to form a hard, durable material. This mixture is used to fill voids in timber or concrete before it hardens, and restores the structural integrity of the member. Epoxy can provide additional strength as well as increased protection from the elements. There are different types of epoxy mixes, each varying for the type of application needed. It can either be applied to the surface of a pile, or injected deep into the timber. In the case of epoxy injection, a closed system is required, such as a fiberglass sleeve wrapped around the timber, to prevent epoxy from escaping the pile. For this type of application, Type A-2 Epoxy should be used (Ritter, 1992). According to Dr. Riding of Kansas State during his lecture of a concrete repair class, epoxy injection can be expensive and difficult to use. While it does not require continued maintenance, special training is needed to correctly install an epoxy injection repair,

C-Channel Jacket: Suggestions from Roe Enchayan, P.E., Nebraska Department of Roads, were presented at the Midwest AASHTO Bridge Preservation Conference in 2010. One of his suggestions involves two C-Channel shapes forming a jacket around a damaged timber pile, as shown in Figures 2.2 and 2.3. These shapes are held together by a series of bolts that run through the pile. When tightened, the C-Channel's compress the pile around the longitudinal axis, strengthening any axial loads applied to the timber (Enchayan ,2010). This repair is inexpensive, but is not as effective as a complete pile replacement.

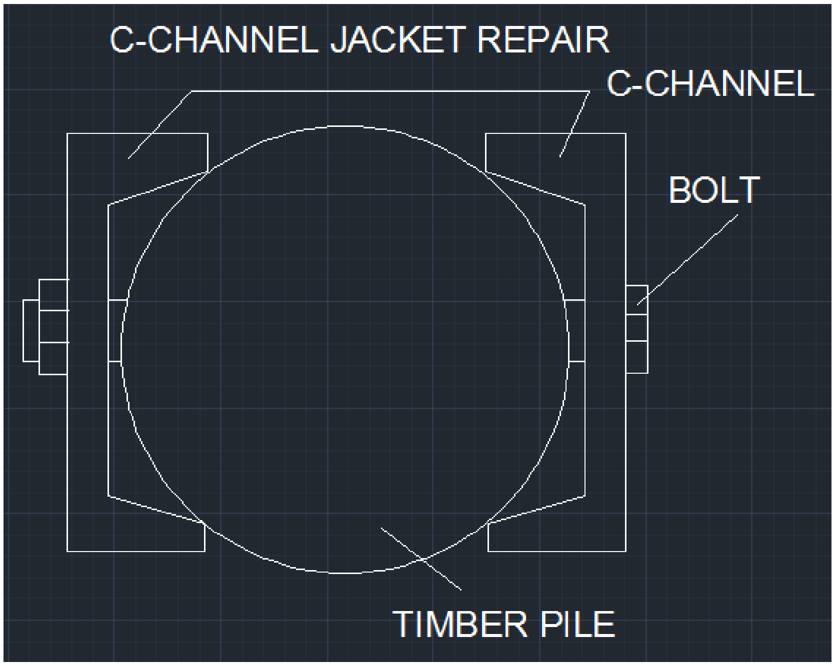


Figure 2.2 Plan View of C-Channel Jacket

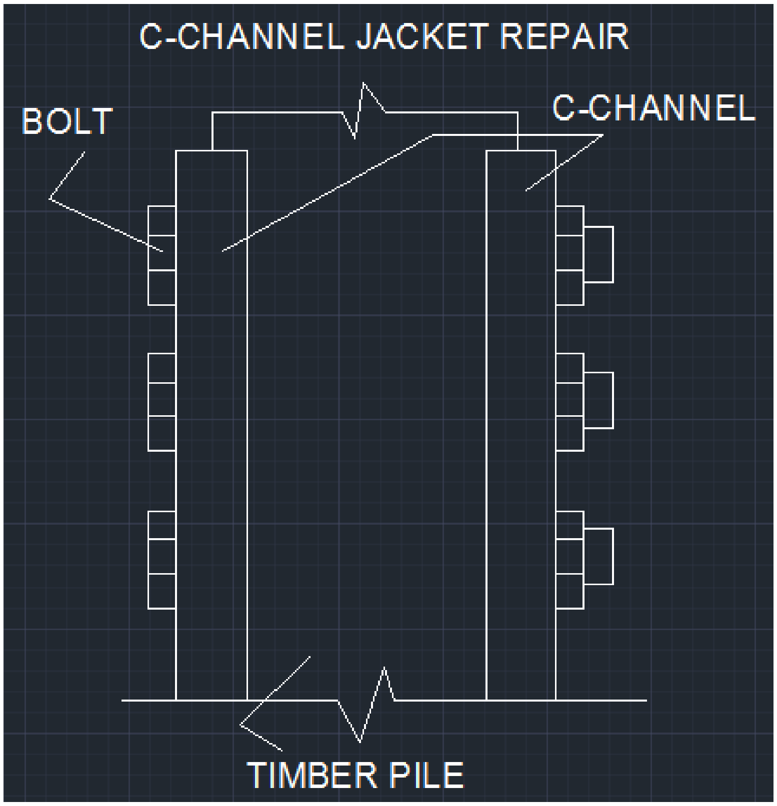


Figure 2.3 Elevation View of C-Channel Jacket

Concrete Casing: Another repair suggested by Enchayan is a concrete casing, illustrated in Figure 2.4. Similar to the C-Channel design, a cast-in-place concrete form is poured around the outside of the damaged timber pile. This repair protects the damaged timber from the elements and adds strength to the pile. However, forming and pouring concrete can be an expensive, labor intensive process.

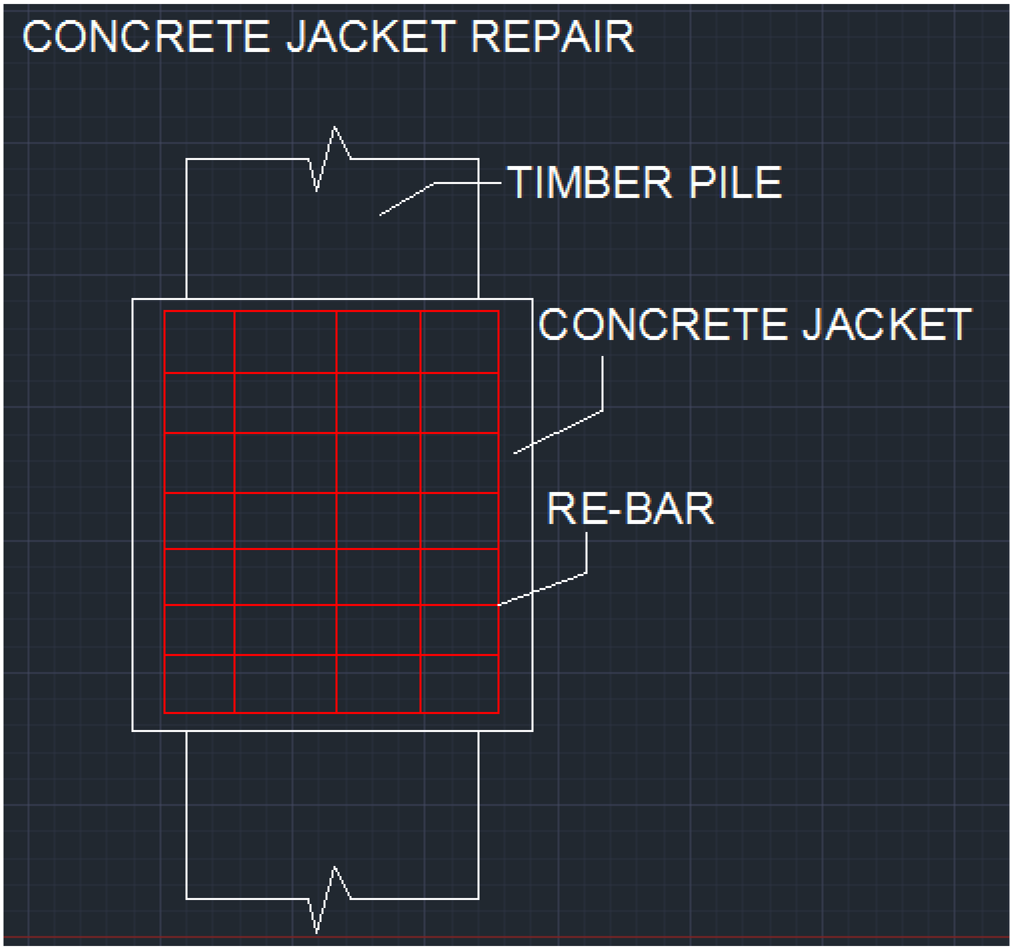


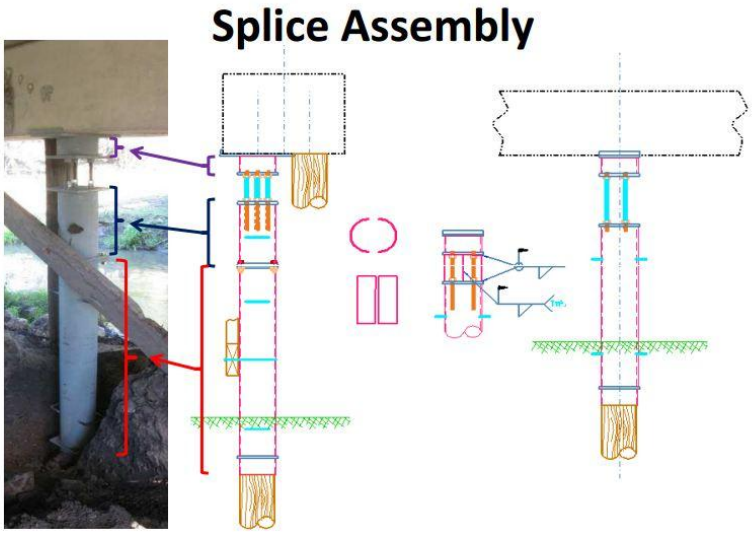
Figure 2.4 Elevation View of Concrete Jacket Repair

Additional Piles: Another simple solution to timber pile decay is to install additional piles as shown in Figure 2.5. This repair requires a large amount of material and labor, especially due to the need for the new piles to be driven. This solution provides an alternate load path, which may be necessary depending on the condition of the existing timber piles.

(Enchayan, 2010)

Figure 2.5 Example of Additional Piles as Repair

Splice: The Splice repair described in Enchayan's presentation is very similar to the repair described in this thesis. A few minor details make Enchayan's more complex and therefore more expensive. As shown in Figures 2.6 through 2.10, the splice is assembled in two sections, the top and bottom. After the decyed timber is cut out and removed, both pieces of the splice assembly are moved into place. The top unit of the splice acts as a mechanism to ensure the entire replacement assembly will take load from the pile cap. By raising the top of the unit with a jack, as shown in Figure 2.10, stress is transferred from the pile cap to the splice to the existing timber pile. The differences between this splice repair and the one designed from this project are in the size of the member and the mechanism through which the steel will take the load. This project specifies a pipe size or H-Pile shape for an individual timber pile, dependent on its length and diameter. By designing for a specific case, the steel shape can be optimized and the cost will be minimized. In addition, this project's splice repair will rely on a jack which is separate from the replacement unit to relieve and then reapply stresses from the pile cap. The process is similar, however the fabrication and design of Enchayan's top unit would be more expensive and more time consuming than the procedure that will be followed in the new repair.



(Enchayan, 2010)

Figure 2.6 Splice Assembly

(Enchayan, 2010)

Figure 2.7 Splice Assembly

(Enchayan, 2010)

Figure 2.8 Installing the Splice

(Enchayan, 2010)

Figure 2.9 Installed Splice

(Enchayan, 2010)

Figure 2.10 Raising the Jack

CHAPTER III

METHODOLOGY

The project can be split into three areas, each of which needed to be investigated thoroughly. These three areas are field testing, the repair design, and the repair installation.

FIELD TESTING METHODOLOGY

Ongoing communications with Donnie Head presented the opportunity to visit a bridge that had utilized the splice repair. By testing the performance of the repair and surrounding piles, the effectiveness of the repair could be determined. As stated before, ACCO had no information or data supporting the ability of the splice repair to effectively transfer load from the bridge to the existing, buried pile. By using bridge testing technology and simple strengths of materials theory, the amount of load passing through the replacement pile could be collected.

BDI TESTING

Bridge Diagnostics Inc. produces a variety of testing systems to evaluate the performance of a bridge. The BDI product used for this project was the Structural Testing System II (STS-II). The STS-II combines sensors and software during a loading event to measure the strain of up to 40 different locations on a testing specimen. By measuring the strain of a member, the load passing through it can be calculated. The STS-II system consists of 40 strain sensors that can be attached to different components of a bridge. These strain sensors, shown attached to timber in

Figure 3.1, are designed to be attached to steel, timber, or concrete bridge parts. To attach to timber, a screw is drilled into each end of the sensor and into the wood. Again, this is illustrated in Figure 3.1.

Figure 3.1 STS-II Strain Transducer Installed in 4X4

To attach to steel, small steel tabs are bolted to each end of the strain transducer. These tabs are shown in Figure 3.2. The tabs are then glued to the bridge using Loctite Prism 410 Black Toughened adhesive and Loctite Tak Pac 7452 accelerator.

Figure 3.2 Tabs and Nuts for STS-II Assembly

If the location of the sensor is on the edge of a member such as a flange, C-clamps can be used to hold both ends of the sensor instead of the tabs, as shown in Figure 3.3.

Figure 3.3 Strain Transducers Installed on H-Pile

To attach the sensors to concrete, either screws or the adhesive can be used. For the field testing purposes, both timber attachments and steel attachments were utilized.

Each one of the strain transducers is plugged into a box, shown in Figure 3.4. These boxes are linked together, and plug into the STS-II Power Supply interface. The power supply interface is plugged into a laptop, which runs the STS-II software program that will record the change in strain from each transducer over a given time period. The STS-II Power Supply and laptop are shown in Figure 3.5.

Figure 3.4 STS-II Boxes and Wires

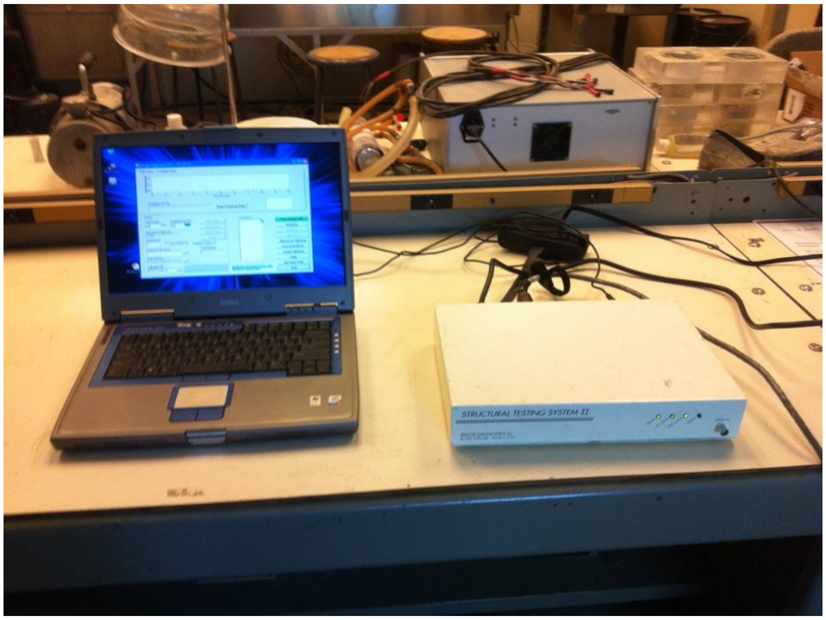


Figure 3.5 STS-II Power Supply and Laptop

The STS-II measures strain at multiple locations on one or multiple components of a bridge. To use this data and discover how much load that component is withstanding, the following equations and theories are used:

$$\varepsilon = \frac{\delta}{L_0} \qquad (3\text{-}1)$$

Where ε is the strain, δ is the change in length of the specimen, and L_o is the original gauge length of the specimen. The STS-II system's output in the strain at a sensor, measured in microstrain. The average strain for each member is calculated. For example, if four transducers are attached to a pile, the average strain of those four sensors is calculated and assumed for that pile. Once the strain is calculated, Hooke's Law can be used to determine the stress at that specific location:

$$\sigma = E\varepsilon \qquad (3\text{-}2)$$

Where σ is the stress, E is the modulus of elasticity, and ε is the strain. The application of Hooke's Law is limited by restraints regarding the amount of loading and deformation. However, in the field test, the piles will not be loaded beyond yield strength; therefore Hooke's Law can be applied. The stress calculated in the piles is the average stress throughout the cross section of the member.

Once the stress through a member is calculated, the force that member is undergoing can be calculating using the following equation:

$$\sigma = \frac{P}{A}$$

Or

$$P = \sigma A \qquad (3\text{-}3)$$

Where P is the internal resultant normal force, A is the cross-sectional area of the pile, and σ is the average stress at any point on the cross sectional area. Equations 3-1 to 3-3 are from Hibbler's *Mechanics of Materials,* 2011.

In conclusion, the strain of the replacement pile can be measured and the load that the pile is “taking” can be calculated. This can be compared to the surrounding piles and the theoretical load the replacement pile should be undergoing.

The STS-II components were initially connected and tested in a controlled lab environment. Four strain transducers were used to test a scrap piece of 4X4. The purpose of this test was to familiarize the graduate students with the STS-II configuration and software. The test specimen was placed in a compression machine, as shown in Figure 3.6, and loaded. The strains were recorded throughout the loading process in the STS-II software program.

Figure 3.6 Testing the STS-II and Sensors in a Compression Machine

Using equations 3-1 through 3-3, the calculated load was compared to the actual load applied to the specimen. Again, the purpose of this lab testing was to familiarize the graduate students with the STS-II system, not to test the accuracy of the sensors. The sensors averaged an 18.5% error in load calculation. It was assumed that this error in the calculation was due to the poor condition of the wood sample, which made the modulus of elasticity difficult to estimate. Furthermore, the sample was not evenly distributing the load throughout the entire cross sectional area because the ends were not exactly perpendicular to the compression machine's loading surfaces. The results of this test were not considered important or relevant.

A separate lab test was later conducted, ensuring the performance of every component of the STS-II system. Unlike the previous lab test, which only used four transducers, this second test required the use of all 40 sensors. Each transducer was plugged into the STS-II system and tested, as shown in Figure 3.7.

Figure 3.7 Testing All (40) Strain Sensors

The results of this simple test concluded that every sensor worked and could be balanced out to provide an accurate strain value during testing.

Field testing took place on a county bridge (NBI No: 14300; Local ID: 355) located approximately seven miles north of Medford, Oklahoma in Grant County. This three-span bridge carried a two-lane, asphalt road (N2960) over a small creek. It was built in 1959 with timber piles, timber pile caps, timber beams, and timber abutments. The bridge, whose load limit is posted at 5 tons, has span lengths of 16 feet, 15 feet, and 16 feet. There are five piles under each bent cap, spaced from 59" to 77" apart, center to center. The pile configuration is illustrated in Figures 3.8 and 3.9.

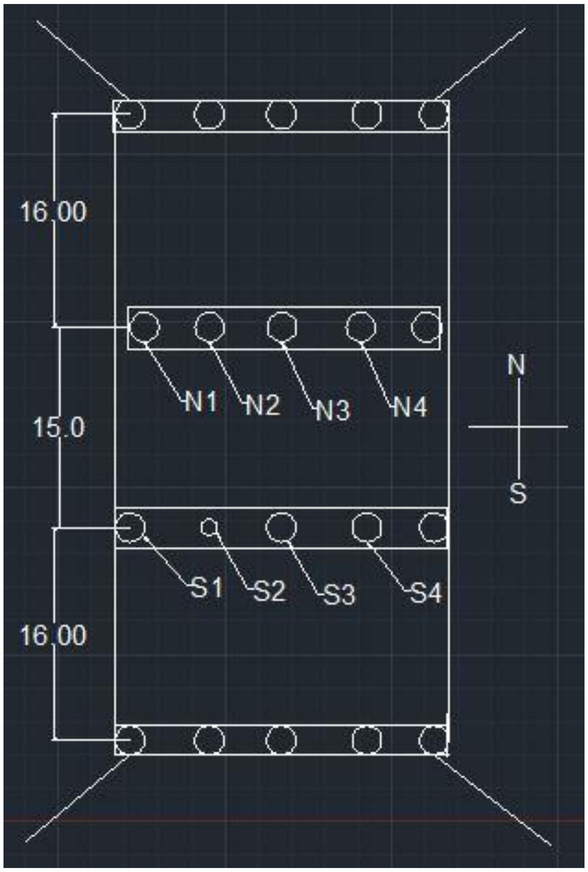


Figure 3.8 Plan View of Grant County Bridge Piles

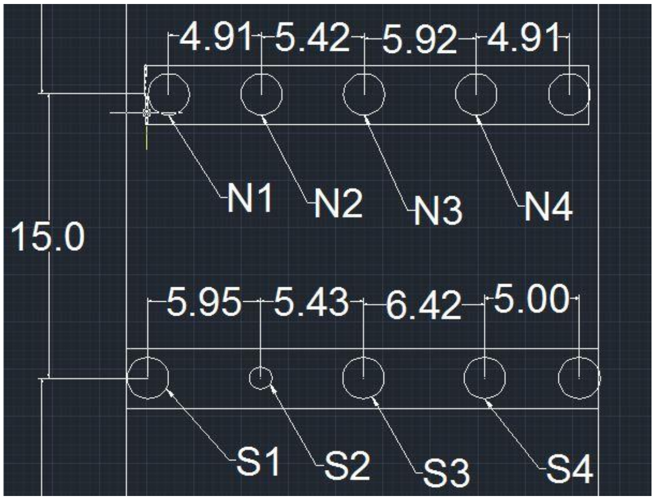


Figure 3.9 Plan View of Grant County Bridge Piles (with dimensions)

The diameters of the piles range from 11.7 inches to 14.2 inches, not including the replaced steel pipe. They also ranged from 71 inches to 93.5 inches in height. The pile properties are summarized in Table 3.1.

Pile Properties		
Pile	**Height (in.)**	**Diameter (in)**
N1	71.00	14.16
N2	69.00	11.70
N3	72.00	12.02
N4	69.00	13.01
S1	89.00	11.94
S2	83.00	7.63
S3	84.50	11.94
S4	93.50	12.77

Table 3.1 Pile Properties

The timber beams are 15 inches by 4 inches and are spaced at 18 inches, center to center. Some are showing signs of damage such as cracking or decay. One of these beams has been replaced with a steel W-Shape, as shown in Figure 3.10.

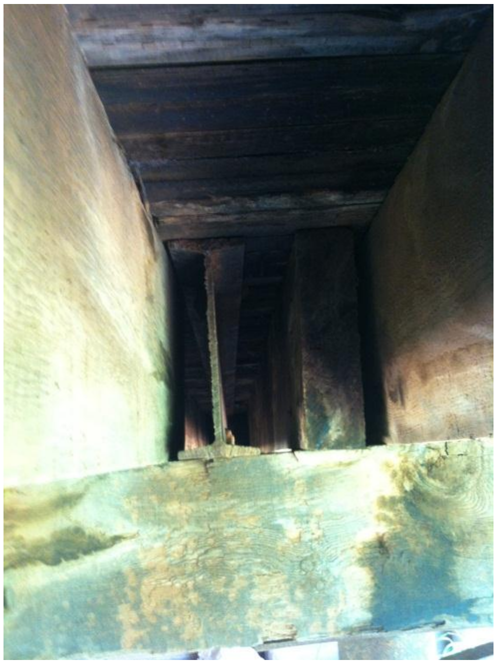


Figure 3.10 W-Shape Acting as a Replacement Timber Beam

The Pile caps are 12 inches by 12 inches, and seem to be in satisfactory condition. The bridge was considered structurally deficient after its last inspection in May of 2011. Throughout the duration of the field test, which took approximately three hours, there were numerous trucks that drove across the bridge that were well beyond the posted load limit of 5 tons.

The splice repair was installed on the south bent cap, designated as S2 (shown in Figures 3.8 and 3.9). According to past inspections the replaced timber pile had undergone more than 50% section loss and severe splitting. The replacement pipe is illustrated in Figure 3.11.

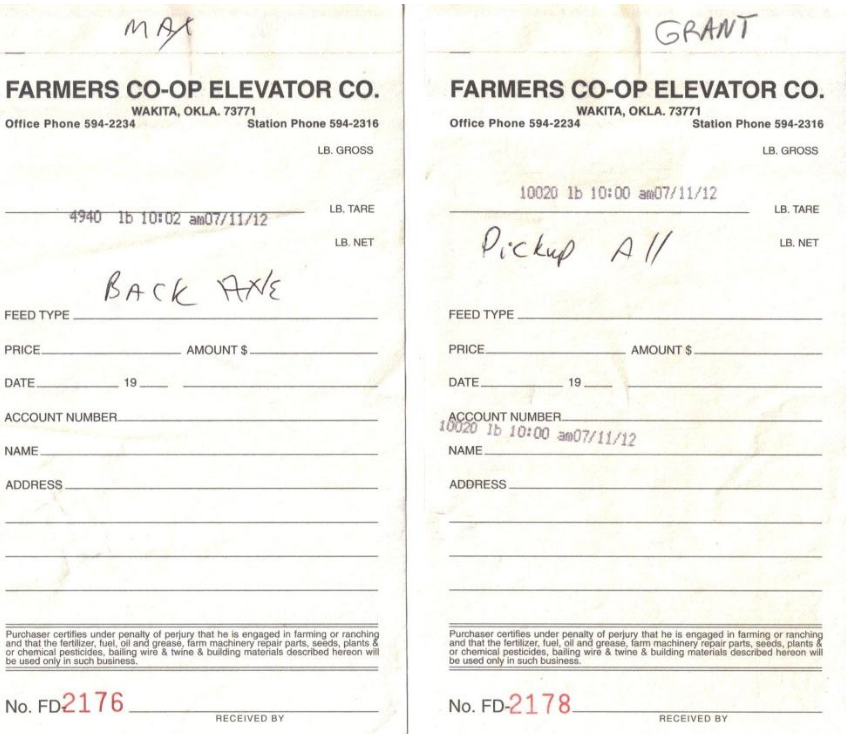
Figure 3.11 Installed Steel Splice

The pipe which replaced the timber pile was 7 5/8 inches in outside diameter and had a wall thickness of 0.450 inches. The grade of the steel is unknown, but was assumed to be grade 50. The pipes connection to the bent cap is shown in Figure 3.12.

Figure 3.12 Top Connection

As illustrated, the pipe is welded to a plate, which is bolted to the bent cap. The bottom of the pipe is welded to the sleeve, underground.

The performance of the bridge and repaired pile were recorded with the STS-II system. The strain of eight piles was recorded as a 5 ton truck drove across the bridge. Max Hess, the county commissioner of Grant County, was courteous enough to supply a 2008 Ford F-250 Extended Cab for the test. The truck had a track of 6'-6" and a wheelbase of 12'-2.5". The truck's front axle weighed 5,060 pounds (2.52 tons) and the back axle weighed 4940 pounds (2.47 tons). The total weight of the truck was 10,020 pounds (5.01 tons). These weights were recorded at the Farmers Co-Op elevator Co. in Wakita Oklahoma. The weigh slips are illustrated in Figures 3.14 and 3.15.



MAX

FARMERS CO-OP ELEVATOR CO.
WAKITA, OKLA. 73771
Office Phone 594-2234 Station Phone 594-2316

LB. GROSS

4940 lb 10:02 am07/11/12 LB. TARE

LB. NET

BACK AXLE

FEED TYPE

PRICE AMOUNT $

DATE 19

ACCOUNT NUMBER

NAME

ADDRESS

Purchaser certifies under penalty of perjury that he is engaged in farming or ranching and that the fertilizer, fuel, oil and grease, farm machinery repair parts, seeds, plants & or chemical pesticides, bailing wire & twine & building materials described hereon will be used only in such business.

No. FD2176 RECEIVED BY

GRANT

FARMERS CO-OP ELEVATOR CO.
WAKITA, OKLA. 73771
Office Phone 594-2234 Station Phone 594-2316

LB. GROSS

10020 lb 10:00 am07/11/12 LB. TARE

Pickup All LB. NET

FEED TYPE

PRICE AMOUNT $

DATE 19

ACCOUNT NUMBER
10020 lb 10:00 am07/11/12

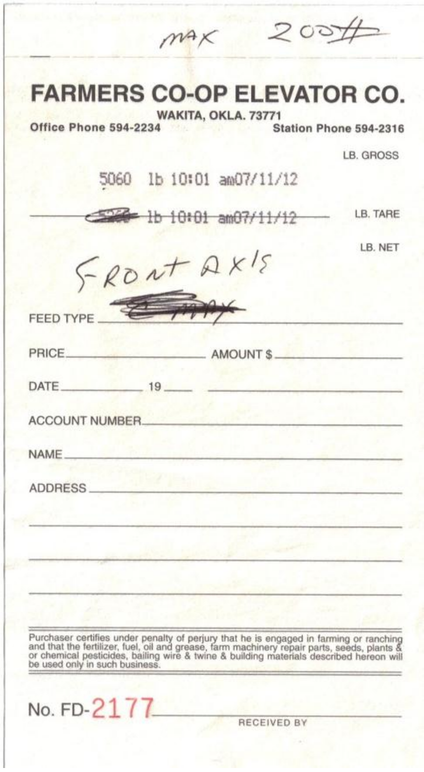
NAME

ADDRESS

Purchaser certifies under penalty of perjury that he is engaged in farming or ranching and that the fertilizer, fuel, oil and grease, farm machinery repair parts, seeds, plants & or chemical pesticides, bailing wire & twine & building materials described hereon will be used only in such business.

No. FD-2178 RECEIVED BY

Figure 3.13 Truck Weight Slip (1)



MAX 200#

FARMERS CO-OP ELEVATOR CO.
WAKITA, OKLA. 73771
Office Phone 594-2234 Station Phone 594-2316

LB. GROSS

5060 lb 10:01 am07/11/12

~~[illegible] lb 10:01 am07/11/12~~ LB. TARE

LB. NET

FRONT AXLE

FEED TYPE ~~[illegible]~~

PRICE AMOUNT $

DATE 19

ACCOUNT NUMBER

NAME

ADDRESS

Purchaser certifies under penalty of perjury that he is engaged in farming or ranching and that the fertilizer, fuel, oil and grease, farm machinery repair parts, seeds, plants & or chemical pesticides, bailing wire & twine & building materials described hereon will be used only in such business.

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Figure 3.14 Truck Weight Slip (2)

Iluustrations of the dimensions of the truck and the distribution of load are provided in Figures 3.15 and 3.16.

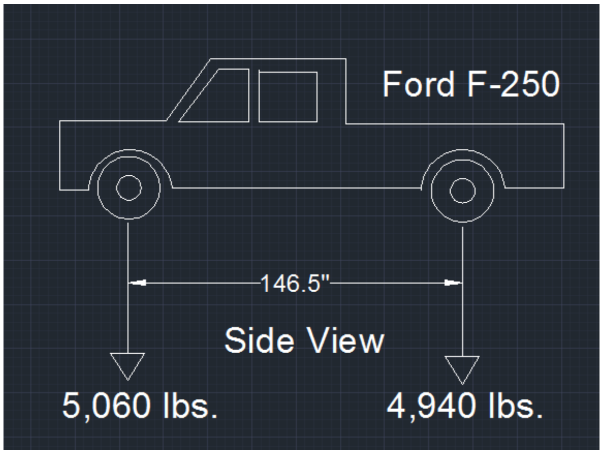


Figure 3.15 Side View of Ford F-250

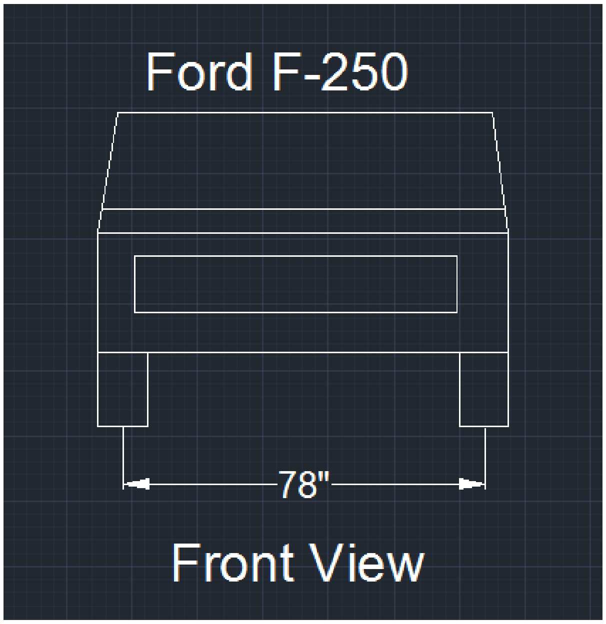


Figure 3.16 Front View of Ford F-250

The truck was driven along the bridge as close to the West edge as possible. By driving the truck in that lane, the loads throughout the bridge would be concentrated on the repaired pile and the piles surrounding it.

The strain transducers were installed on eight different piles. As illustrated in Figure 3.8, these piles have been designated N1, N2, N3, N4, S1, S2, S3, and S4. These piles were chosen because they would theoretically be taking the most load when the load was driving across the bridge. 4 sensors were put on piles N1, N2, N3, S1, and S3. 2 sensors were installed on N4 and S4. 6 sensors were installed on S2. This distribution of sensors was chosen based on the importance of accuracy involved with different piles and the number of sensors available. N4 and S4, although important, were not as high of a priority to calculate an accurate strain value as S2, which had 6 sensors installed. The sensors were installed onto the timber piles with roofing screws on opposite sides of the pile. This is illustrated in Figure 3.17, a picture of pile N1.

Figure 3.17 Pile N1 and Attached Strain Sensors

The other two sensors cannot be seen in the frame. Every "line" of sensors on each pile was the same height. The location of the line of sensors for each pile is described in Table 3.2.

Sensor Location	
Pile	**Distance from Pile Cap to Sensor (in)**
N1	25.00
N2	24.00
N3	22.50
N4	23.00
S1	34.00
S3	34.50
S4	31.75

Table 3.2 Sensor Locations on Grant County Bridge Piles

For pile S2, the repaired pile, six sensors were installed. All were attached using the steel tabs and adhesive method. Four sensors were installed at mid-height of the pile (34 inches from the pile cap), and two were attached towards the top (3 inches from the pile cap). This was done to ensure a high level of accuracy when calculating the average strain of the repaired pile. The selection of these eight piles provided symmetry when comparing the performance of each pile cap.

In order to accurately measure the strain of each pile with a known load being applied to it, the truck stopped 6 times during its drive across the bridge. The truck stopped with its front wheels directly over the south bent (1), centered over the south bent (2), back wheels directly over the south bent (3), front wheels directly over the north bent (4), centered over the north bent (5), and with its back wheels directly over the north bent (6). At each of these stops, a “click” was recorded in the STS-II software. These clicks provided a way to observe the trucks location throughout the duration of the test. For example, the third click in the software represented the third stop on the bridge.

Given the weight and dimensions of the truck and the dimensions of the bridge, structural analysis was used to determine the theoretical load applied to each bent cap at each stop. The known axle loads and their positions were used to calculate the resultant force on each bent cap (Front axle weight=5.060 kip, Rear Axle Weight=4.940 kip). These results are expressed in

Table 3.3. Figures 3.18 to 3.23 illustrate the different positions of the truck along the length of the bridge.

Truck Position	Load (kip)	
	South	North
1	6.23	0
2	6.05	2.06
3	5.88	4.12
4	4.02	5.98
5	2.02	6.04
6	0	6.14

Table 3.3 Theoretical Loads on North and South Bent Cap

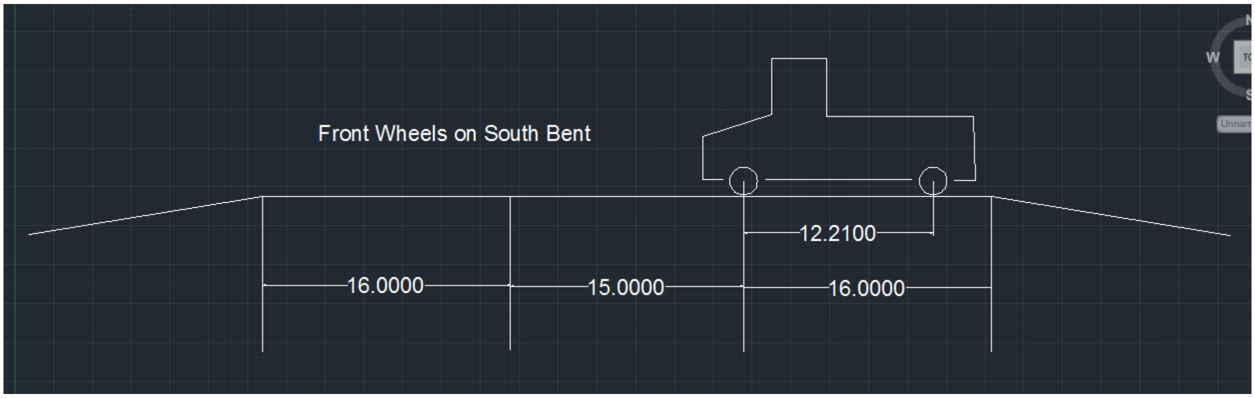


Figure 3.18 Truck Position 1 "Front Wheels on South Bent"

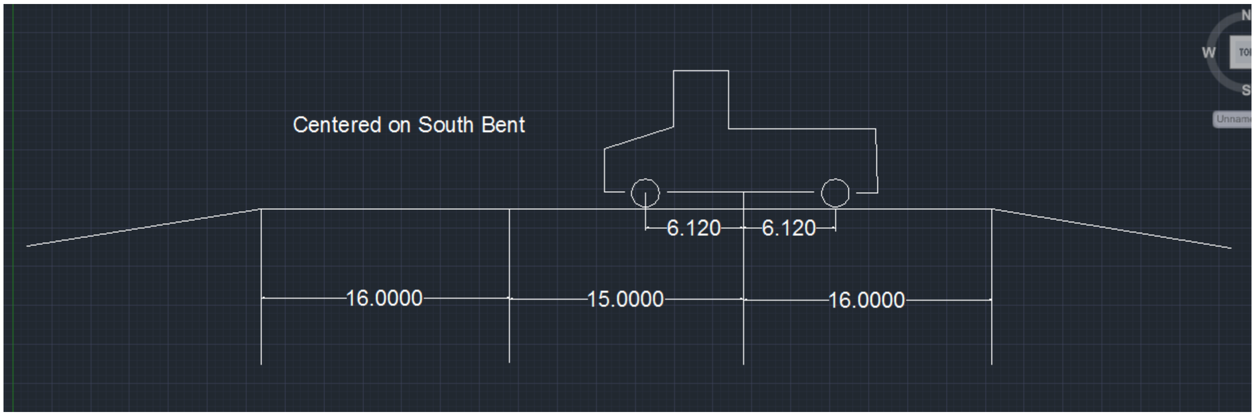


Figure 3.19 Truck Position 2 "Centered on South Bent"

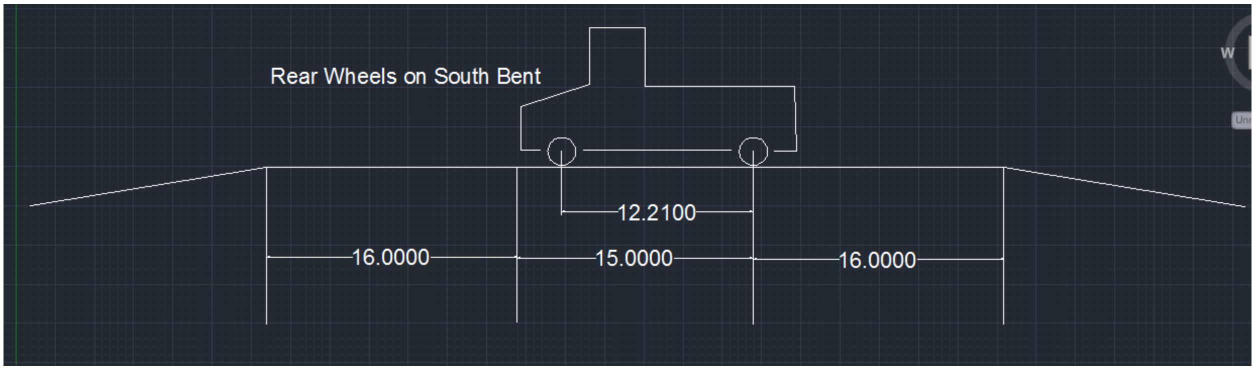


Figure 3.20 Truck Position 3 “Rear Wheels on South Bent”

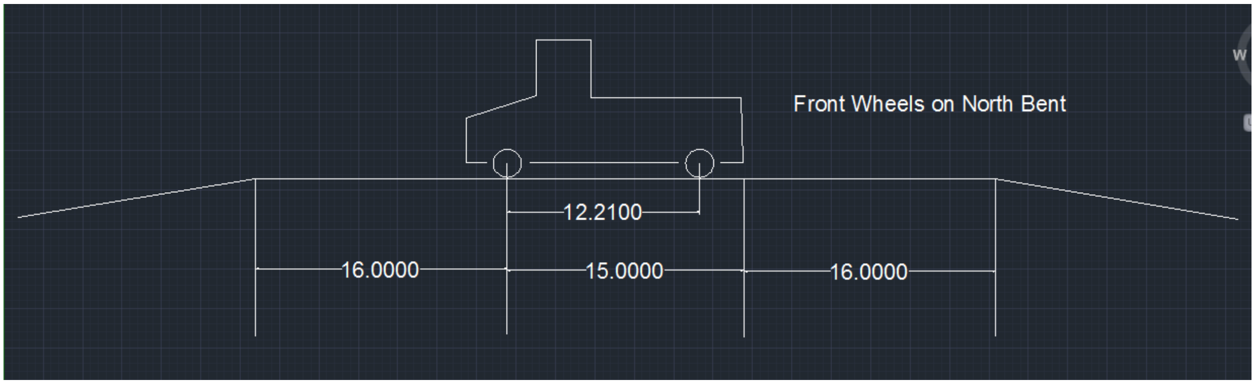


Figure 3.21 Truck Position 4 “Front Wheels on North Bent”

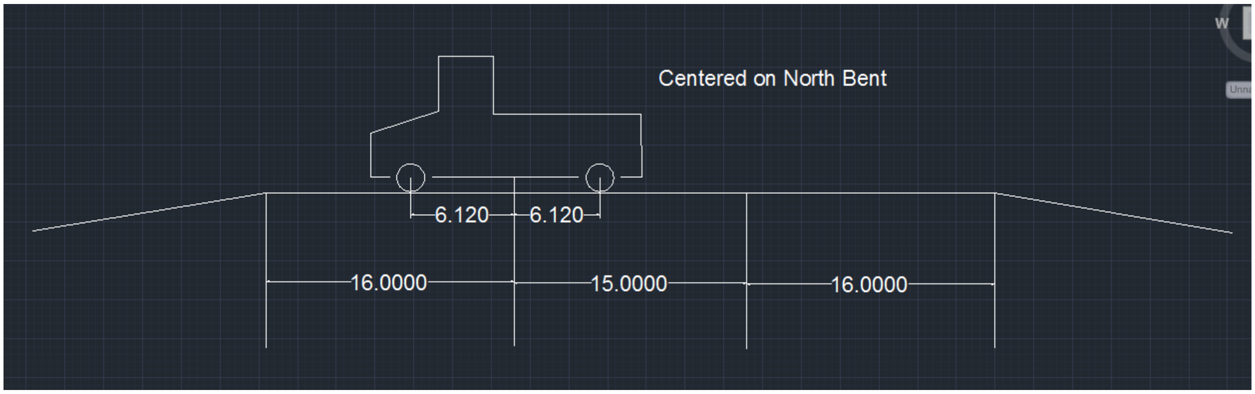


Figure 3.22 Truck Position 5 “Centered on North Bent”

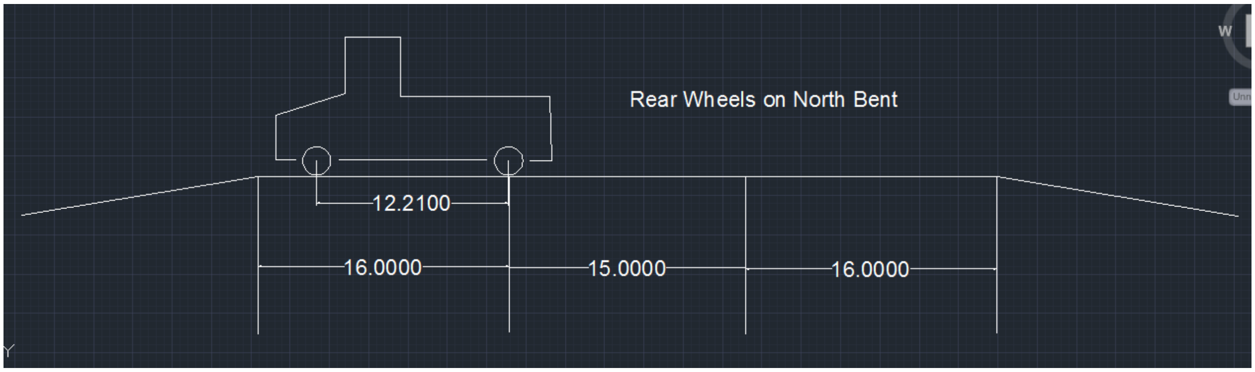


Figure 3.23 Truck Position 6 “Rear Wheels on North Bent”

Both the North and South bent caps were modeled using RISA 3D. To calculate the distribution of load across each bent, a total load (100 Kip) was applied in a position that was similar to the truck. When the load taken by each pile is compared to the total load applied, the percentage of weight applied to the bent can be calculated. As illustrated in Figure 3.24, a 100 Kip load distributed at the width of the truck tires and the axial forces on the South Bent are displayed. The pile cap was modeled to be a 12”X12” Southern Pine continuous beam. All dimensions are plotted as found in the field.

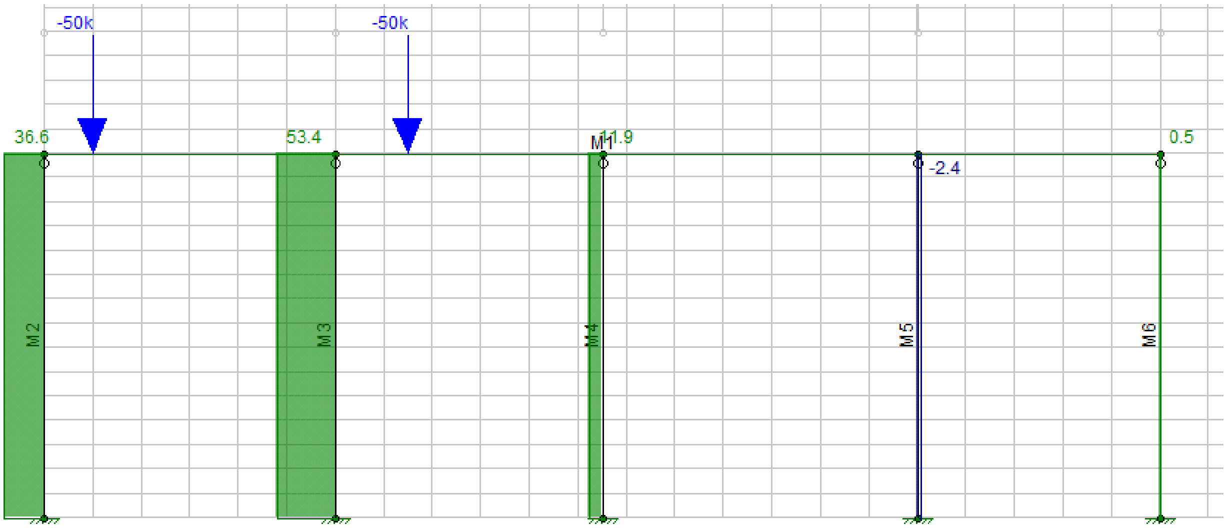


Figure 3.24 RISA3D Model of Load Distribution on South Bent Cap

Note that M3, the second member from the outside on the bent, should take about 53 Kip, or 53% of the axle weight. As a timber pile, this member should strain accordingly. For the North Bent, the spacing between the piles has changed by small amounts. Again, modeled in RISA 3D, the loads in kips taken by each pile is equivalent to the percentage of the load on the bent that the pile will be undergoing. The North bent is illustrated in Figure 3.25.

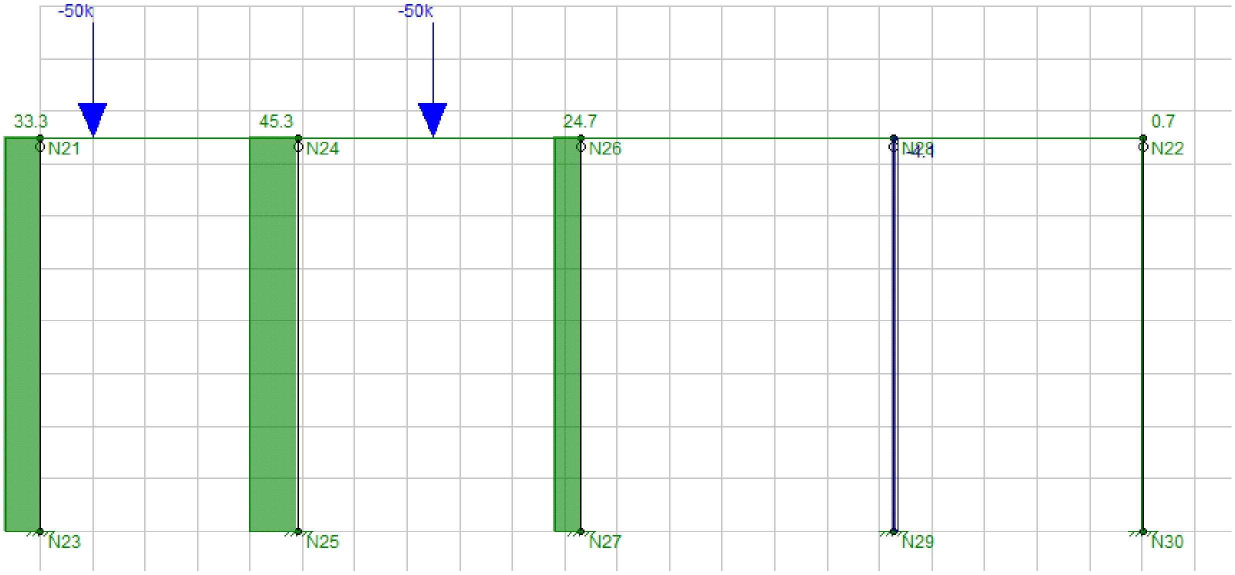


Figure 3.25 RISA3D Model of Load Distribution on North Bent Cap

The theoretical loads from the structural analysis can be combined with the RISA 3D modeling to calculate a theoretical load on each pile for each truck stop. These loads are illustrated in Table 3.4.

After calculating the theoretical loads in each pile and comparing them to the results of the field testing, a more accurate estimation of the modulus of elasticity of the timber piles could be made. Initially, a timber modulus of 1000 ksi was used in the stress calculations. After averaging the ratio of theoretical load to actual load for all points, a correction factor of 2.09 was included into the modulus calculation. Therefore, a more accurate modulus of elasticity for the timer piles which will be used in all timber calculations is 2,090 ksi.

Truck Position	Pile	Theoretical Load (pounds)	Truck Position	Pile	Theoretical Load (pounds)
Front Wheels on South Bent	N1	0	**Front Wheels on North Bent**	N1	1991
	N2	0		N2	2709
	N3	0		N3	1477
	N4	0		N4	-245
	S1	2280		S1	1471
	S2	3326		S2	2147
	S3	741		S3	478
	S4	-150		S4	-97
Centered Over South Bent	N1	656	**Centered Over North Bent**	N1	2011
	N2	933		N2	2736
	N3	509		N3	1492
	N4	-85		N4	-247
	S1	2214		S1	739
	S2	3239		S2	1078
	S3	719		S3	240
	S4	-145		S4	-49
Back Wheels on South Bent	N1	1371	**Back Wheels on North Bent**	N1	2044
	N2	1866		N2	2781
	N3	1078		N3	1517
	N4	-169		N4	-252
	S1	2152		S1	0
	S2	3139		S2	0
	S3	700		S3	0
	S4	-141		S4	0

Table 3.4 Theoretical Loads per Pile

REPAIR DESIGN METHODOLOGY

The final products of the project and this thesis specifically are simple design tables and installation procedures of the splice repair. The design tables will make it easy to choose a replacement shape that will safely take the load from the bridge deck to the old pile underground. Donny Head and Max Hess have listed four common pipe sizes and a few H-Pile shapes that the counties typically have access to. The pipe shapes are listed in Table 3.5.

Available County Pipe		
Pipe	**Outside Diameter (in.)**	**Wall Thickness (in.)**
D=7 5/8 **t=0.450**	7 5/8	0.450
D=7 5/8 **t=0.500**	7 5/8	0.500
D=9 **t=0.450**	9	0.450
D=9 **t=0.500**	9	0.500

Table 3.5 Available County Pipe Sizes

In addition to these pipes, the counties routinely have access to H-Pile shapes HP8X36 and HP10X42. One design table will use only county pipe sizes. Another design table will utilize HP shapes that the county has access to. A third design table will use standard pipe found in the AISC Steel Manual. These pipes consist of pipe 3 X-strong, pipe 4 X-strong, pipe 5 X-strong, pipe 6 X-strong, pipe 8 X-strong, pipe 4 std., pipe 5 std., pipe 6 std., pipe 8 std., and pipe 10 std.

In addition to these three design tables, two more tables specifying a minimum second area, I (in.^{4}), and cross sectional area, A (in.^{2}), will be constructed. The I and A values will be based on the shapes and sizes used in the previous tables.

The final design will specify the details in all welds, including types of weld and sizes of weld. It will also include any details needed pertaining to both connections of the splice. In addition to the derivation and explanation of these details, diagrams will be provided to assist in the installation process.

The design of the replacement steel section will be dependent on the location of the pile being replaced. This is a result of higher lateral loads being placed on abutment piles compared to piers located in the middle of the bridge.

To formulate the design tables of midspan piles or piers, the capacity of the timber pile was calculated first. Conservative values were chosen for material properties that will not be easily measured, such as the modulus of elasticity and compressive strength. In this case, being non-conservative when calculating the capacity of the timber pile results in a higher figure since it is desired to design a steel replacement that will support a higher (conservative) load. Lateral loads were ignored when calculating the capacity of the timber pile in order to achieve a higher capacity. Equations 3-4 to 3-7, from section 3.7 in the *National Design Specification for Wood Construction* (NDS), were used to calculate the capacity of a timber pile.

$$\phi P_n = \phi\, F'_c * A_{pile} \tag{3-4}$$

Where $\phi = 0.9$, A_{pile} is the calculated cross sectional area of the timber pile, and F'_c is the compressive strength of the timber parallel to the grain, calculated using the following:

$$F'_c = F_c * C_p \tag{3-5}$$

Where $F_c = 1{,}250$ psi, and

$$.C_p = \frac{1+\left(\frac{F_{cE}}{F_c}\right)}{2c} - \sqrt{\left(\frac{1+\left(\frac{F_{cE}}{F_c}\right)}{2c}\right)^2 - \frac{\left(\frac{F_{cE}}{F_c}\right)}{c}} \tag{3-6}$$

Where c=0.85 for round timber piles and

$$F_{cE} = \frac{0.822*E}{\left(\frac{l_e}{d}\right)^2} \tag{3-7}$$

Where l_e is the length of the pile and d is the diameter of the pile (both in inches).

As stated before, some material properties were estimated as conservative values in order to calculate the axial capacity of the timber. The modulus of elasticity was chosen to be E=2,090,000 psi (based on the results from field testing), the timber was assumed to stay in an elastic state, and the compressive strength parallel to the grain was chosen to be f_c=1,250 psi. The f_c value was chosen from Table 6A from the NDS. Due to the variability in the field in regards to the length of timber that needs to be removed from under the bridge, the L used in the capacity equations relates to the distance from the bottom of the pile cap to the ground plus 5 feet. This enables a conservative design with any length of pile that is cut less than 5 feet below grade.

The capacity of steel pipes and H-Piles were designed with both axial and lateral loads in mind. After communicating with multiple engineers that work with country bridges, it was concluded that the design would be sufficient when including only debris and water load from creeks or rivers flowing under the bridge. Other lateral loads used in new design include wind and traffic loads (braking), however it was decided that given the small surface area exposed to wind and limited traffic that timber county bridges are typically exposed to, the debris load would be satisfactory.

The design capacity of the installed piers can be treated at beam-columns. The lateral load applied to these beam-columns is a “worst-case” load calculation. A distributed load is applied to the face of the pier, which is simply supported at both ends. This distributed force extends one third up the height of the exposed pier. After communicating with county engineers, this was determined to be a conservative assumption for a worst case scenario loading situation. This loading situation is illustrated in Figure 3.26.

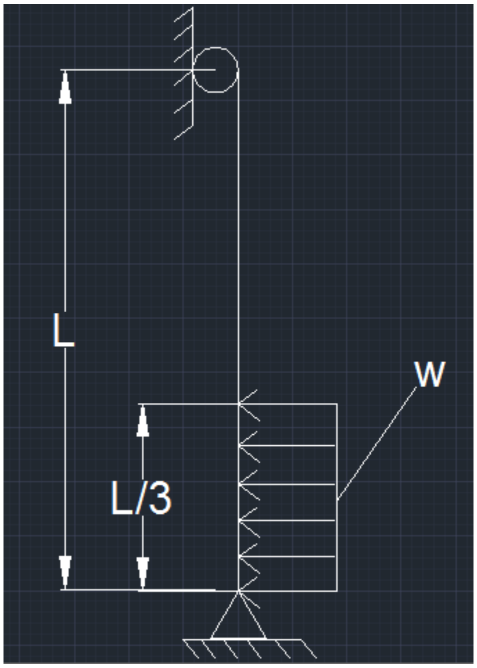


Figure 3.26 Worst Case Loading Scenario for Piers

The following equations (from AASHTO, 2002) describe how this lateral loading was calculated and applied to the repair:

$$w = dP \qquad (3\text{-}8)$$

Where d is the diameter or depth of the replacement steel section in feet, and P is the stream pressure in psf.

$$P = KV^2 \qquad (3\text{-}9)$$

And

$$V = \frac{Q}{A} \qquad (3\text{-}10)$$

Where K is a coefficient, being 1.4 for square ended piers and 0.7 for circular piers, V is the velocity of water in feet per second, Q is flow rate in cubic feet per second, and A is the flow area in square feet. For this repair:

Q=7,500 ft^3/second

and

$$A = 50\text{ft.}*\frac{L}{3}\text{ft.}$$

These figures were chosen based on surveying various engineers whom are familiar with county bridge design. The flow rate is a high number based on small creeks in Oklahoma.

From this load, the following maximum moment and shear calculations were derived:

$$M_{max} = M_u = \frac{25wL^2}{648} \tag{3-11}$$

$$V_{top} = \frac{5wL}{18} \tag{3-12}$$

$$V_{bottom} = \frac{wL}{18} \tag{3-13}$$

Due to the fact that the repair will be under a combined load the following interaction equations were used to check if the design was satisfactory.

$$\text{If } \frac{P_u}{\varphi P_n} \geq 0.2,$$

$$\frac{P_u}{\varphi P_n} + \frac{8}{9}\frac{M_u}{\varphi M_n} \leq 1 \tag{3-14}$$

And

$$\text{If } \frac{P_u}{\varphi P_n} \leq 0.2,$$

$$\frac{P_u}{2\varphi P_n} + \frac{M_u}{\varphi M_n} \leq 1 \tag{3-15}$$

The axial load on the member, P_u, is the axial capacity of the timber pile being replaced. Using this method of loading, the beam-column can be designed for many general applications, rather than by a case-by-case basis. Equations 3-16 to 3-19 were used to calculate the axial capacity of each steel member considered. They were found in Chapter E of the AISC Steel Construction Manual.

$$\phi P_n=\phi F_{cr}A_g \tag{3-16}$$

Where ϕ=0.9, A_g is the gross area of the steel and

$$F_{cr} = 0.658^{F_y/F_e} * F_y \qquad (3\text{-}17)$$

$$\text{If} \qquad \frac{KL}{r} \leq 4.71\sqrt{\frac{E}{F_y}}$$

And

$$F_{cr} = 0.877 * F_e \qquad (3\text{-}18)$$

$$\text{If} \qquad \frac{KL}{r} \geq 4.71\sqrt{\frac{E}{F_y}}$$

And

$$F_e = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2} \qquad (3\text{-}19)$$

Where K=1, L is the length of the steel in inches, r is the radius of gyration in inches, F_y is the yield strength of the steel (50 ksi), and E is the modulus of elasticity for steel at 29,000 ksi.

The calculations used to determine the flexural capacity depended on whether the replacement steel was a pipe or an H-pile. For an H-pile, which is undergoing a lateral load parallel to the flanges, the flexural capacity is about the minor (weak) axis. For weak axis bending (AISC Steel Manual, Chapter F, Section F6):

$$\phi M_n = \phi M_p = F_y Z_y \leq 1.6 F_y S_y \quad \text{(yielding failure)} \qquad (3\text{-}20)$$

if $\lambda < \lambda_{pf}$ (beam is compact),

or

$$\phi M_n = \phi\left[M_p - \left(M_p - 0.7F_y S_y\right)\left(\frac{\lambda - \lambda_{pf}}{\lambda_{rf} - \lambda_{pf}}\right)\right] \qquad (3\text{-}21)$$

if $\lambda_{pf} < \lambda < \lambda_{rf}$ (beam is non-compact)

Where ϕ=0.9, Z_y is the plastic section modulus in inches cubed, and S_y is the elastic section modulus in inches cubed. The flexural capacity cannot exceed ϕM_p. There is another possibility, which includes beams with slender flanges; however no steel sections with slender flanges were used in the repair design. Also,

$$\lambda = \frac{b_f}{2t_f} \tag{3-22}$$

$$\lambda_{pf} = 0.38\sqrt{\frac{E}{F_y}} \tag{3-23}$$

$$\lambda_{rf} = \sqrt{\frac{E}{F_y}} \tag{3-24}$$

Where b_f is the flange width in inches and t_f is the flange thickness in inches.

For pipes, the flexural capacity was calculated by using the following (AISC Steel Manual, Chapter F, Section F8):

For all pipes $D/t < \frac{.45E}{F_y}$

$$\phi M_n = \phi M_p = F_y Z \quad \text{(yielding failure)} \tag{3-25}$$

if $L < L_p$ (compact sections)

or

$$\phi M_n = \phi\left(\frac{0.021E}{D/t}\right)S \quad \text{(Local Buckling failure)} \tag{3-26}$$

if $L > L_p$ (Non-compact sections)

Where ϕ=0.9, D is the outside diameter of the pipe in inches, and t is the thickness of the pipe wall in inches. Again, the flexural capacity cannot exceed ϕM_p. There is also a separate calculation used for pipes with slender walls, however no pipes with slender walls were considered in the design. Also,

L = length of pipe to be installed

$$L_p = 1.76r\sqrt{\frac{E}{F_y}} \tag{3-27}$$

Due to the presence of combined loading, the moment applied by the transverse loads may be amplified by the axial load. To adjust for this increased moment, a moment amplification factor, B_1, is calculated and applied according to the equations 3-28 to 3-30. They were found in Segui's *Steel Design*, 2007.

$$\text{Amplified Moment} = B_1 * M_u \tag{3-28}$$

where

$$B_1 = \frac{C_m}{1-(P_u/P_{e1})} \geq 1 \tag{3-29}$$

Since transverse loading is applied, C_m=1 and P_u is the applied axial load.

Also,

$$P_{e1} = \frac{\pi^2 EI}{(KL)^2}. \tag{3-30}$$

Both ends of the steel member are non-moment transferring connections. They need to transfer shear loading and axial loading. Given the piles will be under a compressive axial load, only the plate thickness needs to be checked in order to transfer the end bearing load. The lateral (shear) loads will need to be able to be transferred through each connection to the pile cap and the existing pile underground. Again, the "worst-case" lateral load which was used in designing the beam-column will be used to design the capacity of the connections. The following equation was used to determine the strength of the welds used on each connection:

$$\phi R_n = (0.02) F_{exx} Dl \tag{3-31}$$

Where F_{exx}=the electrode used in ksi, D=the leg height of the weld in 16ths of an inch, and l= the length of the weld in inches. Any bolts used to connect the steel to the pile cap will be checked for bolt shear from the following equation:

$$\phi R_n = \phi R_v * N \tag{3-32}$$

Where ϕR_v is the shear capacity of the bolt used and N is the number of bolts used. The strength of the connection at each end of the member will be sufficient to transfer all loads to the foundation.

Compared to piers, abutment piles undergo more lateral loads from soil and roadway forces. The amount of lateral load placed on these abutment piles depends on the type of soil used behind the abutment, the height of the abutment, the type and size of roadway traveling over the abutment, and the spacing between piles.

Given that there are many more variables that affect the lateral loading on abutment piles compared to midspan piers, a different approach was used to create the replacement design. A prescriptive method is typically used to design new abutment piles on county bridges. This idea will be utilized in the design of the repair. All replacement piles for abutment components will be specified as one shape with limitations on other variables in the structure. For example, the span length has to be less than a certain value, the distance between piles needs to be less than a certain value, and the height cannot exceed a certain value.

County bridges repeatedly use HP10X42 for abutment piles on new bridges. This shape has also been said to be readily available for the use of this repair across the state. The design for abutment piles will use a HP10X42 with limitations of span length, spacing between piles, and span height. These variables coincide with the prescriptive method used in the design of new bridges and the use of the HP10X42 pile. The following diagram provided by Jimmy Watson of ACCO support the use of this pile and its limitations.

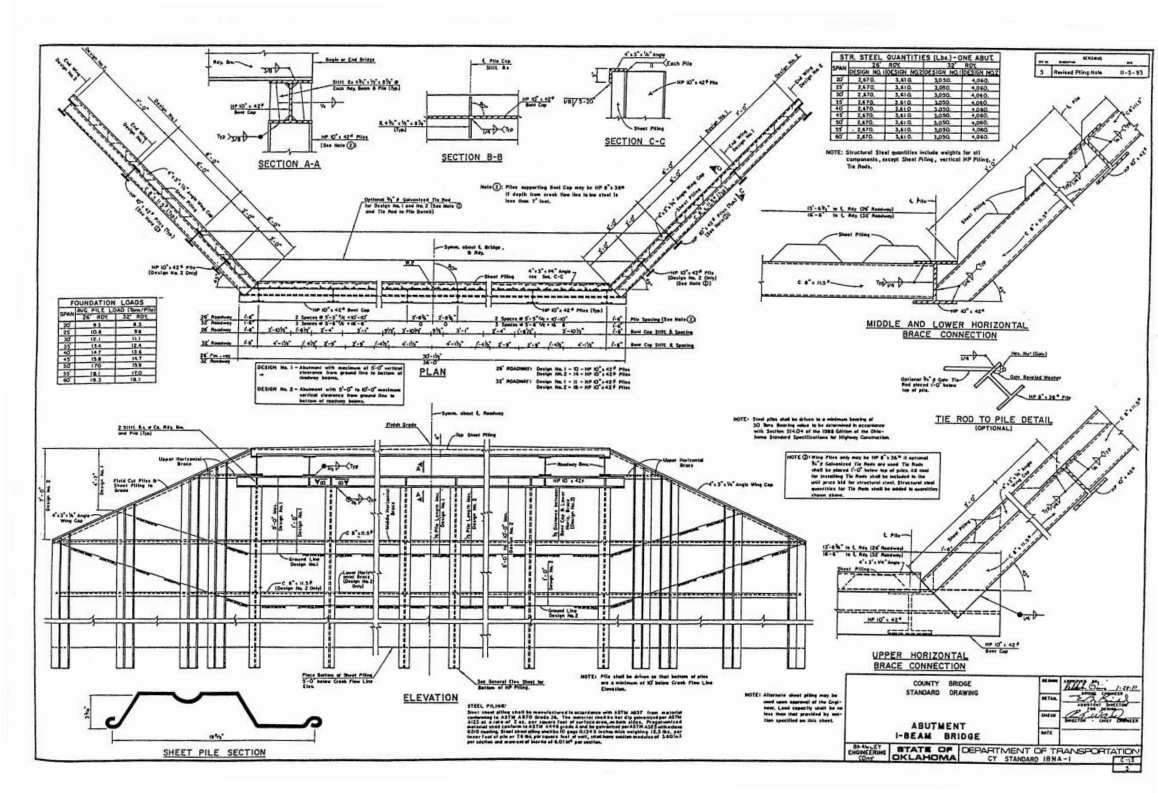


Figure 3.27 Example Abutment Design of New County Bridge

Depending on the top connection, the bottom connection of the abutment piles may or may not need to be a moment connection. Ideally, the steel replacement member will be able to be connected to the pile cap with some sort of shear connection. If however this is not the case, the pile will act as a cantilever, requiring a moment transfer at the connection to the existing timber pile underground. The only plausible design for this moment connection is to extend the length of the sleeve and insert a bolt through both the side of the sleeve and the existing timber pile. With the extension of the pipe underground, the sleeve would be able to transfer moment to the timber pile. The following diagram depicts the reasoning behind the need for a moment transferring connection.

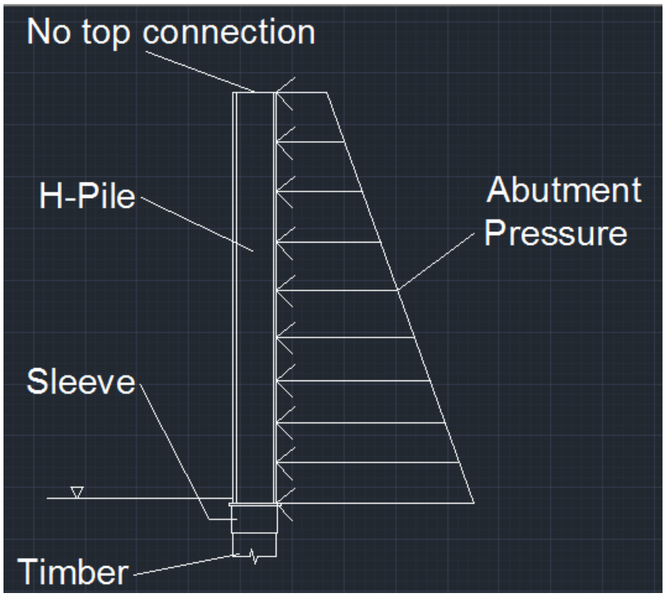


Figure 3.28 Loading Scenario for Abutment Piles

The amount of moment transferred will depend on the length of the pipe of the sleeve that surrounds the timber pile. This moment must not exceed the flexural strength of the timber pile. Given that there will not be a guaranteed snug fit between the timber pile and the sleeve, there is no guarantee that the full potential of this moment connection design will be achieved. Further work is needed to be done on this connection, but is beyond the scope of this project. Ideas involving this connection may include epoxy injection, concrete encasement, or additional steel placement in the connection.

If the abutment pile is connected to the pile cap with a shear connection, the sleeve connection will mimic that of the pier sleeve connections. The capacity of these connections will exceed those designated for the connections used on new structures.

Other general concerns explored in the design of the repair must be considered. Due to load being distributed by stiffness, it was discovered that the amount of load carried to the existing pile under a repaired pier was higher than the original theoretical design load. One problem this may cause is an increased settlement of the timber piles beneath the steel splice. While at first thought this may seem like a significant problem, it is believed that the settlement of the existing timber pile will result in a loss of stiffness. With this loss of stiffness, the load applied to the pile cap will redistribute to other piles and safely find its way to the foundation. Repaired piles should be inspected for amount of settlement, and a drastic amount may require further investigation. Another issue involving the steel splice is the corrosion of the member. While these steel members may be exposed to moisture and other environments that cause corrosion, the members used will not be extremely thin in wall thickness, therefore corrosion should not result in a significant amount of section loss. In addition, this repair is only to be used as a temporary fix, providing a few years of service life to a structure before it can be replaced.

INSTALLATION PROCEDURE METHODOLOGY

The installation procedure was modeled after those used in the Grant County repair. Extensive communication with Max Hess, the county commissioner of Grant County, provided installation details of the repair that have been used across the state. This installation procedure has been tried and tested. It is cost efficient and should not impede traffic. It is simple and utilizes machinery commonly found within county maintenance resources. It can also be completed with as few as two workers in less than eight hours. The procedure, which is found in the results section, calls for the pile cap to be “jacked up”. The reasoning behind this lies in the theory that a member which is under stress and strain must be relieved of that stress and strain before being replaced or repaired. If the bridge was not jacked up before the new steel member was placed, it would be nearly impossible to provide a load path for the stresses to transfer to the foundation. This is common sense and a theory discussed in Dr. Kyle Riding’s Concrete Pavement and Bridge Repair course from Kansas State University.

CHAPTER IV

FINDINGS

FIELD TESTING FINDINGS

The findings from the field testing performed in Grant Country suggest the successful flow of load from the pile cap of the bridge, through the spliced repair, to the existing timber pile in the foundation. Figure 4.1 illustrates that as the truck drives across the bridge, the replaced pile takes up to 4.658 Kip (all values are averaged from three data sets).

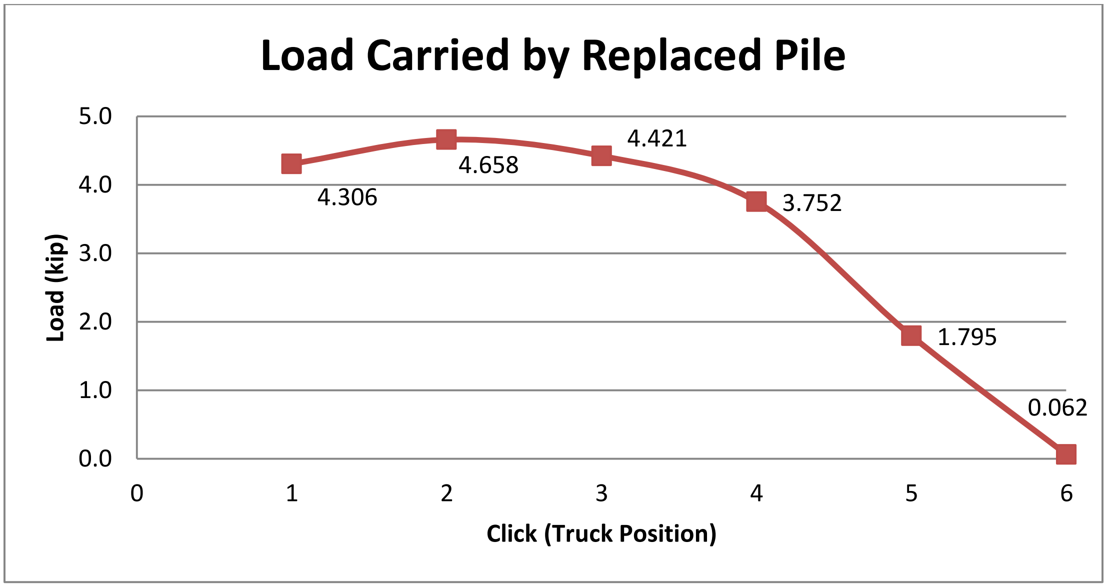


Figure 4.1 Load Carried by Replaced Pile

In addition, the repaired pile took a large percentage of the total load of the truck, as shown in Figure 4.2

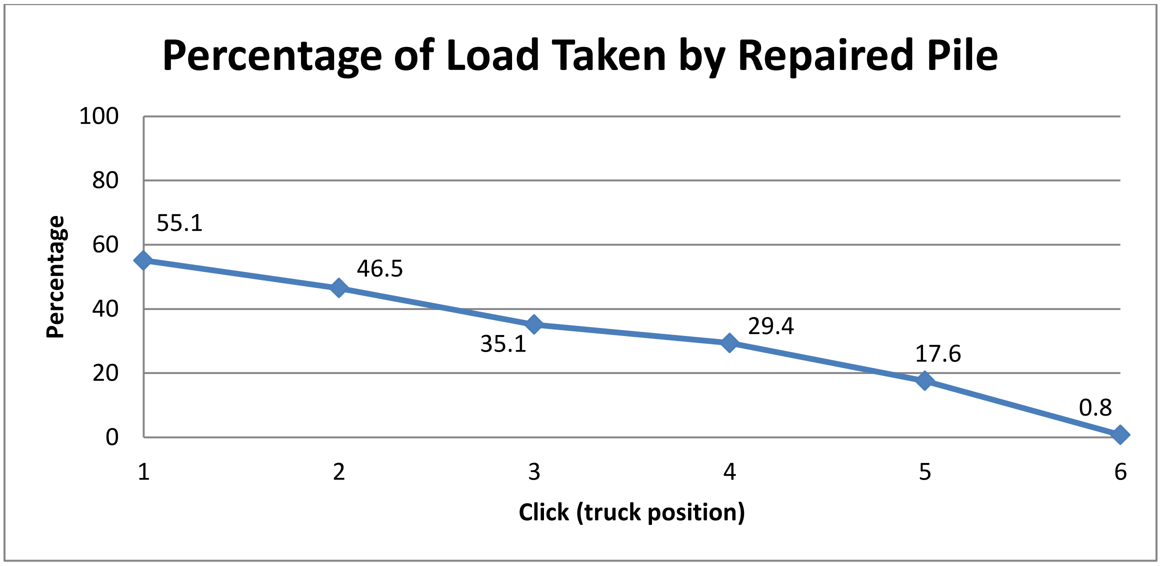


Figure 4.2 Percentage of Load Taken by Repaired Pile

While the location of the repaired pile does affect the amount of load it will take, this is another example of how stiff the repaired pile actually is.

Figures 4.4 to 4.9 illustrate the actual load registered in each pile, measured from the field test, compared to the theoretical load the pile should see based on structural analysis. It should be noted that in indeterminate structures like a pile system, load is distributed by stiffness. Therefore, if an element of a structure is undergoing a high load, then that element is stiff and provides strength to the system. Recall the location of each pile, illustrated in Figure 4.3, and that the truck was traveling from South to North during the testing runs.

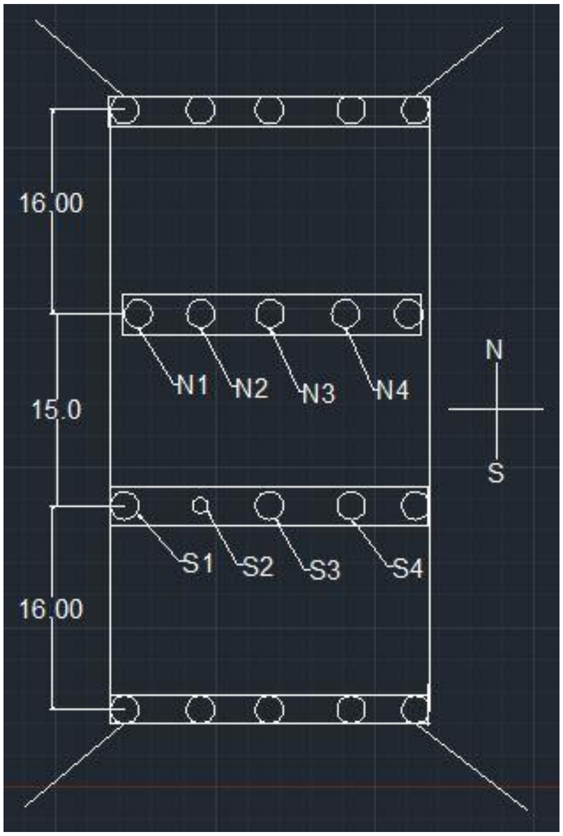


Figure 4.3 Plan View of Grant County Bridge

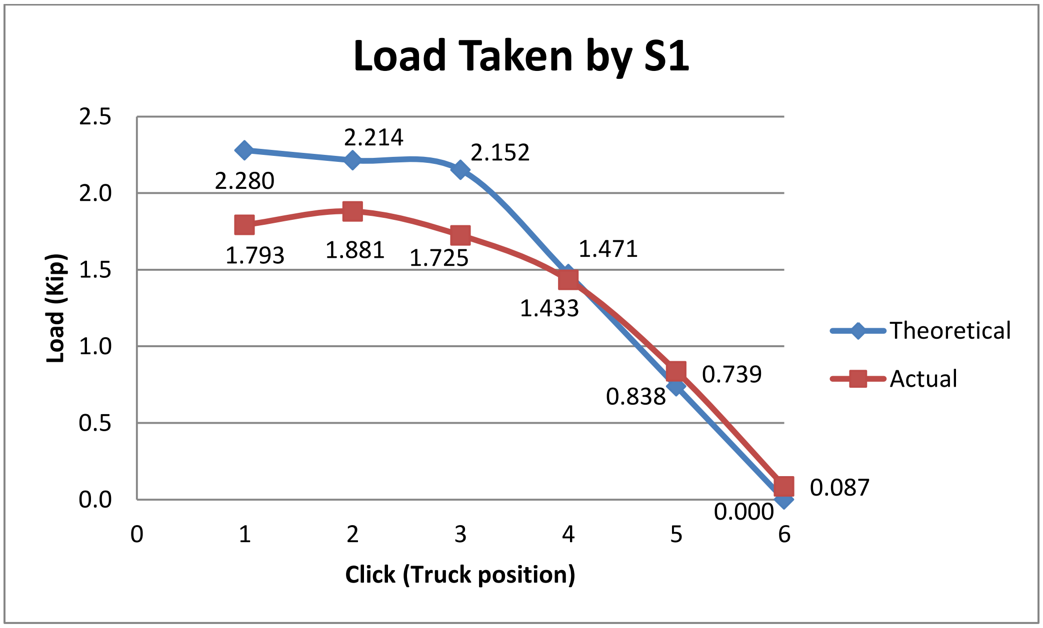


Figure 4.4 Load Taken by Pile S1

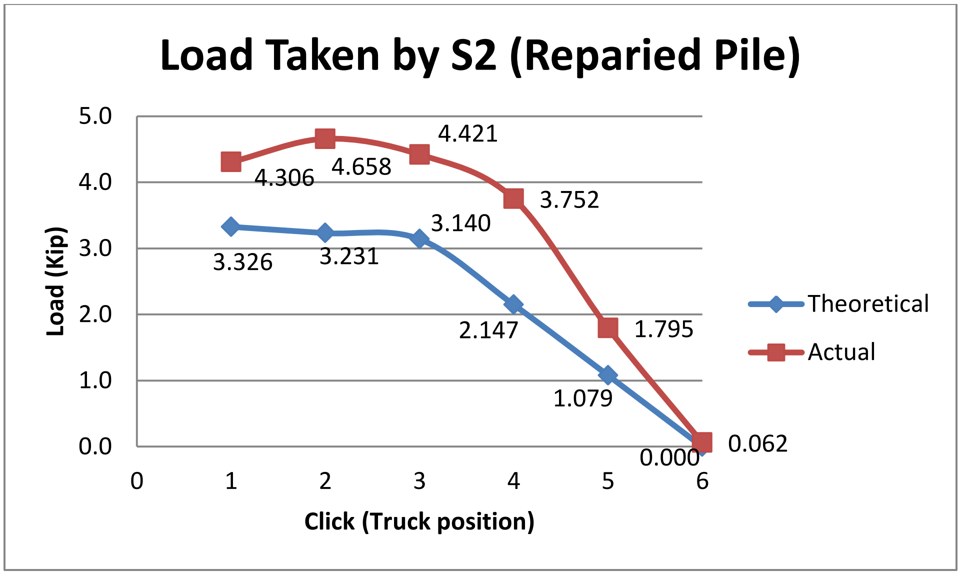


Figure 4.5 Load Taken by S2 (Repaired Pile)

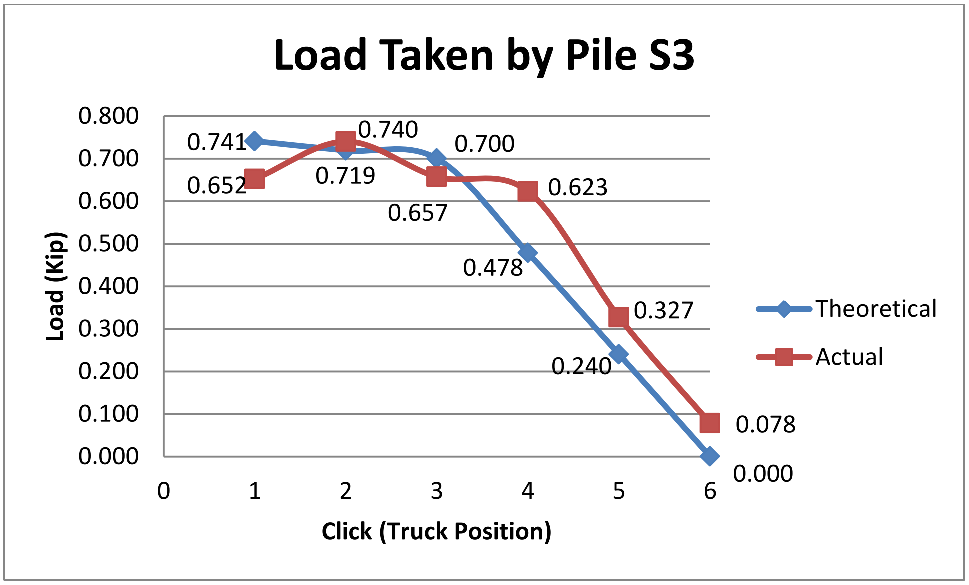


Figure 4.6 Load Taken by Pile S3

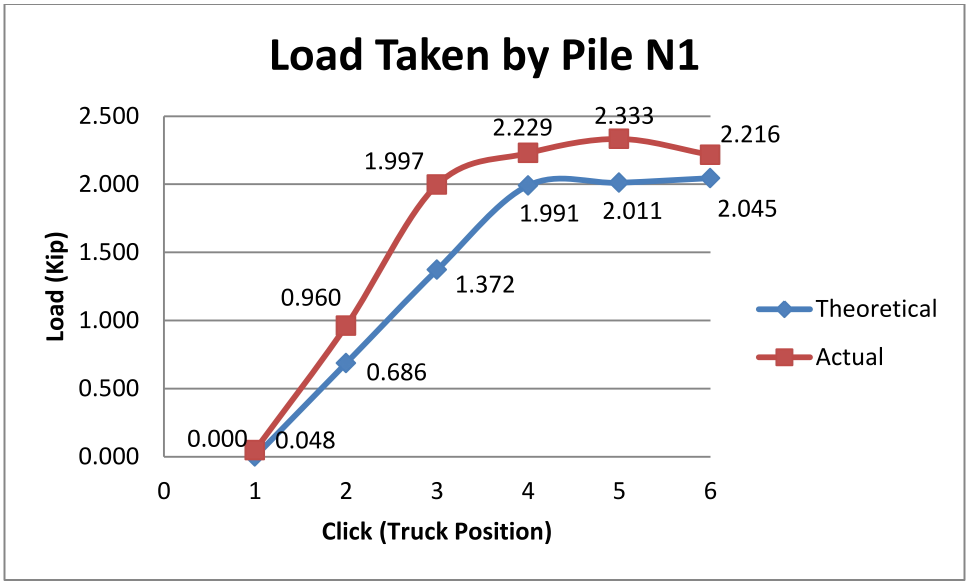


Figure 4.7 Load Taken by Pile N1

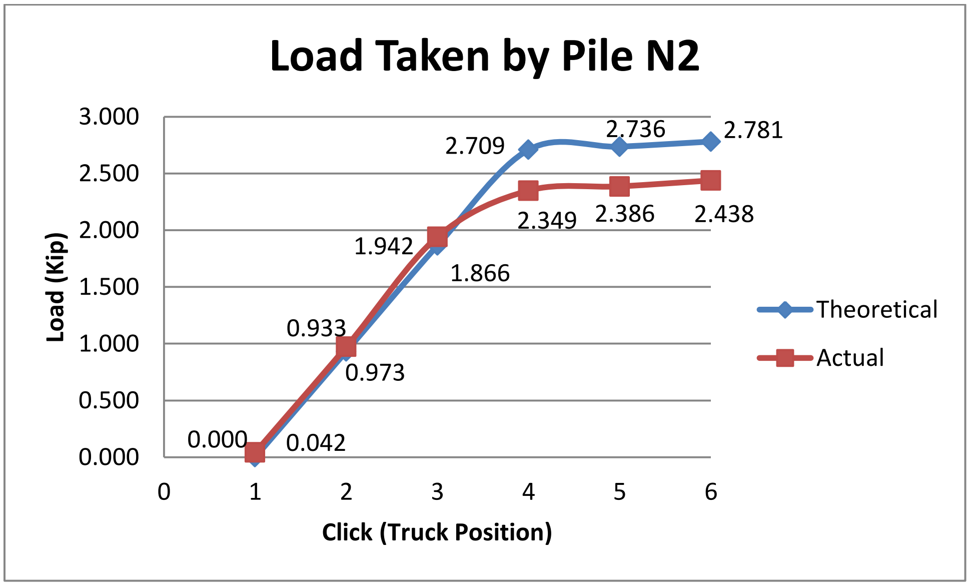


Figure 4.8 Load Taken by Pile N2

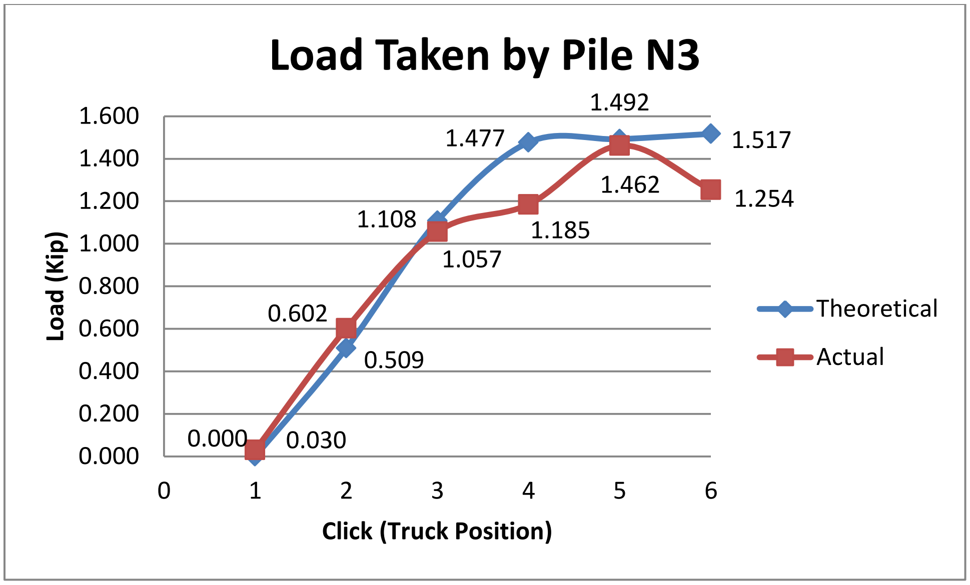


Figure 4.9 Load Taken by Pile N3

Piles S4 and N4 were negated from these illustrations because they underwent a very small theoretical and actual load.

Further illustrations of the load distribution at each truck position are displayed in Figures 4.10 to 4.15. In addition, Figure 4.16 combines all pile loads into one illustration.

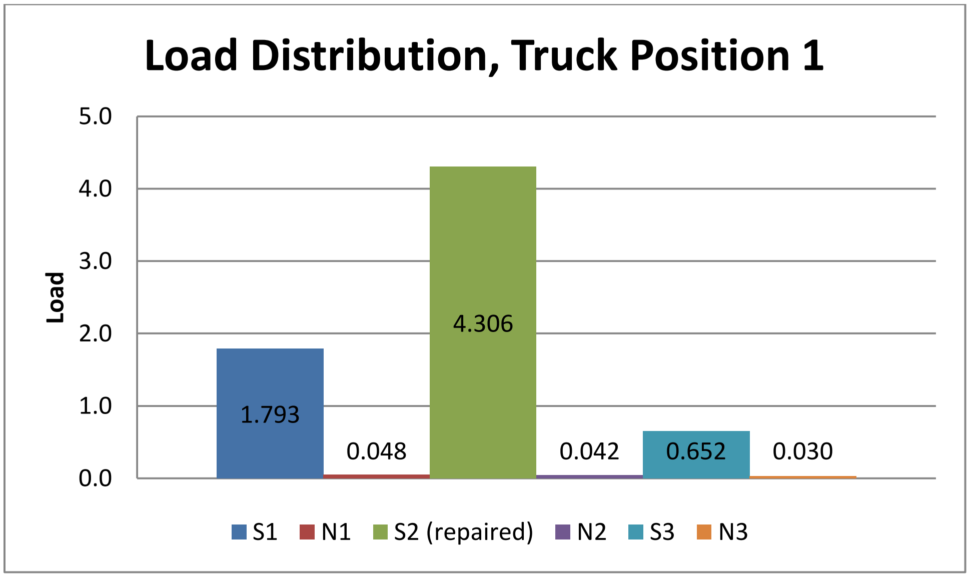


Figure 4.10 Load Distribution, Truck Position 1

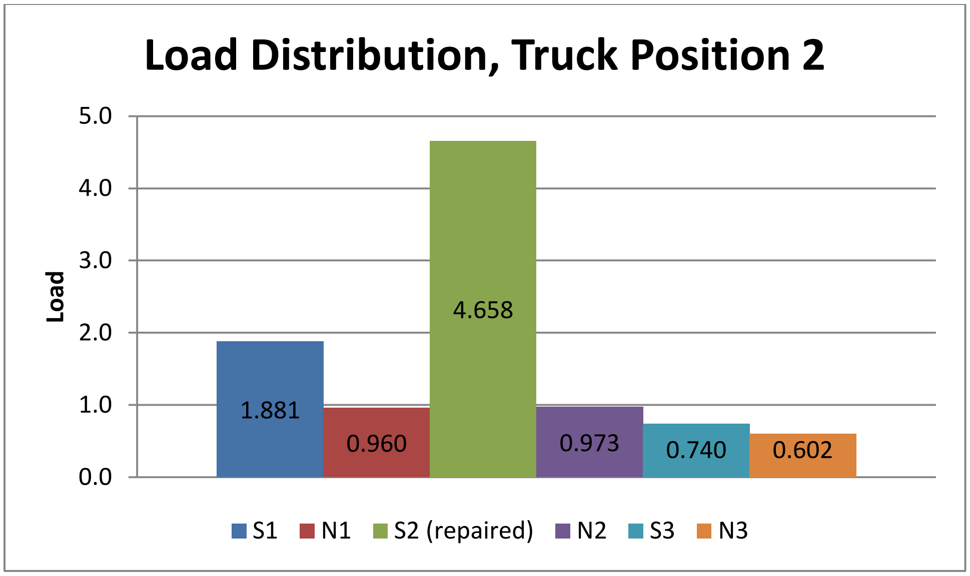


Figure 4.11 Load Distribution, Truck Position 2

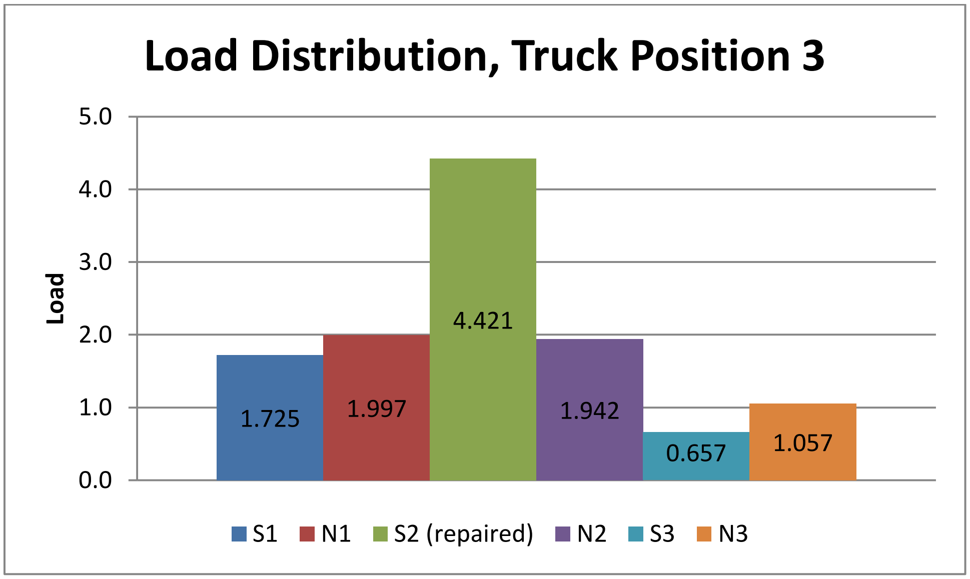


Figure 4.12 Load Distribution, Truck Position 3

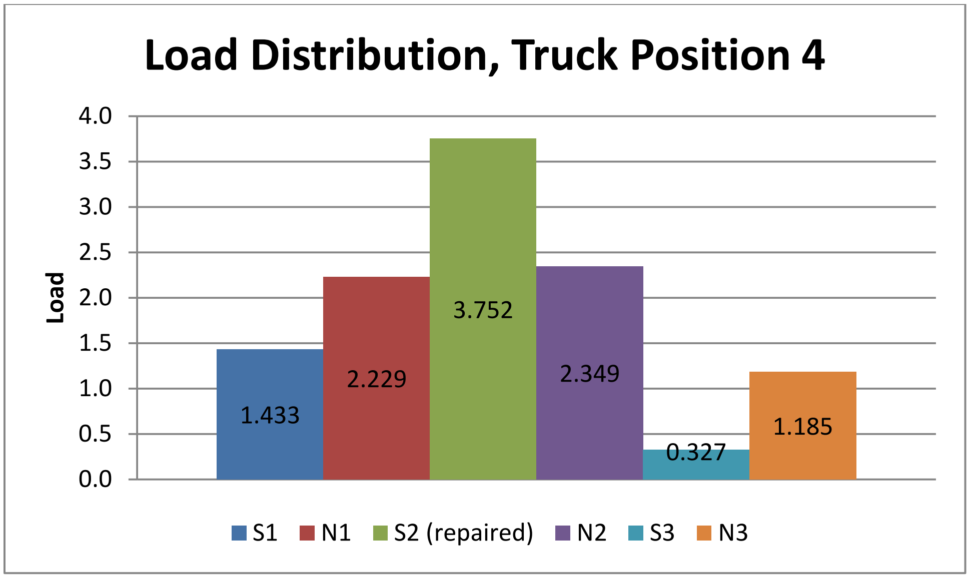


Figure 4.13 Load Distribution, Truck Position 4

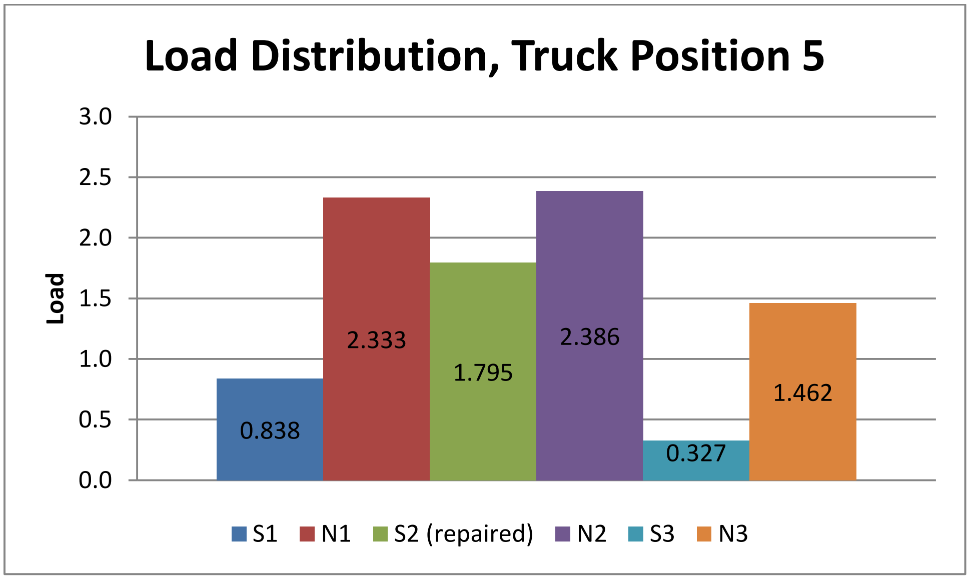


Figure 4.14 Load Distribution, Truck Position 5

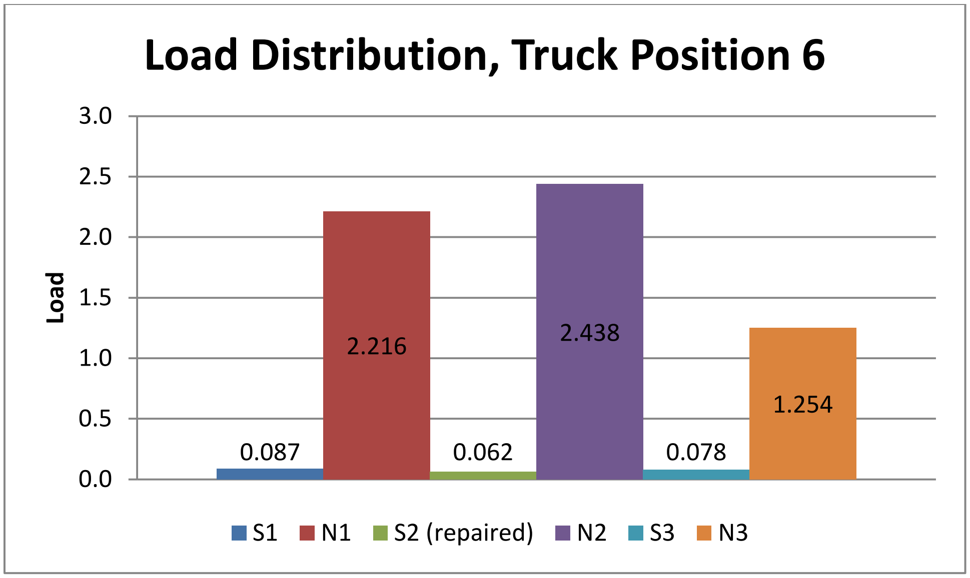


Figure 4.15 Load Distribution, Truck Position 6

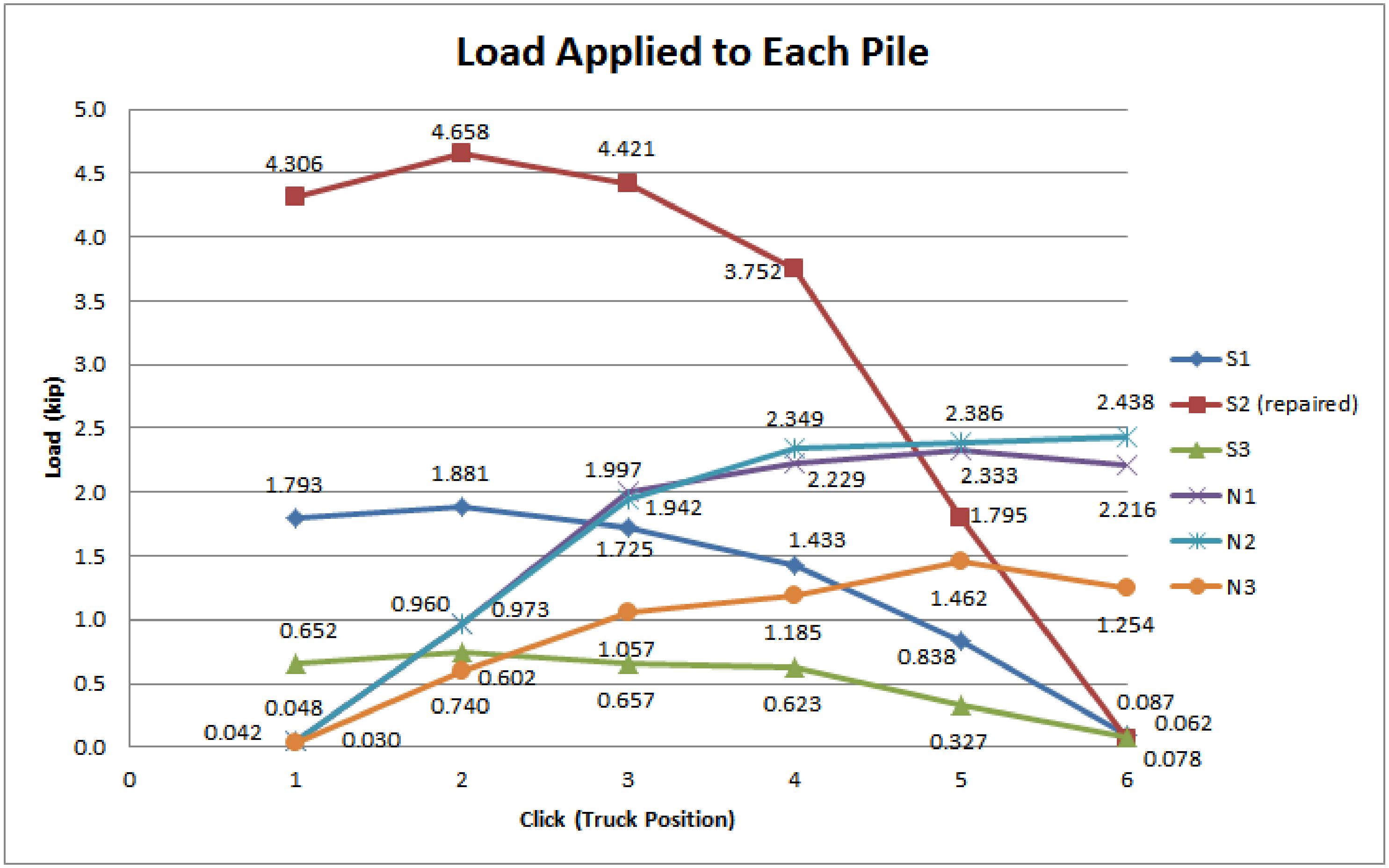


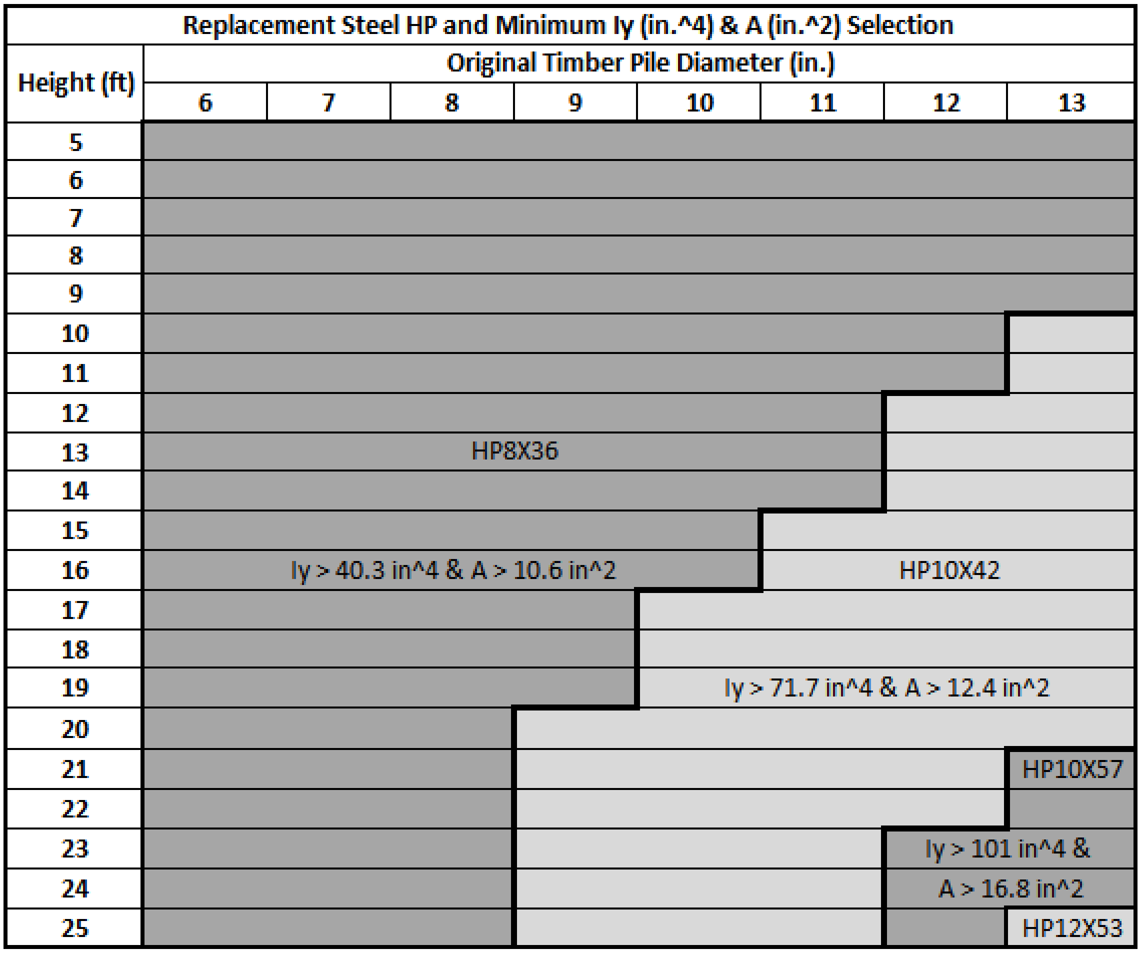
Figure 4.16 Load Applied to Each Pile

Again, the results of the field testing prove that the installed repair is successful in transferring load from the pile cap to the foundation. While more tests involving other additional repaired bridges would be beneficial in proving the effectiveness of the repair, there was only one opportunity to conduct field testing for this project. It is believed that this one test and the conservative measures taken in every aspect of the design will provide a safe repair in the future.

REPAIR DESIGN FINDINGS

DESIGN TABLES

Tables 4.1 to 4.5 are the design tables derived using the methods discussed in the methodology section. These tables are to be used when selecting a replacement steel section for the splice repair. For example, if a 10 inch diameter, 15 foot long section of timber piling is removed, it needs to be replaced with either an HP8X36 (from Table 4.1), a 6 pipe standard (from Table 4.2), or a 7 5/8 inch diameter, 0.450 inch thick pipe (from Table 4.3). Also included in Tables 4.1 and 4.2 are minimum second moment (I) and cross sectional area (A) values. These tables are to be used on piers only, not abutment piles. Design recommendations include using pipe instead of H-Pile on any exterior piers. This recommendation extends from the fact that a pipe will shed debris build up better than an H-Pile, resulting in less lateral load on both the repaired pile and the structure as a whole. Note that the failure mode for all H-Piles is the flange local buckling and the failure mode for all pipes is the formation of a plastic hinge.



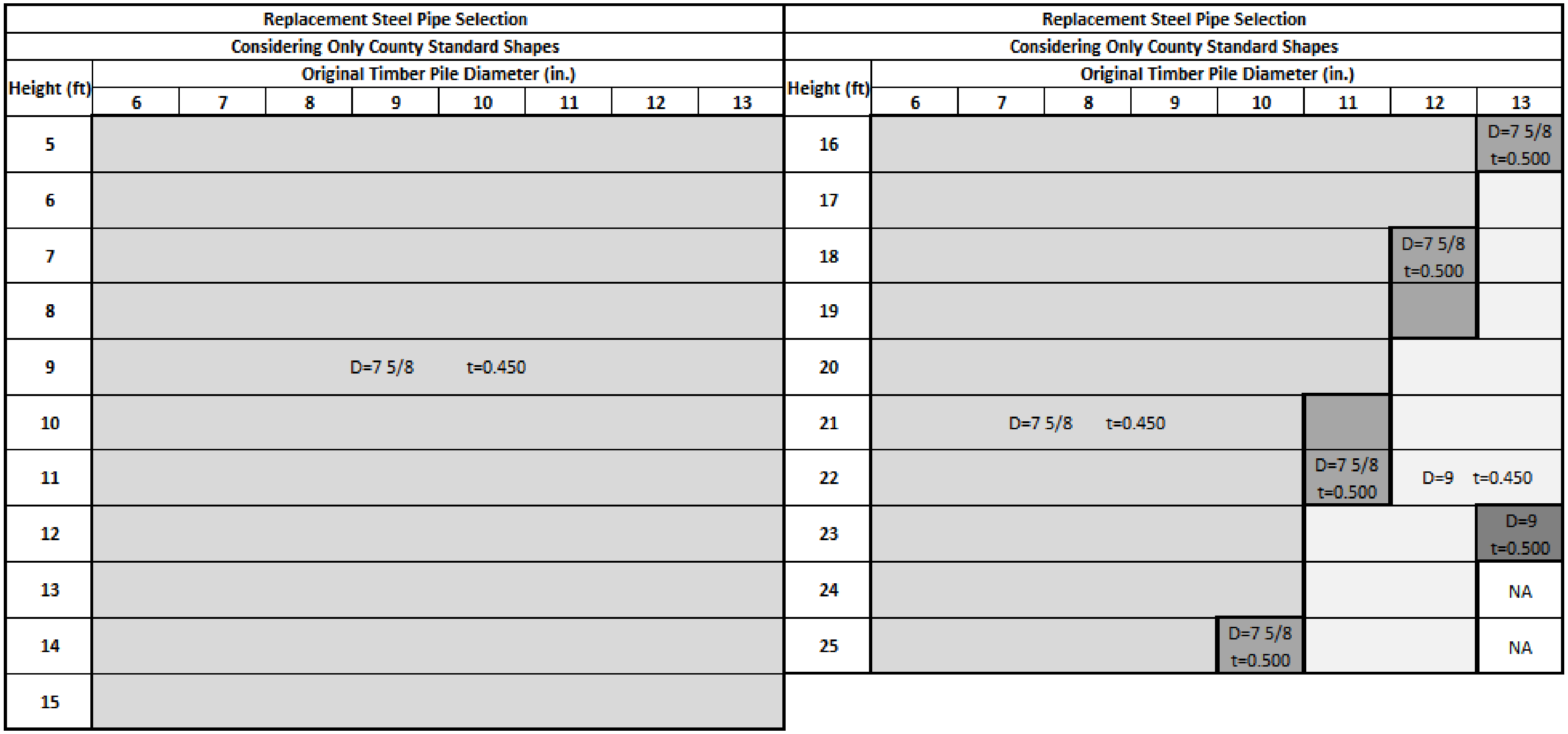
Replacement Steel HP and Minimum Iy (in.^4) & A (in.^2) Selection								
Height (ft)	Original Timber Pile Diameter (in.)							
	6	7	8	9	10	11	12	13
5								
6								
7								
8								
9								
10								
11								
12								
13			HP8X36					
14								
15								
16			Iy > 40.3 in^4 & A > 10.6 in^2				HP10X42	
17								
18								
19						Iy > 71.7 in^4 & A > 12.4 in^2		
20								
21								HP10X57
22								
23							Iy > 101 in^4 &	
24							A > 16.8 in^2	
25								HP12X53

Table 4.1 Replacement Steel HP and Minimum I_y (in.^{4}) & A (in.^{2}) Selection Design Table

	Replacement Steel Pipe Selection							
	Original Timber Pile Diameter (in.)							
Height (ft)	6	7	8	9	10	11	12	13
5	Pipe 3 x-Strong			Pipe 4 Std.				
6								
7	I > 3.7 in^4 A > 2.83 in^2							
8		I > 6.82 in^4 A > 2.97in^2		Pipe 5 Std.				
9								
10	Pipe 4 Std.	I > 14.3 in^4 & A > 4.03 in^2						
11	I > 6.82 in^4					Pipe 6 Std.		
12	A > 2.97 in^2						Pipe 8 Std.	
13				I > 26.5 in^4 A > 5.22 in^2				
14						I > 68.1 in^4 & A > 7.85 in^2		
15								

	Replacement Steel Pipe Selection							
	Original Timber Pile Diameter (in.)							
Height (ft)	6	7	8	9	10	11	12	13
16								
17								
18		Pipe 6 Std.						
19	Pipe 5 Std.			Pipe 8 Std.				
20		I > 26.5 in^4 A > 5.22in^2						Pipe 10 Std.
21	I > 14.3 in^4		I > 68.1 in^4 & A > 7.85 in^2					
22	A > 4.03 in^2						I > 151 in^4 A > 11.1 in^2	
23								
24								
25								

Table 4.2 Replacement Steel Pipe and Minimum I_y (in.^{4}) & A (in.^{2}) Design Table



Replacement Steel Pipe Selection								
Considering Only County Standard Shapes								
Height (ft)	Original Timber Pile Diameter (in.)							
	6	7	8	9	10	11	12	13
5								
6								
7								
8								
9				D=7 5/8	t=0.450			
10								
11								
12								
13								
14								
15								

Replacement Steel Pipe Selection								
Considering Only County Standard Shapes								
Height (ft)	Original Timber Pile Diameter (in.)							
	6	7	8	9	10	11	12	13
16								D=7 5/8 t=0.500
17								
18							D=7 5/8 t=0.500	
19								
20								
21			D=7 5/8	t=0.450				
22						D=7 5/8 t=0.500	D=9	t=0.450
23								D=9 t=0.500
24								NA
25					D=7 5/8 t=0.500			NA

Table 4.3 Replacement Steel Pipe (County Pipe Shapes) Selection Design Table

Note that when using standard county pipe shapes (Table 4.3), no size available is adequate when replacing a 13 inch diameter timber pile longer than 22 feet.

For abutment piles, Table 4.4 displays the replacement steel selection and its limitations in the field.

Replacement Steel Selection and Limitations			
Shape	Maximum Span Length (ft.)	Maximum Height (ft.)	Maximum Pile Spacing (ft.)
HP10X42	60	25	5.5

Table 4.4 Replacement Steel Selection and Limitations for Abutment Piles

As shown, only an HP10X42 can be used to splice into abutment piles. The span length starting from that replacement pile may not exceed 60 feet, the height of the pile may not exceed 25 feet, and the spacing between the adjacent piles may not exceed 5.5 feet.

CONNECTION DESIGN

Figures 4.17 through 4.18 depict the design of the sleeve connection.

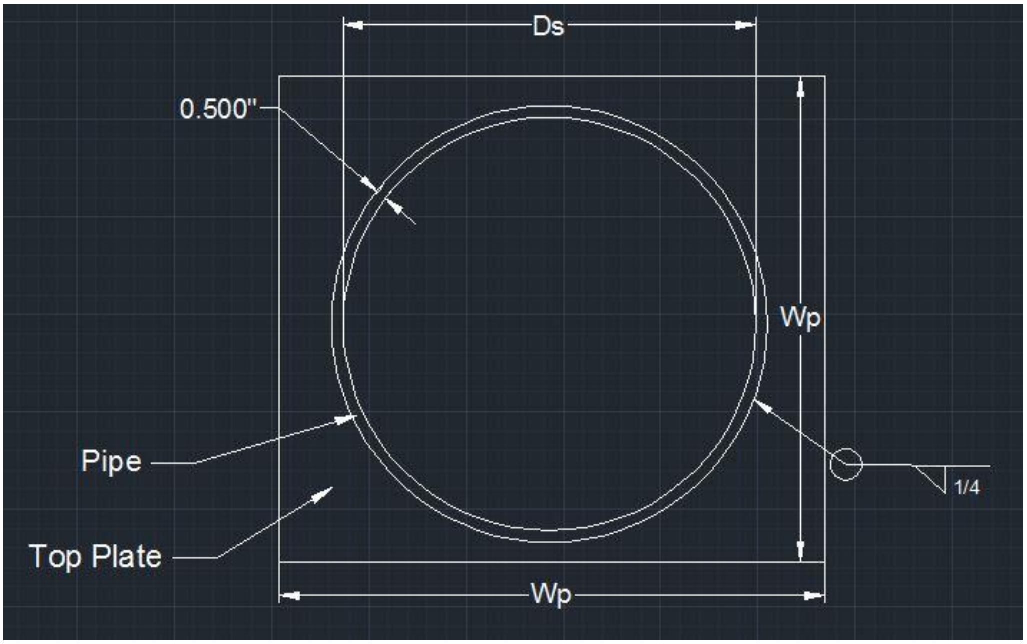


Figure 4.17 Plan View of Sleeve Design

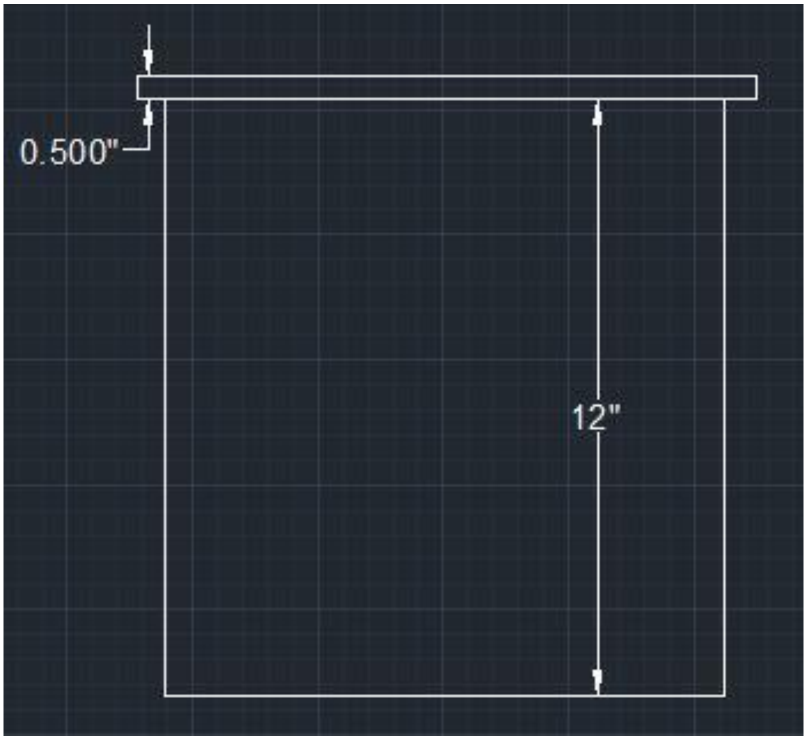


Figure 4.18 Elevation View of Sleeve Design

W_p and D_s will depend on the diameter of the timber piling the sleeve is going over. For this design, D_s should be one inch larger than the diameter of the timber pile. W_p should be 3 inches larger than D_s. All welds are to be E80 electrode.

The steel splice is welded to the top of the sleeve with E80 electrode and a ¼ inch leg height. For pipes, the entire circumference of the pipe is to be welded to the plate. For H-Piles, only the lengths of the flanges are necessary to weld to the top of the sleeve. Tables 4.5 to 4.8 represent proof that the bottom connection has enough capacity in the worst case scenario for multiple repairs.

Bottom, Pipe to Plate Connection				
Pipe	**Diameter (in)**	**Connection Capacity (K)**	**Maximum Shear Load (K)**	**OK?**
Pipe 3 x-Strong	3.5	52.75	2.30	yes
Pipe 4 Std.	4.5	67.82	2.95	yes
Pipe 5 Std.	5.56	83.80	3.65	yes
Pipe 6 Std.	6.63	99.93	4.35	yes
Pipe 8 Std.	8.63	130.07	5.66	yes
Pipe 10 Std.	10.8	162.78	7.09	yes
Pipe 12 Std.	12.8	192.92	8.40	yes

Table 4.5 Bottom, Pipe to Plate Connection

Bottom, Pipe to Plate Connection				
Pipe	**Diameter (in)**	**Connection Capacity (K)**	**Maximum Shear Load (K)**	**OK?**
D=7 5/8 t=0.450	7.625	114.92	5.00	yes
D=7 5/8 t=0.500	7.625	114.92	5.00	yes
D=9 t=0.450	9	135.65	5.91	yes
D=9 t=0.500	9	135.65	5.91	yes

Table 4.6 Bottom, Pipe to Plate Connection

Bottom, H-Pile to Plate Connection				
HP	**Flange Width (in)**	**Connection Capacity (K)**	**Maximum Shear Load (K)**	**OK?**
HP10X42	10.1	96.96	12.73	yes
HP10X57	10.2	97.92	13.10	yes

Table 4.7 Bottom, H-Pile to Plate Connection

Worst Case Scenario for Sleeve Weld Connection			
	Case	**Shear Load (K)**	**OK?**
Maximum shear load	HP10X42, 5 ft. long	12.73	YES
Minimum Shear Capacity	6 in. timber pile	90.57	

Table 4.8 Worst Case Scenario for Sleeve Weld Connection

The top connection design depends on the material the pile cap is constructed from. If the pile cap is steel, then the steel pipe or H-Pile can simply be welded (E80 electrode and ¼ inch leg height) to the pile cap. For pile caps made of either timber or concrete, the steel splice is welded onto a ½ inch plate, which is then bolted into the pile cap. Tables 4.9 to 4.11 represent the strengths of these welds in their respective worst case scenarios.

Top Pipe to Plate Connection				
Pipe	**Diameter (in)**	**Connection Capacity (K)**	**Maximum Shear Load (K)**	**OK?**
Pipe 3 x-Strong	3.5	52.75	0.46	yes
Pipe 4 Std.	4.5	67.82	0.59	yes
Pipe 5 Std.	5.56	83.80	0.73	yes
Pipe 6 Std.	6.63	99.93	0.87	yes
Pipe 8 Std.	8.63	130.07	1.13	yes
Pipe 10 Std.	10.8	162.78	1.42	yes
Pipe 12 Std.	12.8	192.92	1.68	yes

Table 4.9 Top Pipe to Plate Connection

Top Pipe to Plate Connection				
Pipe	**Diameter (in)**	**Connection Capacity (K)**	**Maximum Shear Load (K)**	**OK?**
D=7 5/8 t=0.450	7.625	114.92	1.00	yes
D=7 5/8 t=0.500	7.625	114.92	1.00	yes
D=9 t=0.450	9	135.65	1.18	yes
D=9 t=0.500	9	135.65	1.18	yes

Table 4.10 Top Pipe to Plate Connection

Top H-Pile to Plate Connection				
HP	**Flange Width (in)**	**Connection Capacity (K)**	**Maximum Shear Load (K)**	**OK?**
HP10X42	10.1	96.96	2.55	yes
HP10X57	10.2	97.92	2.62	yes

Table 4.11 Top H-Pile to Plate Connection

The connection between the top plate to the pile cap is designed with 4, ¾ inch diameter, 5 inch long screws. According to McMaster-Carr, the screws shown in Figure 4.19 each supply a shear strength of 11.4 kips. These screws are designed for timber or concrete use.

			Ultimate Strength, lbs.				
Lg.	Min. Install. Dp.	Thread Lg.	Pull Out	Shear	Pkg. Qty.		Pkg.
/8" Dia.—Head Width: 15/16" (Drill Size 5/8")							
4"	2 3/4"	4"	6,500	9,900	1	99795A132	$4.01
5"	2 3/4"	4 1/2"	6,500	9,900	1	99795A135	4.41
6"	2 3/4"	6"	6,500	9,900	1	99795A136	5.18
/4" Dia.—Head Width: 1 1/8" (Drill Size 3/4")							
4"	2 3/4"	4"	6,500	11,400	1	99795A141	5.92
5"	2 3/4"	5"	6,500	11,400	1	99795A144	6.23
6"	2 3/4"	5"	6,500	11,400	1	99795A146	7.49
7"	2 3/4"	6"	6,500	11,400	1	99795A148	6.65

Figure 4.19 Screw Properties

Table 4.12 displays the capacities and loading effects of the worst case scenario between a top plate and a pile cap using four of these screws.

Worst Case Scenario for Bolted Connection to Pile Cap			
	Case	**Shear (K)**	**OK?**
Maximum Shear Load	HP10X42, 5 ft. long	12.73 (load)	YES
Standard Bolt Shear Capacity	4, 3/4" diameter 5" long screws	34.20 (capacity)	

Table 4.12 Worst Case Scenario for Bolted Connection to Pile Cap

The top plate design is illustrated in Figure 4.20.

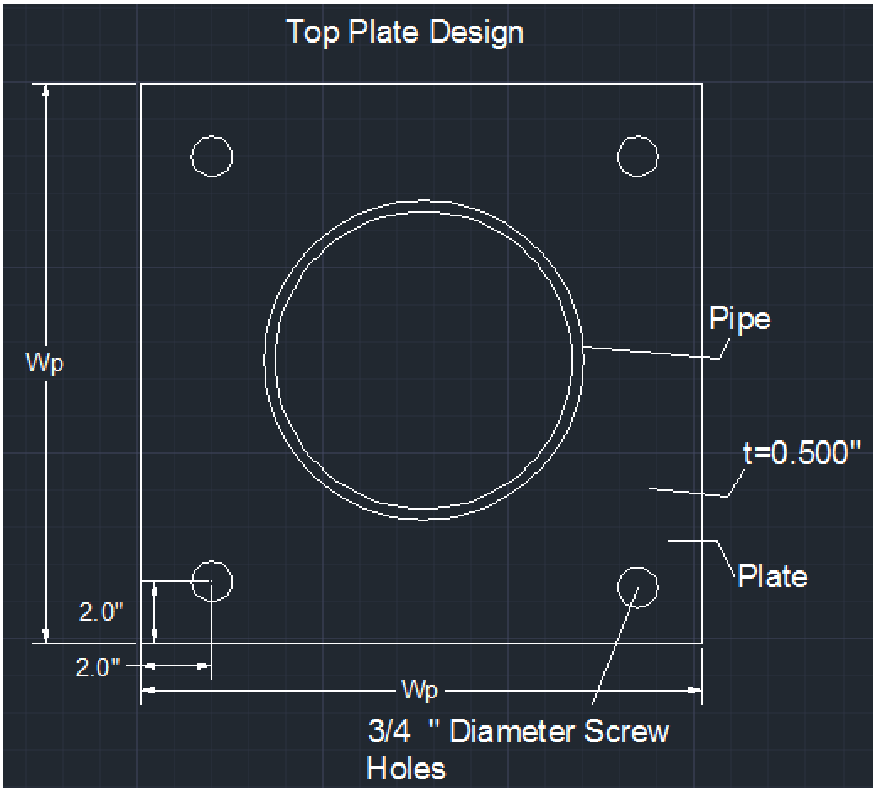


Figure 4.20 Top Plate Design

W_p is again 3 inches longer than the diameter of the pipe or the flange width of the H-Pile. The distance from the center of the bolt hole to the edge of the plate should be 2 inches.

For abutment pile connections, it has been stated that more work needs to be done on the design of the bottom sleeve connection. For the top connection, only connections to steel pile caps are acceptable situations which will provide enough shear load transfer between the abutment pile and the pile cap. This connection is specified as a 3/8 inch leg height, E80 electrode weld around the perimeter of the end of the HP10X42 to the pile cap or steel plate. This design is used in new county bridges, and has been proven through use in the field that it is an acceptable connection.

The design specified in new county bridges provides a shear strength of 273.6 Kips. This capacity cannot be guaranteed in the weld between the pipe and plate on the bottom sleeve unless the timber pile being replaced has a diameter of 13 inches. Again, more work needs to be done on the development of a bottom connection for abutment piles.

INSTALLATION PROCEDURE

The installation procedure for the splice repair is listed below.

I. Uninstall any connection between timber pile and pile cap if necessary

II. Dig out soil around the decayed timber pile

   a. The sound test can be used to estimate a sufficient cut-depth.

III. Jack-Up Pile Cap

   a. The pile cap over the bad timber pile needs to be raised using a jack. It is best to raise the pile cap at a point as close to the decayed timber pile as possible.

   b. A steel plate should be placed on the ground directly under the pile cap at the location chosen.

   c. A 20-50 ton bottle jack is then placed on top of this plate.

   d. Between the jack and the pile cap, a steel member is placed. This steel member should be a HP10X57, cut to a length that allows the jack to be raised and the pile cap to be lifted. In between the H-Pile and the jack, a steel plate can be inserted to provide extra stability. This method has been used in the field and provides enough stability in the bridge to install the splice.

   e. Lift the pile cap off of the timber pile by activating the jack. The pile cap only needs to rise slightly (< ½ inch) off of the pile.

IV. Remove decayed timber pile.

   a. Cut timber using a chainsaw. This cut needs to be as horizontal as possible.

   b. Check quality of remaining timber pile by using the sound check. A deeper cut may be necessary.

   c. Remove pile from under the bridge. This may require some sort of front end loader or other similar machinery.

V. Fabricate and Install Sleeve

   a. Weld sleeve pipe to ½ inch plate.
   b. Install sleeve by sliding it over the top of the timber pile.

VI. Install Steel Splice

   a. Install top connection by welding on the plate if necessary. This plate will be bolted to a timber or concrete pile cap.
   b. Measure and cut the steel splice. The length of the splice needs to be as close as possible between the top of the sleeve and the pile cap connection.
   c. The splice is then installed by erecting the steel to a vertical position and welding the bottom of the splice to the sleeve.

VII. Backfill Soil

   a. Replacing the soil around the bottom connection will prevent further timber decay and steel corrosion.

VIII. Install Top Connection

   a. Install the top connection by first lowering the jack until the pile cap is resting on the steel splice.
   b. Either bolt the steel plate to a timber/concrete pile cap or weld the steel splice to a steel pile cap.

IX. Remove Jack

   a. Lower jack completely and disassemble pieces.

CHAPTER V

CONCLUSION

It has been proven that the steel splice repair technique is an effective method to extend the service life of aging timber bridges. While the repair itself is not ground breaking in terms of new technology, the development of the design tables and standardization of the installation procedures should provide a safe design for local engineers to use on off-system bridges. This information can be distributed to county and tribal governments as a useful tool when repairing bridges.

BENEFITS OF REPAIR

The steel splice repair is cost effective. Most of the materials used can be found in county stock piles, limiting the amount of funding needed to install the repair. The use of the splice repair technique will prolong the service life of a bridge for a few years, freeing up funds and resources that local governments can use elsewhere. Although the repair has already been used, this project will provide a safe, simple, inexpensive design for future repairs.

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APPENDICES

APPENDIX A

Reference Material

3.16 THERMAL FORCES

Provision shall be made for stresses or movements resulting from variations in temperature. The rise and fall in temperature shall be fixed for the locality in which the structure is to be constructed and shall be computed from an assumed temperature at the time of erection. Due consideration shall be given to the lag between air temperature and the interior temperature of massive concrete members or structures.

The range of temperature shall generally be as follows:

Metal structures:
Moderate climate, from 0 to 120°F.
Cold climate, from −30 to 120°F.

	Temperature Rise	Temperature Fall
Concrete structures:		
Moderate climate	30°F	40°F
Cold climate	35°F	45°F

3.17 UPLIFT

3.17.1 Provision shall be made for adequate attachment of the superstructure to the substructure by ensuring that the calculated uplift at any support is resisted by tension members engaging a mass of masonry equal to the largest force obtained under one of the following conditions:

(a) 100% of the calculated uplift caused by any loading or combination of loadings in which the live plus impact loading is increased by 100%.

(b) 150% of the calculated uplift at working load level.

3.17.2 Anchor bolts subject to tension or other elements of the structure stressed under the above conditions shall be designed at 150% of the allowable basic stress.

3.18 FORCES FROM STREAM CURRENT AND FLOATING ICE, AND DRIFT CONDITIONS

All piers and other portions of structures that are subject to the force of flowing water, floating ice, or drift shall be designed to resist the maximum stresses induced thereby.

3.18.1 Force of Stream Current on Piers

3.18.1.1 Stream Pressure

3.18.1.1.1 The effect of flowing water on piers and drift build-up, assuming a second-degree parabolic velocity distribution and thus a triangular pressure distribution, shall be calculated by the formula:

$$P_{avg} = K(V_{avg})^2 \tag{3-4}$$

where,

P_{avg} = average stream pressure, in pounds per square foot,
V_{avg} = average velocity of water in feet per second, computed by dividing the flow rate by the flow area,
K = a constant, being 1.4 for all piers subjected to drift build-up and square-ended piers, 0.7 for circular piers, and 0.5 for angle-ended piers where the angle is 30 degrees or less.

The maximum stream flow pressure, P_{max}, shall be equal to twice the average stream flow pressure, P_{avg}, computed by Equation 3-4. Stream flow pressure shall be a triangular distribution with P_{max} located at the top of water elevation and a zero pressure located at the flow line.

3.18.1.1.2 The stream flow forces shall be computed by the product of the stream flow pressure, taking into account the pressure distribution, and the exposed pier area. In cases where the corresponding top of water elevation is above the low beam elevation, stream flow loading on the superstructure shall be investigated. The stream flow pressure acting on the superstructure may be taken as P_{max} with a uniform distribution.

3.18.1.2 Pressure Components

When the direction of stream flow is other than normal to the exposed surface area, or when bank migration or a change of stream bed meander is anticipated, the effects of the directional components of stream flow pressure shall be investigated.

3.18.1.3 Drift Lodged Against Pier

Where a significant amount of drift lodged against a pier is anticipated, the effects of this drift buildup shall be considered in the design of the bridge opening and the bridge components. The overall dimensions of the drift buildup shall reflect the selected pier locations, site conditions, and known drift supply upstream. When it is anticipated that the flow area will be significantly blocked by drift buildup, increases in high water elevations, stream velocities, stream flow pressures, and the potential increases in scour depths shall be investigated.

R_{pg} is the bending strength reduction factor:

$$R_{pg} = 1 - \frac{a_w}{1200 + 300a_w}\left(\frac{h_c}{t_w} - 5.7\sqrt{\frac{E}{F_y}}\right) \le 1.0 \qquad \text{(F5-}$$

a_w is defined by Equation F4-11 but shall not exceed 10

and

r_t is the effective radius of gyration for lateral buckling as defined in Section F4.

3. Compression Flange Local Buckling

$$M_n = R_{pg} F_{cr} S_{xc} \qquad \text{(F5-7}$$

(a) For sections with compact flanges, the *limit state* of compression flange local *buckling* does not apply.

(b) For sections with noncompact flanges

$$F_{cr} = \left[F_y - (0.3F_y)\left(\frac{\lambda - \lambda_{pf}}{\lambda_{rf} - \lambda_{pf}}\right)\right] \qquad \text{(F5-8}$$

(c) For sections with slender flange sections

$$F_{cr} = \frac{0.9Ek_c}{\left(\frac{b_f}{2t_f}\right)^2} \qquad \text{(F5-9}$$

where

k_c $= \frac{4}{\sqrt{h/t_w}}$ and shall not be taken less than 0.35 nor greater than 0.76 for calculation purposes

λ $= \frac{b_{fc}}{2t_{fc}}$

$\lambda_{pf} = \lambda_p$, the limiting slenderness for a compact flange, Table B4.1

$\lambda_{rf} = \lambda_r$, the limiting slenderness for a noncompact flange, Table B4.1

4. Tension Flange Yielding

(a) When $S_{xt} \ge S_{xc}$, the *limit state* of tension flange *yielding* does not apply.

(b) When $S_{xt} < S_{xc}$

$$M_n = F_y S_{xt} \qquad \text{(F5-10)}$$

F6. I-SHAPED MEMBERS AND CHANNELS BENT ABOUT THEIR MINOR AXIS

This section applies to I-shaped members and channels bent about their minor axis.

The nominal flexural strength, M_n, shall be the lower value obtained according to the *limit states* of *yielding* (*plastic moment*) and flange *local buckling*.

1. Yielding

$$M_n = M_p = F_y Z_y \le 1.6F_y S_y \qquad \text{(F6-1)}$$

2. Flange Local Buckling

(a) For sections with compact flanges the limit state of yielding shall apply.

User Note: All current ASTM A6 W, S, M, C and MC shapes except W21×48, W14×99, W14×90, W12×65, W10×12, W8×31, W8×10, W6×15, W6×9, W6×8.5, and M4×6 have compact flanges at $F_y = 50$ ksi (345 MPa).

(b) For sections with noncompact flanges

$$M_n = \left[M_p - (M_p - 0.7F_yS_y)\left(\frac{\lambda - \lambda_{pf}}{\lambda_{rf} - \lambda_{pf}}\right)\right] \tag{F6-2}$$

(c) For sections with slender flanges

$$M_n = F_{cr}S_y \tag{F6-3}$$

where

$$F_{cr} = \frac{0.69E}{\left(\frac{b_f}{2t_f}\right)^2} \tag{F6-4}$$

$\lambda = \frac{b}{t}$

$\lambda_{pf} = \lambda_p$, the limiting slenderness for a compact flange, Table B4.1

$\lambda_{rf} = \lambda_r$, the limiting slenderness for a noncompact flange, Table B4.1

S_y for a channel shall be taken as the minimum section modulus

F7. SQUARE AND RECTANGULAR HSS AND BOX-SHAPED MEMBERS

This section applies to square and rectangular *HSS*, and doubly symmetric box-shaped members bent about either axis, having compact or noncompact webs and compact, noncompact or slender flanges as defined in Section B4.

The nominal flexural strength, M_n, shall be the lowest value obtained according to the *limit states* of *yielding (plastic moment)*, flange *local buckling* and web *local buckling* under pure flexure.

1. Yielding

$$M_n = M_p = F_yZ \tag{F7-1}$$

where

Z = plastic section modulus about the axis of bending, in.^{3} (mm^3)

2. Flange Local Buckling

(a) For *compact sections*, the *limit state* of flange *local buckling* does not apply.

(b) For sections with noncompact flanges

$$M_n = M_p - (M_p - F_yS)\left(3.57\frac{b}{t}\sqrt{\frac{F_y}{E}} - 4.0\right) \le M_p \tag{F7-2}$$

(c) For sections with slender flanges

$$M_n = F_y S_{eff} \qquad \text{(F7-3)}$$

where

S_{eff} is the *effective section modulus* determined with the *effective width of the* compression flange taken as:

$$b_e = 1.92t\sqrt{\frac{E}{F_y}}\left[1 - \frac{0.38}{b/t}\sqrt{\frac{E}{F_y}}\right] \leq b \qquad \text{(F7-4)}$$

3. Web Local Buckling

(a) For *compact sections*, the *limit state* of web *local buckling* does not apply.

(b) For sections with noncompact webs

$$M_n = M_p - (M_p - F_y S_x)\left(0.305\frac{h}{t_w}\sqrt{\frac{F_y}{E}} - 0.738\right) \leq M_p \qquad \text{(F7-5)}$$

F8. ROUND HSS

This section applies to round *HSS* having D/t ratios of less than $\frac{0.45E}{F_y}$.

The nominal flexural strength, M_n, shall be the lower value obtained according to the *limit states* of *yielding (plastic moment)* and *local buckling*.

1. Yielding

$$M_n = M_p = F_y Z \qquad \text{(F8-1)}$$

2. Local Buckling

(a) For *compact sections*, the *limit state* of flange *local buckling* does not apply.

(b) For noncompact sections

$$M_n = \left(\frac{0.021E}{\frac{D}{t}} + F_y\right)S \qquad \text{(F8-2)}$$

(c) For sections with slender walls

$$M_n = F_{cr} S \qquad \text{(F8-3)}$$

where

$$F_{cr} = \frac{0.33E}{\frac{D}{t}} \qquad \text{(F8-4)}$$

S = elastic section modulus, in.^{3} (mm^3)

where

L = laterally unbraced length of the member, in. (mm)
r = governing radius of gyration, in. (mm)
K = the *effective length factor* determined in accordance with Section C2

User Note: For members designed on the basis of compression, the slenderness ratio KL/r preferably should not exceed 200.

E3. COMPRESSIVE STRENGTH FOR FLEXURAL BUCKLING OF MEMBERS WITHOUT SLENDER ELEMENTS

This section applies to compression members with *compact* and *noncompact sections*, as defined in Section B4, for uniformly compressed elements.

User Note: When the torsional unbraced length is larger than the lateral unbraced length, this section may control the design of wide flange and similarly shaped columns.

The *nominal compressive strength*, P_n, shall be determined based on the *limit state* of *flexural buckling*.

$$P_n = F_{cr} A_g \tag{E3-1}$$

The *flexural buckling stress*, F_{cr}, is determined as follows:

(a) When $\dfrac{KL}{r} \leq 4.71\sqrt{\dfrac{E}{F_y}}$ (or $F_e \geq 0.44F_y$)

$$F_{cr} = \left[0.658^{\frac{F_y}{F_e}}\right] F_y \tag{E3-2}$$

(b) When $\dfrac{KL}{r} > 4.71\sqrt{\dfrac{E}{F_y}}$ (or $F_e < 0.44F_y$)

$$F_{cr} = 0.877F_e \tag{E3-3}$$

where

F_e = elastic critical buckling stress determined according to Equation E3-4, Section E4, or the provisions of Section C2, as applicable, ksi (MPa)

$$F_e = \frac{\pi^2 E}{\left(\dfrac{KL}{r}\right)^2} \tag{E3-4}$$

User Note: The two equations for calculating the limits and applicability of Sections E3(a) and E3(b), one based on KL/r and one based on F_e, provide the same result.

CHAPTER H

DESIGN OF MEMBERS FOR COMBINED FORCES AND TORSION

This chapter addresses members subject to axial *force* and flexure about one or both axes, with or without torsion, and to members subject to torsion only.

The chapter is organized as follows:

- H1. Doubly and Singly Symmetric Members Subject to Flexure and Axial Force
- H2. Unsymmetric and Other Members Subject to Flexure and Axial Force
- H3. Members under Torsion and Combined Torsion, Flexure, Shear and/or Axial Force

User Note: For *composite* members, see Chapter I.

H1. DOUBLY AND SINGLY SYMMETRIC MEMBERS SUBJECT TO FLEXURE AND AXIAL FORCE

1. Doubly and Singly Symmetric Members in Flexure and Compression

The interaction of flexure and compression in doubly symmetric members and singly symmetric members for which $0.1 \leq (I_{yc}/I_y) \leq 0.9$, that are constrained to bend about a *geometric axis* (x and/or y) shall be limited by Equations H1-1a and H1-1b, where I_{yc} is the moment of inertia about the y-axis referred to the compression flange, in.^{4} (mm^4).

User Note: Section H2 is permitted to be used in lieu of the provisions of this section.

(a) For $\dfrac{P_r}{P_c} \geq 0.2$

$$\frac{P_r}{P_c} + \frac{8}{9}\left(\frac{M_{rx}}{M_{cx}} + \frac{M_{ry}}{M_{cy}}\right) \leq 1.0 \qquad \text{(H1-1a)}$$

(b) For $\dfrac{P_r}{P_c} < 0.2$

$$\frac{P_r}{2P_c} + \left(\frac{M_{rx}}{M_{cx}} + \frac{M_{ry}}{M_{cy}}\right) \leq 1.0 \qquad \text{(H1-1b)}$$

where

P_r = required axial compressive strength, kips (N)
P_c = *available axial compressive strength*, kips (N)
M_r = *required flexural strength*, kip-in. (N-mm)

M_c = *available flexural strength*, kip-in. (N-mm)

x = subscript relating symbol to *strong axis* bending

y = subscript relating symbol to *weak axis* bending

For design according to Section B3.3 (LRFD)

P_r = *required axial compressive strength* using *LRFD load combinations*, kips (N)

$P_c = \phi_c P_n$ = *design axial compressive strength*, determined in accordance with Chapter E, kips (N)

M_r = *required flexural strength* using LRFD load combinations, kip-in. (N-mm)

$M_c = \phi_b M_n$ = *design flexural strength* determined in accordance with Chapter F, kip-in. (N-mm)

ϕ_c = *resistance factor* for compression = 0.90

ϕ_b = resistance factor for flexure = 0.90

For design according to Section B3.4 (ASD)

P_r = required axial compressive strength using *ASD load combinations*, kips (N)

$P_c = P_n/\Omega_c$ = *allowable axial compressive strength*, determined in accordance with Chapter E, kips (N)

M_r = required flexural strength using ASD load combinations, kip-in. (N-mm)

$M_c = M_n/\Omega_b$ = *allowable flexural strength* determined in accordance with Chapter F, kip-in. (N-mm)

Ω_c = *safety factor* for compression = 1.67

Ω_b = safety factor for flexure = 1.67

2. Doubly and Singly Symmetric Members in Flexure and Tension

The interaction of flexure and tension in doubly symmetric members and singly symmetric members constrained to bend about a *geometric axis* (x and/or y) shall be limited by Equations H1-1a and H1-1b,

where

For design according to Section B3.3 (LRFD)

P_r = *required tensile strength* using LRFD *load combinations*, kips (N)

$P_c = \phi_t P_n$ = *design tensile strength*, determined in accordance with Section D2, kips (N)

M_r = *required flexural strength* using LRFD load combinations, kip-in. (N-mm)

$M_c = \phi_b M_n$ = *design flexural strength* determined in accordance with Chapter F, kip-in. (N-mm)

ϕ_t = *resistance factor* for tension (see Section D2)

ϕ_b = resistance factor for flexure = 0.90

As a result, each small area ΔA on the cross section is subjected to a force $\Delta F = \sigma\,\Delta A$, and the *sum* of these forces acting over the entire cross-sectional area must be equivalent to the internal resultant force **P** at the section. If we let $\Delta A \rightarrow dA$ and therefore $\Delta F \rightarrow dF$, then, recognizing σ is *constant*, we have

$$+\uparrow F_{Rz} = \Sigma F_z; \qquad \int dF = \int_A \sigma\, dA$$

$$P = \sigma A$$

$$\boxed{\sigma = \frac{P}{A}} \tag{1–6}$$

Here

σ = average normal stress at any point on the cross-sectional area

P = *internal resultant normal force*, which acts through the *centroid* of the cross-sectional area. P is determined using the method of sections and the equations of equilibrium

A = cross-sectional area of the bar where σ is determined

Since the internal load P passes through the centroid of the cross-section the uniform stress distribution will produce zero moments about the x and y axes passing through this point, Fig. 1–13*d*. To show this, we require the moment of P about each axis to be equal to the moment of the stress distribution about the axes, namely,

$$(M_R)_x = \Sigma M_x; \quad 0 = \int_A y\, dF = \int_A y\sigma\, dA = \sigma \int_A y\, dA$$

$$(M_R)_y = \Sigma M_y; \quad 0 = -\int_A x\, dF = -\int_A x\sigma\, dA = -\sigma \int_A x\, dA$$

These equations are indeed satisfied, since by definition of the centroid, $\int y\, dA = 0$ and $\int x\, dA = 0$. (See Appendix A.)

Equilibrium. It should be apparent that only a normal stress exists in any small volume element of material located at each point on the cross section of an axially loaded bar. If we consider vertical equilibrium of the element, Fig. 1–14, then apply the equation of force equilibrium,

$$\Sigma F_z = 0; \qquad \sigma(\Delta A) - \sigma'(\Delta A) = 0$$

$$\sigma = \sigma'$$

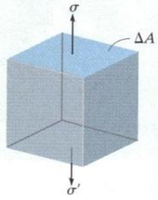


Fig. 1–14

3.4 Hooke's Law

As noted in the previous section, the stress–strain diagrams for most engineering materials exhibit a *linear relationship* between stress and strain within the elastic region. Consequently, an increase in stress causes a proportionate increase in strain. This fact was discovered by Robert Hooke in 1676 using springs and is known as *Hooke's law*. It may be expressed mathematically as

$$\boxed{\sigma = E\epsilon} \qquad (3\text{–}5)$$

Here E represents the constant of proportionality, which is called the ***modulus of elasticity*** or ***Young's modulus***, named after Thomas Young, who published an account of it in 1807.

Equation 3–5 actually represents the equation of the *initial straight-lined portion* of the stress–strain diagram up to the proportional limit. Furthermore, the modulus of elasticity represents the *slope* of this line. Since strain is dimensionless, from Eq. 3–5, E will have the same units as stress, such as psi, ksi, or pascals. As an example of its calculation, consider the stress–strain diagram for steel shown in Fig. 3–6. Here $\sigma_{pl} = 35$ ksi and $\epsilon_{pl} = 0.0012$ in./in., so that

$$E = \frac{\sigma_{pl}}{\epsilon_{pl}} = \frac{35\text{ ksi}}{0.0012\text{ in./in.}} = 29(10^3)\text{ ksi}$$

As shown in Fig. 3–13, the proportional limit for a particular type of steel alloy depends on its carbon content; however, most grades of steel, from the softest rolled steel to the hardest tool steel, have about the

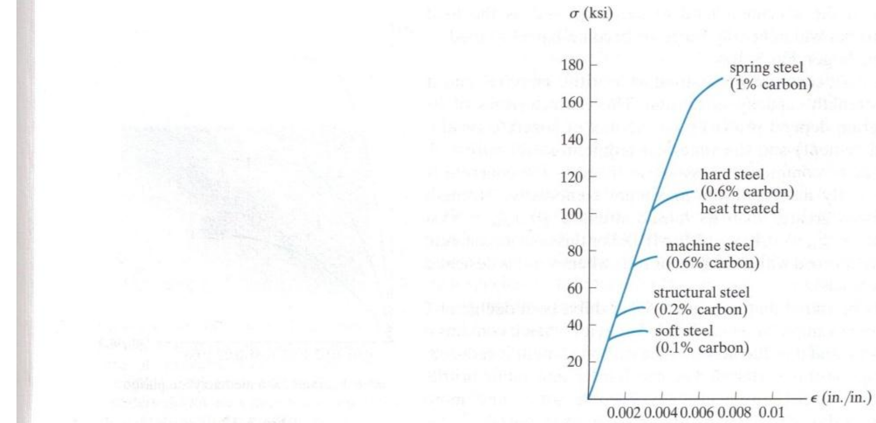


Fig. 3–13

3.6.6 Column Bracing

Column bracing shall be installed where necessary to resist wind or other lateral forces (see Appendix A).

3.6.7 Lateral Support of Arches, Studs, and Compression Chords of Trusses

Guidelines for providing lateral support and determining ℓ_e/d in arches, studs, and compression chords of trusses are specified in Appendix A.11.

3.7 Solid Columns

3.7.1 Column Stability Factor, C_P

3.7.1.1 When a compression member is supported throughout its length to prevent lateral displacement in all directions, $C_P = 1.0$.

3.7.1.2 The effective column length, ℓ_e, for a solid column shall be determined in accordance with principles of engineering mechanics. One method for determining effective column length, when end-fixity conditions are known, is to multiply actual column length by the appropriate effective length factor specified in Appendix G, $\ell_e = (K_e)(\ell)$.

3.7.1.3 For solid columns with rectangular cross section, the slenderness ratio, ℓ_e/d, shall be taken as the larger of the ratios ℓ_{e1}/d_1 or ℓ_{e2}/d_2 (see Figure 3F) where each ratio has been adjusted by the appropriate buckling length coefficient, K_e, from Appendix G.

3.7.1.4 The slenderness ratio for solid columns, ℓ_e/d, shall not exceed 50, except that during construction ℓ_e/d shall not exceed 75.

3.7.1.5 The column stability factor shall be calculated as follows:

$$C_P = \frac{1+(F_{cE}/F_c^*)}{2c} - \sqrt{\left[\frac{1+(F_{cE}/F_c^*)}{2c}\right]^2 - \frac{F_{cE}/F_c^*}{c}} \qquad (3.7\text{-}1)$$

where:

F_c^* = reference compression design value parallel to grain multiplied by all applicable adjustment factors except C_p (see 2.3)

$$F_{cE} = \frac{0.822\ E_{min}'}{(\ell_e/d)^2}$$

c = 0.8 for sawn lumber

c = 0.85 for round timber poles and piles

c = 0.9 for structural glued laminated timber or structural composite lumber

3.7.1.6 For especially severe service conditions and/or extraordinary hazard, use of lower adjusted design values may be necessary. See Appendix H for background information concerning column stability calculations and Appendix F for information concerning coefficient of variation in modulus of elasticity (COV_E).

3.7.2 Tapered Columns

For design of a column with rectangular cross section, tapered at one or both ends, the representative dimension, d, for each face of the column shall be derived as follows:

$$d = d_{min} + (d_{max} - d_{min})\left[a - 0.15\left(1 - \frac{d_{min}}{d_{max}}\right)\right] \qquad (3.7\text{-}2)$$

where:

d_{min} = the minimum dimension for that face of the column

d_{max} = the maximum dimension for that face of the column

Support Conditions

Large end fixed, small end unsupported or simply supported	a = 0.70
Small end fixed, large end unsupported or simply supported	a = 0.30
Both ends simply supported:	
Tapered toward one end	a = 0.50
Tapered toward both ends	a = 0.70
For all other support conditions:	

$$d = d_{min} + (d_{max} - d_{min})(1/3) \qquad (3.7\text{-}3)$$

Calculations of f_c and C_P shall be based on the representative dimension, d. In addition, f_c at any cross section in the tapered column shall not exceed the reference compression design value parallel to grain mul-

Table 6A Reference Design Values for Treated Round Timber Piles

Reference design values for normal load duration and wet service conditions, psi

Species	F_c	F_b	F_v	$F_{c\perp}$	E	E_{min}
Pacific Coast Douglas Fir[1]	1250	2450	115	230	1,500,000	790,000
Red Oak[2]	1100	2450	135	350	1,250,000	660,000
Red Pine[3]	900	1900	85	155	1,280,000	680,000
Southern Pine[4]	1200	2400	110	250	1,500,000	790,000

1. Pacific Coast Douglas Fir reference design values apply to this species as defined in ASTM Standard D 1760. For connection design use Douglas Fir-Larch reference design values.
2. Red Oak reference design values apply to Northern and Southern Red Oak.
3. Red Pine reference design values apply to Red Pine grown in the United States. For connection design use Northern Pine reference design values.
4. Southern Pine reference design values apply to Loblolly, Longleaf, Shortleaf, and Slash Pines.

Table 6B Reference Design Values for Poles Graded in Accordance with ASTM D 3200

Reference design values for normal load duration and wet service conditions, psi

Species	F_b	F_v	$F_{c\perp}$	F_c	E	E_{min}
Pacific Coast Douglas Fir	1850	115	375	1000	1,500,000	790,000
Jack Pine	1500	95	280	800	1,070,000	570,000
Lodgepole Pine	1350	85	240	700	1,080,000	570,000
Northern White Cedar	1050	80	225	525	640,000	340,000
Ponderosa Pine	1300	90	320	650	1,000,000	530,000
Red Pine	1450	85	265	725	1,280,000	680,000
Southern Pine	1700	105	320	900	1,400,000	740,000
Western Hemlock	1650	115	245	900	1,310,000	690,000
Western Larch	2050	120	375	1075	1,460,000	770,000
Western Red Cedar	1350	95	255	750	940,000	500,000

6.3 Adjustment of Reference Design Values

6.3.1 Applicability of Adjustment Factors

Reference design values (F_c, F_b, F_v, $F_{c\perp}$, E, E_{min}) shall be multiplied by all applicable adjustment factors to determine adjusted design values (F_c', F_b', F_v', $F_{c\perp}'$, E', E_{min}'). Table 6.3.1 specifies the adjustment factors which apply to each reference design value for round timber poles and piles.

6.3.2 Load Duration Factor, C_D (ASD only)

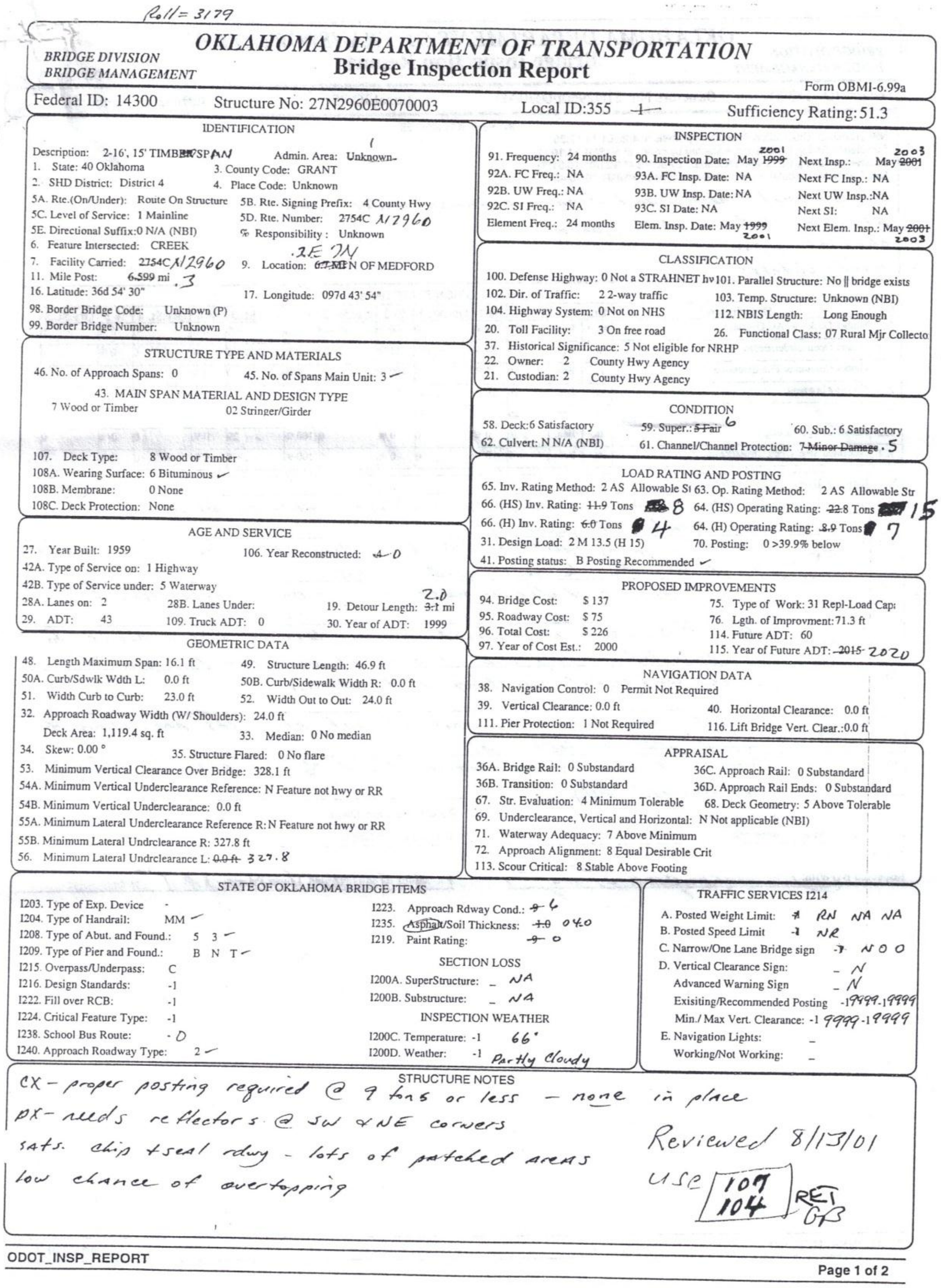
All reference design values except modulus of elasticity, E, and modulus of elasticity for beam and column stability, E_{min}, for poles and piles and compression perpendicular to grain $F_{c\perp}$, for poles shall be multiplied by load duration factors, C_D, as specified in 2.3.2. Load duration factors greater than 1.6 shall not apply to timber poles or piles pressure-treated with water-borne preservatives, (see Reference 30), nor to structural members pressure-treated with fire retardant chemicals (see Table 2.3.2).

6.3.3 Wet Service Factor, C_M

Reference design values apply to wet or dry service conditions.

6.3.4 Temperature Factor, C_t

Reference design values shall be multiplied by temperature factors, C_t, as specified in 2.3.3.



Roll = 3179

BRIDGE DIVISION
BRIDGE MANAGEMENT

OKLAHOMA DEPARTMENT OF TRANSPORTATION
Bridge Inspection Report

Form OBMI-6.99a

Federal ID: 14300 Structure No: 27N2960E0070003 Local ID:355 ~~1~~ Sufficiency Rating: 51.3

IDENTIFICATION

Description: 2-16', 15' TIMBER SPAN
Admin. Area: Unknown
1. State: 40 Oklahoma
3. County Code: GRANT
2. SHD District: District 4
4. Place Code: Unknown
5A. Rte.(On/Under): Route On Structure
5B. Rte. Signing Prefix: 4 County Hwy
5C. Level of Service: 1 Mainline
5D. Rte. Number: 2754C N/2960
5E. Directional Suffix:0 N/A (NBI)
% Responsibility : Unknown
6. Feature Intersected: CREEK
7. Facility Carried: ~~2754C~~ N/2960
9. Location: ~~6.7 MI~~ .2E 7N N OF MEDFORD
11. Mile Post: ~~6.599~~ mi .3
16. Latitude: 36d 54' 30"
17. Longitude: 097d 43' 54"
98. Border Bridge Code: Unknown (P)
99. Border Bridge Number: Unknown

STRUCTURE TYPE AND MATERIALS

46. No. of Approach Spans: 0
45. No. of Spans Main Unit: 3 ✓
43. MAIN SPAN MATERIAL AND DESIGN TYPE
7 Wood or Timber 02 Stringer/Girder
107. Deck Type: 8 Wood or Timber
108A. Wearing Surface: 6 Bituminous ✓
108B. Membrane: 0 None
108C. Deck Protection: None

AGE AND SERVICE

27. Year Built: 1959
106. Year Reconstructed: ~~-1~~ 0
42A. Type of Service on: 1 Highway
42B. Type of Service under: 5 Waterway
28A. Lanes on: 2
28B. Lanes Under:
19. Detour Length: ~~3.1~~ 2.0 mi
29. ADT: 43
109. Truck ADT: 0
30. Year of ADT: 1999

GEOMETRIC DATA

48. Length Maximum Span: 16.1 ft
49. Structure Length: 46.9 ft
50A. Curb/Sdwlk Wdth L: 0.0 ft
50B. Curb/Sidewalk Width R: 0.0 ft
51. Width Curb to Curb: 23.0 ft
52. Width Out to Out: 24.0 ft
32. Approach Roadway Width (W/ Shoulders): 24.0 ft
Deck Area: 1,119.4 sq. ft
33. Median: 0 No median
34. Skew: 0.00 °
35. Structure Flared: 0 No flare
53. Minimum Vertical Clearance Over Bridge: 328.1 ft
54A. Minimum Vertical Underclearance Reference: N Feature not hwy or RR
54B. Minimum Vertical Underclearance: 0.0 ft
55A. Minimum Lateral Underclearance Reference R: N Feature not hwy or RR
55B. Minimum Lateral Undrclearance R: 327.8 ft
56. Minimum Lateral Undrclearance L: ~~0.0 ft~~ 327.8

INSPECTION

91. Frequency: 24 months
90. Inspection Date: May ~~1999~~ 2001
Next Insp.: May ~~2001~~ 2003
92A. FC Freq.: NA
93A. FC Insp. Date: NA
Next FC Insp.: NA
92B. UW Freq.: NA
93B. UW Insp. Date: NA
Next UW Insp.: NA
92C. SI Freq.: NA
93C. SI Date: NA
Next SI: NA
Element Freq.: 24 months
Elem. Insp. Date: May ~~1999~~ 2001
Next Elem. Insp.: May ~~2001~~ 2003

CLASSIFICATION

100. Defense Highway: 0 Not a STRAHNET hv
101. Parallel Structure: No || bridge exists
102. Dir. of Traffic: 2 2-way traffic
103. Temp. Structure: Unknown (NBI)
104. Highway System: 0 Not on NHS
112. NBIS Length: Long Enough
20. Toll Facility: 3 On free road
26. Functional Class: 07 Rural Mjr Collecto
37. Historical Significance: 5 Not eligible for NRHP
22. Owner: 2 County Hwy Agency
21. Custodian: 2 County Hwy Agency

CONDITION

58. Deck:6 Satisfactory
59. Super.: ~~5 Fair~~ 6
60. Sub.: 6 Satisfactory
62. Culvert: N N/A (NBI)
61. Channel/Channel Protection: ~~7 Minor Damage~~ 5

LOAD RATING AND POSTING

65. Inv. Rating Method: 2 AS Allowable St
63. Op. Rating Method: 2 AS Allowable Str
66. (HS) Inv. Rating: ~~11.9~~ Tons 8
64. (HS) Operating Rating: ~~22.8~~ Tons 15
66. (H) Inv. Rating: ~~6.0~~ Tons 4
64. (H) Operating Rating: ~~8.9~~ Tons 7
31. Design Load: 2 M 13.5 (H 15)
70. Posting: 0 >39.9% below
41. Posting status: B Posting Recommended ✓

PROPOSED IMPROVEMENTS

94. Bridge Cost: $ 137
75. Type of Work: 31 Repl-Load Cap
95. Roadway Cost: $ 75
76. Lgth. of Improvment: 71.3 ft
96. Total Cost: $ 226
114. Future ADT: 60
97. Year of Cost Est.: 2000
115. Year of Future ADT: ~~2015~~ 2020

NAVIGATION DATA

38. Navigation Control: 0 Permit Not Required
39. Vertical Clearance: 0.0 ft
40. Horizontal Clearance: 0.0 ft
111. Pier Protection: 1 Not Required
116. Lift Bridge Vert. Clear.:0.0 ft

APPRAISAL

36A. Bridge Rail: 0 Substandard
36C. Approach Rail: 0 Substandard
36B. Transition: 0 Substandard
36D. Approach Rail Ends: 0 Substandard
67. Str. Evaluation: 4 Minimum Tolerable
68. Deck Geometry: 5 Above Tolerable
69. Underclearance, Vertical and Horizontal: N Not applicable (NBI)
71. Waterway Adequacy: 7 Above Minimum
72. Approach Alignment: 8 Equal Desirable Crit
113. Scour Critical: 8 Stable Above Footing

STATE OF OKLAHOMA BRIDGE ITEMS

I203. Type of Exp. Device -
I204. Type of Handrail: MM ✓
I208. Type of Abut. and Found.: 5 3 ✓
I209. Type of Pier and Found.: B N T ✓
I215. Overpass/Underpass: C
I216. Design Standards: -1
I222. Fill over RCB: -1
I224. Critical Feature Type: -1
I238. School Bus Route: -1 0
I240. Approach Roadway Type: 2 ✓
I223. Approach Rdway Cond.: ~~9~~ 6
I235. [✓ Asphalt]/Soil Thickness: ~~1.0~~ 04.0
I219. Paint Rating: ~~9~~ 0

SECTION LOSS

I200A. SuperStructure: _ NA
I200B. Substructure: _ NA

INSPECTION WEATHER

I200C. Temperature: -1 66°
I200D. Weather: -1 Partly Cloudy

TRAFFIC SERVICES I214

A. Posted Weight Limit: ~~-1~~ RN NA NA
B. Posted Speed Limit ~~-1~~ NR
C. Narrow/One Lane Bridge sign ~~-1~~ N 0 0
D. Vertical Clearance Sign: _ N
Advanced Warning Sign _ N
Exisiting/Recommended Posting -19999-19999
Min./ Max Vert. Clearance: -1 9999-19999
E. Navigation Lights: _
Working/Not Working: _

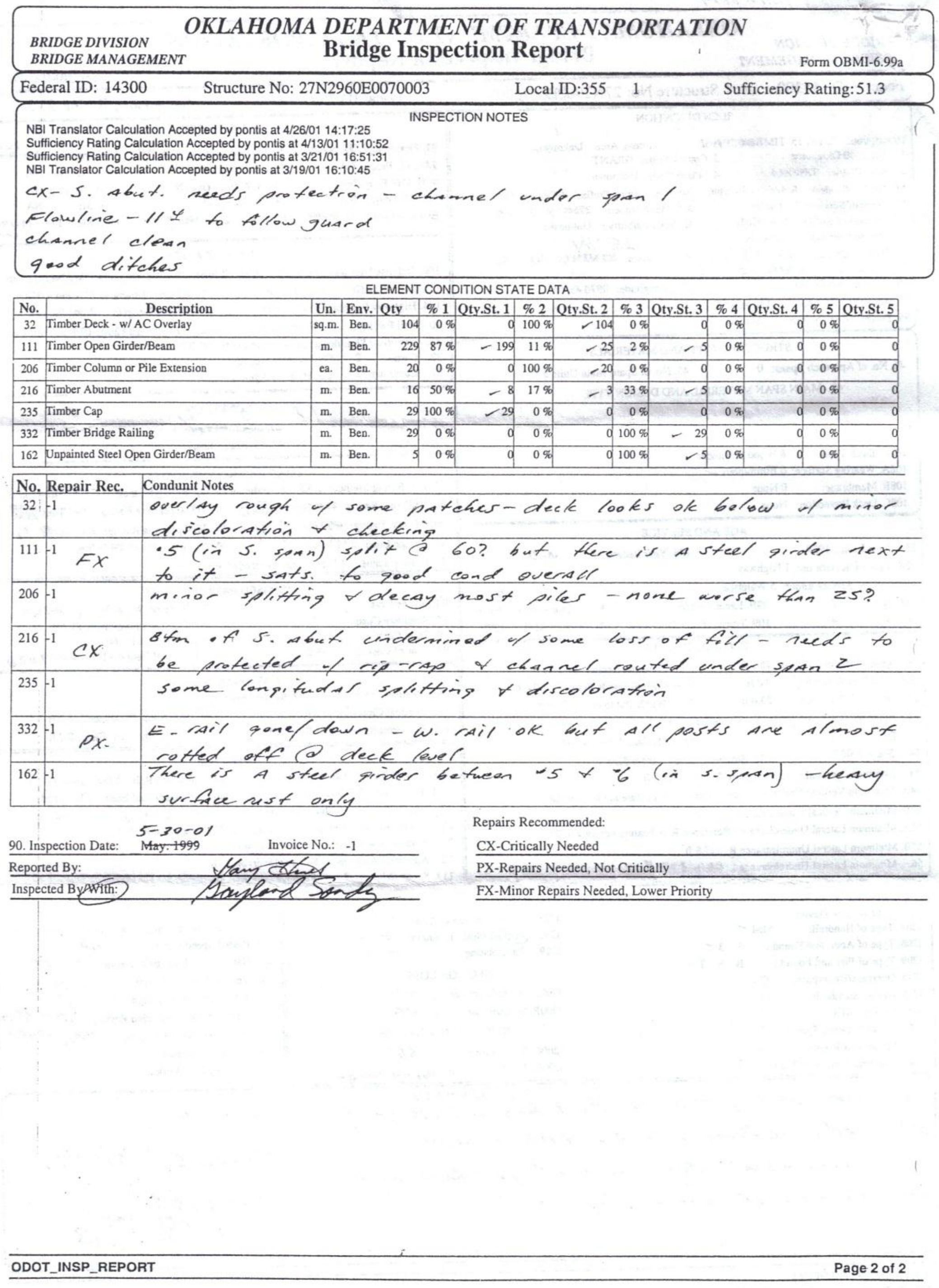
STRUCTURE NOTES

CX – proper posting required @ 9 tons or less – none in place
PX – needs reflectors @ SW & NE corners
sats. chip + seal rdwy – lots of patched areas
low chance of overtopping

Reviewed 8/13/01
USE 107 104 RET GB

ODOT_INSP_REPORT

Page 1 of 2



BRIDGE DIVISION
BRIDGE MANAGEMENT

OKLAHOMA DEPARTMENT OF TRANSPORTATION
Bridge Inspection Report

Form OBMI-6.99a

Federal ID: 14300 Structure No: 27N2960E0070003 Local ID:355 1 Sufficiency Rating: 51.3

INSPECTION NOTES

NBI Translator Calculation Accepted by pontis at 4/26/01 14:17:25
Sufficiency Rating Calculation Accepted by pontis at 4/13/01 11:10:52
Sufficiency Rating Calculation Accepted by pontis at 3/21/01 16:51:31
NBI Translator Calculation Accepted by pontis at 3/19/01 16:10:45

CX- S. abut. needs protection - channel under span 1
Flowline - 11 ℒ to follow guard
channel clean
good ditches

ELEMENT CONDITION STATE DATA

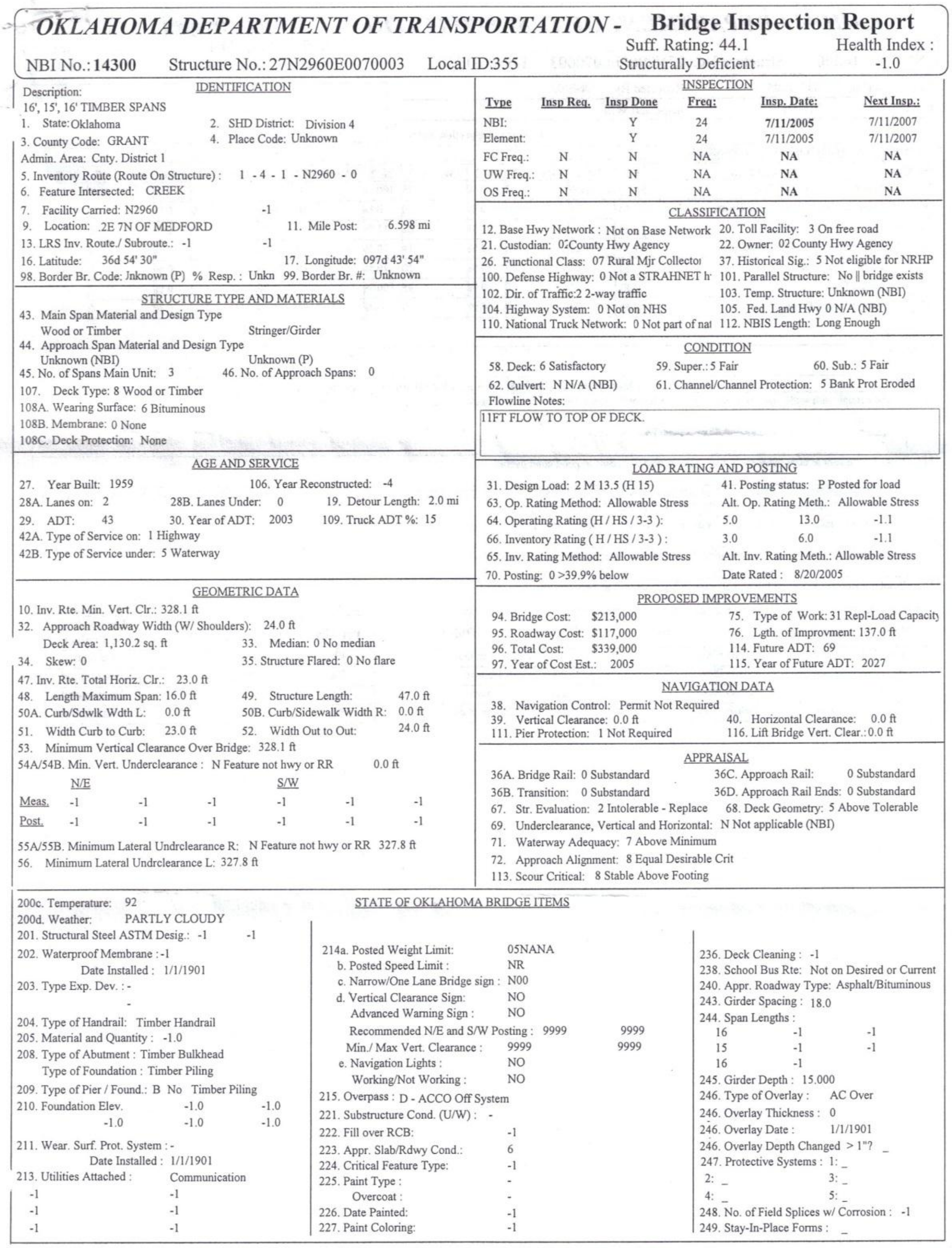
No.	Description	Un.	Env.	Qty	% 1	Qty.St. 1	% 2	Qty.St. 2	% 3	Qty.St. 3	% 4	Qty.St. 4	% 5	Qty.St. 5
32	Timber Deck - w/ AC Overlay	sq.m.	Ben.	104	0 %	0	100 %	✓104	0 %	0	0 %	0	0 %	0
111	Timber Open Girder/Beam	m.	Ben.	229	87 %	✓199	11 %	✓25	2 %	✓5	0 %	0	0 %	0
206	Timber Column or Pile Extension	ea.	Ben.	20	0 %	0	100 %	✓20	0 %	0	0 %	0	0 %	0
216	Timber Abutment	m.	Ben.	16	50 %	✓8	17 %	✓3	33 %	✓5	0 %	0	0 %	0
235	Timber Cap	m.	Ben.	29	100 %	✓29	0 %	0	0 %	0	0 %	0	0 %	0
332	Timber Bridge Railing	m.	Ben.	29	0 %	0	0 %	0	100 %	✓29	0 %	0	0 %	0
162	Unpainted Steel Open Girder/Beam	m.	Ben.	5	0 %	0	0 %	0	100 %	✓5	0 %	0	0 %	0

No.	Repair Rec.	Condunit Notes
32	-1	overlay rough w/ some patches - deck looks ok below w/ minor discoloration + checking
111	-1 FX	#5 (in S. span) split @ 60? but there is a steel girder next to it - sats. to good cond overall
206	-1	minor splitting + decay most piles - none worse than 25?
216	-1 CX	8 ft m of S. abut. undermined w/ some loss of fill - needs to be protected w/ rip-rap + channel routed under span 2
235	-1	some longitudal splitting + discoloration
332	-1 PX-	E. rail gone/down - W. rail ok but all posts are almost rotted off @ deck level
162	-1	There is a steel girder between #5 + #6 (in S. span) - heavy surface rust only

90. Inspection Date: 5-30-01 ~~May. 1999~~ Invoice No.: -1
Reported By:
Inspected By/With: Gaylord

Repairs Recommended:
CX-Critically Needed
PX-Repairs Needed, Not Critically
FX-Minor Repairs Needed, Lower Priority

ODOT_INSP_REPORT Page 2 of 2



OKLAHOMA DEPARTMENT OF TRANSPORTATION - Bridge Inspection Report

NBI No.: **14300** Structure No.: 27N2960E0070003 Local ID:355
Suff. Rating: 44.1
Structurally Deficient
Health Index : -1.0

IDENTIFICATION

Description:
16', 15', 16' TIMBER SPANS
1. State: Oklahoma
2. SHD District: Division 4
3. County Code: GRANT
4. Place Code: Unknown
Admin. Area: Cnty. District 1
5. Inventory Route (Route On Structure) : 1 - 4 - 1 - N2960 - 0
6. Feature Intersected: CREEK
7. Facility Carried: N2960 -1
9. Location: .2E 7N OF MEDFORD
11. Mile Post: 6.598 mi
13. LRS Inv. Route./ Subroute.: -1 -1
16. Latitude: 36d 54' 30"
17. Longitude: 097d 43' 54"
98. Border Br. Code: Jnknown (P) % Resp. : Unkn
99. Border Br. #: Unknown

STRUCTURE TYPE AND MATERIALS

43. Main Span Material and Design Type
Wood or Timber Stringer/Girder
44. Approach Span Material and Design Type
Unknown (NBI) Unknown (P)
45. No. of Spans Main Unit: 3
46. No. of Approach Spans: 0
107. Deck Type: 8 Wood or Timber
108A. Wearing Surface: 6 Bituminous
108B. Membrane: 0 None
108C. Deck Protection: None

AGE AND SERVICE

27. Year Built: 1959
106. Year Reconstructed: -4
28A. Lanes on: 2
28B. Lanes Under: 0
19. Detour Length: 2.0 mi
29. ADT: 43
30. Year of ADT: 2003
109. Truck ADT %: 15
42A. Type of Service on: 1 Highway
42B. Type of Service under: 5 Waterway

GEOMETRIC DATA

10. Inv. Rte. Min. Vert. Clr.: 328.1 ft
32. Approach Roadway Width (W/ Shoulders): 24.0 ft
Deck Area: 1,130.2 sq. ft
33. Median: 0 No median
34. Skew: 0
35. Structure Flared: 0 No flare
47. Inv. Rte. Total Horiz. Clr.: 23.0 ft
48. Length Maximum Span: 16.0 ft
49. Structure Length: 47.0 ft
50A. Curb/Sdwlk Wdth L: 0.0 ft
50B. Curb/Sidewalk Width R: 0.0 ft
51. Width Curb to Curb: 23.0 ft
52. Width Out to Out: 24.0 ft
53. Minimum Vertical Clearance Over Bridge: 328.1 ft
54A/54B. Min. Vert. Underclearance : N Feature not hwy or RR 0.0 ft

	N/E			S/W		
Meas.	-1	-1	-1	-1	-1	-1
Post.	-1	-1	-1	-1	-1	-1

55A/55B. Minimum Lateral Undrclearance R: N Feature not hwy or RR 327.8 ft
56. Minimum Lateral Undrclearance L: 327.8 ft

INSPECTION

Type	Insp Req.	Insp Done	Freq:	Insp. Date:	Next Insp.:
NBI:		Y	24	**7/11/2005**	7/11/2007
Element:		Y	24	7/11/2005	7/11/2007
FC Freq.:	N	N	NA	NA	NA
UW Freq.:	N	N	NA	NA	NA
OS Freq.:	N	N	NA	NA	NA

CLASSIFICATION

12. Base Hwy Network : Not on Base Network
20. Toll Facility: 3 On free road
21. Custodian: 0: County Hwy Agency
22. Owner: 02 County Hwy Agency
26. Functional Class: 07 Rural Mjr Collector
37. Historical Sig.: 5 Not eligible for NRHP
100. Defense Highway: 0 Not a STRAHNET h
101. Parallel Structure: No || bridge exists
102. Dir. of Traffic: 2 2-way traffic
103. Temp. Structure: Unknown (NBI)
104. Highway System: 0 Not on NHS
105. Fed. Land Hwy 0 N/A (NBI)
110. National Truck Network: 0 Not part of nat
112. NBIS Length: Long Enough

CONDITION

58. Deck: 6 Satisfactory
59. Super.: 5 Fair
60. Sub.: 5 Fair
62. Culvert: N N/A (NBI)
61. Channel/Channel Protection: 5 Bank Prot Eroded
Flowline Notes:
11FT FLOW TO TOP OF DECK.

LOAD RATING AND POSTING

31. Design Load: 2 M 13.5 (H 15)
41. Posting status: P Posted for load
63. Op. Rating Method: Allowable Stress
Alt. Op. Rating Meth.: Allowable Stress
64. Operating Rating (H / HS / 3-3): 5.0 13.0 -1.1
66. Inventory Rating (H / HS / 3-3) : 3.0 6.0 -1.1
65. Inv. Rating Method: Allowable Stress
Alt. Inv. Rating Meth.: Allowable Stress
70. Posting: 0 >39.9% below
Date Rated : 8/20/2005

PROPOSED IMPROVEMENTS

94. Bridge Cost: $213,000
75. Type of Work: 31 Repl-Load Capacity
95. Roadway Cost: $117,000
76. Lgth. of Improvment: 137.0 ft
96. Total Cost: $339,000
114. Future ADT: 69
97. Year of Cost Est.: 2005
115. Year of Future ADT: 2027

NAVIGATION DATA

38. Navigation Control: Permit Not Required
39. Vertical Clearance: 0.0 ft
40. Horizontal Clearance: 0.0 ft
111. Pier Protection: 1 Not Required
116. Lift Bridge Vert. Clear.: 0.0 ft

APPRAISAL

36A. Bridge Rail: 0 Substandard
36C. Approach Rail: 0 Substandard
36B. Transition: 0 Substandard
36D. Approach Rail Ends: 0 Substandard
67. Str. Evaluation: 2 Intolerable - Replace
68. Deck Geometry: 5 Above Tolerable
69. Underclearance, Vertical and Horizontal: N Not applicable (NBI)
71. Waterway Adequacy: 7 Above Minimum
72. Approach Alignment: 8 Equal Desirable Crit
113. Scour Critical: 8 Stable Above Footing

200c. Temperature: 92
200d. Weather: PARTLY CLOUDY
201. Structural Steel ASTM Desig.: -1 -1
202. Waterproof Membrane : -1
Date Installed : 1/1/1901
203. Type Exp. Dev. : -
-
204. Type of Handrail: Timber Handrail
205. Material and Quantity : -1.0
208. Type of Abutment : Timber Bulkhead
Type of Foundation : Timber Piling
209. Type of Pier / Found.: B No Timber Piling
210. Foundation Elev. -1.0 -1.0
-1.0 -1.0 -1.0
211. Wear. Surf. Prot. System : -
Date Installed : 1/1/1901
213. Utilities Attached : Communication
-1 -1
-1 -1
-1 -1

STATE OF OKLAHOMA BRIDGE ITEMS

214a. Posted Weight Limit: 05NANA
b. Posted Speed Limit : NR
c. Narrow/One Lane Bridge sign : N00
d. Vertical Clearance Sign: NO
Advanced Warning Sign : NO
Recommended N/E and S/W Posting : 9999 9999
Min./ Max Vert. Clearance : 9999 9999
e. Navigation Lights : NO
Working/Not Working : NO
215. Overpass : D - ACCO Off System
221. Substructure Cond. (U/W) : -
222. Fill over RCB: -1
223. Appr. Slab/Rdwy Cond.: 6
224. Critical Feature Type: -1
225. Paint Type : -
Overcoat : -
226. Date Painted: -1
227. Paint Coloring: -1

236. Deck Cleaning : -1
238. School Bus Rte: Not on Desired or Current
240. Appr. Roadway Type: Asphalt/Bituminous
243. Girder Spacing : 18.0
244. Span Lengths :

16	-1	-1
15	-1	-1
16	-1	

245. Girder Depth : 15.000
246. Type of Overlay : AC Over
246. Overlay Thickness : 0
246. Overlay Date : 1/1/1901
246. Overlay Depth Changed > 1"? _
247. Protective Systems : 1: _
2: _ 3: _
4: _ 5: _
248. No. of Field Splices w/ Corrosion : -1
249. Stay-In-Place Forms : _

Page 1 of 2

OKLAHOMA DEPARTMENT OF TRANSPORTATION - **Bridge Inspection Report**

NBI No.: **14300** Structure No.: 27N2960E0070003 Local ID:355

Suff. Rating: 44.1
Structurally Deficient

Health Index :
-1.0

Inspection Date: 7/11/2005
Reported By: DHEAD
Invoice No.: 427101
Inspected With:

Structure / Inspection Notes

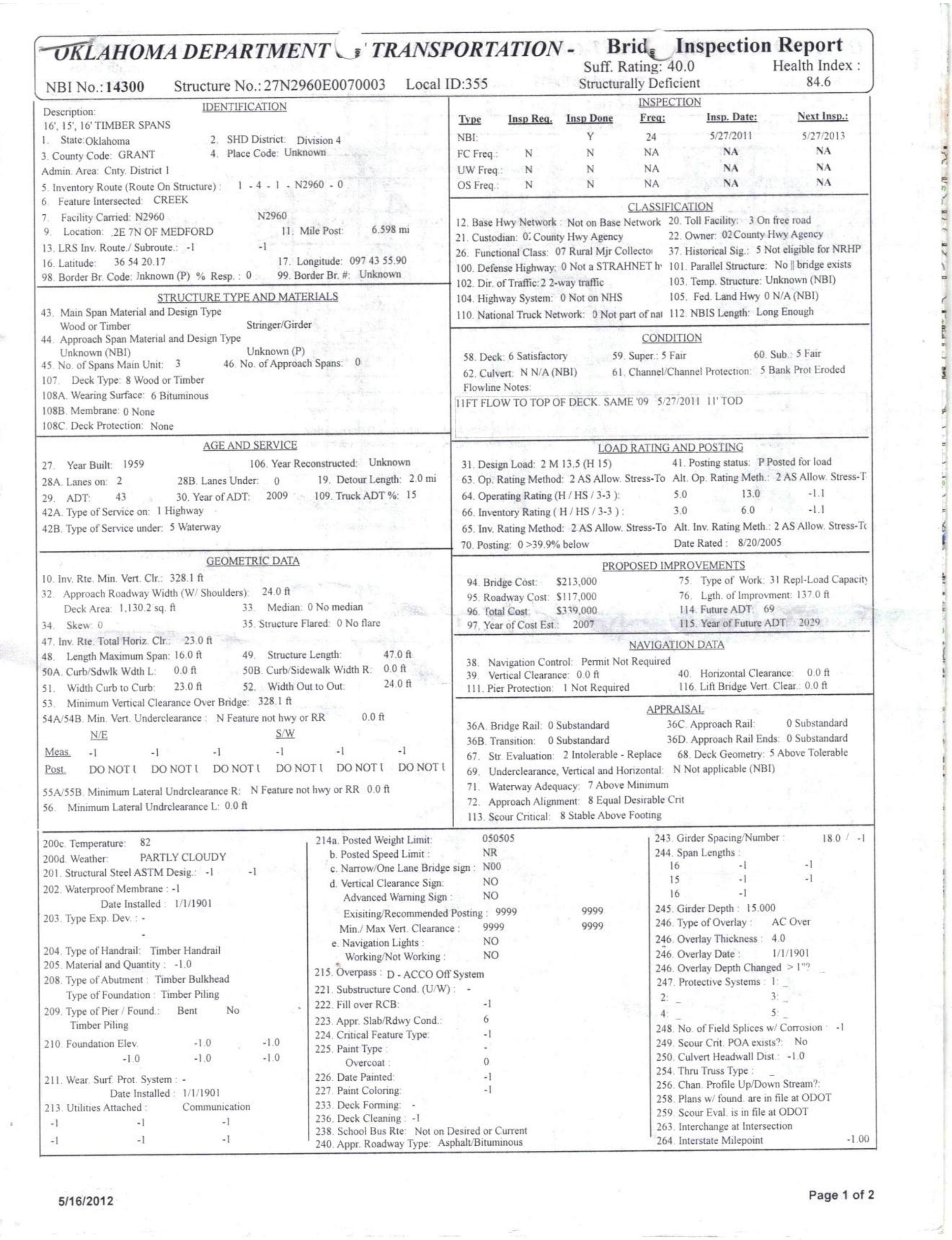
NEEDS PILES AT SOUTH BENT. 2-7TON SIGNS.

Elm.	Env.	Description	Un.	Qty.	Qty.St. 1	% 1	Qty.St. 2	% 2	Qty.St. 3	% 3	Qty.St. 4	% 4	Qty.St. 5	% 5
32	1	Timber Deck - w/ AC Overlay	(SF)	1,128	0	0 %	1,128	100 %	0	0 %	0	0 %	0	0 %
106	1	Unpainted Steel Open Girder/Beam	(LF)	16	0	0 %	0	0 %	16	100 %	0	0 %	0	0 %
111	1	Timber Open Girder/Beam	(LF)	751	653	87 %	82	11 %	16	2 %	0	0 %	0	0 %
206	1	Timber Column or Pile Extension	(EA)	20	0	0 %	14	70 %	5	25 %	1	5 %	0	0 %
216	1	Timber Abutment	(LF)	52	26	50 %	10	19 %	16	31 %	0	0 %	0	0 %
235	1	Timber Cap	(LF)	95	0	0 %	95	100 %	0	0 %	0	0 %	0	0 %
332	1	Timber Bridge Railing	(LF)	95	0	0 %	0	0 %	95	100 %	0	0 %	0	0 %

Additional Elements

Elem.	Element Notes (Include Size and Location of Deterioration
32	Overlay rough with some patches. Deck looks ok below with minor discoloration and checking. Some areas w/ minor decay noted.
106	There is a steel girder between #5 and #6 in S span. Hvy surf rust only.
111	#5 in S span split at 60% but there is a steel girder next to it. Sats to good cond overall.
206	#4 NORTH ABUTMENT 50% HOLLOW SOUND. #5 SOUTH ABUTMENT 25% HOLLOW SOUND. #4 LARGE SPLITS TOP 50% HOLLOW SOUND. #2 75% ROTTEN. #3 SOUTH ABUTMENT 50% ROTTEN. OTHER HAVE MODERATE SPLITS.
216	Btm of S abut undermined with some loss of fill. Needs to be protected with riprap and channel routed under span 2.
235	Some longitudal splitting and discoloration. Bent 1 cap deflected down 1 in. near center line.
332	E rail gone/down. W rail ok but all posts are almost rotted off at deck level.

Work Candidate ID	Action	Elem.	Object	Priority	Rec. Date	Status	Assigned To A Project
FX-14300-111-IWAB	Rehab Elem	111	Timber Open Girder	FX	5/30/2001	-1	Unassigned
PX-14300-206-ABCD	Rehab Elem	206	Timber Column	PX	5/28/2003	-1	Unassigned
CX-14300-216-IWAB	Rehab Elem	216	Timber Abutment	CX	5/30/2001	-1	Unassigned
PX-14300-332-IWAB	Rehab Elem	332	Timb Bridge Railing	PX	5/30/2001	-1	Unassigned



OKLAHOMA DEPARTMENT 'TRANSPORTATION - Brid Inspection Report

NBI No.: **14300** Structure No.: 27N2960E0070003 Local ID:355

Suff. Rating: 40.0
Structurally Deficient

Health Index :
84.6

IDENTIFICATION

Description:
16', 15', 16' TIMBER SPANS
1. State:Oklahoma
2. SHD District: Division 4
3. County Code: GRANT
4. Place Code: Unknown
Admin. Area: Cnty. District 1
5. Inventory Route (Route On Structure) : 1 - 4 - 1 - N2960 - 0
6. Feature Intersected: CREEK
7. Facility Carried: N2960 N2960
9. Location: .2E 7N OF MEDFORD
11. Mile Post: 6.598 mi
13. LRS Inv. Route./ Subroute.: -1 -1
16. Latitude: 36 54 20.17
17. Longitude: 097 43 55.90
98. Border Br. Code: Jnknown (P) % Resp. : 0
99. Border Br. #: Unknown

STRUCTURE TYPE AND MATERIALS

43. Main Span Material and Design Type
Wood or Timber Stringer/Girder
44. Approach Span Material and Design Type
Unknown (NBI) Unknown (P)
45. No. of Spans Main Unit: 3
46. No. of Approach Spans: 0
107. Deck Type: 8 Wood or Timber
108A. Wearing Surface: 6 Bituminous
108B. Membrane: 0 None
108C. Deck Protection: None

AGE AND SERVICE

27. Year Built: 1959
106. Year Reconstructed: Unknown
28A. Lanes on: 2
28B. Lanes Under: 0
19. Detour Length: 2.0 mi
29. ADT: 43
30. Year of ADT: 2009
109. Truck ADT %: 15
42A. Type of Service on: 1 Highway
42B. Type of Service under: 5 Waterway

GEOMETRIC DATA

10. Inv. Rte. Min. Vert. Clr.: 328.1 ft
32. Approach Roadway Width (W/ Shoulders): 24.0 ft
Deck Area: 1,130.2 sq. ft
33. Median: 0 No median
34. Skew: 0
35. Structure Flared: 0 No flare
47. Inv. Rte. Total Horiz. Clr.: 23.0 ft
48. Length Maximum Span: 16.0 ft
49. Structure Length: 47.0 ft
50A. Curb/Sdwlk Wdth L: 0.0 ft
50B. Curb/Sidewalk Width R: 0.0 ft
51. Width Curb to Curb: 23.0 ft
52. Width Out to Out: 24.0 ft
53. Minimum Vertical Clearance Over Bridge: 328.1 ft
54A/54B. Min. Vert. Underclearance : N Feature not hwy or RR 0.0 ft

	N/E			S/W		
Meas.	-1	-1	-1	-1	-1	-1
Post.	DO NOT l	DO NOT l	DO NOT l	DO NOT l	DO NOT l	DO NOT l

55A/55B. Minimum Lateral Undrclearance R: N Feature not hwy or RR 0.0 ft
56. Minimum Lateral Undrclearance L: 0.0 ft

INSPECTION

Type	Insp Req.	Insp Done	Freq:	Insp. Date:	Next Insp.:
NBI:		Y	24	5/27/2011	5/27/2013
FC Freq.:	N	N	NA	NA	NA
UW Freq.:	N	N	NA	NA	NA
OS Freq.:	N	N	NA	NA	NA

CLASSIFICATION

12. Base Hwy Network : Not on Base Network
20. Toll Facility: 3 On free road
21. Custodian: 0: County Hwy Agency
22. Owner: 02 County Hwy Agency
26. Functional Class: 07 Rural Mjr Collecto
37. Historical Sig.: 5 Not eligible for NRHP
100. Defense Highway: 0 Not a STRAHNET h
101. Parallel Structure: No || bridge exists
102. Dir. of Traffic: 2 2-way traffic
103. Temp. Structure: Unknown (NBI)
104. Highway System: 0 Not on NHS
105. Fed. Land Hwy 0 N/A (NBI)
110. National Truck Network: 0 Not part of nat
112. NBIS Length: Long Enough

CONDITION

58. Deck: 6 Satisfactory
59. Super.: 5 Fair
60. Sub.: 5 Fair
62. Culvert: N N/A (NBI)
61. Channel/Channel Protection: 5 Bank Prot Eroded
Flowline Notes:
11FT FLOW TO TOP OF DECK. SAME '09 5/27/2011 11' TOD

LOAD RATING AND POSTING

31. Design Load: 2 M 13.5 (H 15)
41. Posting status: P Posted for load
63. Op. Rating Method: 2 AS Allow. Stress-To
Alt. Op. Rating Meth.: 2 AS Allow. Stress-T
64. Operating Rating (H / HS / 3-3): 5.0 13.0 -1.1
66. Inventory Rating (H / HS / 3-3) : 3.0 6.0 -1.1
65. Inv. Rating Method: 2 AS Allow. Stress-To
Alt. Inv. Rating Meth.: 2 AS Allow. Stress-To
70. Posting: 0 >39.9% below
Date Rated : 8/20/2005

PROPOSED IMPROVEMENTS

94. Bridge Cost: $213,000
75. Type of Work: 31 Repl-Load Capacity
95. Roadway Cost: $117,000
76. Lgth. of Improvment: 137.0 ft
96. Total Cost: $339,000
114. Future ADT: 69
97. Year of Cost Est.: 2007
115. Year of Future ADT: 2029

NAVIGATION DATA

38. Navigation Control: Permit Not Required
39. Vertical Clearance: 0.0 ft
40. Horizontal Clearance: 0.0 ft
111. Pier Protection: 1 Not Required
116. Lift Bridge Vert. Clear.: 0.0 ft

APPRAISAL

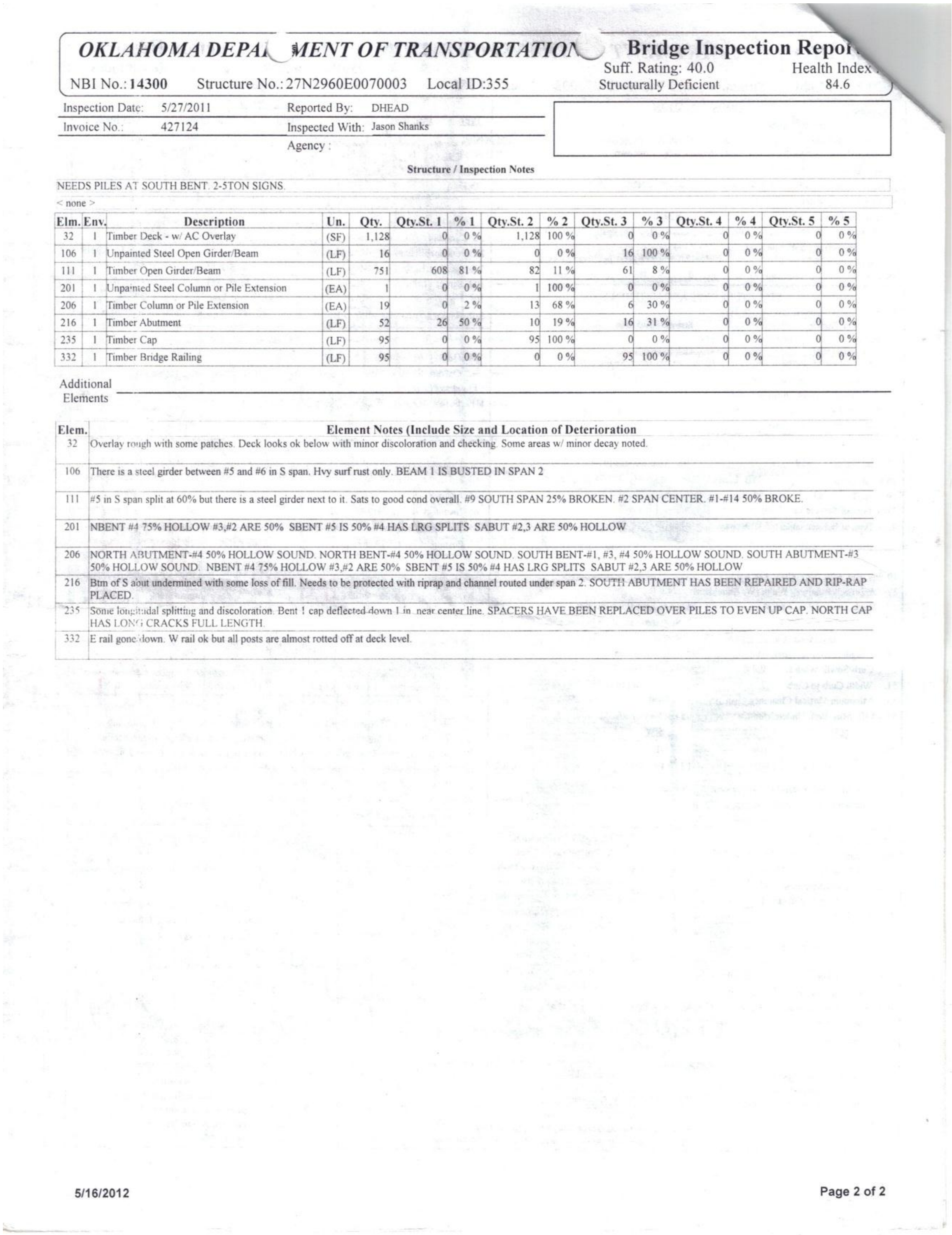
36A. Bridge Rail: 0 Substandard
36C. Approach Rail: 0 Substandard
36B. Transition: 0 Substandard
36D. Approach Rail Ends: 0 Substandard
67. Str. Evaluation: 2 Intolerable - Replace
68. Deck Geometry: 5 Above Tolerable
69. Underclearance, Vertical and Horizontal: N Not applicable (NBI)
71. Waterway Adequacy: 7 Above Minimum
72. Approach Alignment: 8 Equal Desirable Crit
113. Scour Critical: 8 Stable Above Footing

200c. Temperature: 82
200d. Weather: PARTLY CLOUDY
201. Structural Steel ASTM Desig.: -1 -1
202. Waterproof Membrane : -1
Date Installed : 1/1/1901
203. Type Exp. Dev. : -
-
204. Type of Handrail: Timber Handrail
205. Material and Quantity : -1.0
208. Type of Abutment : Timber Bulkhead
Type of Foundation : Timber Piling
209. Type of Pier / Found.: Bent No
Timber Piling
210. Foundation Elev. -1.0 -1.0
-1.0 -1.0 -1.0
211. Wear. Surf. Prot. System : -
Date Installed : 1/1/1901
213. Utilities Attached : Communication
-1 -1 -1
-1 -1 -1

214a. Posted Weight Limit: 050505
b. Posted Speed Limit : NR
c. Narrow/One Lane Bridge sign : N00
d. Vertical Clearance Sign: NO
Advanced Warning Sign : NO
Exisiting/Recommended Posting : 9999 9999
Min./ Max Vert. Clearance : 9999 9999
e. Navigation Lights : NO
Working/Not Working : NO
215. Overpass : D - ACCO Off System
221. Substructure Cond. (U/W) : -
222. Fill over RCB: -1
223. Appr. Slab/Rdwy Cond.: 6
224. Critical Feature Type: -1
225. Paint Type : -
Overcoat : 0
226. Date Painted: -1
227. Paint Coloring: -1
233. Deck Forming: -
236. Deck Cleaning : -1
238. School Bus Rte: Not on Desired or Current
240. Appr. Roadway Type: Asphalt/Bituminous

243. Girder Spacing/Number : 18.0 / -1
244. Span Lengths :
16 -1 -1
15 -1 -1
16 -1
245. Girder Depth : 15.000
246. Type of Overlay : AC Over
246. Overlay Thickness : 4.0
246. Overlay Date : 1/1/1901
246. Overlay Depth Changed > 1"? _
247. Protective Systems : 1: _
2: _ 3: _
4: _ 5: _
248. No. of Field Splices w/ Corrosion : -1
249. Scour Crit. POA exists?: No
250. Culvert Headwall Dist.: -1.0
254. Thru Truss Type : _
256. Chan. Profile Up/Down Stream?:
258. Plans w/ found. are in file at ODOT
259. Scour Eval. is in file at ODOT
263. Interchange at Intersection
264. Interstate Milepoint -1.00

5/16/2012 Page 1 of 2



OKLAHOMA DEPARTMENT OF TRANSPORTATION **Bridge Inspection Repo**

NBI No.: **14300** Structure No.: 27N2960E0070003 Local ID:355

Suff. Rating: 40.0

Structurally Deficient

Health Index

84.6

Inspection Date: 5/27/2011

Invoice No.: 427124

Reported By: DHEAD

Inspected With: Jason Shanks

Agency :

Structure / Inspection Notes

NEEDS PILES AT SOUTH BENT. 2-5TON SIGNS.

< none >

Elm.	Env.	Description	Un.	Qty.	Qty.St. 1	% 1	Qty.St. 2	% 2	Qty.St. 3	% 3	Qty.St. 4	% 4	Qty.St. 5	% 5
32	1	Timber Deck - w/ AC Overlay	(SF)	1,128	0	0 %	1,128	100 %	0	0 %	0	0 %	0	0 %
106	1	Unpainted Steel Open Girder/Beam	(LF)	16	0	0 %	0	0 %	16	100 %	0	0 %	0	0 %
111	1	Timber Open Girder/Beam	(LF)	751	608	81 %	82	11 %	61	8 %	0	0 %	0	0 %
201	1	Unpainted Steel Column or Pile Extension	(EA)	1	0	0 %	1	100 %	0	0 %	0	0 %	0	0 %
206	1	Timber Column or Pile Extension	(EA)	19	0	2 %	13	68 %	6	30 %	0	0 %	0	0 %
216	1	Timber Abutment	(LF)	52	26	50 %	10	19 %	16	31 %	0	0 %	0	0 %
235	1	Timber Cap	(LF)	95	0	0 %	95	100 %	0	0 %	0	0 %	0	0 %
332	1	Timber Bridge Railing	(LF)	95	0	0 %	0	0 %	95	100 %	0	0 %	0	0 %

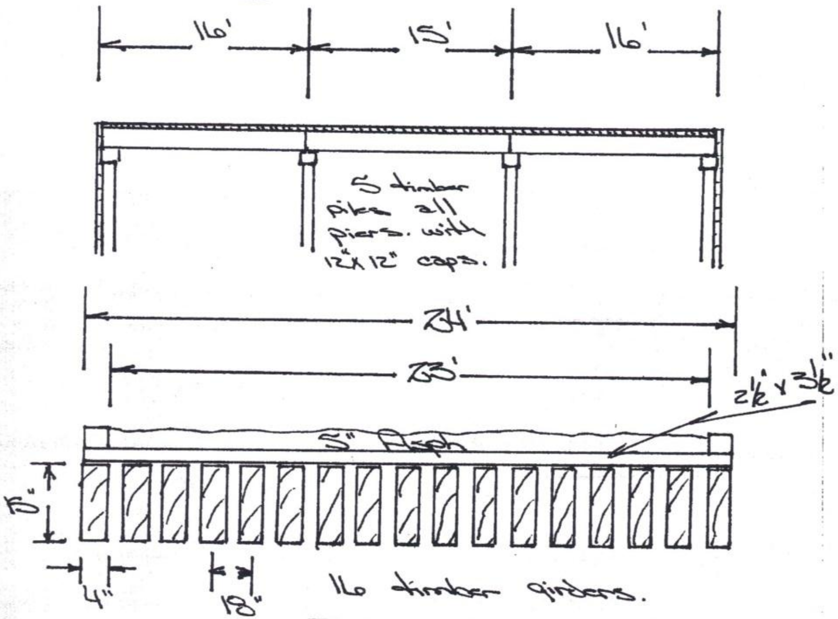
Additional Elements

Elem.	Element Notes (Include Size and Location of Deterioration
32	Overlay rough with some patches. Deck looks ok below with minor discoloration and checking. Some areas w/ minor decay noted.
106	There is a steel girder between #5 and #6 in S span. Hvy surf rust only. BEAM 1 IS BUSTED IN SPAN 2
111	#5 in S span split at 60% but there is a steel girder next to it. Sats to good cond overall. #9 SOUTH SPAN 25% BROKEN. #2 SPAN CENTER. #1-#14 50% BROKE.
201	NBENT #4 75% HOLLOW #3,#2 ARE 50% SBENT #5 IS 50% #4 HAS LRG SPLITS SABUT #2,3 ARE 50% HOLLOW
206	NORTH ABUTMENT-#4 50% HOLLOW SOUND. NORTH BENT-#4 50% HOLLOW SOUND. SOUTH BENT-#1, #3, #4 50% HOLLOW SOUND. SOUTH ABUTMENT-#3 50% HOLLOW SOUND. NBENT #4 75% HOLLOW #3,#2 ARE 50% SBENT #5 IS 50% #4 HAS LRG SPLITS SABUT #2,3 ARE 50% HOLLOW
216	Btm of S abut undermined with some loss of fill. Needs to be protected with riprap and channel routed under span 2. SOUTH ABUTMENT HAS BEEN REPAIRED AND RIP-RAP PLACED.
235	Some longitudal splitting and discoloration. Bent 1 cap deflected down 1 in. near center line. SPACERS HAVE BEEN REPLACED OVER PILES TO EVEN UP CAP. NORTH CAP HAS LONG CRACKS FULL LENGTH.
332	E rail gone down. W rail ok but all posts are almost rotted off at deck level.

Brawley Engineering corp.
6900 NORTH CLASSEN BLVD.
OKLAHOMA CITY, OKLAHOMA 73116
(405) 848-5578

DATE 10-4-95	E-
NAME K. Hopper	SHEET 1 OF 1

#355 27N2960E0070003

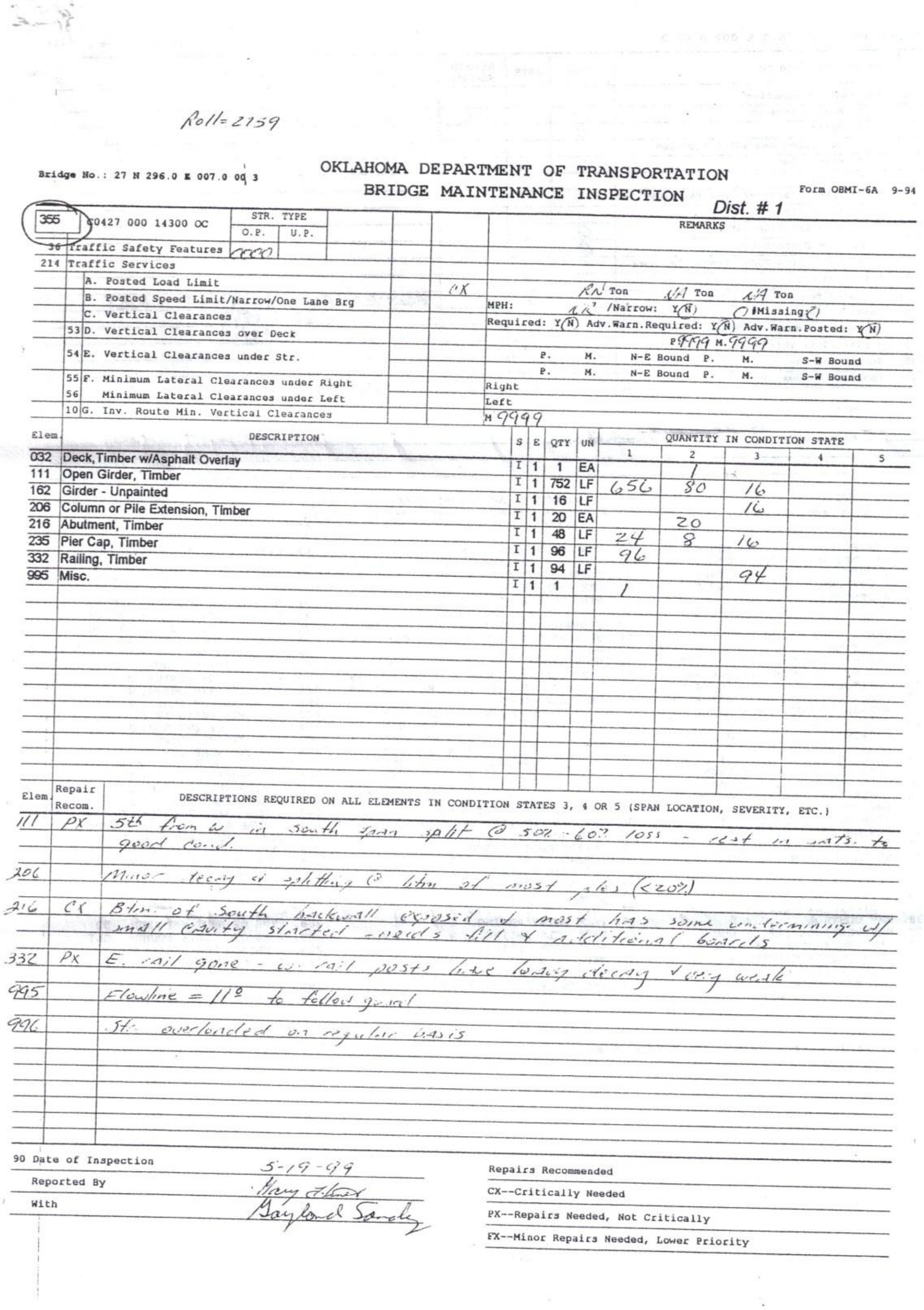


16 timber girders.

The 6th girder from the west in the south span is a steel I. 15" x 5½ x .50 x .88 x .3

The 5th girder from the west in the south span is the only broken girder.

FL = 11'



Roll=2159

Bridge No.: 27 N 296.0 E 007.0 00 3

OKLAHOMA DEPARTMENT OF TRANSPORTATION
BRIDGE MAINTENANCE INSPECTION

Form OBMI-6A 9-94

Dist. # 1

355 C0427 000 14300 OC

STR. TYPE O.P. U.P.

REMARKS

36 Traffic Safety Features 0000

214 Traffic Services

A. Posted Load Limit — CX — RN Ton N/A Ton N/A Ton

B. Posted Speed Limit/Narrow/One Lane Brg — MPH: NR /Narrow: Y [✓ N] ( ) #Missing( )

C. Vertical Clearances — Required: Y [✓ N] Adv.Warn.Required: Y [✓ N] Adv.Warn.Posted: Y [✓ N]

53 D. Vertical Clearances over Deck — P9999 M.9999

54 E. Vertical Clearances under Str. — P. M. N-E Bound P. M. S-W Bound
P. M. N-E Bound P. M. S-W Bound

55 F. Minimum Lateral Clearances under Right — Right

56 Minimum Lateral Clearances under Left — Left

10 G. Inv. Route Min. Vertical Clearances — M 9999

Elem.	DESCRIPTION	S	E	QTY	UN	QUANTITY IN CONDITION STATE 1	2	3	4	5
032	Deck,Timber w/Asphalt Overlay	I	1	1	EA		1			
111	Open Girder, Timber	I	1	752	LF	656	80	16		
162	Girder - Unpainted	I	1	16	LF			16		
206	Column or Pile Extension, Timber	I	1	20	EA		20			
216	Abutment, Timber	I	1	48	LF	24	8	16		
235	Pier Cap, Timber	I	1	96	LF	96				
332	Railing, Timber	I	1	94	LF			94		
995	Misc.	I	1	1		1				

Elem.	Repair Recom.	DESCRIPTIONS REQUIRED ON ALL ELEMENTS IN CONDITION STATES 3, 4 OR 5 (SPAN LOCATION, SEVERITY, ETC.)
111	PX	5th from w in south span split @ 50% - 60% loss - rest in sats. to good cond.
206		Minor decay & splitting @ btm of most piles (<20%)
216	CX	Btm. of South backwall exposed & most has some undermining w/ small cavity started - needs fill & additional boards
332	PX	E. rail gone - W. rail posts have heavy decay & very weak
995		Flowline = 11º to follow guard
996		Str. overloaded on regular basis

90 Date of Inspection 5-19-99

Reported By

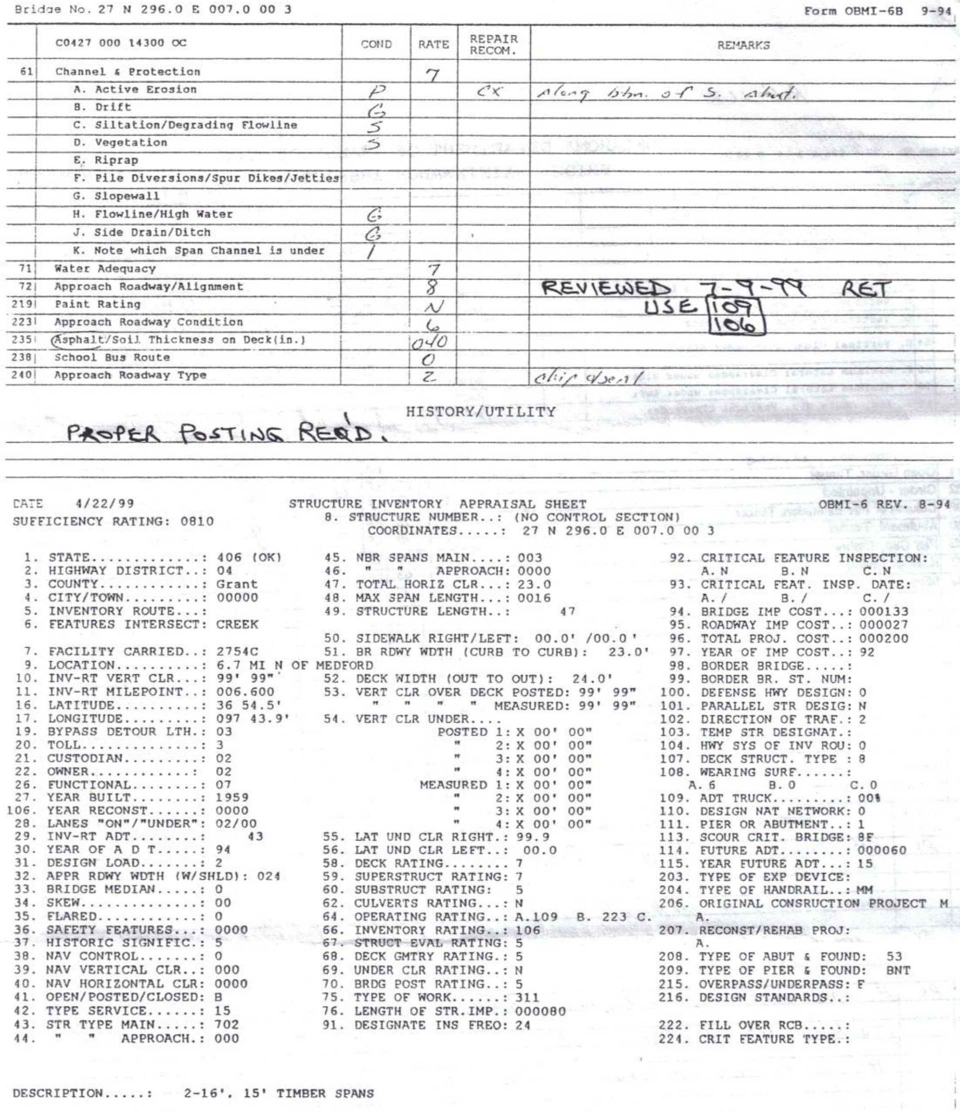
With Gaylord Sandy

Repairs Recommended

CX--Critically Needed

PX--Repairs Needed, Not Critically

FX--Minor Repairs Needed, Lower Priority



Bridge No. 27 N 296.0 E 007.0 00 3 Form OBMI-6B 9-94

	C0427 000 14300 OC	COND	RATE	REPAIR RECOM.	REMARKS
61	Channel & Protection		7		
	A. Active Erosion	P		CX	along btm. of S. abut.
	B. Drift	G			
	C. Siltation/Degrading Flowline	S			
	D. Vegetation	S			
	E. Riprap				
	F. Pile Diversions/Spur Dikes/Jetties				
	G. Slopewall				
	H. Flowline/High Water	G			
	J. Side Drain/Ditch	G			
	K. Note which Span Channel is under	1			
71	Water Adequacy		7		
72	Approach Roadway/Alignment		8		REVIEWED 7-9-99 RET
219	Paint Rating		N		USE 109
223	Approach Roadway Condition		6		106
235	Asphalt/Soil Thickness on Deck(in.)		040		
238	School Bus Route		0		
240	Approach Roadway Type		2		chip & seal

HISTORY/UTILITY

PROPER POSTING REQ'D.

```
DATE     4/22/99                  STRUCTURE INVENTORY  APPRAISAL SHEET                    OBMI-6 REV. 8-94
SUFFICIENCY RATING: 0810               8. STRUCTURE NUMBER..: (NO CONTROL SECTION)
                                          COORDINATES.....:  27 N 296.0 E 007.0 00 3

  1. STATE.............: 406 (OK)     45. NBR SPANS MAIN....: 003                 92. CRITICAL FEATURE INSPECTION:
  2. HIGHWAY DISTRICT..: 04           46.  "   "   APPROACH: 0000                     A. N       B. N       C. N
  3. COUNTY............: Grant        47. TOTAL HORIZ CLR...: 23.0               93. CRITICAL FEAT. INSP. DATE:
  4. CITY/TOWN.........: 00000        48. MAX SPAN LENGTH...: 0016                    A. /       B. /       C. /
  5. INVENTORY ROUTE...:              49. STRUCTURE LENGTH..:      47             94. BRIDGE IMP COST...: 000133
  6. FEATURES INTERSECT: CREEK                                                    95. ROADWAY IMP COST..: 000027
                                      50. SIDEWALK RIGHT/LEFT:  00.0' /00.0'      96. TOTAL PROJ. COST..: 000200
  7. FACILITY CARRIED..: 2754C        51. BR RDWY WDTH (CURB TO CURB):   23.0'    97. YEAR OF IMP COST..: 92
  9. LOCATION..........: 6.7 MI N OF MEDFORD                                      98. BORDER BRIDGE.....:
 10. INV-RT VERT CLR...: 99' 99"      52. DECK WIDTH (OUT TO OUT):  24.0'         99. BORDER BR. ST. NUM:
 11. INV-RT MILEPOINT..: 006.600      53. VERT CLR OVER DECK POSTED: 99' 99"     100. DEFENSE HWY DESIGN: 0
 16. LATITUDE..........: 36 54.5'          "    "    "    "  MEASURED: 99' 99"   101. PARALLEL STR DESIG: N
 17. LONGITUDE.........: 097 43.9'    54. VERT CLR UNDER....                     102. DIRECTION OF TRAF.: 2
 19. BYPASS DETOUR LTH.: 03                          POSTED 1: X 00' 00"         103. TEMP STR DESIGNAT.:
 20. TOLL..............: 3                                "  2: X 00' 00"         104. HWY SYS OF INV ROU: 0
 21. CUSTODIAN.........: 02                               "  3: X 00' 00"         107. DECK STRUCT. TYPE : 8
 22. OWNER............:  02                               "  4: X 00' 00"         108. WEARING SURF......:
 26. FUNCTIONAL........: 07                        MEASURED 1: X 00' 00"              A. 6      B. 0      C. 0
 27. YEAR BUILT........: 1959                             "  2: X 00' 00"         109. ADT TRUCK.........: 008
106. YEAR RECONST......: 0000                             "  3: X 00' 00"         110. DESIGN NAT NETWORK: 0
 28. LANES "ON"/"UNDER": 02/00                            "  4: X 00' 00"         111. PIER OR ABUTMENT..: 1
 29. INV-RT ADT........:      43      55. LAT UND CLR RIGHT.: 99.9               113. SCOUR CRIT. BRIDGE: 8F
 30. YEAR OF A D T.....: 94           56. LAT UND CLR LEFT..:  00.0              114. FUTURE ADT........: 000060
 31. DESIGN LOAD.......: 2            58. DECK RATING........ 7                  115. YEAR FUTURE ADT...: 15
 32. APPR RDWY WDTH (W/SHLD): 024     59. SUPERSTRUCT RATING: 7                  203. TYPE OF EXP DEVICE:
 33. BRIDGE MEDIAN.....: 0            60. SUBSTRUCT RATING:   5                  204. TYPE OF HANDRAIL..: MM
 34. SKEW..............: 00           62. CULVERTS RATING...: N                  206. ORIGINAL CONSRUCTION PROJECT M
 35. FLARED............: 0            64. OPERATING RATING..: A.109   B. 223 C.        A.
 36. SAFETY FEATURES...: 0000         66. INVENTORY RATING..: 106                207. RECONST/REHAB PROJ:
 37. HISTORIC SIGNIFIC.: 5            67. STRUCT EVAL RATING: 5                       A.
 38. NAV CONTROL.......: 0            68. DECK GMTRY RATING.: 5                  208. TYPE OF ABUT & FOUND:   53
 39. NAV VERTICAL CLR..: 000          69. UNDER CLR RATING..: N                  209. TYPE OF PIER & FOUND:   BNT
 40. NAV HORIZONTAL CLR: 0000         70. BRDG POST RATING..: 5                  215. OVERPASS/UNDERPASS: F
 41. OPEN/POSTED/CLOSED: B            75. TYPE OF WORK......: 311                216. DESIGN STANDARDS..:
 42. TYPE SERVICE......: 15           76. LENGTH OF STR.IMP.: 000080
 43. STR TYPE MAIN.....: 702          91. DESIGNATE INS FREO: 24                 222. FILL OVER RCB.....:
 44.  "   "   APPROACH.: 000                                                     224. CRIT FEATURE TYPE.:


DESCRIPTION.....:    2-16', 15' TIMBER SPANS
```

Grant #1 Recommendations

Legend of Repair Codes

CX - Needs Immediate attention
PX - Needs attention within 6 months
FX - Needs to be done to improve struture life or correct flow problems.

Timber

Herman 4

	Circle #	NBI #	Repair Code	Rating Change (from-to)	Recommendations
South Sheehan Frelout	367	11634	CX	34 ft.	Lower 3 ton. Piles need driven S. abutment. Needs cap S. abutment.
Larry Himes	263 ②	02367	CX	24' 9" Beams 24" spacing	Needs piles and cap at S. abutment.
Staten Gillaspy	115 [illegible]	11461	CX	25 ft.	Lower to 3 tons. Needs piles repaired both abutments.
Jimmy Powell	018	07862	CX Let Feb Start Date going to be Replaced		Bridge programmed for BR 2005 plan. Novemeber letting.
½ 1 mile east Livengoods	015	06491	CX 5 yr.	"06" PLAN	Piles need repaired county plans to move to 06 project.
1½ mile North Jakhard Rd & M&M Rd	355 ①	14300 12-13-05	PX		Needs piles at S. bent. Fixed one Pile with steel - Dug out Southend & Added Bank Boards

BRIDGE LOAD RATING VERIFICATIONS

NBI NO. 355/14300

STRUCTURE NO. 27N2960E0070003 DATE 8/20/05

LOAD RATING DETERMINED BY (Check one):

___ Load Rating/ Design load on plans. No ratings calculated.

___ Load Rating calculated (Computer printout or hand calculations attached).

___ Load Rating calculations already in Master Bridge File.

X Load Rating based on engineering judgement. No ratings calculated.

___ Load Rating not calculated. As stated in the <u>AASHTO Manual for Condition Evaluation of Bridges.</u> " A concrete bridge need not be posted for restricted loading when it has been carrying normal traffic for an appreciable amount of time and shows no distress". (This option only available when reinforcing details are not available.)

___ Other (Please Explain): ___

Reduce rating Abuts piles
piers

	H	HS
IN	13	6
OP	5	2

Professional Engineer Seal
(if calculations were not performed):

REGISTERED PROFESSIONAL ENGINEER
THOMAS
RANDALL
ROBINSON
15714
OKLAHOMA

APPENDIX B

Calculation Tables

Diameter=6 in													
Diameter (in.)	E (psi)	Fc (psi)	L (ft)	L (in)	A (in^4)	le/d	FcE	c	R1	R2	Cp	F'c	Capacity (K)
6	2090000	1250	5	60	28.26	10.00	17,179.80	0.85	8.673	16.169	0.989	1,235.64	31.43
6	2090000	1250	6	72	28.26	12.00	11,930.42	0.85	6.203	11.229	0.983	1,228.83	31.25
6	2090000	1250	7	84	28.26	14.00	8,765.20	0.85	4.713	8.250	0.976	1,220.39	31.04
6	2090000	1250	8	96	28.26	16.00	6,710.86	0.85	3.746	6.316	0.968	1,210.07	30.78
6	2090000	1250	9	108	28.26	18.00	5,302.41	0.85	3.083	4.991	0.958	1,197.59	30.46
6	2090000	1250	10	120	28.26	20.00	4,294.95	0.85	2.609	4.042	0.946	1,182.60	30.08
6	2090000	1250	11	132	28.26	22.00	3,549.55	0.85	2.259	3.341	0.932	1,164.68	29.62
6	2090000	1250	12	144	28.26	24.00	2,982.60	0.85	1.992	2.807	0.915	1,143.38	29.08
6	2090000	1250	13	156	28.26	26.00	2,541.39	0.85	1.784	2.392	0.895	1,118.21	28.44
6	2090000	1250	14	168	28.26	28.00	2,191.30	0.85	1.619	2.062	0.871	1,088.74	27.69
6	2090000	1250	15	180	28.26	30.00	1,908.87	0.85	1.487	1.797	0.844	1,054.67	26.82
6	2090000	1250	16	192	28.26	32.00	1,677.71	0.85	1.378	1.579	0.813	1,016.00	25.84
6	2090000	1250	17	204	28.26	34.00	1,486.14	0.85	1.288	1.399	0.778	973.12	24.75
6	2090000	1250	18	216	28.26	36.00	1,325.60	0.85	1.212	1.248	0.741	926.85	23.57
6	2090000	1250	19	228	28.26	38.00	1,189.74	0.85	1.148	1.120	0.703	878.35	22.34
6	2090000	1250	20	240	28.26	40.00	1,073.74	0.85	1.094	1.011	0.663	828.94	21.08
6	2090000	1250	21	252	28.26	42.00	973.91	0.85	1.047	0.917	0.624	779.86	19.84
6	2090000	1250	22	264	28.26	44.00	887.39	0.85	1.006	0.835	0.586	732.13	18.62
6	2090000	1250	23	276	28.26	46.00	811.90	0.85	0.970	0.764	0.549	686.47	17.46
6	2090000	1250	24	288	28.26	48.00	745.65	0.85	0.939	0.702	0.515	643.32	16.36
6	2090000	1250	25	300	28.26	50.00	687.19	0.85	0.912	0.647	0.482	602.92	15.33

Diameter=7 in													
Diameter (in.)	E (psi)	Fc (psi)	L (ft)	L (in)	A (in^4)	le/d	FcE	c	R1	R2	Cp	F'c	Capacity (K)
7	2090000	1250	5	60	38.47	8.57	23,383.62	0.85	11.592	22.008	0.992	1,239.59	42.91
7	2090000	1250	6	72	38.47	10.29	16,238.62	0.85	8.230	15.283	0.988	1,234.76	42.75
7	2090000	1250	7	84	38.47	12.00	11,930.42	0.85	6.203	11.229	0.983	1,228.83	42.54
7	2090000	1250	8	96	38.47	13.71	9,134.23	0.85	4.887	8.597	0.977	1,221.71	42.29
7	2090000	1250	9	108	38.47	15.43	7,217.17	0.85	3.985	6.793	0.971	1,213.23	42.00
7	2090000	1250	10	120	38.47	17.14	5,845.90	0.85	3.339	5.502	0.963	1,203.22	41.65
7	2090000	1250	11	132	38.47	18.86	4,831.33	0.85	2.862	4.547	0.953	1,191.49	41.25
7	2090000	1250	12	144	38.47	20.57	4,059.66	0.85	2.499	3.821	0.942	1,177.80	40.77
7	2090000	1250	13	156	38.47	22.29	3,459.11	0.85	2.216	3.256	0.929	1,161.86	40.22
7	2090000	1250	14	168	38.47	24.00	2,982.60	0.85	1.992	2.807	0.915	1,143.38	39.58
7	2090000	1250	15	180	38.47	25.71	2,598.18	0.85	1.811	2.445	0.898	1,122.06	38.84
7	2090000	1250	16	192	38.47	27.43	2,283.56	0.85	1.663	2.149	0.878	1,097.62	38.00
7	2090000	1250	17	204	38.47	29.14	2,022.80	0.85	1.540	1.904	0.856	1,069.84	37.04
7	2090000	1250	18	216	38.47	30.86	1,804.29	0.85	1.437	1.698	0.831	1,038.65	35.96
7	2090000	1250	19	228	38.47	32.57	1,619.36	0.85	1.350	1.524	0.803	1,004.15	34.76
7	2090000	1250	20	240	38.47	34.29	1,461.48	0.85	1.276	1.376	0.773	966.69	33.47
7	2090000	1250	21	252	38.47	36.00	1,325.60	0.85	1.212	1.248	0.741	926.85	32.09
7	2090000	1250	22	264	38.47	37.71	1,207.83	0.85	1.157	1.137	0.708	885.37	30.65
7	2090000	1250	23	276	38.47	39.43	1,105.09	0.85	1.108	1.040	0.674	843.08	29.19
7	2090000	1250	24	288	38.47	41.14	1,014.91	0.85	1.066	0.955	0.641	800.79	27.72
7	2090000	1250	25	300	38.47	42.86	935.34	0.85	1.028	0.880	0.607	759.19	26.28

Diameter=8 in													
Diameter (in.)	E (psi)	Fc (psi)	L (ft)	L (in)	A (in^4)	le/d	FcE	c	R1	R2	Cp	F'c	Capacity (K)
8	2090000	1250	5	60	50.24	7.50	30,541.87	0.85	14.961	28.745	0.994	1,242.10	56.16
8	2090000	1250	6	72	50.24	9.00	21,209.63	0.85	10.569	19.962	0.991	1,238.48	56.00
8	2090000	1250	7	84	50.24	10.50	15,582.59	0.85	7.921	14.666	0.987	1,234.08	55.80
8	2090000	1250	8	96	50.24	12.00	11,930.42	0.85	6.203	11.229	0.983	1,228.83	55.56
8	2090000	1250	9	108	50.24	13.50	9,426.50	0.85	5.024	8.872	0.978	1,222.67	55.28
8	2090000	1250	10	120	50.24	15.00	7,635.47	0.85	4.181	7.186	0.972	1,215.48	54.96
8	2090000	1250	11	132	50.24	16.50	6,310.30	0.85	3.558	5.939	0.966	1,207.17	54.58
8	2090000	1250	12	144	50.24	18.00	5,302.41	0.85	3.083	4.991	0.958	1,197.59	54.15
8	2090000	1250	13	156	50.24	19.50	4,518.03	0.85	2.714	4.252	0.949	1,186.60	53.65
8	2090000	1250	14	168	50.24	21.00	3,895.65	0.85	2.421	3.666	0.939	1,174.03	53.09
8	2090000	1250	15	180	50.24	22.50	3,393.54	0.85	2.185	3.194	0.928	1,159.69	52.44
8	2090000	1250	16	192	50.24	24.00	2,982.60	0.85	1.992	2.807	0.915	1,143.38	51.70
8	2090000	1250	17	204	50.24	25.50	2,642.03	0.85	1.832	2.487	0.900	1,124.89	50.86
8	2090000	1250	18	216	50.24	27.00	2,356.63	0.85	1.697	2.218	0.883	1,104.04	49.92
8	2090000	1250	19	228	50.24	28.50	2,115.09	0.85	1.584	1.991	0.865	1,080.66	48.86
8	2090000	1250	20	240	50.24	30.00	1,908.87	0.85	1.487	1.797	0.844	1,054.67	47.69
8	2090000	1250	21	252	50.24	31.50	1,731.40	0.85	1.403	1.630	0.821	1,026.09	46.40
8	2090000	1250	22	264	50.24	33.00	1,577.58	0.85	1.331	1.485	0.796	995.05	44.99
8	2090000	1250	23	276	50.24	34.50	1,443.38	0.85	1.267	1.358	0.769	961.83	43.49
8	2090000	1250	24	288	50.24	36.00	1,325.60	0.85	1.212	1.248	0.741	926.85	41.91
8	2090000	1250	25	300	50.24	37.50	1,221.67	0.85	1.163	1.150	0.712	890.61	40.27

Diameter=9 in													
Diameter (in.)	E (psi)	Fc (psi)	L (ft)	L (in)	A (in^4)	le/d	FcE	c	R1	R2	Cp	F'c	Capacity (K)
9	2090000	1250	5	60	63.59	6.67	38,654.55	0.85	18.779	36.381	0.995	1,243.80	71.18
9	2090000	1250	6	72	63.59	8.00	26,843.44	0.85	13.220	25.264	0.993	1,240.98	71.02
9	2090000	1250	7	84	63.59	9.33	19,721.71	0.85	9.869	18.562	0.990	1,237.57	70.82
9	2090000	1250	8	96	63.59	10.67	15,099.43	0.85	7.694	14.211	0.987	1,233.54	70.59
9	2090000	1250	9	108	63.59	12.00	11,930.42	0.85	6.203	11.229	0.983	1,228.83	70.32
9	2090000	1250	10	120	63.59	13.33	9,663.64	0.85	5.136	9.095	0.979	1,223.40	70.01
9	2090000	1250	11	132	63.59	14.67	7,986.48	0.85	4.347	7.517	0.974	1,217.17	69.65
9	2090000	1250	12	144	63.59	16.00	6,710.86	0.85	3.746	6.316	0.968	1,210.07	69.25
9	2090000	1250	13	156	63.59	17.33	5,718.13	0.85	3.279	5.382	0.962	1,202.01	68.79
9	2090000	1250	14	168	63.59	18.67	4,930.43	0.85	2.908	4.640	0.954	1,192.89	68.26
9	2090000	1250	15	180	63.59	20.00	4,294.95	0.85	2.609	4.042	0.946	1,182.60	67.68
9	2090000	1250	16	192	63.59	21.33	3,774.86	0.85	2.365	3.553	0.937	1,171.01	67.01
9	2090000	1250	17	204	63.59	22.67	3,343.82	0.85	2.162	3.147	0.926	1,157.98	66.27
9	2090000	1250	18	216	63.59	24.00	2,982.60	0.85	1.992	2.807	0.915	1,143.38	65.43
9	2090000	1250	19	228	63.59	25.33	2,676.91	0.85	1.848	2.519	0.902	1,127.06	64.50
9	2090000	1250	20	240	63.59	26.67	2,415.91	0.85	1.725	2.274	0.887	1,108.88	63.46
9	2090000	1250	21	252	63.59	28.00	2,191.30	0.85	1.619	2.062	0.871	1,088.74	62.30
9	2090000	1250	22	264	63.59	29.33	1,996.62	0.85	1.528	1.879	0.853	1,066.54	61.03
9	2090000	1250	23	276	63.59	30.67	1,826.77	0.85	1.448	1.719	0.834	1,042.28	59.65
9	2090000	1250	24	288	63.59	32.00	1,677.71	0.85	1.378	1.579	0.813	1,016.00	58.14
9	2090000	1250	25	300	63.59	33.33	1,546.18	0.85	1.316	1.455	0.790	987.84	56.53

Diameter=10 in													
Diameter (in.)	E (psi)	Fc (psi)	L (ft)	L (in)	A (in^4)	le/d	FcE	c	R1	R2	Cp	F'c	Capacity (K)
10	2090000	1250	5	60	78.50	6.00	47,721.67	0.85	23.045	44.915	0.996	1,245.00	87.96
10	2090000	1250	6	72	78.50	7.20	33,140.05	0.85	16.184	31.191	0.994	1,242.74	87.80
10	2090000	1250	7	84	78.50	8.40	24,347.79	0.85	12.046	22.916	0.992	1,240.02	87.61
10	2090000	1250	8	96	78.50	9.60	18,641.28	0.85	9.361	17.545	0.989	1,236.82	87.38
10	2090000	1250	9	108	78.50	10.80	14,728.91	0.85	7.519	13.863	0.986	1,233.10	87.12
10	2090000	1250	10	120	78.50	12.00	11,930.42	0.85	6.203	11.229	0.983	1,228.83	86.82
10	2090000	1250	11	132	78.50	13.20	9,859.85	0.85	5.228	9.280	0.979	1,223.98	86.47
10	2090000	1250	12	144	78.50	14.40	8,285.01	0.85	4.487	7.798	0.975	1,218.48	86.09
10	2090000	1250	13	156	78.50	15.60	7,059.42	0.85	3.910	6.644	0.970	1,212.30	85.65
10	2090000	1250	14	168	78.50	16.80	6,086.95	0.85	3.453	5.729	0.964	1,205.36	85.16
10	2090000	1250	15	180	78.50	18.00	5,302.41	0.85	3.083	4.991	0.958	1,197.59	84.61
10	2090000	1250	16	192	78.50	19.20	4,660.32	0.85	2.781	4.386	0.951	1,188.92	84.00
10	2090000	1250	17	204	78.50	20.40	4,128.17	0.85	2.531	3.885	0.943	1,179.26	83.31
10	2090000	1250	18	216	78.50	21.60	3,682.23	0.85	2.321	3.466	0.935	1,168.52	82.56
10	2090000	1250	19	228	78.50	22.80	3,304.82	0.85	2.143	3.110	0.925	1,156.59	81.71
10	2090000	1250	20	240	78.50	24.00	2,982.60	0.85	1.992	2.807	0.915	1,143.38	80.78
10	2090000	1250	21	252	78.50	25.20	2,705.31	0.85	1.861	2.546	0.903	1,128.77	79.75
10	2090000	1250	22	264	78.50	26.40	2,464.96	0.85	1.748	2.320	0.890	1,112.67	78.61
10	2090000	1250	23	276	78.50	27.60	2,255.28	0.85	1.650	2.123	0.876	1,094.99	77.36
10	2090000	1250	24	288	78.50	28.80	2,071.25	0.85	1.563	1.949	0.861	1,075.67	76.00
10	2090000	1250	25	300	78.50	30.00	1,908.87	0.85	1.487	1.797	0.844	1,054.67	74.51

Diameter=11 in													
Diameter (in.)	E (psi)	Fc (psi)	L (ft)	L (in)	A (in^4)	le/d	FcE	c	R1	R2	Cp	F'c	Capacity (K)
11	2090000	1250	5	60	94.99	5.45	57,743.22	0.85	27.762	54.347	0.997	1,245.88	106.51
11	2090000	1250	6	72	94.99	6.55	40,099.46	0.85	19.459	37.741	0.995	1,244.03	106.35
11	2090000	1250	7	84	94.99	7.64	29,460.82	0.85	14.452	27.728	0.993	1,241.80	106.16
11	2090000	1250	8	96	94.99	8.73	22,555.94	0.85	11.203	21.229	0.991	1,239.19	105.93
11	2090000	1250	9	108	94.99	9.82	17,821.98	0.85	8.975	16.774	0.989	1,236.18	105.68
11	2090000	1250	10	120	94.99	10.91	14,435.80	0.85	7.382	13.587	0.986	1,232.74	105.38
11	2090000	1250	11	132	94.99	12.00	11,930.42	0.85	6.203	11.229	0.983	1,228.83	105.05
11	2090000	1250	12	144	94.99	13.09	10,024.86	0.85	5.306	9.435	0.980	1,224.45	104.67
11	2090000	1250	13	156	94.99	14.18	8,541.90	0.85	4.608	8.039	0.976	1,219.53	104.25
11	2090000	1250	14	168	94.99	15.27	7,365.21	0.85	4.054	6.932	0.971	1,214.06	103.79
11	2090000	1250	15	180	94.99	16.36	6,415.91	0.85	3.607	6.039	0.966	1,207.97	103.27
11	2090000	1250	16	192	94.99	17.45	5,638.99	0.85	3.242	5.307	0.961	1,201.23	102.69
11	2090000	1250	17	204	94.99	18.55	4,995.09	0.85	2.939	4.701	0.955	1,193.77	102.05
11	2090000	1250	18	216	94.99	19.64	4,455.50	0.85	2.685	4.193	0.948	1,185.53	101.35
11	2090000	1250	19	228	94.99	20.73	3,998.84	0.85	2.470	3.764	0.941	1,176.44	100.57
11	2090000	1250	20	240	94.99	21.82	3,608.95	0.85	2.287	3.397	0.933	1,166.44	99.72
11	2090000	1250	21	252	94.99	22.91	3,273.42	0.85	2.129	3.081	0.924	1,155.45	98.78
11	2090000	1250	22	264	94.99	24.00	2,982.60	0.85	1.992	2.807	0.915	1,143.38	97.74
11	2090000	1250	23	276	94.99	25.09	2,728.89	0.85	1.872	2.568	0.904	1,130.16	96.61
11	2090000	1250	24	288	94.99	26.18	2,506.22	0.85	1.768	2.359	0.893	1,115.72	95.38
11	2090000	1250	25	300	94.99	27.27	2,309.73	0.85	1.675	2.174	0.880	1,099.98	94.03

Diameter=12 in													
Diameter (in.)	E (psi)	Fc (psi)	L (ft)	L (in)	A (in^4)	le/d	FcE	c	R1	R2	Cp	F'c	Capacity (K)
12	2090000	1250	5	60	113.04	5.00	68,719.20	0.85	32.927	64.677	0.997	1,246.55	126.82
12	2090000	1250	6	72	113.04	6.00	47,721.67	0.85	23.045	44.915	0.996	1,245.00	126.66
12	2090000	1250	7	84	113.04	7.00	35,060.82	0.85	17.087	32.998	0.995	1,243.15	126.47
12	2090000	1250	8	96	113.04	8.00	26,843.44	0.85	13.220	25.264	0.993	1,240.98	126.25
12	2090000	1250	9	108	113.04	9.00	21,209.63	0.85	10.569	19.962	0.991	1,238.48	126.00
12	2090000	1250	10	120	113.04	10.00	17,179.80	0.85	8.673	16.169	0.989	1,235.64	125.71
12	2090000	1250	11	132	113.04	11.00	14,198.18	0.85	7.270	13.363	0.986	1,232.43	125.38
12	2090000	1250	12	144	113.04	12.00	11,930.42	0.85	6.203	11.229	0.983	1,228.83	125.02
12	2090000	1250	13	156	113.04	13.00	10,165.56	0.85	5.372	9.568	0.980	1,224.83	124.61
12	2090000	1250	14	168	113.04	14.00	8,765.20	0.85	4.713	8.250	0.976	1,220.39	124.16
12	2090000	1250	15	180	113.04	15.00	7,635.47	0.85	4.181	7.186	0.972	1,215.48	123.66
12	2090000	1250	16	192	113.04	16.00	6,710.86	0.85	3.746	6.316	0.968	1,210.07	123.11
12	2090000	1250	17	204	113.04	17.00	5,944.57	0.85	3.386	5.595	0.963	1,204.12	122.50
12	2090000	1250	18	216	113.04	18.00	5,302.41	0.85	3.083	4.991	0.958	1,197.59	121.84
12	2090000	1250	19	228	113.04	19.00	4,758.95	0.85	2.828	4.479	0.952	1,190.43	121.11
12	2090000	1250	20	240	113.04	20.00	4,294.95	0.85	2.609	4.042	0.946	1,182.60	120.31
12	2090000	1250	21	252	113.04	21.00	3,895.65	0.85	2.421	3.666	0.939	1,174.03	119.44
12	2090000	1250	22	264	113.04	22.00	3,549.55	0.85	2.259	3.341	0.932	1,164.68	118.49
12	2090000	1250	23	276	113.04	23.00	3,247.60	0.85	2.117	3.057	0.924	1,154.48	117.45
12	2090000	1250	24	288	113.04	24.00	2,982.60	0.85	1.992	2.807	0.915	1,143.38	116.32
12	2090000	1250	25	300	113.04	25.00	2,748.77	0.85	1.882	2.587	0.905	1,131.31	115.09

Diameter=13 in

Diameter (in.)	E (psi)	Fc (psi)	L (ft)	L (in)	A (in^4)	le/d	FcE	c	R1	R2	Cp	F'c	Capacity (K)
13	2090000	1250	5	60	132.67	4.62	80,649.62	0.85	38.541	75.906	0.998	1,247.06	148.90
13	2090000	1250	6	72	132.67	5.54	56,006.68	0.85	26.944	52.712	0.997	1,245.75	148.74
13	2090000	1250	7	84	132.67	6.46	41,147.76	0.85	19.952	38.727	0.995	1,244.18	148.55
13	2090000	1250	8	96	132.67	7.38	31,503.76	0.85	15.414	29.651	0.994	1,242.35	148.33
13	2090000	1250	9	108	132.67	8.31	24,891.86	0.85	12.302	23.428	0.992	1,240.24	148.08
13	2090000	1250	10	120	132.67	9.23	20,162.40	0.85	10.076	18.976	0.990	1,237.85	147.80
13	2090000	1250	11	132	132.67	10.15	16,663.14	0.85	8.430	15.683	0.988	1,235.17	147.48
13	2090000	1250	12	144	132.67	11.08	14,001.67	0.85	7.177	13.178	0.986	1,232.17	147.12
13	2090000	1250	13	156	132.67	12.00	11,930.42	0.85	6.203	11.229	0.983	1,228.83	146.72
13	2090000	1250	14	168	132.67	12.92	10,286.94	0.85	5.429	9.682	0.980	1,225.15	146.28
13	2090000	1250	15	180	132.67	13.85	8,961.07	0.85	4.805	8.434	0.977	1,221.10	145.80
13	2090000	1250	16	192	132.67	14.77	7,875.94	0.85	4.295	7.413	0.973	1,216.66	145.27
13	2090000	1250	17	204	132.67	15.69	6,976.61	0.85	3.871	6.566	0.969	1,211.79	144.69
13	2090000	1250	18	216	132.67	16.62	6,222.96	0.85	3.517	5.857	0.965	1,206.48	144.05
13	2090000	1250	19	228	132.67	17.54	5,585.15	0.85	3.217	5.257	0.961	1,200.68	143.36
13	2090000	1250	20	240	132.67	18.46	5,040.60	0.85	2.960	4.744	0.955	1,194.37	142.61
13	2090000	1250	21	252	132.67	19.38	4,571.97	0.85	2.740	4.303	0.950	1,187.50	141.79
13	2090000	1250	22	264	132.67	20.31	4,165.79	0.85	2.549	3.921	0.944	1,180.04	140.90
13	2090000	1250	23	276	132.67	21.23	3,811.42	0.85	2.382	3.587	0.938	1,171.95	139.93
13	2090000	1250	24	288	132.67	22.15	3,500.42	0.85	2.235	3.295	0.931	1,163.17	138.88
13	2090000	1250	25	300	132.67	23.08	3,225.98	0.85	2.106	3.036	0.923	1,153.66	137.75

Timber Capacities (kip)								
	Original Timber Pile Diameter (in.)							
Height (ft)	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
5	31.43	42.91	56.16	71.18	87.96	106.51	126.82	148.90
6	31.25	42.75	56.00	71.02	87.80	106.35	126.66	148.74
7	31.04	42.54	55.80	70.82	87.61	106.16	126.47	148.55
8	30.78	42.29	55.56	70.59	87.38	105.93	126.25	148.33
9	30.46	42.00	55.28	70.32	87.12	105.68	126.00	148.08
10	30.08	41.65	54.96	70.01	86.82	105.38	125.71	147.80
11	29.62	41.25	54.58	69.65	86.47	105.05	125.38	147.48
12	29.08	40.77	54.15	69.25	86.09	104.67	125.02	147.12
13	28.44	40.22	53.65	68.79	85.65	104.25	124.61	146.72
14	27.69	39.58	53.09	68.26	85.16	103.79	124.16	146.28
15	26.82	38.84	52.44	67.68	84.61	103.27	123.66	145.80
16	25.84	38.00	51.70	67.01	84.00	102.69	123.11	145.27
17	24.75	37.04	50.86	66.27	83.31	102.05	122.50	144.69
18	23.57	35.96	49.92	65.43	82.56	101.35	121.84	144.05
19	22.34	34.76	48.86	64.50	81.71	100.57	121.11	143.36
20	21.08	33.47	47.69	63.46	80.78	99.72	120.31	142.61
21	19.84	32.09	46.40	62.30	79.75	98.78	119.44	141.79
22	18.62	30.65	44.99	61.03	78.61	97.74	118.49	140.90
23	17.46	29.19	43.49	59.65	77.36	96.61	117.45	139.93
24	16.36	27.72	41.91	58.14	76.00	95.38	116.32	138.88
25	15.33	26.28	40.27	56.53	74.51	94.03	115.09	137.75

Steel Pipe Capacities (Kip)

Height (ft)	Pipe Shape														
	Standard County Pipes				Pipe 3 x-Strong	Pipe 4 x-Strong	Pipe 5 x-Strong	Pipe 6 x-Strong	Pipe 8 x-Strong	Pipe 4 Std.	Pipe 5 Std.	Pipe 6 Std.	Pipe 8 Std.	Pipe 10 Std.	Pipe 12 Std.
	D=7.625 t=0.450	D=7.625 t=0.500	D=9 t=0.450	D=9 t=0.500	D=3.50 t=0.280	D=4.50 t=0.315	D=5.56 t=0.349	D=6.63 t=0.403	D=8.63 t=0.465	D=4.5 t=0.221	D=5.56 t=0.241	D=6.63 t=0.261	D=8.63 t=0.300	D=10.8 t=0.340	D=12.8 t=0.349
5	237.24	238.12	283.35	284.13	82.51	123.20	163.25	202.34	271.27	115.54	156.84	196.44	267.15	341.09	407.48
6	233.05	234.29	279.80	280.90	71.74	114.40	156.32	197.09	267.68	104.30	147.57	188.86	261.85	337.28	404.33
7	228.19	229.85	275.66	277.14	60.80	104.81	148.52	191.05	263.50	92.42	137.32	180.28	255.71	332.82	400.65
8	222.71	224.82	270.95	272.86	50.24	94.73	140.00	184.32	258.76	80.38	126.37	170.87	248.81	327.76	396.44
9	216.66	219.26	265.72	268.08	40.40	84.48	130.93	176.97	253.49	68.62	115.01	160.79	241.22	322.11	391.72
10	210.09	213.21	259.99	262.85	32.72	74.33	121.48	169.11	247.72	57.51	103.52	150.23	233.00	315.92	386.51
11	203.06	206.72	253.80	257.18	27.05	64.53	111.84	160.82	241.50	47.54	92.15	139.36	224.25	309.21	380.83
12	195.63	199.83	247.19	251.11	22.73	55.17	102.15	152.21	234.87	39.95	81.12	128.36	215.04	302.02	374.71
13	187.86	192.61	240.20	244.68	19.36	47.01	92.57	143.38	227.87	34.04	70.63	117.38	205.46	294.40	368.17
14	179.82	185.10	232.87	237.92	16.70	40.53	83.23	134.41	220.54	29.35	60.90	106.58	195.58	286.38	361.23
15	171.57	177.36	225.25	230.86	14.54	35.31	74.24	125.40	212.93	25.57	53.05	96.08	185.51	278.02	353.92
16	163.16	169.44	217.38	223.55	12.78	31.03	65.56	116.44	205.08	22.47	46.62	86.00	175.31	269.35	346.28
17	154.66	161.40	209.30	216.02	11.32	27.49	58.08	107.60	197.05	19.90	41.30	76.30	165.08	260.41	338.32
18	146.14	153.29	201.06	208.31	10.10	24.52	51.80	98.96	188.87	17.75	36.84	68.05	154.87	251.26	330.08
19	137.63	145.16	192.70	200.46	9.07	22.01	46.49	90.57	180.59	15.93	33.06	61.08	144.76	241.93	321.59
20	129.20	137.05	184.27	192.51	8.18	19.86	41.96	82.40	172.26	14.38	29.84	55.12	134.83	232.48	312.87
21	120.90	129.02	175.80	184.49	7.42	18.01	38.06	74.74	163.92	13.04	27.07	50.00	125.11	222.93	303.96
22	112.76	121.10	167.34	176.43	6.76	16.41	34.68	68.10	155.60	11.89	24.66	45.56	115.68	213.34	294.89
23	104.83	113.34	158.92	168.38	6.19	15.02	31.73	62.31	147.35	10.87	22.56	41.68	106.40	203.75	285.69
24	97.14	105.75	150.57	160.36	5.68	13.79	29.14	57.22	139.20	9.99	20.72	38.28	97.72	194.19	276.38
25	89.53	98.39	142.34	152.41	5.24	12.71	26.86	52.74	131.18	9.20	19.10	35.28	90.06	184.71	267.01

Steel HP Capacities (Kip)							
Height (ft)	HP Shape						
	Standard County HP			HP12X53	HP12X63	HP12X74	HP12X84
	HP8X36	HP10X42	HP10X57				
5	326.73	388.85	527.39	490.69	582.68	690.78	779.74
6	319.63	383.30	520.10	485.70	576.84	684.05	772.24
7	311.45	376.85	511.62	479.88	570.02	676.18	763.48
8	302.26	369.53	502.01	473.25	562.26	667.21	753.49
9	292.18	361.41	491.34	465.84	553.58	657.19	742.33
10	281.31	352.55	479.68	457.71	544.04	646.17	730.05
11	269.76	343.01	467.11	448.87	533.69	634.21	716.71
12	257.66	332.86	453.72	439.40	522.57	621.36	702.39
13	245.12	322.16	439.61	429.32	510.76	607.69	687.14
14	232.26	310.99	424.86	418.70	498.29	593.26	671.04
15	219.20	299.43	409.56	407.59	485.25	578.14	654.17
16	206.05	287.55	393.82	396.03	471.68	562.41	636.61
17	192.92	275.41	377.73	384.09	457.65	546.13	618.43
18	179.90	263.10	361.38	371.82	443.23	529.38	599.72
19	167.10	250.68	344.87	359.27	428.48	512.23	580.55
20	154.59	238.23	328.27	346.51	413.46	494.76	561.01
21	142.44	225.81	311.69	333.58	398.23	477.03	541.17
22	130.52	213.47	295.20	320.53	382.87	459.12	521.12
23	119.41	201.28	278.88	307.42	367.43	441.09	500.94
24	109.67	189.29	262.79	294.31	351.96	423.02	480.69
25	101.07	177.55	247.00	281.23	336.53	404.97	460.45

	Fy (ksi)	Q (ft^3/sec)	Diameter (in)	Z (in)	r (in)	I (in^4)	E (ksi)	Lp (ft.)	S (in.)	D/t							
Pipe 3 x-strong	50	7500	3.5	2.91	1.14	3.7	29000	4.026709	2.11	12.5							
	L (ft)	A (ft^2)	V (ft/s)	P (psf)	w (k/ft)	Axial Load	Axial Capacity	Axial load/cap	Max Moment (k/ft)	Moment Cap (plastic hinge) (k-ft)	Moment Cap (Local Buckling) (k-ft)	Moment Capacity	Pe (k)	Moment Amp. Factor	Amplified Max. Moment (K-ft)	Interaction Formula	OK?
	5	83.33	90.00	5670.00	1.654	87.96	82.51	1.066	1.60	10.913	187.469	10.913	293.871	1.427	2.276	1.272	no
	6	100.00	75.00	3937.50	1.148	87.80	71.74	1.224	1.60	10.913	187.469	10.913	204.077	1.755	2.799	1.477	no
	7	116.67	64.29	2892.86	0.844	87.61	60.80	1.441	1.60	10.913	187.469	10.913	149.934	2.406	3.837	1.788	no
	8	133.33	56.25	2214.84	0.646	87.38	50.24	1.739	1.60	10.913	187.469	10.913	114.793	4.188	6.680	2.344	no
	9	150.00	50.00	1750.00	0.510	87.12	40.40	2.156	1.60	10.913	187.469	10.913	90.701	25.319	40.385	5.811	no
	10	166.67	45.00	1417.50	0.413	86.82	32.72	2.653	1.60	10.913	187.469	10.913	73.468	1.000	1.595	2.797	no
	11	183.33	40.91	1171.49	0.342	86.47	27.05	3.197	1.60	10.913	187.469	10.913	60.717	1.000	1.595	3.342	no
	12	200.00	37.50	984.38	0.287	86.09	22.73	3.788	1.60	10.913	187.469	10.913	51.019	1.000	1.595	3.932	no
	13	216.67	34.62	838.76	0.245	85.65	19.36	4.423	1.60	10.913	187.469	10.913	43.472	1.000	1.595	4.568	no
	14	233.33	32.14	723.21	0.211	85.16	16.70	5.100	1.60	10.913	187.469	10.913	37.484	1.000	1.595	5.245	no
	15	250.00	30.00	630.00	0.184	84.61	14.54	5.817	1.60	10.913	187.469	10.913	32.652	1.000	1.595	5.962	no
	16	266.67	28.13	553.71	0.161	84.00	12.78	6.571	1.60	10.913	187.469	10.913	28.698	1.000	1.595	6.715	no
	17	283.33	26.47	490.48	0.143	83.31	11.32	7.358	1.60	10.913	187.469	10.913	25.421	1.000	1.595	7.502	no
	18	300.00	25.00	437.50	0.128	82.56	10.10	8.174	1.60	10.913	187.469	10.913	22.675	1.000	1.595	8.318	no
	19	316.67	23.68	392.66	0.115	81.71	9.07	9.014	1.60	10.913	187.469	10.913	20.351	1.000	1.595	9.159	no
	20	333.33	22.50	354.38	0.103	80.78	8.18	9.874	1.60	10.913	187.469	10.913	18.367	1.000	1.595	10.018	no
	21	350.00	21.43	321.43	0.094	79.75	7.42	10.747	1.60	10.913	187.469	10.913	16.659	1.000	1.595	10.891	no
	22	366.67	20.45	292.87	0.085	78.61	6.76	11.627	1.60	10.913	187.469	10.913	15.179	1.000	1.595	11.771	no
	23	383.33	19.57	267.96	0.078	77.36	6.19	12.506	1.60	10.913	187.469	10.913	13.888	1.000	1.595	12.650	no
	24	400.00	18.75	246.09	0.072	76.00	5.68	13.376	1.60	10.913	187.469	10.913	12.755	1.000	1.595	13.521	no
	25	416.67	18.00	226.80	0.066	74.51	5.24	14.231	1.60	10.913	187.469	10.913	11.755	1.000	1.595	14.375	no

Pipe 4 std.

Fy (ksi)	Q (ft^3/sec)	Diameter (in)	Z (in)	r (in)	I (in^4)	E (ksi)	Lp (ft.)	S (in.)	D/t
50	7500	4.5	4.05	1.51	6.82	29000	5.333624	3.03	20.4

L (ft)	A (ft^2)	V (ft/s)	P (psf)	w (k/ft)	Axial Load	Axial Capacity	Axial load/cap	Max Moment (k/ft)	Moment Cap (plastic hinge) (k-ft)	Moment Cap (Local Buckling) (k-ft)	Moment Capacity	Pe (k)	Moment Amp. Factor	Amplified Max. Moment (K-ft)	Interaction Formula	OK?
5	83.33	90.00	5670.00	2.126	87.96	115.54	0.761	2.05	15.188	217.759	15.188	541.675	1.194	2.448	0.920	yes
6	100.00	75.00	3937.50	1.477	87.80	104.30	0.842	2.05	15.188	217.759	15.188	376.164	1.304	2.675	1.016	no
7	116.67	64.29	2892.86	1.085	87.61	92.42	0.948	2.05	15.188	217.759	15.188	276.365	1.464	3.003	1.143	no
8	133.33	56.25	2214.84	0.831	87.38	80.38	1.087	2.05	15.188	217.759	15.188	211.592	1.703	3.493	1.314	no
9	150.00	50.00	1750.00	0.656	87.12	68.62	1.269	2.05	15.188	217.759	15.188	167.184	2.088	4.282	1.548	no
10	166.67	45.00	1417.50	0.532	86.82	57.51	1.510	2.05	15.188	217.759	15.188	135.419	2.786	5.714	1.881	no
11	183.33	40.91	1171.49	0.439	86.47	47.54	1.819	2.05	15.188	217.759	15.188	111.916	4.399	9.021	2.406	no
12	200.00	37.50	984.38	0.369	86.09	39.95	2.155	2.05	15.188	217.759	15.188	94.041	11.822	24.244	3.732	no
13	216.67	34.62	838.76	0.315	85.65	34.04	2.516	2.05	15.188	217.759	15.188	80.130	1.000	2.051	2.650	no
14	233.33	32.14	723.21	0.271	85.16	29.35	2.902	2.05	15.188	217.759	15.188	69.091	1.000	2.051	3.035	no
15	250.00	30.00	630.00	0.236	84.61	25.57	3.309	2.05	15.188	217.759	15.188	60.186	1.000	2.051	3.443	no
16	266.67	28.13	553.71	0.208	84.00	22.47	3.738	2.05	15.188	217.759	15.188	52.898	1.000	2.051	3.871	no
17	283.33	26.47	490.48	0.184	83.31	19.90	4.186	2.05	15.188	217.759	15.188	46.858	1.000	2.051	4.319	no
18	300.00	25.00	437.50	0.164	82.56	17.75	4.650	2.05	15.188	217.759	15.188	41.796	1.000	2.051	4.783	no
19	316.67	23.68	392.66	0.147	81.71	15.93	5.128	2.05	15.188	217.759	15.188	37.512	1.000	2.051	5.261	no
20	333.33	22.50	354.38	0.133	80.78	14.38	5.617	2.05	15.188	217.759	15.188	33.855	1.000	2.051	5.750	no
21	350.00	21.43	321.43	0.121	79.75	13.04	6.114	2.05	15.188	217.759	15.188	30.707	1.000	2.051	6.247	no
22	366.67	20.45	292.87	0.110	78.61	11.89	6.614	2.05	15.188	217.759	15.188	27.979	1.000	2.051	6.747	no
23	383.33	19.57	267.96	0.100	77.36	10.87	7.114	2.05	15.188	217.759	15.188	25.599	1.000	2.051	7.247	no
24	400.00	18.75	246.09	0.092	76.00	9.99	7.609	2.05	15.188	217.759	15.188	23.510	1.000	2.051	7.743	no
25	416.67	18.00	226.80	0.085	74.51	9.20	8.096	2.05	15.188	217.759	15.188	21.667	1.000	2.051	8.229	no

	Fy (ksi)	Q (ft^3/sec)	Diameter (in)	Z (in)	r (in)	I (in^4)	E (ksi)	Lp (ft.)	S (in.)	D/t
Pipe 5 Std.	50	7500	5.56	6.83	1.88	14.3	29000	6.640538	5.14	23.1

	L (ft)	A (ft^2)	V (ft/s)	P (psf)	w (k/ft)	Axial Load	Axial Capacity	Axial load/cap	Max Moment (k/ft)	Moment Cap (plastic hinge) (k-ft)	Moment Cap (Local Buckling) (k-ft)	Moment Capacity	Pe (k)	Moment Amp. Factor	Amplified Max. Moment (K-ft)	Interaction Formula	OK?
Pipe 5 Std.	5	83.33	90.00	5670.00	2.627	87.96	156.84	0.561	2.53	25.613	353.258	25.613	1135.771	1.084	2.747	0.667	yes
	6	100.00	75.00	3937.50	1.824	87.80	147.57	0.595	2.53	25.613	353.258	25.613	788.730	1.125	2.851	0.705	yes
	7	116.67	64.29	2892.86	1.340	87.61	137.32	0.638	2.53	25.613	353.258	25.613	579.475	1.178	2.985	0.753	yes
	8	133.33	56.25	2214.84	1.026	87.38	126.37	0.691	2.53	25.613	353.258	25.613	443.661	1.245	3.155	0.813	yes
	9	150.00	50.00	1750.00	0.811	87.12	115.01	0.757	2.53	25.613	353.258	25.613	350.547	1.331	3.372	0.888	yes
	10	166.67	45.00	1417.50	0.657	86.82	103.52	0.839	2.53	25.613	353.258	25.613	283.943	1.440	3.650	0.979	yes
	11	183.33	40.91	1171.49	0.543	86.47	92.15	0.938	2.53	25.613	353.258	25.613	234.663	1.584	4.012	1.093	no
	12	200.00	37.50	984.38	0.456	86.09	81.12	1.061	2.53	25.613	353.258	25.613	197.182	1.775	4.497	1.235	no
	13	216.67	34.62	838.76	0.389	85.65	70.63	1.213	2.53	25.613	353.258	25.613	168.013	2.040	5.169	1.412	no
	14	233.33	32.14	723.21	0.335	85.16	60.90	1.398	2.53	25.613	353.258	25.613	144.869	2.426	6.148	1.635	no
	15	250.00	30.00	630.00	0.292	84.61	53.05	1.595	2.53	25.613	353.258	25.613	126.197	3.035	7.689	1.891	no
	16	266.67	28.13	553.71	0.257	84.00	46.62	1.802	2.53	25.613	353.258	25.613	110.915	4.120	10.441	2.204	no
	17	283.33	26.47	490.48	0.227	83.31	41.30	2.017	2.53	25.613	353.258	25.613	98.250	6.578	16.669	2.660	no
	18	300.00	25.00	437.50	0.203	82.56	36.84	2.241	2.53	25.613	353.258	25.613	87.637	17.249	43.706	3.926	no
	19	316.67	23.68	392.66	0.182	81.71	33.06	2.471	2.53	25.613	353.258	25.613	78.655	1.000	2.534	2.569	no
	20	333.33	22.50	354.38	0.164	80.78	29.84	2.707	2.53	25.613	353.258	25.613	70.986	1.000	2.534	2.805	no
	21	350.00	21.43	321.43	0.149	79.75	27.07	2.946	2.53	25.613	353.258	25.613	64.386	1.000	2.534	3.044	no
	22	366.67	20.45	292.87	0.136	78.61	24.66	3.188	2.53	25.613	353.258	25.613	58.666	1.000	2.534	3.285	no
	23	383.33	19.57	267.96	0.124	77.36	22.56	3.429	2.53	25.613	353.258	25.613	53.675	1.000	2.534	3.526	no
	24	400.00	18.75	246.09	0.114	76.00	20.72	3.667	2.53	25.613	353.258	25.613	49.296	1.000	2.534	3.765	no
	25	416.67	18.00	226.80	0.105	74.51	19.10	3.902	2.53	25.613	353.258	25.613	45.431	1.000	2.534	3.999	no

	Fy (ksi)	Q (ft^3/sec)	Diameter (in)	Z (in)	r (in)	I (in^4)	E (ksi)	Lp (ft.)	S (in.)	D/t
Pipe 4 x-Strong	50	7500	4.5	5.53	1.48	9.12	29000	5.227658	4.05	14.3

L (ft)	A (ft^2)	V (ft/s)	P (psf)	w (k/ft)	Axial Load	Axial Capacity	Axial load/cap	Max Moment (k/ft)	Moment Cap (plastic hinge) (k-ft)	Moment Cap (Local Buckling) (k-ft)	Moment Capacity	Pe (k)	Moment Amp. Factor	Amplified Max. Moment (K-ft)	Interaction Formula	OK?
5	83.33	90.00	5670.00	2.126	87.96	123.20	0.714	2.05	20.738	337.481	20.738	724.352	1.138	2.334	0.825	yes
6	100.00	75.00	3937.50	1.477	87.80	114.40	0.767	2.05	20.738	337.481	20.738	503.022	1.211	2.484	0.886	yes
7	116.67	64.29	2892.86	1.085	87.61	104.81	0.836	2.05	20.738	337.481	20.738	369.567	1.311	2.688	0.964	yes
8	133.33	56.25	2214.84	0.831	87.38	94.73	0.922	2.05	20.738	337.481	20.738	282.950	1.447	2.967	1.064	no
9	150.00	50.00	1750.00	0.656	87.12	84.48	1.031	2.05	20.738	337.481	20.738	223.565	1.638	3.360	1.191	no
10	166.67	45.00	1417.50	0.532	86.82	74.33	1.168	2.05	20.738	337.481	20.738	181.088	1.921	3.939	1.356	no
11	183.33	40.91	1171.49	0.439	86.47	64.53	1.340	2.05	20.738	337.481	20.738	149.659	2.369	4.857	1.571	no
12	200.00	37.50	984.38	0.369	86.09	55.17	1.560	2.05	20.738	337.481	20.738	125.756	3.170	6.501	1.870	no
13	216.67	34.62	838.76	0.315	85.65	47.01	1.822	2.05	20.738	337.481	20.738	107.153	4.983	10.219	2.309	no
14	233.33	32.14	723.21	0.271	85.16	40.53	2.101	2.05	20.738	337.481	20.738	92.392	12.773	26.194	3.349	no
15	250.00	30.00	630.00	0.236	84.61	35.31	2.396	2.05	20.738	337.481	20.738	80.484	1.000	2.051	2.494	no
16	266.67	28.13	553.71	0.208	84.00	31.03	2.707	2.05	20.738	337.481	20.738	70.737	1.000	2.051	2.804	no
17	283.33	26.47	490.48	0.184	83.31	27.49	3.031	2.05	20.738	337.481	20.738	62.660	1.000	2.051	3.129	no
18	300.00	25.00	437.50	0.164	82.56	24.52	3.367	2.05	20.738	337.481	20.738	55.891	1.000	2.051	3.465	no
19	316.67	23.68	392.66	0.147	81.71	22.01	3.713	2.05	20.738	337.481	20.738	50.163	1.000	2.051	3.811	no
20	333.33	22.50	354.38	0.133	80.78	19.86	4.067	2.05	20.738	337.481	20.738	45.272	1.000	2.051	4.165	no
21	350.00	21.43	321.43	0.121	79.75	18.01	4.427	2.05	20.738	337.481	20.738	41.063	1.000	2.051	4.525	no
22	366.67	20.45	292.87	0.110	78.61	16.41	4.789	2.05	20.738	337.481	20.738	37.415	1.000	2.051	4.887	no
23	383.33	19.57	267.96	0.100	77.36	15.02	5.151	2.05	20.738	337.481	20.738	34.232	1.000	2.051	5.249	no
24	400.00	18.75	246.09	0.092	76.00	13.79	5.510	2.05	20.738	337.481	20.738	31.439	1.000	2.051	5.608	no
25	416.67	18.00	226.80	0.085	74.51	12.71	5.862	2.05	20.738	337.481	20.738	28.974	1.000	2.051	5.960	no

	Fy (ksi)	Q (ft^3/sec)	Diameter (in)	Z (in)	r (in)	I (in^4)	E (ksi)	Lp (ft.)	S (in.)	D/t
Pipe 6 Std.	50	7500	6.63	10.6	2.25	26.5	29000	7.947452	7.99	25.4

L (ft)	A (ft^2)	V (ft/s)	P (psf)	w (k/ft)	Axial Load	Axial Capacity	Axial load/cap	Max Moment (k/ft)	Moment Cap (plastic hinge) (k-ft)	Moment Cap (Local Buckling) (k-ft)	Moment Capacity	Pe (k)	Moment Amp. Factor	Amplified Max. Moment (K-ft)	Interaction Formula	OK?
5	83.33	90.00	5670.00	3.133	87.96	196.44	0.448	3.02	39.750	531.964	39.750	2104.751	1.044	3.153	0.526	yes
6	100.00	75.00	3937.50	2.175	87.80	188.86	0.465	3.02	39.750	531.964	39.750	1461.632	1.064	3.215	0.545	yes
7	116.67	64.29	2892.86	1.598	87.61	180.28	0.486	3.02	39.750	531.964	39.750	1073.852	1.089	3.290	0.568	yes
8	133.33	56.25	2214.84	1.224	87.38	170.87	0.511	3.02	39.750	531.964	39.750	822.168	1.119	3.381	0.595	yes
9	150.00	50.00	1750.00	0.967	87.12	160.79	0.542	3.02	39.750	531.964	39.750	649.614	1.155	3.489	0.629	yes
10	166.67	45.00	1417.50	0.783	86.82	150.23	0.578	3.02	39.750	531.964	39.750	526.188	1.198	3.619	0.668	yes
11	183.33	40.91	1171.49	0.647	86.47	139.36	0.621	3.02	39.750	531.964	39.750	434.866	1.248	3.771	0.714	yes
12	200.00	37.50	984.38	0.544	86.09	128.36	0.671	3.02	39.750	531.964	39.750	365.408	1.308	3.953	0.769	yes
13	216.67	34.62	838.76	0.463	85.65	117.38	0.730	3.02	39.750	531.964	39.750	311.354	1.379	4.168	0.833	yes
14	233.33	32.14	723.21	0.400	85.16	106.58	0.799	3.02	39.750	531.964	39.750	268.463	1.465	4.425	0.909	yes
15	250.00	30.00	630.00	0.348	84.61	96.08	0.881	3.02	39.750	531.964	39.750	233.861	1.567	4.734	0.998	yes
16	266.67	28.13	553.71	0.306	84.00	86.00	0.977	3.02	39.750	531.964	39.750	205.542	1.691	5.110	1.104	no
17	283.33	26.47	490.48	0.271	83.31	76.30	1.092	3.02	39.750	531.964	39.750	182.072	1.844	5.571	1.230	no
18	300.00	25.00	437.50	0.242	82.56	68.05	1.213	3.02	39.750	531.964	39.750	162.404	2.034	6.145	1.366	no
19	316.67	23.68	392.66	0.217	81.71	61.08	1.338	3.02	39.750	531.964	39.750	145.758	2.276	6.877	1.509	no
20	333.33	22.50	354.38	0.196	80.78	55.12	1.465	3.02	39.750	531.964	39.750	131.547	2.591	7.829	1.660	no
21	350.00	21.43	321.43	0.178	79.75	50.00	1.595	3.02	39.750	531.964	39.750	119.317	3.015	9.111	1.821	no
22	366.67	20.45	292.87	0.162	78.61	45.56	1.726	3.02	39.750	531.964	39.750	108.716	3.611	10.911	1.997	no
23	383.33	19.57	267.96	0.148	77.36	41.68	1.856	3.02	39.750	531.964	39.750	99.468	4.499	13.595	2.194	no
24	400.00	18.75	246.09	0.136	76.00	38.28	1.985	3.02	39.750	531.964	39.750	91.352	5.949	17.975	2.432	no
25	416.67	18.00	226.80	0.125	74.51	35.28	2.112	3.02	39.750	531.964	39.750	84.190	8.700	26.285	2.765	no

Pipe 8 std.

Fy (ksi)	Q (ft^3/sec)	Diameter (in)	Z (in)	r (in)	I (in^4)	E (ksi)	Lp (ft.)	S (in.)	D/t
50	7500	8.63	20.8	2.95	68.1	29000	10.41999	15.8	28.8

L (ft)	A (ft^2)	V (ft/s)	P (psf)	w (k/ft)	Axial Load	Axial Capacity	Axial load/cap	Max Moment (k/ft)	Moment Cap (plastic hinge) (k-ft)	Moment Cap (Local Buckling) (k-ft)	Moment Capacity	Pe (k)	Moment Amp. Factor	Amplified Max. Moment (K-ft)	Interaction Formula	OK?
5	83.33	90.00	5670.00	4.078	87.96	267.15	0.329	3.93	78.000	1011.694	78.000	5408.812	1.017	3.998	0.380	yes
6	100.00	75.00	3937.50	2.832	87.80	261.85	0.335	3.93	78.000	1011.694	78.000	3756.120	1.024	4.027	0.386	yes
7	116.67	64.29	2892.86	2.080	87.61	255.71	0.343	3.93	78.000	1011.694	78.000	2759.598	1.033	4.062	0.394	yes
8	133.33	56.25	2214.84	1.593	87.38	248.81	0.351	3.93	78.000	1011.694	78.000	2112.817	1.043	4.103	0.403	yes
9	150.00	50.00	1750.00	1.259	87.12	241.22	0.361	3.93	78.000	1011.694	78.000	1669.386	1.055	4.149	0.414	yes
10	166.67	45.00	1417.50	1.019	86.82	233.00	0.373	3.93	78.000	1011.694	78.000	1352.203	1.069	4.203	0.426	yes
11	183.33	40.91	1171.49	0.842	86.47	224.25	0.386	3.93	78.000	1011.694	78.000	1117.523	1.084	4.263	0.440	yes
12	200.00	37.50	984.38	0.708	86.09	215.04	0.400	3.93	78.000	1011.694	78.000	939.030	1.101	4.330	0.455	yes
13	216.67	34.62	838.76	0.603	85.65	205.46	0.417	3.93	78.000	1011.694	78.000	800.120	1.120	4.404	0.473	yes
14	233.33	32.14	723.21	0.520	85.16	195.58	0.435	3.93	78.000	1011.694	78.000	689.900	1.141	4.487	0.492	yes
15	250.00	30.00	630.00	0.453	84.61	185.51	0.456	3.93	78.000	1011.694	78.000	600.979	1.164	4.577	0.514	yes
16	266.67	28.13	553.71	0.398	84.00	175.31	0.479	3.93	78.000	1011.694	78.000	528.204	1.189	4.677	0.538	yes
17	283.33	26.47	490.48	0.353	83.31	165.08	0.505	3.93	78.000	1011.694	78.000	467.890	1.217	4.785	0.565	yes
18	300.00	25.00	437.50	0.315	82.56	154.87	0.533	3.93	78.000	1011.694	78.000	417.347	1.247	4.903	0.595	yes
19	316.67	23.68	392.66	0.282	81.71	144.76	0.564	3.93	78.000	1011.694	78.000	374.571	1.279	5.030	0.628	yes
20	333.33	22.50	354.38	0.255	80.78	134.83	0.599	3.93	78.000	1011.694	78.000	338.051	1.314	5.168	0.665	yes
21	350.00	21.43	321.43	0.231	79.75	125.11	0.637	3.93	78.000	1011.694	78.000	306.622	1.352	5.315	0.705	yes
22	366.67	20.45	292.87	0.211	78.61	115.68	0.680	3.93	78.000	1011.694	78.000	279.381	1.392	5.473	0.749	yes
23	383.33	19.57	267.96	0.193	77.36	106.40	0.727	3.93	78.000	1011.694	78.000	255.615	1.434	5.640	0.799	yes
24	400.00	18.75	246.09	0.177	76.00	97.72	0.778	3.93	78.000	1011.694	78.000	234.757	1.479	5.816	0.851	yes
25	416.67	18.00	226.80	0.163	74.51	90.06	0.827	3.93	78.000	1011.694	78.000	216.352	1.525	5.999	0.903	yes

	Fy (ksi)	Q (ft^3/sec)	Diameter (in)	Z (in)	r (in)	I (in^4)	E (ksi)	Lp (ft.)	S (in.)	D/t
Pipe 6 x-Strong	50	7500	6.63	15.6	2.2	38.3	29000	7.770842	11.6	16.4

L (ft)	A (ft^2)	V (ft/s)	P (psf)	w (k/ft)	Axial Load	Axial Capacity	Axial load/cap	Max Moment (k/ft)	Moment Cap (plastic hinge) (k-ft)	Moment Cap (Local Buckling) (k-ft)	Moment Capacity	Pe (k)	Moment Amp. Factor	Amplified Max. Moment (K-ft)	Interaction Formula	OK?
5	83.33	90.00	5670.00	3.133	87.96	202.34	0.435	3.02	58.500	909.680	58.500	3041.960	1.030	3.111	0.487	yes
6	100.00	75.00	3937.50	2.175	87.80	197.09	0.445	3.02	58.500	909.680	58.500	2112.473	1.043	3.153	0.499	yes
7	116.67	64.29	2892.86	1.598	87.61	191.05	0.459	3.02	58.500	909.680	58.500	1552.021	1.060	3.202	0.513	yes
8	133.33	56.25	2214.84	1.224	87.38	184.32	0.474	3.02	58.500	909.680	58.500	1188.266	1.079	3.261	0.529	yes
9	150.00	50.00	1750.00	0.967	87.12	176.97	0.492	3.02	58.500	909.680	58.500	938.877	1.102	3.331	0.549	yes
10	166.67	45.00	1417.50	0.783	86.82	169.11	0.513	3.02	58.500	909.680	58.500	760.490	1.129	3.411	0.571	yes
11	183.33	40.91	1171.49	0.647	86.47	160.82	0.538	3.02	58.500	909.680	58.500	628.504	1.160	3.504	0.597	yes
12	200.00	37.50	984.38	0.544	86.09	152.21	0.566	3.02	58.500	909.680	58.500	528.118	1.195	3.610	0.627	yes
13	216.67	34.62	838.76	0.463	85.65	143.38	0.597	3.02	58.500	909.680	58.500	449.994	1.235	3.732	0.660	yes
14	233.33	32.14	723.21	0.400	85.16	134.41	0.634	3.02	58.500	909.680	58.500	388.005	1.281	3.871	0.699	yes
15	250.00	30.00	630.00	0.348	84.61	125.40	0.675	3.02	58.500	909.680	58.500	337.996	1.334	4.030	0.743	yes
16	266.67	28.13	553.71	0.306	84.00	116.44	0.721	3.02	58.500	909.680	58.500	297.066	1.394	4.213	0.793	yes
17	283.33	26.47	490.48	0.271	83.31	107.60	0.774	3.02	58.500	909.680	58.500	263.145	1.463	4.421	0.849	yes
18	300.00	25.00	437.50	0.242	82.56	98.96	0.834	3.02	58.500	909.680	58.500	234.719	1.543	4.661	0.913	yes
19	316.67	23.68	392.66	0.217	81.71	90.57	0.902	3.02	58.500	909.680	58.500	210.662	1.634	4.936	0.986	yes
20	333.33	22.50	354.38	0.196	80.78	82.40	0.980	3.02	58.500	909.680	58.500	190.123	1.739	5.254	1.069	no
21	350.00	21.43	321.43	0.178	79.75	74.74	1.067	3.02	58.500	909.680	58.500	172.447	1.860	5.621	1.162	no
22	366.67	20.45	292.87	0.162	78.61	68.10	1.154	3.02	58.500	909.680	58.500	157.126	2.001	6.047	1.256	no
23	383.33	19.57	267.96	0.148	77.36	62.31	1.242	3.02	58.500	909.680	58.500	143.760	2.165	6.542	1.352	no
24	400.00	18.75	246.09	0.136	76.00	57.22	1.328	3.02	58.500	909.680	58.500	132.030	2.356	7.119	1.448	no
25	416.67	18.00	226.80	0.125	74.51	52.74	1.413	3.02	58.500	909.680	58.500	121.678	2.580	7.795	1.544	no

	Fy (ksi)	Q (ft^3/sec)	Diameter (in)	Z (in)	r (in)	I (in^4)	E (ksi)	Lp (ft.)	S (in.)	D/t							
Pipe 10 Std.	50	7500	10.8	36.9	3.68	151	29000	12.9985	28.1	31.6							
	L (ft)	A (ft^2)	V (ft/s)	P (psf)	w (k/ft)	Axial Load	Axial Capacity	Axial load/cap	Max Moment (k/ft)	Moment Cap (plastic hinge) (k-ft)	Moment Cap (Local Buckling) (k-ft)	Moment Capacity	Pe (k)	Moment Amp. Factor	Amplified Max. Moment (K-ft)	Interaction Formula	OK?
	5	83.33	90.00	5670.00	5.103	87.96	341.09	0.258	4.92	138.375	1751.893	138.375	11993.108	1.007	4.958	0.293	yes
	6	100.00	75.00	3937.50	3.544	87.80	337.28	0.260	4.92	138.375	1751.893	138.375	8328.547	1.011	4.974	0.296	yes
	7	116.67	64.29	2892.86	2.604	87.61	332.82	0.263	4.92	138.375	1751.893	138.375	6118.933	1.015	4.993	0.299	yes
	8	133.33	56.25	2214.84	1.993	87.38	327.76	0.267	4.92	138.375	1751.893	138.375	4684.808	1.019	5.015	0.302	yes
	9	150.00	50.00	1750.00	1.575	87.12	322.11	0.270	4.92	138.375	1751.893	138.375	3701.577	1.024	5.041	0.306	yes
	10	166.67	45.00	1417.50	1.276	86.82	315.92	0.275	4.92	138.375	1751.893	138.375	2998.277	1.030	5.069	0.311	yes
	11	183.33	40.91	1171.49	1.054	86.47	309.21	0.280	4.92	138.375	1751.893	138.375	2477.915	1.036	5.100	0.316	yes
	12	200.00	37.50	984.38	0.886	86.09	302.02	0.285	4.92	138.375	1751.893	138.375	2082.137	1.043	5.134	0.322	yes
	13	216.67	34.62	838.76	0.755	85.65	294.40	0.291	4.92	138.375	1751.893	138.375	1774.128	1.051	5.172	0.328	yes
	14	233.33	32.14	723.21	0.651	85.16	286.38	0.297	4.92	138.375	1751.893	138.375	1529.733	1.059	5.212	0.335	yes
	15	250.00	30.00	630.00	0.567	84.61	278.02	0.304	4.92	138.375	1751.893	138.375	1332.568	1.068	5.256	0.342	yes
	16	266.67	28.13	553.71	0.498	84.00	269.35	0.312	4.92	138.375	1751.893	138.375	1171.202	1.077	5.302	0.350	yes
	17	283.33	26.47	490.48	0.441	83.31	260.41	0.320	4.92	138.375	1751.893	138.375	1037.466	1.087	5.352	0.358	yes
	18	300.00	25.00	437.50	0.394	82.56	251.26	0.329	4.92	138.375	1751.893	138.375	925.394	1.098	5.404	0.367	yes
	19	316.67	23.68	392.66	0.353	81.71	241.93	0.338	4.92	138.375	1751.893	138.375	830.548	1.109	5.459	0.377	yes
	20	333.33	22.50	354.38	0.319	80.78	232.48	0.347	4.92	138.375	1751.893	138.375	749.569	1.121	5.516	0.387	yes
	21	350.00	21.43	321.43	0.289	79.75	222.93	0.358	4.92	138.375	1751.893	138.375	679.881	1.133	5.576	0.398	yes
	22	366.67	20.45	292.87	0.264	78.61	213.34	0.368	4.92	138.375	1751.893	138.375	619.479	1.145	5.637	0.409	yes
	23	383.33	19.57	267.96	0.241	77.36	203.75	0.380	4.92	138.375	1751.893	138.375	566.782	1.158	5.700	0.420	yes
	24	400.00	18.75	246.09	0.221	76.00	194.19	0.391	4.92	138.375	1751.893	138.375	520.534	1.171	5.763	0.432	yes
	25	416.67	18.00	226.80	0.204	74.51	184.71	0.403	4.92	138.375	1751.893	138.375	479.724	1.184	5.827	0.445	yes

Pipe 8 x-Strong	Fy (ksi)	Q (ft^3/sec)	Diameter (in)	Z (in)	r (in)	I (in^4)	E (ksi)	Lp (ft.)	S (in.)	D/t									
	50	7500	8.63	31	2.89	100	29000	10.20806	23.1	18.5									
	L (ft)	A (ft^2)	V (ft/s)	P (psf)	w (k/ft)	Axial Load	Axial Capacity	Axial load/cap	Max Moment (k/ft)	Moment Cap (plastic hinge) (k-ft)	Moment Cap (Local Buckling) (k-ft)	Moment Capacity	Pe (k)	Moment Amp. Factor	Amplified Max. Moment (K-ft)	Interaction Formula	OK?		
	5	83.33	90.00	5670.00	4.078	87.96	271.27	0.324	3.93	116.250	1723.884	116.250	7942.456	1.011	3.977	0.358	yes		
	6	100.00	75.00	3937.50	2.832	87.80	267.68	0.328	3.93	116.250	1723.884	116.250	5515.594	1.016	3.997	0.362	yes		
	7	116.67	64.29	2892.86	2.080	87.61	263.50	0.332	3.93	116.250	1723.884	116.250	4052.273	1.022	4.020	0.367	yes		
	8	133.33	56.25	2214.84	1.593	87.38	258.76	0.338	3.93	116.250	1723.884	116.250	3102.522	1.029	4.047	0.372	yes		
	9	150.00	50.00	1750.00	1.259	87.12	253.49	0.344	3.93	116.250	1723.884	116.250	2451.375	1.037	4.078	0.378	yes		
	10	166.67	45.00	1417.50	1.019	86.82	247.72	0.350	3.93	116.250	1723.884	116.250	1985.614	1.046	4.113	0.385	yes		
	11	183.33	40.91	1171.49	0.842	86.47	241.50	0.358	3.93	116.250	1723.884	116.250	1641.003	1.056	4.152	0.393	yes		
	12	200.00	37.50	984.38	0.708	86.09	234.87	0.367	3.93	116.250	1723.884	116.250	1378.899	1.067	4.195	0.402	yes		
	13	216.67	34.62	838.76	0.603	85.65	227.87	0.376	3.93	116.250	1723.884	116.250	1174.919	1.079	4.242	0.412	yes		
	14	233.33	32.14	723.21	0.520	85.16	220.54	0.386	3.93	116.250	1723.884	116.250	1013.068	1.092	4.294	0.423	yes		
	15	250.00	30.00	630.00	0.453	84.61	212.93	0.397	3.93	116.250	1723.884	116.250	882.495	1.106	4.350	0.434	yes		
	16	266.67	28.13	553.71	0.398	84.00	205.08	0.410	3.93	116.250	1723.884	116.250	775.630	1.121	4.411	0.447	yes		
	17	283.33	26.47	490.48	0.353	83.31	197.05	0.423	3.93	116.250	1723.884	116.250	687.064	1.138	4.476	0.461	yes		
	18	300.00	25.00	437.50	0.315	82.56	188.87	0.437	3.93	116.250	1723.884	116.250	612.844	1.156	4.545	0.476	yes		
	19	316.67	23.68	392.66	0.282	81.71	180.59	0.452	3.93	116.250	1723.884	116.250	550.032	1.174	4.619	0.492	yes		
	20	333.33	22.50	354.38	0.255	80.78	172.26	0.469	3.93	116.250	1723.884	116.250	496.403	1.194	4.697	0.509	yes		
	21	350.00	21.43	321.43	0.231	79.75	163.92	0.487	3.93	116.250	1723.884	116.250	450.253	1.215	4.779	0.527	yes		
	22	366.67	20.45	292.87	0.211	78.61	155.60	0.505	3.93	116.250	1723.884	116.250	410.251	1.237	4.865	0.547	yes		
	23	383.33	19.57	267.96	0.193	77.36	147.35	0.525	3.93	116.250	1723.884	116.250	375.352	1.260	4.954	0.567	yes		
	24	400.00	18.75	246.09	0.177	76.00	139.20	0.546	3.93	116.250	1723.884	116.250	344.725	1.283	5.045	0.589	yes		
	25	416.67	18.00	226.80	0.163	74.51	131.18	0.568	3.93	116.250	1723.884	116.250	317.698	1.306	5.138	0.612	yes		

	Fy (ksi)	Q (ft^3/sec)	Diameter (in)	Z (in)	r (in)	I (in^4)	E (ksi)	Lp (ft.)	S (in.)	D/t
Pipe 12 Std.	50	7500	12.8	53.7	4.39	262	29000	15.50636	41	36.5

	L (ft)	A (ft^2)	V (ft/s)	P (psf)	w (k/ft)	Axial Load	Axial Capacity	Axial load/cap	Max Moment (k/ft)	Moment Cap (plastic hinge) (k-ft)	Moment Cap (Local Buckling) (k-ft)	Moment Capacity	Pe (k)	Moment Amp. Factor	Amplified Max. Moment (K-ft)	Interaction Formula	OK?
Pipe 12 Std.	5	83.33	90.00	5670.00	6.048	87.96	407.48	0.216	5.83	201.375	2460.674	201.375	20809.234	1.004	5.858	0.245	yes
	6	100.00	75.00	3937.50	4.200	87.80	404.33	0.217	5.83	201.375	2460.674	201.375	14450.857	1.006	5.869	0.246	yes
	7	116.67	64.29	2892.86	3.086	87.61	400.65	0.219	5.83	201.375	2460.674	201.375	10616.956	1.008	5.882	0.248	yes
	8	133.33	56.25	2214.84	2.363	87.38	396.44	0.220	5.83	201.375	2460.674	201.375	8128.607	1.011	5.897	0.249	yes
	9	150.00	50.00	1750.00	1.867	87.12	391.72	0.222	5.83	201.375	2460.674	201.375	6422.603	1.014	5.914	0.251	yes
	10	166.67	45.00	1417.50	1.512	86.82	386.51	0.225	5.83	201.375	2460.674	201.375	5202.308	1.017	5.932	0.254	yes
	11	183.33	40.91	1171.49	1.250	86.47	380.83	0.227	5.83	201.375	2460.674	201.375	4299.428	1.021	5.953	0.256	yes
	12	200.00	37.50	984.38	1.050	86.09	374.71	0.230	5.83	201.375	2460.674	201.375	3612.714	1.024	5.976	0.259	yes
	13	216.67	34.62	838.76	0.895	85.65	368.17	0.233	5.83	201.375	2460.674	201.375	3078.289	1.029	6.000	0.262	yes
	14	233.33	32.14	723.21	0.771	85.16	361.23	0.236	5.83	201.375	2460.674	201.375	2654.239	1.033	6.027	0.265	yes
	15	250.00	30.00	630.00	0.672	84.61	353.92	0.239	5.83	201.375	2460.674	201.375	2312.137	1.038	6.055	0.269	yes
	16	266.67	28.13	553.71	0.591	84.00	346.28	0.243	5.83	201.375	2460.674	201.375	2032.152	1.043	6.085	0.272	yes
	17	283.33	26.47	490.48	0.523	83.31	338.32	0.246	5.83	201.375	2460.674	201.375	1800.107	1.049	6.116	0.276	yes
	18	300.00	25.00	437.50	0.467	82.56	330.08	0.250	5.83	201.375	2460.674	201.375	1605.651	1.054	6.150	0.280	yes
	19	316.67	23.68	392.66	0.419	81.71	321.59	0.254	5.83	201.375	2460.674	201.375	1441.083	1.060	6.184	0.284	yes
	20	333.33	22.50	354.38	0.378	80.78	312.87	0.258	5.83	201.375	2460.674	201.375	1300.577	1.066	6.220	0.289	yes
	21	350.00	21.43	321.43	0.343	79.75	303.96	0.262	5.83	201.375	2460.674	201.375	1179.662	1.073	6.256	0.293	yes
	22	366.67	20.45	292.87	0.312	78.61	294.89	0.267	5.83	201.375	2460.674	201.375	1074.857	1.079	6.294	0.297	yes
	23	383.33	19.57	267.96	0.286	77.36	285.69	0.271	5.83	201.375	2460.674	201.375	983.423	1.085	6.331	0.302	yes
	24	400.00	18.75	246.09	0.263	76.00	276.38	0.275	5.83	201.375	2460.674	201.375	903.179	1.092	6.369	0.306	yes
	25	416.67	18.00	226.80	0.242	74.51	267.01	0.279	5.83	201.375	2460.674	201.375	832.369	1.098	6.407	0.310	yes

	Fy (ksi)	Q (ft^3/sec)	Diameter (in)	Z (in)	r (in)	E (ksi)	Lp (ft.)	S (in.)	D/t	I (in. ^4)	y (in.)	t (in.)
D=7 5/8 t=0.450	50	7500	7.625	12.325	2.167	29000	7.65	9.395	16.944	35.819	3.8125	0.450

	L (ft)	A (ft^2)	V (ft/s)	P (psf)	w (k/ft)	Axial Load	Axial Capacity	Axial load/cap	Max Moment (k/ft)	Moment Cap (plastic hinge) (k-ft)	Moment Cap (Local Buckling) (k-ft)	Moment Capacity	Pe (k)	Moment Amp. Factor	Amplified Max. Moment (K-ft)	Interaction Formula	OK?
	5	83.33	90.00	5670.00	3.603	87.96	237.24	0.371	3.47	46.218	726.694	46.218	2844.942	1.032	3.586	0.447	yes
	6	100.00	75.00	3937.50	2.502	87.80	233.05	0.377	3.47	46.218	726.694	46.218	1975.654	1.047	3.637	0.454	yes
	7	116.67	64.29	2892.86	1.838	87.61	228.19	0.384	3.47	46.218	726.694	46.218	1451.501	1.064	3.698	0.463	yes
	8	133.33	56.25	2214.84	1.407	87.38	222.71	0.392	3.47	46.218	726.694	46.218	1111.306	1.085	3.771	0.473	yes
	9	150.00	50.00	1750.00	1.112	87.12	216.66	0.402	3.47	46.218	726.694	46.218	878.069	1.110	3.858	0.485	yes
	10	166.67	45.00	1417.50	0.901	86.82	210.09	0.413	3.47	46.218	726.694	46.218	711.236	1.139	3.958	0.498	yes
	11	183.33	40.91	1171.49	0.744	86.47	203.06	0.426	3.47	46.218	726.694	46.218	587.798	1.172	4.074	0.513	yes
	12	200.00	37.50	984.38	0.625	86.09	195.63	0.440	3.47	46.218	726.694	46.218	493.914	1.211	4.208	0.530	yes
	13	216.67	34.62	838.76	0.533	85.65	187.86	0.456	3.47	46.218	726.694	46.218	420.849	1.256	4.363	0.549	yes
	14	233.33	32.14	723.21	0.460	85.16	179.82	0.474	3.47	46.218	726.694	46.218	362.875	1.307	4.540	0.571	yes
	15	250.00	30.00	630.00	0.400	84.61	171.57	0.493	3.47	46.218	726.694	46.218	316.105	1.365	4.745	0.595	yes
	16	266.67	28.13	553.71	0.352	84.00	163.16	0.515	3.47	46.218	726.694	46.218	277.826	1.433	4.981	0.621	yes
	17	283.33	26.47	490.48	0.312	83.31	154.66	0.539	3.47	46.218	726.694	46.218	246.102	1.512	5.253	0.651	yes
	18	300.00	25.00	437.50	0.278	82.56	146.14	0.565	3.47	46.218	726.694	46.218	219.517	1.603	5.570	0.684	yes
	19	316.67	23.68	392.66	0.250	81.71	137.63	0.594	3.47	46.218	726.694	46.218	197.018	1.709	5.938	0.721	yes
	20	333.33	22.50	354.38	0.225	80.78	129.20	0.625	3.47	46.218	726.694	46.218	177.809	1.833	6.368	0.761	yes
	21	350.00	21.43	321.43	0.204	79.75	120.90	0.660	3.47	46.218	726.694	46.218	161.278	1.978	6.874	0.807	yes
	22	366.67	20.45	292.87	0.186	78.61	112.76	0.697	3.47	46.218	726.694	46.218	146.949	2.150	7.472	0.857	yes
	23	383.33	19.57	267.96	0.170	77.36	104.83	0.738	3.47	46.218	726.694	46.218	134.449	2.355	8.184	0.913	yes
	24	400.00	18.75	246.09	0.156	76.00	97.14	0.782	3.47	46.218	726.694	46.218	123.478	2.601	9.037	0.975	yes
	25	416.67	18.00	226.80	0.144	74.51	89.53	0.832	3.47	46.218	726.694	46.218	113.798	2.897	10.066	1.047	no

	Fy (ksi)	Q (ft^3/sec)	Diameter (in)	Z (in)	r (in)	E (ksi)	Lp (ft.)	S (in.)	D/t	I (in. ^4)	y (in.)	t (in.)
D=7 5/8 t=0.500	50	7500	7.625	13.603	2.273	29000	8.03	10.336	15.250	39.406	3.8125	0.500

L (ft)	A (ft^2)	V (ft/s)	P (psf)	w (k/ft)	Axial Load	Axial Capacity	Axial load/cap	Max Moment (k/ft)	Moment Cap (plastic hinge) (k-ft)	Moment Cap (Local Buckling) (k-ft)	Moment Capacity	Pe (k)	Moment Amp. Factor	Amplified Max. Moment (K-ft)	Interaction Formula	OK?
5	83.33	90.00	5670.00	3.603	87.96	238.12	0.369	3.47	51.011	836.610	51.011	3129.820	1.029	3.575	0.439	yes
6	100.00	75.00	3937.50	2.502	87.80	234.29	0.375	3.47	51.011	836.610	51.011	2173.486	1.042	3.621	0.445	yes
7	116.67	64.29	2892.86	1.838	87.61	229.85	0.381	3.47	51.011	836.610	51.011	1596.847	1.058	3.677	0.452	yes
8	133.33	56.25	2214.84	1.407	87.38	224.82	0.389	3.47	51.011	836.610	51.011	1222.586	1.077	3.742	0.461	yes
9	150.00	50.00	1750.00	1.112	87.12	219.26	0.397	3.47	51.011	836.610	51.011	965.994	1.099	3.819	0.471	yes
10	166.67	45.00	1417.50	0.901	86.82	213.21	0.407	3.47	51.011	836.610	51.011	782.455	1.125	3.909	0.483	yes
11	183.33	40.91	1171.49	0.744	86.47	206.72	0.418	3.47	51.011	836.610	51.011	646.657	1.154	4.011	0.496	yes
12	200.00	37.50	984.38	0.625	86.09	199.83	0.431	3.47	51.011	836.610	51.011	543.371	1.188	4.129	0.511	yes
13	216.67	34.62	838.76	0.533	85.65	192.61	0.445	3.47	51.011	836.610	51.011	462.991	1.227	4.264	0.527	yes
14	233.33	32.14	723.21	0.460	85.16	185.10	0.460	3.47	51.011	836.610	51.011	399.212	1.271	4.417	0.546	yes
15	250.00	30.00	630.00	0.400	84.61	177.36	0.477	3.47	51.011	836.610	51.011	347.758	1.322	4.592	0.566	yes
16	266.67	28.13	553.71	0.352	84.00	169.44	0.496	3.47	51.011	836.610	51.011	305.646	1.379	4.792	0.589	yes
17	283.33	26.47	490.48	0.312	83.31	161.40	0.516	3.47	51.011	836.610	51.011	270.746	1.445	5.020	0.613	yes
18	300.00	25.00	437.50	0.278	82.56	153.29	0.539	3.47	51.011	836.610	51.011	241.498	1.519	5.280	0.641	yes
19	316.67	23.68	392.66	0.250	81.71	145.16	0.563	3.47	51.011	836.610	51.011	216.747	1.605	5.578	0.671	yes
20	333.33	22.50	354.38	0.225	80.78	137.05	0.589	3.47	51.011	836.610	51.011	195.614	1.703	5.919	0.704	yes
21	350.00	21.43	321.43	0.204	79.75	129.02	0.618	3.47	51.011	836.610	51.011	177.427	1.816	6.312	0.740	yes
22	366.67	20.45	292.87	0.186	78.61	121.10	0.649	3.47	51.011	836.610	51.011	161.664	1.946	6.764	0.780	yes
23	383.33	19.57	267.96	0.170	77.36	113.34	0.683	3.47	51.011	836.610	51.011	147.912	2.097	7.285	0.824	yes
24	400.00	18.75	246.09	0.156	76.00	105.75	0.719	3.47	51.011	836.610	51.011	135.843	2.270	7.888	0.871	yes
25	416.67	18.00	226.80	0.144	74.51	98.39	0.757	3.47	51.011	836.610	51.011	125.193	2.470	8.584	0.924	yes

	Fy (ksi)	Q (ft^3/sec)	Diameter (in)	Z (in)	r (in)	E (ksi)	Lp (ft.)	S (in.)	D/t	I (in. ^4)	y (in.)	t (in.)
D=9 t=0.450	50	7500	9	17.329	2.576	29000	9.099	13.269	20.000	59.710	4.5	0.450

L (ft)	A (ft^2)	V (ft/s)	P (psf)	w (k/ft)	Axial Load	Axial Capacity	Axial load/cap	Max Moment (k/ft)	Moment Cap (plastic hinge) (k-ft)	Moment Cap (Local Buckling) (k-ft)	Moment Capacity	Pe (k)	Moment Amp. Factor	Amplified Max. Moment (K-ft)	Interaction Formula	OK?
5	83.33	90.00	5670.00	4.253	87.96	283.35	0.310	4.10	64.9835	960.7339	64.9835	4742.440	1.019	4.179	0.374	yes
6	100.00	75.00	3937.50	2.953	87.80	279.80	0.314	4.10	64.9835	960.7339	64.9835	3293.361	1.027	4.214	0.378	yes
7	116.67	64.29	2892.86	2.170	87.61	275.66	0.318	4.10	64.9835	960.7339	64.9835	2419.612	1.038	4.256	0.382	yes
8	133.33	56.25	2214.84	1.661	87.38	270.95	0.322	4.10	64.9835	960.7339	64.9835	1852.516	1.050	4.305	0.388	yes
9	150.00	50.00	1750.00	1.313	87.12	265.72	0.328	4.10	64.9835	960.7339	64.9835	1463.716	1.063	4.361	0.394	yes
10	166.67	45.00	1417.50	1.063	86.82	259.99	0.334	4.10	64.9835	960.7339	64.9835	1185.610	1.079	4.426	0.401	yes
11	183.33	40.91	1171.49	0.879	86.47	253.80	0.341	4.10	64.9835	960.7339	64.9835	979.843	1.097	4.499	0.409	yes
12	200.00	37.50	984.38	0.738	86.09	247.19	0.348	4.10	64.9835	960.7339	64.9835	823.340	1.117	4.580	0.418	yes
13	216.67	34.62	838.76	0.629	85.65	240.20	0.357	4.10	64.9835	960.7339	64.9835	701.544	1.139	4.672	0.428	yes
14	233.33	32.14	723.21	0.542	85.16	232.87	0.366	4.10	64.9835	960.7339	64.9835	604.903	1.164	4.774	0.438	yes
15	250.00	30.00	630.00	0.473	84.61	225.25	0.376	4.10	64.9835	960.7339	64.9835	526.938	1.191	4.886	0.450	yes
16	266.67	28.13	553.71	0.415	84.00	217.38	0.386	4.10	64.9835	960.7339	64.9835	463.129	1.222	5.010	0.463	yes
17	283.33	26.47	490.48	0.368	83.31	209.30	0.398	4.10	64.9835	960.7339	64.9835	410.246	1.255	5.147	0.476	yes
18	300.00	25.00	437.50	0.328	82.56	201.06	0.411	4.10	64.9835	960.7339	64.9835	365.929	1.291	5.296	0.491	yes
19	316.67	23.68	392.66	0.294	81.71	192.70	0.424	4.10	64.9835	960.7339	64.9835	328.424	1.331	5.460	0.507	yes
20	333.33	22.50	354.38	0.266	80.78	184.27	0.438	4.10	64.9835	960.7339	64.9835	296.403	1.375	5.638	0.524	yes
21	350.00	21.43	321.43	0.241	79.75	175.80	0.454	4.10	64.9835	960.7339	64.9835	268.846	1.422	5.831	0.542	yes
22	366.67	20.45	292.87	0.220	78.61	167.34	0.470	4.10	64.9835	960.7339	64.9835	244.961	1.473	6.040	0.562	yes
23	383.33	19.57	267.96	0.201	77.36	158.92	0.487	4.10	64.9835	960.7339	64.9835	224.123	1.527	6.264	0.582	yes
24	400.00	18.75	246.09	0.185	76.00	150.57	0.505	4.10	64.9835	960.7339	64.9835	205.835	1.585	6.502	0.604	yes
25	416.67	18.00	226.80	0.170	74.51	142.34	0.523	4.10	64.9835	960.7339	64.9835	189.698	1.647	6.755	0.626	yes

	Fy (ksi)	Q (ft^3/sec)	Diameter (in)	Z (in)	r (in^4)	E (ksi)	Lp (ft.)	S (in.)	D/t	I (in. ^4)	y (in.)	t (in.)						
D=9 t=0.500	50	7500	9	19.146	2.704	29000	9.551	14.620	18.000	65.790	4.5	0.500						
	L (ft)	A (ft^2)	V (ft/s)	P (psf)	w (k/ft)	Axial Load	Axial Capacity	Axial load/cap	Max Moment (k/ft)	Moment Cap (plastic hinge) (k-ft)	Moment Cap (Local Buckling) (k-ft)	Moment Capacity	Pe (k)	Moment Amp. Factor	Amplified Max. Moment (K-ft)	Interaction Formula	OK?
	5	83.33	90.00	5670.00	4.253	87.96	284.13	0.310	4.10	71.797	1103.079	71.797	5225.342	1.017	4.172	0.367	yes
	6	100.00	75.00	3937.50	2.953	87.80	280.90	0.313	4.10	71.797	1103.079	71.797	3628.709	1.025	4.203	0.370	yes
	7	116.67	64.29	2892.86	2.170	87.61	277.14	0.316	4.10	71.797	1103.079	71.797	2665.991	1.034	4.241	0.374	yes
	8	133.33	56.25	2214.84	1.661	87.38	272.86	0.320	4.10	71.797	1103.079	71.797	2041.149	1.045	4.285	0.379	yes
	9	150.00	50.00	1750.00	1.313	87.12	268.08	0.325	4.10	71.797	1103.079	71.797	1612.760	1.057	4.336	0.385	yes
	10	166.67	45.00	1417.50	1.063	86.82	262.85	0.330	4.10	71.797	1103.079	71.797	1306.335	1.071	4.394	0.391	yes
	11	183.33	40.91	1171.49	0.879	86.47	257.18	0.336	4.10	71.797	1103.079	71.797	1079.616	1.087	4.459	0.398	yes
	12	200.00	37.50	984.38	0.738	86.09	251.11	0.343	4.10	71.797	1103.079	71.797	907.177	1.105	4.532	0.405	yes
	13	216.67	34.62	838.76	0.629	85.65	244.68	0.350	4.10	71.797	1103.079	71.797	772.980	1.125	4.613	0.413	yes
	14	233.33	32.14	723.21	0.542	85.16	237.92	0.358	4.10	71.797	1103.079	71.797	666.498	1.146	4.702	0.423	yes
	15	250.00	30.00	630.00	0.473	84.61	230.86	0.366	4.10	71.797	1103.079	71.797	580.594	1.171	4.801	0.433	yes
	16	266.67	28.13	553.71	0.415	84.00	223.55	0.376	4.10	71.797	1103.079	71.797	510.287	1.197	4.910	0.443	yes
	17	283.33	26.47	490.48	0.368	83.31	216.02	0.386	4.10	71.797	1103.079	71.797	452.019	1.226	5.028	0.455	yes
	18	300.00	25.00	437.50	0.328	82.56	208.31	0.396	4.10	71.797	1103.079	71.797	403.190	1.257	5.158	0.467	yes
	19	316.67	23.68	392.66	0.294	81.71	200.46	0.408	4.10	71.797	1103.079	71.797	361.866	1.292	5.298	0.481	yes
	20	333.33	22.50	354.38	0.266	80.78	192.51	0.420	4.10	71.797	1103.079	71.797	326.584	1.329	5.449	0.495	yes
	21	350.00	21.43	321.43	0.241	79.75	184.49	0.432	4.10	71.797	1103.079	71.797	296.221	1.368	5.613	0.509	yes
	22	366.67	20.45	292.87	0.220	78.61	176.43	0.446	4.10	71.797	1103.079	71.797	269.904	1.411	5.787	0.525	yes
	23	383.33	19.57	267.96	0.201	77.36	168.38	0.459	4.10	71.797	1103.079	71.797	246.944	1.456	5.973	0.542	yes
	24	400.00	18.75	246.09	0.185	76.00	160.36	0.474	4.10	71.797	1103.079	71.797	226.794	1.504	6.169	0.559	yes
	25	416.67	18.00	226.80	0.170	74.51	152.41	0.489	4.10	71.797	1103.079	71.797	209.014	1.554	6.374	0.577	yes

	Fy (ksi)	Q (ft^3/sec)	HP Depth (in)	Zy (in)	r (in)	Sy (in.)	I (in^4)	E (ksi)	λ	λpf	λrf
HP8X36	50	7500	8.02	15.2	1.95	9.88	40.3	29000	18.32	9.15161188	24.08318916

	L (ft)	A (ft^2)	V (ft/s)	P (psf)	w (k/ft)	Axial Load	Axial Capacity	Axial load/cap	Max Moment (k/ft)	Moment Cap (plastic hinge) (k-ft)	Moment Cap (Flange Local Buckling) (k-ft)	Moment Capacity	Pe (k)	Moment Amp. Factor	Amplified Max. Moment (K-ft)	Interaction Formula	OK?
HP8X36	5	83.33	90.00	11340.00	7.579	87.96	326.73	0.269	7.31	57.000	17.758	17.758	3200.810	1.028	7.516	0.687	yes
	6	100.00	75.00	7875.00	5.263	87.80	319.63	0.275	7.31	57.000	17.758	17.758	2222.784	1.041	7.611	0.698	yes
	7	116.67	64.29	5785.71	3.867	87.61	311.45	0.281	7.31	57.000	17.758	17.758	1633.066	1.057	7.724	0.711	yes
	8	133.33	56.25	4429.69	2.961	87.38	302.26	0.289	7.31	57.000	17.758	17.758	1250.316	1.075	7.859	0.726	yes
	9	150.00	50.00	3500.00	2.339	87.12	292.18	0.298	7.31	57.000	17.758	17.758	987.904	1.097	8.017	0.744	yes
	10	166.67	45.00	2835.00	1.895	86.82	281.31	0.309	7.31	57.000	17.758	17.758	800.202	1.122	8.199	0.765	yes
	11	183.33	40.91	2342.98	1.566	86.47	269.76	0.321	7.31	57.000	17.758	17.758	661.324	1.150	8.410	0.788	yes
	12	200.00	37.50	1968.75	1.316	86.09	257.66	0.334	7.31	57.000	17.758	17.758	555.696	1.183	8.650	0.815	yes
	13	216.67	34.62	1677.51	1.121	85.65	245.12	0.349	7.31	57.000	17.758	17.758	473.493	1.221	8.924	0.846	yes
	14	233.33	32.14	1446.43	0.967	85.16	232.26	0.367	7.31	57.000	17.758	17.758	408.267	1.264	9.236	0.880	yes
	15	250.00	30.00	1260.00	0.842	84.61	219.20	0.386	7.31	57.000	17.758	17.758	355.646	1.312	9.592	0.919	yes
	16	266.67	28.13	1107.42	0.740	84.00	206.05	0.408	7.31	57.000	17.758	17.758	312.579	1.367	9.996	0.964	yes
	17	283.33	26.47	980.97	0.656	83.31	192.92	0.432	7.31	57.000	17.758	17.758	276.887	1.430	10.456	1.013	no
	18	300.00	25.00	875.00	0.585	82.56	179.90	0.459	7.31	57.000	17.758	17.758	246.976	1.502	10.980	1.070	no
	19	316.67	23.68	785.32	0.525	81.71	167.10	0.489	7.31	57.000	17.758	17.758	221.663	1.584	11.578	1.133	no
	20	333.33	22.50	708.75	0.474	80.78	154.59	0.523	7.31	57.000	17.758	17.758	200.051	1.677	12.261	1.204	no
	21	350.00	21.43	642.86	0.430	79.75	142.44	0.560	7.31	57.000	17.758	17.758	181.452	1.784	13.042	1.285	no
	22	366.67	20.45	585.74	0.391	78.61	130.52	0.602	7.31	57.000	17.758	17.758	165.331	1.906	13.936	1.377	no
	23	383.33	19.57	535.92	0.358	77.36	119.41	0.648	7.31	57.000	17.758	17.758	151.267	2.047	14.962	1.480	no
	24	400.00	18.75	492.19	0.329	76.00	109.67	0.693	7.31	57.000	17.758	17.758	138.924	2.208	16.138	1.590	no
	25	416.67	18.00	453.60	0.303	74.51	101.07	0.737	7.31	57.000	17.758	17.758	128.032	2.392	17.487	1.710	no

Fy (ksi)	Q (ft^3/sec)	HP Depth (in)	Zy (in)	r (in)	Sy (in.)	I (in^4)	E (ksi)	λ	λpf	λrf
50	7500	9.7	21.8	2.41	14.2	71.7	29000	24	9.15161188	24.08318916

	L (ft)	A (ft^2)	V (ft/s)	P (psf)	w (k/ft)	Axial Load	Axial Capacity	Axial load/cap	Max Moment (k/ft)	Moment Cap (plastic hinge) (k-ft)	Moment Cap (Flange Local Buckling) (k-ft)	Moment Capacity	Pe (k)	Moment Amp. Factor	Amplified Max. Moment (K-ft)	Interaction Formula	OK?
HP10X42	5	83.33	90.00	11340.00	9.167	87.96	388.85	0.226	8.84	81.750	37.105	37.105	5694.741	1.016	8.980	0.465	yes
	6	100.00	75.00	7875.00	6.366	87.80	383.30	0.229	8.84	81.750	37.105	37.105	3954.681	1.023	9.042	0.470	yes
	7	116.67	64.29	5785.71	4.677	87.61	376.85	0.232	8.84	81.750	37.105	37.105	2905.480	1.031	9.116	0.475	yes
	8	133.33	56.25	4429.69	3.581	87.38	369.53	0.236	8.84	81.750	37.105	37.105	2224.508	1.041	9.203	0.481	yes
	9	150.00	50.00	3500.00	2.829	87.12	361.41	0.241	8.84	81.750	37.105	37.105	1757.636	1.052	9.302	0.489	yes
	10	166.67	45.00	2835.00	2.292	86.82	352.55	0.246	8.84	81.750	37.105	37.105	1423.685	1.065	9.415	0.497	yes
	11	183.33	40.91	2342.98	1.894	86.47	343.01	0.252	8.84	81.750	37.105	37.105	1176.599	1.079	9.542	0.506	yes
	12	200.00	37.50	1968.75	1.591	86.09	332.86	0.259	8.84	81.750	37.105	37.105	988.670	1.095	9.684	0.516	yes
	13	216.67	34.62	1677.51	1.356	85.65	322.16	0.266	8.84	81.750	37.105	37.105	842.417	1.113	9.842	0.528	yes
	14	233.33	32.14	1446.43	1.169	85.16	310.99	0.274	8.84	81.750	37.105	37.105	726.370	1.133	10.015	0.540	yes
	15	250.00	30.00	1260.00	1.019	84.61	299.43	0.283	8.84	81.750	37.105	37.105	632.749	1.154	10.206	0.554	yes
	16	266.67	28.13	1107.42	0.895	84.00	287.55	0.292	8.84	81.750	37.105	37.105	556.127	1.178	10.414	0.569	yes
	17	283.33	26.47	980.97	0.793	83.31	275.41	0.303	8.84	81.750	37.105	37.105	492.625	1.204	10.641	0.586	yes
	18	300.00	25.00	875.00	0.707	82.56	263.10	0.314	8.84	81.750	37.105	37.105	439.409	1.231	10.886	0.604	yes
	19	316.67	23.68	785.32	0.635	81.71	250.68	0.326	8.84	81.750	37.105	37.105	394.373	1.261	11.152	0.623	yes
	20	333.33	22.50	708.75	0.573	80.78	238.23	0.339	8.84	81.750	37.105	37.105	355.921	1.294	11.437	0.644	yes
	21	350.00	21.43	642.86	0.520	79.75	225.81	0.353	8.84	81.750	37.105	37.105	322.831	1.328	11.742	0.666	yes
	22	366.67	20.45	585.74	0.473	78.61	213.47	0.368	8.84	81.750	37.105	37.105	294.150	1.365	12.066	0.689	yes
	23	383.33	19.57	535.92	0.433	77.36	201.28	0.384	8.84	81.750	37.105	37.105	269.128	1.403	12.408	0.715	yes
	24	400.00	18.75	492.19	0.398	76.00	189.29	0.401	8.84	81.750	37.105	37.105	247.168	1.444	12.766	0.741	yes
	25	416.67	18.00	453.60	0.367	74.51	177.55	0.420	8.84	81.750	37.105	37.105	227.790	1.486	13.139	0.769	yes

	Fy (ksi)	Q (ft^3/sec)	HP Depth (in)	Zy (in)	r (in)	Sy (in.)	I (in^4)	E (ksi)	λ	λpf	λrf					
HP10X57	50	7500	9.99	30.3	2.45	19.7	101	29000	18.1	9.15161188	24.08318916					
	L (ft)	A (ft^2)	V (ft/s)	P (psf)	w (k/ft)	Axial Load	Axial Capacity	Axial load/cap	Max Moment (k/ft)	Moment Cap (plastic hinge) (k-ft)	Moment Cap (Flange Local Buckling) (k-ft)	Moment Capacity	Pe (k)	Moment Amp. Factor	Amplified Max. Moment (K-ft)	Interaction Formula	OK?
	5	83.33	90.00	11340.00	9.441	87.96	527.39	0.167	9.11	113.625	34.785	34.785	8021.880	1.011	9.206	0.377	yes
	6	100.00	75.00	7875.00	6.556	87.80	520.10	0.169	9.11	113.625	34.785	34.785	5570.750	1.016	9.251	0.380	yes
	7	116.67	64.29	5785.71	4.817	87.61	511.62	0.171	9.11	113.625	34.785	34.785	4092.796	1.022	9.305	0.383	yes
	8	133.33	56.25	4429.69	3.688	87.38	502.01	0.174	9.11	113.625	34.785	34.785	3133.547	1.029	9.367	0.386	yes
	9	150.00	50.00	3500.00	2.914	87.12	491.34	0.177	9.11	113.625	34.785	34.785	2475.889	1.036	9.438	0.390	yes
	10	166.67	45.00	2835.00	2.360	86.82	479.68	0.181	9.11	113.625	34.785	34.785	2005.470	1.045	9.517	0.395	yes
	11	183.33	40.91	2342.98	1.951	86.47	467.11	0.185	9.11	113.625	34.785	34.785	1657.413	1.055	9.607	0.399	yes
	12	200.00	37.50	1968.75	1.639	86.09	453.72	0.190	9.11	113.625	34.785	34.785	1392.688	1.066	9.705	0.405	yes
	13	216.67	34.62	1677.51	1.397	85.65	439.61	0.195	9.11	113.625	34.785	34.785	1186.669	1.078	9.814	0.411	yes
	14	233.33	32.14	1446.43	1.204	85.16	424.86	0.200	9.11	113.625	34.785	34.785	1023.199	1.091	9.932	0.482	yes
	15	250.00	30.00	1260.00	1.049	84.61	409.56	0.207	9.11	113.625	34.785	34.785	891.320	1.105	10.060	0.492	yes
	16	266.67	28.13	1107.42	0.922	84.00	393.82	0.213	9.11	113.625	34.785	34.785	783.387	1.120	10.199	0.503	yes
	17	283.33	26.47	980.97	0.817	83.31	377.73	0.221	9.11	113.625	34.785	34.785	693.934	1.136	10.348	0.514	yes
	18	300.00	25.00	875.00	0.728	82.56	361.38	0.228	9.11	113.625	34.785	34.785	618.972	1.154	10.507	0.527	yes
	19	316.67	23.68	785.32	0.654	81.71	344.87	0.237	9.11	113.625	34.785	34.785	555.532	1.172	10.676	0.540	yes
	20	333.33	22.50	708.75	0.590	80.78	328.27	0.246	9.11	113.625	34.785	34.785	501.368	1.192	10.854	0.554	yes
	21	350.00	21.43	642.86	0.535	79.75	311.69	0.256	9.11	113.625	34.785	34.785	454.755	1.213	11.042	0.569	yes
	22	366.67	20.45	585.74	0.488	78.61	295.20	0.266	9.11	113.625	34.785	34.785	414.353	1.234	11.237	0.585	yes
	23	383.33	19.57	535.92	0.446	77.36	278.88	0.277	9.11	113.625	34.785	34.785	379.106	1.256	11.440	0.602	yes
	24	400.00	18.75	492.19	0.410	76.00	262.79	0.289	9.11	113.625	34.785	34.785	348.172	1.279	11.648	0.620	yes
	25	416.67	18.00	453.60	0.378	74.51	247.00	0.302	9.11	113.625	34.785	34.785	320.875	1.302	11.859	0.638	yes

	Fy (ksi)	Q (ft^3/sec)	HP Depth (in)	Zy (in)	r (in)	Sy (in.)	I (in^4)	E (ksi)	λ	λpf	λrf
HP12X53	50	7500	11.8	32.2	2.86	21.1	127	29000	27.6	9.15161188	24.08318916

L (ft)	A (ft^2)	V (ft/s)	P (psf)	w (k/ft)	Axial Load	Axial Capacity	Axial load/cap	Max Moment (k/ft)	Moment Cap (plastic hinge) (k-ft)	Moment Cap (Flange Local Buckling) (k-ft)	Moment Capacity	Pe (k)	Moment Amp. Factor	Amplified Max. Moment (K-ft)	Interaction Formula	OK?
5	83.33	90.00	11340.00	11.151	87.96	490.69	0.179	10.76	120.750	66.063	66.063	10086.919	1.009	10.850	0.272	yes
6	100.00	75.00	7875.00	7.744	87.80	485.70	0.181	10.76	120.750	66.063	66.063	7004.805	1.013	10.892	0.274	yes
7	116.67	64.29	5785.71	5.689	87.61	479.88	0.183	10.76	120.750	66.063	66.063	5146.387	1.017	10.941	0.275	yes
8	133.33	56.25	4429.69	4.356	87.38	473.25	0.185	10.76	120.750	66.063	66.063	3940.203	1.023	10.999	0.277	yes
9	150.00	50.00	3500.00	3.442	87.12	465.84	0.187	10.76	120.750	66.063	66.063	3113.246	1.029	11.065	0.280	yes
10	166.67	45.00	2835.00	2.788	86.82	457.71	0.190	10.76	120.750	66.063	66.063	2521.730	1.036	11.139	0.282	yes
11	183.33	40.91	2342.98	2.304	86.47	448.87	0.193	10.76	120.750	66.063	66.063	2084.074	1.043	11.221	0.285	yes
12	200.00	37.50	1968.75	1.936	86.09	439.40	0.196	10.76	120.750	66.063	66.063	1751.201	1.052	11.311	0.288	yes
13	216.67	34.62	1677.51	1.650	85.65	429.32	0.199	10.76	120.750	66.063	66.063	1492.148	1.061	11.410	0.292	yes
14	233.33	32.14	1446.43	1.422	85.16	418.70	0.203	10.76	120.750	66.063	66.063	1286.597	1.071	11.518	0.376	yes
15	250.00	30.00	1260.00	1.239	84.61	407.59	0.208	10.76	120.750	66.063	66.063	1120.769	1.082	11.633	0.382	yes
16	266.67	28.13	1107.42	1.089	84.00	396.03	0.212	10.76	120.750	66.063	66.063	985.051	1.093	11.758	0.388	yes
17	283.33	26.47	980.97	0.965	83.31	384.09	0.217	10.76	120.750	66.063	66.063	872.571	1.106	11.891	0.395	yes
18	300.00	25.00	875.00	0.860	82.56	371.82	0.222	10.76	120.750	66.063	66.063	778.312	1.119	12.031	0.402	yes
19	316.67	23.68	785.32	0.772	81.71	359.27	0.227	10.76	120.750	66.063	66.063	698.540	1.132	12.180	0.410	yes
20	333.33	22.50	708.75	0.697	80.78	346.51	0.233	10.76	120.750	66.063	66.063	630.432	1.147	12.336	0.418	yes
21	350.00	21.43	642.86	0.632	79.75	333.58	0.239	10.76	120.750	66.063	66.063	571.821	1.162	12.498	0.426	yes
22	366.67	20.45	585.74	0.576	78.61	320.53	0.245	10.76	120.750	66.063	66.063	521.019	1.178	12.666	0.435	yes
23	383.33	19.57	535.92	0.527	77.36	307.42	0.252	10.76	120.750	66.063	66.063	476.697	1.194	12.839	0.444	yes
24	400.00	18.75	492.19	0.484	76.00	294.31	0.258	10.76	120.750	66.063	66.063	437.800	1.210	13.014	0.453	yes
25	416.67	18.00	453.60	0.446	74.51	281.23	0.265	10.76	120.750	66.063	66.063	403.477	1.227	13.191	0.462	yes

Fy (ksi)	Q (ft^3/sec)	HP Depth (in)	Zy (in)	r (in)	Sy (in.)	I (in^4)	E (ksi)	λ	λpf	λrf
50	7500	11.9	38.7	2.88	25.3	153	29000	11.8	9.15161188	24.08318916

	L (ft)	A (ft^2)	V (ft/s)	P (psf)	w (k/ft)	Axial Load	Axial Capacity	Axial load/cap	Max Moment (k/ft)	Moment Cap (plastic hinge) (k-ft)	Moment Cap (Flange Local Buckling) (k-ft)	Moment Capacity	Pe (k)	Moment Amp. Factor	Amplified Max. Moment (K-ft)	Interaction Formula	OK?
HP12X63	5	83.33	90.00	11340.00	11.246	87.96	582.68	0.151	10.85	145.125	21.728	21.728	12151.957	1.007	10.925	0.634	yes
	6	100.00	75.00	7875.00	7.809	87.80	576.84	0.152	10.85	145.125	21.728	21.728	8438.859	1.011	10.960	0.637	yes
	7	116.67	64.29	5785.71	5.738	87.61	570.02	0.154	10.85	145.125	21.728	21.728	6199.978	1.014	11.002	0.639	yes
	8	133.33	56.25	4429.69	4.393	87.38	562.26	0.155	10.85	145.125	21.728	21.728	4746.858	1.019	11.050	0.643	yes
	9	150.00	50.00	3500.00	3.471	87.12	553.58	0.157	10.85	145.125	21.728	21.728	3750.604	1.024	11.104	0.647	yes
	10	166.67	45.00	2835.00	2.811	86.82	544.04	0.160	10.85	145.125	21.728	21.728	3037.989	1.029	11.165	0.651	yes
	11	183.33	40.91	2342.98	2.323	86.47	533.69	0.162	10.85	145.125	21.728	21.728	2510.735	1.036	11.233	0.655	yes
	12	200.00	37.50	1968.75	1.952	86.09	522.57	0.165	10.85	145.125	21.728	21.728	2109.715	1.043	11.308	0.661	yes
	13	216.67	34.62	1677.51	1.664	85.65	510.76	0.168	10.85	145.125	21.728	21.728	1797.627	1.050	11.389	0.666	yes
	14	233.33	32.14	1446.43	1.434	85.16	498.29	0.171	10.85	145.125	21.728	21.728	1549.995	1.058	11.477	0.672	yes
	15	250.00	30.00	1260.00	1.250	84.61	485.25	0.174	10.85	145.125	21.728	21.728	1350.217	1.067	11.571	0.679	yes
	16	266.67	28.13	1107.42	1.098	84.00	471.68	0.178	10.85	145.125	21.728	21.728	1186.715	1.076	11.673	0.686	yes
	17	283.33	26.47	980.97	0.973	83.31	457.65	0.182	10.85	145.125	21.728	21.728	1051.207	1.086	11.780	0.693	yes
	18	300.00	25.00	875.00	0.868	82.56	443.23	0.186	10.85	145.125	21.728	21.728	937.651	1.097	11.894	0.701	yes
	19	316.67	23.68	785.32	0.779	81.71	428.48	0.191	10.85	145.125	21.728	21.728	841.548	1.108	12.013	0.710	yes
	20	333.33	22.50	708.75	0.703	80.78	413.46	0.195	10.85	145.125	21.728	21.728	759.497	1.119	12.137	0.718	yes
	21	350.00	21.43	642.86	0.638	79.75	398.23	0.200	10.85	145.125	21.728	21.728	688.886	1.131	12.266	0.758	yes
	22	366.67	20.45	585.74	0.581	78.61	382.87	0.205	10.85	145.125	21.728	21.728	627.684	1.143	12.399	0.769	yes
	23	383.33	19.57	535.92	0.531	77.36	367.43	0.211	10.85	145.125	21.728	21.728	574.289	1.156	12.535	0.780	yes
	24	400.00	18.75	492.19	0.488	76.00	351.96	0.216	10.85	145.125	21.728	21.728	527.429	1.168	12.672	0.792	yes
	25	416.67	18.00	453.60	0.450	74.51	336.53	0.221	10.85	145.125	21.728	21.728	486.078	1.181	12.810	0.804	yes

VITA

David Neil Pretorius

Candidate for the Degree of

Master of Science

Thesis: DESIGN OF STEEL SPLICE REPAIR FOR DECAYING TIMBER PILES ON OKLAHOMA COUNTY BRIDGES

Major Field: Civil Engineering

Biographical:

Education: Graduated From Plano West Senior High School, Plano, Texas in Spring 2007; received Bachelor of Science in Civil Engineering from Texas A&M University, College Station, Texas in May 2011; Completed the requirements for the Master of Science in Civil Engineering at Oklahoma State University, Stillwater, Oklahoma in December 2012.

Experience: Employed by Oklahoma State University, Department of Civil Engineering as a Research Assistant, Spring 2012 to Fall 2012. Employed by Oklahoma State University, Department of Civil Engineering as Graduate Teaching Assistant, Fall 2011. Employed by Satterfield & Pontikes as an intern, Summer or 2010.

Professional Memberships: American Society of Professional Engineers, American Concrete Institute, American Institute of Steel Construction