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16. Abstract

Several new truss bridges are planned throughout the state. Currently, the bridge railing proposed for these structures consists of a standard Texas Department of Transportation (TxDOT) railing, the T101, which is supported by a cast-in-place concrete deck. TxDOT would prefer to have the option to support a bridge rail system from the truss members in lieu of supporting the railing from the concrete deck. The primary advantage of using a truss-supported bridge rail is to allow alternate types of deck. One disadvantage to using a truss-supported bridge rail is the bridge structure must be adequately designed to resist the crash loads imparted from the bridge rail directly to the truss members.

The purpose of this project was to design a bridge railing system and develop design criteria that can be used on steel truss bridges. A new truss-mounted bridge rail and railing loading criteria were developed for this project to be used on new truss bridges. The new bridge rail design developed for this project meets the strength requirements of National Cooperative Highway Research Program (*NCHRP) Report 350* Test Level 3 and was designed to attach to vertical truss members. The bridge rail system can be used on spans up to and including 20 ft between supporting truss members and incorporates the use of crushable pipe blockouts that limit concentrated forces applied to the truss members. In addition, reactions from the impact loads applied to the truss members from the crushable blockouts are provided in this report and can be used by the bridge designer to design the bridge truss members.

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RAILING DESIGN FOR NEW TRUSS BRIDGES

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Report 0-4419-4
Project Number 0-4419
Project Title: Retrofit Railing for Existing Truss Bridges

Performed in Cooperation with the
Texas Department of Transportation
and the
U.S. Department of Transportation
Federal Highway Administration

October 2003
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DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data, and the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official view or policies of the Texas Department of Transportation (TxDOT), Federal Highway Administration (FHWA), The Texas A&M University System, or the Texas Transportation Institute. This report does not constitute a standard, specification, or regulation, and its contents are not intended for construction, bidding, or permit purposes. In addition, the above listed agencies assume no liability for its contents or use thereof. The names of specific products or manufacturers listed herein do not imply endorsement of those products or manufacturers. The engineer in charge was William Williams, P.E. (Texas, 71898).

ACKNOWLEDGMENTS

This research project was conducted under a cooperative program between the Texas Transportation Institute, the Texas Department of Transportation, and the U.S. Department of Transportation, Federal Highway Administration. The TxDOT program coordinator for this research was David P. Hohmann, P.E.; the project director was Charles E. Walker, P.E.; and the project monitor was Mark J. Bloschock, P.E. The valuable guidance and assistance of Mr. Hohmann, Mr. Walker, and Mr. Bloschock throughout the course of this project are acknowledged and appreciated.

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CHAPTER 1. INTRODUCTION

BACKGROUND

Several new truss bridges are planned throughout the state. Currently, the bridge railing proposed for these structures consists of a standard Texas Department of Transportation (TxDOT) railing, the T101, which is supported by a cast-in-place concrete deck. TxDOT would prefer to have the option to support a bridge rail system from the truss members in lieu of supporting the railing from the concrete deck. The primary advantage of using a truss-supported bridge rail is to allow alternate types of deck. One disadvantage to using a truss-supported bridge rail is the bridge structure must be adequately designed to resist the crash loads imparted from the bridge rail directly to the truss members. A truss-mounted bridge railing system will provide the bridge designer with more options and greater flexibility in designing steel truss bridges.

OBJECTIVES/SCOPE OF RESEARCH

The purpose of this research was to develop a truss-mounted bridge railing system that meets the strength requirements of National Cooperative Highway Research Program (*NCHRP) Report 350* Test Level 3 (TL-3) *(1)*. In addition, the railing system should be designed to minimize the force imparted to supporting truss members and be acceptable for varying span lengths up to 20 ft between supporting truss members. In addition to developing a new rail design, another objective of this research was to develop design forces from TL-3 crash loads on the railing system that can be used by the bridge designer to design the steel truss bridge.

CHAPTER 2. DEVELOPMENT OF BRIDGE RAIL DESIGN FOR NEW TRUSS BRIDGES

On February 23, 2004, the Texas Transportation Institute (TTI) and TxDOT personnel met to discuss and establish requirements and guidelines for the design of a truss-mounted bridge rail for new truss bridges. The typical new truss is assumed to be a Warren-type or Pratt-type pony truss with vertical truss web members at each panel point. The new bridge rail design should meet the requirements of *NCHRP Report 350* TL-3 and be supported by vertical truss web members and end posts only. The loading conditions for TL-3 consist of a 54-kip force distributed over 4 ft along the railing system. For a 2-rail bridge rail system, this 54-kip force is divided evenly for each rail element, or 27-kip force distributed over 4 ft per rail element. The new design should also incorporate the use of crushable blockouts that limit concentrated forces applied to supporting truss members. Magnitude of the reactions applied to the truss members from the crushable blockouts were to be defined and will be used by the bridge designer to design the bridge truss members. The new design should be suitable for attachment to vertical truss members spaced up to 20 ft.

For this project, finite element modeling was performed on several sizes of crushable pipe blockouts using the computer modeling program LS-DYNA. The blocks were loaded with diametrically opposing plate loads. The crushable pipe blockouts analyzed for this project ranged in size from 6-inch diameter Schedule 40 pipe to 10-inch diameter Schedule 80 pipe. Seven different crushable pipe blockouts were analyzed. Five of the seven blockouts were 6 inches in length and the remaining two were 8 inches in length. A summary of the force versus crush distance for each pipe blockout type is shown in the calculations in the appendix.

Structural analyses of several different rails using the results obtained from the crushable pipe blockouts were performed using STAAD Pro. Test Level 3 conditions require that the bridge rail system resist 54 kips of transverse load distributed over a 4-ft longitudinal distance. For the two-rail system considered, the load was divided equally between the two rail elements, i.e., 27 kips applied to each rail element. Analyses were performed on several different combinations of rail sizes and crushable pipe blockout types using five continuous spans with span lengths ranging from 10 ft to 20 ft. The crushable pipe blockouts were modeled as multi-linear springs with spring constants, “k” (force/crush), used to approximate the graphs shown on page seven of the calculations in the Appendix. Analyses were performed on each rail/crushable pipe combination with the 27 kips distributed over 4 ft located at:

- mid-span;
- centered over a crushable pipe support (vertical truss member support); and
- at the end of the rail element.

A summary of the data obtained from the analyses on the different rail/crushable pipe blockout combinations are presented in the calculations in the Appendix.

SUMMARY OF RESEARCH

A new bridge rail design was selected based on the results from the analyses. This new bridge rail design consists of two railing members fabricated from HSS8x8x6 tubular members. The recommended height of the top and bottom rail members is 30 inches and 16 inches, respectively. We recommend 10-inch diameter Schedule 80 (extra strong) A53, grade B pipe blockouts, 6 inches in length be used to support the rail at all vertical truss member locations. Considering the height and geometry of the rail elements, there is a low potential of vehicular interaction with the truss members based on Figures A13.1.1-2 and A13.1.1-3 in Section 13 of the American Association of State Highway and Transportation Officials (*AASHTO) Load Resistance Factor Design (LRFD) Bridge Design Specifications (2)*. Details of the recommended design are shown as Figures 1 and 2. A graph of the force versus crush displacement of the selected 10-inch Schedule 80 pipe blockout is shown as Figure 3.

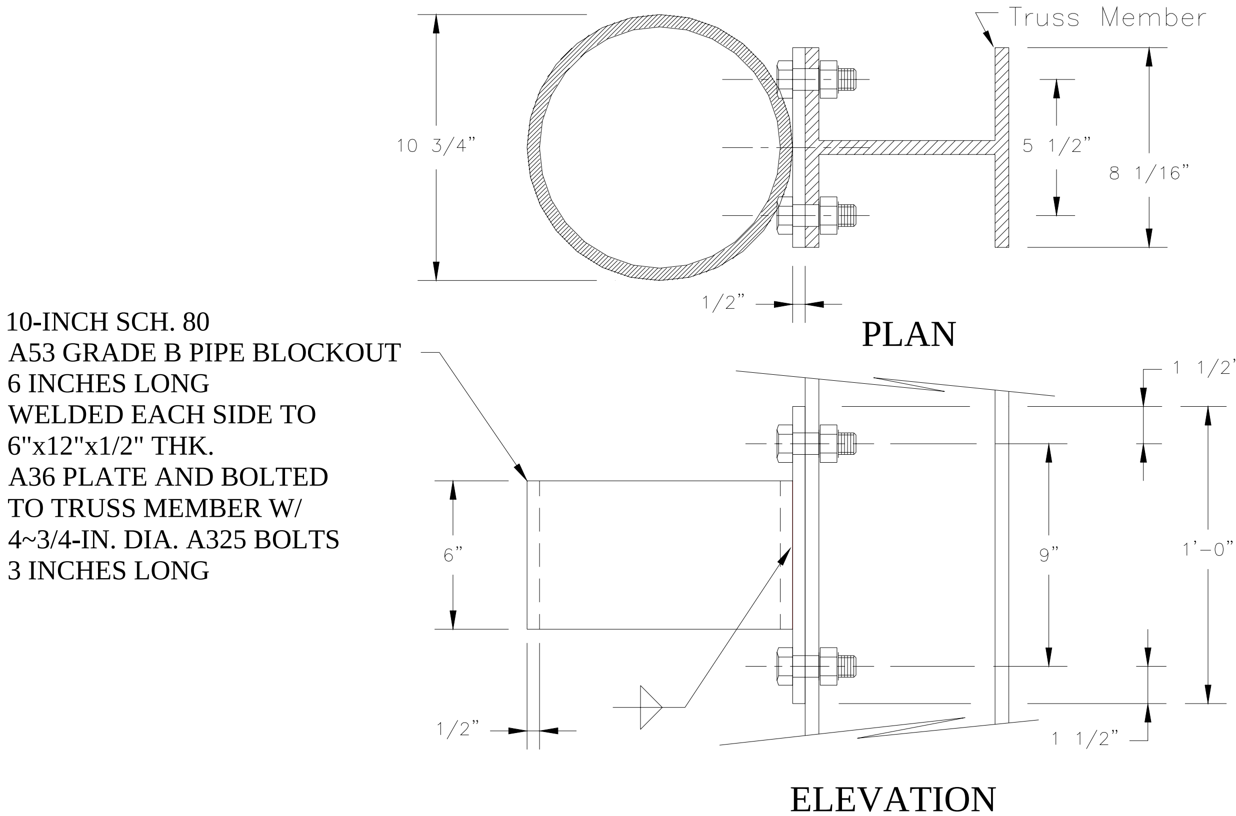


Figure 1. Details of the Recommended Crushable Pipe Blockout.

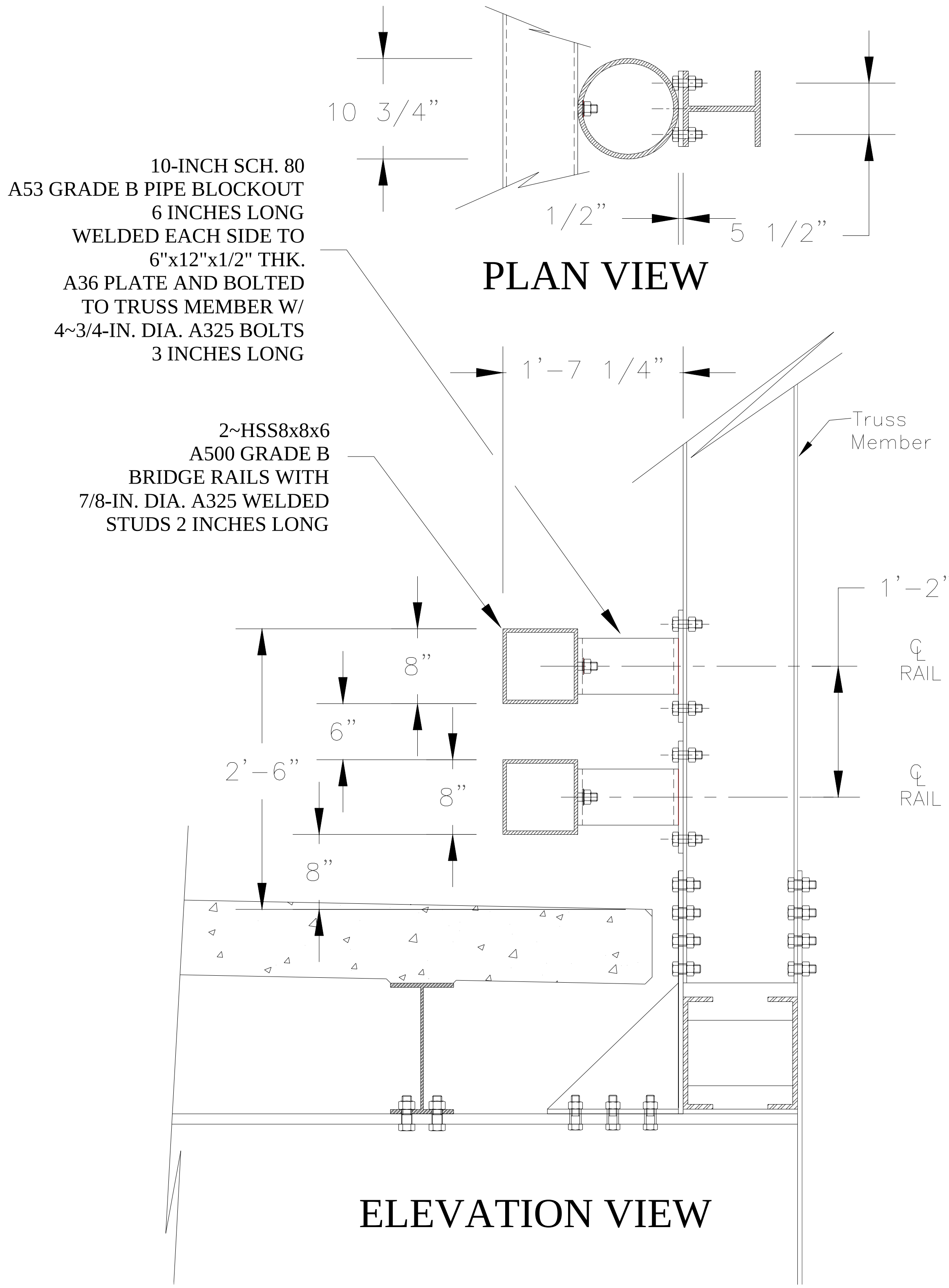
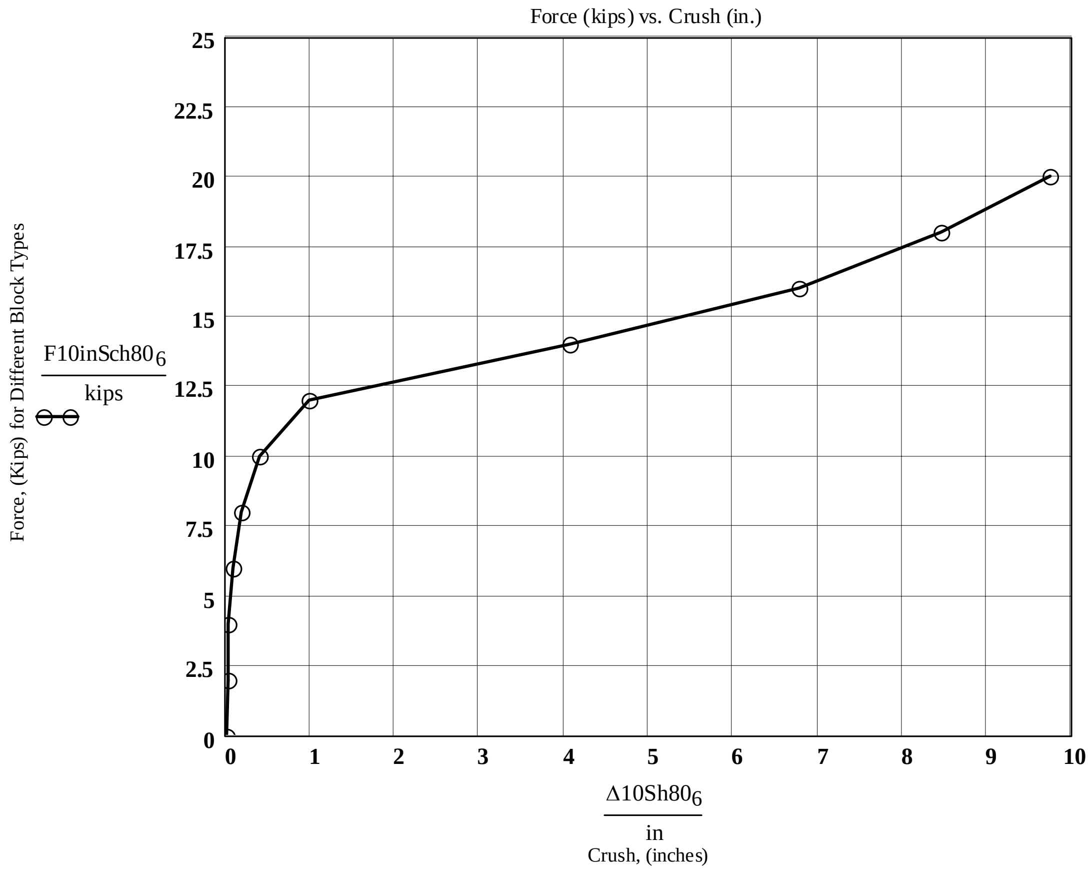


Figure 2. Details of Recommended New Bridge Rail Design.



$F10inSch80_6$ = 10-inch Diameter Schedule 80, A53 Grade B Pipe, 6 inches in Length

Figure 3. Plot of Force (kips) vs. Crush Distance (inches) for 10-inch Schedule 80 Pipe Blockout, 6 inches in Length.

The new bridge rail design developed from this research meets the strength requirements of *NCHRP Report 350*, Test Level 3. This railing is designed for mounting directly to Pratt-type or Warren-type trusses that have vertical truss members spaced 20 feet or less and rigidly connected to the transverse floorbeams. A minimum clear space of 3 inches is recommended between the railing and any diagonal truss members that do not support the rail. The railing is designed for installation by bolted connection to vertical members. The railing will meet *NCHRP Report 350* TL-3 requirements provided that:

1) the spacing between vertical members does not exceed 20 feet, and

2) the truss members and all associated components are designed for the theoretical crash loads transmitted to the truss through the rail plus all dead load including the rail weight.

The following tables provide recommended crash loads to be used in the design of the bridge structure. Table 1 refers to crash loads applied to intermediate truss members (see Figure 4). Table 2 refers to the situation where crash loads are applied to the end of the bridge railing system connected to the end truss members. These loads are applicable where the bridge railing system does not extend beyond the end of the truss (See Figure 5). The loads presented in these tables should be used to analyze a 3-D model of the truss bridge and connections in conjunction with the dead load of the structure. The bridge designer should consider the application of these loads at the various locations along the truss to produce the highest stress in the truss members. The designer should confirm that the capacities of the members exceed the maximum member force due to the loading. For additional information, please refer to the calculations included in the appendix.

TxDOT anticipates that most new truss construction will be of the pre-fabricated, fabricator-designed type. Implementation of the new rail system with this type of truss would require that the fabricator/designer could demonstrate that the truss has been designed for the crash rail impact load case.

Table 1: Recommended Lateral Design Loads for Intermediate Steel Truss Members. Bridge Rail Type: 2~HSS8x8x6 Rails with 10-inch Schedule 80 A53 Pipe Blockouts, 6 inches Long		
Support Spacing (ft)	Lateral Design Force Per Rail Element Load at Support* (Intermediate Truss Members) (Force F1, kips)	Lateral Design Force Per Rail Element Load at Adjacent Supports (X2) (Intermediate Truss Members)* (Force F2, kips)
10	12.5	9.0
12	13.0	9.0
14	13.5	9.0
16	14.0	9.0
18	14.5	8.5
20	15.5	8.5

* Load applied to Upper and Lower Rail

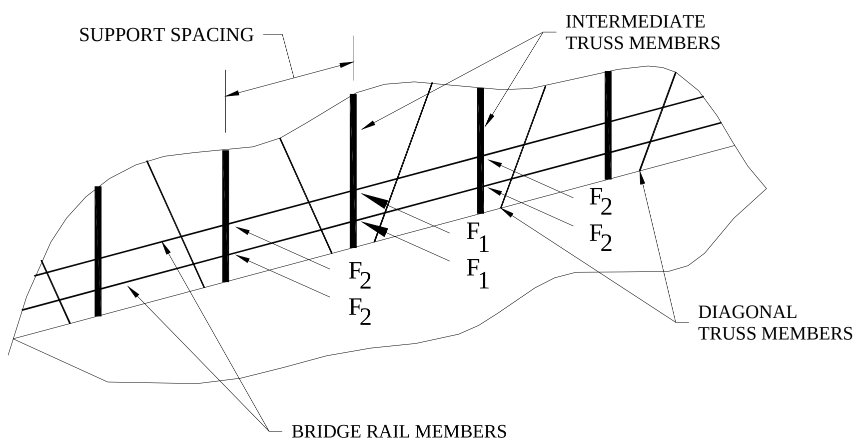


Figure 4. Crash Loads at Intermediate Truss Members.

Table 2: Recommended Lateral Design Loads at End Steel Truss Member and Adjacent Member.

(Loads Based on Railing terminating at End Truss Member)
Bridge Rail Type: 2~HSS8x8x6 Rails with 10-inch Schedule 80 A53 Pipe Blockouts, 6 inches Long

Support Spacing (ft)	Lateral Design Force Per Rail Element Load at End Support* (Force F3, kips)	Lateral Design Force Per Rail Element Load at Adjacent Support* (Force F4, kips)
10	16.5	13.0
12	17.5	13.0
14	18.5	13.0
16	19.0	12.5
18	20.0	12.0
20	21.0	10.0

* Load applied to Upper & Lower Rail

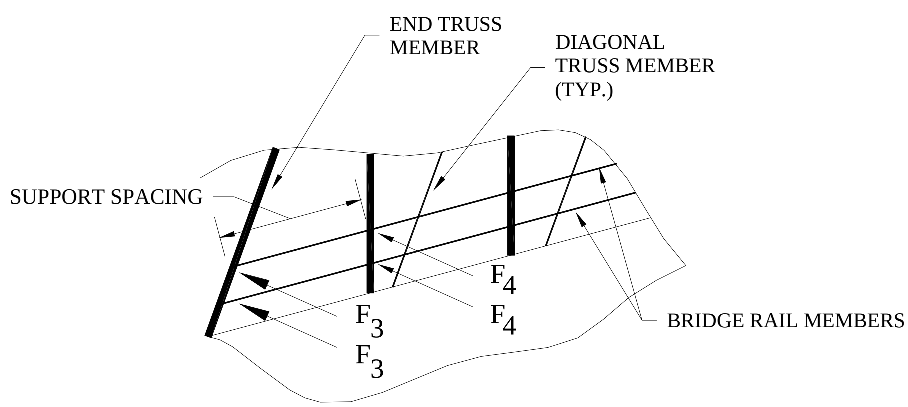


Figure 5. Crash Loads at End Truss Members.

CHAPTER 3. APPLICATION TO DEER CREEK BRIDGE

On July 1, 2003, TTI personnel received from TxDOT a set of fabrication drawings entitled “98' Truss Bridge, 28' Roadway Width, Deer Creek Bridge, Dewitt County, Texas” and dated March 7, 2002. The Deer Creek Bridge is typical of new truss bridges used by TxDOT that are prefabricated and designed by the fabricator. These drawings present details for a 98-ft long Warren Type Steel Pony Truss Bridge with verticals at panel points. The total height of the steel trusses is 10 ft from the center of the bottom chords to the center of the top chords. These drawings have been approved for construction. This bridge will be constructed using a TxDOT Type T101 bridge rail supported by an 8-inch thick concrete deck. TxDOT proposes to use several bridge structures of this type in the future for new bridge construction. As part of this project, TTI has performed preliminary analyses to determine if the Deer Creek structure as designed is adequate to support crash loads from the railing design proposed for new truss bridges in the study reported herein.

DETAILS OF CURRENT 98-FT DEER CREEK TRUSS BRIDGE

The current 98-ft long Deer Creek Steel Truss Bridge in Dewitt County, Texas, consists of two Warren Type Steel Pony Trusses with vertical and suspended floor beams. The bridge trusses consist of 7 panels, with each panel 14 ft in length. The center-to-center height between the top and bottom chords is 10 ft. The width of the bridge between the pony trusses is 31 ft-8 inches. W27x129 floor beams suspended below the bottom chord are supported at the panel points and are used to support five equally spaced W14x34 stringers. These stringers are used to support an 8-inch thick concrete deck with a 2 percent cross-slope. The concrete deck is 30 ft-3 inches wide and is used to support a TxDOT Type T101 bridge rail on each side of the concrete deck. The clear roadway width between the railings is 28 ft-0 inch. The steel trusses consist of W12x26 diagonals and verticals. The bottom chords of the trusses consist of two C12x30 structural shapes in the exterior panels and two MC12x40 structural shapes in the center panel. The top chords in the trusses range in size from a W12x50 on the ends to a W12x87 in the center of the trusses. Steel rods, 1-inch in diameter, are used as lateral cross bracing between the suspended floor beams. All superstructure steel is designated as American Society for Testing and Materials (ASTM) A709, grade 50W (A588 weathering type) steel.

ANALYSES OF CURRENT 98-FT DEER CREEK TRUSS BRIDGE

Analyses of the current bridge design were performed using the three dimensional structural engineering program RISA-3D. The loads used in the analysis consisted of the dead load weight of the structure plus the impact rail loads developed for this project for a truss-mounted rail system. The design dead loads used in the analysis consist of the self-weight of the steel members and the dead load of the 8-inch thick slab with the stay-in-place forms. The distributed force of the slab and the pan forms total 135 pound-force per square foot (psf). The impact loads used in the analysis consist of the loads developed for the design of the new truss-mounted bridge rail supported by vertical truss members spaced 14 feet apart which were developed for this project. These loads consist of 13.5 kips located at a vertical support with 9.0 kips on the adjacent vertical truss members per rail element. A brief sketch of the imposed crash loads from the new truss-mounted rail is shown in Figure 6.

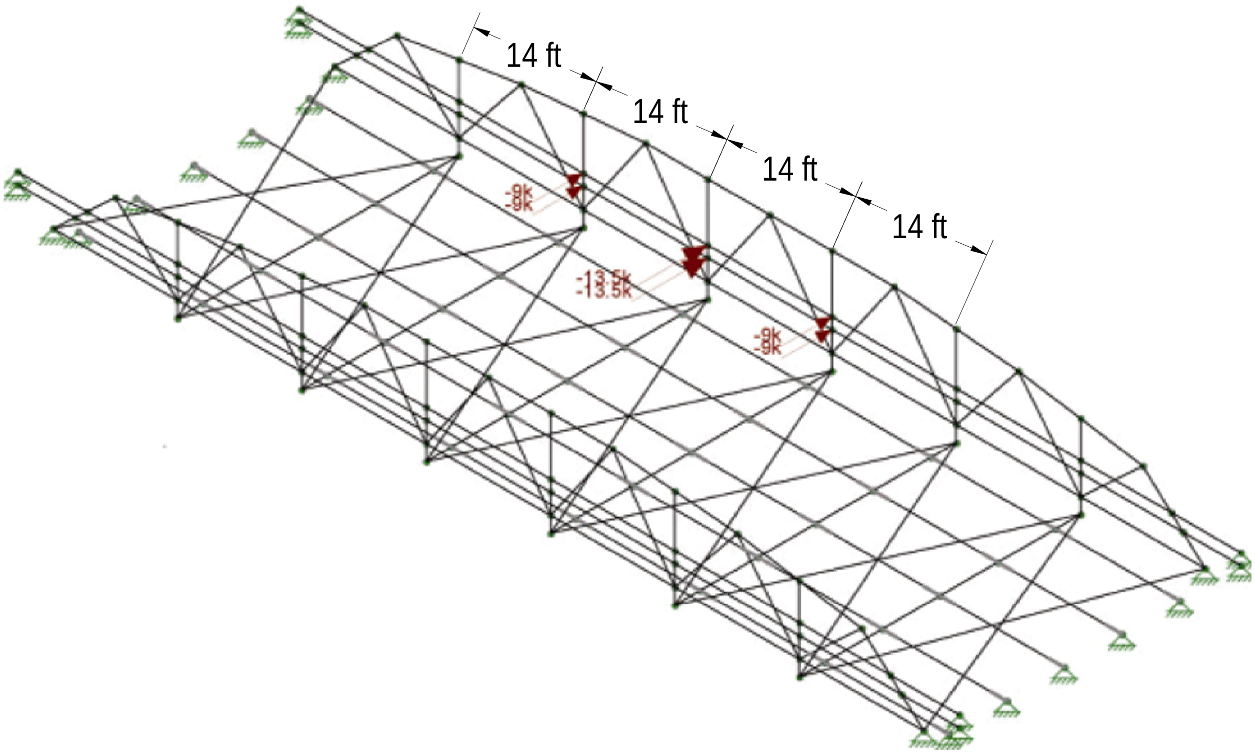


Figure 6. Superimposed Crash Loads from New Truss-Mounted Bridge Rail for Deer Creek Bridge Analysis.

The bridge railing members used in the analysis consist of two (2) HSS8x8x6 tubes similar to the design shown in Figure 2. The bridge rails were connected to the vertical truss members and extended beyond the exterior members and connected to simple pin-type connection beyond the exterior members to simulate the connection to a concrete parapet. The height of the bridge rail above the pavement surface was approximately 30 inches.

Based on the results from the analysis of the existing Deer Creek Bridge with the proposed rail loads shown in Figure 4, several design modifications are required. The primary modifications required for the structure are increased moment resisting connections between the floor beams and the vertical truss members to resist the lateral crash loads. Moment resisting connections are also required at the exterior truss members (chords). If adequate moment resisting connections are provided at exterior chord members and at all connections between vertical truss members and bottom floor beams, some resizing of the truss members will be required to meet the strength requirements of AASHTO's *LRFD Bridge Design Specifications*. In addition, other changes will likely be required, such as resizing of gusset plates in the top chord member connections to adequately resist the crash loads. The modifications presented in this report pertain to the 98-ft Deer Creek Bridge structure and may or may not apply to other bridge structures similar in type, length, size and geometry.

CHAPTER 4. IMPLEMENTATION STATEMENT

The new bridge rail design developed from this research meets the strength requirements of *NCHRP Report 350*, Test Level 3. This railing is designed for mounting directly to Pratt-type or Warren-type trusses that have vertical truss members rigidly connected to transverse floorbeams. A minimum clear space of 3 inches is recommended between the railing and any diagnonal truss members that do not support the rail. The railing is designed for installation by bolted connection to the vertical members. The railing will meet *NCHRP Report 350* TL-3 requirements provided that:

1) the spacing between vertical members does not exceed 20 ft, and
2) the truss members and all associated components are designed for the theoretical crash loads transmitted to the truss through the rail, plus all dead load including the rail weight.

The following tables provide recommended crash loads to be used in the design of the bridge structure. Table 3 refers to crash loads applied to intermediate truss members (see Figure 7). Table 4 refers to the situation where crash loads are applied to the end of the bridge railing system connected to the end truss members. These loads are applicable where the bridge railing system does not extend beyond the end of the truss (see Figure 8). The loads presented in these tables should be used to analyze a 3-D model of the truss bridge and connections in conjunction with the dead load of the structure. The designer should confirm that the capacities of the members exceed the maximum member force due to the loading.

TxDOT anticipates that most new truss construction will be of the pre-fabricated, fabricator-designed type. Implementation of the new rail system with this type of truss would require that the fabricator/designer could demonstrate that the truss has been designed for the crash rail impact load case.

Table 3. Design Transverse Crash Loads for Intermediate Steel Truss Members.		
Bridge Rail Type 2~HSS8x8x6 Rails with 10-inch Schedule 80 A53 Pipe Blockouts, 6 inches Long.		
Support Spacing (ft)	Lateral Design Force Per Rail Element Load at Support* (Intermediate Truss Members) (Force F1)	Lateral Design Force Per Rail Element Load at Adjacent Supports (X2) (Intermediate Truss Members)* (Force F2)
10	12.5	9.0
12	13.0	9.0
14	13.5	9.0
16	14.0	9.0
18	14.5	8.5
20	15.5	8.5

* Load applied to Upper and Lower Rail

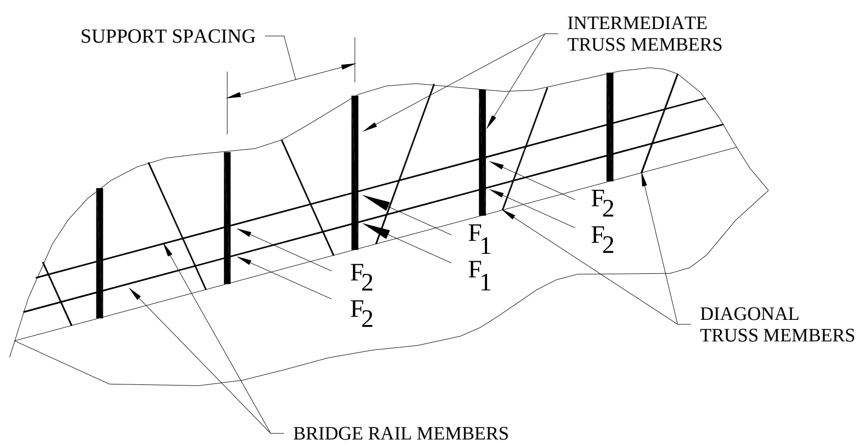


Figure 7. Configuration of Design Crash Loads at Intermediate Truss Members.

Table 4. Design Transverse Crash Loads at End Steel Truss Member and Adjacent Member.		
(Loads based on railing terminating at end truss member) Bridge Rail Type: 2~HSS8x8x6 Rails with 10-inch Schedule 80 A53 Pipe Blockouts, 6 inches Long		
Support Spacing (ft)	Lateral Design Force Per Rail Element Load at End Support* (Force F3)	Lateral Design Force Per Rail Element Load at Adjacent Support* (Force F4)
10	16.5	13.0
12	17.5	13.0
14	18.5	13.0
16	19.0	12.5
18	20.0	12.0
20	21.0	10.0

* Load applied to Upper & Lower Rail

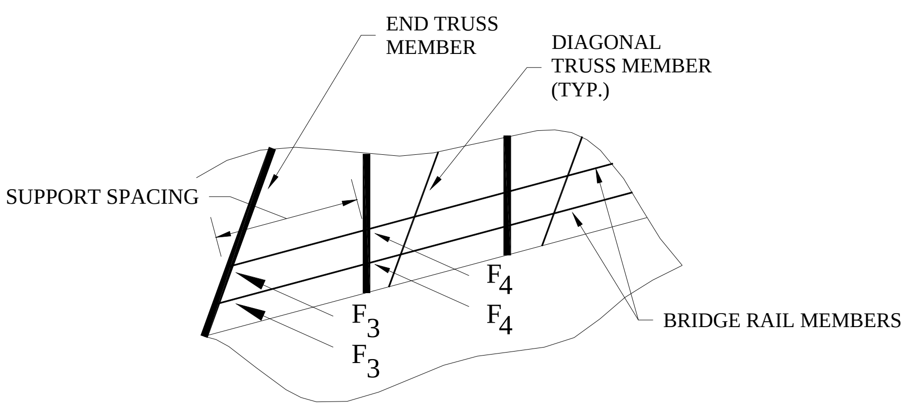


Figure 8. Configuration of Design Crash Loads at End Truss Members.

REFERENCES

1. H. E. Ross, Jr., D. L. Sicking, R. A. Zimmer, and J. D. Michie. *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, National Cooperative Highway Research Program Report 350, Transportation Research Board, National Research Council, Washington, D.C., 1993.

2. American Association of State Highway and Transportation Officials (AASHTO), *LRFD Bridge Design Specifications*, 2000 Interim Revision, dated May 2000.

APPENDIX. CALCULATIONS

Texas Transportation Institute

Page: 1 of 16

Job #: 444193

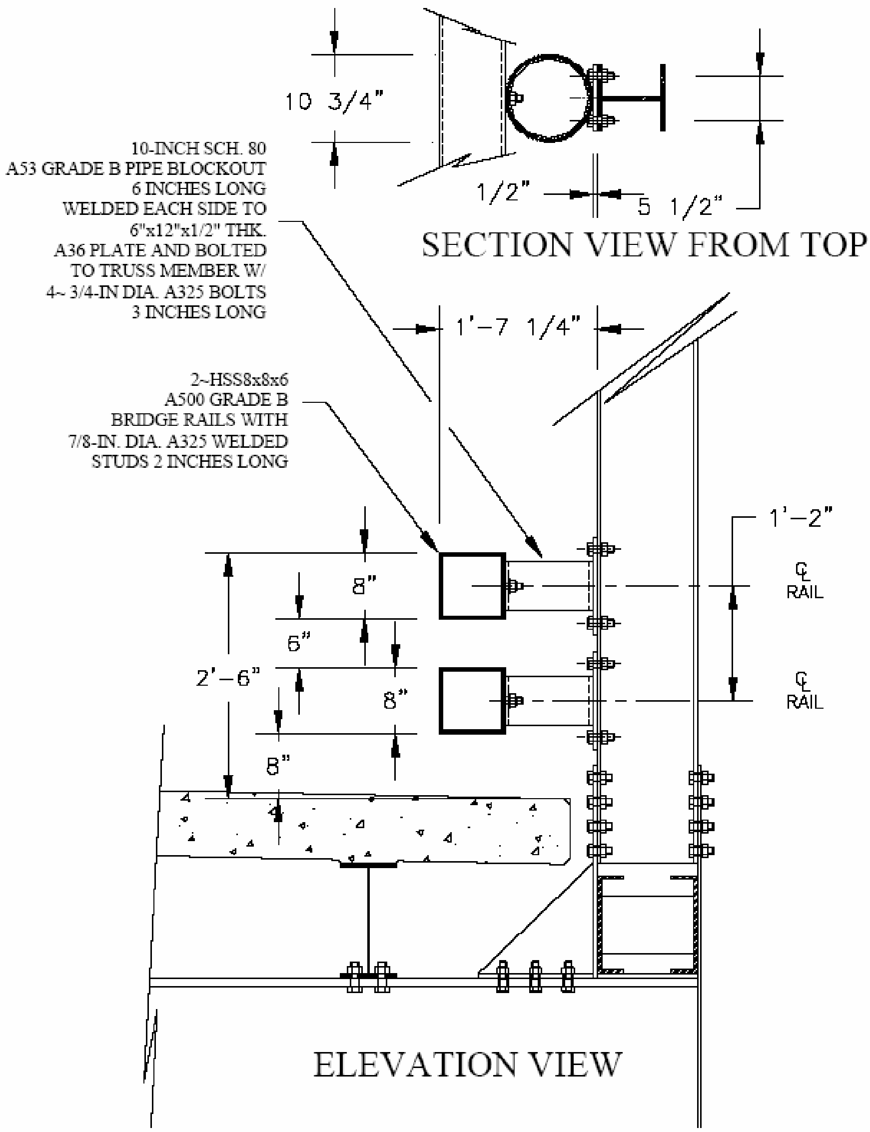
By: William Williams

Checked: ______

Subject: New Bridge Rail Design

2-Rail Tubular Design with Crushable Pipe Blockouts

Client: Texas Department of Transportation



New 2-Rail Design Concept

Texas Transportation Institute

Subject: New Bridge Rail Design

2-Rail Tubular Design with Crushable Pipe Blockouts

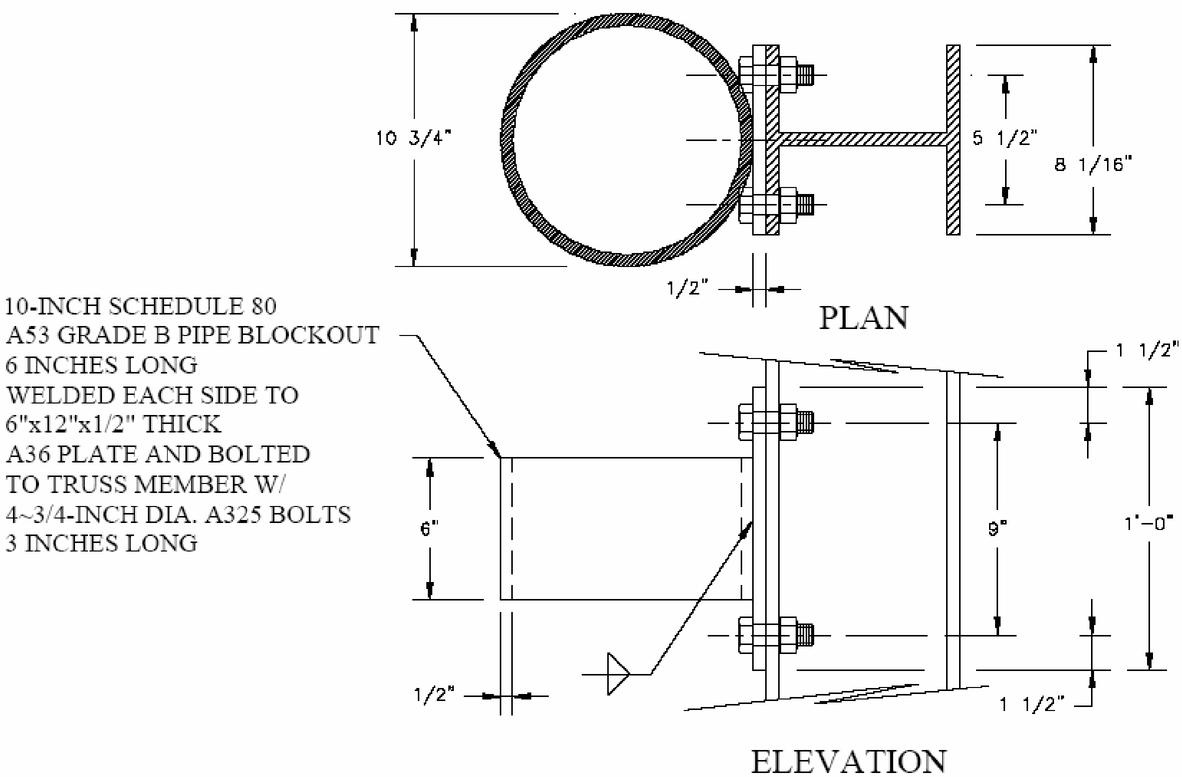
Client: Texas Department of Transportation

Page: 2 of 16

Job #: 444193

By: William Williams

Checked: ______



10-inch Schedule 80 Crushable Pipe Blockout for
New 2-Rail Bridge Rail

Texas Transportation Institute

Page: 3 of 16

Job #: 444193

By: William Williams

Checked: ______

Subject: Pipe Crush Data for Different Size Pipe Blockouts for New Bridge Rail Design

Client: Texas Department of Transportation

$Data6inSch40_6$:=

Force (lbs)	Crush (inches)
0	0
2000	0.140913386
4000	0.392027559
6000	1.294885827
8000	3.930688976
10000	5.747448819

$Data6inSch40_8$:=

Force (lbs)	Crush (inches)
0	0
2000	0.07057874
4000	0.236811024
6000	0.502334646
8000	1.193807087
10000	3.038102362
12000	4.819767717
14000	5.922043307

$Data8inSch40_6$:=

Force (lbs)	Crush (inches)
0	0
2000	0.059102362
4000	0.123783465
6000	0.28230315
8000	4.142566929
10000	7.453043307
12000	8.143645669
14000	8.143645669
16000	8.143645669
18000	8.143645669
20000	8.143645669
22000	8.143645669
24000	8.143645669

Texas Transportation Institute

Job #: 444193

By: William Williams

Checked: ______

Subject: Pipe Crush Data for Different Size Pipe Blockouts for New Bridge Rail Design

Client: Texas Department of Transportation

$Data6inSch80_8$:=

Force (lbs)	Crush (inches)
0	0
2000	0.017822835
4000	0.062874016
6000	0.078992126
8000	0.121948819
10000	0.198744094
12000	0.279090551
14000	0.369185039
16000	0.45346063
18000	0.655952756
20000	1.018673228
22000	1.435393701
24000	2.127169291
26000	2.964208661
28000	3.66223622
30000	4.268208661
32000	4.764094488
34000	5.19730315
36000	5.568318898
38000	5.899047244

$Data8inSch80_6$:=

Force (lbs)	Crush (inches)
0	0
2000	0.009708661
4000	0.017429134
6000	0.022291339
8000	0.033047244
10000	0.060795276
12000	0.095870079
14000	0.136255906
16000	0.199669291
18000	0.683074803
20000	2.893992126
22000	5.18373622
24000	6.329173228
26000	7.094594488
28000	7.674011811

Texas Transportation Institute

Job #: 444193

By: William Williams

Checked: ______

Subject: **Pipe Crush Data for Different Size Pipe Blockouts for New Bridge Rail Design**

Client: **Texas Department of Transportation**

Data10inSch80$_6$:=

Force (lbs)	Crush (inches)
0	0
2000	0.019685
4000	0.035433
6000	0.07874
8000	0.192913
10000	0.397638
12000	0.988189
14000	4.055118
16000	6.780315
18000	8.449606
20000	9.731102

Data6inSch80$_6$:=

Force (lbs)	Crush (inches)
0	0
2000	0.040688976
4000	0.101011811
6000	0.164385827
8000	0.238846457
10000	0.350767717
12000	0.518098425
14000	0.895244094
16000	1.440015748
18000	2.453862205
20000	3.441066929
22000	4.248090551
24000	4.880496063
26000	5.411582677
28000	5.849248031

Subject: **Pipe Crush Data for Different Size Pipe Blockouts for New Bridge Rail Design**

Client: **Texas Department of Transportation**

By: **William Williams**

Checked: ______

$$F6inSch80_6 := \frac{Data6inSch80_6^{\langle 1 \rangle}}{1000} \cdot kips \qquad \Delta 6Sh80_6 := Data6inSch80_6^{\langle 2 \rangle} \cdot in$$

$$F6inSch40_6 := \frac{Data6inSch40_6^{\langle 1 \rangle}}{1000} \cdot kips \qquad \Delta 6Sh40_6 := Data6inSch40_6^{\langle 2 \rangle} \cdot in$$

$$F6inSch40_8 := \frac{Data6inSch40_8^{\langle 1 \rangle}}{1000} \cdot kips \qquad \Delta 6Sh40_8 := Data6inSch40_8^{\langle 2 \rangle} \cdot in$$

$$F8inSch40_6 := \frac{Data8inSch40_6^{\langle 1 \rangle}}{1000} \cdot kips \qquad \Delta 8Sh40_6 := Data8inSch40_6^{\langle 2 \rangle} \cdot in$$

$$F6inSch80_8 := \frac{Data6inSch80_8^{\langle 1 \rangle}}{1000} \cdot kips \qquad \Delta 6Sh80_8 := Data6inSch80_8^{\langle 2 \rangle} \cdot in$$

$$F8inSch80_6 := \frac{Data8inSch80_6^{\langle 1 \rangle}}{1000} \cdot kips \qquad \Delta 8Sh80_6 := Data8inSch80_6^{\langle 2 \rangle} \cdot in$$

$$F10inSch80_6 := \frac{Data10inSch80_6^{\langle 1 \rangle}}{1000} \cdot kips \qquad \Delta 10Sh80_6 := Data10inSch80_6^{\langle 2 \rangle} \cdot in$$

Texas Transportation Institute

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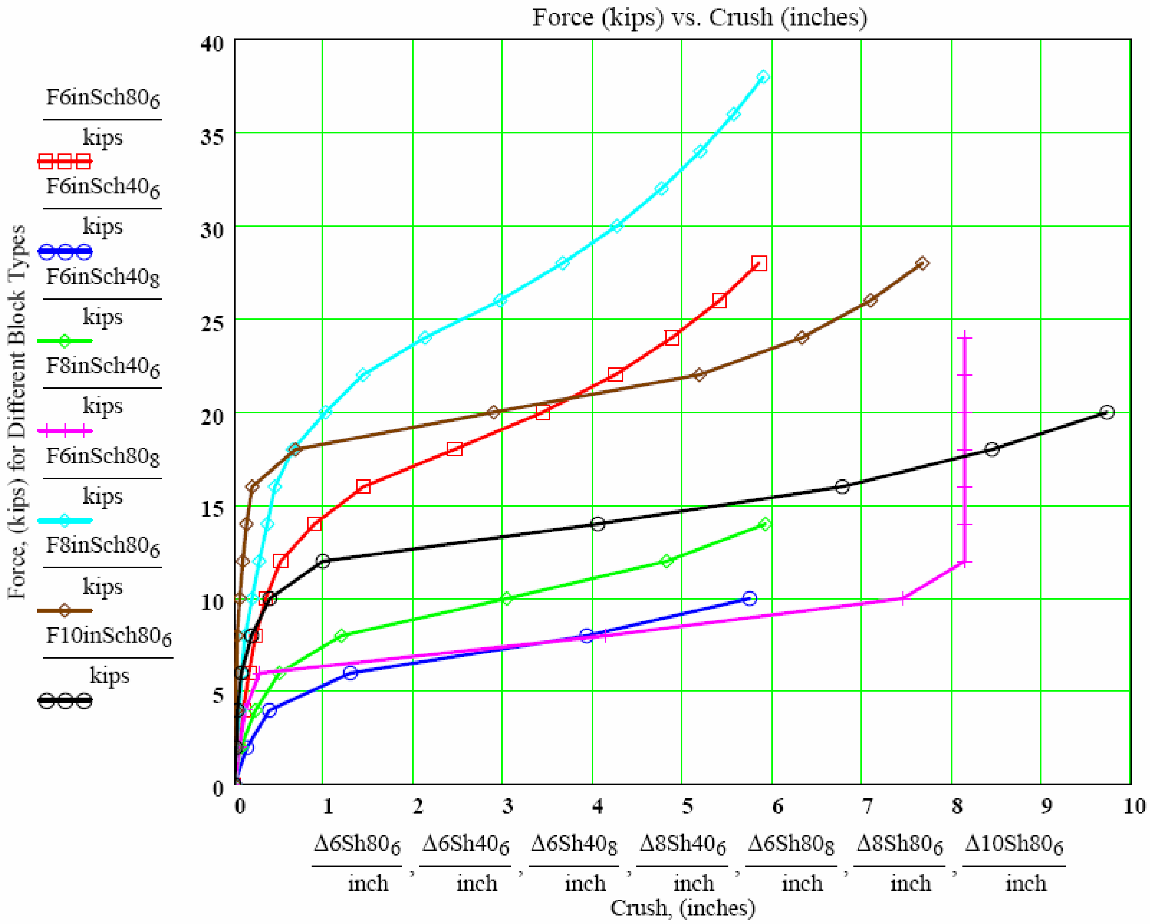
Job #: 444193

Subject: **Pipe Crush Data for Different Pipe Blockout Types**

By: **William Williams**

Checked: ______

Client: **Texas Department of Transportation**



Texas Transportation Institute

Subject: **Pipe Crush Data**

for 10-inch Schedule 80 Pipe Blockout ~ 6 inches Long

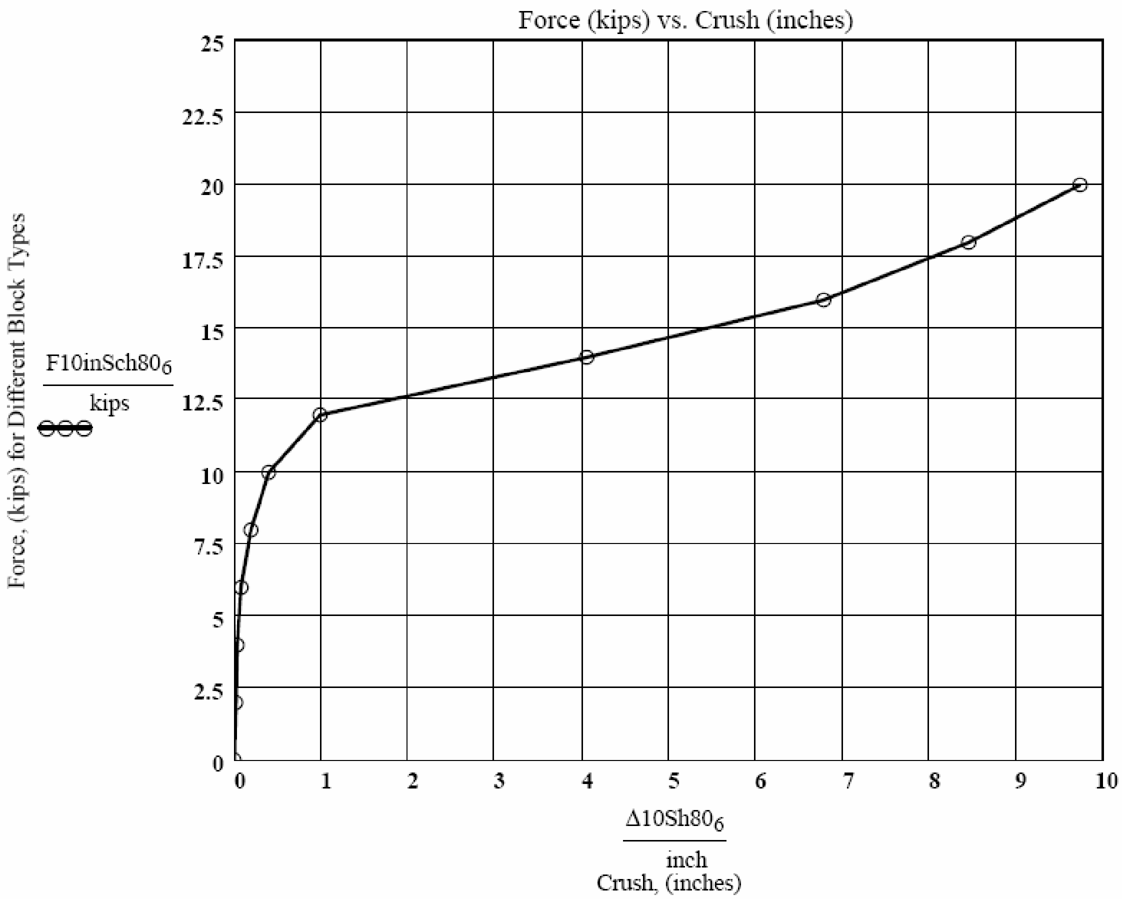
Client: **Texas Department of Transportation**

Page: **8 of 16**

Job #: **444193**

By: **William Williams**

Checked: ______



$F10inSch80_6$ = 10-inch Diameter Schedule 80, A53 Grade B Pipe, 6 inches in Length

Texas Transportation Institute

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Job #: 444193

By: William Williams

Checked: ______

Subject: **HSS8x6x6 Rail w/8-inch Sch 40 Pipe Blockouts ~ 6 inches Long**

STAAD Analysis Data, Load at: 1.) Mid-span 2.) At support, 3.) End of rail

Client: **Texas Department of Transportation**

This data is for STAAD analyses on HSS8x6x6 tube continous over 5 spans at the span lengths given using 8-inch Schedule 40 pipe blocks ~ 6 inches long, with 27 kips distributed over 4 ft at: 1.) mid-span of middle span (3rd); 2.) centered over 3rd support; and 3.) at the end of the rail

$Design1_{MID}$:= (Load at Mid-Span)

Span (ft)	$F_{zsupport}$ (kips)	Crush (in.)	$M_{xsupport}$ (k-in)	$M_{xmidspan}$ (k-in)	$\Delta_{supp.}$ (in)	Δ_{mid} (in)	S.R.
20	10.17	−10.72	−151.91	−1609.91	−10.717	−14.52	2.26
18	10.15	−7.93	−141.56	−1437.56	−7.93	−10.70	2.02
16	9.57	−6.2	−181.82	−1315.82	−6.24	−8.29	1.85
14	9.10	−4.88	−209.37	−1181.37	−4.88	−6.32	1.66
12	8.83	−4.10	−236.12	−1046.12	−4.10	−5.06	1.47
10	8.53	−3.23	−262.03	−910.03	−3.23	−3.83	1.28

$Design1_{SUP}$:= (Load at Support (Centered))

Span (ft)	$F_{zsupp.}$ (kips)	Crush (in)	M_{xsupp} (k-in)	$M_{xAdj.supp.}$ (k-in)	$\Delta_{supp.}$ (in)	$\Delta_{Adj.}$ Supp. (in)	S.R.
20	10.17	−17.9	−1347.24	555.19	−17.92	−6.89	1.9
18	10.17	−14.44	−1236.96	472.88	−14.44	−5.86	1.74
16	10.17	−11.28	−1127.81	395.33	−11.28	−4.81	1.59
14	10.17	−8.39	−1013.34	322.18	−8.39	−3.74	1.42
12	9.59	−6.30	−924.55	252.22	−6.30	−2.97	1.31
10	8.92	−4.37	−838.34	182.45	−4.37	−2.19	1.18

$Design1_{END}$:= (Load at End of Rail)

Span (ft)	F_{zsup} (kips)	Crush (in)	F_{zupp} (adj.) (k-in)	$\Delta_{Adj.Sup.}$ (in)	$M_{xadj.}$ supp. (k-in)	S.R.
20	21.75	−10.78	7.98	−1.63	−611.34	0.86
18	21.30	−10.67	8.22	−2.33	−583.73	0.83
16	20.73	−10.54	8.42	−2.90	−566.20	0.79
14	19.97	−10.35	8.57	−3.34	−532.77	0.75
12	18.90	−10.10	8.67	−3.65	−518.91	0.73
10	17.26	−9.70	8.74	−3.84	−521.14	0.74

Subject: **HSS8x6x6 Rail w/8-inch Sch 80 Pipe Blockouts ~ 6 inches Long**

STAAD Analysis Data, Load at: 1.) Mid-span; 2.) At support; 3.) End of rail

Client: **Texas Department of Transportation**

This data is for STAAD analyses on HSS8x6x6 tube continous over 5 spans at the span lengths given using 8-inch Schedule 80 pipe blocks ~ 6 inches long, with 27 kips distributed over 4 ft at: 1.) mid-span of middle span (3rd); 2.) centered over 3rd support; and 3.) at the end of the rail

Design2$_{MID}$:= (Load at Mid-Span)

Span (ft)	$F_{zsupport}$ (kips)	Crush (in)	$M_{xsupport}$ (k-in)	$M_{xmidspan}$ (k-in)	$\Delta_{supp.}$ (in)	Δ_{mid} (in)	S.R.
20	15.95	−0.23	486.63	−971.37	−0.23	−2.03	1.37
18	15.88	−0.23	430.79	−865.21	−0.23	−1.55	1.22
16	15.78	−0.23	373.38	−760.62	−0.23	−1.16	1.07
14	15.62	−0.22	313.69	−658.31	−0.22	−0.86	0.95
12	15.35	−0.22	250.59	−559.41	−0.22	−0.63	0.79
10	14.90	−0.21	182.48	−465.52	−0.21	−0.46	0.65

Design2$_{SUP}$:= (Load at Support (Centered))

Span (ft)	$F_{zsupp.}$ (kips)	Crush (in)	M_{xsupp} (k-in)	$M_{xAdj.supp.}$ (k-in)	$\Delta_{supp.}$ (in)	$\Delta_{Adj.}$ Supp. (in)	S.R.
20	20.00	−3.06	−453.78	320.72	−3.060	−0.07	0.64
18	19.44	−2.43	−435.72	309.16	−2.434	−0.08	0.61
16	18.93	−1.85	−407.92	290.05	−1.857	−0.08	0.57
14	18.48	−1.35	−370.71	263.07	−1.349	−0.09	0.52
12	18.10	−0.93	−325.34	228.31	−0.929	−0.09	0.45
10	17.81	−0.60	−273.99	186.29	−0.603	−0.09	0.38

Design2$_{END}$:= (Load at End of Rail)

Span (ft)	F_{zsup} (kips)	Crush (in)	F_{zupp} (adj.) (k-in)	$\Delta_{Adj.Sup.}$ (in)	$M_{xadj.}$ supp. (k-in)	S.R.
20	22.21	−5.54	7.38	−0.11	−502.54	0.71
18	21.59	−4.84	8.37	−0.12	−521.31	0.74
16	20.87	−4.04	9.47	−0.14	−528.80	0.75
14	20.07	−3.14	10.57	−0.15	−515.44	0.73
12	19.24	−2.21	11.48	−0.16	−468.80	0.66
10	18.46	−1.33	11.89	−0.17	−376.52	0.54

Subject: **HSS8x8x6 Rail w/10-inch Sch 80 Pipe Blockouts ~ 6 inches Long**

By: **William Williams**

STAAD Analysis Data, Load at: 1.) Mid-span; 2.) At Support; 3.) End of Rail

Checked: ______

Client: **Texas Department of Transportation**

This data is for STAAD analyses on HSS8x8x6 tube continous over 5 spans at the span lengths given using 10-in Schedule 80 pipe blocks ~ 6 inches long, with 27 kips distributed over 4 ft at: 1.) mid-span of middle span (3rd); 2.) centered over 3rd support; and 3.) at the end of the rail

$Design3_{MID}$:= (Load at Mid-Span)

Span (ft)	$F_{zsupport}$ (kips)	Crush (in)	$M_{xsupport}$ (k-in)	$M_{xmidspan}$ (k-in)	$\Delta_{supp.}$ (in)	Δ_{mid} (in)	S.R.
20	13.82	−3.27	−249.90	1208.11	−3.27	−5.29	1.35
18	13.46	−2.83	−186.80	1109.20	−2.83	−4.37	1.24
16	13.09	−2.37	−128.50	1005.53	−2.37	−3.50	1.12
14	12.73	−1.91	−76.18	895.84	−1.91	−2.70	1.00
12	12.38	−1.48	−30.27	779.73	−1.48	−2.00	0.87
10	12.08	−1.10	10.50	658.50	−1.10	−1.42	0.74

$Design3_{SUP}$:= (Load at Support (Centered))

Span (ft)	$F_{zsupp.}$ (kips)	Crush (in)	M_{xsupp} (k-in)	$M_{xAdj.supp.}$ (k-in)	$\Delta_{supp.}$ (in)	$\Delta_{Adj.}$ Supp. (in)	S.R.	$F_{xAdj.}$ supp.(kips)
20	15.23	−5.03	754.90	−498.40	−5.03	−0.68	0.89	8.15
18	14.53	−4.16	764.30	−460.68	−4.16	−0.70	0.85	8.43
16	13.90	−3.37	722.26	−412.24	−3.37	−0.72	0.81	8.70
14	13.35	−2.69	669.93	−354.13	−2.69	−0.72	0.75	8.91
12	12.88	−2.10	609.60	−287.83	−2.10	−0.70	0.68	8.92
10	12.49	−1.62	544.31	−213.94	−1.62	−0.68	0.61	8.61

$Design3_{END}$:= (Load at End of Rail)

Span (ft)	F_{zsup} (kips)	Crush (in)	F_{zupp} (adj.) (k-in)	$\Delta_{Adj.Sup.}$ (in)	$M_{xadj.}$ supp. (k-in)	S.R.
20	20.91	−10.43	9.83	−0.82	−813.19	0.91
18	19.84	−10.16	11.58	−0.96	−897.81	1.00
16	18.99	−9.74	12.42	−1.53	−889.08	1.00
14	18.22	−8.78	12.76	−1.95	−826.29	0.93
12	17.31	−7.64	12.94	−2.17	−746.76	0.84
10	16.22	−6.28	12.94	−2.18	−645.29	0.73

Texas Transportation Institute

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Job #: 444193

Subject: **HSS8x8x5 Rail w/10-inch Sch 80 Pipe Blockouts ~ 6 inches Long**

By: **William Williams**

STAAD Analysis Data, Load at: 1.) Mid-Span; 2.) At Support; 3.) End of Rail

Checked: ______

Client: **Texas Department of Transportation**

This data is for STAAD analyses on HSS8x8x5 tube continous over 5 spans at the spanlengths given using 10-inch Schedule 80 pipe blocks ~ 6 inches long, with 27 kips distributed over 4 ft at: 1.) mid-span of middle span (3rd); 2.) centered over 3rd support; and 3.) at the end of the rail

$Design4_{MID}$:=

Span (ft)	$F_{zsupport}$ (kips)	Crush (in)	$M_{xsupport}$ (k-in)	$M_{xmidspan}$ (k-in)	$\Delta_{supp.}$ (in)	Δ_{mid} (in.)	S.R.
20	13.92	−3.40	−261.70	1196.30	−3.40	−5.58	1.38
18	13.56	−2.96	−197.54	1098.46	−2.96	−4.62	1.27
16	13.19	−2.48	−137.79	996.21	−2.48	−3.71	1.15
14	12.80	−2.00	−83.98	888.02	−2.00	−2.87	1.03
12	12.44	−1.55	−36.83	773.19	−1.55	−2.12	0.89
10	12.12	−1.15	4.69	652.69	−1.15	−1.50	0.75

Load at Mid-Span

$Design4_{SUP}$:=

Span (ft)	$F_{zsupp.}$ (kips)	Crush (in)	M_{xsupp} (k-in)	$M_{xAdj.supp.}$ (k-in)	$\Delta_{supp.}$ (in)	$\Delta_{Adj.}$ Supp. (in)	S.R.
20	15.45	−5.32	776.20	−492.41	−5.32	−0.67	0.90
18	14.72	−4.40	749.01	−457.86	−4.40	−0.70	0.87
16	14.05	−3.56	709.43	−412.15	−3.56	−0.71	0.82
14	13.46	−2.83	658.81	−356.11	−2.83	−0.72	0.76
12	12.96	−2.20	599.46	−291.31	−2.20	−0.71	0.69
10	12.55	−1.69	534.43	−218.74	−1.69	−0.69	0.62

Load at Support (Centered)

$Design4_{END}$:=

Span (ft)	F_{zsup} (kips)	Crush (in)	F_{zupp} (adj.) (k-in)	$\Delta_{Adj.Sup.}$ (in)	$M_{xadj.}$ supp. (k-in)	S.R.
20	21.29	−9.74	9.05	−0.75	−721.18	0.83
18	20.32	−9.49	10.63	−0.89	−794.64	0.92
16	19.23	−9.21	12.17	−1.20	−844.16	0.98
14	18.34	−8.92	12.70	−1.86	−807.36	0.93
12	17.43	−7.79	12.91	−2.14	−730.15	0.84
10	16.34	−6.42	12.94	−2.18	−631.47	0.73

Load at End of Rail

Subject: **HSS8x8x4 Rail w/10-inch Sch 80 Pipe Blockouts ~ 6 inches Long** By: **William Williams**

STAAD Analysis Data, Load at: 1.) Mid-Span; 2.) At Support; 3.) End of Rail Checked: ______

Client: **Texas Department of Transportation**

This data is for STAAD analyses on HSS8x8x4 tube continous over 5 spans at the span lengths given using 10-inch Schedule 80 pipe blocks ~ 6 inches long, with 27 kips distributed over 4 ft at: 1.) mid-span of middle span (3rd); 2.) centered over 3rd support; and 3.) at the end of the rail

$Design5_{MID}$:= (Load at Mid-Span)

Span (ft)	$F_{zsupport}$ (kips)	Crush (in)	$M_{xsupport}$ (k-in)	$M_{xmidspan}$ (k-in)	$\Delta_{supp.}$ (in)	Δ_{mid} (in)	S.R.
20	14.13	−3.66	−285.97	1172.03	−3.66	−6.22	1.65
18	13.78	−3.21	−219.91	1076.09	−3.22	−5.17	1.52
16	13.38	−2.72	−157.47	976.53	−2.73	−4.17	1.38
14	12.98	−2.22	−100.55	871.45	−2.22	−3.24	1.23
12	12.58	−1.72	−50.50	759.50	−1.72	−2.39	1.07
10	12.22	−1.27	−7.11	640.88	−1.27	−1.68	0.90

$Design5_{SUP}$:= (Load at Support (Centered))

Span (ft)	$F_{zsupp.}$ (kips)	Crush (in)	M_{xsupp} (k-in)	$M_{xAdj.supp.}$ (k-in)	$\Delta_{supp.}$ (in)	$\Delta_{Adj.Supp.}$ (in)	S.R.
20	15.96	−5.95	736.67	−477.22	−5.95	−0.65	1.04
18	15.14	−4.93	716.12	−449.59	−4.93	−0.68	1.01
16	14.39	−3.98	682.14	−409.99	−3.98	−0.71	0.96
14	13.72	−3.15	635.67	−358.81	−3.15	−0.72	0.90
12	13.14	−2.43	578.83	−297.47	−2.43	−0.71	0.82
10	12.67	−1.84	514.75	−227.62	−1.84	−0.70	0.73

$Design5_{END}$:= (Load at End of Rail)

Span (ft)	F_{zsup} (kips)	Crush (in)	F_{zupp} (adj.) (k-in)	$\Delta_{Adj.Sup.}$ (in)	$M_{xadj.supp.}$ (k-in)	S.R.
20	21.63	−9.82	8.39	−0.70	−640.08	0.90
18	20.73	−9.60	9.86	−0.82	−706.62	1.00
16	19.56	−9.30	11.71	−0.98	−781.26	1.10
14	18.60	−9.05	12.53	−1.66	−763.43	1.08
12	17.66	−8.08	12.85	−2.06	−696.45	0.98
10	16.57	−6.72	12.94	−2.18	−603.21	0.85

Subject: New Rail Design for New Truss Bridges

Matrix Data Summary

By: William Williams

Checked:

Client: Texas Department of Transportation

Data for plotting and graphing from the matrices above

$Span_1 := Design1_{SUP}^{\langle 1 \rangle} \cdot ft$

$Span_2 := Design2_{SUP}^{\langle 1 \rangle} \cdot ft$ $\quad Crush_{SUPP2} := Design2_{SUP}^{\langle 3 \rangle} \cdot in^{-1}$ $\quad Crush_{END2} := Design2_{END}^{\langle 3 \rangle} \cdot in^{-1}$

$Span_3 := Design3_{SUP}^{\langle 1 \rangle} \cdot ft$ $\quad Crush_{SUPP3} := Design3_{SUP}^{\langle 3 \rangle} \cdot in^{-1}$ $\quad Crush_{END3} := Design3_{END}^{\langle 3 \rangle} \cdot in^{-1}$

$Span_4 := Design4_{SUP}^{\langle 1 \rangle} \cdot ft$ $\quad Crush_{SUPP4} := Design4_{SUP}^{\langle 3 \rangle} \cdot in^{-1}$ $\quad Crush_{END4} := Design4_{END}^{\langle 3 \rangle} \cdot in^{-1}$

$Span_5 := Design5_{SUP}^{\langle 1 \rangle} \cdot ft$ $\quad Crush_{SUPP5} := Design5_{SUP}^{\langle 3 \rangle} \cdot in^{-1}$ $\quad Crush_{END5} := Design5_{END}^{\langle 3 \rangle} \cdot in^{-1}$

$F_{SUPP2} := Design2_{SUP}^{\langle 2 \rangle} \cdot kips$ $\quad F_{END2} := Design2_{END}^{\langle 2 \rangle} \cdot kips$

$F_{SUPP3} := Design3_{SUP}^{\langle 2 \rangle} \cdot kips$ $\quad F_{END3} := Design3_{END}^{\langle 2 \rangle} \cdot kips$

$F_{SUPP4} := Design4_{SUP}^{\langle 2 \rangle} \cdot kips$ $\quad F_{END4} := Design4_{END}^{\langle 2 \rangle} \cdot kips$

$F_{SUPP5} := Design5_{SUP}^{\langle 2 \rangle} \cdot kips$ $\quad F_{END5} := Design5_{END}^{\langle 2 \rangle} \cdot kips$

Texas Transportation Institute

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Job #: 444193

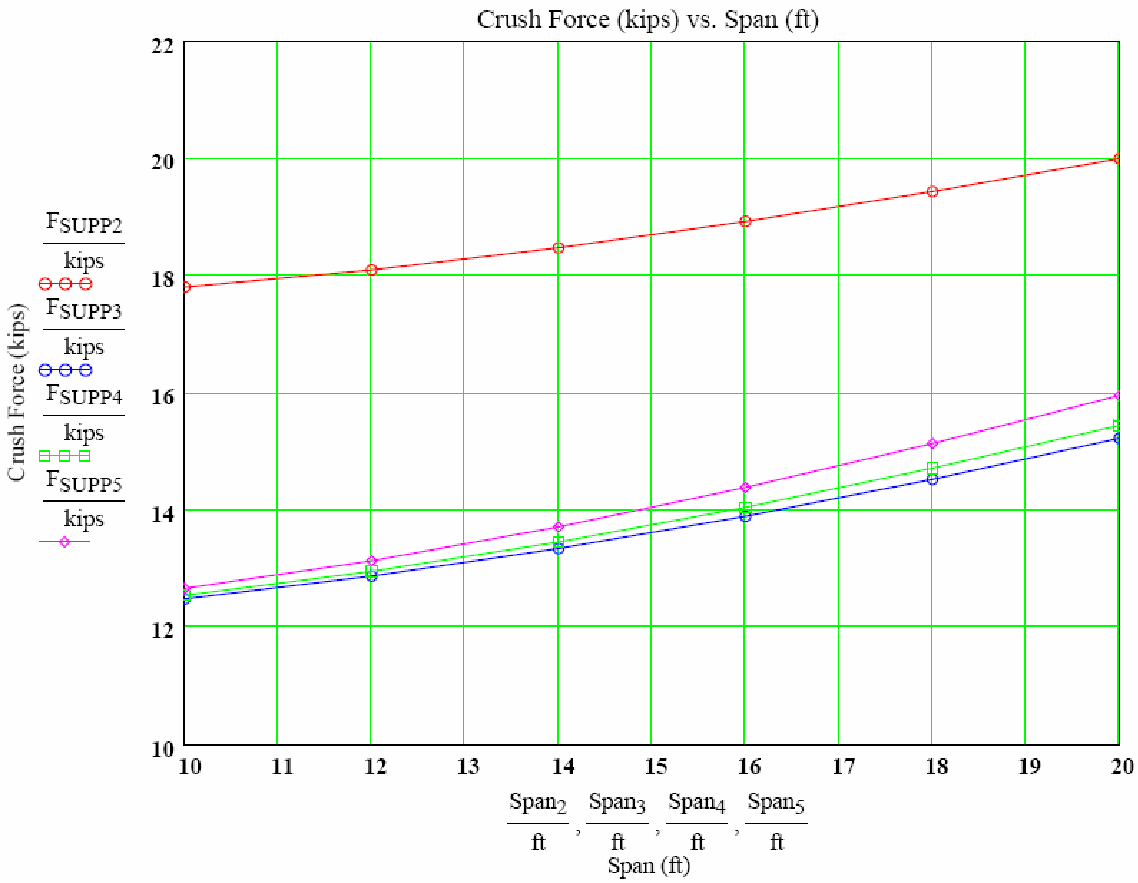
Subject: New Rail Design for New Truss Bridges

Plot of Force vs. Span for Load @ support case

By: William Williams

Checked: ______

Client: Texas Department of Transportation



Design #2: HSS 8x6x6 w/ 8-inch Schedule 80 Pipe Blocks, 6 inches long

Design #3: HSS8x8x6 w/ 10-inch Schedule 80 Pipe Blocks, 6 inches long

Design #4: HSS8x8x5 w/ 10-inch Schedule 80 Pipe Blocks, 6 inches long

Design #5: HSS8x8x4 w/ 10-inch Schedule 80 Pipe Blocks, 6 inches long

Texas Transportation Institute

Job #: 444193

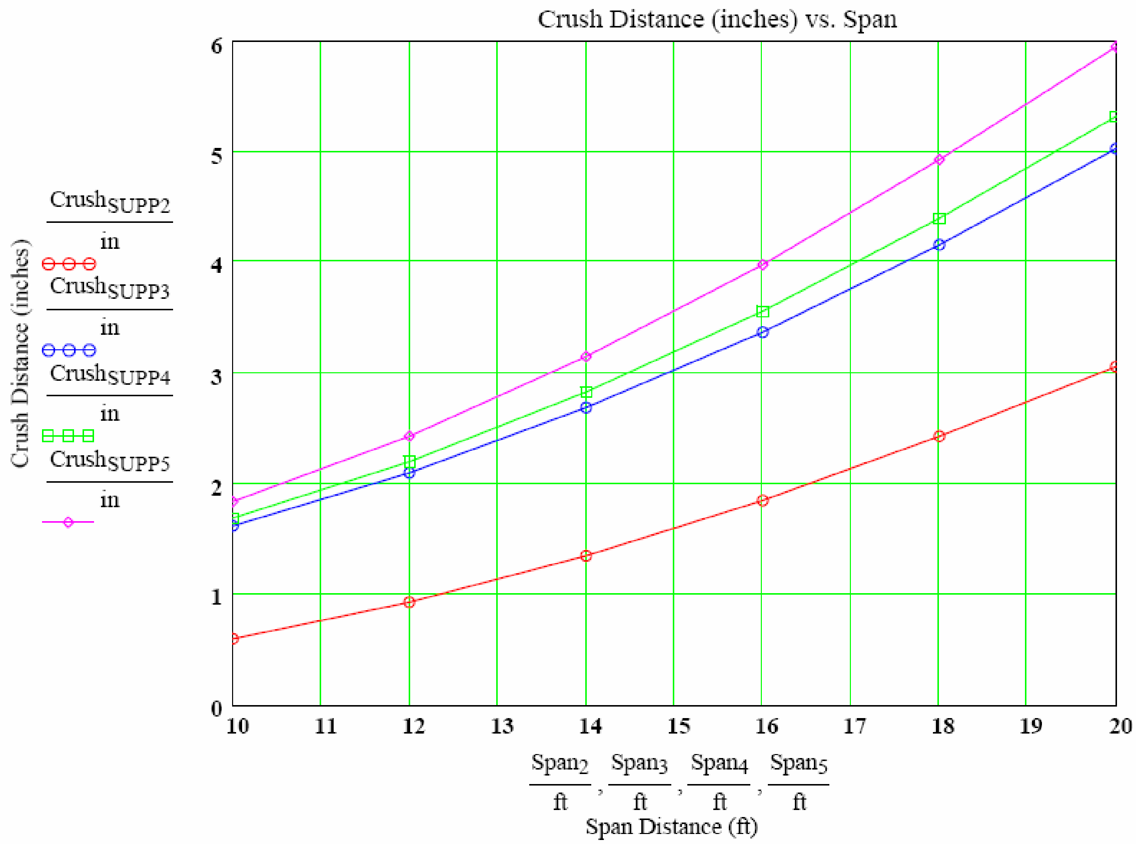
Subject: **New Rail Design for New Truss Bridges**

By: **William Williams**

Plot of Crush vs. Span for Load @ support case

Checked: ______

Client: **Texas Department of Transportation**



Design #2: HSS 8x6x6 with 8-inch Schedule 80 Pipe Blocks, 6 inches long
Design #3: HSS8x8x6 with 10-inch Schedule 80 Pipe Blocks, 6 inches long
Design #4: HSS8x8x5 with 10-inch Schedule 80 Pipe Blocks, 6 inches long
Design #5: HSS8x8x4 with 10-inch Schedule 80 Pipe Blocks, 6 inches long