U.S. Department
of Transportation
Federal Highway Administration

1200 New Jersey Ave., SE
Washington, D.C. 20590

September 28, 2016

In Reply Refer To:
HSST-1/B-265 REVISED

Mr. Rajesh Taneja
New York State Thruway Authority
200 Southern Blvd., P.O. Box 189
Albany, NY 12201-0189

Dear Mr. Rajesh Taneja

This letter is in response to your July 21, 2016 request for the Federal Highway Administration (FHWA) to review a roadside safety device, hardware, or system for eligibility for reimbursement under the Federal-aid highway program. This FHWA letter of eligibility is assigned FHWA control number B-265 and is valid until a subsequent letter is issued by FHWA that expressly references this device.

Decision

The following devices are eligible, with details provided in the form which is attached as an integral part of this letter:

- Modified Three-Tube Bridge Rail (BR208)

Scope of this Letter

To be found eligible for Federal-aid funding, modified roadside safety devices should meet the crash test and evaluation criteria contained in the National Cooperative Highway Research Program (NCHRP) Report 350. However, the FHWA, the Department of Transportation, and the United States Government do not regulate the manufacture of roadside safety devices. Eligibility for reimbursement under the Federal-aid highway program does not establish approval, certification or endorsement of the device for any particular purpose or use.

This letter is not a determination by the FHWA, the Department of Transportation, or the United States Government that a vehicle crash involving the device will result in any particular outcome, nor is it a guarantee of the in-service performance of this device. Proper manufacturing, installation, and maintenance are required in order for this device to function as tested.

This finding of eligibility is limited to the crashworthiness of the system and does not cover other structural features, nor conformity with the Manual on Uniform Traffic Control Devices.

Eligibility for Reimbursement

FHWA previously issued an eligibility letter for the roadside safety system described in your pending request. Your pending request now identifies a modification to that roadside safety system.

The original roadside safety device information is provided here:

Name of system: BR208 Bridge Rail
Type of system: Longitudinal Barrier
Date of original request: April 18, 2003
Date of original FHWA eligibility letter: April 22, 2003
FHWA Control number: B118

The pending modification(s) consists of the following changes:

1. Changing the post type from a W8x24 to W6x25.
2. Decreasing the post spacing from 9.84 feet on center to 4 feet on center.
3. Increasing the overall top-of-rail height from 42 inches to 45 inches.
4. Eliminating the block out sections for lower rails and changing the rail sections to TS 6 x 6 x 3/16 inch for all three rails. The design also includes a 1/2-inch thick shim plate between the post and rails, which was not included in the model. With the shim plate the resulting distance from the traffic face of the rails to the front flange of the posts is 6.5 inches, which is ½ inch less than the BR208.
5. Replacing the 3/4-inch diameter stud bolts that fasten the rails to the posts in the original system with 3/4-inch diameter round-head bolts for the top and middle rails. The lower rail in the modified design is supported on an L5 x 5 x 5/8 inch angle section with a single 3/4-inch diameter bolt passing vertically through the tube and angle support bracket. The support is fastened to the post using two 3/4-inch bolts with nuts and washers.
6. Increasing the number of mounting bolts used to fasten the bridge rail to the top of the curb from 4 bolts to 5 bolts. The additional bolt is placed on the traffic side of the mount-plate (tensile side) in-line and at the midpoint of the other two mounting bolts.
7. Increasing the embedment depth for the anchor bolts from 14 inches to 16.75 inches.
8. Increasing the curb width by 3/4-inch (i.e., increasing from 19.5 inches to 20.25 inches).

FHWA concurs with the recommendation of the accredited crash testing laboratory as stated within the attached form.

Full Description of the Eligible Device

The device and supporting documentation, including Finite Element Analysis (FEA) report, reports of the base-line crash tests or other testing done, videos of base-line crash testing, and/or drawings of the device, are described in the attached form. The NYSTA is expected to be responsive to users or other agencies relying on this eligibility letter on questions that may arise from this documentation and if necessary provide the same data that was submitted to FHWA for review.

Notice

If a manufacturer makes any modification to any of their roadside safety hardware that has an existing eligibility letter from FHWA, the manufacturer must notify FHWA of such modification with a request for continued eligibility for reimbursement. The notice of all modifications to a device must be accompanied by:

- Significant modifications – For these modifications, crash test results must be submitted with accompanying documentation and videos.
- Non-signification modifications – For these modifications, a statement from the crash test laboratory on the potential effect of the modification on the ability of the device to meet the relevant crash test criteria.

FHWA's determination of continued eligibility for the modified hardware will be based on whether the modified hardware will continue to meet the relevant crash test criteria.

Any user or agency relying on this eligibility letter, is expected to use the same designs, specifications, drawings, installation and maintenance instructions as those submitted for review.

Any user or agency relying on this eligibility letter, is expected to ensure that the hardware used has the same chemistry, mechanical properties, and geometry as that submitted for review, and that it will meet the test and evaluation criteria of the NCHRP Report 350.

Issuance of this letter does not convey property rights of any sort or any exclusive privilege. This letter is based on the premise that information and reports submitted by you are accurate and correct. We reserve the right to modify or revoke this letter if: (1) there are any inaccuracies in the information submitted in support of your request for this letter, (2) the qualification testing was flawed, (3) in-service performance or other information reveals safety problems, (4) the system is significantly different from the version that was crash tested, or (5) any other information indicates that the letter was issued in error or otherwise does not reflect full and complete information about the crashworthiness of the system.

Standard Provisions

- To prevent misunderstanding by others, this letter of eligibility designated as FHWA control number B-265 shall not be reproduced except in full. This letter and the test documentation upon which it is based are public information. All such letters and documentation may be reviewed upon request.

- This letter shall not be construed as authorization or consent by the FHWA to use, manufacture, or sell any patented system for which the applicant is not the patent holder.

- If the subject device is a patented product it may be considered to be proprietary. If proprietary systems are specified by a highway agency for use on Federal-aid projects: (a) they must be supplied through competitive bidding with equally suitable unpatented items; (b) the highway agency must certify that they are essential for synchronization with the existing highway facilities or that no equally suitable alternative exists; or (c) they must be used for research or for a distinctive type of construction on relatively short sections of road for experimental purposes. Our regulations concerning proprietary products are contained in Title 23, Code of Federal Regulations, Section 635.411.

Sincerely yours,

(for) Michael S. Griffith
Director, Office of Safety Technologies
Office of Safety

Enclosures

Request for Federal Aid Reimbursement Eligibility of Highway Safety Hardware using Finite Element Analysis (FEA)

Submitter			
	Date of Request:	July 21, 2016	(•) New ( ) Resubmission
	Name:	Chuck A. Plaxico, Ph.D.	
	Company:	RoadSafe, LLC	
	Address:	12 Main Street, Canton, ME 04221	
	Country:	United States of America	
	To:	Michael S. Griffith, Director FHWA, Office of Safety Technologies	

I request the following devices be considered eligible for reimbursement under the Federal-aid highway program.

System Type	Submission Type	Device Name / Variant	Testing Criterion	Test Level
'B': Barriers (Roadside, Median, Bridge Railings)	(•) FEA & V&V Analysis	Modified Three-Tube Bridge Rail (BR208)	NCHRP Report 350	TL4

By submitting this request for review and evaluation by the Federal Highway Administration, I certify that the product(s) was (were) tested in conformity with the NCHRP Report 350 (Report 350) and that the evaluation results meet the appropriate evaluation criteria in the Report 350.

Identification of the individual or organization responsible for the product:

Contact Name:	Rajesh Taneja	Same as Submitter ☐
Company Name:	New York State Thruway Authority	Same as Submitter ☐
Address:	200 Southern Blvd., P.O. Box 189, Albany, NY 12201-0189	Same as Submitter ☐
Country:	United States of America	Same as Submitter ☐
Enter below all disclosures of financial interests as required by the FHWA 'Federal-Aid Reimbursement Eligibility Process for Safety Hardware Devices' document.		
RoadSafe, LLC is a paid Consultant for NYSTA for this eligibility request. The barrier is non-proprietary and RoadSafe, LLC has no further financial interest in the use of this barrier.		

This request is for a determination of Federal-aid reimbursement eligibility using Finite Element Analysis and Verification and Validation Analysis [NCHRP Web-Only Document 179] (WD-179) for a structural change to previously eligible hardware where the effect on the crash test performance of the hardware is Non-Significant - Effect is Positive or Inconsequential.

FEA PRODUCT DESCRIPTION

Modification to Existing Hardware	◉ Non-Significant - Effect is Positive or Inconsequential

The baseline BR208 bridge rail consists of three TS 7 x 4 x ¼ inch tubes supported by W8x24 steel posts on 9.84-ft (118 in) centers. The distance from the deck surface to the center of the lower rail element is 16 inches; the distance from the deck to the center of the middle rail element is 28.8 inches; and the distance from the deck to the center of the top rail element is 40 inches. The two lower rails are blocked out from the support posts with TS 7 x 3 x ¼ inch steel tubes that are 6.5 inches long. The top tube is installed with the narrow side against the post. A single ¾-inch diameter stud bolt is welded onto the backside of the tubes at each post location, and each rail is then fastened to the W8x24 post using a flat-washer, lock-washer and nut. The posts are welded to a 12″ x 13″ x 1″ steel plate; the plate is then mounted onto the top of a 7-inch high curb using four 7/8-inch diameter A325 steel bolts.

The modified design consists of three TS 6 x 6 x 3/16 inch tubes supported by W6x25 steel posts on 4-ft centers. The distance from the deck surface to the center of the lower rail element is 18 inches; the distance from the deck to the center of the middle rail element is 30 inches; and the distance from the deck to the center of the top rail element is 42 inches. The rails are blocked out from the support posts using ½-inch thick shim plates (as necessary) such that the face of the rail is flush with the curb face of the curb. The top two rail elements are each fastened to the post using two 3/4-inch diameter round-head bolts. The lower rail is supported on an L5 x 5 x 5/8-inch angle section with a single 3/4-inch diameter bolt passing vertically through the tube and angle support bracket. The support is fastened to the post using two 3/4-inch bolts with nuts and washers. The posts are welded to a 16.5″ x 12.25″ x 1.5″ steel plate; the plate is then mounted onto the top of a 7-inch high curb using five 7/8-inch diameter A325 steel bolts.

The key modifications to the system include:

1) Changing the post type from a W8x24 to W6x25.

2) Decreasing the post spacing from 9.84 feet on center to 4 feet on center.

3) Increasing the overall top-of-rail height from 42 inches to 45 inches.

4) Eliminating the blockout sections for the lower rails and changing the rail sections to TS 6 x 6 x 3/16 inch for all three rails. The design also includes a 1/2-inch thick shim plate between the post and rails, which was not included in the model. With the shim plate the resulting distance from the traffic face of the rails to the front flange of the posts is 6.5 inches, which is ½ inch less than the BR208.

5) Replacing the 3/4-inch diameter stud bolts that fasten the rails to the posts in the original system with 3/4-inch diameter round-head bolts for the top and middle rails. The lower rail in the modified design is supported on an L5 x 5 x 5/8 inch angle section with a single 3/4-inch diameter bolt passing vertically through the tube and angle support bracket. The support is fastened to the post using two 3/4-inch bolts with nuts and washers.

6) Increasing the number of mounting bolts used to fasten the bridge rail to the top of the curb from 4 bolts to 5 bolts. The additional bolt is placed on the traffic side of the mount-plate (tensile side) in-line and at the midpoint of the other two mounting bolts.

7) Increasing the embedment depth for the anchor bolts from 14 inches to 16.75 inches.

8) Increasing the curb width by 3/4-inch (i.e., increasing from 19.5 inches to 20.25 inches).

FEA PRODUCT DESCRIPTION

9) Increasing depth of the curb and deck by 6.12 inches (i.e., increasing from 14.88 inches to 21 inches).

Based on strength calculations performed according to the procedures contained in Appendix A13.2 of the AASHTO LRFD Bridge Design Specifications, 6th Ed. 2012, the modified bridge rail design is approximately 53 percent stronger than the baseline design. The modified design also results in better distribution of the load between the bridge rail and curb to reduce the possibility for damage to the curb and deck.

FEA ANALYSIS OF BASELINE CRASH

Description shall include comparison of FEA results

Required Baseline Crash Test Number	Narrative Description	FEA Analysis Results According to Report 350?	V&V Analysis Results in accordance to WD-179?
4-10 (820C)	The 820C vehicle model impacted the modified bridge rail at 62.6 mph at an impact angle of 19.7 degrees, which was consistent with the full-scale test. The impact point was 3.61 feet upstream of the critical post, or 1.6 feet upstream of the rail splice. The results of the showed that the system would successfully contain and redirect the vehicle with negligible damage to the bridge rail. The maximum dynamic deflection of the rail was 0.315 inches (8 mm) on the lower rail element at the splice connection, and the maximum permanent deformation was 0.0236 inches (0.6 mm) on the lower rail just upstream of the splice. The occupant risk measures and the vehicle trajectory also met the criteria specified in R350. The overall phenomenological behavior of the barrier and the vehicle was very similar for both the baseline and modified designs. There was good agreement with respect to event timing, overall kinematics of the vehicle, barrier damage and barrier deflections. Both the qualitative and quantitative comparisons of the time-history data indicated that the analysis of the modified design sufficiently replicates the results of the crash test on the baseline design. Based on these assessments it was concluded that the performance of the modified design meets the FHWA criteria for a non-significant change.	PASS	YES

Required Baseline Crash Test Number	Narrative Description	FEA Analysis results according to AASHTO MASH?	V&V Analysis Results in accordance to WD-179?
S4-10 (700C)	This test involves the 700C vehicle impacting at 62.2 mph and 20 degrees. This is a non-critical test and was not performed on the baseline design. This test was also not simulated for the modified design.	NON-CRITICAL, TEST NOT CONDUCTED	NON-CRITICAL, TEST NOT CONDUCTED

4-11 (2000P)	The vehicle model used in the analysis was the NCAC C2500D version 5B. The impact conditions for the analysis involved the 4,577-lb pickup model striking the bridge rail at 3.94 feet upstream of Post 8 (or 1.94 feet upstream of the splice) traveling at a speed of 62.6 mph (100.7 km/hr) and at an angle of 25.4 degrees with respect to the bridge rail. These conditions are consistent with those used in the assessment of the baseline bridge rail system in the full-scale crash test 404201-8 and the baseline FE analysis cases, except that the impact point was approximately 4 inches closer to the critical post for the analysis of the modified barrier. This impact point was considered to be more critical based on the closer spacing of the bridge rail posts in the modified design and is also consistent with recommendations in R350. The results of the FEA of the 2000P vehicle model impacting the proposed three-rail (modified Oregon 3-Tube rail) bridge rail under R350 Test 4-11 impact conditions showed that the system would successfully contain and redirect the vehicle with minimal damage to the bridge rail. The occupant risk measures and the vehicle trajectory also met the criteria specified in R350. In the full-scale test of the baseline design, the concrete curb ruptured the critical post downstream of the rail splice connection, resulting in higher lateral deflections of the bridge rail compared to the deflections for modified design. The decreased spacing of the posts in the modified design, as well as the increased reinforcing of the curb, therefore, resulted in better performance regarding the structural capacity of the bridge rail and the integrity of the curb/deck system. Based on these assessments it was concluded that the performance of the modified design meets the FHWA criteria for a non-significant change.	PASS	YES

4-12 (8000S)	The vehicle model used in analysis was the 8000S single unit truck model developed at the National Crash Analysis Center (NCAC) in Ashburn, VA which has been further modified by various researchers over the years to improve their fidelity in analysis of impact conditions corresponding to R350 Test 4-12. The impact conditions for the analysis involved the 17,363-lb (7,876 kg) single unit truck model striking the bridge rail at speed of 50.5 mph and at an impact angle of 15 degrees. These conditions are consistent with those used in the assessment of the baseline bridge rail system in the full-scale crash test and the baseline FE analysis cases. Recall that the impact point for the baseline case was approximately 4.6 feet upstream of a bridge rail post and approximately 2.63 feet downstream of the tube-rail splice. For the analysis of the modified design, the impact point was set to 4.92 feet upstream of the critical post (based on the critical impact point recommended in Report 350) located immediately downstream of the rail-tube splice. This corresponded to an impact point of 2.93 feet upstream of the splice. The results of the analysis showed that the system would successfully contain and redirect the 8000S with minimal damage to the bridge rail. The occupant risk measures and the vehicle trajectory also met the criteria specified in R350. The overall phenomenological behavior of the barrier and the vehicle for Test 4-12 was also very similar for both the baseline and modified designs. There was good agreement with respect to event timing, overall kinematics of the vehicle, barrier damage and barrier deflections. Both the qualitative and quantitative comparisons of the time-history data indicated that the analysis of the modified design sufficiently replicates the results of the crash test on the baseline design. Based on these assessments it was concluded that the performance of the modified design meets the FHWA criteria for a non-significant change.	PASS	YES

4-20 (820C)	This test is considered optional in R350 and is recommended only when there is a reasonable uncertainty regarding impact performance with smaller passenger vehicles. The bridge rail in this case is connecting to a rigid concrete parapet. Since both the railing and the concrete parapet are rigid systems (e.g., rail deflection was 0.315 inches) a transition is not required and the railing can be connected directly to the concrete parapet.	NON-CRITICAL, TEST NOT CONDUCTED	NON-CRITICAL, TEST NOT CONDUCTED
S4-20 (700C)	This test is optional and was not evaluated for the same reasons as stated for Test 4-20.	NON-CRITICAL, TEST NOT CONDUCTED	NON-CRITICAL, TEST NOT CONDUCTED
4-21 (2000P)	This test is considered optional in R350 and is recommended only when there is a reasonable uncertainty regarding impact performance with larger passenger vehicles. The bridge rail in this case is also considered rigid since the deflection under Test 4-11 was only 0.7 inches; thus a transition is not required and the railing can be connected directly to the concrete parapet.	NON-CRITICAL, TEST NOT CONDUCTED	NON-CRITICAL, TEST NOT CONDUCTED
4-22 (8000S)	This test is considered optional in R350 and is recommended only when there is a reasonable uncertainty regarding strength capacity of the section in containing and redirecting the heavy test vehicle. The bridge rail in this case is also considered rigid since the deflection under Test 4-12 was only 0.55 inches; thus a transition is not required and the railing can be connected directly to the concrete parapet.	NON-CRITICAL, TEST NOT CONDUCTED	NON-CRITICAL, TEST NOT CONDUCTED

VALIDATION /VERIFICATION PHENOMENA IMPORTANCE RANKING TABLES

Check all of the following model validation forms that are included as enclosures to this eligibility submission. In addition for each submitted form provide commenary on results and all relevant exceptions including a list of all model parameter variances within in the submitted analysis.

☒ TYPE OF REPORT	☒ PART II: ANALYSIS SOLUTION	☒ PART IV: PIRT ROADSIDE
☒ PART I: BASIC INFORMARTION	☒ PART III: TIME HISTORY EVAL.	☒ PART V: PIRT TEST VEHICLE

TYPE OF REPORT

Two validation reports for the baseline design model were submitted. These include comparison of FEA vs full-scale tests 404201-8 (i.e., R350 Test 4-11) and 404201-9 (i.e., R350 Test 4-12). Three validation reports for the modified design model were submitted. These include comparison of FEA for modified design vs full-scale tests of baseline design for simulation of Tests 404201-7 (Test R350 Test 4-10), 404201-8 (i.e., R350 Test 4-11) and 404201-9 (i.e., R350 Test 4-12). FEA Summary Sheets for these cases are included with this FORM. Additional analysis results were included in the final report which was submitted separately.

PART I: BASIC INFORMARTION

The system type is a longitudinal barrier named “Modified Three-Tube Bridge Rail (BR208)”. The barrier was tested using NCHRP Report 350 criteria to a Test Level 4.

PART II: ANALYSIS SOLUTION
The analysis verification met NCHRP Report W179 in all cases without exceptions, except for the baseline validation for Test 4-11 (2000P test). The increase in energy was assumed to be related to the failure of the concrete (including the erosion of the failed concrete elements) and possibly the release of the constraints between the rebar and the failed concrete elements. This was further verified in a later analysis involving the same model in which the concrete did not fail and the change in total energy was 0%.
PART III: TIME HISTORY EVAL.
The multi-channel evaluation of the time-history data passes all criteria without exceptions for all cases.

PART IV: PIRT ROADSIDE

2000P Vehicle FEM: The finite element model used for the 2000P vehicle was the NCAC C2500D version 5B model. This model has been used extensively over the past decade in simulating R350 TL3 impact scenarios with great success. [Plaxico06; Plaxico07; Marzougui08; Marzougui10; Plaxico15] It has also been validated against NHTSA end-cap tests [Zaouk96]. Additional validation PIRTs for the model were provided by George Mason University and are included with this report as Appendix M. Modifications to the model included remeshing various parts in the impact region of the model and changing the element type to the fully integrated shell element (i.e., type 16 in LS-DYNA).

2000P References:

Marzougui08: Marzougui, D. and S. Kan, “Advanced Crash Analyses to Improve Safety & Security”, FHWA Contract DTFH61-09-D-00001, National Crash Analysis Center, George Washington University, VA (2008).

Marzougui10: Marzougui, D., M. Zink, A. Zaouk, C.D. Kan, and N. Dedewi, “Development and Validation of a Vehicle Suspension Finite Element Model for Use in Crash Simulations,” International Journal of Crashworthiness, 9:6, 565-576, DOI: 10.1533/ijcr.2004.0311 (2010).

Plaxico06: Plaxico, C.A., J.C. Kennedy and C.R. Miele, “Development of an NCHRP Report 350 TL-3 New Jersey Shape 50-inch Portable Concrete Barrier,” Final Report No. FHWA/OH-2006/16, Ohio Department of Transportation, Columbus, OH (June 2006).

Plaxico07: Plaxico, C.A., Kennedy, J.C., and Miele, C.R., “Evaluation and Redesign of a Culvert Guardrail and Transition System,” Technical Report, Ohio Department of Transportation, 2007.

Plaxico15: Plaxico, C.A., M.H. Ray, C.E. Carrigan, T.O. Johnson, and A. Ray, “Criteria for Restoration of Longitudinal Barriers, Phase II,” Final Report, NCHRP Project 22-28, National Academy of Sciences, Washington D.C. (2015).

Zaouk96: Zaouk, A.K., N.E. Bedewi, C.D. Kan, and D. Marzougui, “Validation of a Non-Linear Finite Element Vehicle Model Using Multiple Impact Data,” The American Society of Mechanical Engineers (1996).

8000S Vehicle FEM: The 8000S single unit truck finite element model used in this study was developed at the National Crash Analysis Center (NCAC) in Ashburn, VA and has been further modified by various researchers over the years to improve its fidelity in analysis of impact conditions corresponding to R350 Test 4-12. [Miele05; Mohan07; Plaxico13] For this impact case, the model of the ballast was modified in order to calibrate the mass inertial properties of the vehicle model to the properties of the test vehicle. The ballast was modeled as a rigid block with dimensions 48 inches wide x 52 inches long x 30.5 inches tall.

8000S References:

Miele05: Miele, C.R., C.A. Plaxico, J.C. Kenedy, S. Simunovic and N. Zisi, “Heavy Vehicle-Infrastructure Asset Interaction and Collision,” Final Report Prepared for the U.S. Department of transportation, Cooperative Agreement No. DTFH61-03-X-00030, McLean, Virginia (2005).

Mohon07: Mohan, P.D. Marzougi and C.D. Kan, “Validation of a Single Unit Truck Model for Roadside Hardware Impact,” Int. J. of Vehicle Systems Modeling and Testing, Vol. 2, No. 1, pp. 1-15 (2007).

Plaxico13: Plaxico, C.A. and M.H. Ray, “Modified NETC 4-Bar Bridge Rail for Steel Through-Truss Bridges,” Final Report No. 14-0224, Performed for Structal Bridges, Inc., Performed by RoadSafe LLC, Canton, ME (December 2013).

820C Vehicle FEM: The 820C vehicle model used in this study was the Geo Metro reduced element model version V02c developed at the NCAC with updates to the tires and suspension made by researchers at Polytechnic Di Milano. Researchers in the European community have used the 820C vehicle model much more extensively than U.S. researchers and have made significant improvements to the model. Dr. Marco Anghileri at Politechnico di Milano has made the most notable improvements to the model. In a previous study conducted by Dr. Plaxico for Plastic Safety Systems, Inc. Dr. Anghileri’s model was used to evaluate a sand barrel crash cushion under R350 Test 3-40 and 3-42 impact conditions. [Plaxico05] The front suspension showed an overly stiff response (probably due to the characterization of the shock absorber model), but overall the model performed reasonably well based on comparisons to the full-scale tests. Professor Anghileri’s version of the Geo Metro model was used in this study with additional modifications made by the research team in this project. The modifications were limited to adding hourglass control to all shell element parts and modifications to the self-contact definitions for the vehicle components.

820C References:

Plaxico05: Plaxico, C.A., Kennedy, J.C., and Miele, C.R., “Analysis of Plastic Safety System’s Crashgard Sand Barrel System,” Technical Report, Ohio Department of Transportation, 2005.

Plaxico07: Plaxico, C.A., Kennedy, J.C., and Miele, C.R., “Evaluation and Redesign of a Culvert Guardrail and Transition System,” Technical Report, Ohio Department of Transportation, 2007.

PART V: PIRT TEST VEHICLE

2000P Vehicle FEM: The finite element model used for the 2000P vehicle was the NCAC C2500D version 5B model. This model has been used extensively over the past decade in simulating R350 TL3 impact scenarios with great success; it has also been validated against NHTSA end-cap tests [see final report for references]. Additional validation PIRTs for the model were provided by George Mason University and are included as Appendix M. Modifications made to the model for this study included remeshing various parts in the impact region of the model and changing the element type to the fully integrated shell element (i.e., type 16 in LS-DYNA).

8000S Vehicle FEM: The 8000S single unit truck finite element model used in this study was developed at the National Crash Analysis Center (NCAC) in Ashburn, VA and has been further modified by various researchers over the years to improve its fidelity in analysis of impact conditions corresponding to R350 Test 4-12 [see final report for references]. For this study the model of the ballast was modified to calibrate the mass and inertial properties of the vehicle model to the properties of the test vehicle. The ballast was modeled as a rigid block with dimensions 48 inches wide x 52 inches long x 30.5 inches tall.

820C Vehicle FEM: The 820C vehicle model used in this study was the Geo Metro reduced element model version V02c developed at the NCAC with updates to the tires and suspension made by researchers at Polytechnic Di Milano. Researchers in the European community have used the 820C vehicle model much more extensively than U.S. researchers and have made significant improvements to the model. Dr. Marco Anghileri at Politechnico di Milano has made the most notable improvements to the model. In a previous study conducted by Dr. Plaxico for Plastic Safety Systems, Inc. Dr. Anghileri's model was used to evaluate a sand barrel crash cushion under R350 Test 3-40 and 3-42 impact conditions [see final report for references]. The front suspension showed an overly stiff response (probably due to the characterization of the shock absorber model), but overall the model performed reasonably well based on comparisons to the full-scale tests. Professor Anghileri's version of the Geo Metro model was used in this study with some additional modifications, which were limited to adding hourglass control to all shell element parts and modifications to the self-contact definitions for the vehicle components.

The submitted Finite Element Analysis was conducted in compliance with FHWA Memorandum 'Roadside Safety Hardware -Federal-Aid Reimbursement Eligibility Process', dated May 21, 2012 including all updates to this memorandum by the following accredited laboratory (cite laboratory's accreditation status in the FEA Analysis final report):

I certify that the product(s) was (were) analyzed in conformity with the NCHRP Report 350 and that the evaluation results meet the appropriate evaluation criteria in the Report 350.		
FEA & V&V Laboratory Name:	Roadsafe LLC, Canton ME.	
FEA & V&V Laboratory Contact:	Chuck A. Plaxico, Ph.D	Same as Submitter ☐
Address:	12 Main Street, Canton, ME 04221	Same as Submitter ☐
Country:	United States of America	Same as Submitter ☐

Submitter Signature*: Chuck Plaxico

ATTACHMENTS

Attach to this form:

Finite Element Analysis using LS-Dyna that shows the modified hardware will perform in a similar manner to the NCHRP Report 350 crash testing that was first used to evaluate roadside hardware.

2) Validation and Verification (V&V) analysis and report conforming to Appendix E as per the NCHRP W 179 [NCHRP Web-Only Document 179] shall be submitted for both the original model compared to the baseline test and the model of the non-significant change compared to the baseline test.

3) A drawing or drawings of the device(s) that conform to the Task Force-13 Drawing Specifications [Hardware Guide Drawing Standards]. For proprietary products, a single isometric line drawing is usually acceptable to illustrate the product, with detailed specifications, intended use, and contact information provided on the reverse. Additional drawings (not in TF-13 format) showing details that are key to understanding the performance of the device should also be submitted to facilitate our review.

FHWA Official Business Only:

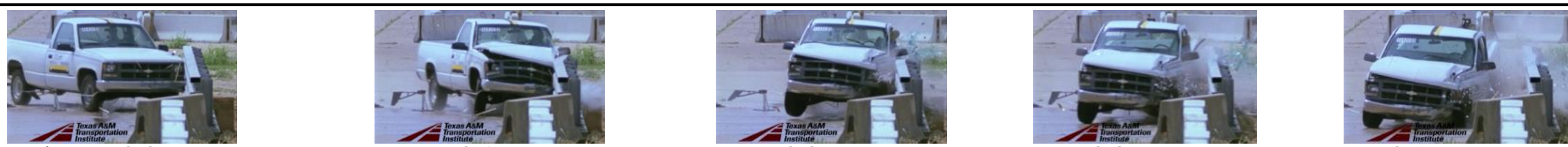
Eligibility Letter		AASHTO TF13	
Number	Date	Designator	Key Words

Table 20. Summary of validation metrics for the model in simulation of Test 404201-8 (pickup test).

Summary of FEA vs. Test Validation Metrics

System Type:	Bridge Rail	Comparison:	Crash tested original design to FEA of original design
Device Name:/Variant:	Oregon Three-Tube Bridge Rail	Submissions Type:	[ ] Non-Significant -- Effect is Uncertain
Testing Criterion:	Report 350		[ ] Non-Significant -- Effect is Positive
Test Level:	TL4		[ ] Non-Significant -- Effect is Inconsequential
FHWA Letter:	B118		[X] Baseline Validation of Crash Test to FEA Analysis.

Crash Test



Time = 0.0 sec | 0.1 sec | 0.2 sec | 0.3 sec | 0.4 sec

FEA Analysis

Baseline Crash Test	
Test Number:	TTI 404201-8
Vehicle:	1995 Chevrolet Chyenne 2500
Vehicle Mass:	4,577 lb
Impact Speed:	62.6 mph
Impact Location:	51.2" upstream of Post 4
Tested Hardware:	Original Design
FEA Hardware:	Original Design

W-179 Table E-1: Verification Evaluation Summary		
Total Energy:	14%	No
Hourglass Energy:	0%	Pass
Mass Added:	0%	Pass
Shooting Nodes:	no	Pass
Negative Volumes:	no	Pass

W-179 Table E-5: Roadside PIRTS

Structural Adequacy	Test	FEA
A1 - Acceptable perf.?	yes	yes
A2 – Permanent Deflection:	4.3 in	5.1 in
A3 – Contact Length	11.9 ft	10.8 ft
A4 - Component Failure	yes	yes
A5 – Barrier Rupture?	no	no
A7 – Wheel Snagging?	no	no
A8 – Vehicle Snagging?	no	no
Occupant Risk	**Test**	**FEA**
D – Detached elements?	no	no
F2 – Max. Vehicle Roll	2	7.2
F3 – Max. Vehicle Pitch	4	2
F4 – Max. Vehicle Yaw	29.7	31.1

Occupant Risk (cont.)	Test	FEA
H2 – Long. OIV	5.0m/s	5.1 m/s
H3 – Lat. OIV	-8 m/s	-9.3 m/s
I2 – Long. ORA	4.2 g	7.8 g
I3 – Lat. ORA	9.3 g	10.5 g
Vehicle Trajectory		
K – Intruded into travel lanes?	no	no
N – Travel behind barrier?	no	no
W-179 Table E-3 (Multi-Channel Method)		
Sprague-Geer Magnitude < 40	13.6	Pass
Sprague-Geer Phase < 40	22.8	Pass
ANOVA Mean	1.2	Pass
ANOVA Standard Deviation	20.6	Pass

Table 21. Summary of validation metrics for the model in simulation of Test 404201-9 (SUT test).

Summary of FEA vs. Test Validation Metrics

System Type:	Bridge Rail	Comparison:	Crash tested original design to FEA of original design
Device Name:/Variant:	Oregon Three-Tube Bridge Rail	Submissions Type:	[ ] Non-Significant -- Effect is Uncertain
Testing Criterion:	Report 350		[ ] Non-Significant -- Effect is Positive
Test Level:	TL4		[ ] Non-Significant -- Effect is Inconsequential
FHWA Letter:	B118		[X] Baseline Validation of Crash Test to FEA Analysis.

Crash Test

Time = 0.0 sec | 0.2 sec | 0.4 sec | 0.6 sec | 0.8 sec

FEA Analysis

Baseline Crash Test	
Test Number:	TTI 404201-9
Vehicle:	1996 GMC single-unit truck
Vehicle Mass:	17,363 lbs
Impact Speed:	50.5 mph
Impact Location:	55.1" upstream of Post 4
Tested Hardware:	Original Design
FEA Hardware:	Original Design

W-179 Table E-1: Verification Evaluation Summary		
Total Energy:	0%	Pass
Hourglass Energy:	0%	Pass
Mass Added:	0%	Pass
Shooting Nodes:	no	Pass
Negative Volumes:	no	Pass

W-179 Table E-5: Roadside PIRTS

Structural Adequacy	Test	FEA	Occupant Risk (cont.)	Test	FEA
A1 - Acceptable perf.?	yes	yes	H2 – Long. OIV	1.7 m/s	2.5 m/s
A2 – Dynamic Deflection:	2 in	1.6 in	H3 – Lat. OIV	4.9 m/s	4.3 m/s
A3 – Contact Length	17 ft	20.5 ft	I2 – Long. ORA	2.3 g	2.1 g
A4 - Component Failure	no	no	I3 – Lat. ORA	9.2 g	7.3 g
A5 – Barrier Rupture?	no	no	**Vehicle Trajectory**		
A7 – Wheel Snagging?	no	no	K – Intruded into travel lanes?	no	no
A8 – Vehicle Snagging?	no	no	N – Travel behind barrier?	no	no
Occupant Risk	**Test**	**FEA**	**W-179 Table E-3 (Multi-Channel Method)**		
D – Detached elements?	no	no	Sprague-Geer Magnitude < 40	30.7	Pass
F2 – Max. Vehicle Roll	4.3	7.3	Sprague-Geer Phase < 40	30.6	Pass
F3 – Max. Vehicle Pitch	1.3	4.5	ANOVA Mean	1.7	Pass
F4 – Max. Vehicle Yaw	18.3	17.7	ANOVA Standard Deviation	30.8	Pass

Table 45. Summary of comparison metrics for the modified design (FEA) and baseline design (full-scale test) for NCHRP Report 350 test 4-10 impact conditions.

System Type:	Bridge Rail	Comparison:	Crash tested original design to FEA of modified design	
Device Name:/Variant:	Oregon Three-Tube Bridge Rail	Submissions Type:		Non-Significant -- Effect is Uncertain
Testing Criterion:	Report 350			Non-Significant -- Effect is Positive
Test Level:	TL4		X	Non-Significant -- Effect is Inconsequential
FHWA Letter:	B118			Baseline Validation of Crash Test to FEA Analysis.

Baseline

Modified

Time = 0.0 sec | 0.05 sec | 0.1 sec | 0.15 sec | 0.2 sec | 0.25 sec | 0.3 sec

Baseline Crash Test	
Test Number:	TTI 404201-7
Vehicle:	1995 Geo Metro
Vehicle Mass:	1,975 lb
Impact Speed:	62.6 mph
Impact Location:	59.1" upstream of Post 4
Tested Hardware:	Original Design
FEA Hardware:	Modified Design

W-179 Table E-1: Verification Evaluation Summary		
Total Energy:	0%	No
Hourglass Energy:	0%	Pass
Mass Added:	0%	Pass
Shooting Nodes:	no	Pass
Negative Volumes:	no	Pass

W-179 Table E-5: Roadside PIRTS

Structural Adequacy	Test	FEA
A1 - Acceptable perf.?	yes	yes
A2 – Permanent Deflection:	2 mm	2.4
A3 – Contact Length	7.8 ft	7.3 ft
A4 - Component Failure	yes	no
A5 – Barrier Rupture?	no	no
A7 – Wheel Snagging?	no	no
A8 – Vehicle Snagging?	no	no
Occupant Risk	**Test**	**FEA**
D – Detached elements?	no	no
F2 – Max. Vehicle Roll	7.3	1
F3 – Max. Vehicle Pitch	3.1	1.1
F4 – Max. Vehicle Yaw	32.4	34.7

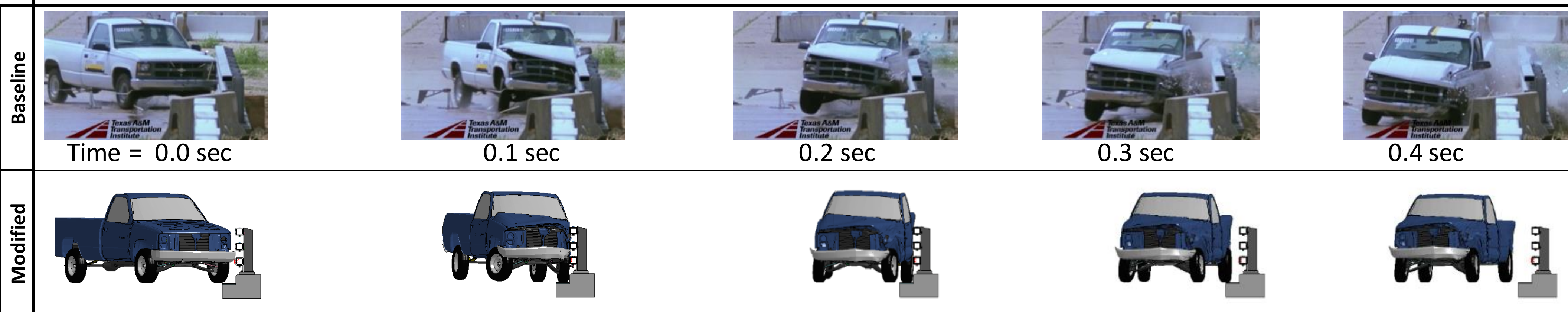
Occupant Risk (cont.)	Test	FEA
H2 – Long. OIV	3.6 m/s	4.1 m/s
H3 – Lat. OIV	-8.4 m/s	-7.1 m/s
I2 – Long. ORA	-5.2 g	-2.9 g
I3 – Lat. ORA	13.0 g	15.8 g
Vehicle Trajectory		
K – Intruded into travel lanes?	yes	probable
N – Travel behind barrier?	no	no

W-179 Table E-3 (Multi-Channel Method)		
Sprague-Geer Magnitude < 40	10.7	Pass
Sprague-Geer Phase < 40	18.6	Pass
ANOVA Mean	2.2	Pass
ANOVA Standard Deviation	17.2	Pass

Table 46. Summary of comparison metrics for the modified design (FEA) and baseline design (full-scale test) for NCHRP Report 350 test 4-11 impact conditions.

System Type:	Bridge Rail
Device Name:/Variant:	Oregon Three-Tube Bridge Rail
Testing Criterion:	Report 350
Test Level:	TL4
FHWA Letter:	B118

Comparison:	Crash tested original design to FEA of modified design	
Submissions Type:		Non-Significant -- Effect is Uncertain
		Non-Significant -- Effect is Positive
	X	Non-Significant -- Effect is Inconsequential
		Baseline Validation of Crash Test to FEA Analysis.



Baseline Crash Test	
Test Number:	TTI 404201-8
Vehicle:	1995 Chevrolet Chyenne 2500
Vehicle Mass:	4,577 lb
Impact Speed:	62.6 mph
Impact Location:	51.2" upstream of Post 4
Tested Hardware:	Original Design
FEA Hardware:	Modified Design
W-179 Table E-1: Verification Evaluation Summary	
Total Energy:	0% No
Hourglass Energy:	
Mass Added:	
Shooting Nodes:	
Negative Volumes:	

W-179 Table E-5: Roadside PIRTS

Structural Adequacy	Test	FEA	Occupant Risk (cont.)	Test	FEA
A1 - Acceptable perf.?	yes	yes	H2 – Long. OIV	5 m/s	4.8
A2 – Dynamic Deflection:	4.3 in	0.7 in	H3 – Lat. OIV	-8 m/s	-9.2
A3 – Contact Length	11.9 ft	10.2 ft	I2 – Long. ORA	4.2 g	8.6
A4 - Component Failure	yes	no	I3 – Lat. ORA	17.1 g	13.9
A5 – Barrier Rupture?	no	no	**Vehicle Trajectory**		
A7 – Wheel Snagging?	no	no	K – Intruded into travel lanes?	yes	prob
A8 – Vehicle Snagging?	no	no	N – Travel behind barrier?	no	no
Occupant Risk	**Test**	**FEA**	**W-179 Table E-3 (Multi-Channel Method)**		
D – Detached elements?			Sprague-Geer Magnitude < 40		
F2 – Max. Vehicle Roll			Sprague-Geer Phase < 40		
F3 – Max. Vehicle Pitch			ANOVA Mean		
F4 – Max. Vehicle Yaw	29.7	34.6	ANOVA Standard Deviation	20.8	

Table 47. Summary of comparison metrics for the modified design (FEA) and baseline design (full-scale test) for NCHRP Report 350 test 4-12 impact conditions.

System Type:	Bridge Rail	Comparison:	Crash tested original design to FEA of original design	
Device Name:/Variant:	Oregon Three-Tube Bridge Rail	Submissions Type:		Non-Significant -- Effect is Uncertain
Testing Criterion:	Report 350			Non-Significant -- Effect is Positive
Test Level:	TL4		X	Non-Significant -- Effect is Inconsequential
FHWA Letter:	B118			Baseline Validation of Crash Test to FEA Analysis.

Baseline

Time = 0.0 sec 0.2 sec 0.4 sec 0.6 sec 0.8 sec

Modified

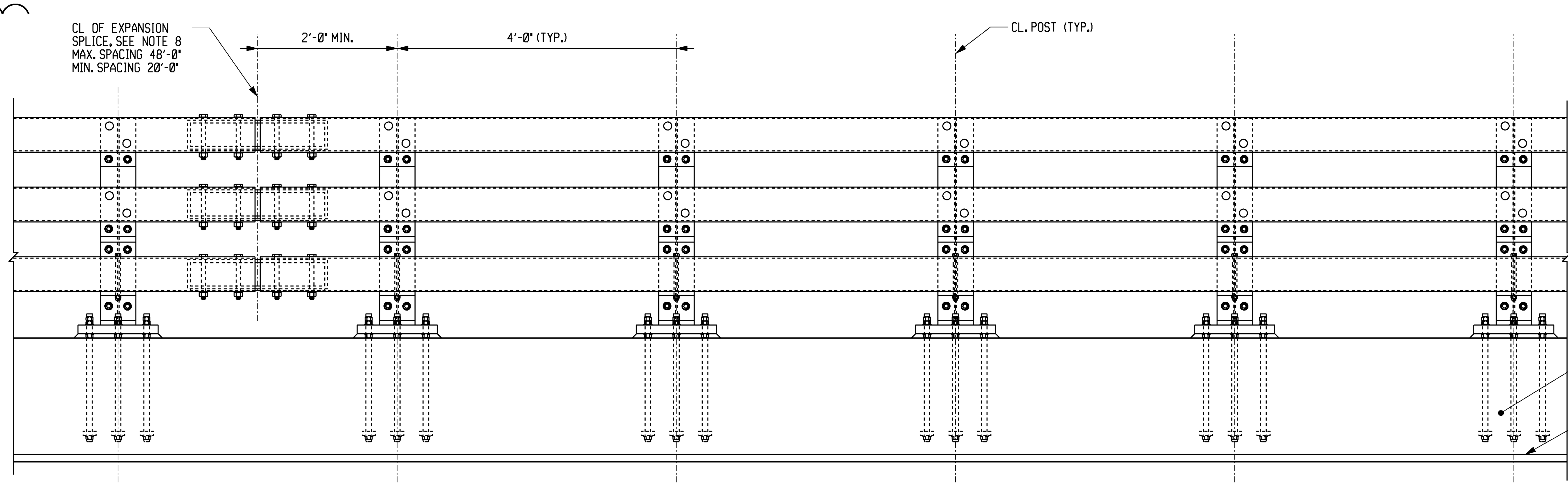
Baseline Crash Test	
Test Number:	TTI 404201-9
Vehicle:	1996 GMC single-unit truck
Vehicle Mass:	17,363 lbs
Impact Speed:	50.5 mph
Impact Location:	55.1" upstream of Post 4
Tested Hardware:	Original Design
FEA Hardware:	Modified Design

W-179 Table E-1: Verification Evaluation Summary		
Total Energy:	0%	Pass
Hourglass Energy:	0%	Pass
Mass Added:	0%	Pass
Shooting Nodes:	no	Pass
Negative Volumes:	no	Pass

W-179 Table E-5: Roadside PIRTS

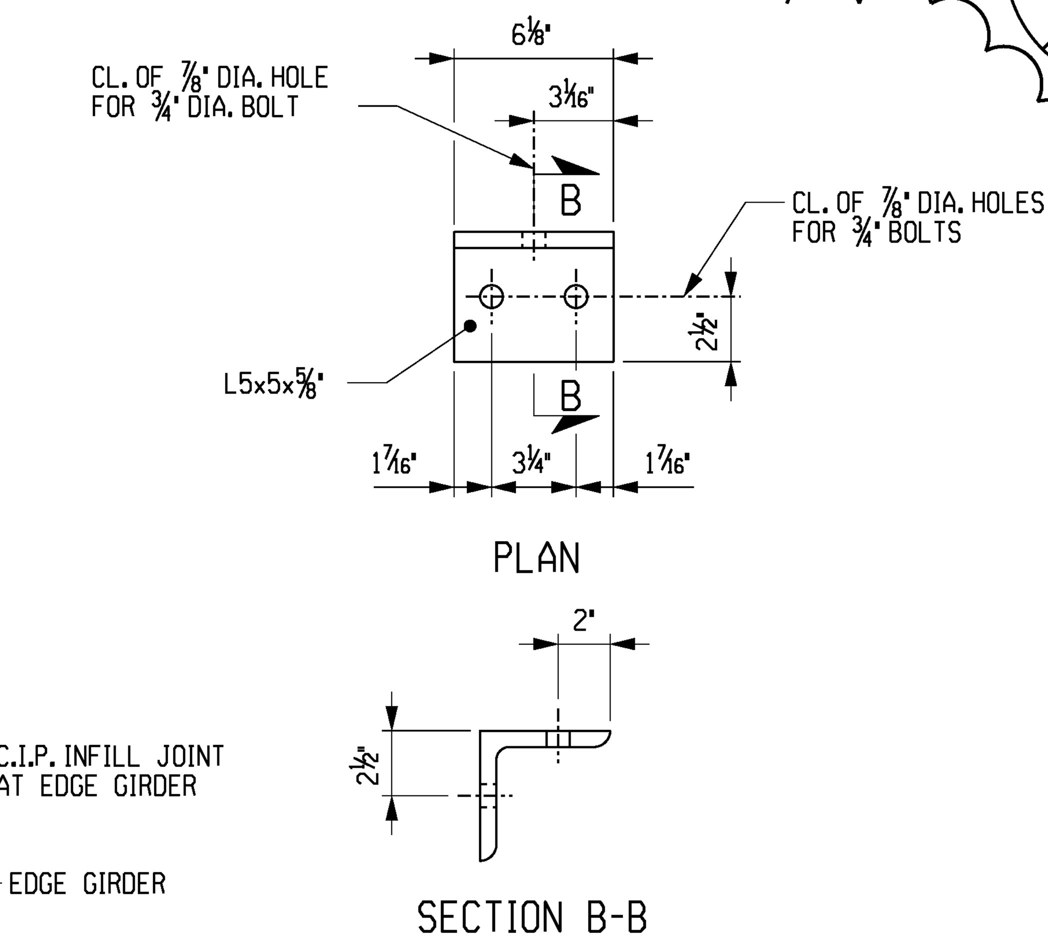
Structural Adequacy	Test	FEA
A1 - Acceptable perf.?	yes	yes
A2 – Dynamic Deflection:	2 in	0.63 in
A3 – Contact Length	17 ft	15.4 ft
A4 - Component Failure	no	no
A5 – Barrier Rupture?	no	no
A7 – Wheel Snagging?	no	no
A8 – Vehicle Snagging?	no	no
Occupant Risk	**Test**	**FEA**
D – Detached elements?	no	no
F2 – Max. Vehicle Roll	N.A.	19
F3 – Max. Vehicle Pitch	1.3	2.8
F4 – Max. Vehicle Yaw	18.3	20.6

Occupant Risk (cont.)	Test	FEA
H2 – Long. OIV	1.7 m/s	1.5 m/s
H3 – Lat. OIV	4.9 m/s	4.0 m/s
I2 – Long. ORA	2.3 g	1.6 g
I3 – Lat. ORA	9.2 g	9.2 g
Vehicle Trajectory		
K – Intruded into travel lanes?	no	no
N – Travel behind barrier?	no	no
W-179 Table E-3 (Multi-Channel Method)		
Sprague-Geer Magnitude < 40	23.4	Pass
Sprague-Geer Phase < 40	29.3	Pass
ANOVA Mean	1.5	Pass
ANOVA Standard Deviation	25.1	Pass

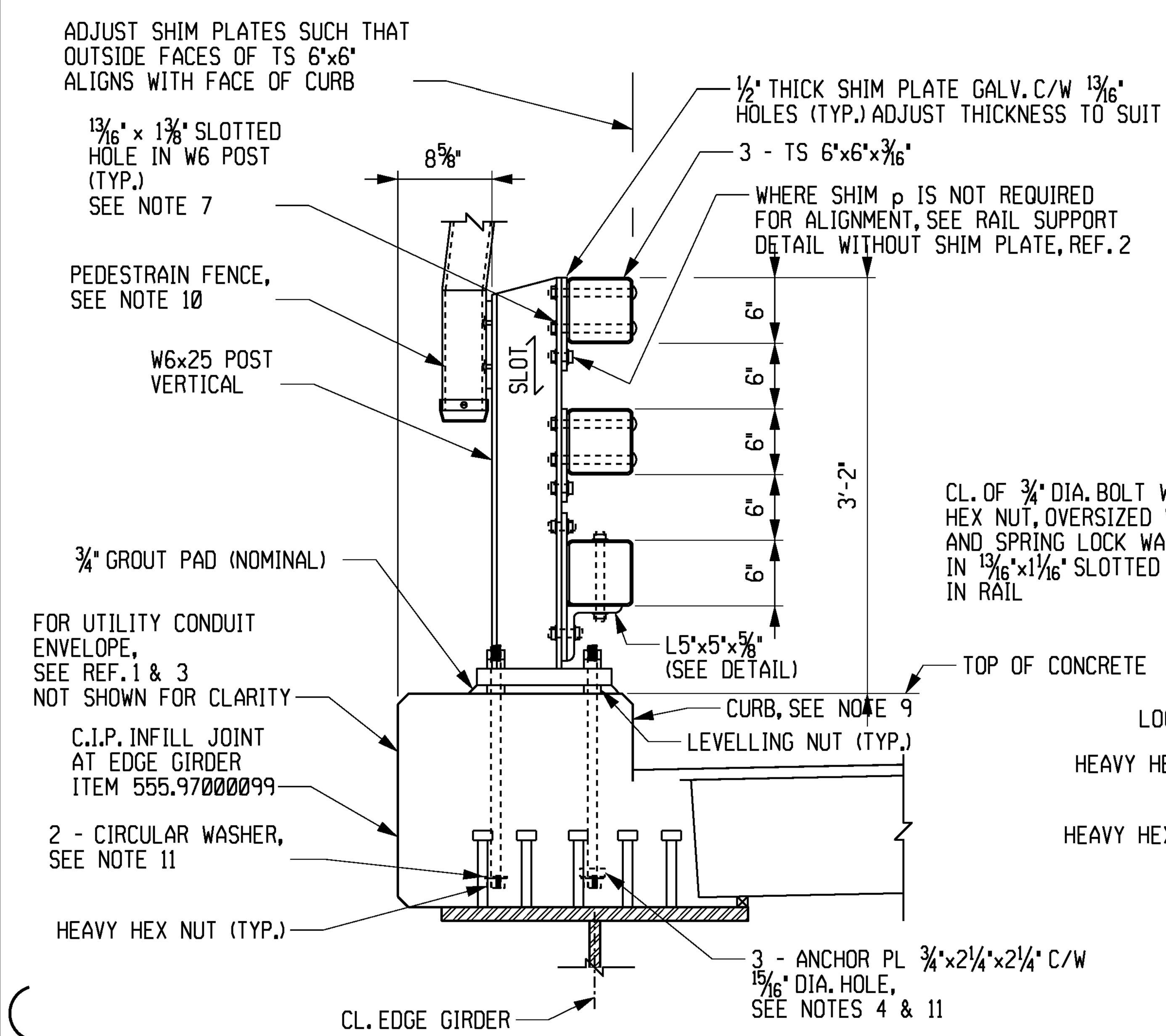


STEEL BRIDGE RAILING FOR MAIN SPANS - ELEVATION
SCALE: ½" = 1'-0"

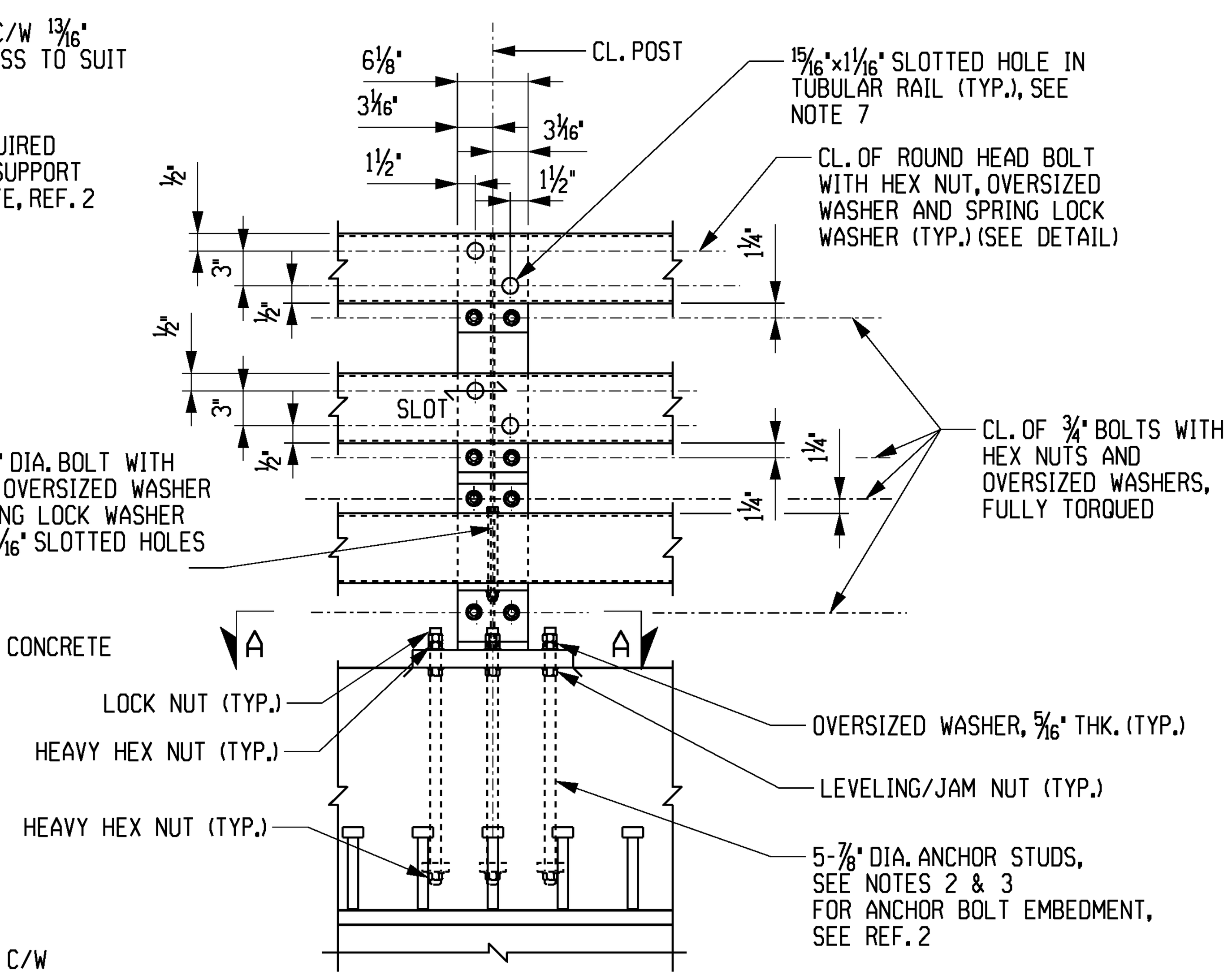
PEDESTRIAN FENCE AND CONDUITS NOT SHOWN FOR CLARITY



RAIL ANGLE DETAILS
SCALE: 1" = 1'-0"

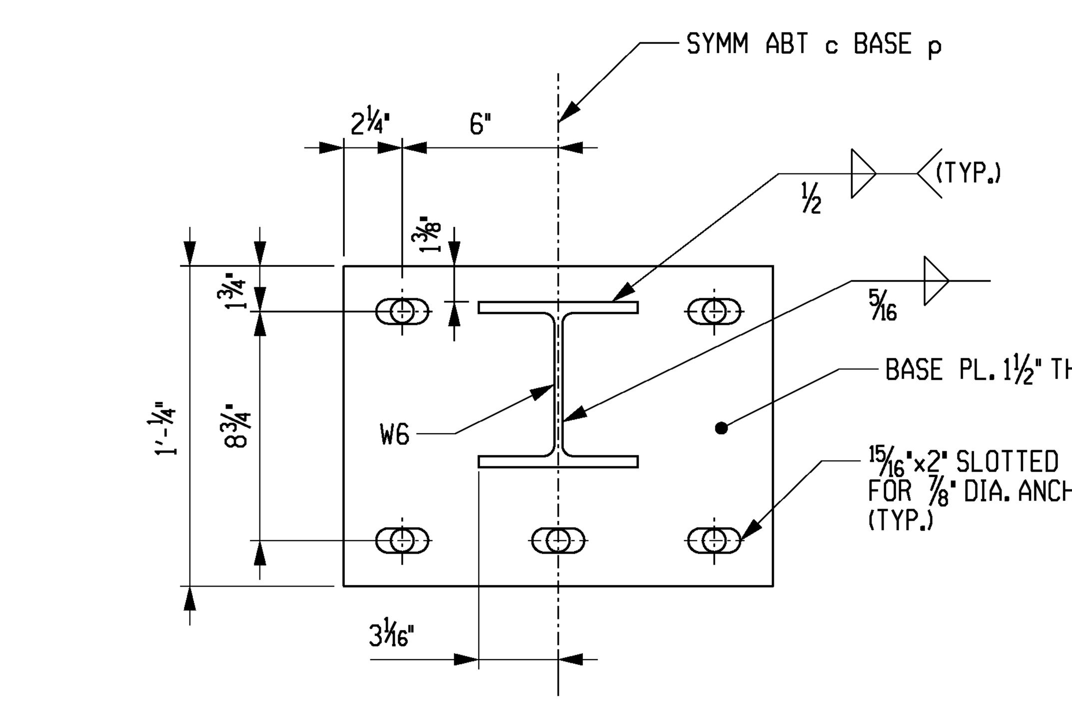


STEEL BRIDGE RAILING SECTION
SCALE: ½" = 1'-0"

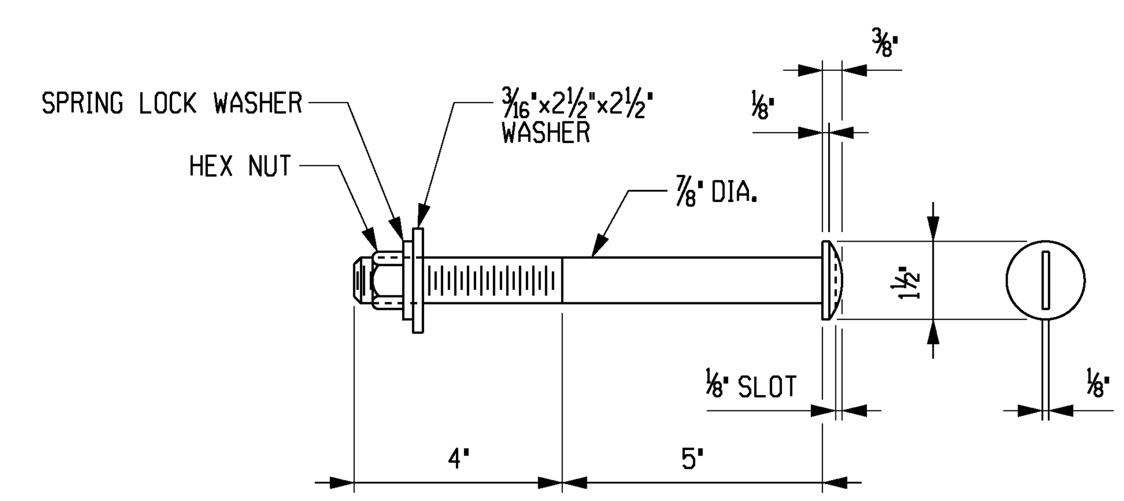


STEEL BRIDGE RAILING DETAILS
SCALE: ½" = 1'-0"

PEDESTRIAN FENCE AND CONDUITS NOT SHOWN FOR CLARITY



SECTION A-A
SCALE: 1" = 1'-0"



SLOTTED ROUND HEAD BOLT
SCALE: 2" = 1'-0"

NOTES:

1. UNLESS NOTED OTHERWISE, ALL RAILING IS TO BE FABRICATED AND ERECTED ACCORDING TO SECTION 568 OF THE STANDARD SPECIFICATIONS.
2. ANCHOR STUDS SHALL CONFORM TO ASTM A193 GRADE B7 AND SHALL BE GALVANIZED (MECHANICALLY CLEANED).
3. ANCHOR STUDS SHALL BE TORQUED TO SNUG TIGHT CONDITION WITH THE HEAVY HEX NUT. EXPOSED ANCHOR STUD NUT SHALL BE SECURED BY A LOCK NUT. ANCHOR STUD THREADS SHALL NOT BE CUT OR DAMAGED. ANCHOR STUD SHALL NOT BE FLAME CUT.
4. ANCHOR PLATES FOR ANCHOR STUDS SHALL CONFORM TO ASTM A573 GR 70 OR APPROVED EQUAL GALVANIZED.
5. PRIOR TO GALVANIZING THE ASSEMBLED POST, GRIND ALL EDGES TO A MINIMUM RADIUS OF ¹⁄₁₆".
6. BOLTS IN TUBULAR RAILS SHALL BE TORQUED SNUG TIGHT (APPROXIMATELY 100 ft-lb.).
7. ALL BOLT HOLES IN TUBULAR RAILS AND POSTS SHALL BE SLOTTED PARALLEL TO THE AXIS OF THE MEMBER.
8. FOR SPLICE DETAILS, SEE REF. 2. SPLICES SHALL BE SPACED AS SHOWN. ADDITIONALLY, SPLICES SHALL BE PROVIDED TO COINCIDE WITH LOCATIONS OF CENTERLINE OF EDGE GIRDER SPLICES GS313 AND GS713, SEE REF. 4 & 5.
9. FOR CURB REINFORCEMENT, SEE REF. 2.
10. FOR DETAILS OF PEDESTRIAN FENCE AND CONNECTION TO RAILING, SEE REF. 1.
11. ANCHOR PLATES AND WASHERS AT ANCHOR STUD ENDS SHALL BE SECURED IN PLACE TO PREVENT DISLODGING DURING CASTING OF CONCRETE.
12. GALVANIZED STEEL AND ANCHOR STUDS SHALL NOT BE PLACED IN CONTACT WITH SHEAR STUDS AND WEATHERING STEEL UNLESS INSULATION IS PROVIDED.
13. PRIOR TO BRIDGE BEING SUBJECT TO VEHICULAR TRAFFIC, FULL SCALE CRASH TESTING PER MASH OF THE SUBJECT BARRIER SYSTEM SHOWN IN THE DRAWINGS MUST BE COMPLETED, OR PRIOR DETERMINATION MUST BE RECEIVED FROM FHWA AND NYSTA THAT THE BARRIER DESIGN IS SUFFICIENTLY SIMILAR IN PERFORMANCE WITH SUCCESSFULLY CRASH TESTED BARRIER SYSTEMS AND THAT THE MASH REQUIREMENTS TO CRASH TEST THE BARRIER SYSTEM IS WAIVED.

REFERENCES

REF. NO.	DRAWING TITLE
1	FASCIA FENCE SUPPORT (UNIT 12)
2	SUPERSTRUCTURE - BRIDGE BARRIERS-OUTLINE & REINFORCEMENT 3
3	LIGHTING AND POWER PLANS (UNIT 13)
4	SUPERSTRUCTURE - FRAMING PLAN (EASTBOUND) 2
5	SUPERSTRUCTURE - FRAMING PLAN (WESTBOUND) 2

UNLESS NOTED OTHERWISE, ALL REFERENCED DRAWINGS ARE WITHIN THIS DESIGN PACKAGE.

SPECIFICATION ITEM NUMBERS

ITEM NO.	DESCRIPTION
568	BRIDGE RAILING
555.97000099	CONCRETE FOR STRUCTURES

ALTERED ON:
AFFIXED ON:
SIGNATURE: STAMP:
SIGNATURE: STAMP:

REVISIONS

DATE	DESCRIPTION	BY	SYM.

NEW YORK STATE THRUWAY AUTHORITY
DEPARTMENT OF ENGINEERING
200 SOUTHERN BLVD., ALBANY, N.Y. 12209

TITLE OF PROJECT: BARRIER CRASH TEST SIMULATION
LOCATION OF PROJECT:
TITLE OF DRAWING: UNIT 11 – SUPERSTRUCTURE BRIDGE BARRIERS OUTLINE & REINFORCEMENT 2
CONTRACT NUMBER:
DATE: 04/19/2016
DRAWING NUMBER:

218A
248

DOCUMENT TRACKING CODE: H11R-05

USER$USERNAME$ DATE:5/4/2016 TIME:12:32:49 PM FILES$

pw:\\PWTZHRC7Z_HRC\Documents\Tappan_Zee_Bridge\13.00_CAD\13.02_Structures\13.02.11_Main_Span Unit 11\13.02.11.05_Superstructure Sheet Files\H11F-05-S2865A

RECHECKER: UPDATER: BACKCHECKER: CHECKER: ORIGINATOR: