Interim Report – Literature Review

Development of MASH Computer Simulated Steel Bridge Rail and Transition Details

Prepared for: **Maine Department of Transportation**

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PROBLEM STATEMENT

The current policy for roadside hardware installed on federal aid projects requires upgrading non-conforming systems to MASH acceptance level for certain structural rehabilitations projects, such as bridge surface overlays, replacing the wearing surface of the bridge deck, or repairing a critically damaged bridge rail systems.[*AASHTO16]* The Maine Department of Transportation (MaineDOT) and other New England DOTs have a need to evaluate and, if necessary, improve their existing steel post-and-beam bridge rail designs and corresponding approach guardrail transition (AGT) designs to meet the new crash testing standards of MASH.

The predominate bridge rail and approach guardrail transition (AGT) systems used in Maine, as well as the other New England states, includes details for 2-bar, 3-bar and 4-bar designs which were developed and tested under the auspices of the New England Transportation Consortium (NETC) under AASHTO Guide Selection for Bridge Rails Performance Level 2 (GSBR PL2) and/or NCHRP Report 350 (R350) test procedures. Per the joint agreement of AASHTO and FHWA, each state will need to specify MASH compliant bridge rails for new and full-replacements on the National Highway System (NHS) with contract lettings after December 31, 2019. As such, it is of interest to the New England DOT's to determine if these existing NETC bridge rail systems meet the strength and safety criteria of *MASH*, which involve higher impact severities for each test case.

OBJECTIVES

The objectives of this project are to: 1) review existing NETC bridge rail and AGT designs and assess performance aspects to determine preliminary MASH compliance/equivalency, 2) review current standard details and specifications for NETC style bridge rails and transitions used by MaineDOT, NHDOT, RIDOT and VTrans to identify differences in material specifications and dimensional details and 3) evaluate the crash performance of the NETC bridge rail and approach guardrail transition (AGT) designs using finite element analysis (FEA) computer simulation. The impact conditions and assessment procedures for the FEA will conform to the specifications in *MASH* for TL-3 or TL-4 (as appropriate) and will included evaluations of structural capacity of the railing, risk of occupant injury, and vehicle stability during impact and redirection. The systems included in the evaluation are listed below along with the target test level for each system:

- Bridge Rail Systems:
  - NETC curb-mounted 2-Bar Rail (TL3)
  - NETC curb-mounted 3-Bar Rail (TL4) (4-bar curb mounted NETC rail would be considered equivalent to this type)
  - NETC sidewalk-mounted 4-Bar Rail (TL4)
- Bridge Rail Transitions:
  - NETC Style 2-Bar Rail to Thrie Beam (TL3) (NHDOT steel rail transition)
  - NETC Style 3-Bar Rail to Thrie Beam (TL4) (NHDOT steel rail transition)
  - Concrete Transition Barrier to Thrie Beam (TL4) (MaineDOT standard detail)

These basic designs are used by several New England states, with slight variations in design details, such as spacing between tube rails and curb height. The standard bridge rail drawings for Maine, New Hampshire, Vermont and Rhode Island are provided in Appendices A, B, C, and D, respectively.

RESEARCH APPROACH AND SCOPE OF THE STUDY

A critical review of current standard details and specifications for NETC style bridge rails and transitions used by MaineDOT, NHDOT, RIDOT and VTrans was conducted to identify differences in material specifications and dimensional details. An initial performance assessment was made for each bridge rail design based on strength calculations and rail geometrics calculations for MASH loading conditions according to procedures in Section 13 of the AASHTO LRFD Bridge Design Specifications. Preliminary recommendations were made for NETC bridge rail and AGT design details for further crash performance evaluations in this project, which will be provided to the project panel for review. The recommendations were based on the least conservative design details that have an acceptable crash testing record. In this way the more conservative designs would be assumed to have sufficient strength.

The design details approved by the project panel will then be evaluated using finite element analysis (FEA). Prior to use of the models for assessing the crashworthiness under MASH conditions, detailed FEA models of select bridge rails and transition systems will be developed, and the finite element analysis code LS-DYNA will be used to simulate crash tests to assess the validity of the models.[*LSDYNA15*] Model validity will be assessed through comparison of simulated results with the full-scale test results using the procedures outlined in NCHRP Web-Document 179. [*Ray11*] The validated models will then be used as a baseline for the MASH evaluations. Revisions to the system designs will be made according to the approved recommendations; LS-DYNA will then be used to simulate MASH test conditions to assess crash performance.

The initial focus of the project will be assessment of the NETC curb-mounted 3-bar bridge rail and transition; it is assumed that the 4-bar curb-mounted design would be considered equivalent to this system and is therefore not included in the evaluations. Once the evaluation of the 3-Bar system is complete, the priority order for the remaining systems will be determined through discussions with the project panel.

For the AGT's transitioning to the 2-Bar and 3-Bar bridge rail systems, the study will involve evaluation of the transition from the thrie-beam to the steel tube rails. For the AGT transitioning to the 4-Bar bridge rail systems, the evaluations will focus on the transition of the thrie-beam to the concrete buttress. The evaluations will use critical impact points that lead to the greatest potential for structural failure or occupant harm and will be determined based on the FEA results as well as previous testing. The section of the AGT that transitions from the w-beam to the thrie-beam have been evaluated via full-scale testing in previous studies and is therefore not included in this study (e.g., see *Winkelbauer14*).

The results of these analyses cannot guarantee MASH compliance – only full-scale testing can do that; but the simulations results should provide reliable predictions for the outcome of such tests.

LITERATURE REVIEW

A review of published literature and ongoing research was conducted to investigate performance aspects of select bridge rail systems used among the New England States, as well as, other designs that have demonstrated MASH compliance/equivalency. A critical review of current standard details and specifications for NETC style bridge rails and transitions used by MaineDOT, NHDOT, RIDOT and VTrans was also performed to identify differences in material and dimensional details compared to each other as well as to the tested designs. Strength calculations, per Section 13 of the AASHTO *LRFD Bridge Design Specifications,* were performed to determine the strength and capacity of the current bridge railing designs. *[AASHTO12]*

Preliminary recommendations for dimensional and material specifications are provided based on the review to better ensure consistency for NETC style designs, considering constructability and performance.

Summary of Current NETC Bridge Rail Designs

The current NETC bridge designs are shown in Figures 1 and 2. In general, these designs include a W6x25 steel post that is welded to a 10x14x1-inch steel base plate and mounted onto the top of a concrete curb or sidewalk using four (4) 1-inch diameter threaded rods 12 inches long. The posts are spaced at 8 feet on centers. The longitudinal rails are composed of HSS 8x4x5/16-inch and HSS 4x4x1/4-inch sections, as shown in Figure 1. The rails are fastened to the post using ¾-inch diameter round-head bolts inserted through the face of the rail bar.

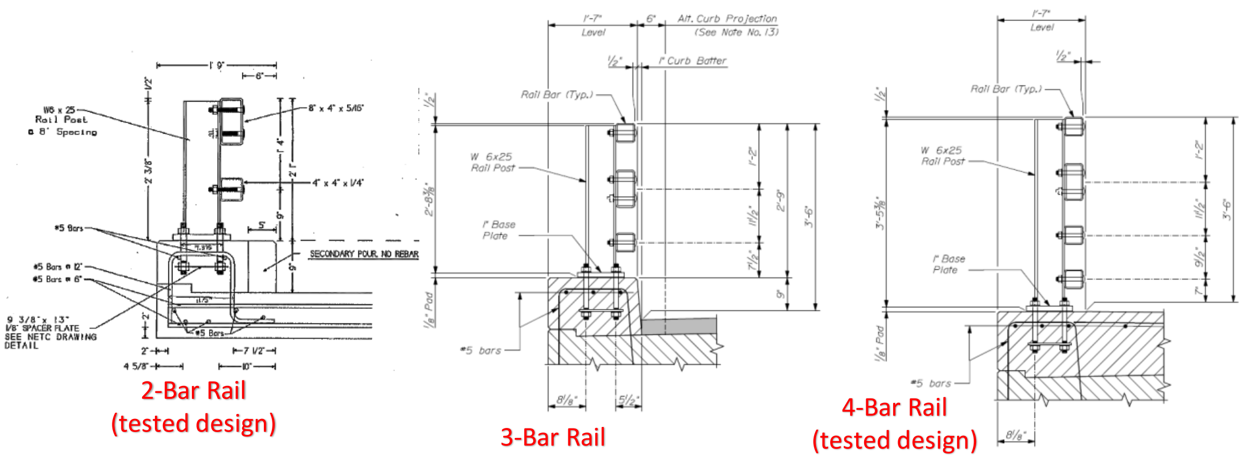


Figure 1. NETC bridge rail designs.

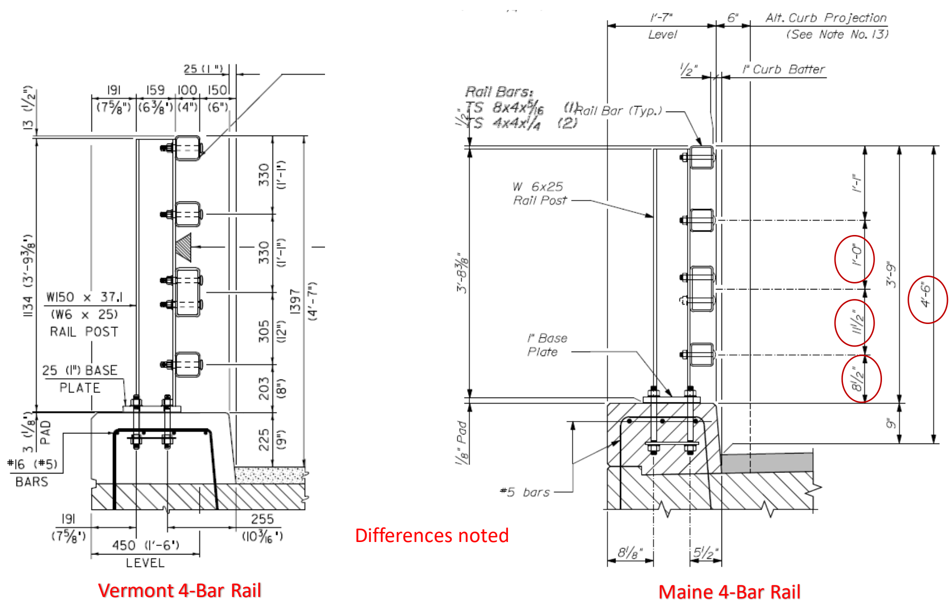


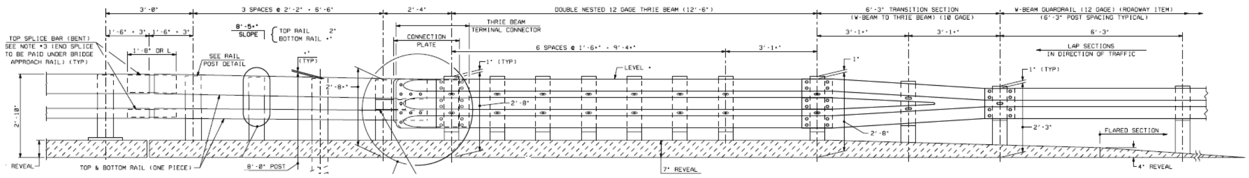
Figure 2. NETC 4-Bar curb-mounted bridge rail design.

The 2-bar and 4-bar NETC bridge rail designs shown in Figure 1 were successfully tested under GSBR PL2 and R350 TL4 guidelines. [*Mak98; Kimball99*] The eligibility letter for these two systems is B-50 which can be obtained from the FHWA website. To our knowledge, there is no eligibility letter for the NETC curb-mounted 3-bar design or the curb-mounted 4-bar design, as these systems have not been tested. Additional drawing details are provided in the Appendices and in the crash test reports. [*Mak98; Kimbal99*]

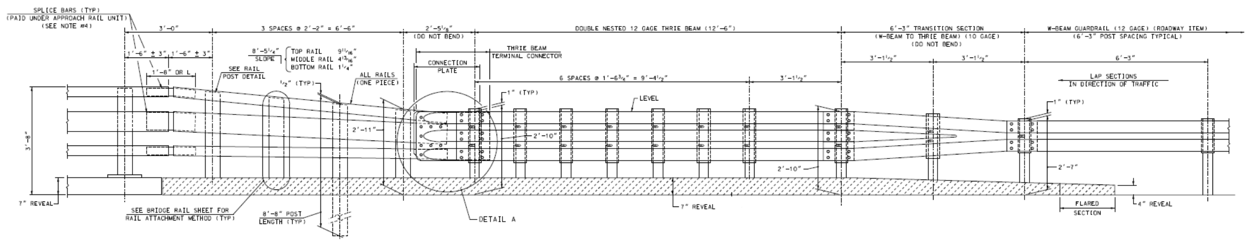
Summary of Current NETC Transition Designs

When two barrier systems of different stiffness are connected, such as connecting a semi-rigid guardrail to a rigid bridge rail, it is necessary to ensure a gradual transition across the connection point. Any abrupt change in stiffness of the barrier can lead to pocketing, snagging and/or penetration of the barrier during impact. Thus, a transition guardrail section is necessary to develop a gradual stiffness transition between the two barrier systems.

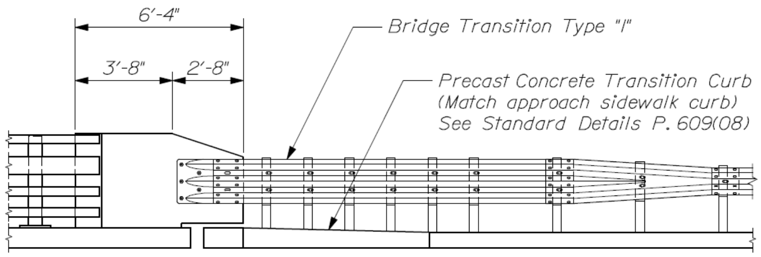
The approach guardrail transitions (AGT) that are to be evaluated in this study are shown in Figures 3 and 4. In general, these designs include a w-beam rail attached to a symmetrical thrie-beam transition rail, which is attached to a nested thrie-beam rail, which is then attached to either a tube rail section (e.g., for the 2-Bar and 3-Bar bridge rail designs) or to a concrete buttress (e.g., for the 4-Bar bridge rail design). These guardrails are supported by W6x8.5 steel posts and blockouts. The posts are typically 7’, 8’ or 8’-8” long and are mounted at decreasing post spacing as the system starts at the w-beam guardrail (e.g., 6’-3” spacing) and approaches the rigid bridge rail (e.g., 18.75-inch spacing). Additional drawing details are provided in the detailed drawing in the Appendices.



(a) NETC Style 2-Bar Rail to Thrie Beam (TL3)



(b) NETC Style 3-Bar Rail to Thrie Beam (TL3)



(c) Maine Concrete to Thrie Beam (TL3)

Figure 3. Elevation drawing of the current AGTs to be evaluated in this study.

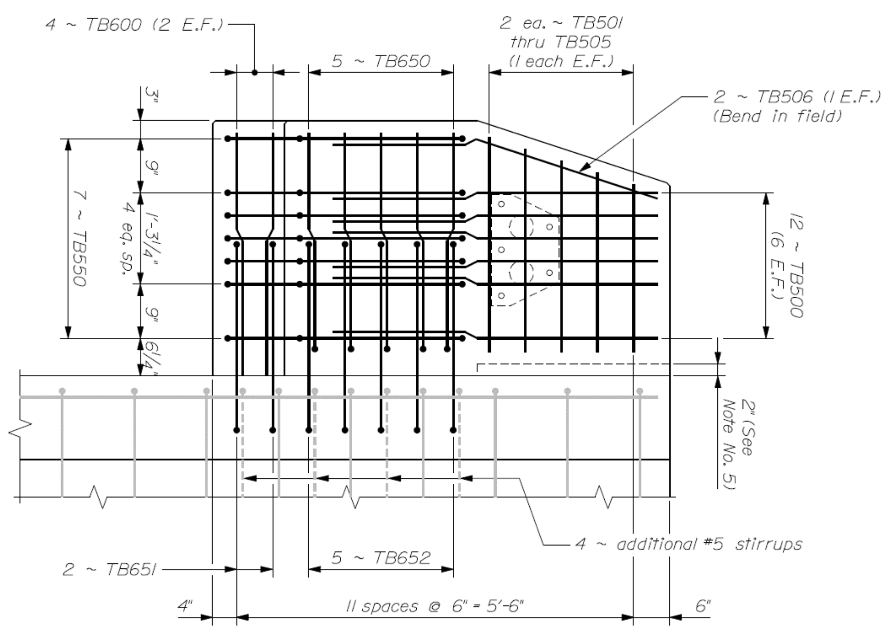


Figure 4. Concrete buttress for the Maine AGT to 4-Bar bridge rail.

The NETC 2-Bar to thrie-beam AGT was successfully full-scale crash tested to R350 TL3 by the Texas Transportation Institute (TTI) in 2005. [Alberson06] The NETC 3-Bar AGT and NETC 4-Bar AGT with transition from thrie-beam to tube rail have not been crash tested but received

R350 TL3 approval from the FHWA based on the 2005 test (see problem statement of [Mak98] and Eligibility Letter 146). To our knowledge, the Maine concrete-to-thrie-beam AGT has not been tested; however, based on results of similar systems, it is expected that the system may require some geometrical changes to the concrete buttress design to prevent vehicle impacting and snagging on the end of the buttress. Additional discussion is provided later in the critical review for the Discrepancies in Drawing

The same discrepancies that were discussed at the end of the NHDOT 2-bar transition section also apply to the NHDOT 3-bar transition drawings.

MaineDOT 4-Bar Transition section of this report.

Previous Full-Scale Testing of NETC Hardware

The following is a summary of the NETC hardware designs that have been successfully crash tested under previous test procedures (e.g., GSBR PL2, R350) and the test results. These include the curb-mounted NETC 2-Bar bridge rail, the sidewalk-mounted NETC 4-Bar bridge rail, and the NHDOT AGT for the 2-Bar bridge rail. To our knowledge, neither the 3-Bar bridge rail nor the AGTs for the 3-Bar and 4-Bar bridge rail systems have been full-scale crash tested. The test for the NHDOT transition to the 3-Bar system was "waived" by the FHWA based on the full-scale test results for the AGT for the 2-Bar system.

NETC 2-Bar Bridge Rail

The NETC 2-Bar bridge rail system was tested according to the crash test specifications of 1989 AASHTO *Guide Specifications for Bridge Railings* (GSBR) for performance level 2 (PL2) and R350 TL4. [*Mak98*] The tests were conducted at the Texas Transportation Institute (TTI).

The NETC 2-bar bridge rail, shown in Figure 1, is an *R350* TL-4 34-inch tall curb-mounted bridge rail composed of two longitudinal tubular rails. The test article was a 100-foot long section of the bridge rail mounted on a simulated bridge deck. The top rail was fabricated from TS8x4x5/16-inch structural tubing; the lower rail was fabricated from TS4x4x0.25-inch structural tubing. Each rail was fastened to a W6x25 steel post using two (2) ¾-inch diameter round-head bolts. The posts were spaced at 8-ft center-to-center. The posts were welded to a 10x14x1-inch base plate. The base plate was mounted to the top of a 9-inch tall steel reinforced concrete curb using four 1-inch diameter double-threaded studs. The threaded rods were 9 inches long and were fastened to a 9-3/8 x 13 x 1/8-inch anchor plate embedded in the curb. The curb section was 9 inches tall and 21 inches wide, including a 5-inch wide facing cast in a separate pour on the front of the curb to simulate a granite facing. The distance from the face of the curb to the face of the bridge rail was 6 inches.

Test 471470-18 corresponded to the impact conditions of PL2 and involved a 1986 Yugo GV with gross static mass of 1,970 lb, including a 170-lb dummy impacting the bridge rail at 62.7 mph and 20.6 degrees. Test 471470-19 corresponded to the impact conditions of PL2 and involved a 1984 Ford F250 with gross static mass of 5,568 lb impacting the bridge rail at 57.3 mph and 20.6 degrees. Test 471470-29 corresponded to the impact conditions of Report 350 Test 4-12 and involved a 1980 GMC 6000 single unit truck ballasted to 17,621-lb, impacting the bridge rail system at 50.7 mph and angle of 15.5 degrees.

The bridge rail system successfully passed all required structural adequacy and occupant safety criteria for AASHTO PL2 and R350 TL-4. Table 2 shows a summary of test results for the NETC 2-bar bridge rail system. Additional details of the tests and results can be found in the test report.[*Mak98*] The eligibility letter for this system is B-50 which can be found on the FHWA website.

Table 1. Summary of test results for NETC 2-bar bridge rail design. [*Mak98*]

	471470-18	NETC-2	NETC-3
Test Designation	PL2-car	PL2-Pickup	R350 Test 4-12
Test Vehicle	1986 Yugo GV	1984 Ford F25	198 GMC 6000
Gross Vehicle Weight (lb)	1,970	5,568	17,621
Impact Speed (mph)	62.7	57.3	50.8
Impact Angle (deg)	20.6	20.6	15.5
Exit Speed (mph)	55.1	48.6	-
Exit Angle (deg)	2.2	2.2	2
Occupant Impact Velocity			
Longitudinal (ft/s)	16.9	12.2	7.5
Lateral (ft/s)	27.5	21.5	12
Ridedown Accel			
Longitudinal (g's)	1.6	2.5	4
Lateral (g's)	6.8	12.2	3.2
Maximum 50 msec Avg Accel			
Longitudinal (g's)	6.1	3.4	1.8
Lateral (g's)	15.2	10.3	2.6
Max Deflection (in)	0.25	0.25	-
Vehicle Trajectory			
Maximum YawAngle (deg)	15	25	16
Maximum Roll Angle (deg)	15	26	19
Maximum Pitch Angle (deg)	32	5	6
NCHRP Report 350 Evaluation			
Structural Adequacy	Pass	Pass	Pass
Ocupant Risk	Pass	Pass	Pass
Vehicle Trajectory	Pass	Pass	Pass

NETC 4-Bar Bridge Rail

The NETC 4-bar bridge rail, shown in Figure 1, is an *R350* TL-4 42-inch tall bridge rail (not including the height of the 9-inch sidewalk) with four longitudinal tubular rails. The top rail, the third rail from the top, and the bottom rail are fabricated from TS4x4x0.25-inch structural tubing; the second rail from the top is fabricated from TS8x4x0.3125-inch structural tubing. The rails are attached to W6x25 steel posts using ¾-inch diameter studs with steel washers and lock-nuts. The posts are spaced at 8-ft center-to-center. The posts are welded to a 10x14 inch steel 1-inch thick base plate. The base plate is fastened to the top of a 9-inch tall steel reinforced concrete sidewalk using four 1-inch diameter anchor bolts.

Figure 5. NETC 4-Bar (SBB44b) Bridge Rail.[Kimball99]

Each tubular rail section is 23.9 feet long and spans three posts. The rail tubes are joined to the neighboring rails using a 20-inch long tubular sleeve inserted 9-5/8 inches into the ends of the adjoining rails. The adjoining main rails are separated by a ¾-inch gap and the sleeve is fastened to each main rail tube using two 5/8-inch diameter cap screws. The sleeve tube is fabricated from ¼-inch steel plate welded along the edges. The clearance of the splice tube inside the main rail tube is 1/16-inch on all sides. Refer to the drawings in the crash test report for additional construction details. [*Kimbal99*]

The material for the rail bars is ASTM A500 Grade B or ASTM A501 steel. The material for the rail posts is ASTM A709 Grade 50. The material for all other shapes and plates are ASTM A709 Grade 36. Anchor studs, washers and exposed nuts conform to ASTM A449, which has a minimum yield of 92 ksi, ultimate strength of 120 ksi, and 14 percent elongation. All other bolts and nuts conform to ASTM A307 with minimum yield of 36 ksi, minimum ultimate strength of 60 ksi and 18 percent elongation.

The NETC 4-Bar bridge rail system was tested according to the crash test specifications of NCHRP Report 350 for Test Level 4. The test article was a 108-foot long section of the bridge rail mounted on a 6.5-ft wide concrete sidewalk. The side walk was 8 inches tall at the traffic face and sloped up to 9 inches tall at the point where the bridge rail was mounted. The distance from the face of the curb to the face of the bridge rail was 4.67 feet.

The tests were conducted at the Southwest Research Institute (SwRI). Test NETC-1 corresponded to the impact conditions of Report 350 Test 4-10 and involved a 1991 Ford Festiva with gross static mass of 1,989 lb, including a 165-lb dummy impacting the bridge rail at 62.14 mph and 20 degrees. Test NETC-2 corresponded to the impact conditions of Report 350 Test 4-11 and involved a 1991 Ford F-250 with gross static mass of 4,484 lb impacting the bridge rail at 62.14 mph and 25 degrees. Test NETC-3 corresponded to the impact conditions of Report 350 Test 4-12 and involved a 1993 International 4600 LP single unit truck ballasted to 17,875-lb, impacting the bridge rail system at 49.8 mph and angle of 15 degrees.

The bridge rail system successfully passed all required structural adequacy and occupant safety criteria of NCHRP Report 350. Test NETC-3 (i.e., Test 4-12) resulted in an exit trajectory of the vehicle that would indicate intrusion into adjacent lanes; however, this was a preferred, not required, criterion. Table 2 shows a summary of test results for the NETC 4-bar bridge rail system. The maximum dynamic deflection of the bridge rail was zero inches for NETC-1 and was 1.0 inch for both test NETC-2 and NETC-3. Additional details of the tests and results can be found in the test report.[*Kimball99*] The eligibility letter for this system is also B-50 which can be obtained from the FHWA website.

Table 2. Summary of test results for NETC 4-bar bridge rail design. [*Kimball99*]

	NETC-1	NETC-2	NETC-3
Report 350 Test No.	Test 4-10	Test 4-11	Test 4-12
Test Vehicle	1991 Ford Destiva	1991 Ford F-250	1993 International 4600 LP
Gross Vehicle Weight (lb)	1823	4484	17,875
Impact Speed (mph)	62.1	62.1	49.7
Impact Angle (deg)	20	25	15
Exit Speed (mph)	11.4	10.6	35.8
Exit Angle (deg)	6.6	8.2	4.1
Occupant Impact Velocity			
Longitudinal (ft/s)	*	13.1	5.41
Lateral (ft/s)	*	*	9.48
Ridedown Accel			
Longitudinal (g's)	*	2.55	8.95
Lateral (g's)	*	*	14.3
Maximum 50 msec Avg Accel			
Longitudinal (g's)	-	-	2.7
Lateral (g's)	-	-	5.8
Max Deflection (in)	0	1	1
Vehicle Trajectory			
Maximum YawAngle (deg)	34	*	*
Maximum Roll Angle (deg)	10	20	20
Maximum Pitch Angle (deg)	5	15	5
NCHRP Report 350 Evaluation			
Structural Adequacy	Pass	Pass	Pass
Ocupant Risk	*	Pass	Pass
Vehicle Trajectory	Pass	Pass	Pass

** No occupant risk data - lateral accelerometer malfunctioned during test.*

NHDOT 2-Bar Rail to Thrie-Beam AGT

The NHDOT 2-Bar rail to thrie-beam AGT, shown in Figure 6, is an R350 TL-3 system. The total length of the transition section was 29 feet from the end of the standard w-beam guardrail to the beginning of the bridge rail. The upstream end of the transition system consisted of a 12-gauge w-beam rail connected to a 10-gauge symmetric w-beam-to-thrie-beam transition rail supported by three 6x8 wood posts that were 7 feet long and spaced 37.5 inches on centers (e.g., half post-spacing). The symmetric transition rail was then connected to two nested 12-gauge thrie-beam rails supported by four 6x8 inch wood posts that were 7 feet long. The first post was spaced at 37.5 inches and the next six (6) posts were spaced at 18.5 inches on centers (quarter post-spacing). The height of the thrie-beam section was 32 inches. The downstream end of the nested thrie-beams was connected to the two-tube transition rail by means of a 10-

gauge thrie-beam terminal connector. The two tube transition rails used in the transition section are the same tubular elements used in the bridge rail. The top rail was a TS 8x4x5/16 and the lower rail was a TS 4x4x1/4. The tube rails were supported on four (4) W6x25 steel posts 8 feet long and spaced at 26 inches on centers. The ends of the rail tubes are connected to the bridge rail through a splice connection. The height of the top rail tube at the connection point to the thrie-beam was 32 inches. The rail element slanted upward slightly such that the downstream end was at the same height of the bridge rail (i.e., 34 inches). The tube rails were connected to the W6x25 steel posts with two 6-inch long, 3/4-inch diameter round-headed bolts. A 7-inch tall simulated granite curb was installed throughout the transition and extend in front of the rail tubes by 6 inches and the thrie-beam by 2-1/4 inches.

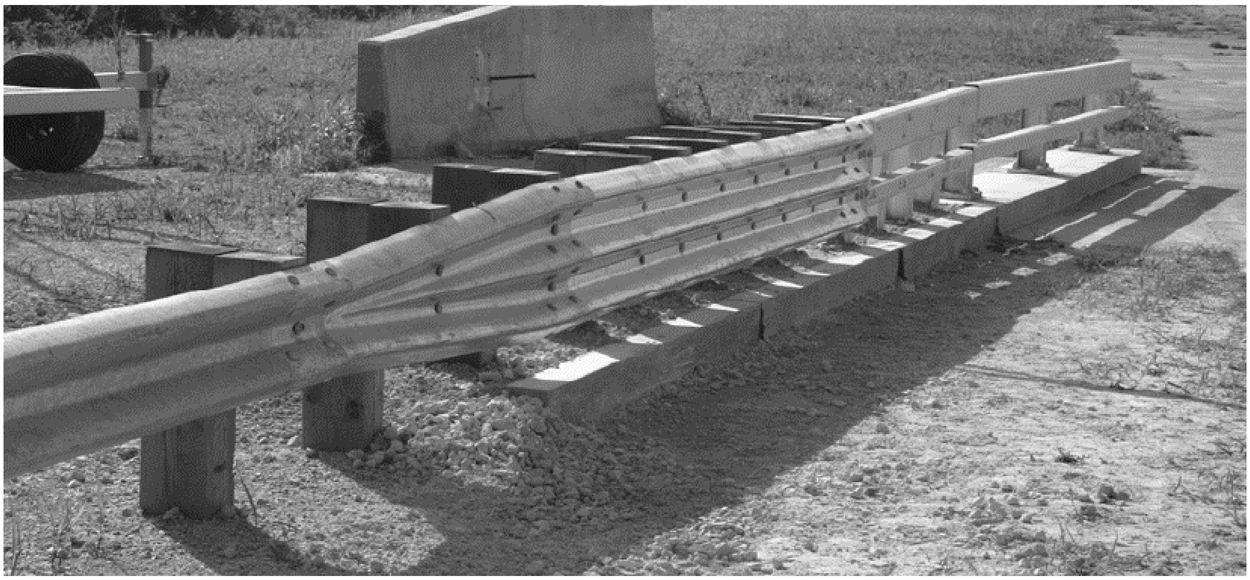


Figure 6. NHDOT 2-Bar rail to thrie-beam AGT. [*Alberson06*]

The NHDOT 2-Bar rail to thrie-beam AGT was tested according to the crash test specifications of NCHRP Report 350 Test 3-21 (i.e., pickup test). The tests were conducted at the Texas Transportation Institute (TTI). Test 401181-1 involved a 4,706-lb Chevrolet 2500 impacting the system at 64.37 inches downstream of the first bridge rail post at 63.6 mph (102.3 km/hr) and 24.9 degrees.

The bridge rail system successfully passed all required structural adequacy and occupant safety criteria for R350 TL-3. Table 3 shows a summary of test results for the AGT to 2-bar bridge rail system. Additional details of the tests and results can be found in the test report. [*Alberson06*]

Table 3. Summary of test results for NHDOT 2-Bar Rail to Thrie-Beam AGT. [*Alberson06*]

	401181-1
Test Designation	Test 3-21
Test Vehicle	2000 Chevrolet 2500
Gross Vehicle Weight (lb)	4,706
Impact Speed (mph)	63.6
Impact Angle (deg)	24.9
Exit Speed (mph)	52.9
Exit Angle (deg)	11.7
Occupant Impact Velocity	
Longitudinal (ft/s)	17.1
Lateral (ft/s)	24.6
Ridedown Accel	
Longitudinal (g's)	8.3
Lateral (g's)	10
Maximum 50 msec Avg Accel	
Longitudinal (g's)	8.1
Lateral (g's)	13.5
Max Deflection (in)	7.87
Vehicle Trajectory	
Maximum YawAngle (deg)	56
Maximum Roll Angle (deg)	14
Maximum Pitch Angle (deg)	19
NCHRP Report 350 Evaluation	
Structural Adequacy	Pass
Ocupant Risk	Pass
Vehicle Trajectory	Pass

NHDOT 3-Bar Rail to Thrie-Beam AGT

A photo of this system was not available for this proposal; however, the drawings can be found in Appendix B. The upstream section of the NHDOT 3-Bar AGT design from the w-beam guardrail to the end of the thrie-beam terminal connector is identical to the 2-Bar AGT design described in the preceding section. The primary difference in these two systems is the number of rails in the tube-rail section. For the 3-Bar AGT, the three tube transition rails used in the transition section are the same tubular elements used in the bridge rail. The top and lower rails are a TS 4x4x1/4 and the middle rail is a TS 8x4x5/16. The tube rails were supported on four (4) W6x25 steel posts 8’-8” long and spaced at 26 inches on centers. The ends of the rail tubes are connected to the bridge rail through a splice connection. The height of the top rail tube at the connection point to the thrie-beam was 34 inches. The top and middle rail elements slanted upward such that the downstream end was at the same height of the bridge rail (i.e., 44 inches for the top rail). The tube rails were connected to the W6x25 steel posts with two 6-inch long, 3/4-inch diameter round-headed bolts. A 7-inch tall simulated granite curb was installed throughout the transition and extend in front of the rail tubes by 6 inches and the thrie-beam by 2-1/4 inches.

This system is considered R350 TL-3 compliant, although it has not been full-scale tested. Full-scale testing of this system was not required by FHWA based on review of the drawings and results of the NETC 2-Bar rail to thrie-beam tests. [*Alberson06*]

MASH Equivalency Assessment

In a recent study performed by the Texas Transportation Institute (TTI) under NCHRP Project 20-07 (Task 395) an assessment of several types and styles of existing bridge rails was conducted to determine if they met suggested MASH performance criteria. [Silvestri17] If a system was deemed equivalent to a specific MASH test level then it could be 'grandfathered' to MASH without further testing. The equivalency assessments considered vehicle stability, strength of the railing, and geometry of the railing. According to the assessment, a design was deemed MASH equivalent if:

- Rail height is sufficient for the MASH test level (see Table 4);
- The system has sufficient strength capacity to withstand MASH loads based on strength calculations from Section 13 of the AASHTO LRFD Bridge Design Specifications (see Table 4);
- Potential for vehicle snag on the bridge rail posts is less than critical values based on: (1) "ratio of rail contact width to height" vs "post setback distance" and (2) "vertical clear opening" vs "post setback distance" also contained in the AASHTO LRFD Bridge Design Specifications (see Figure 7).

Table 4. Critical rail height and design lateral impact loads for MASH bridge railing. [Dolobrovolny*17*]

MASH Test Level	Rail Height (in)	Design Impact Force (kip)	Height of Design Impact Force (in)
TL-3	≥ 29	71	19
TL-4	36	68	25
	> 36	80	30
TL-5	42	160	35
	> 42	262	43

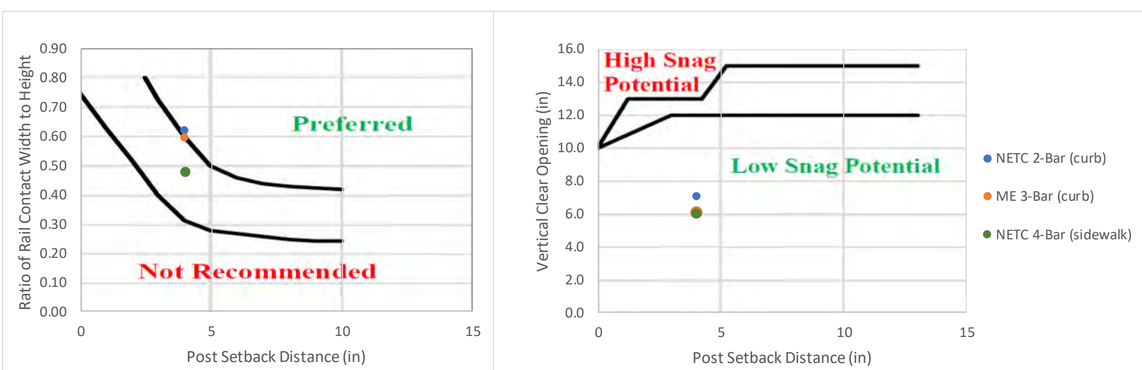


Figure 7. AASHTO Section 13 Figures A13.1.1-2 and A13.1.1-3 including NETC bridge rail.[*AASHTO12*]

The minimum rail height requirement for stability were determined from a combination of full-scale testing and FEA. For MASH TL-3, the minimum height was determined using finite element analysis (FEA). The FEA model was validated by comparing the analysis results to a full-scale crash test conducted on a 32-inch tall vertical concrete barrier under MASH Test 3-11 conditions (i.e., 5000-lb pickup impacting at 62 mph and 25 degrees). The validated model was then used to assess vehicle stability for MASH Test 3-11 on 27-inch, 28-inch, and 29-inch tall vertical concrete barriers. The pickup was determined to be unstable for the 27- and 28-inch barriers but was stable for the 29-inch tall barrier case. [*Dolbrovolny17*]

For MASH TL-4, the minimum height was determined to be 36 inches using FEA and was then verified via full-scale testing on a 36-inch tall single-slope barrier. [*Sheikh11*] Previous full-scale testing showed that the 22,000-lb single unit truck rolled over the top of the 32-inch tall barrier under MASH Test 4-12 conditions (i.e., 55 mph and 15 degrees) [*Bullard08; Polivka06*].

Rail Geometric Evaluations

The geometric relationships for bridge railings are contained in Figures A13.1.1-2 and A13.1.1-3 of Section 13 of the AASHTO LRFD Bridge Design Specifications, as illustrated in Figure 7 herein. [*AASHTO12*] These relationships were developed based on a review of NCHRP Report 230 crash test data to relate impact performance to the geometric characteristics of bridge railing systems. The rail geometric criteria correlate the potential for the wheel, bumper or hood snagging against a bridge rail post to high vehicle decelerations and occupant compartment intrusions. These relationships have not yet been evaluated for NCHRP Report 350 or MASH test cases but are still commonly applied to bridge rail design.

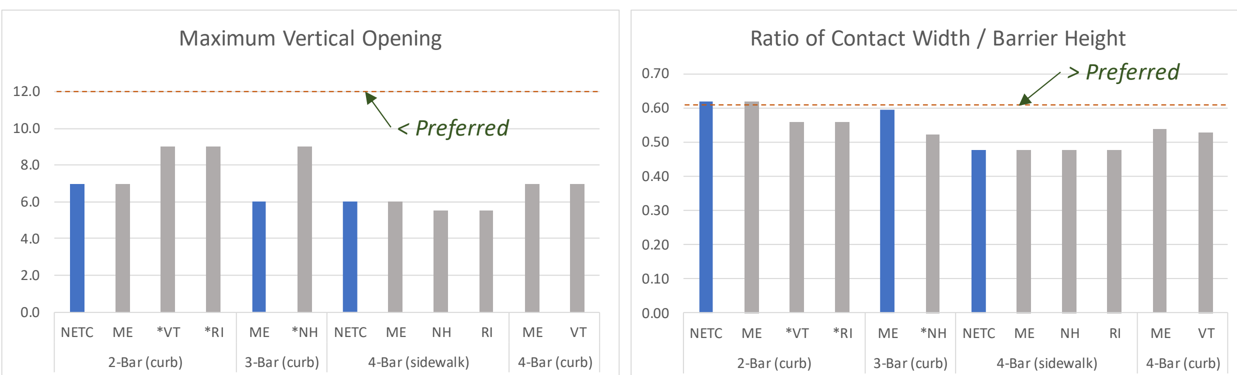
Table 5 and Figure 8 show a summary of the rail-geometric calculations for the NETC and New England bridge rail designs with the highest priority systems highlighted. Example calculations are shown in Figure 9. For a *post setback distance* of 4 inches, the 2-Bar system meets the recommended geometric criteria when the curb height is 9 inches (e.g., NETC and ME); however, there is not sufficient contact width relative to the height of the rail when a 7-inch curb is used (e.g., VT and RI). The 3-Bar system also meets the recommended criteria when a 9-inch curb is used (e.g., ME) but not for the 7-inch curb (e.g., NH). The 4-Bar systems, however, do not meet recommended criteria for *contact width / barrier height*.

Table 5. **Rail geometrics calculations for NETC bridge rails.**

Bridge Rail Design (Mount)	State	Post Setback (in)	Rail Height (in)	Max. Vertical Opening (in)	Contact Width (in)	Ratio Contact/ Height	Result
2-Bar (curb)	NETC	4	34	7.0	21	0.62	S
	ME	4	34	7.0	21	0.62	S
	*VT	4	34	9.0	19	0.56	M
	*RI	4	34	9.0	19	0.56	M
3-Bar (curb)	ME	4	42	6.0	25	0.60	S
	*NH	4	44	*9	23	0.52	M
4-Bar (sidewalk)	NETC 4-bar	4	42	6.0	20	0.48	M
	ME	4	42	6.0	20	0.48	M
	NH	4	42	5.5	20	0.48	M
	RI	4	42	5.5	20	0.48	M
4-Bar (curb)	ME	4	54	7.0	29	0.54	M
	VT	4	55	7.0	29	0.53	M

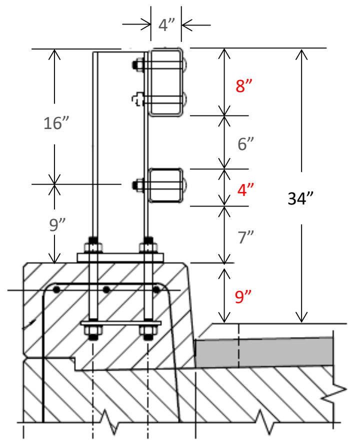
* *VT, NH, and RI use 7-inch curbs for the 2- Bar and 3-Bar systems. The max opening is between the lower rail and top of*

S: *Satisfactory*
M: *Marginal*
N.S.: *Not Satisfactory*



(a) (b)

Figure 8. Rail geometrics summary for NETC style barriers by State (blue denotes priority designs).



$$\frac{Contact\ Width}{Barrier\ Height} = \frac{8+4+9}{34} = 0.62 > 0.6 \ \text{(ok)}$$

$$maximum\ opening = 7" < 12" \ \text{(ok)}$$

Figure 9. Example calculations for the rail geometric criteria based on a *post setback distance* of 4 inches.

Rail Strength Evaluations (Bridge Rails)

The design forces for bridge railing is provided in Table A13.2-1 of the AASHTO LRFD Bridge Design Specifications, which is shown here in Table 6. Under MASH impact conditions, the impact severity increased significantly compared to its predecessors for Test Level 3 (e.g., 13.6 percent) and Test Level 4 (e.g., 56.8 percent). Accordingly, the design forces for bridge railing have also been increased for MASH designs. In a research project sponsored by TxDOT, TTI used finite element analysis to calculate lateral impact force characteristics, including magnitude and loading height, for MASH TL-4 impact conditions for rigid single slope barriers with various heights. As part of the NCHRP 20-07(395) project, FEA was used in a similar manner to calculate lateral impact load characteristics for NCHRP Report 350 and MASH TL-3 impact conditions for a rigid vertical parapet. [*Dolobrolvony17*] The resulting TL-3 and TL-4 design loads are shown in Table 7.

Table 6. Design forces for NCHRP Report 350 traffic railings [*AASHTO12*]

Design Forces and Designations	Railing Test Levels					
	TL-1	TL-2	TL-3	TL-4	TL-5	TL-6
F_t Transverse (kips)	13.5	27.0	54.0	54.0	124.0	175.0
F_L Longitudinal (kips)	4.5	9.0	18.0	18.0	41.0	58.0
F_v Vertical (kips) Down	4.5	4.5	4.5	18.0	80.0	80.0
L_t and L_L (ft)	4.0	4.0	4.0	3.5	8.0	8.0
L_v (ft)	18.0	18.0	18.0	18.0	40.0	40.0
H_e (min) (in.)	18.0	20.0	24.0	32.0	42.0	56.0
Minimum H Height of Rail (in.)	27.0	27.0	27.0	32.0	42.0	90.0

Table 7: Design forces and load height for MASH TL-3 with comparison to NCHRP Report 350. [*Dolbrovolny17*]

Design Forces and Designations	Test Level 3			Test Level 4				
	Report 350[(1)]	Report 350[(2)]	MASH[(3)]	Report 350[(1)]	MASH[(3)]			
	Barrier Height (in)			Barrier Height (in)				
	all	all	all	all	36	39	42	Tall
F_t Transverse (kip)	54	61	71	54	67.2	72.3	79.1	93.3
F_L Longitudinal (kip)	18			18	21.6	23.6	26.8	27.5
F_v Vertical (kip)	4.5			18	37.8	32.7	22	N/A
L_t and L_L (ft)	4			3.5	4	5	5	14
H_e (in)	24	18	19.5	32	25.1	28.7	30.2	45.5

(1) [*AASHTO12*]

(2) [*Dolbrolvony17*]

(3) [*Sheikh11*]

N/A Not applicable

The design load for MASH TL-3 increased to 71 kips applied at 19.5 inches above the reference surface (e.g., top of pavement for curb- and deck-mounted systems, or top of sidewalk for sidewalk-mounted systems). The design loads for MASH TL-4 also increased and are now a function of rail height, since taller barriers engage more of the cargo bed and reduce roll angle of the vehicle, both of which increase the lateral forces on the barrier.

The design loads used in the 20-07(395) project are shown in Table 8, which were based on those presented in Table 7; the values in Table 8 were adopted for this study. The NETC 2-Bar design is being evaluated as a MASH TL-3 barrier with a design load of 71 kips applied at 19 inches, since it does not meet minimum height requirement for MASH TL-4. The NETC 3-

Bar and 4-Bar designs are 42 inches tall and are being assessed as MASH TL-4 barriers, so the lateral design load for those cases is 80 kips applied at 30 inches above the reference surface.

Table 8. Design loads for MASH barriers used in NCHRP 20-07(395) project. [*Dolbrovony17*]

MASH Test Level	Rail Height (in)	Design Impact Force (kip)	H_e (in)
TL-3	≥ 29	71	19
TL-4	36	68	25
	> 36	80	30
TL-5	42	160	35
	> 42	262	43

Materials

The material types and strengths for the primary components of the NETC bridge rail designs used in the New England states are listed in Table 9. In all cases the railing material was AASHTO A500 Grade B with minimum yield strength of 46 ksi. The post and base plate material were generally ASTM Grade 50 or AASHTO M270 Grade 50 with minimum yield strength of 50 ksi, except for the base plate in the tested NETC system which was Grade 36. The concrete strength was 4 ksi or 5 ksi depending on State, and the anchor bolts were either ASTM A449 or AASHTO M314 Grade 105, with minimum tensile strength of 120 ksi and 125 ksi, respectively.

Table 9. Materials for NETC bridge rail designs.

Description		Variable	Units	NETC	NHDOT and Vtrans	Maine DOT	RIDOT
Rail	Material Type			A500 GrB	A500 GrB	A500 GrB	A500 GrB
	Yield Strength	F_{ytube}	ksi	46	46	46	46
Post	Material Type			A572 Gr50	A572 Gr50	M270 Gr 50	A572 Gr50
	Yield Strength	F_{ypost}	ksi	50	50	50	50
Base Plate	Material Type			M270 Gr36	A572 Gr50	M270 Gr 50	M270 Gr36
	Yield Strength	$F_{ybaseplate}$	ksi	36	50	50	50
Anchor Bolts	Material Type			A449	A449	M314 Gr105	A449
	Tensile Strength	F_{ybolt}	ksi	120	120	125	120
Concrete	UCS	f'_c	psi	4000.00	4000.00	5000.00	5000.00

Strength Calculations Equations

A strength analysis for the 2-Bar, 3-Bar and 4-Bar NETC designs was performed according to the procedures contained in Section 13 of the AASHTO LRFD Bridge Design Specifications based on plastic strength analysis methods. [*AASHTO12*] For post-and-beam railings, the critical rail nominal resistance, *R´*, is taken as the lowest value determined from the following equation (e.g., A13.3.2-3 in [*AASHTO12*]):

$$R' = \frac{2M_p + 2P_pL(\sum_{i=1}^{N} i)}{2NL - L_t}$$

Where,

M_p = Inelastic resistance of all rails contributing to plastic hinge (kip-ft) (i.e., $\sum F_{yi}Z_i$)

F_{yi} = Yield strength of each rail element (ksf)

Z_i = Plastic section modulus for each rail element (ft^3)

P_p = Lateral resistance of a single post (kip)

L = Post spacing (ft)

N = Number of spans included in failure hinge evaluations

L_t = length of distributed load on rail

It is assumed that the critical resistive force, R', corresponds to a resultant resistive force of the rail elements applied a height, $\bar{Y}$, above the bridge deck, where $\bar{Y}$ is computed as:

$$\bar{Y} = \frac{\sum_{i=1}^{N} M_{Pi} h_i}{M_P}$$

Where

M_{Pi} = Inelastic resistance of each rail element

h_i = height to center of each rail element relative to reference base

The lateral resistance of the post is a function of the post material and geometry, as well as the mounting connections of the post to the curb/deck. Thus, the critical value for post strength, P_p, is defined as the minimum of:

- P_{p1}: Plastic strength of the post.
- P_{p2}: Anchor bolt strength (tension and shear).
- P_{p3}: Weld strength.
- P_{p4}: Pry-out of front anchor bolts from concrete (concrete shear cone).
- P_{p5}: Push-out block shear of concrete (lateral shear).
- P_{p6}: Vertical punching shear of concrete from post baseplate.

Calculations for each of these cases are presented in the following sections.

P_{p1} – Plastic Strength of Post

The plastic strength of the post is calculated as:

$$P_{p1} = \frac{Z_{post} * F_y}{\bar{Y} - h_{curb} - t_{bp}} = \frac{Z_{post} * F_y}{h_p}$$

Where

Z_{post} = plastic section modulus for post

F_y = yield strength of post

$\bar{Y}$ = equivalent load height above reference surface (e.g., deck or sidewalk)

h_{curb} = curb height

t_{bp} = thickness of baseplate

h_p = height from top of baseplate to $\bar{Y}$

P_{P2} – Based on Anchor Bolt Strength

The peak tensile forces of the anchor bolts arise from the bending moment at the base on the post from the lateral impact force on the railing. It is assumed that as the post is pushed back it will tend to rotate about the back edge of the base plate, which will result in a combination of tensile and shear forces in all mounting bolts. The nominal tensile strength of an anchor bolt, ϕF_{ut}, is computed as:

$$\phi F_{ut} = \phi_t F_u A_{bolt}$$

Where

ϕ_t = *strength reduction factor for tension load (1.0)*

F_u = *ultimate strength of bolt (ksi)*

A_{bolt} = *stress area of bolt in the thread region (in^2)*

The stress area is calculated as:

$$A_{bolt} = 0.785\left(D - \frac{0.9743}{n}\right)^2$$

Where

D = *bolt diameter (in)*

n = *number of threads per inch (e.g., n = 8 for 1" diameter UNC bolt)*

The resultant plastic moment resistance for the anchor bolt system is:

$$M_{P2} = \phi F_{ut} w_{bolts} N_{bolts}$$

Where

w_{bolts} = *resultant moment arm for bolt group from back edge of baseplate*

N_{blts} = *number of anchor bolts in the bolt group*

The effective strength of the post relative to the anchor bolts is then:

$$P_{P2} = \frac{M_{P2}}{h_p}$$

P_{P3} – Based on Weld Strength:

For all NETC designs, the post is welded to the baseplate using a *seal* weld or an *all-around* weld at the post flanges and web, as illustrated in Figure 10. The weld strength calculations are based elastic strength of the weld and only consider the welds on the tension flange of the post. In this respect, the calculations are considered to be conservative.

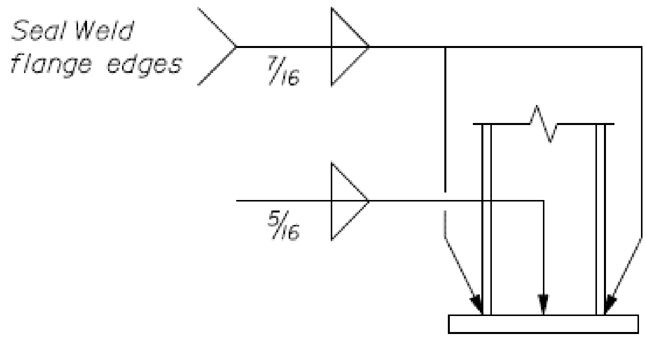


Figure 10. Weld specifications for post-to-baseplate in NETC railing designs.

The design strength, ϕR_n, of the weld is computed as:

$$\phi R_n = \phi_{weld}(0.6F_{EXX})(1 + 0.5\sin(\theta)^{1.5})A_{eff}$$

Where

ϕ_{weld} = strength reduction factor for the weld (0.75)

F_{EXX} = nominal weld strength (70 ksi)

θ = angle of loading with respect to the longitudinal axis of the weld (90 degrees)

A_{eff} = effective area of the weld

The effective area of the weld is computed as:

$$A_{eff} = t_w b_{post} N_w$$

Where

t_w = weld throat size = 0.707*weld size

b_{post} = width of post flange

N_w = number of welds = 2 (one on each side of flange)

The effective moment strength at the base of the post due to tensile loading on the welds is calculated as:

$$M_{weld} = \frac{\phi R_n}{d_w} = \frac{\phi R_n}{d_{post} - t_f}$$

Where

d_w = distance from center of weld group on flange to back flange of post

d_{post} = depth of post (flange to flange)

t_f = thickness of flange

The effective strength of the post relative to the welds at the base plate is then:

$$P_{P3} = \frac{M_{weld}}{h_p}$$

P_{P4}, P_{P5}, and P_{P6} – Based on Concrete Failure

There are basically three concrete failure modes for bridge rails mounted to concrete curbs and decks: 1) pry-out shear cone failure due to tensile load on front anchors, 2) push-out shear failure due to shear load from the anchor bolts and 3) punching shear failure due to the baseplate rotating and punching through the concrete deck at the backside of the deck. The later failure mode is typically only common for thinner decks where the post is mounted very close to the back edge of the deck. Examples of these failure modes are shown in Figures 11 and 12. Figure 11 includes two post-test photos from NCHRP Report 350 Test 3-11 on the TxDOT T77 bridge rail. [*Bullard02*] The primary failure mode of the concrete for that test was pry-out shear failure; however, the concrete curb showed notable cracks from all three damage modes, as annotated on the photos. Figure 12 shows post-test photos from NCHRP Report 350 Test 3-11 on the TxDOT T101 bridge rail, which clearly illustrates the results from punching shear when the post is set at the edge of a thin bridge deck. [*Bligh11*]

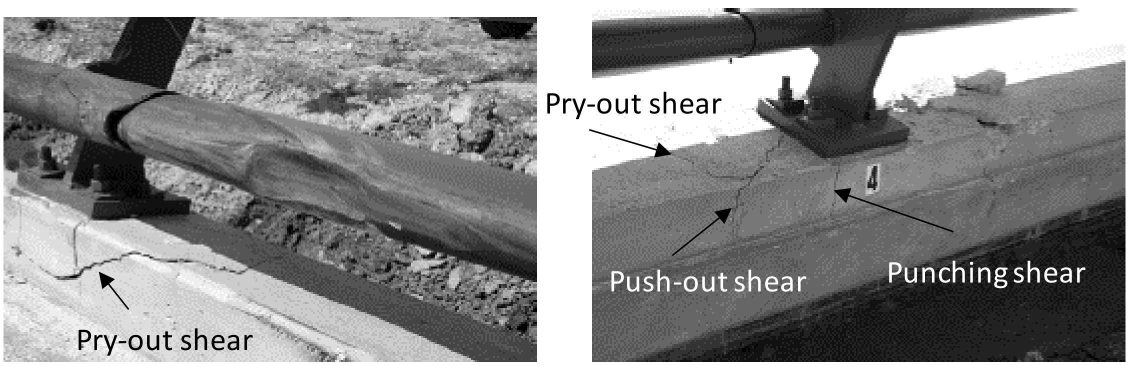


Figure 11. Concrete damage modes experienced in NCHRP Report 350 Test 3-11 on the TxDOT T77 bridge rail.

Figure 12. Punching shear damage mode experienced in NCHRP Report 350 Test 3-11on the TxDOT T101 bridge rail.

Pry-Out Failure Calculations

The theoretical shear cone failure area, A_p, for tensile loading, T_c, on anchor bolts in concrete is shown in Figure 13, where L_c is the depth of the anchor bolt, m is the distance from the center of the anchor bolt to the curb edge, d_b is the longitudinal spacing between front anchor bolts, and θ is the shear angle taken as 45 degrees. Since there is an anchor plate at the bottom of the anchor bolts, the shear surface extending between the anchor bolts was approximated by a rectangular plane starting at the bolt positions on the anchor plate and extending upward at angle θ of 45 degrees toward the concrete surfaces (i.e., toward both the front and back of the curb).

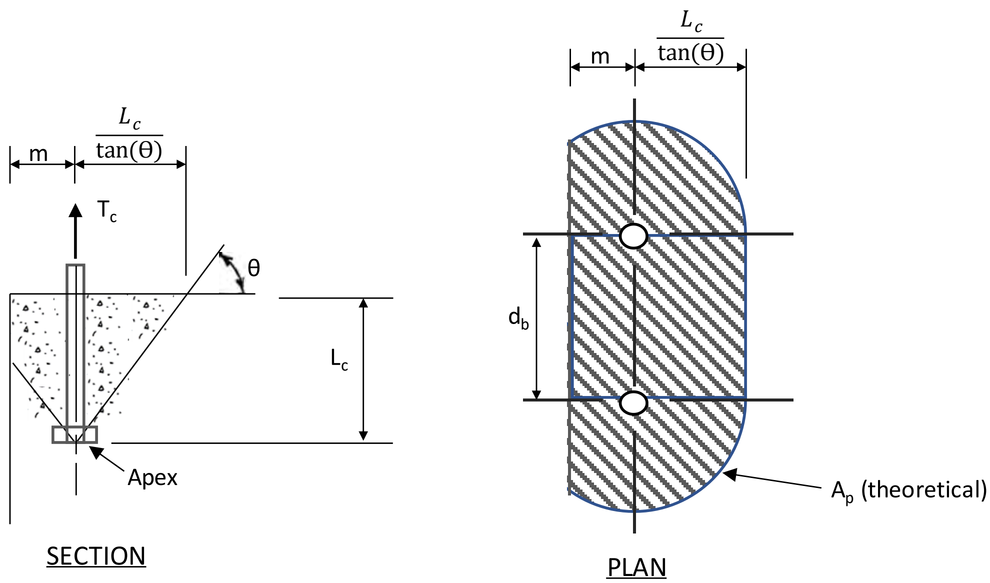


Figure 13. Theoretical failure planes for pry-out shear cone failure in concrete.

The pull-out shear cone strength, T_c, of the anchor is computed as:

$$T_c = 4\phi_t\sqrt{f_c'} * A_p$$

where

ϕ_t = Tensile stress reduction factor (0.85 when anchor head is beyond far face reinforcement)

f_c' = Unconfined compressive strength of concrete.

The effective moment resistance, M_{Tc}, at the base of the post due to pry-out force of the concrete anchor, as illustrated in Figure 14, is calculated as:

$$M_{Tc} = T_c * d_{Tc}$$

Where d_{Tc} is the distance from the tensile anchor to the point of compression on the baseplate, which is taken here as the lateral distance between anchor bolts, as shown in Figure 14a. This distance is often set as the distance from the front bolt to the back flange of the post but may extend to the back edge of the base plate, if the baseplate has sufficiently greater stiffness than the post. Note, however, that for the NETC designs the anchor bolts are essentially aligned with the post flanges, as shown in Figure 14b.

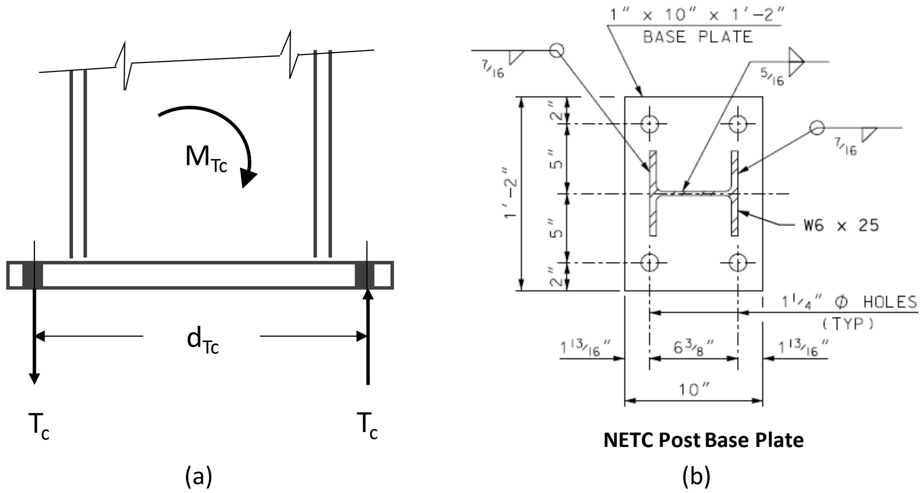


Figure 14. (a) Assumed load/reaction points for the anchor bolt pry-out resistance calculations and (b) dimensions of the NETC base plate.

The effective strength of the post relative to the pry-out resistance of the anchor bolts is then:

$$P_{P4} = \frac{M_{Tc}}{h_p}$$

<u>Push-Out Shear Failure Calculations</u>

The theoretical failure area, A_p, for push-out shear, R_c, of the concrete due to shear loading on the anchor bolts is illustrated in Figure 15. It is assummed that the shear failure cracks start at the top of the concrete surface at each of the the front anchor bolts. These cracks extend at a 45 degree angle, θ, laterally across the top of the curb and downward toward the bottom of the curb/deck forming three failure plannes. The two failure surface extending outward from the baseplate are denoted in Figure 15 as Failure Plane A. The shear planes between the two anchors under the base plate will overlap and, for simplitiy, a rectangular shear plane is approximated as a rectangular surface starting at the line between the two bolts at the surface and extending at 45 degrees downward and toward the back of the curb/deck surface. This shear plane is denoted in Figure 15 as Failure Plane B. Plane A in is shown as a trapazoid in Figure 15, since the failure plane reached the "cold joint" between the curb and deck in this example. However, if the curb were deep enough the failure plane would eventually reach the back face of the curb and form a triangular shape (refer to edge d_2 in the bottom-left image in Figure 15).

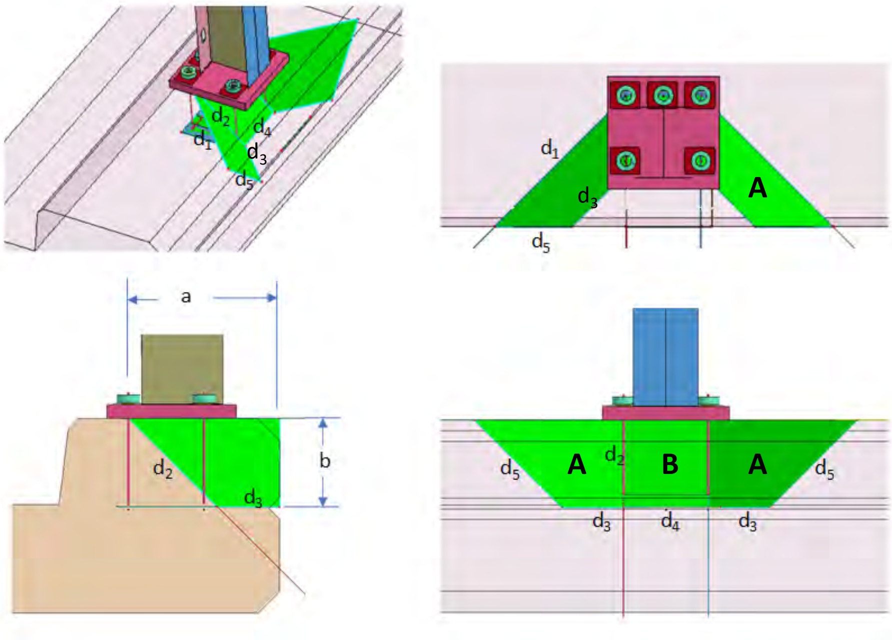
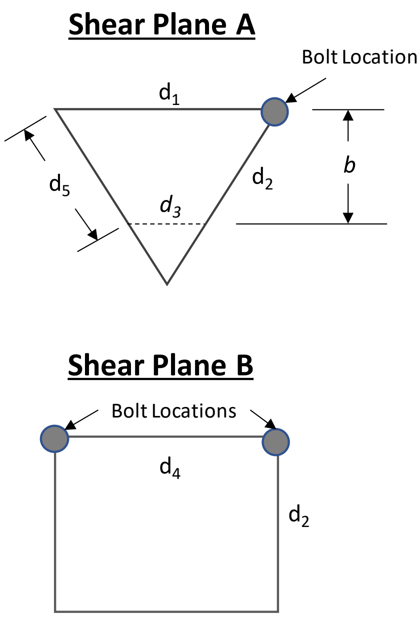


Figure 15. Approximated failure planes for push-out shear failure in concrete.

To compute the shear areas for Planes A and B, the only information required is the horizontal distance, *a*, from the front anchor bolts to the backedge of the curb, the vertical distance, *b*, from the top of the curb to either the cold joint or the bottom of the deck (which ever comes first), and the longitudinal distance, d_4, between anchor bolts.



If b > a ➔ set b=a

$$d_1 = \frac{a}{\sin(45°)}$$

$$d_2 = d_5 = \frac{b}{\sin(45°)}$$

$$d_3 = \left(1 - \frac{d_2}{d_1}\right) d_1$$

$$A = \frac{d_3 + d_1}{2}(b)$$

$d_4 \equiv$ distance between anchor bolts

$$B = d_2 * d_4$$

Figure 16. Calculation for Shear Planes A and B for Push-Out Shear Failure.

The push-out block shear resistance of the concrete due to shear on the anchor bolts is computed as:

$$P_{P5} = 2\sqrt{f_c'} * (2A + B)$$

Punching Shear Failure Calculations

The punching shear is calculated by first calculating the nominal shear resistance provided by tensile stresses in the concrete in ksi (v_c).

$$v_c = \left(0.0633 + \frac{0.1265}{\beta_c}\right)\sqrt{f_c'}$$

Where:

$\beta_c = W_b/d_b$

W_b = Width of baseplate (in.)

d_b = Distance from the outer edge of the baseplate to the innermost row of bolts (in.)

f_c' = 28-day compressive strength of concrete.

Next, the nominal shear resistance of the section being considered in kips (V_n) is calculated.

$$V_n = v_c\left[W_b + h + 2\left(E + \frac{B}{2} + \frac{h}{2}\right)\right]h$$

Where:

h = Depth of slab (in.)

E = Distance from edge of slab to centroid of compressive stress resultant in post (in.)

B = Distance between centroids of tensile and compressive stress resultants in post (in.)

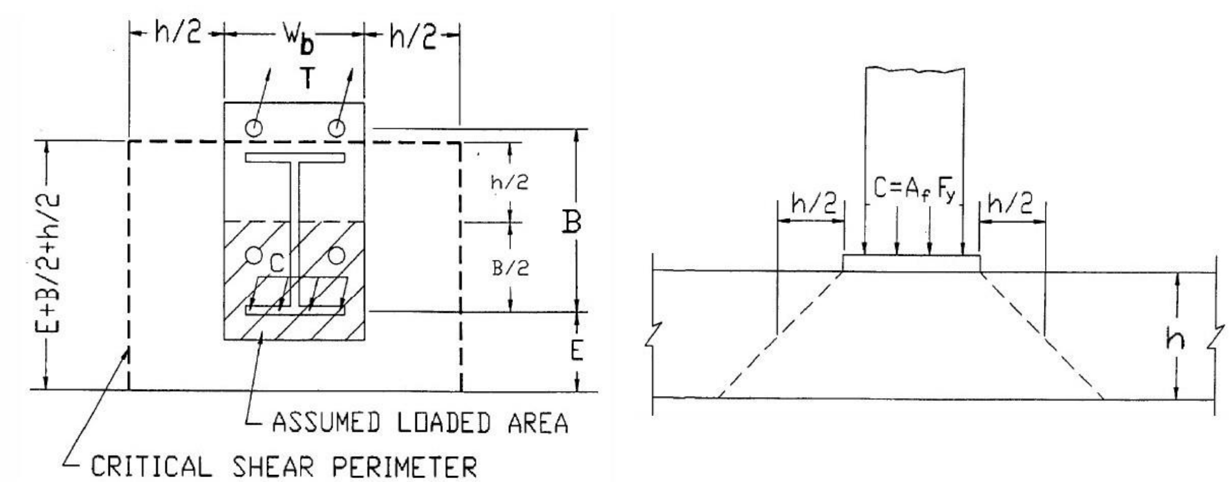


Figure 17. Punching shear failure mode (Figure A13.4.3.2-1 in 2012 LRFD)

The factored shear resistance in kips (V_r) is then calculated as:

$$V_r = \phi V_n$$

Where:

ϕ = Resistance factor = 1.0

The effective moment resistance, M_{Pc}, at the base of the post due to punching shear of the concrete deck, as illustrated in Figure 18, is calculated as:

$$M_{Pc} = V_r * B$$

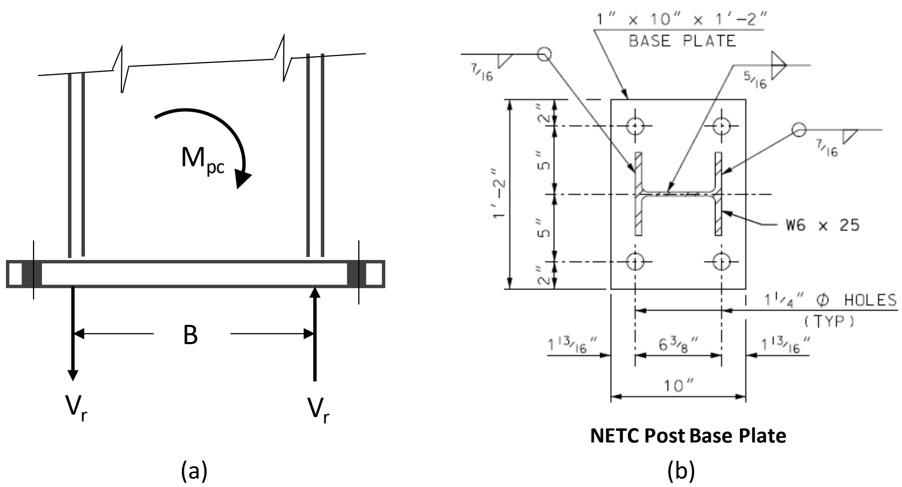


Figure 18. (a) Assumed load/reaction points for the punching shear resistance calculations and (b) dimensions of the NETC base plate.

The effective strength of the post relative to the punching resistance of the concrete deck is then:

$$P_{P6} = \frac{M_{Pc}}{h_p}$$

Effective Strength of Bridge Railing for MASH Conditions

The critical resistive force, *R*, of the bridge railing system for MASH design loads is computed from the following equation. The value of *R* should be greater than or equal to the MASH design load applied at H_e as provided in Table 8.

$$R = \frac{R' * \bar{Y}}{H_e} \geq Design\ Load$$

A summary of rail strength calculations based on each State's design details for the 2-Bar, 3-Bar, and 4-Bar NETC designs are shown in Tables 10 - 13. The strength calculations for the 2-Bar designs were based on MASH TL-3 loading conditions, as shown in Table 10. In all cases, the post strength was governed by the pry-out resistance of the concrete due to tensile load on the anchor bolts, except for the NETC tested design in which the pushout shear was critical. The calculated strength for MASH TL-3 conditions was 102.68 kips, which was well above the minimum criterion of 71 kips.

The strength calculations for the 3-Bar designs were based on MASH TL-4 loading conditions, as shown in Table 11. Only New Hampshire and Maine standards include drawing specifications for the NETC 3-bar design. In both cases, the calculated strengths met MASH TL-4 criterion of 80 kips. The critical post strength for both designs was governed by concrete pry-out resistance due to anchor bolt tensile force, followed by plastic strength of the post. The primary differences in these two systems were, for New Hampshire and Maine respectively, system height (44" vs. 42"), curb height (7" vs. 9"), and curb projection (integral vs. alternate). The MaineDOT drawing standards specify that the alternate curb projection detail is intended for use with granite bridge curb. If the MainDOT design included an integral curb projection, the resulting strength of the system would increase approximately 9 percent (i.e., 81.3 kips to 88.5 kips).

The strength calculations for the sidewalk-mounted 4-Bar bridge railing were based on MASH TL-4 loading conditions, as shown in Table 12. New Hampshire, Maine and Rhode Island include this system in their standards. In all cases the strength calculations did not meet the MASH TL-4 criterion of 80 kips, with system strengths of 71.7 kips (e.g., NHDOT), 75.08 (MaineDOT), and 76.7 kips (RIDOT). The critical post strength for the New Hampshire design was governed by concrete pry-out resistance, followed closely by concrete punching shear and the plastic strength of the post. The critical post strength for the Maine design was governed by the punching shear of concrete followed closely by plastic strength of the post and pry-out resistance. The critical post strength for the Rhode Island design was governed by the plastic strength of the post followed closely by pry-out resistance. The primary difference in these designs is that New Hampshire specifies 4000 psi concrete, while Maine and Rhode Island specify 5000 psi concrete. For the 4-Bar design to meet MASH TL-4 conditions, the minimum strength for the post would need to be 45 kips. This could be achieved by using a W8x24 post, a minimum concrete strength of 5000 psi, and an embedment of 10.38 inches for the anchor plate (e.g., 2 inches deeper than current designs).

Table 10. Strength calculations for 2-Bar bridge rail based on MASH TL-3 load conditions.

Description			Variable	Units	2-Bar Bridge Rail			
					NETC	NHDOT and Vtrans	Maine DOT	RIDOT
Materials	Rail	Material Type			A500 GrB	A500 GrB	A500 GrB	A500 GrB
		Yield Strength	F_{ytube}	ksi	46	46	46	46
	Post	Material Type			A572 Gr50	A572 Gr50	M270 Gr 50	A572 Gr50
		Yield Strength	F_{ypost}	ksi	50	50	50	50
	Base Plate	Material Type			M270 Gr36	A572 Gr50	M270 Gr 50	M270 Gr36
		Yield Strength	$F_{ybaseplate}$	ksi	36	50	50	50
	Anchor Bolts	Material Type			A449	A449	M314 Gr105	A449
		Tensile Strength	F_{ybolt}	ksi	120	120	125	120
	Concrete	Unconfined Compressive Strength	f'_c	psi	4000.00	4000.00	5000.00	5000.00
Components	Rail 1 (top)	Shape			4x8x5/16	4x8x5/16	4x8x5/16	4x8x5/16
		Plastic Moment	M_{P1}	kip-ft	37.99	37.99	37.99	37.99
	Rail 2 (bottom)	Shape			4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4
		Plastic Moment	M_{P2}	kip-ft	17.98	17.98	17.98	17.98
	Post	Shape			W6x25	W6x25	W6x25	W6x25
		Post Spacing		ft	8	8	8	8
	Base Plate	Thickness of Baseplate		in	1.00	1.00	1.00	1.00
	Weld	Weld Size	t_{weld}	in	0.44	0.44	0.44	0.44
		Number of Weld Sides per Flange	N_w		2.00	2.00	2.00	2.00
		Weld Strength	F_{7exx}	ksi	70.00	70.00	70.00	70.00
	Anchor Bolts	Diameter of Bolts	d_{bolts}	in	1.00	1.00	1.00	1.00
		Number of Bolts	N_{bolts}		4	4	4	4
		Center of Bolts to Back Edge of Baseplate	w_{bolts}	in	4.69	5.00	5.00	5.00
	Curb	Curb Height			9.00	7.00	9.00	7.00
Design Parameters		Test Level			**TL3**	**TL3**	**TL3**	**TL3**
		Transverse Design Force	F_T	kips	71.00	71.00	71.00	71.00
		Longitdinal Design Force	F_L	kips	18.00	18.00	18.00	18.00
		Vertical Design Force	F_v	kips	4.50	4.50	4.50	4.50
		Length of Equivalent Distributed Transverse Load	L_L	ft	4.00	4.00	4.00	4.00
		Height of Equivalent Distributed Transverse Load	H_e	in	19.00	19.00	19.00	19.00
Vehicle		Vehicle Type			**2270P**	**2270P**	**2270P**	**2270P**
		Weight	W	kips	5.00	5.00	5.00	5.00
		Wheel Base	B	ft	6.50	6.50	6.50	6.50
		Center of Gravity	G	in	27.00	27.00	27.00	27.00
Component Strength	Summary of Strength by Component	**Critical Plastic Moment of Rail**	M_p	**kip-ft**	**55.97**	**55.97**	**55.97**	**55.97**
		Post Strength Based on Plastic Strength of Post	P_{p1}	kips	58.53	52.08	58.53	52.08
		Post Strength Based on Anchor Bolt Tension	P_{p2}	kips	63.31	60.06	70.31	60.06
		Post Strength based on Weld Strength	P_{p3}	kips	65.22	58.20	65.22	58.03
		Post Strength based on Pryout Shear Cone	P_{p4}	kips	47.68	46.21	44.36	38.18
		Post Strength based on Pushout Shear	P_{p5}	kips	46.69	50.09	52.20	56.00
		Post Strength based on Punching Shear	P_{p6}	kips	52.39	50.85	56.11	56.92
		Critical Plastic Strength of Post	P_p	**kips**	**46.69**	**46.21**	**44.36**	**38.18**
Bridge Railing Strength	Aussumed Multi-Span Failure Modes	Rail Strength based on failure of 1 rail span	$R'_{1\text{-}Span}$	kips	74.62	74.62	74.62	74.62
		Rail Strength based on failure of 2 rail spans	$R'_{2\text{-}Span}$	kips	85.34	84.79	82.68	75.62
		Rail Strength based on failure of 3 rail spans	$R'_{3\text{-}Span}$	kips	88.26	87.57	84.87	75.89
		Rail Strength based on failure of 4 rail spans	$R'_{4\text{-}Span}$	kips	114.53	113.50	109.56	96.38
		Rail Strength based on failure of 5 rail spans	$R'_{5\text{-}Span}$	kips	129.73	128.52	123.85	108.24
		Rail Strength based on failure of 6 rail spans	$R'_{6\text{-}Span}$	kips	155.89	154.39	148.60	129.26
		Crtitical Bridge Rail Strength at y_{bar} :	R'	kips	**74.62**	**74.62**	**74.62**	**74.62**
		Critical Bridge Rail Strength at H_e :	**R**	**kips**	**102.68**	**102.68**	**102.68**	**102.68**
		Strength Assessment for MASH TL-3			**OK**	**OK**	**OK**	**OK**

Critical strength values highlighted in red font

Table 11. Strength calculations for 3-Bar bridge rail based on MASH TL-4 load conditions.

Description			Variable	Units	3-Bar Bridge Rail	
					NHDOT 3 Bar Curb Mounted	MaineDOT 3 Bar Curb Mounted
Materials	Rail	Material Type			A500 GrB	A500 GrB
		Yield Strength	F_{ytube}	ksi	46	46
	Post	Material Type			A572 Gr50	M270 Gr 50
		Yield Strength	F_{ypost}	ksi	50	50
	Base Plate	Material Type			A572 Gr50	M270 Gr 50
		Yield Strength	$F_{ybaseplate}$	ksi	50	50
	Anchor Bolts	Material Type			A449	M314 Gr105
		Tensile Strength	F_{ybolt}	ksi	120	125
	Concrete	Unconfined Compressive Strength	f'_c	psi	4000.00	5000.00
Component Parameters	Rail 1 (top)	Shape			4x4x1/4	4x4x1/4
		Height		in	42.00	40.00
	Rail 2	Shape			4x8x5/16	4x8x5/16
		Height		in	30.00	28.00
	Rail 3 (bottom)	Shape			4x4x1/4	4x4x1/4
		Height		in	18.00	16.50
	Post	Shape			W6x25	W6x25
		Post Spacing		ft	8	8
	Base Plate	Thickness of Baseplate	t_{BP}	in	1.00	1.00
	Weld	Weld Size	t_{weld}	in	0.44	0.44
		Number of Weld Sides per Flange	N_w		2.00	2.00
		Weld Strength	F_{7exx}	ksi	70.00	70.00
	Anchor Bolts	Diameter of Bolts	d_{bolts}	in	1.00	1.00
		Number of Bolts	N_{bolts}		4	4
		Center of Bolts to Back Edge of Baseplate	w_{bolts}	in	5.00	5.00
	Curb	Curb Height		in	7.00	9.00
Design Parameters		Test Level			**TL4**	**TL4**
		Transverse Design Force	F_T	kips	80.00	80.00
		Longitdinal Design Force	F_L	kips	27.00	27.00
		Vertical Design Force	F_v	kips	22.00	22.00
		Length of Equivalent Distributed Transverse Load	L_L	ft	5.00	5.00
		Height of Equivalent Distributed Transverse Load	H_e	in	30.00	30.00
Vehicle		Vehicle Type			SUT	SUT
		Weight	W	kips	22.00	22.00
		Wheel Base	B	ft	7.50	7.50
		Center of Gravity	G	in	63.00	63.00
Component Strength	Summary of Strength by Component	**Critical Plastic Moment of Rail**	M_p	kip-ft	**73.95**	**73.95**
		Post Strength Based on Plastic Strength of Post	P_{p1}	kips	42.95	52.15
		Post Strength Based on Anchor Bolt Tension	P_{p2}	kips	49.54	62.64
		Post Strength based on Weld Strength	P_{p3}	kips	47.86	58.11
		Post Strength based on Pryout Shear Cone	P_{p4}	kips	38.46	39.77
		Post Strength based on Pushout Shear	P_{p5}	kips	50.09	52.20
		Post Strength based on Punching Shear	P_{p6}	kips	42.33	50.31
		Critical Plastic Strength of Post	P_p	**kips**	**38.46**	**39.77**
Bridge Railing Strength	Aussumed Multi-Span Failure Modes	Rail Strength based on failure of 1 rail span	$R'_{1\text{-}Span}$	kips	107.56	107.56
		Rail Strength based on failure of 2 rail spans	$R'_{2\text{-}Span}$	kips	89.41	90.96
		Rail Strength based on failure of 3 rail spans	$R'_{3\text{-}Span}$	kips	84.76	86.71
		Rail Strength based on failure of 4 rail spans	$R'_{4\text{-}Span}$	kips	103.50	106.34
		Rail Strength based on failure of 5 rail spans	$R'_{5\text{-}Span}$	kips	114.24	117.60
		Rail Strength based on failure of 6 rail spans	$R'_{6\text{-}Span}$	kips	134.74	138.88
		Crtitical Bridge Rail Strength at y_{bar} :	R'	kips	84.76	86.71
		Critical Bridge Rail Strength at H_e :	R	kips	**84.76**	**81.28**
		Strength Assessment for MASH TL-4			**OK**	**OK**

Critial strength values highlted

Table 12. Strength calculations for sidewalk-mounted 4-Bar bridge rail based on MASH TL-4 load conditions

Description			Variable	Units	NETC	NHDOT	MaineDOT	RIDOT
					4-Bar Bridge Rail			
					Sidewalk-Mounted			
Materials	Rail	Material Type			A500 GrB	A500 GrB	A500 GrB	A500 GrB
		Yield Strength	F_{ytube}	ksi	**46**	**46**	**46**	**46**
	Post	Material Type			A709 Gr50	A572 Gr50	M270 Gr 50	M270 Gr 50
		Yield Strength	F_{ypost}	ksi	**50**	**50**	**50**	**50**
	Base Plate	Material Type			A709 Gr36	A572 Gr50	M270 Gr 50	M270 Gr 50
		Yield Strength	$F_{ybaseplate}$	ksi	**36**	**50**	**50**	**50**
	Anchor Bolts	Material Type			A449	A449	M314 Gr105	A449
		Tensile Strength	F_{ybolt}	ksi	**120**	**120**	**125**	**120**
	Concrete	Unconfined Compressive Strength of Concrete	f'_c	psi	4000.00	4000.00	5000.00	5000.00
Component Parameters	Rail 1 (top)	Shape			4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4
		Height		in	39.50	40.00	40.00	40.00
	Rail 2	Shape			4x8x5/16	4x8x5/16	4x8x5/16	4x8x5/16
		Height		in	27.50	28.50	28.00	28.50
	Rail 3	Shape			4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4
		Height		in	16.50	17.00	16.50	17.00
	Rail 4 (bottom)	Shape			4x4x1/4	4x4x1/4	4x4x1/4	4x4x1/4
		Height		in	7.00	7.50	7.00	7.50
	Post	Shape			W6x25	W6x25	W6x25	W6x25
		Post Spacing		ft	8	8	8	8
	Base Plate	Thickness of Baseplate	t_{BP}	in	1.00	1.00	1.00	1.00
	Weld	Weld Size	t_{weld}	in	0.44	0.44	0.44	0.44
		Number of Weld Sides per Flange	N_w		2.00	2.00	2.00	2.00
		Weld Strength	F_{7exx}	ksi	70.00	70.00	70.00	70.00
	Anchor Bolts	Diameter of Bolts	d_{bolts}	in	1.00	1.00	1.00	1.00
		Number of Bolts	N_{bolts}		4.00	4.00	4.00	5.00
		Center of Bolts to Back Edge of Baseplate	w_{bolts}	in	5.00	5.00	5.00	6.00
	Curb	Curb Height		in	0.00	0.00	0.00	0.00
Design Parameters		Test Level				**TL4**	**TL4**	**TL4**
		Transverse Design Force	F_T	kips	80.00	80.00	80.00	80.00
		Longitdinal Design Force	F_L	kips	27.00	27.00	27.00	27.00
		Vertical Design Force	F_v	kips	22.00	22.00	22.00	22.00
		Length of Equivalent Distributed Transverse Load	L_L	ft	5.00	5.00	5.00	5.00
		Height of Equivalent Distributed Transverse Load	H_e	in	30.00	30.00	30.00	30.00
Vehicle		Vehicle Type			SUT	SUT	SUT	SUT
		Weight	W	kips	22.00	22.00	22.00	22.00
		Wheel Base	B	ft	7.50	7.50	7.50	7.50
		Center of Gravity	G	in	63.00	63.00	63.00	63.00
Component Strength		**Critical Plastic Moment of Rail**	M_p	kip-ft	**91.92**	**91.92**	**91.92**	**91.92**
	Summary of Strength by Component	Post Strength Based on Plastic Strength of Post	P_{p1}	kips	41.66	40.40	41.10	40.40
		Post Strength Based on Anchor Bolt Tension	P_{p2}	kips	48.04	46.59	49.38	69.88
		Post Strength based on Weld Strength	P_{p3}	kips	46.42	45.01	45.76	44.98
		Post Strength based on Pryout Shear Cone	P_{p4}	kips	37.35	36.27	41.23	40.55
		Post Strength based on Pushout Shear	P_{p5}	kips	42.93	50.09	52.20	56.00
		Post Strength based on Punching Shear	P_{p6}	kips	30.52	39.91	40.10	69.22
		Critical Plastic Strength of Post	P_p	**kips**	**30.52**	**36.27**	**40.10**	**40.40**
Bridge Railing Strength	Aussumed Multi-Span Failure Modes	Rail Strength based on failure of 1 rail span	$R'_{1\text{-}Span}$	kips	133.71	133.71	133.71	133.71
		Rail Strength based on failure of 2 rail spans	$R'_{2\text{-}Span}$	kips	90.64	97.46	102.00	102.35
		Rail Strength based on failure of 3 rail spans	$R'_{3\text{-}Span}$	kips	79.63	88.18	93.89	94.33
		Rail Strength based on failure of 4 rail spans	$R'_{4\text{-}Span}$	kips	91.14	103.61	111.93	112.57
		Rail Strength based on failure of 5 rail spans	$R'_{5\text{-}Span}$	kips	97.74	112.46	122.27	123.03
		Rail Strength based on failure of 6 rail spans	$R'_{6\text{-}Span}$	kips	112.75	130.95	143.08	144.01
		Crtitical Bridge Rail Strength at y_{bar} :	R'	kips	79.63	88.18	93.89	94.33
		Critical Bridge Rail Strength at H_e :	**R**	**kips**	**62.87**	**71.70**	**75.08**	**76.70**
		Strength Assessment for MASH TL-4			**FAIL**	**FAIL**	**FAIL**	**FAIL**

Critial strength values highlted in red font

Table 13. Strength calculations for curb-mounted 4-Bar bridge rail based on MASH TL-4 load conditions

Description			Variable	Units	4-Bar Bridge Rail	
					Curb-Mounted	
					MaineDOT	Vtrans
Materials	Rail	Material Type			A500 GrB	A500 GrB
		Yield Strength	F_{ytube}	ksi	**46**	46
	Post	Material Type			M270 Gr 50	A572 Gr50
		Yield Strength	F_{ypost}	ksi	**50**	50
	Base Plate	Material Type			M270 Gr 50	A572 Gr50
		Yield Strength	$F_{ybaseplate}$	ksi	**50**	50
	Anchor Bolts	Material Type			M314 Gr105	A449
		Tensile Strength	F_{ybolt}	ksi	**125**	120
	Concrete	Unconfined Compressive Strength of Concrete	f'_c	psi	5000.00	4000.00
Component Parameters	Rail 1 (top)	Shape			4x4x1/4	4x4x1/4
		Height		in	52.00	53.00
	Rail 2	Shape			4x4x1/4	4x4x1/4
		Height		in	41.00	42.00
	Rail 3	Shape			4x8x5/16	4x8x5/16
		Height		in	29.00	29.00
	Rail 4 (bottom)	Shape			4x4x1/4	4x4x1/4
		Height		in	17.50	17.00
	Post	Shape			W6x25	W6x25
		Post Spacing		ft	8	8
	Base Plate	Thickness of Baseplate	t_{BP}	in	1.00	1.00
	Weld	Weld Size	t_{weld}	in	0.44	0.44
		Number of Weld Sides per Flange	N_w		2.00	2.00
		Weld Strength	F_{7exx}	ksi	70.00	70.00
	Anchor Bolts	Diameter of Bolts	d_{bolts}	in	1.00	1.00
		Number of Bolts	N_{bolts}		4.00	4.00
		Center of Bolts to Back Edge of Baseplate	w_{bolts}	in	5.00	5.00
	Curb	Curb Height		in	9.00	9.00
Design Parameters		Test Level			**TL4**	**TL4**
		Transverse Design Force	F_T	kips	80.00	80.00
		Longitdinal Design Force	F_L	kips	27.00	27.00
		Vertical Design Force	F_v	kips	22.00	22.00
		Length of Equivalent Distributed Transverse Load	L_L	ft	5.00	5.00
		Height of Equivalent Distributed Transverse Load	H_e	in	30.00	30.00
Vehicle		Vehicle Type			SUT	SUT
		Weight	W	kips	22.00	22.00
		Wheel Base	B	ft	7.50	7.50
		Center of Gravity	G	in	63.00	63.00
Component Strength		**Critical Plastic Moment of Rail**	M_p	kip-ft	**91.92**	**91.92**
	Summary of Strength by Component	Post Strength Based on Plastic Strength of Post	P_{p1}	kips	40.05	39.56
		Post Strength Based on Anchor Bolt Tension	P_{p2}	kips	48.11	45.62
		Post Strength based on Weld Strength	P_{p3}	kips	44.63	44.21
		Post Strength based on Pryout Shear Cone	P_{p4}	kips	30.94	30.90
		Post Strength based on Pushout Shear	P_{p5}	kips	59.40	50.09
		Post Strength based on Punching Shear	P_{p6}	kips	51.31	39.12
		Critical Plastic Strength of Post	P_p	**kips**	**30.94**	**30.90**
Bridge Railing Strength	Aussumed Multi-Span Failure Modes	Rail Strength based on failure of 1 rail span	$R'_{1\text{-}Span}$	kips	133.71	133.71
		Rail Strength based on failure of 2 rail spans	$R'_{2\text{-}Span}$	kips	91.15	91.09
		Rail Strength based on failure of 3 rail spans	$R'_{3\text{-}Span}$	kips	80.26	80.19
		Rail Strength based on failure of 4 rail spans	$R'_{4\text{-}Span}$	kips	92.06	91.96
		Rail Strength based on failure of 5 rail spans	$R'_{5\text{-}Span}$	kips	98.83	98.71
		Rail Strength based on failure of 6 rail spans	$R'_{6\text{-}Span}$	kips	114.09	113.95
		Crtitical Bridge Rail Strength at y_{bar} :	R'	kips	**80.26**	**80.19**
		Critical Bridge Rail Strength at H_e :	**R**	**kips**	**89.88**	**90.59**
		Strength Assessment for MASH TL-4			**OK**	**OK**

Critial strength values highlted in red font

The strength calculations for the curb-mounted 4-Bar bridge railing were based on MASH TL-4 loading conditions, as shown in Table 13. Only Maine and Vermont include this system in their standards. In both cases the strength calculations meet MASH TL-4 criterion of 80 kips, with system strengths of 89.9 kips (e.g., MaineDOT) and 90.6 (e.g., VTrans). The critical post strength for both designs was governed by concrete pry-out resistance. The primary differences in these designs are, for Maine and Vermont respectively, concrete strength (minimum 5000 psi vs. 4000 psi) and curb projection (0 inches vs. 5 inches). The curb projection in the VTrans design counters the lower concrete strength, resulting in essentially equivalent pry-out strength as the MaineDOT design.

It is also worth noting that these calculations were based on a design load height, H_e, of 30 inches according to Table 8. In these cases, the rail height is 54 and 55 inches for Maine and Vermont designs, respectively, which would classify the system as "tall" in Table 7. Table 7 suggests a design load height of 45.5 inches for tall bridge railing, in which case both curb-mounted 4-Bar designs would fail MASH strength requirements, with a calculated strength of approximately 60 kips.

Summary of Strength Assessments for Baseline NETC Designs

Table 14 shows a summary of the overall assessment results for the baseline NETC systems (i.e., lowest strength design). Based on the assessment, it was determined that both the NETC 2-Bar and the Maine 3-Bar systems would likely meet MASH TL-3. The NETC 3-Bar system will likely meet MASH TL-4 requirements; however, only the Maine Design with the 9-inch curb meets the rail geometrics requirements. The sidewalk-mounted 4-Bar system did not meet either the rail-geometrics requirements or strength requirements and may, therefore, require redesign. The curb-mounted 4-bar design was considered "marginal" based on potential for vehicle snagging on posts (e.g., the 4-inch setback distance is too low); however, the system was shown to have adequate strength, when considering a design load height of 30 inches. Note that previous study by TTI researchers [*Sheikh11*] indicated that a design height of 45.5 inches should be used for tall systems, as indicated in Table 7, in which case the system would not meet strength requirements.

Table 14. Summary of assessment of Maine curb-mounted 4-bar design.

	NETC 2-Bar (TL3)			NETC 3-Bar (TL4)			NETC 4-Bar (TL4)			Curb-Mounted 4-Bar (TL4)		
	Rail Height	Rail Geometrics	Strength	Rail Height	Rail Geometrics	Strength	Rail Height	Rail Geometrics	Strength	Rail Height	Rail Geometrics	Strength
Required	29	(see Table 5)	71 k	36 in	(see Table 5)	80 k	36 in	(see Table 5)	80 k	36 in	(see Table 5)	80 k
Actual	34		103 k	42 in		85 k	42 in		71 k*	54 in		90 k*
Assessment	S	S	S(1)	S	S(2)	S	S	M	NS	S	M	S

NS - Not Satisfactory
M - Marginal
S - Satisfactory
S (1) - Satisfactory Rating for TL-3 Only
S (2) - Satisfactory when 9" curb is used
** - Differs from 20-07(395) report*

Critical Review of Current Standard Details for NETC Style Bridge Rails

Over all the systems are quite similar. They will be compared and contrasted along with the Roadsafe recommendations in the following sections. When selecting recommended values, Roadsafe typically uses the least conservative value that has an acceptable crash testing record. In this way the more conservative values would be assumed to have sufficient strength.

Rail Bars

Most of the features of the bridge rail bars and positions are consistent between designs as can be seen from Table 15 through Table 18, for the 2-Bar, 3-Bar, 4-Bar and 4-Bar curb mounted designs, respectively. The material for the rail bars in all cases is ASTM A500 Gr. B which has a minimum yield strength of 46 ksi. The shape and size of all small rail bars is HSS 4"x4"x1/4" while it is HSS 8"x4"x5/16" for all large bars.

2-Bar System

There are five NETC Style 2-bar bridge rail designs in use in New England states. The five designs come from the NETC, MaineDOT, NHDOT, RIDOT and VTrans. The size of all bars and their order is the same between designs. The top rail height and bottom rail height (from the vehicle running surface) is the same between designs at 2'-10" and 18" respectively. The only difference between designs in the curb height, for the MaineDOT and NETC designs the curb height is 9" while it is only 7" for the other designs, as shown in Table 15.

3-Bar System

There are two NETC Style 3-bar bridge rail designs in use in New England states. The two designs come from MaineDOT and NHDOT. The size of all bars and their order is the same for both designs. The height of each rail bar and the curb height vary slightly between the two designs as can be seen in Table 16.

4-Bar System

There are four NETC Style 4-bar sidewalk mounted bridge rail designs in use in New England states. The four designs come from the NETC, MaineDOT, NHDOT and RIDOT. As with the 3-Bar system, the size of all bars and their order is the same for each design, while the height of each rail bar and the curb height vary slightly between designs as shown in Table 17.

4-Bar Curb Mounted System

There are two NETC Style 4-bar curb mounted bridge rail designs in use in New England states. The two designs come from MaineDOT and VTrans. The size of all bars, their order and the large rail height is the same between both designs. The top rail height varies slightly between the designs as can be seen in Table 18. While the drawings for both 4-bar curb mounted designs calls for 9" tall curbs, Roadsafe recommends using 7", to be consistent with the other systems (2-bar and 3-bar curb mounted).

Table 15. Comparison of bridge rail features for NETC Style 2-bar bridge rails.

Design	Material	Size	Order of Bars (from top)	Top Rail Height	Bottom Rail Height	Curb Height
Recommendations	ASTM A500 Grade B (46 ksi)	HSS 4" x 4" x $\frac{1}{4}$" HSS 8" x 4" x $\frac{5}{16}$"	8x4, 4x4	2'-10"	18"	7"
NETC	*	*	*	*	*	9"
MaineDOT	*	*	*	*	*	9"
NHDOT	*	*	*	*	*	*
RIDOT	*	*	*	*	*	*
VTrans	*	*	*	*	*	*

** Same as recommended*
N.S.: Not Specified

Table 16. Comparison of bridge rail features for NETC Style 3-bar bridge rails.

Design	Material	Size	Order of Bars (from top)	Top Rail Height (to top)	Middle Rail Height (to center)	Bottom Rail Height (to center)	Curb Height
Recommendations	ASTM A500 Grade B (46 ksi)	HSS 4" x 4" x $\frac{1}{4}$" HSS 8" x 4" x $\frac{5}{16}$"	4x4, 8x4, 4x4	3'-8"	30"	18"	7"
MaineDOT	*	*	*	3'-6"	28"	16$\frac{1}{2}$"	9"
NHDOT	*	*	*	*	*	*	*

** Same as recommended*
N.S.: Not Specified

Table 17. Comparison of bridge rail features for NETC Style 4-bar sidewalk mounted bridge rails.

Design	Material	Size	Order of Bars (from top)	Top Rail Height (to top)	Large Rail Height (to center)	Mid-Btm Rail Height (to center)	Bottom Rail Height (to center)
Recommendations	ASTM A500 Grade B (46 ksi)	HSS 4" x 4" x $\frac{1}{4}$" HSS 8" x 4" x $\frac{5}{16}$"	4x4, 8x4, 4x4, 4x4	3'-6"	28"	16$\frac{1}{2}$"	7"
NETC	*	*	*	*	*	*	*
MaineDOT	*	*	*	*	*	*	*
NHDOT	*	*	*	*	28$\frac{1}{2}$"	17"	7$\frac{1}{2}$"
RIDOT	*	*	*	*	28$\frac{1}{2}$"	17"	7$\frac{1}{2}$"

** Same as recommended*
N.S.: Not Specified

Table 18. Comparison of bridge rail features for NETC Style 4-bar curb mounted bridge rails.

Design	Material	Size	Order of Bars (from top)	Top Rail Height (to top)	Top-Mid Height (to center)	Large Rail Height (to center)	Bottom Rail Height (to center)	Curb Height
Recommendations	ASTM A500 Grade B (46 ksi)	HSS 4" x 4" x $\frac{1}{4}$" HSS 8" x 4" x $\frac{5}{16}$"	4x4, 4x4, 8x4, 4x4	Curb: 3'-9" Pavement: 4'-6"	Curb: 32" Pavement: 41"	Curb: 20" Pavement: 29"	Curb: 8" Pavement: 17"	7"
MaineDOT	*	*	*	*	*	*	Curb: 8$\frac{1}{2}$" Pavement: 17$\frac{1}{2}$"	9"
VTrans	*	*	*	Curb: 3'-8" Pavement: 4'-7	Curb: 33" Pavement: 42"	*	*	9"

** Same as recommended*
N.S.: Not Specified

Bridge Rail Post

Three different material types are specified in the designs for posts. All specified materials have the same yield strength, 50 ksi. NETC specifies ASTM A709 Gr. 50, MaineDOT specifies AASHTO M270 Gr. 50 while NHDOT, VTrans and RIDOT spec ASTM 572 Gr. 50. The material specifications for all post materials are shown in Table 19. The specific detail for the 2-

Bar, 3-Bar and 4-Bar designs are shown in Table 20 through Table 23, respectively. All designs specify W6x25 for the post shape, 8'-0" maximum spacing, $\frac{7}{16}$" flange fillet welds, and $\frac{5}{16}$" web fillet welds. When evaluating designs Roadsafe will align the posts normal to grade, thus "normal to grade" will be the recommended practice for vertical alignment. However, it is understood that for some applications in the mountains there may be limits to when posts should be set vertically, rather than normal to the grade. Roadsafe will rely on feedback from the states on how these situations should be handled. As in the NHDOT and RIDOT designs, Roadsafe recommends a minimum of 3 posts per rail bar length. The MaineDOT and VTrans designs both specify that a minimum of two, but preferably four posts, be used per rail bar. Roadsafe will rely on feedback from the states on how to address situations where railings are in use that have 2 posts per rail, or if this is even a concern. The minimum offset to an expansion joint varies slightly between designs but these values are similar.

Table 19. Material strength properties for post materials

Material	Yield (ksi)	Ultimate (ksi)	Elongation at Break
ASTM A709 Gr. 50	50	65.4	18%
AASHTO M270 Gr. 50	50	65.4	18%
ASTM 572 Gr. 50	50	65.3	18%

Table 20. Comparison of bridge rail post features for NETC Style 2-bar bridge rails.

Design	Material	Size	Vert Alignment	Max Spacing	# of Posts per Rail Bar	Min. Offset to Expansion Splice	Flange to Base Plate Weld	Web to Base Plate Weld
Recommendations	AASHTO M270 Grade 50	W6x25	Normal to Grade	8'-0"	3	2'-0"	$\frac{7}{16}$" All Around Fillet Weld	$\frac{5}{16}$" All Around Fillet Weld
NETC	N.S.	*	N.S.	*	N.S.	*	N.S.	N.S.
MaineDOT	*	*	*	*	Min. 2 - 4	*	*	*
NHDOT	ASTM 572 Grade 50	*	Normal to Grade except on 5% grade set vertical	*	*	1'-6" (± 3")	*	*
RIDOT	*	*	Normal to Grade except on 1.5% grade set vertical	*	*	2'-0" (± 3")	*	*
VTrans	ASTM 572 Grade 50	*	*	*	Min. 2 - 4	1'-6" (± 3")	*	*

** Same as recommended*
N.S.: Not Specified

Table 21. Comparison of bridge rail post features for NETC Style 3-bar bridge rails.

Design	Material	Size	Vert Alignment	Max Spacing	# of Posts per Rail Bar	Min. Offset to Expansion Splice	Flange to Base Plate Weld	Web to Base Plate Weld
Recommendations	AASHTO M270 Grade 50	W6x25	Normal to Grade	8'-0"	3	2'-0"	$\frac{7}{16}$" All Around Fillet Weld	$\frac{5}{16}$" All Around Fillet Weld
MaineDOT	*	*	*	*	Min. 2 - 4	*	*	*
NHDOT	ASTM A572 Grade 50	*	* except on 5% grade set vertical	*	*	1'-6" (± 3")	*	*

** Same as recommended*
N.S.: Not Specified

Table 22. Comparison of bridge rail post features for NETC Style 4-bar sidewalk mounted bridge rails.

Design	Material	Size	Vert Alignment	Max Spacing	# of Posts per Rail Bar	Min. Offset to Expansion Splice	Flange to Base Plate Weld	Web to Base Plate Weld
Recommendations	AASHTO M270 Grade 50	W6x25	Normal to Grade	8'-0"	3	2'-0"	$\frac{7}{16}$" All Around Fillet Weld	$\frac{5}{16}$" All Around Fillet Weld
NETC	ASTM A709 Grade 50	*	*	*	Min. 2	*	*	*
MaineDOT	*	*	*	*	Min. 2-4	*	*	*
NHDOT	ASTM A572 Grade 50	*	* except on 5% grade, set vertical	*	*	1'-6" (± 3")	*	*
RIDOT	ASTM A572 Grade 50	*	* except on 1.5% grade, set vertical	*	*	N.S.	*	*

** Same as recommended*
N.S.: Not Specified

Table 23. Comparison of post features for NETC Style 4-bar curb mounted bridge rails.

Design	Material	Size	Vert Alignment	Max Spacing	# of Posts per Rail Bar	Min. Offset to Expansion Splice	Flange to Base Plate Weld	Web to Base Plate Weld
Recommendations	AASHTO M270 Grade 50	W6x25	Normal to Grade	8'-0"	3	2'-0"	$\frac{7}{16}$" All Around Fillet Weld	$\frac{5}{16}$" All Around Fillet Weld
MaineDOT	*	*	*	*	Min. 2-4	*	*	*
VTrans	ASTM A572 Grade 50	*	*	*	Min. 2-4	*	*	*

** Same as recommended*
N.S.: Not Specified

Rail-to-Post Attachment

Two methods of rail-to-post attachment exist among the NETC style bridge rail designs, the welded stud design and the bolted connection. Based on discussions with personnel from the New England states it is believed that the most common (i.e. only) method used in the field is the bolted connection method. NHDOT and RIDOT provide details for using threaded studs welded to the bar. Based on feedback of the states the welded stud method will not be pursued in the evaluation portion of this project. The bolt specifications vary between designs. Table 24 displays the minimum strength values for each bolt material specified, as well as the effective strength, calculated from the tensile stress area for each diameter bolt. There are differences between the designs for size of the holes in both the rail member and the post, however these differences are consistent for each state across all its designs. For evaluation the largest hole diameter (or slot) was selected. If the slotted design passes the evaluation, then it will be assumed that the tighter hole tolerances will also pass evaluation. Specific details for each design are shown in Table 25 through Table 28.

Table 24. Strength values for different bolts specifications for rail-to-post attachment.

Bolt Spec	Minimum Strength Requirement		Effective Strength for Ø	
	Tensile (ksi)	Yield (ksi)	Tensile (kips)	Yield (kips)
$\frac{3}{4}$" Ø A325	120	92	40.080	30.728
$\frac{3}{4}$" Ø A307[†]	58	36	19.372	12.024

$\frac{5}{8}$" Ø A325	120	92	27.120	20.792
$\frac{3}{4}$" Ø A449‡	120	92	40.080	30.728
$\frac{3}{4}$" Ø AASHTO M164 (Type1)§	120	92	40.080	30.728
† As of August 2007, replaced by F1554 Gr. 36 ‡ Virtually identical in chemistry and strength to ASTM A325 § This standard is identical to ASTM A325				

Table 25. Comparison of rail-to-post attachment features for NETC Style 2-bar bridge rails.

Design	Specified Method	Number of Bolts	Welded Stud (Detail A)		Bolted (Detail B)		
			Hole in Post	Stud Dimension	Hole in Rail	Hole in Post	Bolt Specifications
Recommendations	Bolted	2/Rail	--	--	$\frac{7}{8}$"	$1\frac{1}{8}$" x $1\frac{3}{8}$" slotted hole	6″ x $\frac{3}{4}$" A325
NETC	*	*	--	--	N.S	N.S.	*
MaineDOT	*	*	--	--	Bolt Ø + $\frac{1}{16}$"	Bolt Ø + $\frac{1}{16}$"	6″ x $\frac{3}{4}$" A307 6″ x $\frac{5}{8}$" A325
NHDOT	Bolted or Welded Stud	*	$1\frac{1}{8}$" x $1\frac{3}{8}$" slotted hole	$\frac{3}{4}$" x $1\frac{3}{4}$"	*	*	*
RIDOT	Bolted or Welded Stud	*	$1\frac{1}{8}$" x $1\frac{3}{8}$" slotted hole	$\frac{3}{4}$" x $1\frac{3}{4}$"	*	*	* or A449
VTrans	*	*	--	--	Bolt Ø + $\frac{1}{16}$"	Bolt Ø + $\frac{1}{16}$"	6″ x $\frac{3}{4}$" A449

** Same as recommended*
N.S.: Not Specified
-- Not applicable

Table 26. Comparison of rail-to-post attachment features for NETC Style 3-bar bridge rails.

Design	Specified Method	Number of Bolts	Welded Stud (Detail A)		Bolted (Detail B)		
			Hole in Post	Stud Dimension	Hole in Rail	Hole in Post	Bolt Specifications
Recommendations	Bolted	2/Rail	--	--	$\frac{7}{8}$"	$1\frac{1}{8}$" x $1\frac{3}{8}$" slotted hole	6″ x $\frac{3}{4}$" A325
MaineDOT	*	*	--	--	Bolt Ø + $\frac{1}{16}$"	Bolt Ø + $\frac{1}{16}$"	6″ x $\frac{3}{4}$" A307 6″ x $\frac{5}{8}$" A325
NHDOT	Bolted or Welded Stud	*	$1\frac{1}{8}$" x $1\frac{3}{8}$" slotted hole	$\frac{3}{4}$" x $1\frac{3}{4}$"	*	*	*

** Same as recommended*
N.S.: Not Specified
-- Not applicable

Table 27. Comparison of rail-to-post attachment features for NETC Style 4-bar sidewalk mounted bridge rails.

Design	Specified Method	Number of Bolts	Welded Stud (Detail A)		Bolted (Detail B)		
			Hole in Post	Stud Dimension	Hole in Rail	Hole in Post	Bolt Specifications
Recommendations	Bolted	2/Rail	--	--	$\frac{7}{8}$"	$1\frac{1}{8}$" x $1\frac{3}{8}$" slotted hole	6" x $\frac{3}{4}$" A325
NETC	Welded	*	1"Ø	$\frac{3}{4}$" x 2" A307	--	--	--
MaineDOT	*	*	--	--	Bolt Ø + $\frac{1}{16}$"	Bolt Ø + $\frac{1}{16}$"	6" x $\frac{3}{4}$" A307 6" x $\frac{5}{8}$" A325
NHDOT	Bolted or Welded Stud	*	$1\frac{1}{8}$" x $1\frac{3}{8}$" slotted hole	$\frac{3}{4}$" x $1\frac{3}{4}$" A304	*	*	*
RIDOT	Bolted or Welded Stud	*	$1\frac{1}{8}$" x $1\frac{3}{8}$" slotted hole	$\frac{3}{4}$" x $1\frac{3}{4}$" A304	*	*	*

** Same as recommended*
N.S.: Not Specified
-- Not applicable

Table 28. Comparison of rail-to-post attachment features for NETC Style 4-bar curb mounted bridge rails.

Design	Specified Method	Number of Bolts	Welded Stud (Detail A)		Bolted (Detail B)		
			Hole in Post	Stud Dimension	Hole in Rail	Hole in Post	Bolt Specifications
Recommendations	Bolted	2/Rail	--	--	Bolt Ø + $\frac{1}{8}$"	Bolt Ø + $\frac{1}{16}$"	6" x 3/4" A325
MaineDOT	*	*	--	--	Bolt Ø + $\frac{1}{16}$"	*	6" x $\frac{3}{4}$" A307 6" x $\frac{5}{8}$" A325
VTrans	*	*	--	--	*	*	6" x $\frac{3}{4}$" AASHTO M164M (Type I)

** Same as recommended*
N.S.: Not Specified
-- Not applicable

Base Plate and Anchor Bolts

Material selection for the base plate matches the material selections for the post for each design. Baseplate dimensions are consistent across all designs with the exception of RIDOT 4-Bar Sidewalk mounted design, described below. While most of the designs and the Roadsafe recommendation are for ASTM A449 anchor bolts, MaineDOT specifies AASHTO M314 Gr. 105 bolts. The strength features of these materials are displayed in Table 29. Embedment of the anchor plate also varies between designs. This value also likely varies to some degree in the field. During evaluation the more critical 7.5" embedment depth will be used, and greater embedment depths will be assumed to pass if the 7.5" embedment depth design passes. All designs called for 3" of exposed rod above the concrete. The amount of thread varied between the designs. Roadsafe has chosen to evaluate the 2.5" thread because this offers the greatest chance that some diameter reduction will be in the base plate shear zone. Like the embedment depth issue, if the 2.5" threaded design passes evaluation the 2.25" thread will be assumed to pass as well. Specific details for each design are shown in Table 30 through Table 33.

4-Bar System

The base plate dimensions are consistent across all 4-bar system designs except RIDOT. The RIDOT design has a 5-anchor bolt pattern with an offset post. The 5-bolt design and the post offset yields higher strength for the anchor bolts and the concrete pry-out resistance; however, the plastic strength of the post governed the critical post strength based on the LRFD strength calculations for this system. The 4-bolt design will be evaluated and if it passes testing then the 5-bolt design will be assumed to pass.

Table 29. Strength values for different bolts specifications for anchor bolts.

Bolt Spec	Minimum Strength Requirement		Effective Strength for Ø	
	Tensile (ksi)	Yield (ksi)	Tensile (kips)	Yield (kips)
1" Ø A449	120	92	72.720	55.752
1" Ø AASHTO M314 Gr. 105	125	105	75.750	63.630

Table 30. Comparison of base plate and anchor bolt features for NETC Style 2-bar bridge rails.

Design	Material	Size	Number of Bolts	Bolt Pattern	Size of Holes	Anchor Bolts					
						Size	Material	Embedment	Exposed Rod	Exposed Nut	Nut Torque
Recommendations	ASHTO M270 Grade 50 (50 ksi)	1" x 10" x 1'-2"	4	See drawing	1.25"	1" Ø x 12" L	ASTM A449	$7\frac{1}{2}$"	3" $2\frac{1}{2}$" threaded	Heavy hex nut & washer	Snug + 1/8 turn
NETC	*	*	*	*	N.S.	1" Ø x 9" L	N.S.	N.S.	N.S.	N.S.	N.S.
MaineDOT	*	*	*	*	*	*	AASHTO M314, Grade 105	$8\frac{1}{2}$"	3" $2\frac{1}{4}$" threaded	*	*
NHDOT	*	*	*	*	*	*	*	9"	*	1"Ø-8 steel nut & 1"Ø washer	*
RIDOT	*	*	*	*	*	*	*	9" (min)	*	*	*
VTrans	*	*	*	*	*	*	*	*	3" $2\frac{1}{4}$" threaded	*	*

** Same as recommended*
N.S.: Not Specified

Table 31. Comparison of base plate and anchor bolt features for NETC Style 3-bar bridge rails.

Design	Material	Size	Number of Bolts	Bolt Pattern	Size of Holes	Anchor Bolts					
						Size	Material	Embedment	Exposed Rod	Exposed Nut	Nut Torque
Recommendations	AASHTO M270 Grade 50	1" x 10" x 1'-2"	4	See Below	1.25"	1" Ø x 12" L	ASTM A449	$7\frac{1}{2}$"	3" $2\frac{1}{2}$" threaded	Heavy hex nut & washer	Snug + 1/8 turn
MaineDOT	*	*	*	*	*	*	AASHTO M314 Grade 105	$8\frac{1}{2}$"	3" $2\frac{1}{4}$" threaded	*	*
NHDOT	ASTM A572 Grade 50	*	*	*	*	*	*	9" (min)	*	Steel hex nut & washer	*

** Same as recommended*
N.S.: Not Specified

Table 32. Comparison of base plate and anchor bolt features for NETC Style 4-bar sidewalk mounted bridge rails.

						Anchor Bolts					
Design	Material	Size	Number of Bolts	Bolt Pattern	Size of Holes	Size	Material	Embedment	Exposed Rod	Exposed Nut	Nut Torque
Recommendations	ASHTO M270 Grade 50	1" x 10" x 1'-2"	4	See NHDOT on Next Slide	$1\frac{1}{4}$"	1" Ø x 12" L	ASTM A449	$7\frac{1}{2}$"	3" $2\frac{1}{2}$" threaded	Heavy hex nut & washer	Snug + 1/8 turn
NETC	ASHTO M270 Grade 36	*	*	*	*	*	*	$8\frac{1}{2}$"	3" $2\frac{1}{4}$" threaded	*	*
MaineDOT	*	*	*	*	*	*	ASHTO M314 Grade 105	$8\frac{1}{2}$"	3" $2\frac{1}{4}$" threaded	*	*
NHDOT	ASTM A572 Grade 50	*	*	*	*	*	*	9" (min)	*	Steel nut & washer	*
RIDOT	ASTM A572 Grade 50	1" x 11" x 1'-2"	5	See RIDOT on Next Slide	$1\frac{1}{16}$"	*	*	9" (min)	*	Steel nut & washer	*

** Same as recommended*
N.S.: Not Specified

Table 33. Comparison of base plate and anchor bolt features for NETC Style 4-bar curb mounted bridge rails.

						Anchor Bolts					
Design	Material	Size	Number of Bolts	Bolt Pattern	Size of Holes	Size	Material	Embedment	Exposed Rod	Exposed Nut	Nut Torque
Recommendations	ASHTO M270 Grade 50	1" x 10" x 1'-2"	4	See drawing	$1\frac{1}{4}$"	1" Ø x 12" L	ASTM A449	$7\frac{1}{2}$"	3" $2\frac{1}{2}$" threaded	Heavy hex nut & washer	Snug + 1/8 turn
MaineDOT	*	*	*	*	*	*	ASHTO M314 Grade 105	$8\frac{1}{2}$"	3" $2\frac{1}{4}$" threaded	*	*
VTrans	ASTM A572 Grade 50	*	*	*	*	*	*	$8\frac{1}{2}$"	3" $2\frac{1}{4}$" threaded	*	*

** Same as recommended*
N.S.: Not Specified

Field Splice

Most field splice features are the same between designs, the biggest differences being the size of the hole in the rail member and the gap between rail bars. Roadsafe recommends evaluating the least conservative option, the slotted design, used by NHDOT and RIDOT for the rail hole feature and 3/4" gap between bars. If the design passes the evaluation with these details the smaller holes and smaller gap will be assumed to pass as well. Specific details for each design are shown in Table 34 through Table 37.

Table 34. Comparison of field splice features for NETC Style 2-bar bridge rails.

Design	Splice Tube Dimensions	Connection Details	Number of Bolts	Size of Hole in Rail	Hole in Splice Tube	Bolt	Nut?	Pipe Spacer	Space Between Rail Bars	Splice Tube L	Drain Hole?
Recommendations	HSS 3" x 3" x $\frac{5}{16}$" HSS 7" x 3" x $\frac{3}{8}$"	See Figure Below	4	$1\frac{1}{8}$" x $2\frac{1}{2}$" slot	$\frac{5}{8}$" Ø tapped hole	$\frac{5}{8}$" Ø x $1\frac{3}{4}$" Cap Screw	Tack weld on outer holes only	$\frac{3}{4}$" Ø x $\frac{1}{2}$" Schd. 40†	$\frac{3}{4}$"	1'-8"	Yes, $\frac{1}{2}$" Ø
NETC	*	*	*	N.S.	N.S.	*	N.S.	N.S.	*	*	N.S.
MaineDOT	*	*	*	$\frac{13}{16}$" Ø hole	*	*	*	No	*	*	N.S.
NHDOT	*	*	*	*	*	* A307	*	*	$\frac{1}{2}$"	*	*
RIDOT	*	*	*	*	*	* A307	*	*	$\frac{1}{2}$"	*	*
VTrans	*	*	*	$\frac{3}{4}$" Ø hole	*	$\frac{5}{8}$" Ø x $1\frac{3}{4}$" Bolt	*	*	$\frac{1}{2}$"	*	*

** Same as recommended*
N.S.: Not Specified
† only 1 side each splice, both rails

Table 35. Comparison of field splice features for NETC Style 3-bar bridge rails.

Design	Splice Tube Dimensions	Connection Details	Number of Bolts	Size of Hole in Rail	Hole in Splice Tube	Bolt	Nut?	Pipe Spacer	Space Between Rail Bars	Splice Tube L	Drain Hole?
Recommendations	HSS 3" x 3" x $\frac{5}{16}$" HSS 7" x 3" x $\frac{3}{8}$"	See Figure Below	4	$1\frac{1}{8}$" x $2\frac{1}{2}$" slot	$\frac{5}{8}$" Ø tapped hole	$\frac{5}{8}$" Ø x $1\frac{3}{4}$" Cap Screw	Tack weld on outer holes only	$\frac{3}{4}$" Ø x $\frac{1}{2}$" Schd. 40†	$\frac{3}{4}$"	1'-8"	Yes, $\frac{1}{2}$" Ø
MaineDOT	*	*	*	$\frac{13}{16}$" Ø hole	*	*	*	No	*	*	N.S.
NHDOT	*	*	*	*	*	*	*	*	*	*	*

** Same as recommended*
N.S.: Not Specified
† only 1 side each splice, both rails

Table 36. Comparison of field splice features for NETC Style 4-bar sidewalk mounted bridge rails.

Design	Splice Tube Dimensions	Connection Details	Number of Bolts	Size of Hole in Rail	Hole in Splice Tube	Bolt	Nut?	Pipe Spacer	Space Between Rail Bars	Splice Tube L	Drain Hole?
Recommendations	HSS 3" x 3" x $\frac{5}{16}$" HSS 7" x 3" x $\frac{3}{8}$"	See Figure Below	4	$1\frac{1}{8}$" x $2\frac{1}{2}$" slot	$\frac{5}{8}$" Ø tapped hole	$\frac{5}{8}$" Ø x $1\frac{3}{4}$" Cap Screw	Tack weld on outer holes only	$\frac{3}{4}$" Ø x $\frac{1}{2}$" Schd. 40†	$\frac{3}{4}$"	1'-8"	Yes, $\frac{1}{2}$" Ø
NETC	*	*	*	N.S.	N.S.	*	N.S.	N.S.	*	*	N.S.
MaineDOT	*	*	*	$\frac{13}{16}$" Ø hole	*	$\frac{5}{8}$" Ø x $1\frac{3}{4}$" Bolt & plain hardened washer	*	No	*	*	N.S.
NHDOT	*	*	*	*	*	* A307	*	*	*	*	*
RIDOT	*	*	*	*	*	* A307	*	*	*	*	*

** Same as recommended*
N.S.: Not Specified
† only 1 side each splice, both rails

Table 37. Comparison of field splice features for NETC Style 4-bar curb mounted bridge rails.

Design	Splice Tube Dimensions	Connection Details	Number of Bolts	Size of Hole in Rail	Hole in Splice Tube	Bolt	Nut?	Pipe Spacer	Space Between Rail Bars	Splice Tube L	Drain Hole?
Recommendations	HSS 3" x 3" x $\frac{5}{16}$" HSS 7" x 3" x $\frac{3}{8}$"	See Figure Below	4	$1\frac{1}{8}$" x $2\frac{1}{2}$" slot	$\frac{5}{8}$" Ø tapped hole	$\frac{5}{8}$" Ø x $1\frac{3}{4}$" Bolt & plain hardened washer	Tack weld on outer holes only	No	$\frac{3}{4}$"	1'-8"	Yes, $\frac{1}{2}$" Ø
MaineDOT	*	*	*	$\frac{13}{16}$" Ø hole	*	*	*	No	*	*	N.S.
VTrans	*	*	*	$\frac{3}{4}$" Ø hole	*	*	*	No	*	*	N.S.

** Same as recommended*
N.S.: Not Specified

Expansion Splice

A comparison of the expansion joint details for the NETC style bridge rail designs is displayed in Table 38 through Table 41. The NETC designs do not specify any dimensional requirements for expansion joints. There are many differences in the expansion joint details, one main difference being the range of "bridge movements" that the details cover. A supplemental summary of details for each design for each range of bridge movements is provided in Table 42. Roadsafe recommends using the MaineDOT details for the expansion joints during the evaluation since the MaineDOT design covers the greatest amount of bridge movements.

Table 38. Comparison of expansion splice features for NETC Style 2-bar bridge rails.

Design	Splice Tube Dimensions	Connection Details	Number of Bolts	Size of Hole in Rail	Hole in Splice Tube	Bolt	Nut?	Pipe Spacer	Space Between Rail Bars	Splice Tube L	Drain Hole?
Recommendations	HSS 3" x 3" x $\frac{5}{16}$" HSS 7" x 3" x $\frac{3}{8}$"	See Figures on Next Slide	4	See MaineDOT next slide	$\frac{5}{8}$" Ø tapped hole	$\frac{5}{8}$" Ø x $1\frac{3}{4}$" Cap Screw	Tack weld on outer holes only	$\frac{3}{4}$" Ø x $\frac{1}{2}$" Schd. 40	See MaineDOT next slide	See MaineDOT next slide	Yes, $\frac{1}{2}$" Ø
NETC	N.S.	N.S.	N.S.	N.S.	N.S.	*	N.S.	N.S.	N.S.	N.S.	N.S.
MaineDOT	*	*	*	*	*	*	*	N.S.	*	*	N.S.
NHDOT	*	*	*	See NHDOT next slide	*	* A307	*	*	See NHDOT next slide	See NHDOT next slide	*
RIDOT	*	*	*	See RIDOT next slide	*	* A307	*	*	See RIDOT next slide	See RIDOT next slide	*
VTrans	*	*	*	$1\frac{1}{8}$" x $3\frac{1}{2}$" slot	*	$\frac{5}{8}$" Ø x $1\frac{3}{4}$" Bolt	*	*	4" @68°F	1'-11 $\frac{3}{4}$"	*

** Same as recommended*
N.S.: Not Specified

Table 39. Comparison of expansion splice features for NETC Style 3-bar bridge rails.

Design	Splice Tube Dimensions	Connection Details	Number of Bolts	Size of Hole in Rail	Hole in Splice Tube	Bolt	Nut?	Pipe Spacer	Space Between Rail Bars	Splice Tube L	Drain Hole?
Recommendations	HSS 3" x 3" x $\frac{5}{16}$" HSS 7" x 3" x $\frac{3}{8}$"	See Figures on Next Slide	4	See MaineDOT Next Slide	$\frac{5}{8}$" Ø tapped hole	$\frac{5}{8}$" Ø x $1\frac{3}{4}$" Cap Screw	Tack weld on outer holes only	$\frac{3}{4}$" Ø x $\frac{1}{2}$" Schd. 40	See MaineDOT Next Slide	See MaineDOT Next Slide	Yes, $\frac{1}{2}$" Ø
MaineDOT	*	*	*	*	*	*	*	*	*	*	N.S.
NHDOT	*	*	*	See NHDOT Next Slide	*	*	*	*	See NHDOT Next Slide	See NHDOT Next Slide	*

** Same as recommended*
N.S.: Not Specified

Table 40. Comparison of expansion splice features for NETC Style 4-bar sidewalk mounted bridge rails.

Design	Splice Tube Dimensions	Connection Details	Number of Bolts	Size of Hole in Rail	Hole in Splice Tube	Bolt	Nut?	Pipe Spacer	Space Between Rail Bars	Splice Tube L	Drain Hole?
Recommendations	HSS 3" x 3" x $\frac{5}{16}$" HSS 7" x 3" x $\frac{3}{8}$"	See Figures on Next Slide	4	See MaineDOT next slide	$\frac{5}{8}$" Ø tapped hole	$\frac{5}{8}$" Ø x $1\frac{3}{4}$" A307 Cap Screw	Tack weld on outer holes only	$\frac{3}{4}$" Ø x $\frac{1}{2}$" Schd. 40	--	See MaineDOT next slide	Yes, $\frac{1}{2}$" Ø
NETC	*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
MaineDOT	*	*	*	*	*	$\frac{5}{8}$" Ø x $1\frac{3}{4}$" Bolt & plain hardened washer	*	*	*	*	N.S.
NHDOT	*	*	*	See NHDOT next slide	*	*	*	*	See NHDOT next slide	See NHDOT next slide	*
RIDOT	*	*	*	See RIDOT next slide	*	*	*	*	See RIDOT next slide	See RIDOT next slide	*

** Same as recommended*
N.S.: Not Specified

Table 41. Comparison of expansion splice features for NETC Style 4-bar curb mounted bridge rails.

Design	Splice Tube Dimensions	Connection Details	Number of Bolts	Size of Hole in Rail	Hole in Splice Tube	Bolt	Nut?	Pipe Spacer	Space Between Rail Bars	Splice Tube L	Drain Hole?
Recommendations	HSS 3" x 3" x $\frac{5}{16}$" HSS 7" x 3" x $\frac{3}{8}$"	See Figures on Next Slide	4	See MaineDOT next slide	$\frac{5}{8}$" Ø tapped hole	$\frac{5}{8}$" Ø x $1\frac{3}{4}$" Bolt & plain hardened washer	Tack weld on outer holes only	$\frac{3}{4}$" Ø x $\frac{1}{2}$" Schd. 40	See MaineDOT next slide	See MaineDOT next slide	Yes, $\frac{1}{2}$" Ø
MaineDOT	*	*	*	*	*	*	*	*	*	*	N.S.
VTrans	*	*	*	See VTrans next slide	*	*	*	*	See VTrans next slide	See VTrans next slide	N.S.

** Same as recommended*
N.S.: Not Specified

Table 42. Comparison of expansion splice details for different amounts of bridge movement.

Design	Bridge Movement	Gap Between Rails	Rail Hole Slot	Distance Between Bolts	Inside Bolt to Splice Bar CL	Outside Bolt to Splice Bar End	Splice Tube L
MaineDOT	≤ 4" 4" < T ≤ 6.5" 6.5" < T ≤ 9" 9" < T ≤ 13"	2.50" 3.75" 5.00" 7.00"	2.50" 3.50" 9.00" 11.00"	4.00" 4.00" 4.00" 4.00"	4.00" 5.50" 6.50" 8.50"	2.00" 2.50" 3.50" 4.50"	1'-8" 2'-0" 2'-4" 2'-10"
RIDOT & NHDOT	≤ 3.25" 3.25" < T ≤ 5.25"	2.00" 3.00"	2.50" 3.50"	4.00" 5.00"	4.00" 5.00"	2.00" 2.50"	1'-8" 2'-1"
VTrans 2-Bar	N/A	4.00"	3.50"	4.00"	5.50"	2.375"	1'-11.75"
VTrans 4-Bar Curb Mounted	≤ 4" 4" < T ≤ 6.5" 6.5" < T ≤ 9" 9" < T ≤ 13"	2.50" 4.00" 5.00" 7.00"	2.50" 3.50" 9.00" 11.00"	4.00" 4.00" 4.00" 4.00"	4.00" 5.50" 6.50" 8.50"	2.00" 2.375" 3.375" 4.375"	20" 23.75" 27.75" 33.75"

Concrete Curb

A comparison of the concrete curb details are provided in Table 43 through Table 46. There are many small dimensional differences between the designs. For the recommended evaluation dimensions Roadsafe recommends using the smallest values which are anticipated to pass evaluation. For back bolts to deck edge that is 7 5/8” and for front bolts to curb edge it is 4”. Concrete strength of 4000 psi is used in the strength evaluations, states that require 5000 psi concrete strength will be considered to pass if 4000 psi does. There are some differences in the reinforcement bars, particularly the longitudinal bar length. Some only require 5’ length while others require full length of the curb and NHDOT doesn’t specify a required length. Secondary pours and granite curbs are not included in the strength evaluations since they are not reinforced. Although not used for the strength calculations, the curb projections may affect vehicle dynamics during the simulations.

Table 43. Comparison of concrete curb features for NETC Style 2-bar bridge rails.

Design	Strength Requirement	Curb Dimensions				Reinforcing Steel	
		Curb Height	Curb Width	Back Bolts to Deck Edge	Front Bolts to Curb Edge	Longitudinal Reinforcement Near Post Anchor	Reinforcement Hoop Bars Near Post Anchor
Recommendations	4000 psi	7”	1’-6”	$7\frac{5}{8}$”	4”	3 - #5 Bars 5' L minimum	7 - #5 Bars at 6" spacing, engagement required from some deck rebars
NETC	N.S.	9”	1’-4”	$4\frac{5}{8}$”	5”	2 - #5 Bars length not specified	*
MaineDOT	5000 psi	9”	1’-8”	$8\frac{1}{8}$”	$5\frac{1}{2}$”	3 - #5 Bars full length of curb	*
NHDOT	*	*	2’-0”	*	10”	3 - #5 Bars	*
RIDOT	5000 psi	*	*	*	*	*	7 - #5 Bars at 6" spacing. Must engage min. two deck rebars
VTrans	*	*	2’-0”	*	10”	3 - #5 Bars, middle 5' L min, outsides full length of curb	*

** Same as recommended*
N.S.: Not Specified

Table 44. Comparison of concrete curb features for NETC Style 3-bar bridge rails.

Design	Strength Requirement	Curb Dimensions				Reinforcing Steel	
		Curb Height	Curb Width	Back Bolts to Deck Edge	Front Bolts to Curb Edge	Longitudinal Reinforcement Near Post Anchor	Reinforcement Hoop Bars Near Post Anchor
Recommendations	4000 psi	7”	1’-6”	$7\frac{5}{8}$”	4”	3 - #5 Bars 5' L minimum	7 - #5 Bars at 6" spacing
MaineDOT	5000 psi	9”	1’-8”	$8\frac{1}{8}$”	$5\frac{1}{2}$”	3 - #5 Bars full length of curb	*
NHDOT	*	*	2’-0”	*	10”	3 - #5 Bars	*

** Same as recommended*
N.S.: Not Specified
--: Not Applicable

Table 45. Comparison of concrete curb features for NETC Style 4-bar sidewalk mounted bridge rails.

Design	Strength Requirement	Sidewalk Dimensions				Reinforcing Steel	
		Sidewalk Height	Sidewalk Width	Back Bolts to Deck Edge	Front Bolts to Sidewalk Edge	Longitudinal Reinforcement Near Post Anchor	Reinforcement Hoop Bars Near Post Anchor
Recommendations	4000 psi	9”	5’ (Min.)	$7\frac{5}{8}$”	5’-2”	3 - #5 Bars minimum 5' L	7 - #5 Bars at 6" spacing, engagement required from some deck rebars
NETC	N.S.	N.S	N.S	*	N.S.	3 - #5 Bars, middle 5' L min, outsides full length of sidewalk	*
MaineDOT	5000 psi	*	N.S	$8\frac{1}{8}$”	N.S.	3 - #5 Bars full length of curb	*
NHDOT	*	7”	*	*	Min. 5’-4”	3 - #5 Bars, length requirement N.S.	*
RIDOT	5000 psi	7”	*	*	Min. 5’-2”	*	*

** Same as recommended*
N.S.: Not Specified

Table 46. Comparison of concrete curb features for NETC Style 4-bar curb mounted bridge rails.

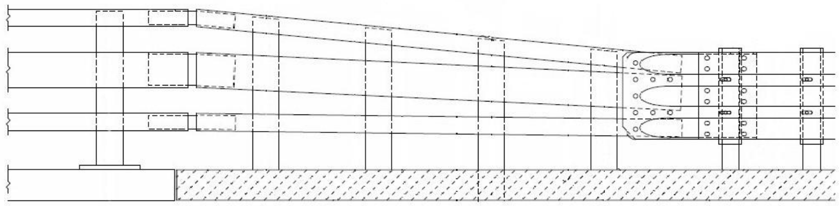
Design	Strength Requirement	Curb Dimensions				Reinforcing Steel	
		Curb Height	Curb Width	Back Bolts to Deck Edge	Front Bolts to Curb Edge	Longitudinal Reinforcement Near Post Anchor	Reinforcement Hoop Bars Near Post Anchor
Recommendations	4000 psi	7″	1′-8″	$7\frac{5}{8}$″	4″	3 - #5 Bars minimum 5' L	7 - #5 Bars at 6" spacing, engagement required from some deck rebars
MaineDOT	5000 psi	9″	*	$8\frac{1}{8}$″	$5\frac{1}{2}$″	3 - #5 Bars full length of curb	*
VTrans	5000 psi	9″	2′-1″	*	$10\frac{3}{16}$″	3 - #5 Bars, middle 5' L min, outsides full length of curb	*

** Same as recommended*
N.S.: Not Specified

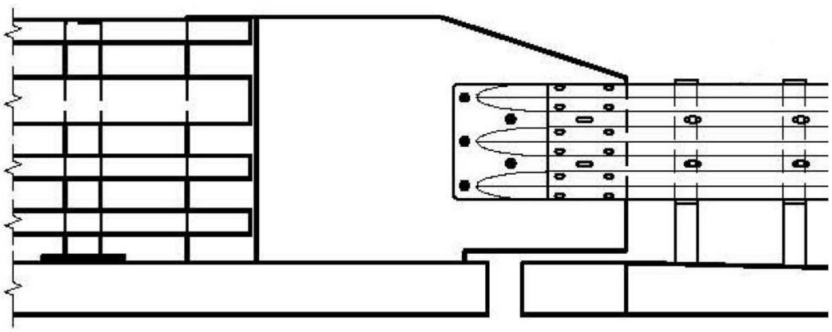
Critical Review of Current Standard Details for NETC Style Bridge Rail Transitions

Categorically speaking there are two design concepts for approach guardrail transitions (AGT) on New England bridges, i.e., a sloped rail bar design and a concrete buttress design. Both designs connect a typical highway w-beam to a thrie-beam section using a w-beam to thrie-beam transition. In the "sloped bridge rail" design the thrie-beam section is connected to the sloped rails using a thrie-beam terminal connector element. The downstream end of the sloped rail section is connected to the bridge rail using an angled expansion joint. The sloped rails are composed of HSS steel tubular sections of the same size and material as the bridge rail bars. The "concrete buttress" design replaces the sloped bridge rail with a concrete buttress. The sloped rail design and concrete buttress design are shown in Figure 19. These designs were described in Previous Full-Scale Testing of NETC Hardware section of this report and are further detailed in the following paragraphs.

For the 2 bar AGT system detail are provided by NH and Vtrans are dimensionally the same and only differ in the material specifications (same materials used in the bridge rail designs). NHDOT is the only state with 3 bar AGT drawings. The MaineDOT concrete buttress design is the only concrete buttress design. Design drawings for the 4-bar sloped rail bar AGT designs are available from NHDOT and VTrans; these two designs vary significantly both in concept and dimensions.



a) Sloped Rail Bar



b) Concrete Buttress

Figure 19. Drawings of the two design concepts for NETC approach guardrail transitions (AGT).

NHDOT 2-Bar Transition

The NHDOT T2 Steel Bridge Approach Rail was successfully crash tested in April 2005 by NETC and accepted as NCHRP 350 TL-3. An FHWA acceptance letter was provided for the design, HSSD/B-146. See section NHDOT 2-Bar Rail to Thrie-Beam AGT of this report for more details.

A standard 12-gauge w-beam roadway guardrail is used upstream of the AGT as shown in Figure 20. A 25’-0” section of guardrail is flared at 80:1 to restore the rail-to-rail width. Post spacing in this section is 6’3” (e.g., standard post spacing) and the guardrails are lapped in the direction of traffic. The curb is flared away from the roadway at a 10:1 rate and has a 4” reveal. The curb increases in height from 4” to 7” over the next approximately 9 feet.

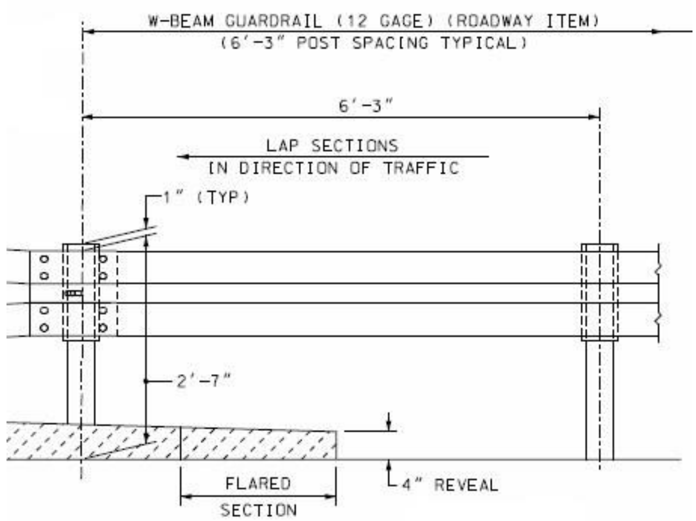


Figure 20. NHDOT T2 AGT upstream w-beam section.

A symmetrical 10-gage w-beam to thrie-beam transition rail is attached to the standard w-beam on the upstream end as seen in Figure 21. The transition rail is 6'-3" long and post spacing in this section is 3'-1.5" (half post spacing). The height of the rail at the upstream end of the thrie-beam transition rail is 31 inches high and is 34 inches at the downstream end.

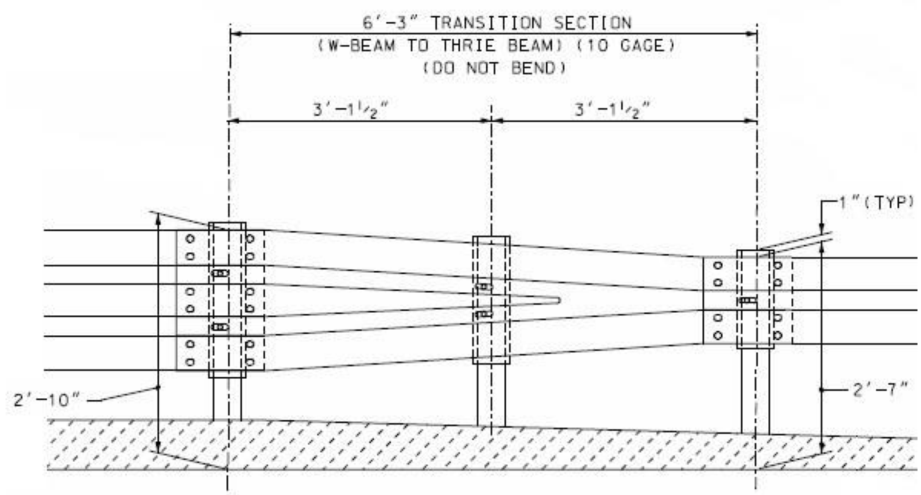


Figure 21. NHDOT T2 AGT symmetrical w-beam to thrie-beam transition section.

The next section is a 12'-6" long double nested 12-gage thrie-beam section as seen in Figure 22. The first upstream post is spaced at 3'-1.5" (e.g., half post spacing), while the next six posts are spaced 1'-6.75" (quarter-post spacing). A connection plate and thrie-beam terminal connector are used to connect the thrie-beam to the top and bottom sloped bridge rails. An important component of the downstream end of the thrie-beam section where the connection plate fastens to the sloped rail bars is the use of a deflector plate between the top and bottom rail. This deflector plate helps to minimize the risk of the bumper or fender of the vehicle snagging on the post at the end of connector plate; it also reduces the risk of the vehicle snagging on the end of the connector plate in reverse-direction impacts.

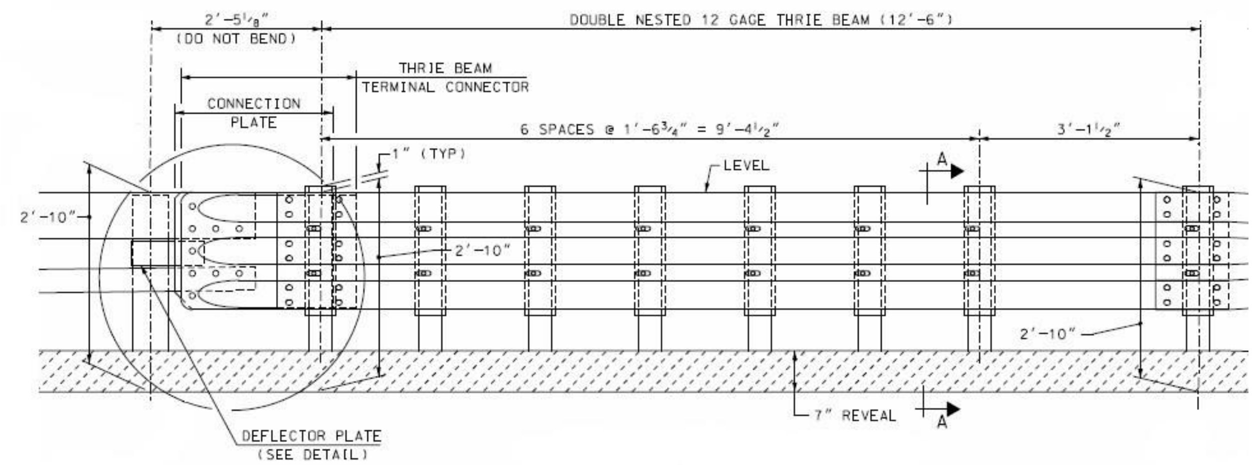


Figure 22. NHDOT T2 AGT double nested thrie-beam section.

The 6'-6" sloped rail section is shown in Figure 23. This section uses rail bars of the same material type and shape as used for the bridge rail. The slope for each rail bar in the transition section is provided in Table 47. The splice bars that connect the sloped section to the bridge rail are adjusted for slope and bend using complete joint penetration butt welds. The splice bar length and other details should match the details discussed in the bridge rail sections. The posts are set at 2'-2" spacing in this section. The top rail height of 34 inches is maintained throughout this section and on into the bridge rail section.

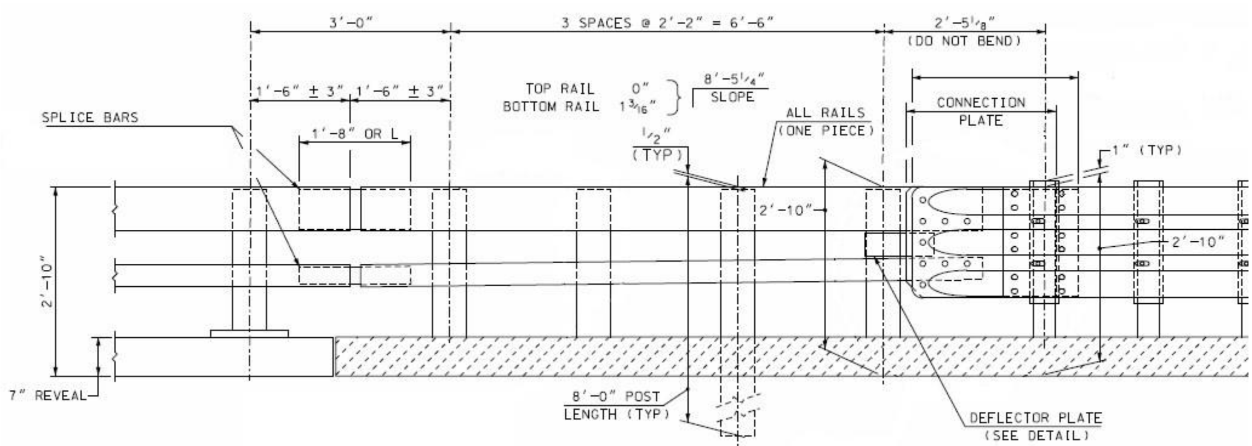


Figure 23. NHDOT T2 AGT sloped rail section.

Table 47. NHDOT T2 AGT slope of rail bar transition section.

	Top Bar	Bottom Bar
Y Displacement	0"	$-1\frac{3}{16}$"
X Displacement	8'-$5\frac{1}{4}$"	8'-$5\frac{1}{4}$"
Slope (Y/X)	0	-0.012

Discrepancies in Drawing

When reviewing the drawings Roadsafe identified discrepancies in the drawings of the NHDOT T2 (and NHDOT T3) Bridge Approach Rail. The first discrepancy is the detail for the post bolts in the thrie-beam and transition section. The discrepancies are highlighted in Figure 24. The thrie-beam to post bolts are called out as both <u>5/8" Ø A307 B.H Post Bolt</u> (green highlight) and <u>5/8" x 1 ½" Ø Hex Head Bolt</u> (blue highlight). Additionally, the post bolts are indicated to go through both the front and back flange of the post (orange highlight). It is suspected by the Roadsafe team that, instead, these bolts are bolted on the back side of the front post flange.

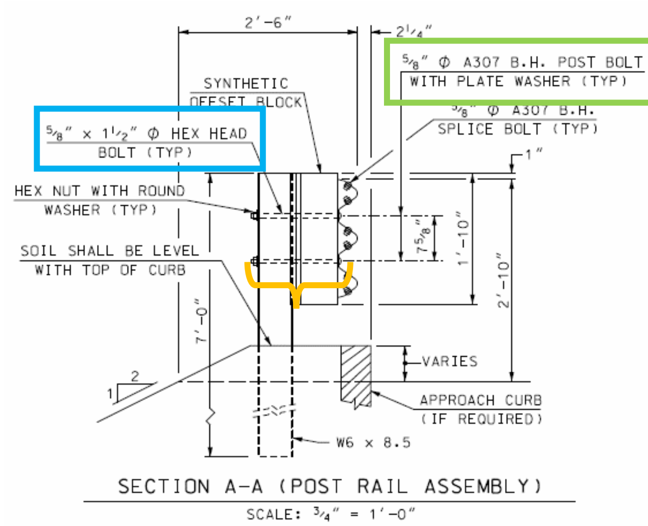


Figure 24. Post rail assembly NHDOT T2 AGT (T3 similar)

The second discrepancy found in the NHDOT T2 (and T3) drawings is also an inconsistency between bolt details. This discrepancy is highlighted in Figure 25. The clamping bolts are called out as <u>3/4" Ø Button Head Bolts</u> (purple highlight) and <u>3/4" Carriage Bolt</u> (red highlight).

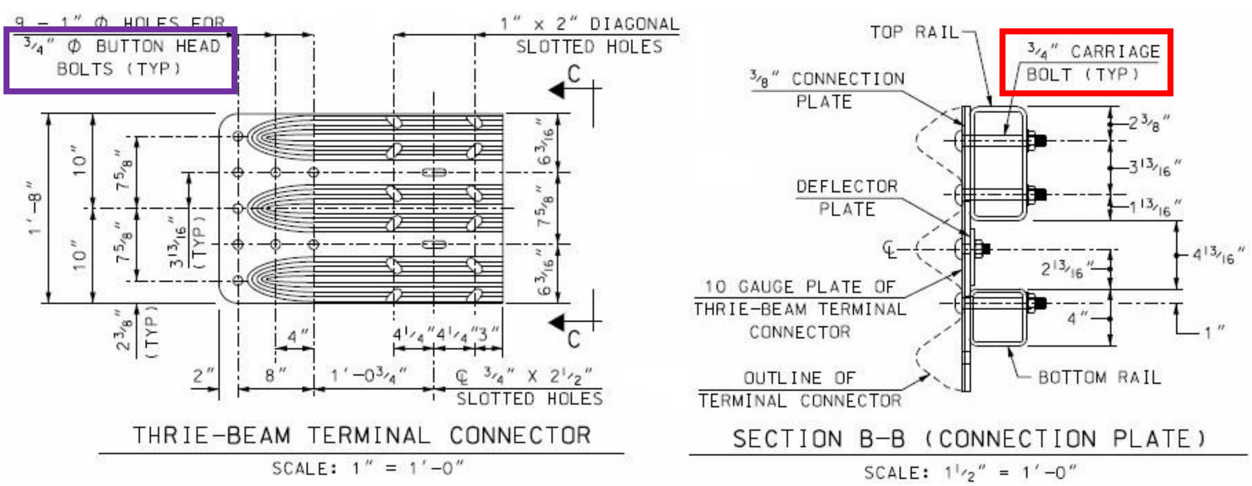


Figure 25. Terminal and connection plate detail drawings for NHDOT T2 AGT (T3 similar)

NHDOT 3-Bar Transition

The NHDOT T3 Steel Bridge Approach Rail was successfully crash tested in April 2005 by NETC and accepted as NCHRP 350 TL-3. An FHWA acceptance letter was provided for the design, HSSD/B-146. See section NHDOT 3-Bar Rail to Thrie-Beam AGTof this report for more details.

A standard 12-gauge w-beam roadway guardrail is used upstream of the AGT as seen in Figure 26. A 25'-0" section of guardrail flared at 80:1 to restore the rail-to-rail width. Post spacing in this section is 6'3" (e.g., standard post spacing) and the guardrails are lapped in the direction of traffic. The curb is flared away from the roadway at a 10:1 rate and has a 4" reveal. The curb increases in height from 4" to 7" over the next approximately 9'.

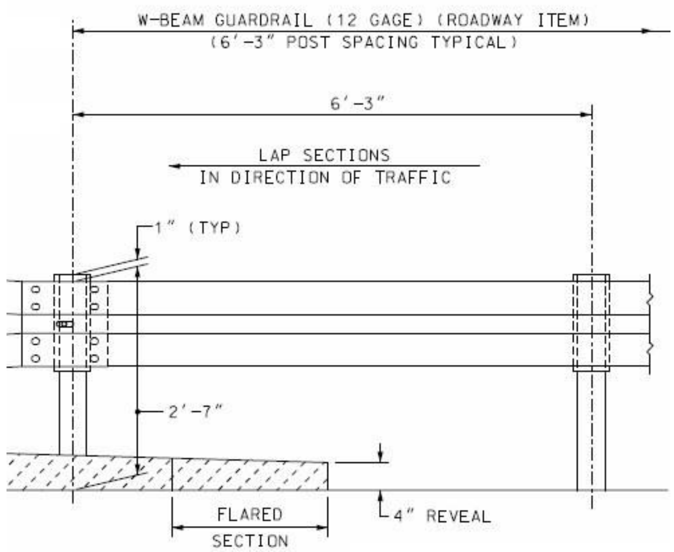


Figure 26. NHDOT T3 AGT upstream w-beam section.

A symmetrical 10-gage w-beam to thrie-beam transition rail is attached to the standard w-beam on the upstream end as seen in Figure 27. The transition rail is 6'-3" long and post spacing in this section is 3'-1.5" (e.g., half post spacing). The height of the rail at the upstream end of the thrie-beam transition rail is 31 inches high and is 34 inches at the downstream end.

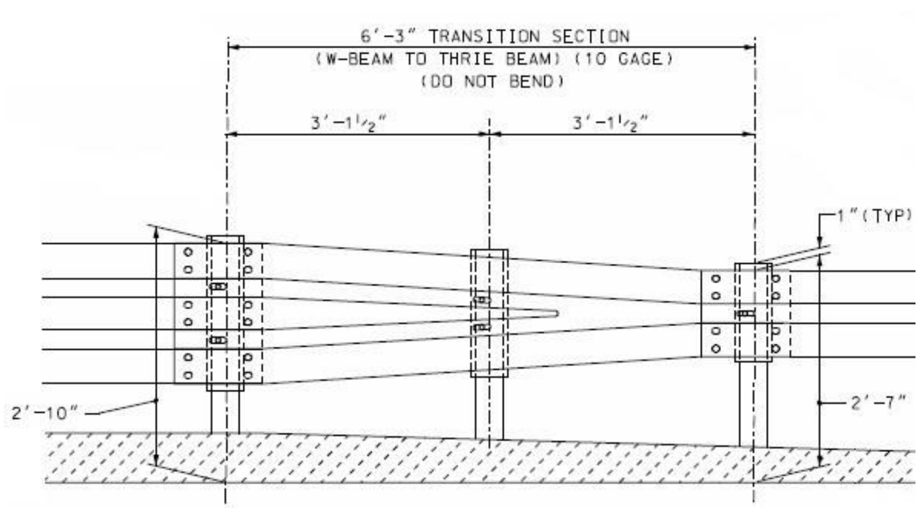


Figure 27. NHDOT T3 AGT symmetrical w-beam to thrie-beam transition section.

The next section is a 12’-6” long double nested 12-gage thrie-beam section as seen in Figure 28. The first upstream post is spaced at 3’-1.5” (e.g., half-post spacing), while the other posts are spaced 1’-6.75” (e.g., quarter post spacing). A connection plate and thrie-beam terminal connector are used to connect the thrie-beam to the top and bottom sloped bridge rails. The deflector plate, which is specified in the 2-bar design (see Figure 23), is not present in the 3-bar design.

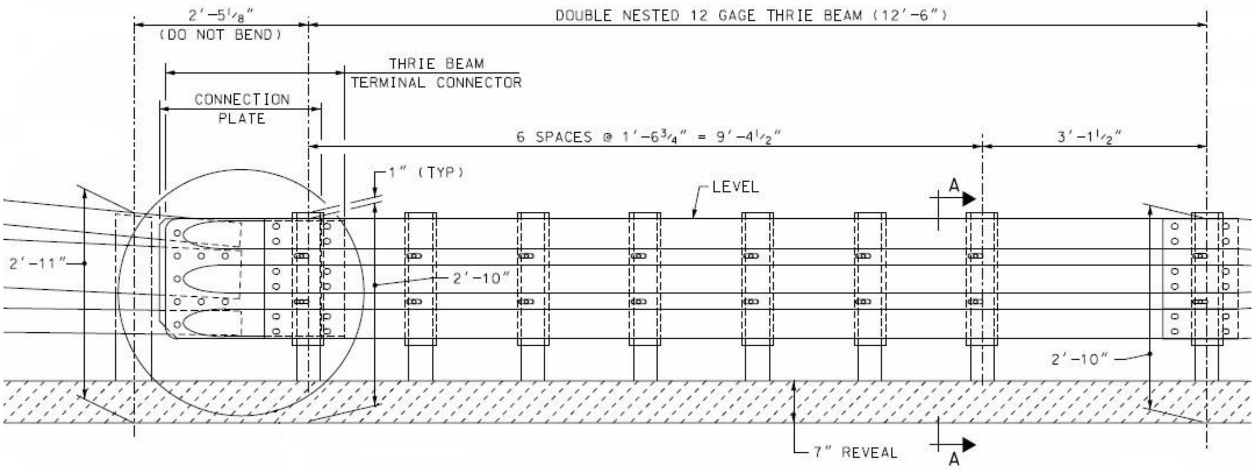


Figure 28. NHDOT T3 AGT double nested thrie-beam section.

The 6’-6” sloped rail section is shown in Figure 29. This section uses rail bars of the same material type and shape as used for the bridge rail. The slope for each rail bar in the transition section is provided in Table 48.

The splice bars that connect the sloped section to the bridge rail are adjusted for slope and bend using complete joint penetration butt welds. The splice bar length and other details should match the details discussed in the bridge rail sections. The posts are set at 2’-2” spacing in this section. The sloped-rail section transitions the height of the system from 34 inches at the thrie-beam section to 44 inches at the bridge rail section.

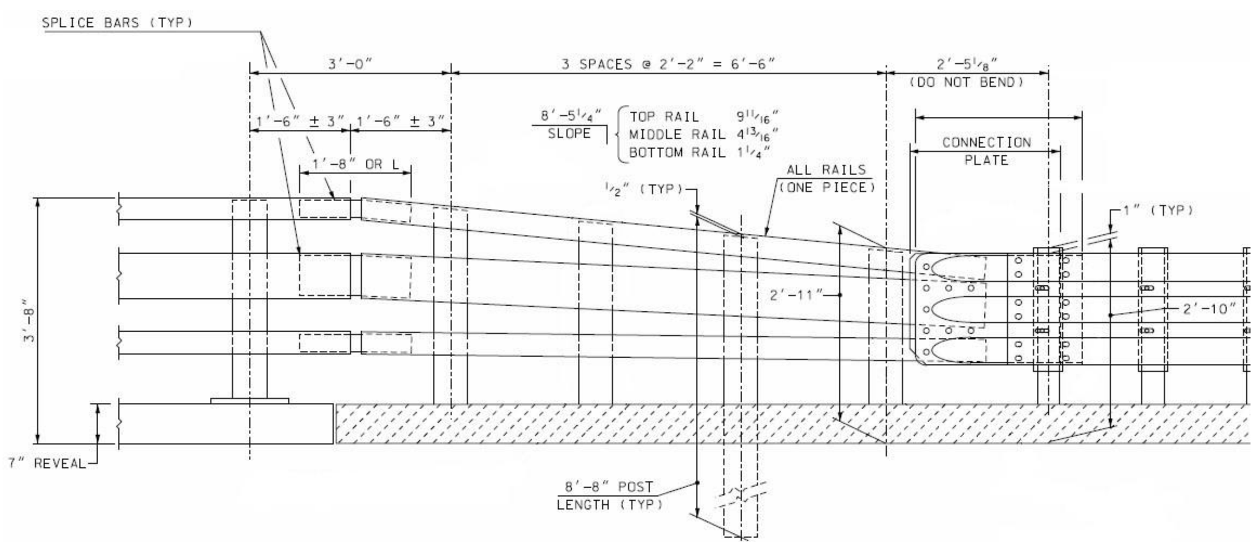


Figure 29. NHDOT T3 AGT sloped rail section.

Table 48. NHDOT T3 AGT slope of rail bar transition section.

	Top Bar	Middle Bar	Bottom Bar
Y Displacement	$9\frac{11}{16}$"	$4\frac{13}{16}$"	$1\frac{1}{4}$"
X Displacement	8'-$5\frac{1}{4}$"	8'-$5\frac{1}{4}$"	8'-$5\frac{1}{4}$"
Slope (Y/X)	0.096	0.048	0.012

Discrepancies in Drawing

The same discrepancies that were discussed at the end of the NHDOT 2-bar transition section also apply to the NHDOT 3-bar transition drawings.

MaineDOT 4-Bar Transition

The detail package that was provided to Roadsafe contains designs for Type I and Type IA Bridge transitions. The Type IA is discussed here since the upstream guardrail is specified to be a MASH compliant guardrail while the Type I only calls for a Type 3 guardrail. It is believed that the Type IA is required for MASH height requirements. A MASH compliant w-beam guardrail is used upstream of the AGT as seen in Figure 30. A 25'-0" section of guardrail is provided to match rail heights. Post spacing in this section is 6'3" (e.g., standard post spacing). For the sidewalk mounted 4-bar bridge rail design there should be a sidewalk in this section, not shown in Figure 30.

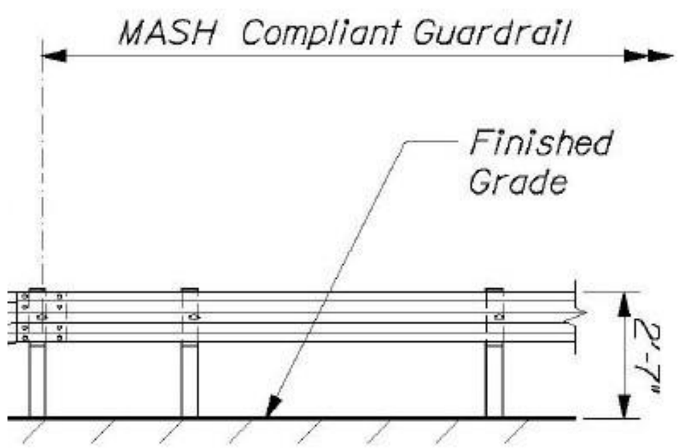


Figure 30. MaineDOT Type IA AGT upstream w-beam section.

An asymmetrical w-beam to thrie-beam transition rail is attached to the standard w-beam on the upstream end as seen in Figure 31. The transition rail is 6'-3" long and post spacing in this section is 3'-1.5" (e.g., half-post spacing). The height of the rail at the upstream end of the transition rail is 31 inches high.

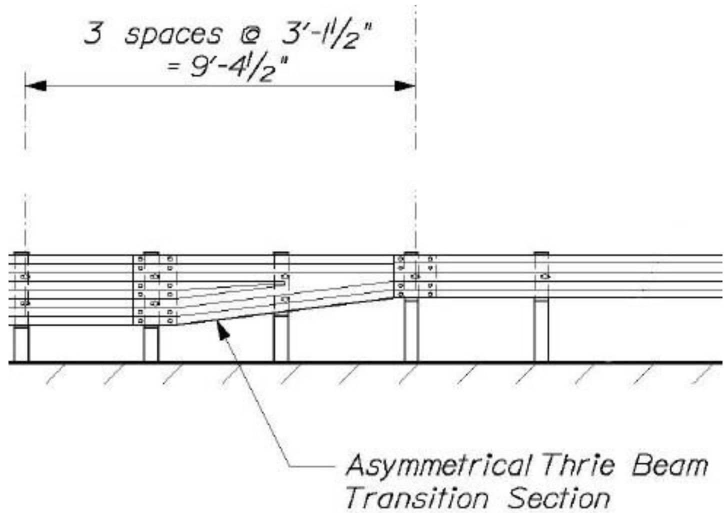


Figure 31. MaineDOT Type IA AGT asymmetrical w-beam to thrie-beam transition section.

The next section is a 12’-6” long double nested thrie-beam section as seen in Figure 32. The first upstream post is spaced at 3’-1.5” (e.g., half-post spacing), while the other posts are spaced 1’-6.75” (quarter post spacing). A connection plate is used to connect the thrie-beam to the concrete buttress. In this section a precast concrete transition curb is used for the sidewalk, further details are found in the MaineDOT Standard Specifications 609(08).

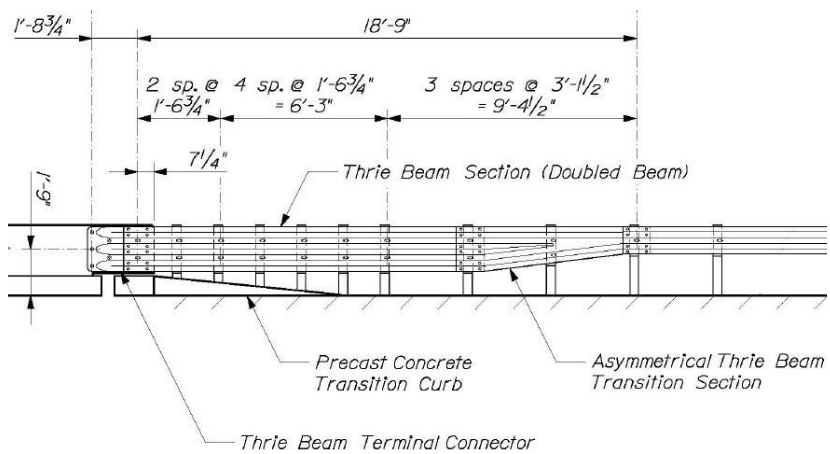


Figure 32. MaineDOT Type IA AGT double nested thrie-beam section.

The 6’-4” concrete buttress section is shown in Figure 33. This section uses a concrete buttress constructed if 5000 psi Class LP concrete. Additional details for rebar placement are provided in the MaineDOT Standard Specification 526(34-37). The guardrail anchorage bolts that connect to the connection plate are cast inside the buttress using a ¼” thick guardrail anchor plate. The rail bars are placed into the concrete buttress recess. No hardware is specified to secure the rail bars to the concrete buttress. Other similar designs, such as the MassDOT concrete buttress AGT use studs that are adhesively attached to the buttress to secure the rails in place on the concrete end wall.

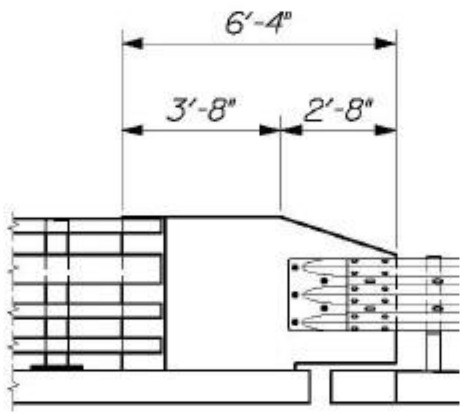


Figure 33. MaineDOT Type IA AGT concrete buttress section.

It is unlikely that the current design will meet MASH TL4, due to the potential for snagging on the end of the concrete buttress, which generally involves the tire of the vehicle pushing underneath the rail and impacting the buttress. Other crashworthy buttress designs have been evaluated and/or tested which may be adopted without further analysis. For example, the Midwest Roadside Safety Facility (MwRSF) recently designed and successfully tested a buttress design to MASH TL-3 in which the lower section of the buttress was beveled at the connection to the thrie-beam to prevent tire snag as the vehicle wheel pushes underneath the rail at the thrie-beam-to-abutment juncture. [Rosenbaugh18] As part of the MwRSF study, thirty-nine crash tests, involving 20 different transition systems, were reviewed. The majority of observed failures were the result of excessive vehicle contact with the rigid parapet, especially for AGTs that did not utilize a curb beneath the guardrail.

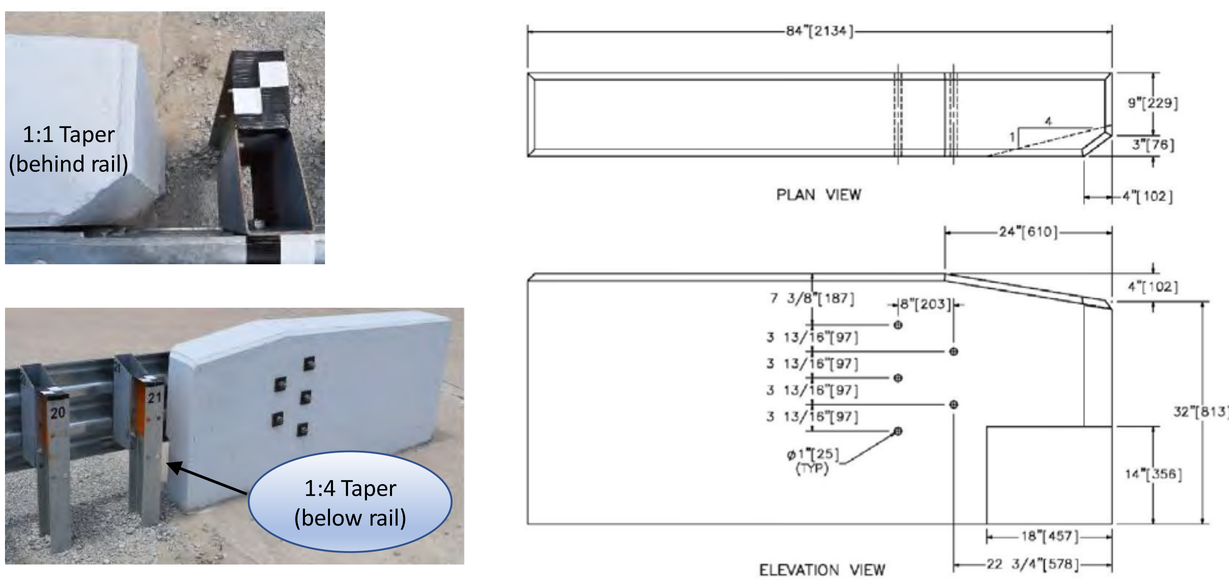


Figure 34. Standardized buttress design. [*Rosenbaugh18*]

In a recent study performed by Roadsafe for the Massachusetts DOT, a transition system involving a flared face on the upstream end of the buttress, as illustrated in Figure 35 was evaluated. The results of that evaluation indicated that there was minimal risk for the vehicle to snag on the end of the buttress and that system would successfully meet MASH TL-3 conditions.

However, MASH TL-4 compliance was uncertain due to difficulty identifying the CIP for Test 4-22. [*Plaxico18*] This system was also successfully evaluated in full-scale crash tests at the Texas Transportation Institute (TTI) under R350 Test Level 4 conditions. [*Ross93; Alberson06*]

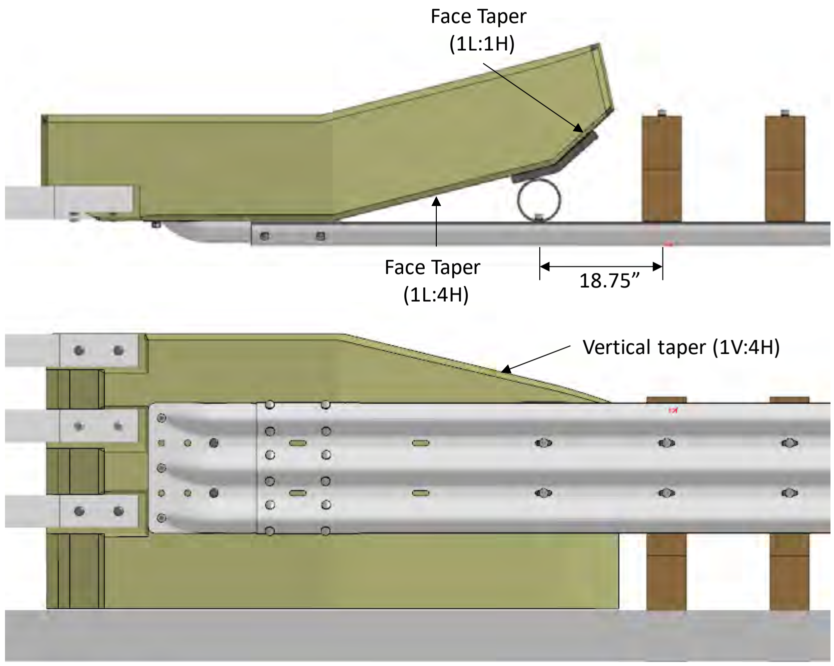


Figure 35. Plan and profile view of the shaped buttress.

Alternate 4-Bar Transition (Sloped Rail Style)

NHDOT and VTrans states provided engineering drawings for an alternate 4-bar AGT system that uses the sloped rail style, rather than the concrete buttress. The NHDOT T4 Steel Bridge Approach Rail was successfully crash tested in April 2005 by NETC and accepted as NCHRP 350 TL-3. An FHWA acceptance letter was provided for the design, HSSD/B-146.

Both designs utilize a standard 12-gauge w-beam roadway guardrail upstream of the AGT as seen in Figure 36. A 25’-0” section of guardrail flared at 80:1 to restore the rail-to-rail width. Post spacing in this section is 6’3” (e.g., standard post spacing) and the guardrails are lapped in the direction of traffic. The VTrans design curb is flared away from the roadway at a 10:1 rate and has a 4” reveal. The curb increases in height from 4” to 9” over approximately 6’. The NHDOT design is mounted on a sidewalk. The bottom bar on the NHDOT design continues from the bridge railing, through all transition sections and terminates behind the first upstream post in the guardrail section.

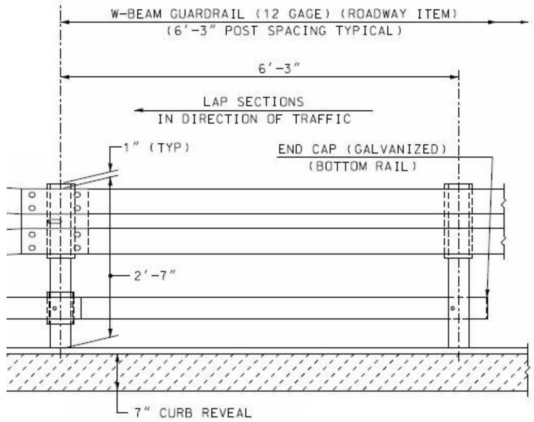


Figure 36. NHDOT T4 AGT upstream w-beam section (VTrans similar except bottom bar and sidewalk).

A symmetrical w-beam to thrie-beam transition rail is attached to the standard w-beam on the upstream end as seen in Figure 37. NHDOT specifies a 10-gage transition rail and VTrans specifies a 12-gage transition rail. The transition rails are 6'-3" long and post spacing in this section is 3'-1.5" (e.g., half post spacing). For the NHDOT design the height of the rail at the upstream end of the thrie-beam transition rail is 31 inches high and is 34 inches at the downstream end. For the VTrans design the height of the rail at the upstream end of the thrie-beam transition rail is 27 inches high and is 33.3125 inches at the downstream end.

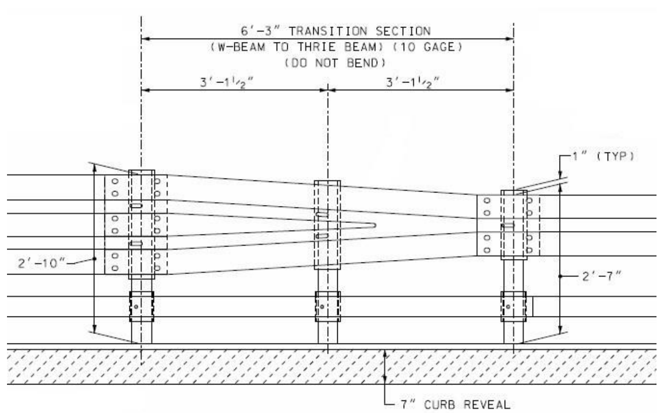


Figure 37. NHDOT T4 AGT symmetrical w-beam to thrie-beam transition section (VTrans similar except bottom bar and height).

The next section of the NHDOT design is a 12'-6" long double nested 12-gage thrie-beam section as seen in Figure 38. The first upstream post is spaced at 3'-1.5" (e.g., half-post spacing), while the other posts are spaced 1'-6.75" (e.g., quarter post spacing). A connection plate is used to connect the thrie-beam to the top and bottom sloped bridge rails. The deflector plate, which is specified in the 2-bar design (see Figure 23), is not present in the 4-bar design. The VTrans design does not include a thrie-beam section.

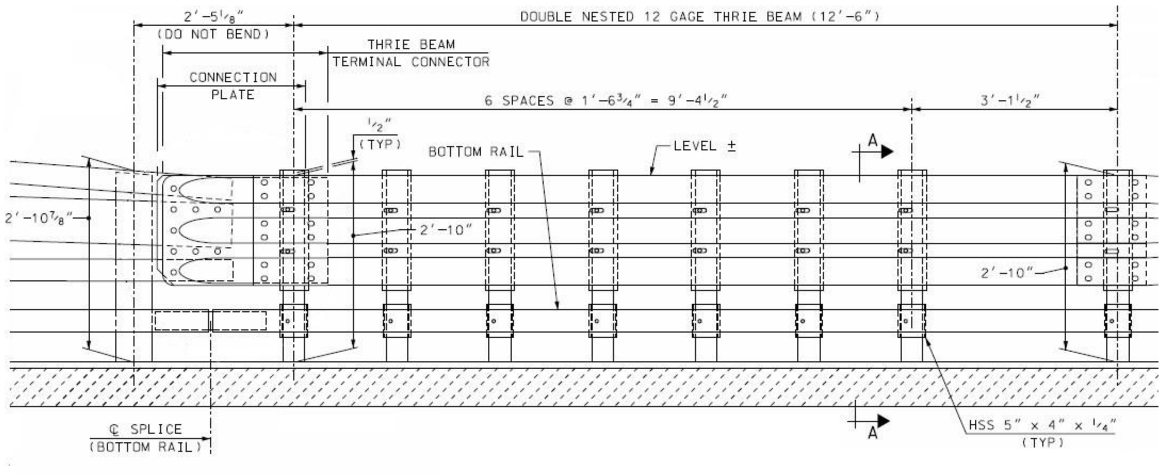


Figure 38. NHDOT T4 AGT double nested thrie-beam section.

The sloped rail sections differ greatly between NHDOT (Figure 39) and VTrans (Figure 40). The distance of the sloped section is approximately 8' for NHDOT and 22'8" for VTrans. The designs use rail bars of the same material type and shape as used for the bridge rail. The splice bars that connect the sloped section to the bridge rail are adjusted for slope and bend using complete joint penetration butt welds. The splice bar length and other details match the details discussed in the bridge rail sections. The NHDOT design uses 2'-2" post spacing, while the VTrans design uses decreasing spacing in the following order:

- 1 space at 4'-8"
- 3 spaces at 3'-2"
- 3 spaces at 2'-2"

The bottom rail on the VTrans design terminates at the bottom rail in the post web section (i.e. between the post flanges) of Post #8. As mentioned earlier the NHDOT design carries the bottom rail all the way through the AGT and terminates it at the guardrail. The slope for each rail bar in the both transition sections is provided in Table 49

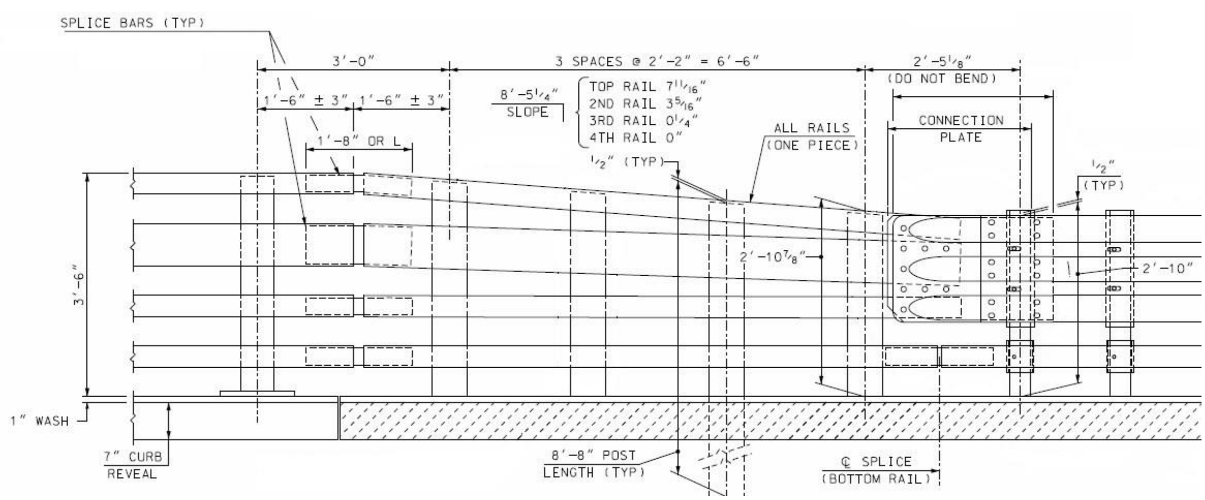


Figure 39. NHDOT T4 AGT sloped rail section.

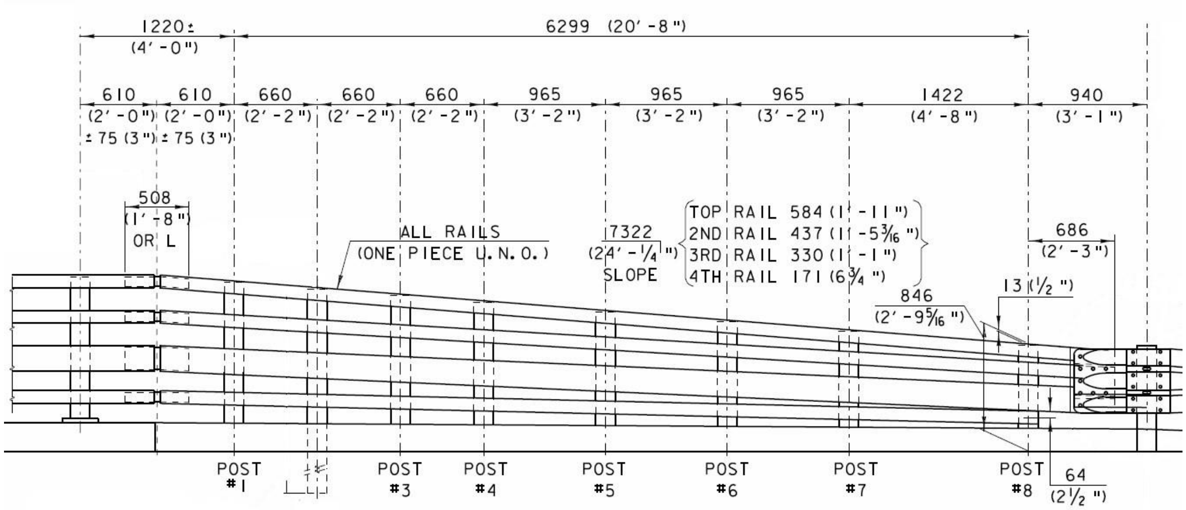


Figure 40. VTrans 4-bar AGT sloped rail section.

Table 49. NHDOT T4 and VTrans 4-bar AGT slope of rail bar transition section.

	Top Bar		Mid-Top Bar		Mid-Btm Bar		Bottom Bar	
	NH	VT	NH	VT	NH	VT	NH	VT
Y Displacement	$7\frac{11}{16}$”	1’-11”	$3\frac{5}{16}$”	1’-$5\frac{3}{16}$”	$\frac{1}{4}$”	1’-1”	0”	$6\frac{3}{4}$”
X Displacement	8’-$5\frac{1}{4}$”	24’-$\frac{1}{4}$”	8’-$5\frac{1}{4}$”	24’-$\frac{1}{4}$”	8’-$5\frac{1}{4}$”	24’-$\frac{1}{4}$”	8’-$5\frac{1}{4}$”	24’-$\frac{1}{4}$”
Slope (Y/X)	0.076	0.080	0.033	0.060	0.002	0.045	0.00	0.023

RECOMMENDATIONS FOR DIMENSIONAL AND MATERIAL SPECIFICATIONS FOR NETC BRIDGE RAIL DESIGNS

The following recommendations are based on using the least conservative value for each design detail which has shown acceptable R350 crash testing performance and/or met the LRFD strength criteria for MASH loading. In this way the more conservative design details are assumed to have sufficient strength. Table 50 summarizes the Roadsafe recommendations for specific details for the NETC style bridge rails. Even though the sidewalk-mounted 4-Bar bridge railing was not shown to meet strength requirements for MASH TL-4, it is expected to meet MASH TL-3 performance criteria based on LRFD strength calculations for those cases (not shown herein). It is therefore recommended that it be included for further evaluation with FEA crash simulation for both TL-3 and TL-4 conditions.

Table 50. Summary of recommended specifications for NETC style bridge rails.

Feature	**2-Bar Bridge Rail**	**3-Bar Bridge Rail**	**4-Bar Bridge Rail**
		Rail Bars	
Material	ASTM A500 Gr. B	ASTM A500 Gr. B	ASTM A500 Gr. B

Feature	2-Bar Bridge Rail	3-Bar Bridge Rail	4-Bar Bridge Rail
Sizes	HSS 4" x 4" x $\frac{1}{4}$" HSS 8" x 4" x $\frac{5}{16}$"	HSS 4" x 4" x $\frac{1}{4}$" HSS 8" x 4" x $\frac{5}{16}$"	HSS 4" x 4" x $\frac{1}{4}$" HSS 8" x 4" x $\frac{5}{16}$"
Order of Bars (from top)	Lg – Sm	Sm – Lg – Sm	Sm – Lg – Sm – Sm
1st Bar Height (to top)	34"	44"	42"
2nd Bar Height (center)	18"	30"	28"
3rd Bar Height (center)	N/A	18"	16.5"
4th Bar Height (center)	N/A	N/A	7"
Post			
Material	AASHTO M270 Gr 50	AASHTO M270 Gr 50	AASHTO M270 Gr 50
Size	W6x25	W6x25	W6x25
Vertical Alignment	Normal to grade	Normal to grade	Normal to grade
Max Spacing	8'-0"	8'-0"	8'-0"
Number of Posts/Rail	3	3	3
Min Offset from Post to Expansion Splice	2'-0"	2'-0"	2'-0"
Post Flange to Base Plate Weld	$\frac{7}{16}$" all around fillet weld	$\frac{7}{16}$" all around fillet weld	$\frac{7}{16}$" all around fillet weld
Post Web to Base Plate Weld	$\frac{5}{16}$" all around fillet weld	$\frac{5}{16}$" all around fillet weld	$\frac{5}{16}$" all around fillet weld
Rail Bar-Post Attachment			
Method	Bolted	Bolted	Bolted
Number of Bolts/Rail	2	2	2
Hole Size in Rail	$\frac{7}{8}$"	$\frac{7}{8}$"	$\frac{7}{8}$"
Hole Size in Post	$1\frac{1}{8}$" x $1\frac{3}{8}$" slotted hole	$1\frac{1}{8}$" x $1\frac{3}{8}$" slotted hole	$1\frac{1}{8}$" x $1\frac{3}{8}$" slotted hole
Bolt Specification	6" x $\frac{3}{4}$" A325	6" x $\frac{3}{4}$" A325	6" x $\frac{3}{4}$" A325
Base Plate			
Material	ASHTO M270 Gr. 50	ASHTO M270 Gr. 50	ASHTO M270 Gr. 50
Size	1" x 10" x 1'-2"	1" x 10" x 1'-2"	1" x 10" x 1'-2"
Number of Bolts	4	4	4
Bolt Pattern	See MaineDOT details	See MaineDOT details	See MaineDOT details
Size of Holes	1.25"	1.25"	1.25"
Anchor Bolts			
Material	ASTM A449	ASTM A449	ASTM A449
Size	1" Ø x 12" L	1" Ø x 12" L	1" Ø x 12" L
Embedment	7.5"	7.5"	7.5"
Exposed Rod	3"	3"	3"
Threaded Length	2.5	2.5	2.5
Exposed Nut Type	Heavy hex nut	Heavy hex nut	Heavy hex nut
Nut Torque	Snug + $\frac{1}{8}$ turn	Snug + $\frac{1}{8}$ turn	Snug + $\frac{1}{8}$ turn

Feature	2-Bar Bridge Rail	3-Bar Bridge Rail	4-Bar Bridge Rail
Field Splice			
Tube Dimensions	HSS 3“ x 3” x $\frac{5}{16}$" HSS 7” x 3” x $\frac{3}{8}$”	HSS 3“ x 3” x $\frac{5}{16}$" HSS 7” x 3” x $\frac{3}{8}$”	HSS 3“ x 3” x $\frac{5}{16}$" HSS 7” x 3” x $\frac{3}{8}$”
Details	See MaineDOT details	See MaineDOT details	See MaineDOT details
Number of Bolts	4	4	4
Size of Hole in Rail	$1\frac{1}{8}$" x $2\frac{1}{2}$" slot	$1\frac{1}{8}$" x $2\frac{1}{2}$" slot	$1\frac{1}{8}$" x $2\frac{1}{2}$" slot
Hole in Splice Tube	$\frac{5}{8}$" Ø tapped hole	$\frac{5}{8}$" Ø tapped hole	$\frac{5}{8}$" Ø tapped hole
Bolt	$\frac{5}{8}$" Ø x $1\frac{3}{4}$"Cap Screw	$\frac{5}{8}$" Ø x $1\frac{3}{4}$"Cap Screw	$\frac{5}{8}$" Ø x $1\frac{3}{4}$"Cap Screw
Tack Weld Nut Required?	On outer holes only	On outer holes only	On outer holes only
Pipe Spacer	$\frac{3}{4}$" Ø x $\frac{1}{2}$“ Schd. 40 (Only 1 side ea splice)	$\frac{3}{4}$" Ø x $\frac{1}{2}$“ Schd. 40 (Only 1 side ea splice)	$\frac{3}{4}$" Ø x $\frac{1}{2}$“ Schd. 40 (Only 1 side ea splice)
Space Between Bars	$\frac{3}{4}$"	$\frac{3}{4}$"	$\frac{3}{4}$"
Splice Tube Length	1’-8”	1’-8”	1’-8”
Drain Hole Required?	Yes, $\frac{1}{2}$" Ø	Yes, $\frac{1}{2}$" Ø	Yes, $\frac{1}{2}$" Ø
Expansion Splice			
Tube Dimensions	HSS 3” x 3” x $\frac{5}{16}$" HSS 7” x 3” x $\frac{3}{8}$”	HSS 3” x 3” x $\frac{5}{16}$" HSS 7” x 3” x $\frac{3}{8}$”	HSS 3” x 3” x $\frac{5}{16}$" HSS 7” x 3” x $\frac{3}{8}$”
Details	See MaineDOT details	See MaineDOT details	See MaineDOT details
Number of Bolts	4	4	4
Size of Hole in Rail	See MaineDOT details	See MaineDOT details	See MaineDOT details
Hole in Splice Tube	$\frac{5}{8}$" Ø tapped hole	$\frac{5}{8}$" Ø tapped hole	$\frac{5}{8}$" Ø tapped hole
Bolt	$\frac{5}{8}$" Ø x $1\frac{3}{4}$"Cap Screw	$\frac{5}{8}$" Ø x $1\frac{3}{4}$"Cap Screw	$\frac{5}{8}$" Ø x $1\frac{3}{4}$"Cap Screw
Tack Weld Nut Required?	On outer holes only	On outer holes only	On outer holes only
Pipe Spacer	$\frac{3}{4}$" Ø x $\frac{1}{2}$“ Schd. 40	$\frac{3}{4}$" Ø x $\frac{1}{2}$“ Schd. 40	$\frac{3}{4}$" Ø x $\frac{1}{2}$“ Schd. 40
Space Between Bars	See MaineDOT details	See MaineDOT details	See MaineDOT details
Splice Tube Length	See MaineDOT details	See MaineDOT details	See MaineDOT details
Drain Hole Required?	Yes, $\frac{1}{2}$" Ø	Yes, $\frac{1}{2}$" Ø	Yes, $\frac{1}{2}$" Ø
Concrete Curb/Sidewalk			
Strength Required	4000 psi	4000 psi	4000 psi
Height	7”	7”	9”
Width	1’-6”	1’-6”	5’ min.
Back Base Plate Bolts to Deck Edge	$7\frac{5}{8}$”	$7\frac{5}{8}$”	$7\frac{5}{8}$”
Front Base Plate Bolts to Concrete Edge	4”	4”	5’-2”

Feature	2-Bar Bridge Rail	3-Bar Bridge Rail	4-Bar Bridge Rail
Longitudinal Rebar	3 - #5 bars 5' L min	3 - #5 bars 5' L min	3 - #5 bars 5' L min
Hoop Bar Rebar	7 - #5 bars at 6"	7 - #5 bars at 6"	7 - #5 bars at 6"
Hoop Bar Engagement w/ Deck Rebar?	Yes	Yes	Yes

RECOMMENDATIONS FOR DIMENSIONAL AND MATERIAL SPECIFICATIONS FOR NETC BRIDGE RAIL TRANSITIONS

Table 51 outlines the features, materials and dimensional specifications for the selected AGTs.

Table 51. Summary of recommended specifications for NETC style bridge rail transitions.

Feature	NH T2 AGT	NH T3 AGT	MaineDOT AGT
Approach Curb			
Upstream Reveal	4”	4”	
Flare Rate	10:1 away from road	10:1 away from road	
Curb Full Height	7”	7”	
Curb Face to Thrie Beam	$2\frac{1}{4}$"	$2\frac{1}{4}$"	N.S.
Curb Face to Face of Rail	6”	6”	N.S.
Height from Top of Curb to Bottom of Thrie Beam	3”	3”	N.S.
Strength	4000 psi	4000 psi	5000 psi
Roadway Guardrail Section			
Guardrail Type	12 gage w-beam	12 gage w-beam	MASH Compliant
Guardrail Specification	AASHTO M180 Type II, Class A	AASHTO M180 Type II, Class A	N.S.
Flare Back	80:1 for 25’-0” to restore rail-to-rail W	80:1 for 25’-0” to restore rail-to-rail W	25’ - As required to match rail heights
Post Type	W6x8.5	W6x8.5	N.S.
Post Material	ASTM A36	ASTM A36	N.S.
Post Spacing	6’-3”	6’-3”	6’-3”
Block-out Type	Synthetic	Synthetic	Composite or wood
Post Length	7’-0”	7’-0”	N.S.
Rail Height	2’-7”	2’-7”	2’-7”
W-Beam to Thrie Beam Transition Section			
Transition Type	10 gauge symmetrical	10 gauge symmetrical	Asymmetrical
Transition Specification	AASHTO M180 Type II, Class A	AASHTO M180 Type II, Class A	N.S.
Total Transition Length	7’-$3\frac{1}{4}$"	7’-$3\frac{1}{4}$"	N.S.
Post Attachment Hole Size	$\frac{3}{4}$" x $2\frac{1}{2}$" slot	$\frac{3}{4}$" x $2\frac{1}{2}$" slot	N.S.
Post Attachment Hardware	$\frac{5}{8}$” Ø A307 button head post bolts with washer	$\frac{5}{8}$” Ø A307 button head post bolts with washer	N.S.
W-Beam Hole Size	$\frac{29}{32}$" x $1\frac{1}{8}$" slot	$\frac{29}{32}$" x $1\frac{1}{8}$" slot	N.S.

Feature	NH T2 AGT	NH T3 AGT	MaineDOT AGT
W-Beam Hardware	$\frac{5}{8}$" Ø A307 button head splice bolts	$\frac{5}{8}$" Ø A307 button head splice bolts	N.S.
Thrie Beam Attachment Hole Size	$\frac{29}{32}$" x $1\frac{1}{8}$" slot	$\frac{29}{32}$" x $1\frac{1}{8}$" slot	N.S.
Thrie Beam Attachment Hardware	$\frac{5}{8}$" Ø A307 button head splice bolts	$\frac{5}{8}$" Ø A307 button head splice bolts	N.S.
Post Type	W6x8.5	W6x8.5	N.S.
Post Material	ASTM A36	ASTM A36	N.S.
Post Spacing	3'-$1\frac{1}{2}$"	3'-$1\frac{1}{2}$"	3'-$1\frac{1}{2}$"
Block-Out Type	Synthetic	Synthetic	N.S.
Block-Out Size	8" deep x 1'-6" long	8" deep x 1'-6" long	N.S.
Post Length	7'-0"	7'-0"	N.S.
Upstream Rail Height	2'-7"	2'-7"	2'-7"
Downstream Rail Height	2'-10"	2'-10"	2'-7"
Thrie Beam Section			
Thrie Beam Configuration	Double nested 12 gage	Double nested 12 gage	Double beam
Thrie Beam Specification	AASHTO M180 Type II, Class A	AASHTO M180 Type II, Class A	N.S.
Total Thrie Beam Section Length	12'-6"	12'-6"	12'-0"
Post Attachment Hole Size	$\frac{3}{4}$" x $2\frac{1}{2}$" slot	$\frac{3}{4}$" x $2\frac{1}{2}$" slot	N.S.
Post Attachment Hardware	$\frac{5}{8}$" Ø A307 button head post bolts	$\frac{5}{8}$" Ø A307 button head post bolts	N.S.
Thrie Beam Attachment Hole Size	$\frac{29}{32}$" x $1\frac{1}{8}$" slot	$\frac{29}{32}$" x $1\frac{1}{8}$" slot	N.S.
Thrie Beam Attachment Hardware	$\frac{5}{8}$" Ø A307 button head splice bolts	$\frac{5}{8}$" Ø A307 button head splice bolts	N.S.
Post Type	W6x8.5	W6x8.5	N.S.
Post Material	ASTM A36	ASTM A36	N.S.
Post Spacing	One @ 3'-$1\frac{1}{2}$" Six @ 1'-$6\frac{3}{4}$"	One @ 3'-$1\frac{1}{2}$" Six @ 1'-$6\frac{3}{4}$"	One @ 3'-$1\frac{1}{2}$" Six @ 1'-$6\frac{3}{4}$"
Block-Out Type	Synthetic	Synthetic	N.S.
Block-Out Size	8" deep x 1'-10" long	8" deep x 1'-10" long	N.S.
Post Length	7'-0"	7'-0"	N.S.
Rail Height	2'-10"	2'-10"	2'-7"
Connection Plate			

Feature	NH T2 AGT	NH T3 AGT	MaineDOT AGT
Connection Plate Size	$\frac{3}{8}$" thick x 27" x 20"	$\frac{3}{8}$" thick x 27" x 20"	$\frac{1}{4}$" thick x 11$\frac{1}{4}$" x 1'-6$\frac{1}{2}$", cast 6$\frac{1}{2}$" deep in buttress
Connection Plate Material	Grade 36	Grade 36	N.S.
Thrie Beam Terminal Connector Size	3 $\frac{3}{8}$" deep x 30" x 20"	3 $\frac{3}{8}$" deep x 30" x 20"	N.S.
Order of Components (from Traffic Side)	Thrie beam terminal connector – connection plate – sloped bridge rails	Thrie beam terminal connector – connection plate – sloped bridge rails	Thrie beam terminal connector – concrete buttress – anchor plate
Thrie Beam to Terminal Connector Hole	1" x 2" diagonal slots	1" x 2" diagonal slots	N.S.
Thrie Beam to Terminal Connector Bolt	$\frac{5}{8}$" Ø A307 button head splice bolts	$\frac{5}{8}$" Ø A307 button head splice bolts	N.S.
Clamping Hardware Hole Size	1" Ø hole	1" Ø hole	N.S.
Clamping Bolt Type	$\frac{3}{4}$" Ø button head, various lengths (or carriage bolt)	$\frac{3}{4}$" Ø button head, various lengths (or carriage bolt)	$\frac{7}{8}$" Ø x 8" L A325 bolts cast in buttress
Deflector Plate	$\frac{3}{8}$" bent @ $\frac{3}{4}$" radius	--	--
Upstream Post Type	W6x8.5	W6x8.5	N.S.
Upstream Post Material	ASTM A36	ASTM A36	N.S.
Upstream Post Block-Out Material	Synthetic	Synthetic	N.S.
Upstream Post Block-Out Size	8" deep x 1'-10" long	8" deep x 1'-10" long	N.S.
Upstream Post Length	7'-0"	7'-0"	N.S.
Upstream Rail Height	2'-10"	2'-10"	2'-7"
Downstream Post Type	W6x25	W6x25	--
Downstream Post Material	ASTM A572 Gr 50	ASTM A572 Gr 50	--
Downstream Block-Out	None	None	--
Downstream Post Length	8'-0"	8'-8"	--
Downstream Rail Height	2'-10"	2'-11"	3'-6$\frac{1}{2}$"
Post Spacing	2'-5$\frac{1}{8}$"	2'-5$\frac{1}{8}$"	--
Sloped Rail/Concrete Buttress Section			
Bar Material	ASTM A500 Gr B	ASTM A500 Gr B	--
Bar Size	HSS 4 x 4" x $\frac{1}{4}$"	HSS 4" x 4" x $\frac{1}{4}$"	--

Feature	NH T2 AGT	NH T3 AGT	MaineDOT AGT
	HSS 8” x 4” x $\frac{5}{16}$”	HSS 8” x 4” x $\frac{5}{16}$”	
Sloped Bar Length	8’-5$\frac{1}{4}$”	8’-5$\frac{1}{4}$”	--
Top Bar Vertical Displacement	0”	9$\frac{11}{16}$”	--
Top Bar Slope	0.000	0.096	--
Mid Bar Vertical Displacement	--	4$\frac{13}{16}$”	--
Mid Bar Slope	--	0.048	--
Bottom Bar Vertical Displacement	-1$\frac{3}{16}$”	1$\frac{1}{4}$”	--
Bottom Bar Slope	-0.012	0.012	--
Rail-to-Post Attachment Preferred Method	Bolted	Bolted	--
Rail-to-Post Attachment Hole in Rail	$\frac{7}{8}$"	$\frac{7}{8}$"	--
Rail-to-Post Attachment Hole in Post	1 $\frac{1}{8}$" x 1 $\frac{3}{8}$" slotted hole	1 $\frac{1}{8}$" x 1 $\frac{3}{8}$" slotted hole	--
Rail-to-Post Attachment Bolt Specification	6” x $\frac{3}{4}$" A325	6” x $\frac{3}{4}$" A325	--
Post Type	W6x25	W6x25	--
Post Material	ASTM A572 Gr 50	ASTM A572 Gr 50	--
Block-Out	None	None	--
Post Length	8’-0”	8’-8”	--
Upstream Rail Height	2’-10”	2’-11”	--
Downstream Rail Height	2’-10”	3’-8”	--
Post Spacing	2’-2”	2’-2”	--
Buttress Width	--	--	1’-7”
Butress Length	--	--	6’-4”
Upstream Buttress Height	--	--	2’8”
Downstream Buttress Height	--	--	3’-6”
Slope	--	--	~0.303
Recess Depth	--	--	5”
Recess Height	--	--	3’-6” (full height)
Rail Bar Attachment to Buttress	--	--	None
Rebar Detail	--	--	Shown in 526(34-37)
Bridge Rail Splice Bar Section			
Splice Bar Size	HSS 3” x 3” x $\frac{5}{16}$" HSS 7” x 3” x $\frac{3}{8}$”	HSS 3” x 3” x $\frac{5}{16}$" HSS 7” x 3” x $\frac{3}{8}$”	--

Feature	NH T2 AGT	NH T3 AGT	MaineDOT AGT
Splice Bar Material	ASTM A500 Gr B	ASTM A500 Gr B	--
Splice Bar Length	1'-8" or L	1'-8" or L	--
Splice Bar Configuration	Adjusted for slope using complete joint penetration butt welds	Adjusted for slope using complete joint penetration butt welds	--
Upstream Post Type	W6x25	W6x25	--
Upstream Post Material	ASTM A572 Gr 50	ASTM A572 Gr 50	--
Upstream Post Length	8'-0"	8'-8"	--
Upstream Rail Height	2'-10"	Less than 3'-8"	--
Downstream Post Type	W6x25	W6x25	--
Downstream Post Material	ASTM A572 Gr 50	ASTM A572 Gr 50	--
Downstream Post Length	2'-1$\frac{3}{8}$" welded to base plate bolted to bridge	2'-11$\frac{3}{8}$" welded to base plate bolted to bridge	--
Downstream Rail Height	2'-10"	3'-8"	--
Post Spacing	3'-0"	3'-0"	--

CONCLUSIONS

A critical review of current standard details and specifications for NETC style bridge rails and transitions used by MaineDOT, NHDOT, RIDOT and VTrans was performed to 1) determine *MASH* equivalency for each State's design per Section 13 of the AASHTO *LRFD Bridge Design Specifications [AASHTO12]* and 2) identify differences in material and dimensional details for each state's design. Preliminary recommendations for standardized designs were then provided based on the review to better ensure consistency for NETC style designs, considering constructability and performance. The crash performance of the recommended designs will be further evaluated based on *MASH* crash testing conditions and criteria using finite element analysis in subsequent tasks of this study.

In most cases, the recommendations included the least conservative value for each design detail, which has either shown acceptable R350 crash testing performance or met the LRFD strength criteria for *MASH* loading. In this way the more conservative design details are assumed to have sufficient strength. The one exception was the sidewalk-mounted 4-bar design, which did not meet the current recommended strength requirements based on the LRFD calculations. In that case, it was decided that the current design would be evaluated using finite element analysis to determine crash performance (e.g., MASH TL-3 or TL-4).

Redesign of the bridge rail systems is outside the scope of the study; however, if the FEA analyses shows poor performance for any system design, then recommended modifications will be provided for improving crash performance.

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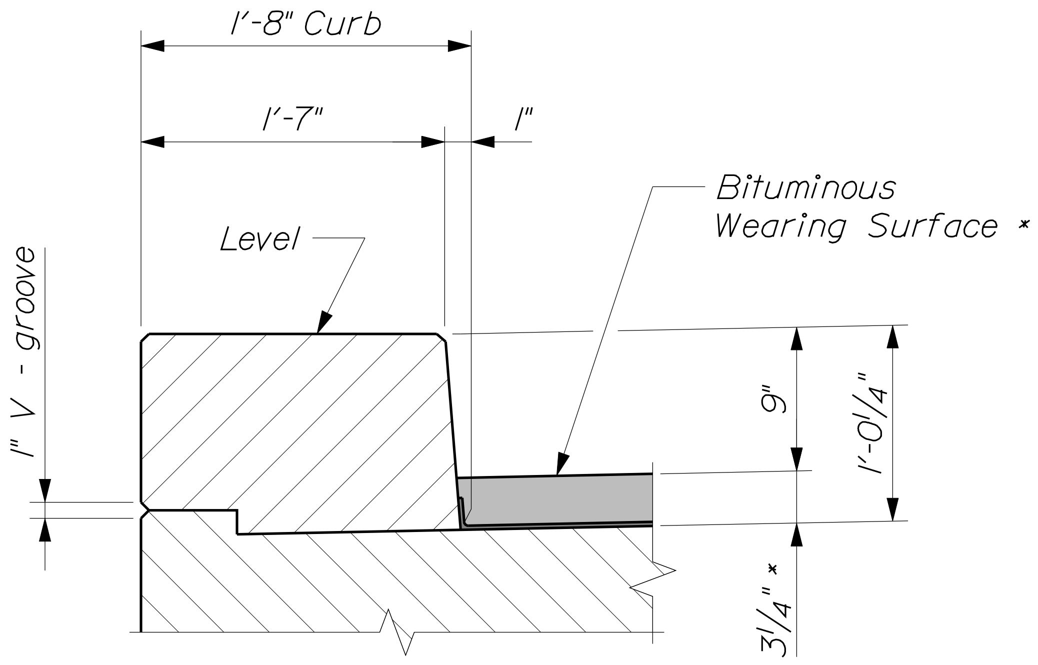
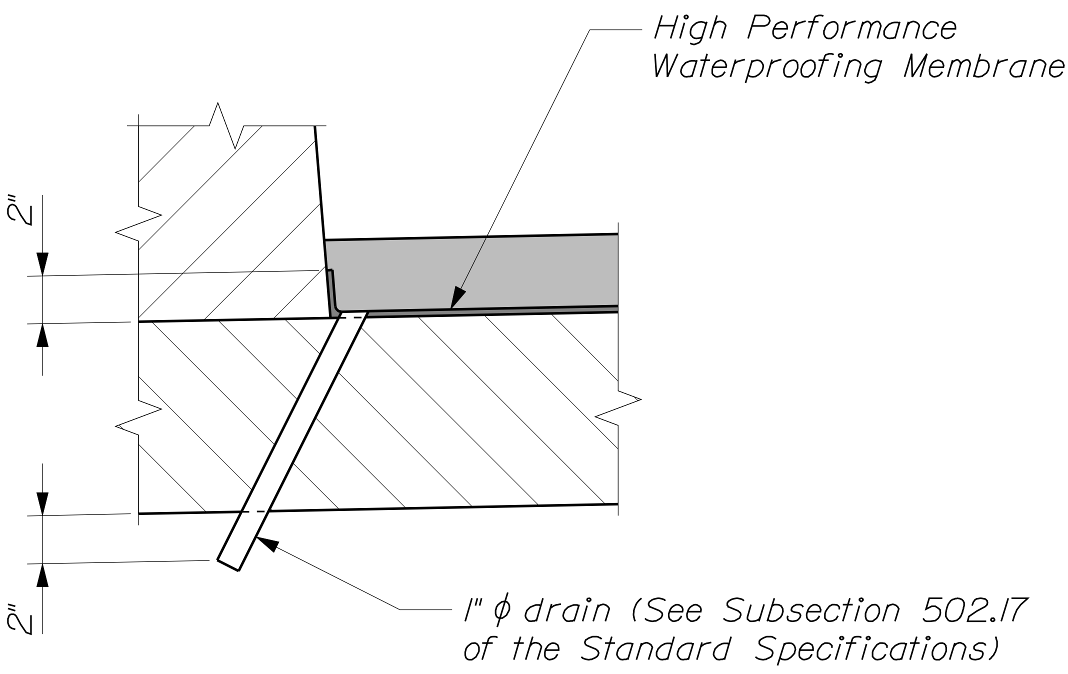
APPENDIX A: MAINE DOT STANDARD BRIDGE RAIL DRAWINGS



~ CURB WITH BITUMINOUS WEARING SURFACE ~

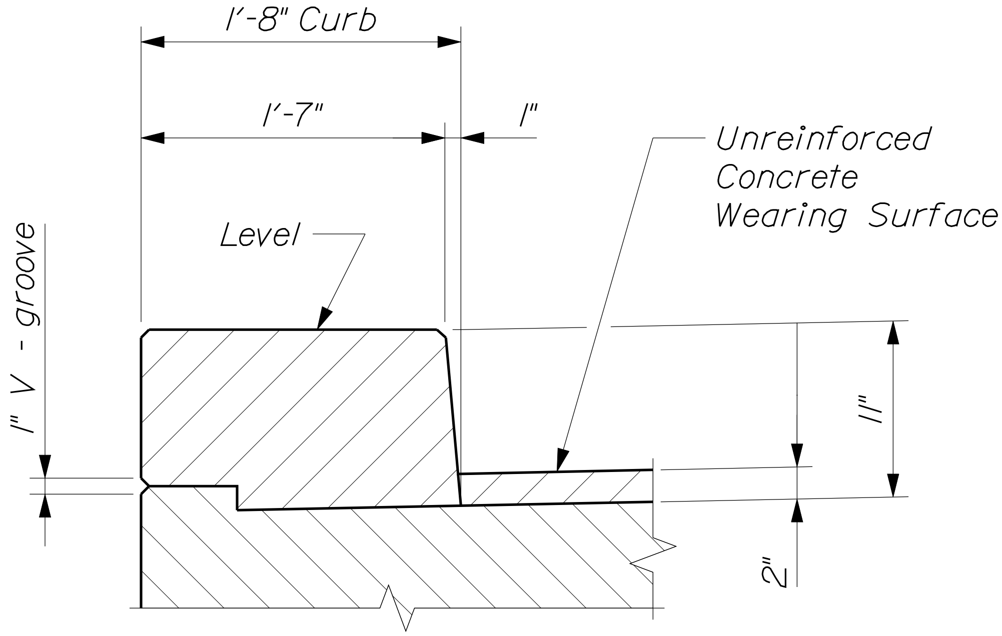
* 3" Hot Mix Asphalt + ¼" (nom.) High Performance Waterproofing Membrane



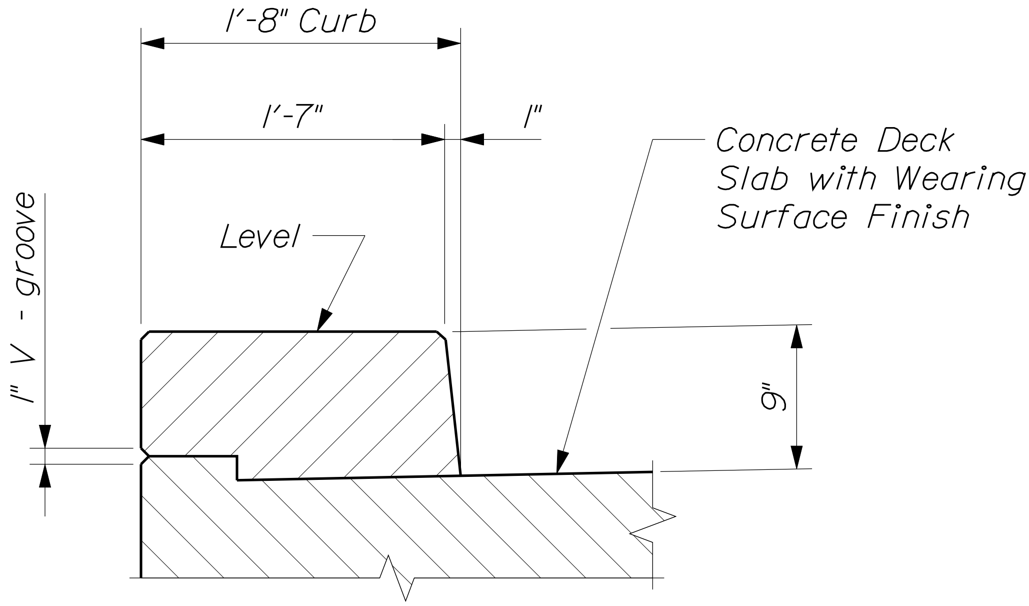
~ GUTTER DETAIL FOR BITUMINOUS W. S. ~

CONCRETE CURB

502(04)



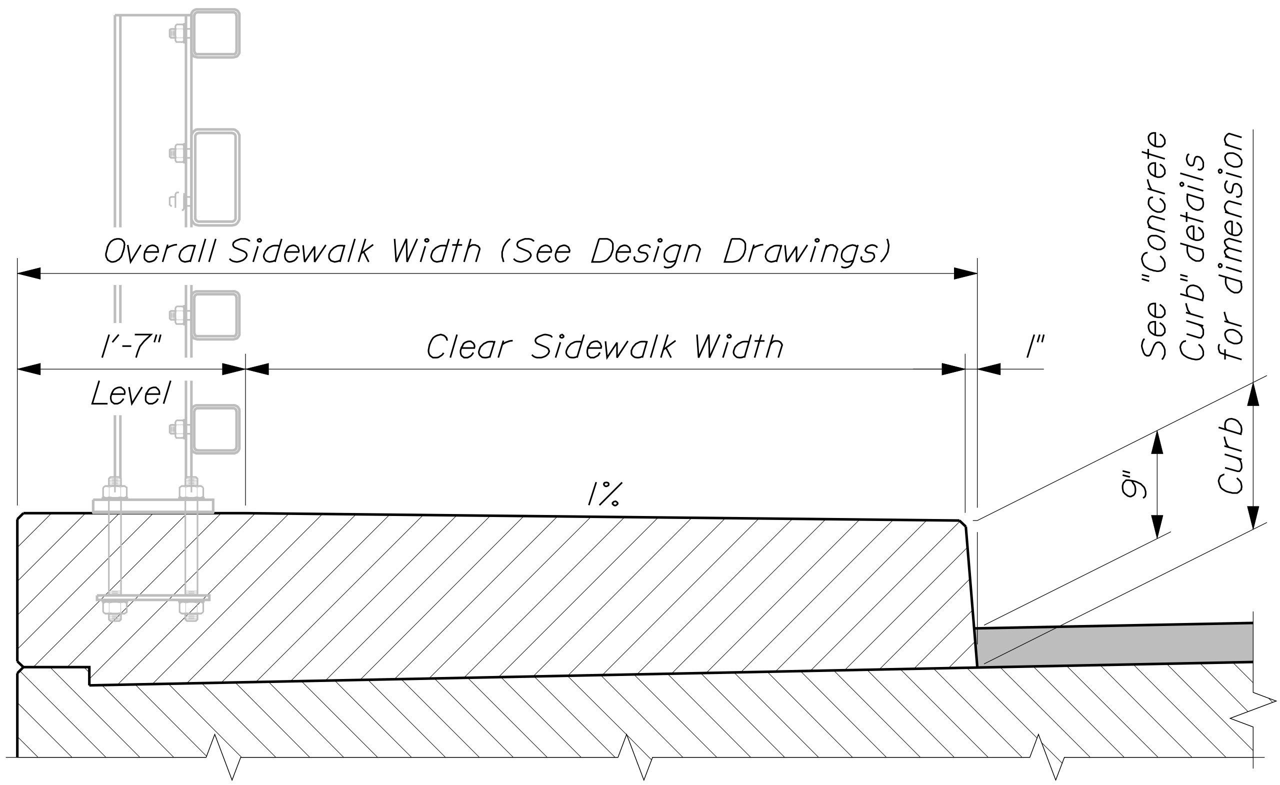
-- CURB WITH CONCRETE WEARING SURFACE --



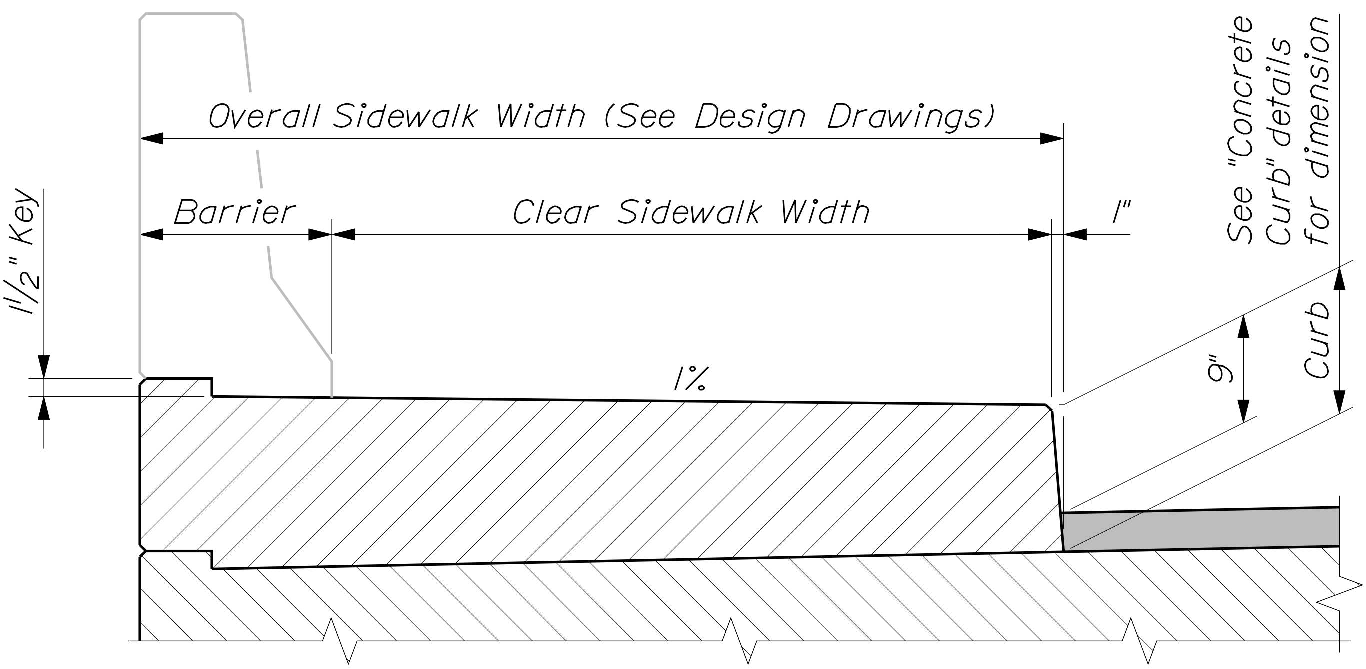
-- CURB WITH INTEGRAL WEARING SURFACE --

CONCRETE CURB

502(05)



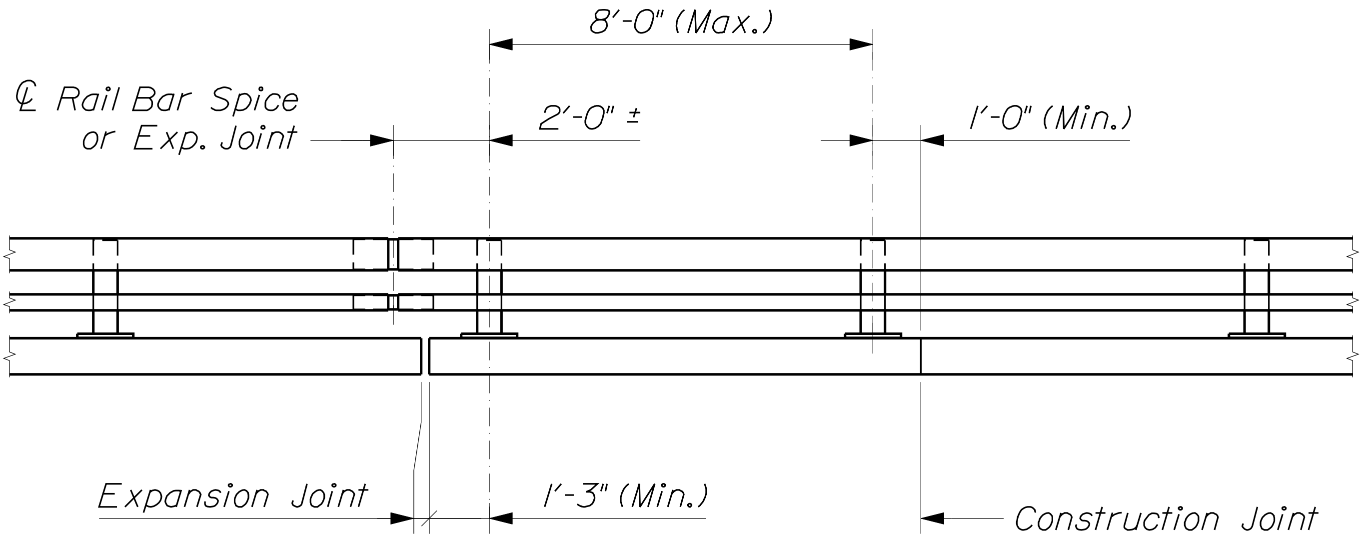
~ WITH STEEL BRIDGE RAILING ~



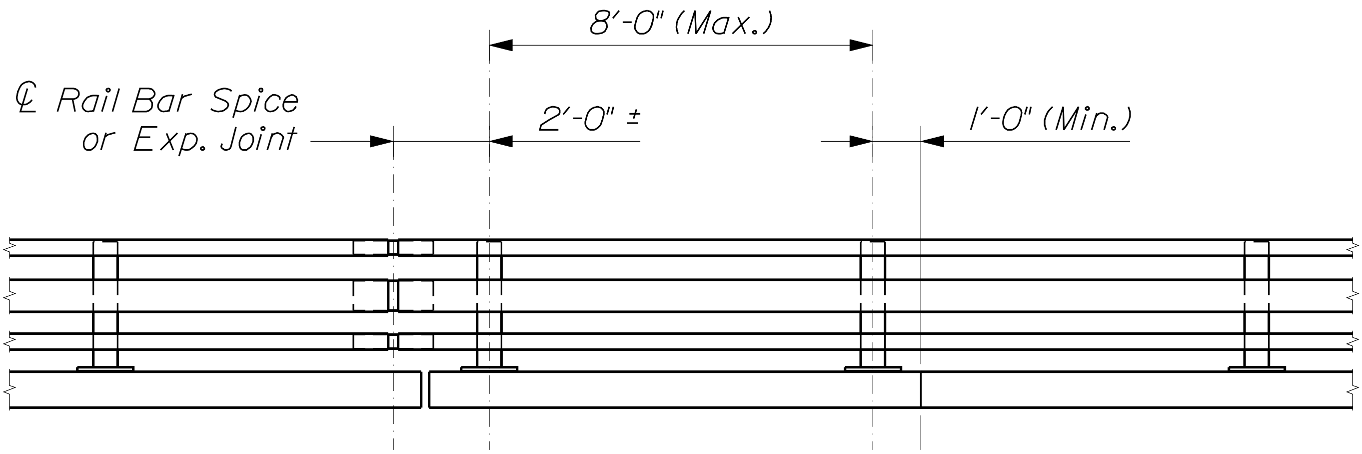
~ WITH PERMANENT CONCRETE BARRIER ~

CONCRETE SIDEWALK ON BRIDGES

502(06)

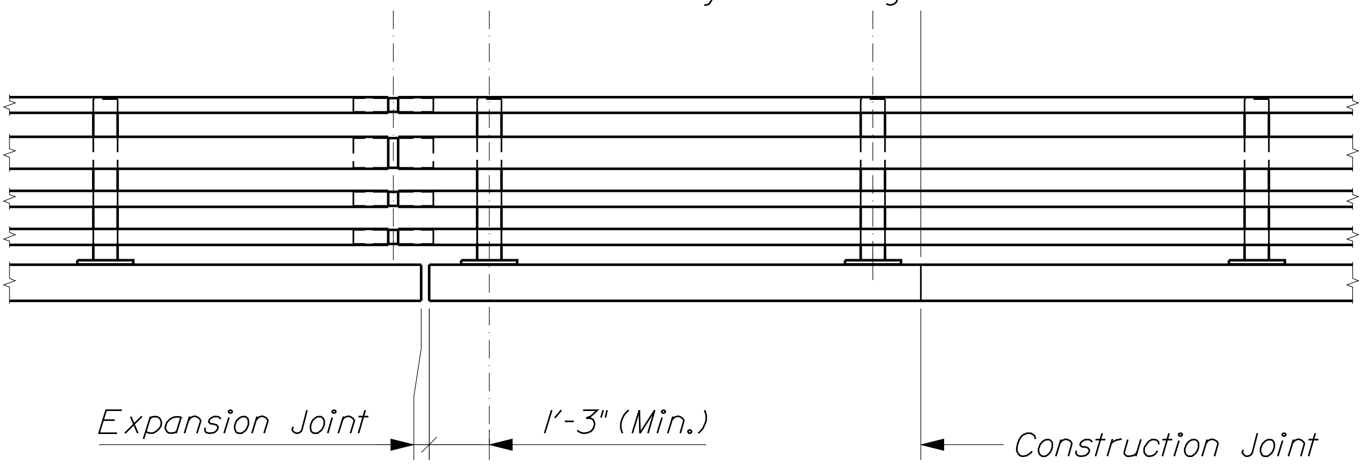


~ 2 - BAR TRAFFIC RAILING ~



~ 3 - BAR TRAFFIC / BICYCLE RAILING ~

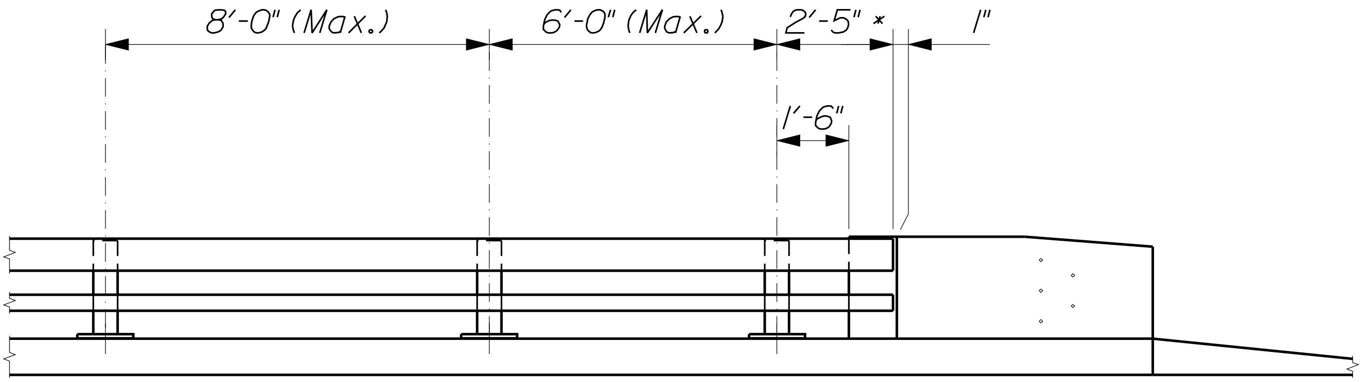
(4 - Bar Traffic / Bicycle Railing similar)



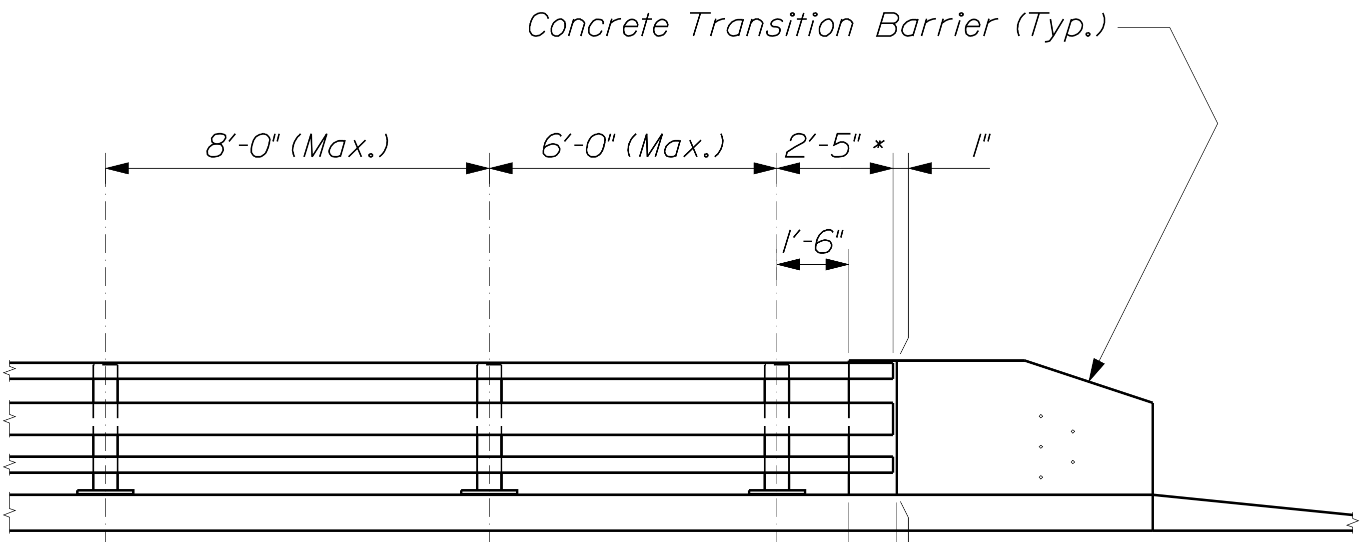
~ 4 - BAR TRAFFIC / PEDESTRIAN RAILING ~

STEEL BRIDGE RAILING

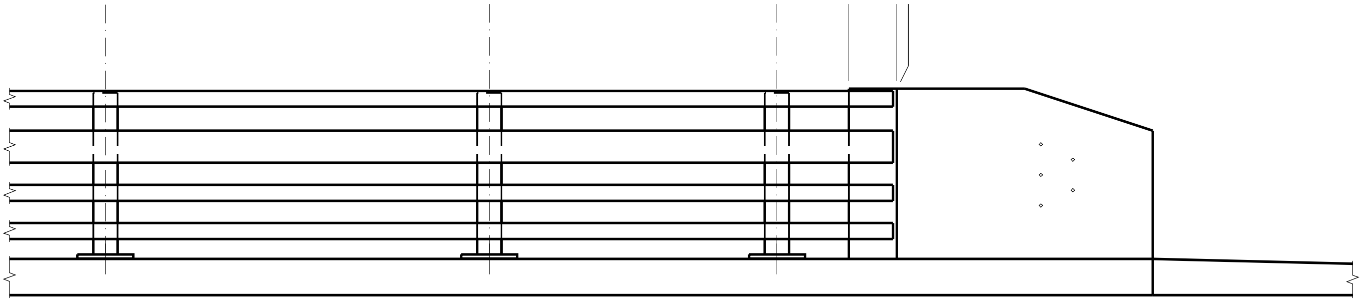
507(01)



~ 2 - BAR TRAFFIC RAILING ~



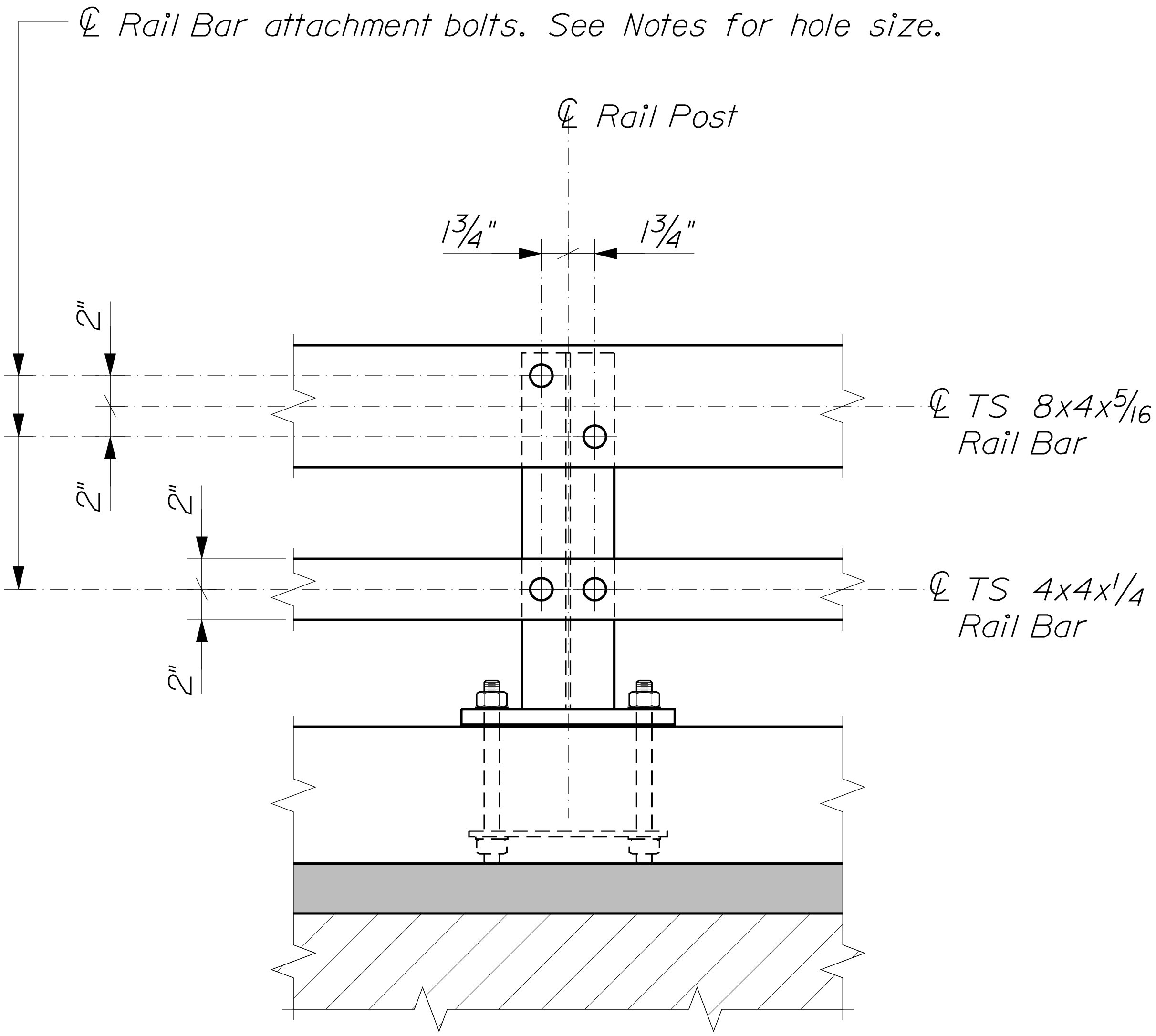
~ 3 - BAR TRAFFIC / BICYCLE RAILING ~
(4 - Bar Traffic / Bicycle Railing similar)



~ 4 - BAR TRAFFIC / PEDESTRIAN RAILING ~

* Including Rail Bar Cap (Typ.)

# STEEL BRIDGE RAILING
507(02)

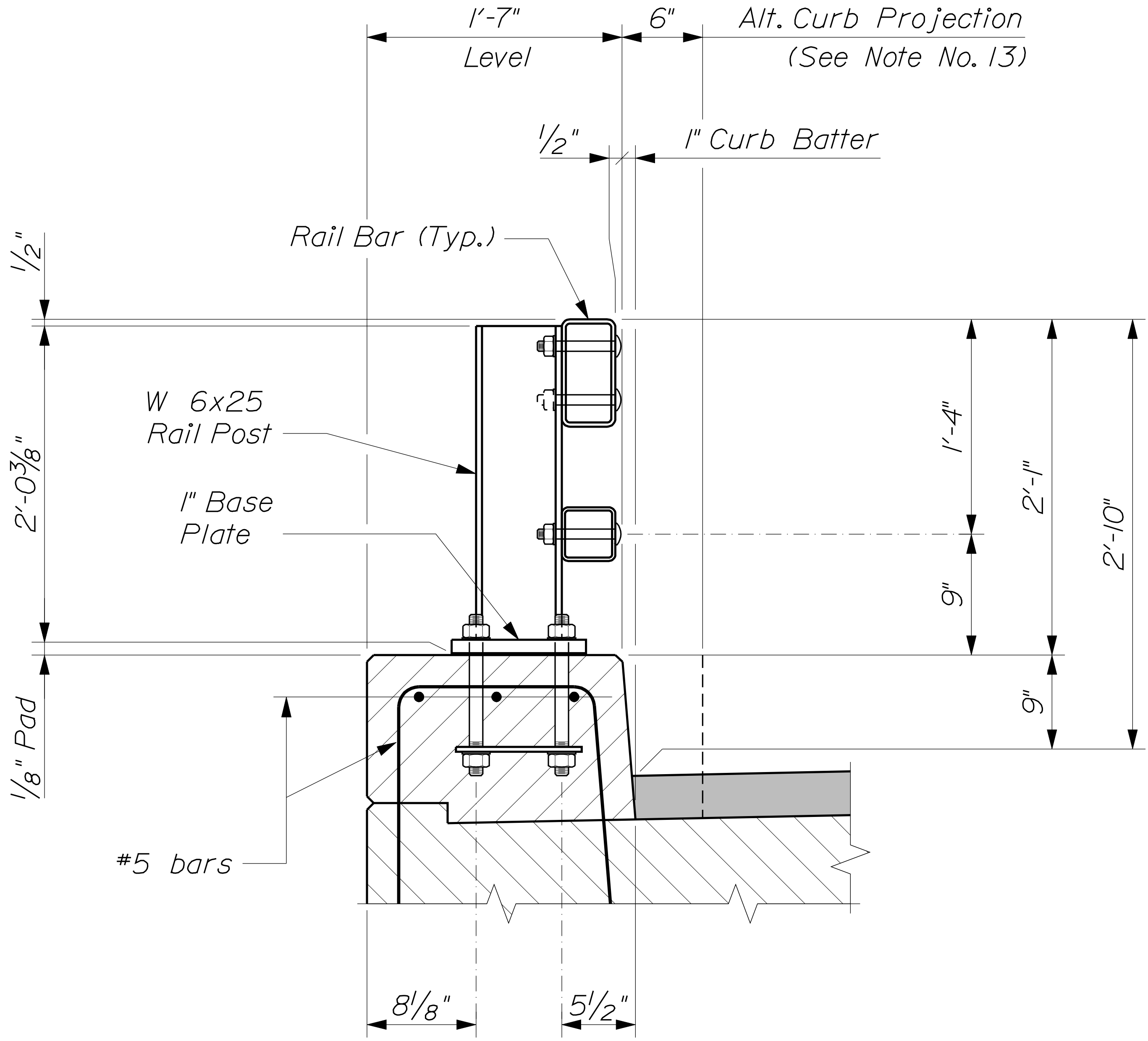


~ TYPICAL RAILING ELEVATION ~
2 - Bar Traffic Railing is shown.
Other railing configurations are similar.

STEEL BRIDGE RAILING

507(03)

Rail Bars:
TS 8x4x5/16 (1)
TS 4x4x1/4 (1)

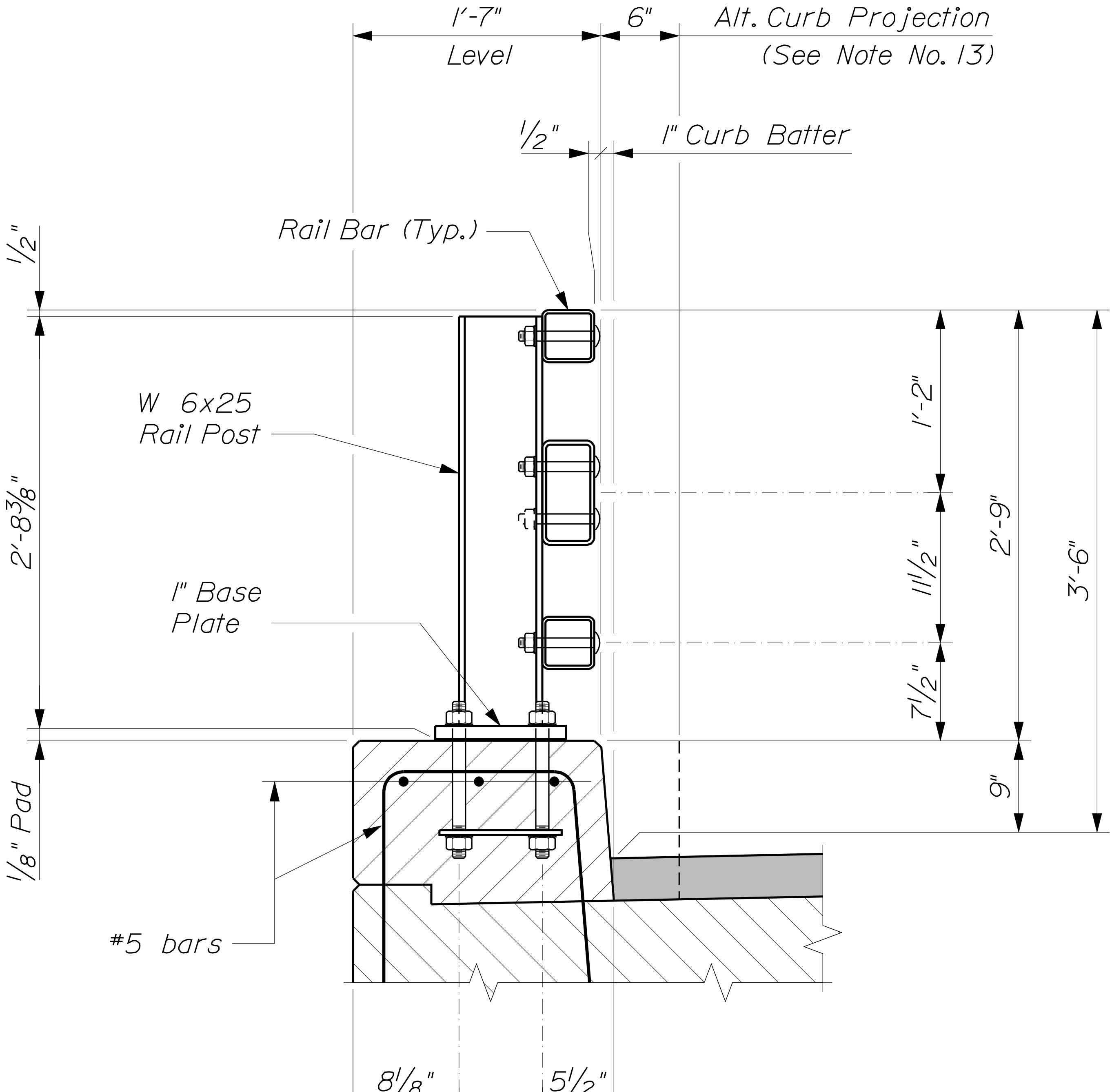


~ TYPICAL RAILING SECTION ~
(2 - Bar Traffic Railing)

STEEL BRIDGE RAILING

507(04)

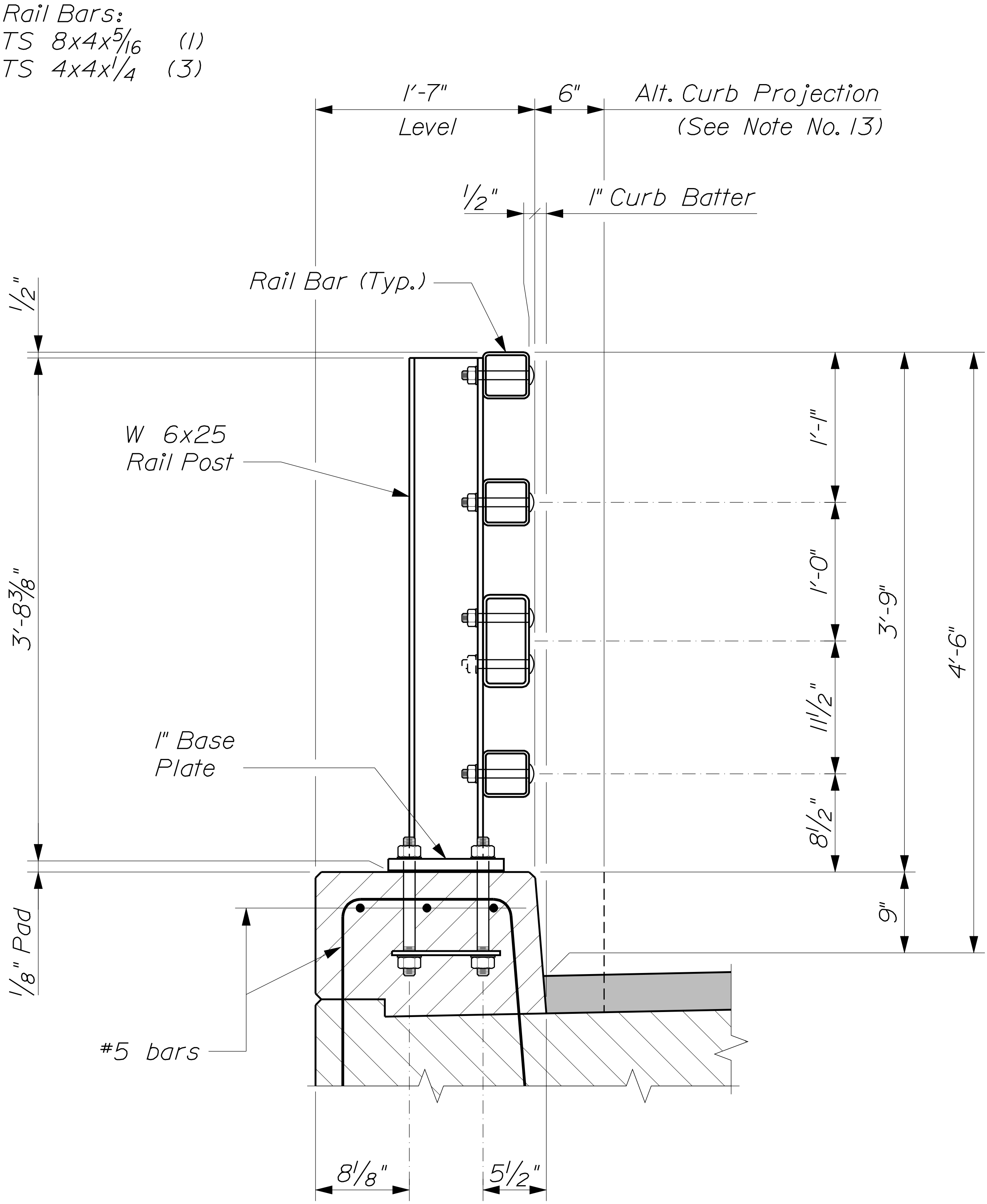
Rail Bars:
TS 8x4x5/16 (1)
TS 4x4x1/4 (2)



~ TYPICAL RAILING SECTION ~
(3 - Bar Traffic / Bicycle Railing)

STEEL BRIDGE RAILING

507(05)

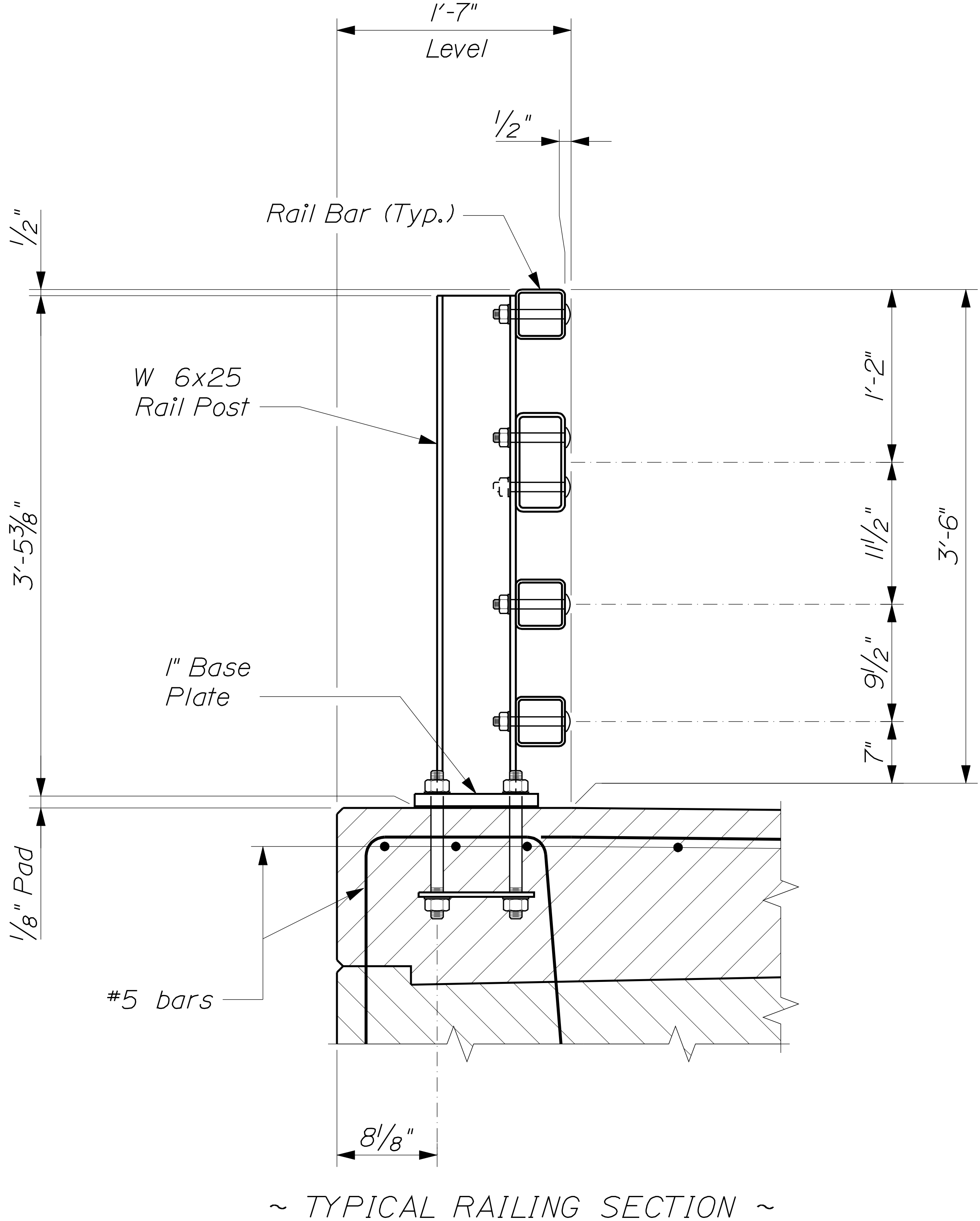


~ TYPICAL RAILING SECTION ~
(4 - Bar Traffic / Bicycle Railing)

STEEL BRIDGE RAILING

507(06)

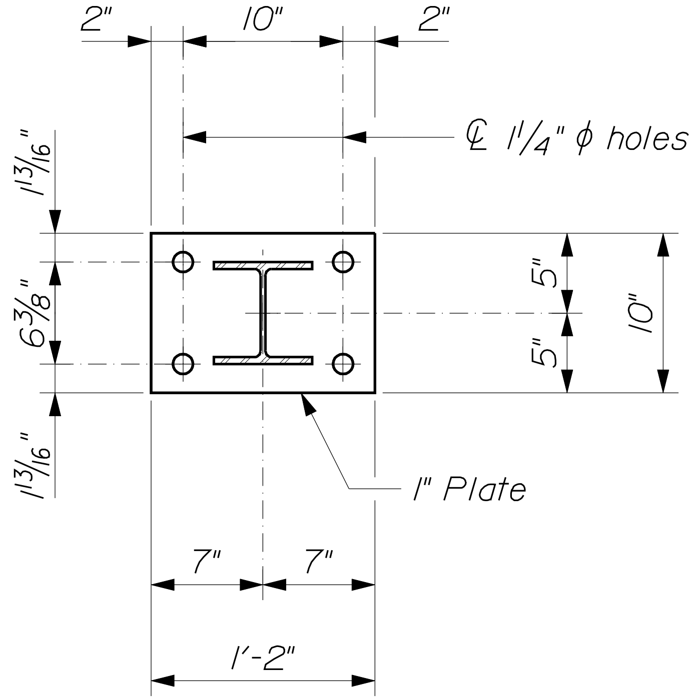
Rail Bars:
TS 8x4x5/16 (1)
TS 4x4x1/4 (3)



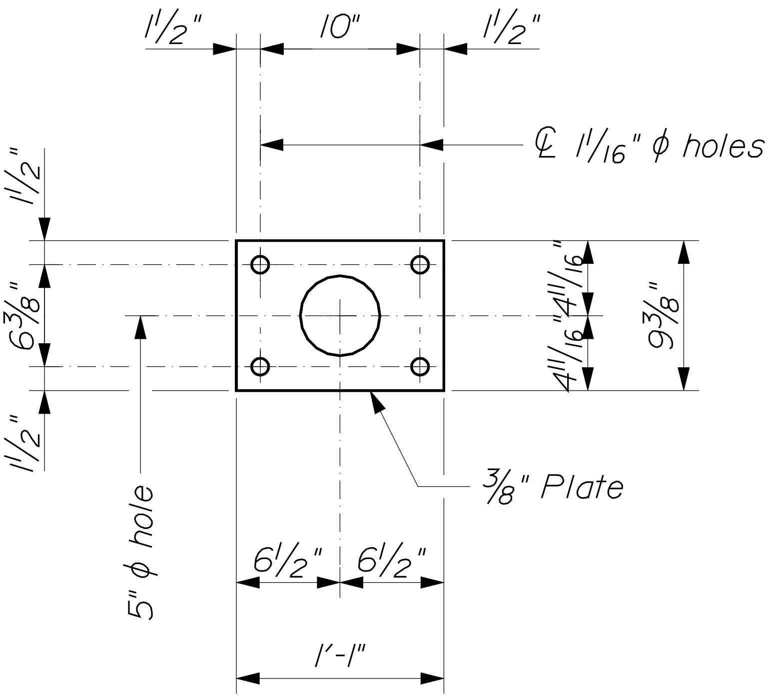
~ TYPICAL RAILING SECTION ~
(4 - Bar Traffic / Pedestrian Railing)

STEEL BRIDGE RAILING

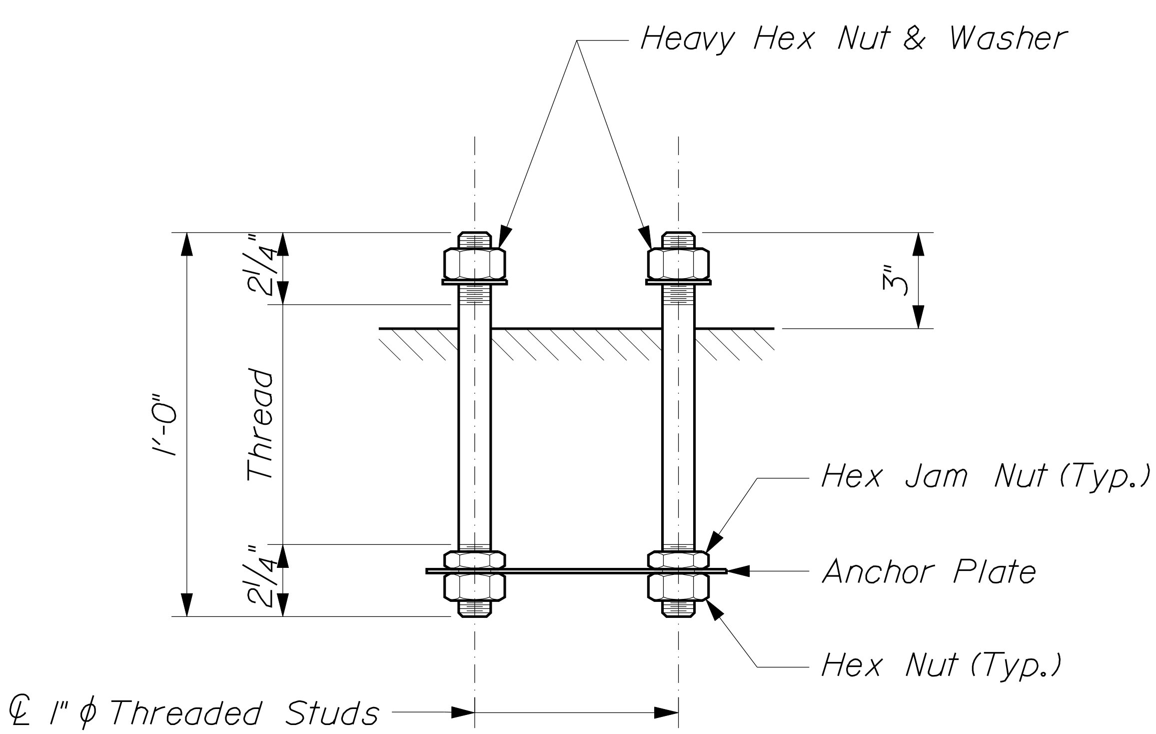
507(07)



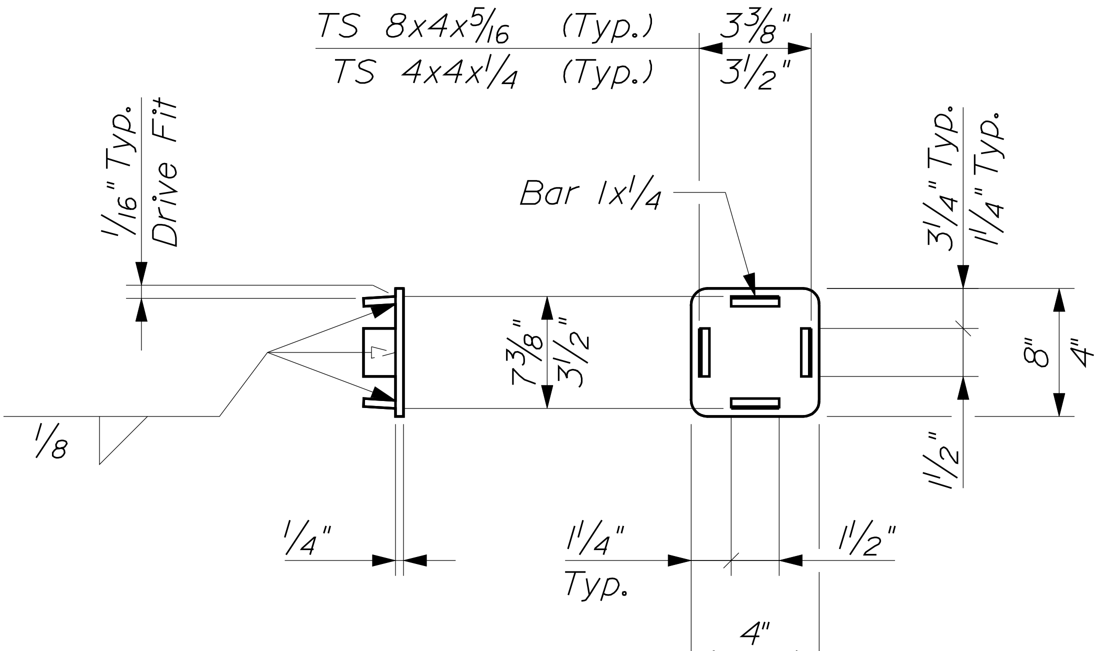
~ POST & BASE PLATE PLAN ~



~ ANCHOR PLATE PLAN ~



~ RAIL POST ANCHORAGE ~

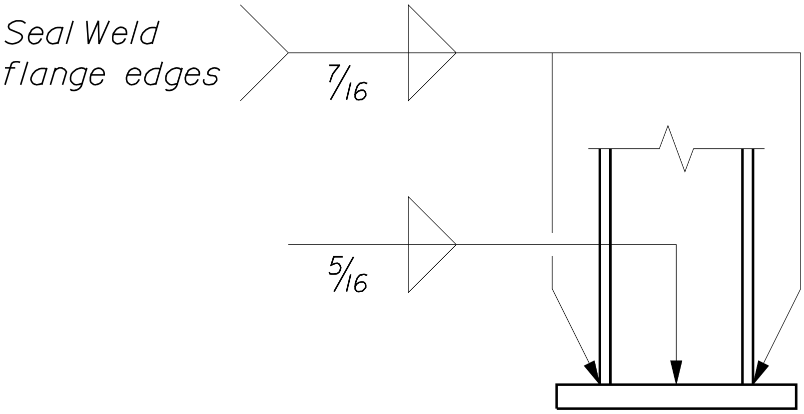


~ RAIL BAR CAP ~

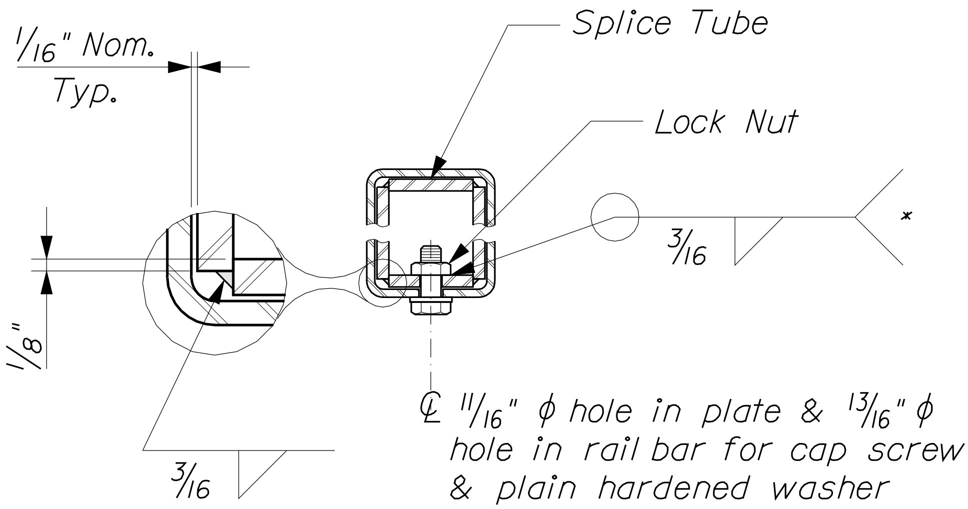
Note: Match corner radius of rail bar

STEEL BRIDGE RAILING

507(09)

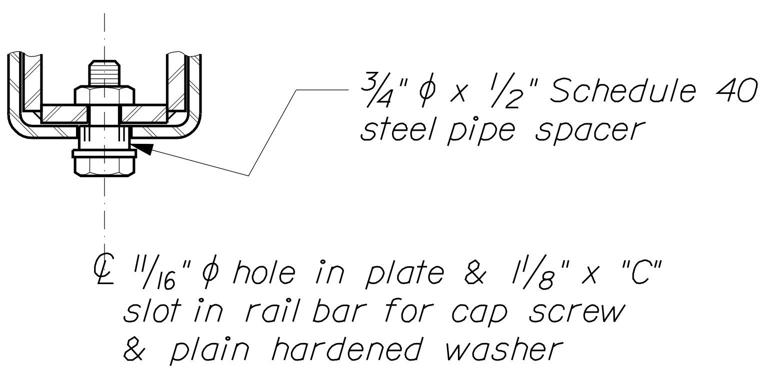


~ POST - TO - BASE WELD DETAIL ~



~ RAIL BAR SPLICE SECTION ~

* Weld nuts to plate before assembling splice tube

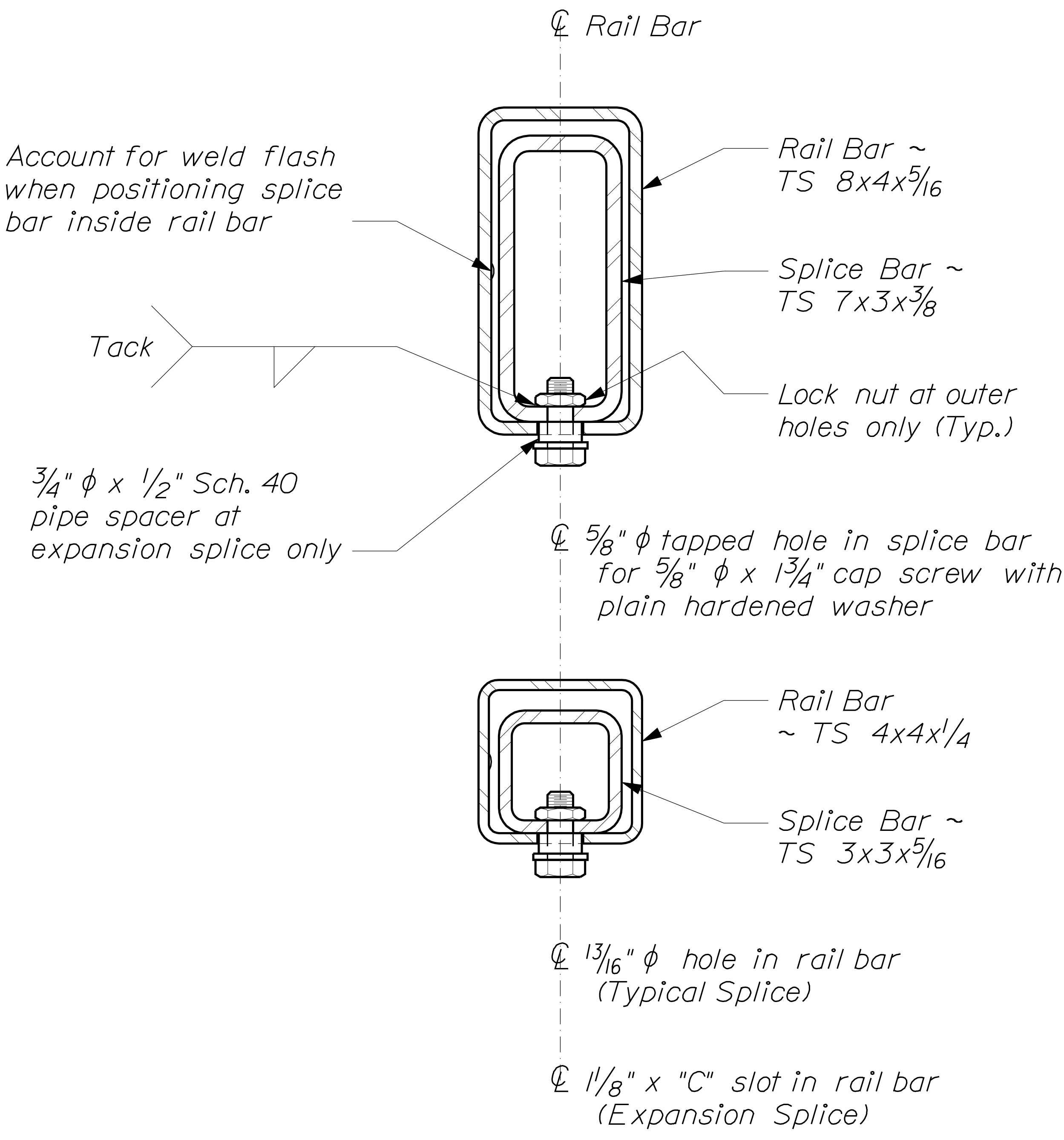


~ RAIL BAR EXPANSION JOINT SECTION ~

For details not shown, see "Rail Bar Splice Section"

STEEL BRIDGE RAILING

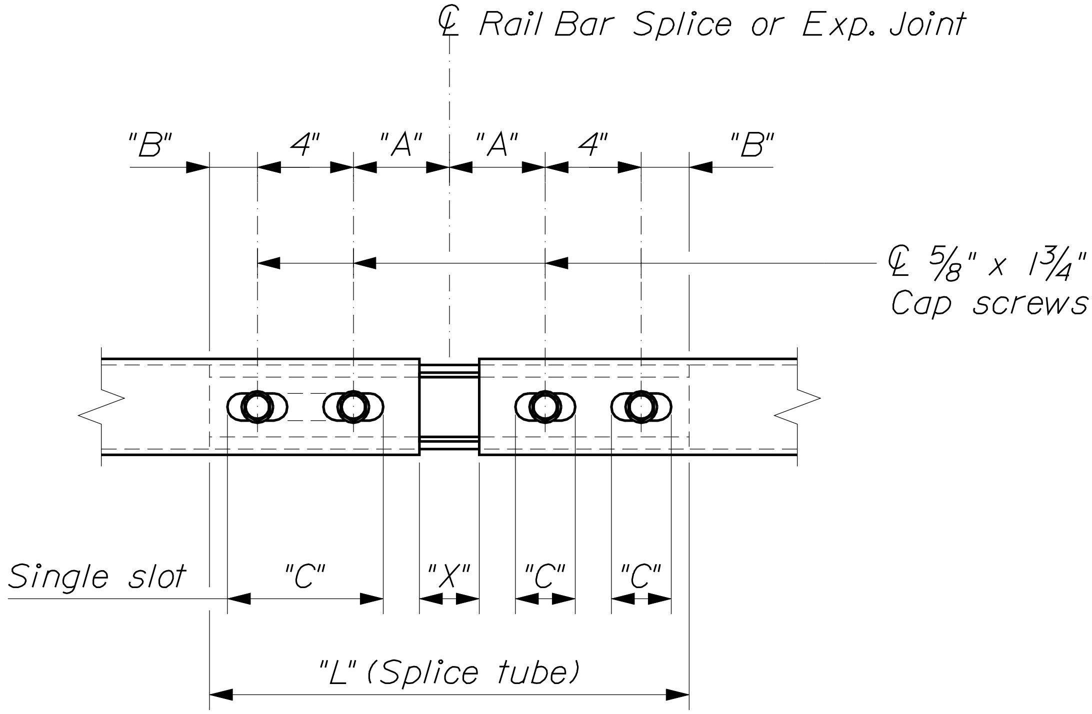
507(10)



-- OPTIONAL RAIL BAR SPLICE SECTION --
(Details Typical for both rail bars)

STEEL BRIDGE RAILING

507(II)



~ RAIL BAR SPLICE & EXPANSION JOINT DETAIL ~
(Bottom View)

SPLICE TUBE DIMENSIONS		
	TS 8x4	TS 4x4
Top & Bot. Plates	2 1/2 x 3/8 x "L"	2 5/8 x 3/8 x "L"
Side Plates	6 3/4 x 3/8 x "L"	2 7/8 x 3/8 x "L"

SPLICE & EXPANSION JOINT TABLE					
"T"	"A"	"B"	"C"	"L"	"X"
Splice	4"	2"	--	1'-8"	3/4"
≤ 4"	4"	2"	2 1/2"	1'-8"	2 1/2"
> 4" ≤ 6 1/2"	5 1/2"	2 1/2"	3 1/2"	2'-0"	3 3/4"
> 6 1/2" ≤ 9"	6 1/2"	3 1/2"	9" *	2'-4"	5"
> 9" ≤ 13"	8 1/2"	4 1/2"	11" *	2'-10"	7"

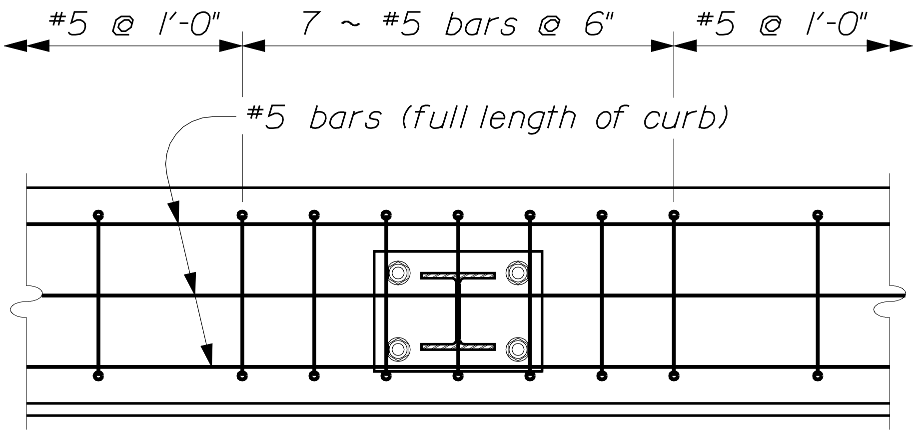
T = Total Movement * = Single Slot

MATERIALS:

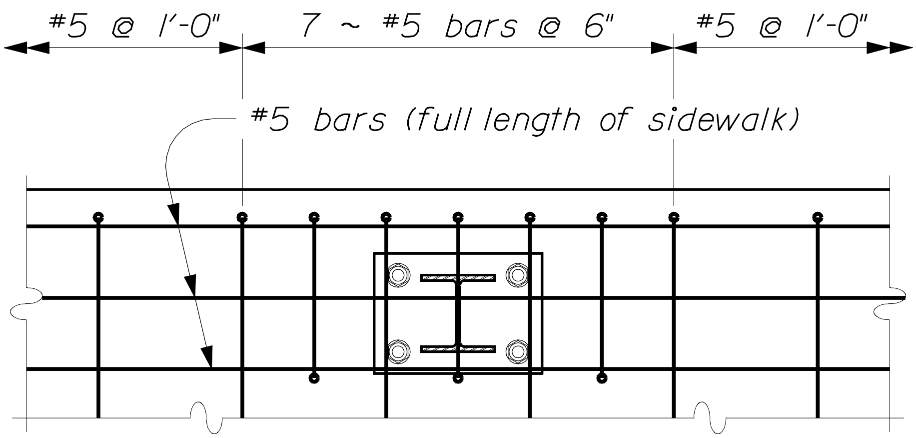
Rail bars .... ASTM A 500, Grade B
Rail posts, shapes & plates .... AASHTO M 270M/M 270, Grade 50
Anchor studs, washers & heavy hex nuts .... AASHTO M 314, Grade 105
All other bolts & nuts (unless noted) .... AASHTO A 307, Grade C

STEEL BRIDGE RAILING

507(12)



~ CURB REINFORCING PLAN ~



~ SIDEWALK REINFORCING PLAN ~

NOTES:

1. All work and materials shall conform to the provisions of Section 507 - Railings of the Standard Specifications.

2. Tubing shall meet the longitudinal CVN minimum requirements of 15 ft-lb at 0° F or proportional values of sub - size specimens. Testing shall be done in accordance with ASTM A 673. The H frequency shall be used and the material shall be as - rolled.

3. Twenty - five percent of the post - to - base welds in a production lot shall be tested by the Magnetic Particle Method. If rejectable discontinuities are found, another twenty - five percent of that production lot shall be tested. If rejectable discontinuities are found in the second twenty - five percent, all post - to - base welds in that lot shall be tested. Acceptance criteria shall be in accordance with the latest edition of the AWS D1.5 Bridge Welding Code.

STEEL BRIDGE RAILING

507(13)

NOTES (Continued):

4. All exposed cut or sheared edges shall be broken and free of burrs. The inside weld flash of tubing shall be removed at splices and expansion joints.

5. Rail posts shall be set normal to grade unless otherwise shown.

6. Lengths of rail bar shall be attached to a minimum of 2 rail posts and to at least 4 posts whenever possible.

7. Rail bar expansion joints shall be provided in any rail bay spanning a superstructure expansion joint. Expansion joint width shall be "X" at 45° F and will be adjusted in the field as directed by the Resident. Refer to detail and table on page 507(12) for dimension "X".

8. All parts shall be galvanized after fabrication in accordance with ASTM A 123, except that hardware shall meet the requirements of either ASTM A 153 or ASTM B 695, Class 50, Type I. Parts except hardware shall be blast - cleaned prior to galvanizing in accordance with SSPC - SP6.

9. Anchor bolts shall be set with a template. Nuts securing the post base plate shall be tightened to a snug fit and given an additional $1/8$ turn.

10. Rail bars shall be attached to posts using $3/4$" ϕ ~ ASTM A 307 bolts ($5/8$" ϕ ~ ASTM A 325 bolts may be substituted) inserted through the face of the rail bar. Bolts shall be round or dome head and may be rib neck, slotted, wrench head or tension control (TC or twist - off). Holes in posts shall be $1/16$" larger than the diameter of the bolt. Holes in rail bars shall be drilled to size as follows:

Slotted, wrench head or TC bolts: $1/16$" larger than bolt diameter
Rib neck bolts: Size appropriate to accomodate an interference fit

All bolts for fastening the rail bars to the posts shall be 6 inches in length and shall include a flat washer under the nut.

11. Holes in rail bars shall be field - drilled and shall be coated with an approved zinc - rich paint prior to erection.

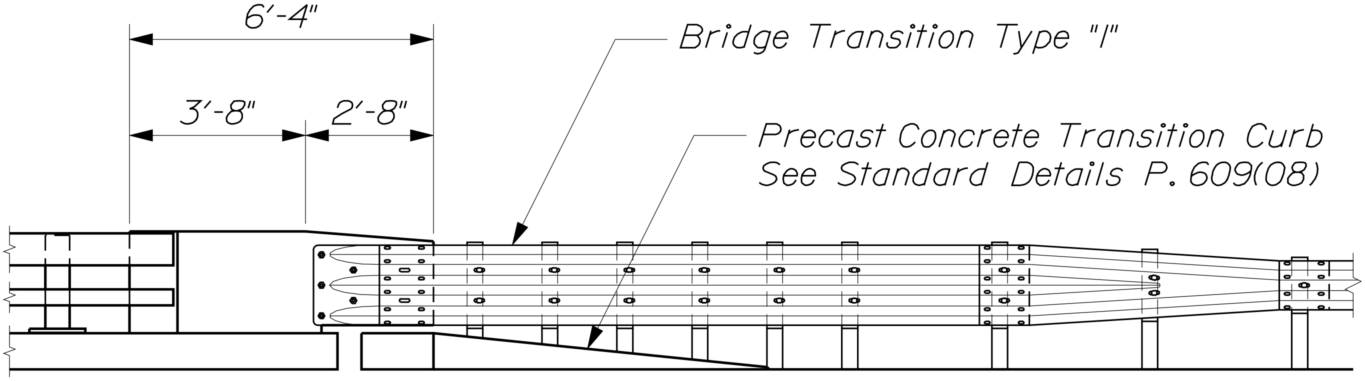
12. Bolts in expansion joints shall be tightened only to a point that will allow rail movement.

13. The alternate curb projection shown for the curb - mounted railings is intended for use with granite bridge curb.

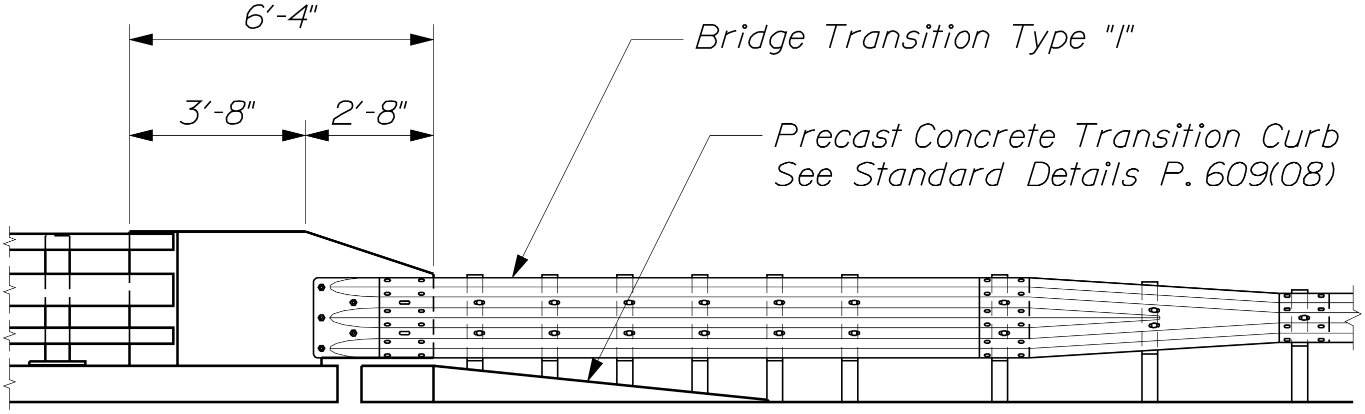
14. If there is a conflict between these Standard Details and the Design Drawings, the Contractor shall notify the Resident immediately.

STEEL BRIDGE RAILING

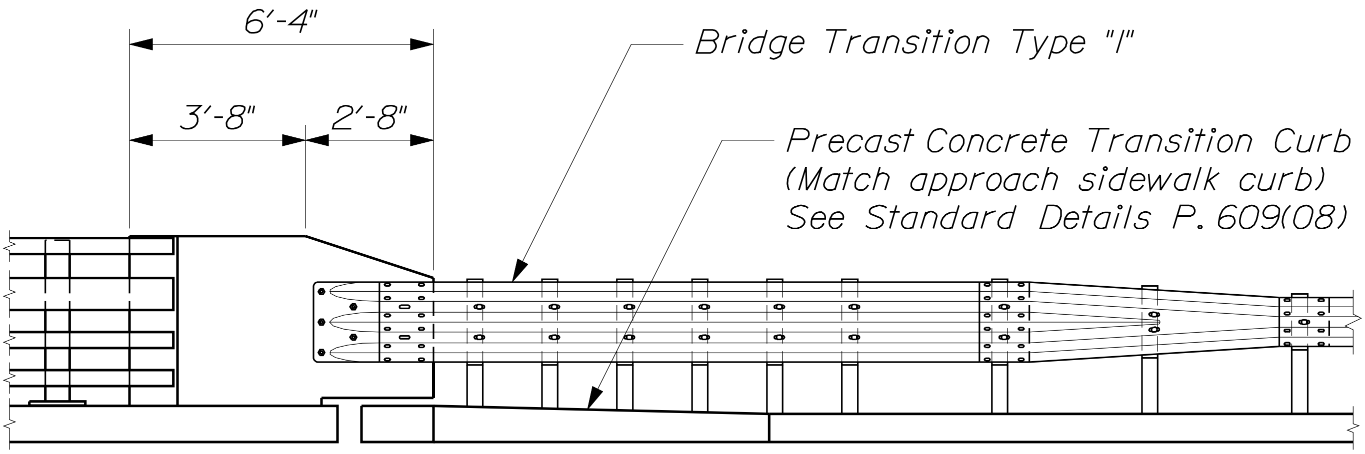
507(14)



~ CONCRETE TRANSITION BARRIER ~
(2 - Bar Traffic Railing)



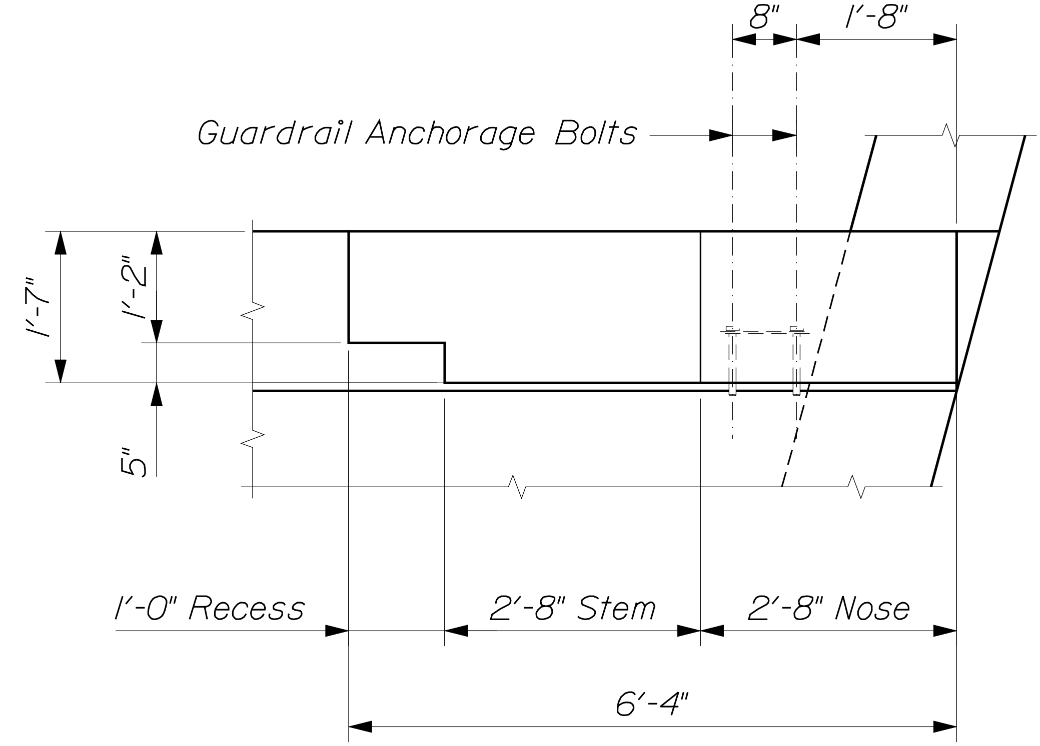
~ CONCRETE TRANSITION BARRIER ~
(3 - Bar Traffic / Bicycle Railing)
(4 - Bar Traffic / Bicycle Railing similar)



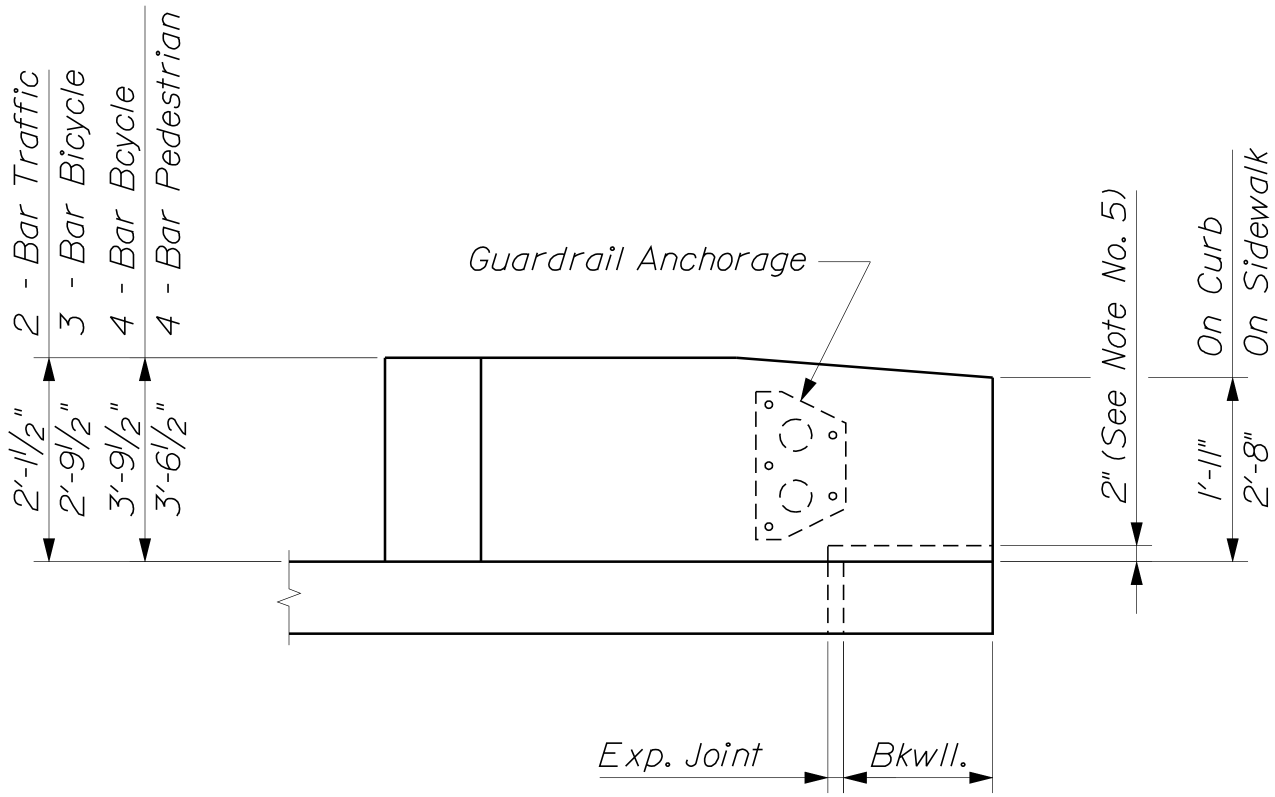
~ CONCRETE TRANSITION BARRIER ~
(4 - Bar Traffic / Pedestrian Railing)

CONCRETE TRANSITION BARRIER

526(22)



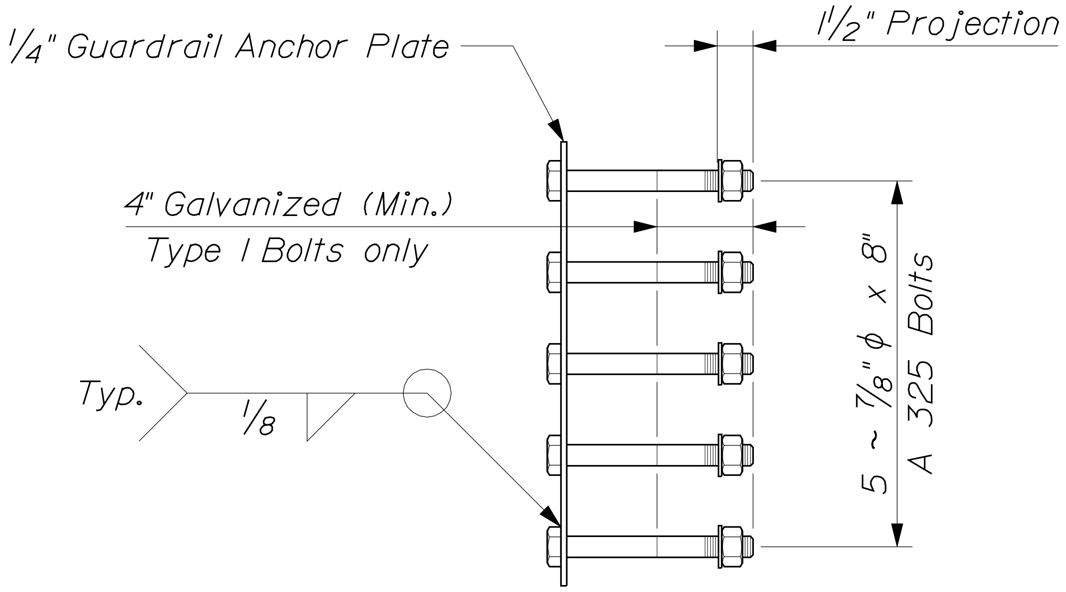
~ TRANSITION BARRIER PLAN ~



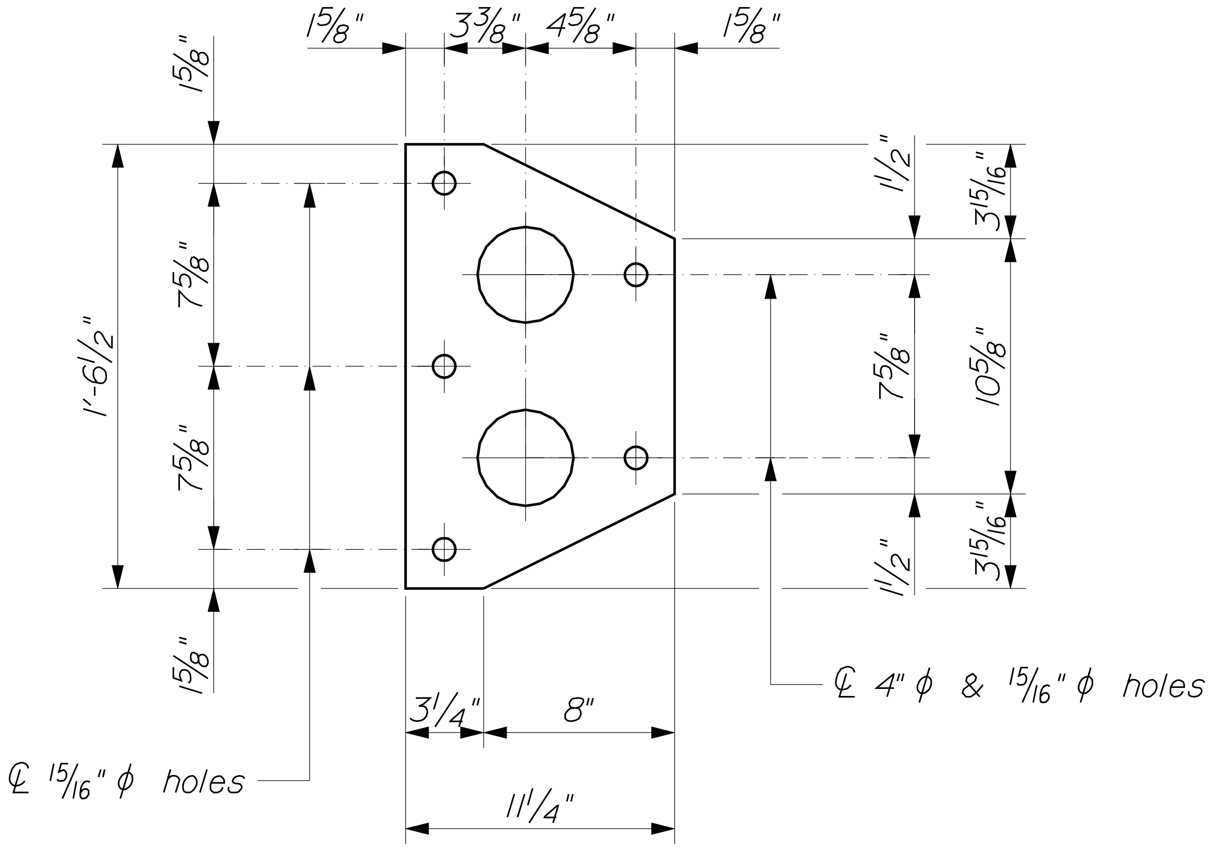
~ TRANSITION BARRIER ELEVATION ~

CONCRETE TRANSITION BARRIER

526(23)



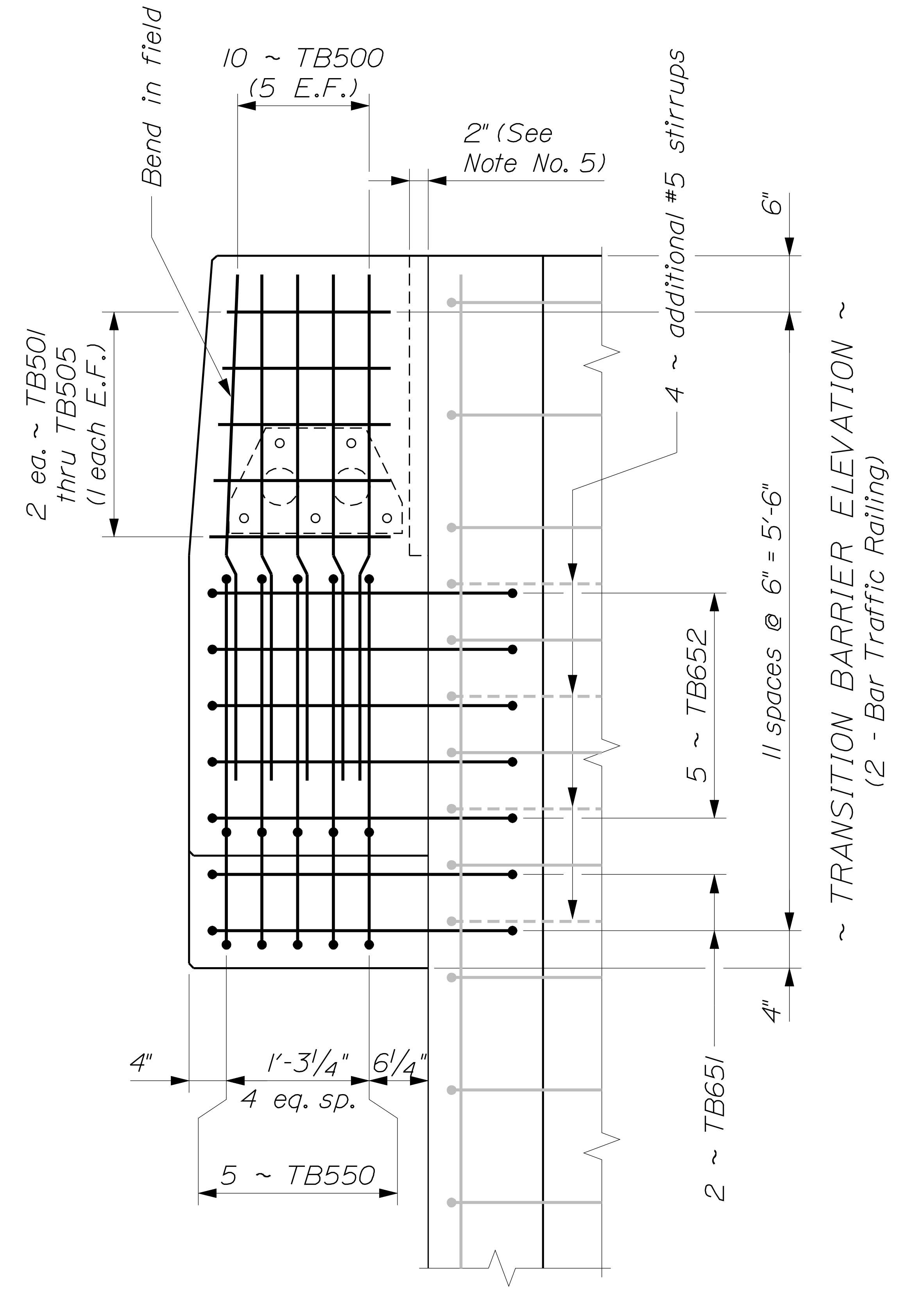
~ GUARDRAIL ANCHORAGE SECTION ~



~ GUARDRAIL ANCHOR PLATE ~

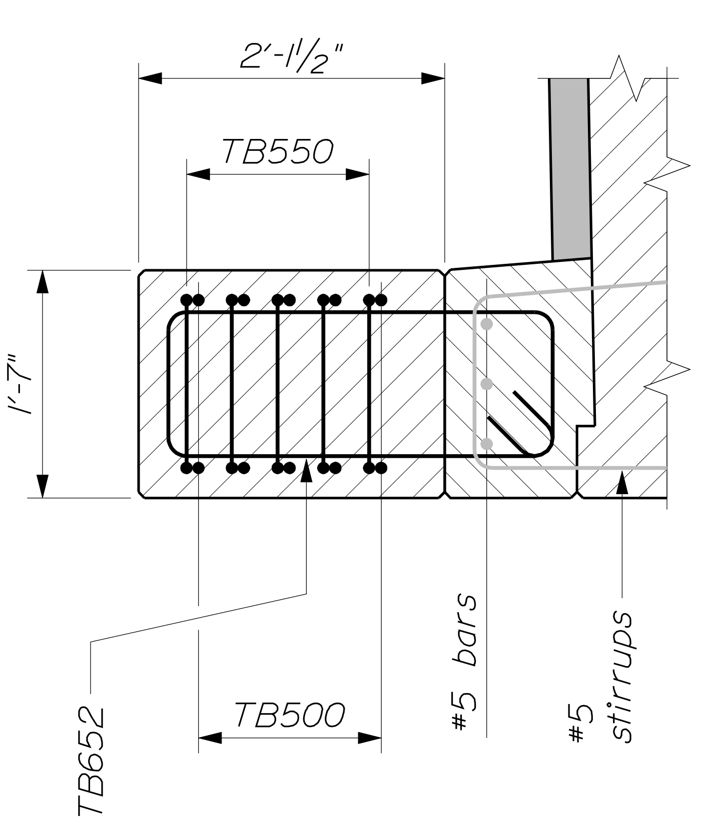
CONCRETE TRANSITION BARRIER

526(24)

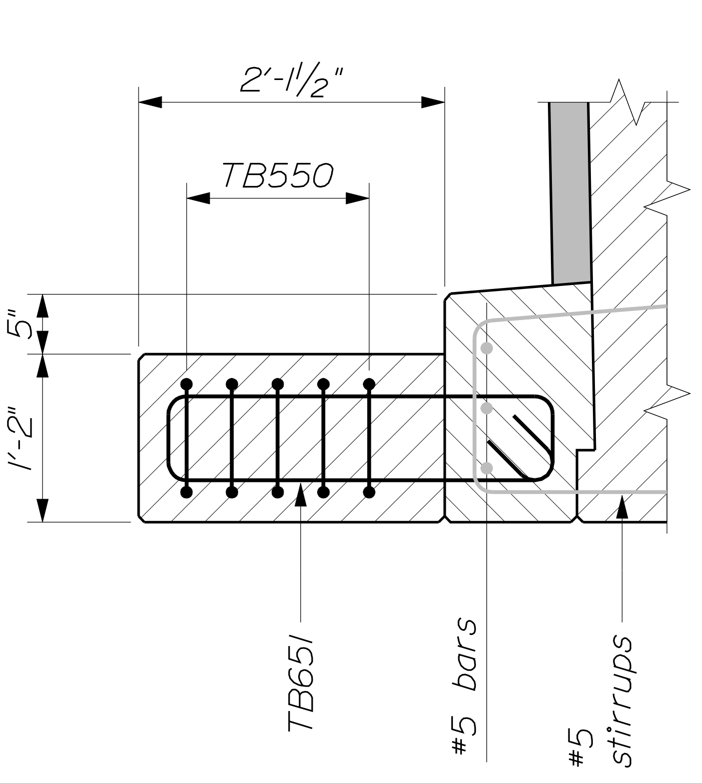


CONCRETE TRANSITION BARRIER

526(25)



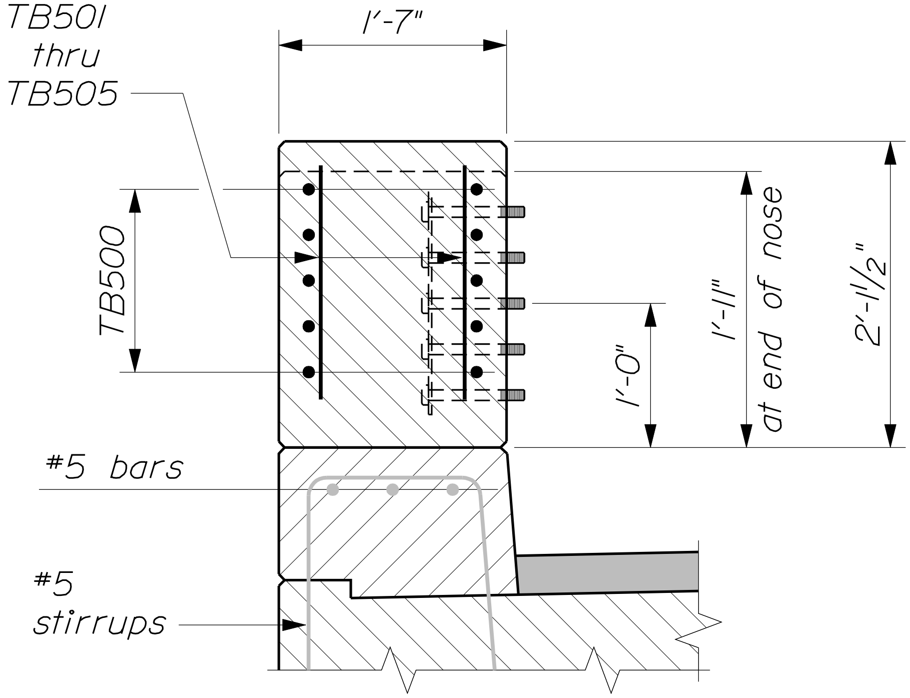
~ SECTION THRU STEM ~
(2 - Bar Traffic Railing)



~ SECTION THRU RECESS ~
(2 - Bar Traffic Railing)

CONCRETE TRANSITION BARRIER

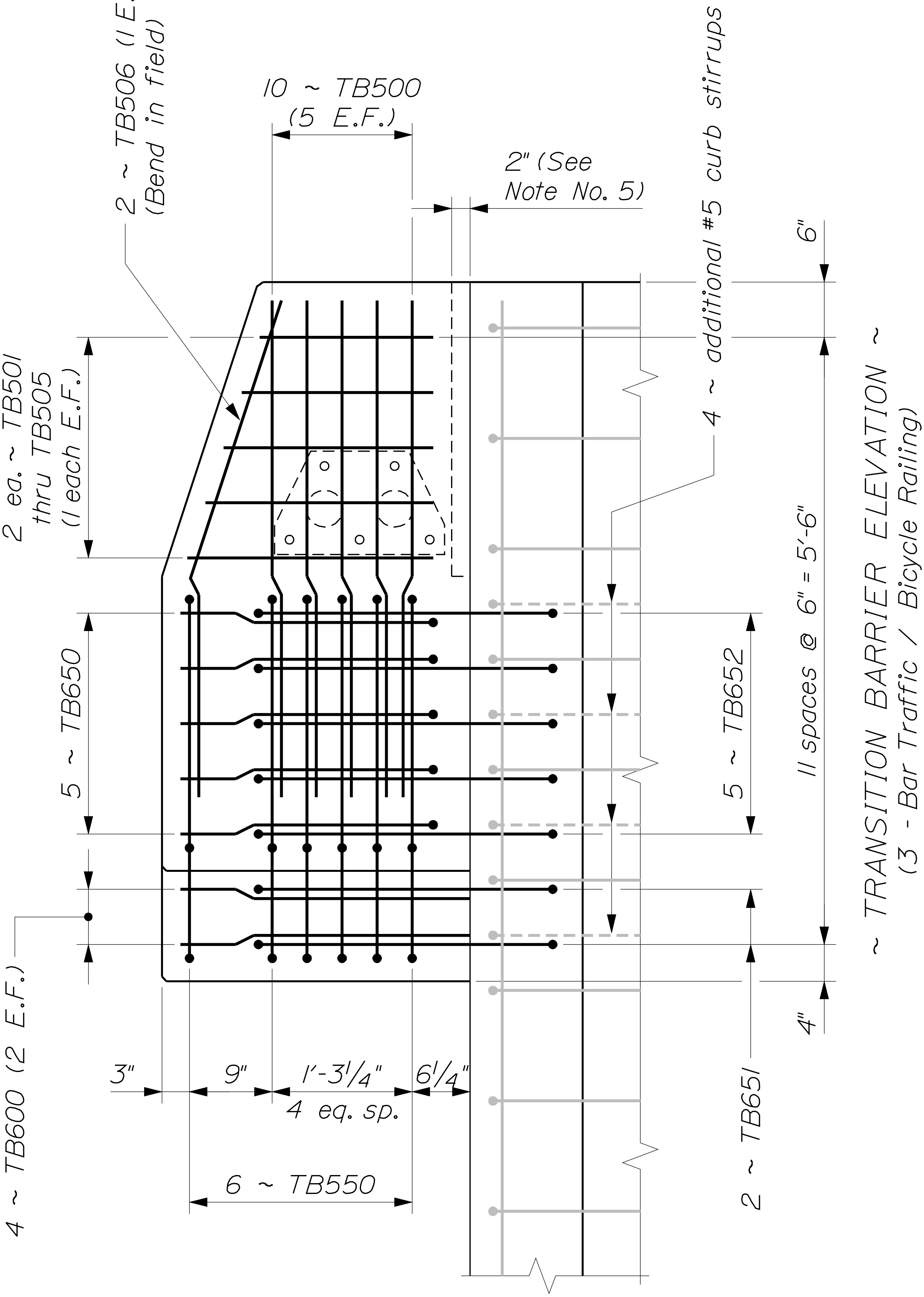
526(26)



~ SECTION THRU NOSE ~
(2 - Bar Traffic Railing)

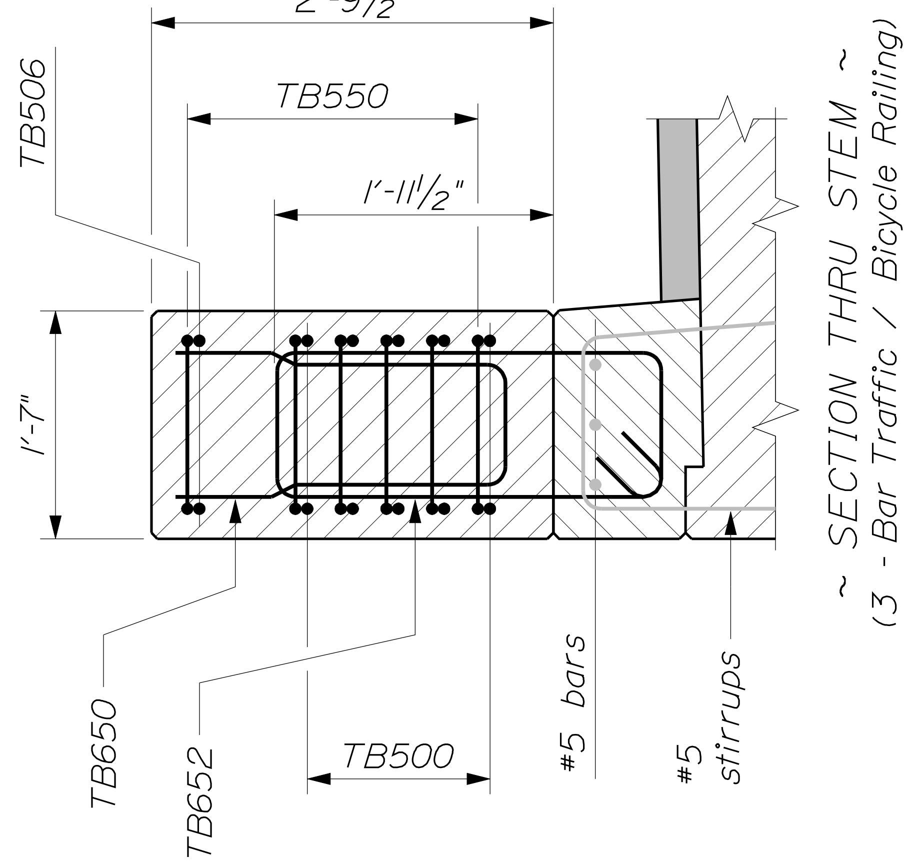
CONCRETE TRANSITION BARRIER

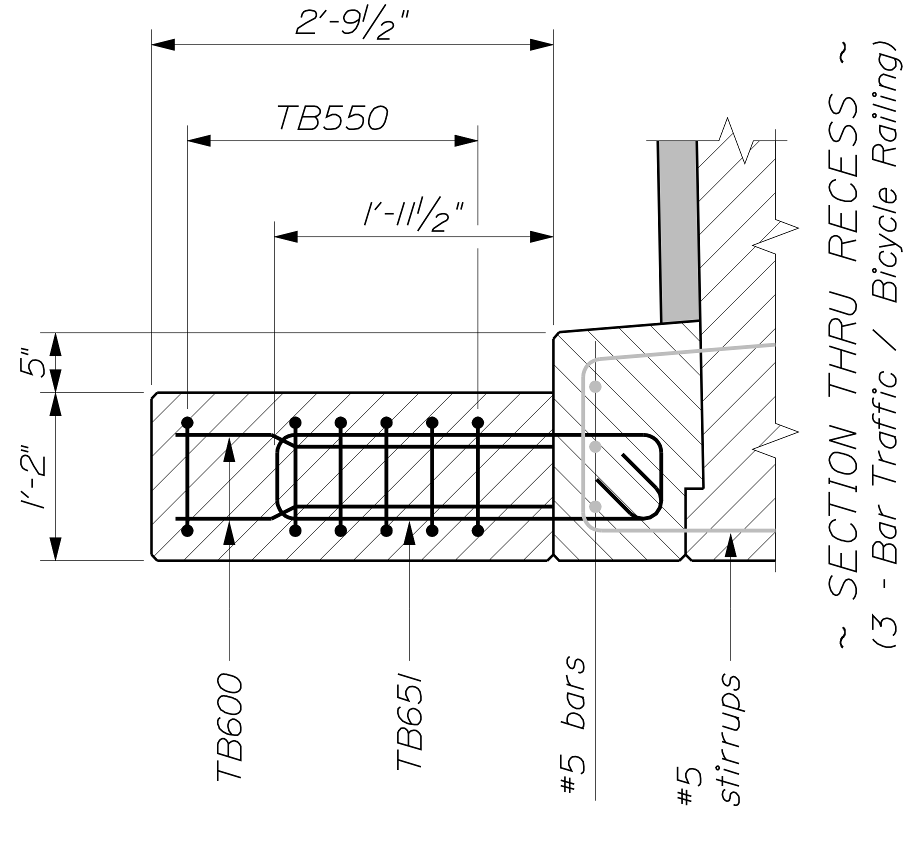
526(27)



CONCRETE TRANSITION BARRIER

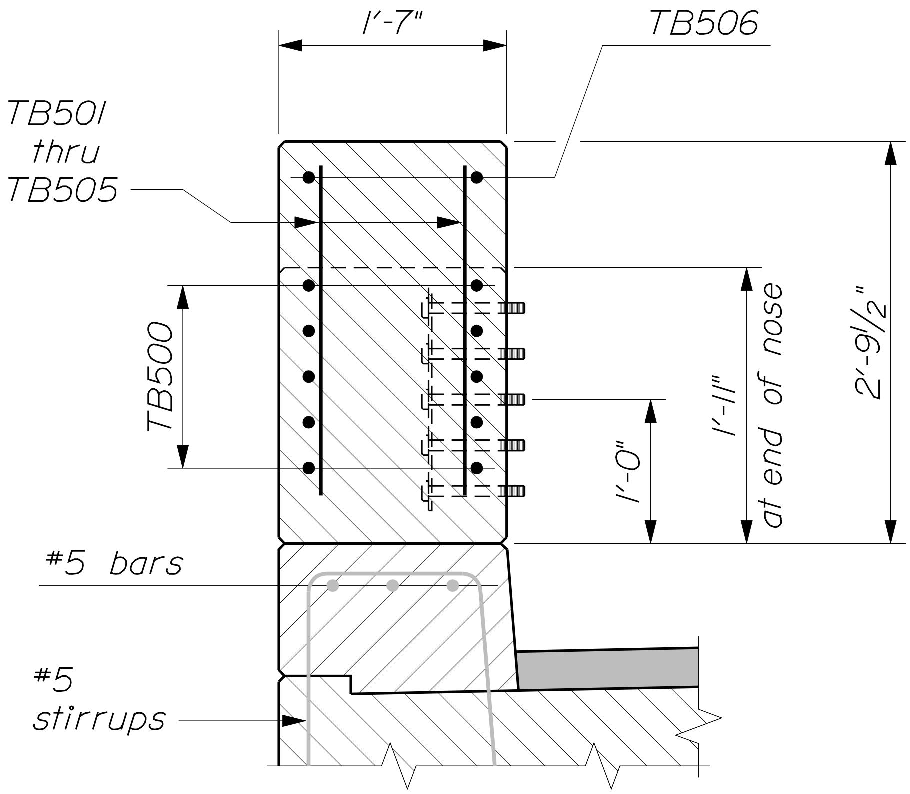
526(28)





CONCRETE TRANSITION BARRIER

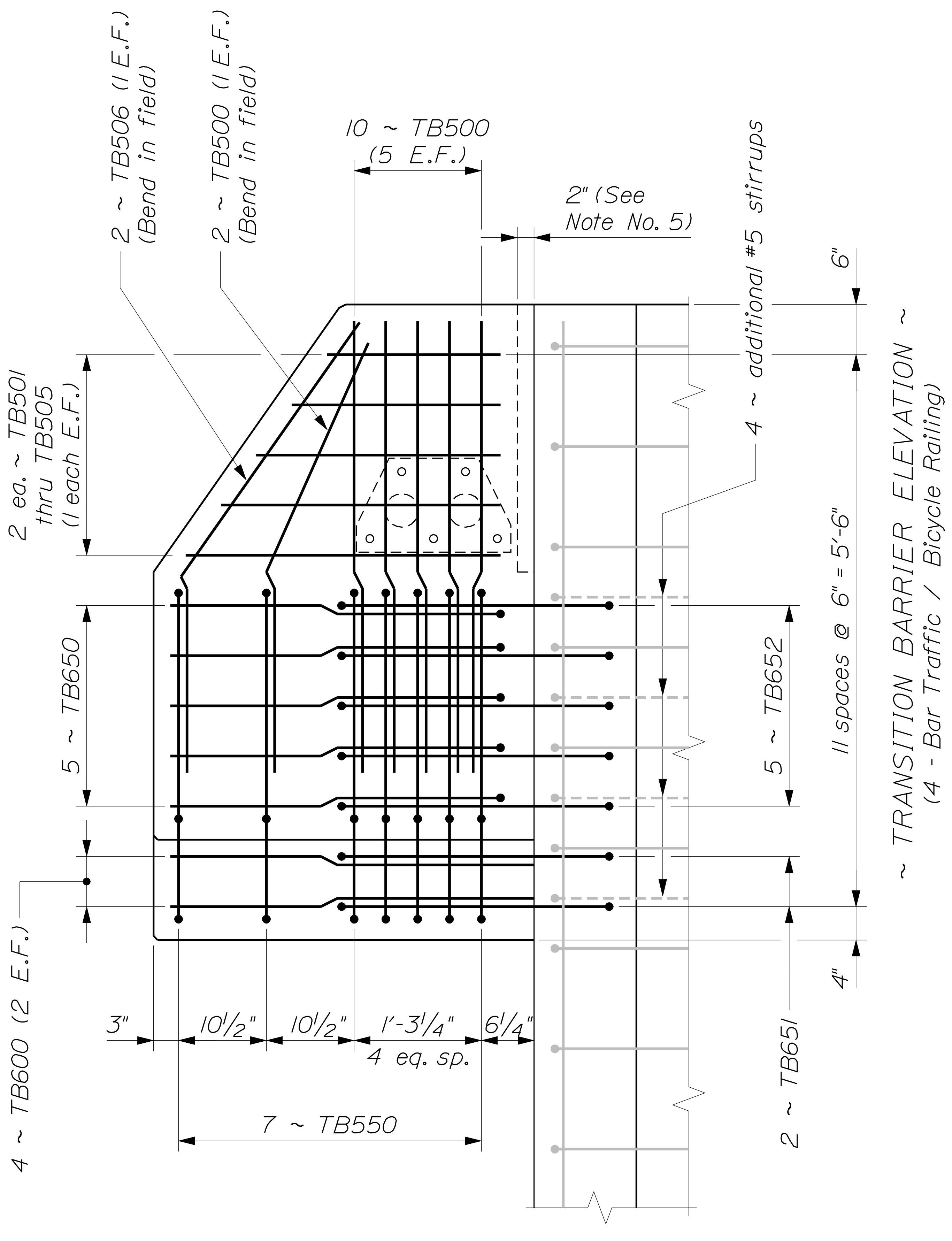
526(29)



~ SECTION THRU NOSE ~
(3 - Bar Traffic / Bicycle Railing)

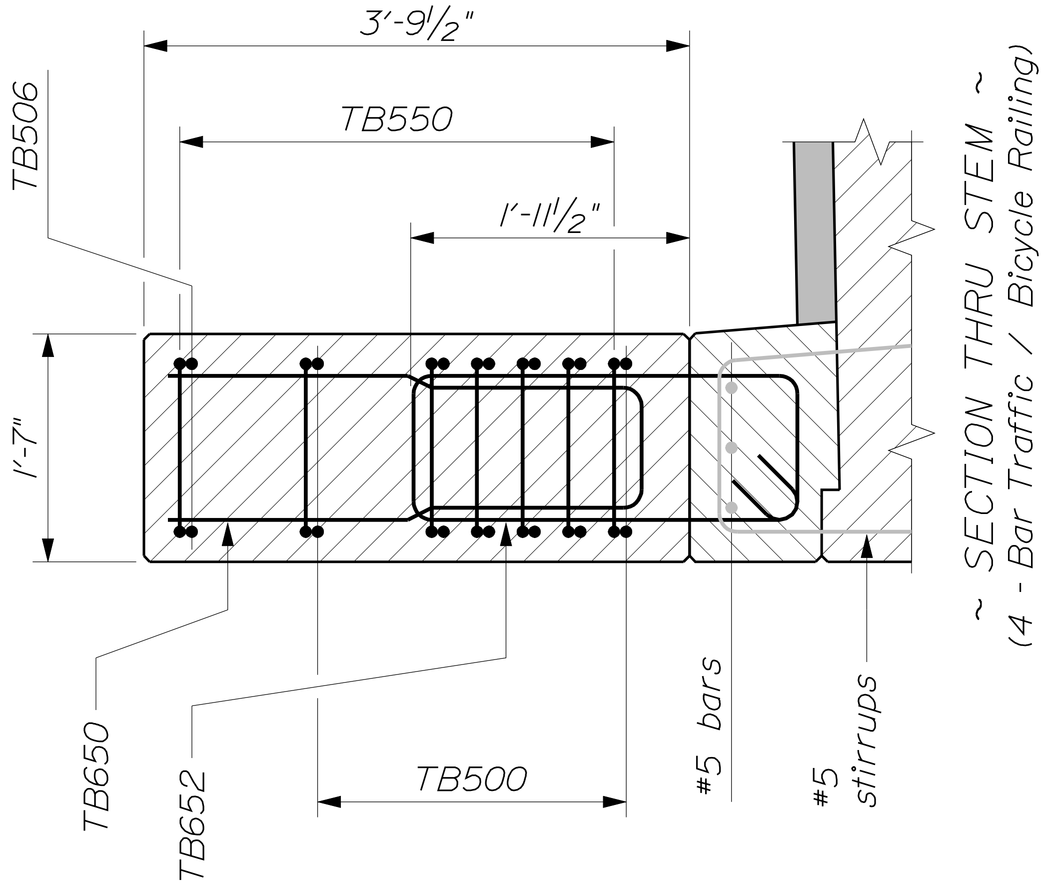
CONCRETE TRANSITION BARRIER

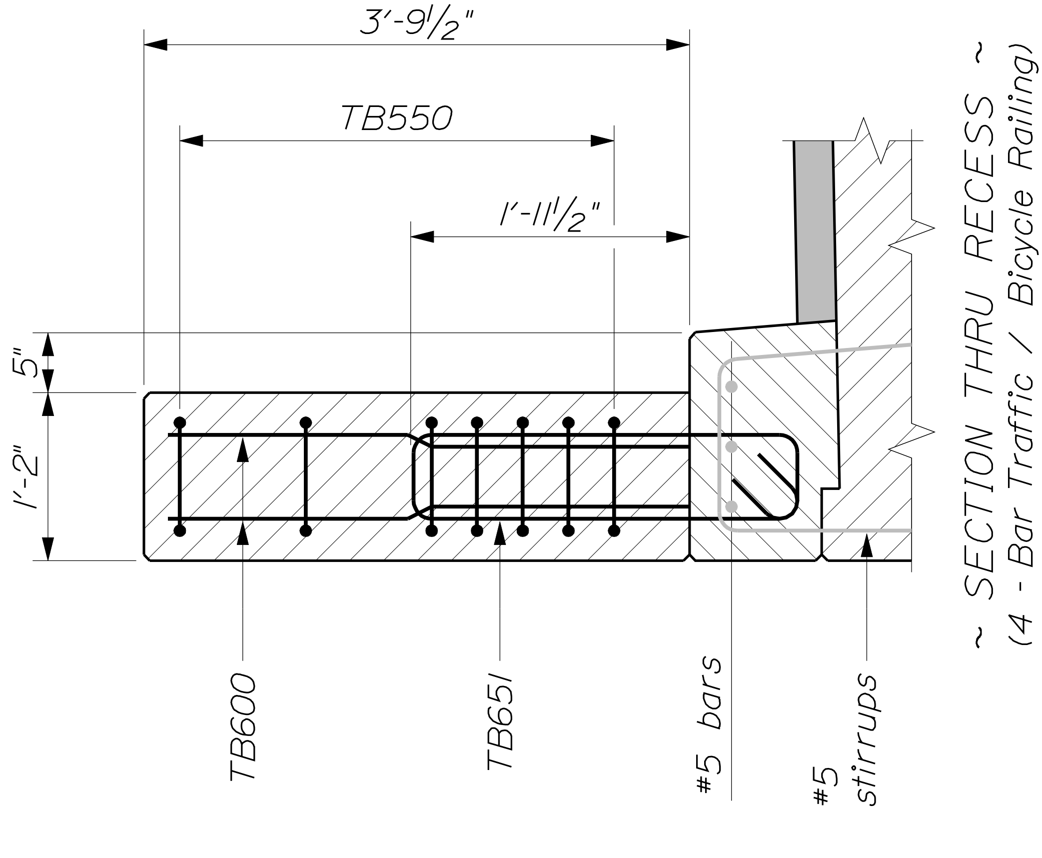
526(30)



CONCRETE TRANSITION BARRIER

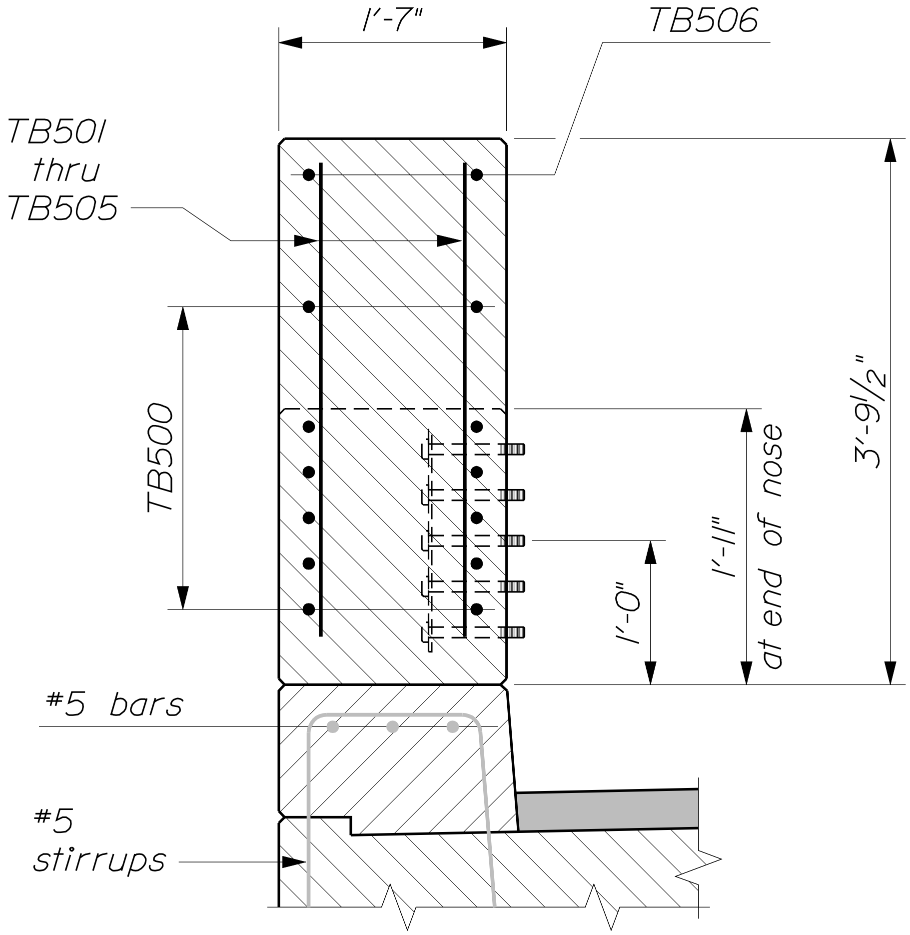
526(31)





CONCRETE TRANSITION BARRIER

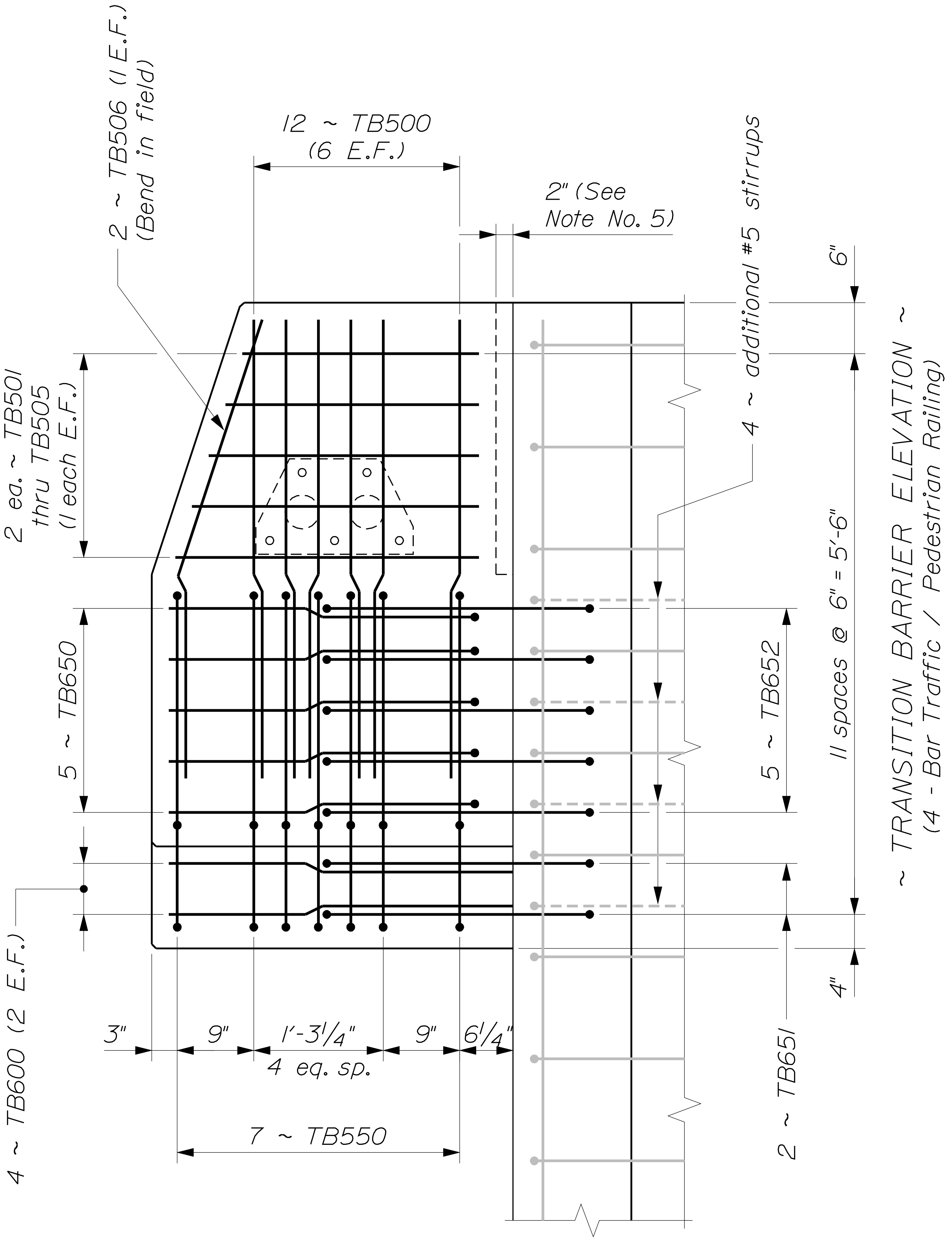
526(32)



~ SECTION THRU NOSE ~
(4 - Bar Traffic / Bicycle Railing)

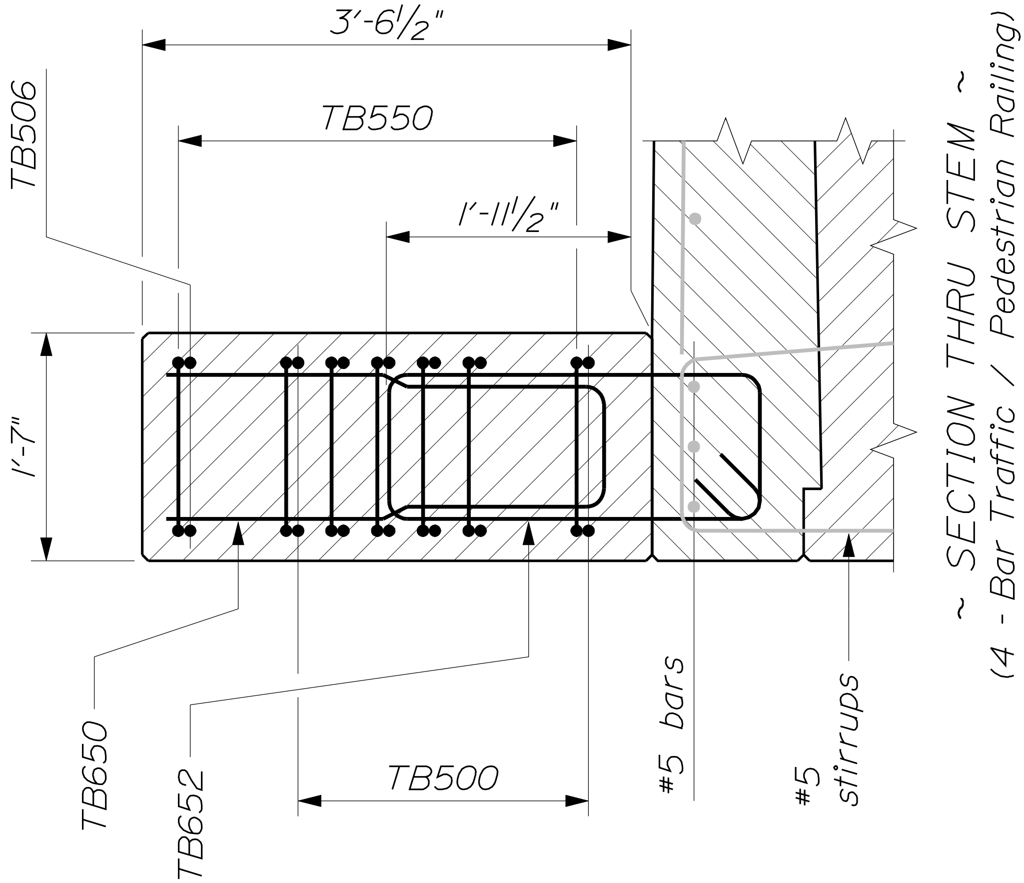
CONCRETE TRANSITION BARRIER

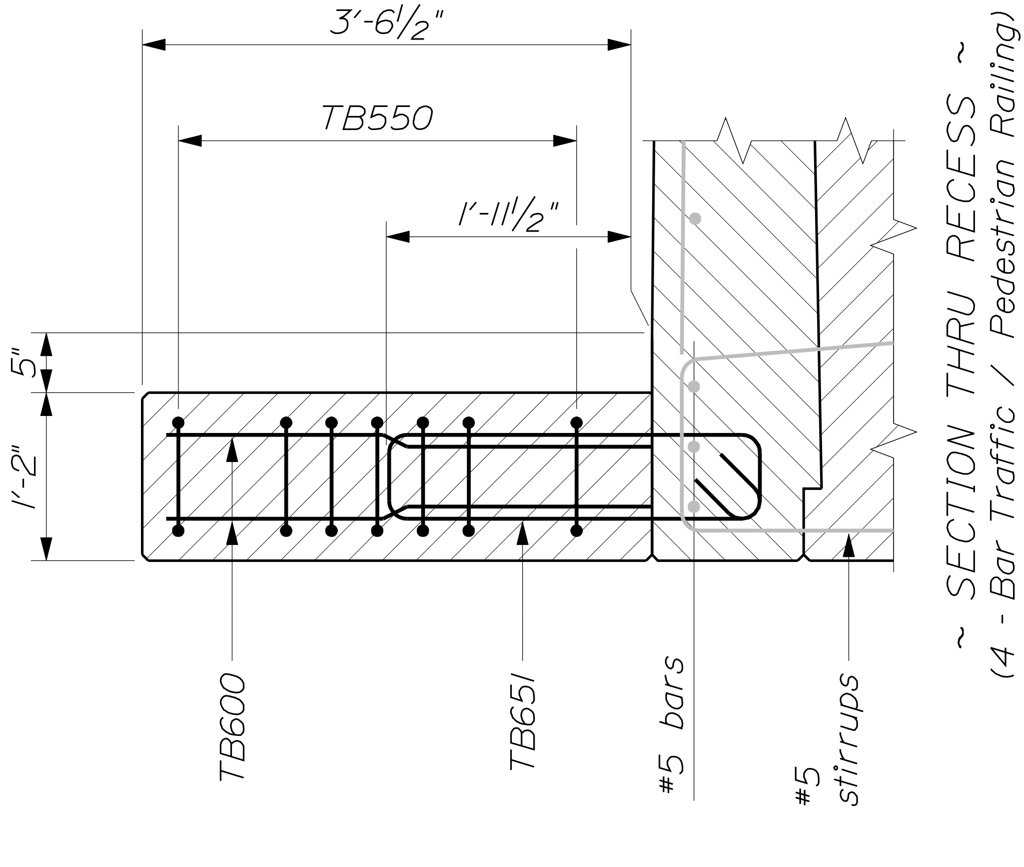
526(33)



CONCRETE TRANSITION BARRIER

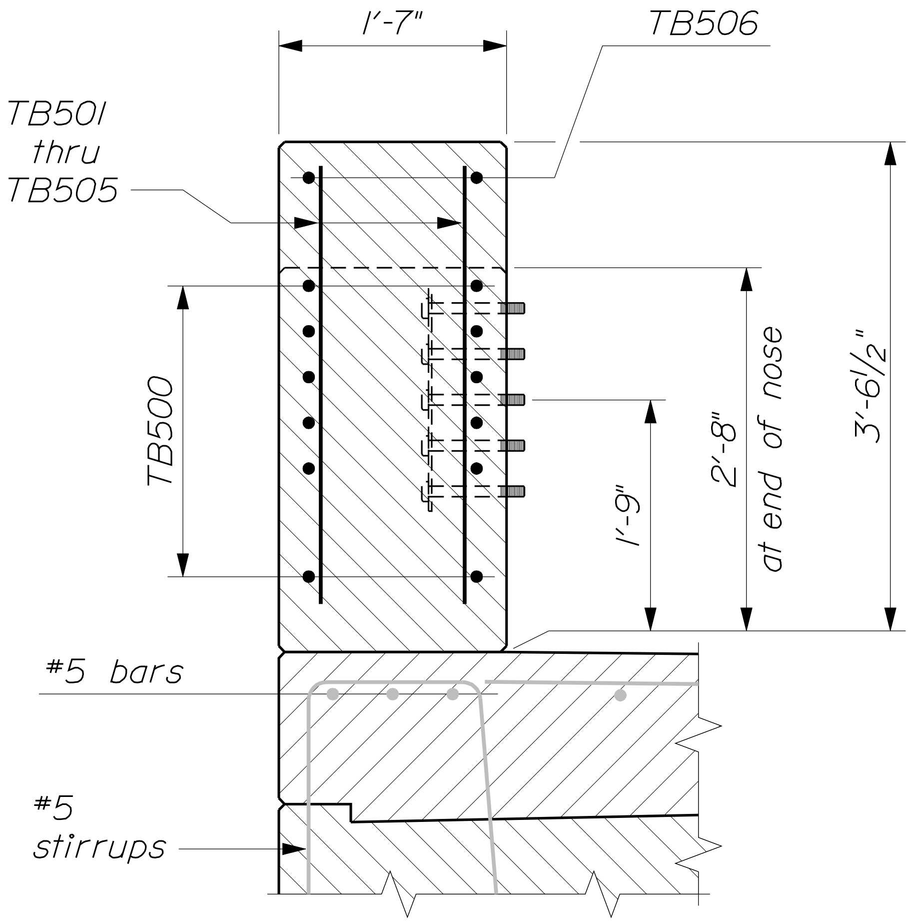
526(34)





CONCRETE TRANSITION BARRIER

526(35)



~ SECTION THRU NOSE ~
(4 - Bar Traffic / Pedestrian Railing)

CONCRETE TRANSITION BARRIER

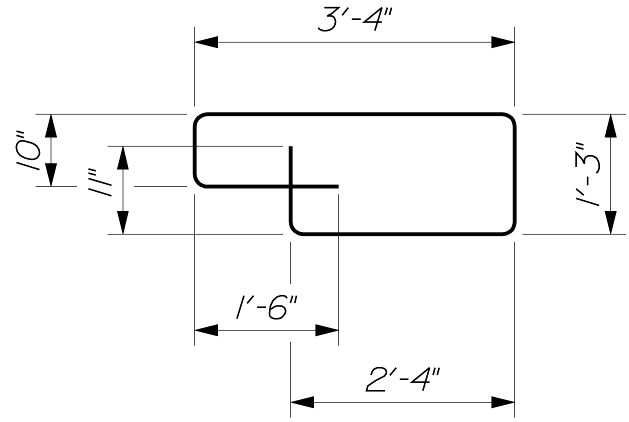
526(36)

REINFORCING STEEL SCHEDULE								
	2 - Bar Traffic		3 - Bar Bike		4 - Bar Bike		4 - Bar Ped.	
	Qty.	Length	Qty.	Length	Qty.	Length	Qty.	Length
TB500	10	4'-6"	10	4'-6"	12	4'-6"	12	4'-6"
TB501	2	1'-8"	2	2'-2"	2	3'-2"	2	2'-11"
TB502	2	1'-7"	2	2'-0"	2	2'-10"	2	2'-9"
TB503	2	1'-7"	2	1'-10"	2	2'-6"	2	2'-7"
TB504	2	1'-6"	2	1'-8"	2	2'-2"	2	2'-5"
TB505	2	1'-6"	2	1'-6"	2	1'-10"	2	2'-3"
TB506	--	--	2	4'-8"	2	5'-1"	2	4'-8"
TB550	5	10'-2"	6	10'-2"	7	10'-2"	7	10'-2"
TB600	--	--	4	2'-7"	4	3'-7"	4	3'-4"
TB650	--	--	5	5'-10"	5	7'-10"	5	7'-4"
TB651	2	7'-11"	2	7'-11"	2	7'-11"	2	7'-11"
TB652	5	8'-9"	5	8'-9"	5	8'-9"	5	8'-9"

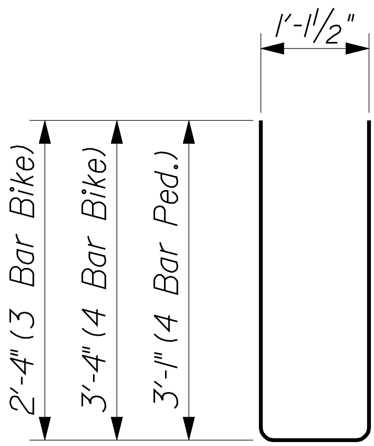
Notes:

The first digit following the letters of the mark indicate the size of the reinforcing bar. (TB500 = bar size #5.) All dimensions are out - to - out of bar.

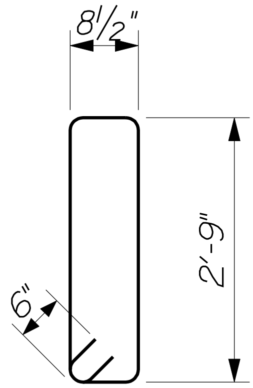
Quantities given are for one Transition Barrier.



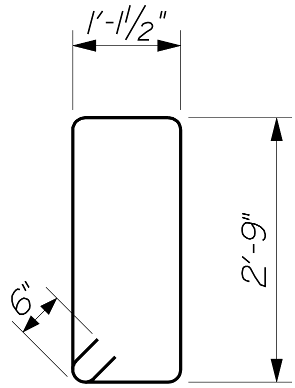
~ TB550 ~



~ TB650 ~



~ TB651 ~



~ TB652 ~

CONCRETE TRANSITION BARRIER

526(37)

NOTES:

1. All work and materials shall conform to the provisions of Standard Specifications Section 526 - Concrete Barrier.

2. The Contractor is responsible for ensuring that vertical reinforcing bars TB651 and TB652 are installed prior to placement of the curb or sidewalk concrete. Payment for these bars will be considered incicdental to Item No. 526.34, Permanent Concrete Transition Barrier.

3. Reinforcing steel shall have a minimum concrete cover of 2 inches.

4. Quantities of reinforcing bars shown are for one transition barrier only.

5. When the Concrete Transition Barrier is cantilevered over an expansion joint, the nose shall be blocked out as shown.

6. Payment for guardrail anchorage will be considered incidental to the transition barrier pay item. Class 8.8.3 bolts shall be used when corrosion - resistant steel guardrail is specified on the approach roadway

7. Precast Concrete Transition Curb shall meet the requirements of Standard Specifications Section 609 - Curb. The bridge end of the curb shall be saw cut in the field to fit flush against the backwall, as dictated by the bridge skew angle and the profile grade. Where curbing is specified on the adjacent highway, the transition shall be modified accordingly. Payment for transition curb will be considered incidental to the Concrete Transition Barrier pay item.

8. Concrete Transition Barrier is designed for attachment of Bridge Transition Type "I" unless otherwise indicated on the Design Drawings. Refer to Section 606 for details.

9. After installation of the guardrail is complete, upset the threads on the anchor bolts in three (3) places around each bolt, at the junction of the nut and the exposed thread, with a center punch or similar tool.

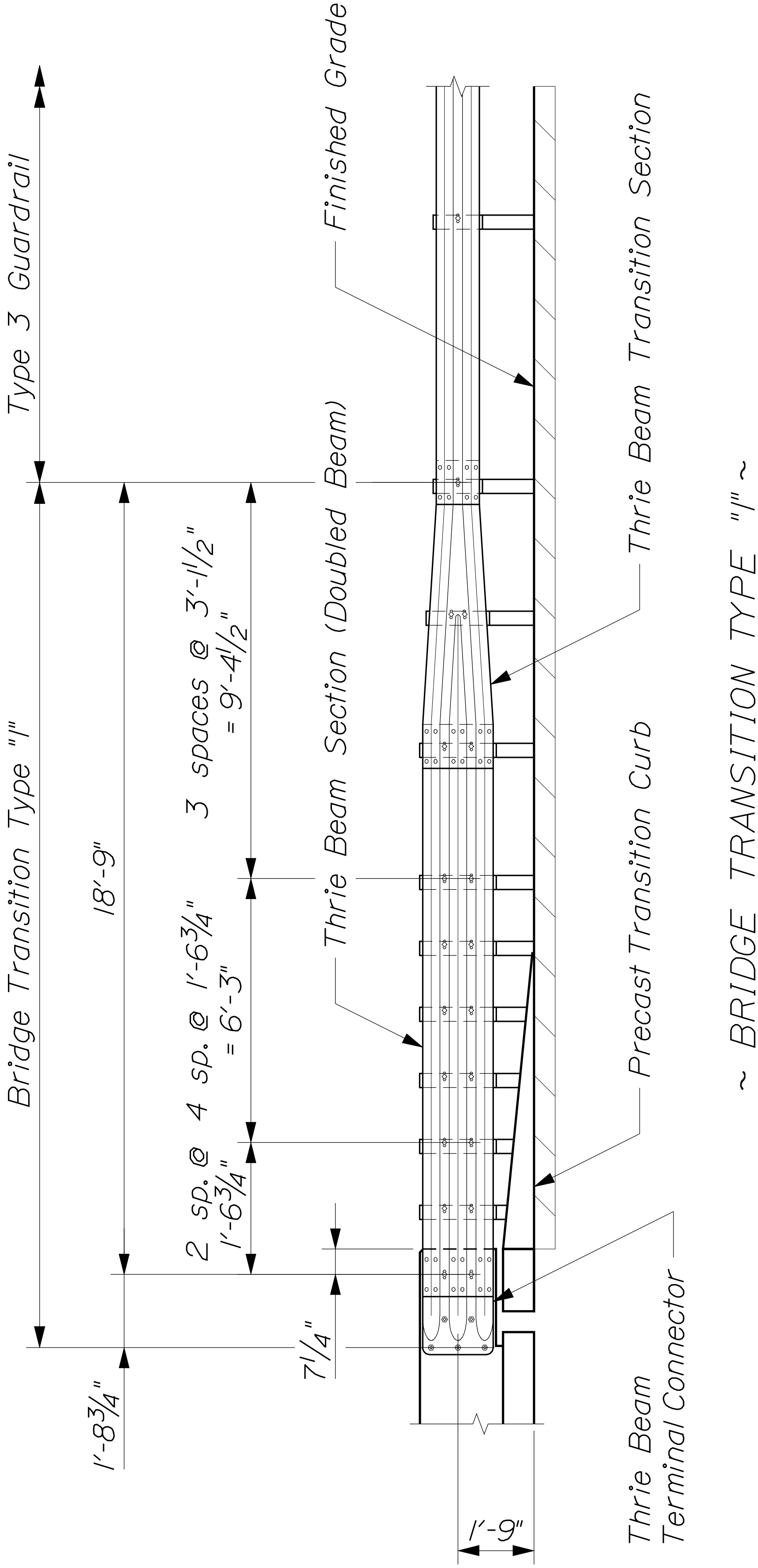
10. If there is a conflict between these Standard Details and the Design Drawings, the requirements of the Design Drawings shall be followed.

MATERIALS:

Concrete ____________ Class "LP"
Reinforcing Steel ____________ AASHTO M 31M/M 31, Grade 60
Spacer Plate ____________ AASHTO M 270M/M 270, Grade 36 (Galvanized)
Bolts ____________ AASHTO M 314, Grade 105 (Galvanized)

CONCRETE TRANSITION BARRIER

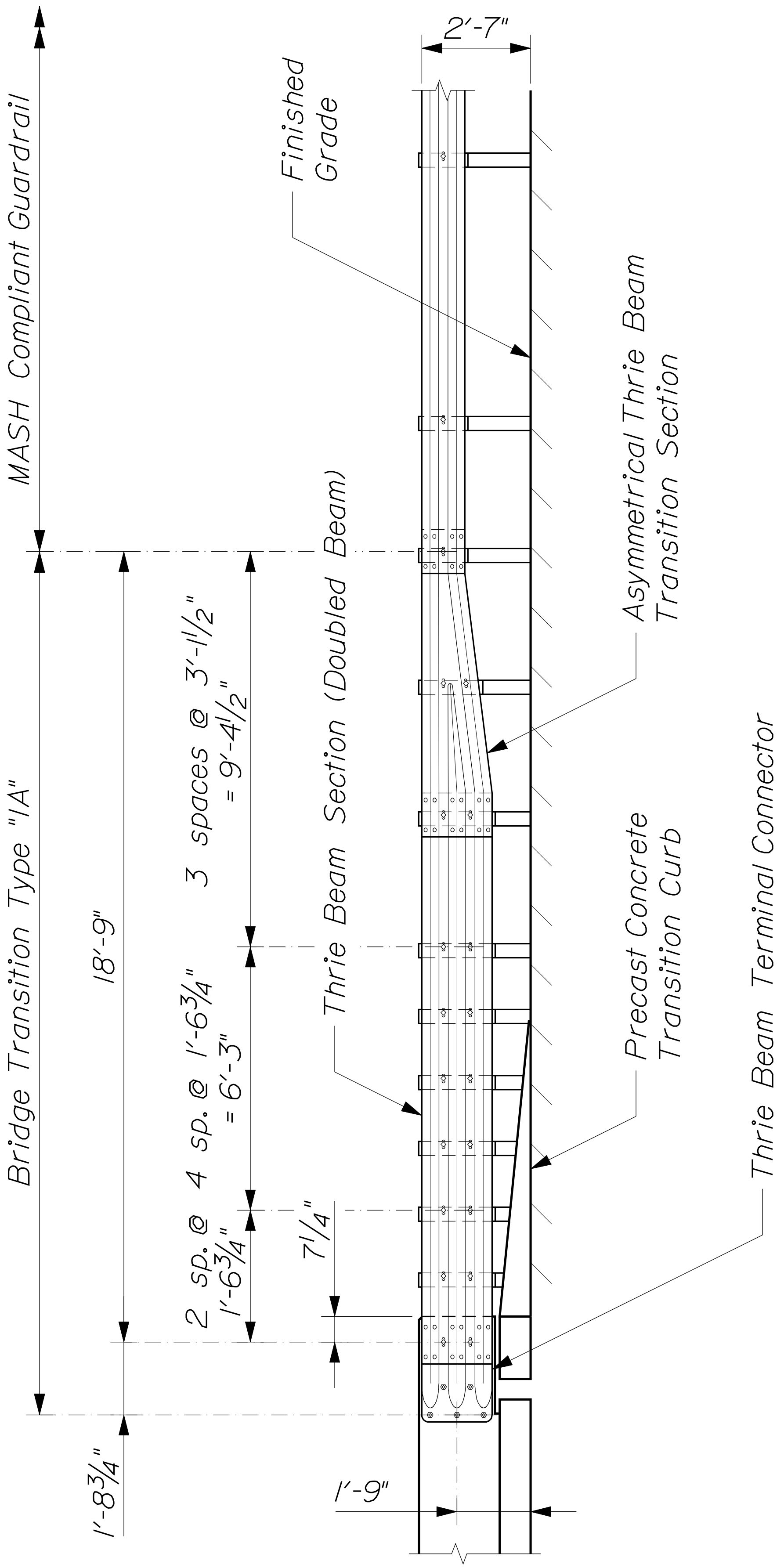
526(38)



NOTE: Part designations are shown in "A Guide to Standardized Highway Barrier Hardware" as prepared and approved by the AASHTO - AGC - ARTBA Joint Committee, Task Force 13 Report.

STANDARD BRIDGE TRANSITION - TYPE "I"

606(21)



~ BRIDGE TRANSITION TYPE "1A" ~

NOTE: Part designations are shown in "A Guide to Standardized Highway Barrier Hardware" as prepared and approved by the AASHTO - AGC - ARTBA Joint Committee, Task Force 13 Report.

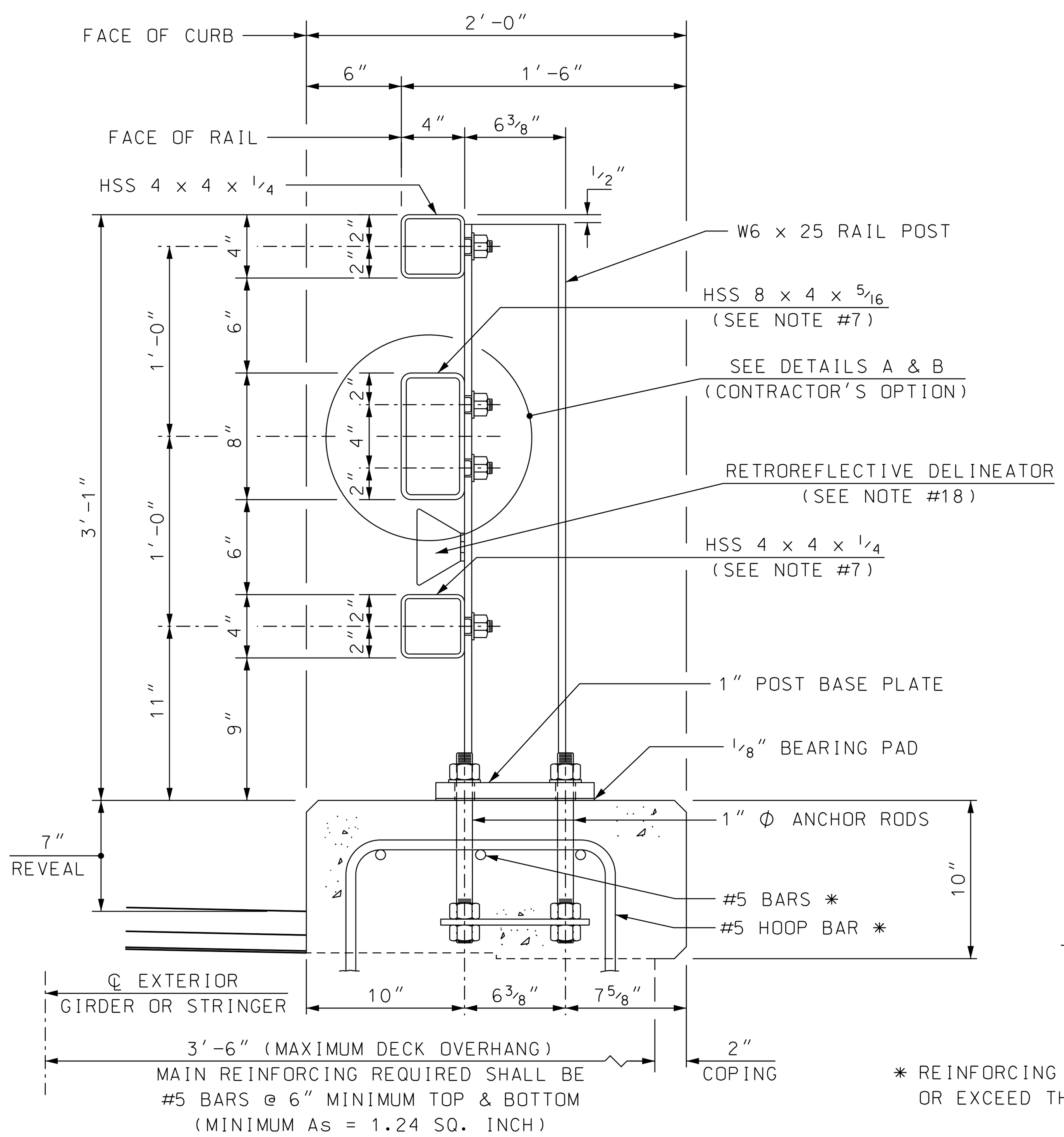
BRIDGE TRANSITION - TYPE "1A"

Suppl.
Std. Detail

606(21A)

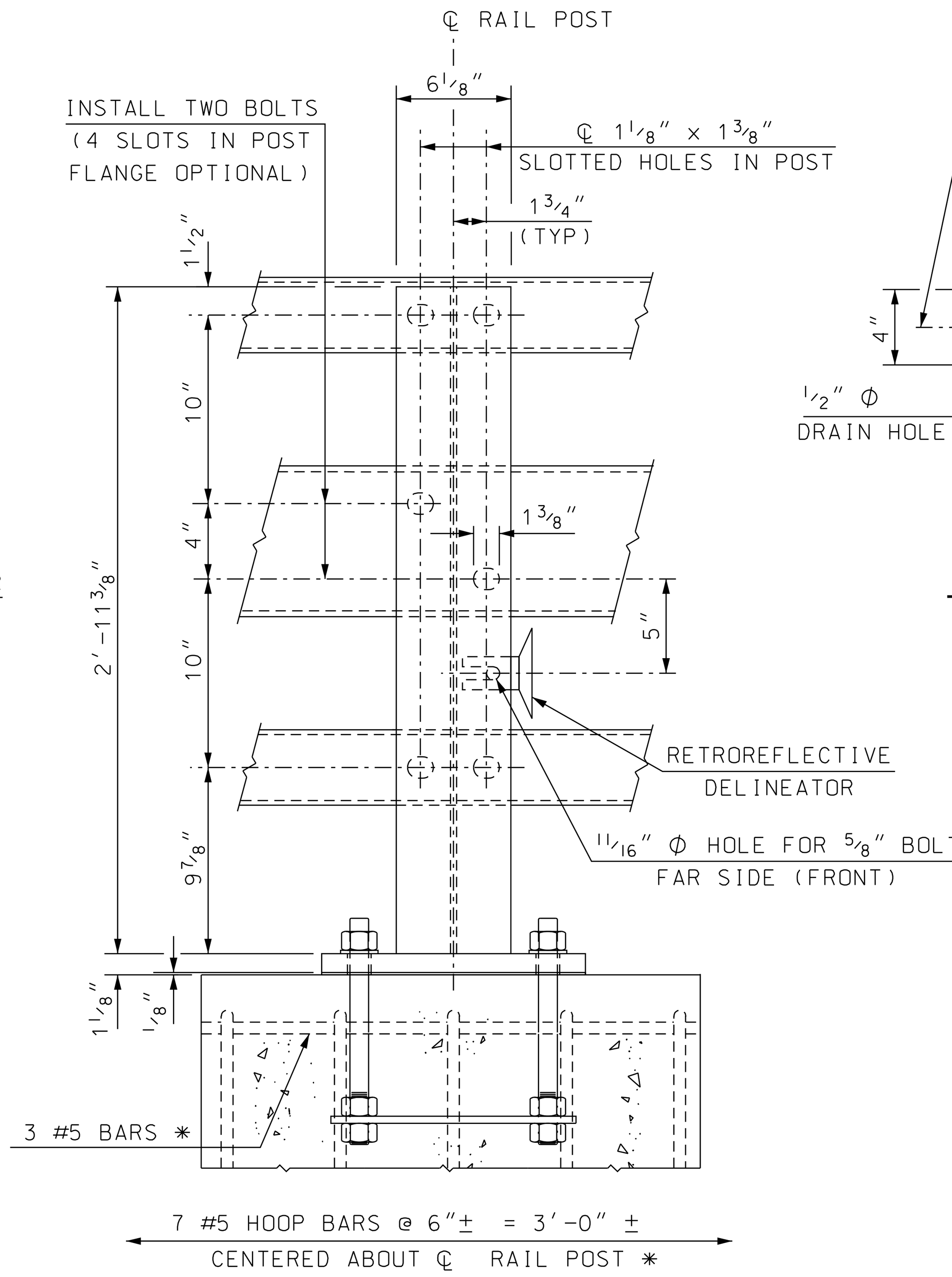
Sept. 6, 2017

APPENDIX B: NEW HAMPSHIRE DOT STANDARD BRIDGE RAIL DRAWINGS



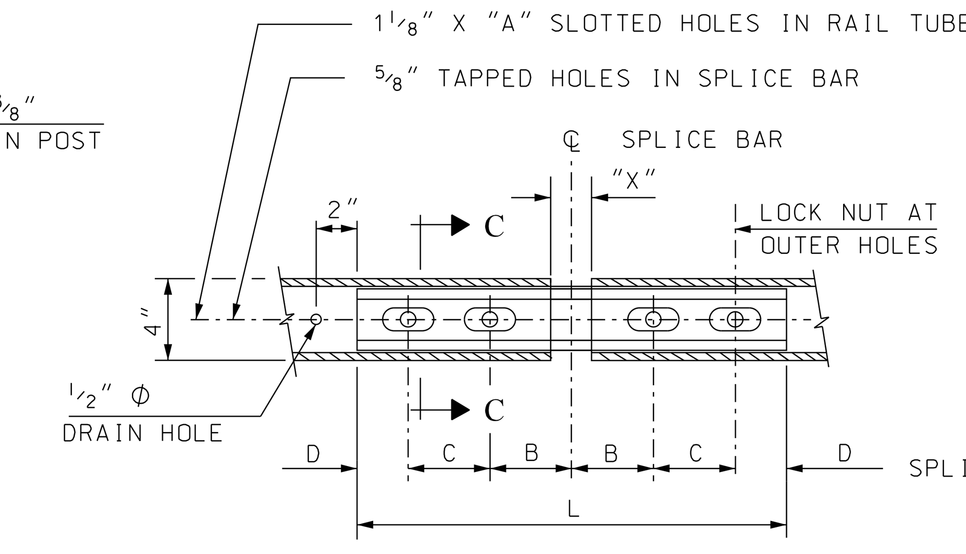
POST ASSEMBLY

SCALE: $1^1/_2$" = 1'-0"



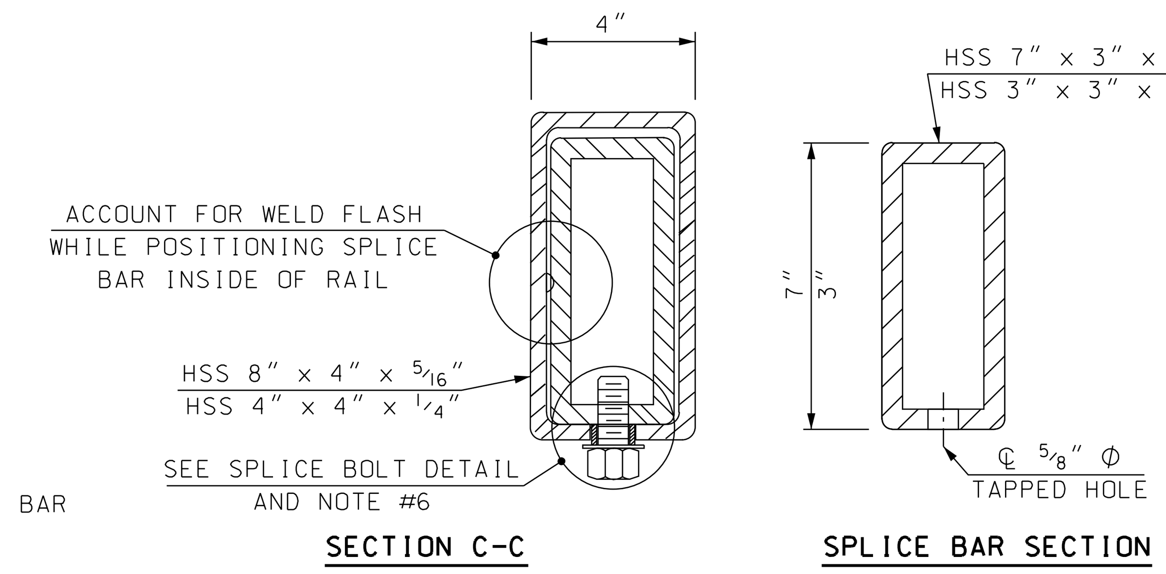
* REINFORCING CAPACITY SHALL MEET OR EXCEED THAT SHOWN

BACK ELEVATION VIEW



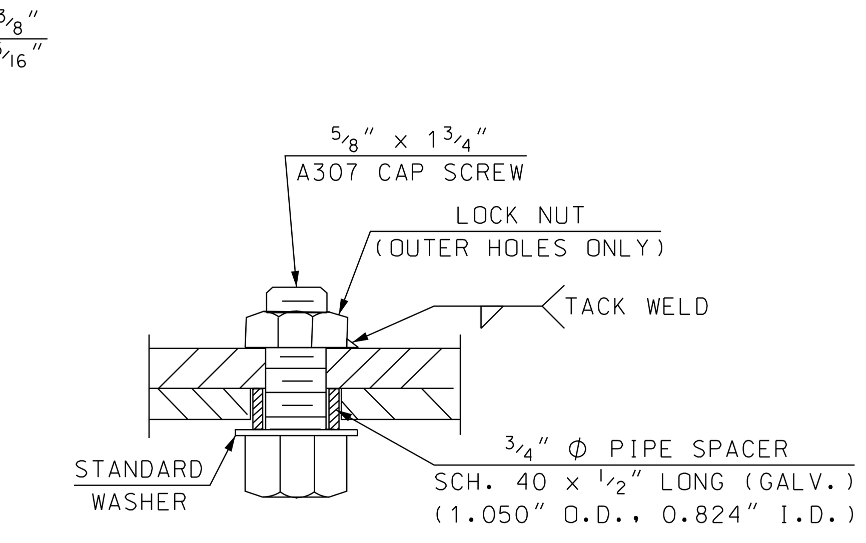
RAIL SPLICE (BOTTOM VIEW)

SCALE: $1^1/_2$" = 1'-0"



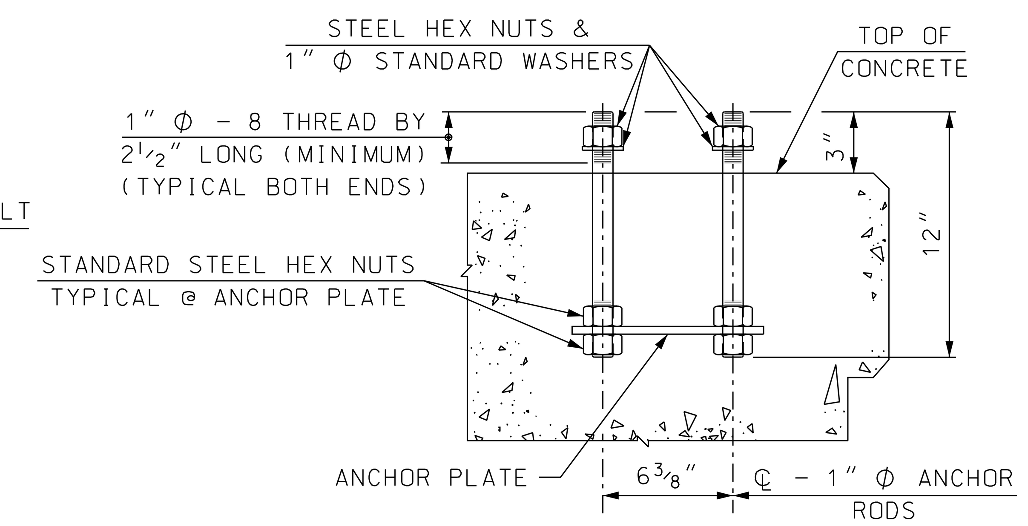
RAIL SPLICE DETAILS

SCALE: 3" = 1'-0"



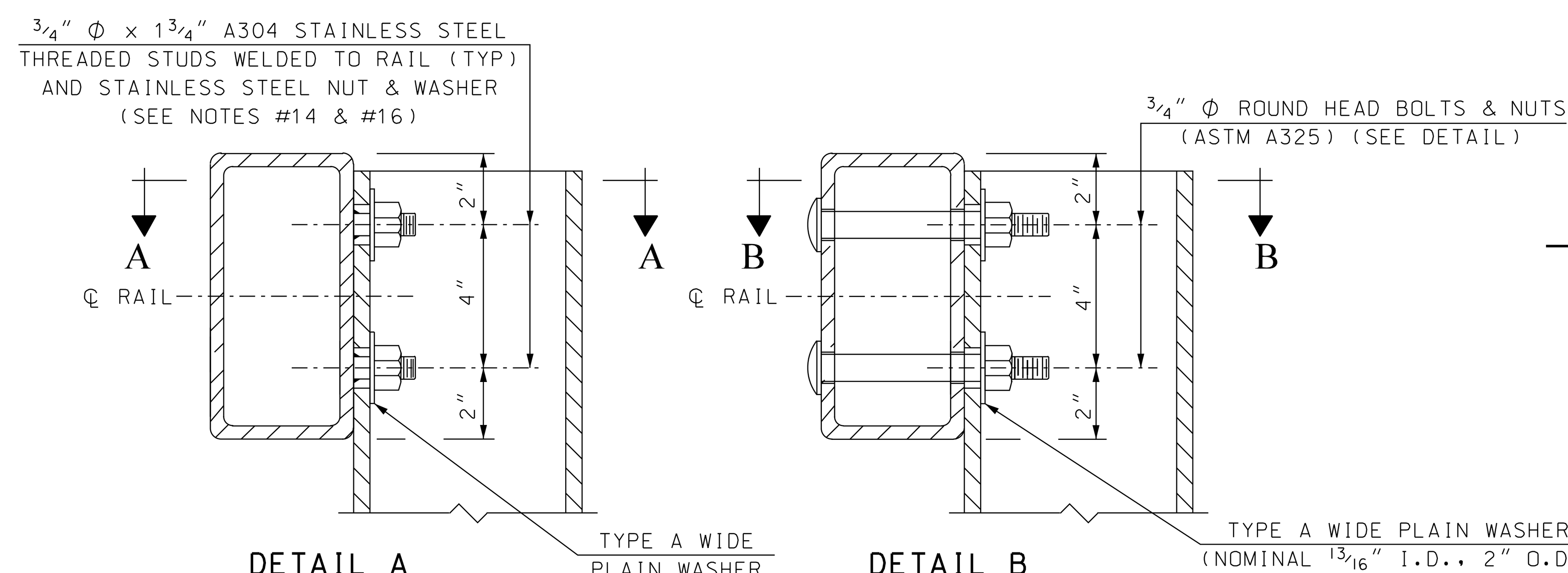
SPLICE BOLT DETAIL

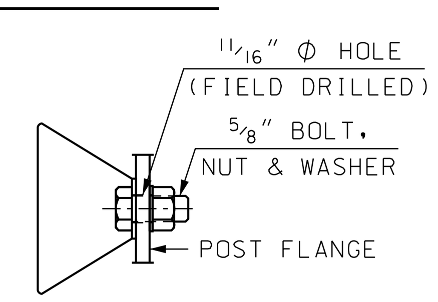
SCALE: 6" = 1'-0"



POST ANCHOR ASSEMBLY

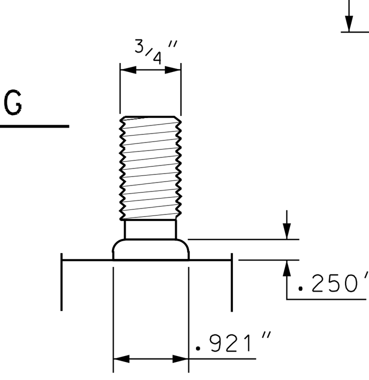
SCALE: $1^1/_2$" = 1'-0"





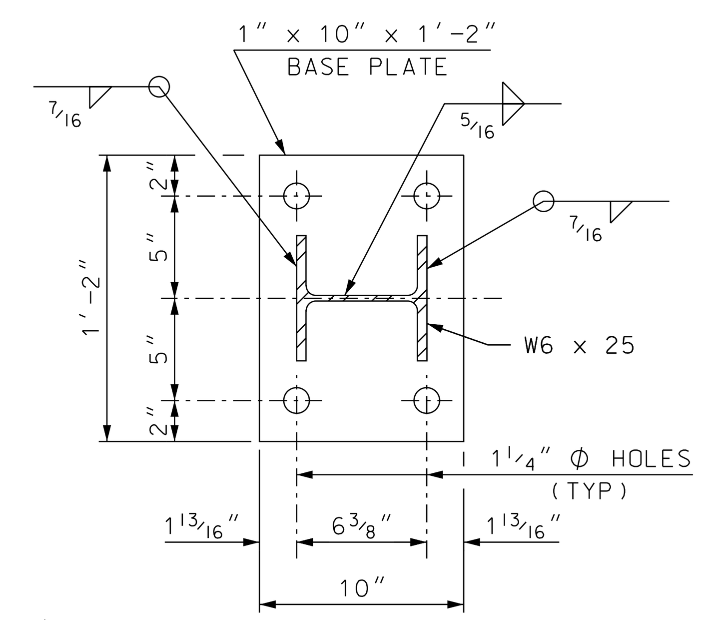
DELINEATOR MOUNTING

NOT TO SCALE



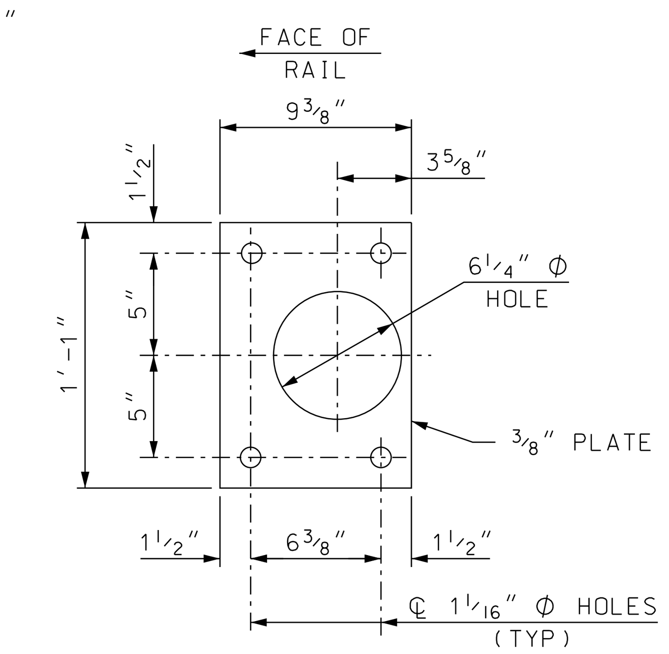
STUD WELD DETAIL

SCALE: 6" = 1'-0"



POST BASE PLATE

SCALE: $1^1/_2$" = 1'-0"

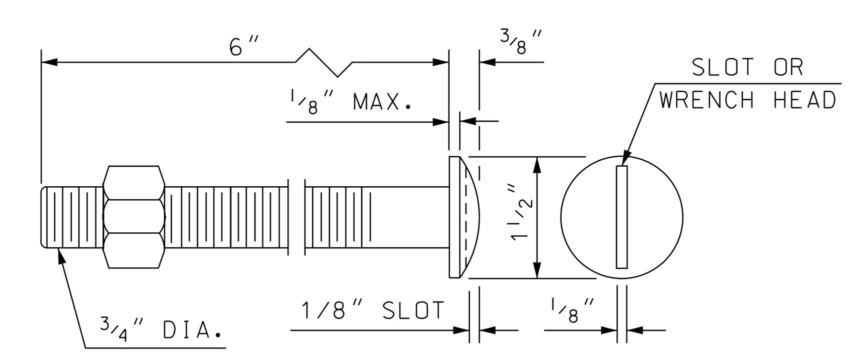


ANCHOR PLATE

SCALE: $1^1/_2$" = 1'-0"

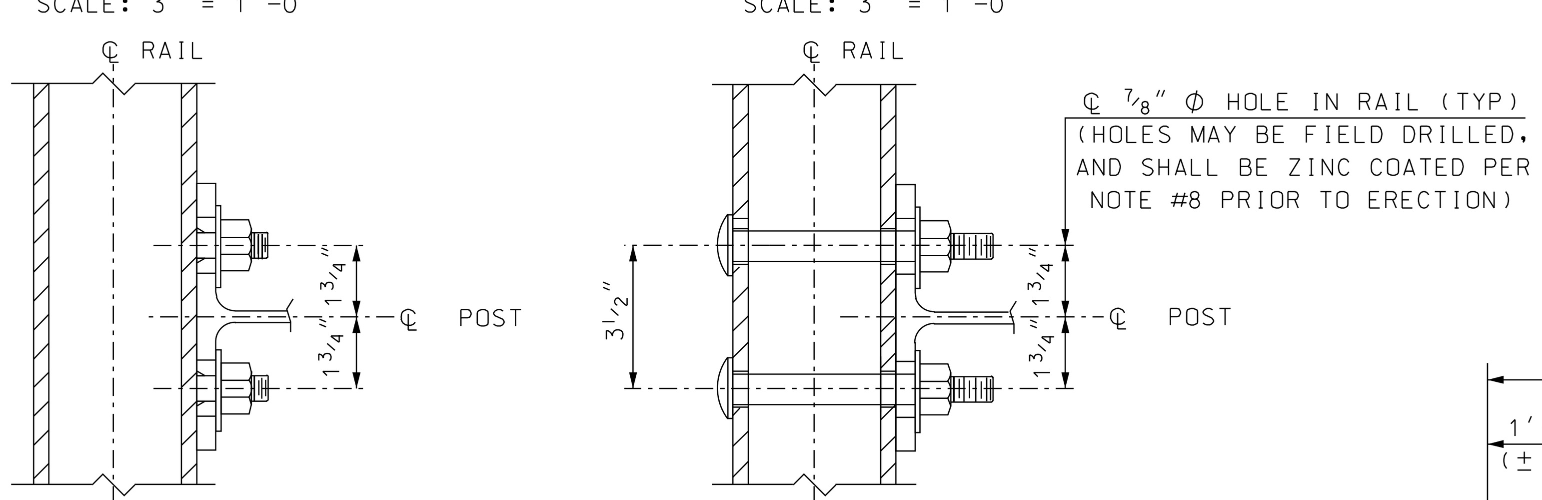
NO MODIFICATIONS PERMITTED TO THIS SHEET, EXCEPT AS NOTED BELOW:

1. POST SPACING @ RAIL ELEVATION
2. ITEM NUMBER AND DESCRIPTION IF SNOW SCREENING AND/OR PROTECTIVE SCREENING WILL BE USED
3. DESIGN OF DECK OVERHANG REINFORCING IS REQUIRED FOR DECK OVERHANG DISTANCE GREATER THAN 3'-6"



A325 ROUND HEAD BOLT DETAIL

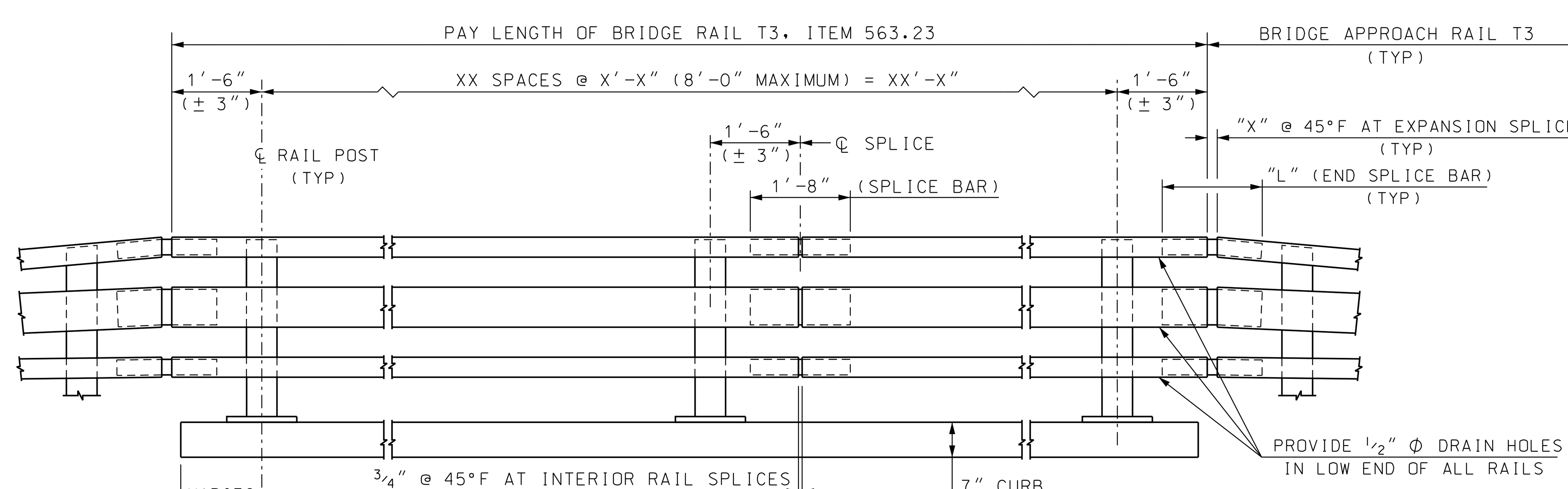
SCALE: 6" = 1'-0"



SPLICE BAR DIMENSION TABLE						
T	A	B	C	D	X	L
INTERIOR	$2^1/_2$"	4"	4"	2"	$^3/_4$"	1'-8"
** ≤ $3^1/_4$"	$2^1/_2$"	4"	4"	2"	2"	1'-8"
** $3^1/_4$" < T ≤ $5^1/_4$"	$3^1/_2$"	5"	5"	$2^1/_2$"	3"	2'-1"

T = TOTAL MOVEMENT OF BRIDGE

** = END SPLICE BAR



RAIL ELEVATION

SCALE: $^1/_2$" = 1'-0"

RAIL NOTES

(1) ITEM 563.23, BRIDGE RAIL T3, SHALL INCLUDE POSTS, BASE PLATES, ANCHOR PLATES, ANCHOR RODS, PREFORMED PADS, RAIL ASSEMBLY BOLTS, NUTS, WASHERS, STUDS, STRUCTURAL TUBING, SPLICE BARS, PIPE SPACERS, ALL APPURTENANCES, AND GALVANIZING.

(2) BRIDGE RAIL POSTS SHALL BE SET NORMAL (90 DEGREES) TO THE PROFILE GRADE, EXCEPT ON GRADES OVER 5% WHERE POSTS SHALL BE SET VERTICAL.

(3) ENDS OF RAIL TUBE SECTIONS SHALL BE SAWED OR MILLED AND SHALL BE TRUE AND SMOOTH. ALL CUT EDGES OF ALL MATERIAL SHALL BE GROUND SMOOTH.

(4) EACH PIECE OF RAIL TUBING SHALL BE ATTACHED TO A MINIMUM OF THREE (3) POSTS.

(5) BOLT HOLES SHALL BE DRILLED OR PUNCHED. FLAME CUTTING MAY BE USED TO FINISH SLOTTED HOLES IF MECHANICALLY GUIDED.

(6) AT INTERIOR SPLICES, PIPE SPACERS SHALL BE USED ON ONLY ONE SIDE OF THE SPLICE TO ALLOW MOVEMENT ON THAT SIDE. ALL RAILS IN A SPLICE SHALL RECEIVE THE SAME TREATMENT. AT END SPLICES PIPE SPACERS SHALL BE USED ON BOTH SIDES OF THE SPLICE TO ALLOW MOVEMENT ON EACH SIDE.

(7) MILL OR SHOP TRANSVERSE WELDS SHALL NOT BE PERMITTED ON ANY RAIL ELEMENT. RAIL ELEMENTS USED ON CURVES SHALL USE $^3/_8$" WALL TUBES AND SHALL BE SHOP FORMED TO THE REQUIRED CURVATURE (SEE SECTION 563.3.2.1).

(8) NO PUNCHING, DRILLING, CUTTING OR WELDING SHALL BE PERMITTED AFTER GALVANIZING, EXCEPT AS ALLOWED IN DETAILS A AND B, AND FOR INSTALLATION OF DELINEATORS. DAMAGED AREAS OF GALVANIZING SHALL BE THOROUGHLY CLEANED, PRETREATED, AND PAINTED WITH TWO COATS OF ORGANIC ZINC-RICH GALVANIZING REPAIR PAINT, HAVING A MINIMUM 92% ZINC BY WEIGHT, TO A THICKNESS EQUAL TO THE ORIGINAL COATING, ACCORDING TO SECTION 550.2.9.1 AND ASTM A780.

(9) NUTS FOR 1" Φ THREADED ANCHOR RODS CONNECTING THE BASE PLATE TO THE CONCRETE SHALL BE TIGHTENED TO A SNUG FIT AND GIVEN AN ADDITIONAL $^1/_8$ TURN.

(10) THREADS FOR ANCHOR RODS MAY BE ROLLED OR CUT. IF CUT THREADS ARE USED, BOLT DIAMETER SHALL NOT BE LESS THAN NOMINAL DIAMETER. IF ROLLED THREADS ARE USED, ROD DIAMETER SHALL NOT BE LESS THAN ROOT DIAMETER OF THREADS.

(11) THIS BRIDGE RAIL SYSTEM IS IN COMPLIANCE WITH T2 STEEL BRIDGE RAIL WHICH WAS SUCCESSFULLY CRASH TESTED FOR AASHTO PL2 IN 1994 BY THE NEW ENGLAND TRANSPORTATION CONSORTIUM AND ACCEPTED AS NCHRP 350 TL-4 PER FHWA LETTER HMHS-B50, MARCH 11, 1999.

MATERIAL NOTES

(12) STRUCTURAL TUBING SHALL CONFORM TO THE REQUIREMENTS OF ASTM A500, GRADE B, STRUCTURAL STEEL TUBING. RAIL TUBING SHALL MEET THE LONGITUDINAL CHARPY V-NOTCH REQUIREMENTS OF 15 FT. LBS. AT 0°F. FOR ASTM A500, GRADE B, THE TEST SAMPLES SHALL BE TAKEN AFTER FORMING THE TUBES. CHARPY V-NOTCH IS NOT REQUIRED FOR SPLICE TUBES.

(13) RAIL POSTS AND BASE PLATES SHALL CONFORM TO THE REQUIREMENTS OF ASTM A572 GR 50, EXCEPT ANCHOR PLATES MAY BE ASTM A36.

(14) THREADED STUDS AND MATCHING NUTS FOR RAIL-TO-POST ATTACHMENT (DETAIL A) SHALL CONFORM TO ASTM A276 TYPE 304, STAINLESS STEEL, AND SHALL BE TORQUE TESTED PER AWS D1.5, 7.7.1. DETAIL B BOLTS SHALL BE ASTM A325 OR A449. ALL OTHER BOLTS AND NUTS SHALL CONFORM TO ASTM A307 AND ASTM A563 GRADE A RESPECTIVELY OR BETTER, EXCEPT THAT ASTM A307 NUTS MAY BE USED ON THE BOTTOM OF ANCHOR ASSEMBLY. WASHERS SHALL BE HARDENED STEEL COMMERCIAL TYPE A PLAIN WIDE WASHERS AND SHALL MEET THE DIMENSIONAL REQUIREMENTS OF A.N.S.I. B18.22. ANCHOR RODS SHALL CONFORM TO ASTM A449.

(15) ALL STEEL COMPONENTS (EXCEPT STAINLESS) SHALL BE GALVANIZED AFTER FABRICATION IN COMPLIANCE WITH AASHTO M232 (ASTM A153) AND AASHTO M111 (ASTM A123). THE GALVANIZING KETTLE SHALL HAVE 0.05 TO 0.09 PERCENT NICKEL. GALVANIZED SURFACES SHALL HAVE A UNIFORM APPEARANCE AND GALVANIZED MATERIAL SHALL BE PROPERLY STORED. IF PAINTING IS REQUIRED SEE SPECIAL PROVISIONS FOR 708.

(16) DETAIL A STUDS SHALL BE WELDED ON AFTER TUBES ARE GALVANIZED BY SPOT GRINDING OFF GALVANIZING, WELDING ON STUDS, THEN TOUCH UP GALVANIZING PER NOTE #8 ABOVE.

(17) PREFORMED BEARING PADS (1/8" THICK) SHALL CONFORM TO AASHTO M251.

(18) RETROREFLECTIVE DELINEATORS, BOLTS, NUTS, WASHERS AND FIELD DRILLING OF POSTS, INCLUDING GALVANIZING TOUCH-UP, SHALL BE SUBSIDIARY TO ITEM 563.23. SEE STANDARD PLANS FOR ROAD AND BRIDGE CONSTRUCTION (DL-1) FOR ADDITIONAL DETAILS AND SPACING.

STATE OF NEW HAMPSHIRE

DEPARTMENT OF TRANSPORTATION * BUREAU OF BRIDGE DESIGN

TOWN | BRIDGE NO. | STATE PROJECT

LOCATION

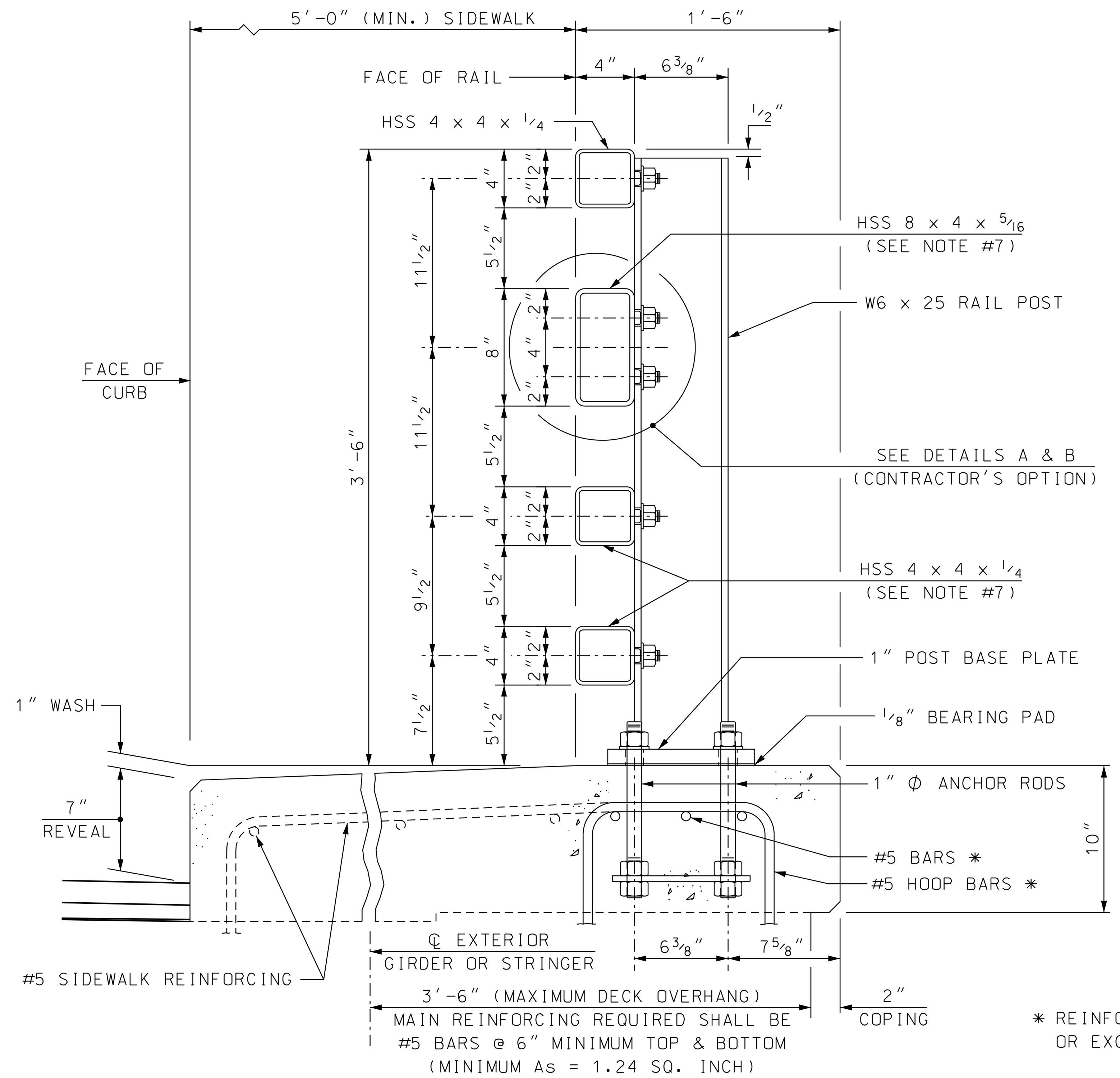
T3 STEEL BRIDGE RAIL

REVISIONS AFTER PROPOSAL		BY	DATE		BY	DATE
	DESIGNED	NETC/JSZ	3/02	CHECKED	NHDOT	
	DRAWN	PJP	10/05	CHECKED	JSZ	10/05
	QUANTITIES			CHECKED		
	ISSUE DATE	11/15/05		FEDERAL PROJECT NO.	SHEET NO.	TOTAL SHEETS
	REV. DATE	11/1/16				

BRIDGE SHEET OF

FILE NUMBER

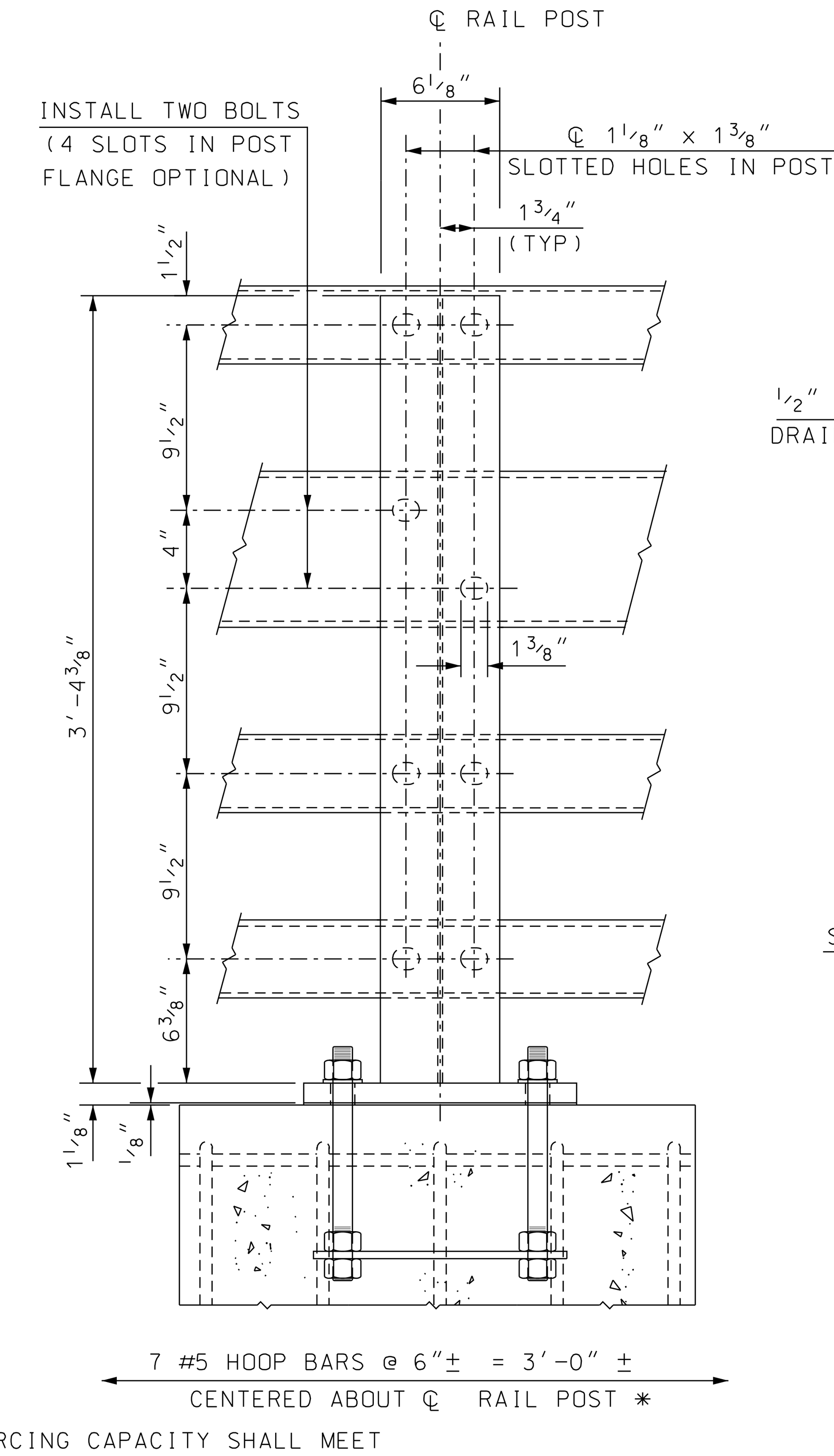
SUBDIRECTORY	.DGN LOCATOR	SHEET SCALE
English/BR-RAIL	T3_BR-RAIL	AS NOTED



SECTION VIEW

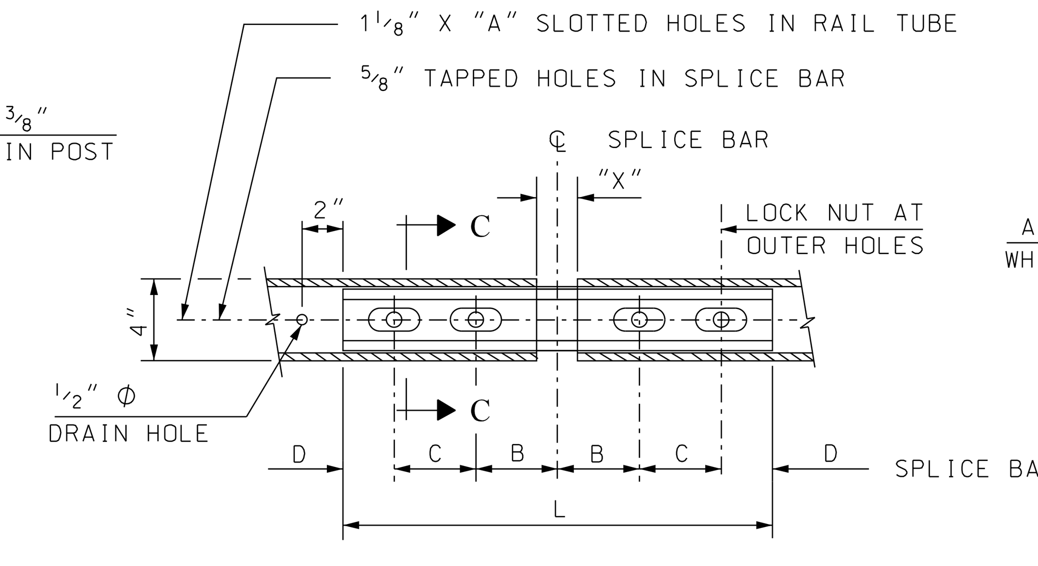
POST ASSEMBLY

SCALE: 1 1/2" = 1'-0"



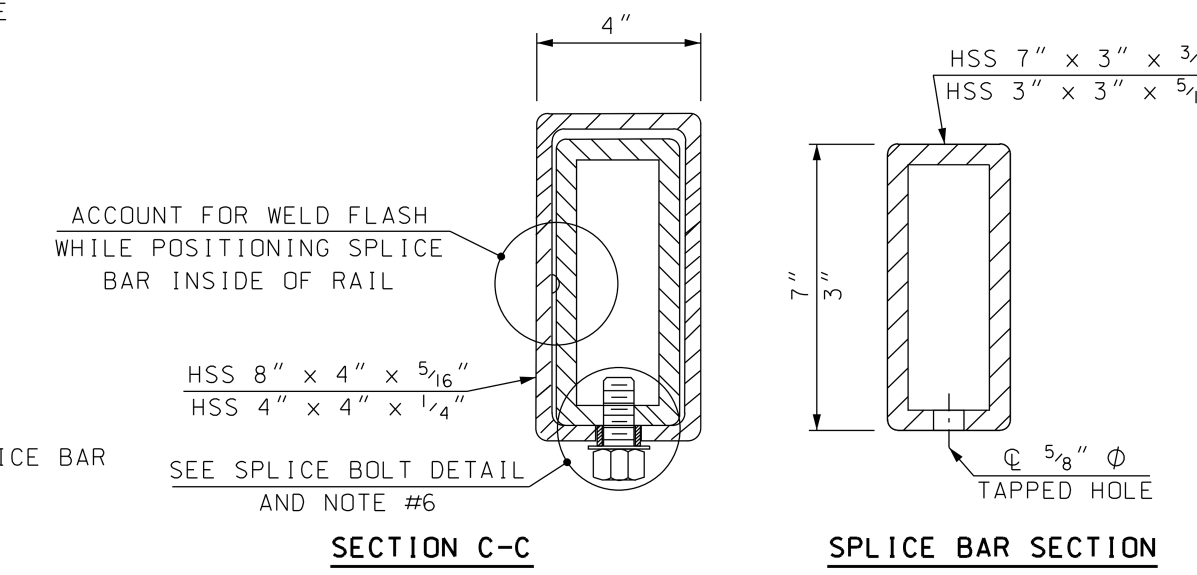
* REINFORCING CAPACITY SHALL MEET OR EXCEED THAT SHOWN

BACK ELEVATION VIEW



RAIL SPLICE (BOTTOM VIEW)

SCALE: 1 1/2" = 1'-0"

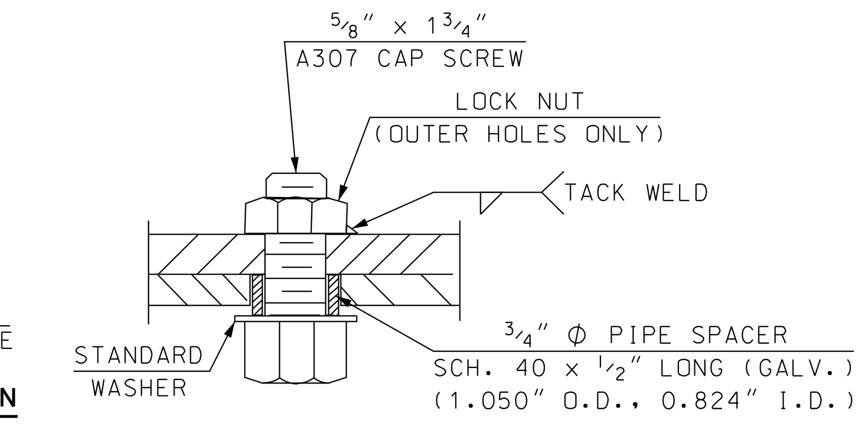


SECTION C-C

SPLICE BAR SECTION

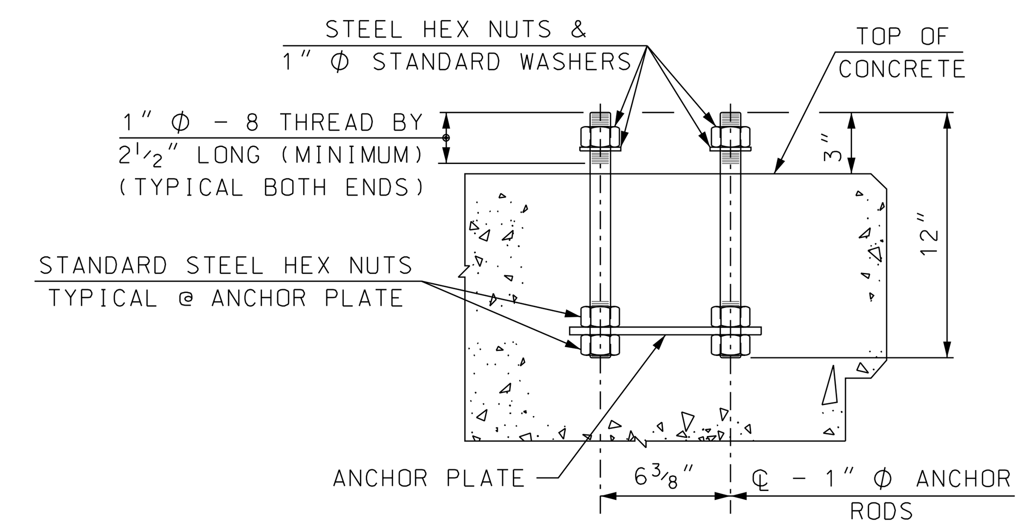
RAIL SPLICE DETAILS

SCALE: 3" = 1'-0"



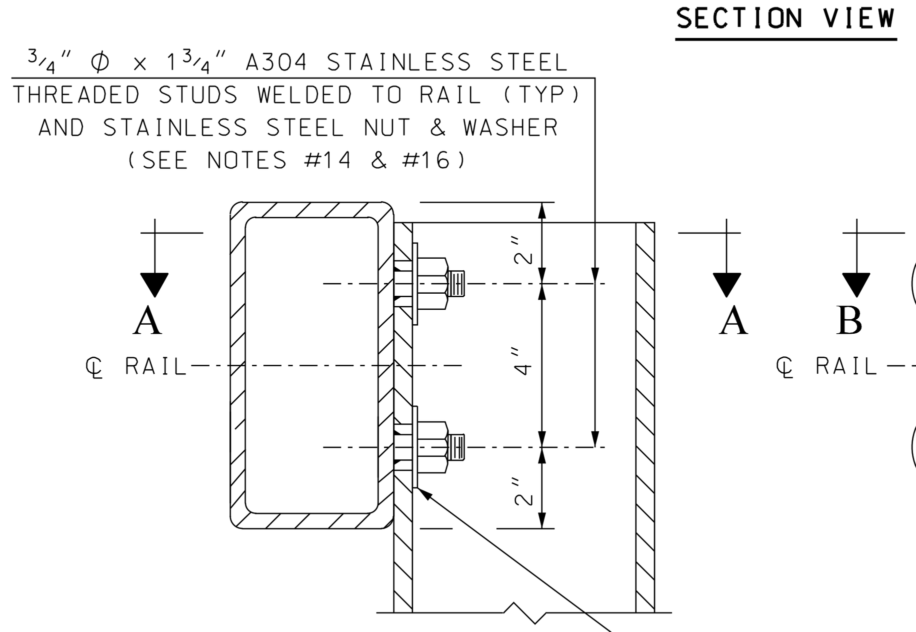
SPLICE BOLT DETAIL

SCALE: 6" = 1'-0"



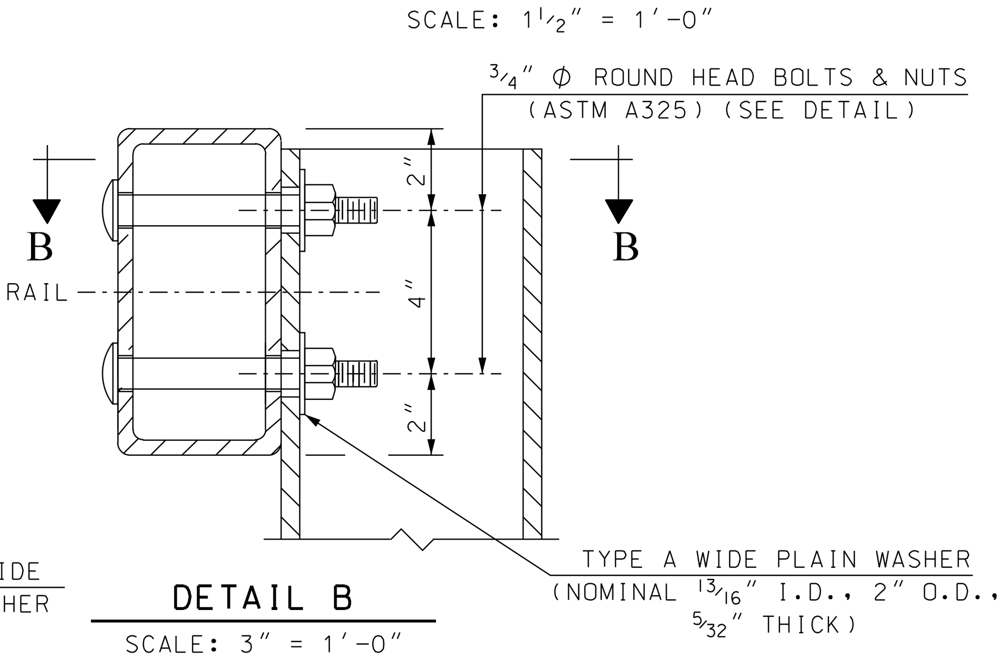
POST ANCHOR ASSEMBLY

SCALE: 1 1/2" = 1'-0"



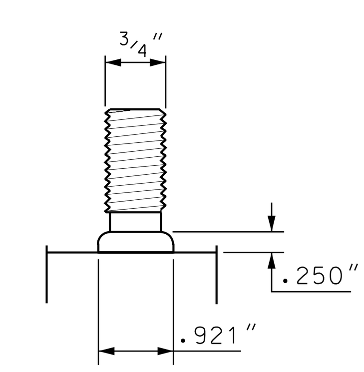
DETAIL A

SCALE: 3" = 1'-0"



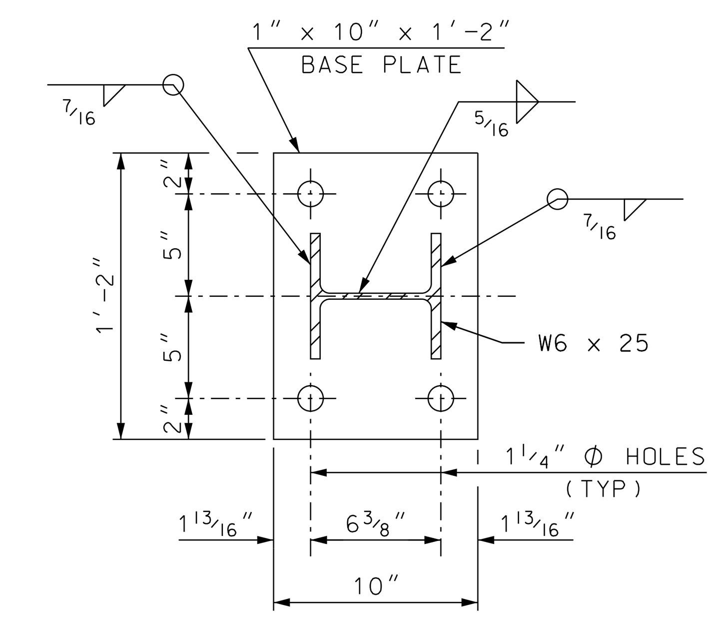
DETAIL B

SCALE: 3" = 1'-0"



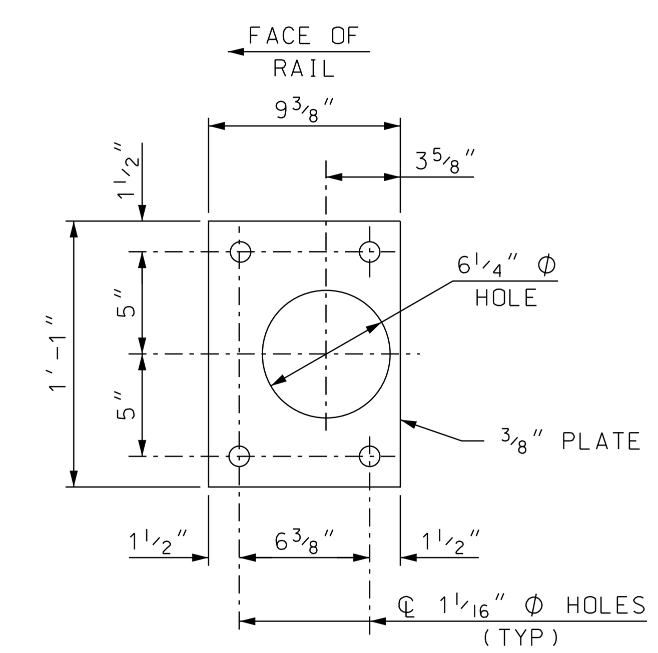
STUD WELD DETAIL

SCALE: 6" = 1'-0"



POST BASE PLATE

SCALE: 1 1/2" = 1'-0"

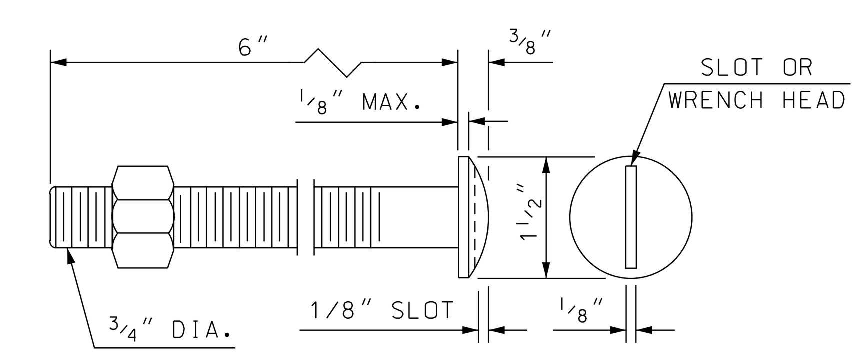


ANCHOR PLATE

SCALE: 1 1/2" = 1'-0"

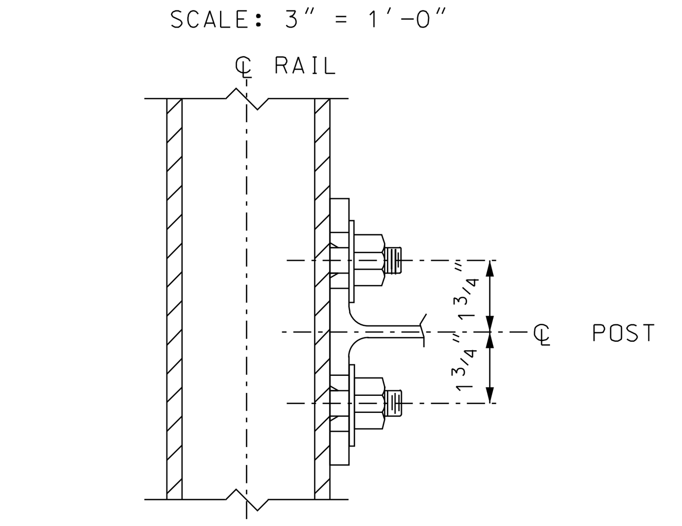
NO MODIFICATIONS PERMITTED TO THIS SHEET, EXCEPT AS NOTED BELOW:

1. POST SPACING @ RAIL ELEVATION
2. ITEM NUMBER AND DESCRIPTION IF SNOW SCREENING AND/OR PROTECTIVE SCREENING WILL BE USED
3. DESIGN OF DECK OVERHANG REINFORCING IS REQUIRED FOR DECK OVERHANG DISTANCE GREATER THAN 3'-6"



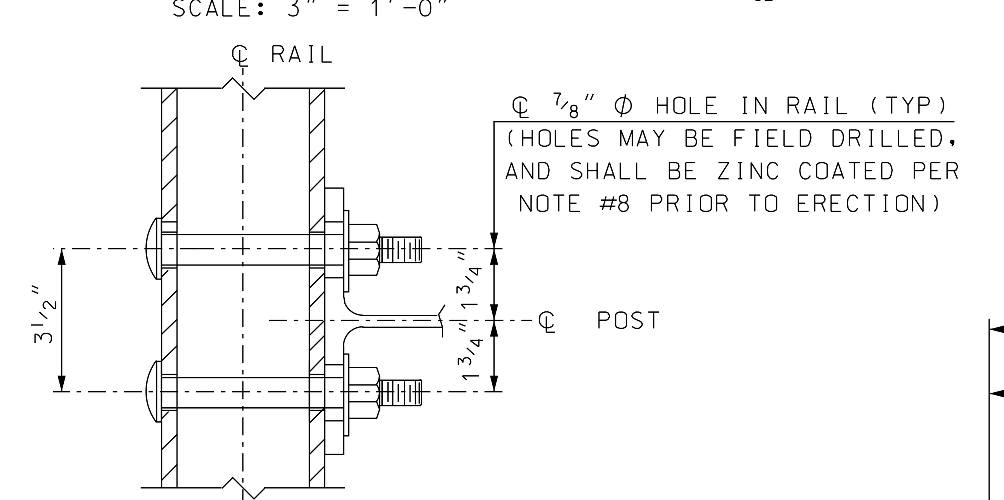
A325 ROUND HEAD BOLT DETAIL

SCALE: 6" = 1'-0"



SECTION A-A

SCALE: 3" = 1'-0"



SECTION B-B

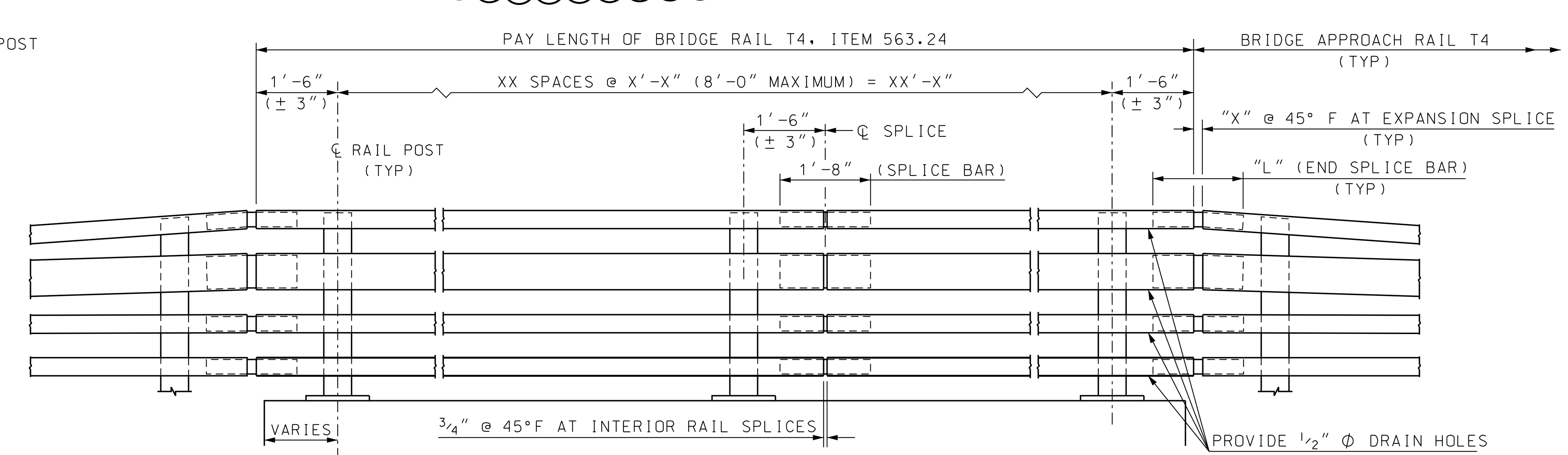
SCALE: 3" = 1'-0"

SPLICE BAR DIMENSION TABLE

	T	A	B	C	D	X	L
	INTERIOR	2 1/2"	4"	4"	2"	3/4"	1'-8"
**	≤ 3 1/4"	2 1/2"	4"	4"	2"	2"	1'-8"
**	3 1/4" < T ≤ 5 1/4"	3 1/2"	5"	5"	2 1/2"	3"	2'-1"

T = TOTAL MOVEMENT OF BRIDGE

** = END SPLICE BAR



RAIL ELEVATION

SCALE: 1/2" = 1'-0"

RAIL NOTES

(1) ITEM 563.24, BRIDGE RAIL T4, SHALL INCLUDE POSTS, BASE PLATES, ANCHOR PLATES, ANCHOR RODS, PREFORMED PADS, RAIL ASSEMBLY BOLTS, NUTS, WASHERS, STUDS, STRUCTURAL TUBING, SPLICE BARS, PIPE SPACERS, ALL APPURTENANCES, AND GALVANIZING.

(2) BRIDGE RAIL POSTS SHALL BE SET NORMAL (90 DEGREES) TO THE PROFILE GRADE, EXCEPT ON GRADES OVER 5% WHERE POSTS SHALL BE SET VERTICAL.

(3) ENDS OF RAIL TUBE SECTIONS SHALL BE SAWED OR MILLED AND SHALL BE TRUE AND SMOOTH. ALL CUT EDGES OF ALL MATERIAL SHALL BE GROUND SMOOTH.

(4) EACH PIECE OF RAIL TUBING SHALL BE ATTACHED TO A MINIMUM OF THREE (3) POSTS.

(5) BOLT HOLES SHALL BE DRILLED OR PUNCHED. FLAME CUTTING MAY BE USED TO FINISH SLOTTED HOLES IF MECHANICALLY GUIDED.

(6) AT INTERIOR SPLICES, PIPE SPACERS SHALL BE USED ON ONLY ONE SIDE OF THE SPLICE TO ALLOW MOVEMENT ON THAT SIDE. ALL RAILS IN A SPLICE SHALL RECEIVE THE SAME TREATMENT. AT END SPLICES PIPE SPACERS SHALL BE USED ON BOTH SIDES OF THE SPLICE TO ALLOW MOVEMENT ON EACH SIDE.

(7) MILL OR SHOP TRANSVERSE WELDS SHALL NOT BE PERMITTED ON ANY RAIL ELEMENT. RAIL ELEMENTS USED ON CURVES SHALL USE 3/8" WALL TUBES AND SHALL BE SHOP FORMED TO THE REQUIRED CURVATURE (SEE SECTION 563.3.2.1).

(8) NO PUNCHING, DRILLING, CUTTING OR WELDING SHALL BE PERMITTED AFTER GALVANIZING, EXCEPT AS ALLOWED IN DETAILS A AND B. DAMAGED AREAS OF GALVANIZING SHALL BE THOROUGHLY CLEANED, PRETREATED, AND PAINTED WITH TWO COATS OF ORGANIC ZINC-RICH GALVANIZING REPAIR PAINT, HAVING A MINIMUM 92% ZINC BY WEIGHT, TO A THICKNESS EQUAL TO THE ORIGINAL COATING, ACCORDING TO SECTION 550.2.9.1 AND ASTM A780.

(9) NUTS FOR 1" Φ THREADED ANCHOR RODS CONNECTING THE BASE PLATE TO THE CONCRETE SHALL BE TIGHTENED TO A SNUG FIT AND GIVEN AN ADDITIONAL 1/8 TURN.

(10) THREADS FOR ANCHOR RODS MAY BE ROLLED OR CUT. IF CUT THREADS ARE USED, BOLT DIAMETER SHALL NOT BE LESS THAN NOMINAL DIAMETER. IF ROLLED THREADS ARE USED, ROD DIAMETER SHALL NOT BE LESS THAN ROOT DIAMETER OF THREADS.

(11) THIS BRIDGE RAIL SYSTEM WAS SUCCESSFULLY CRASH TESTED FOR AASHTO PL2 IN 1994 BY THE NEW ENGLAND TRANSPORTATION CONSORTIUM AND ACCEPTED AS NCHRP 350 TL-4 PER FHWA LETTER HMHS-B50, MARCH 11, 1999.

MATERIAL NOTES

(12) STRUCTURAL TUBING SHALL CONFORM TO THE REQUIREMENTS OF ASTM A500, GRADE B, STRUCTURAL STEEL TUBING. RAIL TUBING SHALL MEET THE LONGITUDINAL CHARPY V-NOTCH REQUIREMENTS OF 15 FT. LBS. AT 0°F. FOR ASTM A500, GRADE B, THE TEST SAMPLES SHALL BE TAKEN AFTER FORMING THE TUBES. CHARPY V-NOTCH IS NOT REQUIRED FOR SPLICE TUBES.

(13) RAIL POSTS AND BASE PLATES SHALL CONFORM TO THE REQUIREMENTS OF ASTM A572 GR 50, EXCEPT ANCHOR PLATES MAY BE ASTM A36.

(14) THREADED STUDS AND MATCHING NUTS FOR RAIL-TO-POST ATTACHMENT (DETAIL A) SHALL CONFORM TO ASTM A276 TYPE 304, STAINLESS STEEL, AND SHALL BE TORQUE TESTED PER AWS D1.5, 7.7.1. DETAIL B BOLTS SHALL BE ASTM A325 OR A449. ALL OTHER BOLTS AND NUTS SHALL CONFORM TO ASTM A307 AND ASTM 563 GRADE A RESPECTIVELY OR BETTER, EXCEPT THAT ASTM A307 NUTS MAY BE USED ON THE BOTTOM OF ANCHOR ASSEMBLY. WASHERS SHALL BE HARDENED STEEL COMMERCIAL TYPE A PLAIN WIDE WASHERS AND SHALL MEET THE DIMENSIONAL REQUIREMENTS OF A.N.S.I. B18.22. ANCHOR RODS SHALL CONFORM TO ASTM A449.

(15) ALL STEEL COMPONENTS (EXCEPT STAINLESS) SHALL BE GALVANIZED AFTER FABRICATION IN COMPLIANCE WITH AASHTO M232 (ASTM A153) AND AASHTO M111 (ASTM A123). THE GALVANIZING KETTLE SHALL HAVE 0.05 TO 0.09 PERCENT NICKEL. GALVANIZED SURFACES SHALL HAVE A UNIFORM APPEARANCE AND GALVANIZED MATERIAL SHALL BE PROPERLY STORED. IF PAINTING IS REQUIRED SEE SPECIAL PROVISIONS FOR 708.

(16) DETAIL A STUDS SHALL BE WELDED ON AFTER TUBES ARE GALVANIZED BY SPOT GRINDING OFF GALVANIZING, WELDING ON STUDS, THEN TOUCH UP GALVANING PER NOTE #8 ABOVE.

(17) PREFORMED BEARING PADS (1/8" THICK) SHALL CONFORM TO AASHTO M251.

STATE OF NEW HAMPSHIRE

DEPARTMENT OF TRANSPORTATION * BUREAU OF BRIDGE DESIGN

TOWN	BRIDGE NO.	STATE PROJECT
LOCATION		

T4 STEEL BRIDGE RAIL

REVISIONS AFTER PROPOSAL		BY	DATE		BY	DATE
	DESIGNED	NETC/JSZ	3/02	CHECKED	NHDOT	
	DRAWN	PJP	10/05	CHECKED	JSZ	10/05
	QUANTITIES			CHECKED		
	ISSUE DATE	11/15/05				
	REV. DATE	11/1/16				

BRIDGE SHEET	OF	FILE NUMBER	FEDERAL PROJECT NO.	SHEET NO.	TOTAL SHEETS

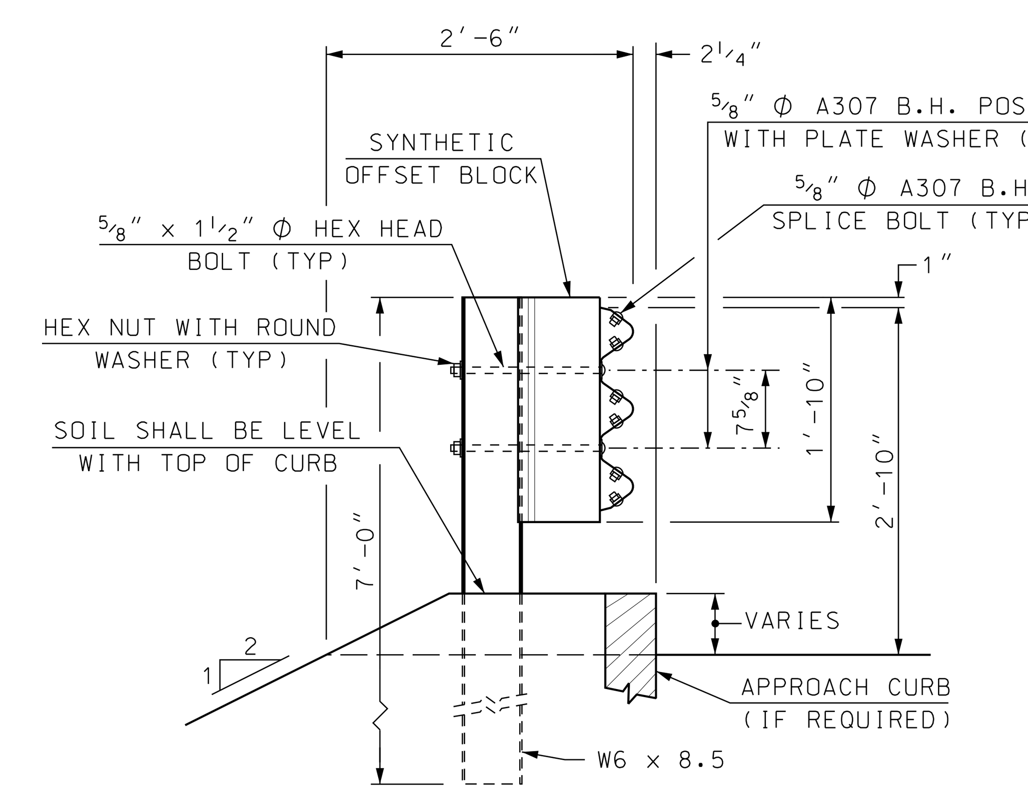
SUBDIRECTORY	.DGN LOCATOR	SHEET SCALE
English/BR-RAIL	T4_BR-RAIL	AS NOTED

PLAN VIEW - APPROACH RAIL

SCALE: $^3/_4$" = 1'-0"

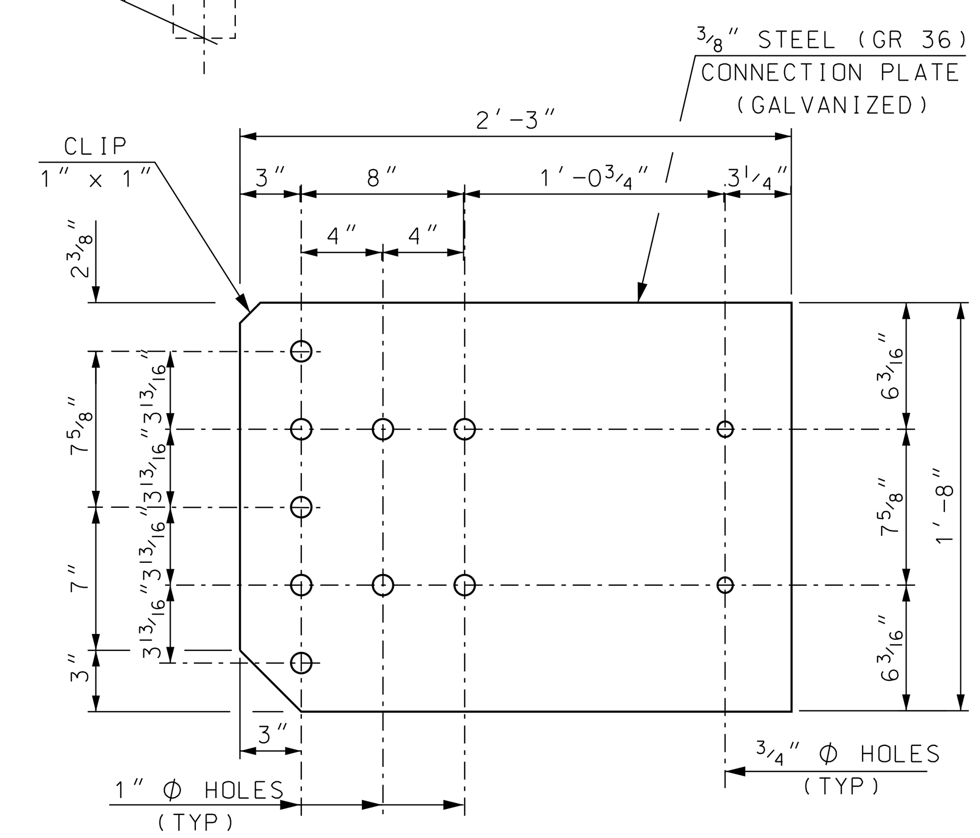
ELEVATION - APPROACH RAIL

SCALE: $^3/_4$" = 1'-0"



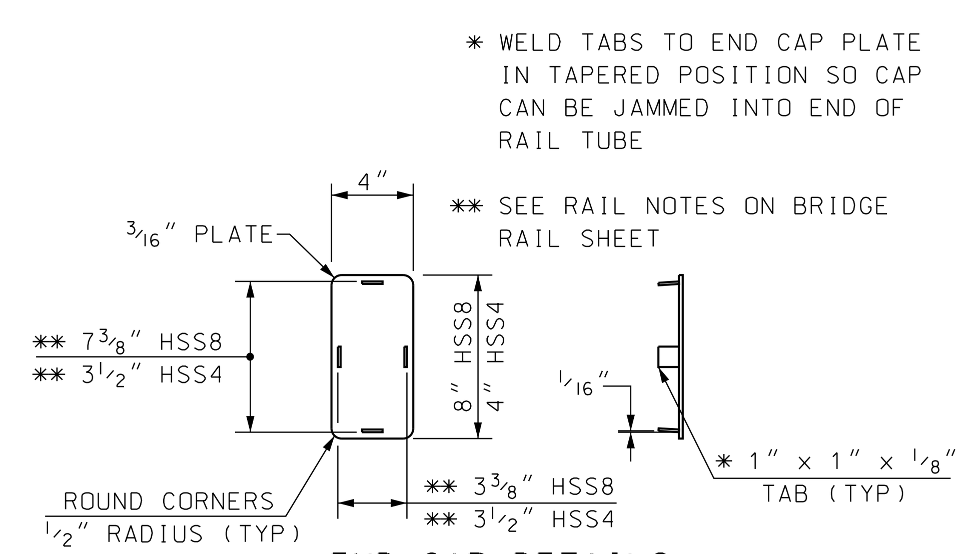
SECTION A-A (POST RAIL ASSEMBLY)

SCALE: $^3/_4$" = 1'-0"



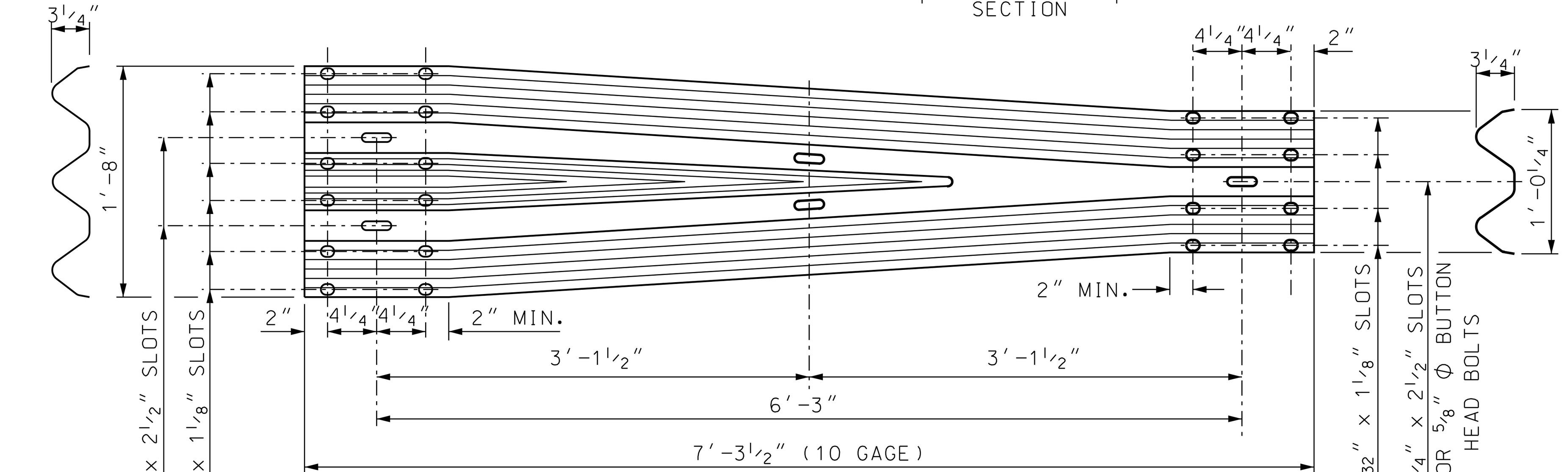
CONNECTION PLATE

SCALE: $1^1/_2$" = 1'-0"



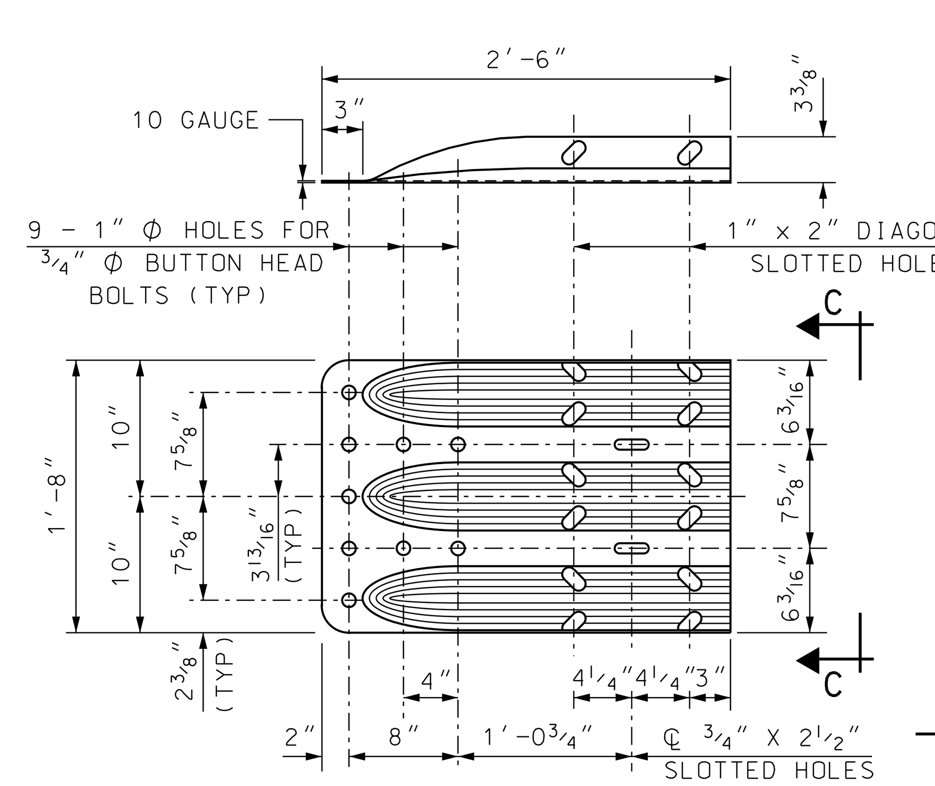
END CAP DETAILS

SCALE: $1^1/_2$" = 1'-0"



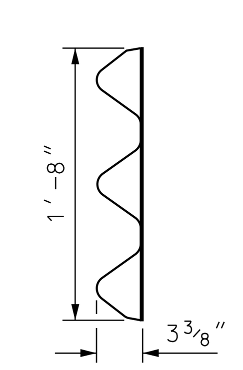
THRIE-BEAM TO W-BEAM TRANSITION SECTION

SCALE: 1" = 1'-0"



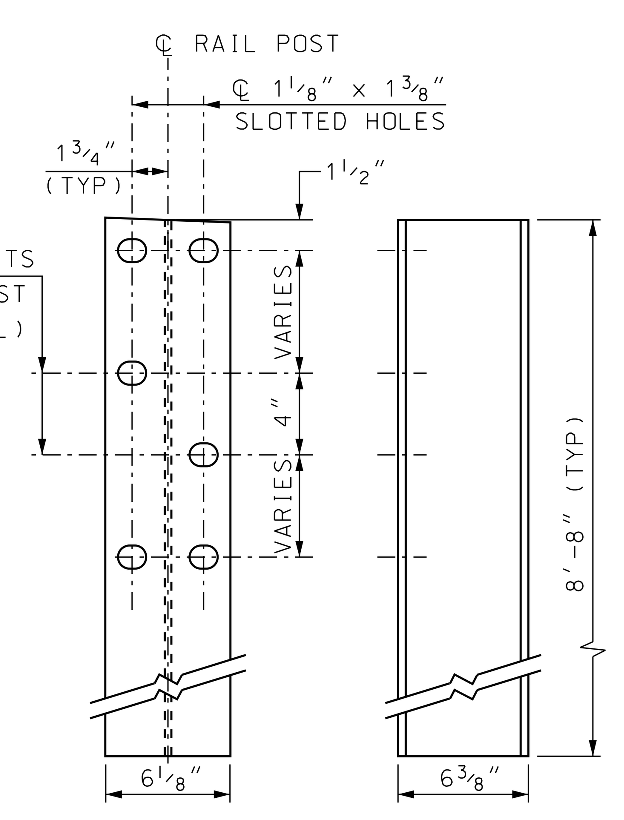
THRIE-BEAM TERMINAL CONNECTOR

SCALE: 1" = 1'-0"



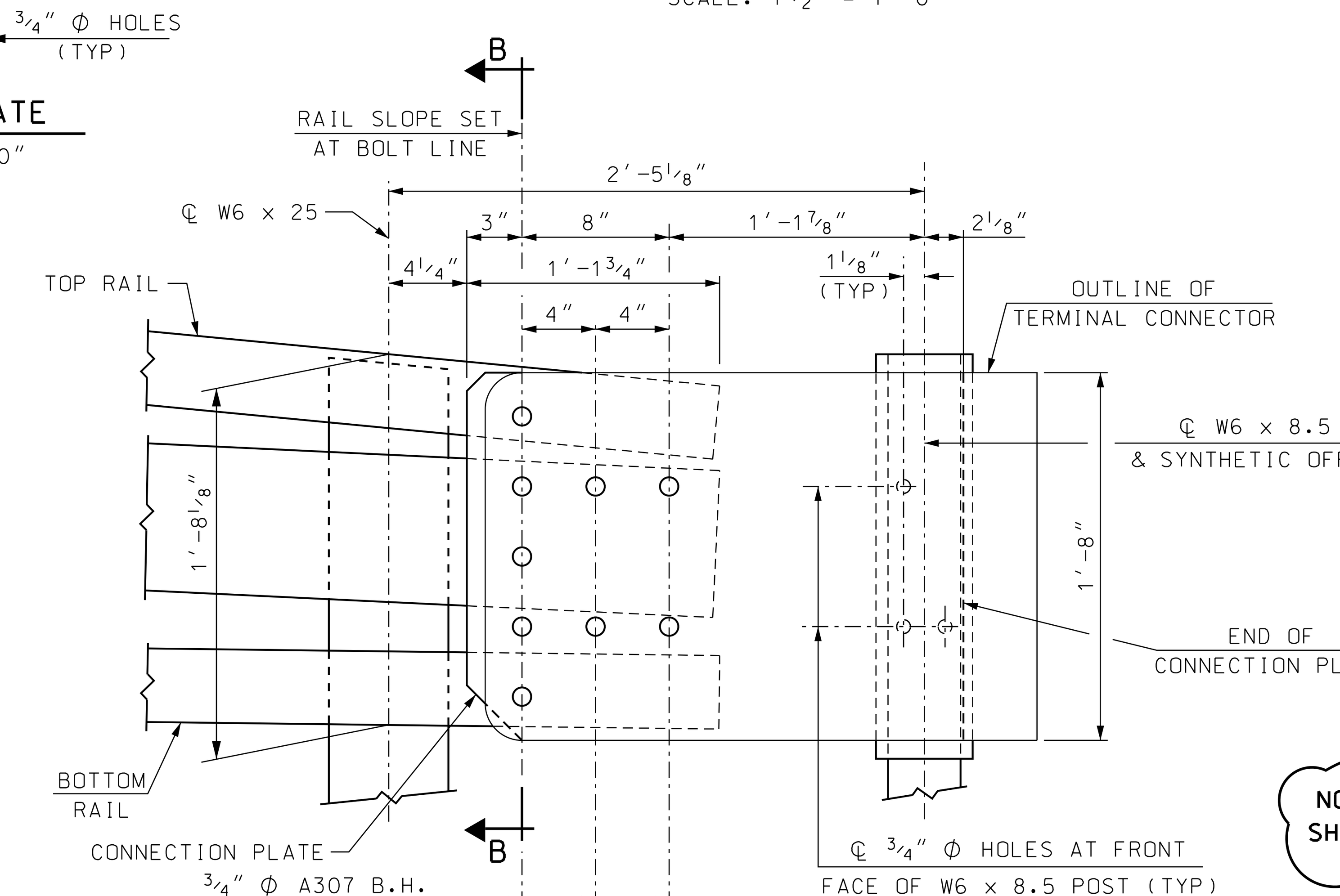
VIEW C-C

SCALE: 1" = 1'-0"



RAIL POST (W6 x 25)

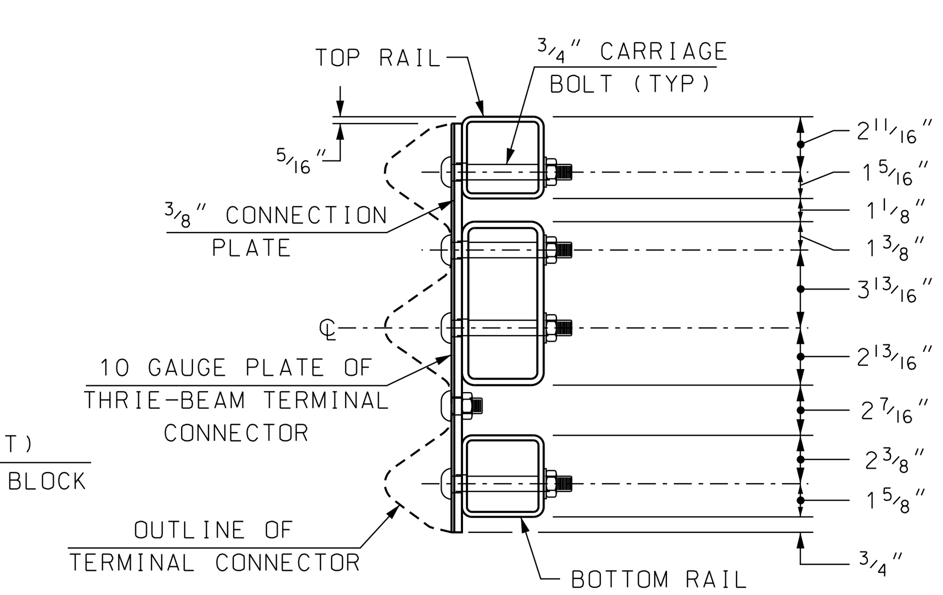
SCALE: $1^1/_2$" = 1'-0"



DETAIL A

OVERLAPPING OF DOUBLE NESTED THRIE-BEAM NOT SHOWN FOR CLARITY

SCALE: $1^1/_2$" = 1'-0"



SECTION B-B (CONNECTION PLATE)

SCALE: $1^1/_2$" = 1'-0"

NOTES:

(1) ALL BRIDGE APPROACH RAIL MATERIALS, DIMENSIONS, SIZES, AND NOTES SHALL BE THE SAME AS THOSE OF THE BRIDGE RAIL, UNLESS OTHERWISE NOTED. SEE BRIDGE RAIL SHEET FOR NOTES AND ADDITIONAL INFORMATION.

(2) W6 x 25 POSTS SHALL BE THE SAME MATERIAL AS THE BRIDGE RAIL POSTS. W6 x 8.5 POSTS SHALL BE THE SAME AS W-BEAM GUARDRAIL POSTS.

(3) CARRIAGE BOLTS SHALL BE ASTM A307, AND NUTS SHALL BE ASTM A563 GRADE A OR BETTER (GALVANIZED).

(4) WELD BARS ADJUSTED FOR SLOPE & BEND. USE COMPLETE JOINT PENETRATION BUTT WELD (B-U2).

(5) THIS BRIDGE RAIL TRANSITION SYSTEM WAS SUCCESSFULLY CRASH TESTED IN APRIL 2005 BY THE NEW ENGLAND TRANSPORTATION CONSORTIUM AND ACCEPTED AS NCHRP 350 TL-3 PER FHWA LETTER HSSD/B-146.

(6) ALL COMPONENTS, EXCEPT TUBULAR RAIL, SHALL CONFORM TO SECTION 606 OF NHDOT SPECIFICATIONS.

NO MODIFICATIONS SHOULD BE MADE TO THIS SHEET

STATE OF NEW HAMPSHIRE

DEPARTMENT OF TRANSPORTATION * BUREAU OF BRIDGE DESIGN

TOWN	BRIDGE NO.	STATE PROJECT
LOCATION		

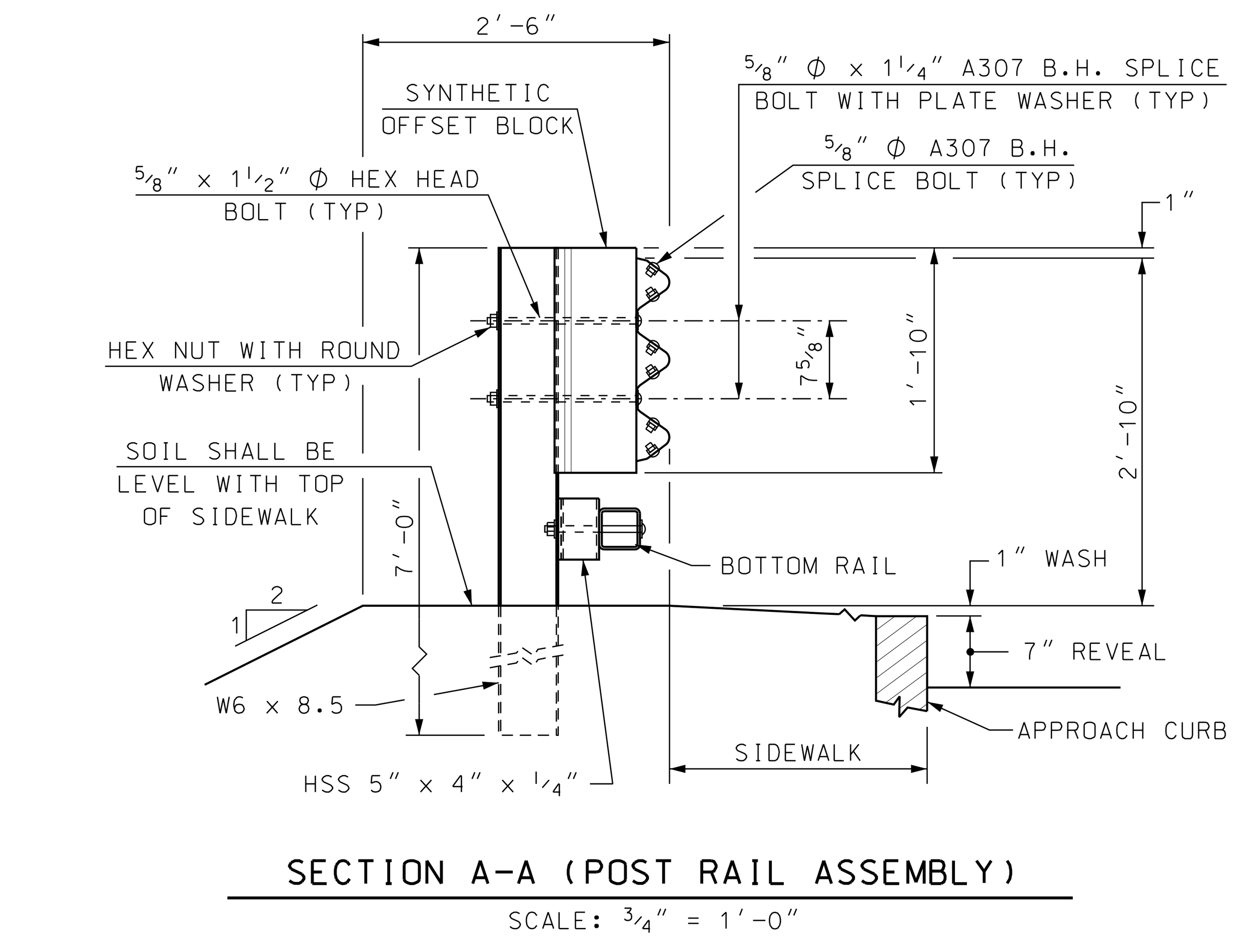
T3 STEEL BRIDGE APPROACH RAIL (STEEL POSTS)

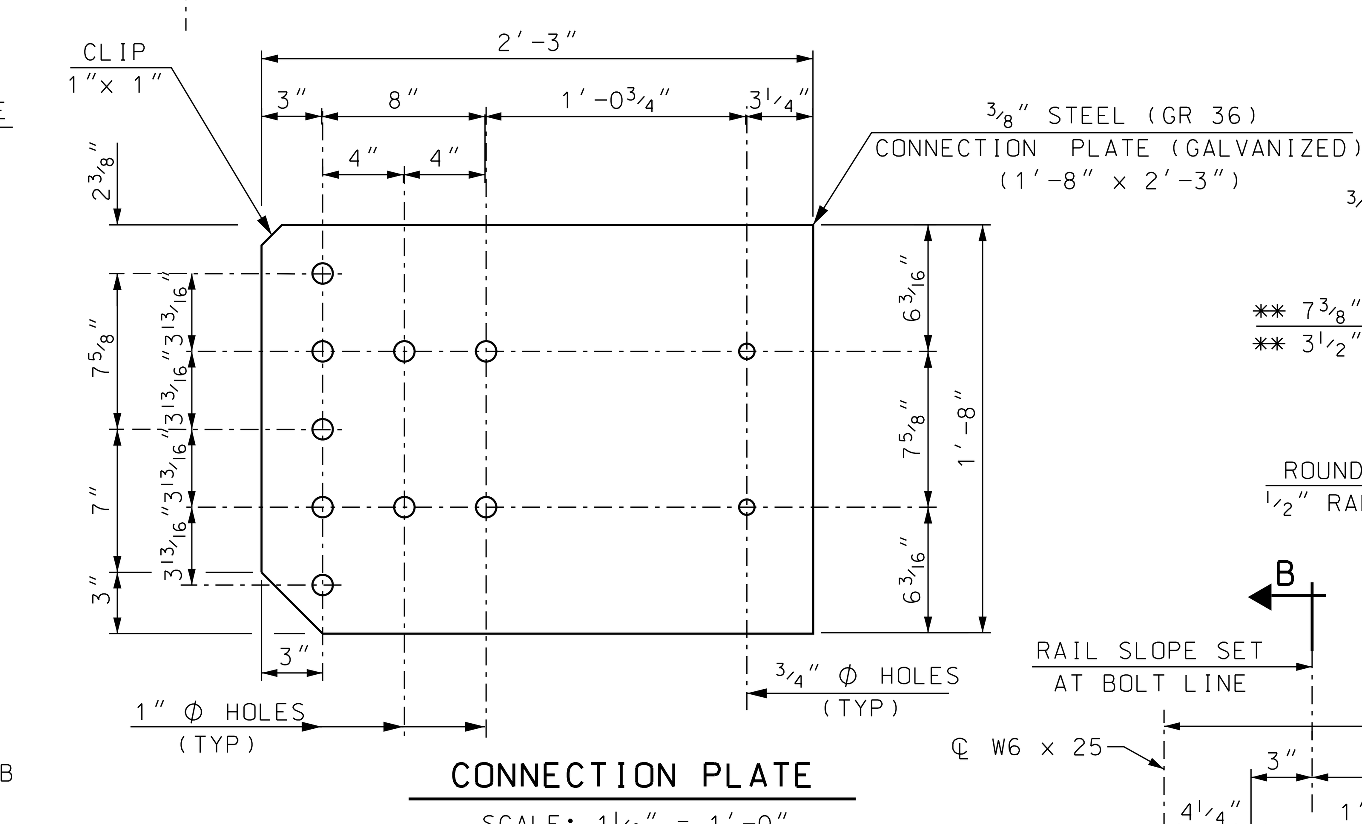
REVISIONS AFTER PROPOSAL		BY	DATE		BY	DATE
DESIGNED		NETC/JSZ	3/02	CHECKED	NHDOT	
DRAWN		PJP	10/05	CHECKED	JSZ	10/05
QUANTITIES				CHECKED		
ISSUE DATE		11/15/05		FEDERAL PROJECT NO.	SHEET NO.	TOTAL SHEETS
REV. DATE		3/20/18				

BRIDGE SHEET OF

FILE NUMBER

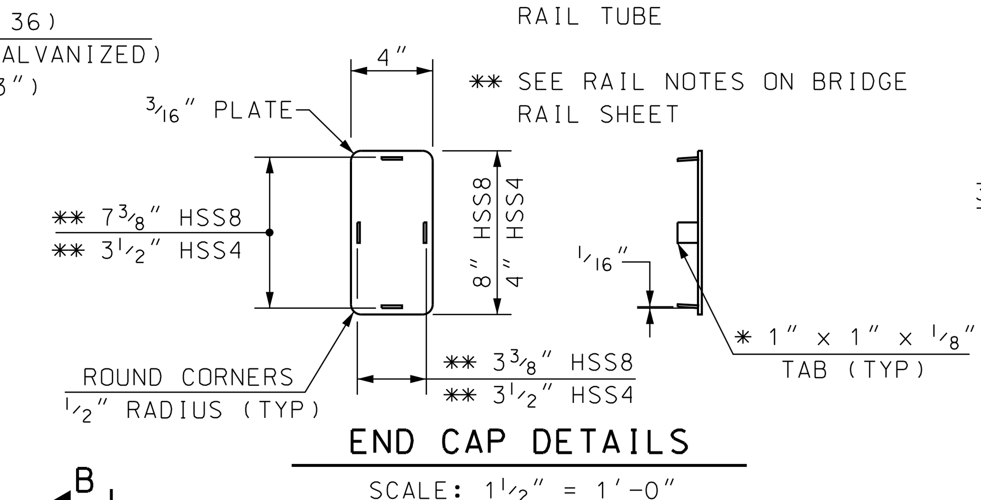
SUBDIRECTORY	.DGN LOCATOR	SHEET SCALE
English/BR-RAIL	T3SP_APPRAIL	AS NOTED

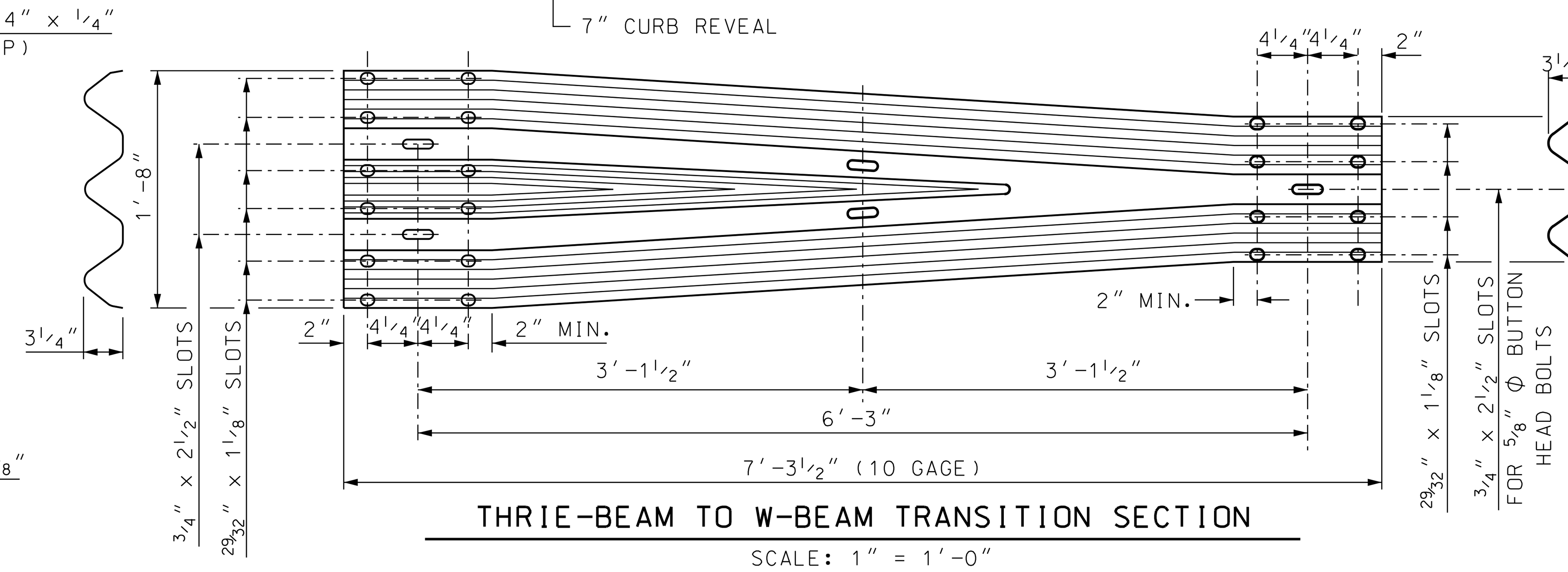


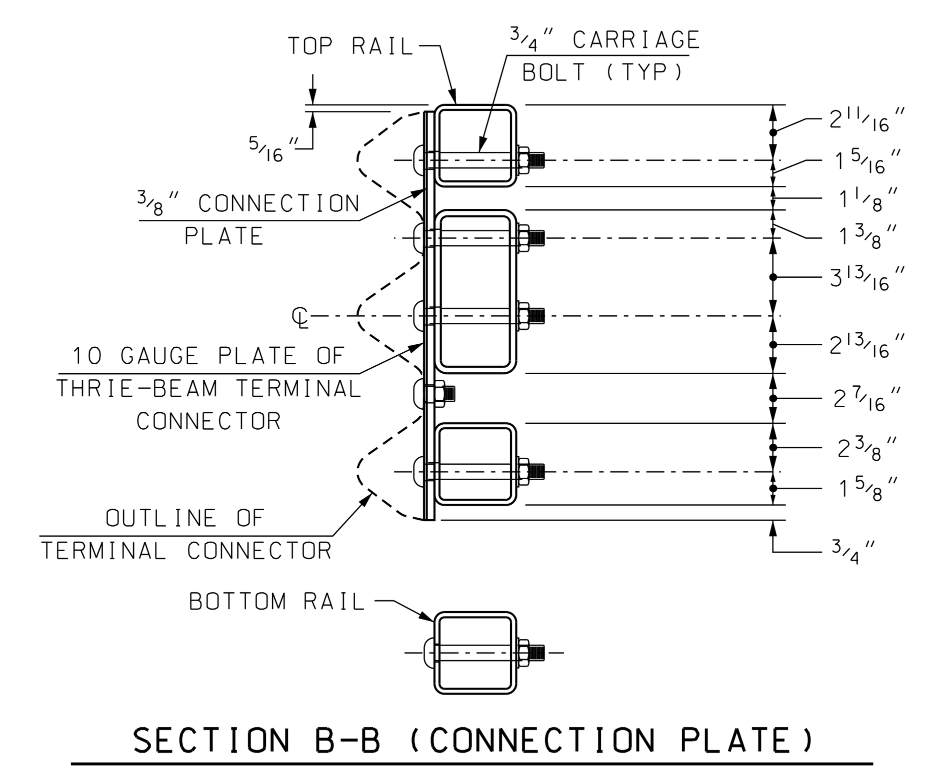


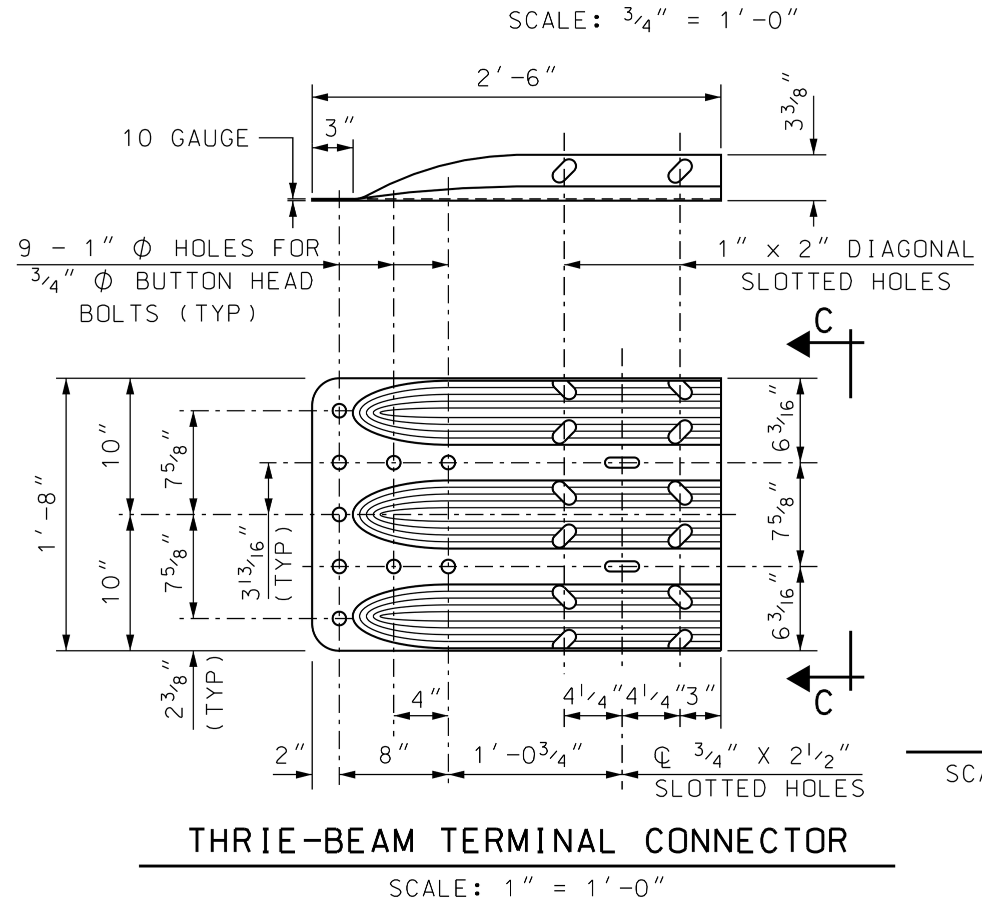
* WELD TABS TO END CAP PLATE IN TAPERED POSITION SO CAP CAN BE JAMMED INTO END OF RAIL TUBE

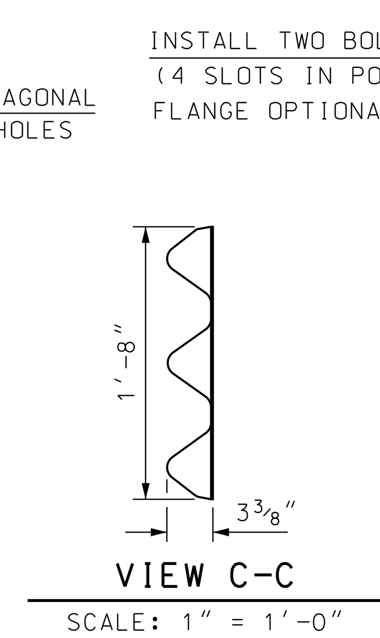
** SEE RAIL NOTES ON BRIDGE RAIL SHEET

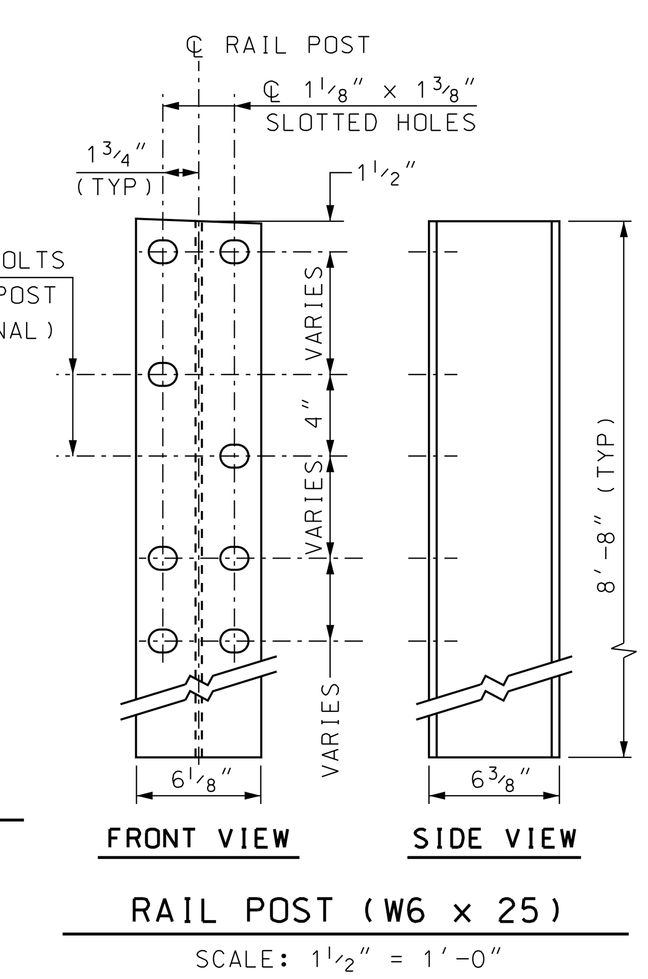


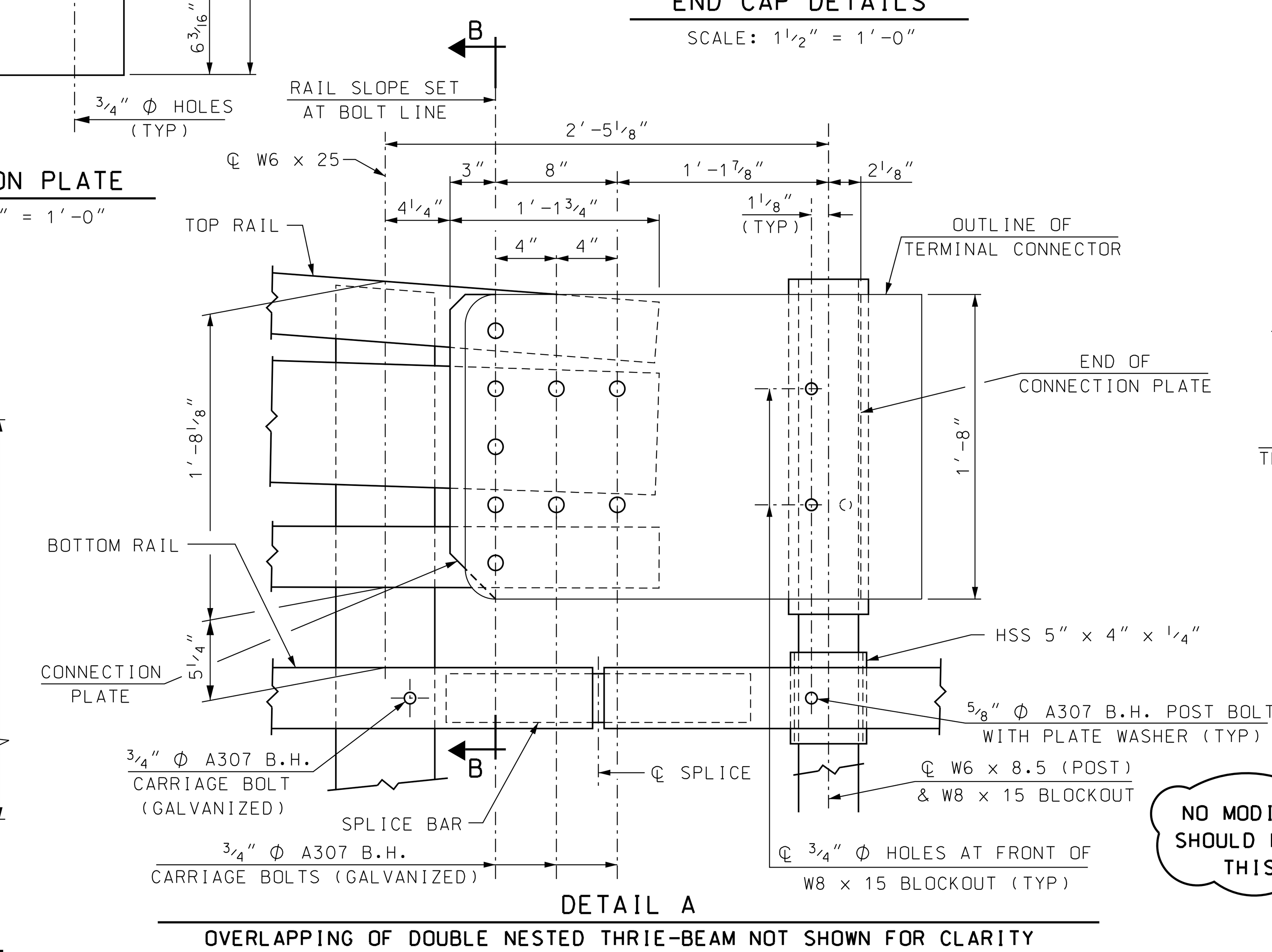












NO MODIFICATIONS SHOULD BE MADE TO THIS SHEET

NOTES:

(1) ALL BRIDGE APPROACH RAIL MATERIALS, DIMENSIONS, SIZES, AND NOTES SHALL BE THE SAME AS THOSE OF THE BRIDGE RAIL, UNLESS OTHERWISE NOTED. SEE BRIDGE RAIL SHEET FOR NOTES AND ADDITIONAL INFORMATION.

(2) W6 x 25 POSTS SHALL BE THE SAME MATERIAL AS THE BRIDGE RAIL POSTS. W6 x 8.5 POSTS SHALL BE THE SAME AS W-BEAM GUARDRAIL POSTS.

(3) CARRIAGE BOLTS SHALL BE ASTM A307, AND NUTS SHALL BE ASTM A563 GRADE A OR BETTER (GALVANIZED).

(4) WELD BARS ADJUSTED FOR SLOPE OR BEND. USE COMPLETE JOINT PENETRATION BUTT WELD (B-U2).

(5) THIS BRIDGE RAIL TRANSITION SYSTEM WAS SUCCESSFULLY CRASH TESTED IN APRIL 2005 BY THE NEW ENGLAND TRANSPORTATION CONSORTIUM AND ACCEPTED AS NCHRP 350 TL-3 PER FHWA LETTER HSSD/B-146.

(6) ALL COMPONENTS, EXCEPT TUBULAR RAIL, SHALL CONFORM TO SECTION 606 OF NHDOT SPECIFICATIONS.

STATE OF NEW HAMPSHIRE
DEPARTMENT OF TRANSPORTATION * BUREAU OF BRIDGE DESIGN

TOWN	BRIDGE NO.	STATE PROJECT
LOCATION		

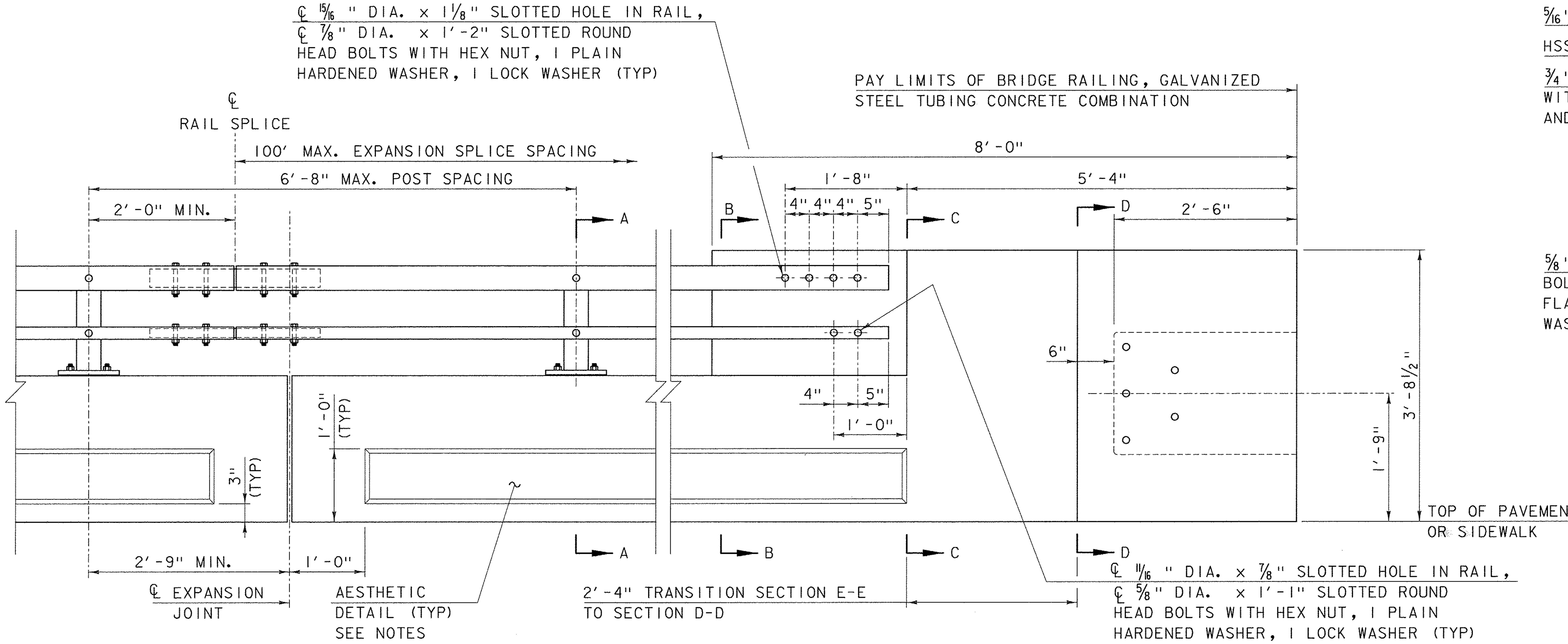
T4 STEEL BRIDGE APPROACH RAIL (STEEL POSTS)

REVISIONS AFTER PROPOSAL		BY	DATE		BY	DATE
	DESIGNED	NETC/JSZ	3/02	CHECKED	NHDOT	
	DRAWN	PJP	10/05	CHECKED	JSZ	10/05
	QUANTITIES			CHECKED		
	ISSUE DATE	11/15/05		FEDERAL PROJECT NO.		
	REV. DATE	3/20/18				

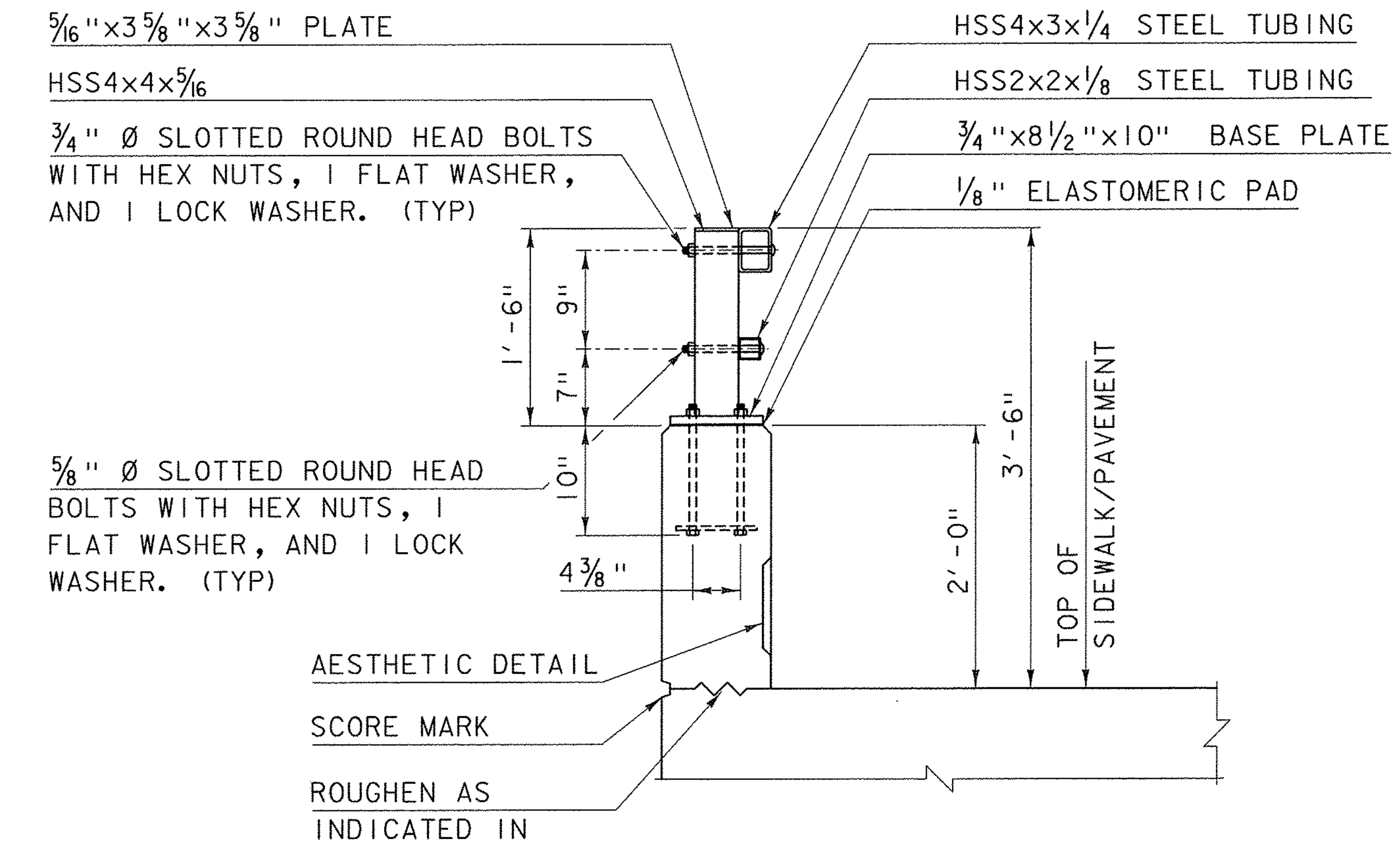
BRIDGE SHEET OF | FILE NUMBER | SHEET NO. | TOTAL SHEETS

SUBDIRECTORY	.DGN LOCATOR	SHEET SCALE
English/BR-RAIL	T4SP_APPRAIL	AS NOTED

APPENDIX C: VERMONT DOT STANDARD BRIDGE RAIL DRAWINGS



RAILING & END WALL APPROACH

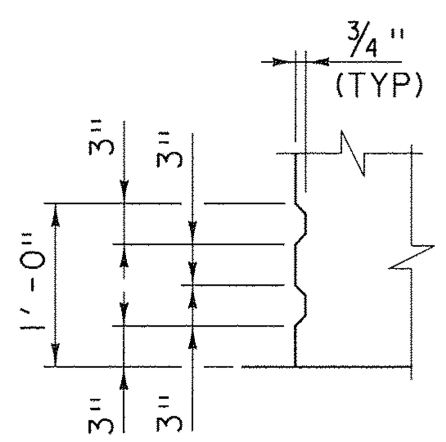


RAIL TYPICAL SECTION

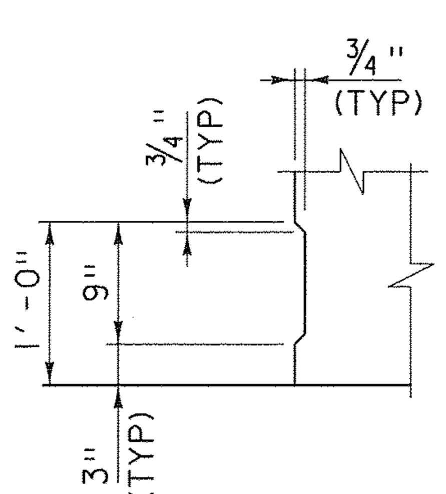
NOTES:

1. ALL WORK AND MATERIALS SHALL CONFORM TO SECTION 525.
2. PRIOR TO GALVANIZING THE ASSEMBLED POST, GRIND ALL EDGES TO A MINIMUM RADIUS OF 1/16".
3. ALL POSTS SHALL BE SET NORMAL TO GRADE.
4. SECTIONS OF RAIL TUBE SHALL BE ATTACHED TO A MINIMUM OF TWO BRIDGE POSTS AND PREFERABLY TO AT LEAST 4 POSTS.
5. HOLES IN RAILS FOR TUBE ATTACHMENT MAY BE FIELD-DRILLED. HOLES SHALL BE COATED WITH AN APPROVED ZINC-RICH PAINT PRIOR TO INSTALLATION.
6. BOLTS SHALL BE TORQUED SNUG TIGHT (APPROXIMATELY 100 FT-LB).
7. RAIL TUBES SHALL BE ATTACHED USING 3/4" FULL DIAMETER BODY ASTM A 449 (TYPE 1) ROUND HEAD BOLTS INSERTED THROUGH THE FACE OF THE TUBE.
8. SEE STANDARD DRAWING G-1 FOR DETAILS OF DELINEATORS. A DELINEATOR SHALL BE INSTALLED AT 30 FOOT SPACING OR THE NEAREST POST. WHITE IS TO BE INSTALLED ON THE DRIVER'S RIGHT. FOR ONE WAY BRIDGES, YELLOW IS TO BE INSTALLED ON THE DRIVER'S LEFT. PAYMENT FOR DELINEATORS SHALL BE INCIDENTAL TO OTHER ITEMS.
9. AESTHETIC TREATMENT TYPE SHALL BE APPLIED AS SPECIFIED IN THE CONTRACT PLANS. IF NONE IS SPECIFIED IT SHALL NOT BE USED. AESTHETIC TREATMENT DETAILED ON THIS SHEET MAY ALSO BE APPLIED ON THE FASCIA SIDE OF THE RAIL, IF SPECIFIED IN THE CONTRACT PLANS.
10. BRIDGE RAILING SHALL HAVE A RUBBED FINISH IN ACCORDANCE WITH SECTION 501.
11. THIS RAILING MEETS THE REQUIREMENTS FOR A NCHRP REPORT 350 TL-4 SERVICE LEVEL.

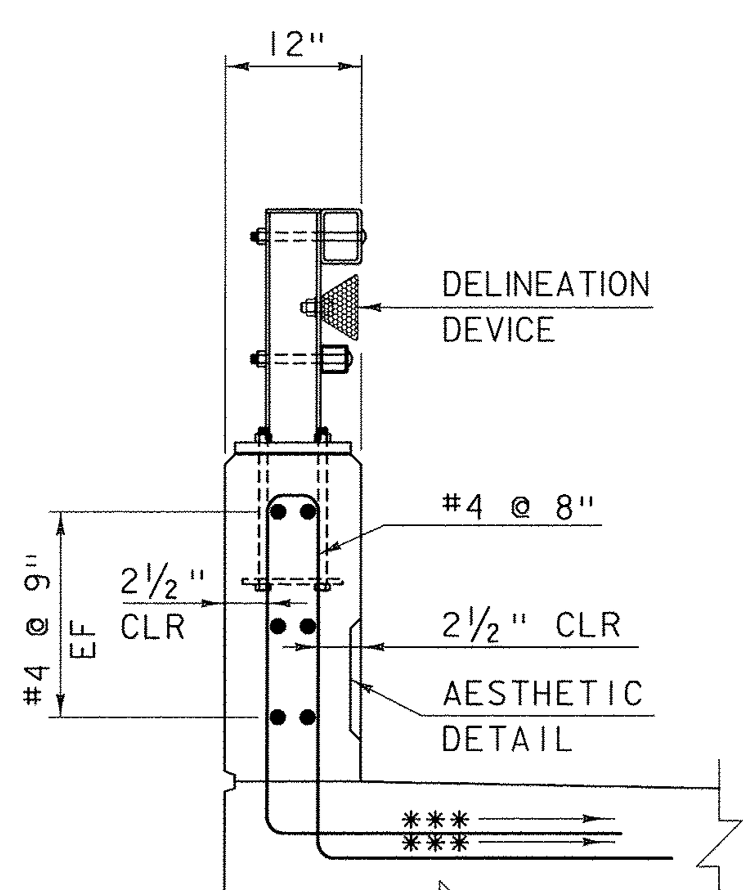
NOTE:
EF = EACH FACE
3" CLEAR, UNLESS OTHERWISE SPECIFIED ON THE PLANS.
2'-2" BAR LAP UNLESS OTHERWISE SPECIFIED ON THE PLANS.
*** MATCH SLOPE OF NEAREST TRANSVERSE STEEL



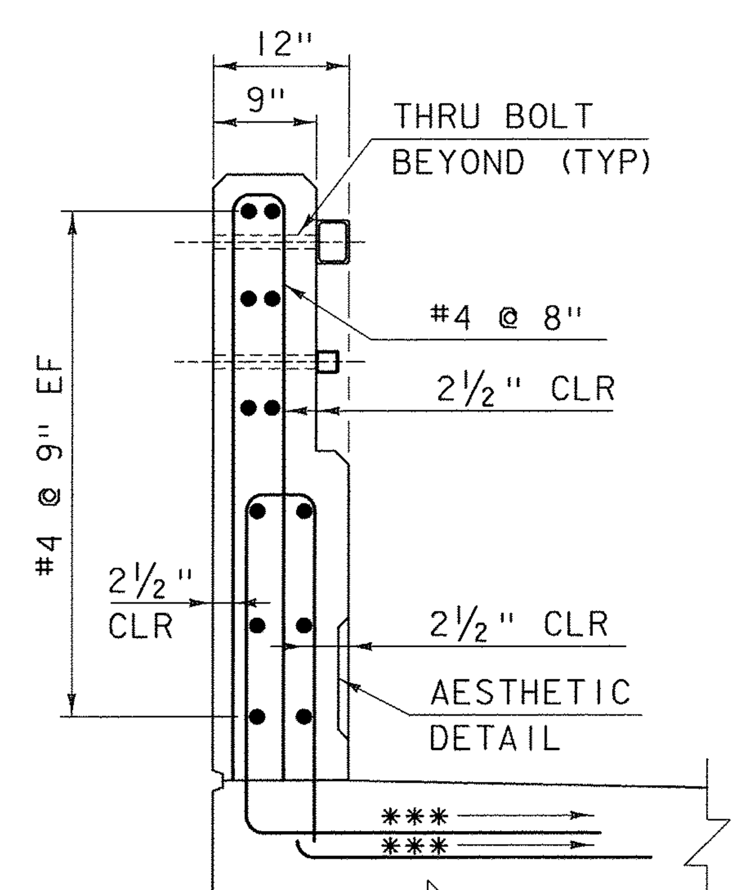
AESTHETIC DETAIL A



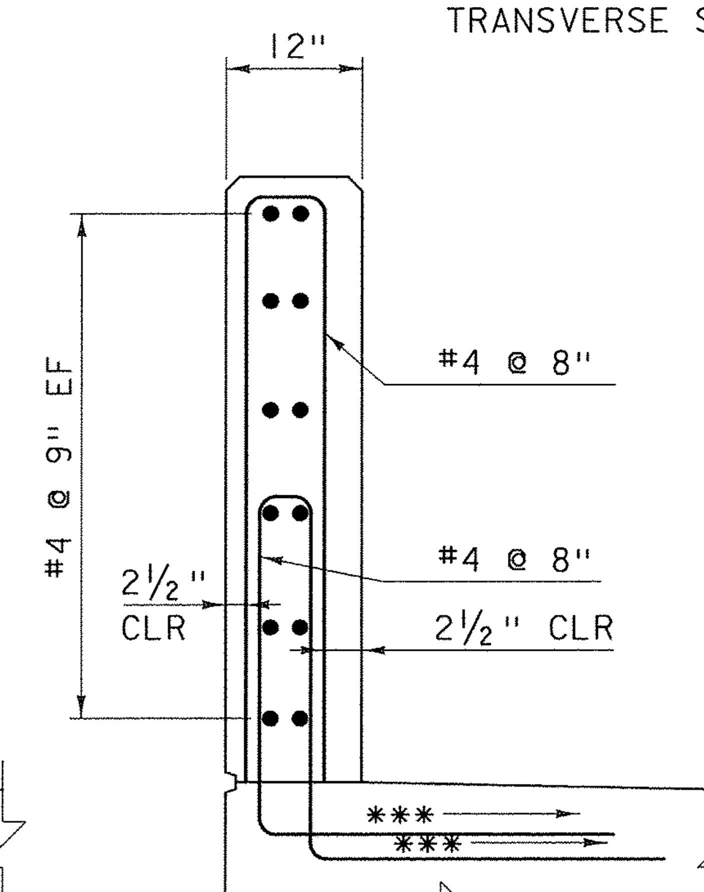
AESTHETIC DETAIL B



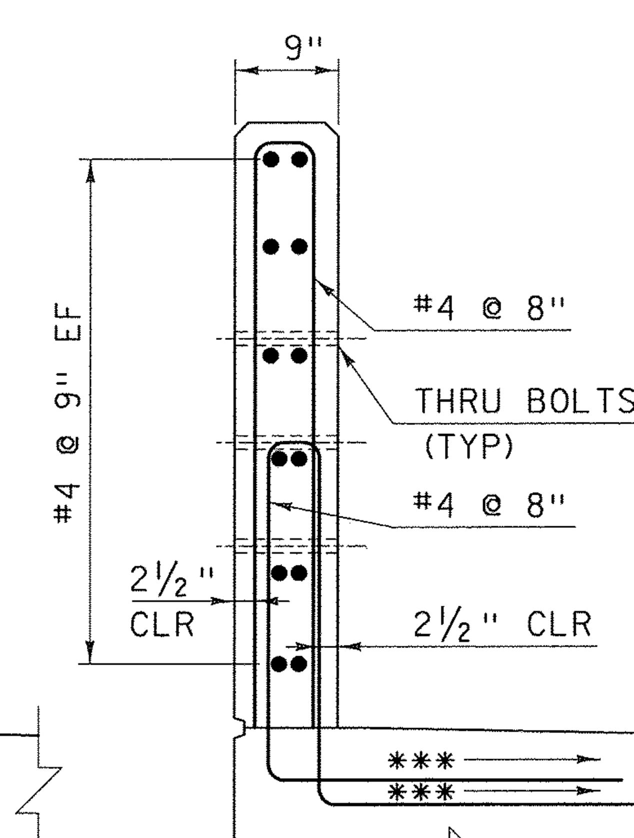
SECTION A-A



SECTION B-B



SECTION C-C



SECTION D-D

OTHER STDS. REQUIRED: G-1

REVISIONS AND CORRECTIONS

AUGUST 22, 2012 - ORIGINAL APPROVAL

APPROVED

Wm. Michael Hedges
STRUCTURES ENGINEER

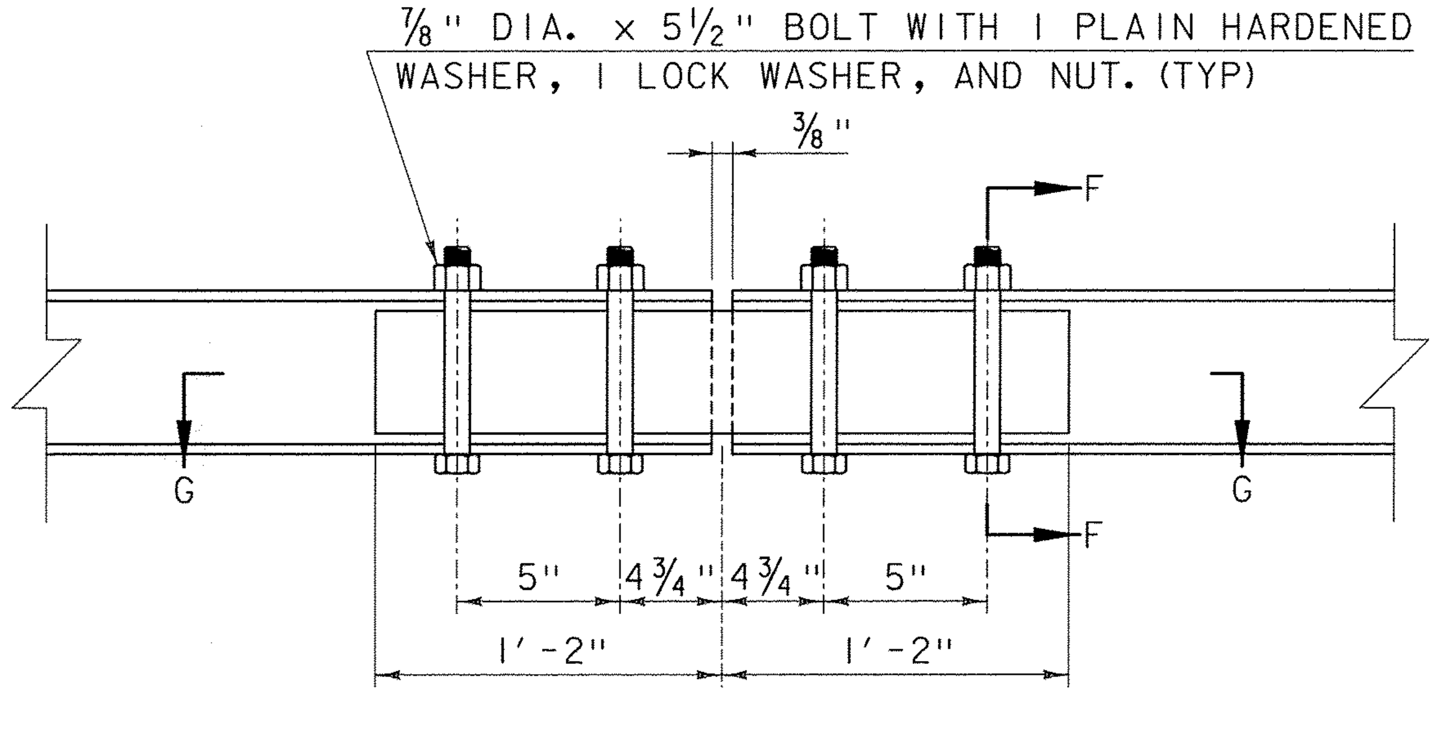
Richard Tetreault
DIRECTOR OF PROGRAM DEVELOPMENT

Mark D. Richter
FEDERAL HIGHWAY ADMINISTRATION

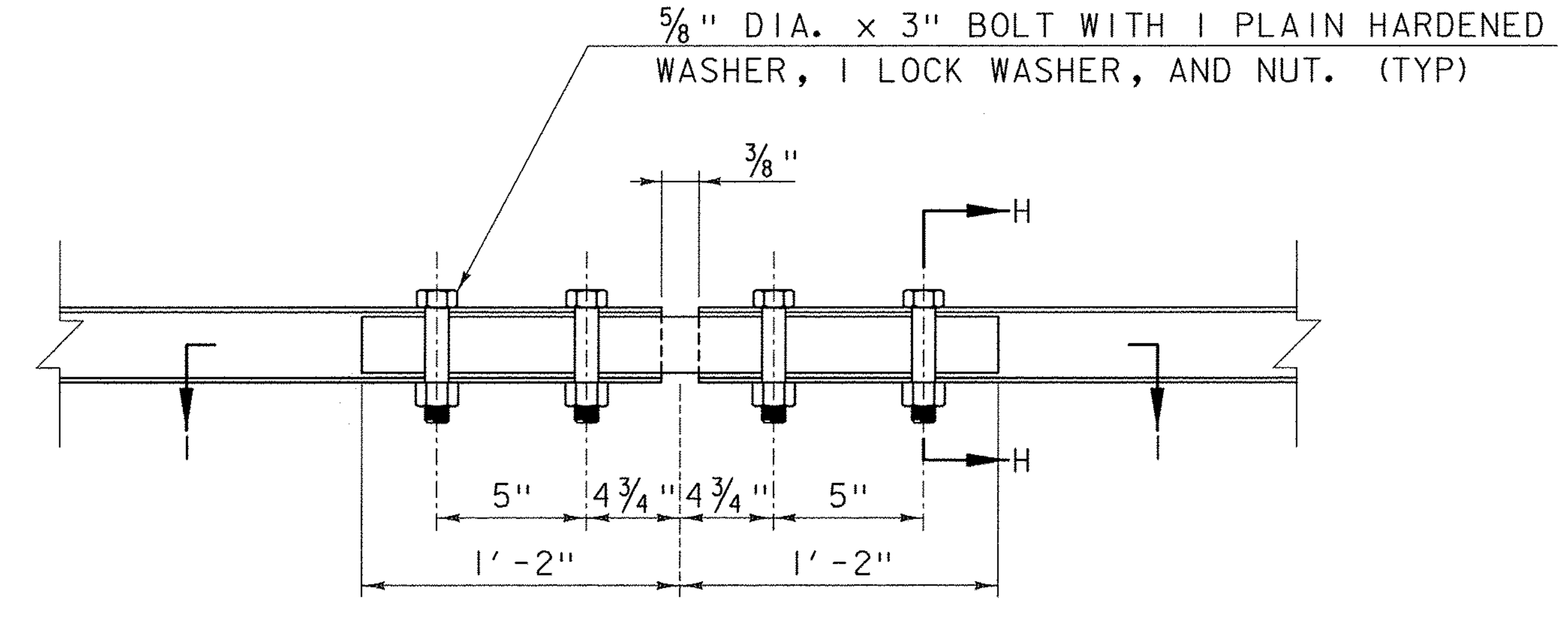
BRIDGE RAILING, GALVANIZED STEEL TUBING / CONCRETE COMBINATION

VERMONT AGENCY OF TRANSPORTATION

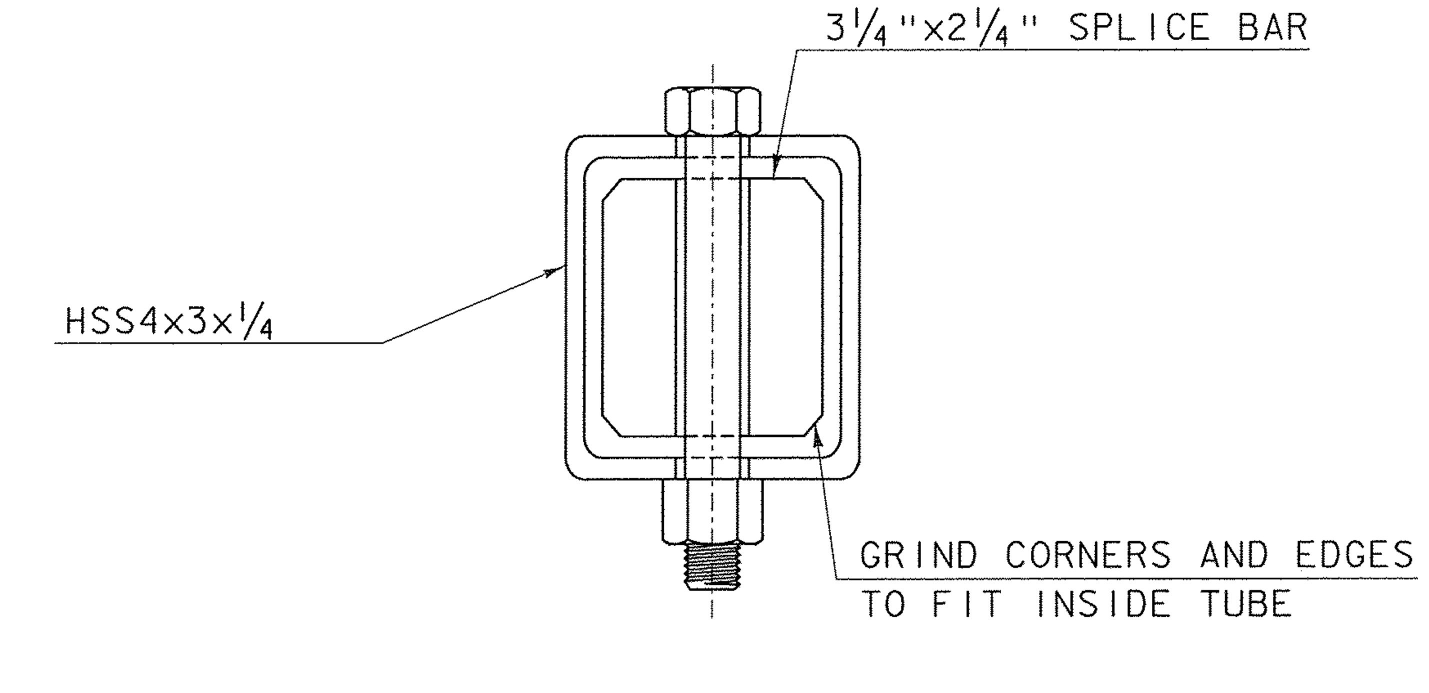
STANDARD S-352A



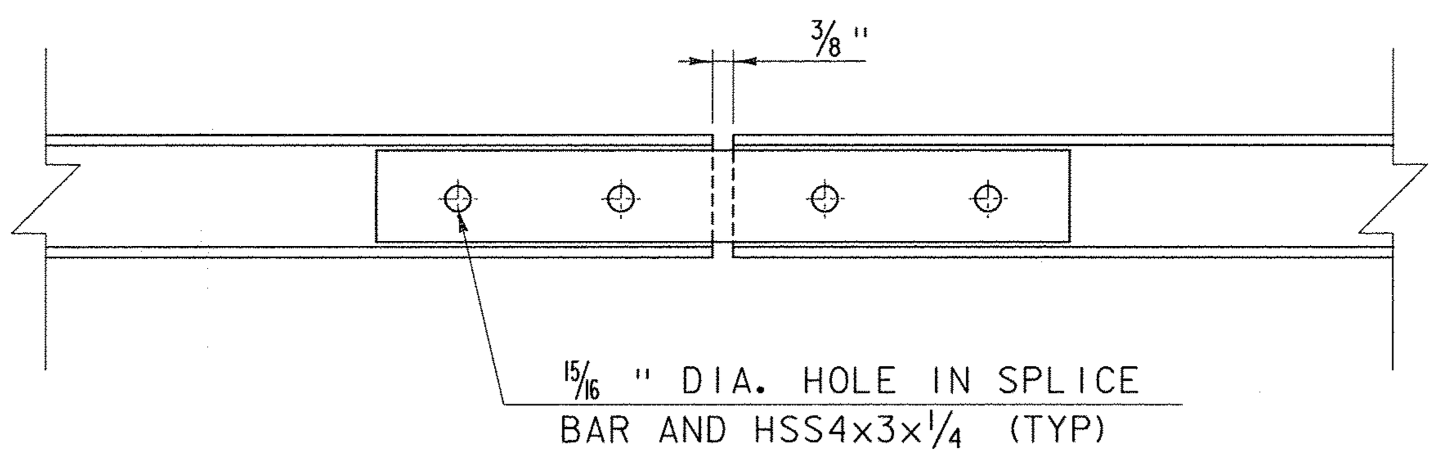
TOP RAIL FIXED SPLICE DETAIL



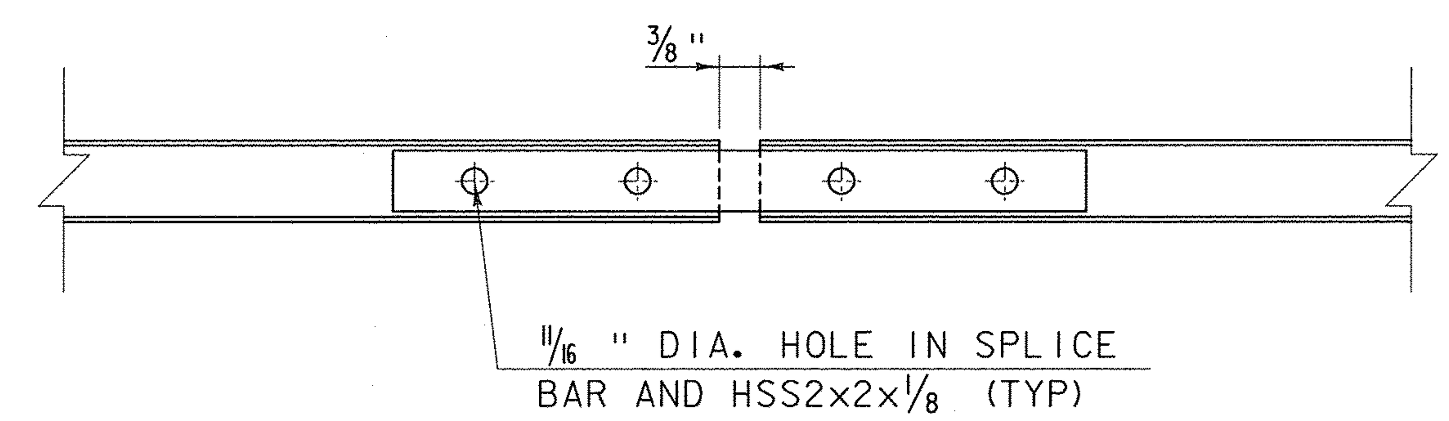
BOTTOM RAIL FIXED SPLICE DETAIL



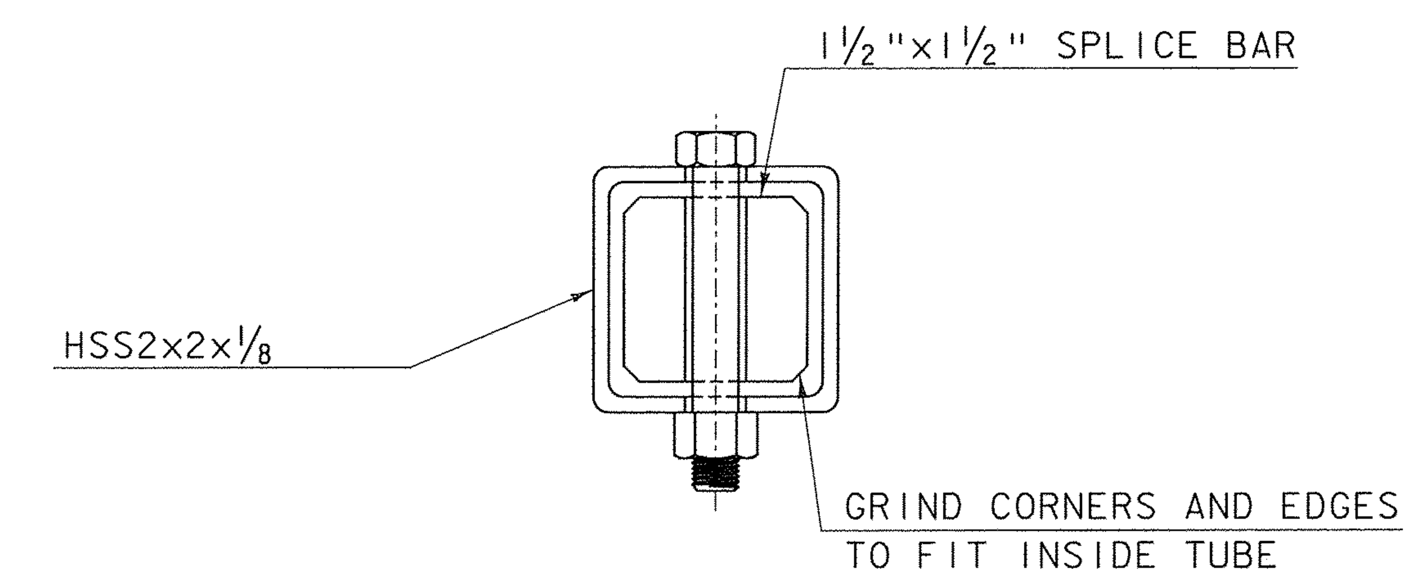
SECTION F-F



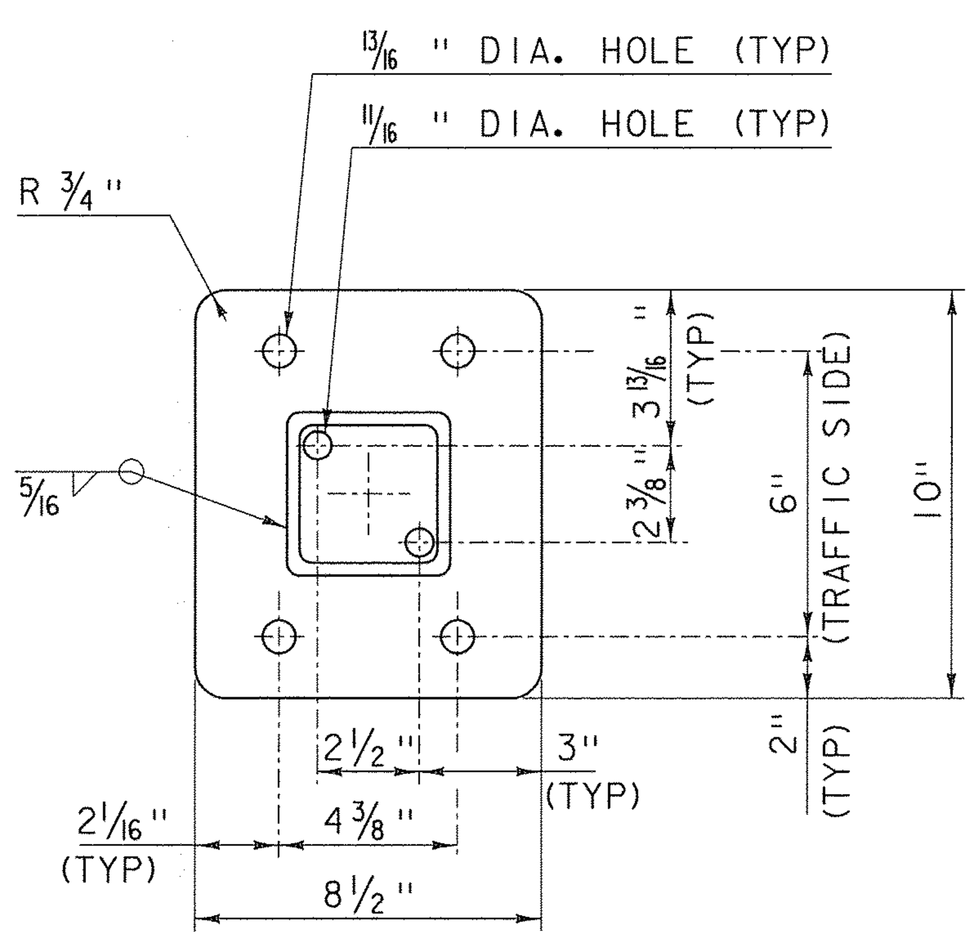
SECTION G-G



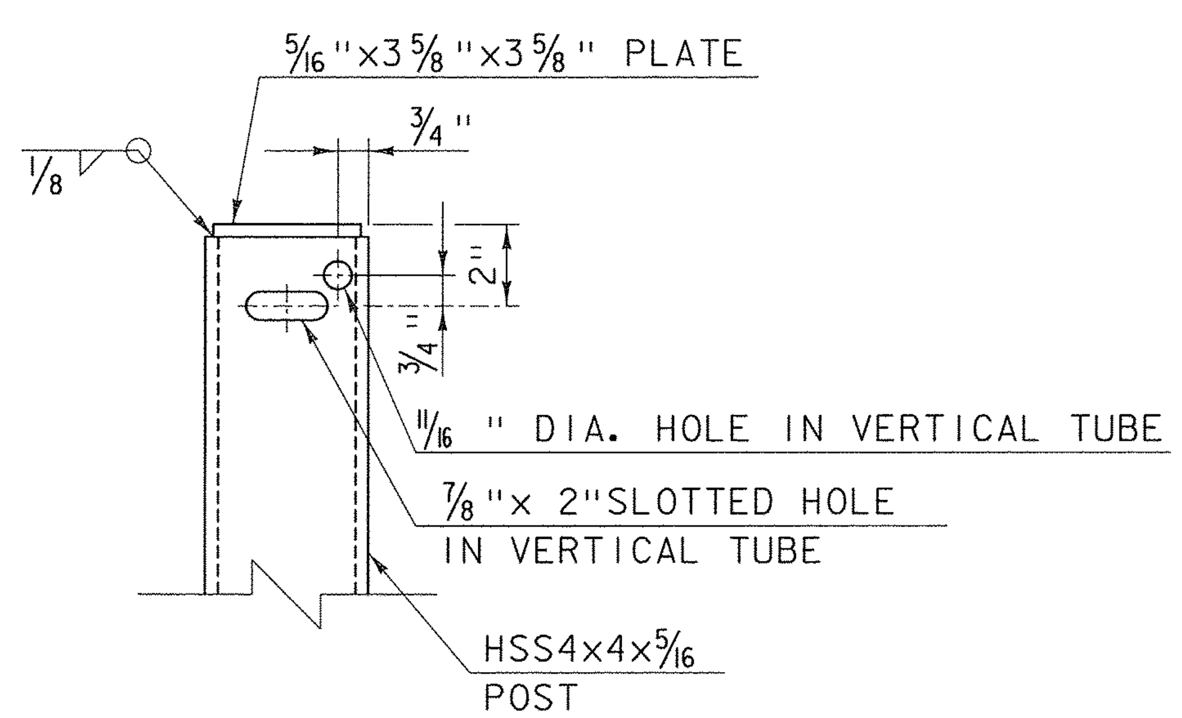
SECTION I-I



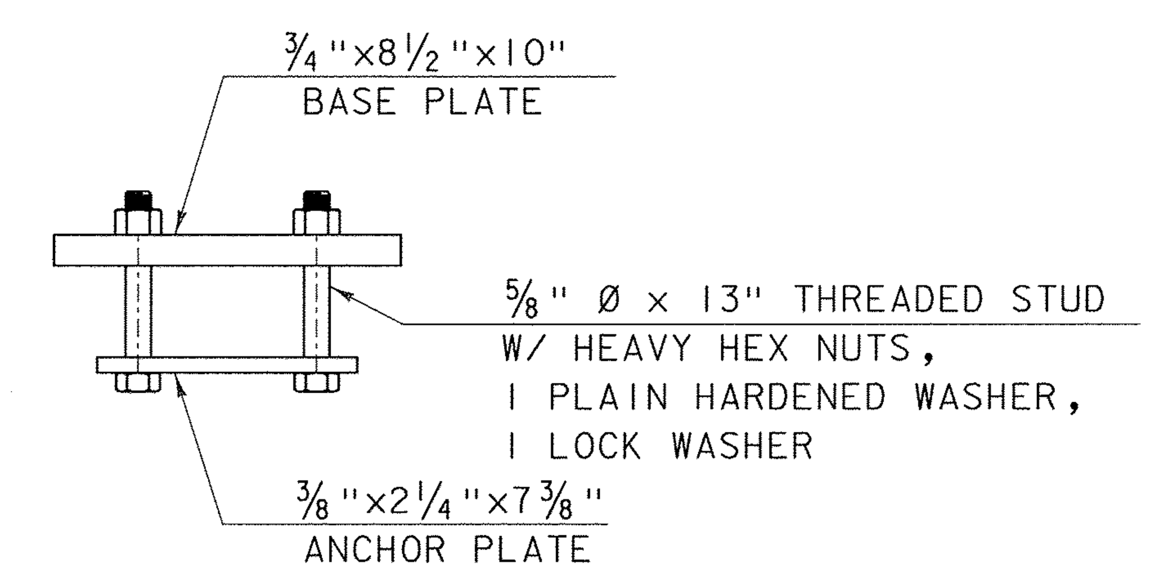
SECTION H-H



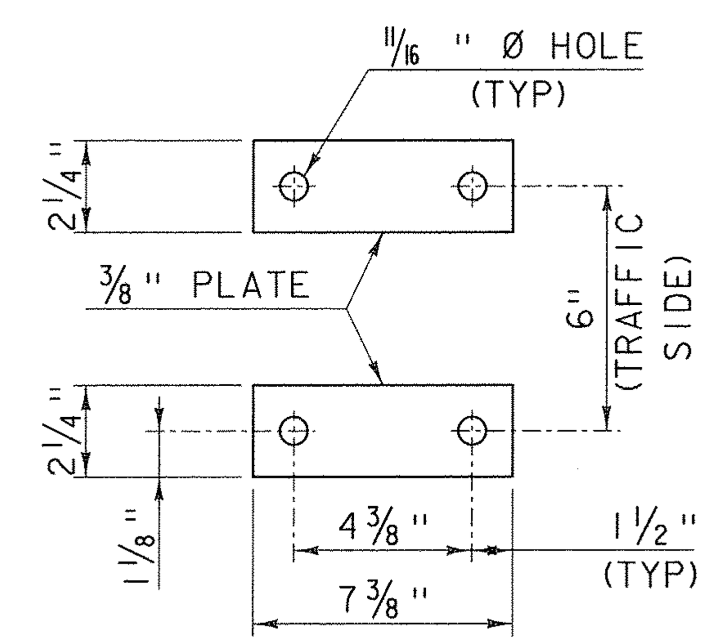
BASE PLATE



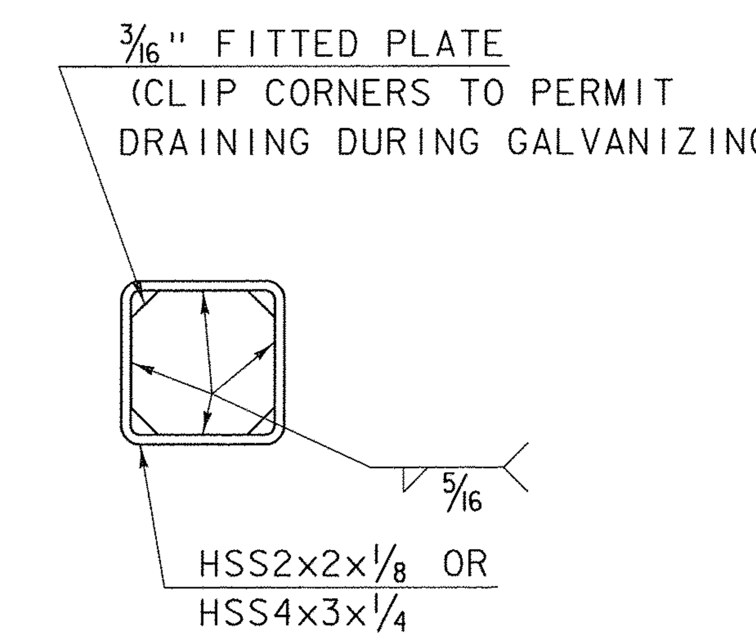
VERTICAL TUBE DETAIL
(FRONT VIEW)



RAIL POST ANCHORAGE



ANCHOR PLATES



END OF RAIL DETAIL

OTHER STDS. REQUIRED: G-1

REVISIONS AND CORRECTIONS

AUGUST 22, 2012 - ORIGINAL APPROVAL

APPROVED

Wm. Michael Hedges
STRUCTURES ENGINEER

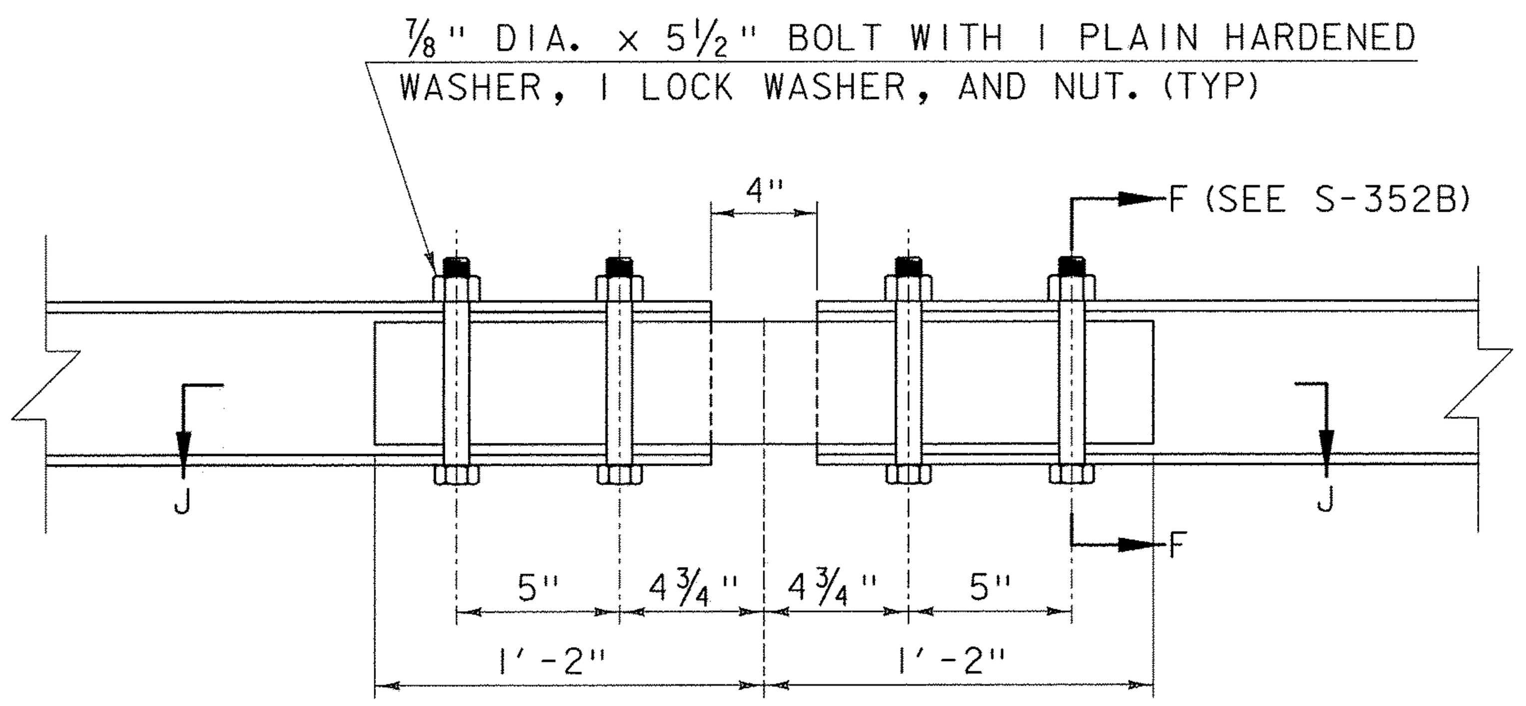
Richard Tetreault
DIRECTOR OF PROGRAM DEVELOPMENT

Mark D. Richter
FEDERAL HIGHWAY ADMINISTRATION

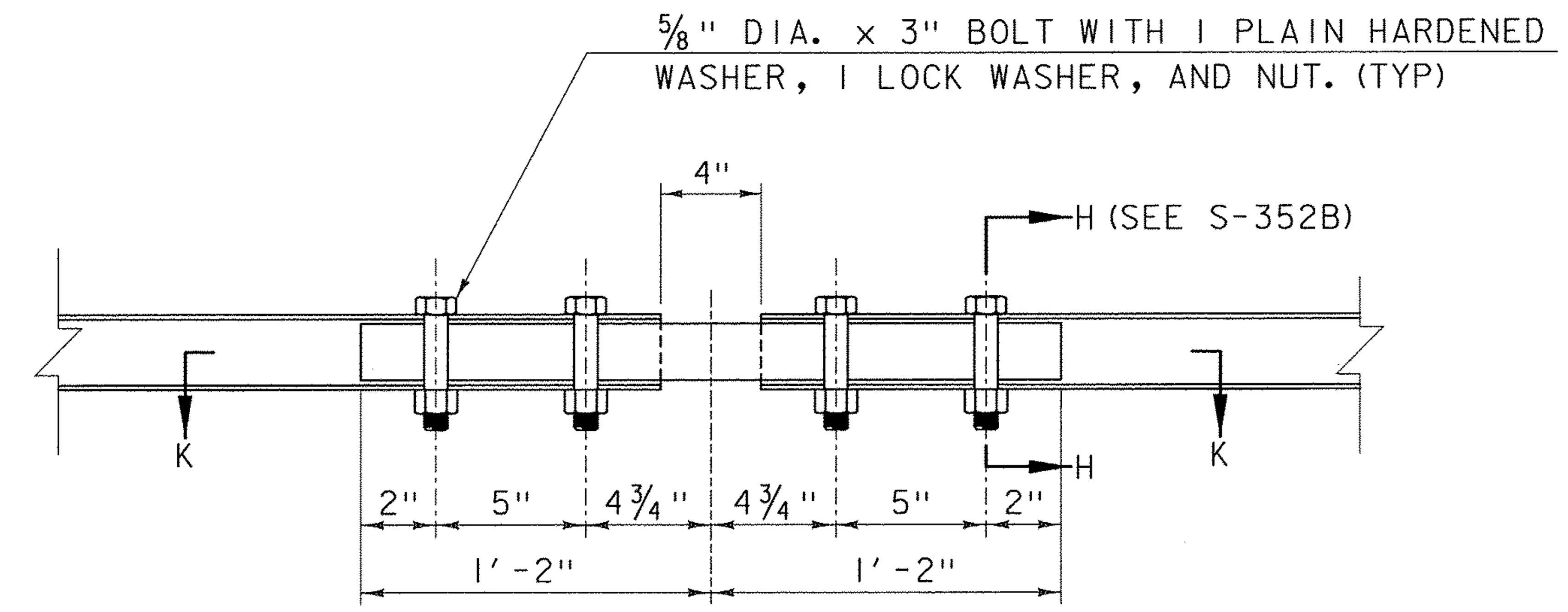
BRIDGE RAILING, GALVANIZED STEEL TUBING / CONCRETE COMBINATION

VERMONT AGENCY OF TRANSPORTATION

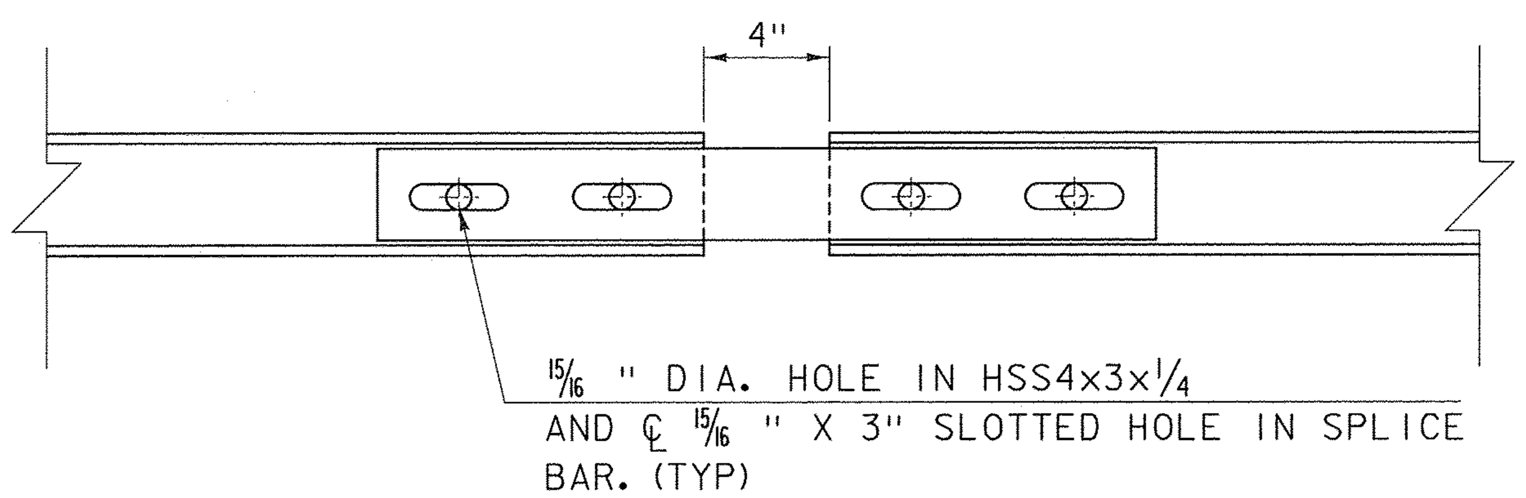
STANDARD
S-352B



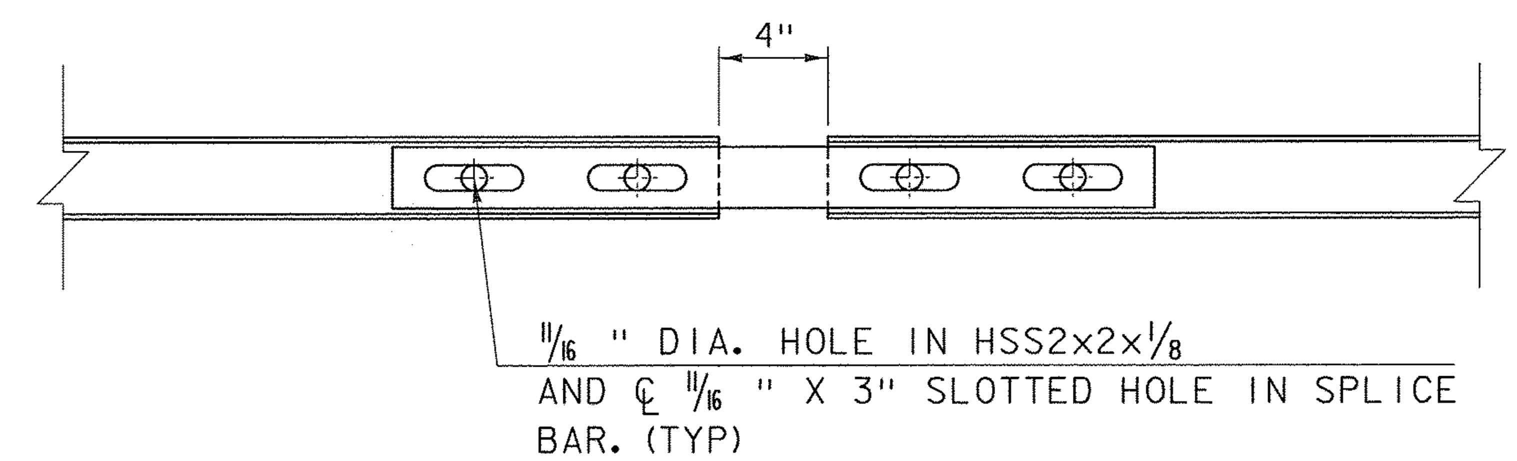
TOP RAIL EXPANSION SPLICE DETAIL



BOTTOM RAIL EXPANSION SPLICE DETAIL



SECTION J-J



SECTION K-K

OTHER STDS. REQUIRED: G-1

REVISIONS AND CORRECTIONS

AUGUST 22, 2012 - ORIGINAL APPROVAL

APPROVED

STRUCTURES ENGINEER

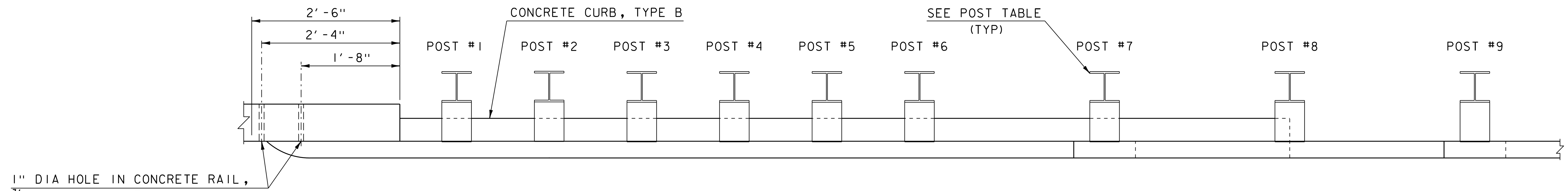
DIRECTOR OF PROGRAM DEVELOPMENT

FEDERAL HIGHWAY ADMINISTRATION

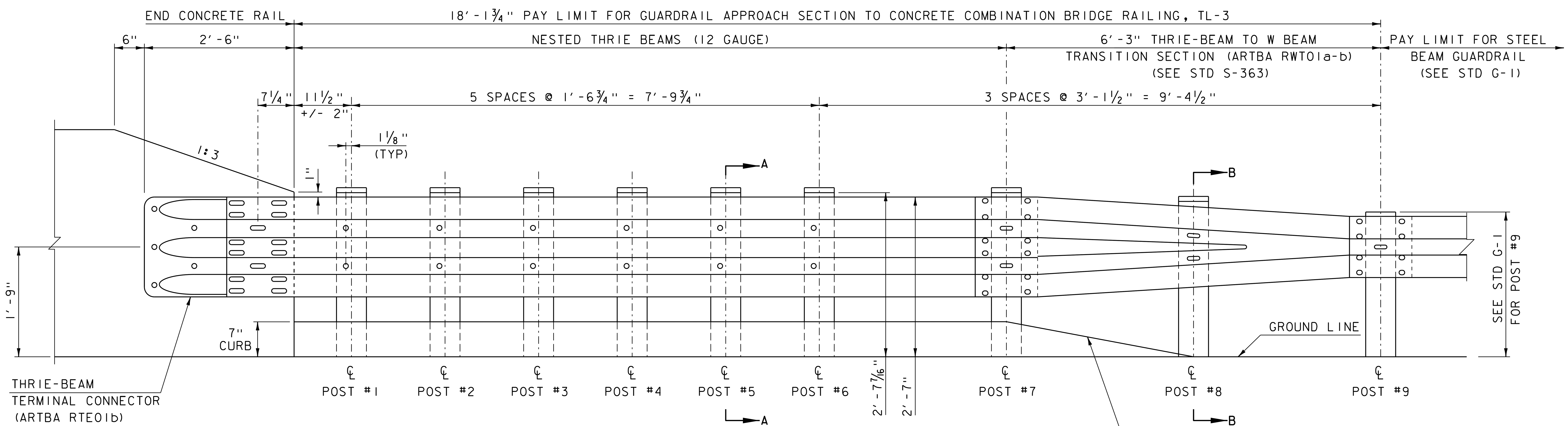
BRIDGE RAILING, GALVANIZED STEEL TUBING / CONCRETE COMBINATION

VERMONT AGENCY OF TRANSPORTATION

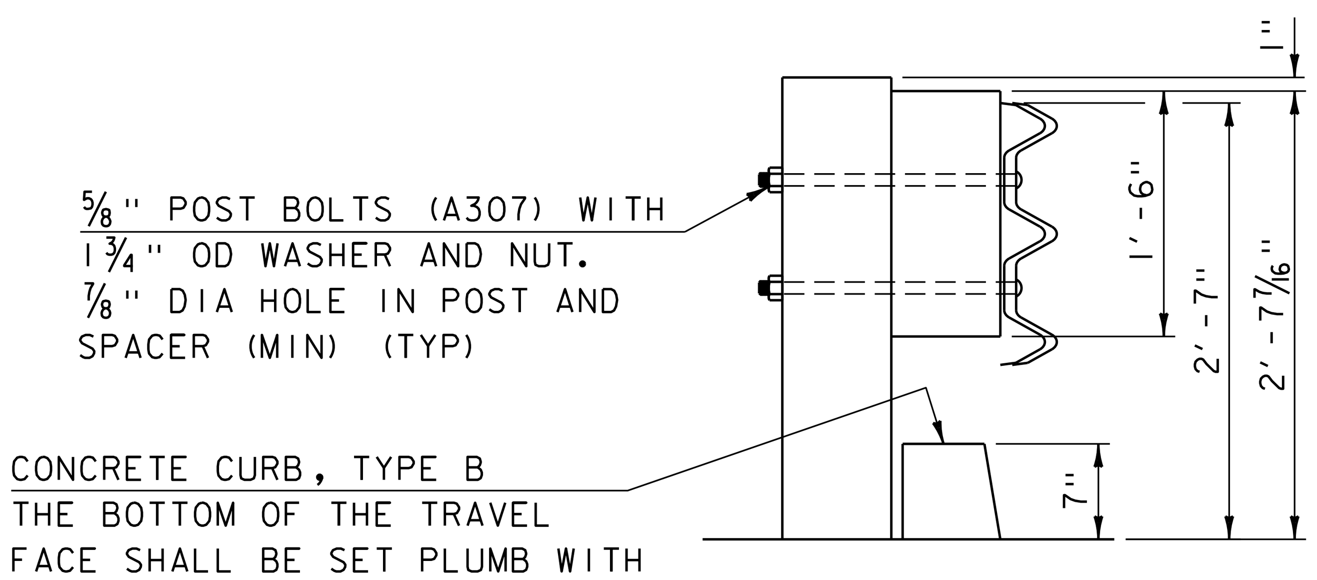
STANDARD S-352C



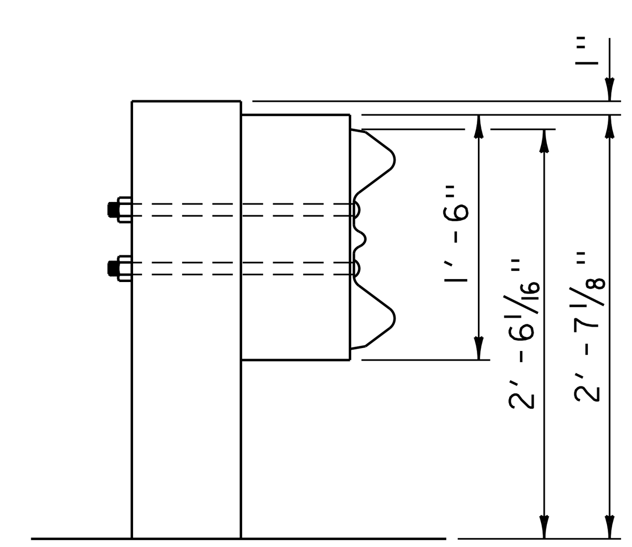
CONCRETE RAIL-GUARDRAIL TRANSITION PLAN



CONCRETE RAIL-GUARDRAIL TRANSITION ELEVATION



SECTION A-A



SECTION B-B

		WOOD	STEEL
SECTION		6"X8"	W6x9
OFFSET BLOCK		6"X8" WOOD	6"X8" RECESSED WOOD
POST LENGTH	POST# 1-6	7'-0"	7'-0"
	POST# 7&8	6'-0"	6'-0"
	POST# 9	SEE STD G-1	SEE STD G-1

POST TABLE

NOTES:

1. THRIE-BEAM TERMINAL CONNECTOR SHALL BE INCLUDED IN THE UNIT BID PRICE FOR GUARDRAIL APPROACH SECTION TO CONCRETE COMBINATION BRIDGE RAILING, TL-3.
2. UNLESS OTHERWISE DIRECTED BY THE ENGINEER, A COMPOSITE MATERIAL BLOCKOUT FROM THE APPROVED PRODUCTS LIST MAY BE SUBSTITUTED FOR A BLOCKOUT OF SIMILAR DIMENSIONS.
3. THIS RAILING MEETS THE REQUIREMENTS FOR A NCHRP REPORT 350 TL-3 SERVICE LEVEL.

REV.	DATE	DESCRIPTION
0	AUGUST 22, 2012	ORIGINAL APPROVAL
1	FEBRUARY 2, 2017	REVISED POST DIMENSIONS AND CURB LAYOUT

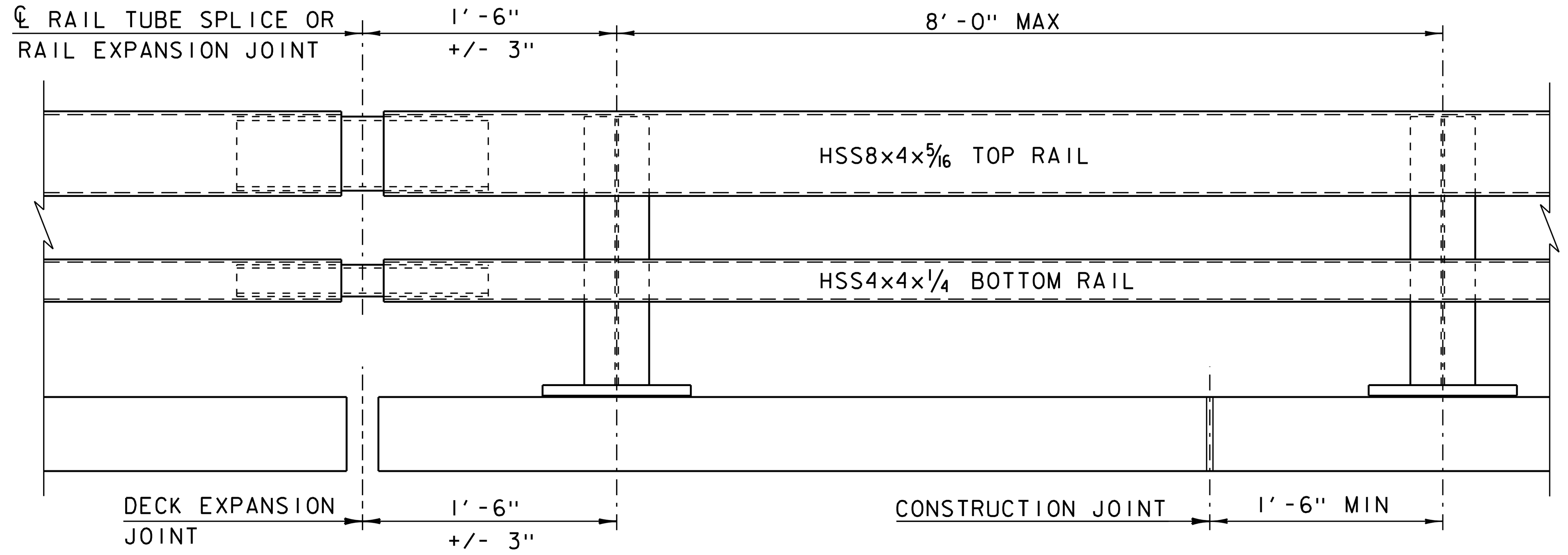
OTHER STANDARDS REQUIRED: C-10, G-1, S-363

VTRANS AND FHWA APPROVAL ON FILE WITH CONTRACT ADMINISTRATION

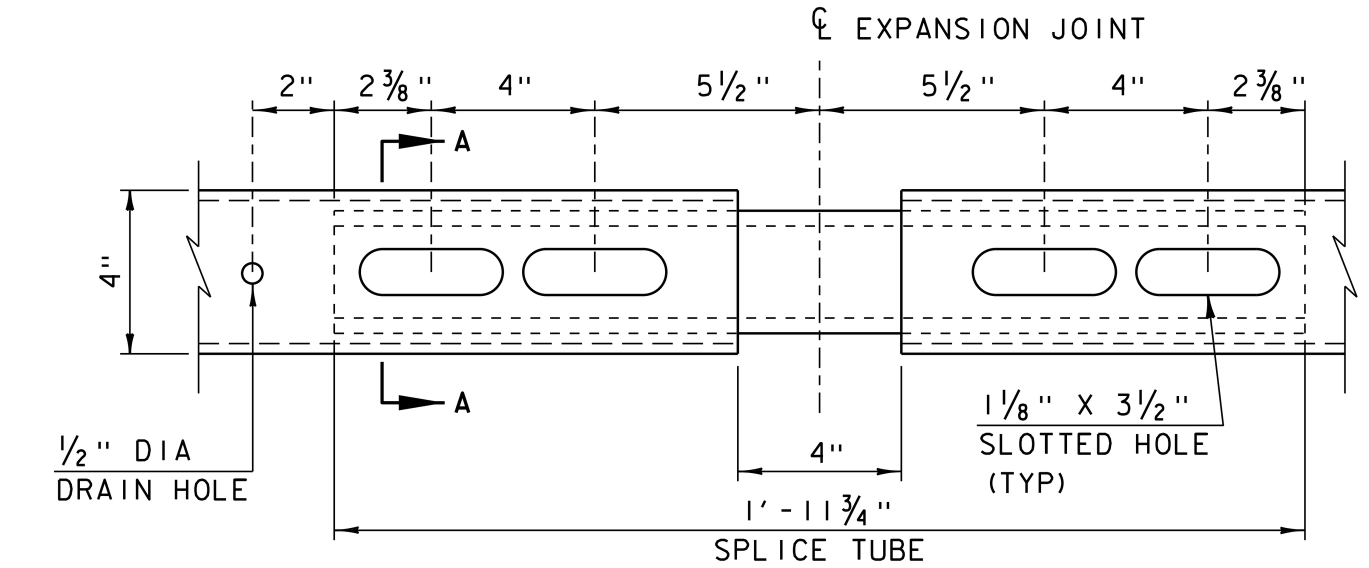
GUARDRAIL APPROACH SECTION TO CONCRETE COMBINATION BRIDGE RAILING, TL-3

VTrans Working to Get You There VERMONT AGENCY OF TRANSPORTATION

STANDARD S-352D

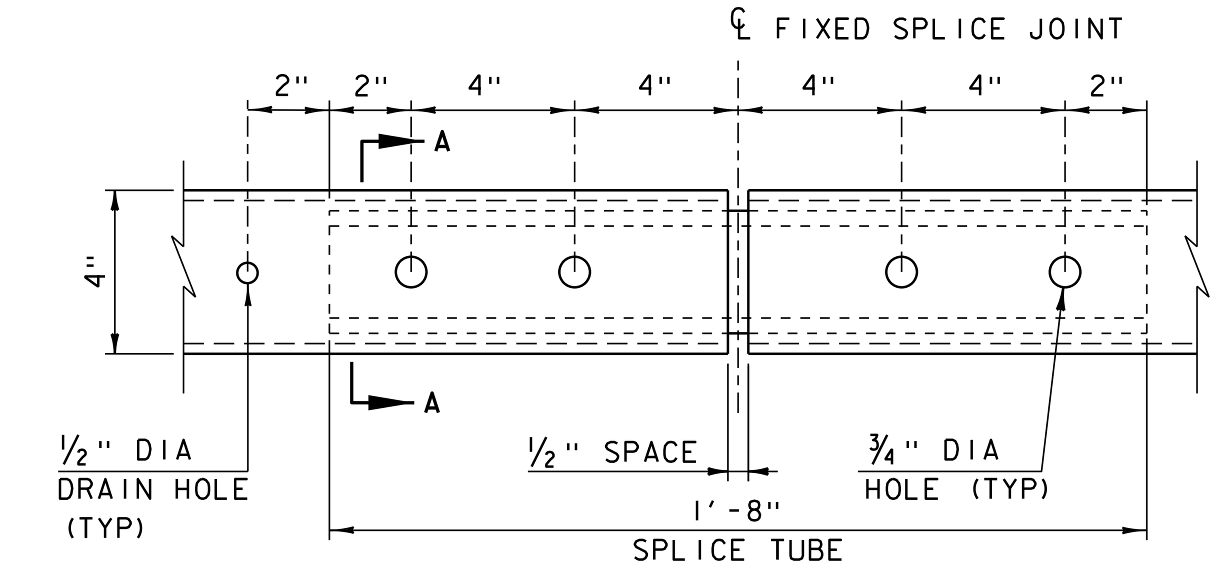


BRIDGE RAILING ELEVATION



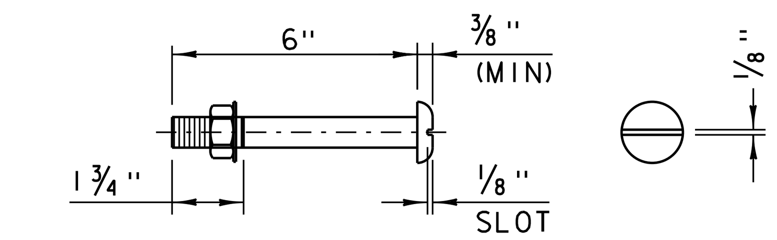
EXPANSION JOINT DETAIL

(BOTTOM VIEW)



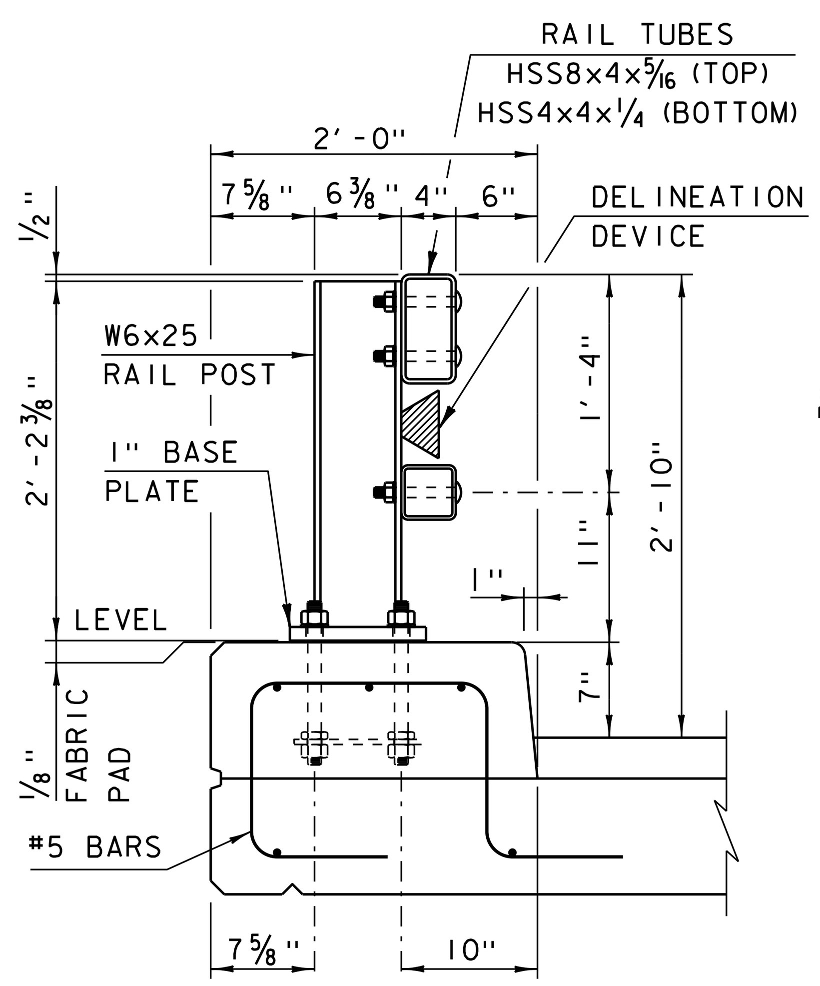
FIXED SPLICE JOINT DETAIL

(BOTTOM VIEW)

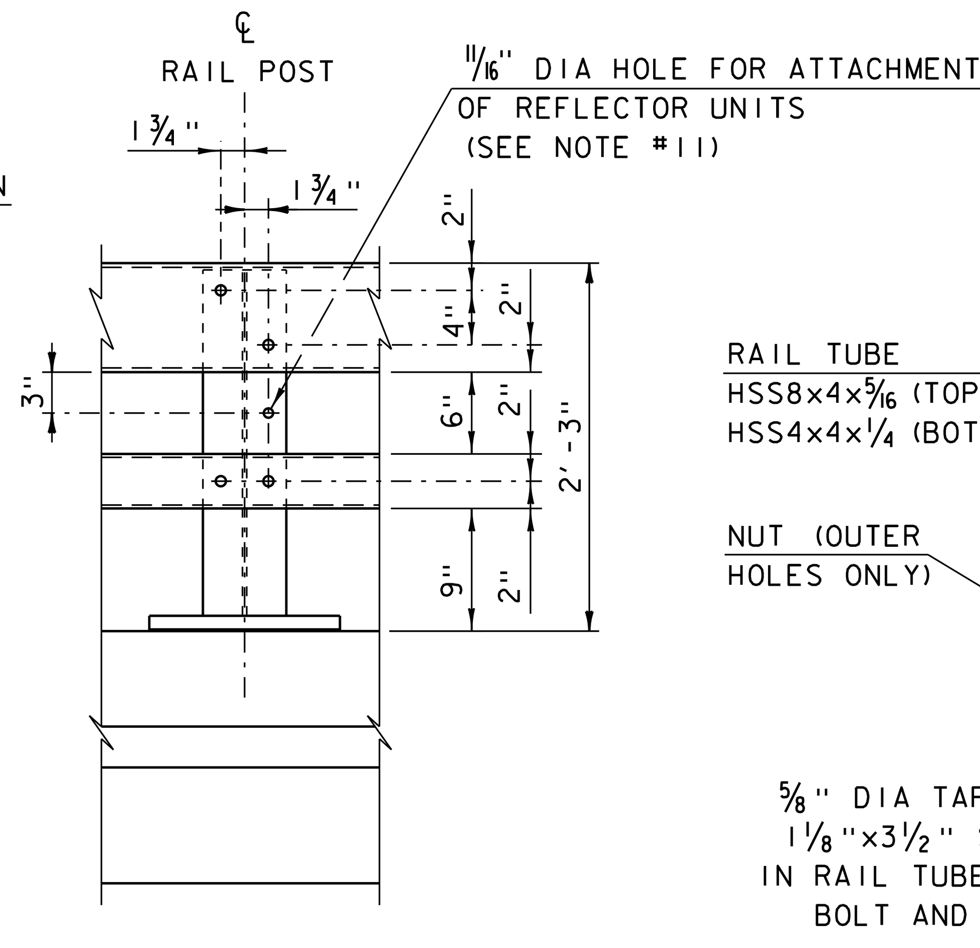


3/4" DIA A449 (TYPE 1) ROUND HEAD BOLT

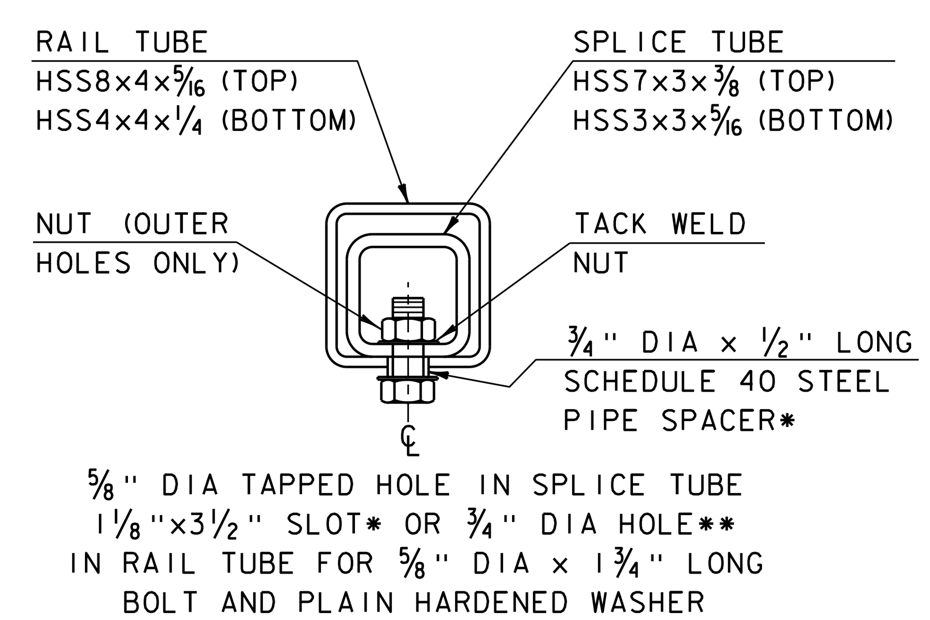
(WITH WASHER AND PREVAILING TORQUE TYPE LOCK NUT) (SEE NOTE #8)
ONLY FULL DIAMETER BODY BOLTS WILL BE ALLOWED.



TYPICAL SECTION

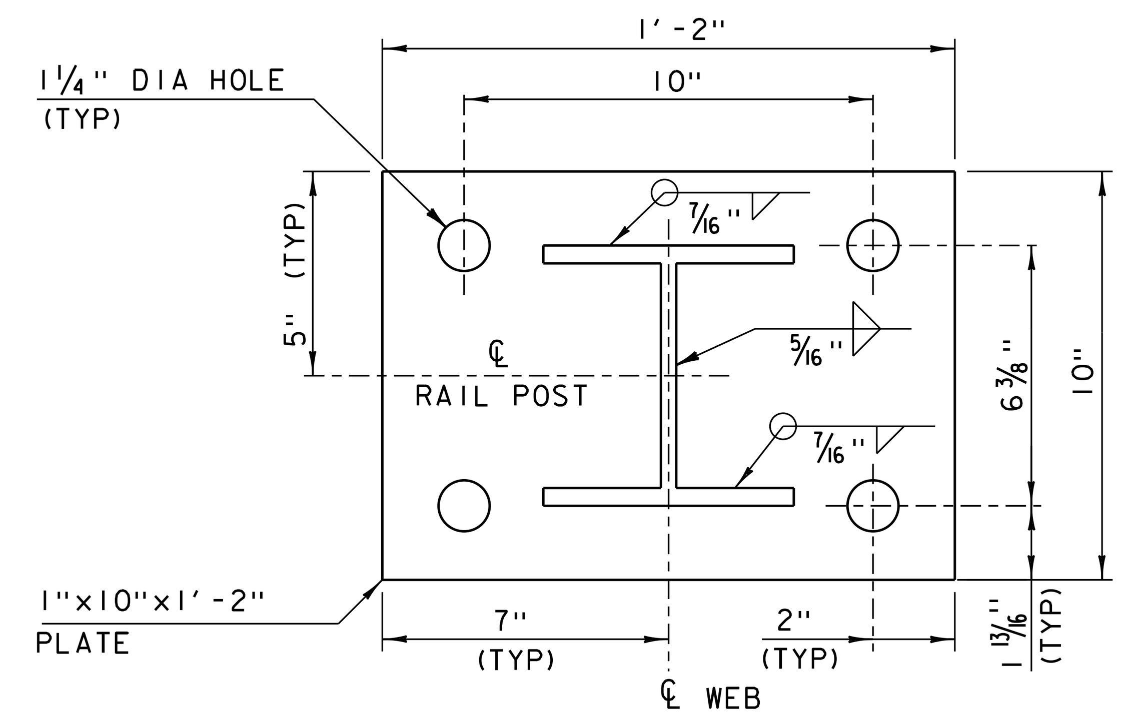


ELEVATION

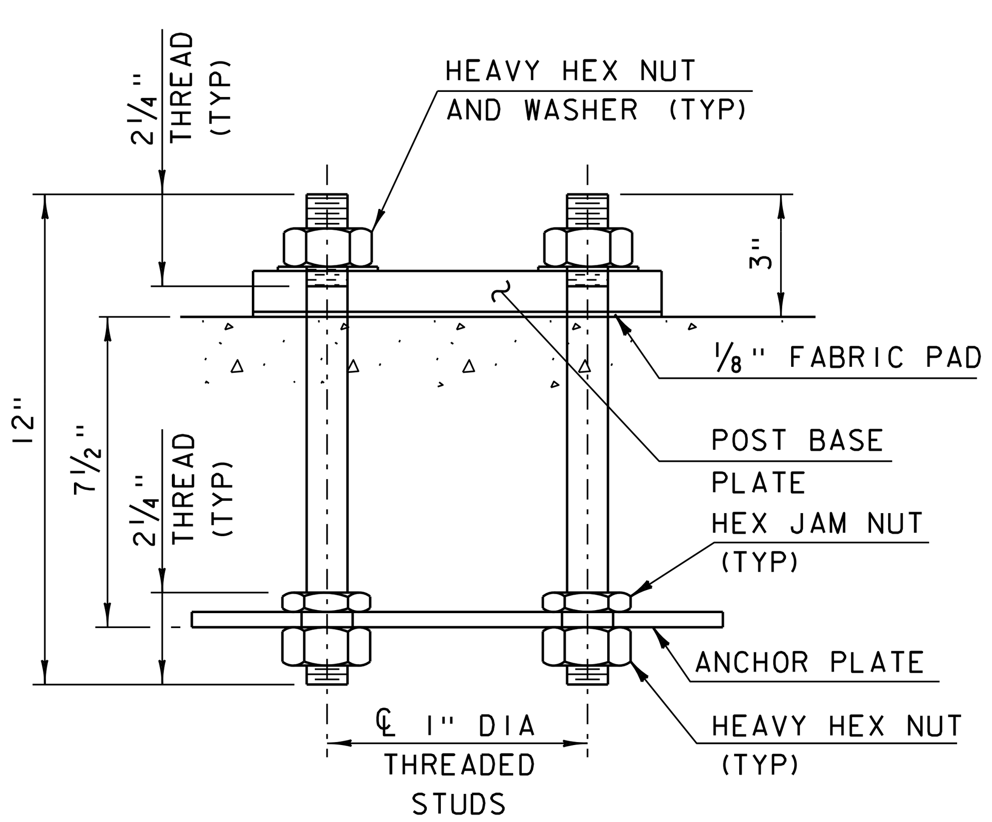


A-A RAIL TUBE SPLICE AND
RAIL EXPANSION JOINT SECTION

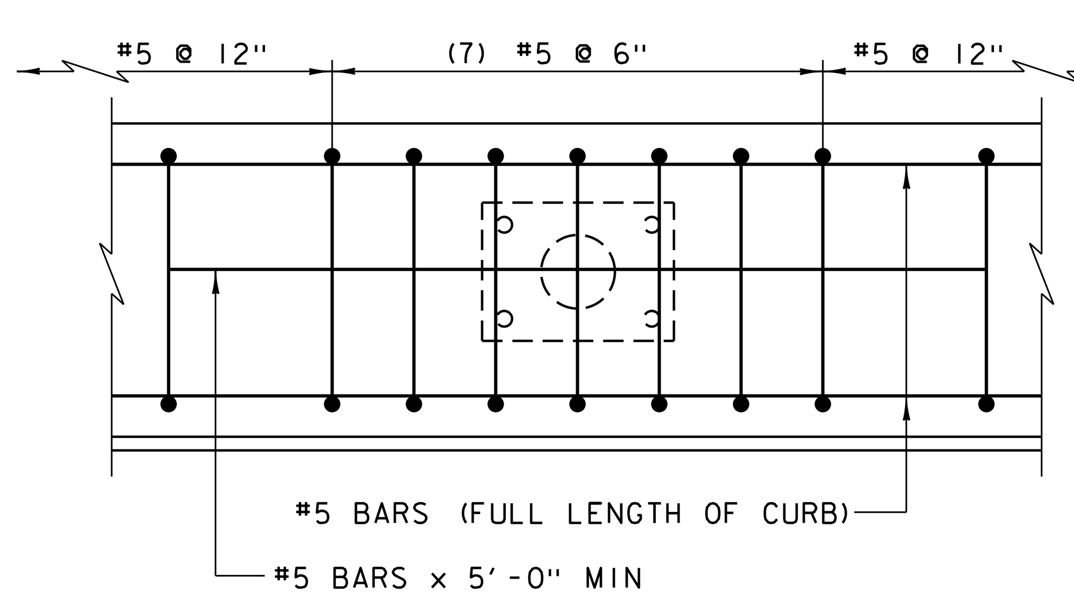
*EXPANSION JOINT **SPLICE



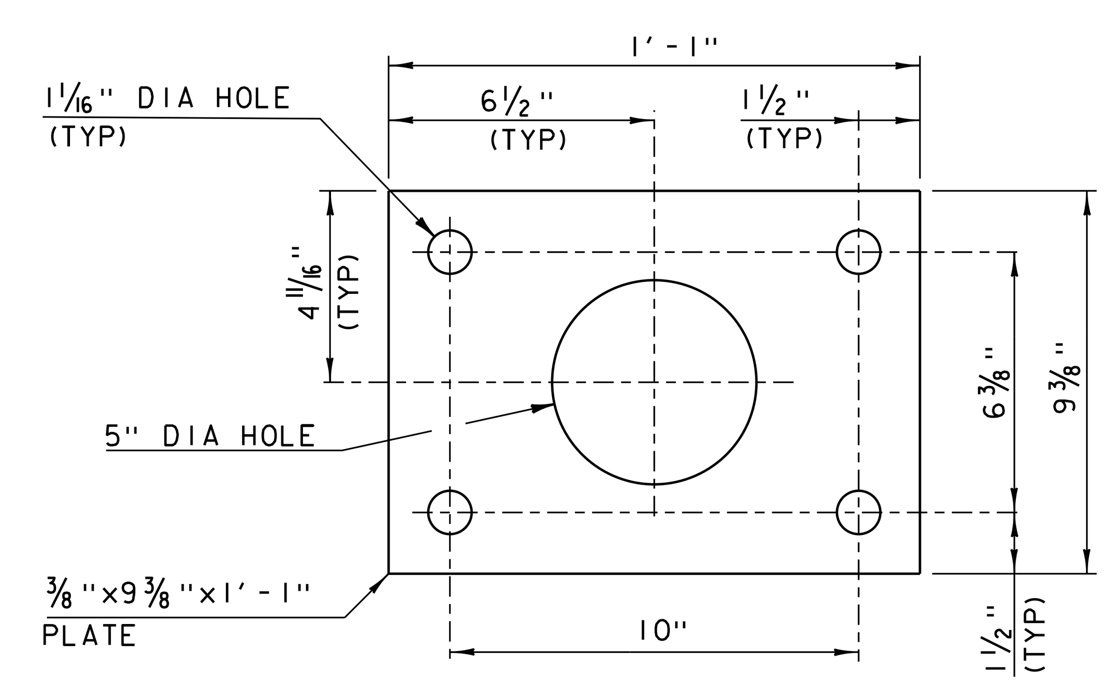
POST BASE PLATE



RAIL POST ANCHORAGE



CURB REINFORCING PLAN



ANCHOR PLATE

NOTES:

1. ALL WORK AND MATERIALS SHALL CONFORM TO SECTION 525.
2. PRIOR TO GALVANIZING THE ASSEMBLED POST, GRIND ALL EDGES TO A MINIMUM RADIUS OF 1/16".
3. ALL POSTS SHALL BE SET NORMAL TO GRADE.
4. SECTIONS OF RAIL TUBE SHALL BE ATTACHED TO A MINIMUM OF TWO BRIDGE RAIL POSTS AND PREFERABLY TO AT LEAST FOUR POSTS.
5. RAIL TUBE EXPANSION JOINTS SHALL BE PROVIDED IN ANY RAIL BAY SPANNING THE END OF AN INTEGRAL ABUTMENT BRIDGE AND AT ALL SUPERSTRUCTURE EXPANSION JOINTS. EXPANSION JOINT WIDTH SHALL BE 4" AT 68°F AND WILL BE ADJUSTED IN THE FIELD BY THE ENGINEER FOR OTHER TEMPERATURES.
6. HOLES IN RAILS FOR RAIL TUBE ATTACHMENT MAY BE FIELD-DRILLED. HOLES SHALL BE COATED WITH AN APPROVED ZINC-RICH PAINT PRIOR TO INSTALLATION.
7. RAIL POST ANCHORING NUTS SHALL BE TIGHTENED TO A SNUG FIT AND GIVEN AN ADDITIONAL ONE-EIGHTH TURN.
8. RAIL TUBES SHALL BE ATTACHED USING 3/4" FULL DIAMETER BODY ASTM A 449 (TYPE 1) ROUND HEAD BOLTS INSERTED THROUGH THE FACE OF THE TUBE. HOLES IN POSTS SHALL BE 1/16" LARGER THAN THE BOLT SIZE.
9. ANY BENDING OF RAIL SHALL BE DONE AT A FABRICATION PLANT ACCORDING TO A PROCEDURE PROVIDED BY THE FABRICATOR.
10. THE MINIMUM DISTANCE FROM THE POST TO AN EXPANSION JOINT SHALL BE DETERMINED BY THE MINIMUM EDGE DISTANCE OF 5" FROM ANY ANCHOR STUD TO THE END OF THE SLAB, OR TO THE EXPANSION JOINT RECESS POUR, IF ONE IS USED.
11. SEE STANDARD DRAWING G-1 FOR DETAILS OF DELINEATORS. A DELINEATOR SHALL BE INSTALLED AT 30 FOOT SPACING OR THE NEAREST POST. WHITE IS TO BE INSTALLED ON THE DRIVER'S RIGHT. FOR ONE WAY BRIDGES, YELLOW IS TO BE INSTALLED ON THE DRIVER'S LEFT. PAYMENT SHALL BE INCIDENTAL TO OTHER ITEMS.
12. THIS RAILING MEETS THE REQUIREMENTS FOR A TL-4 SERVICE LEVEL.

REV.	DATE	DESCRIPTION
0	DECEMBER 14, 2009	ORIGINAL APPROVAL
1	APRIL 23, 2012	GENERAL UPDATE 2012
2	FEBRUARY 2, 2017	BORDER UPDATE, MISC. REVISIONS

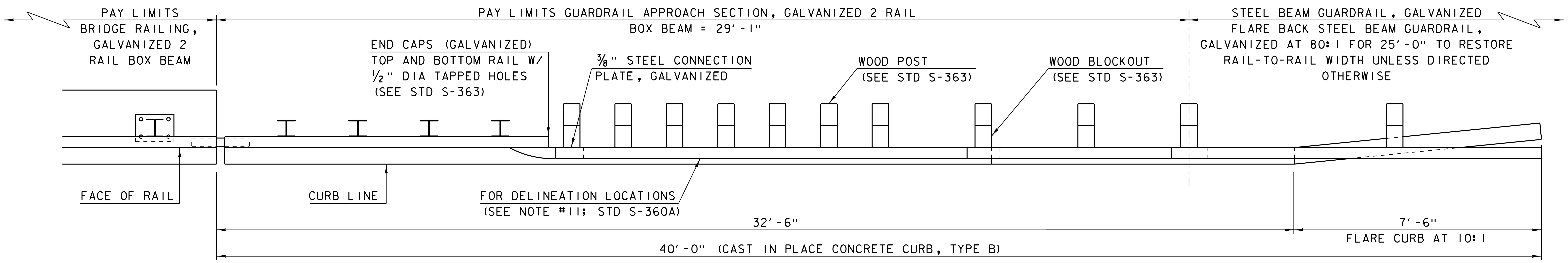
OTHER STANDARDS REQUIRED: G-1

VTRANS AND FHWA APPROVAL ON FILE WITH CONTRACT ADMINISTRATION

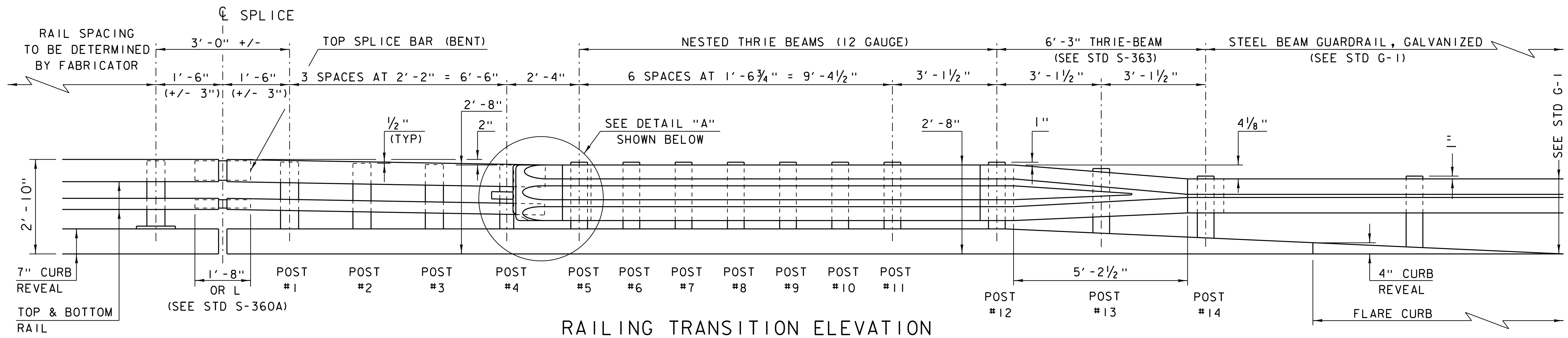
BRIDGE RAILING, GALVANIZED
2 RAIL BOX BEAM

VTrans Working to Get You There
VERMONT AGENCY OF TRANSPORTATION

STANDARD
S-360A



RAILING TRANSITION PLAN

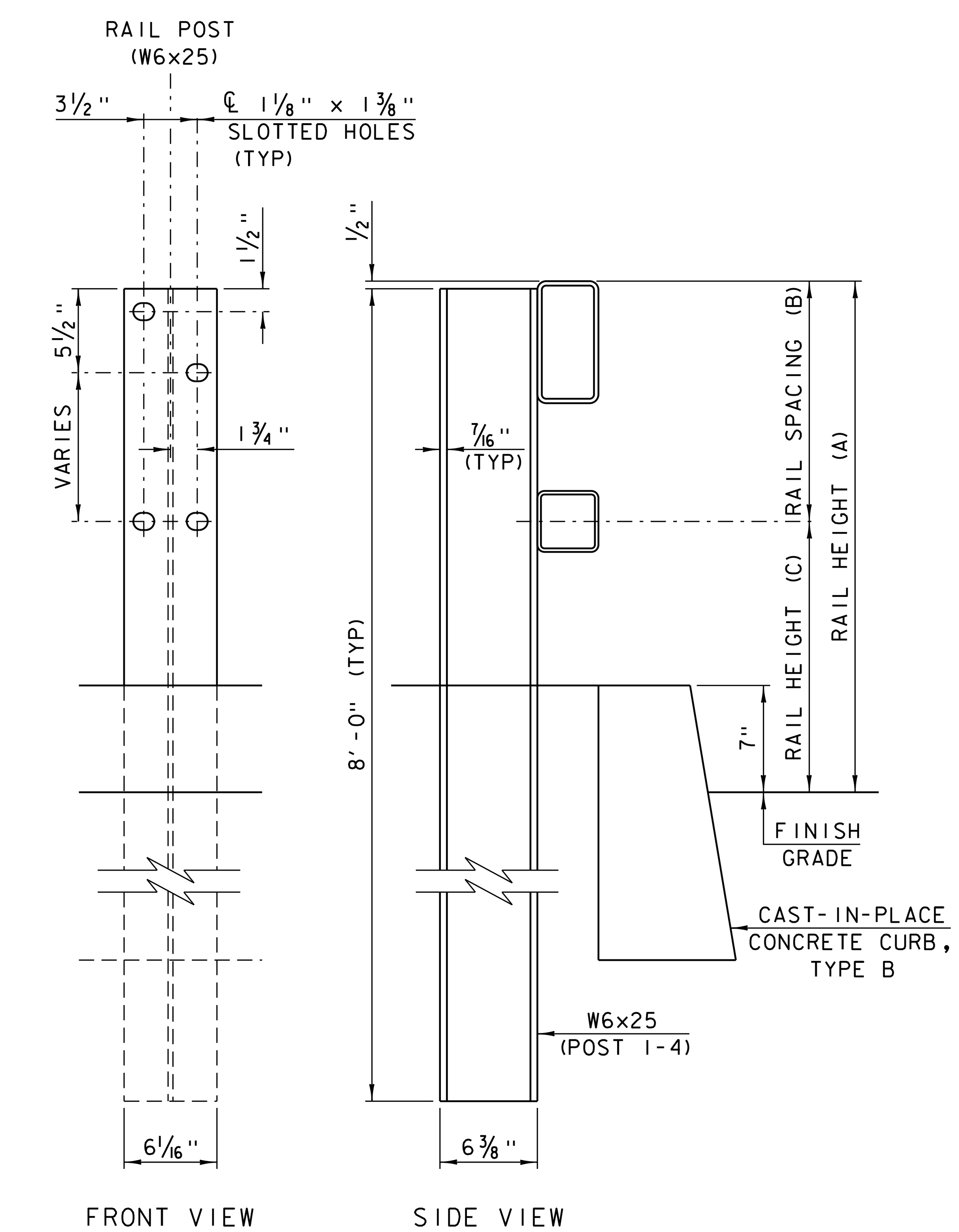


RAILING TRANSITION ELEVATION

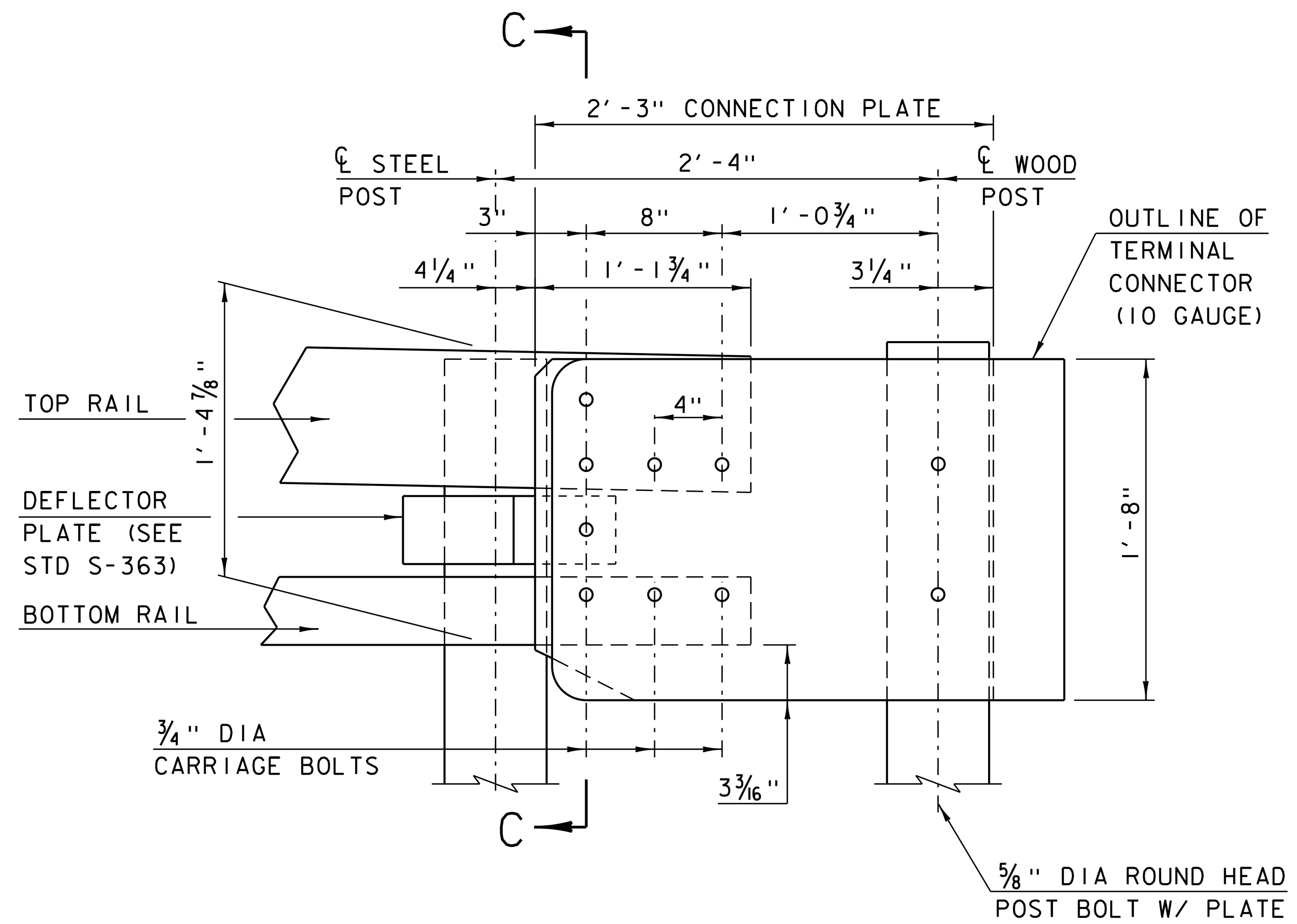
POST NUMBER	RAIL HEIGHT (A)	RAIL SPACING (B)	RAIL HEIGHT (C)
1	2'-9½"	1'-3¾"	1'-5¾"
2	2'-9"	1'-3½"	1'-5½"
3	2'-8½"	1'-3$\frac{5}{16}$"	1'-5$\frac{5}{16}$"
4	2'-8"	1'-2⅞"	1'-5⅛"

NOTES:

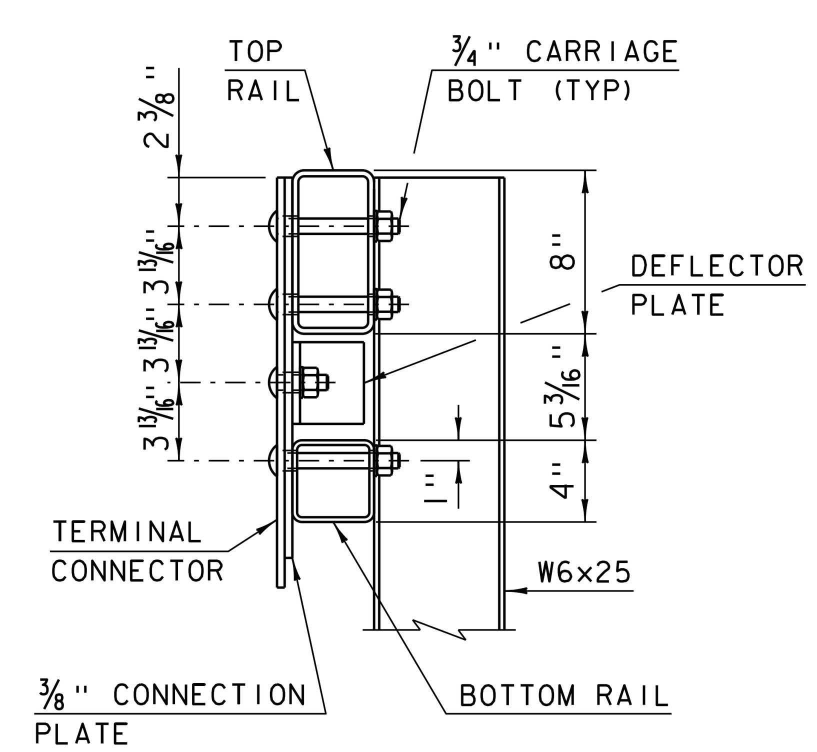
1. PAYMENT FOR GUARDRAIL APPROACH SECTION, GALVANIZED 2 RAIL BOX BEAM SHALL INCLUDE THE TERMINAL CONNECTOR, CONNECTION PLATE, DEFLECTOR PLATE, RAIL, POSTS, BLOCKS AND ATTACHMENT HARDWARE.
2. ALL APPROACH RAIL SPLICES SHALL BE LAPPED IN THE DIRECTION OF TRAFFIC FLOW.
3. TUBE AND STEEL POST MATERIALS, DIMENSION SIZES AND NOTES SHALL BE THE SAME AS THOSE OF THE BRIDGE RAIL, UNLESS OTHERWISE NOTED.
4. APPROACH RAIL BOLTS SHALL BE ASTM A307 GRADE A AND NUTS SHALL BE AASHTO M291 (ASTM A563 GRADE A OR BETTER) (GALVANIZED). WASHERS SHALL BE ASTM F844.
5. PRIOR TO GALVANIZING, GRIND ALL EDGES TO A MINIMUM RADIUS OF $\frac{1}{16}$".



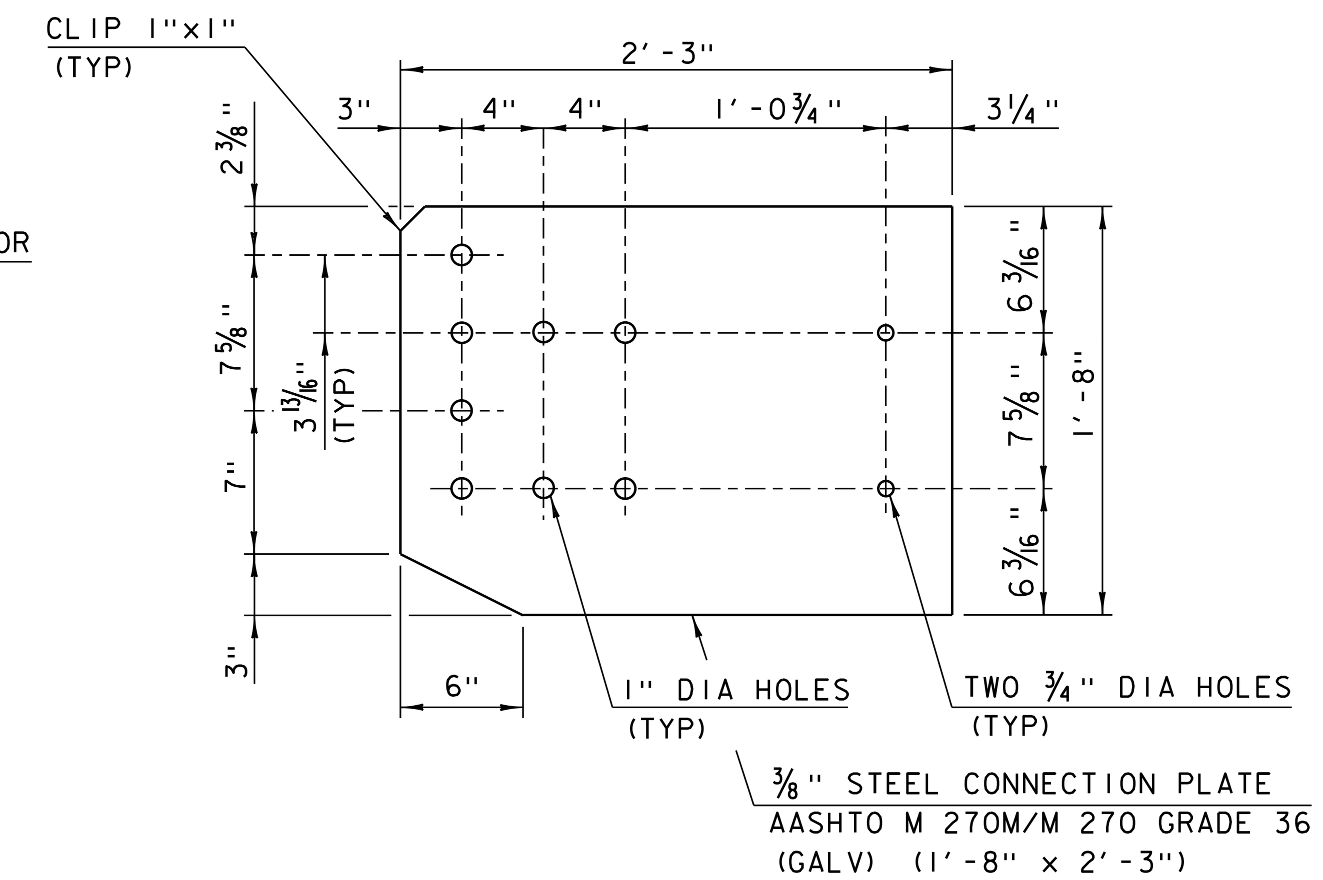
RAIL POST SECTION (POSTS 1-4)



DETAIL A



SECTION C-C (CONNECTION PLATE)



CONNECTION PLATE

REV.	DATE	DESCRIPTION
0	DECEMBER 14, 2009	ORIGINAL APPROVAL
1	APRIL 23, 2012	GENERAL UPDATE 2012
2	MARCH 10, 2017	BORDER UPDATE, MISC. REVISIONS

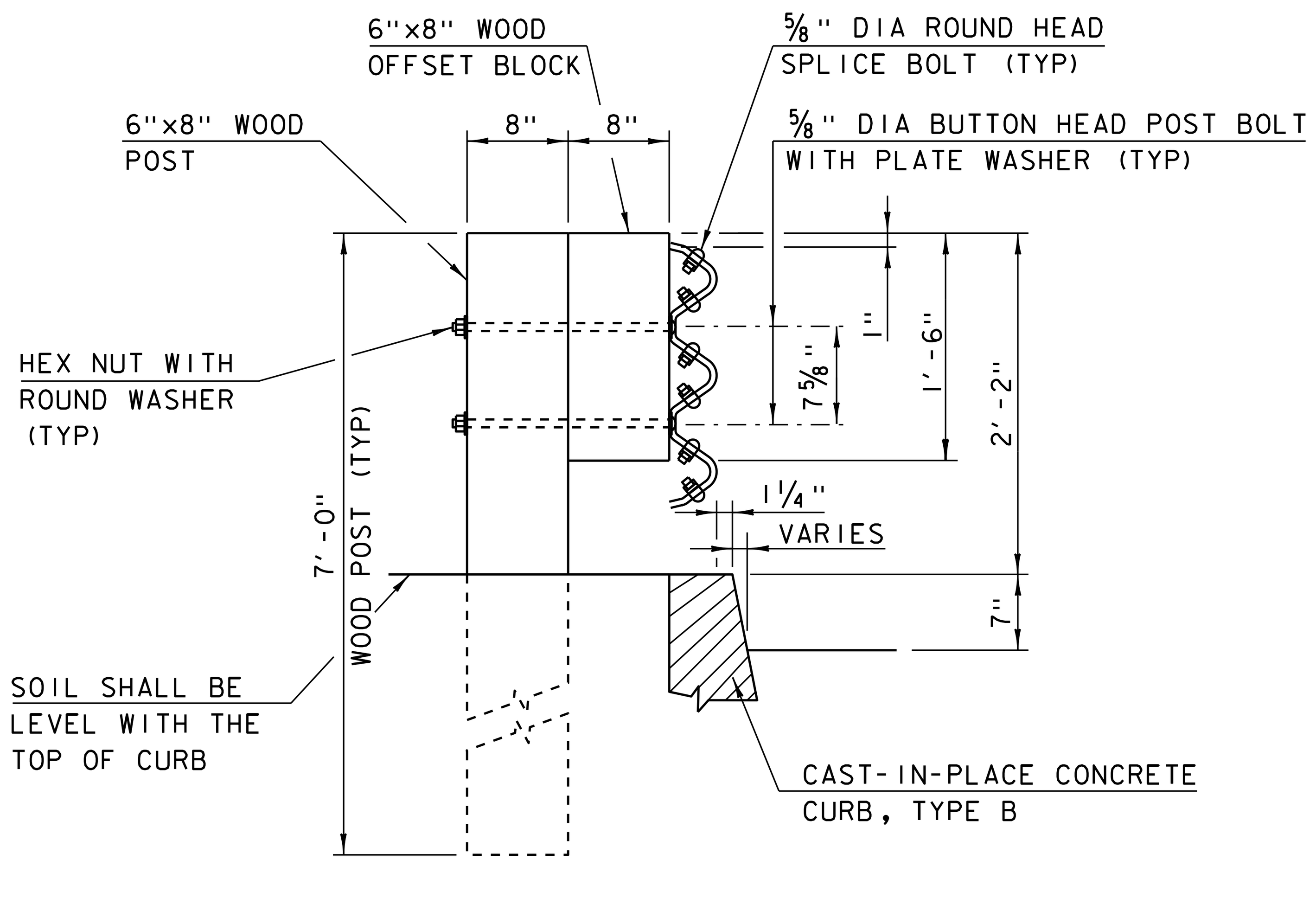
OTHER STANDARDS REQUIRED: C-10, G-1, S-360A, S-363

VTRANS AND FHWA APPROVAL ON FILE WITH CONTRACT ADMINISTRATION

GUARDRAIL APPROACH SECTION, GALVANIZED 2 RAIL BOX BEAM

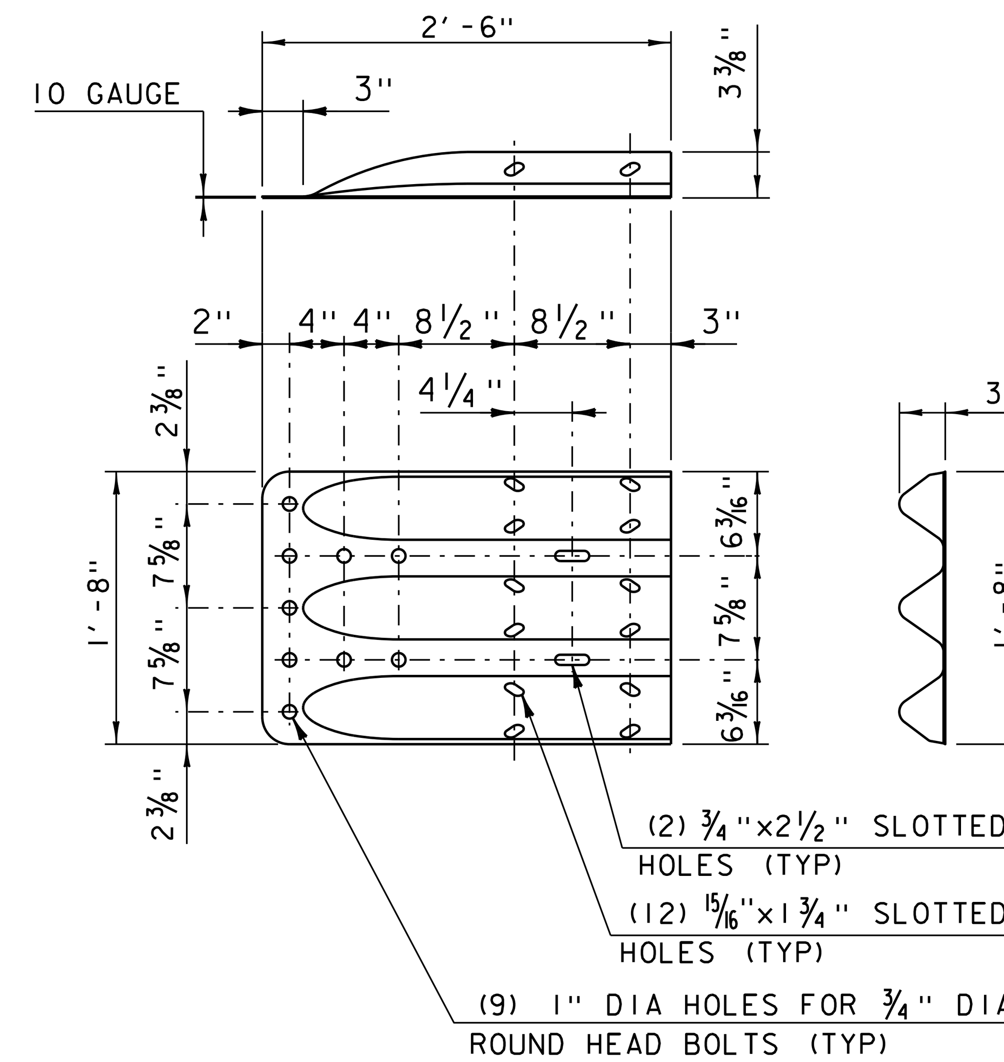
VTrans Working to Get You There VERMONT AGENCY OF TRANSPORTATION

STANDARD S-360B



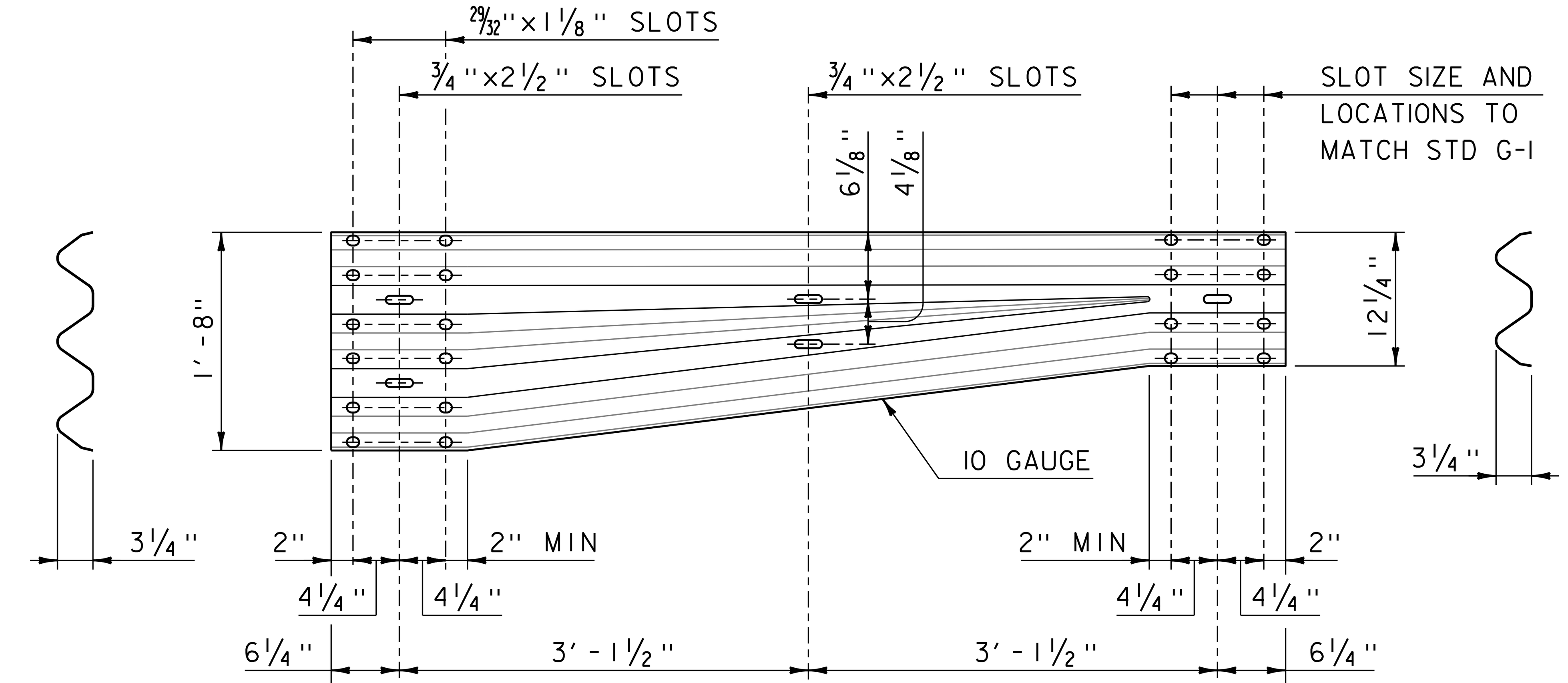
THRIE BEAM GUARDRAIL ASSEMBLY

(SEE STD S-360B)



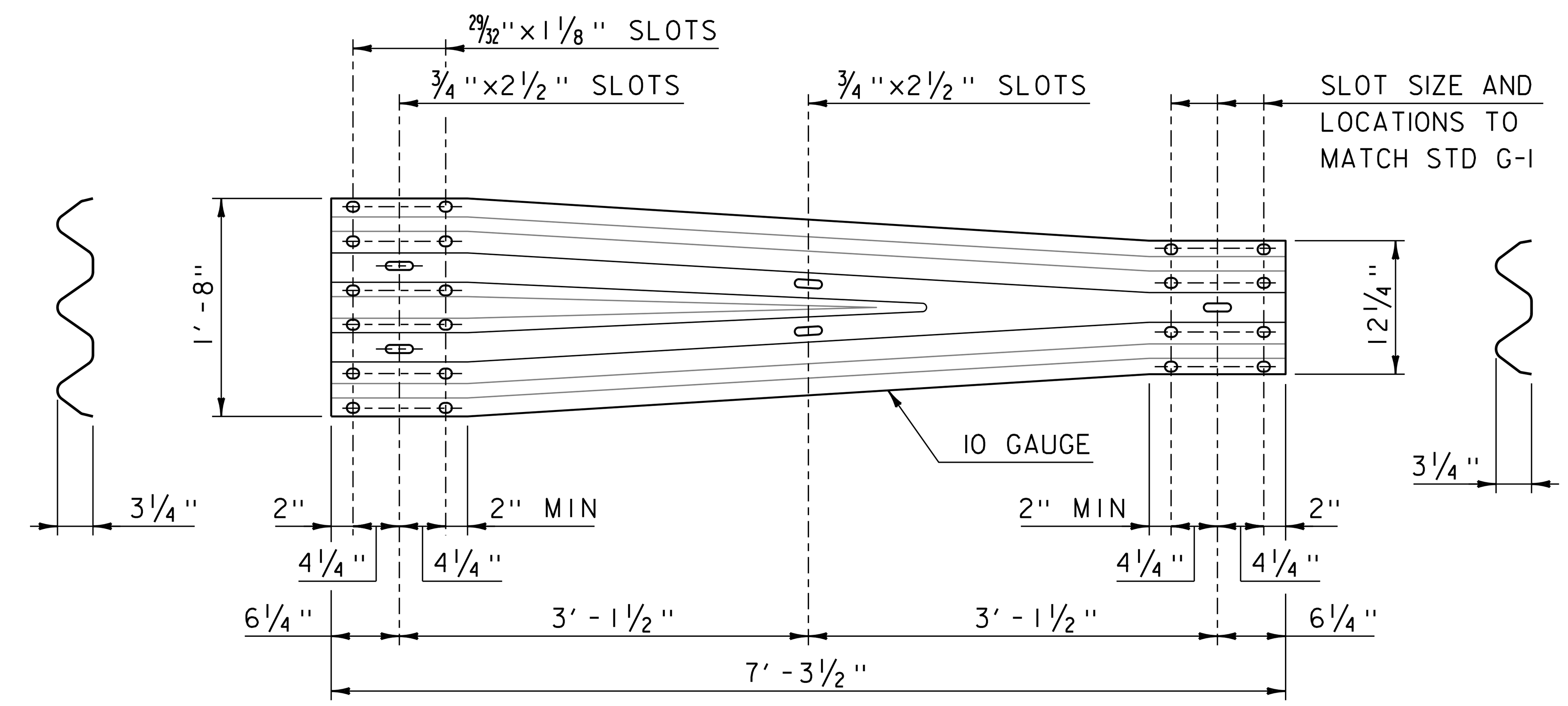
THRIE-BEAM TERMINAL CONNECTOR

(ARTBA RTE01b)



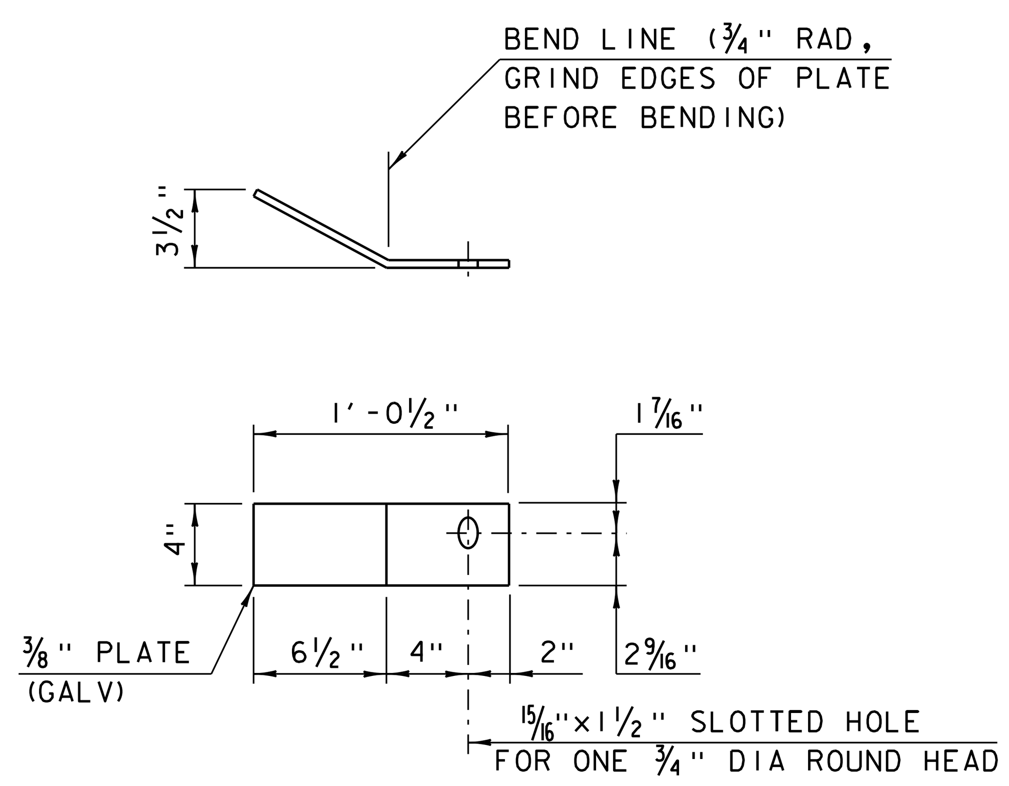
ASYMMETRICAL THRIE-BEAM TO STANDARD STEEL BEAM TRANSITION SECTION

(ARTBA RWT02) (SEE NOTE #1)

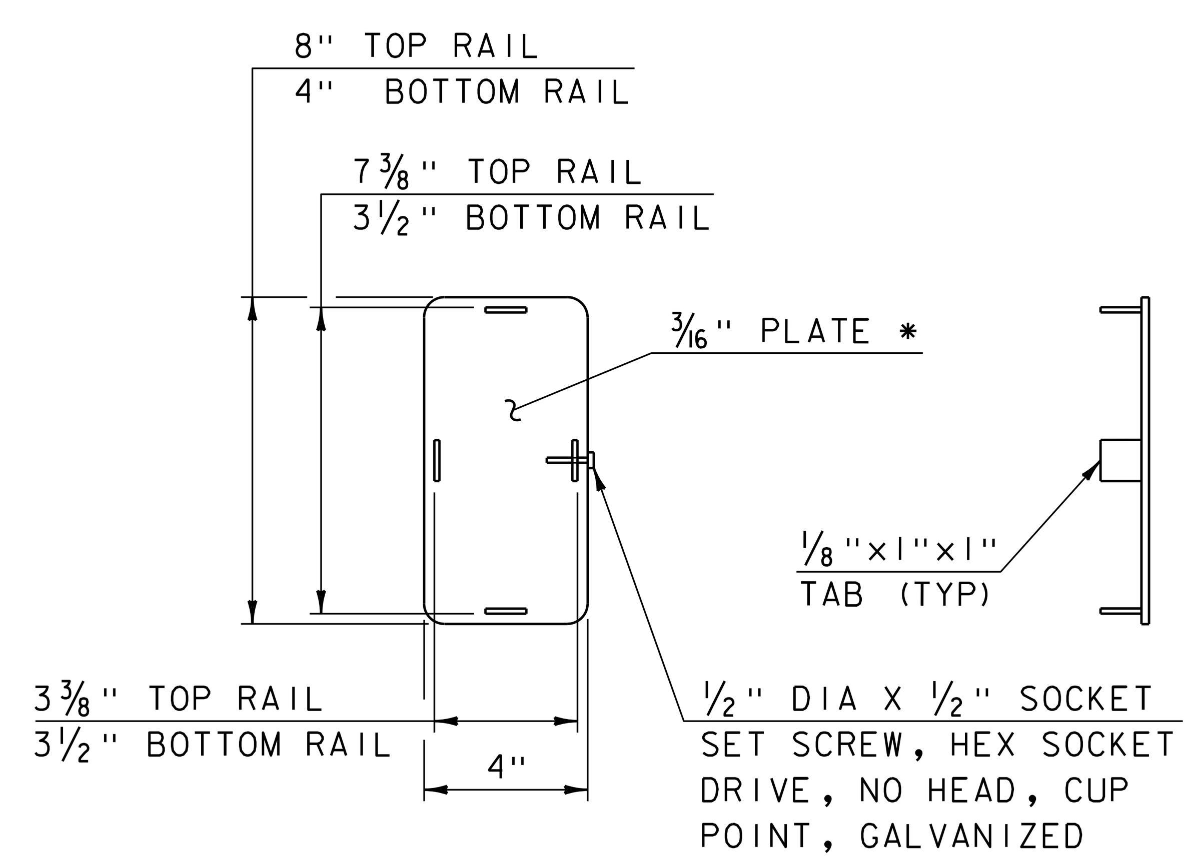


THRIE-BEAM TO STANDARD STEEL BEAM TRANSITION SECTION

(ARTBA RWT01a-b)



DEFLECTOR PLATE DETAIL



END CAP DETAIL

* ROUND CORNERS 1/2" RADIUS (TYP)

NOTES:

1. THE ASYMMETRICAL THRIE-BEAM TO STANDARD STEEL BEAM TRANSITION SECTION IS TO BE USED WITH THE G-1 STANDARD STEEL BEAM WHEN THE RAIL HEIGHT IS 32".

REV.	DATE	DESCRIPTION
0	DECEMBER 14, 2009	ORIGINAL APPROVAL
1	APRIL 23, 2012	GENERAL UPDATE 2012
2	FEBRUARY 2, 2017	BORDER UPDATE, MISC. REVISIONS

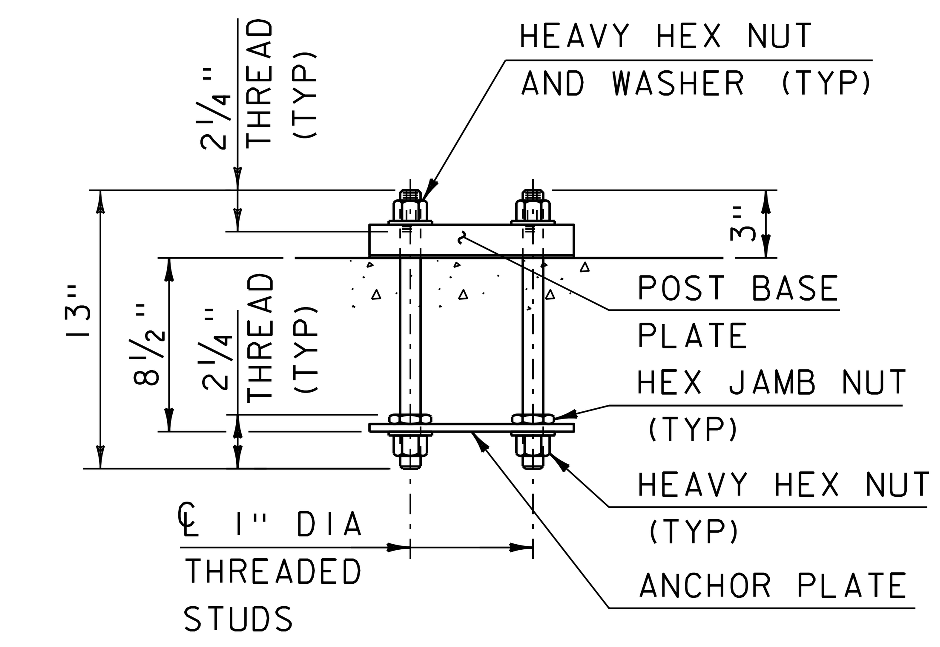
OTHER STANDARDS REQUIRED: C-10, G-1, S-360B

VTRANS AND FHWA APPROVAL ON FILE WITH CONTRACT ADMINISTRATION

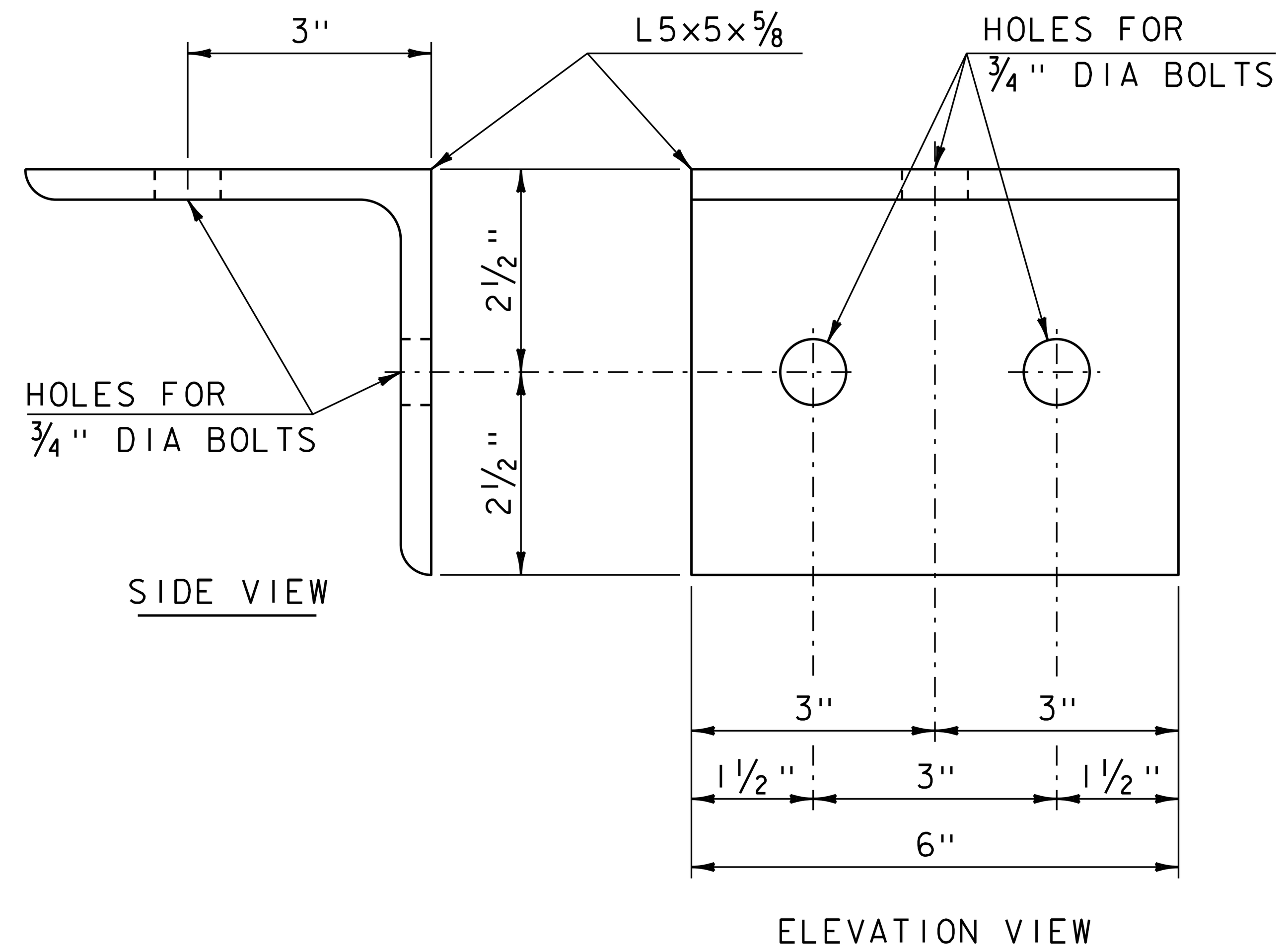
THRIE-BEAM TO STANDARD STEEL BEAM TRANSITION SECTION

VTrans Working to Get You There VERMONT AGENCY OF TRANSPORTATION

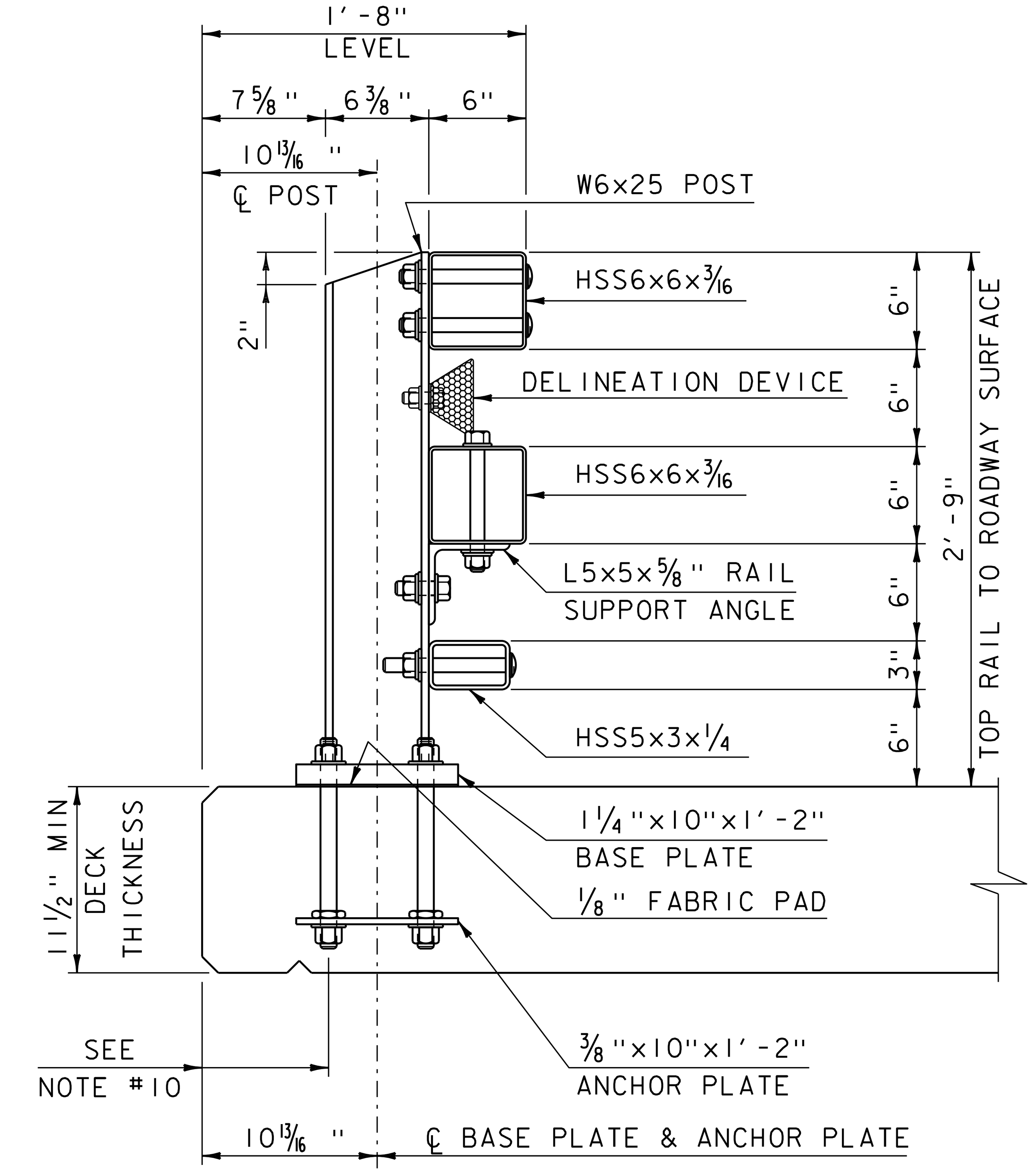
STANDARD S-363



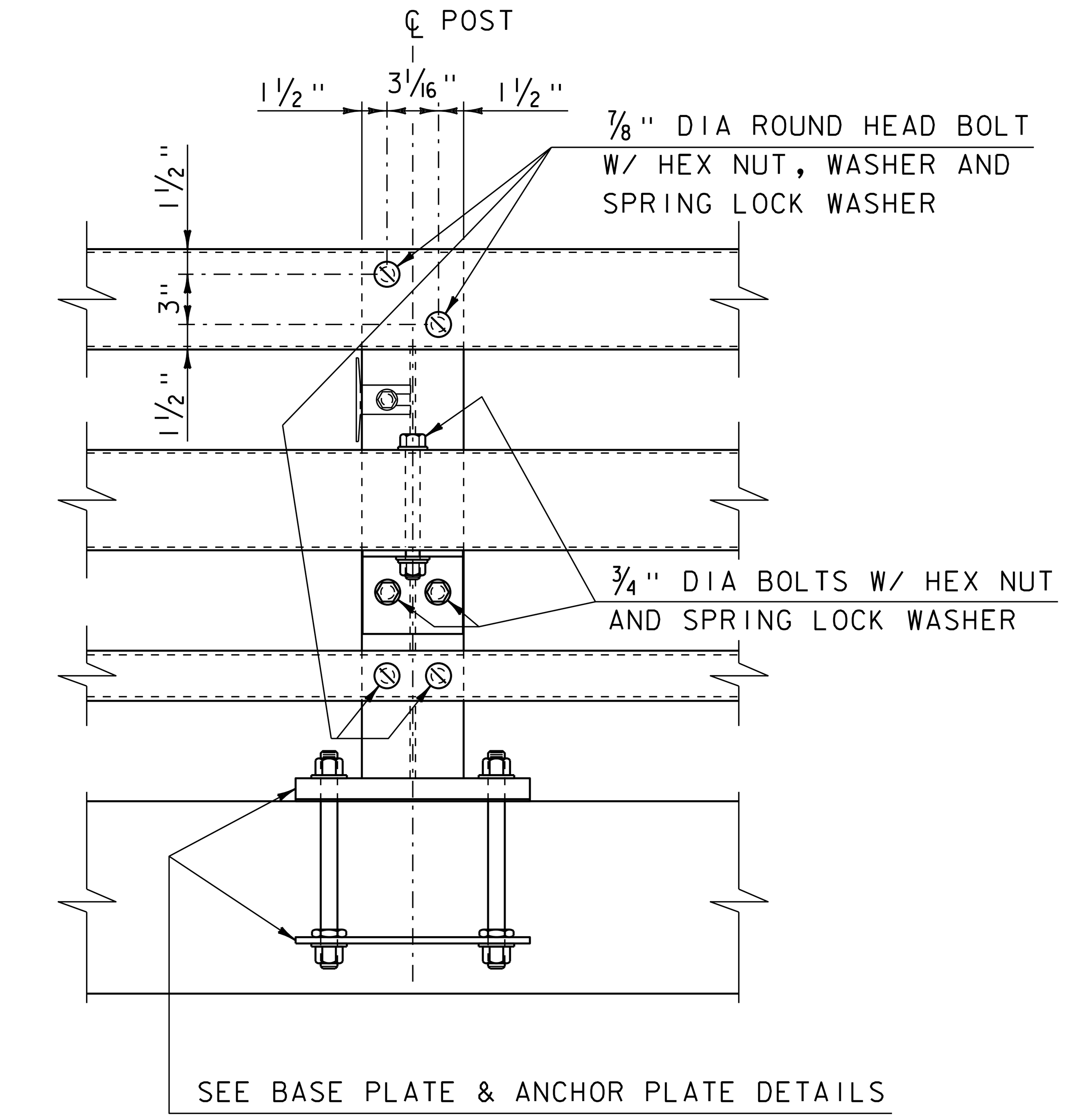
RAILING POST ANCHORAGE



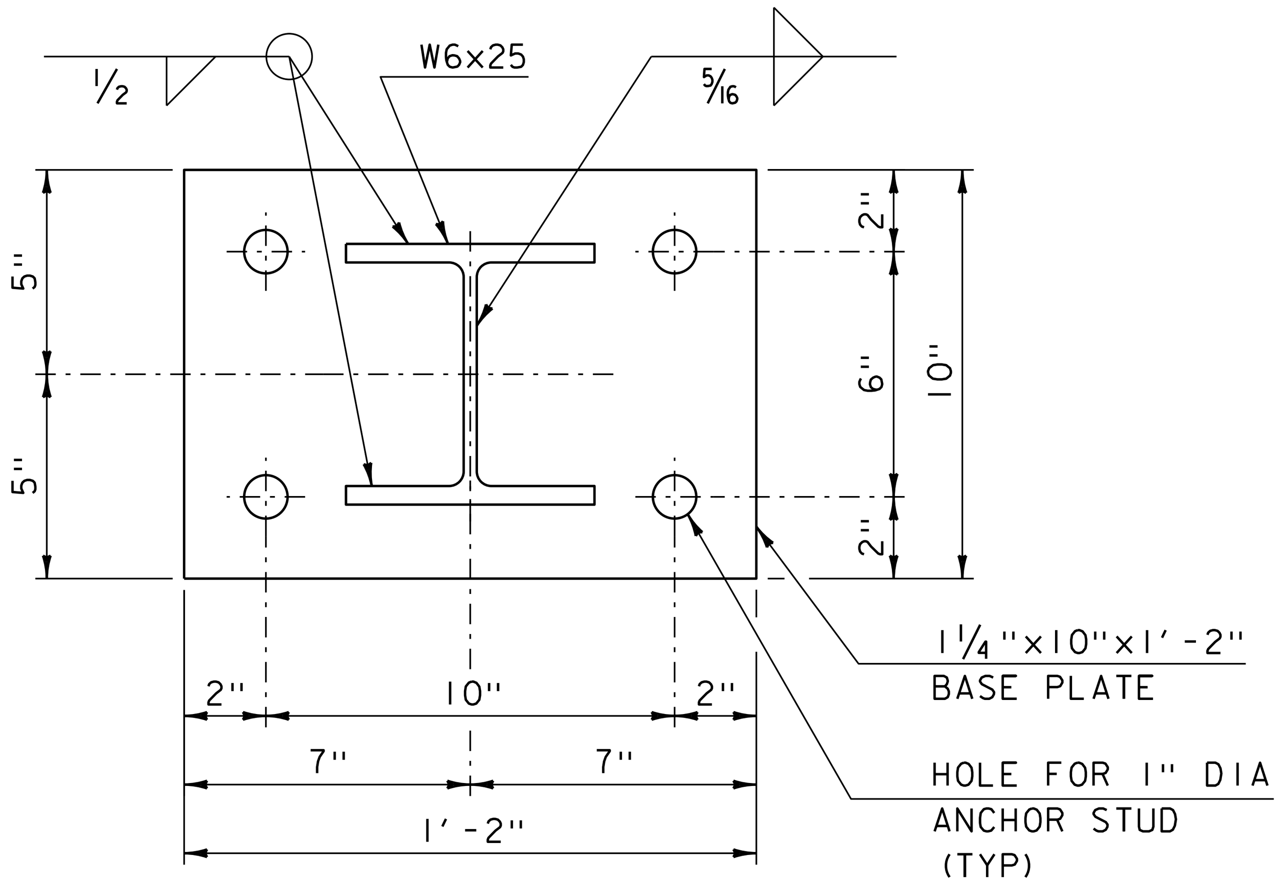
RAILING ANGLE DETAILS



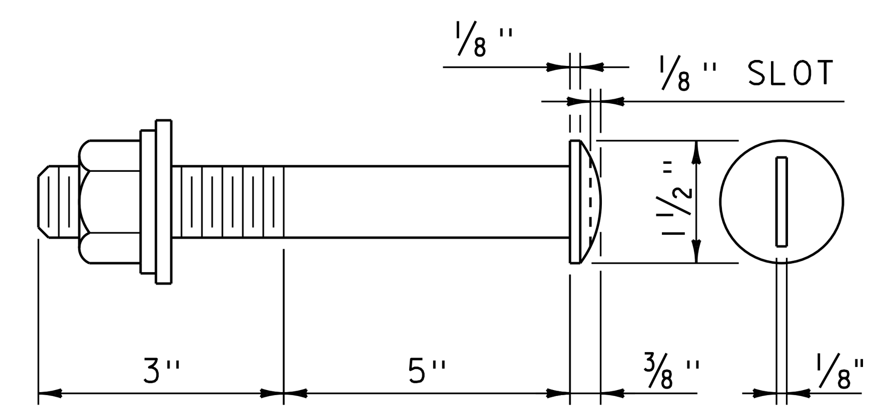
RAILING SECTION



RAILING ELEVATION

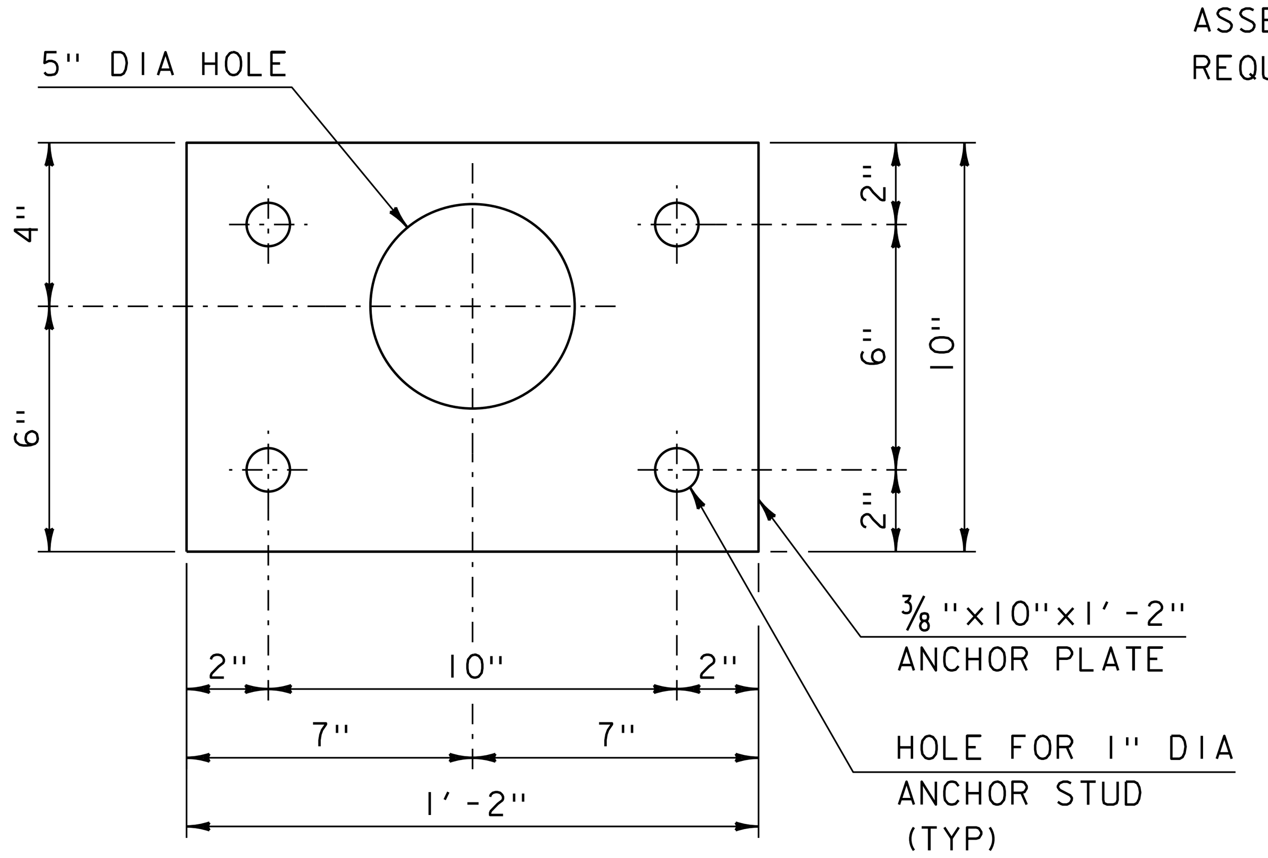


BASE PLATE DETAIL

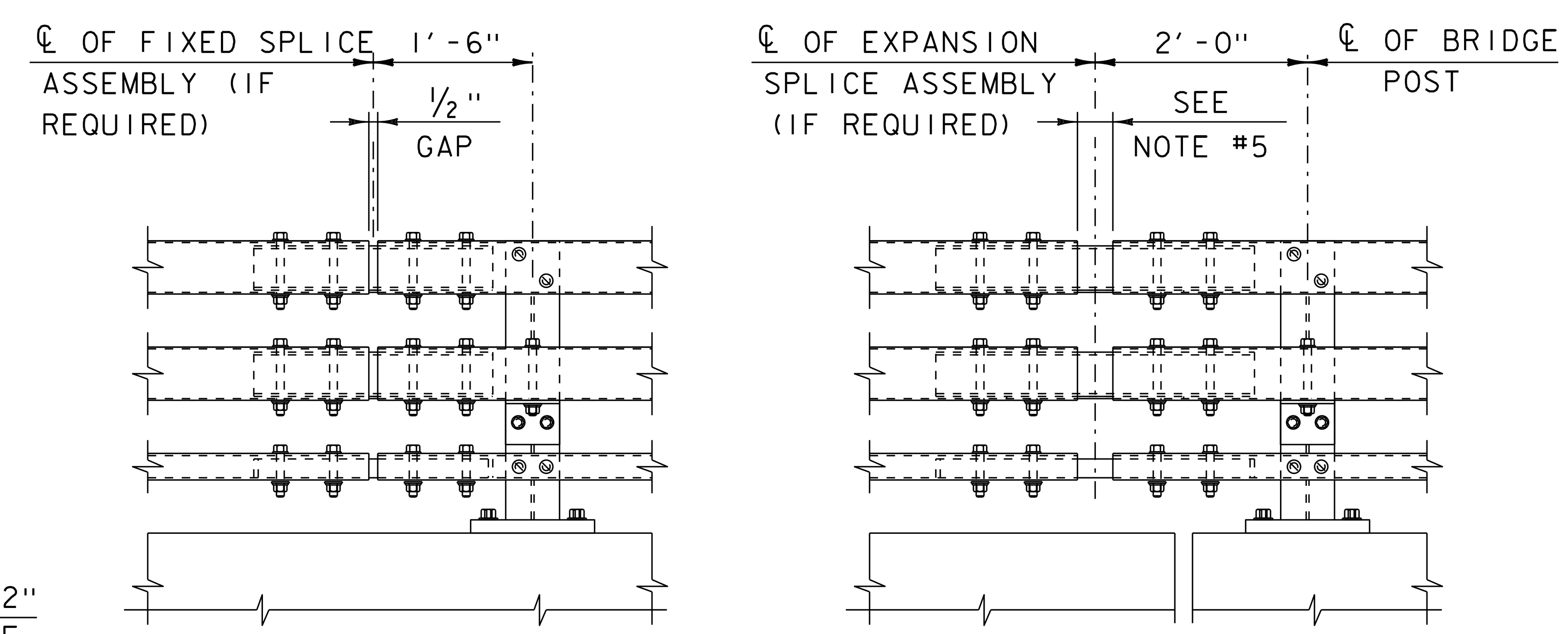


ROUND HEAD BOLT DETAIL

⅞" DIA ROUND HEAD BOLT (A449 TYPE 1), W/ HEX NUT, WASHER AND SPRING LOCK WASHER



ANCHOR PLATE DETAIL



RAILING SPLICE DETAIL ELEVATION

A RAILING EXPANSION SPLICE IS REQUIRED IN ANY POST SPACING THAT CONTAINS A SUPERSTRUCTURE EXPANSION JOINT

NOTES:

1. ALL WORK AND MATERIALS SHALL CONFORM TO SECTION 525.
2. PRIOR TO GALVANIZING, GRIND ALL EDGES TO A MINIMUM RADIUS OF 1/16".
3. ALL POSTS SHALL BE SET NORMAL TO GRADE. THE MAXIMUM CENTER TO CENTER SPACING OF BRIDGE RAIL POSTS IS 8'-3".
4. SECTIONS OF RAIL TUBE SHALL BE ATTACHED TO A MINIMUM OF TWO BRIDGE POSTS AND PREFERABLY TO AT LEAST 4 POSTS.
5. RAIL TUBE EXPANSION JOINTS SHALL BE PROVIDED IN ANY RAIL BAY SPANNING THE END OF AN INTEGRAL ABUTMENT BRIDGE AND AT ALL SUPERSTRUCTURE EXPANSION JOINTS. EXPANSION JOINT WIDTH SHALL BE 4" @ 68°F AND WILL BE ADJUSTED IN THE FIELD BY THE ENGINEER FOR OTHER TEMPERATURES.
6. HOLES IN RAILS FOR TUBE ATTACHMENT MAY BE FIELD-DRILLED. HOLES SHALL BE COATED WITH AN APPROVED ZINC-RICH PAINT PRIOR TO INSTALLATION.
7. BOLTS SHALL BE TORQUED SNUG TIGHT (APPROXIMATELY 100 FT-LB).
8. SEE STANDARD DRAWING G-1 FOR DETAILS OF DELINEATORS. A DELINEATOR SHALL BE INSTALLED AT 30 FOOT SPACING OR THE NEAREST POST. WHITE IS TO BE INSTALLED ON THE DRIVER'S RIGHT. FOR ONE WAY BRIDGES, YELLOW IS TO BE INSTALLED ON THE DRIVER'S LEFT. PAYMENT SHALL BE INCIDENTAL TO OTHER ITEMS.
9. ANY BENDING OF RAIL SHALL BE DONE AT THE FABRICATION PLANT ACCORDING TO A PROCEDURE PROVIDED BY THE FABRICATOR.
10. THE MINIMUM DISTANCE FROM THE POST TO AN EXPANSION JOINT SHALL BE DETERMINED BY THE MINIMUM EDGE DISTANCE OF 5" FROM ANY ANCHOR STUD TO THE END OF THE SLAB OR TO THE EXPANSION JOINT RECESS POUR IF ONE IS USED.
11. THIS RAILING MEETS THE REQUIREMENTS FOR A TL-4 SERVICE LEVEL.

REV.	DATE	DESCRIPTION
0	AUGUST 9, 2010	ORIGINAL APPROVAL
1	APRIL 23, 2012	GENERAL UPDATE 2012
2	FEBRUARY 10, 2014	REVISED NOTE 2
3	FEBRUARY 2, 2017	BORDER UPDATE, MISC. REVISIONS

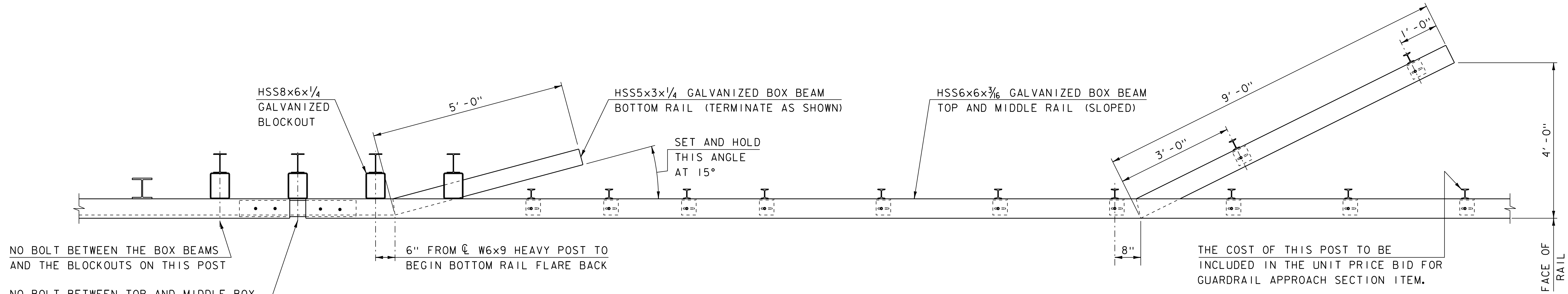
OTHER STANDARDS REQUIRED: G-1, S-364C

VTRANS AND FHWA APPROVAL ON FILE WITH CONTRACT ADMINISTRATION

BRIDGE RAILING, GALVANIZED 3 RAIL BOX BEAM

VTrans Working to Get You There VERMONT AGENCY OF TRANSPORTATION

STANDARD S-364A



3 RAIL BOX BEAM PLAN VIEW

3 RAIL BOX BEAM ELEVATION

* LONG LEG HORIZONTAL

NOTES:

1. BOX BEAM TUBE AND STEEL POST MATERIALS, DIMENSION SIZES AND NOTES SHALL BE THE SAME AS THOSE OF THE BRIDGE RAIL, UNLESS OTHERWISE NOTED.
2. S3x5.7 POSTS SHALL MEET THE REQUIREMENTS OF 728.01(c).

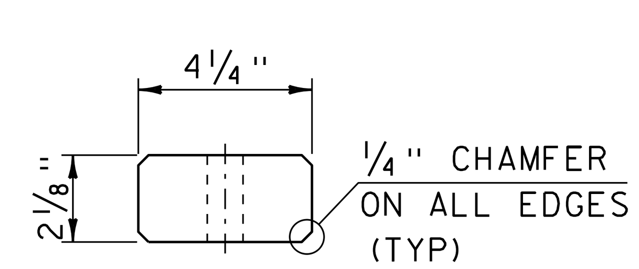
REV.	DATE	DESCRIPTION
0	AUGUST 9, 2010	ORIGINAL APPROVAL
1	APRIL 23, 2012	GENERAL UPDATE 2012
2	FEBRUARY 10, 2014	CLARIFY TRANSITION POST REQUIREMENTS
3	FEBRUARY 2, 2017	BORDER UPDATE, MISC. REVISIONS

OTHER STANDARDS REQUIRED: G-IBM, S-364A
VTRANS AND FHWA APPROVAL ON FILE WITH CONTRACT ADMINISTRATION

GUARDRAIL APPROACH SECTION, GALVANIZED 3 RAIL BOX BEAM

VTrans Working to Get You There
VERMONT AGENCY OF TRANSPORTATION

STANDARD
S-364B



NOTES:

1. PROTRUSIONS CAUSED BY WELDING OR GALVANIZING ARE NOT PERMITTED ON THE ADJOINING SURFACES OF THE BOX BEAM RAILS, SPLICE TUBES AND FILL PLATES.
2. FOUR 3/4" DIAMETER FULLY THREADED BOLTS WITH TWO PLAIN HARDENED (F436) WASHERS AND A HEAVY HEX NUT ON EACH BOLT. NUT TO BE FINGER TIGHT AND THE FIRST THREAD BELOW THE NUT TO BE BURRED TO PREVENT DISLODGING. FOUR BOLTS AT EACH SPLICE.

REV.	DATE	DESCRIPTION
0	AUGUST 9, 2010	ORIGINAL APPROVAL
1	APRIL 23, 2012	GENERAL UPDATE 2012
2	FEBRUARY 10, 2014	CORRECTED SPLICE BAR DETAILS
3	FEBRUARY 2, 2017	BORDER UPDATE, MISC. REVISIONS

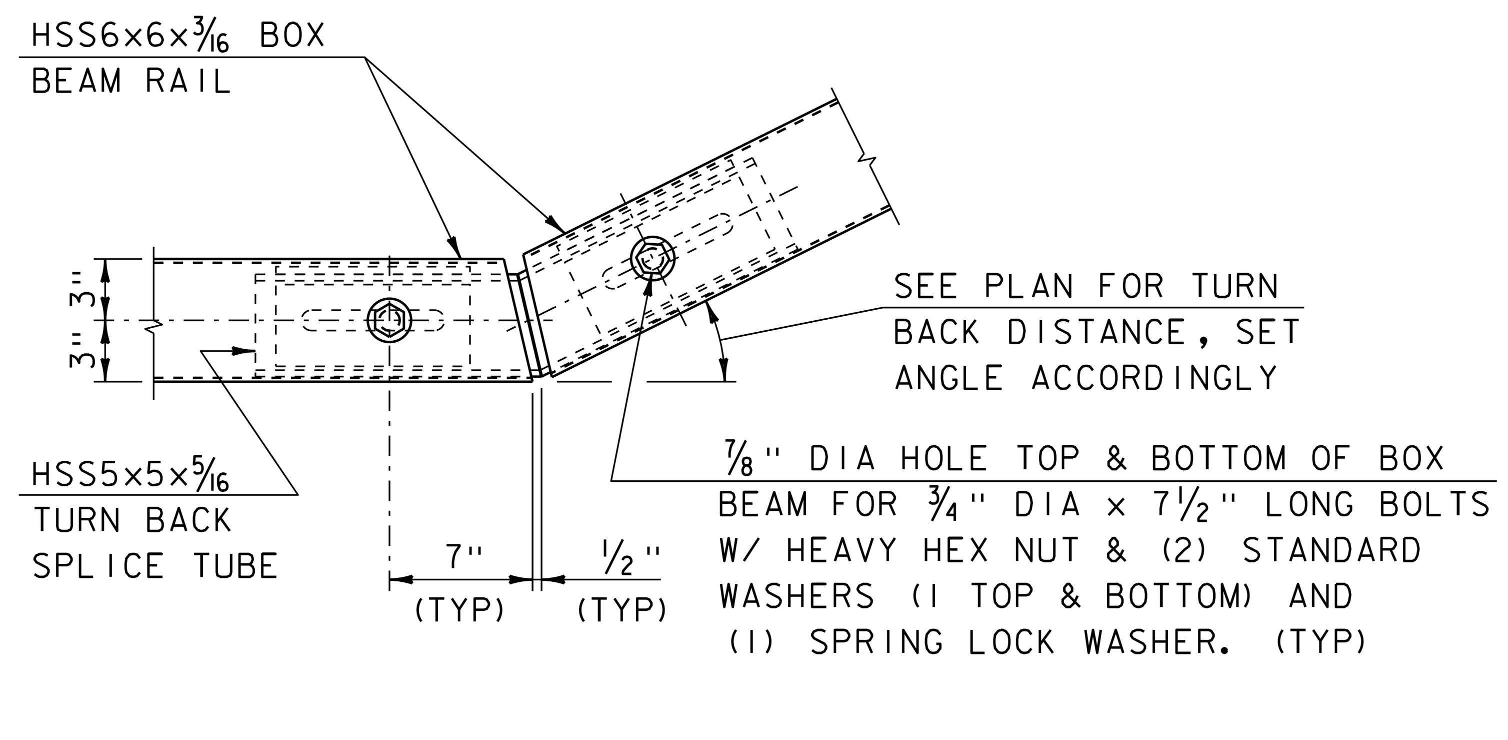
OTHER STANDARDS REQUIRED: NONE

VTRANS AND FHWA APPROVAL ON FILE WITH CONTRACT ADMINISTRATION

GUARDRAIL APPROACH SECTION, GALVANIZED 3 RAIL BOX BEAM

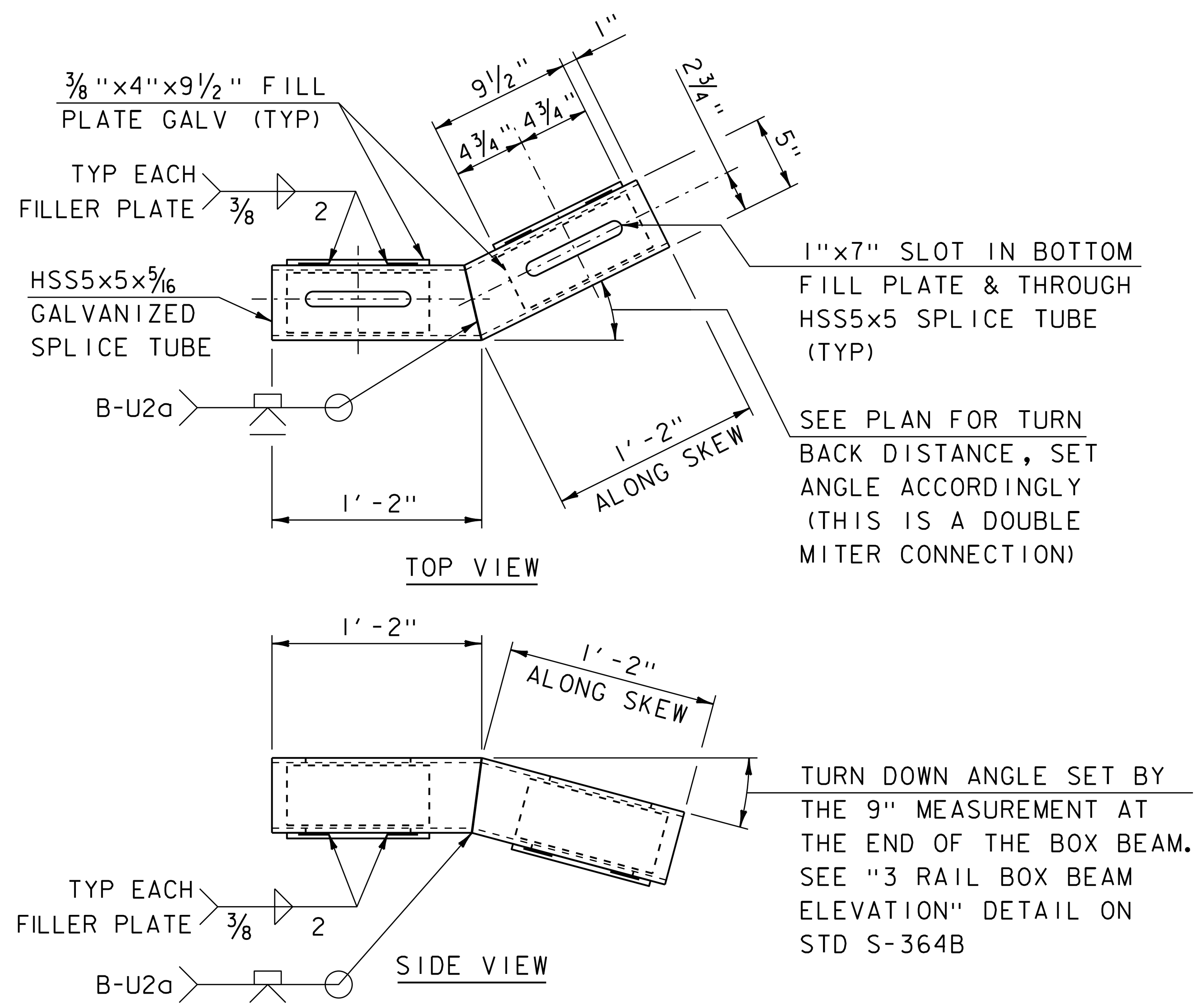
VTrans Working to Get You There VERMONT AGENCY OF TRANSPORTATION

STANDARD S-364C



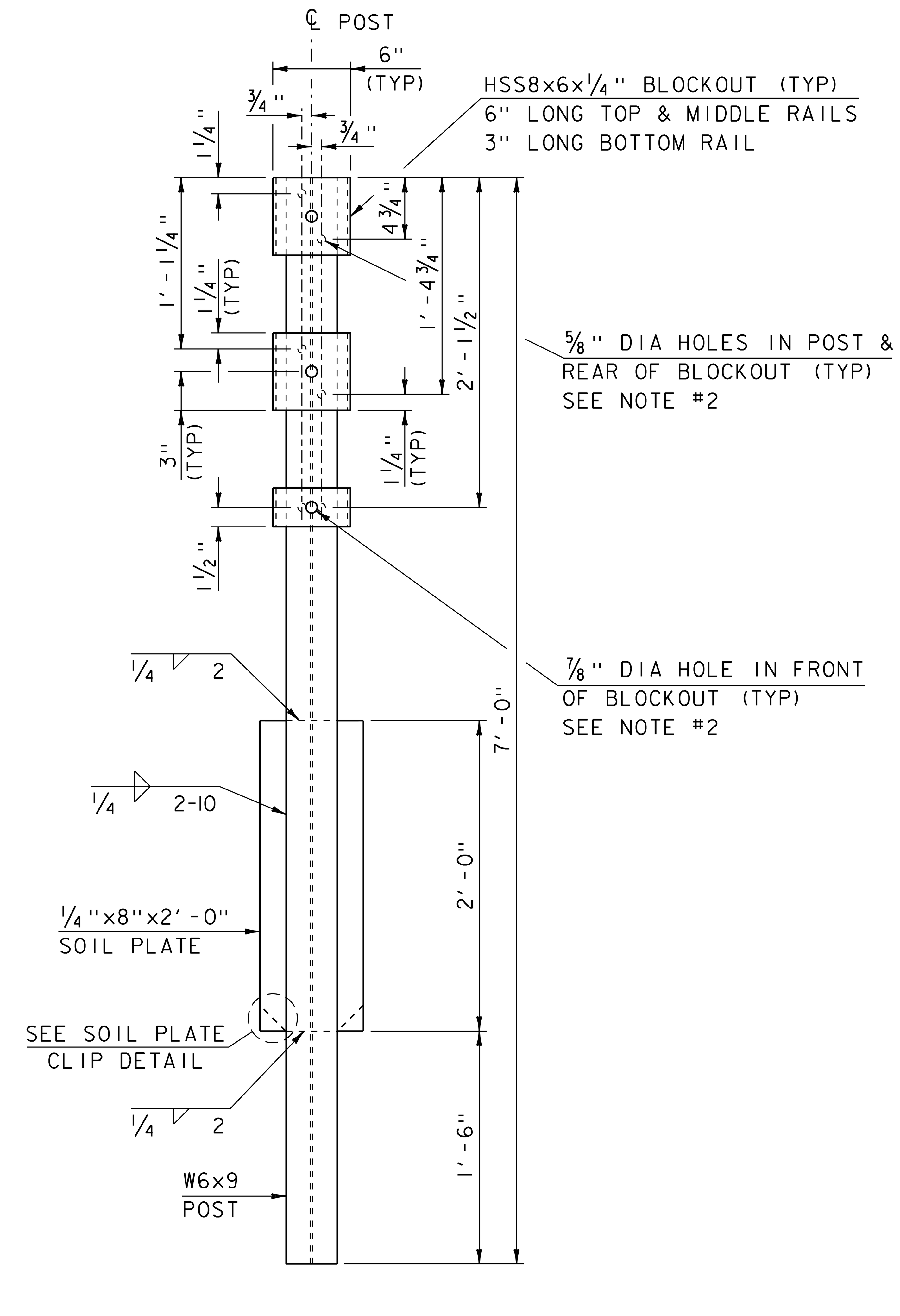
TOP VIEW

TURN BACK SPLICE TUBE ASSEMBLY

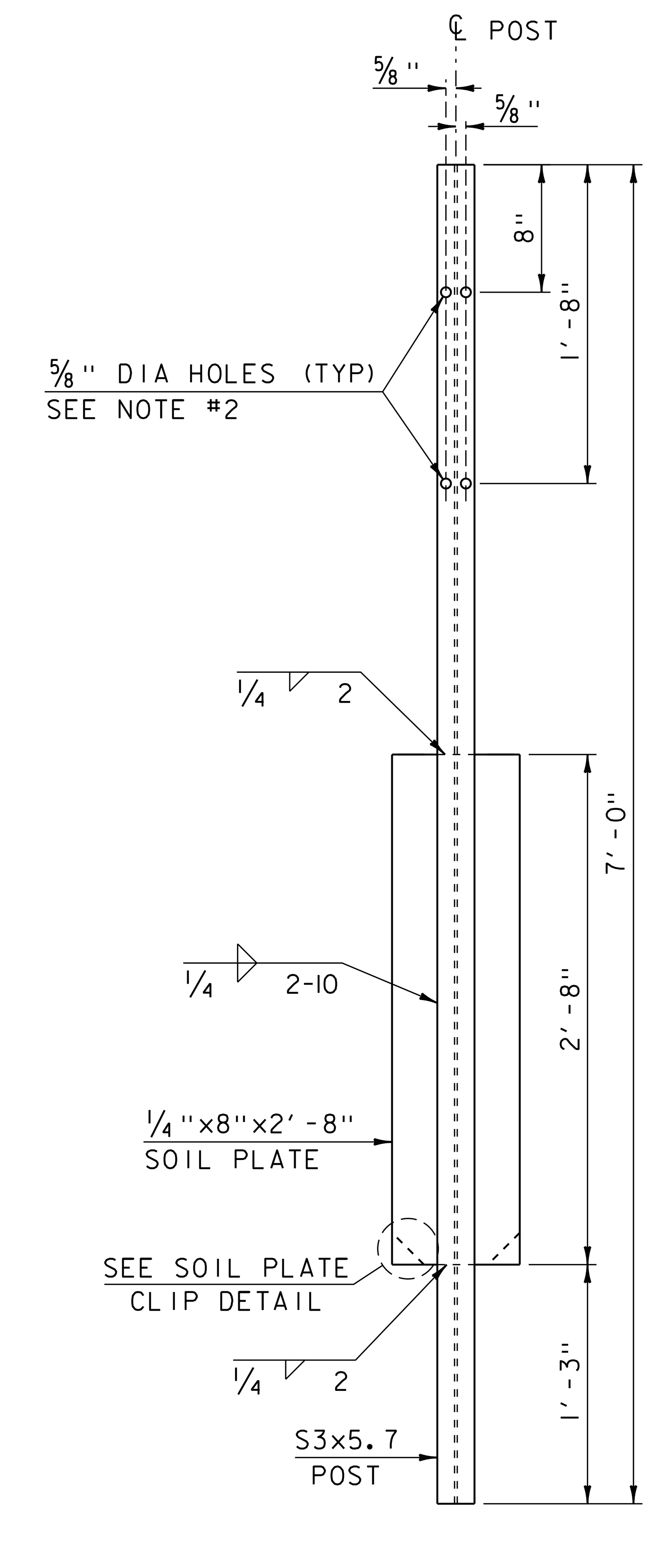


TURN BACK SPLICE TUBE DETAIL

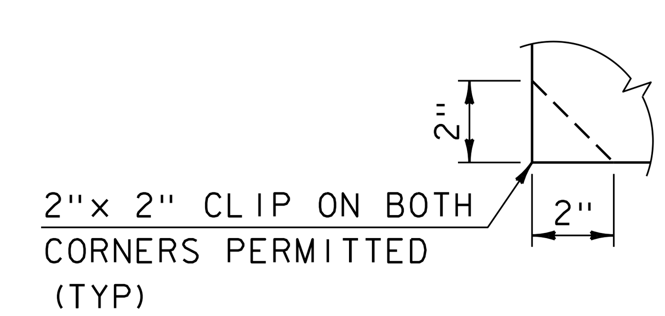
TURN BACK & TURN DOWN TUBE JOINT



HEAVY POST DETAIL



TRANSITION POST DETAIL



SOIL PLATE CLIP DETAIL

NOTES:

1. PROTRUSIONS CAUSED BY WELDING OR GALVANIZING ARE NOT PERMITTED ON THE ADJOINING SURFACES OF THE BOX BEAM RAILS, SPLICE TUBES AND FILL PLATES.

2. HOLES IN THE POST FOR MIDDLE AND BOTTOM RAILS MAY BE LOCATED AND DRILLED IN THE FIELD. IF SO, THE GALVANIZING SHALL BE REPAIRED IN ACCORDANCE WITH SPECIFICATION SECTION 525.

REV.	DATE	DESCRIPTION
0	AUGUST 9, 2010	ORIGINAL APPROVAL
1	APRIL 23, 2012	GENERAL UPDATE 2012
2	FEBRUARY 2, 2017	BORDER UPDATE, MISC. REVISIONS

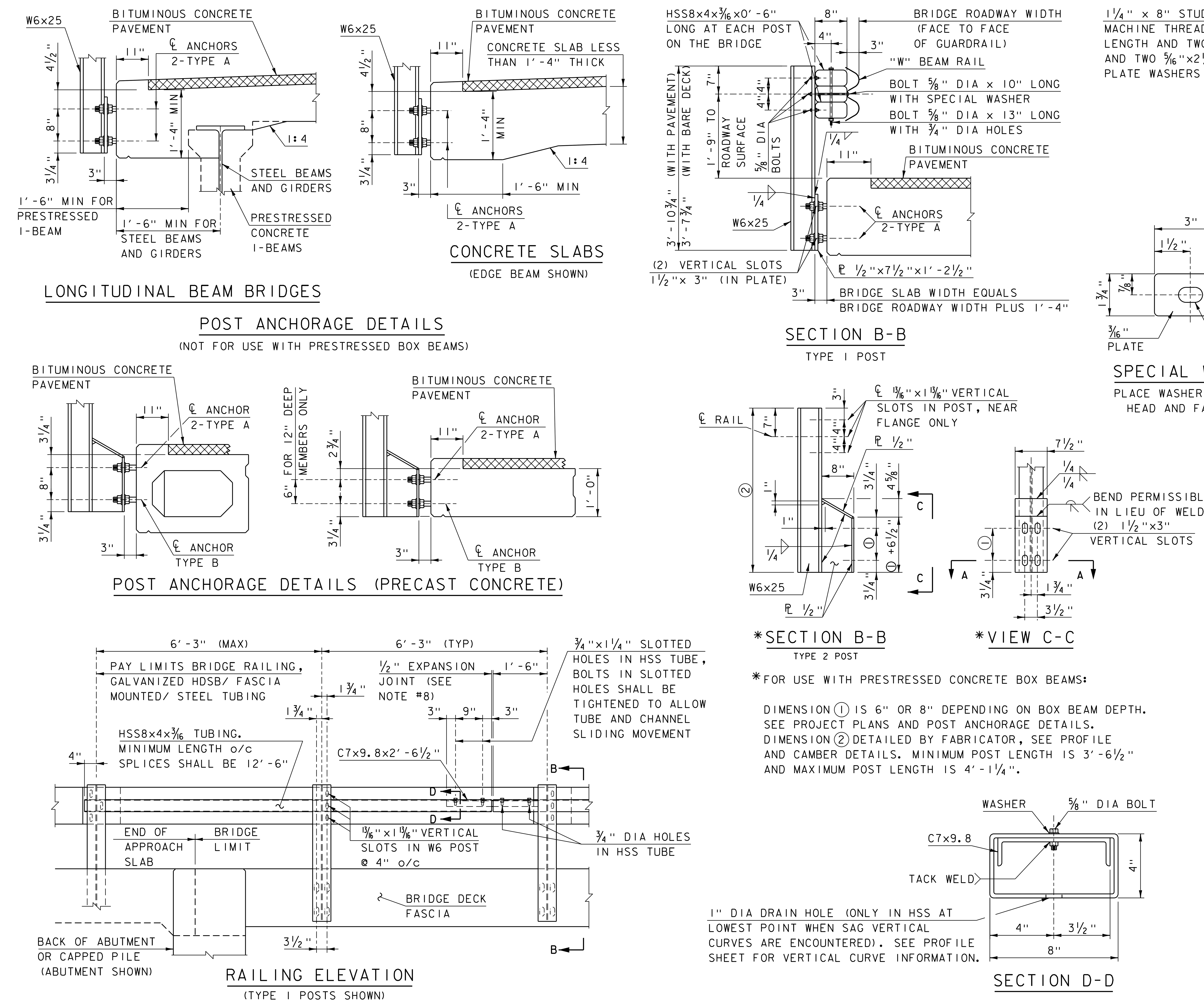
OTHER STANDARDS REQUIRED: S-364B

VTRANS AND FHWA APPROVAL ON FILE WITH CONTRACT ADMINISTRATION

GUARDRAIL APPROACH SECTION, GALVANIZED 3 RAIL BOX BEAM

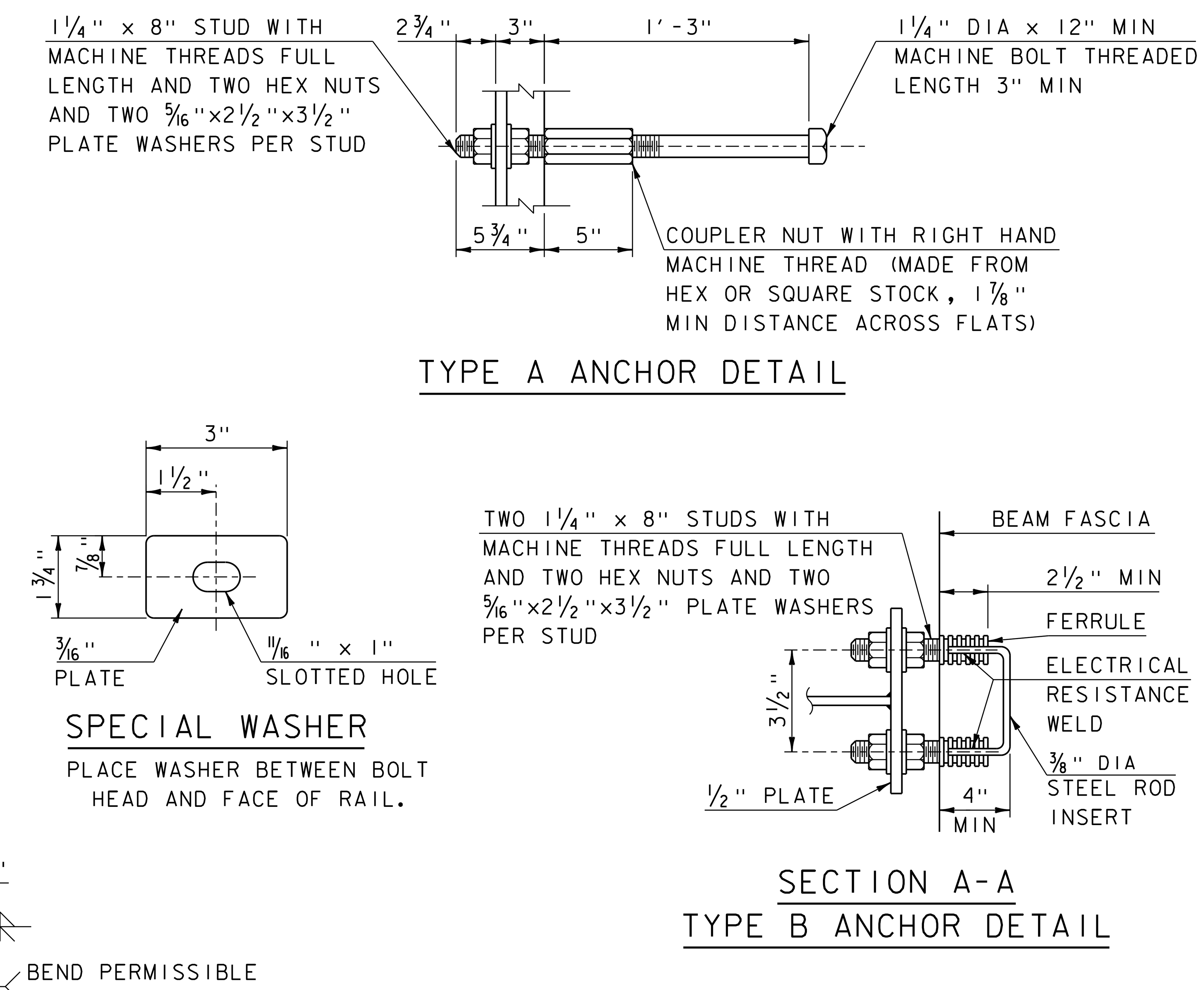
VTrans Working to Get You There VERMONT AGENCY OF TRANSPORTATION

STANDARD S-364D



*FOR USE WITH PRESTRESSED CONCRETE BOX BEAMS:

DIMENSION ① IS 6" OR 8" DEPENDING ON BOX BEAM DEPTH. SEE PROJECT PLANS AND POST ANCHORAGE DETAILS. DIMENSION ② DETAILED BY FABRICATOR, SEE PROFILE AND CAMBER DETAILS. MINIMUM POST LENGTH IS 3'-6 1/2" AND MAXIMUM POST LENGTH IS 4'-1 1/4".



NOTES:

1. ALL WORK AND MATERIALS SHALL CONFORM TO SECTION 525.
2. PRIOR TO GALVANIZING THE ASSEMBLED POST, GRIND ALL EDGES TO A MINIMUM RADIUS OF 1/16".
3. ALL POSTS SHALL BE SET NORMAL TO GRADE.
4. SPLICES FOR THE STEEL BEAM GUARDRAIL SHALL LAP IN THE DIRECTION OF TRAFFIC.
5. A RAILING JOINT SPLICE SHALL BE PROVIDED IN ANY RAIL BAY SPANNING THE END OF AN INTEGRAL ABUTMENT BRIDGE AND AT ALL SUPERSTRUCTURE EXPANSION JOINTS.
6. SEE STANDARD DRAWING G-1 FOR DETAILS OF DELINEATORS. A DELINEATOR SHALL BE INSTALLED AT 30 FOOT SPACING OR THE NEAREST POST. WHITE IS TO BE INSTALLED ON THE DRIVER'S RIGHT. FOR ONE WAY BRIDGES, YELLOW IS TO BE INSTALLED ON THE DRIVER'S LEFT.
7. THE 1/2" EXPANSION JOINT SHOWN IN THE RAILING ELEVATION IS DESIGNED FOR BRIDGE LENGTHS UP TO 80 FEET, ANY LONGER SPANS WILL HAVE TO BE MODIFIED TO ACCOUNT FOR THEIR MOVEMENT.
8. FOR RADII LESS THAN 950 FEET, HSS8x4 TUBES SHALL BE SHOP BENT TO FIT THE APPLICABLE CURVE.
9. THE MINIMUM DISTANCE FROM THE LAST POST TO THE END OF SLAB IS 1'-6".
10. FERRULES SHALL BE 12L14 COLD DRAWN CARBON STEEL.
11. HOLES IN RAIL FOR RAIL TUBE ATTACHMENT MAY BE FIELD DRILLED. HOLES SHALL BE COATED WITH AN APPROVED ZINC-RICH PAINT PRIOR TO INSTALLATION.
12. THIS RAILING MEETS THE REQUIREMENTS FOR A TL-2 SERVICE LEVEL.

REV.	DATE	DESCRIPTION
0	MAY 24, 2012	ORIGINAL APPROVAL
1	FEBRUARY 2, 2017	BORDER UPDATE, MISC. REVISIONS

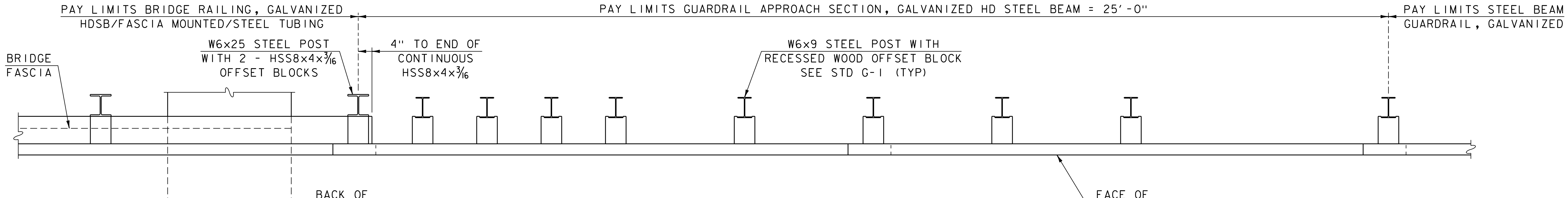
OTHER STANDARDS REQUIRED: G-1

VTRANS AND FHWA APPROVAL ON FILE WITH CONTRACT ADMINISTRATION

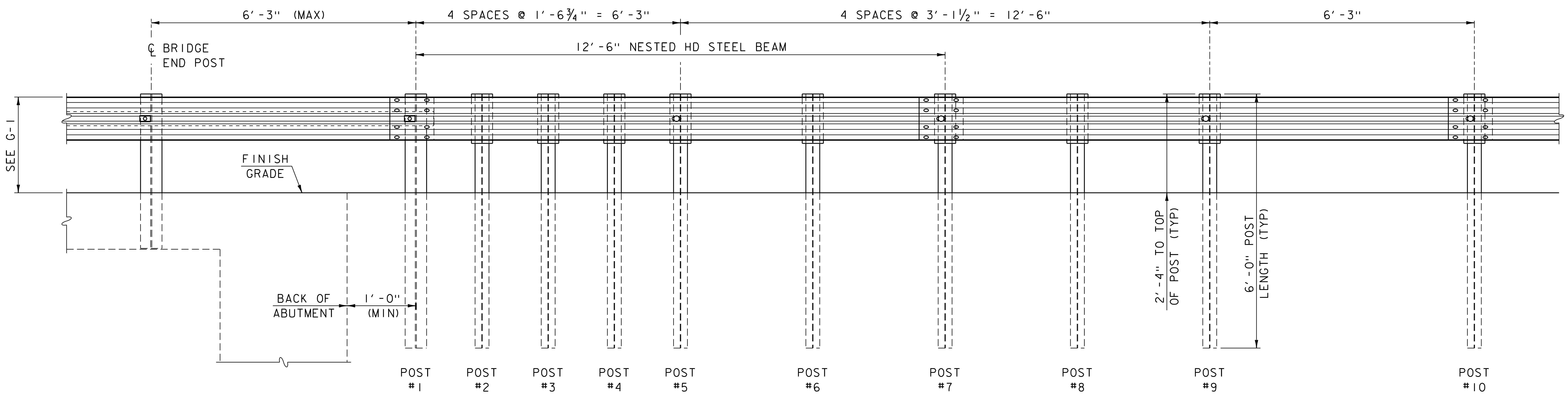
BRIDGE RAILING, GALVANIZED HDSB/FASCIA MOUNTED/STEEL TUBING

VTrans Working to Get You There VERMONT AGENCY OF TRANSPORTATION

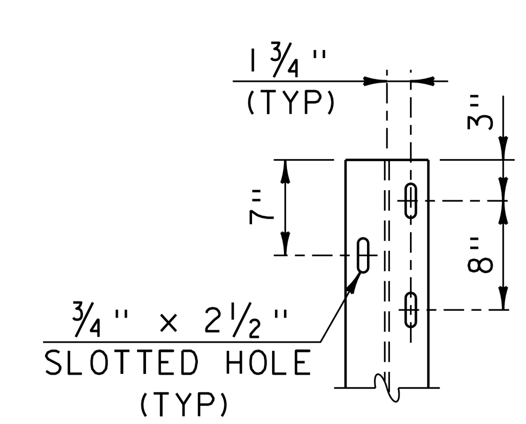
STANDARD S-367A



RAILING PLAN



RAILING ELEVATION



POST #1 HOLE DETAIL

NOTES:

1. PAYMENT FOR POST #1, HSS8x4x3/16 OFFSET BLOCKS AND TUBULAR BACKUP RAIL EXTENDING TO POST #1 OFF THE BRIDGE SHALL BE MADE UNDER BRIDGE RAILING, GALVANIZED HDSB/FASCIA MOUNTED/STEEL TUBING.

2. BLOCKOUTS SHALL BE RECESSED WOOD ONLY. STEEL OR PLASTIC BLOCKOUTS ARE NOT PERMITTED.

3. GUARDRAIL IS NOT ATTACHED TO POST NUMBERS 2-4, 6 AND 8. THERE SHALL BE NO GAP BETWEEN THE POSTS THAT ARE NOT ATTACHED AND THE RAIL. OFFSET BLOCKS SHALL BE ATTACHED TO POST WITH STANDARD POST BOLT.

4. POSTS MAY BE SET IN DRILLED HOLES OR DRIVEN TO GRADE.

5. THIS RAILING MEETS THE REQUIREMENTS FOR A NCHRP REPORT 350 TL-3 SERVICE LEVEL.

REV.	DATE	DESCRIPTION
0	MAY 24, 2012	ORIGINAL APPROVAL
1	FEBRUARY 2, 2017	BORDER UPDATE, MISC. REVISIONS

OTHER STANDARDS REQUIRED: G-1

VTRANS AND FHWA APPROVAL ON FILE WITH CONTRACT ADMINISTRATION

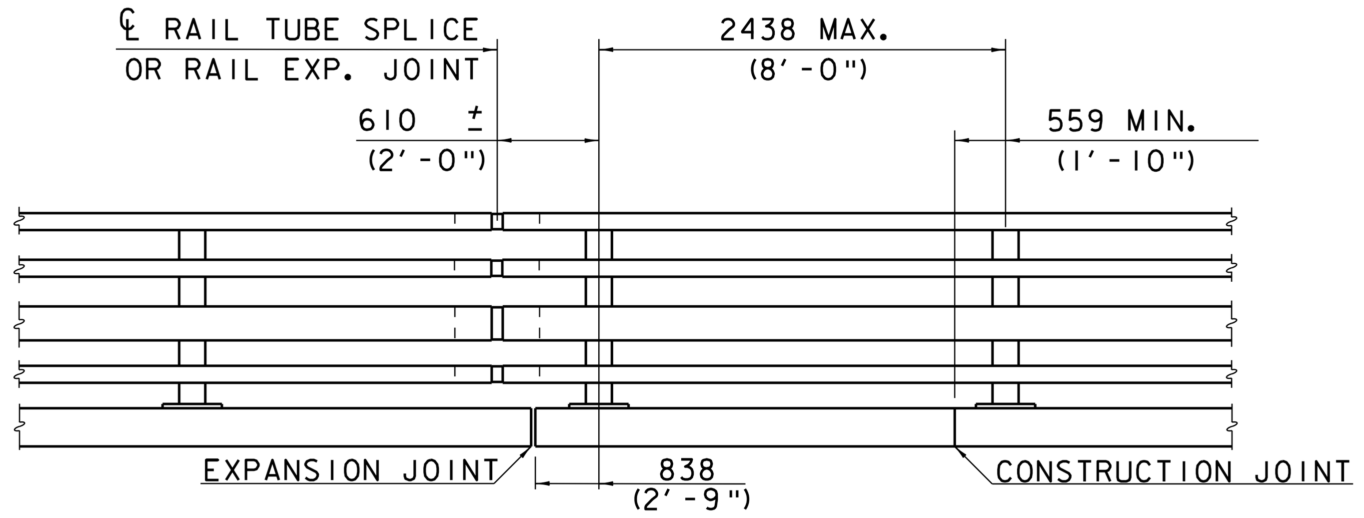
GUARDRAIL APPROACH SECTION, GALVANIZED HD STEEL BEAM

VTrans Working to Get You There VERMONT AGENCY OF TRANSPORTATION

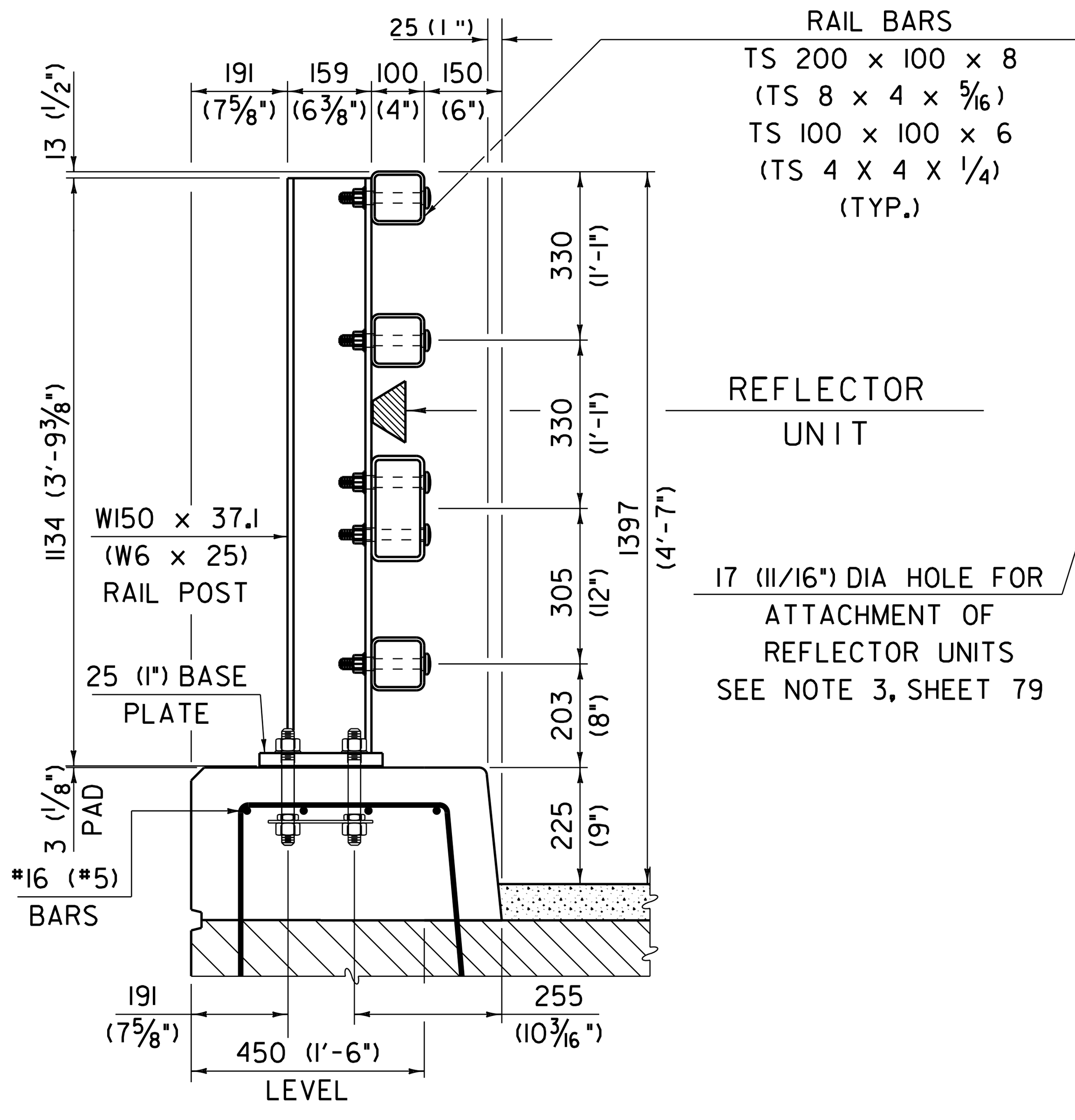
STANDARD

S-367B

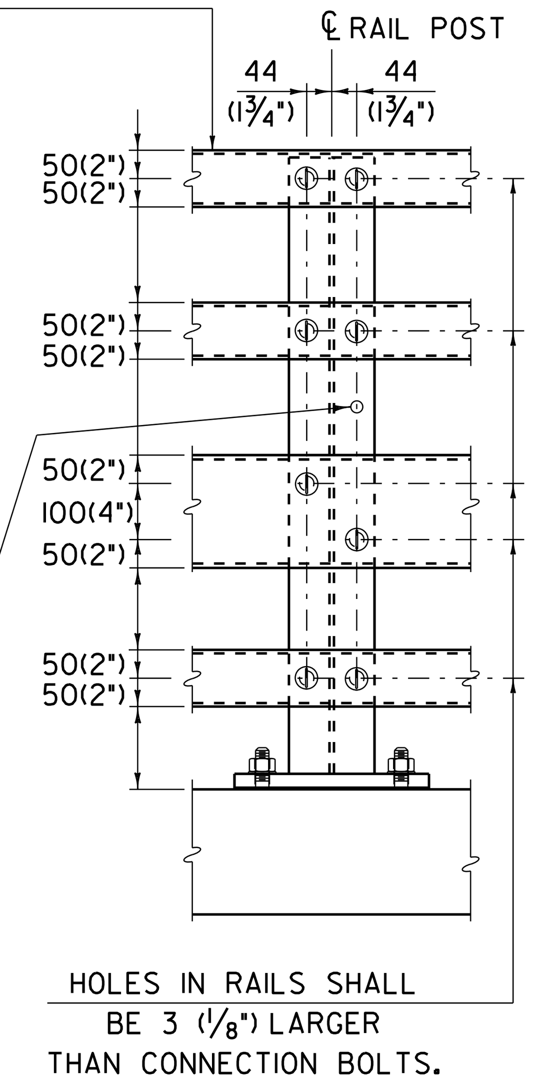
Metric



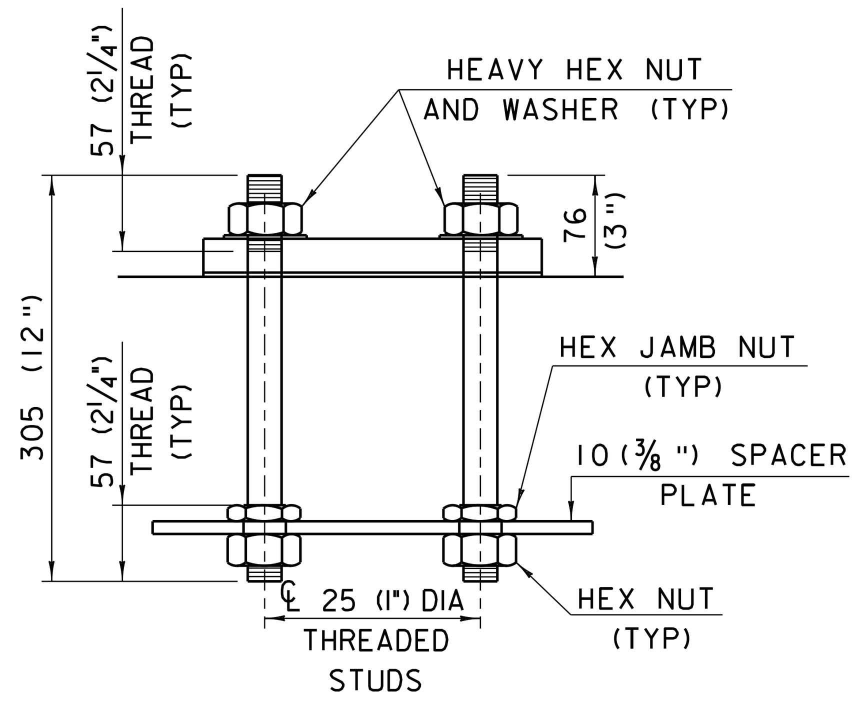
BRIDGE RAILING ELEVATION



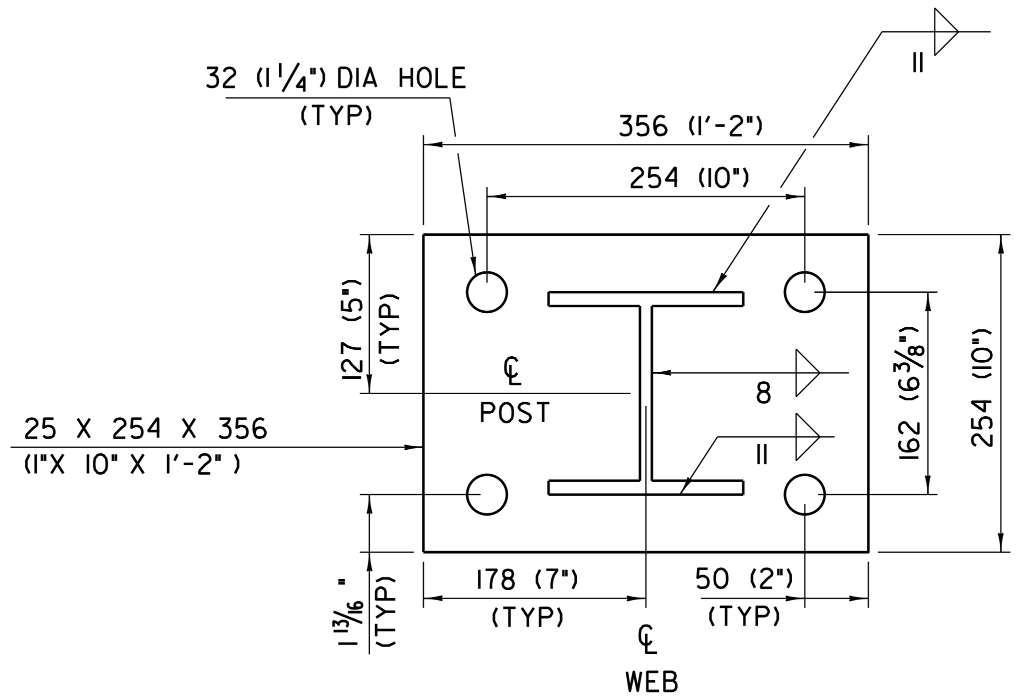
TYPICAL SECTION



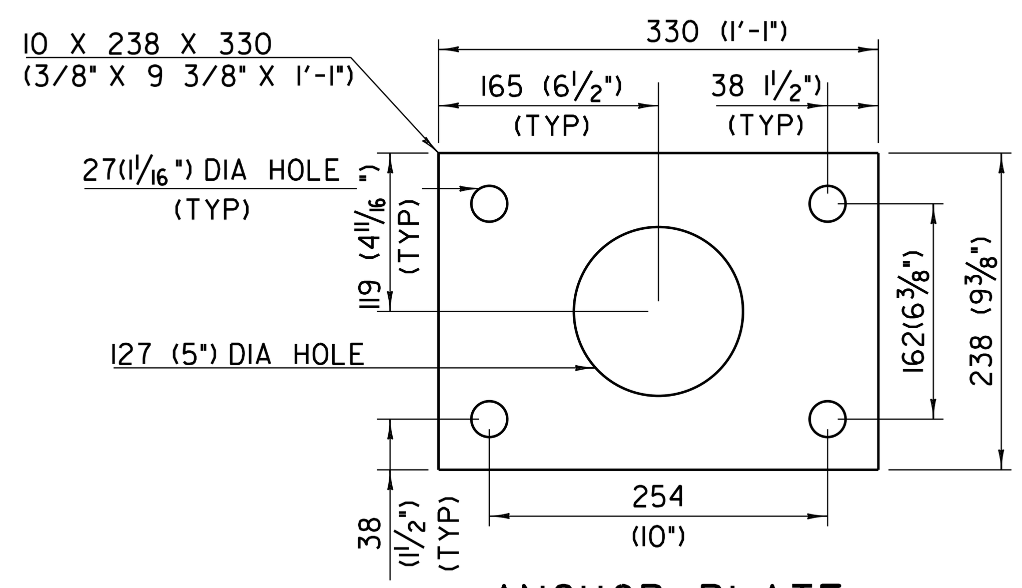
ELEVATION



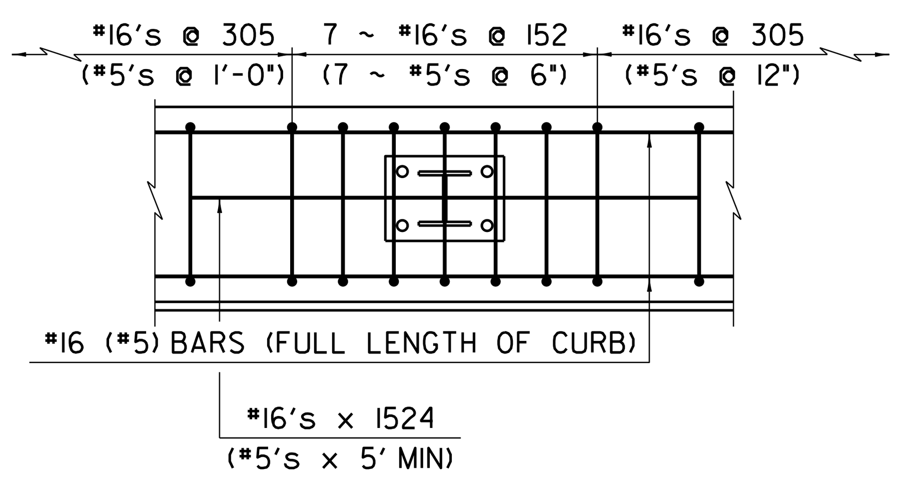
RAIL POST ANCHORAGE



POST AND BASE PLATE



ANCHOR PLATE



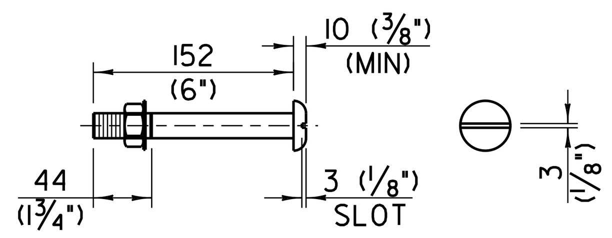
CURB REINFORCING PLAN

NOTES

1. ALL WORK AND MATERIALS SHALL CONFORM TO THE PROVISIONS OF SECTION 525 - RAILINGS OF THE STANDARD SPECIFICATION FOR CONSTRUCTION.
2. TUBING AND POSTS SHALL MEET THE REQUIREMENTS OF SECTION 732.
3. ALL EXPOSED CUT OR SHEARED EDGES SHALL BE ROUNDED TO A 2 mm (1/16") RADIUS AND BE FREE OF BURRS.
4. RAIL POSTS SHALL BE SET NORMAL TO GRADE.
5. SECTIONS OF RAIL TUBE SHALL BE ATTACHED TO A MINIMUM OF TWO (2) RAIL POSTS AND PREFERABLY TO AT LEAST FOUR (4) POSTS.
6. RAIL TUBE EXPANSION JOINTS SHALL BE PROVIDED IN ANY RAIL BAY SPANNING A SUPERSTRUCTURE EXPANSION JOINT. EXPANSION JOINT WIDTH SHALL BE "X" AT 7°C (45°F) AND WILL BE ADJUSTED IN THE FIELD BY THE ENGINEER FOR OTHER TEMPERATURES.
7. RAIL POSTS ANCHORING NUTS SHALL BE TIGHTENED TO A SNUG FIT AND GIVEN AN ADDITIONAL ONE-EIGHTH TURN.
8. RAIL TUBES SHALL BE ATTACHED USING 75 mm (3") FULL DIAMETER BODY AASHTO M164M (TYPE 1) ROUND HEAD BOLTS INSERTED THROUGH THE FACE OF THE TUBE. HOLES IN POSTS SHALL BE 2 mm (1/16") LARGER THAN THE BOLT SIZE.
9. HOLES IN RAILS FOR RAIL TUBE ATTACHMENT MAY BE FIELD-DRILLED. HOLES SHALL BE COATED WITH AN APPROVED ZINC-RICH PAINT PRIOR TO ERECTION.
10. ANY BENDING OF RAIL SHALL BE DONE AT A FABRICATOR PLANT, ACCORDING TO A PROCEDURE PROVIDED BY THE FABRICATOR.
11. THE FABRICATOR SHALL SUBMIT FABRICATION DRAWINGS INCLUDING WELDING PROCEDURES TO THE STRUCTURES SECTION FOR APPROVAL IN ACCORDANCE WITH SECTION 105.

MATERIALS

3 mm (1/8") PAD SHALL COMPLY WITH SUBSECTION 731.01 OR 731.02.

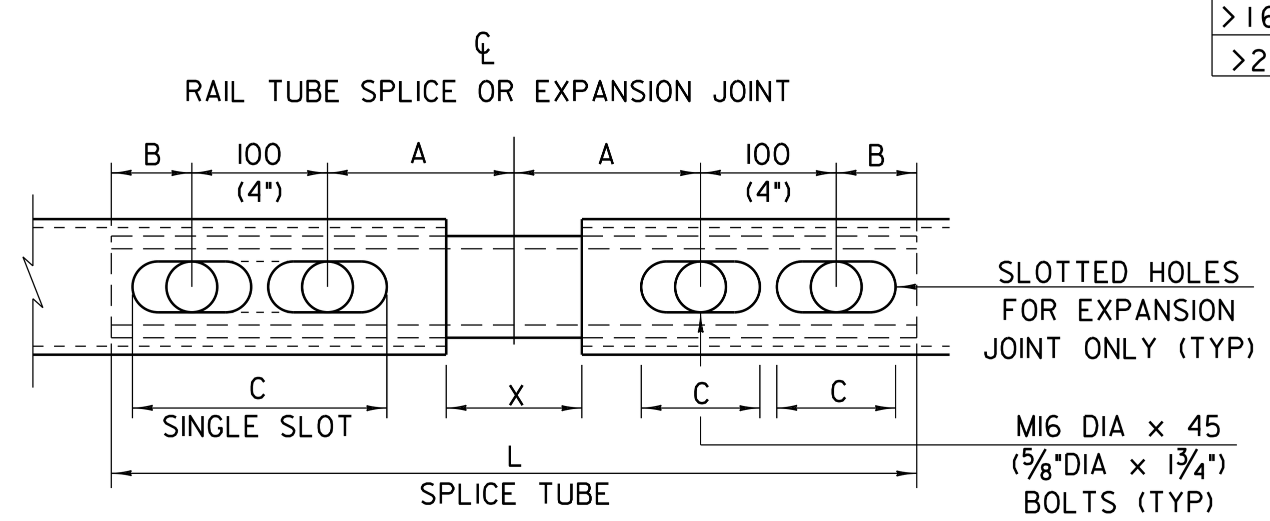


19 (¾") DIA M164 (TYPE 1)
ROUND HEAD BOLT

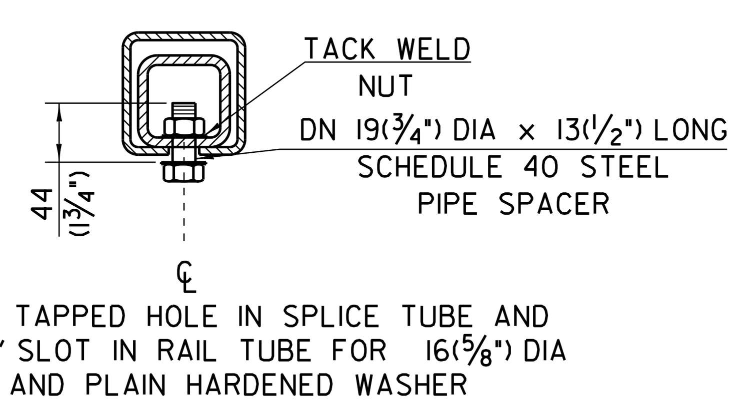
(WITH WASHER AND PREVAILING TORQUE TYPE LOCK NUT)
(SEE NOTE #8)
ONLY FULL DIAMETER BODY BOLTS WILL BE ALLOWED.

SPLICE TABLE					
T	A	B	C	L	X
N/A	100 (4")	50 (2")	--	508 (20")	19 (¾")
EXPANSION JOINT TABLE					
<100 (4")	100 (4")	50 (2")	64 (2½")	508 (20")	64 (2½")
>100 (4") <165 (6½")	140 (5½")	60 (2⅜")	89 (3½")	603 (23¾")	100 (4")
>165 (6½") <229 (9")	163 (6½")	86 (3⅜")	229 (9") *	705 (27¾")	127 (5")
>229 (9") <330 (13")	216 (8½")	111 (4⅜")	279 (11") *	857 (33¾")	179 (7")

T = TOTAL MOVEMENT AT RAIL EXPANSION JOINT AS SHOWN ON THE CONTRACT PLANS. SEE NOTE 6.
* = SINGLE SLOT

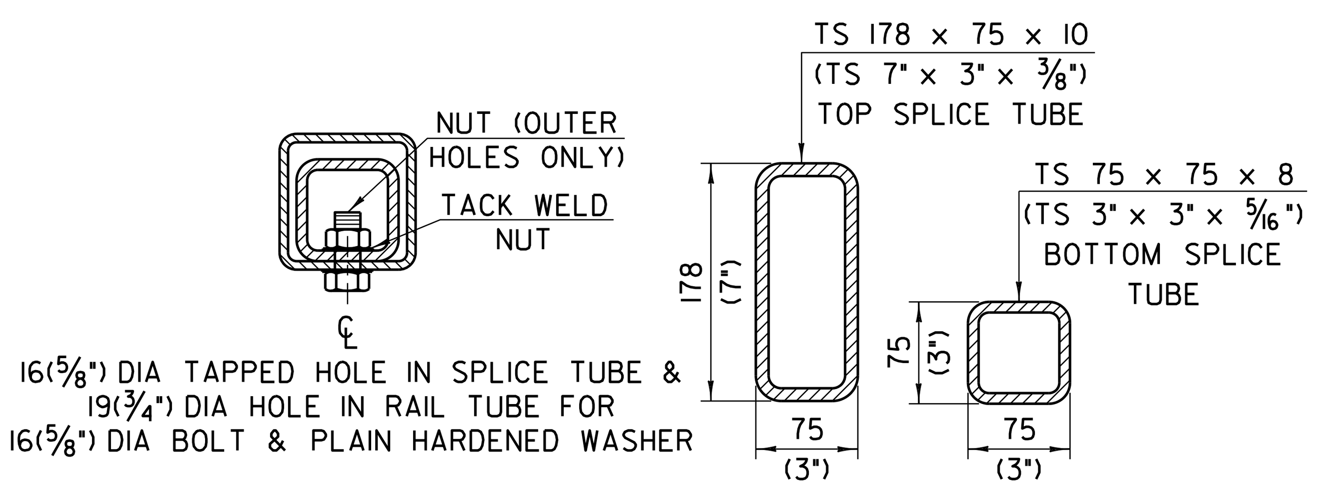


RAIL TUBE SPLICE AND RAIL
EXPANSION JOINT DETAIL
(BOTTOM VIEW)



EXPANSION JOINT SECTION

FOR DETAILS NOT SHOWN,
SEE "RAIL TUBE SPLICE SECTION."

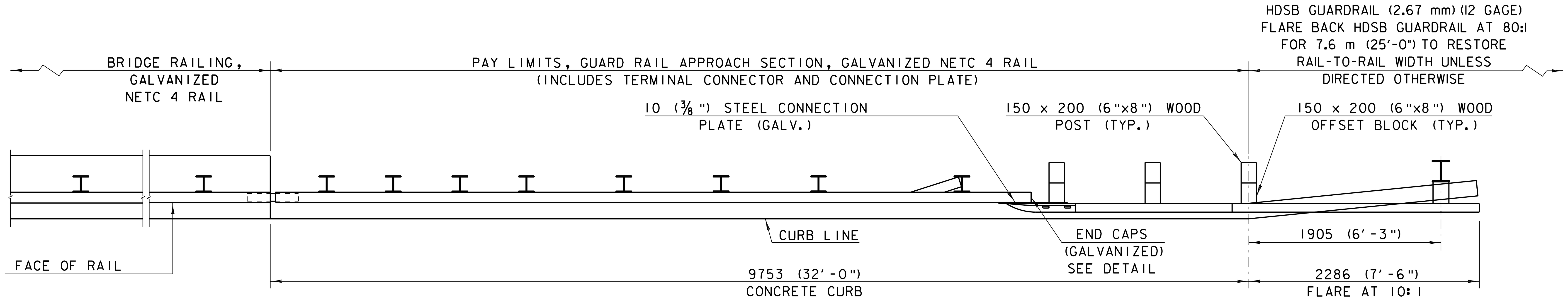


RAIL TUBE SPLICE SECTION

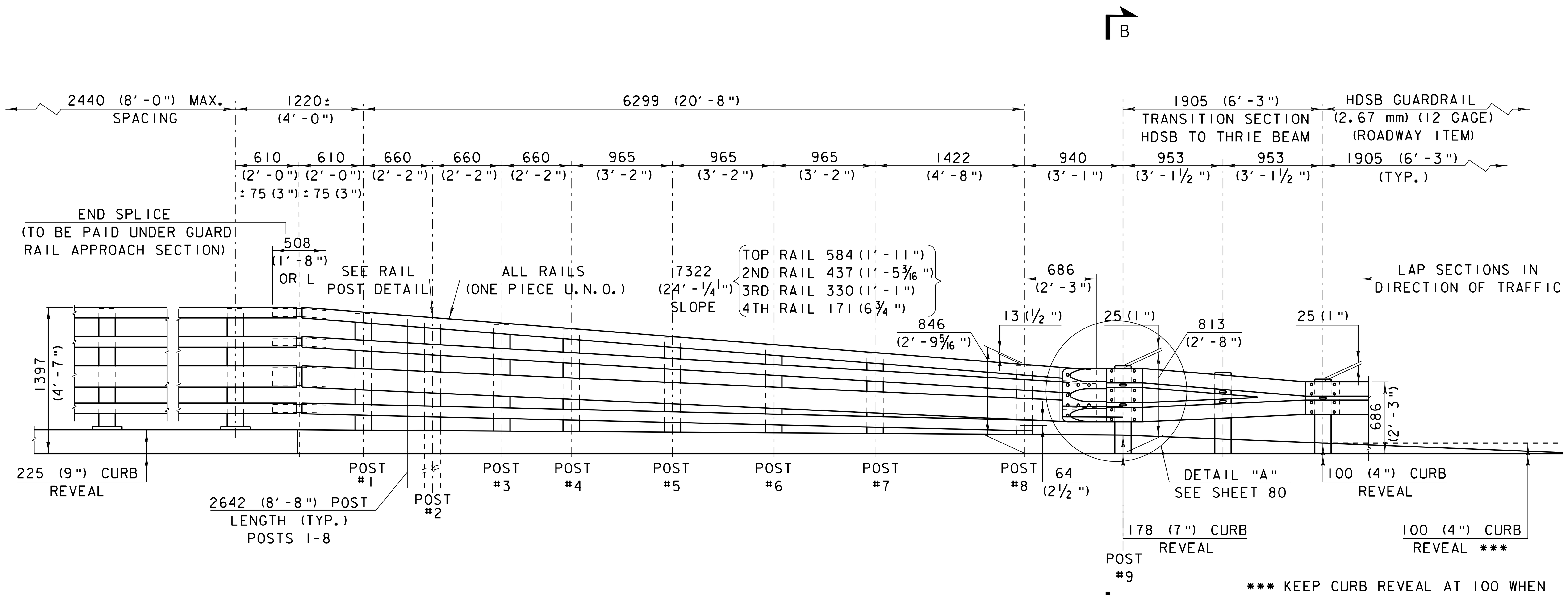
ALL DETAILS NOT TO SCALE

PROJECT: STOCKBRIDGE	PROJECT NO.: BRF 022-1 (20)
DESIGN FILE NAME: 85e039\Structures\de039rail.dgn	
IPARM FILE NAME: de039rail2m.i	PLOT DATE: 08-APR-2010
DESIGNED BY: H. I. SALLS	DRAWN BY: H. I. SALLS
SQUAD LEADER: C. P. WILLIAMS	CHECKED BY: R. S. YOUNG
RAILING DETAIL 1	SHEET: 78 OF 139

Metric



PLAN VIEW - APPROACH RAIL



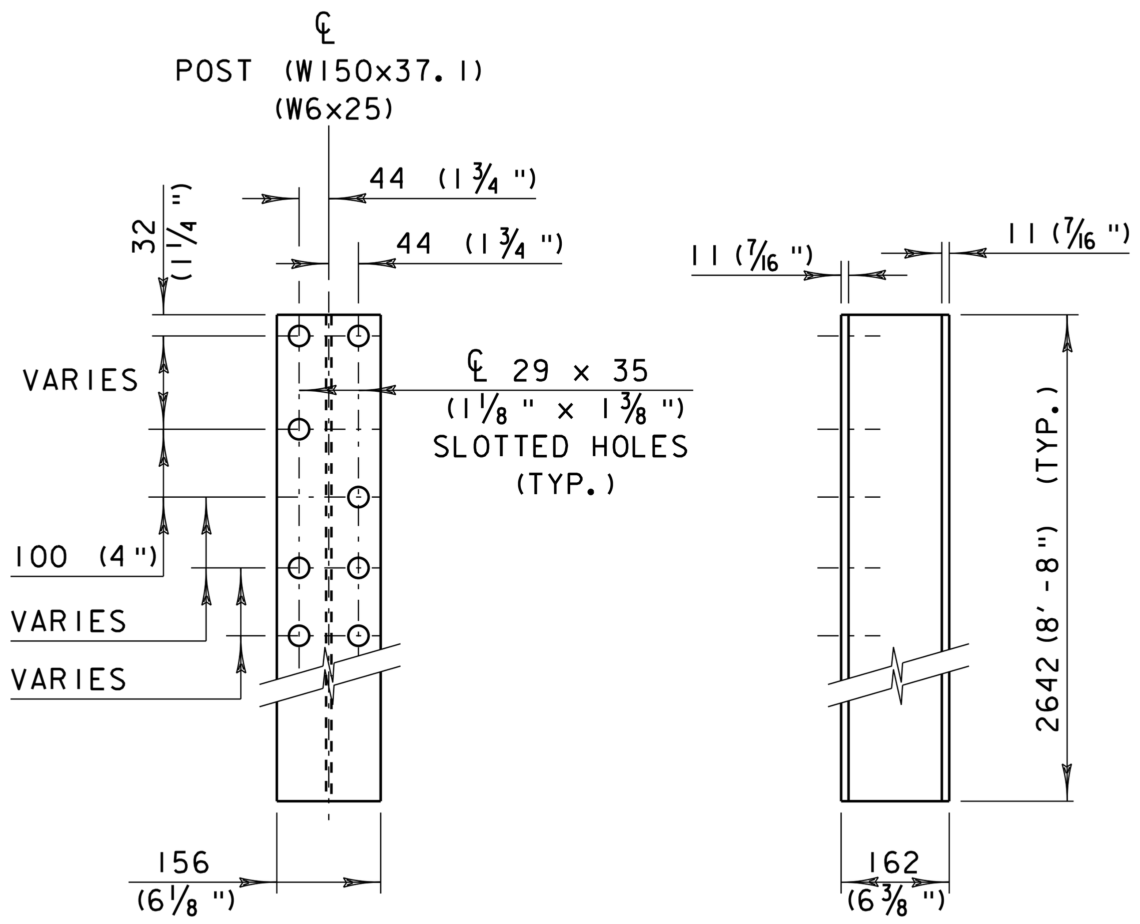
*** KEEP CURB REVEAL AT 100 WHEN MATCHING INTO BITUMINOUS CONCRETE CURB

ELEVATION VIEW - APPROACH RAIL

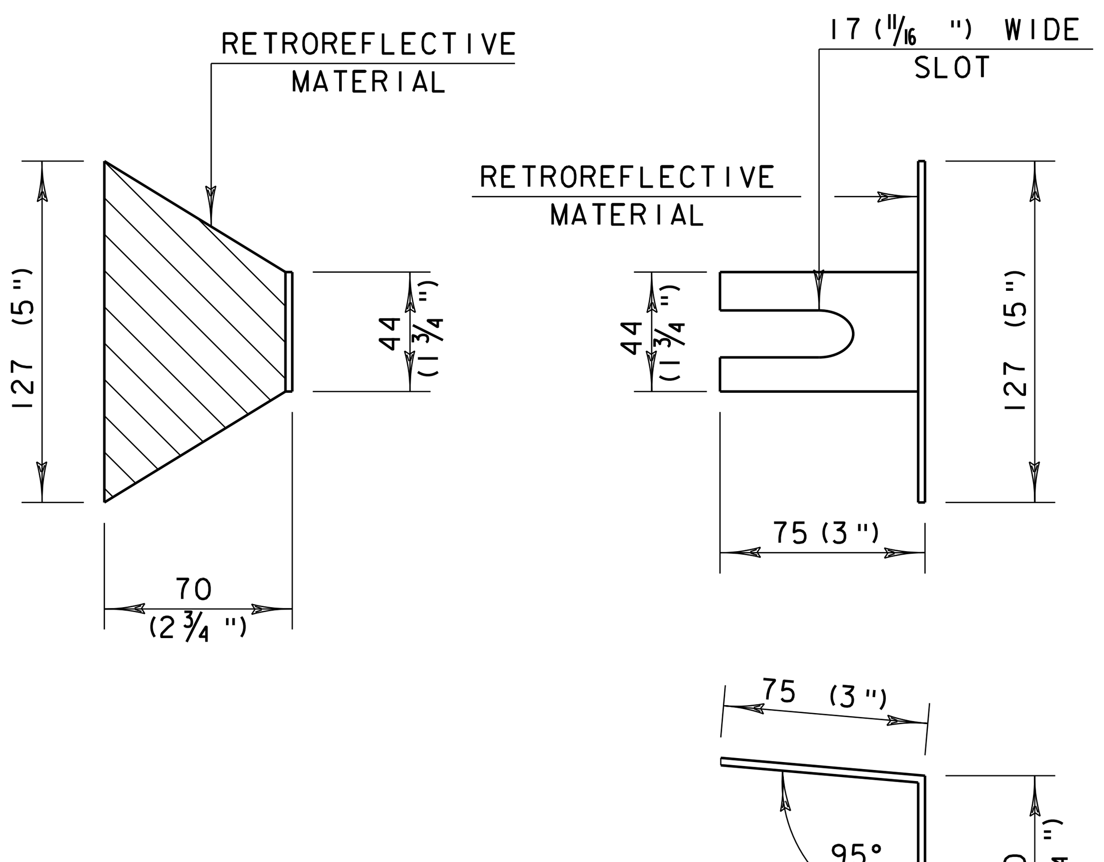
SEE SHEET 80 FOR SECTION B-B

NOTES

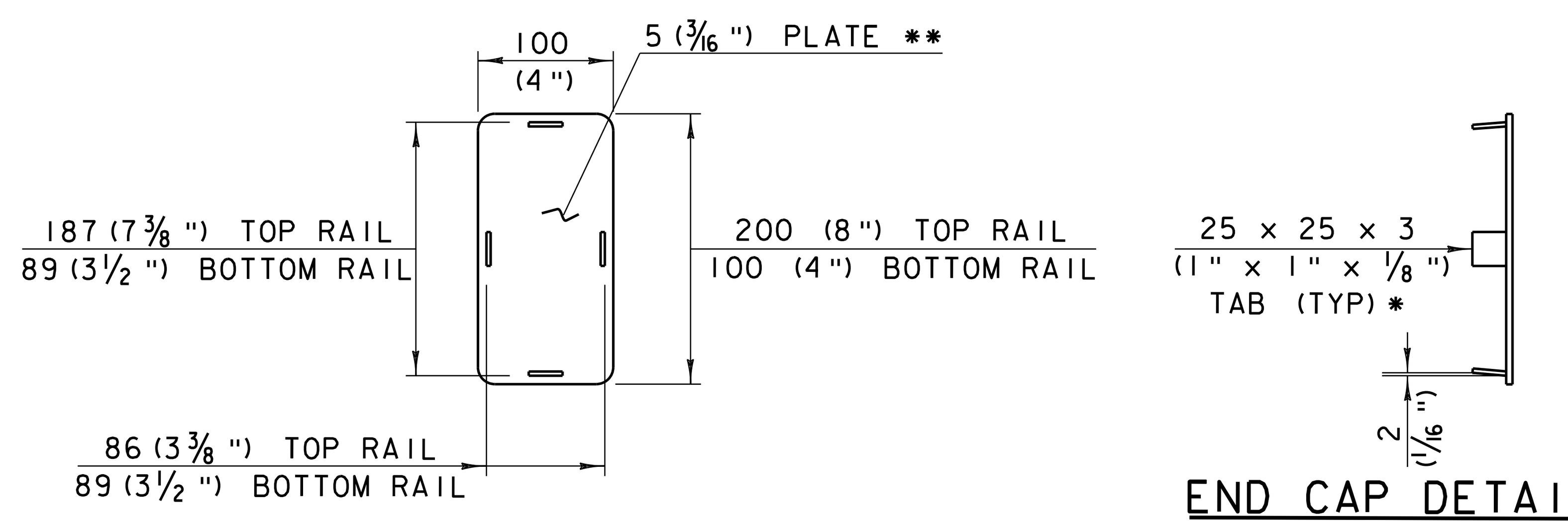
1. REFER TO SHEET 78 FOR ADDITIONAL DETAILS, NOTES AND MATERIAL SPECIFICATIONS.
2. PAYMENT FOR GUARD RAIL APPROACH SECTION, GALVANIZED NETC 4 RAIL SHALL INCLUDE THE TERMINAL CONNECTOR, THE CONNECTION PLATE, RAIL, POSTS, BLOCKS AND ATTACHMENT HARDWARE.
3. RETROREFLECTIVE MATERIAL SHALL MEET REQUIREMENTS OF SUBSECTION 750.08 AND SHALL BE OF ENCAPSULATED LENS SILVER INSTALLED ON DRIVER'S RIGHT.
4. ALL APPROACH RAIL SPLICES SHALL BE LAPPED IN THE DIRECTION OF TRAFFIC FLOW.
5. ALL BRIDGE APPROACH RAIL MATERIALS, DIMENSION SIZES AND NOTES SHALL BE THE SAME AS THOSE OF THE BRIDGE RAIL, UNLESS OTHERWISE NOTED.
6. APPROACH RAIL BOLTS SHALL BE ASTM A307 GRADE A AND NUTS SHALL BE AASHTO M291M (ASTM A563 GRADE A OR BETTER) (GALVANIZED). WASHERS SHALL BE ASTM F844.
7. WELD SPLICE BARS TO FIT BEND. USE COMPLETE PENETRATION WELD (B-U2).
8. THE CONCRETE CURB WILL BE PAID FOR AS ITEM 616.28, "CAST-IN-PLACE CONCRETE CURB, TYPE B."



RAIL POST



DELINEATION DEVICE DETAILS



END CAP DETAIL

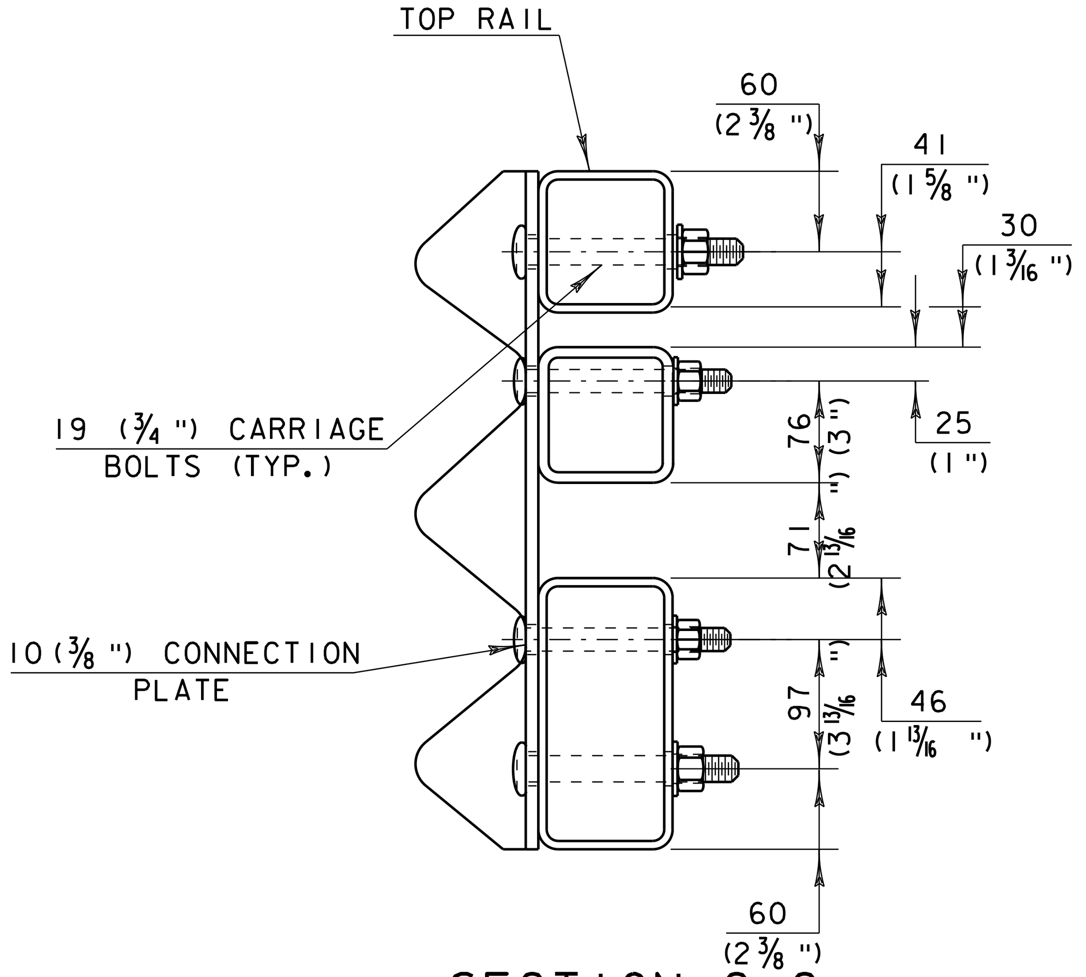
* WELD TABS TO END CAP PLATE IN TAPERED POSITION SO CAP CAN BE JAMMED INTO END OF RAIL TUBE.

** ROUND CORNERS 13 (1/2") RADIUS (TYP)

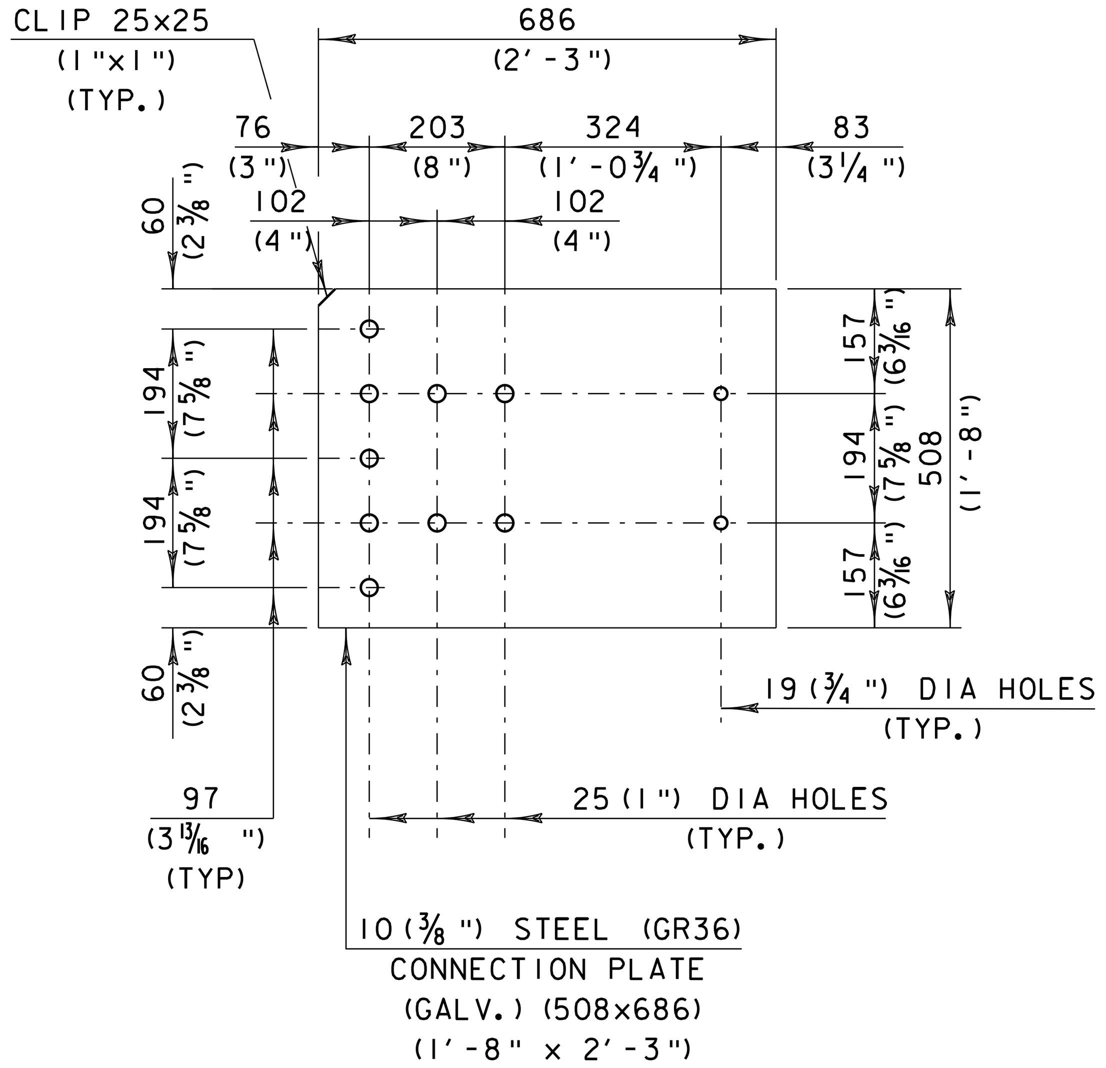
ALL DETAILS NOT TO SCALE

PROJECT: STOCKBRIDGE	PROJECT NO.: BRF 022-1(20)
DESIGN FILE NAME: 85e039\Structures\de039rail.dgn	
IPARM FILE NAME: de039raillm.i	PLOT DATE: 08-APR-2010
DESIGNED BY: H. I. SALLS	DRAWN BY: H. I. SALLS
SQUAD LEADER: C. P. WILLIAMS	CHECKED BY: R. S. YOUNG
RAILING DETAIL 2	SHEET: 79 OF 139

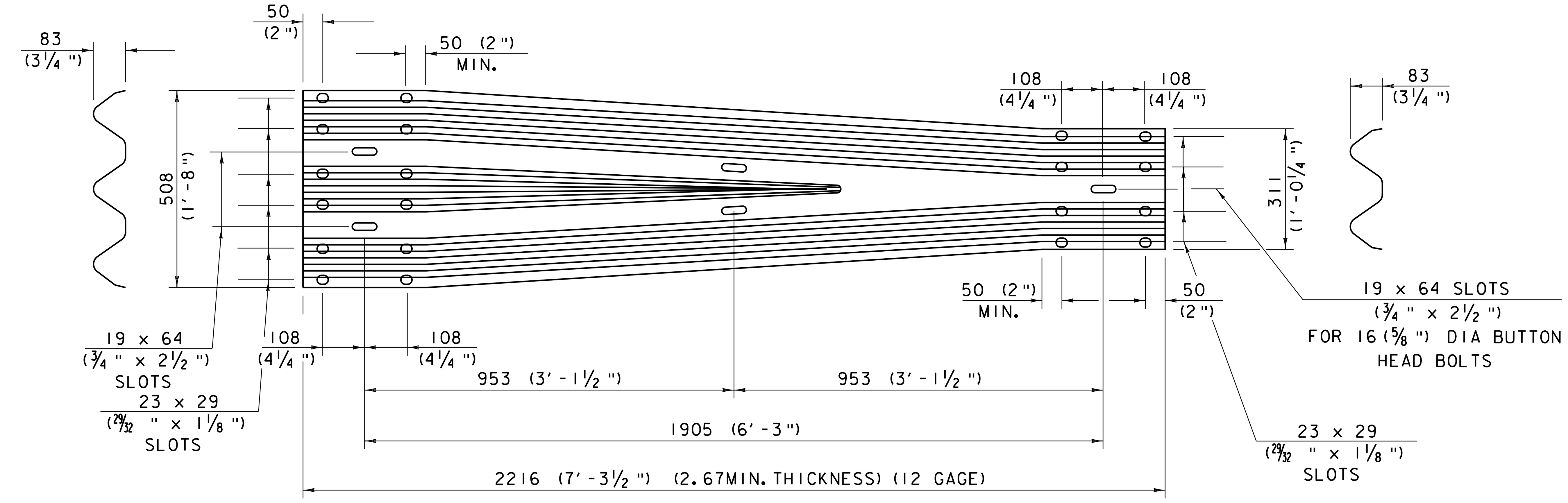
Metric



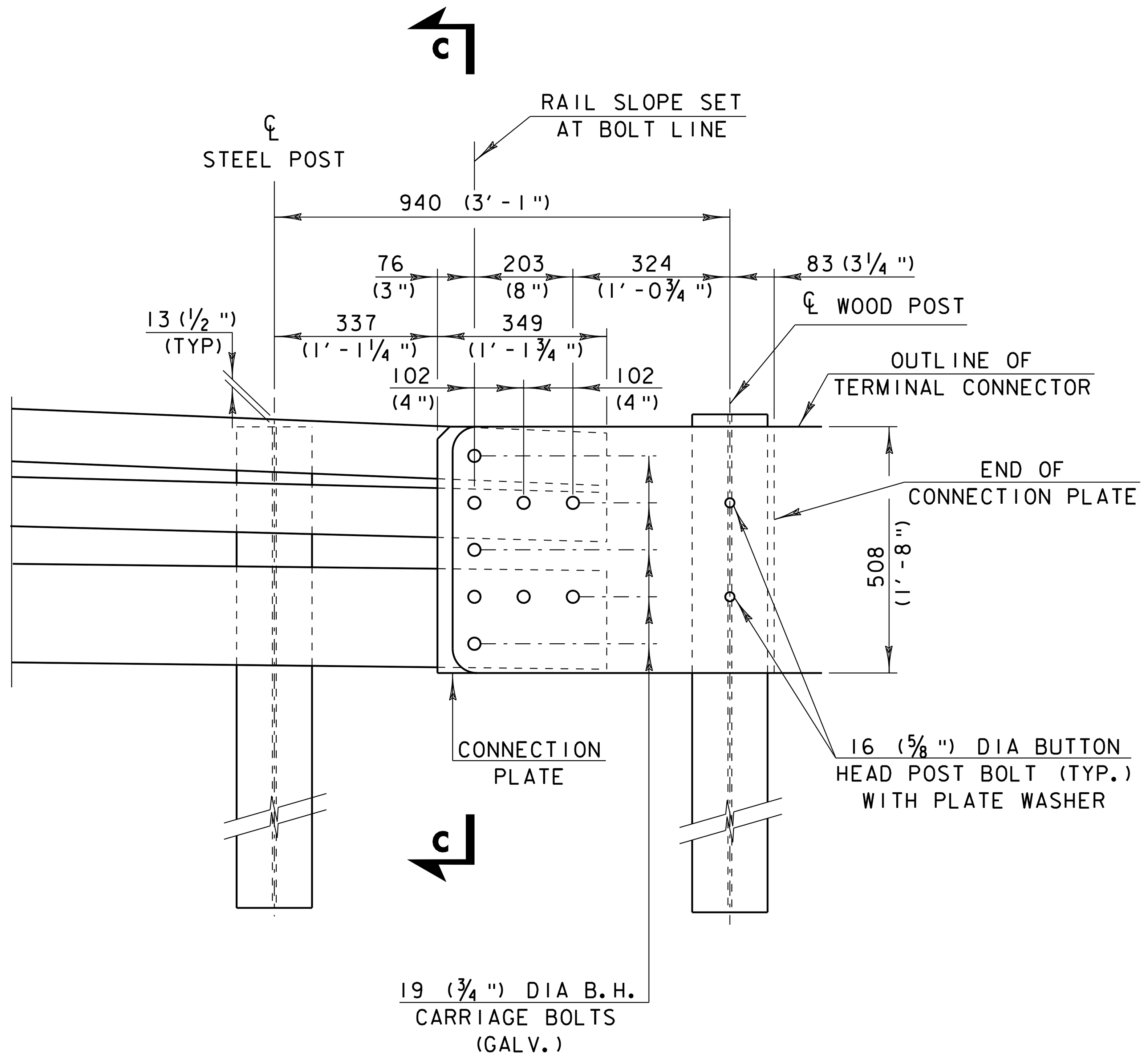
SECTION C-C
(CONNECTION PLATE)



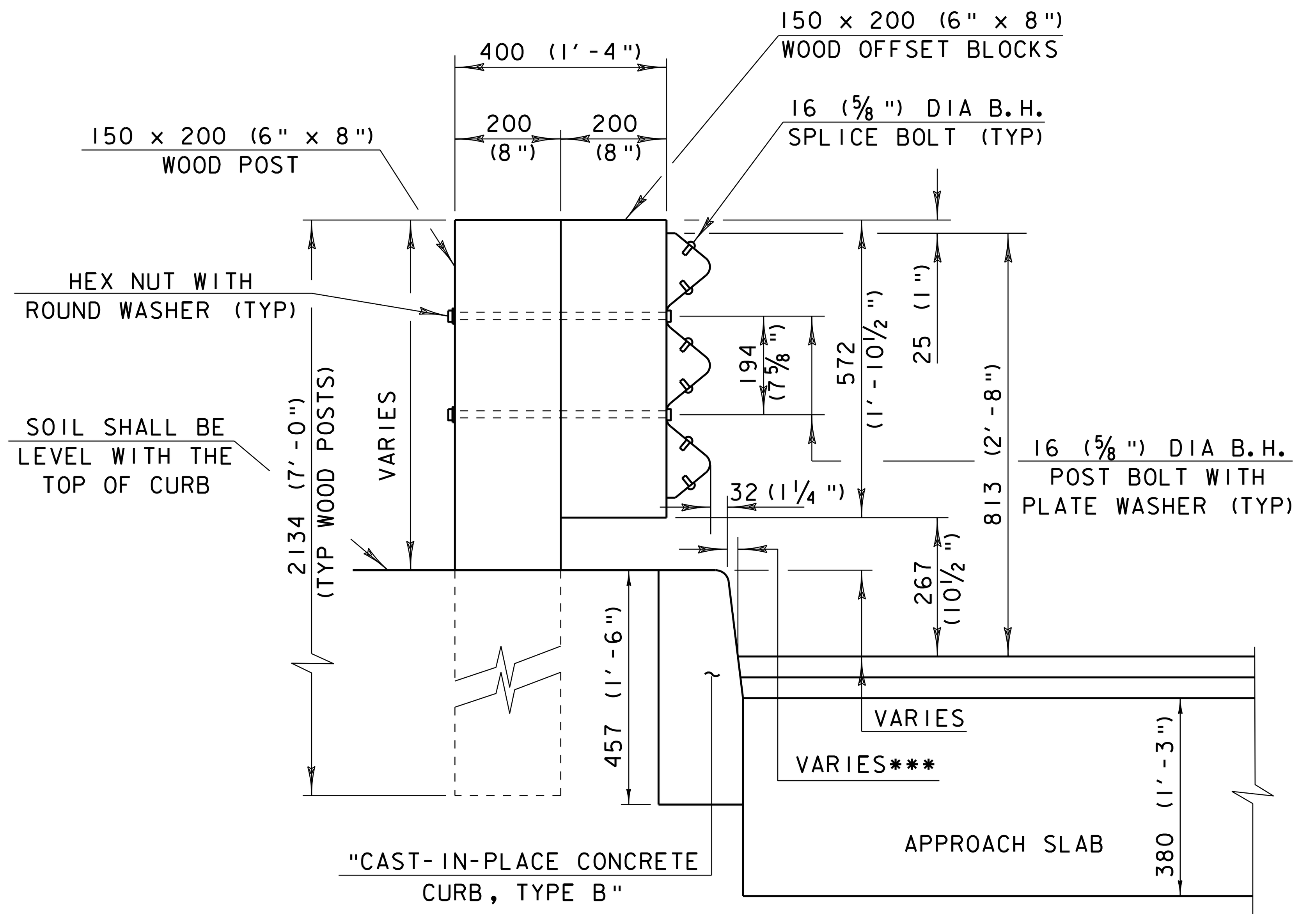
CONNECTION PLATE



THRIE-BEAM TO HDSB
TRANSITION SECTION
(HM-TF-13/RE-69)

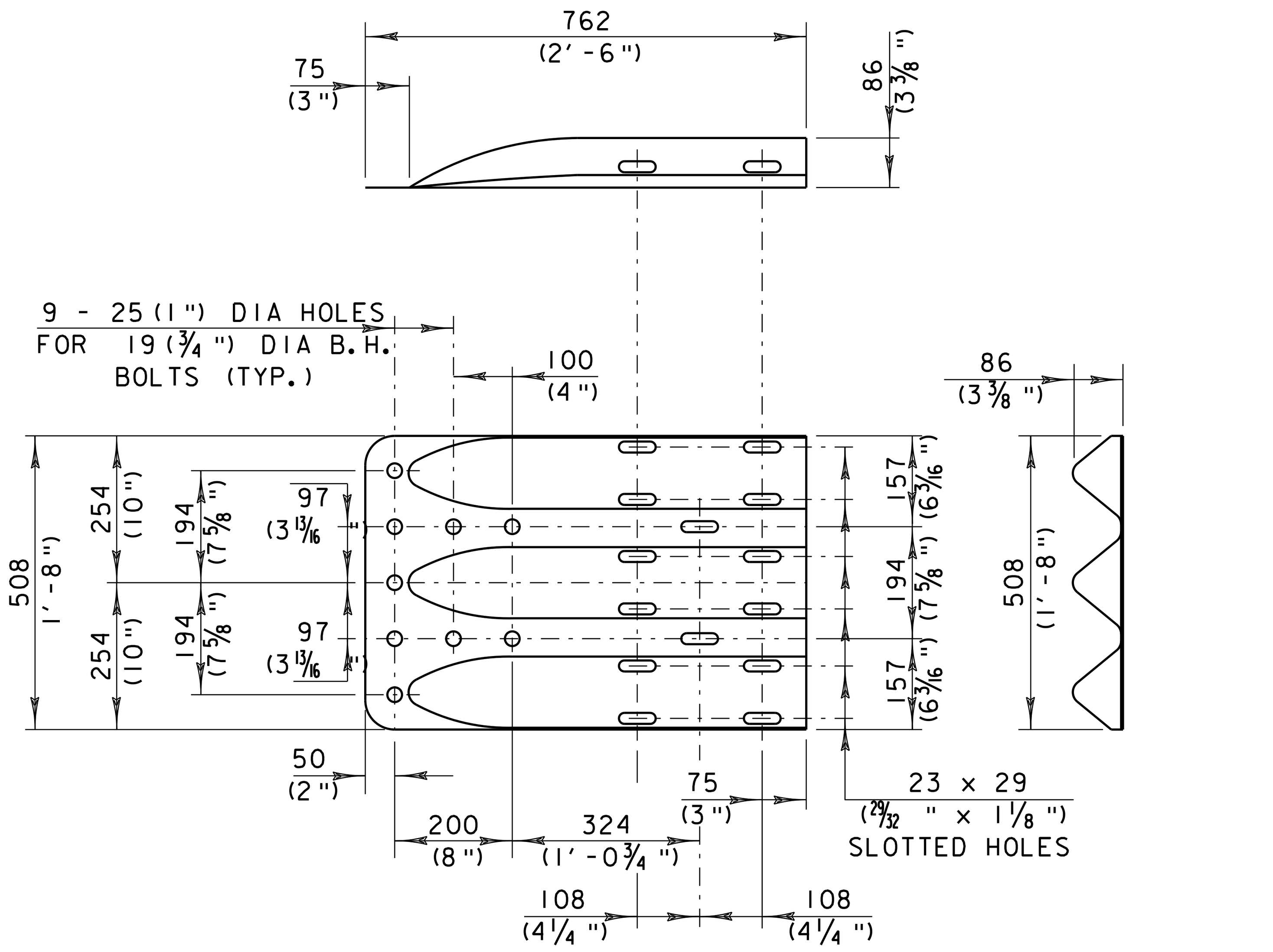


DETAIL A



*** CHANGE SLOPE FROM 25 (1") IN 300 (12") AT BRIDGE TO 25 (1") IN 150 (6") PER STANDARD C-10 OVER A DISTANCE OF 3050 (10'-0")

SECTION B-B (POST RAIL ASSEMBLY)

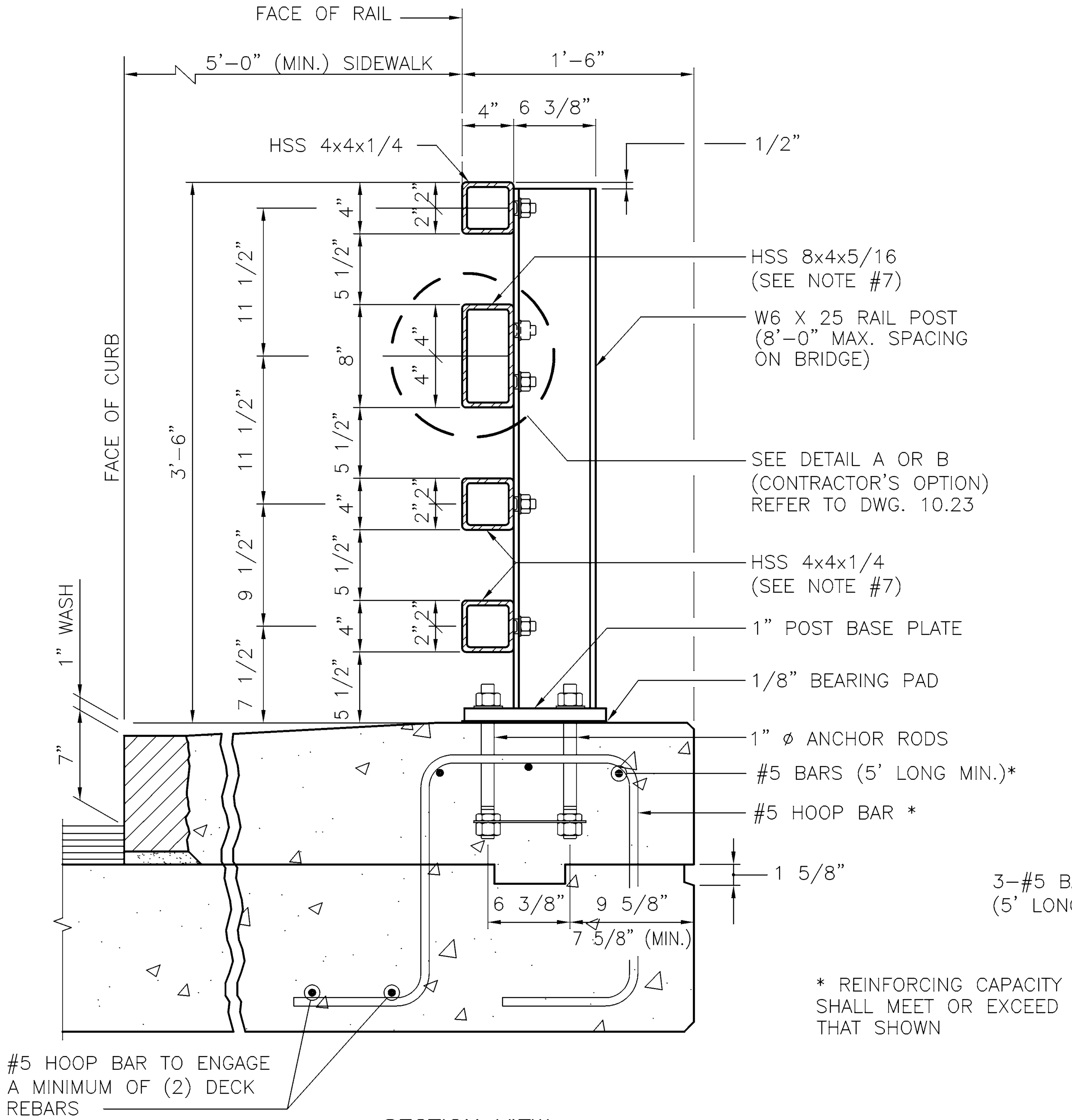


THRIE-BEAM TERMINAL CONNECTOR
(HM-TF-13/RE-67)

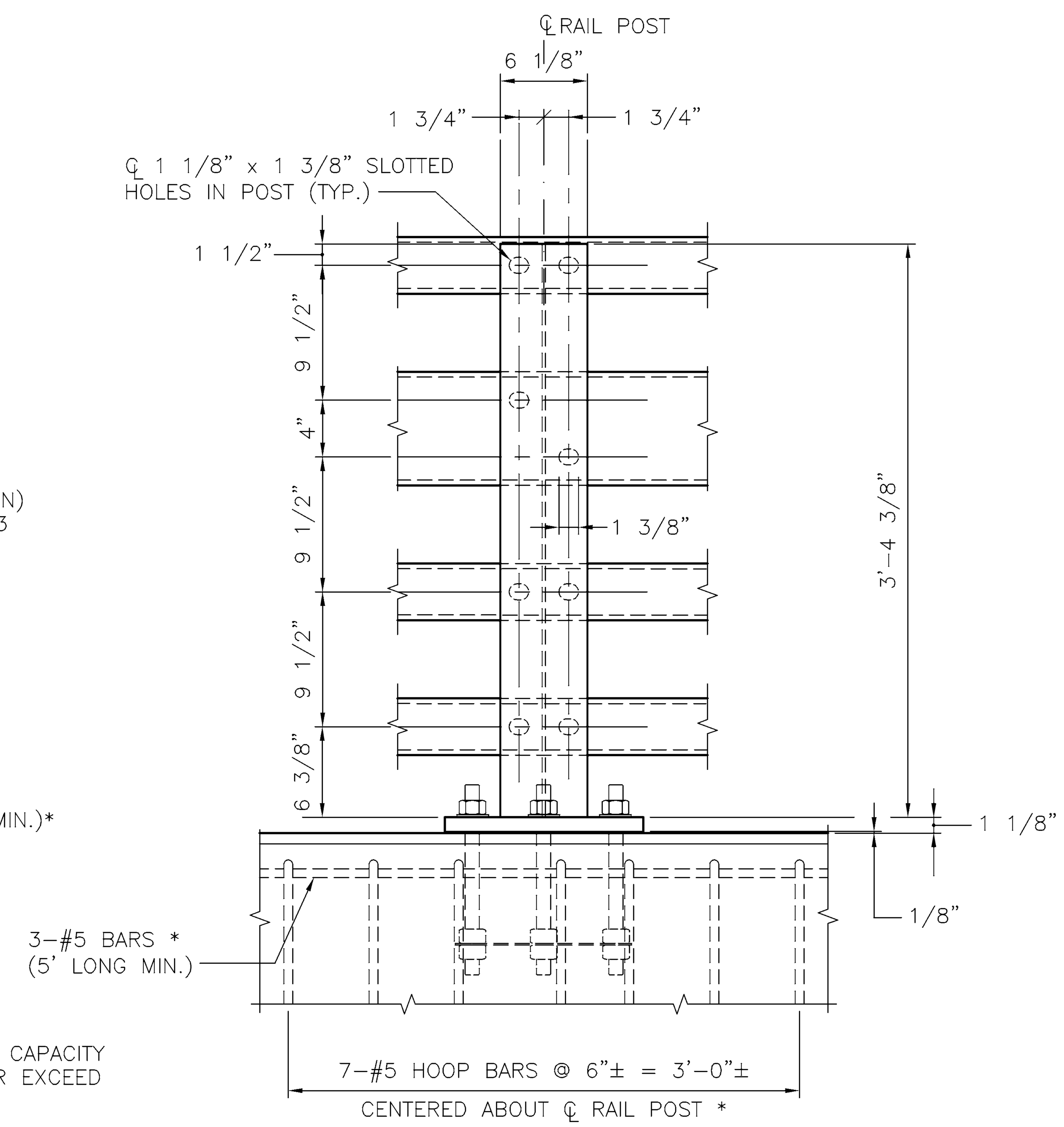
ALL DETAILS NOT TO SCALE

PROJECT: STOCKBRIDGE	PROJECT NO.: BRF 022-1(20)
DESIGN FILE NAME: 85e039\Structures\de039rail.dgn	
IPARM FILE NAME: de039rail3m.i	PLOT DATE: 08-APR-2010
DESIGNED BY: H. I. SALLS	DRAWN BY: H. I. SALLS
SQUAD LEADER: C. P. WILLIAMS	CHECKED BY: R. S. YOUNG
RAILING DETAIL 3	SHEET: 80 OF 139

APPENDIX D: RHODE ISLAND DOT STANDARD BRIDGE RAIL DRAWINGS



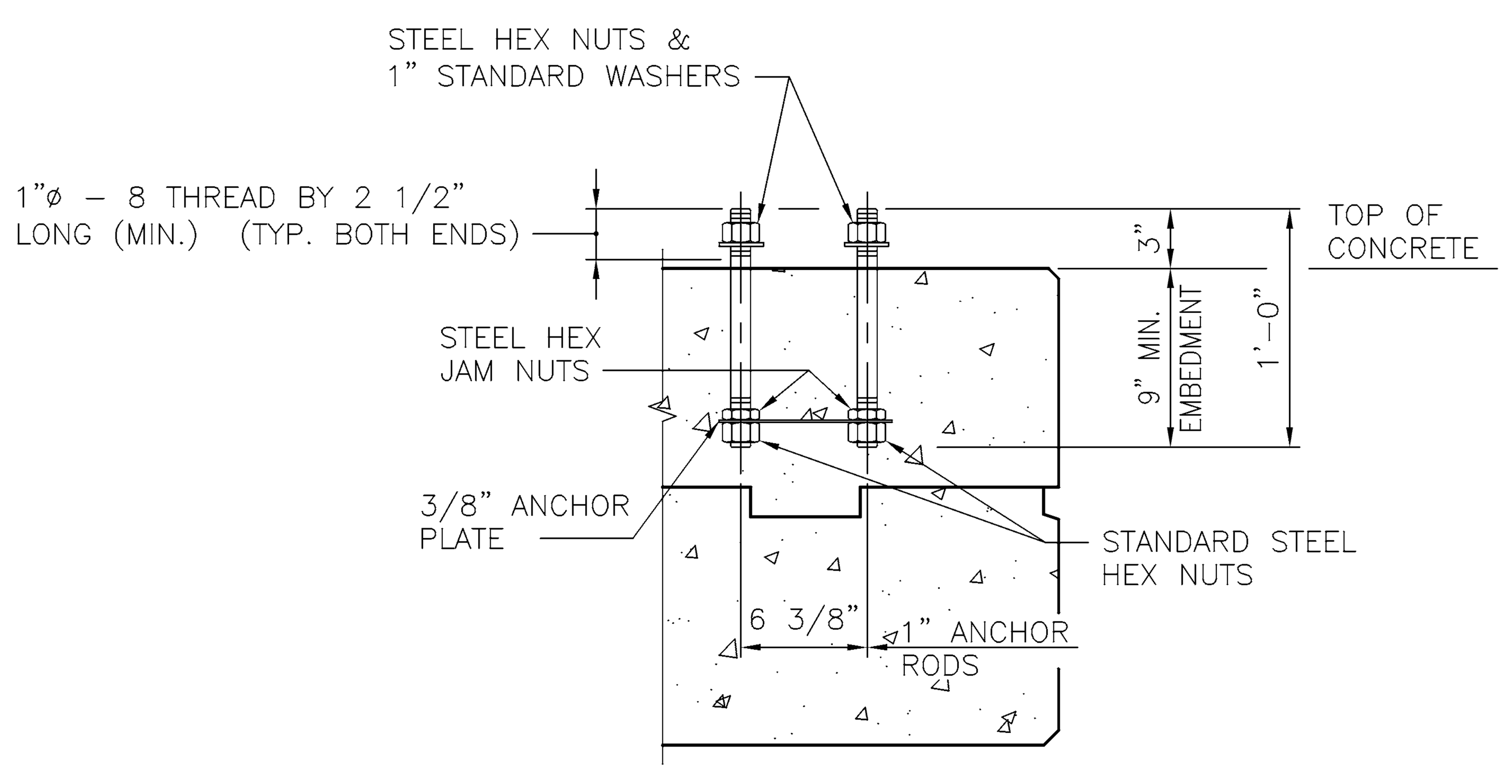
SECTION VIEW



BACK ELEVATION VIEW

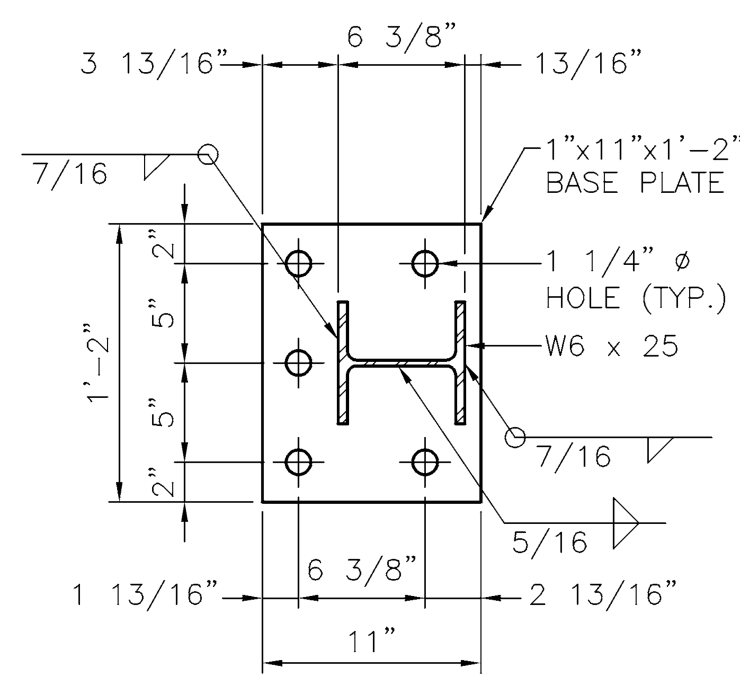
POST ASSEMBLY

SCALE:1 1/2"=1'–0"



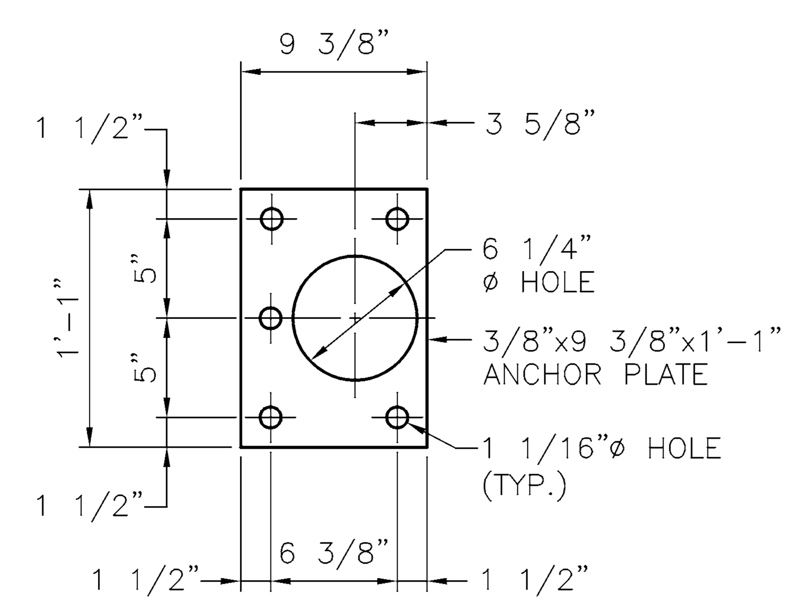
POST ANCHOR ASSEMBLY

SCALE:1 1/2"=1'–0"



POST BASE PLATE

SCALE:1 1/2"=1'–0"



ANCHOR PLATE

SCALE:1 1/2"=1'–0"

RAIL NOTES:

1. FOUR BAR (CRASH–TESTED) STEEL BRIDGE RAIL SHALL INCLUDE POSTS, BASE PLATES, ANCHOR RODS, PREFORMED PADS, RAIL ASSEMBLY BOLTS, NUTS, WASHERS, STUDS, STRUCTURAL TUBING, SPLICE BARS, PIPE SPACERS, RETRO REFLECTIVE DELINEATORS, ALL APPURTENANCES, METALIZING, AND PAINTING (IF SPECIFIED).
2. BRIDGE RAIL POSTS SHALL BE SET NORMAL (90 DEGREES) TO THE PROFILE GRADE, EXCEPT ON GRADES OVER 1.5% WHERE POSTS SHALL BE SET VERTICAL.
3. ENDS OF RAIL TUBE SECTIONS SHALL BE SAWED OR MILLED AND SHALL BE TRUE AND SMOOTH. ALL CUT EDGES OF ALL MATERIAL SHALL BE GROUND SMOOTH.
4. EACH PIECE OF RAIL TUBING SHALL BE ATTACHED TO A MINIMUM OF THREE (3) POSTS.
5. BOLT HOLES SHALL BE DRILLED OR PUNCHED. FLAME CUTTING MAY BE USED TO FINISH SLOTTED HOLES IF MECHANICALLY GUIDED.
6. AT INTERIOR SPLICES, PIPE SPACERS SHALL BE USED ON ONLY ONE SIDE OF THE SPLICE TO ALLOW MOVEMENT ON THAT SIDE. ALL 4 RAILS AT A SPLICE SHALL RECEIVE THE SAME TREATMENT. AT END SPLICES AND AT INTERIOR EXPANSION SPLICES PIPE SPACERS SHALL BE USED ON BOTH SIDES OF THE SPLICE TO ALLOW MOVEMENT ON BOTH SIDES.
7. MILL OR SHOP TRANSVERSE WELDS SHALL NOT BE PERMITTED ON ANY RAIL ELEMENT. RAIL ELEMENTS USED ON CURVES SHALL USE 3/8" WALL TUBES AND SHALL BE SHOP FORMED TO THE REQUIRED CURVATURE.
8. NO PUNCHING, DRILLING, CUTTING OR WELDING SHALL BE PERMITTED AFTER METALIZING, (EXCEPT FOR DETAIL "A"). DAMAGED AREAS OF METALIZING SHALL BE REPAIRED IN STRICT CONFORMANCE WITH THE MATERIAL SUPPLIER'S RECOMMENDATIONS AND SHALL BE APPROVED BY THE ENGINEER.
9. NUTS FOR 1"ø THREADED ANCHOR RODS CONNECTING THE BASE PLATE TO THE CONCRETE SHALL BE TIGHTENED TO A SNUG FIT AND GIVEN AN ADDITIONAL 1/8 TURN.
10 THREADS FOR ANCHOR RODS MAY BE ROLLED OR CUT. IF CUT THREADS ARE USED BOLT DIAMETER SHALL NOT BE LESS THAN NOMINAL DIAMETER. IF ROLLED THREADS ARE USED, ROD DIAMETER SHALL NOT BE LESS THAN ROOT DIAMETER OF THREADS.

MATERIAL NOTES:

11. STRUCTURAL TUBING SHALL CONFORM TO THE REQUIREMENTS OF ASTM A500, GRADE B, STRUCTURAL STEEL TUBING. RAIL TUBING SHALL MEET THE LONGITUDINAL CHARPY V–NOTCH REQUIREMENTS OF 15 LBS. AT 0°F FOR ASTM A500, GRADE B. THE TEST SAMPLES SHALL BE TAKEN AFTER FORMING THE TUBES. CHARPY V–NOTCH IS NOT REQUIRED FOR SPLICE TUBES.
12. RAIL POSTS AND BASE PLATES SHALL CONFORM TO THE REQUIREMENTS OF ASTM A572 GR. 50, EXCEPT ANCHOR PLATES MAY BE ASTM A36.
13. THREADED STUDS AND MATCHING NUTS FOR RAIL–TO–POST ATTACHMENT (DETAIL A) SHALL CONFORM TO ASTM A276 TYPE 304, STAINLESS STEEL, AND SHALL BE TORQUE TESTED PER AWS D1.5, 7.7.1. DETAIL B BOLTS SHALL BE ASTM A325 OR A449. ALL OTHER BOLTS AND NUTS SHALL CONFORM TO ASTM A307 AND ASTM 563 GRADE A RESPECTIVELY OR BETTER. ANCHOR RODS SHALL CONFORM TO ASTM A449 EXCEPT THAT ASTM A307 NUTS MAY BE USED ON THE BOTTOM OF ANCHOR ASSEMBLY. WASHERS SHALL BE HARDENED STEEL COMMERCIAL TYPE A PLAIN WIDE WASHERS AND SHALL MEET THE DIMENSIONAL REQUIREMENTS OF A.N.S.I. B18.22.
14. ALL STEEL COMPONENTS (EXCEPT STAINLESS) SHALL BE METALIZED AFTER FABRICATION IN CONFORMANCE WITH SECTION 827 "THERMAL SPRAYED ZINC COATING FOR NEW STRUCTURAL STEEL" OF THE RHODE ISLAND STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION. THE METALIZING SHALL HAVE A UNIFORM APPEARANCE, AND METALIZED MATERIAL SHALL BE PROPERLY STORED.
15. DETAIL "A" STUDS SHALL BE WELDED BEFORE TUBES ARE METALIZED.
16. PREFORMED BEARING PADS (1/8" THICK) SHALL CONFORM TO AASHTO M251.

DESIGNER NOTE:
PROVIDE PAINT COLOR FOR RAILING SYSTEM.

THIS BRIDGE RAIL SYSTEM WAS SUCCESSFULLY CRASH TESTED FOR AASHTO TL4 IN 1997 BY THE NEW ENGLAND TRANSPORTATION CONSORTIUM.

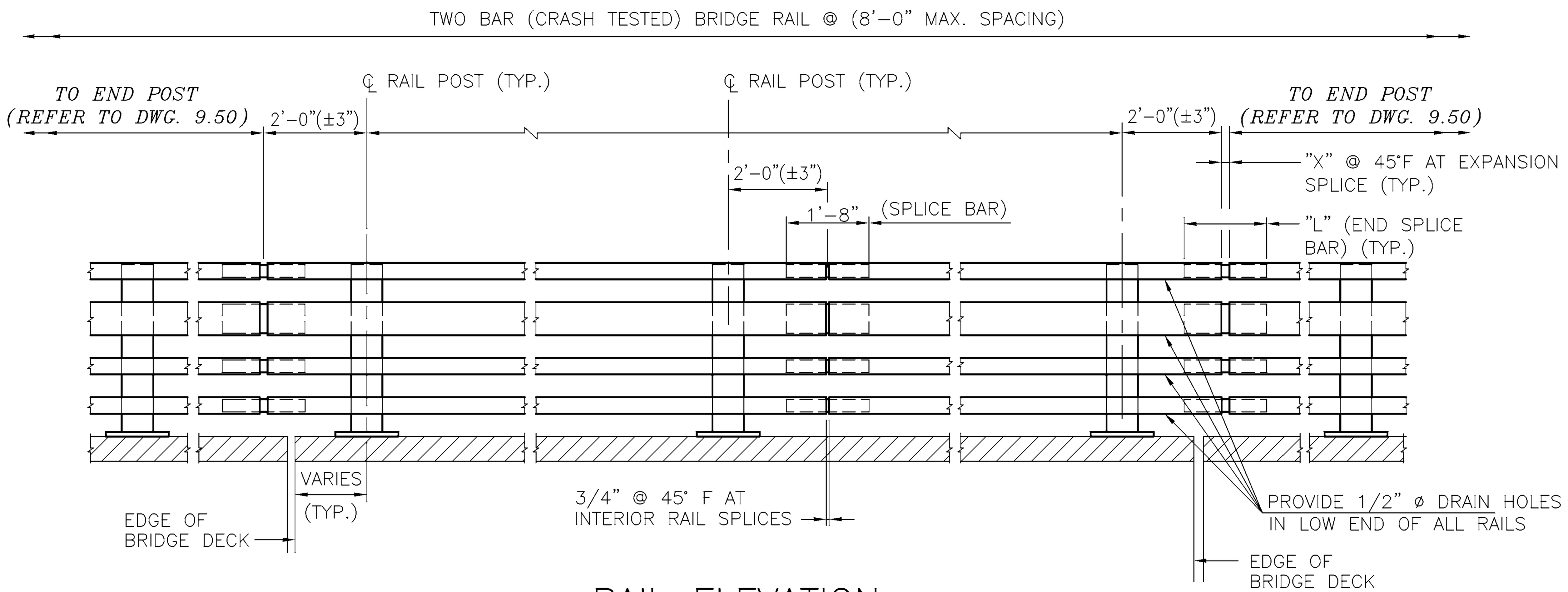
REVISIONS	
No.	DATE

RHODE ISLAND
DEPARTMENT OF TRANSPORTATION

BRIDGE STANDARDS

FOUR BAR STEEL BRIDGE RAIL (CRASH–TESTED TL–4) SHEET 1

DRAWING NUMBER: 10.22

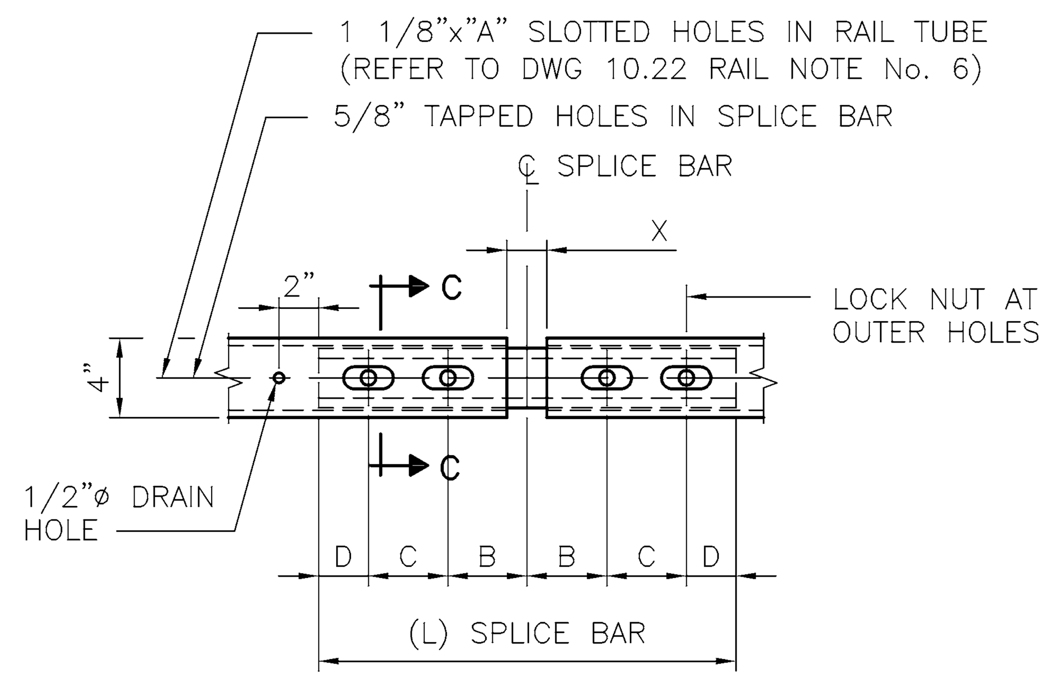


RAIL ELEVATION

SCALE: 1/2"=1'-0"

SPLICE BAR DIMENSION TABLE							
	T	A	B	C	D	X	L
	INTERIOR	2 1/2"	4"	4"	2"	3/4"	1'-8"
*	<3 1/4"	2 1/2"	4"	4"	2"	2"	1'-8"
*	3 1/4" TO 5 1/4"	3 1/2"	5"	5"	2 1/2"	3"	2'-1"

T = TOTAL MOVEMENT OF BRIDGE
* = END SPLICE BAR

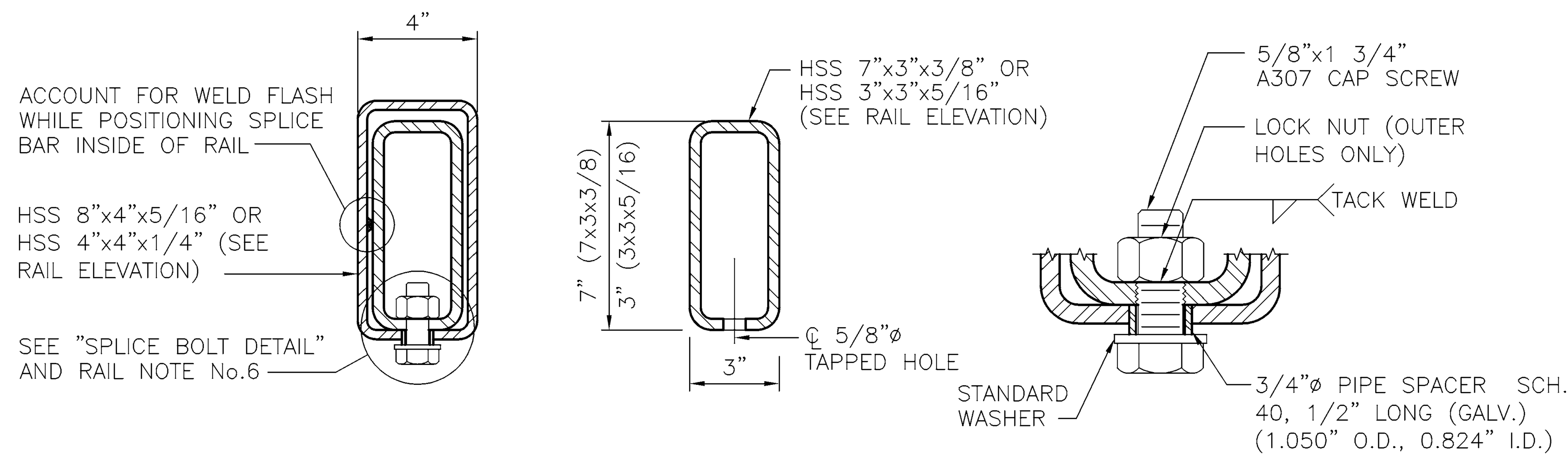


SEE SPLICE BAR DIMENSION TABLE THIS SHEET

(BOTTOM VIEW)

RAIL SPLICE

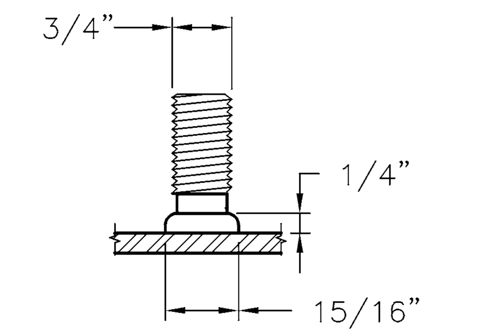
SCALE: 1 1/2"=1'-0"



SECTION C-C | SPLICE BAR SECTION | SPLICE BOLT DETAIL

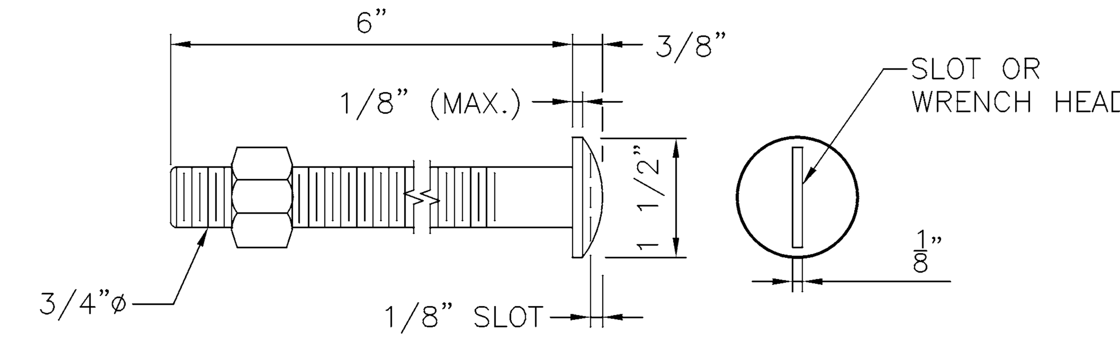
RAIL SPLICE DETAILS

SCALE: 3"=1'-0"



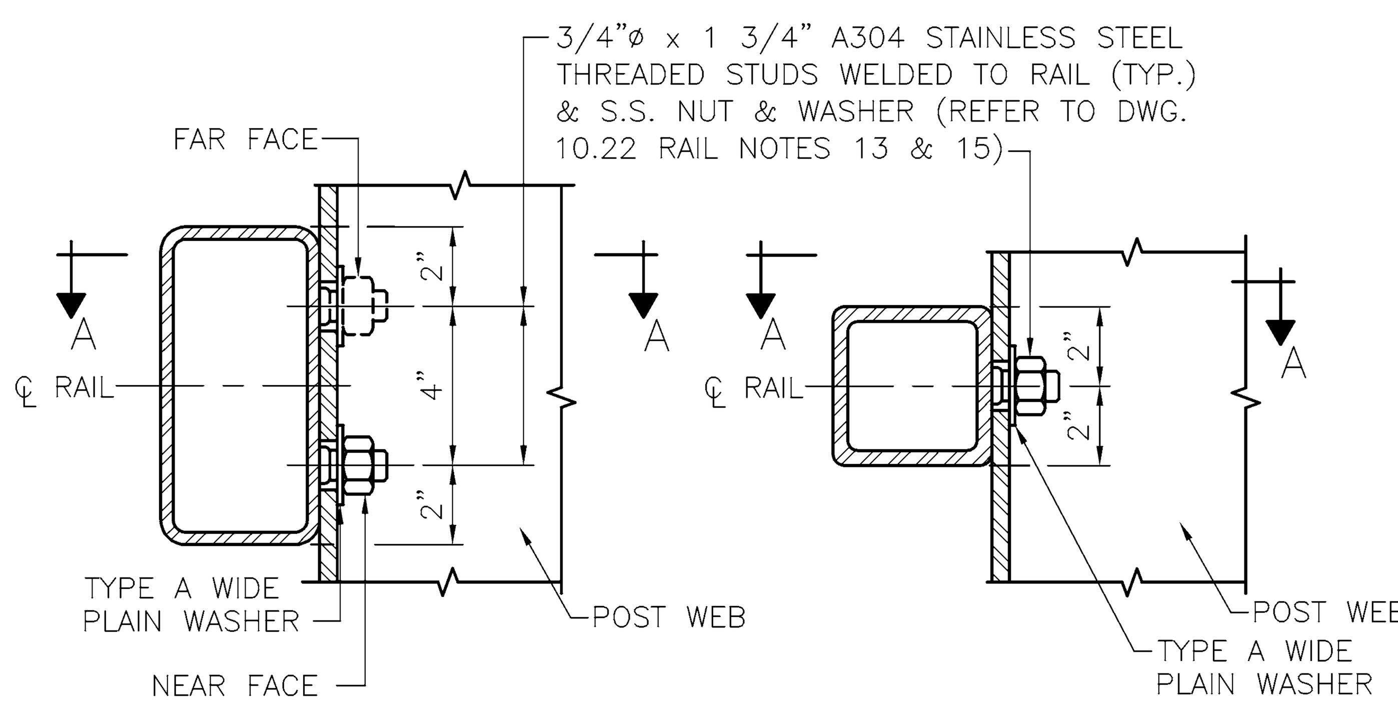
STUD WELD DETAIL

NOT TO SCALE



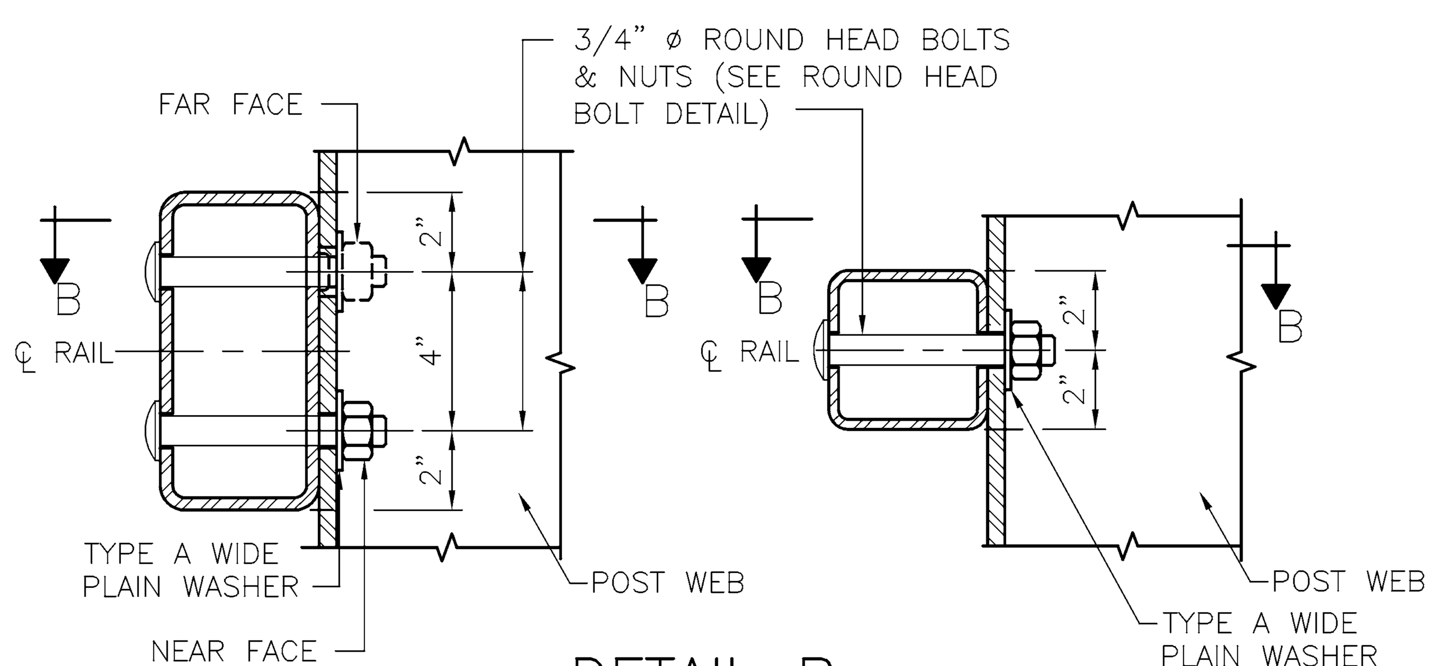
ROUND HEAD BOLT DETAIL

NOT TO SCALE



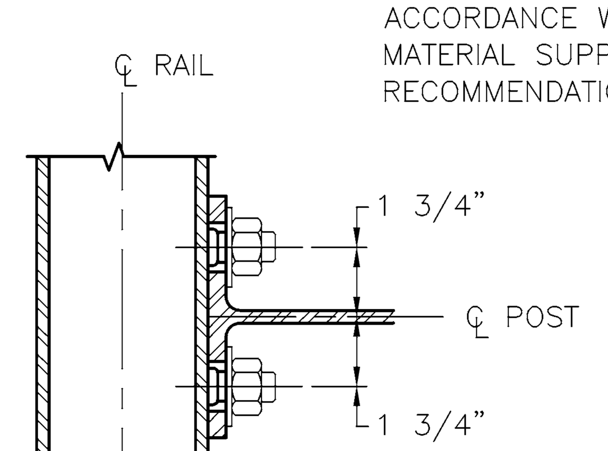
DETAIL A

SCALE: 3"=1'-0"



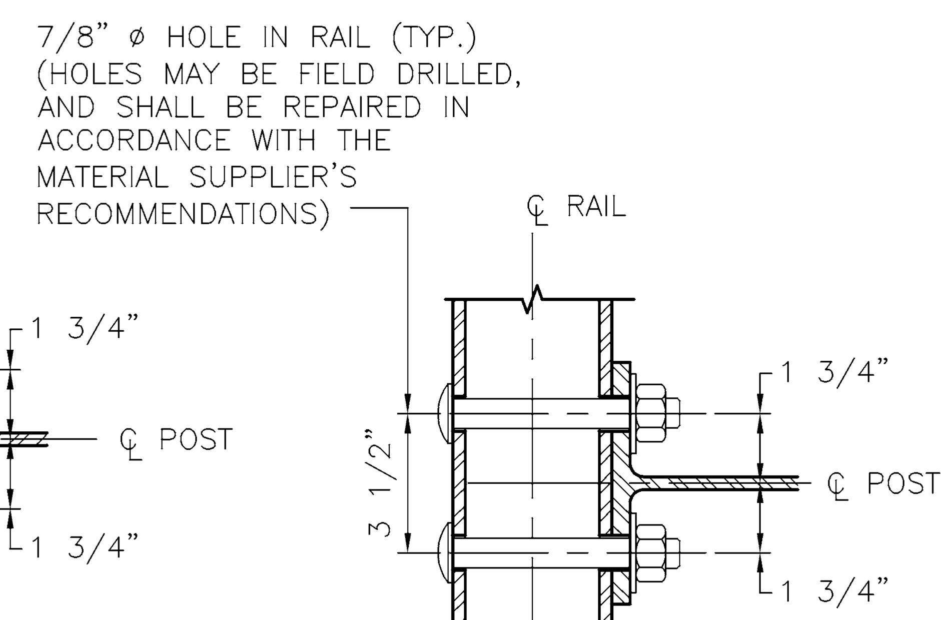
DETAIL B

SCALE: 3"=1'-0"



SECTION A-A

SCALE: 3"=1'-0"



SECTION B-B

SCALE: 3"=1'-0"

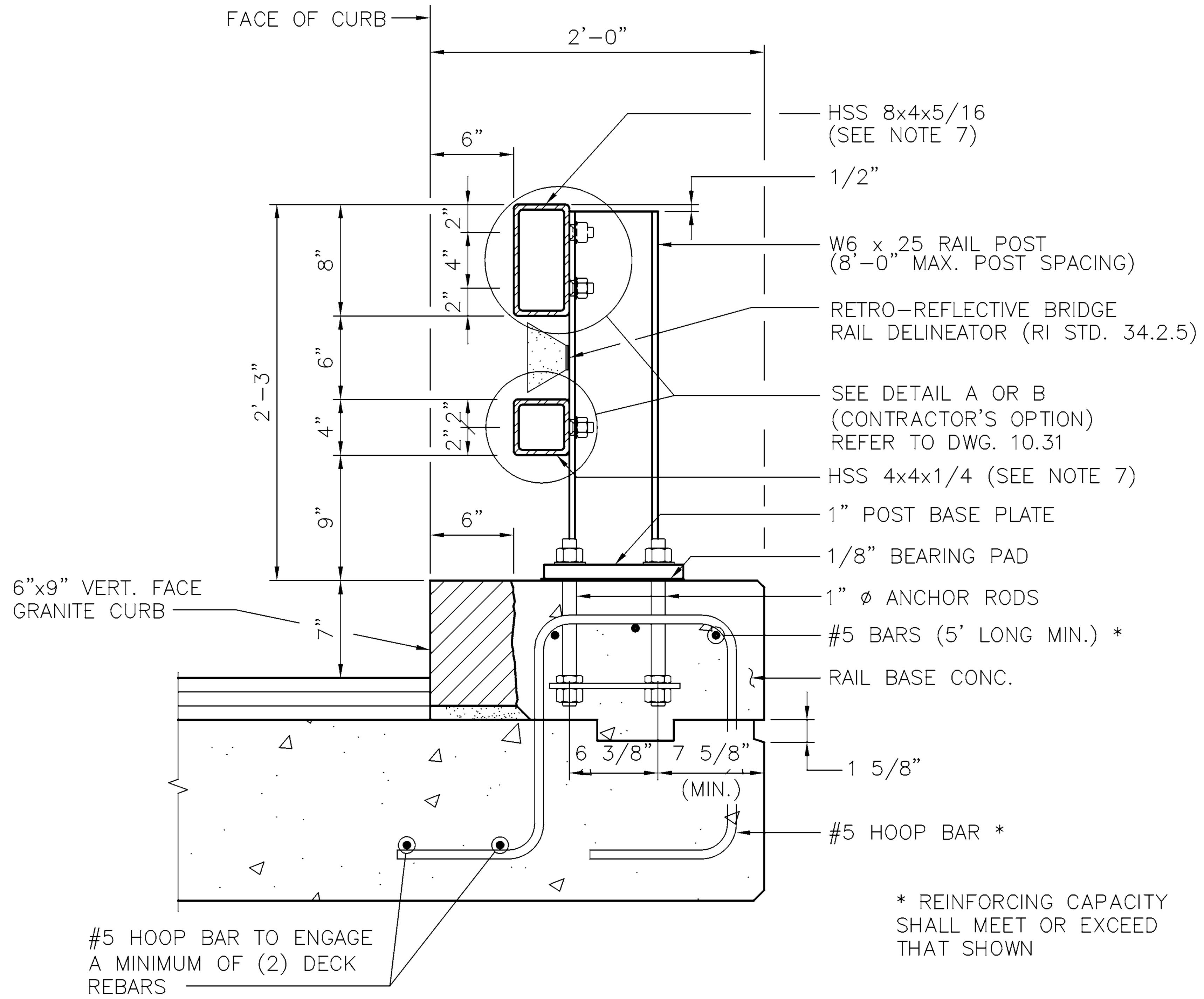
REVISIONS	
No.	DATE

RHODE ISLAND
DEPARTMENT OF TRANSPORTATION

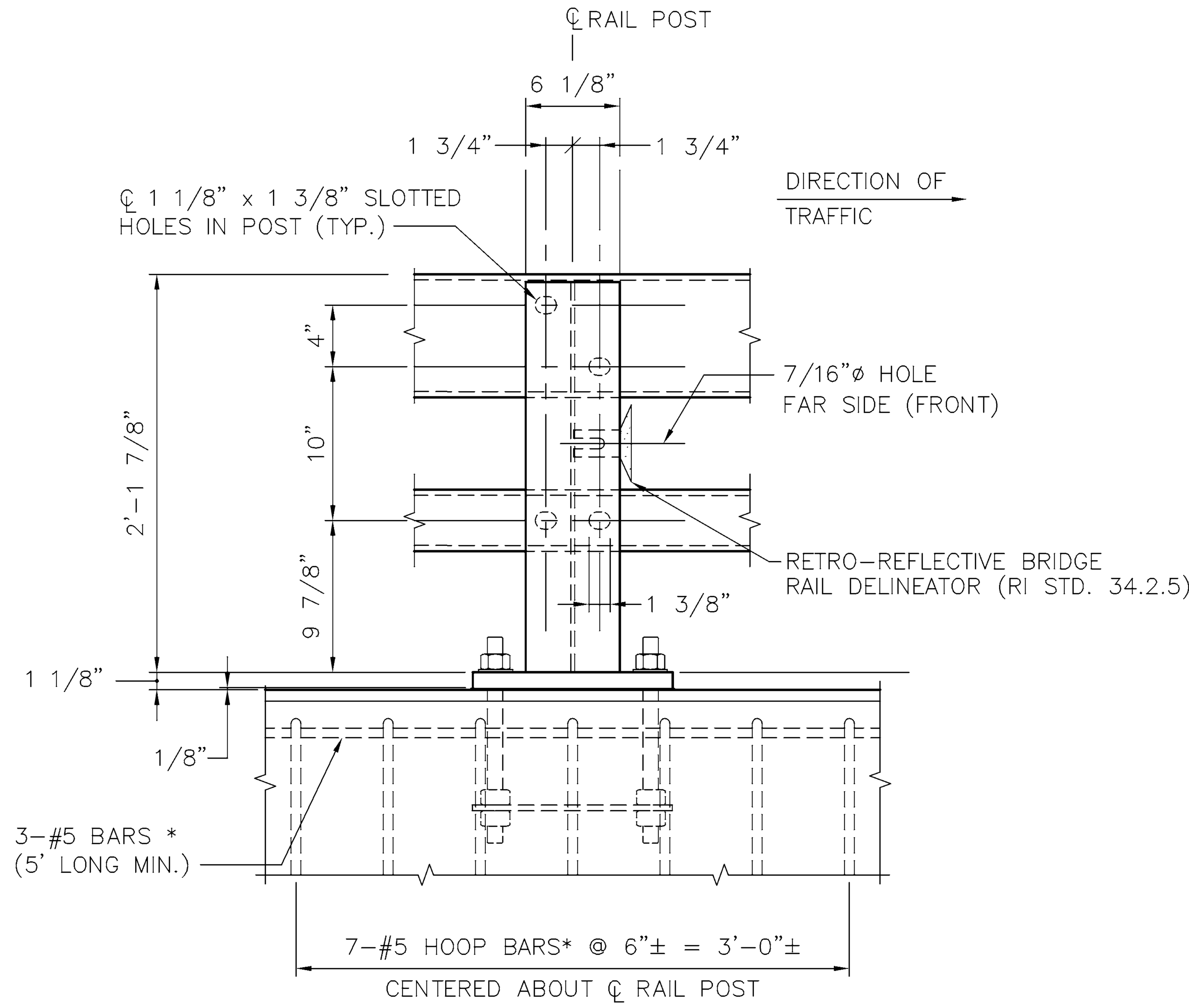
BRIDGE STANDARDS

FOUR BAR STEEL BRIDGE RAIL (CRASH-TESTED TL-4) SHEET 2

DRAWING NUMBER: 10.23



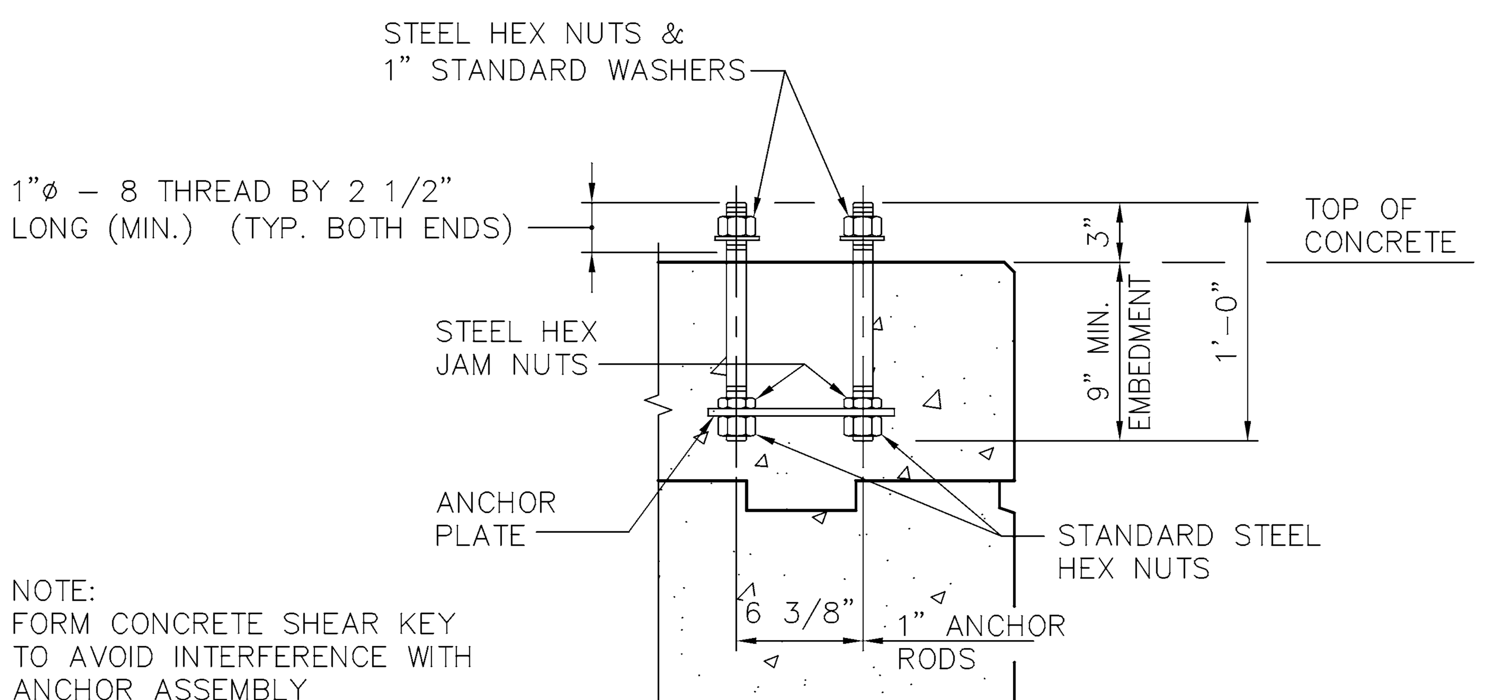
SECTION VIEW



BACK ELEVATION VIEW

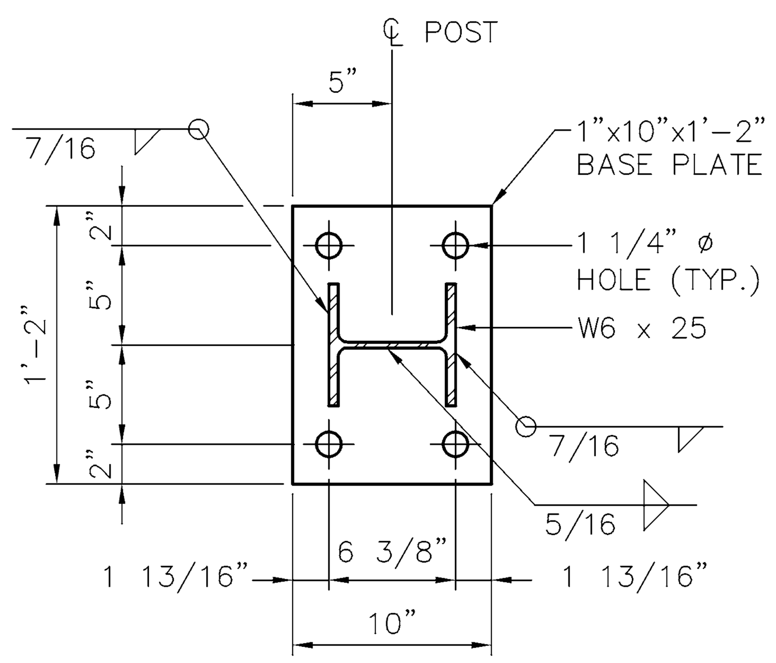
POST ASSEMBLY

SCALE:1 1/2"=1'-0"



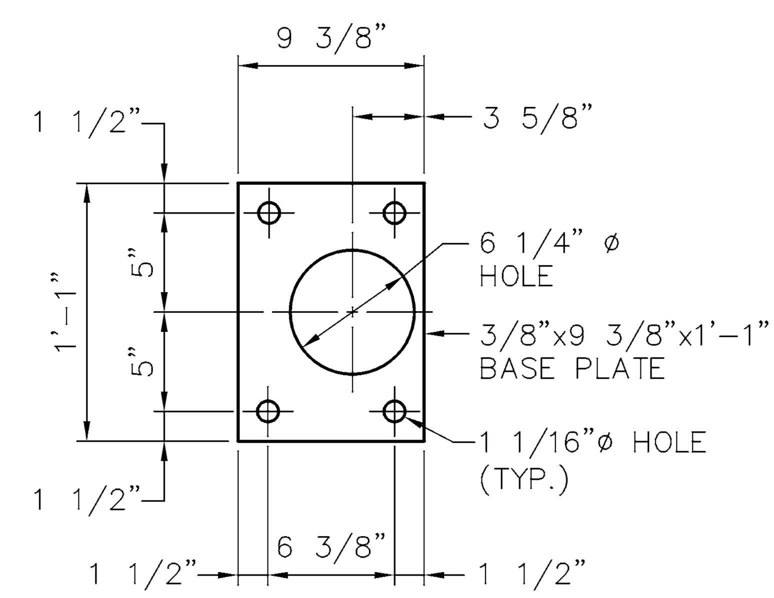
POST ANCHOR ASSEMBLY

SCALE:1 1/2"=1'-0"



POST BASE PLATE

SCALE:1 1/2"=1'-0"



ANCHOR PLATE

SCALE:1 1/2"=1'-0"

RAIL NOTES:

1. TWO BAR (CRASH-TESTED) STEEL BRIDGE RAIL, SHALL INCLUDE POSTS, BASE PLATES, ANCHOR RODS, PREFORMED PADS, RAIL ASSEMBLY BOLTS, NUTS, WASHERS, STUDS, STRUCTURAL TUBING, SPLICE BARS, PIPE SPACERS, RETRO REFLECTIVE DELINEATORS, ALL APPURTENANCES, METALIZING, AND PAINTING (IF SPECIFIED).
2. BRIDGE RAIL POSTS SHALL BE SET NORMAL (90 DEGREES) TO THE PROFILE GRADE, EXCEPT ON GRADES OVER 1.5% WHERE POSTS SHALL BE SET VERTICAL.
3. ENDS OF RAIL TUBE SECTIONS SHALL BE SAWED OR MILLED AND SHALL BE TRUE AND SMOOTH. ALL CUT EDGES OF ALL MATERIAL SHALL BE GROUND SMOOTH.
4. EACH PIECE OF RAIL TUBING SHALL BE ATTACHED TO A MINIMUM OF THREE (3) POSTS.
5. BOLT HOLES SHALL BE DRILLED OR PUNCHED. FLAME CUTTING MAY BE USED TO FINISH SLOTTED HOLES IF MECHANICALLY GUIDED.
6. AT INTERIOR SPLICES, PIPE SPACERS SHALL BE USED ON ONLY ONE SIDE OF THE SPLICE TO ALLOW MOVEMENT ON THAT SIDE. BOTH RAILS AT A SPLICE SHALL RECEIVE THE SAME TREATMENT. AT INTERIOR EXPANSION JOINTS AND AT ALL END SPLICES, THE SLOTTED HOLES AND PIPE SPACERS SHALL BE USED ON BOTH SIDES OF THE SPLICE TO ALLOW MOVEMENT ON EACH SIDE.
7. MILL OR SHOP TRANSVERSE WELDS SHALL NOT BE PERMITTED ON ANY RAIL ELEMENT. RAIL ELEMENTS USED ON CURVES SHALL USE 3/8" WALL TUBES AND SHALL BE SHOP FORMED TO THE REQUIRED CURVATURE.
8. NO PUNCHING, DRILLING, CUTTING OR WELDING SHALL BE PERMITTED AFTER METALIZING, (EXCEPT FOR DETAIL "A"). DAMAGED AREAS OF METALIZING SHALL BE REPAIRED IN STRICT CONFORMANCE WITH THE MATERIAL SUPPLIER'S RECOMMENDATIONS AND SHALL BE APPROVED BY THE ENGINEER.
9. NUTS FOR 1"ø THREADED ANCHOR RODS CONNECTING THE BASE PLATE TO THE CONCRETE SHALL BE TIGHTENED TO A SNUG FIT AND GIVEN AN ADDITIONAL 1/8 TURN.
10. THREADS FOR ANCHOR RODS MAY BE ROLLED OR CUT. IF CUT THREADS ARE USED, BOLT DIAMETER SHALL NOT BE LESS THAN NOMINAL DIAMETER. IF ROLLED THREADS ARE USED, ROD DIAMETER SHALL NOT BE LESS THAN ROOT DIAMETER OF THREADS.
11. THE RAIL POST, BASE PLATE AND ANCHOR CAGE MUST BE INSTALLED PRECISELY TO THE LOCATION DIMENSIONED ON THESE PLANS. THE POSITION OF THE (3)-#5 LONGITUDINAL REBARS MAY BE ADJUSTED TO ACCOMMODATE THE ANCHOR CAGE, BUT MUST NOT BE CUT.

MATERIAL NOTES:

12. STRUCTURAL TUBING SHALL CONFORM TO THE REQUIREMENTS OF ASTM A500, GRADE B, STRUCTURAL STEEL TUBING. RAIL TUBING SHALL MEET THE LONGITUDINAL CHARPY V-NOTCH REQUIREMENTS OF 15 LBS. AT 0°F FOR ASTM A500, GRADE B. THE TEST SAMPLES SHALL BE TAKEN AFTER FORMING THE TUBES. CHARPY V-NOTCH IS NOT REQUIRED FOR SPLICE TUBES.
13. RAIL POSTS AND BASE PLATES SHALL CONFORM TO THE REQUIREMENTS OF ASTM A572 GR. 50, EXCEPT ANCHOR PLATES MAY BE ASTM A36.
14. THREADED STUDS AND MATCHING NUTS FOR RAIL-TO-POST ATTACHMENT (DETAIL A) SHALL CONFORM TO ASTM A276 TYPE 304, STAINLESS STEEL, AND SHALL BE TORQUE TESTED PER AWS D1.5, 7.7.1. DETAIL B BOLTS SHALL BE ASTM A325 OR A449. ALL OTHER BOLTS AND NUTS SHALL CONFORM TO ASTM A307 AND ASTM 563 GRADE A RESPECTIVELY OR BETTER. ANCHOR RODS SHALL CONFORM TO ASTM A449 EXCEPT THAT ASTM A307 NUTS MAY BE USED ON THE BOTTOM OF ANCHOR ASSEMBLY. WASHERS SHALL BE HARDENED STEEL COMMERCIAL TYPE A PLAIN WIDE WASHERS AND SHALL MEET THE DIMENSIONAL REQUIREMENTS OF A.N.S.I. B18.22.
15. ALL STEEL COMPONENTS (EXCEPT STAINLESS) SHALL BE METALIZED AFTER FABRICATION IN CONFORMANCE WITH SECTION 827 "THERMAL SPRAYED ZINC COATING FOR NEW STRUCTURAL STEEL" OF THE RHODE ISLAND STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION. THE METALIZING SHALL HAVE A UNIFORM APPEARANCE, AND METALIZED MATERIAL SHALL BE PROPERLY STORED.
16. DETAIL "A" STUDS SHALL BE WELDED BEFORE TUBES ARE METALIZED.
17. PREFORMED BEARING PADS (1/8" THICK) SHALL CONFORM TO AASHTO M251.

DESIGNER NOTE:
PROVIDE PAINT COLOR FOR RAILING SYSTEM.

THIS BRIDGE RAIL SYSTEM WAS SUCCESSFULLY CRASH TESTED FOR AASHTO TL4 IN 1994 BY THE NEW ENGLAND TRANSPORTATION CONSORTIUM.

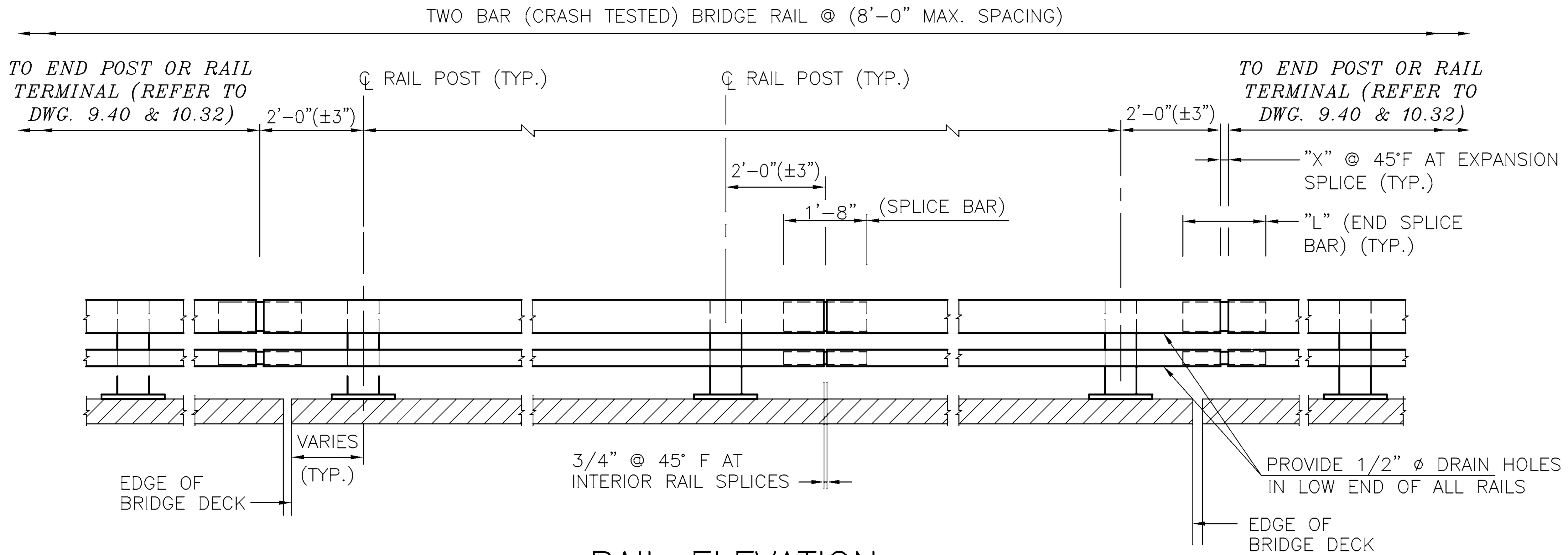
REVISIONS	
No.	DATE

RHODE ISLAND
DEPARTMENT OF TRANSPORTATION

BRIDGE STANDARDS

TWO BAR STEEL BRIDGE RAIL (CRASH-TESTED TL-4) SHEET 1

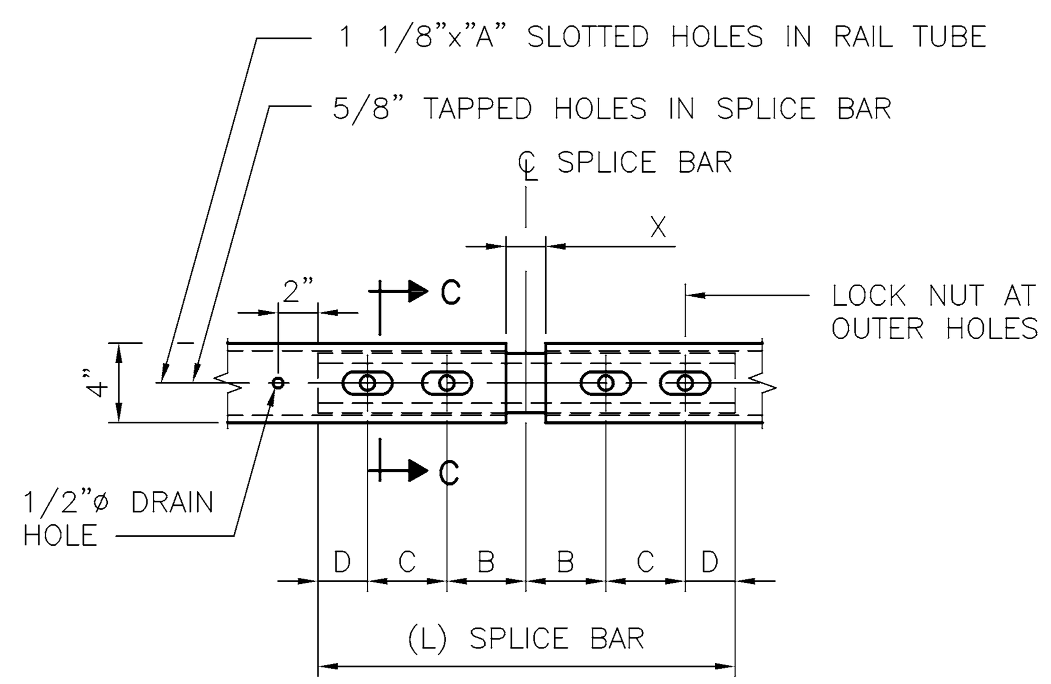
DRAWING NUMBER: 10.30



RAIL ELEVATION
SCALE:1/2"=1'-0"

	SPLICE BAR DIMENSION TABLE						
	T	A	B	C	D	X	L
	INTERIOR	2 1/2"	4"	4"	2"	3/4"	1'-8"
*	<3 1/4"	2 1/2"	4"	4"	2"	2"	1'-8"
*	3 1/4" TO 5 1/4"	3 1/2"	5"	5"	2 1/2"	3"	2'-1"

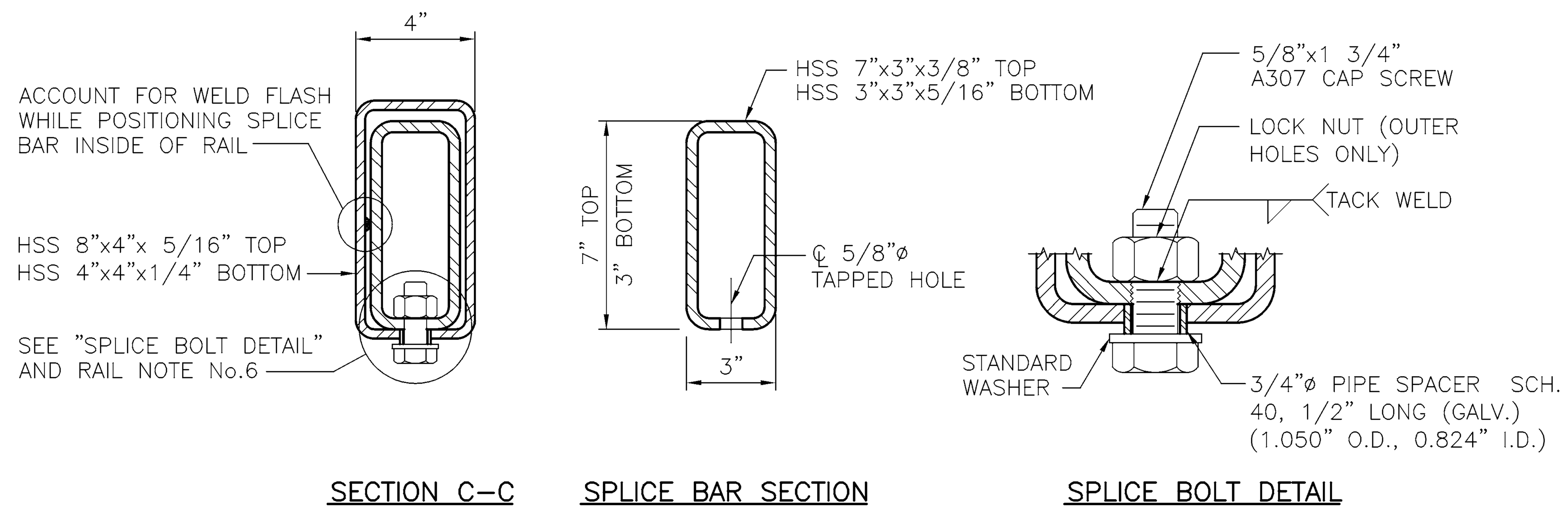
T = TOTAL MOVEMENT OF BRIDGE
* = END SPLICE BAR



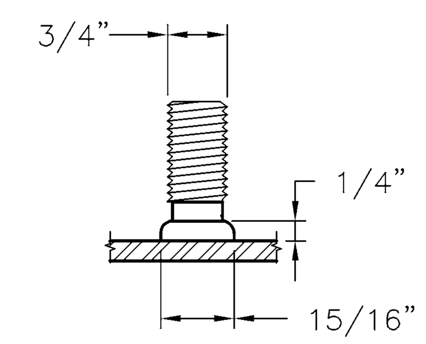
SEE SPLICE BAR DIMENSION TABLE THIS SHEET

(BOTTOM VIEW)

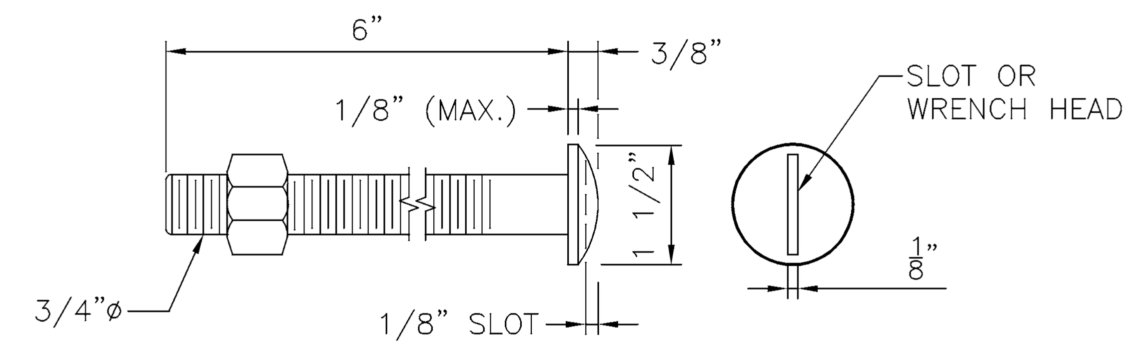
RAIL SPLICE
SCALE: 1 1/2"=1'-0"



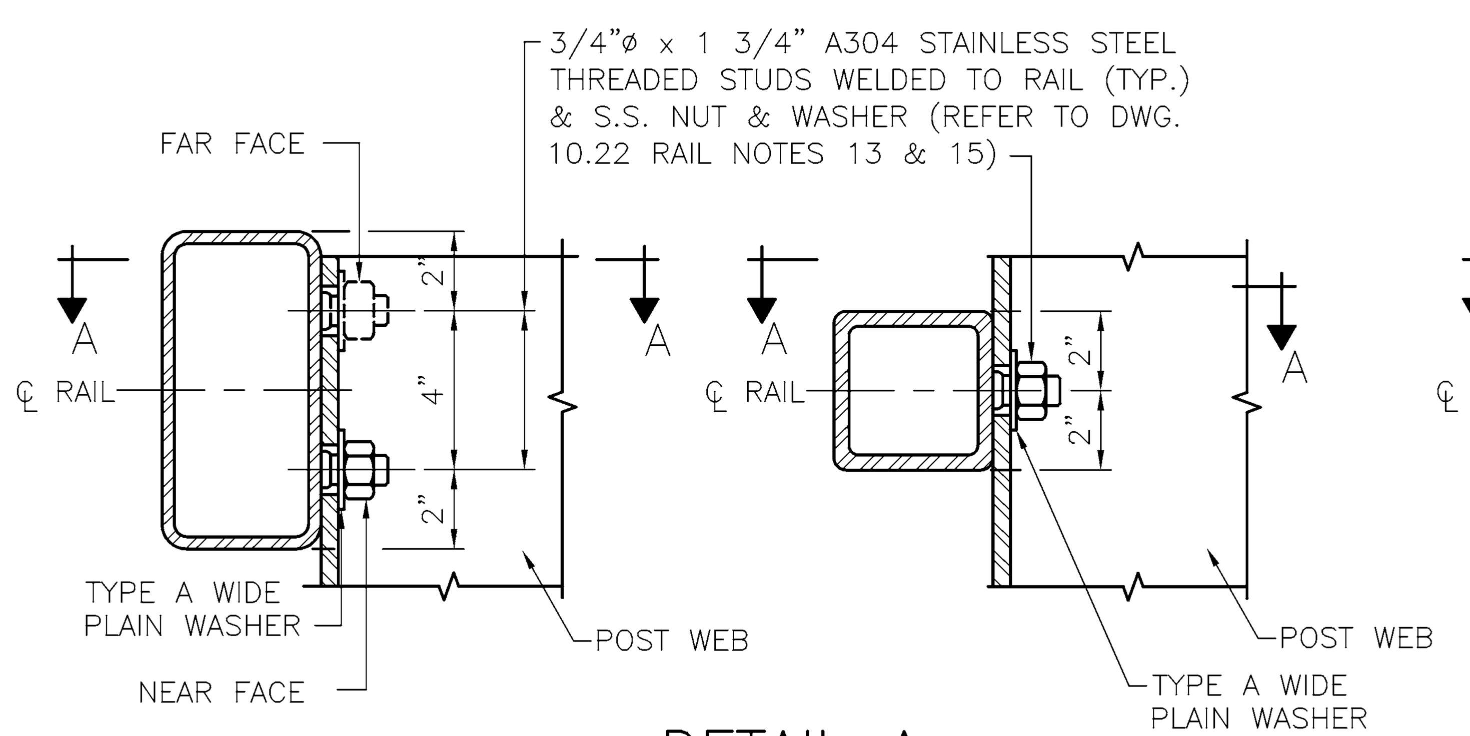
RAIL SPLICE DETAILS
SCALE: 3"=1'-0"



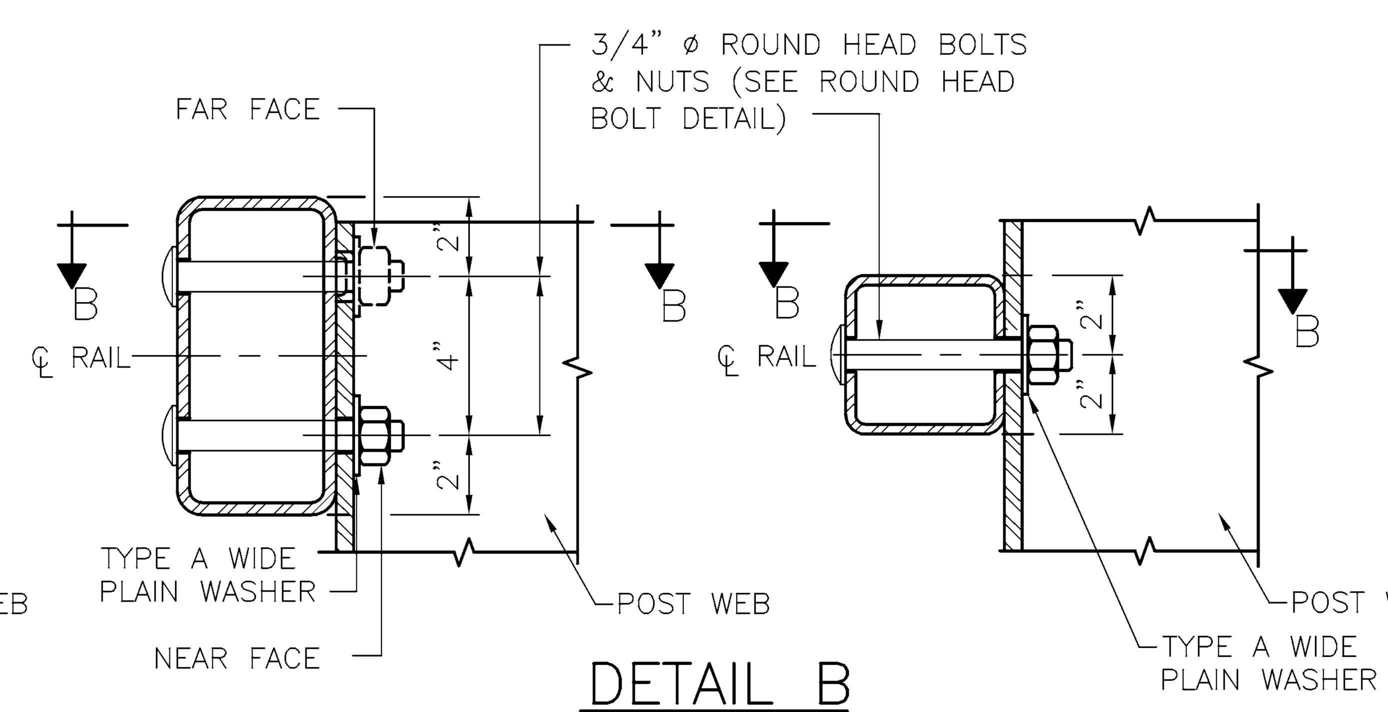
STUD WELD DETAIL
NOT TO SCALE



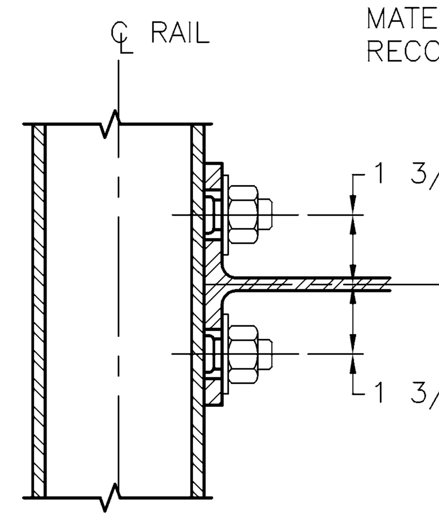
ROUND HEAD BOLT DETAIL
NOT TO SCALE



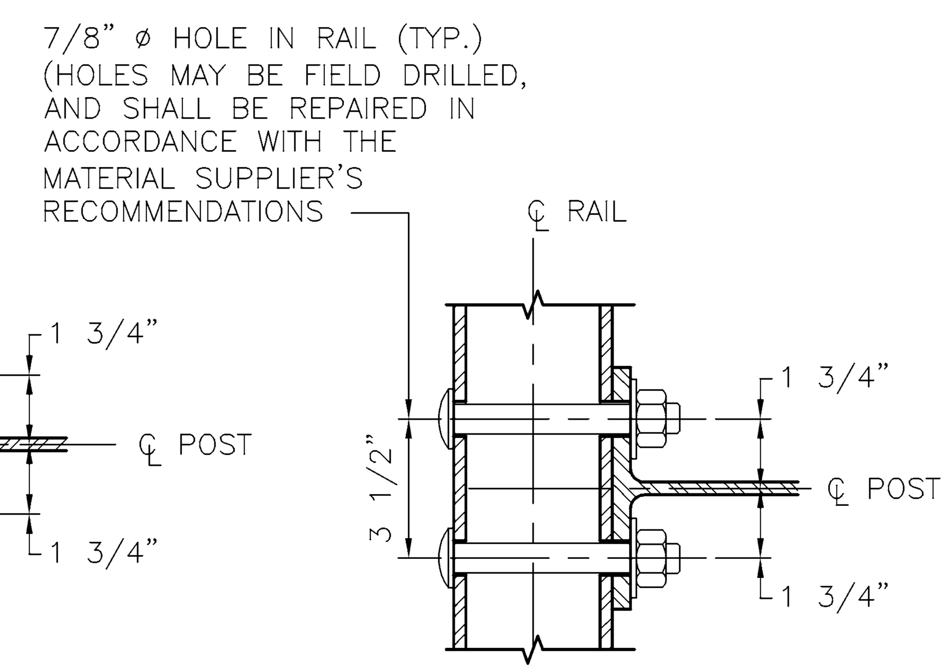
DETAIL A
SCALE: 3"=1'-0"



DETAIL B
SCALE: 3"=1'-0"



SECTION A-A
SCALE: 3"=1'-0"



SECTION B-B
SCALE: 3"=1'-0"

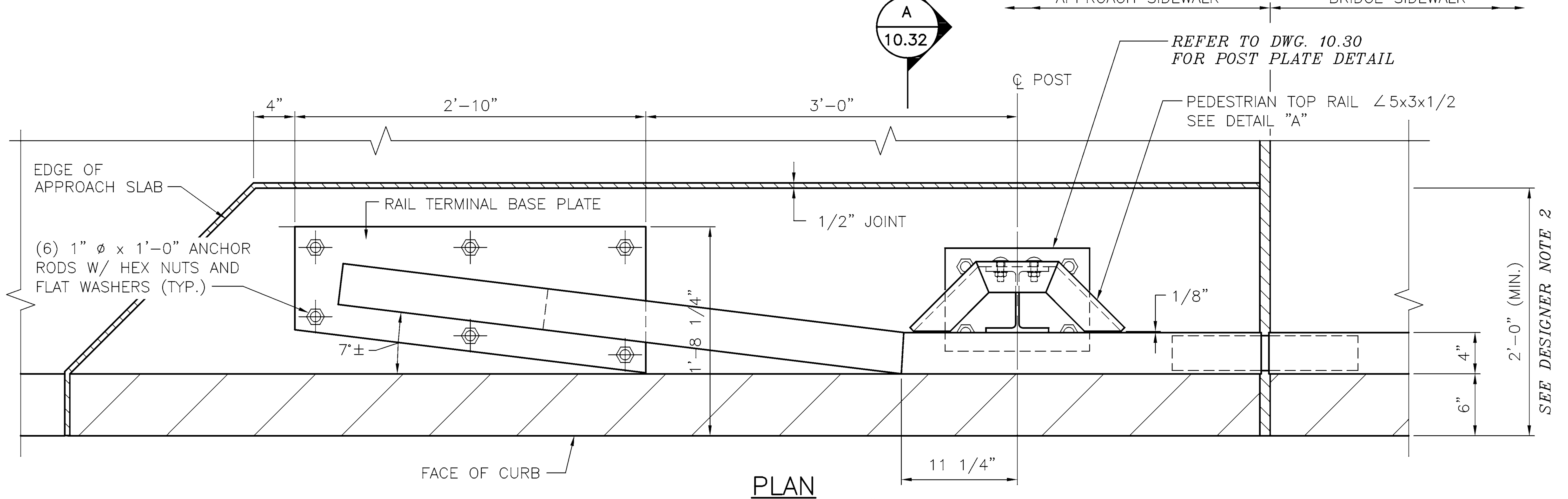
REVISIONS	
No.	DATE

RHODE ISLAND
DEPARTMENT OF TRANSPORTATION

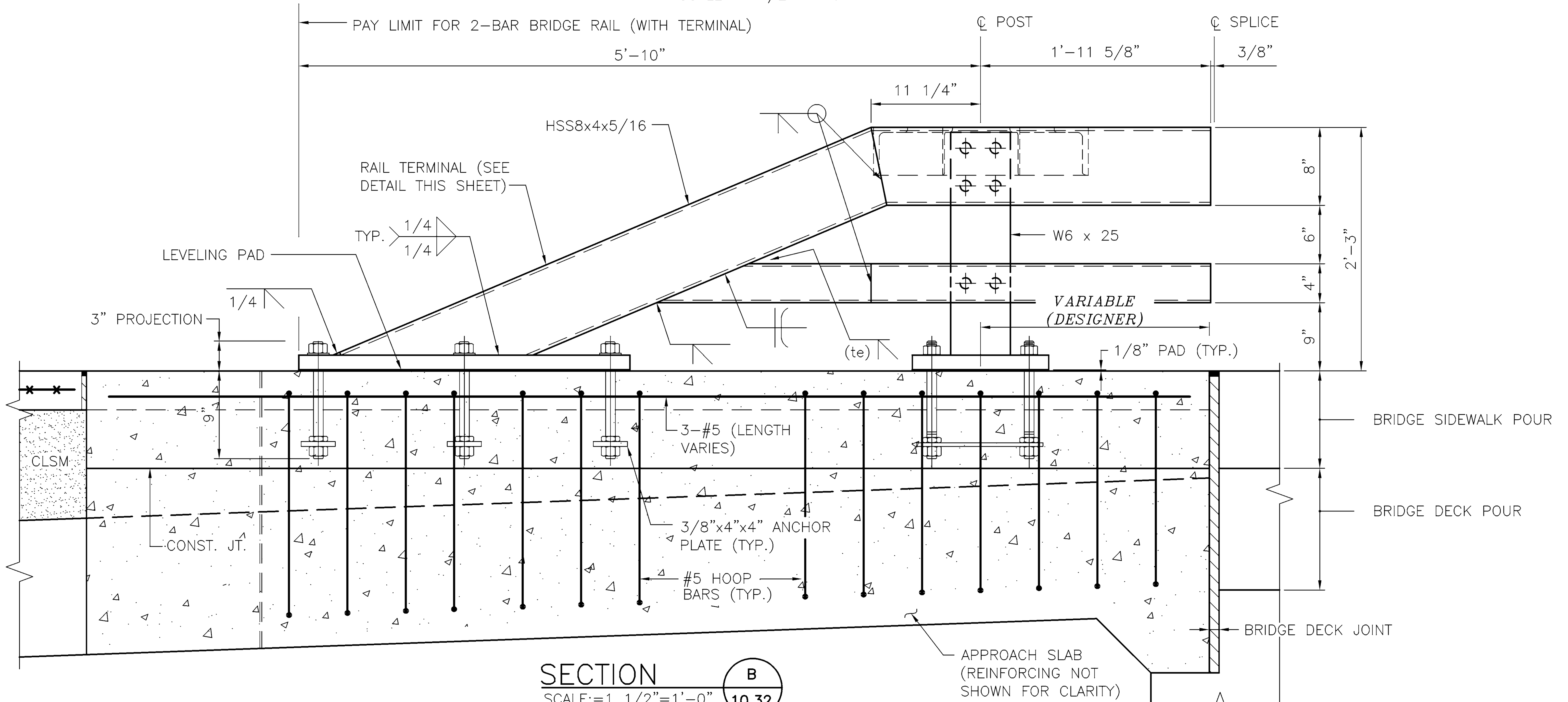
BRIDGE STANDARDS

TWO BAR STEEL BRIDGE RAIL (CRASH-TESTED TL-4) SHEET 2

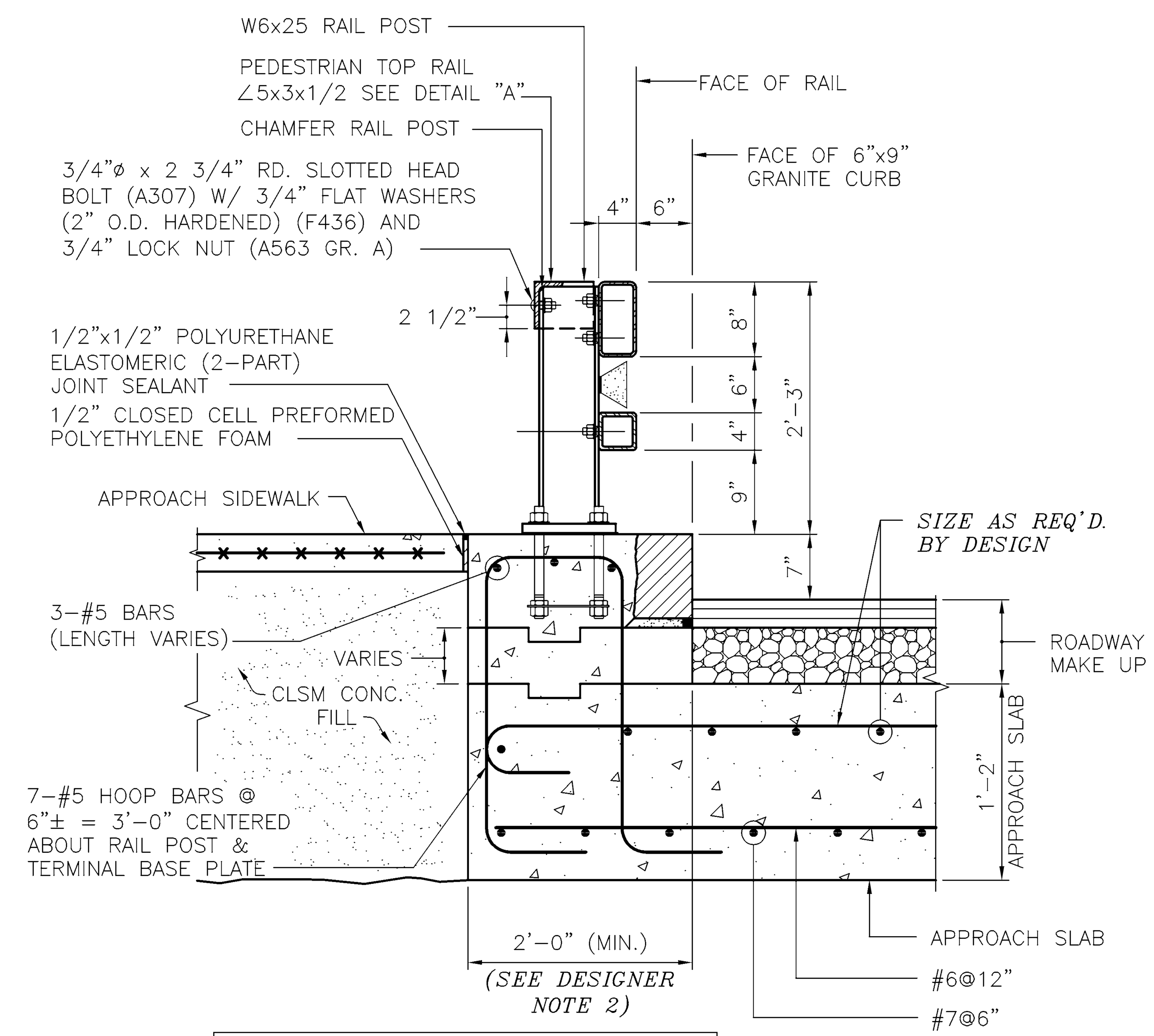
DRAWING NUMBER: 10.31



PLAN
SCALE:=1 1/2"=1'-0"



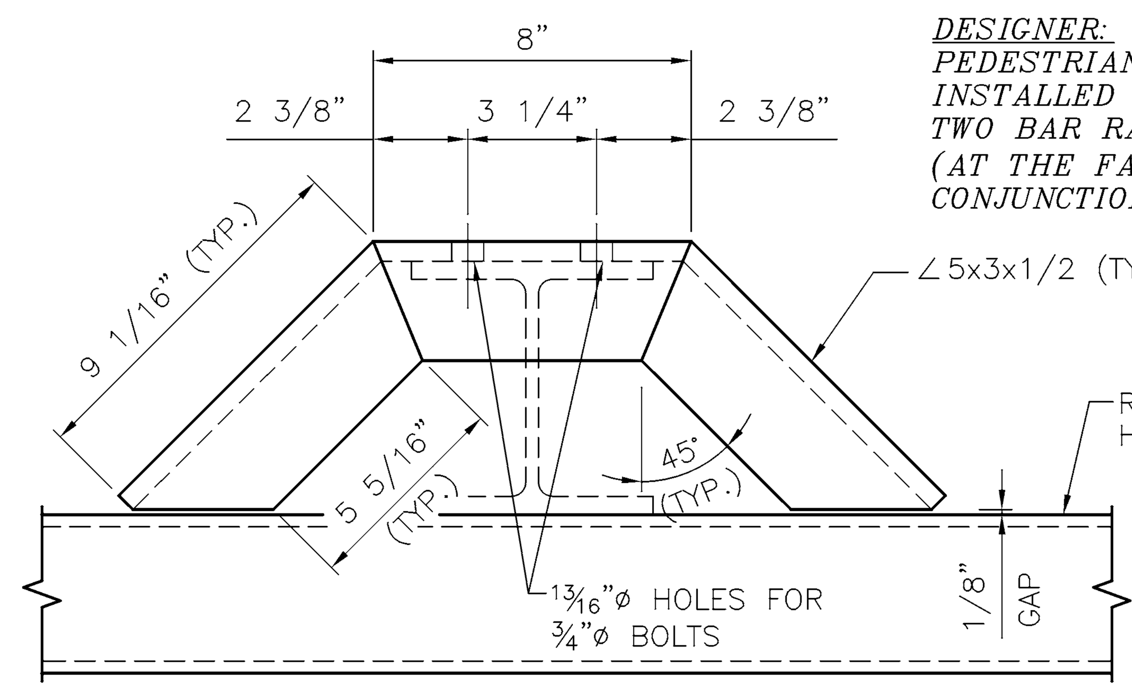
SECTION B 10.32
SCALE:=1 1/2"=1'-0"



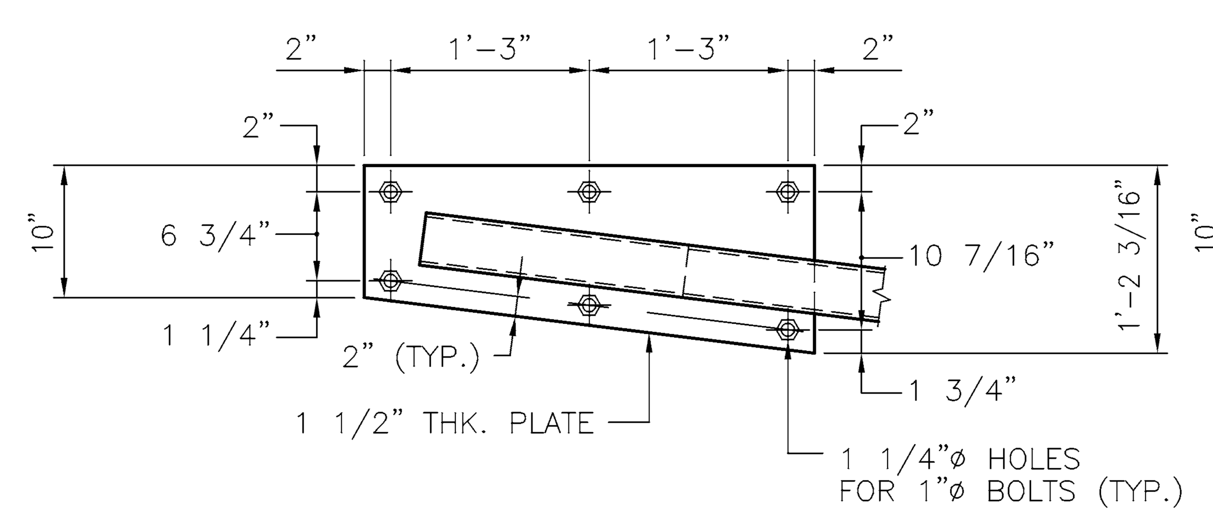
DESIGNER:
FOR RAIL AND POST DETAILS, REFER TO DRAWINGS No. 10.30 & 10.31

SECTION A 10.32
SCALE:=1"=1'-0"

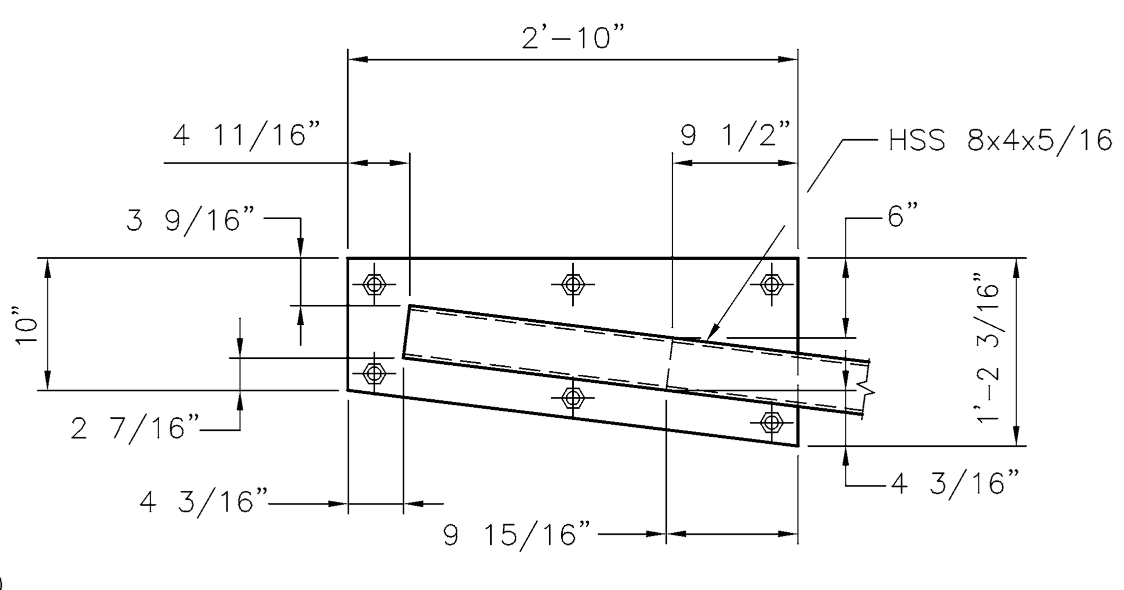
DESIGNER:
PEDESTRIAN TOP RAIL IS TO BE INSTALLED ON ALL POSTS WHEN TWO BAR RAILING SYSTEM IS USED (AT THE FACE OF CURB) IN CONJUNCTION WITH A SIDEWALK



DETAIL–A
SCALE:3"=1'-0"



ANCHOR HOLE LAYOUT



RAIL TERMINAL LAYOUT

RAIL TERMINAL BASE PLATE
SCALE: 1"=1'-0"

DESIGNER NOTES:

1. *THE DETAILS SHOWN ARE FOR TWO BAR RAIL TERMINALS (AT THE FACE OF CURB) ENDING OFF OF THE BRIDGE DECK. RAIL TERMINALS ENDING ON THE BRIDGE DECK WOULD BE SIMILAR.*
2. *THE RAIL TERMINAL FOUNDATION SHALL BE AS REQUIRED TO ACCOMMODATE THE APPLICABLE AASHTO LRFD RAIL IMPACT LOADING.*
3. *ALTERNATE RAIL TERMINAL FOUNDATIONS (SUCH AS FOUNDATIONS CANTILEVERED FROM THE REAR FACES OF THE ABUTMENT STEMS/BACKWALLS OR FOUNDATIONS SET ON INDIVIDUAL WALL STEMS AND FOOTINGS AND CAST INTEGRALLY WITH THE ABUTMENT STEMS AND FOOTINGS) MAY BE CONSIDERED.*

REVISIONS	
No.	DATE

RHODE ISLAND
DEPARTMENT OF TRANSPORTATION

BRIDGE STANDARDS

TWO BAR STEEL BRIDGE RAIL (CRASH–TESTED TL–4) SHEET 3

DRAWING NUMBER: 10.32