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Final Report 658

Retrofit of Existing Statewide Louisiana Safety Walk Bridge Barrier Railing Systems

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13. Abstract

Louisiana has approximately 200 miles of vintage 1960s concrete safety walk bridge rail systems currently in use on bridges throughout Louisiana. Many of these systems do not meet the current crash performance requirements of the American Association of State Highway and Transportation Officials *Manual for Assessing Safety Hardware* Second Edition (MASH) specifications for Test Level 3 (TL-3).

Researchers at the Texas A&M Transportation Institute (TTI) have conducted a full literature review of various bridge railing retrofits that have been used throughout the United States and abroad. A literature review search was performed using the Transportation Research Information Services database to document the pertinent findings of others on this proposed study. TTI researchers also obtained all available design information and details of safety walk barriers used throughout Louisiana. Two of the most common types of vintage bridge railings with safety walks were selected for further analysis and details. These included a concrete post and rail system with a sidewalk and a solid concrete parapet

system with a sidewalk. Retrofits were developed that can be used on both common rail types used in Louisiana.

Two full-scale crash tests were performed on the retrofit design anchored to the concrete post and rail system. During MASH Test 3-10 on the Louisiana Retrofit post and beam bridge rail with safety walk Option 1, the vehicle experienced occupant ridedown accelerations above the limit of 20.49 g as specified in MASH.

The bridge rail was redesigned, and MASH Tests 3-10 and 3-11 were repeated. The Louisiana Retrofit post and beam bridge rail with safety walk Option 2 met the requirements for MASH TL-3 longitudinal barriers.

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Two full-scale crash tests were performed on the retrofit design anchored to the concrete post and rail system. During MASH Test 3-10 on the Louisiana Retrofit post and beam bridge rail with safety walk Option 1, the vehicle experienced occupant ridedown accelerations above the limit of 20.49 g as specified in MASH.

The bridge rail was redesigned, and MASH Tests 3-10 and 3-11 were repeated. The Louisiana Retrofit post and beam bridge rail with safety walk Option 2 met the requirements for MASH TL-3 longitudinal barriers.

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The authors would like to thank Walid Alaywan, Ph.D., senior structures research engineer at the Louisiana Transportation Research Center, Kurt Brauner, bridge engineer manager at the Louisiana Department of Transportation and Development (DOTD), and Steve Mazur, bridge engineer at DOTD. These gentlemen contributed greatly to the success of this project. Their assistance and involvement in this project are greatly appreciated.

Implementation Statement[1]

The retrofit bridge rail as tested herein met all the strength and performance requirements for MASH TL-3 specifications. This retrofit bridge rail is recommended for implementation on Louisiana post and beam and solid concrete barriers with 10 in. high or less by 18 in. wide or less safety walks.

For additional information, please refer to the information provided in this report.

[1] The opinions/interpretations identified/expressed in this section of the report are outside the scope of TTI Proving Ground's A2LA Accreditation.

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Introduction

The purpose of the tests reported herein was to assess the performance of the Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk according to the safety-performance evaluation guidelines included in the American Association of State Highway and Transportation Officials (AASHTO), *Manual for Assessing Safety Hardware, Second Edition* (MASH) [1]. The crash tests were performed in accordance with MASH Test Level 3 (TL-3), which involves an 1100C and a 2270P vehicle impacting the bridge barrier at a target impact speed of 62 mi/h and an impact angle of 25 degrees.

A retrofit bridge rail system that anchors to the top or sides of the existing concrete parapets, and that meets the current safety performance criteria of MASH TL-3, is needed for Louisiana's vintage concrete railings. The retrofit bridge rail must meet the current safety requirements of MASH TL-3 and continue to accommodate use of the concrete safety walk. The existing safety walk areas on these vintage concrete bridges are needed for proper and safe bridge inspection, maintenance or stranded drivers, and for general pedestrian safety. The objective of this project is to develop a retrofit bridge rail design for the two most common types of bridge railing systems that are currently used by Louisiana Department of Transportation and Development (DOTD). This design shall also maintain the safety walk areas and meet the performance requirements of MASH TL-3. The two most common types of barriers are concrete post and beam and solid concrete parapet bridge rails installed with the 18 in. wide by 10 in. high safety walk curb. The purpose of this technical report is to present the retrofit method and the information necessary to fabricate and construct the retrofit bridge rail design which was successfully crash tested in accordance with MASH TL-3 specifications for Task 7A of this project. All material specifications used for the successful crash tested design are also provided in this report.

This report provides details of the Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk, detailed documentation of the crash test results, and an assessment of the performance of the Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk for MASH TL-3 evaluation criteria.

Task 1 – Literature Review

For this project, Texas A&M Transportation Institute (TTI) conducted a full literature review of various bridge railing retrofits that have been used throughout the United States and abroad on safety walk bridge barrier railing systems like those used in Louisiana. As part of this task, TTI performed a literature review search using the TRIS database to document the pertinent findings of others on this proposed study. TTI has performed an extensive search to find all the available research information on the topic of crashworthy rail designs that include the features of the bridge rails that are involved in this study. TTI considered all the available information obtained from this search into the proposed research and design efforts planned for this project.

Several retrofit bridge rail designs were reviewed as part of this task. A few retrofit designs were obtained and considered as part of this review. This section contains a summary of the retrofit designs that utilized a walkway and were tested to MASH specifications. A brief summary of these designs are provided as follows.

Design and Full-Scale Testing of Retrofit Bridge Rail for 24.8 Miles Long Southbound Causeway Bridge, New Orleans, Louisiana–Option A

TTI previously designed and tested a new retrofit bridge rail for the Southbound Causeway Bridge, New Orleans, Louisiana [2]. The purpose of this project was to design and test a retrofit bridge rail for the Southbound Lake Pontchartrain Causeway Bridge in New Orleans, Louisiana. This bridge is approximately 24.8 mi. in length and was constructed in the late 1950s. When the bridge opened it carried two-way traffic from New Orleans to the north shore of Lake Pontchartrain. The previous bridge railing, shown in Figure 1, consists of a 15-in. high concrete parapet mounted on top of a 10-in. high by 18-in. wide concrete curb.

Several retrofit options were developed for this project. A few retrofit designs were selected for full-scale testing. The purpose of the testing reported herein was to assess the performance of the Lake Pontchartrain Causeway Single Rail Bridge Rail Design Option A (25-in.-tall concrete parapet, with steel posts and a single steel railing standing 14 in. above the parapet, atop a 10-in. curb, for a total height of 39 in.) according to the safety-performance evaluation guidelines included in AASHTO MASH Specifications. Details of the design are shown in Figure 2. A picture of the pre-test installation of the Option A bridge rail design can be found in Figure 3.

Figure 1. Photo of the old southbound causeway bridge rail

Figure 2. Option A details

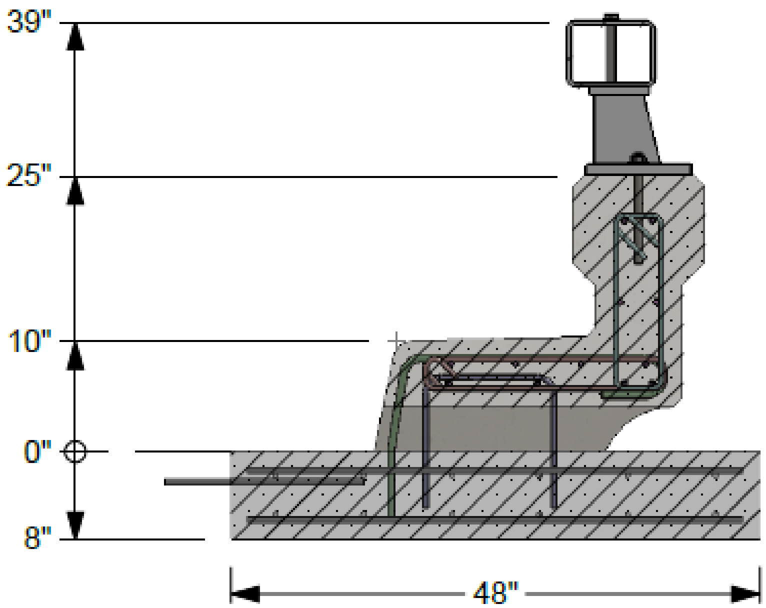


Figure 3. Photos of full-scale test installation

(a) Traffic face of bridge rail

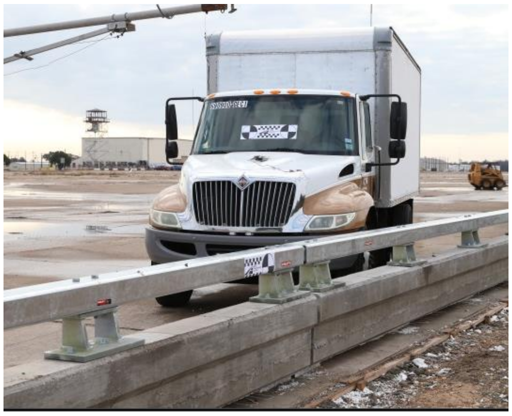
(b) Steel post

(c) Joint

(d) Field side of bridge rail

Three crash tests were required to evaluate the bridge rail's performance for TL-4 of MASH [1]. These tests involved a 10000S vehicle (22,000-lb. single unit truck), a 2270P vehicle (a 5000-lb. (½-ton) quad cab pickup), and a smaller 1100C vehicle (2420-lb. small car). Figure 4 through Figure 12 show the conditions of each of the cars before and after each respective test, as well as the bridge rail damage after each test. Table 1 through Table 3 provide a summary of the MASH criteria evaluation of each individual test.

Figure 4. Bridge rail and test vehicle before MASH Test 4-12



(a) Test vehicle at target impact point

(b) 10000S test vehicle

Figure 5. Bridge rail after MASH Test 4-12

(a) Traffic face of bridge rail

(b) Joint

(c) Impact point

(d) Field side of bridge rail

Figure 6. Test vehicle after MASH Test 4-12

(a) Damage to left side of test vehicle

(b) Damage to right side of test vehicle

Figure 7. Bridge rail and test vehicle before MASH Test 4-11

(a) Test vehicle at target impact point

(b) 2270P test vehicle

Figure 8. Bridge rail after MASH Test 4-11

(a) Traffic face of bridge rail

(b) Traffic side of joint

(c) Field side of bridge rail

(d) Field side of joint

Figure 9. Test vehicle after MASH Test 4-11

(a) Damage to left side of test vehicle (b) Damage to left front tire

Figure 10. Test vehicle before MASH Test 4-10

(a) Test vehicle at target impact point (b) 1100C test vehicle

Figure 11. Bridge rail after MASH Test 4-10

(a) Traffic side of bridge rail

(b) Impact point

(c) Joint

(d) Post

Figure 12. Test vehicle after MASH Test 4-10

(a) Damage to front of test vehicle

(b) Damage to left front tire

Table 1. Performance evaluation summary for MASH Test 4-12 on Option A Bridge Rail

Evaluation Factors	Evaluation[2] Criteria	Test Results	Assessment
Structural Adequacy	A.	The option A bridge rail contained and redirected the 10000S vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 6.9 in.	Pass
Occupant Risk	D.	Small fragments of concrete broke loose from the parapet, but did not penetrate or show potential for penetrating the occupant compartment, or show hazard for others in the area.	Pass
		No occupant compartment deformation or intrusion was observed.	
	G.	The 10000S vehicle remained upright during and after the collision event.	Pass

[2] See Table 9 for details of respective evaluation criteria.

Table 2. Performance evaluation summary for MASH Test 4-11 on Option A Bridge Rail

Evaluation Factors	Evaluation[3] Criteria	Test Results	Assessment
Structural Adequacy	A.	The option A bridge rail contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the bridge rail. Maximum dynamic deflection during the test was 3.1 in.	Pass
Occupant Risk	D.	Small fragments of concrete broke loose from the parapet, but did not penetrate or show potential for penetrating the occupant compartment, or show hazard for others in the area.	Pass
		Maximum occupant compartment deformation was 7.5 in. in the left front firewall area, but there was no penetration.	
	F.	The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 18 degrees and 22 degrees.	Pass
	H.	Longitudinal OIV was 17.7 ft/s, and lateral OIV was 26.2 ft/s, which was within the preferred limits.	Pass
	I.	Maximum longitudinal RDA was 11.0 G, and maximum lateral RDA was 9.7 G, which was within the preferred limits.	Pass

[3] See Table 9 for details of respective evaluation criteria.

Table 3. Performance evaluation summary for MASH Test 4-10 on Option A Bridge Rail

Evaluation Factors	Evaluation[4] Criteria	Test Results	Assessment
Structural Adequacy	A.	The option A bridge rail contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the bridge rail. Maximum dynamic deflection during the test was 0.74 in.	Pass
Occupant Risk	D.	Small fragments of concrete broke loose from the parapet, but did not penetrate or show potential for penetrating the occupant compartment, or show hazard for others in the area.	Pass
		Maximum occupant compartment deformation was 0.25 in. in the left front kickpanel area, and there was no penetration.	
	F.	The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 18 degrees and 10 degrees.	Pass
	H.	Longitudinal OIV was 14.4 ft/s, and lateral OIV was 21.0 ft/s, which was within the preferred limits.	Pass
	I.	Maximum longitudinal RDA was 5.5 G, and maximum lateral RDA was 11.7 G, which was within the preferred limits.	Pass

[4] See Table 9 for details of respective evaluation criteria.

Design and Full-Scale Testing of Retrofit Bridge Rail for 24.8 Miles Long Southbound Causeway Bridge, New Orleans, Louisiana–Option B1

TTI designed and tested a second retrofit bridge rail for the Southbound Causeway Bridge in New Orleans, LA [2]. This second design (Option B1) was taller than the previous tested Option A design. The test installation was a 160 ft.-6¾ in. long double steel rail on a concrete parapet comprised of four 40-ft. long rail segments with 2¼-in. long gaps at spliced expansion joints between each segment. The 2-tube bridge rail retrofit measured 46 in. in overall height (at the top of the upper rail) above the bridge deck. The top of the lower rail measured 34 in. above the bridge deck. The rail was anchored to the top of a 25-in.-tall steel reinforced concrete sectionalized curb and parapet that replicated the existing structure on the subject Lake Pontchartrain Causeway bridge deck. The curb was 10 in. high and 18 in. wide (walkway area). Additionally, the parapet had a 2¼-in. wide expansion joint overlap gap every 40 ft. along the length of the installation, which coincided with the expansion splice between adjacent spliced rail segments. Details of the Option B1 design is shown in Figure 13.

Figure 14 shows photographs of the installation before full-scale crash testing. Figure 15 through Figure 29 show photographs (before and after) for MASH Test 4-12. Figure 30 through Figure 33 show photographs (before and after) for MASH Test 4-10. Figure 34 through Figure 40 show photographs (before and after) for MASH Test 4-11. These photos show the conditions of the rail installation and test vehicles before and after tests 690900-GEC7, GEC7a, GEC8, and GEC9, as well as damage to the bridge rail after each test. Table 4 through Table 7 provide a summary of the MASH criteria evaluation of each individual test.

Figure 13. Option B1 details

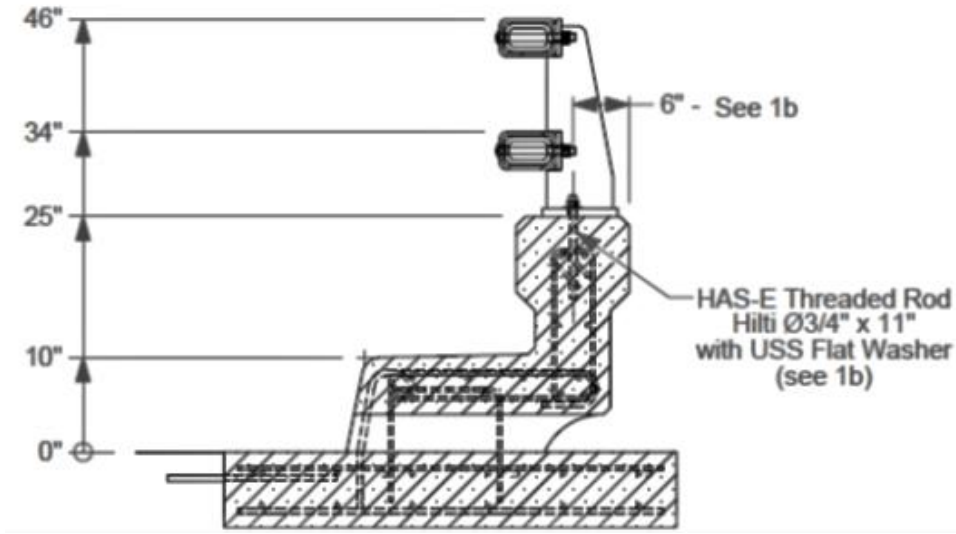


Figure 14. Design Option B1 before testing

(a) Traffic face of bridge rail

(b) Steel post

(c) Joint

(d) Metal joint and sleeve

(e) Field side of post connection

(f) Field side of bridge rail

Figure 15. Test vehicle before Test No. 690900-GEC7

(a) 10000S test vehicle at impact point

(b) Left side of 10000S test vehicle

Figure 16. Rail option B1 after Test No. 690900-GEC7

(a) Traffic Side

(b) Field Side

Figure 17. Post 4 after Test No. 690900-GEC7

(a) Traffic side

(b) Field side

Figure 18. Post 5 after Test No. 690900-GEC7

(a) Traffic side (b) Field side

Figure 19. Post 6 and 7 after Test No. 690900-GEC7

(a) Traffic side (b) Field side

Figure 20. Post 8 after Test No. 690900-GEC7

(a) Traffic side (b) Field side

Figure 21. Test vehicle after Test No. 690900-GEC7

(a) Damage to right side of test vehicle

(b) Damage to right front tire

Figure 22. Test vehicle before Test No. 690900-GEC7a

(a) 10000S test vehicle and bridge rail

(b) Right side of 10000S test vehicle

Figure 23. Rail Option B1 positions after Test No. 690900-GEC7a

(a) Traffic side of bridge rail

(b) Parallel with bridge rail

Figure 24. Posts 1 through 5 and rear of post 4 after Test No. GEC7a

(a) Traffic side

(b) Field side of post 4

Figure 25. Post 5 after Test No. 690900-GEC7a

(a) Traffic side

(b) Field side

Figure 26. Post 6 and 7 after Test No. 690900-GEC7a

(a) Post 6

(b) Post 7

Figure 27. Post 8 after Test No. 690900-GEC7a

(a) Traffic side

(b) Field side

Figure 28. Post 9 through 14 after Test No. 690900-GEC7a

(a) Field side of bridge rail

(b) Damage at post 9

Figure 29. Test vehicle after Test No. 690900-GEC7a

(a) Damage to left side of test vehicle

(b) Damage to left front tire

Figure 30. Test vehicle before Test No. 690900-GEC8

(a) 1100C test vehicle and bridge rail

(b) 1100C test vehicle

Figure 31. Rail Option B1 after Test No. 690900-GEC8

(a) Traffic side

(b) Parallel with bridge rail

Figure 32. Installation after Test No. 690900-GEC8

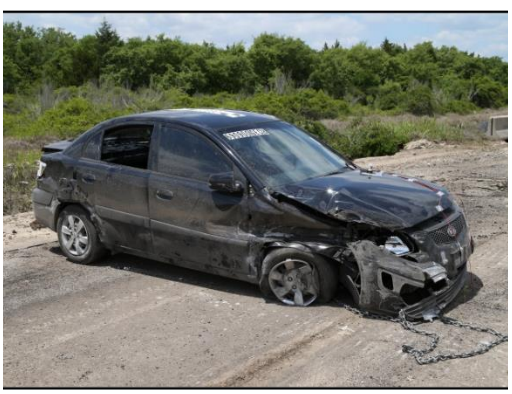
(a) Traffic face of bridge rail

(b) Joint

(c) Field side of bridge rail

(d) Crack in concrete curb

Figure 33. Test vehicle after Test No. 690900-GEC8



(a) Damage to right side

(b) Damage to right front tire

Figure 34. Test vehicle before Test No. 690900-GEC9

(a) 2270P test vehicle and bridge rail

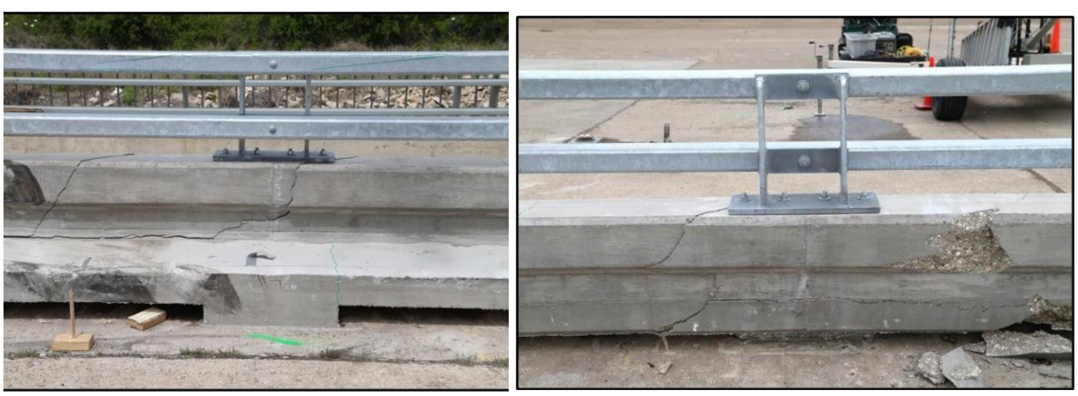
(b) 2270P test vehicle

Figure 35. Position of vehicle/installation after Test No. 690900-GEC9

(a) Traffic side

(b) Along traffic face of bridge rail

Figure 36. Post 11 after Test No. 690900-GEC9



(a) Traffic side

(b) Field side

Figure 37. Post 12 and 13 after Test No. 690900-GEC9

(a) Traffic side impact area damage test

(b) Field side damage

Figure 38. Photos after Test No. 690900-GEC9

(a) Traffic side

(b) Field side

Figure 39. Test vehicle after Test No. 690900-GEC9

(a) Damage to right side

(b) Damage to right front wheel assembly

Figure 40. Interior of test vehicle for Test No. 690900-GEC9

(a) Before test (b) After test

Table 4. Performance evaluation summary for MASH test 4-12 (Test No. 690900-GEC7) on Option B1 Bridge Rail

Evaluation Factors	Evaluation[5] Criteria	Test Results	Assessment
Structural Adequacy	A.	The option B1 bridge rail contained and redirected the 10000S vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 8.2 in.	Pass
Occupant Risk	D.	No detached elements, fragments, or other debris from the bridge rail were present to penetrate or show potential for penetrating the occupant compartment, or show undue hazard to others in the area.	Pass
		No occupant compartment deformation or intrusion was observed.	
	G.	The 10000S remained upright during and after the collision event. Maximum roll during the collision event was 29 degrees.	Pass

[5] See Table 9 for details of respective evaluation criteria.

Table 5. Performance evaluation summary for MASH Test 4-12 (Test No. 690900-GEC7a) on Option B1 Bridge Rail

Evaluation Factors	Evaluation[6] Criteria	Test Results	Assessment
Structural Adequacy	A.	The Option B1 bridge rail contained and redirected the 10000S vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 19.6 in.	Pass
Occupant Risk	D.	Pieces of the concrete broke off from the bridge rail parapet and deck but did not show potential for penetrating the occupant compartment, nor show undue hazard to others in the area.	Pass
		No occupant compartment deformation or intrusion was observed.	
	G.	The 10000S remained upright during and after the collision event. Maximum roll during the collision event was 35 degrees.	Pass

[6] See Table 9 for details of respective evaluation criteria.

Table 6. Performance evaluation summary for MASH Test 4-10 (Test No. 690900-GEC8) on Option B1 Bridge Rail

Evaluation Factors	Evaluation[7] Criteria	Test Results	Assessment
Structural Adequacy	A.	The Option B1 bridge rail contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 1.5 in.	Pass
Occupant Risk	D.	No detached elements, fragments, or other debris from the bridge rail were present to penetrate or show potential for penetrating the occupant compartment, or show undue hazard to others in the area.	Pass
		Maximum occupant compartment deformation was 1.0 in. in the right front kickpanel area.	
	F.	The 1100C vehicle remained upright during and after the collision event. Maximum roll angle was 10 degrees and pitch was 8 degrees.	Pass
	H.	Longitudinal OIV was 23.0 ft/s, and lateral OIV was 32.8 ft/s.	Pass
	I.	Longitudinal RDA was 6.1 g, and lateral RDA was 8.8 g.	Pass

[7] See Table 9 for details of respective evaluation criteria.

Table 7. Performance evaluation summary for MASH Test 4-11 (Test No. 690900-GEC9) on Option B1 Bridge Rail

Evaluation Factors	Evaluation[8] Criteria	Test Results	Assessment
Structural Adequacy	A.	The Option B1 bridge rail contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 8.2 in.	Pass
Occupant Risk	D.	No detached elements, fragments, or other debris from the bridge rail were present to penetrate or show potential for penetrating the occupant compartment, or show undue hazard to others in the area.	Pass
		Maximum occupant compartment deformation was 1.0 in. in the right front kickpanel area.	
	F.	The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 12 degrees and 10 degrees.	Pass
	H.	Longitudinal OIV was 15.1 ft/s, and lateral OIV was 25.6 ft/s.	Pass
	I.	Longitudinal occupant ridedown acceleration was 13.5 g, and lateral occupant ridedown acceleration was 11.7 g.	Pass

The Lake Pontchartrain Causeway Bridge Design Option B1 contained and redirected all test vehicles. Maximum dynamic deflection was 19.6 in. in the repeat MASH Test 4-12. In all three tests, no detached elements, fragments, or other debris from the bridge rail were present to penetrate or show potential for penetrating the occupant compartment, or show undue hazard to others in the area. No occupant compartment intrusion occurred, and minimal (1.0 in.) to no occupant compartment deformation occurred during the test. All test vehicles remained upright during and after the collision event. During the crash test with the car and pickup (MASH Test 4-10 and 4-11), the occupant risk factors were within the preferred limits specified in MASH. In conclusion, the Lake Pontchartrain

[8] See Table 9 for details of respective evaluation criteria.

Causeway Bridge Design Option B1 performed acceptably according to MASH evaluation criteria for TL-4.

These designs were relevant to this project since these designs utilized a 10-in. high by 18-in. wide walkway curb. Information used from these projects were considered in this project.

Task 2 – Review of DOTD Bridge Rail Database

A literature review was completed for this project as part of Task 1. From Task 1, information was gathered on all the available retrofit options used previously that might be considered for this project. After Task 1 was completed, TTI received a database in Excel format from DOTD listing an inventory of bridges using concrete barriers with walkways used throughout the state. These bridges, approximately 200 total miles, used older types of concrete post and beam rails and solid concrete rails. The bridges in this database used a sidewalk for pedestrian access.

DOTD also provided numerous drawings and details for the common types of bridges in this database. These drawings, along with the Excel database provided to TTI researchers from DOTD, are provided in Bridge Curbed Barrier Retrofit Project. The information in the database and drawings were reviewed as part of this task. From this task, two bridge rail types were selected for analyses and detailing for retrofitting with respect to MASH TL-3. The bridge rails selected from this review were considered critical with respect to strength and performance for MASH TL-3. Other factors were also considered, such as their frequency of use, and geometrical considerations such as curb height, curb width, deck cantilever, and deck thickness.

Based on the researchers' review, the bridge rail designs from the Task 2 effort are provided as follows. For further information, please refer to the drawings provided in Appendix A. Approximately 20 drawings of different vintage bridge rail projects are provided in Bridge Curbed Barrier Retrofit Project. With the assistance of DOTD engineers, these drawings were selected from the larger database provided to TTI researchers on a spreadsheet database from DOTD. Engineering strength analyses were performed on the selected designs as follows.

Based on the researchers' review, the details shown on DOTD SCJ5C-90-24P appeared to be critical, based on strength and performance with respect to MASH TL-3. This design was also common for the concrete post and beam bridge rails with a safety walk. In addition, a solid concrete parapet was reviewed and analyzed during this reporting period. Figure 41 shows concrete geometry and reinforcement details for the concrete post and beam bridge rail with safety walk from drawing DOTD SCJ5C-90-24P. Details from SCJ5C-90-24P were used to develop the crash test installation details for the retrofit designs for this project. A retrofit design was also designed for a solid concrete parapet bridge rail with a safety walk. Drawing SC15A-60-24P and the details shown on this drawing were used for this design. Details of the solid concrete parapet as shown on this drawing SC15A-60-24P are shown in Figure 42. Please note that the aluminum rail element for the solid concrete parapet was not considered crashworthy with respect to MASH Specifications and therefore needs to be removed prior to retrofitting.

Figure 41. Details from drawing SCJ5C-90-24P concrete post and beam

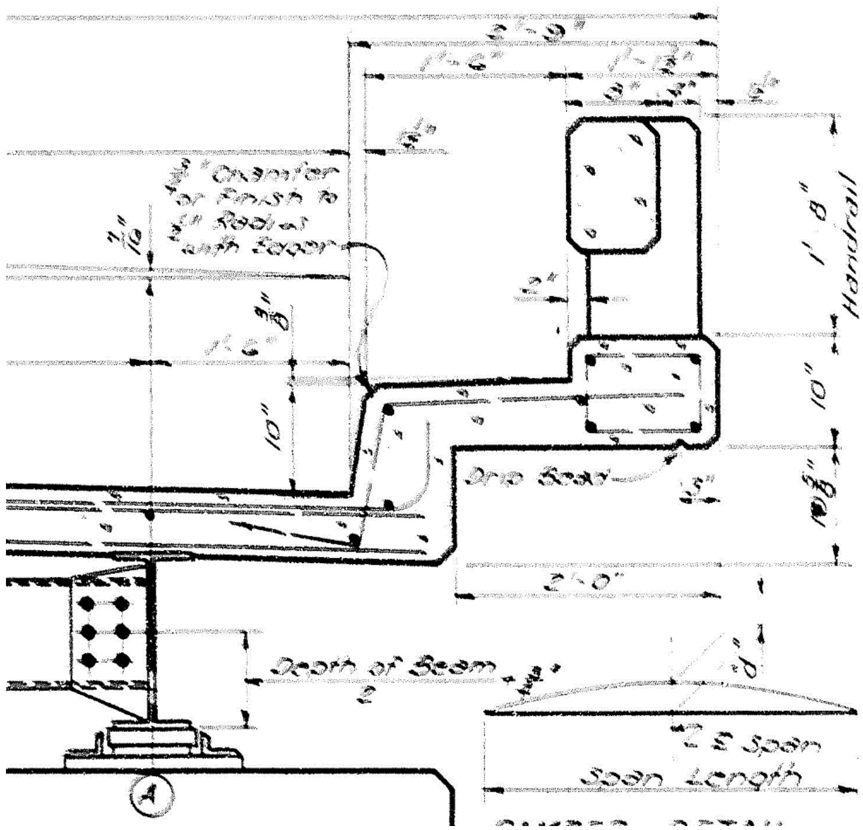
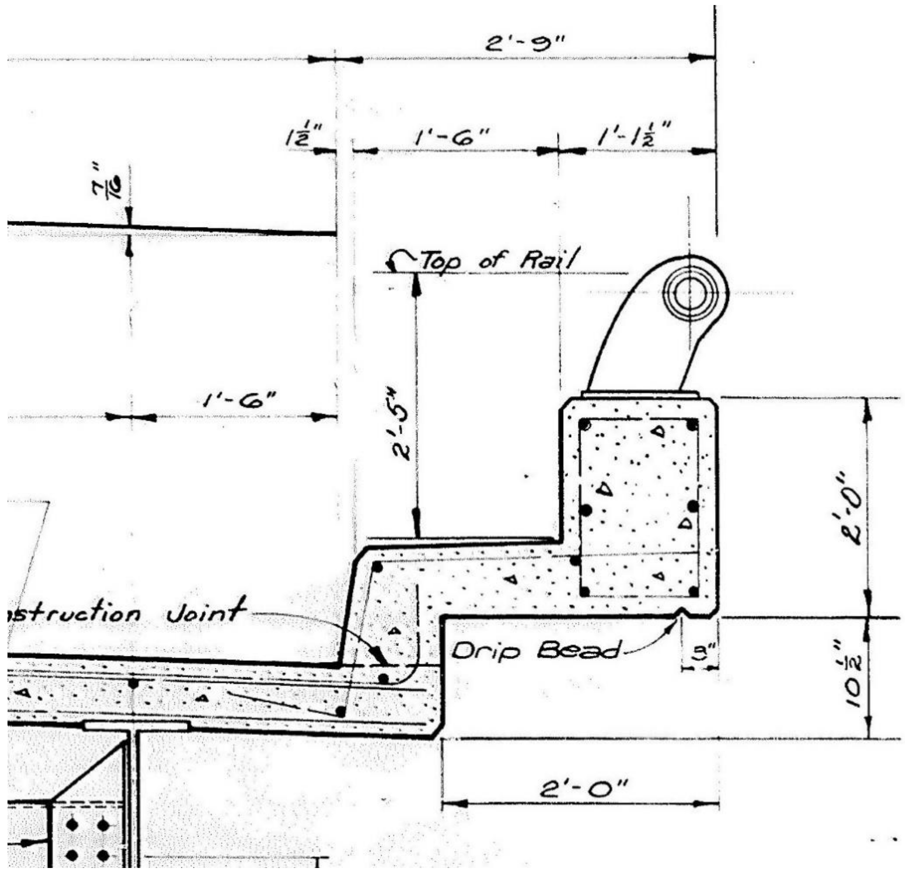


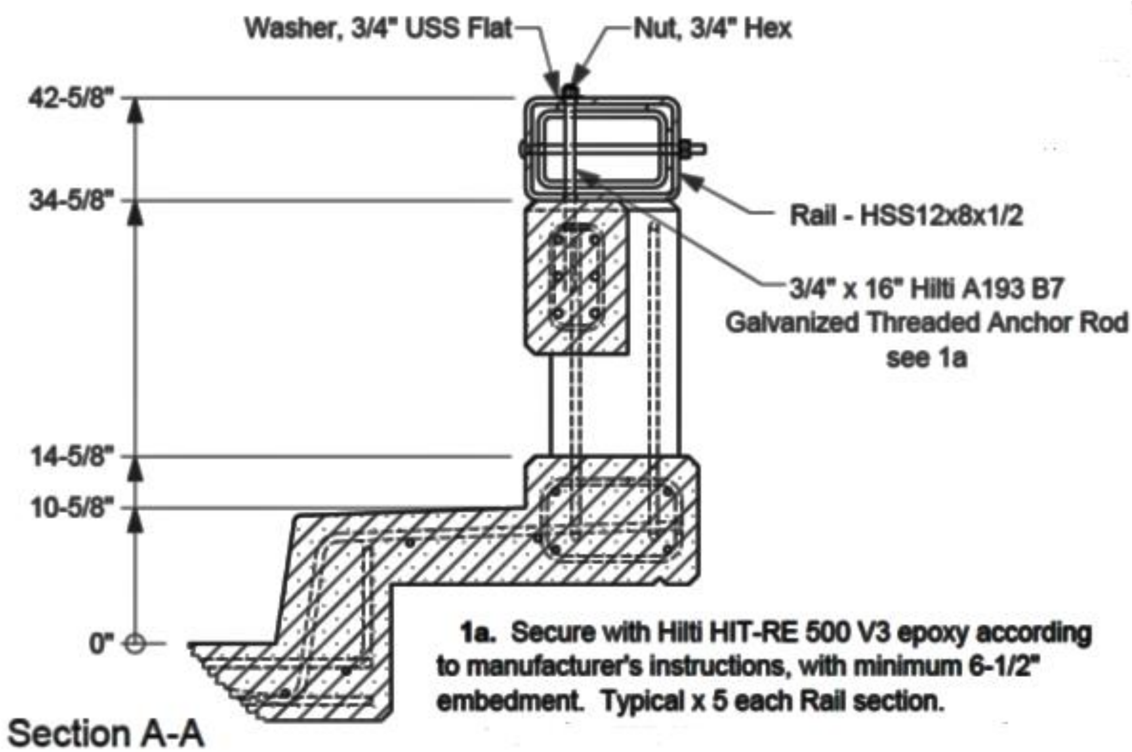
Figure 42. Details from drawing SC15A-60-24P solid concrete parapet with aluminum hand rail (to be removed)



Task 7 – Full Scale Testing of Retrofit Bridge Rail Option 1, Tested October 2018

In October 2018, full-scale testing was performed on the following bridge rail retrofit with respect to MASH TL-3. The retrofit bridge rail designed and tested for this option consisted of an HSS12x8x1/2 tubular rail element anchored to the top of the concrete post and beam with safety walk barrier selected in Task 2. A cross section view of the retrofit is shown in Figure 43.

Figure 43. Retrofit bridge rail Option 1 cross section details



Complete test installation details developed as part of Task 7 for retrofit Option 1 is presented in Appendix B. Please refer to these details in the appendix for additional information for this retrofit Option 1. As part of Task 7, these test installation details were used to construct a test installation for full scale crash testing with respect to MASH TL-3. Full-scale crash testing was performed on Option 1 in October 2018. A summary of the crash testing criteria and results are as follows.

Test Requirements and Evaluation Criteria

Crash Tests Performed

Table 8 shows the test conditions and evaluation criteria for MASH TL-3 for longitudinal barriers. MASH Test 3-10 involves an 1100C vehicle weighing 2420 lb. ±55 lb. impacting the critical impact point (CIP) of the bridge barrier at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 25 degrees ±1.5 degrees. MASH Test 3-11 involves a 2270P vehicle weighing 5000 lb. ±110 lb. impacting the CIP of the bridge barrier at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 25 degrees ±1.5 degrees.

Table 8. Test conditions and evaluation criteria specified for MASH TL-3 longitudinal barriers

Test Article	Test Designation	Test Vehicle	Impact Conditions		Evaluation Criteria
			Speed	Angle	
Longitudinal Barrier	3-10	1100C	62 mi/h	25°	A, D, F, H, I
	3-11	2270P	62 mi/h	25°	A, D, F, H, I

The target CIPs for tests on the Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk and the redesigned bridge rail were determined using the information provided in MASH Section 2.2.1, Section 2.3.2, and MASH Figure 2-1. Figure 44 depicts target CIPs for MASH Test 3-10 (crash Test No. 606861-2) and Test 3-11 (crash Test No. 606861-1) on the Louisiana Retrofit post and beam bridge rail with safety walk Option 1. Figure 45 depicts target CIP for MASH Test 3-10 (crash Test No. 606861-4) on the Redesigned Louisiana Retrofit post and beam bridge rail with safety walk Option 2. Figure 46 shows the target CIP for Test 3-11 (crash Test No. 606861-3) Redesigned Louisiana Retrofit post and beam bridge rail with safety walk Option 2.

The crash tests and data analysis procedures were in accordance with guidelines presented in MASH. Brief descriptions of these procedures are described under the section entitled Test Conditions.

Figure 44. Target CIPs for MASH tests on Louisiana Retrofit Post and Beam Bridge Rail With Safety Walk

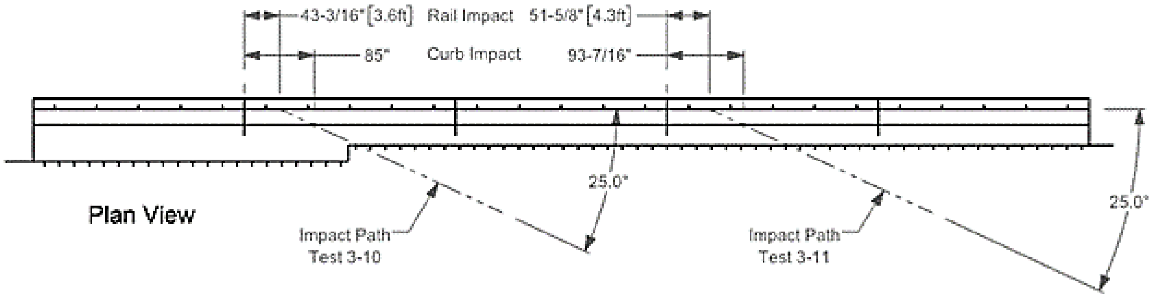


Figure 45. Target CIPs for MASH Test 3-10 on redesigned Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk

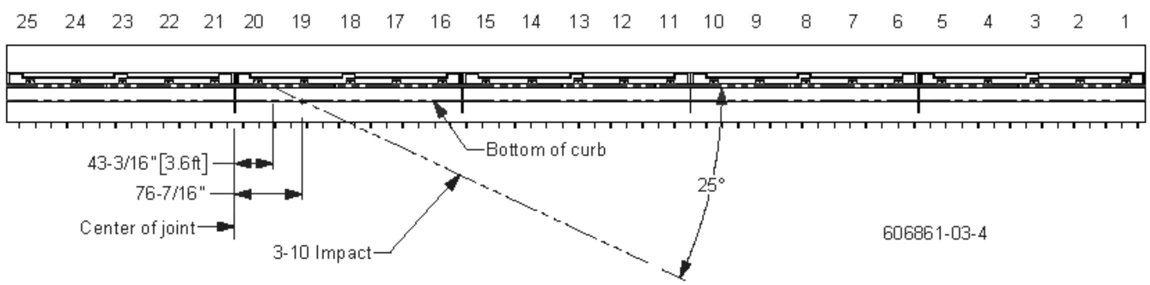
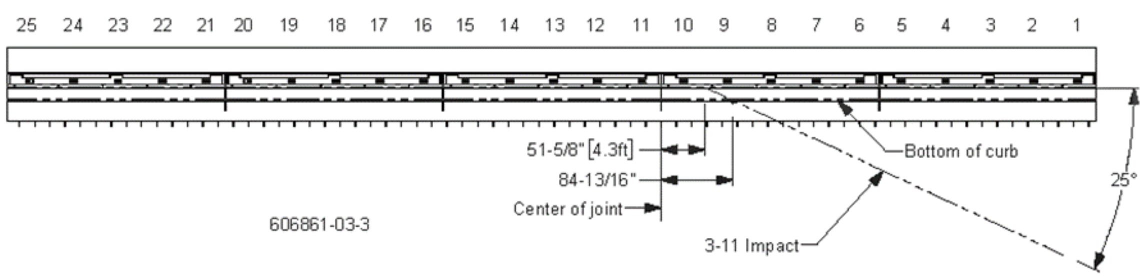


Figure 46. Target CIP for MASH Test 3-11 on redesigned Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk



Evaluation Criteria

The appropriate safety evaluation criteria from Tables 2-2A and 5-1 of MASH were used to evaluate the crash tests reported herein. The test conditions and evaluation criteria required for MASH TL-3 are listed in Table 8, and the substance of the evaluation criteria in Table 9. An evaluation of the crash test results is presented in detail under the section Assessment of Test Results.

Table 9. Evaluation criteria required for MASH TL-4 longitudinal barriers

Evaluation Factors	Evaluation Criteria	
Structural Adequacy	A.	Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.
Occupant Risk	D.	Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment or present undue hazard to other traffic, pedestrians, or personnel in a work zone.
		Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH.
	F.	The vehicle should remain upright during and after collision for Tests 4-10 and 4-11. The maximum roll and pitch angles are not to exceed 75 degrees.
	H.	Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 30 ft/s, or maximum allowable value of 40 ft/s for Tests 4-10 and 4-11.
	I.	The occupant ridedown accelerations should satisfy the following: Preferred value of 15.0 g, or maximum allowable value of 20.49 g for Tests 4-10 and 4-11.

Test Conditions

Test Facility

The full-scale crash tests reported herein were performed at Texas A&M Transportation Institute (TTI) Proving Ground, an International Standards Organization (ISO)/International Electrotechnical Commission (IEC) 17025-accredited laboratory with American Association for Laboratory Accreditation (A2LA) Mechanical Testing Certificate 2821.01. The full-scale crash tests were performed according to TTI Proving Ground quality procedures, and according to the MASH guidelines and standards.

The test facilities of the TTI Proving Ground are located on the Texas A&M University System RELLIS Campus, which consists of a 2000-acre complex of research and training facilities situated 10 miles northwest of the flagship campus of Texas A&M University. The site, formerly a United States Army Air Corps base, has large expanses of concrete runways and parking aprons well suited for experimental research and testing in the areas of vehicle performance and handling, vehicle-roadway interaction, durability and efficacy of highway pavements, and evaluation of roadside safety hardware and perimeter protective devices. The site selected for construction and testing of the bridge barrier was along the edge of an out-of-service apron. The apron consists of an unreinforced jointed-concrete pavement in 12.5-ft. × 15 ft. blocks nominally 6 in. deep. The aprons were built in 1942, and the joints have some displacement, but are otherwise flat and level.

Vehicle Tow and Guidance System

Each test vehicle was towed into the test installation using a steel cable guidance and reverse tow system. A steel cable for guiding the test vehicle was tensioned along the path, anchored at each end, and threaded through an attachment to the front wheel of the test vehicle. An additional steel cable was connected to the test vehicle, passed around a pulley near the impact point, through a pulley on the tow vehicle, and then anchored to the ground such that the tow vehicle moved away from the test site. A 2:1 speed ratio between the test and tow vehicle existed with this system. The test vehicle was released just prior to impact, and ran unrestrained. The vehicle remained freewheeling (i.e., no steering or braking inputs) until it cleared the immediate area of the test site (no sooner than 2 s after impact), after which the brakes were activated, if needed, to bring the test vehicle to a safe and controlled stop.

Data Acquisition Systems

Vehicle Instrumentation and Data Processing

Each test vehicle was instrumented with a self-contained, on-board data acquisition system. The signal conditioning and acquisition system is a 16-channel, Tiny Data Acquisition System (TDAS) Pro produced by Diversified Technical Systems, Inc. The accelerometers, which measure the x, y, and z axis of vehicle acceleration, are strain gauge type with linear millivolt output proportional to acceleration. Angular rate sensors, measuring vehicle roll, pitch, and yaw rates, are ultra-small, solid state units designed for crash test service. The TDAS Pro hardware and software conform to the latest SAE J211, Instrumentation for Impact Test. Each of the 16 channels is capable of providing precision amplification, scaling, and filtering based on transducer specifications and calibrations. During the test, data are recorded from each channel at a rate of 10,000 values per second with a resolution of one part in 65,536. Once data are recorded, internal batteries back these up inside the unit should the primary battery cable be severed. Initial contact of the pressure switch on the vehicle bumper provides a time zero mark as well as initiates the recording process. After each test, the data are downloaded from the TDAS Pro unit into a laptop computer at the test site. The Test Risk Assessment Program (TRAP) software then processes the raw data to produce detailed reports of the test results.

Each of the TDAS Pro units is returned to the factory annually for complete recalibration and all instrumentation used in the vehicle conforms to all specifications outlined by SAE J211. All accelerometers are calibrated annually by means of an ENDEVCO™ 2901, precision primary vibration standard. This standard and its support instruments are checked annually and receive a National Institute of Standards Technology (NIST) traceable calibration. The rate transducers used in the data acquisition system receive a calibration via a Genisco Rate-of-Turn table. The subsystems of each data channel are also evaluated annually, using instruments with current NIST traceability, and the results are factored into the accuracy of the total data channel, per SAE J211. Calibrations and evaluations are also made any time data are suspect. Acceleration data is measured with an expanded uncertainty of ±1.7 percent at a confidence factor of 95 percent (k=2).

TRAP uses the data from the TDAS Pro to compute occupant/compartment impact velocities, time of occupant/compartment impact after vehicle impact, and the highest 10-millisecond (ms) average ridedown acceleration. TRAP calculates change in vehicle velocity at the end of a given impulse period. In addition, maximum average accelerations over 50-ms intervals in each of the three directions are computed. For reporting purposes, the data from the vehicle-mounted accelerometers are filtered with a 60-Hz low-pass digital filter, and acceleration versus time curves for the longitudinal, lateral, and vertical directions are plotted using TRAP.

TRAP uses the data from the yaw, pitch, and roll rate transducers to compute angular displacement in degrees at 0.0001-s intervals, then plots yaw, pitch, and roll versus time. These displacements are in reference to the vehicle-fixed coordinate system with the initial position and orientation of the vehicle-fixed coordinate systems being initial impact. Rate of rotation data is measured with an expanded uncertainty of ±0.7 percent at a confidence factor of 95 percent (k=2).

Anthropomorphic Dummy Instrumentation

An Alderson Research Laboratories Hybrid II, 50th percentile male anthropomorphic dummy, restrained with lap and shoulder belts, was placed in the front seat on the impact side of the 1100C vehicle. The dummy was not instrumented.

According to MASH, it is recommended a dummy be used when testing “any longitudinal barrier with a height greater than or equal to 33 in..” Use of the dummy in the 2270P vehicle is recommended for tall rails to evaluate the “potential for an occupant to extend out of the vehicle and come into direct contact with the test article.” Although this information is reported, it is not part of the impact performance evaluation. Since the height of the top of the rail on the Option 1 bridge rail was 42⅝ in. and the redesigned Option 2 bridge rail was 40 in., a dummy was placed in the front seat of the 2270P vehicles on the impact side and restrained with lap and shoulder belts.

Vehicle Instrumentation and Data Processing

Photographic coverage of each test included three digital high-speed cameras:

1. One overhead with a field of view perpendicular to the ground and directly over the impact point;
2. One placed on the traffic side of the installation at an angle behind the impact; and

3. A third placed to have a field of view parallel to and aligned with the installation at the downstream end.

A flashbulb on the impacting vehicle was activated by a pressure-sensitive tape switch to indicate the instant of contact with the bridge rail. The flashbulb was visible from each camera. The video files from these digital high-speed cameras were analyzed to observe phenomena occurring during the collision and to obtain time-event, displacement, and angular data. A digital camera recorded and documented conditions of each test vehicle and the installation before and after the test.

MASH TL-3 Testing of Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk Option 1

Test Installation Details

Test Installation Description

The test installation was 106 ft.-10¾ in. long and consisted of a reinforced cantilevered concrete deck, a stepped-up sidewalk, with a curb and posts topped by a concrete beam, and a rectangular hollow steel rail anchored on top of the concrete beam. The sidewalk, curb, posts, and beam were comprised of five separate segments with 1-in. gaps between the sidewalk and curb segments and 6-in. gaps between the post and beam segments. Each segment contained three concrete posts with one at each end and one at center.

Each steel rail section measured 21 ft.-3¾ in. long, and each was anchored to the top of the concrete rail such that the impact face of the steel tubes was flush with the impact face of the concrete rails. A 36-in. long fabricated rail splice section spanned the 1-in. gaps between the steel rail sections. The steel rail sections were attached to the concrete beam with ¾-in. diameter ×16-in. long threaded rods secured with Hilti HIT-RE500V3 epoxy adhesive.

Appendix B presents the drawings and information on the Louisiana Retrofit post and beam bridge rail with safety walk Option 1, and Figure 47 through Figure 49 provide photographs of the completed installation.

Material Specifications

The specified compressive strength of the concrete used in the wall, deck, curb, and parapet was 3000 psi. On October 2, 2018, the average compressive strengths of the concrete were as follows:

- Average concrete strength for the wall and deck: 4535 psi at 75 days of age.
- Average concrete strength for the curb: 4643 psi at 66 and 67 days of age (2 pours).
- Average concrete strength for the parapet: 4044 psi at 54 and 61 days of age (2 pours).

Appendix C provides material certification documents for the materials used to install/construct the Louisiana Retrofit post and beam bridge rail with safety walk Option 1.

Figure 47. Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk Option 1 prior to testing

(a) Traffic face of bridge rail

(b) Field side of bridge rail

(c) Upstream of joint

(d) Downstream of joint

Figure 48. Joint 2 of Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk Option 1 prior to testing

(a) Metal rail element at joint 2 (b) Concrete parapet at joint 2

Figure 49. Field side of Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk Option 1 prior to testing

(a) Field side of joint 2 (b) Field side of joint 4

MASH Test 3-11 (Crash Test No. 606861-1)

Test Designation and Actual Impact Conditions

MASH Test 3-11 involves a 2270P vehicle weighing 5000 lbs ±110 lbs impacting the CIP of the bridge barrier at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 25 degrees ±1.5 degrees. The CIP for MASH Test 3-11 on the Louisiana Retrofit post and beam bridge rail with safety walk Option 1 was determined to be 4.3 ft. ±1 ft. upstream of the centerline of the second open joint in the concrete deck/beam. Figure 44 and Figure 50 depict the target CIP.

Figure 50. Test vehicle/bridge rail geometrics for Test No. 606861-1

(a) Frontal view of 2270P test vehicle at target impact point

(b) Rear view of 2270P test vehicle at target impact point

The 2270P vehicle used in the test weighed 5015 lbs, and the actual impact speed and angle were 63.5 mi/h and 25.2 degrees. The actual impact point was 3.9 ft. upstream of the centerline of the second open joint in the concrete deck/beam. Minimum target impact severity (IS) was 106 kip ft., and actual IS was 123 kip-ft.

Weather Conditions

The test was performed on the morning of October 2, 2018. Weather conditions at the time of testing were as follows: wind speed: 2 mi/h; wind direction: 153 degrees (vehicle was traveling at a heading of 150 degrees); temperature: 77°F; relative humidity: 98 percent.

Test Vehicle

Figure 51 shows the 2012 RAM 1500 pickup truck used for the crash test. The vehicle's test inertia weight was 5015 lbs, and its gross static weight was 5180 lbs. The height to the lower edge of the vehicle bumper was 11.75 in., and the height to the upper edge of the bumper was 27.0 in. The height to the vehicle's center of gravity was 28.5 in. Figure 106 and Figure 107 in Appendix D give additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system and was released to be freewheeling and unrestrained just prior to impact.

Figure 51. Test vehicle prior to Test No. 606861-1

(a) Right side of 2270P test vehicle

(b) Left side of 2270P test vehicle

Test Description

Table 10 lists times and significant events that occurred during Test No. 606861-1. Figure 108 through Figure 110 in Appendix D present sequential photographs during the test.

Table 10. Events during Test No. 606861-1

Time (s)	Events
0.0000	Data acquisition trigger activated by curb
0.0160	Right front tire of vehicle contacts curb
0.0480	Right front bumper contacts concrete rail
0.0630	Vehicle begins to redirect
0.2330	Maximum deflection of rail element
0.2710	Left front tire leaves pavement surface
0.3230	Left front tire returns to pavement surface
0.3990	Vehicle is parallel to the bridge barrier
0.4450	Right rear tire rides up onto curb
0.5300	Left rear tire leaves pavement surface
0.5420	Rear right side of vehicle contacts concrete rail
0.6830	Vehicle loses contact with bridge rail while traveling 31.6 mi/h, at a trajectory angle of 6.3 degrees, and a heading angle of 9.7 degrees
1.0600	Left rear tire returns to pavement surface

For longitudinal barriers, it is desirable that the vehicle redirects and exits the barrier within the exit box criteria (not less than 32.8 ft. downstream from loss of contact for cars and pickups). The test vehicle exited within the exit box criteria defined in MASH. Brakes on the vehicle were not applied. After loss of contact with the barrier, the vehicle came to rest 122 ft. downstream of the impact and 20 ft. toward the traffic side.

Damage to Test Installation

Figure 52 through Figure 55 show the damage to the Option 1 bridge rail. The concrete at both posts at joint 2, and the middle post in section 3, failed with rebar exposed. Numerous cracks were observed in the beam and middle post of section 2 and along the beam of section 3, ending 30 in. upstream of the downstream end of section 3. The rear of the deck was broken out at the middle post of section 2, the end posts at the second joint, and the middle post of section 3. Working width[9] was 22.1 in., and height of the working width was 42.6 in.. Maximum dynamic deflection during the test was 10.0 in., and maximum permanent deformation was 7.25 in.

Figure 52. Option 1 bridge rail after Test No. 606861-1

(a) Bridge rail/test vehicle after test

(b) Permanent deformation of bridge rail

[9] Per MASH, "The working width is the maximum dynamic lateral position of any major part of the system or vehicle. These measurements are all relative to the pre-impact traffic face of the test article." In other words, working width is the total barrier width plus the maximum dynamic intrusion of any portion of the barrier or test vehicle past the field side edge of the barrier.

Figure 53. Damage at joint 2 after Test No. 606861-1

(a) Damage to curb and beam

(b) Damage at joint 2

Figure 54. Damage at section 3 after Test No. 606861-1

(a) Section 3 just downstream of joint 2

(b) Middle post of section 3

Figure 55. Damage on field side of bridge rail after Test No. 606861-1

(a) Field side of section 2

(b) Field side of middle post of section 2

(c) Field side of end posts at joint 2

(d) Field side of middle post of section 3

Damage to Test Vehicle

Figure 56 shows the damage sustained by the vehicle. The front bumper, grill, hood, right front fender, right front upper and lower ball joints, right front tire and rim, right frame rail, right front door, right rear tire, and rear bumper were damaged. Maximum exterior crush to the vehicle was 16.0 in. in the front plane at the right front corner at bumper height. Maximum occupant compartment deformation was 2.0 in. in the right firewall. Figure 57 shows the interior of the vehicle. Figure 111 and Figure 112 in Appendix D provide exterior crush and occupant compartment measurements.

Figure 56. Test vehicle after Test No. 606861-1

(a) Front of 2270P test vehicle after test

(b) Right front of 2270P test vehicle

Figure 57. Interior of test vehicle after Test No. 606861-1

(a) Interior of cab of 2270P test vehicle

(a) Right front floor pan of 2270P test vehicle

Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk and results are shown in Table 11. Figure 58, Table 12, and Table 13 summarize these data and other pertinent information from the test. Figure 113 in Appendix D shows the vehicle angular displacements, and Figure 114 through Figure 116 in Appendix D show acceleration versus time traces.

Table 11. Occupant risk factors for Test No. 606861-1

Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV)		
Longitudinal	28.9 ft/s	at 0.1472 s on right side of interior
Lateral	21.7 ft/s	
Occupant Ridedown Accelerations		
Longitudinal	11.8 g	0.2803 - 0.2903 s
Lateral	6.5 g	0.2912 - 0.3012 s
Theoretical Head Impact Velocity (THIV)	10.9 m/s	at 0.1444 s on right side of interior
Acceleration Severity Index (ASI)	1.6	0.1079 - 0.1579 s
Maximum 50-ms Moving Average		
Longitudinal	−12.0 g	0.0940 - 0.1440 s
Lateral	−10.9 g	0.0783 - 0.1283 s
Vertical..	−3.5 g	0.0657 - 0.1157 s
Maximum Roll, Pitch, and Yaw Angles		
Roll..	14 degrees	1.2803 s
Pitch	6 degrees	0.6268 s
Yaw	35 degrees	0.6866 s

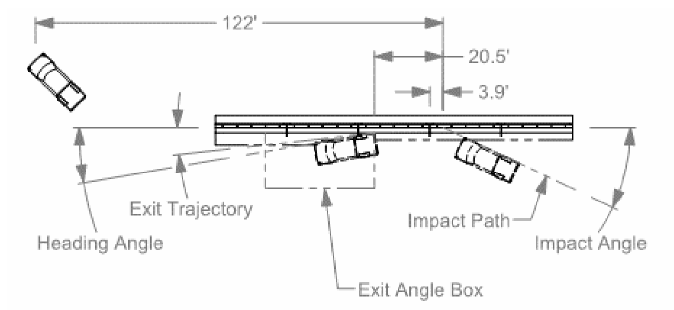
Figure 58. Summary of results for MASH Test 3-11 on Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk Option 1

(a) 0.000 s

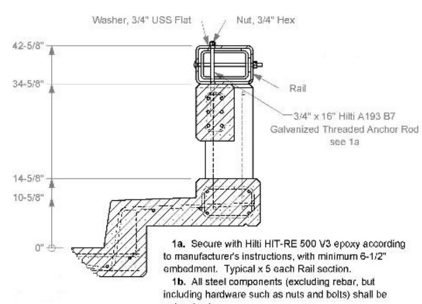
(b) 0.200 s

(c) 0.400 s

(d) 0.600 s



(e) Impact summary



(f) Cross-section of bridge rail

Table 12. Summary of results for MASH Test 3-11 on Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk Option 1—Pre-Impact Information

General Information	
Test Agency	Texas A&M Transportation Institute
Test Standard Test No.	MASH Test 3-11
TTI Test No.	606861-1
Test Date	2018-10-02
Test Article	
Type	Longitudinal Barrier—Bridge Rail
Name	Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk
Installation Length	106 ft.-10¾ in.
Material or Key Elements	Reinforced cantilevered concrete deck, stepped-up sidewalk, curb and posts topped by a concrete beam, rectangular hollow steel rail secured on top of the concrete beam
Foundation Type/Condition	Concrete Bridge Deck, Damp
Test Vehicle	
Type/Designation	2270P
Make and Model	2012 RAM 1500 Pickup
Curb	4983 lbs.
Test Inertial	5015 lbs.
Dummy	165 lbs.
Gross Static	5180 lbs.
Impact Conditions	
Speed	63.5 mi/h
Angle	25.2 degrees
Location	3.9 ft. upstream of joint 2
Impact Severity	123 kip-ft.
Exit Conditions	
Speed	31.6 mi/h
Exit Trajectory/Heading	6.3 degrees/9.7 degrees

Table 13. Summary of results for MASH Test 3-11 on Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk Option 1—Post-Impact Information

Occupant Risk Values	
Longitudinal OIV	28.9 ft/s
Lateral OIV	21.7 ft/s
Longitudinal Ridedown	11.8 g
Lateral Ridedown	6.5 g
THIV	10.9 m/s
ASI	1.6
Max. 0.050-s Average	
Longitudinal	−12.0 g
Lateral	−10.9 g
Vertical	−3.5 g
Post-Impact Trajectory	
Stopping Distance	122 ft. downstream / 20 ft. toward traffic lanes
Vehicle Stability	
Maximum Roll Angle	14 degrees
Maximum Pitch Angle	6 degrees
Maximum Yaw Angle	35 degrees
Vehicle Snagging	No
Vehicle Pocketing	No
Test Article Deflections	
Dynamic	10.0 in.
Permanent	7.25 in.
Working Width	22.1 in.
Height of Working Width	42.6 in.
Vehicle Damage	
VDS	01RFQ5
CDC	01FREW5
Max Exterior Deformation	16.0 in.
OCDI	FR0010000
Max Occupant Compartment Deformation	2.0 in.

MASH Test 3-10 (Crash Test No. 606861-2)

Test Designation and Actual Impact Conditions

MASH Test 3-10 involves an 1100C vehicle weighing 2420 lbs ±55 lbs impacting the CIP of the bridge barrier at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 25 degrees ±1.5 degrees. The CIP for MASH Test 3-10 on the Louisiana Retrofit post and beam bridge rail with safety walk Option 1 was 3.6 ft. ±1 ft. upstream of the centerline of the fourth open joint in the concrete deck/beam. Figure 44 and Figure 59 depict the target impact point.

Figure 59. Test vehicle/bridge rail geometrics for Test No. 606861-2

(a) Frontal view of 1100C test vehicle at target impact point

(b) Rear view of 1100C test vehicle at target impact point

The 1100C vehicle used in the test weighed 2425 lbs, and the actual impact speed and angle were 62.0 mi/h and 25.2 degrees. The actual impact point was 3.3 ft. upstream of the centerline of the fourth open joint in the concrete deck/beam. Minimum target IS was 51 kip-ft., and actual IS was 57 kip-ft.

Weather Conditions

The test was performed on the morning of October 3, 2018. Weather conditions at the time of testing were as follows: wind speed: 5 mi/h; wind direction: 166 degrees (vehicle was traveling at a heading of 150 degrees); temperature: 83°F; relative humidity: 83 percent.

Test Vehicle

Figure 60 shows the 2009 Kia Rio[10] used for the crash test. The vehicle's test inertia weight was 2425 lbs, and its gross static weight was 2590 lbs. The height to the lower edge of the vehicle bumper was 7.75 in., and the height to the upper edge of the bumper was 21.5 in. Figure 117 in Appendix E gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

Figure 60. Test vehicle before Test No. 606861-2

(a) Right side of 1100C test vehicle

(b) Left side of 1100C test vehicle

Test Description

Table 14 lists events that occurred during Test No. 606861-2. Figure 118 through Figure 120 in Appendix E present sequential photographs during the test.

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[10] The 2009 model vehicle used is older than the 6-year age noted in MASH, and was selected based upon availability. An older model vehicle is permitted by AASHTO as long as it is otherwise MASH compliant. Other than the vehicle's year model, this 2009 model vehicle met the MASH requirements.

Table 14. Events during Test No. 606861-2

Time (s)	Events
0.0000	Data acquisition trigger activated by curb
0.0180	Vehicle lower front right bumper contacts curb
0.0490	Vehicle begins to redirect
0.0620	Vehicle contacts concrete beam
0.1020	Left front tire leaves pavement surface
0.1920	Left rear tire leaves pavement surface
0.2550	Vehicle traveling parallel to bridge barrier
0.2760	Left rear of vehicle contacts bridge barrier
0.3530	Vehicle loses contact with bridge rail while traveling at 47.4 mi/h, at a trajectory angle of 2.0 degrees, and a heading angle of 5.8 degrees
0.4570	Left front tire returns to pavement surface

For longitudinal barriers, it is desirable that the vehicle redirects and exits the barrier within the exit box criteria (not less than 32.8 ft. downstream from loss of contact for cars and pickups). The test vehicle exited within the exit box criteria defined in MASH. Brakes on the vehicle were not applied. After loss of contact with the barrier, the vehicle came to rest 145 ft. downstream of the impact and 23 ft. toward traffic lanes.

Damage to Test Installation

Figure 61 through Figure 63 show the damage to the Option 1 bridge rail. The concrete curb was cracked through on the upstream side of the post on the downstream end of section 4, and a small crack in the curb was observed on the downstream side. The metal rail element was scuffed and scratched. Working width[11] was 12.7 in., and height of

[11] Per MASH, "The working width is the maximum dynamic lateral position of any major part of the system or vehicle. These measurements are all relative to the pre-impact traffic face of the test article." In other words, working width is the total barrier width plus the maximum dynamic intrusion of any portion of the barrier or test vehicle past the field side edge of the barrier.

working width was 42.6 in. Maximum dynamic deflection during the test was 0.7 in., and there was no measurable permanent deformation.

Figure 61. Option 1 bridge rail after Test No. 606861-2

(a) Bridge rail/test vehicle after test

(b) Traffic side of bridge rail at impact

Figure 62. Damage to traffic face of bridge rail after Test No. 606861-2

(a) Traffic side at impact point

(b) Traffic side of joint 4

(c) Traffic side of posts at joint 4

(d) Traffic side of metal rail at joint 4

Figure 63. Damage on field side of bridge rail after Test No. 606861-2

(a) Field side of joint 4

(b) Close up view of field side of joint 4

Damage to Test Vehicle

Figure 64 shows the damage sustained by the vehicle. The front bumper, grill, hood, radiator and support, right front tire and rim, right front strut and strut tower, right front fender, right front door and window glass, right rear quarter panel, right rear rim, and rear bumper were damaged. Maximum exterior crush to the vehicle was 9.0 in. in the side plane at the right front corner at bumper height. Maximum occupant compartment deformation was 1.5 in. in the right firewall area. Figure 65 shows the interior of the vehicle. Figure 121 and Figure 122 in Appendix E provide exterior crush and occupant compartment measurements.

Figure 64. Test vehicle after Test No. 606861-2

(a) Front of 1100C test vehicle after test

(b) Right front of 1100C test vehicle

Figure 65. Interior of test vehicle after Test No. 606861-2

(a) Interior of cab of 1100C test vehicle

(b) Right front floor pan

Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk and results are shown in Table 15. Figure 66, Table 16, and Table 17 summarize these data and other pertinent information from the test. Figure 123 in Appendix E shows the vehicle angular displacements, and Figure 124 through Figure 126 in Appendix E show acceleration versus time traces.

Table 15. Occupant risk factors for Test No. 606861-2

Occupant Risk Factor	Value	Time
OIV		
Longitudinal	18.4 ft/s	at 0.1103 s on right side of interior
Lateral	24.3 ft/s	
Occupant Ridedown Accelerations		
Longitudinal	23.1 g	0.1103 - 0.1203 s
Lateral	21.4 g	0.1103 - 0.1203 s
THIV..	9.1 m/s	at 0.1070 s on right side of interior
ASI	1.7	0.1063 - 0.1563 s
Maximum 50-ms Moving Average		
Longitudinal	-9.9 g	0.0700 - 0.1200 s
Lateral	-12.6 g	0.0804 - 0.1304 s
Vertical..	-5.5 g	0.0000 - 0.0500 s
Maximum Roll, Pitch, and Yaw Angles		
Roll...	21 degrees	0.8788 s
Pitch	10 degrees	0.5391 s
Yaw	51 degrees	1.4091 s

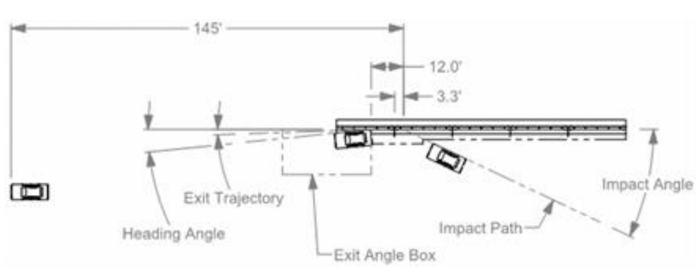
Figure 66. Summary of results for MASH Test 3-10 on Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk Option 1

(a) 0.000 s

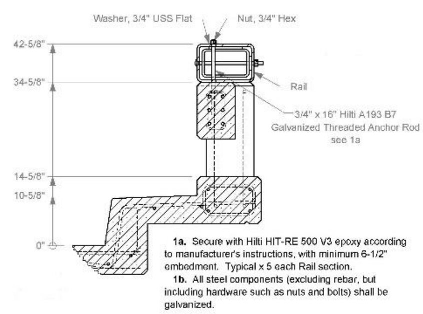
(b) 0.200 s

(c) 0.400 s

(d) 0.600 s



(e) Impact summary



(f) Cross-section of bridge rail

Table 16. Summary of results for MASH Test 3-10 on Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk Option 1—Pre-Impact Information

General Information	
Test Agency	Texas A&M Transportation Institute
Test Standard Test No.	MASH Test 3-10
TTI Test No.	606861-2
Test Date	2018-10-03
Test Article	
Type	Longitudinal Barrier—Bridge Rail
Name	Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk
Installation Length	106 ft.-10¾ in.
Material or Key Elements	Reinforced cantilevered concrete deck, stepped-up sidewalk, curb and posts topped by a concrete beam, rectangular hollow steel rail secured on top of the concrete beam
Foundation Type/Condition	Concrete Bridge Deck, Damp
Test Vehicle	
Type/Designation	1100C
Make and Model	2009 Kia Rio
Curb	2457 lbs.
Test Inertial	2425 lbs.
Dummy	165 lbs.
Gross Static	2590 lbs.
Impact Conditions	
Speed	62.0 mi/h
Angle	25.2 degrees
Location	3.3 ft. upstream of fourth joint
Impact Severity	57 kip-ft.
Exit Conditions	
Speed	47.4 mi/h
Exit Trajectory/Heading	2.0 degrees/5.8 degrees

Table 17. Summary of results for MASH Test 3-10 on Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk Option 1—Post-Impact Information

Occupant Risk Values	
Longitudinal OIV	18.4 ft/s
Lateral OIV	24.3 ft/s
Longitudinal Ridedown	23.1 g (High)
Lateral Ridedown	21.4 g (High)
THIV	9.1 m/s
ASI	1.7
Max. 0.050-s Average	
Longitudinal	−9.9 g
Lateral	−12.6 g
Vertical	−5.5 g
Post-Impact Trajectory	
Stopping Distance	145 ft. downstream / 23 ft. toward traffic lanes
Vehicle Stability	
Maximum Roll Angle	21 degrees
Maximum Pitch Angle	10 degrees
Maximum Yaw Angle	51 degrees
Vehicle Snagging	No
Vehicle Pocketing	No
Test Article Deflections	
Dynamic	0.7 in.
Permanent	None measurable
Working Width	12.7 in.
Height of Working Width	42.6 in.
Vehicle Damage	
VDS	01RFQ5
CDC	01FREW5
Max Exterior Deformation	9.0 in.
OCDI	RF0010000
Max Occupant Compartment Deformation	1.5 in.

Discussion of Results for MASH TL-3 Tests on Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk Option 1

Table 18 shows the Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk met the specified criteria for MASH Test 3-11. However, for MASH Test 3-10, Table 19 shows that the longitudinal and lateral occupant ridedown accelerations were both above the maximum allowable limit of 20.49 g specified in MASH. <u>Therefore, the Louisiana Retrofit post and beam bridge rail with safety walk Option 1 failed to meet occupant risk criteria for MASH Test 3-10, and thus MASH TL-3.</u>

The researchers determined that the bridge rail should be redesigned to achieve performance of the bridge rail to MASH TL-3 specifications.

Table 18. Performance evaluation summary for MASH Test 3-11 on Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk Option 1

Evaluation Factors	Evaluation[12] Criteria	Test Results	Assessment
Structural Adequacy	A.	The Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 10.0 in.	Pass
Occupant Risk	D.	The concrete curb and posts fractured into several pieces. However, these fragments did not penetrate or show potential for penetrating the occupant compartment, or present undue hazard for others on the bridge barrier (several fragments came to rest below the bridge deck).	Pass
		Maximum occupant compartment deformation was 2.0 in. in the right firewall area.	
	F.	The 2270P vehicle remained upright during and after the collision event. Maximum roll was 14 degrees and pitch was 6 degrees.	Pass
	H.	Longitudinal OIV was 28.9 ft/s, and lateral OIV was 21.7 ft/s.	Pass
	I.	Maximum longitudinal occupant ridedown was 11.8 g, and maximum lateral occupant ridedown was 6.5 g.	Pass

[12] See Table 9 for details of respective evaluation criteria.

Table 19. Performance evaluation summary for MASH Test 3-10 on Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk Option 1

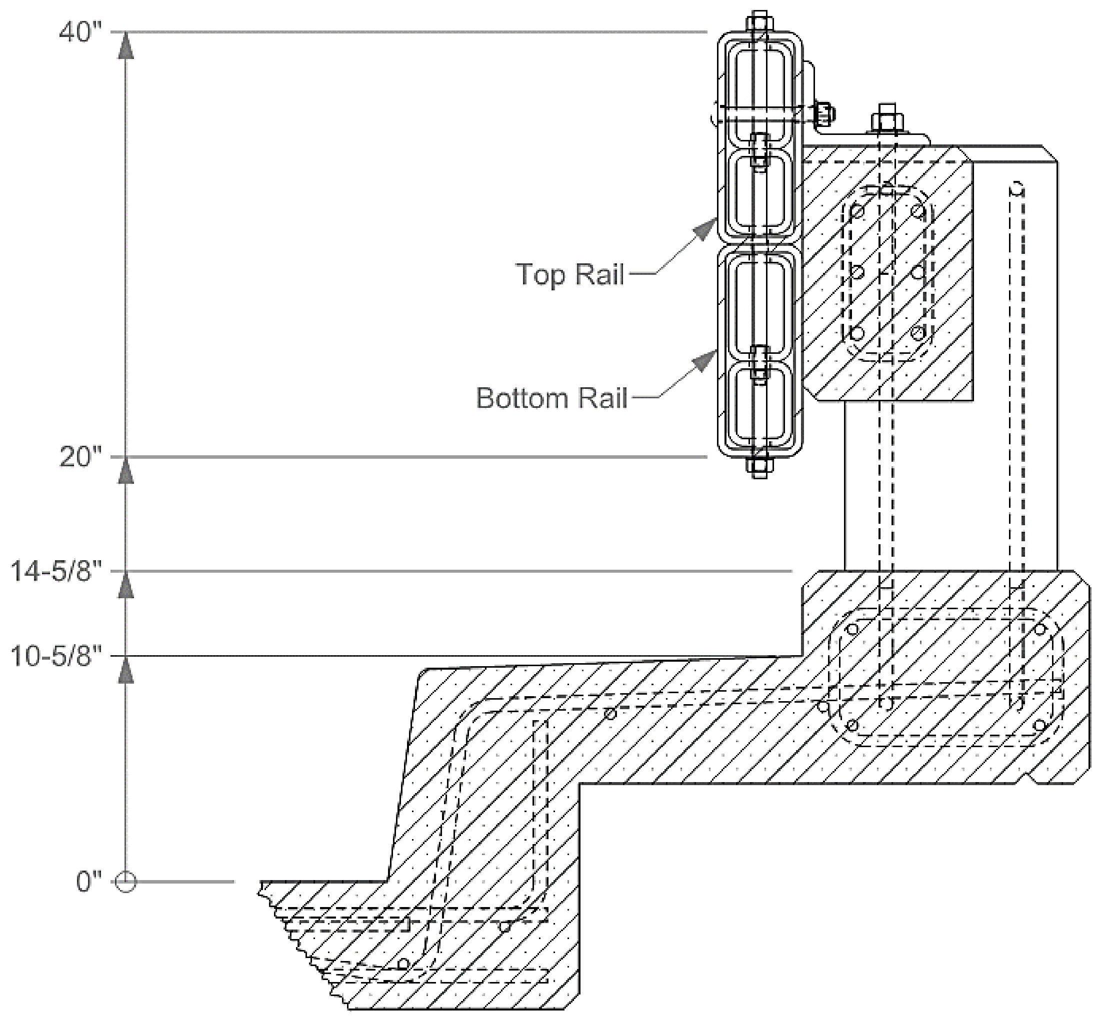
Evaluation Factors	Evaluation[13] Criteria	Test Results	Assessment
Structural Adequacy	A.	The Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 0.7 in.	Pass
Occupant Risk	D.	No detached elements, fragments, or other debris was present to penetrate or show potential for penetrating the occupant compartment, or present undue hazard for others on the bridge barrier.	Pass
		Maximum occupant compartment deformation was 1.5 in. in the right firewall area.	
	F.	The 1100C vehicle remained upright during and after the collision event. Maximum roll was 21 degrees and pitch was 10 degrees.	Pass
	H.	Longitudinal OIV was 18.4 ft/s, and lateral OIV was 24.3 ft/s.	Pass
	I.	Maximum longitudinal occupant ridedown was 23.1 g, and maximum lateral occupant ridedown was 21.4 g.	Fail

[13] See Table 9 for details of respective evaluation criteria.

Design and Strength Analysis of the Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk Option 2

Due to the unsuccessful MASH Test 3-10 performed on October 3, 2018, for Task 3 of this project, a new retrofit design Option (Option 2) was designed and detailed. A strength analysis procedure using the AASHTO LRFD Bridge Design Specifications, Section 13 [4] was used to analyze the structural capacity of the new bridge rail retrofit. Figure 67 shows a section view of the new retrofitted bridge rail system designed for this project. Appendix F presents the strength analysis performed on the new retrofitted bridge rail. Appendix G presents the structural details for the new retrofit bridge rail.

Figure 67. Section view of retrofitted bridge rail system



The inelastic or yield line resistance of the concrete rail using the principles of the Whitney Stress Block method combined with the elastic resistance of the retrofitted metal rails contributing to an inelastic hinge mechanism in the rail contributing to a plastic hinge (denoted M_p in AASHTO Section 13, but denoted M_{rail} in the worksheet) was calculated. The plastic moment resistance of the concrete post at three critical failure sections (denoted M_{FS} in the worksheet) is calculated using the principles of the Whitney Stress Block method.

The strength of a single post (denoted P_p in AASHTO Section 13 and in the worksheet in Appendix E) at a failure section was calculated using Equation 1.

$$P_p = \frac{M_{FS}}{y_{FS}} \tag{1}$$

where:

P_p = Minimum strength of a single post which corresponds to M_{FS} and is located y_{bar} above the deck (kips) considering several possible failure modes

y_{FS} = Height of rail force measured from the centroid of the failure section (in.)

M_{FS} = Minimum plastic moment resistance at the failure section (kip-in)

For post strength P_p, three different failure sections were considered. Failure Section 1 is assumed to be located at the interface between the bottom of a post and the top of curb. Failure Section 2 is assumed to be located at the vertical interface of the curb with the sidewalk at the center of sidewalk section (see Figure 68). Failure Section 3 is assumed to be located at the vertical interface between the deck and curb at the center of deck section (see Figure 69).

Once the strength of each failure section was calculated, the minimum strength (i.e., the minimum P_p value) was taken as the limiting or “worst case” post strength used in the AASHTO Section 13 equations.

The total resistance of the railing (denoted R in AASHTO Section 13) is calculated using AASHTO Section 13 Equation A13.3.2-3 (Equation 2).

Figure 68. Plan view of failure section 2

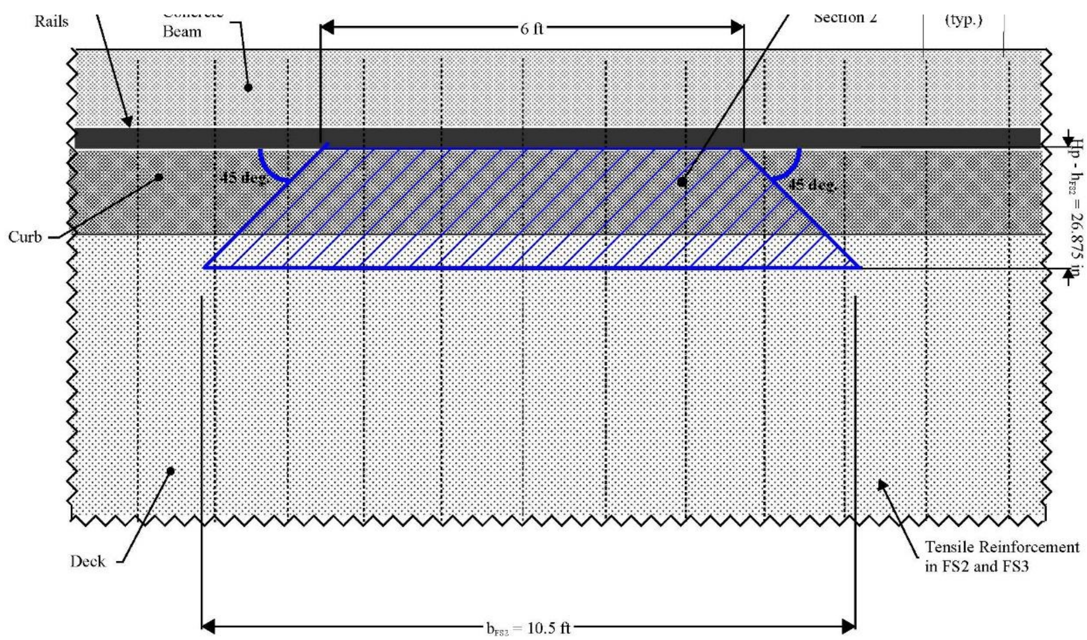
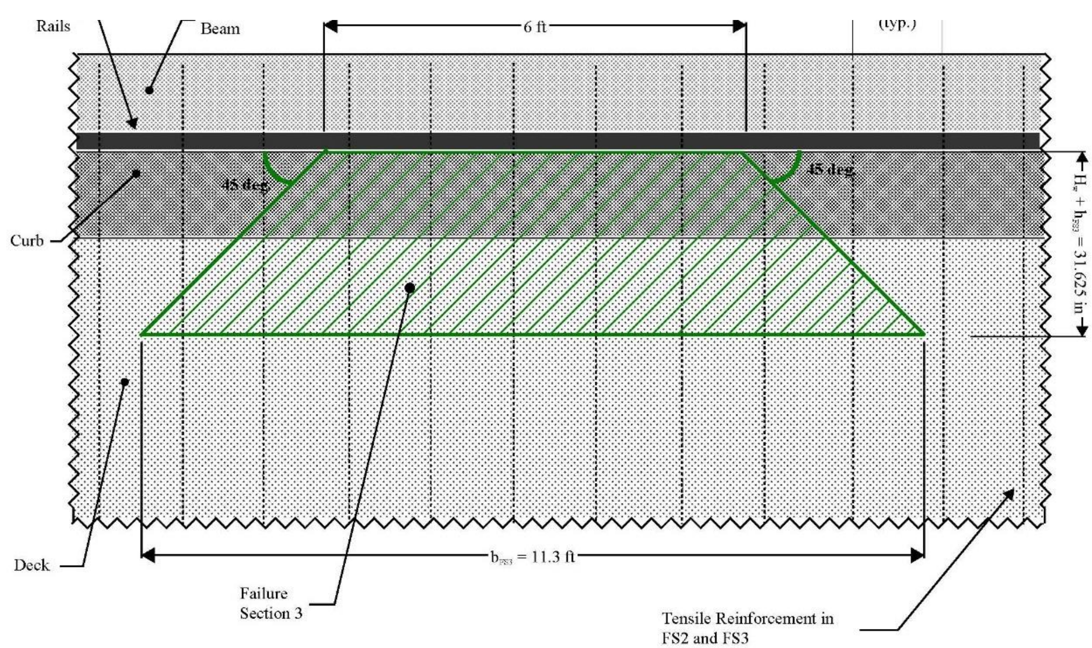


Figure 69. Plan view of failure section 3



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

where:

R = Total ultimate resistance, i.e., nominal resistance, of the railing (kips)

L = Post spacing of single span (ft.)

M_p (denoted M_{rail} on spreadsheet) = Inelastic or yield line resistance of all rails contributing to a plastic hinge (kip-ft.).

N = Number of railing spans.

The structural analysis conducted on the new DOTD retrofitted bridge rail system are presented in Appendix F. The resistance of the new retrofit bridge rail design was compared to the MASH TL-3 design transverse impact load (F_t) of 71 kips located an effective height (H_e) of 19 in. above the deck surface. The new retrofit bridge rail system has a calculated resistance of 75.4 kips located at an effective height (H_e) of 19 in. above the deck. Since the calculated resistance is greater than the design impact load, the retrofitted bridge rail system meets MASH TL-3 structural adequacy criterion. TTI completed test installation details necessary for construction of the new retrofit bridge rail design. Please refer to the calculations in Appendix F for additional information. For additional information on the details of the new retrofit bridge rail please refer to the details presented in Appendix G. The details shown in Appendix G were developed for MASH full-scale crash testing. The concrete post and beam bridge rail, safety sidewalk, and deck cantilever are the same as those constructed for full-scale crash testing in late 2018.

Based on the results of the structural analysis, the new retrofit bridge rail design as shown herein meets the strength requirements for MASH TL-3. This new design improves the strength of the existing concrete bridge rail and still allows some access to the existing safety sidewalk. This design was recommended for full-scale crash testing.

It was recommended that this design be full-scale crash tested as per the MASH specifications for TL-3. Two full-scale crash tests were planned. MASH Test 3-10 (small car) was performed on December 11, 2020. MASH Test 3-11 (pickup truck) was planned for December 14, 2020.

The new retrofit bridge rail design was also considered for a solid concrete parapet used by DOTD. The details of the retrofit design will require a small post with a base plate anchoring the retrofit bridge rail on top of the solid concrete parapet. These posts are necessary to maintain the rail height of 40 in. from the roadway surface. These posts will maintain the same geometry as the crash tested design. The centerline of the posts shall be located 24 in. minimum from the end of the concrete parapet. Details of the retrofit bridge rail anchored to the solid concrete parapet are shown in Figure 70 through Figure 72. The calculated strength of the new retrofit design anchored to the solid concrete parapet was 140 kips at a height of 19 in. above the roadway surface. Therefore, this retrofit design meets the strength requirements of MASH TL-3. Calculations for the retrofit design are presented in Appendix H.

Figure 70. Details of the retrofit bridge rail anchored to the solid concrete parapet, sheet 1

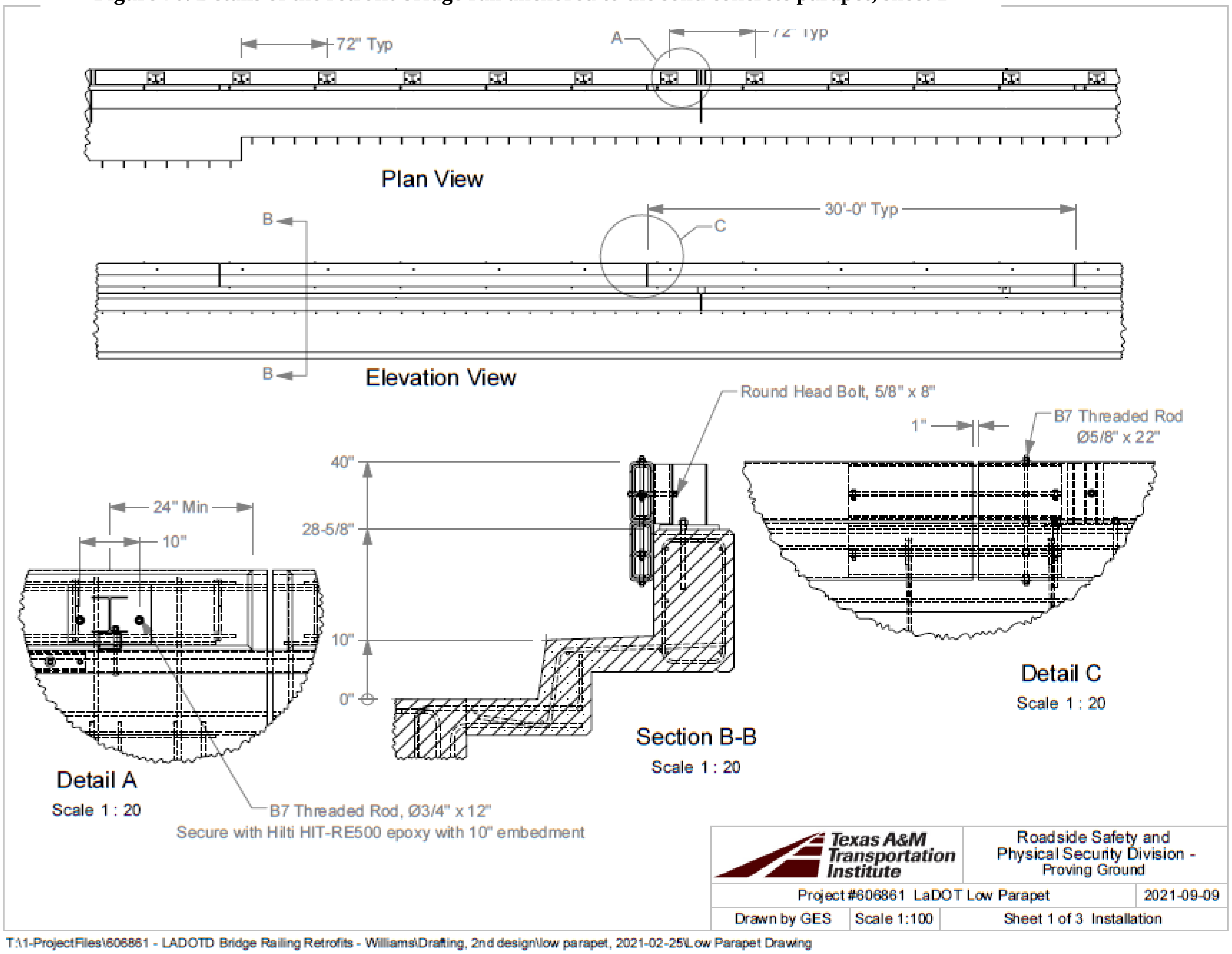


Figure 71. Details of the retrofit bridge rail anchored to the solid concrete parapet, sheet 2

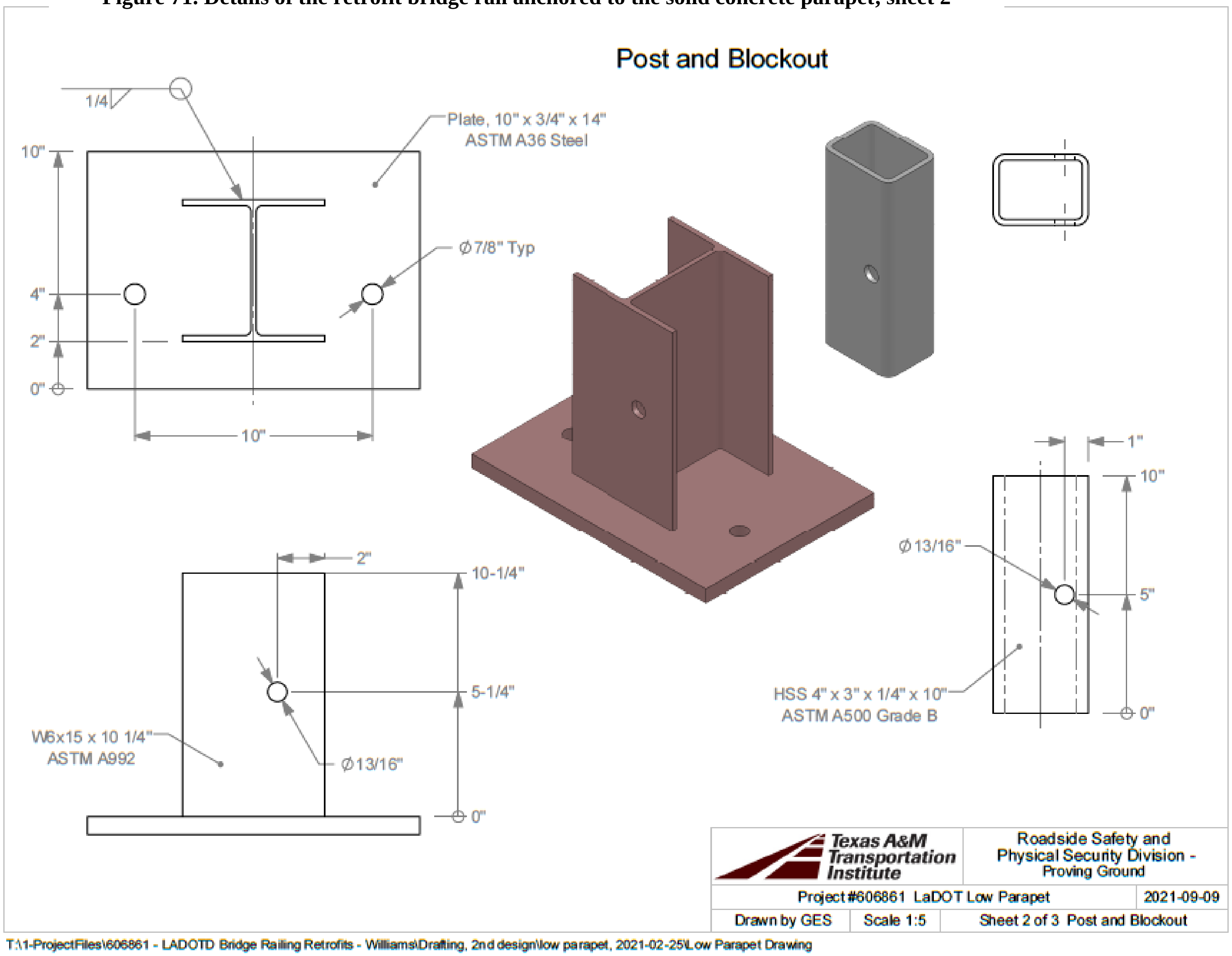
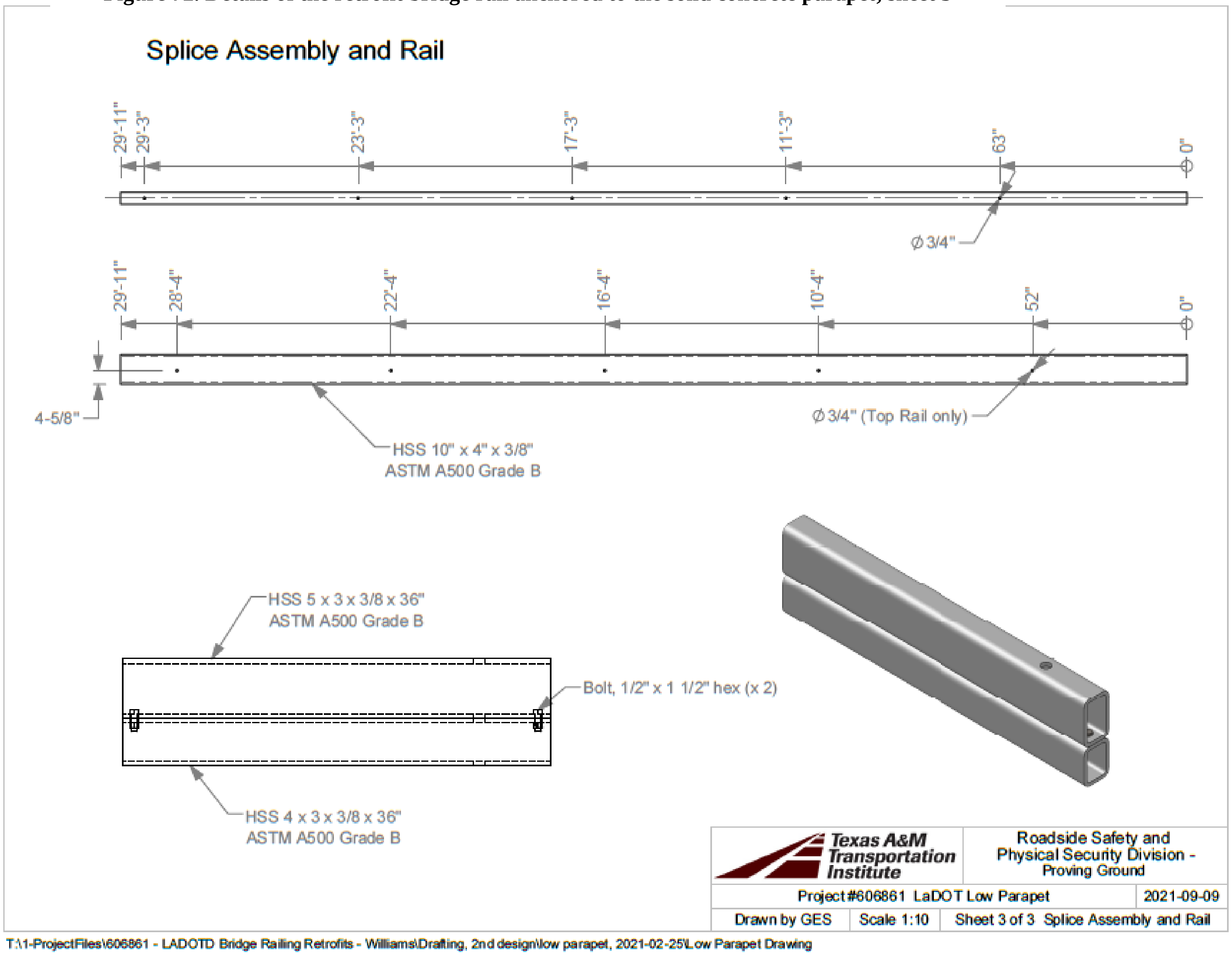


Figure 72. Details of the retrofit bridge rail anchored to the solid concrete parapet, sheet 3



MASH TL-3 Testing of Retrofit Post and Beam Bridge Rail with Safety Walk Option 2

Test Installation Details

Test Installation Description

The test installation was 106 ft.-10¾ in. long, and consisted of a reinforced cantilevered concrete deck, a stepped-up sidewalk, with a curb and posts topped by a concrete beam, and two rectangular hollow steel rails anchored to the front face of the concrete beam. The sidewalk, curb, posts, and beams were comprised of five separate segments, with 1-in. gaps between the sidewalk, curb, and rail segments, and 6-in. gaps between the post and beam segments. Each segment contained three concrete posts, with one at each end and one at center.

Each steel rail section measured 21 ft.-3¾ in. long. A 36-in. long fabricated rail splice section spanned the 1-in. gaps between the steel rail sections. The top steel rail sections were attached to the concrete beam with L6×4×½ in. angle brackets that were anchored to the concrete beam with ¾-in. diameter × 8-in. long B7 threaded rods secured with Hilti HIT-RE500V3 epoxy adhesive. The bottom steel rails were secured through and to the top rails with ⅝-in. diameter × 22-in. long grade B7 threaded rods, washers, and bolts.

Appendix G presents the drawings and information on the Louisiana Retrofit post and beam bridge rail with safety walk Option 2, and Figure 73 and Figure 74 provides photographs of the completed installation.

Material Specifications

The specified compressive strength of the concrete used in the wall, deck, curb, and parapet was 3000 psi. On December 10, 2020, the average compressive strengths of the concrete were as follows:

- Average concrete strength for the wall and deck: 4448 psi at 41 days of age.
- Average concrete strength for the curb: 4563 psi at 35 days of age.
- Average concrete strength for the parapet: 4033 psi at 21 days of age.

Appendix I provides material certification documents for the materials used to install/construct the Louisiana Retrofit post and beam bridge rail with safety walk Option 2.

Figure 73. Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk Option 2 prior to testing

(a) Traffic face of bridge rail

(b) Field side of bridge rail

(c) Upstream of joint

(d) Downstream of joint

Figure 74. Joint of Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk Option 2 prior to testing

(a) Traffic face at joint

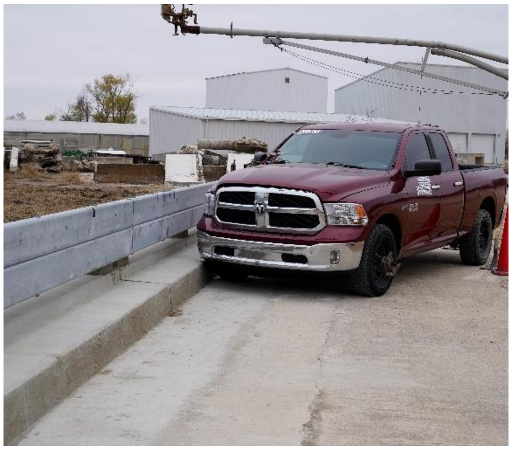
(b) Field side at joint

MASH Test 3-11 (Crash Test No. 606861-3)

Test Designation and Actual Impact Conditions

MASH Test 3-11 involved a 2270P vehicle weighing 5000 lbs ±110 lbs impacting the CIP of the bridge barrier at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 25 degrees ±1.5 degrees. The CIP for MASH Test 3-11 on the Louisiana Retrofit post and beam bridge rail with safety walk Option 2 was determined to be 4.3 ft. upstream of the centerline of the second open joint in the deck/beam. Figure 46 and Figure 75 depict the target CIP.

Figure 75. Test vehicle/bridge rail geometrics for Test No. 606861-3



(a) Frontal view of 2270P test vehicle at target impact point

(b) Rear view of 2270P test vehicle at target impact point

The 2270P vehicle used in the test weighed 5056 lbs, and the actual impact speed and angle were 62.7 mi/h and 25.0 degrees. The actual impact point was 4.8 ft. upstream of the centerline of the second open joint in the concrete deck/beam. Minimum target IS was 106 kip-ft., and actual IS was 119 kip-ft.

Weather Conditions

The test was performed on the morning of December 14, 2020. Weather conditions at the time of testing were as follows: wind speed: 6 mi/h; wind direction: 4 degrees (vehicle was travelling at a heading of 150 degrees); temperature: 42°F; relative humidity: 83 percent

Test Vehicle

Figure 76 shows the 2014 RAM 1500 pickup truck used for the crash test. The vehicle's test inertia weight was 5056 lbs, and its gross static weight was 5221 lbs. The height to the lower edge of the vehicle bumper was 11.75 in., and the height to the upper edge of the bumper was 27.0 in. The height to the vehicle's center of gravity was 28.5 in. Figure 127 and Figure 128 in Appendix J give additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

Figure 76. Test vehicle prior to Test No. 606861-3

(a) Right side of 2270P test vehicle

(b) Left side of 2270P test vehicle

Test Description

Table 20 lists times and significant events that occurred during Test No. 606861-3. Figure 129 through Figure 131 in Appendix J present sequential photographs during the test.

Table 20. Events during Test No. 606861-3

Time (s)	Events
0.0000	Data acquisition trigger activated by curb
0.0220	Vehicle impacted the bridge rail
0.0410	Vehicle begins to redirect
0.1380	Left front tire lifts off pavement
0.2130	Vehicle travelling parallel to bridge rail
0.2600	Left front tire contacts pavement
0.2700	Left rear tire lifts off pavement
0.3700	Right front tire contacts pavement
0.4540	Vehicle loses contact with installation while traveling at 50.2 mi/h, at a trajectory angle of 4.2 degrees, and a heading angle of 7.8 degrees

For longitudinal barriers, it is desirable that the vehicle redirects and exits the barrier within the exit box criteria (not less than 32.8 ft. downstream from loss of contact for cars and pickups). The test vehicle exited within the exit box criteria defined in MASH.

Brakes on the vehicle were applied at 3.0 s after impact, and the vehicle subsequently came to rest 221 ft. downstream of the impact 40 ft. toward traffic lanes.

Damage to Test Installation

Figure 77 through Figure 79 show the damage to the Option 2 bridge rail. There was some gouging and scuffing of the sidewalk at impact. The concrete deck and posts had significant damage at posts 5, 6, 7, and 8, with exposed rebar at posts 6, 7, and 8. There were several large cracks at the top of posts 6 and 7. There was also some scuffing on the metal rail element. Working width[14] was 38.7 in., and height of the working width was 28.0 in. Maximum dynamic deflection during the test was 6.8 in., and maximum permanent deformation was 3.4 in.

Figure 77. Option 2 bridge rail after Test No. 606861-3

(a) Bridge rail/test vehicle after test

(b) Traffic side of bridge rail at impact

[14] Per MASH, “The working width is the maximum dynamic lateral position of any major part of the system or vehicle. These measurements are all relative to the pre-impact traffic face of the test article.” In other words, working width is the total barrier width plus the maximum dynamic intrusion of any portion of the barrier or test vehicle past the field side edge of the barrier.

Figure 78. Damage to traffic face of bridge rail after Test No. 606861-3

(a) Traffic side at impact point

(b) Traffic side of joint

(c) Traffic side of posts at joint

(d) Traffic side loss of contact

Figure 79. Damage on field side of bridge rail after Test No. 606861-3

(a) Field side of joint

(b) Field side of middle post

Damage to Test Vehicle

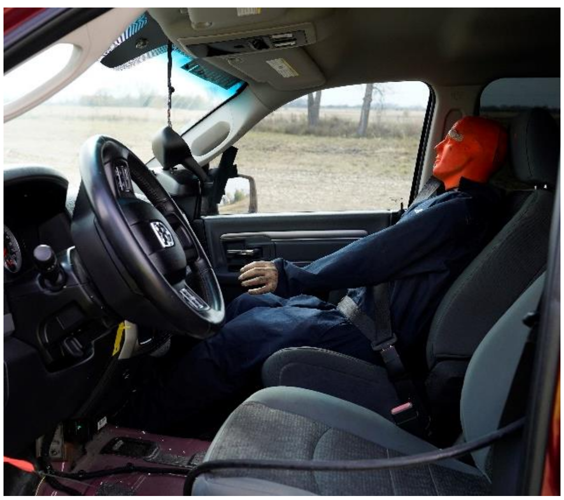
Figure 80 shows the damage sustained by the vehicle. The front bumper, grill, hood, radiator and support, right front fender, right front tire and rim, right front and rear doors, right rear cab corner, right rear exterior bed, right rear tire, and rear bumper were damaged. Maximum exterior crush to the vehicle was 11.0 in. in the front plane at the right front corner at bumper height. No occupant compartment deformation was observed. Figure 81 shows the interior of the vehicle. Figure 132 and Figure 133 in Appendix J provide exterior crush and occupant compartment measurements.

Figure 80. Test vehicle after Test No. 606861-3

(a) Front of 2270P test vehicle after test

(b) Right front of 2270P test vehicle

Figure 81. Interior of test vehicle after Test No. 606861-3



(b) Interior of cab of 2270P test vehicle

(a) Right front floor pan of 2270P test vehicle

Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk and results are shown in Table 21. Figure 82, Table 22, and Table 23 summarize these data and other pertinent information from the test. Figure 134 in Appendix J shows the vehicle angular displacements, and Figure 135 through Figure 137 in Appendix J show acceleration versus time traces.

Table 21. Occupant risk factors for Test No. 606861-3

Occupant Risk Factor	Value	Time
OIV		
Longitudinal	13.1 ft/s	at 0.1207 s on right side of interior
Lateral	24.6 ft/s	
Occupant Ridedown Accelerations		
Longitudinal	6.1 g	0.1215 - 0.1315 s
Lateral	8.2 g	0.2089 - 0.2189 s
THIV...	8.7 m/s	at 0.1183 s on right side of interior
ASI	1.8	0.0851 - 0.1351 s
Maximum 50-ms Moving Average		
Longitudinal	−5.4 g	0.0746 - 0.1246 s
Lateral	−14.0 g	0.0565 - 0.1065 s
Vertical..	1.8 g	0.2949 - 0.3449 s
Maximum Roll, Pitch, and Yaw Angles		
Roll..	7 degrees	0.6206 s
Pitch	9 degrees	0.5326 s
Yaw..	34 degrees	0.7969 s

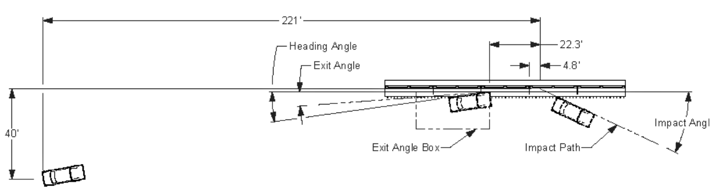
Figure 82. Summary of results for MASH Test 3-11 On Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk Option 2

(a) 0.000 s

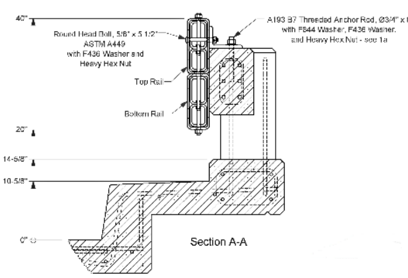
(b) 0.200 s

(c) 0.400 s

(d) 0.600 s



(e) Impact summary



(f) Cross-section of bridge rail

Table 22. Summary of results for MASH Test 3-11 on Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk Option 2—Pre-Impact Information

General Information	
Test Agency	Texas A&M Transportation Institute
Test Standard Test No.	MASH Test 3-11
TTI Test No.	606861-3
Test Date	2020-12-14
Test Article	
Type	Longitudinal Barrier—Bridge Rail
Name	Louisiana Retrofit post and beam bridge rail with safety walk Option 2
Installation Length	106 ft.-10¾ in.
Material or Key Elements	Reinforced cantilevered concrete deck, with 10-in. high sidewalk, curb and posts topped by a concrete beam, 2 rectangular hollow steel rails secured to concrete beam
Foundation Type/Condition	Concrete Bridge Deck, Damp
Test Vehicle	
Type/Designation	2270P
Make and Model	2014 RAM 1500
Curb	5056 lbs.
Test Inertial	5056 lbs.
Dummy	165 lbs.
Gross Static	5221 lbs.
Impact Conditions	
Speed	62.7 mi./h
Angle	25.0 degrees
Location	4.8 ft. upstream of second joint
Impact Severity	119 kip-ft.
Exit Conditions	
Speed	50.2 mi./h
Exit Trajectory/Heading	4.2 degrees/7.8 degrees

Table 23. Summary of results for MASH Test 3-11 on Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk Option 2—Post-Impact Information

Occupant Risk Values	
Longitudinal OIV	13.1 ft/s
Lateral OIV	24.6 ft/s
Longitudinal Ridedown	6.1 g
Lateral Ridedown	8.2 g
THIV	8.7 m/s
ASI	1.8
Max. 0.050-s Average	
Longitudinal	−5.4 g
Lateral	−14.0 g
Vertical	1.8 g
Post-Impact Trajectory	
Stopping Distance	221 ft. downstream / 40 ft. toward traffic lanes
Vehicle Stability	
Maximum Roll Angle	7 degrees
Maximum Pitch Angle	9 degrees
Maximum Yaw Angle	34 degrees
Vehicle Snagging	No
Vehicle Pocketing	No
Test Article Deflections	
Dynamic	6.8 in.
Permanent	3.4 in.
Working Width	38.7 in.
Height of Working Width	28.0 in.
Vehicle Damage	
VDS	01RFQ5
CDC	01FREW4
Max Exterior Deformation	11.0 in.
OCDI	RF0000000
Max Occupant Compartment Deformation	None

MASH Test 3-10 (Crash Test No. 606861-4)

Test Designation and Actual Impact Conditions

MASH Test 3-10 involves an 1100C vehicle weighing 2420 lbs ±55 lbs impacting the CIP of the bridge barrier at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 25 degrees ±1.5 degrees. The CIP for MASH Test 3-10 on the Louisiana Retrofit post and beam bridge rail with safety walk Option 2 was 3.6 ft. ±1 ft. upstream of the centerline of the fourth open joint in the deck/beam. Figure 45 and Figure 83 depict the target impact point.

Figure 83. Test vehicle/bridge rail geometrics for Test No. 606861-4

(a) Frontal view of 1100C test vehicle at target impact point

(b) Field side view of 1100C test vehicle at target impact point

The 1100C vehicle used in the test weighed 2404 lbs, and the actual impact speed and angle were 61.5 mi/h and 25.7 degrees. The actual impact point was 3.7 ft. upstream of the centerline of the fourth open joint in the deck/beam. Minimum target IS was 51 kip-ft., and actual IS was 57 kip-ft.

Weather Conditions

The test was performed on the morning of December 11, 2020. Weather conditions at the time of testing were as follows: wind speed: 5 mi/h; wind direction: 215 degrees (vehicle was travelling at a heading of 150 degrees); temperature: 64°F; relative humidity: 100 percent.

Test Vehicle

Figure 84 shows the 2014 Nissan Versa used for the crash test. The vehicle's test inertia weight was 2404 lbs, and its gross static weight was 2569 lbs. The height to the lower edge of the vehicle bumper was 7.0 in., and the height to the upper edge of the bumper was 22.25 in. Figure 138 in Appendix K gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

Figure 84. Test vehicle before Test No. 606861-4

(a) Right side of 1100C test vehicle

(b) Left side of 1100C test vehicle

Test Description

Table 24 lists events that occurred during Test No. 606861-4. Figure 139 through Figure 141 in Appendix K present sequential photographs during the test.

Table 24. Events during Test No. 606861-4

Time (s)	Events
0.0000	Vehicle impacts curb
0.0160	Right front tire lifts off of the pavement
0.0310	Vehicle begins to redirect
0.0330	Right front bumper contacts bridge rail
0.0990	Left front tire lifts off of the pavement
0.1570	Left rear tire lifts off of pavement
0.1990	Vehicle travelling parallel to bridge rail
0.2130	Right rear bumper contacts bridge rail
0.4160	Vehicle loses contact with bridge rail while traveling at 53.2 mi/h, trajectory angle of 5.5 degrees, and heading angle of 10.7 degrees

For longitudinal barriers, it is desirable that the vehicle redirects and exits the barrier within the exit box criteria (not less than 32.8 ft. downstream from loss of contact for cars and pickups). The test vehicle exited within the exit box criteria defined in MASH. Brakes on the vehicle were applied at 2.75 s, and the vehicle subsequently came to rest 175 ft. downstream of the impact and 11 ft. toward traffic lanes.

Damage to Test Installation

Figure 85 through Figure 87 show the damage to the Option 2 bridge rail. There was some gouging and scuffing of the sidewalk at the point of impact, and the curb cracked at posts 12, 13, and 14. The cracks at posts 12 and 13 extended from the traffic side of the curb to the field side, and under the deck 11 in. at post 12 and 9 in. at post 13. The posts were also cracked at posts 12 and 13. At post 14, the curb and post were cracked on the field side. There was also some scuffing on the rail. Working width[15] was 33.0 in., and

[15] Per MASH, "The working width is the maximum dynamic lateral position of any major part of the system or vehicle. These measurements are all relative to the pre-impact traffic face of the test article." In other words, working width is the total barrier width plus the maximum dynamic intrusion of any portion of the barrier or test vehicle past the field side edge of the barrier.

height of working width was 4.6 in. Maximum dynamic deflection during the test was 1.8 in., and maximum permanent deformation was 0.6 in.

Figure 85. Option 2 ridge rail after Test No. 606861-4

(a) Bridge rail/test vehicle after test

(b) Traffic side of bridge rail at impact

Figure 86. Damage to traffic face of bridge rail after Test No. 606861-4

(a) Traffic side at impact point

(b) Traffic side of joint

(c) Traffic side of posts at joint

(d) Traffic side loss of contact

Figure 87. Damage on field side of bridge rail after Test No. 606861-4

(a) Field side upstream of joint

(b) Field side downstream of joint

Damage to Test Vehicle

Figure 88 shows the damage sustained by the vehicle. The front bumper, grill, hood, radiator and support, right front fender, right front tire and rim, right strut and tower, right front and rear doors, right rear quarter panel, right rear tire and rim, and rear bumper were damaged. Maximum exterior crush to the vehicle was 9.0 in. in the front plane at the right front corner at bumper height. Maximum occupant compartment deformation was 0.5 in. in the right front floor pan and right front kick panel area. Figure 89 shows the interior of the vehicle. Figure 142 and Figure 143 in Appendix K provide exterior crush and occupant compartment measurements.

Figure 88. Test vehicle after Test No. 606861-4

(a) Front of 1100C test vehicle after test

(b) Right front of 1100C test vehicle

Figure 89. Interior of test vehicle after Test No. 606861-4

(c) Interior of cab of 1100C

(a) Right front floor pan of 1100C test vehicle

Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk and results are shown in Table 25. Figure 90, Table 26, and Table 27 summarize these data and other pertinent information from the test. Figure 144 in Appendix K shows the vehicle angular displacements, and Figure 145 through Figure 147 in Appendix K show acceleration versus time traces.

Table 25. Occupant risk factors for Test No. 606861-4

Occupant Risk Factor	Value	Time
OIV		
Longitudinal	19.7 ft/s	at 0.1069 s on right side of interior
Lateral	31.2 ft/s	
Occupant Ridedown Accelerations		
Longitudinal	4.0 g	0.1383 - 0.1483 s
Lateral	8.6 g	0.2297 - 0.2397 s
THIV	11.0 m/s	at 0.1049 s on right side of interior
ASI	2.1	0.0830 - 0.1330 s
Maximum 50-ms Moving Average		
Longitudinal	−8.8 g	0.0509 - 0.1009 s
Lateral	−16.0 g	0.0561 - 0.1061 s
Vertical	−3.6 g	0.0224 - 0.0724 s
Maximum Roll, Pitch, and Yaw Angles		
Roll	12 degrees	2.5000 s
Pitch	16 degrees	0.5178 s
Yaw	46 degrees	0.9913 s

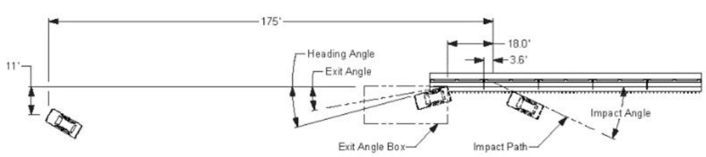
Figure 90. Summary of results for MASH Test 3-10 on Louisiana Retrofit Post and Beam Bridge Rail with Safety walk Option 2

(a) 0.000 s

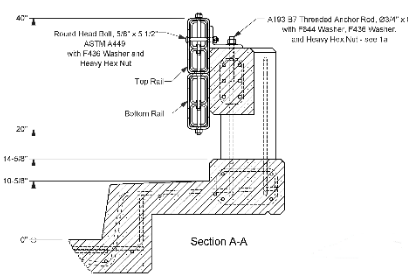
(b) 0.200 s

(c) 0.400 s

(d) 0.600 s



(e) Impact summary



(f) Cross-section of bridge rail

Table 26. Summary of results for MASH Test 3-10 on Louisiana Retrofit Post and Beam Bridge Rail with Safety walk Option 2—Pre-Impact Information

General Information	
Test Agency	Texas A&M Transportation Institute
Test Standard Test No.	MASH Test 3-10
TTI Test No.	606861-4
Test Date	2020-12-11
Test Article	
Type	Longitudinal Barrier—Bridge Rail
Name	Louisiana Retrofit post and beam bridge rail with safety walk Option 2
Installation Length	106 ft.-10¾ in.
Material or Key Elements	Reinforced cantilevered concrete deck, with 10-in. high sidewalk with curb and posts topped by a concrete beam, with two retrofit rectangular hollow steel rails secured to concrete beam
Foundation Type/Condition	Concrete Bridge Deck, Damp
Test Vehicle	
Type/Designation	1100C
Make and Model	2014 Nissan Versa
Curb	2343 lbs.
Test Inertial	2404 lbs.
Dummy	165 lbs.
Gross Static	2569 lbs.
Impact Conditions	
Speed	61.5 mi/h
Angle	25.7 degrees
Location	3.7 ft. upstream of fourth joint
Impact Severity	57 kip-ft.
Exit Conditions	
Speed	53.2 mi/h
Exit Trajectory/Heading	5.5 degrees/10.7 degrees

Table 27. Summary of results for MASH Test 3-10 on Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk Option 2—Post-Impact Information

Occupant Risk Values	
Longitudinal OIV	19.7 ft/s
Lateral OIV	31.2 ft/s
Longitudinal Ridedown	4.0 g
Lateral Ridedown	8.6 g
THIV	11.0 m/s
ASI	2.1
Max. 0.050-s Average	
Longitudinal	−8.8 g
Lateral	−16.0 g
Vertical	−3.6 g
Post-Impact Trajectory	
Stopping Distance	175 ft. downstream 11 ft. toward traffic lanes
Vehicle Stability	
Maximum Roll Angle	12 degrees
Maximum Pitch Angle	16 degrees
Maximum Yaw Angle	46 degrees
Vehicle Snagging	No
Vehicle Pocketing	No
Test Article Deflections	
Dynamic	1.8 in.
Permanent	0.6 in.
Working Width	33.0 in.
Height of Working Width	4.6 in.
Vehicle Damage	
VDS	01RFQ5
CDC	01FREW4
Max Exterior Deformation	9.0 in.
OCDI	RF0000000
Max Occupant Compartment Deformation	0.5 in.

Discussion of Results for MASH TL-3 Tests on Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk Option 2

Table 28 and Table 29 show that the Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk performed acceptably and met the specifications for MASH TL-3 longitudinal barriers.

Table 28. Performance evaluation summary for Test 3-11 on Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk Option 2

Evaluation Factors	Evaluation[16] Criteria	Test Results	Assessment
Structural Adequacy	A.	The Louisiana Retrofit post and beam bridge rail with safety walk Option 2 contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 6.8 in.	Pass
Occupant Risk	D.	The concrete curb and posts fractured into several pieces. However, these fragments did not penetrate or show potential for penetrating the occupant compartment, or present undue hazard for others on the bridge barrier (several fragments came to rest below the bridge deck). No occupant compartment deformation was observed.	Pass
	F.	The 2270P vehicle remained upright during and after the collision event. Maximum roll was 7 degrees and pitch was 9 degrees.	Pass
	H.	Longitudinal OIV was 13.1 ft/s, and lateral OIV was 24.6 ft/s.	Pass
	I.	Maximum longitudinal occupant ridedown was 6.1 g, and maximum lateral occupant ridedown was 8.2 g.	Pass

[16] See Table 9 for details of respective evaluation criteria.

Table 29. Performance evaluation summary for MASH Test 3-10 on Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk Option 2

Evaluation Factors	Evaluation[17] Criteria	Test Results	Assessment
Structural Adequacy	A.	The Louisiana Retrofit post and beam bridge rail with safety walk Option 2 contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 1.8 in.	Pass
Occupant Risk	D.	No detached elements, fragments, or other debris was present to penetrate or show potential for penetrating the occupant compartment, or present undue hazard for others on the bridge barrier.	Pass
		Maximum occupant compartment deformation was 0.5 in. in the right floor pan/kick panel area.	
	F.	The 1100C vehicle remained upright during and after the collision event. Maximum roll was 12 degrees and pitch was 16 degrees.	Pass
	H.	Longitudinal OIV was 19.7 ft/s, and lateral OIV was 31.2 ft/s.	Pass
	I.	Maximum longitudinal occupant ridedown was 4.0 g, and maximum lateral occupant ridedown was 8.6 g.	Pass

[17] See Table 9 for details of respective evaluation criteria.

Developing Retrofitting Methods and Procedures for Single Bridge Rail Design

Summary of Results of Full-Scale Crash Testing

For this project, a new retrofit bridge rail was designed and succesfully crash tested with respect to MASH Test Level 3. The retrofit bridge rail design was developed from typical details used on existing safety walk bridge barrier railing systems used on vintage Louisiana bridges. Details of the bridge rail retrofit constructed and tested for this project are shown in Figure 91 through Figure 100. In December, 2020, two crash tests, MASH Test 3-10 and 3-11, were performed on the new retrofit design shown in Appendix F. Both crash tests were successful with respect to MASH TL-3 specifications.

Installation of MASH TL-3 of Option 2 Retrofit Bridge Rail

The retrofit bridge rail presented on the drawings in this report has been successfully crash tested to MASH TL-3 Specifications. The following installation procedure can be used to assist in installing the retrofit bridge rail on existing DOTD bridges with vintage concrete post and beam or solid concrete parapet bridge rails with safety walks. This retrofit bridge rail attaches to the top of a concrete post and rail or solid concrete parapet as shown in the previous figures. The retrofit bridge rail is located in front of the concrete bridge rail and still preserves much of the walkway area. In some cases, any existing attachments on top of the existing concrete barriers in the field should be removed to provide the necessary clearance for the new retrofit bridge rail as presented herein. In no way shall existing hardware remain in place, or be added other than what is shown on the "as-tested" test installation drawings as presented in Appendix F. Please refer to the section below for all material specifications required for the retrofit bridge rail to be used on all MASH TL-3 retrofit applications using this design.

Installation Procedure

1. Figure 91 shows a view of the simulated Louisiana safety walk bridge barrier railing system with concrete deck cantilever (TTI simulated crash test installation) without the retrofit bridge rail.

Figure 91. Safety walk barrier with concrete post and beam bridge rail

2. Drill and install adhesive anchors for L6×4×½ angle support brackets on top of concrete bridge rail. These holes shall be drilled and the anchors installed as per the manufacturer's specifications. Hilti RE500-V3 adhesive shall be used for these ¾-in. diameter by 8 in. long anchors. The anchors shall be embedded 6 in. minimum. These anchors shall be A193-B7 galvanized threaded rods installed typically using 52 in. maximum spacing on the top of the barrier as shown in the drawings provided herein. For the solid concrete parapet design Option shown in Figures 70 to 72, the anchors shall be embedded 10 in. minimum. Photographs of the adhesive anchoring system used for this project and recommended for use for this retrofit design are provided in Figure 92 and Figure 93.

Figure 92. Hot dipped A193 B7 ¾-in. diameter Hilti threaded rod

Figure 93. Hilti HIT-RE500-V3 Adhesive Anchoring System used (anchor bolts installed as per manufacturer's specifications)

3. Install L6×4×½ angle brackets and allow complete cure time as per Hilti HIT-RE500-V3 specifications. Figure 94 shows the bracket installed. The bracket shall be installed with the 4-in. angle face flush (even) with the face of the existing concrete barrier as shown in the photos and drawings. Please note, the concrete bridge rail is flush with the face of the support angle to provide a good uniform bearing surface for the new retrofit bridge rail. Also note, two additional holes

were provided in the L6×4×½ angle. These holes can be used if rebar is encountered in the drilling operation using the center hole in the angle.

Figure 94. Installed L6×4×½ angle support bracket with ¾-in. A193 B7 galvanized threaded rod with Hilti RE500-V3 adhesive

4. Install/connect the top HSS10×4×⅜ rail to the L6×4×½ angle support brackets. At each bracket location, the top rail element is attached to the bracket using a single round head 5/8-in. diameter x 5 ½ in. long bolt. Some temporary shoring support might be required to bolt this top rail element to the L6×4×½ angle support bracket. Figure 95 shows the top rail installed with the temporary shoring. Installation of the top rail should progress from one end of the bridge installation to the other adding bridge rail splices and additional rail elements as you proceed toward the opposite end of the bridge.

Figure 95. Installation of first/top rail element with temporary shoring support

5. Install lower HSS10×4×⅜ rail element by connecting lower element to top rail element using ⅝-in. × 22 in. long B7 threaded rods with F436 washers and two hex nuts. Figure 96 shows the lower rail installation.

Figure 96. Installation of lower HSS10×4×⅜ rail and bolting to top rail with ⅝-in. diameter B7 threaded rods

Figure 97 shows the installation of a typical splice joint assembly as installation of the rail progresses from one end of the installation (bridge) to the other. Photos of the completed rail section are shown in Figure 98 through Figure 100. From start to finish (after curing of the adhesive anchors), installation of the bridge rail installation was completed within 3 hours.

Figure 97. Typical splice assembly of rail prior to adding adjacent rail section

Figure 98. Front view completed retrofit rail installation

Figure 99. End view completed retrofit rail installation

Figure 100. Field side view completed retrofit rail installation

Material Specifications for MASH TL-3 Retrofit Bridge Rail

The retrofit bridge rail design tested for this project met all the safety and performance criteria for MASH TL-3. To meet the requirements for MASH TL-3, the following material specifications shall be used for the retofit bridge design for implematation in the field on DOTD bridges. A list of the material specifications for this retrofit bridge rail design are provided as follows. Please refer to the drawings provided in this report for further information.

- Anchor bolts – ¾-in. diameter, 8 in. long A193 B7 hot-dipped galvanized threaded rods, embedded 6 in. minimum.
- Anchor bolt epoxy – Hilti HIT-RE500 V3 Epoxy. Anchor bolts shall be installed as per the manufacturer's specifications.
- HSS10×4×⅜ Steel Tube – ASTM A500 grade B material, hot dipped galvanized. The maximum distance of 60 ft. is recommended between splice. It is recommended that 60 ft. maximum section lengths be used.
- Joint assembly, HSS5×3×⅜ and HSS4×3×⅜ – ASTM A500 grade B material, hot dipped galvanized.
- Rail attachment bolts, round head bolt, ⅝-in. diameter × 5½ in. long attaching rail to L6×4×½ bracket angles – ASTM A449 with F436 washer and heavy hex nut, hot dipped galvanized.
- Rail connecting bolts, ⅝-in. diameter × 22 in. long bolts connecting HSS10×4×⅜ tubes – A193 B7 threaded rods, with F436 washers (2) and heavy hex nuts (2), hot-dipped galvanized.
- L6×4×½ attachment bracket – ASTM A36 material, hot-dipped galvanized.
- Splice connection bolts, ½-in. diameter × 1½-in. long – ASTM A307 material, hot-dipped galvanized.

Preliminary Transition Details for New Retrofit Bridge Rail Design for Concrete Barriers with Safety Walks

TTI received current details used for safety walk barriers from Kurt Brauner, with DOTD. Figure 101 shows the current details used for safety walk barriers. In addition, TTI has received details for the DOTD proposed transition standard. Figure 102 shows the DOTD proposed transition standard details.

TTI has developed preliminary details for two approach guardrail transitions for the retrofit bridge rail designed and successfully crash tested with respect to MASH TL-3 specifications for this project. Two concepts have been developed for this project. Option 1, as shown in Figure 103 below, utilizes similar details to the one shown in Figure 101. The transition connects directly to the steel retrofit bridge rail and concrete post and rail. The transition rail laps over the new retrofit bridge rail over a distance of approximately 20 ft. and is blocked out over this distance as shown in Figure 103. After further analyses and detailing of this transition concept, full scale crash testing will be necessary to meet the requirements of MASH TL-3 specifications.

Option 2, as shown in Figure 104 and Figure 105, connects directly to the end of the retrofit bridge rail. The retrofit bridge rails extend off the ends of the existing concrete bridge rail a sufficient length to make the connection to the steel retrofit tubular rail elements. A new tapered curb section is constructed off the bridge end and tapers the curb back and down beneath the guardrail as shown in Figure 104 and Figure 105. Some additional connection hardware will likely be necessary to connect the transition end shoe to the retrofit tubular rail elements. After further analyses and detailing of this transition concept, full scale crash testing will be necessary to meet the requirements of MASH TL-3 specifications.

Figure 101. Current retrofit transition for safety walk barriers received from DOTD

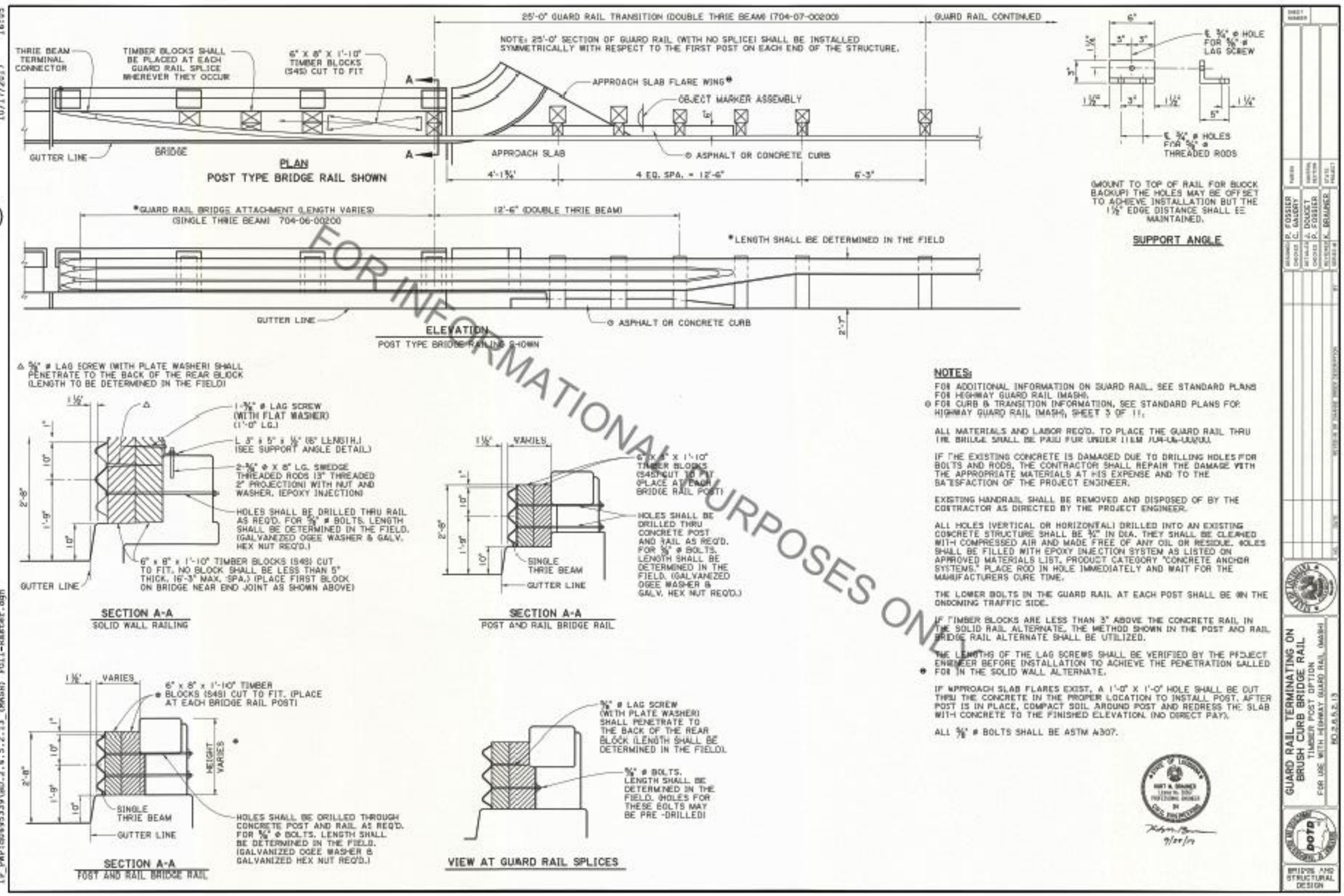


Figure 102. Proposed transition standard

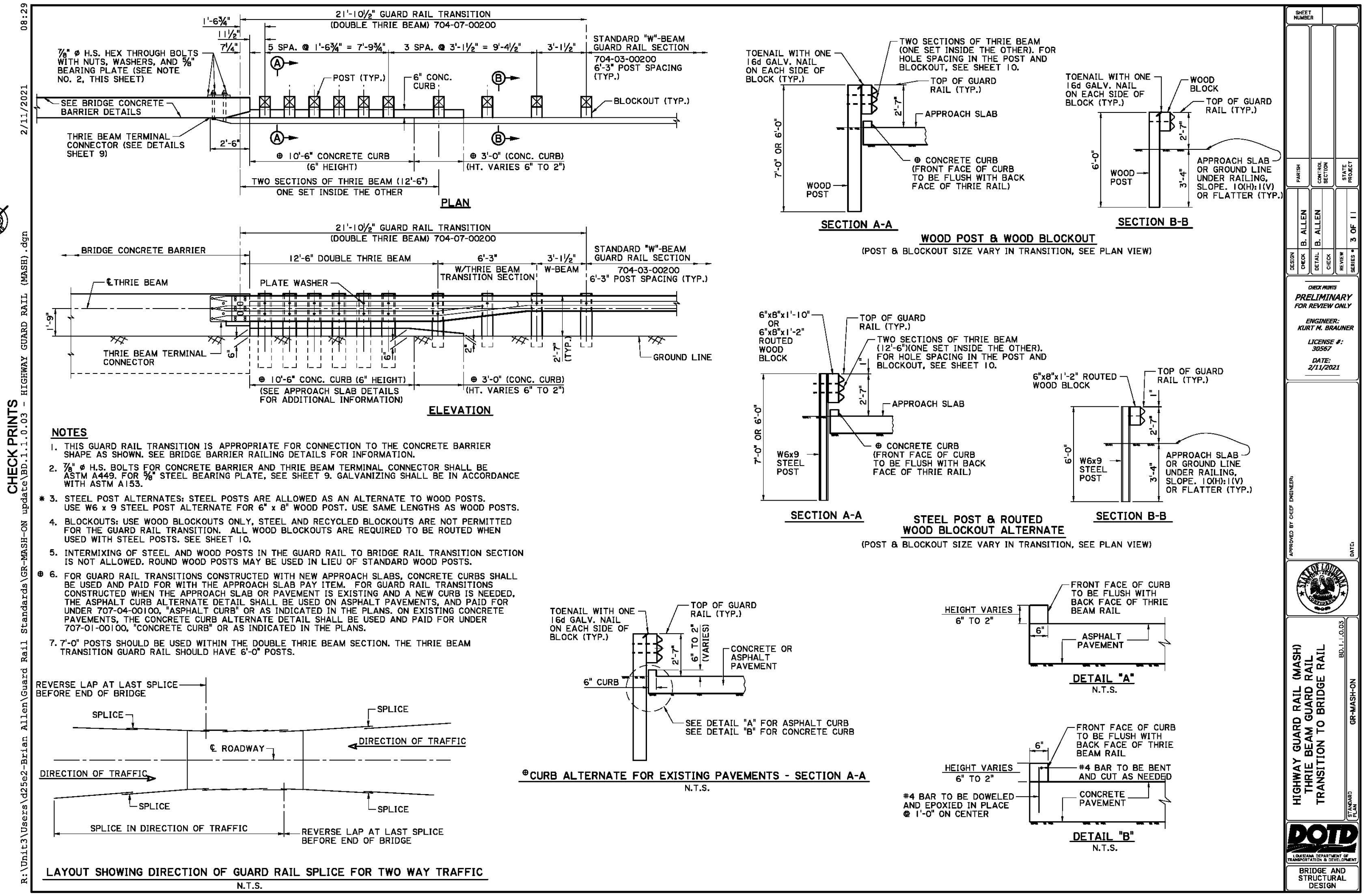


Figure 103. New transition concept option 1

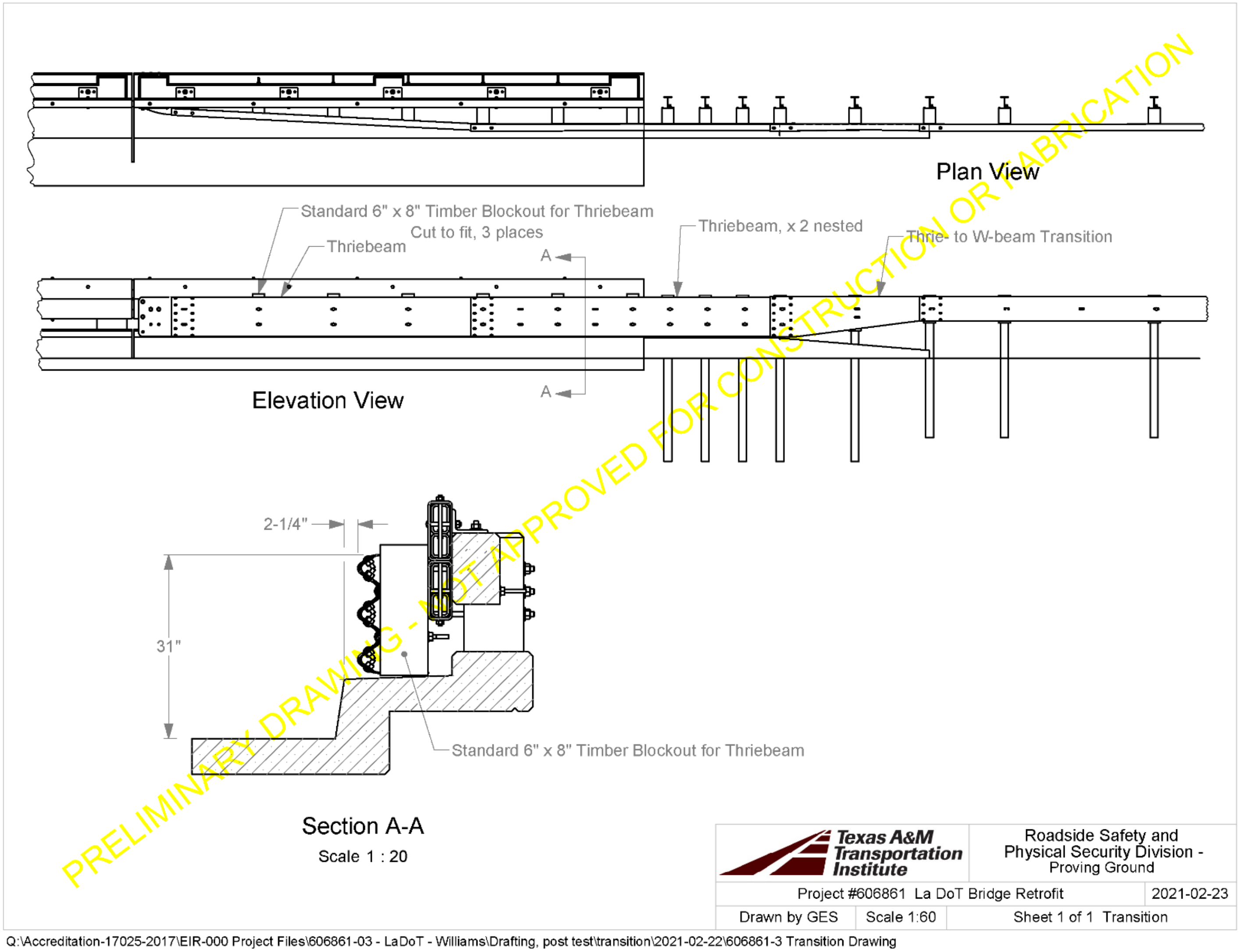


Figure 104. New transition concept option 2, sheet 1

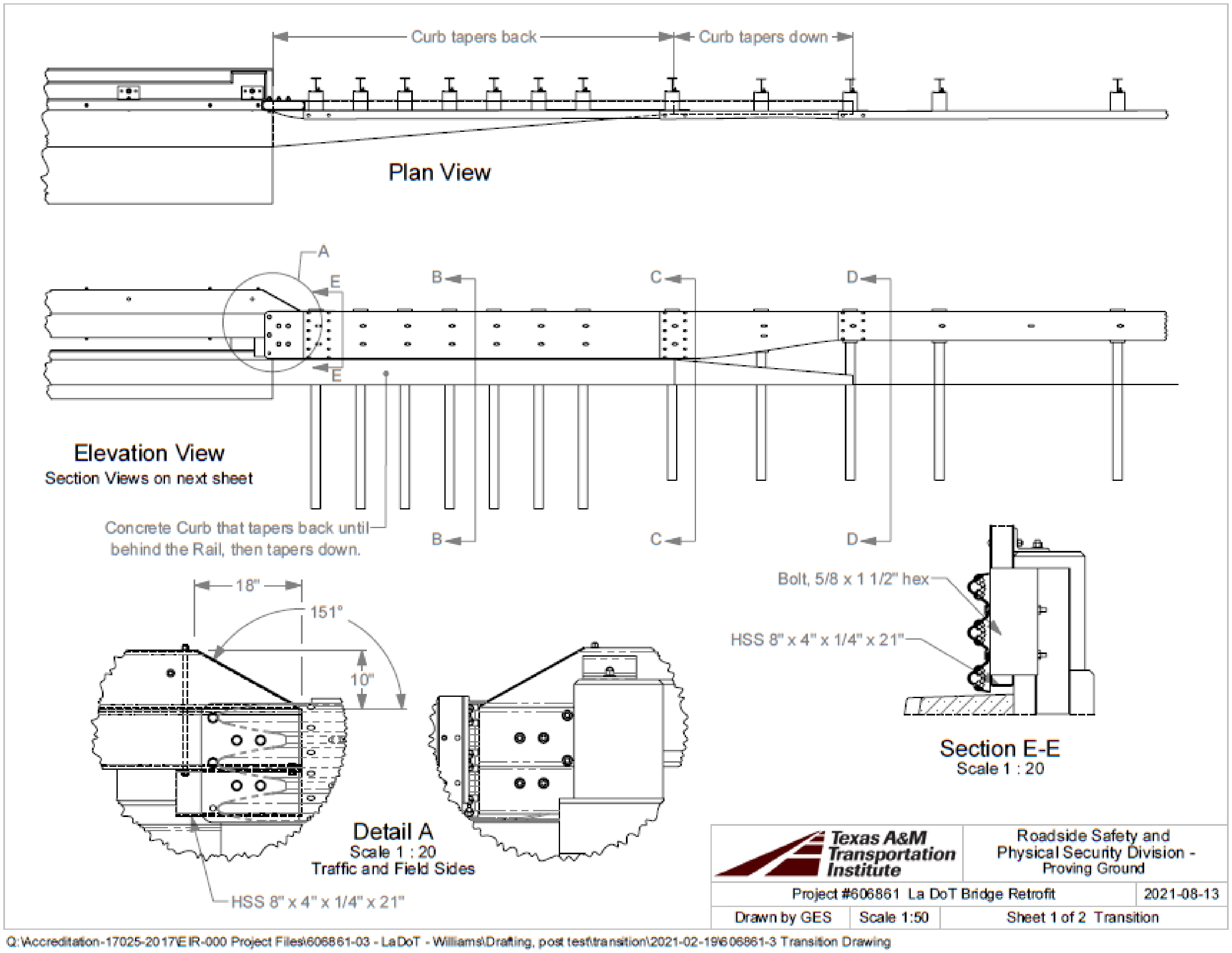
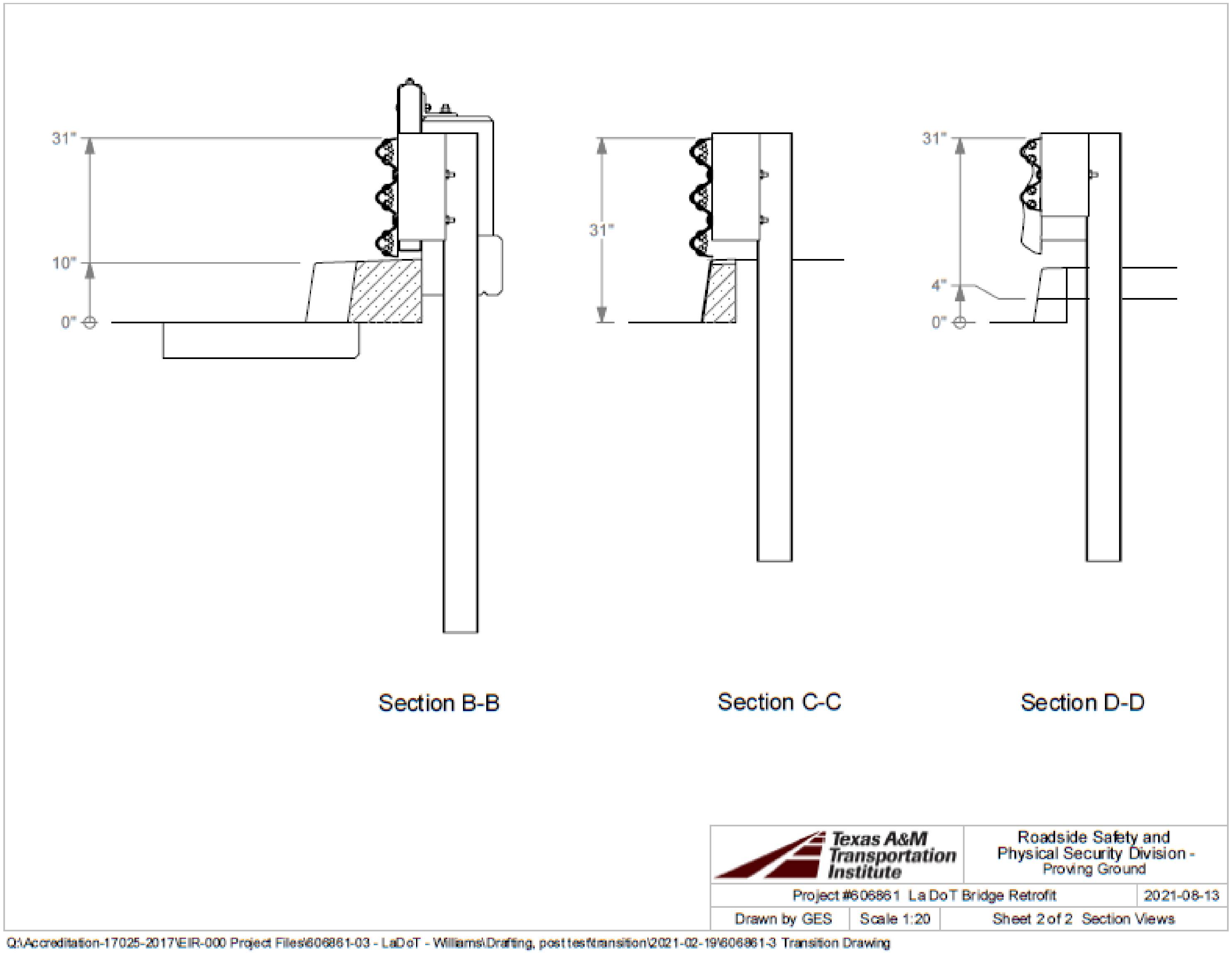


Figure 105. New transition concept option 2, sheet 2



Conclusions

The purpose of the tests reported herein was to assess the performance of the Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk according to the safety-performance evaluation guidelines included in MASH. The crash tests were performed in accordance with MASH TL-3, which involves an 1100C and a 2270P vehicle impacting the bridge barrier at a target impact speed of 62 mi/h and an impact angle of 25 degrees.

During MASH Test 3-10 on the Louisiana Retrofit post and beam bridge rail with safety walk Option 1, the vehicle experienced occupant ridedown accelerations above the limit of 20.49 g as specified in MASH. Table 30 shows that the bridge rail did not meet the specifications for MASH longitudinal barriers.

Table 30. Assessment summary for MASH TL-3 Tests on Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk Option 1

Evaluation Factors	Evaluation Criteria	Test No. 606861-1	Test No. 606861-2
Structural Adequacy	A.	S	S
Occupant Risk	D.	S	S
	F.	S	S
	H.	S	S
	I.	S	U
	Test No.	**MASH Test 3-11**	**MASH Test 3-10**
	Pass/Fail	Pass	Fail

S = Satisfactory
U = Unsatisfactory

The bridge rail was redesigned and MASH Tests 3-10 and 3-11 were repeated. Table 31 shows the Retrofit post and beam bridge rail with safety walk Option 2 met the requirements for MASH TL-3 longitudinal barriers.

Table 31. Assessment summary for MASH TL-3 Tests on Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk Option 2

Evaluation Factors	Evaluation Criteria	Test No. 606861-3	Test No. 606861-4
Structural Adequacy	A.	S	S
Occupant Risk	D.	S	S
	F.	S	S
	H.	S	S
	I.	S	S
	Test No.	**MASH Test 3-11**	**MASH Test 3-10**
	Pass/Fail	Pass	Pass

S = Satisfactory
U = Unsatisfactory

Recommendations[18]

The retrofit bridge rail Option 2 as tested herein, and anchored to a safety walk concrete post and beam bridge rail as shown herein, met all the safety and performance requirements of MASH TL-3 specifications. This retrofit bridge rail is recommended for use on all concrete post and beam and solid concrete barriers with safety walks 10 in. high or less and 18 in. wide or less. The retrofit bridge rail should be installed as per the recommendations provided in this report. Please refer to the section entitled "Developing Retrofitting Methods and Procedures for Single Bridge Rail Design." The height of the retrofit bridge rail should always be 40 in. from the roadway surface as successfully tested herein. The retrofit bridge rail shall be installed as per the specifications and procedures provided in the referenced section. In cases where the retrofit bridge using the L6×4×½ angle brackets is lower than the as tested height of 40 in., short steel baseplated posts shall be used instead of the L6×4×½ angle brackets. These short posts shall be W6×15 baseplated posts spaced on 6.0 ft. on centers (maximum) as shown on the solid concrete parapet design and presented herein, and shall be used to achieve the required height of 40 in. above the roadway surface. For the solid concrete parapet, the L6x4x1/2 angle bracket can be used if this bracket results in the steel tubes being mounted at the correct height (as-tested height of 40 in.). Otherwise, the W6x15 baseplated post is recommend to achieve this correct height. Please refer to the drawings and material specifications contained in this report for additional information.

[18] The opinions/interpretations identified/expressed in this section of the report are outside the scope of TTI Proving Ground's A2LA Accreditation.

Acronyms, Abbreviations, and Symbols

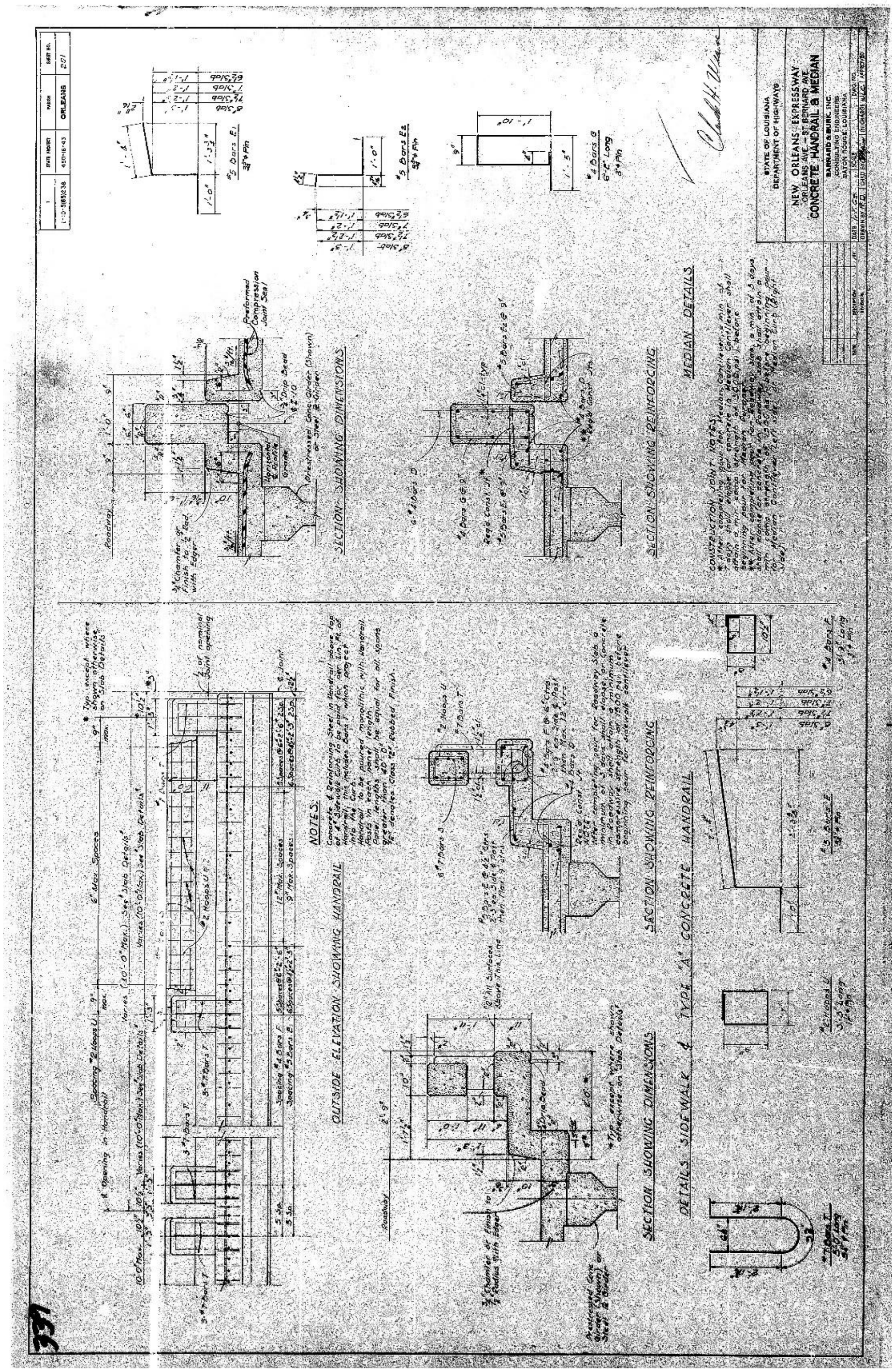
Term	Description
1100C	small (compact) test vehicle
2270P	pickup truck test vehicle
A2LA	American Association for Laboratory Accreditation
AASHTO	American Association of State Highway and Transportation Officials
ASI	Acceleration Severity Index
CDC	SAE Collision Damage Classification
CG	center of gravity
cm	centimeter(s)
FHWA	Federal Highway Administration
ft.	foot (feet)
ft./s	foot (feet)/second
g	unit of gravity
h	hour(s)
in.	inch(es)
IEC	International Electrotechnical Commission
IS	impact severity
ISO	International Standards Organization
kip-ft.	kilopound [kip] which is one thousand pounds [lbf], a unit of force, with feet [ft.], which is a unit of length
DOTD	Louisiana Department of Transportation and Development
LTRC	Louisiana Transportation Research Center
lb.	pound(s)
m	meter(s)
m/s	meters/second
MASH	AASHTO *Manual for Assessing Roadside Safety Hardware, Second Edition*
mi.	mile(s)
ms	millisecond

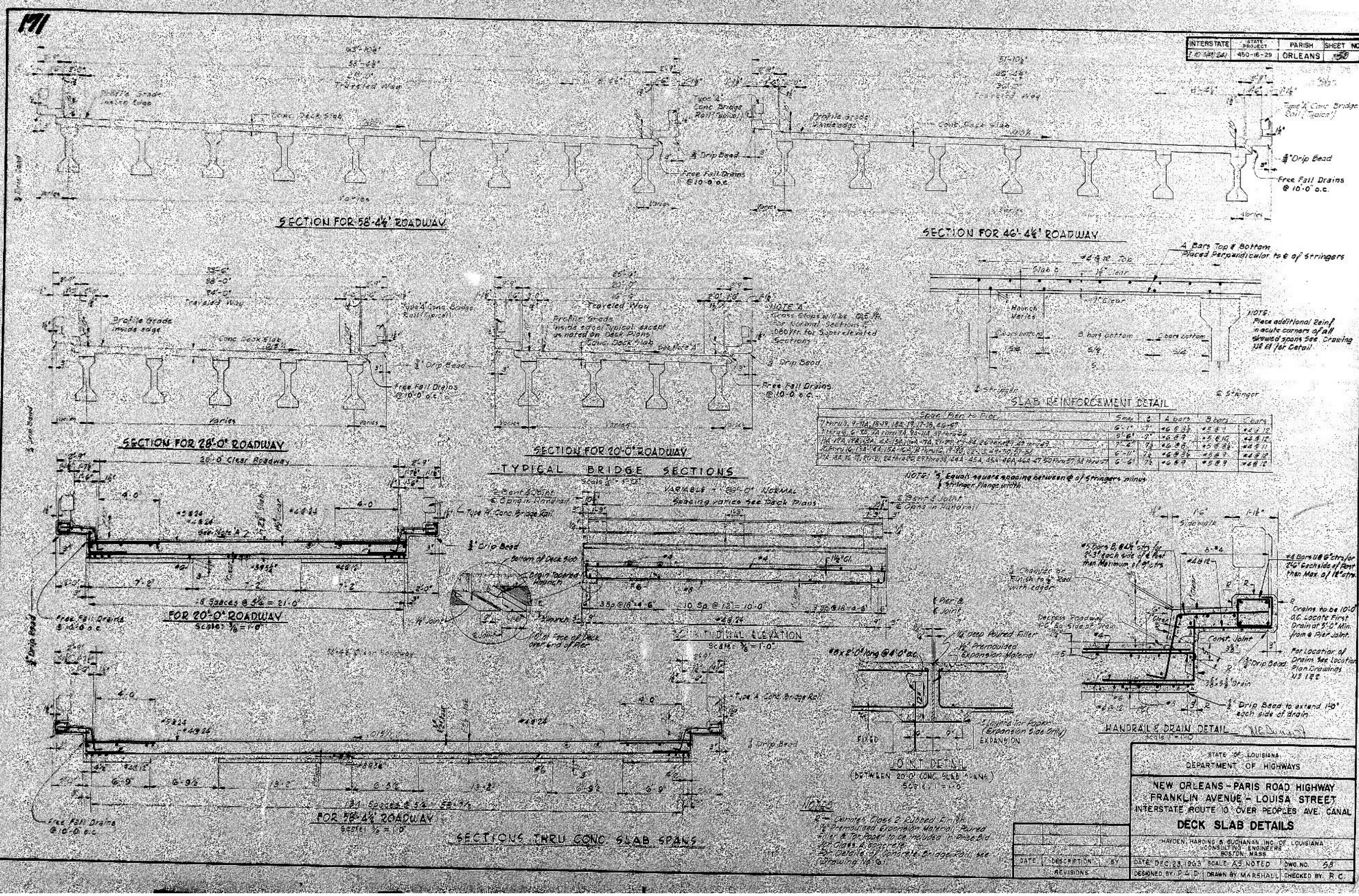
Term	Description
NCHRP	National Cooperative Highway Research Program
NIST	National Institute of Standards Technology
OCDI	*NCHRP Report 350* Appendix E: Occupant Compartment Deformation Index
OIV	Occupant Impact Velocity
psi	pound(s) per square inch
s	second(s)
SAE	Society of Automotive Engineers
TDAS	Tiny Data Acquisition System
THIV	Theoretical Head Impact Velocity
TRAP	Test Risk Assessment Program
TTI	Texas A&M Transportation Institute
VDS	National Safety Council Vehicle Damage Scale for Traffic Accident Investigators

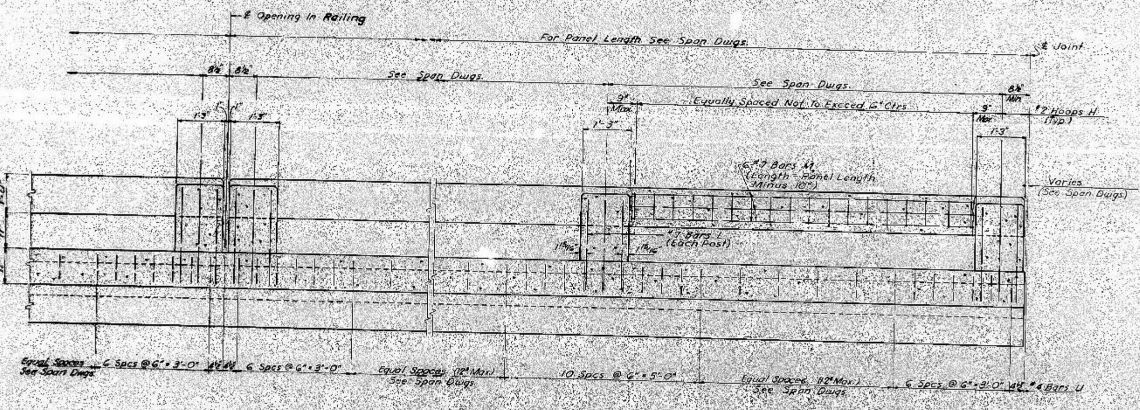
References

1. AASHTO. *Manual for Assessing Roadside Safety Hardware, Second Edition.* American Association of State Highway and Transportation Officials, Washington, DC, 2016.
2. W. F. Williams, "4.3. Design & Full Scale Testing of Retrofit Bridge Rail for 24.8 Miles Long Southbound Causeway Bridge, New Orleans, Louisiana," Texas Transportation Institute, College Station, 2015

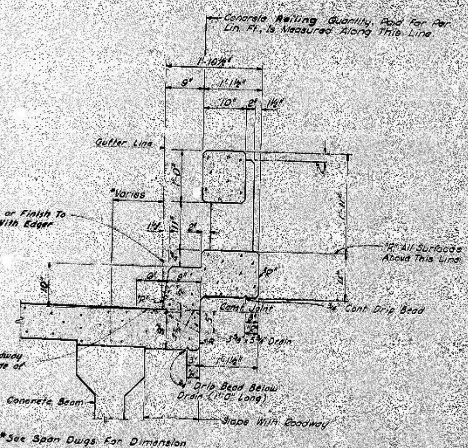
Appendix A. DOTD Bridge Rails




171
INTERSTATE
STATE PROJECT
PARISH
SHEET NO.
450-16-29
ORLEANS
SECTION FOR 58'-4¼" ROADWAY
SECTION FOR 46'-4¼" ROADWAY
SECTION FOR 28'-0" ROADWAY
SECTION FOR 20'-0" ROADWAY
TYPICAL BRIDGE SECTIONS
SLAB REINFORCEMENT DETAIL
FOR 20'-0" ROADWAY
FOR 58'-4¼" ROADWAY
SECTIONS THRU CONC. SLAB SPANS
JOINT DETAIL
HANDRAIL & DRAIN DETAIL
Free Fall Drains @ 10'-0" o.c.
Drip Bead
Traveled Way
Profile Grade
Conc. Deck Slab
A Bars Top & Bottom Placed Perpendicular to ℄ of Stringers
Place additional Reinf. in acute corners of all skewed spans
EXPANSION
FIXED
STATE OF LOUISIANA
DEPARTMENT OF HIGHWAYS
NEW ORLEANS - PARIS ROAD HIGHWAY
FRANKLIN AVENUE - LOUISA STREET
INTERSTATE ROUTE 10 OVER PEOPLES AVE. CANAL
DECK SLAB DETAILS
HAYDEN, HARDING & BUCHANAN INC. OF LOUISIANA
CONSULTING ENGINEERS
BOSTON, MASS.
DATE DEC. 23, 1963
SCALE AS NOTED
DWG. NO. 58
DESIGNED BY P.A.D.
DRAWN BY MARSHALL
CHECKED BY R.C.
DATE
DESCRIPTION
BY
REVISIONS



OUTSIDE ELEVATION SHOWING RAILING



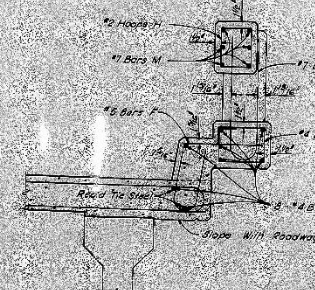
NOTE:
When Drains Are Required They are To Be Located Between The Railing Posts. No Drains Required In End Spans Over Unprotected Slopes Or Over Underpass Roadways. Block Used To Form Opening *May Be Slightly Tapered To Facilitate Withdrawal.

*See Span Dwgs For Dimension

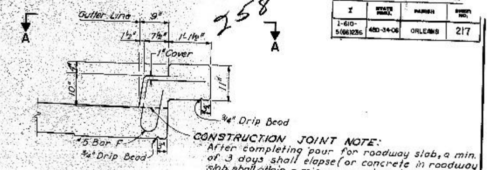
PART SECTION SHOWING DIMENSIONS

NO 7 BARS "L" (5½" Dia. Pin) (5'-0" Long)

NO 2 HOOPS "H" (1" Dia. Pin) (3'-5" Long)

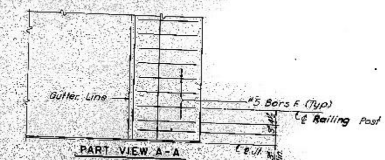


PART SECTION SHOWING REINFORCING



CONSTRUCTION JOINT NOTE:
After completing pour for roadway slab, a min. of 3 days shall elapse (or concrete in roadway slab shall attain a min. compressive strength of 1500 p.s.i.) before beginning pour for Curb and Railing Parapet.

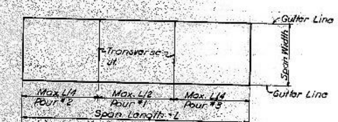
TYPICAL SECTION THRU CURB



PART VIEW A-A

CURB POURING DETAILS

(For Details Not Shown See Span Drawings)



ORDER OF POURING DECKS

At The Contractors Option, Spans Greater Than 80' May Be Poured With Three Transverse Construction Joints As Shown, Or The Entire Span May Be Poured In One Pour.
Not Less Than 3 Days Shall Have Elapsed Between Pour #1 & Pour #2 And Between Pour #1 & Pour #3, But The Contractor Will Be Permitted To Make Pours #2 & 3 Simultaneously If He So Desires.
Spans 80' And Less To Be Poured In One Continous Pour.

NOTES:

1. "R" — Denotes Class 2 Rubbed Finish.
2. Railing To Be Poured Monolithic With Railing Post In Each Panel Length.
3. Exposed Corners To Be Chamfered 3/4" Unless Otherwise Noted.
4. For General Notes See Sheet No. 161
5. Concrete & Reinforcing Steel In Railing Above Top Of 4" Parapet To Be Paid For Per Lin. Ft. Of Railing This Includes Bars "L" That Project Into Said Parapet.

I	STATE PROJ.	PARISH	SHEET NO.
I-610-5(66)236	450-34-06	ORLEANS	217

258

CONCRETE RAILING DETAILS AND ORDER OF POURING DECKS

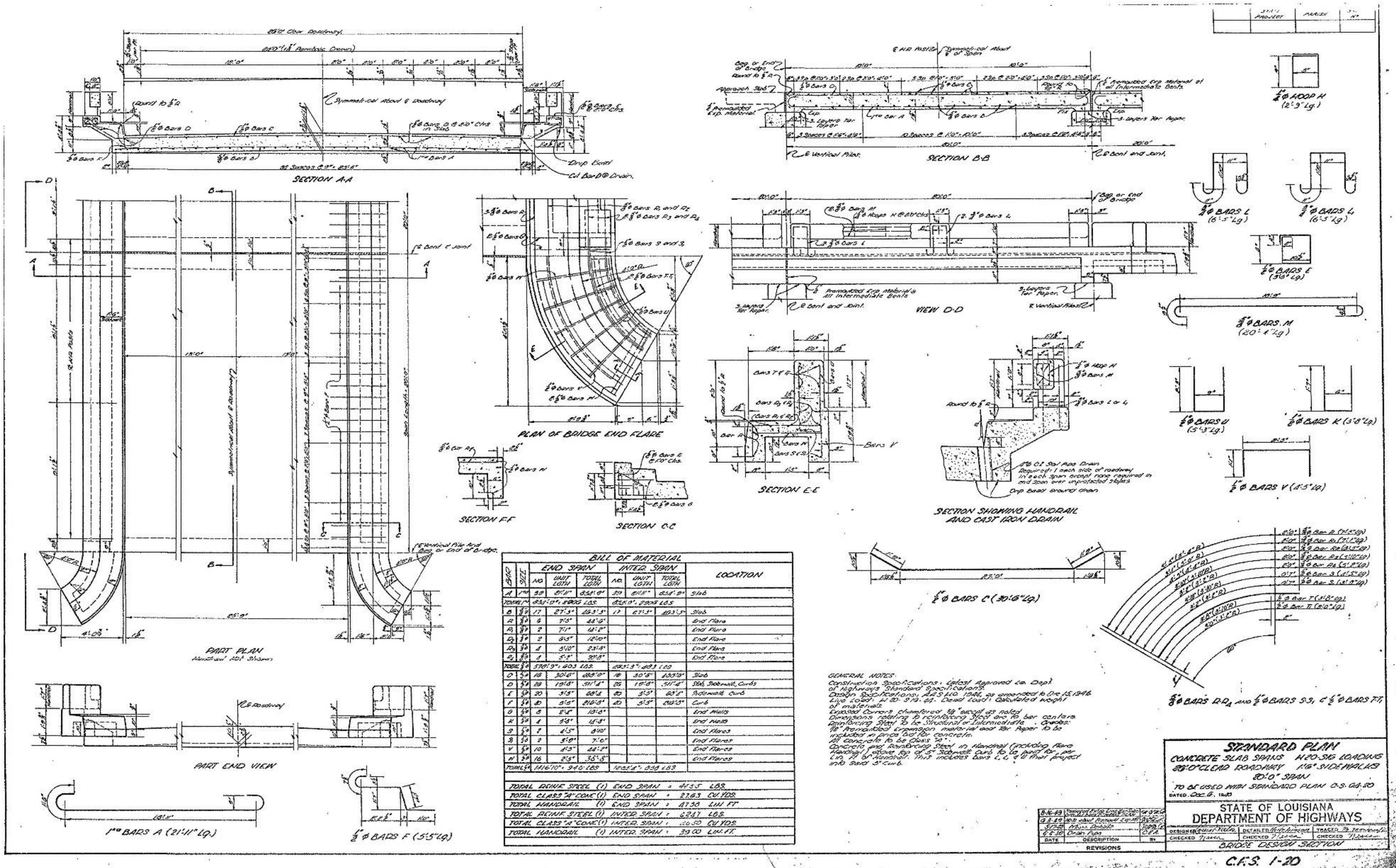
NEW ORLEANS BY-PASS HIGHWAY I-610
LONDON AVE CANAL - FRANKLIN AVE.

DAVID VOLKERT & ASSOCIATES
CONSULTING ENGINEERS

STATE OF LOUISIANA
DEPARTMENT OF HIGHWAYS

DESIGNED L.D.B. | DETAILED R.H. | TRACED L.G.
CHECKED T.M.S. | CHECKED T.M.S. | CHECKED J.D.T.
DATE Nov. 14, 1968

DATE	DESCRIPTION	BY
	REVISIONS	



BILL OF MATERIAL								
BAR	SIZE	END SPAN			INTER. SPAN			LOCATION
		NO.	UNIT LGTH	TOTAL LGTH	NO.	UNIT LGTH	TOTAL LGTH	
A	1" ϕ	39	21'-11"	854'-9"	39	21'-11"	854'-9"	Slab
TOTAL 1" ϕ		854'-9" = 2905 LBS.			854'-9" = 2905 LBS.			
B	5/8" ϕ	17	27'-3"	463'-3"	17	27'-3"	463'-3"	Slab
R	5/8" ϕ	6	7'-5"	44'-6"				End Flare
R1	5/8" ϕ	2	7'-1"	14'-2"				End Flare
R2	5/8" ϕ	2	6'-5"	12'-10"				End Flare
R3	5/8" ϕ	4	5'-10"	23'-4"				End Flare
R4	5/8" ϕ	4	5'-2"	20'-8"				End Flare
TOTAL 5/8" ϕ		578'-9" = 603 LBS.			463'-3" = 483 LBS.			
C	1/2" ϕ	16	30'-6"	488'-0"	16	30'-6"	488'-0"	Slab
D	1/2" ϕ	28	18'-3"	511'-4"	28	18'-3"	511'-4"	Slab, Sidewalk, Curbs
E	1/2" ϕ	20	3'-5"	68'-4"	20	3'-5"	68'-4"	Sidewalk Curb
F	1/2" ϕ	40	5'-5"	216'-8"	40	5'-5"	216'-8"	Curb
G	1/2" ϕ	8	2'-4"	18'-8"				End Walls
K	1/2" ϕ	4	3'-8"	14'-8"				End Walls
S	1/2" ϕ	2	4'-5"	8'-10"				End Flares
S1	1/2" ϕ	2	3'-9"	7'-6"				End Flares
V	1/2" ϕ	10	4'-5"	44'-2"				End Flares
N	1/2" ϕ	16	2'-5"	35'-8"				End Flares
TOTAL 1/2" ϕ		1416'-10" = 946 LBS.			1284'-4" = 858 LBS.			

TOTAL REINF. STEEL (1) END SPAN	= 4455 LBS.
TOTAL CLASS "A" CONC. (1) END SPAN	= 27.63 CU. YDS.
TOTAL HANDRAIL (1) END SPAN	= 47.38 LIN. FT.
TOTAL REINF. STEEL (1) INTER. SPAN	= 4247 LBS.
TOTAL CLASS "A" CONC. (1) INTER. SPAN	= 26.50 CU. YDS.
TOTAL HANDRAIL (1) INTER. SPAN	= 39.00 LIN. FT.

GENERAL NOTES:
Construction Specifications: Latest Approved La. Dept. of Highways Standard Specifications.
Design Specifications: A.A.S.H.O. 1944, as amended to Dec. 15, 1946.
Live Load: H 20-S 16-44. Dead Load: Calculated weight of materials.
Exposed Corners chamfered 3/4" except as noted.
Dimensions relating to reinforcing Steel are to bar centers.
Reinforcing Steel to be Structural or Intermediate Grades.
1/2" Premoulded Expansion material and Tar Paper to be included in price bid for concrete.
All Concrete to be Class "A".
Concrete and Reinforcing Steel in Handrail (including Flare Handrail) above top of 5" Sidewalk Curb to be paid for, per Lin. Ft. of Handrail. This includes bars L, L & U that project into said 5" Curb.

DATE	DESCRIPTION	BY
8-16-49	Premoulded Exp. Mat. (illegible)	[illegible]
6-3-49	Note about Premould Exp. Mat.	[illegible]
5-17-49	Misc. Details	[illegible]
6-6-50	Drain Pipe	C.E.A.
REVISIONS		

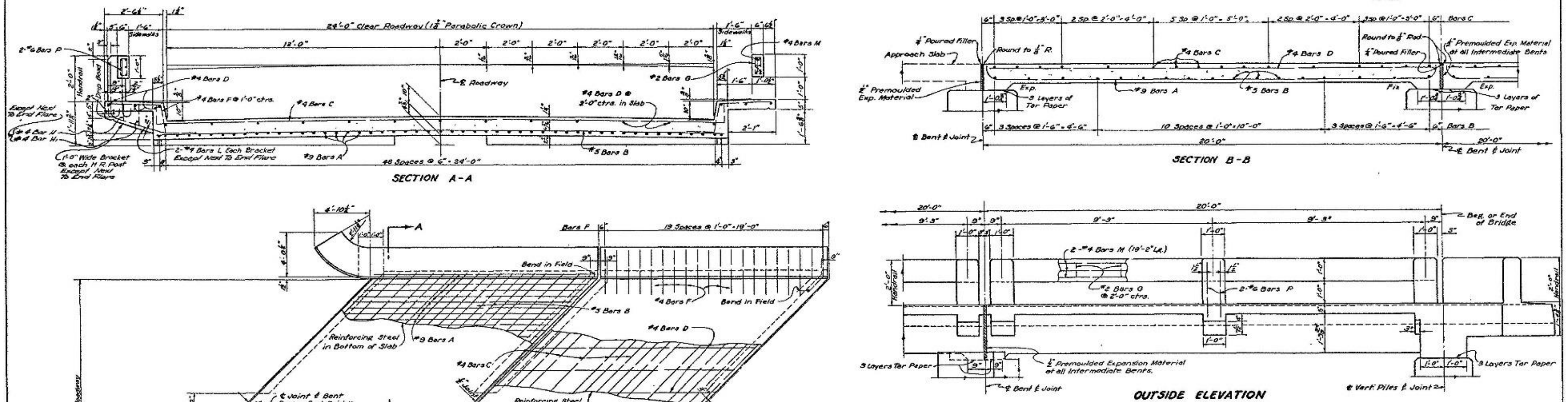
STANDARD PLAN
CONCRETE SLAB SPANS H20-S16 LOADING
28'-0" CLEAR ROADWAY 1'-6" SIDEWALKS
20'-0" SPAN
TO BE USED WITH STANDARD PLAN C-S. G4-20
DATED Dec. 6, 1948

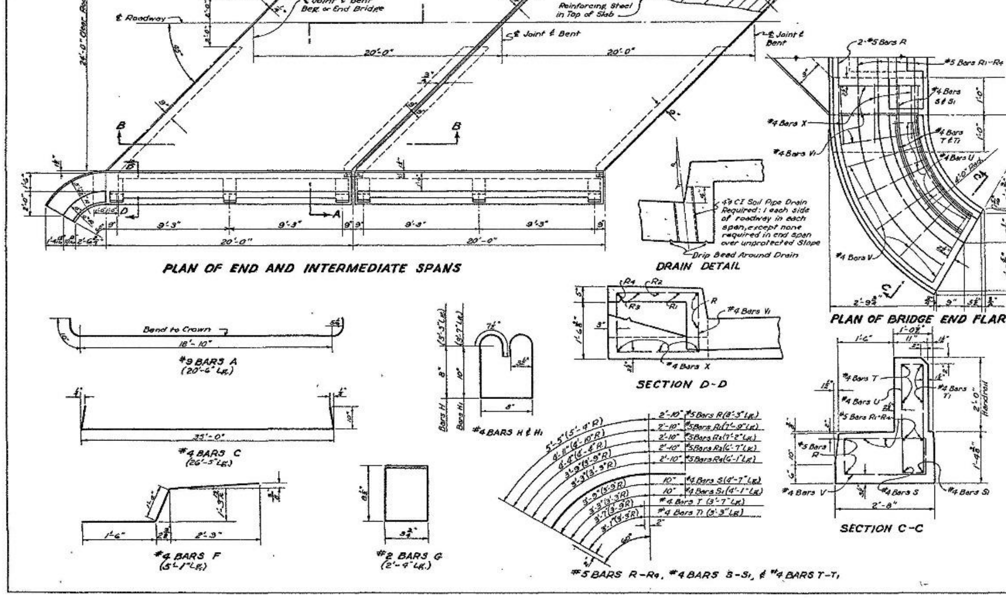
STATE OF LOUISIANA
DEPARTMENT OF HIGHWAYS

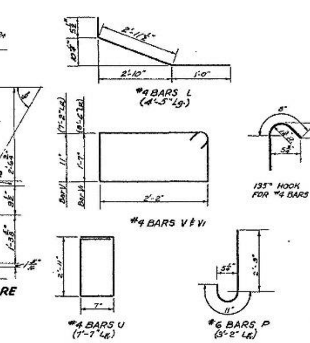
DESIGNED [illegible] DETAILED [illegible] TRACED [illegible]
CHECKED [illegible] CHECKED [illegible] CHECKED [illegible]

BRIDGE DESIGN SECTION

C.F.S. 1-20







BILL OF MATERIAL

BAR	SIZE	END SPAN NO.	END SPAN UNIT LENGTH	END SPAN TOTAL LENGTH	INTER. SPAN NO.	INTER. SPAN UNIT LENGTH	INTER. SPAN TOTAL LENGTH	LOCATION
A	#9	51	20'-6"	1045'-6"	51	20'-6"	1045'-6"	Slab
TOTAL #9		1045'-6" =		3555 Lbs.	1045'-6" =		3555 Lbs.	
B	#5	17	35'-0"	595'-0"	17	35'-0"	595'-0"	Slab
R	#5	4	8'-3"	33'-0"				End Flare
R1	#5	2	7'-9"	15'-6"				End Flare
R2	#5	2	7'-2"	14'-4"				End Flare
R3	#5	2	6'-7"	13'-2"				End Flare
R4	#5	2	6'-1"	12'-2"				End Flare
TOTAL #5		683'-2" =		713 Lbs.	595'-0" =		621 Lbs.	
C	#4	16	36'-8"	586'-8"	16	36'-8"	586'-8"	Slab
D	#4	19	19'-8"	373'-8"	19	19'-8"	373'-8"	Slab, Curbs, & Sidewalk
F	#4	40	5'-2"	206'-8"	40	5'-2"	206'-8"	Curbs & Sidewalk
H	#4	4	3'-3"	13'-0"	6	3'-3"	19'-6"	Brackets
H1	#4	4	3'-7"	14'-4"	6	3'-7"	21'-6"	Brackets
L	#4	8	4'-5"	35'-4"	12	4'-5"	53'-0"	Brackets
S	#4	2	4'-7"	9'-2"				End Flares
S1	#4	2	4'-1"	8'-2"				End Flares
V	#4	10	7'-2"	71'-8"				End Flares
V1	#4	6	8'-6"	51'-0"				End Flares
X	#4	6	1'-8"	10'-0"				End Flares
TOTAL #4		1379'-8" =		922 LBS.	1261'-0" =		842 LBS.	

ITEM	END SPAN	INTER. SPAN
CLASS "A" CONCRETE	19.74 CU.YDS.	18.31 CU.YDS.
DEFORMED REINFORCING STEEL	5190 LBS.	5018 LBS.
CONCRETE HANDRAIL	47.38 LIN. FT.	39.00 LIN. FT.

GENERAL NOTES:

Constructions Specifications: Latest Approved Louisiana Department of Highways Standard Specifications.

Design Specifications: A.A.S.H.O. 1949 Amended Dec. 1950.

Live Load: H15-44

Exposed Corners to be Chamfered ¾" unless otherwise noted.

Reinforcement Bars shall be Intermediate, or Hard Grade, A.S.T.M. A15 or Rail Steel, A.S.T.M. A16.

Dimensions relating to Reinforcing Steel are to bar centers.

½" Premoulded Expansion Material, Poured Filler and Tar Paper to be included in price bid for Concrete.

Concrete and Reinforcing Steel in Handrail above Top of Sidewalk to be paid for Per Lin. Ft. of Handrail. This includes bars P, U, M, G, T & T1.

DATE	DESCRIPTION	BY
2-4-54	Correct Bars F & L Lgth.	[illegible]
7-17-52	Correct Bars B & C Lgth.	[illegible]

REVISIONS

STANDARD PLAN
20'-0" CONCRETE SLAB SPAN ~ 45° SKEW
H-15 LOADING
24'-0" CLEAR ROADWAY & 1'-6" SIDEWALKS
To Be Used With STD. PLAN C.S. 202-15

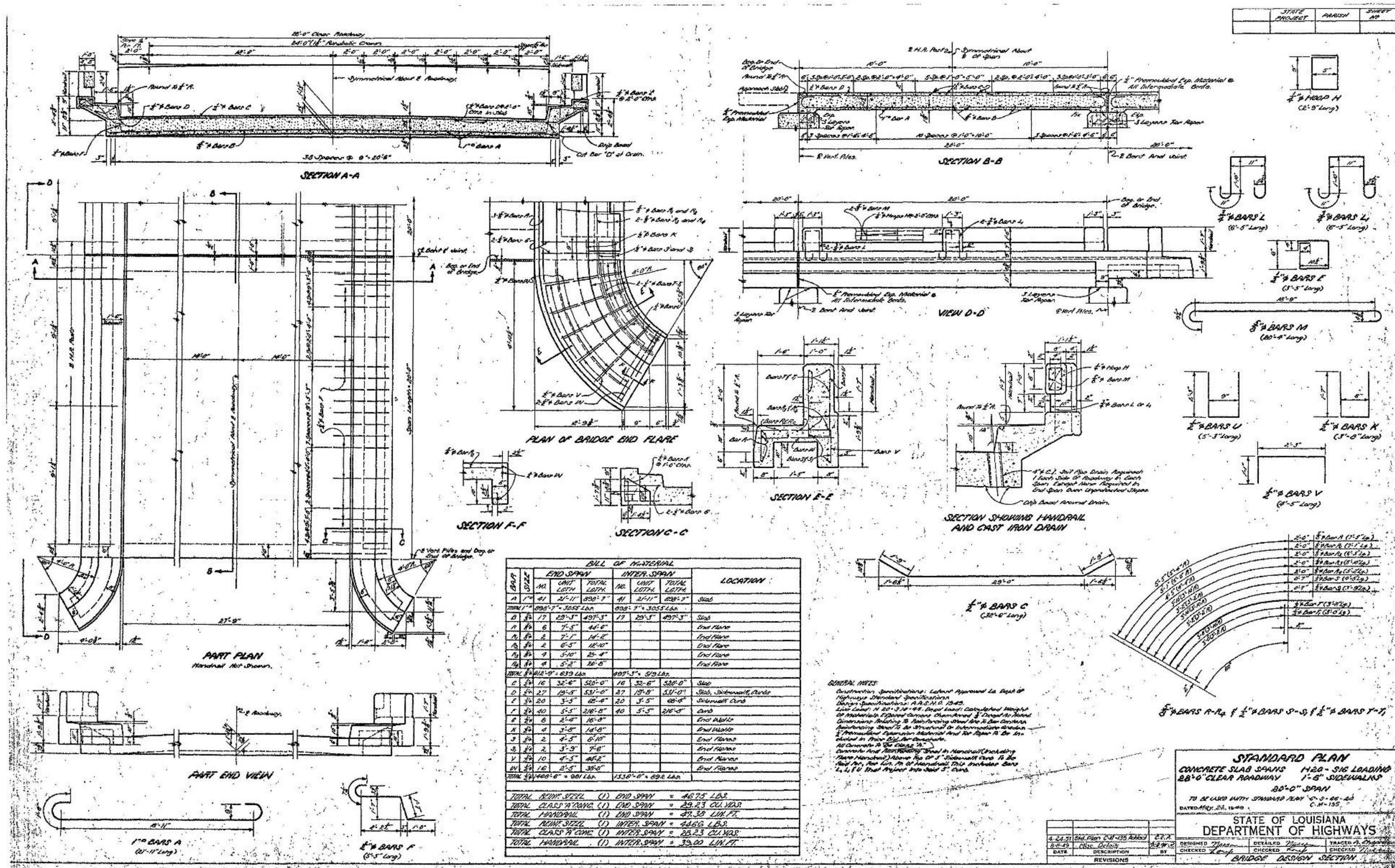
DATED. Oct. 31, 1951

STATE OF LOUISIANA
DEPARTMENT OF HIGHWAYS

DESIGNED Hutchinson | DETAILED Hutchinson | TRACED E. Hinkley
CHECKED Loup | CHECKED Loup | CHECKED Loup

BRIDGE DESIGN SECTION

C.F.S. 3 -15

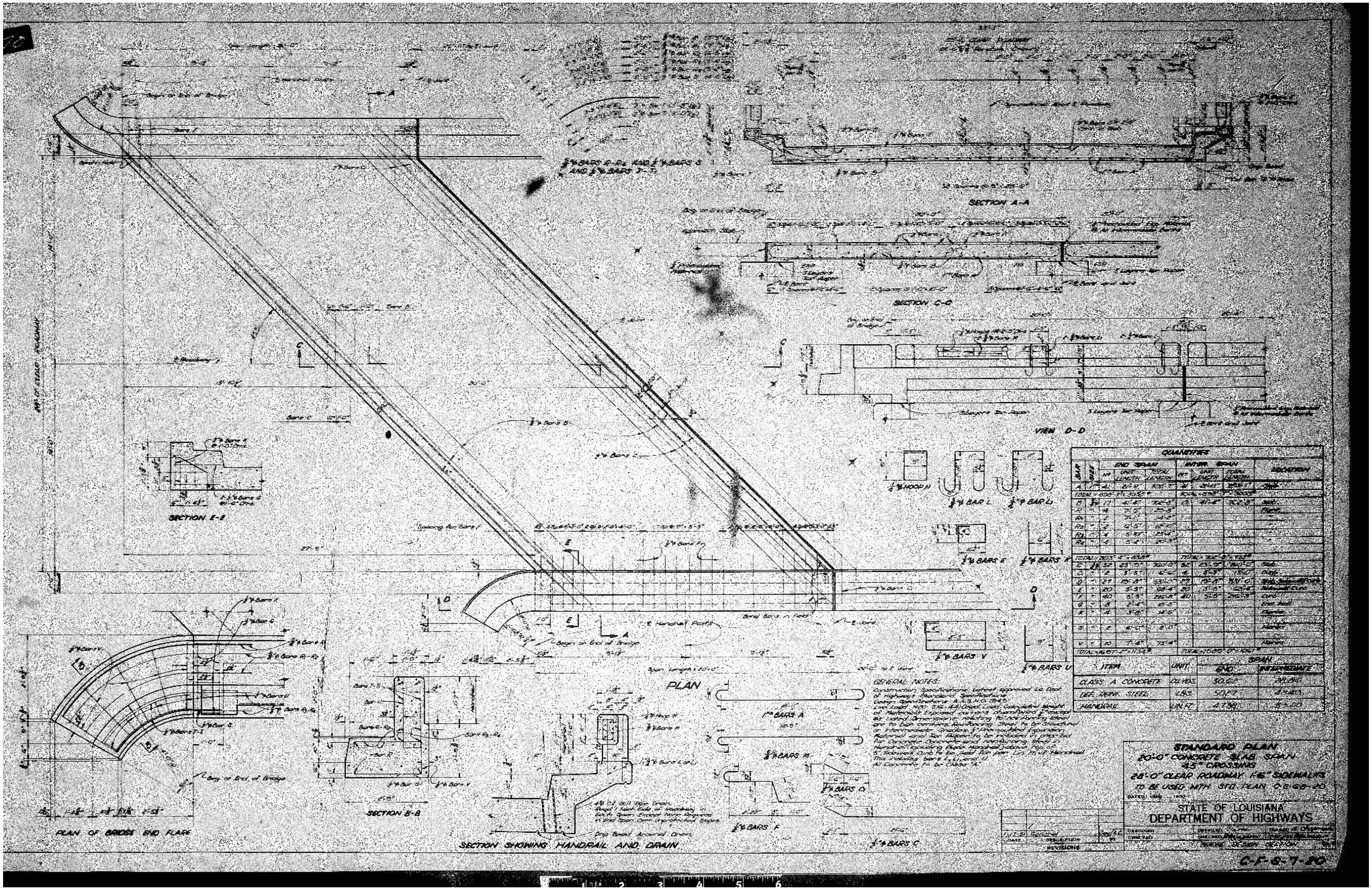


BILL OF MATERIAL								
BAR	SIZE	END SPAN			INTER. SPAN			LOCATION
		NO.	UNIT LGTH.	TOTAL LGTH.	NO.	UNIT LGTH.	TOTAL LGTH.	
A	1"□	41	21'-11"	898'-7"	41	21'-11"	898'-7"	Slab
TOTAL	1"□	898'-7" = 3055 Lbs.			898'-7" = 3055 Lbs.			
B	⅝"⌀	17	29'-3"	497'-3"	17	29'-3"	497'-3"	Slab
R	⅝"⌀	6	7'-5"	44'-6"				End Flare
R1	⅝"⌀	2	7'-1"	14'-2"				End Flare
R2	⅝"⌀	2	6'-5"	12'-10"				End Flare
R3	⅝"⌀	4	5'-10"	23'-4"				End Flare
R4	⅝"⌀	4	5'-2"	20'-8"				End Flare
TOTAL	⅝"⌀	612'-9" = 639 Lbs.			497'-3" = 519 Lbs.			
C	½"⌀	16	32'-6"	520'-0"	16	32'-6"	520'-0"	Slab
D	½"⌀	27	19'-8"	531'-0"	27	19'-8"	531'-0"	Slab, Sidewalk, Curbs
E	½"⌀	20	3'-5"	68'-4"	20	3'-5"	68'-4"	Sidewalk Curb
F	½"⌀	40	5'-5"	216'-8"	40	5'-5"	216'-8"	Curb
G	½"⌀	6	2'-4"	16'-8"				End Walls
K	½"⌀	4	3'-8"	14'-8"				End Walls
S	½"⌀	2	4'-5"	8'-10"				End Flares
S1	½"⌀	2	3'-9"	7'-6"				End Flares
V	½"⌀	10	4'-5"	44'-2"				End Flares
W	½"⌀	16	2'-5"	38'-8"				End Flares
TOTAL	½"⌀	1468'-6" = 981 Lbs.			1336'-0" = 892 Lbs.			

TOTAL	REINF. STEEL	(1)	END SPAN	= 4675 LBS.
TOTAL	CLASS "A" CONC.	(1)	END SPAN	= 29.23 CU. YDS.
TOTAL	HANDRAIL	(1)	END SPAN	= 47.38 LIN. FT.
TOTAL	REINF. STEEL	(1)	INTER. SPAN	= 4466 LBS.
TOTAL	CLASS "A" CONC.	(1)	INTER. SPAN	= 28.23 CU. YDS.
TOTAL	HANDRAIL	(1)	INTER. SPAN	= 39.00 LIN. FT.

GENERAL NOTES:

Construction Specifications: Latest Approved La. Dept. of Highways Standard Specifications.
Design Specifications: A.A.S.H.O. 1949.
Live Load: H 20-S 16-44. Dead Load: Calculated Weight of Materials. Exposed Corners Chamfered ¾" Except As Noted.
Dimensions Relating To Reinforcing Steel Are To Bar Centers.
Reinforcing Steel To Be Structural Or Intermediate Grades.
½" Premoulded Expansion Material And Tar Paper To Be Included in Price Bid Per Concrete.
All Concrete To Be Class "A."
Concrete And Reinforcing Steel In Handrail (Including Flare Handrail) Above Top Of 5" Sidewalk Curb To Be Paid For Per Lin. Ft. Of Handrail. This Includes Bars L, L1 & U That Project Into Said 5" Curb.



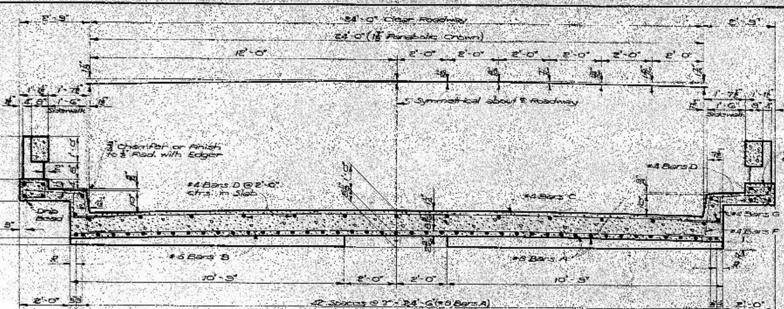
QUANTITIES

BAR	SIZE	END SPAN No.	END SPAN UNIT LENGTH	END SPAN TOTAL LENGTH	INTER. SPAN No.	INTER. SPAN UNIT LENGTH	INTER. SPAN TOTAL LENGTH	LOCATION
A	1"	41	21'-11"	898'-7"	41	21'-11"	898'-7"	Slab
TOTAL = 898'-7" = 3055#					TOTAL = 898'-7" = 3055#			
B	3/4"	17	41'-4"	702'-8"	17	41'-4"	702'-8"	Slab
R	"	4	7'-5"	29'-8"				Flare
R1	"	2	7'-1"	14'-2"				
R2	"	2	6'-5"	12'-10"				
R3	"	4	5'-10"	23'-4"				
R4	"	4	5'-2"	20'-8"				
TOTAL = 803'-4" = 838#					TOTAL = 702'-8" = 733#			
C	1/2"?	32	23'-9"	760'-0"	32	23'-9"	760'-0"	Slab
C1	"	2	3'-3"	6'-6"	4	3'-3"	13'-0"	Curb
D	"	27	19'-8"	531'-0"	27	19'-8"	531'-0"	Slab, Sidewalk & Curb
E	"	20	3'-5"	68'-4"	20	3'-5"	68'-4"	Sidewalk Curb
F	"	40	5'-5"	216'-8"	40	5'-5"	216'-8"	Curb
G	"	8	2'-4"	18'-8"				End Wall
K	"	4	3'-8"	14'-8"				Flare
S	"	2	4'-0"	8'-0"				Flare
V	"	10	7'-4"	73'-4"				Flare
TOTAL = 1697'-2" = 1134#					TOTAL = 1580'-0" = 1061#			

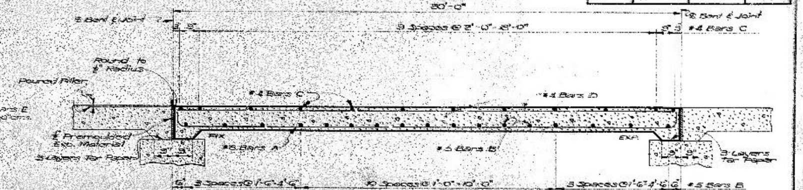
ITEM	UNIT	SPAN END	SPAN INTERMEDIATE
CLASS A CONCRETE	CU. YDS.	30.62	28.86
DEF. REINF. STEEL	LBS.	5027	4849
HANDRAIL	LIN. FT.	47.38	59.00

101

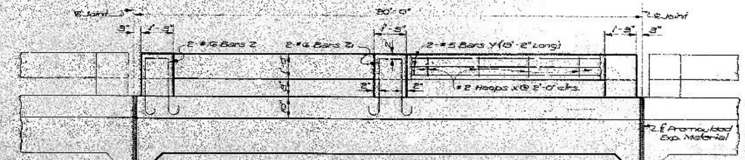
	STATE PROJECT	PARISH	SHEET NO.
	389-03-05	ACADIA	[illegible]



SECTION A-A

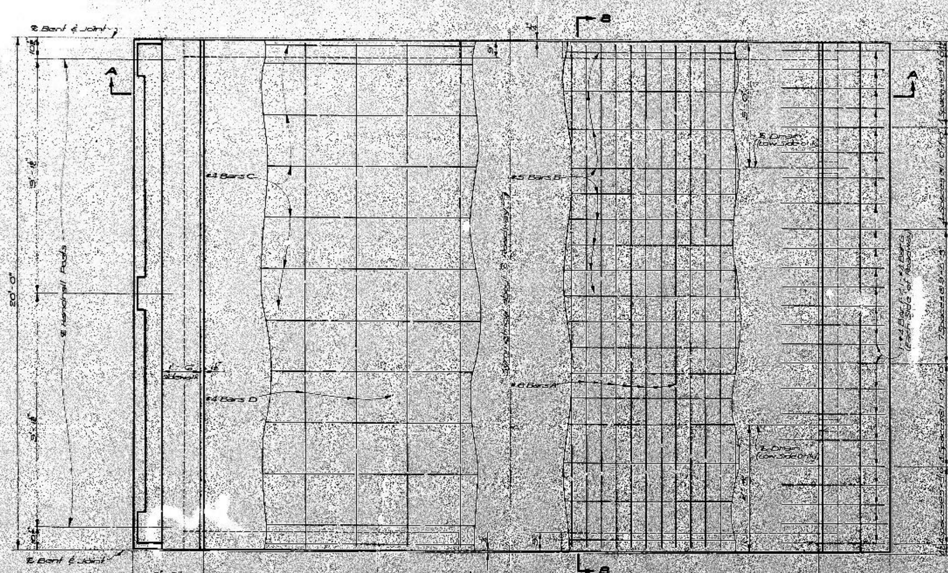


SECTION B-B



ELEVATION

(DENTS NOT SHOWN)

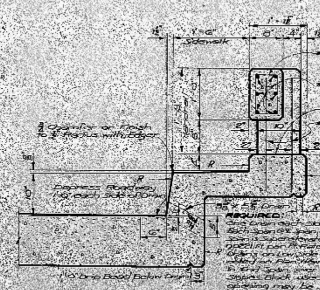


REINFORCING STEEL IN TOP OF SLAB

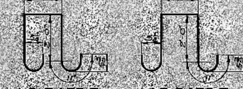
REINFORCING STEEL IN BOTTOM OF SLAB

CURB & SIDEWALK REINF. STEEL

PLAN VIEW



SECTION SHOWING HANDRAIL & DRAIN



#6 BARS Z (6'-5" LONG) #6 BARS Z1 (6'-5" LONG)

#2 HOOPS X #4 BARS G #8 BARS A #4 BARS E #4 BARS F

BILL OF MATERIALS FOR ONE SPAN					
BAR	SIZE	NO.	UNIT LENGTH	TOTAL LENGTH	LOCATION
A	#8	45	20'-10"	937'-6"	Bottom of Slab
TOTAL #8 BARS - 937'-6" - 2503 LBS.					
B	#5	17	25'-2"	427'-10"	Bottom of Slab
TOTAL #5 BARS - 427'-10" - 446 LBS.					
C	#4	12	25'-2"	302'-0"	Top of Slab
D	#4	25	19'-7"	489'-7"	Top of Slab & Curbs
E	#4	20	3'-7"	71'-8"	Stirrups in S.W. Curb
F	#4	48	5'-4"	256'-0"	Curb
G	#4	48	2'-4"	112'-0"	Curb
TOTAL #4 BARS - 1231'-3" - 822 LBS.					
TOTAL DEF. REINF. STEEL - 3771 LBS.					
TOTAL CLASS "A" CONCRETE - 22.22 CU. YDS.					
TOTAL CONCRETE HANDRAIL - 39.00 LIN. FT.					

GENERAL NOTES:

Construction Specifications; Latest approved La. Dept. of Hwys. Standard Specs.
Design Specifications: A.A.S.H.O. 1949 as amended to Dec. 31, 1955.
Live Load: H15-44.
All Concrete to be Class "A".
Exposed Corners to have ¾" Chamfer.
Reinforcement Bars shall be Intermediate or Hard Grade, A.S.T.M. A15, or Rail Steel, A.S.T.M. A16, conforming to A.S.T.M. A305.
Dimensions relating to Reinforcing Steel are to Bar centers.
½" Premoulded Expansion Material, Poured Filler and Tar Paper to be included in Price Bid for Class "A" Concrete.
Concrete and Reinf. Steel in Handrail on Slab Span to be paid for per Lin. Ft. of CONCRETE HANDRAIL. This includes Bars Z and Z1.
R — Denotes Class 2 Rubbed Finish.

DESIGN TAKEN FROM STD. PLAN CFS 9-15 DATED: MARCH 14, 1956

SPANS (BRIDGE No. 1)

STANDARD PLAN
20'-0" CONC. SLAB SPAN
LIVE LOAD H15-44
24'-0" ROADWAY 1'-6" SIDEWALKS
90° CROSSING PARABOLIC CROWN
DATED JAN. 28, 1959

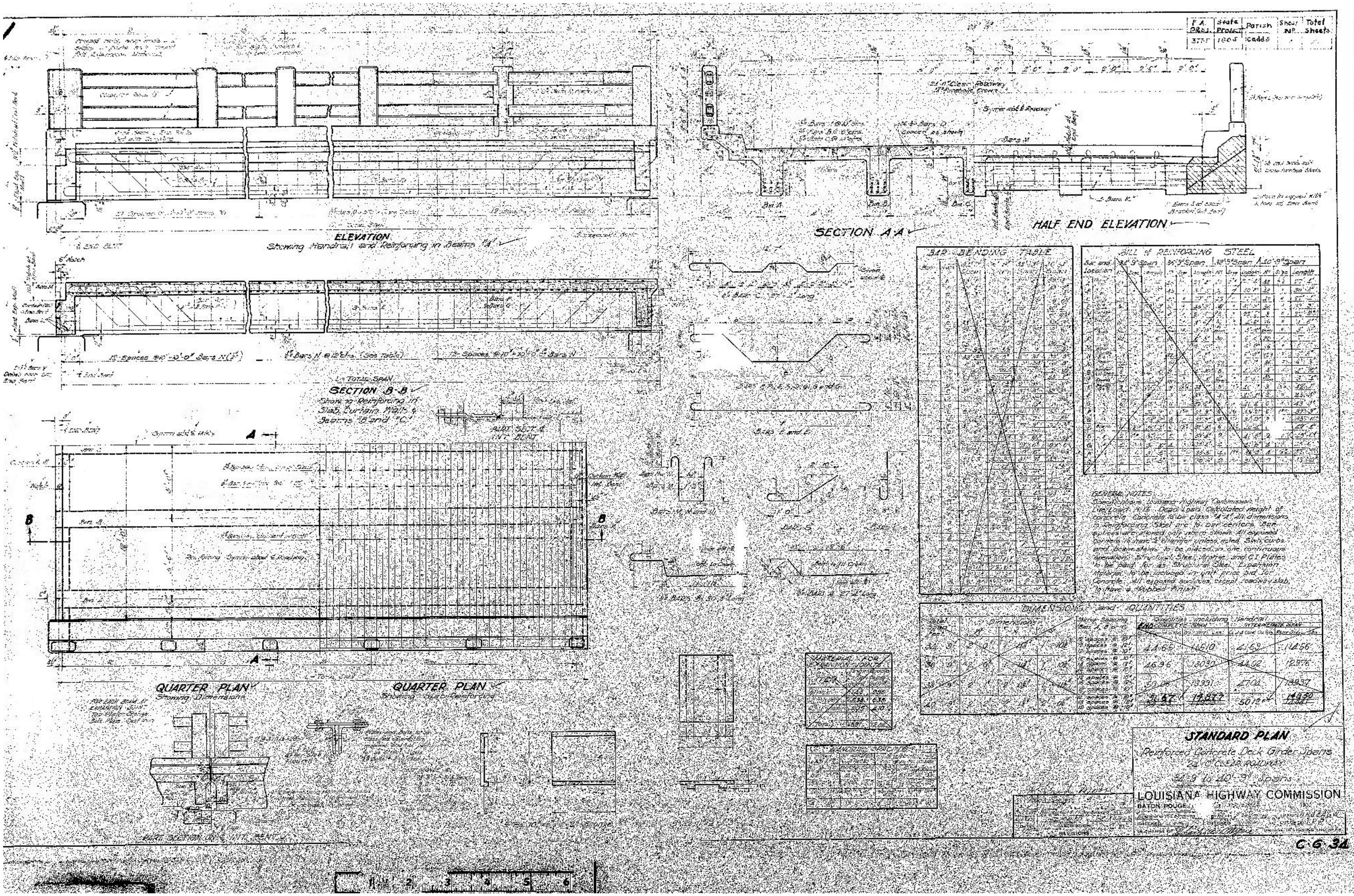
STATE OF LOUISIANA
DEPARTMENT OF HIGHWAYS

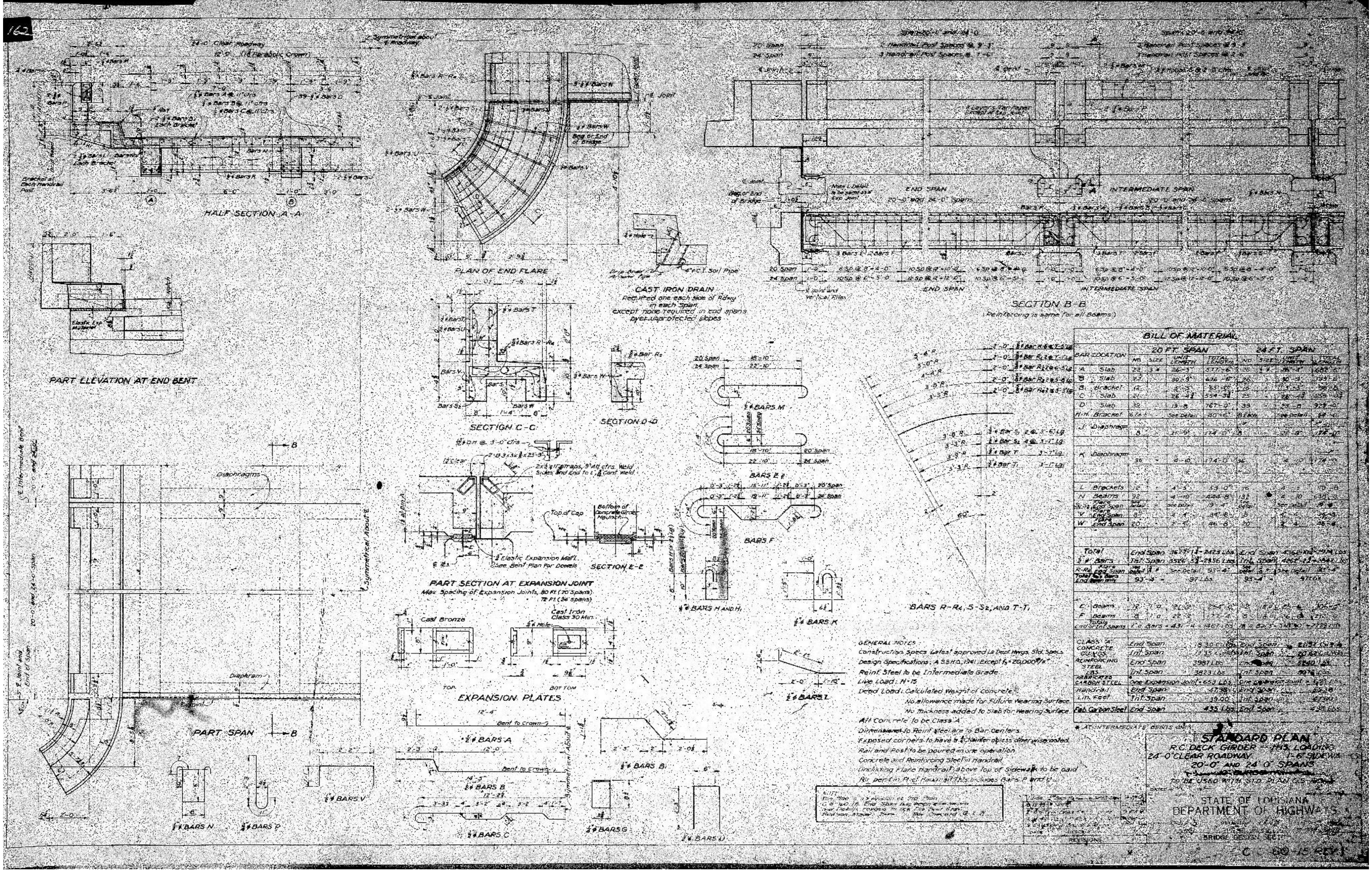
DESIGNED	DETAILED	TRACED
CHECKED	CHECKED	CHECKED

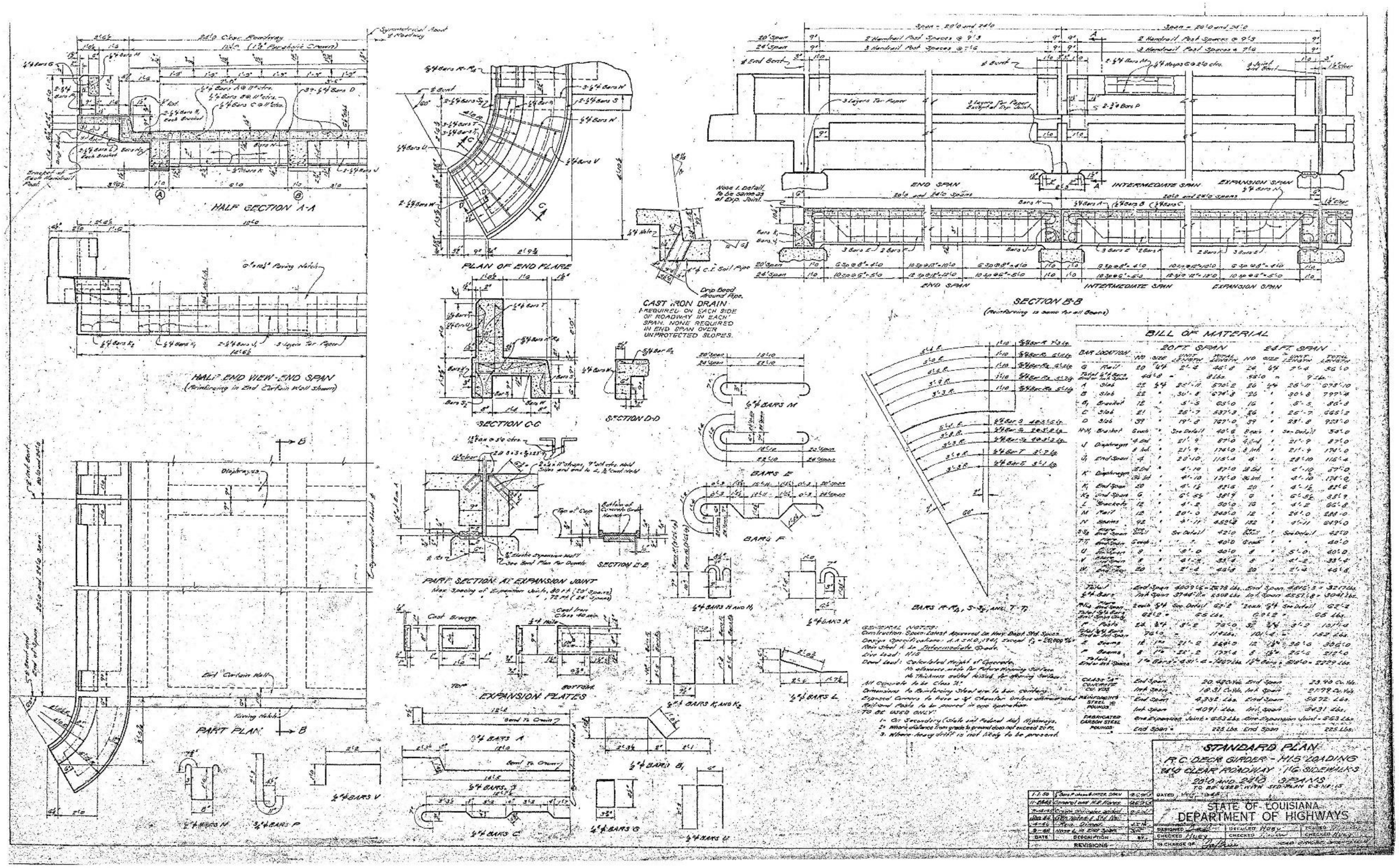
BRIDGE DESIGN SECTION

DATE	DESCRIPTION	BY
REVISIONS		

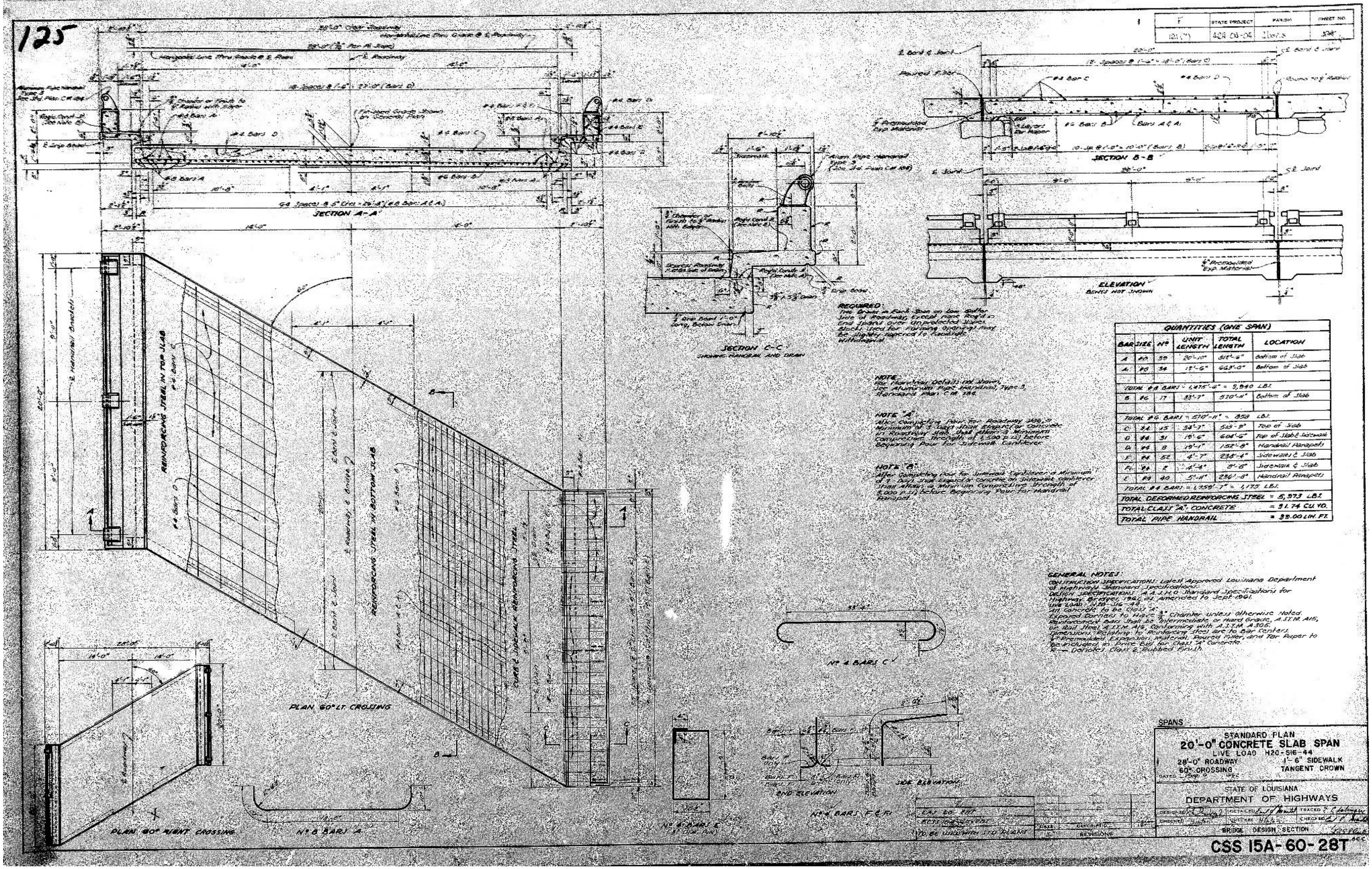
CFS15C-90-24P


ELEVATION
Showing Handrail and Reinforcing in Beams "A"
SECTION B-B
Showing Reinforcing in Slab, Curtain Walls & Beams "B" and "C"
QUARTER PLAN
Showing Dimensions
QUARTER PLAN
Showing Slab Reinforcing
SECTION A-A
HALF END ELEVATION
BAR BENDING TABLE
BILL of REINFORCING STEEL
GENERAL NOTES
DIMENSIONS and QUANTITIES
STANDARD PLAN
Reinforced Concrete Deck Girder Spans
24'-0" CLEAR ROADWAY
34'-9" to 40'-9" Spans
LOUISIANA HIGHWAY COMMISSION
BATON ROUGE
REVISIONS
C-G-34

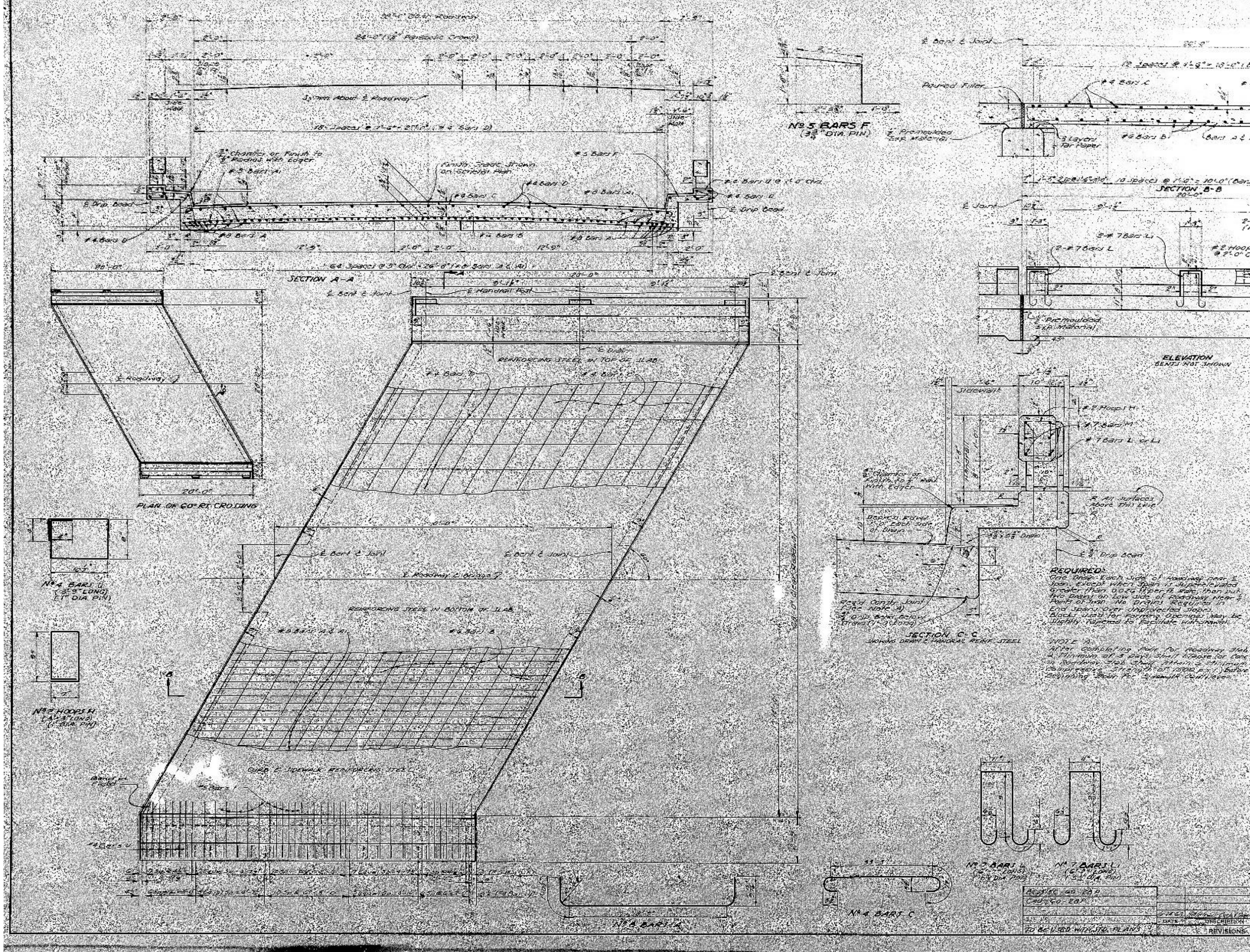

HALF SECTION A-A
PART ELEVATION AT END BENT
PLAN OF END FLARE
CAST IRON DRAIN
Required one each side of Rdwy in each Span except none required in end spans over unprotected slopes
SECTION B-B
(Reinforcing is same for all Beams)
END SPAN
INTERMEDIATE SPAN
SECTION C-C
SECTION D-D
SECTION E-E
PART SECTION AT EXPANSION JOINT
Max. Spacing of Expansion Joints, 80 Ft. (20 Spans) 72 Ft. (24 Spans)
Cast Bronze
Cast Iron Class 30 Min.
TOP
BOTTOM
EXPANSION PLATES
PART SPAN
BARS M
BARS E
BARS F
BARS H AND H1
BARS K
BARS L
BARS R-R4, S-S2, AND T-T1
BARS A
BARS B
BARS C
BARS B1
BARS G
BARS U
BARS N
BARS P
BARS V
BILL OF MATERIAL
20 FT. SPAN
24 FT. SPAN
Fabricated Carbon Steel: One Expansion Joint = 653 Lbs.
Handrail Lin. Feet: End Span 47.98; Int. Span 39.00
Fab. Carbon Steel: End Span 435 Lbs.
* AT INTERMEDIATE BENTS ONLY
GENERAL NOTES
Construction Specs. Latest approved La. Dept. Hwys. Std. Specs.
Design Specifications: A.S.S.H.O., 1941, Except fs = 20,000#/□"
Reinf. Steel to be Intermediate Grade.
Live Load: H-15
Dead Load: Calculated Weight of Concrete.
No allowance made for Future Wearing Surface.
No thickness added to Slab for Wearing Surface.
All Concrete to be Class A
Dimensions to Reinf. Steel are to Bar Centers.
Exposed corners to have a Chamfer unless otherwise noted.
Rail and Post to be poured in one operation.
Concrete and Reinforcing Steel in Handrail
(including Flare Handrail) above top of Sidewalk to be paid
for per Lin. Ft. of Handrail. This includes Bars P and U.
REVISIONS
STANDARD PLAN
R.C. DECK GIRDER — H15 LOADING
24'-0" CLEAR ROADWAY 1'-6" SIDEWALKS
20'-0" AND 24'-0" SPANS
TO BE USED WITH STD. PLAN C.S.
STATE OF LOUISIANA
DEPARTMENT OF HIGHWAYS
BRIDGE DESIGN SECT.
C 80-15 REV 1


HALF SECTION A-A
HALF END VIEW - END SPAN
PLAN OF END FLARE
SECTION C-C
SECTION D-D
CAST IRON DRAIN
REQUIRED ON EACH SIDE OF ROADWAY IN EACH SPAN. NONE REQUIRED IN END SPAN OVER UNPROTECTED SLOPES.
END SPAN
INTERMEDIATE SPAN
EXPANSION SPAN
SECTION B-B
BILL OF MATERIAL
20 FT. SPAN
24 FT. SPAN
PART SECTION AT EXPANSION JOINT
SECTION E-E
EXPANSION PLATES
PART PLAN
GENERAL NOTES:
STANDARD PLAN
R.C. DECK GIRDER - H15 LOADING
24'-0" CLEAR ROADWAY - 1'-6" SIDEWALKS
20'-0" AND 24'-0" SPANS
TO BE USED WITH STD. PLAN C-S No. 15
STATE OF LOUISIANA
DEPARTMENT OF HIGHWAYS
DESIGNED
DETAILED
TRACED
CHECKED
IN CHARGE OF
DATE
DESCRIPTION
BY
REVISIONS

125



QUANTITIES (ONE SPAN)					
BAR	SIZE	Nº	UNIT LENGTH	TOTAL LENGTH	LOCATION
A	#8	39	20'-10"	812'-6"	Bottom of Slab
A1	#8	34	19'-6"	663'-0"	Bottom of Slab
TOTAL #8 BARS = 1,475'-6" = 3,940 LBS.					
B	#6	17	33'-7"	570'-11"	Bottom of Slab
TOTAL #6 BARS = 570'-11" = 858 LBS.					
C	#4	15	34'-7"	518'-9"	Top of Slab
D	#4	31	19'-6"	604'-6"	Top of Slab & Sidewalk
D1	#4	8	19'-1"	152'-8"	Handrail Parapets
F	#4	52	4'-7"	238'-4"	Sidewalks & Slab
F1	#4	2	4'-4"	8'-8"	Sidewalk & Slab
E	#4	40	5'-11"	236'-8"	Handrail Parapets
TOTAL #4 BARS = 1,759'-7" = 1,175 LBS.					
TOTAL DEFORMED REINFORCING STEEL = 5,973 LBS.					
TOTAL CLASS "A" CONCRETE = 31.74 CU. YD.					
TOTAL PIPE HANDRAIL = 33.00 LIN. FT.					



QUANTITIES (ONE SPAN)					
BAR	SIZE	Nº	UNIT LENGTH	TOTAL LENGTH	LOCATION
A	#8	41	20'-10"	834'-2"	Bottom of Slab
A1	#8	32	19'-6"	624'-0"	Bottom of Slab
TOTAL #8 BARS = 1478'-2" = 3947 LBS.					
B	#6	17	33'-7"	570'-11"	Bottom of Slab
TOTAL #6 BARS = 570'-11" = 858 LBS.					
F	#5	86	5'-0"	430'-0"	Sidewalk and Slab
TOTAL #5 BARS = 430'-0" = 448 LBS.					
C	#4	15	34'-6"	517'-6"	Top of Slab
D	#4	33	19'-7"	646'-3"	Top of Slab & S.W.
U	#4	66	3'-9"	247'-6"	Handrail Parapet
TOTAL #4 BARS = 1411'-3" = 943 LBS.					
TOTAL DEFORMED REINF. STEEL = 6196 LBS.					
TOTAL CLASS "A" CONCRETE = 30.19 CU. YDS.					
TOTAL CONCRETE HANDRAIL = 39.00 LIN. FT.					

GENERAL NOTES:
CONSTRUCTION SPECIFICATIONS: Latest Approved in Department of Highways Std. Specs.
DESIGN SPECIFICATIONS: A.A.S.H.O. Std. Specs. for Hwy. Bridges, 196_, as amended to Dec. 31, 1960
LIVE LOAD: H20-S16-44
All Concrete to be Class "A"
Exposed Corners to have a 3/4" Chamfer, Unless Otherwise Noted.
Reinforcing Bars Shall be Intermediate or Hard Grade, A.S.T.M. A15 or Rail Steel, A.S.T.M. A16, Conforming with A.S.T.M. A305.
Dimensions Relating to Reinforcing Steel are to Bar Centers.
Premoulded Expansion Material, Poured Filler & Tar Paper to be Included in Price Bid for Class "A" Concrete.
Concrete and Reinforcing Steel in Handrail to be Paid for Per Lin. Ft. of Concrete Handrail. This Includes Bars L & L1.
R — Denotes Class 2 Rubbed Finish.

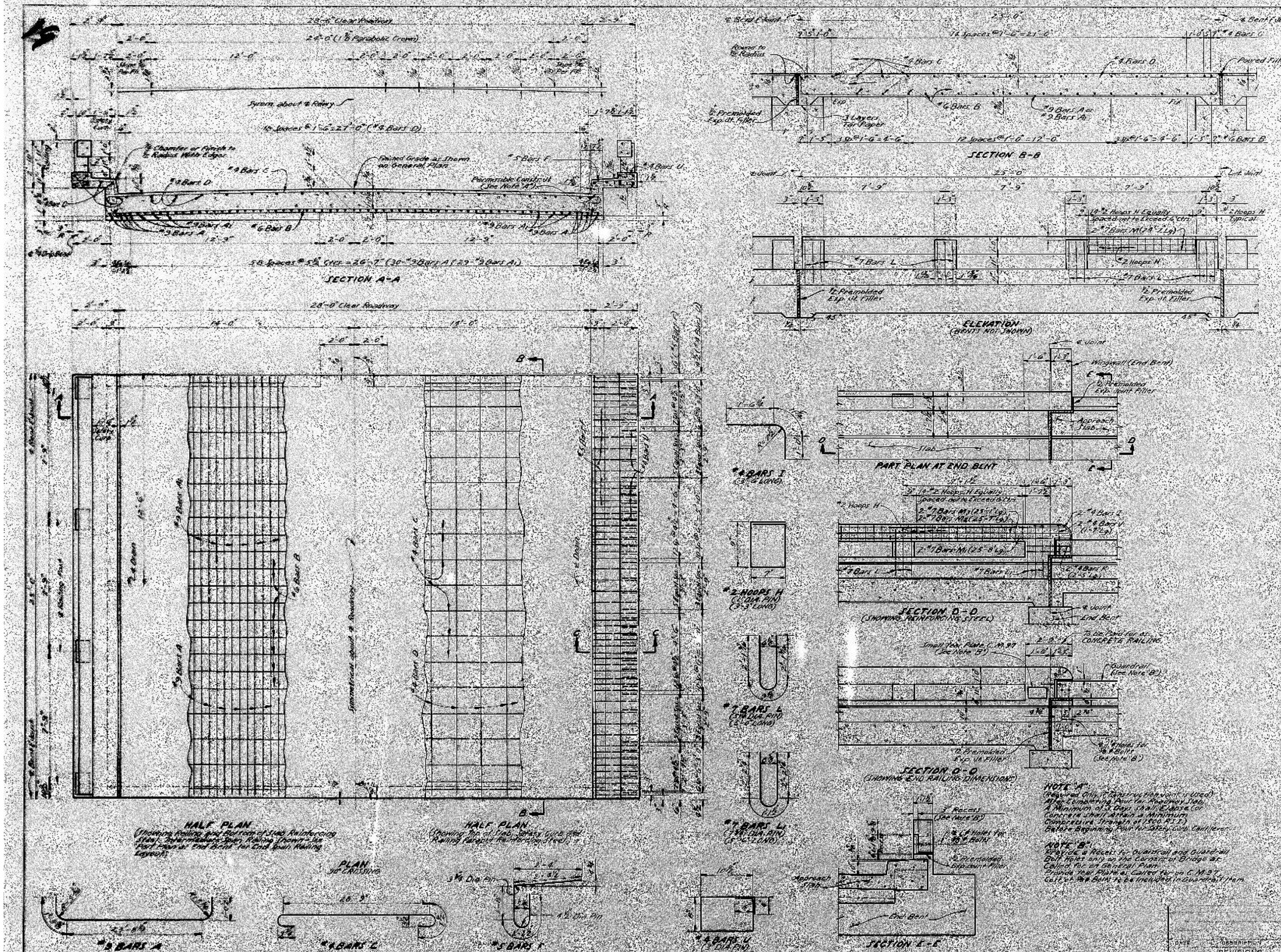
STANDARD PLAN
20'-0" CONCRETE SLAB SPAN
LIVE LOAD: H20-S16-44
28'-0" ROADWAY — 1'-6" SIDEWALKS
60° CROSSING — PARABOLIC CROWN
DATED July 18, 1962

STATE OF LOUISIANA
DEPARTMENT OF HIGHWAYS
DESIGNED — DETAILED — TRACED
CHECKED — CHECKED — CHECKED
BRIDGE DESIGN SECTION

REVISIONS — DESCRIPTION — BY

CSSI5C-60-28P

S	STATE PROJECT	PARISH	SHEET NO.
551(8)	67-05-14	OUACHITA	105



ESTIMATED QUANTITIES (ONE SLAB)					
BAR	SIZE	Nº	UNIT LENGTH	TOTAL LENGTH	LOCATION
A	#9	38	26'-3"	997'-6"	Bottom of Slab
A1	#9	29	24'-7"	712'-11"	Bottom of Slab
TOTAL #9 BARS = 1710'-5" = 5,815 LBS.					
B	#6	21	29'-1"	610'-9"	Bottom of Slab
TOTAL #6 BARS = 610'-9" = 917 LBS.					
F	#5	112	6'-3"	700'-0"	Safety Curb & Slab
TOTAL #5 BARS = 700'-0" = 730 LBS.					
C	#4	19	30'-0"	570'-0"	Top of Slab
D	#4	35	24'-7"	860'-5"	Top of Slab & S.C.
U	#4	84	3'-9"	315'-0"	Railing Parapet
TOTAL #4 BARS = 1745'-5" = 1,166 LBS.					
TOTAL DEFORMED REINFORCING STEEL = 8,628 LBS.					
TOTAL CLASS "A(A)" CONCRETE = 42.04 CU. YDS.					
TOTAL CONCRETE RAILING (INTER SPAN) = 49.00 LIN. FT.					
TOTAL CONCRETE RAILING (END SPAN) = 52.00 LIN. FT.					

GENERAL NOTES:

CONSTRUCTION SPECIFICATIONS: Latest Approved La. Dept. of Highways Standard Specifications.
DESIGN SPECIFICATIONS: A.A.S.H.O. Standard Specifications for Highway Bridges, 1961, as Amended by Interim Specs. 1964.
LIVE LOAD: HS 20-44.
All Concrete to be Class "A(A)".
Exposed Corners to have a ¾" Chamfer unless Otherwise Noted.
Reinforcing Steel Bars shall be Intermediate or Hard Grade A.S.T.M. A15 or A.S.T.M. A160, or Rail Steel A.S.T.M. A16 and Shall Conform to A.S.T.M. A305.
Dimensions Relating to Reinforcing Steel are to Bar Centers.
½" Premolded Expansion Joint Filler, Poured Filler and Tar Paper to be Included in Price Bid for Class "A(A)" Concrete.
Concrete and Reinforcing Steel in Concrete Railing above Top of 4" Sidewalk Curb to be Paid for Per Lin. Ft. of CONCRETE RAILING. This Includes Bars L and L1 that Project into Curb.
R ← Denotes Class 2 Rubbed Finish.

SPANS

STANDARD PLAN
25'-0" CONCRETE SLAB SPAN
LIVE LOAD: HS 20-44
28'-0" ROADWAY 1'-6" SAFETY CURBS
90° CROSSING PARABOLIC CROWN

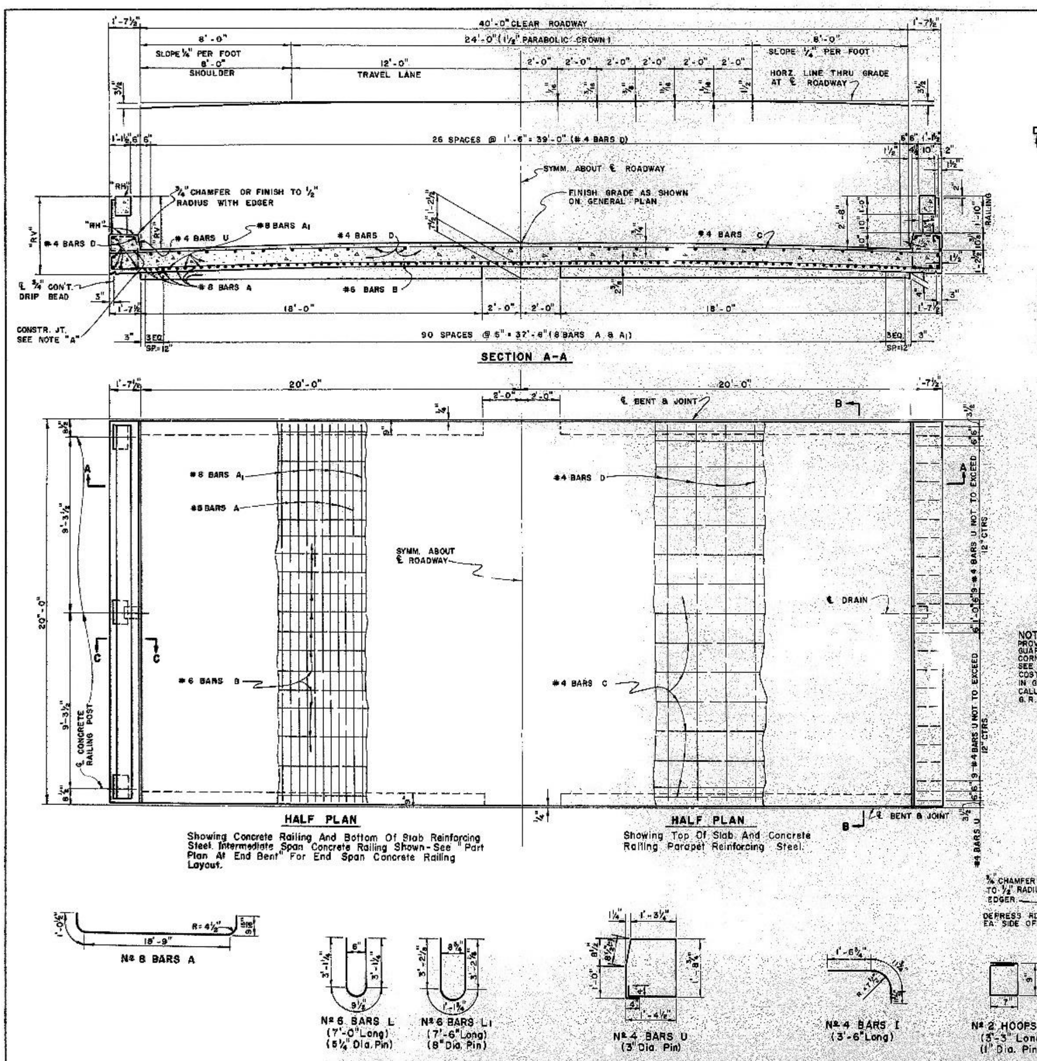
DATED Mar. 13, 1967

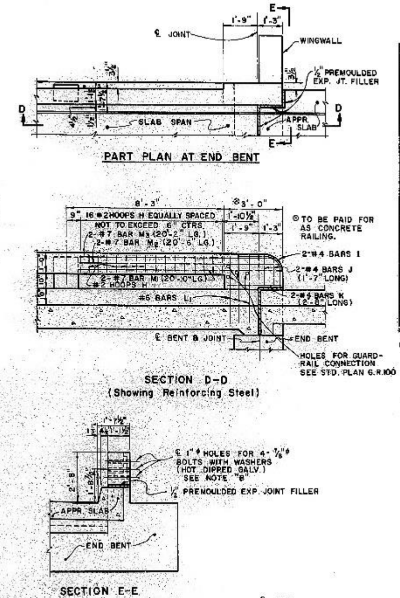
STATE OF LOUISIANA
DEPARTMENT OF HIGHWAYS

BRIDGE DESIGN SECTION

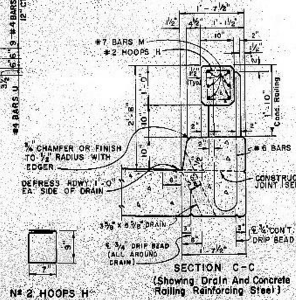
REVISIONS

CSSI5C-90-28PA(MOD.)66





NOTE "B"
PROVIDE GUARD RAIL BOLT HOLES ON ALL FOUR (4) CORNERS OF BRIDGE (SEE STD. PLAN G.R.100). SEE GEN. PLAN FOR ANY REQ'D. GUARD RAIL. COST OF BOLTS & WASHERS TO BE INCLUDED IN GUARDRAIL ITEM. PROVIDE YEAR PLATE AS CALLED FOR ON STD. PLAN C.M. 97 AND G.R. 100.



STATE PROJECT	PARISH	SHEET NO.
88-02-03	Bienville	105

ESTIMATED QUANTITIES (ONE SPAN)

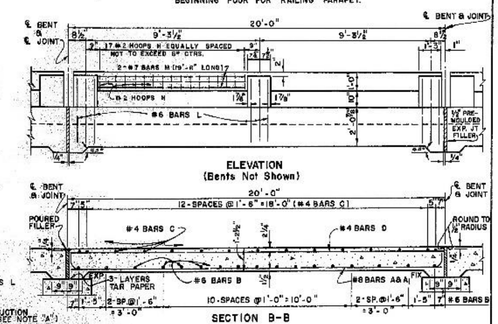
BAR	SIZE	Nº	UNIT LENGTH	TOTAL LENGTH	LOCATION
A	#8	52	20'-10"	1083'-4"	BOTTOM OF SLAB
A1	#8	45	19'-7"	881'-3"	BOTTOM OF SLAB
TOTAL #8 BARS = 1964'-7" = 5245 LBS.					
B	#6	17	42'-11"	729'-7"	BOTTOM OF SLAB
TOTAL #6 BARS = 729'-7" = 1096 LBS.					
C	#4	15	*44'-5"	666'-3"	TOP OF SLAB
D	#4	39	19'-7"	763'-9"	TOP OF SLAB & RAILING PARAPET
U	#4	48	6'-9"	324'-0"	RAILING PARAPET
TOTAL #4 BARS = 1754'-0" = 1172 LBS.					
TOTAL DEFORMED REINFORCING STEEL = 7513 LBS.					
CLASS A CONCRETE FOR SUPERSTRUCTURES = 41.52 CU. YDS.					
CONCRETE RAILING (INTERMEDIATE SPAN) = 39.67 LIN FT.					
CONCRETE RAILING (END SPAN) = 42.33 LIN FT.					

*INCLUDES 1'-8" MIN. LAP SPLICE (STAGGER ALL SPLICES).

GENERAL NOTES:
CONSTRUCTION SPECIFICATIONS: LATEST APPROVED LA. DEPT. OF HIGHWAYS STANDARD SPECIFICATIONS, SPECIAL PROVISIONS & SUPPLEMENTAL SPECS.
DESIGN SPECIFICATIONS: A.A.S.H.O. STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, 1969 AND INTERIM SPECIFICATIONS, 1972.
LIVE LOAD: HS20-44
ALL CONCRETE TO BE CLASS A.
EXPOSED CORNERS TO HAVE 3/4" CHAMFER UNLESS OTHERWISE NOTED.

DIMENSIONS RELATING TO REINFORCING STEEL ARE TO BAR CENTERS.
1/2" PREMOULDED EXPANSION JOINT FILLER, POURED FILLER AND TAR PAPER TO BE INCLUDED IN PRICE BID FOR CLASS A CONC. FOR SPRSTRS.
CONCRETE AND REINFORCING STEEL IN CONCRETE RAILING TO BE PAID FOR PER LIN. FT. OF CONCRETE RAILING. THIS INCLUDES BARS L, L1, I, J & K.
"RV" DENOTES EXTERIOR VERTICAL & SLOPING FACES & CHAMFERS, AS SEEN IN ELEVATION, & "RH" DENOTES HORIZONTAL SURFACES WHICH ARE TO RECEIVE A CLASS "2" RUBBED FINISH. ALL OTHER SURFACES ARE TO RECEIVE A CLASS "1" ORDINARY SURFACE FINISH.

NOTE "A".
AFTER COMPLETING POUR FOR ROADWAY SLAB, A MINIMUM OF 3 DAYS SHALL ELAPSE (OR CONCRETE IN ROADWAY SLAB SHALL ATTAIN A MINIMUM COMPRESSIVE STRENGTH OF 1500 P.S.I.) BEFORE BEGINNING POUR FOR RAILING PARAPET.



REQUIRED:
ONE DRAIN EACH SIDE OF RDWY. AS SHOWN ON PLAN. NO DRAINS REQ'D. IN END SPANS OVER UNPROTECTED SLOPES.

BLOCK USED IN FORMING OPENING MAY BE SLIGHTLY TAPERED TO FACILITATE WITHDRAWAL.

SPANS

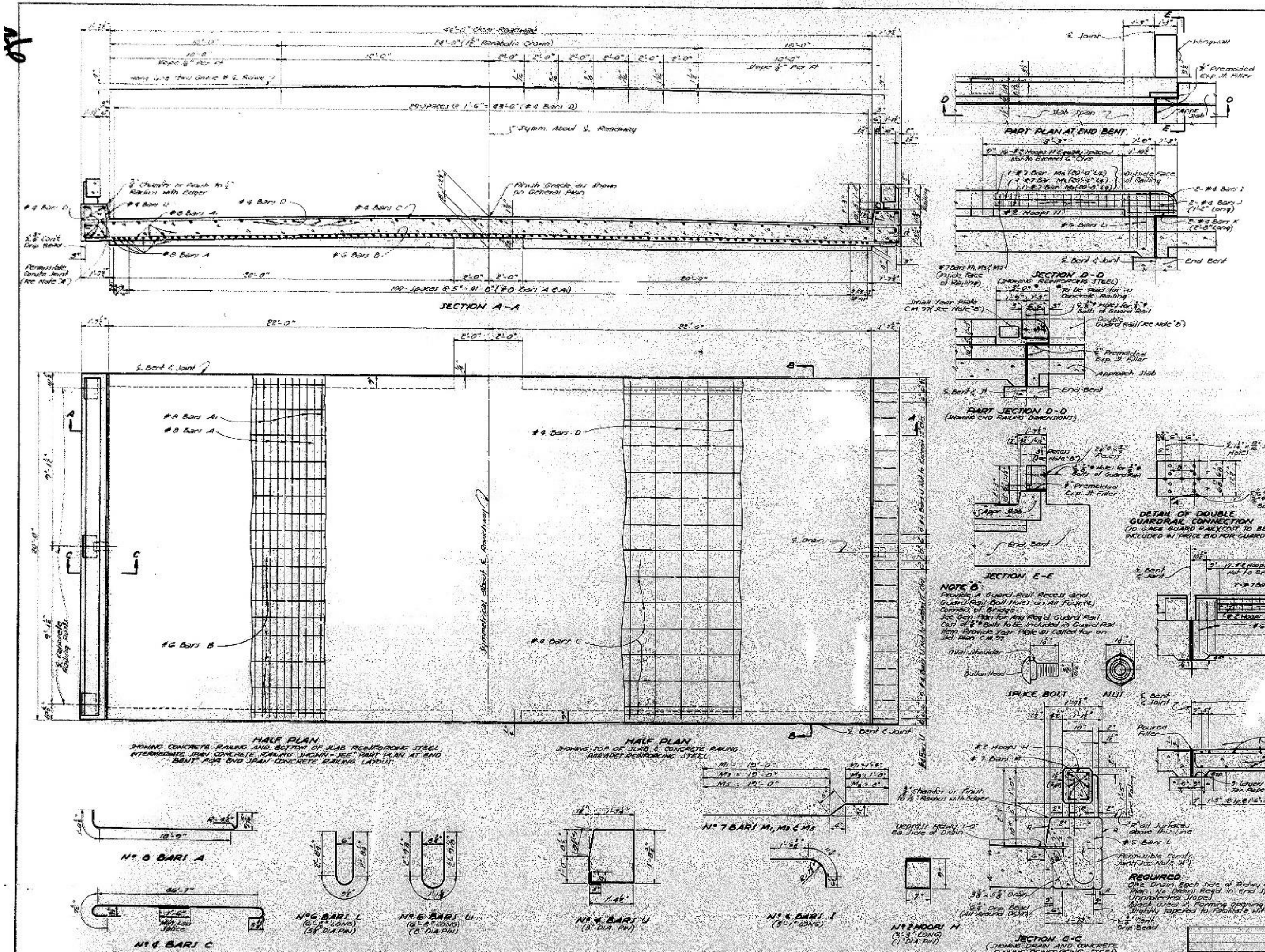
STANDARD PLAN
20'-0" CONCRETE SLAB SPAN
LIVE LOAD: HS 20-44
40'-0" ROADWAY — 6" BRUSH CURB
90° CROSSING — PARABOLIC CROWN
DATED JAN. 29, 1971

DATE	DESCRIPTION	BY
3-21-73	General Notes	GSH
3-14-73	Gen. Notes & Conc. Rail	DSH
3-2-75	GEN. NOTES	D.S.H.
1-25-72	RETRACED	E.D./KW
12-28-71	GUARDRAIL CONNECTION	C.B.J.
5-18-71	#4 BARS C & RUBBED FINISH	D.S.H.

REVISIONS

STATE OF LOUISIANA
DEPARTMENT OF HIGHWAYS
DESIGNED Louis Valenti — DETAILED M. Burgos — TRACED E. St. Germain
CHECKED R.B. — CHECKED E. McClendon — CHECKED Neil J. Albrecht
BRIDGE DESIGN SECTION

CSSBC-90-40P



	STATE PROJECT	PARISH	SHEET NO
	88-05-08	BIENVILLE	106

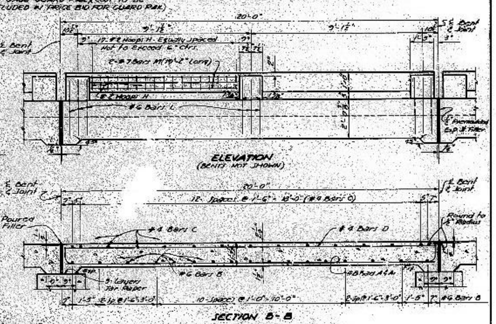
ESTIMATED QUANTITIES (ONE SPAN)					
BAR	SIZE	Nº	UNIT LENGTH	TOTAL LENGTH	LOCATION
A	#8	57	20'-10"	1187'-6"	Bottom of Slab
A1	#8	50	19'-7"	979'-2"	Bottom of Slab
TOTAL #8 BARS = 2166'-8" = 5785 LBS.					
B	#6	17	46'-11"	797'-7"	Bottom of Slab
TOTAL #6 BARS = 797'-7" = 1198 LBS.					
C	#4	15	*49'-4"	740'-0"	Top of Slab
D	#4	42	19'-7"	822'-6"	Top of Slab & Railing Parapet
U	#4	49	6'-9	325'-0"	Railing Parapet
TOTAL #4 BARS = 1887'-6" = 1261 LBS.					
TOTAL DEFORMED REINFORCING STEEL					= 8244 LBS.
CLASS "A(A)" CONCRETE					= 45.80 CU. YDS.
CONCRETE RAILING (INTERMEDIATE SPAN)					= 39.00 LIN. FT.
CONCRETE RAILING (END SPAN)					= 42.00 LIN. FT.

*Includes 1'-6" Min. Lap Splice. (Stagger all Splices)

GENERAL NOTES:

CONSTRUCTION SPECIFICATIONS: Latest Approved La. Dept. of Highways Standard Specifications Dated Oct. 1966.
DESIGN SPECIFICATIONS: A.A.S.H.O. Standard Specifications for Highway Bridges, 1965, As Amended by Interim Specs. 1966-67.
LIVE LOAD: HS20-44.
All Concrete to be Class "A(A)".
Exposed Corners to have ¾" Chamfer. Unless Otherwise Noted Reinforcing Steel Bars Shall be Intermediate or Hard Grade, A.S.T.M. A15 or A.S.T.M. A160 or Rail Steel A.S.T.M. A16, and Shall Conform to A.S.T.M. A305.
Dimensions Relating to Reinforcing Steel are to Bar Centers.
½" Premolded Expansion Joint Filler, Poured Filler and Tar Paper to be Included in Price Bid for Class "A(A)" Concrete.
Concrete and Reinforcing Steel in Concrete Railing to be Paid for per Lin. Ft. of Concrete Railing. This includes Bars L, U, I, J & K.
R — Denotes Class 2 Rubbed Finish.

NOTE "A": (Req'd. only if Construction Joint is Used) After Completing Pour for Roadway Slab, A Minimum of 3-Days Shall Elapse (or Concrete in Roadway Slab Shall Attain a Minimum Compressive Strength of 1500 p.s.i.) Before Beginning Pour for Railing Parapet.



SPANS

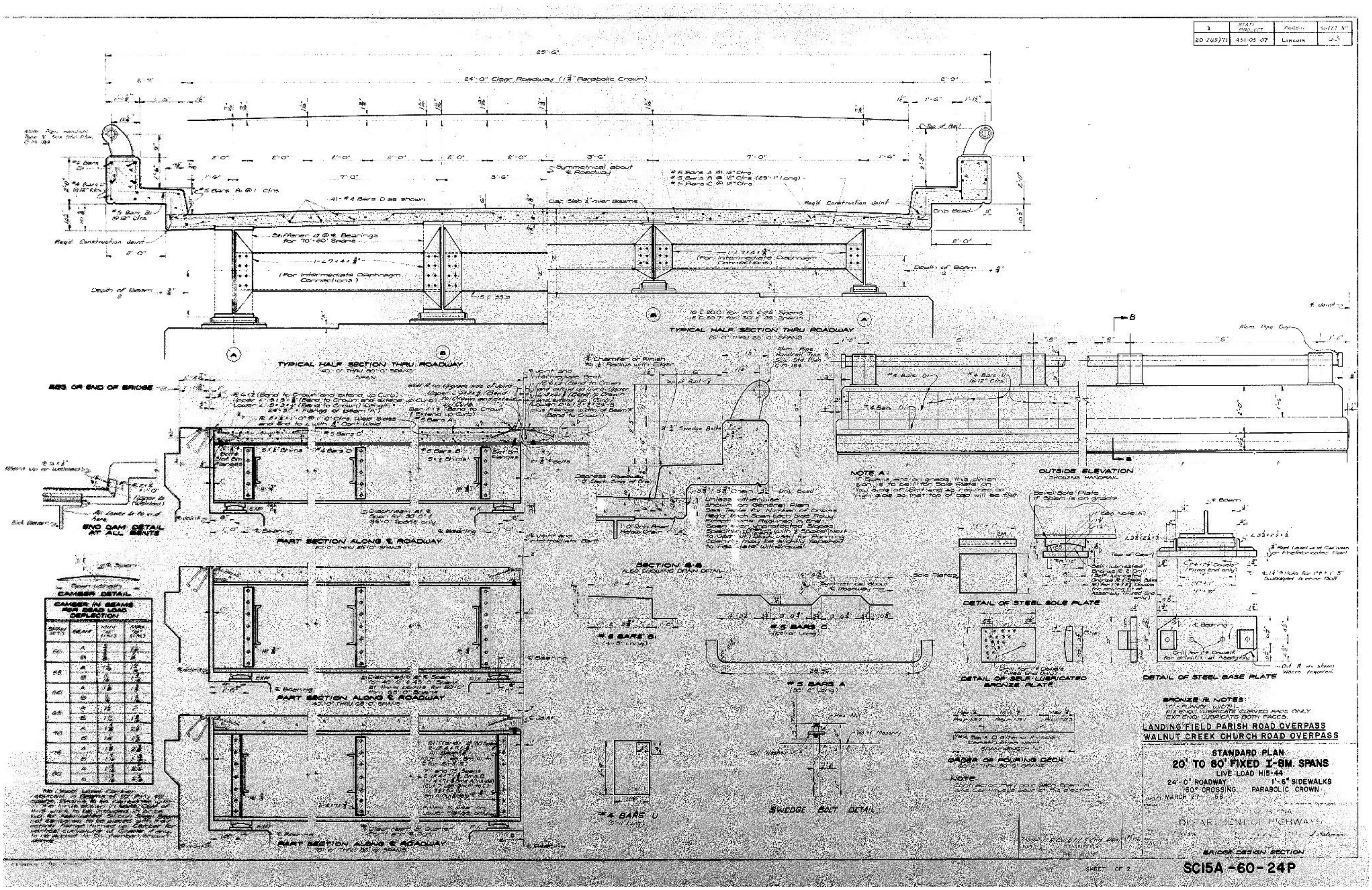
STANDARD PLAN
20'-0" CONCRETE SLAB SPAN
LIVE LOAD: HS 20-44
44'-0" ROADWAY — 6" BRUSH CURB
90° CROSSING — PARABOLIC CROWN
DATED Feb. 1968

DATE	DESCRIPTION	BY
8-2-68	Guard Rail Conn. & "M" Bars	[illegible]

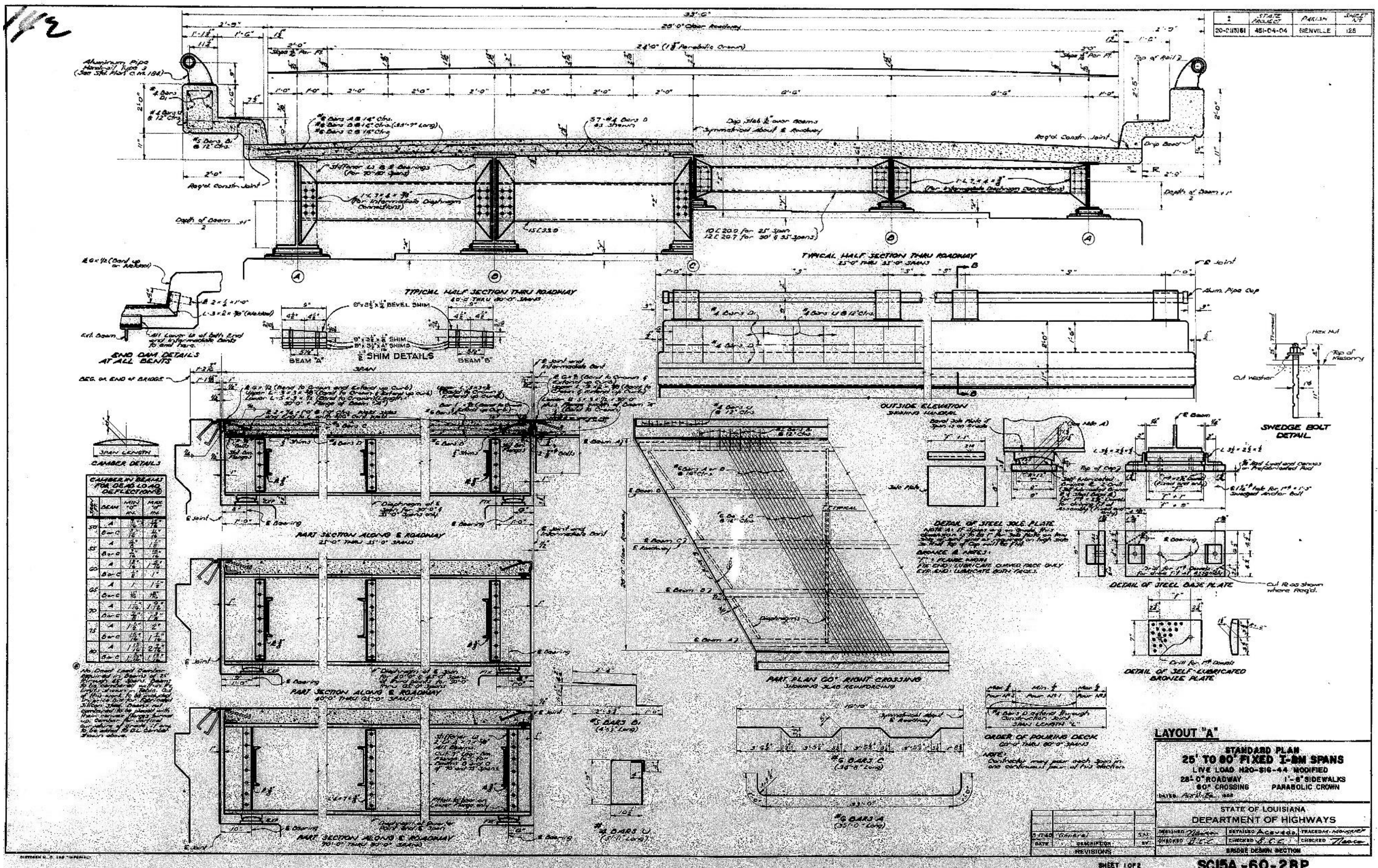
REVISIONS

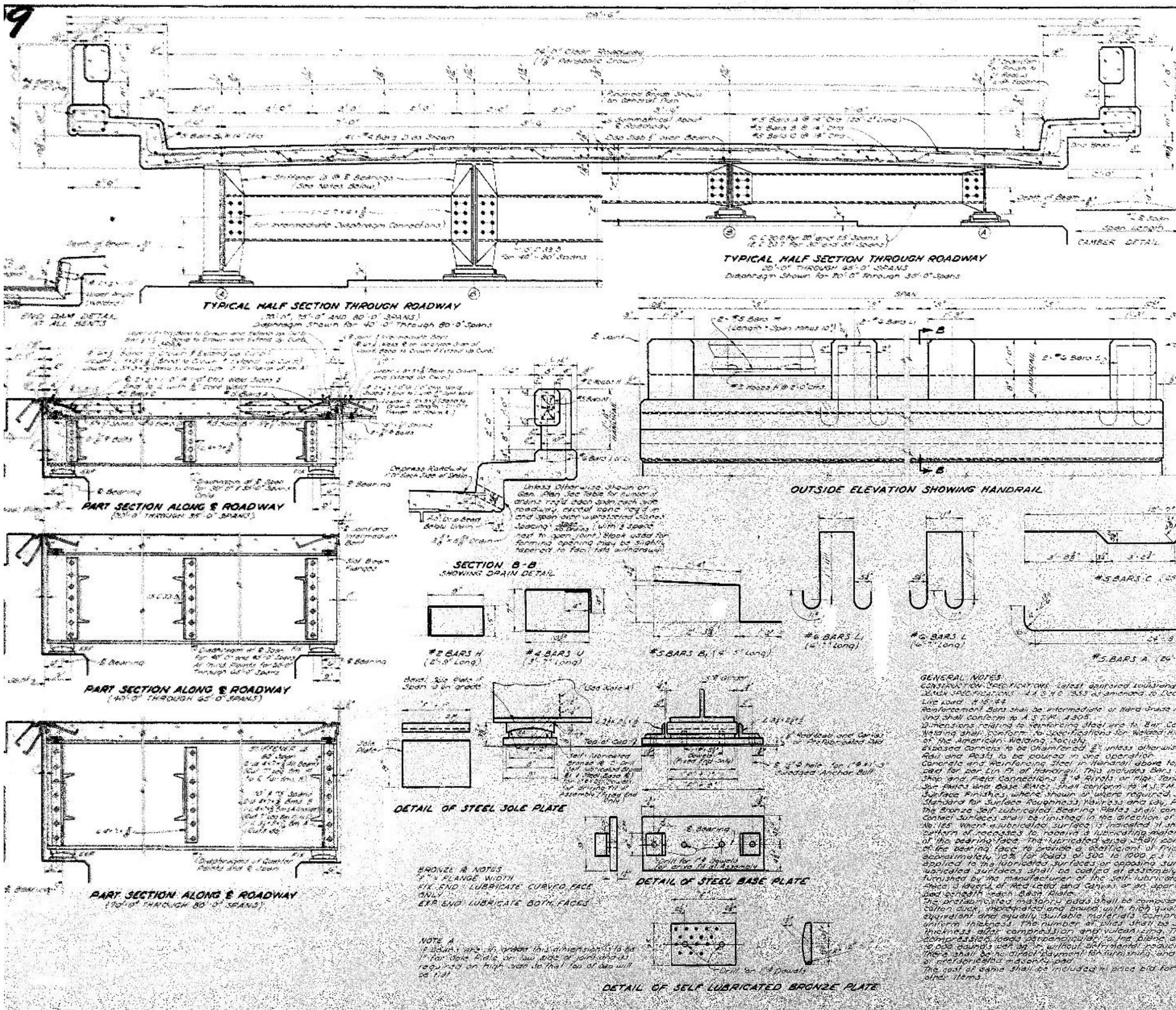
STATE OF LOUISIANA
DEPARTMENT OF HIGHWAYS
DESIGNED E. Bazzi — DETAILED [illegible] — TRACED [illegible]
CHECKED K. Sinno — CHECKED E. Bazzi — CHECKED [illegible]
BRIDGE DESIGN SECTION

CSSBC-90-44P



24'-0" Clear Roadway (1 3/8" Parabolic Crown)
TYPICAL HALF SECTION THRU ROADWAY
TYPICAL HALF SECTION THRU ROADWAY
PART SECTION ALONG ℄ ROADWAY
PART SECTION ALONG ℄ ROADWAY
PART SECTION ALONG ℄ ROADWAY
END DAM DETAIL AT ALL BENTS
CAMBER DETAIL
SECTION B-B
OUTSIDE ELEVATION
SHOWING HANDRAIL
NOTE A
DETAIL OF STEEL SOLE PLATE
DETAIL OF SELF-LUBRICATED BRONZE PLATE
DETAIL OF STEEL BASE PLATE
SWEDGE BOLT DETAIL
ORDER OF POURING DECK
BRONZE ℞ NOTES:
FIX END: LUBRICATE CURVED FACE ONLY
EXP. END: LUBRICATE BOTH FACES.
LANDING FIELD PARISH ROAD OVERPASS
WALNUT CREEK CHURCH ROAD OVERPASS
STANDARD PLAN
20' TO 80' FIXED I-BM. SPANS
LIVE LOAD H15-44
24'-0" ROADWAY
1'-6" SIDEWALKS
60° CROSSING
PARABOLIC CROWN
MARCH 27 58
DEPARTMENT OF HIGHWAYS
BRIDGE DESIGN SECTION
SHEET 1 OF 2
SC15A-60-24P


LAYOUT "A"
STANDARD PLAN
25' TO 60' FIXED I-BM SPANS
LIVE LOAD H20-S16-44 MODIFIED
28'-0" ROADWAY
1'-6" SIDEWALKS
60° CROSSING
PARABOLIC CROWN
STATE OF LOUISIANA
DEPARTMENT OF HIGHWAYS
BRIDGE DESIGN SECTION
REVISIONS
SHEET 1 OF 2
SC15A-60-28P
TYPICAL HALF SECTION THRU ROADWAY
OUTSIDE ELEVATION
SWEDGE BOLT DETAIL
END DAM DETAILS AT ALL BENTS
SHIM DETAILS
CAMBER DETAILS
PART SECTION ALONG ℄ ROADWAY
PART PLAN 60° RIGHT CROSSING
DETAIL OF STEEL SOLE PLATE
DETAIL OF STEEL BASE PLATE
DETAIL OF SELF-LUBRICATED BRONZE PLATE
ORDER OF POURING DECK
Contractor may pour each span in one continuous pour at his election.



BEAM SIZES AND DIMENSIONS

SPAN FEET	BEAM A	BEAM B								SPAN FEET
20	16WF36	16WF40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	20
25	18WF50	18WF50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	25
30	21WF63	21WF62	[illegible]	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	30
35	24WF76	24WF76	[illegible]	[illegible]	[illegible]	4	[illegible]	[illegible]	[illegible]	35
40	24WF84	24WF84	[illegible]	[illegible]	[illegible]	4	[illegible]	[illegible]	[illegible]	40
45	27WF102	27WF94	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	45
50	30WF108	30WF108	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	50
55	30WF124	30WF108	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	55
60	33WF130	33WF130	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	60
65	33WF152	33WF130	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	65
70	36WF170	36WF150	[illegible]	[illegible]	[illegible]	8	[illegible]	60	3	70
75	36WF194	36WF160	[illegible]	[illegible]	[illegible]	8	[illegible]	[illegible]	[illegible]	75
80	36WF230	36WF182	[illegible]	[illegible]	[illegible]	9	[illegible]	[illegible]	4	80

QUANTITIES

SPAN FEET	CLASS "A" CONCRETE CU. YDS	DEF. REINF. STEEL LBS	FAB. SILICON STEEL LBS	FABRICATED CARBON STEEL END SPAN LBS	FABRICATED CARBON STEEL INT. SPAN LBS	CONC. HANDRAIL LIN. FT.	SPAN FEET
20	12.21	2110	3570	3655	3523	39.0	20
25	15.27	2683	5463	37?5	3583	49.0	25
30	18.32	3190	7257	4424	4292	59.0	30
35	21.37	3727	10583	4546	4414	69.0	35
40	24.43	4234	14181	5385	5253	79.0	40
45	27.47	4848	17575	5527	5395	89.0	45
50	30.52	5354	21528	6439	6507	99.0	50
55	33.57	5892	25443	6439	6507	109.0	55
60	36.60	6501	31113	6766	6574	119.0	60
65	39.65	7013	36566	6711	6579	129.0	65
70	42.69	7548	44693	8282	8090	139.0	70
75	45.74	8056	52988	8228	8096	149.0	75
80	48.70	8625	45783	8529	8397	159.0	80

MOMENTS AND REACTIONS

[illegible]

ORDER OF POURING DECKS
(40'-0" THROUGH 80'-0" SPANS)

Pour No. 2 | Pour No. 1 | Pour No. 3

NOTE: Contractor may pour each span in one continuous pour at his election.

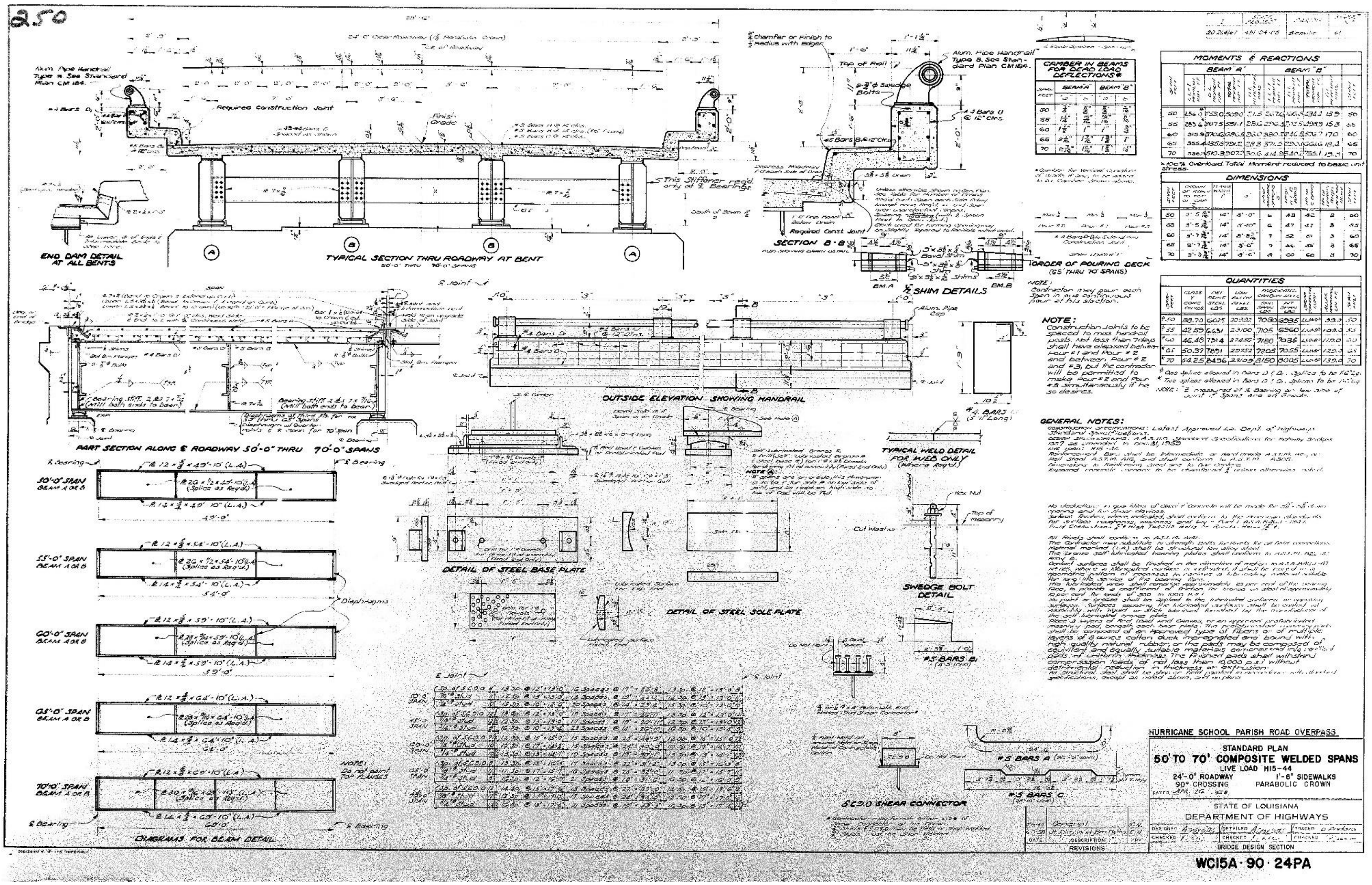
PARISH ROAD OVERPASS (STA. 701+39.59)

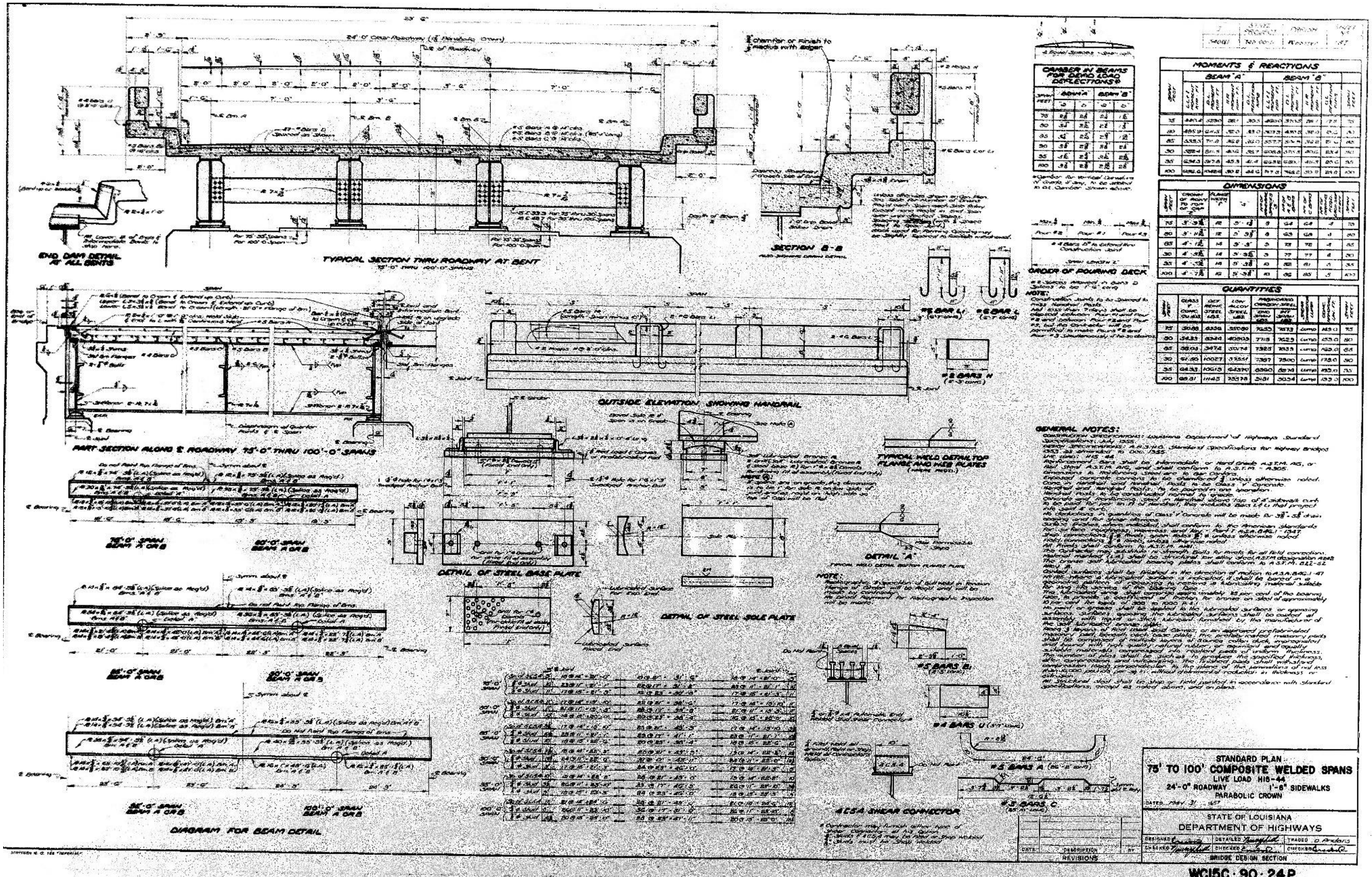
STANDARD PLAN
20' TO 80' FIXED I-BM SPANS
LIVE LOAD H15-44
24'-0" ROADWAY 1'-6" SIDEWALKS
90° CROSSING PARABOLIC CROWN

STATE OF LOUISIANA
DEPARTMENT OF HIGHWAYS
BRIDGE DESIGN SECTION

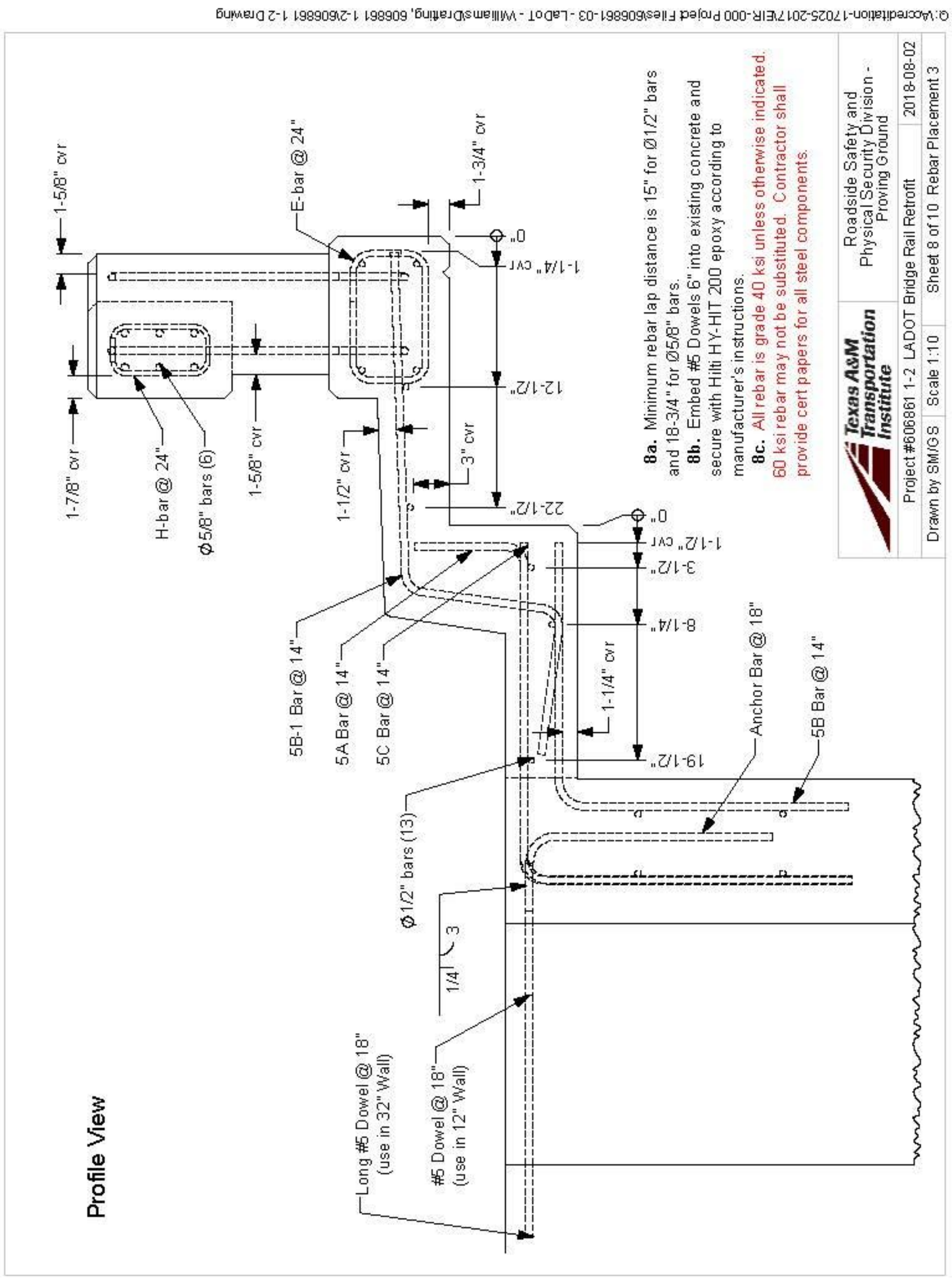
REVISIONS

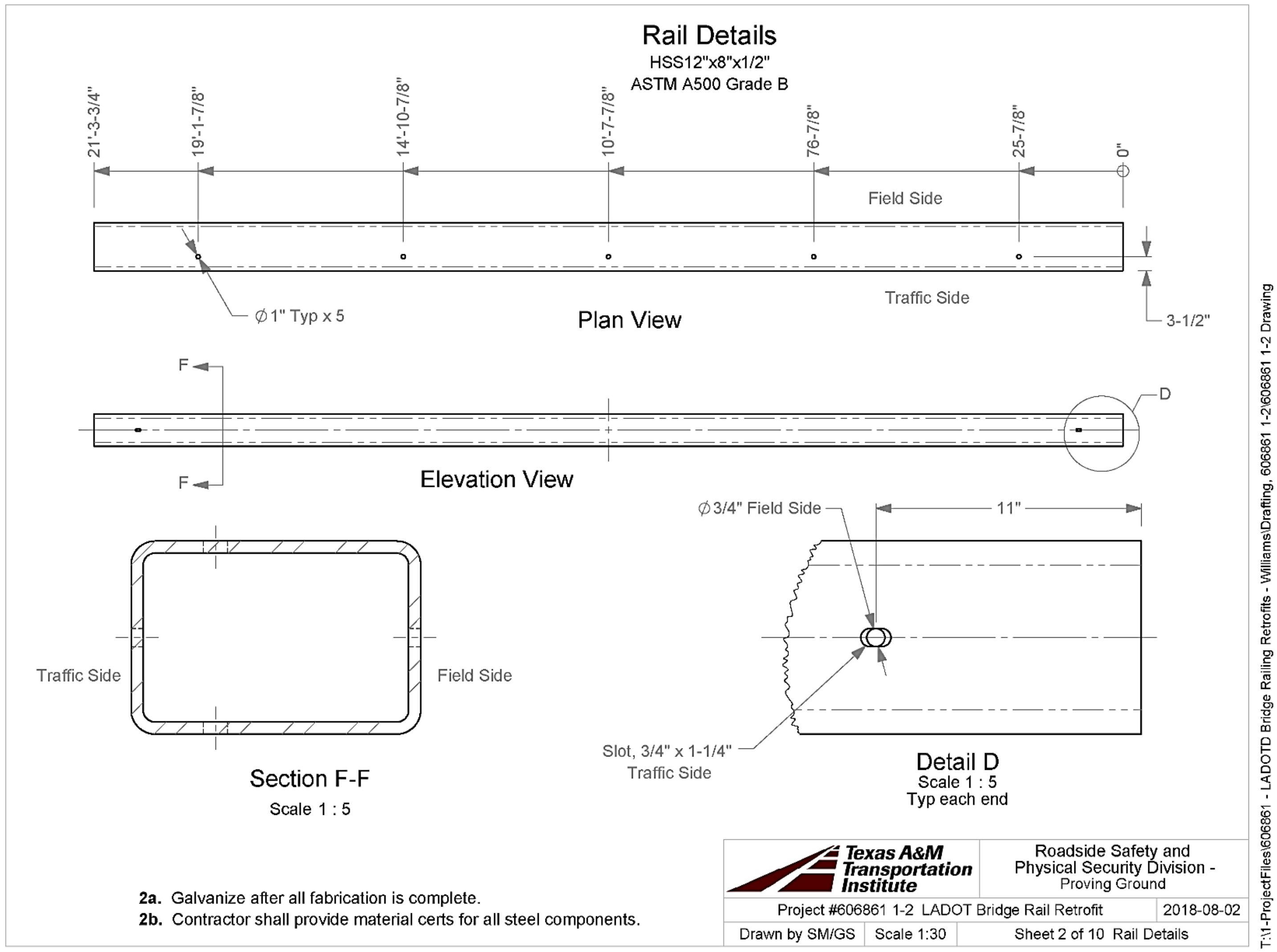
SC15C-90-24P


250
END DAM DETAIL AT ALL BENTS
TYPICAL SECTION THRU ROADWAY AT BENT
SECTION B-B
1/2 SHIM DETAILS
ORDER OF POURING DECK (65 THRU 70 SPANS)
CAMBER IN BEAMS FOR DEAD LOAD DEFLECTIONS
MOMENTS & REACTIONS
DIMENSIONS
QUANTITIES
PART SECTION ALONG ℄ ROADWAY 50'-0" THRU 70'-0" SPANS
OUTSIDE ELEVATION SHOWING HANDRAIL
NOTE:
GENERAL NOTES:
TYPICAL WELD DETAIL FOR WEB ONLY
DETAIL OF STEEL BASE PLATE
DETAIL OF STEEL SOLE PLATE
SWEDGE BOLT DETAIL
50'-0" SPAN BEAM A OR B
55'-0" SPAN BEAM A OR B
60'-0" SPAN BEAM A OR B
65'-0" SPAN BEAM A OR B
70'-0" SPAN BEAM A OR B
DIAGRAMS FOR BEAM DETAIL
SC9.0 SHEAR CONNECTOR
#5 BARS A
#5 BARS C
#5 BARS B1
REVISIONS
HURRICANE SCHOOL PARISH ROAD OVERPASS
STANDARD PLAN
50' TO 70' COMPOSITE WELDED SPANS
LIVE LOAD H15-44
24'-0" ROADWAY
1'-6" SIDEWALKS
90° CROSSING
PARABOLIC CROWN
STATE OF LOUISIANA
DEPARTMENT OF HIGHWAYS
BRIDGE DESIGN SECTION
WC15A · 90 · 24PA

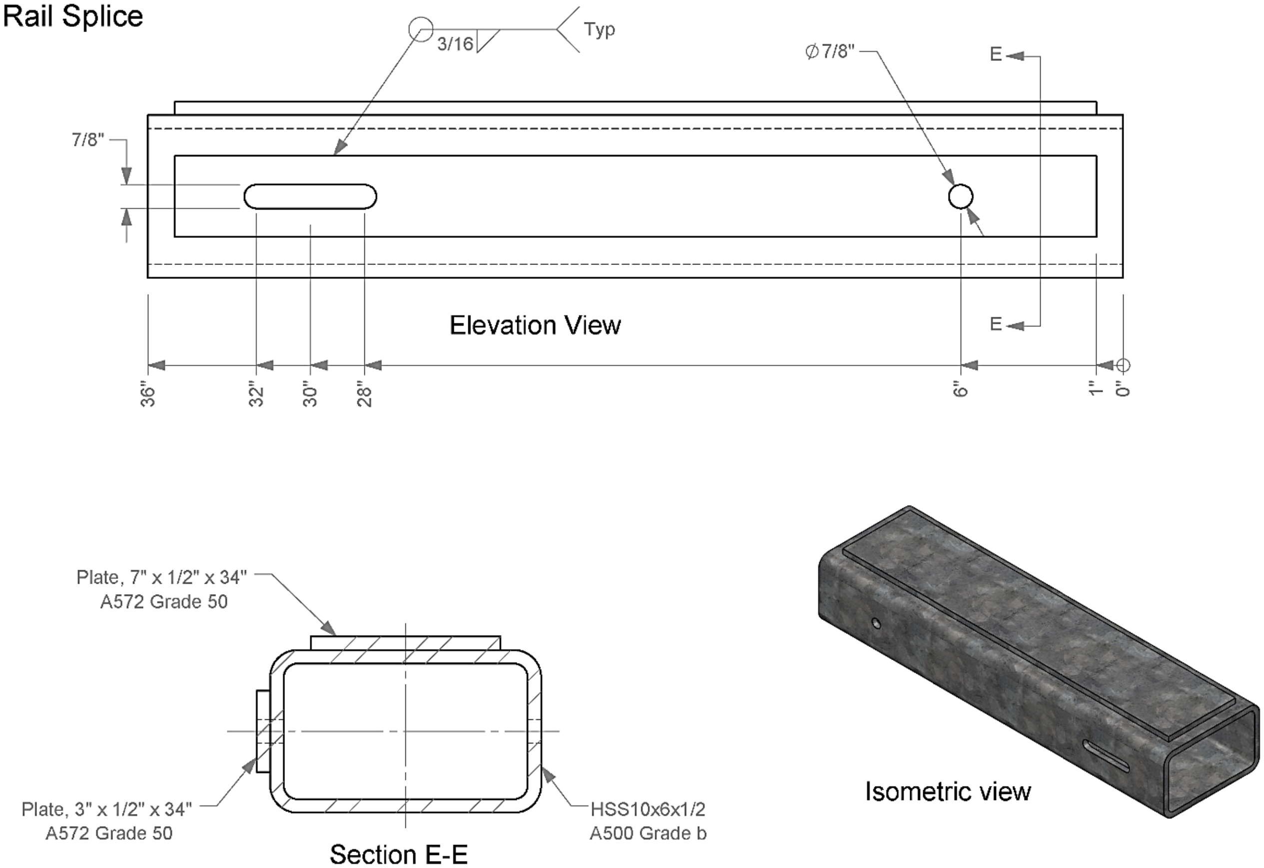

TYPICAL SECTION THRU ROADWAY AT BENT
END DAM DETAIL AT ALL BENTS
SECTION B-B
PART SECTION ALONG ℄ ROADWAY 75'-0" THRU 100'-0" SPANS
OUTSIDE ELEVATION SHOWING HANDRAIL
ORDER OF POURING DECK
CAMBER IN BEAMS FOR DEAD LOAD DEFLECTIONS
MOMENTS & REACTIONS
DIMENSIONS
QUANTITIES
GENERAL NOTES:
TYPICAL WELD DETAIL TOP FLANGE AND WEB PLATES
DETAIL "A"
DETAIL OF STEEL BASE PLATE
DETAIL OF STEEL SOLE PLATE
4CSA SHEAR CONNECTOR
DIAGRAM FOR BEAM DETAIL
75'-0" SPAN BEAM A OR B
80'-0" SPAN BEAM A OR B
85'-0" SPAN BEAM A OR B
90'-0" SPAN BEAM A OR B
95'-0" SPAN BEAM A OR B
100'-0" SPAN BEAM A OR B
STANDARD PLAN
75' TO 100' COMPOSITE WELDED SPANS
LIVE LOAD H15-44
24'-0" ROADWAY 1'-6" SIDEWALKS
PARABOLIC CROWN
STATE OF LOUISIANA
DEPARTMENT OF HIGHWAYS
BRIDGE DESIGN SECTION
REVISIONS
WC15C · 90 · 24P

Appendix B. Details of Louisiana Retrofit Post and Beam with Safety Walk for Tests 606861-1&2




Rail Details
HSS12"x8"x1/2"
ASTM A500 Grade B
21'-3-3/4"
19'-1-7/8"
14'-10-7/8"
10'-7-7/8"
76-7/8"
25-7/8"
0"
Field Side
Traffic Side
3-1/2"
∅1" Typ x 5
Plan View
F
F
D
Elevation View
∅3/4" Field Side
11"
Traffic Side
Field Side
Slot, 3/4" x 1-1/4"
Traffic Side
Section F-F
Scale 1 : 5
Detail D
Scale 1 : 5
Typ each end
2a. Galvanize after all fabrication is complete.
2b. Contractor shall provide material certs for all steel components.
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #606861 1-2 LADOT Bridge Rail Retrofit
2018-08-02
Drawn by SM/GS
Scale 1:30
Sheet 2 of 10 Rail Details
T:\1-ProjectFiles\606861 - LADOTD Bridge Railing Retrofits - Williams\Drafting, 606861 1-2\606861 1-2 Drawing

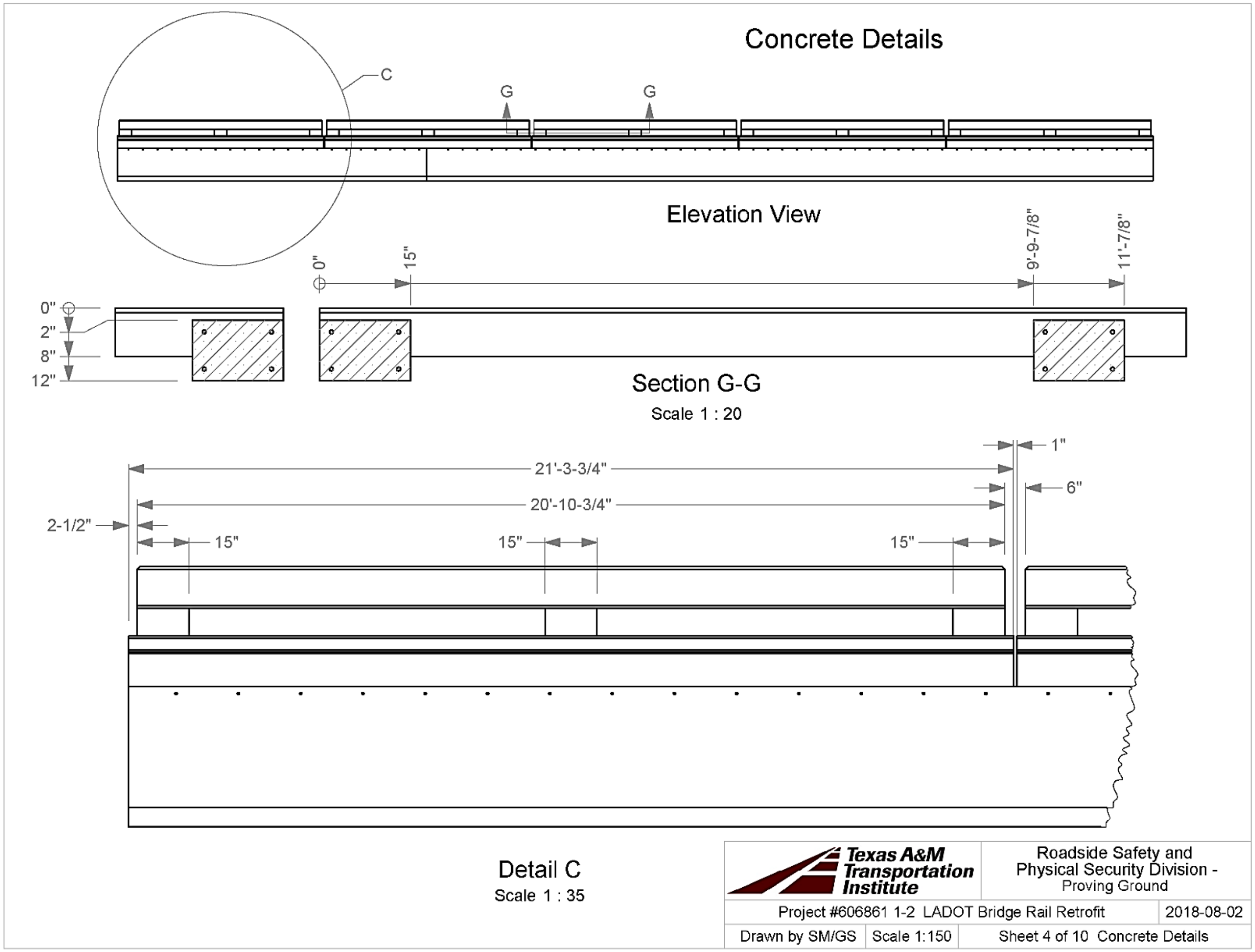
Rail Splice



3a. Galvanize after all fabrication is complete.
3b. Contractor shall provide material certs for all steel components.

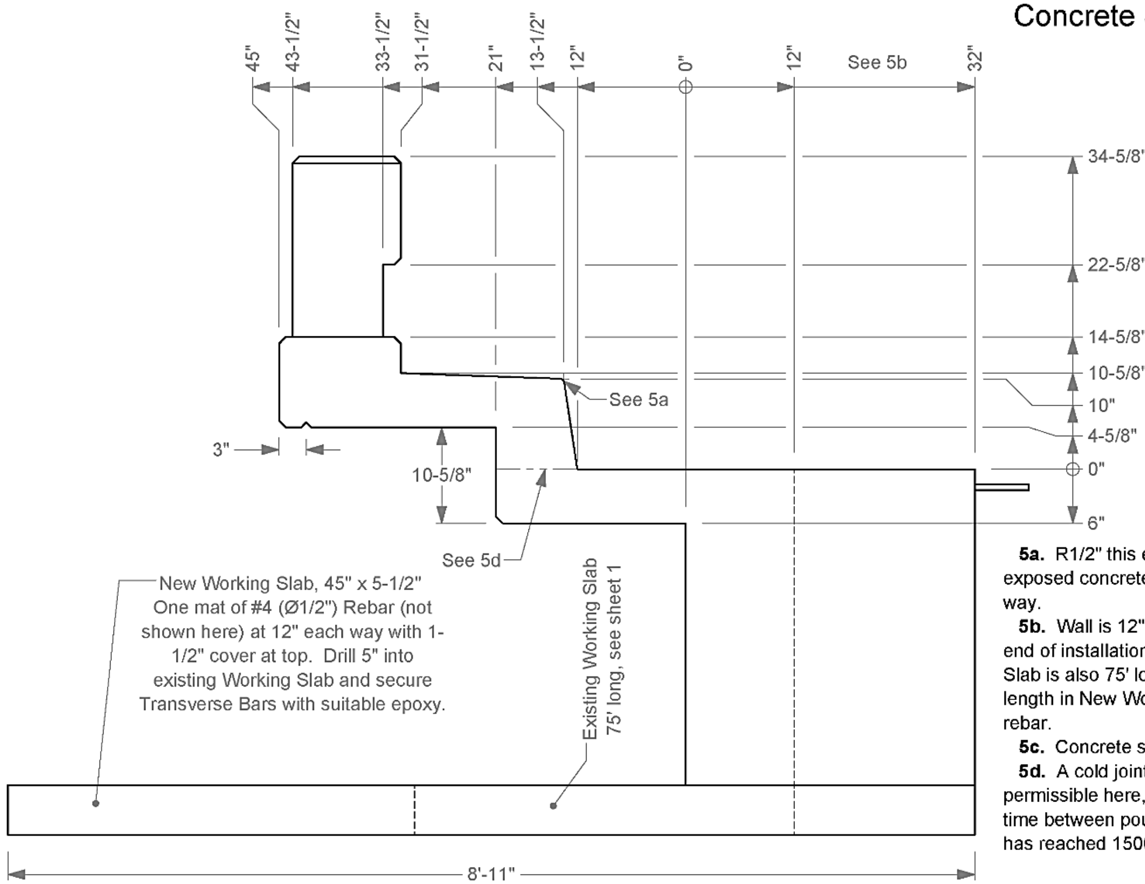
Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #606861 1-2 LADOT Bridge Rail Retrofit		2018-08-02
Drawn by SM/GS	Scale 1:5	Sheet 3 of 10 Rail Splice

T:\1-ProjectFiles\606861 - LADOTD Bridge Railing Retrofits - Williams\Drafting, 606861 1-2\606861 1-2 Drawing



T:\1-ProjectFiles\606861 - LADOTD Bridge Railing Retrofits - Williams\Drafting, 606861 1-2\606861 1-2 Drawing

Concrete Section



5a. R1/2" this edge. Drip Stop and other exposed concrete edges as shown 3/4" each way.

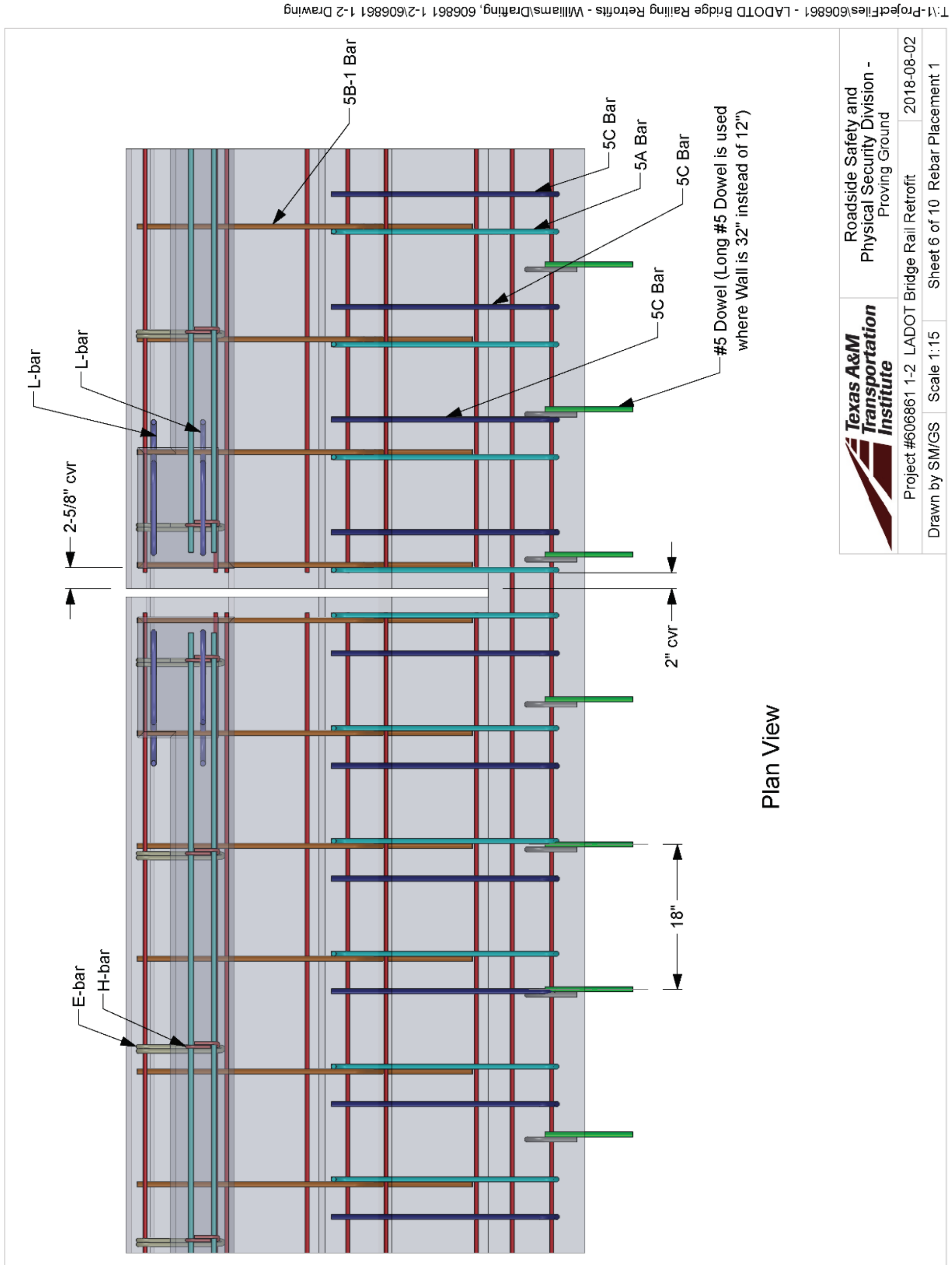
5b. Wall is 12" for 75', then 32" thick to end of installation. The Existing Working Slab is also 75' long. Incorporate additional length in New Working Slab, with same rebar.

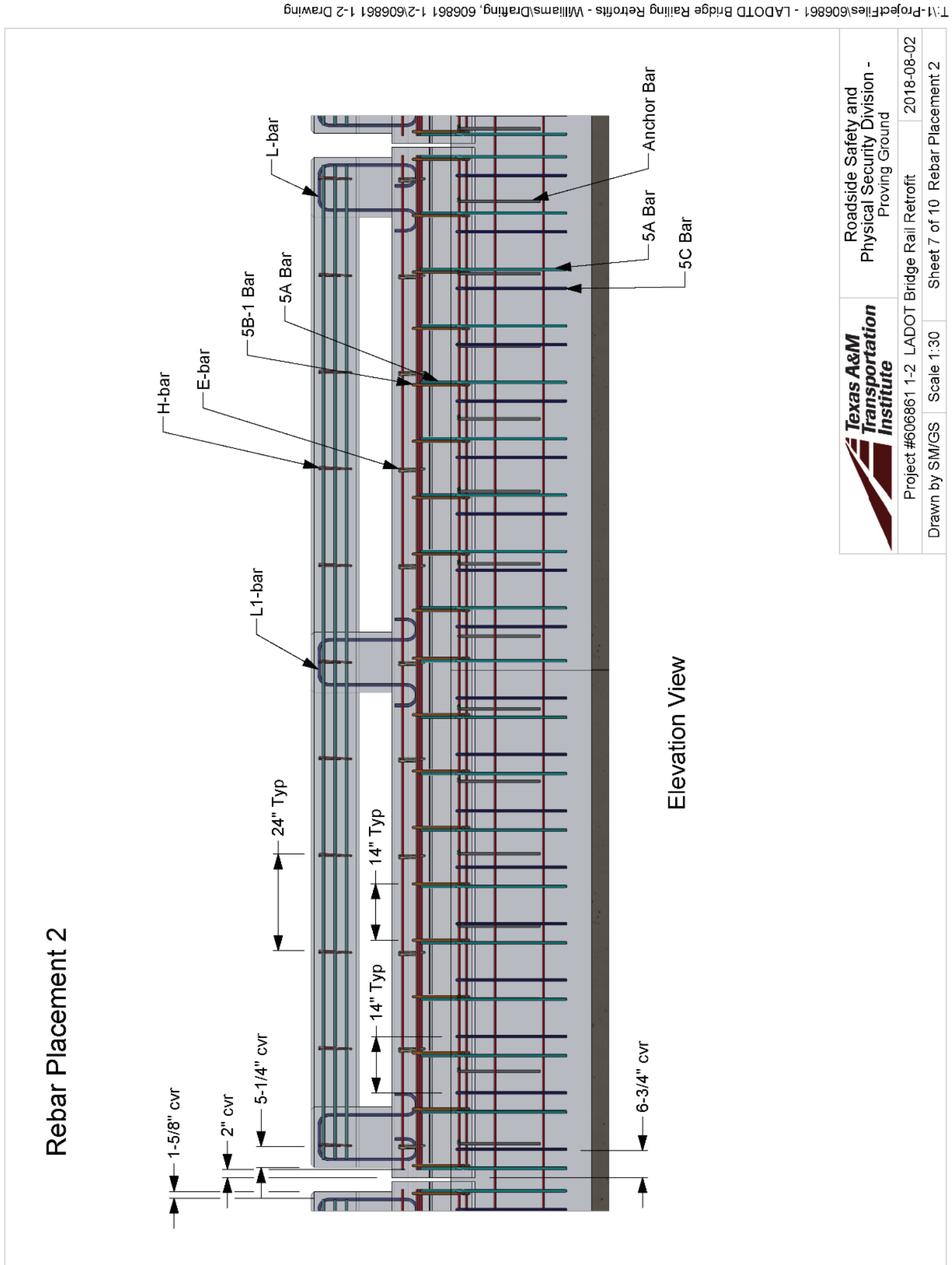
5c. Concrete strength is 3,000 psi.

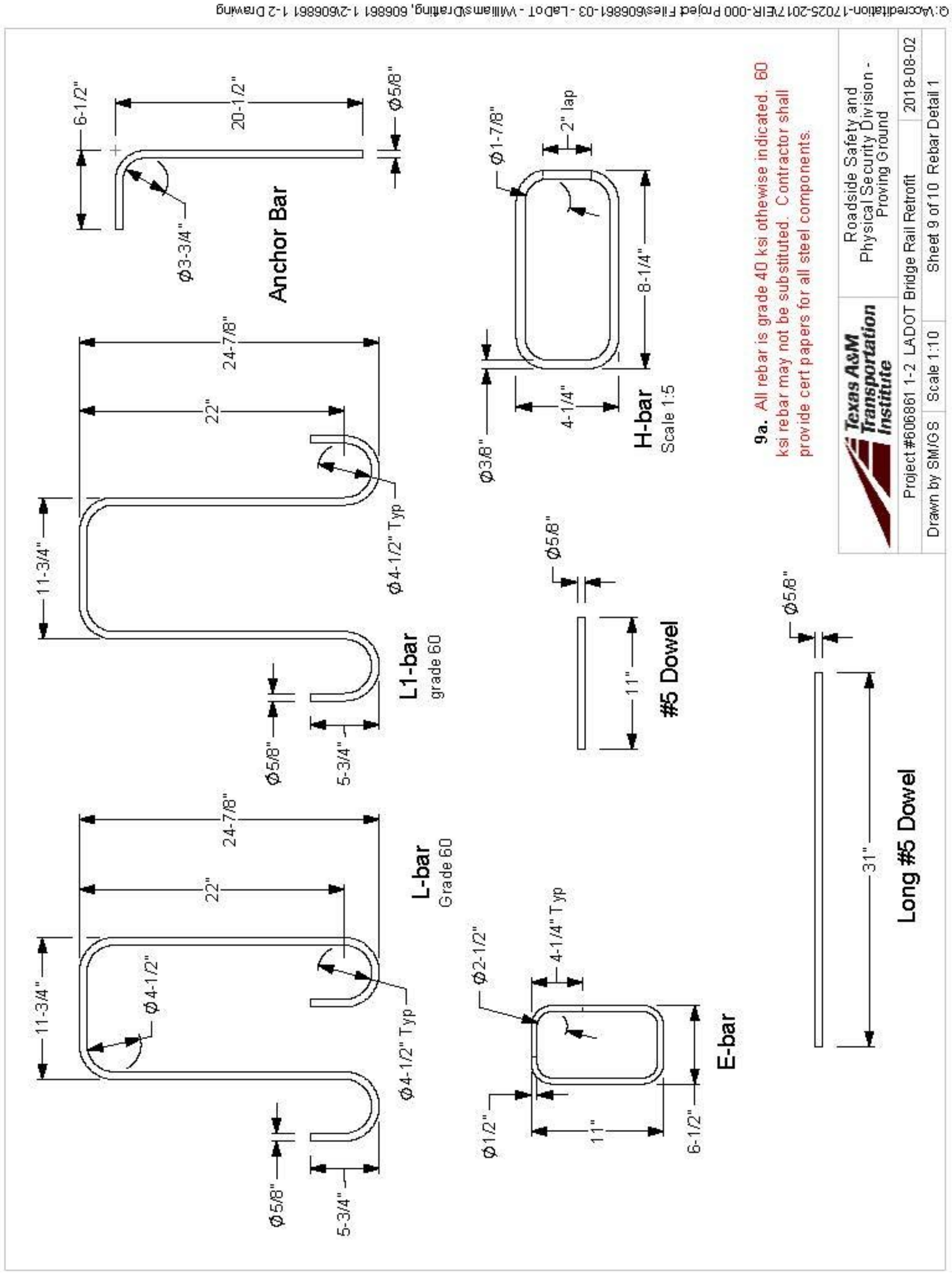
5d. A cold joint in the concrete is permissible here, with minimum 3 days cure time between pours (or when the first pour has reached 1500 psi compressive strength).

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #606861 1-2 LADOT Bridge Rail Retrofit		2018-08-02
Drawn by SM/GS	Scale 1:15	Sheet 5 of 10 Concrete Section

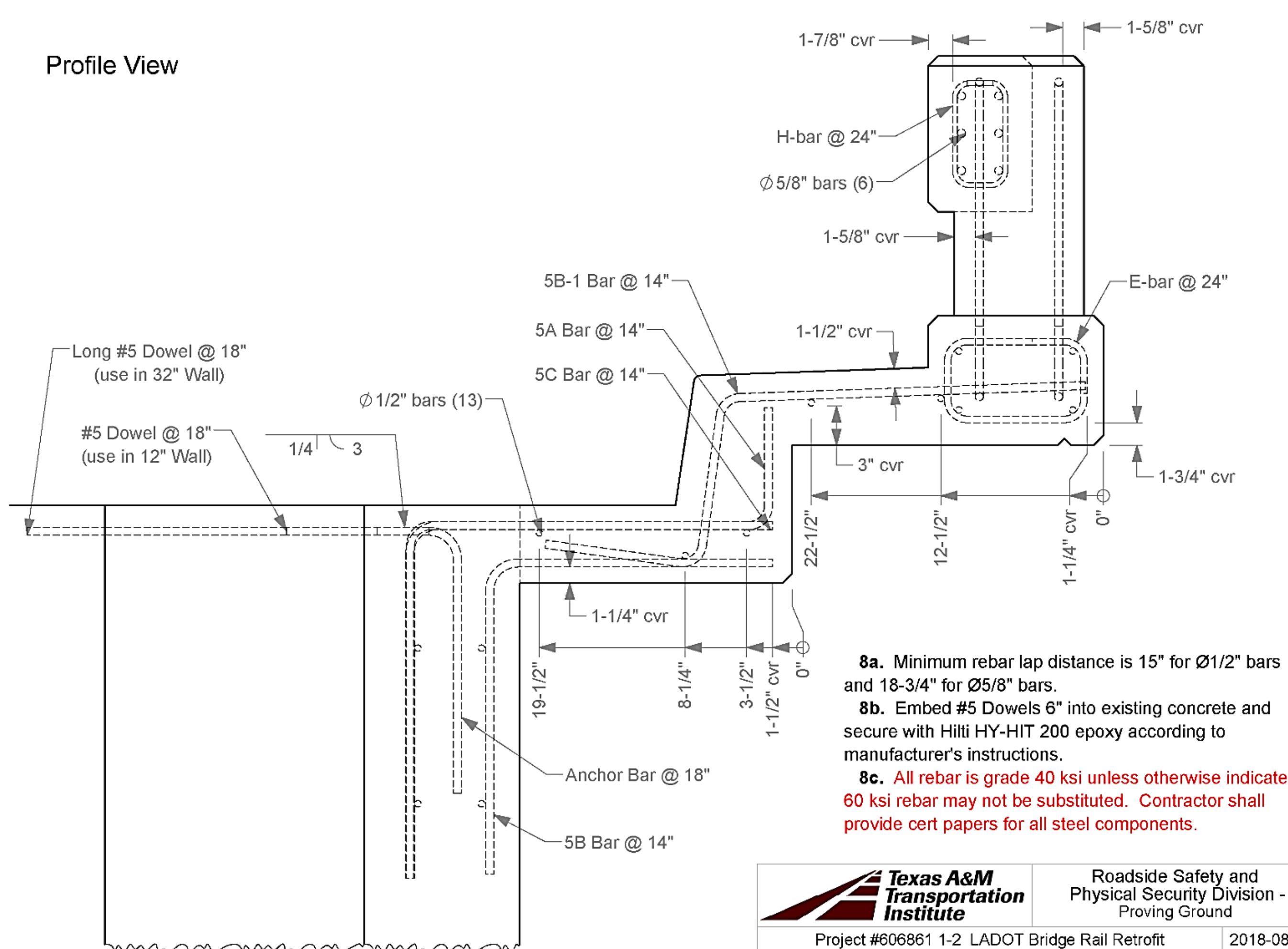
T:\1-ProjectFiles\606861 - LADOTD Bridge Railing Retrofits - Williams\Drafting, 606861 1-2\606861 1-2 Drawing


T:\1-ProjectFiles\606861 - LADOTD Bridge Railing Retrofits - Williams\Drafting, 606861 1-2\606861 1-2 Drawing
5B-1 Bar
5C Bar
5A Bar
5C Bar
5C Bar
#5 Dowel (Long #5 Dowel is used where Wall is 32" instead of 12")
L-bar
L-bar
2-5/8" cvr
2" cvr
E-bar
H-bar
18"
Plan View
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #606861 1-2 LADOT Bridge Rail Retrofit
2018-08-02
Drawn by SM/GS
Scale 1:15
Sheet 6 of 10 Rebar Placement 1


Rebar Placement 2
1-5/8" cvr
2" cvr
5-1/4" cvr
14" Typ
14" Typ
24" Typ
6-3/4" cvr
L1-bar
H-bar
E-bar
5B-1 Bar
5A Bar
L-bar
Anchor Bar
5A Bar
5C Bar
Elevation View
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #606861 1-2 LADOT Bridge Rail Retrofit
2018-08-02
Drawn by SM/GS
Scale 1:30
Sheet 7 of 10 Rebar Placement 2
T:\1-ProjectFiles\606861 - LADOTD Bridge Railing Retrofits - Williams\Drafting, 606861 1-2\606861 1-2 Drawing



G:\Accreditation-17025-2017\EIR-000 Project Files\606861-03 - LaDoT - Williams\Drafting, 606861 1-2\606861 1-2 Drawing
Anchor Bar
6-1/2"
20-1/2"
Ø5/8"
Ø3-3/4"
L1-bar
grade 60
24-7/8"
22"
11-3/4"
Ø4-1/2" Typ
Ø5/8"
5-3/4"
L-bar
Grade 60
24-7/8"
22"
11-3/4"
Ø4-1/2"
Ø4-1/2" Typ
Ø5/8"
5-3/4"
H-bar
Scale 1:5
Ø1-7/8"
2" lap
8-1/4"
4-1/4"
Ø3/8"
#5 Dowel
Ø5/8"
11"
E-bar
Ø2-1/2"
4-1/4" Typ
Ø1/2"
11"
6-1/2"
Long #5 Dowel
Ø5/8"
31"
9a. All rebar is grade 40 ksi othewise indicated. 60 ksi rebar may not be substituted. Contractor shall provide cert papers for all steel components.
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #606861 1-2 LADOT Bridge Rail Retrofit
2018-08-02
Drawn by SM/GS
Scale 1:10
Sheet 9 of 10 Rebar Detail 1



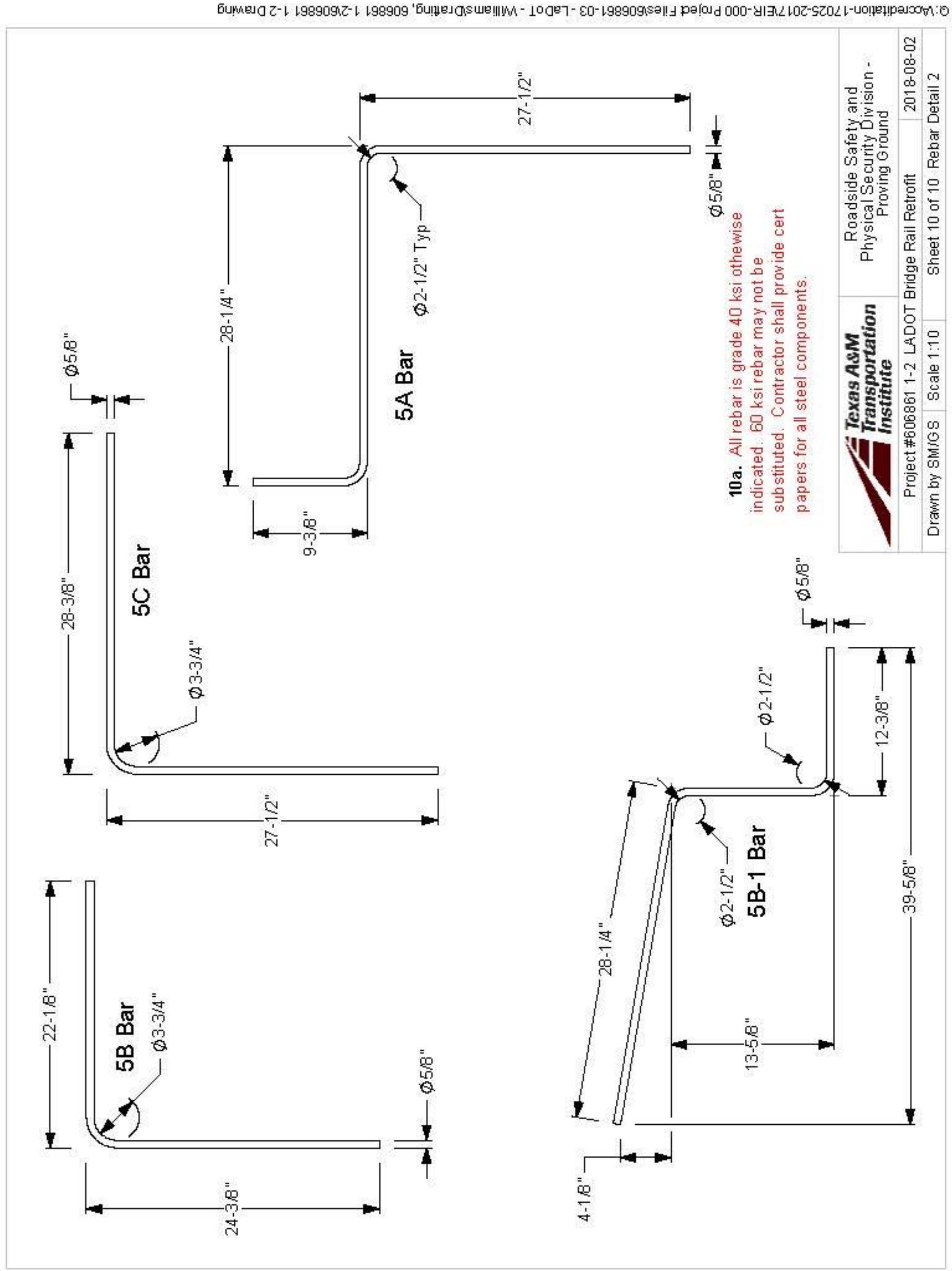
8a. Minimum rebar lap distance is 15" for Ø1/2" bars and 18-3/4" for Ø5/8" bars.

8b. Embed #5 Dowels 6" into existing concrete and secure with Hilti HY-HIT 200 epoxy according to manufacturer's instructions.

8c. All rebar is grade 40 ksi unless otherwise indicated. 60 ksi rebar may not be substituted. Contractor shall provide cert papers for all steel components.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #606861 1-2 LADOT Bridge Rail Retrofit		2018-08-02
Drawn by SM/GS	Scale 1:10	Sheet 8 of 10 Rebar Placement 3

T:\1-ProjectFiles\606861 - LADOTD Bridge Railing Retrofits - Williams\Drafting, 606861 1-2\606861 1-2 Drawing



G:\Accreditation-17025-2017\EIR-000 Project Files\606861-03 - LaDoT - Williams\Drafting, 606861 1-2\606861 1-2 Drawing
5A Bar
28-1/4"
27-1/2"
9-3/8"
Ø5/8"
Ø2-1/2" Typ
5C Bar
28-3/8"
27-1/2"
Ø3-3/4"
Ø5/8"
5B Bar
22-1/8"
24-3/8"
Ø3-3/4"
Ø5/8"
5B-1 Bar
28-1/4"
4-1/8"
13-5/8"
39-5/8"
12-3/8"
Ø2-1/2"
Ø2-1/2"
Ø5/8"
10a. All rebar is grade 40 ksi othewise indicated. 60 ksi rebar may not be substituted. Contractor shall provide cert papers for all steel components.
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #606861 1-2 LADOT Bridge Rail Retrofit
2018-08-02
Drawn by SM/GS
Scale 1:10
Sheet 10 of 10 Rebar Detail 2

Appendix C. Supporting Certification Documents for Test No. 606861-1&2

SOLD TO: KATY STEEL
PO BOX 735
KATY, TX 77492-

SHIP TO: KATY STEEL-CUSTOMER PU
N/A
KATY, TX 77492-

NUCOR
NUCOR CORPORATION
NUCOR STEEL TEXAS

CERTIFIED MILL TEST REPORT Page: 2

Ship from:
MTR #: 0000335081
Nucor Steel - Texas
8812 Hwy 79 W
JEWETT, TX 75846
800-527-6445

Date: 11-May-2018
B.L. Number: 820362
Load Number: 410652

Material Safety Data Sheets are available at www.nucorbar.com or by contacting your inside sales representative.

NBMG-08 January 1, 2012

LOT # / HEAT #	DESCRIPTION	PHYSICAL TESTS					CHEMICAL TESTS						
		YIELD P.S.I.	TENSILE P.S.I.	ELONG % IN 8"	BEND	WT% / DEF	C / Ni	Mn / Cr	P / Mo	S / V	Si / Cb	Cu / Sn	C.E.
PO# =>	322637-4												
JW1810394401	Nucor Steel - Texas	59,400	84,200	20.0%	OK		.23	.87	.014	.016	.20	.25	
JW18103944	10/#3 Rebar	410MPa	581MPa				.25	.23	.047	.003	.003		
	20' A615M GR280 (Gr40)												
	ASTM A615/A615M-14 GR 40[280]												
	AASHTO M31-07												

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.
1.) Weld repair was not performed on this material.
2.) Melted and Manufactured in the United States.
3.) Mercury, Radium, or Alpha source materials in any form

QUALITY

KYOEI STEEL GROUP
VINTON STEEL
Spirit of Challenge

150

MILL TEST CERTIFICATE
MANUFACTURER: VINTON STEEL LLC

SOLD TO: KATY STEEL COMPANY, INC.
P. O. BOX 735
KATY TX 77492
SHIP TO: KATY STEEL COMPANY
28011 HW 90
KATY TX 77494
MATERIAL: RV13040B13PA #4 X 20' GRADE 40 (ASTM A615) (ASTM A615/A615M)
DELIVERY LIST NUMBER:
P.O. CUSTOMER NUMBER: 417207

PROGRAM NUMBER: 0080665407

ISSUING DATE: 25.06.2018
CERTIFICATE NUMBER: 55757
PAGE: 1/1

MECHANICAL PROPERTIES

HEAT NUMBER	YIELD STRENGTH psi	TENSILE STRENGTH psi	PERCENT ELONGATION %	BEND	ACTUAL W. PER FOOT lb/ft
1811351	52483	81011	19	ACCEPTABLE	0.642

CHEMICAL COMPOSITION

HEAT NUMBER	C %	Mn %	P %	S %	Si %	Ni %	Cr %	Mo %	Cu %	V %	Cb %	CE %			
1811351	0.3000	0.5454	0.0294	0.0325	0.1930	0.1423	0.1535	0.0199	0.2396	0.0000	0.0000	0.4180			

WE HEREBY CERTIFY THAT THE ABOVE FIGURES ARE CORRECT AS CONTAINED IN THE RECORDS OF THE COMPANY.
MELTED AND MANUFACTURED IN THE U.S.A.
This reinforcing steel meets all the requirements of the Buy America Act requirements of 23 CFR 635.410
Approved by BSGV Quality Assurance
Manual REV-20 10/09/2014

Hector De Aquino

CERTIFIED BY THE QUALITY DEPARTMENT - SIGNATURE ON FILE

MAILING ADDRESS
VINTON STEEL LLC VINTON P.O. BOX 12843
EL PASO, TEXAS 79913-0843 915 886-2000

STREET ADDRESS
I-10 & VINTON ROAD
VINTON, TEXAS 79835-9998

KYOEI STEEL GROUP
VINTON STEEL
Spirit of Challenge

MILL TEST CERTIFICATE
MANUFACTURER: VINTON STEEL LLC

SOLD TO: KATY STEEL COMPANY, INC.
P. O. BOX 735
KATY TX 77492

SHIP TO: KATY STEEL COMPANY
28011 HW 90
KATY TX 77494

PROGRAM NUMBER: 0080665407

MATERIAL: RV16040B17PA #5 X 20' GRADE 40 (ASTM A615) (ASTM A615/A615M)
DELIVERY LIST NUMBER:
P.O. CUSTOMER NUMBER: 417207

ISSUING DATE: 25.06.2018
CERTIFICATE NUMBER: 55756
PAGE: 1/1

MECHANICAL PROPERTIES

HEAT NUMBER	YIELD STRENGTH psi	TENSILE STRENGTH psi	PERCENT ELONGATION %	BEND	ACTUAL W. PER FOOT lb/ft
1820222	48000	76669	21	ACCEPTABLE	0.987

CHEMICAL COMPOSITION

HEAT NUMBER	C %	Mn %	P %	S %	Si %	Ni %	Cr %	Mo %	Cu %	V %	Cb %	CE %			
1820222	0.2775	0.5971	0.0145	0.0393	0.1457	0.0700	0.0995	0.0112	0.2497	-0.003	-0.001	0.3972			

WE HEREBY CERTIFY THAT THE ABOVE FIGURES ARE CORRECT AS CONTAINED IN THE RECORDS OF THE COMPANY.
MELTED AND MANUFACTURED IN THE U.S.A.
This reinforcing steel meets all the requirements of the Buy America Act requirements of 23 CFR 635.410
Approved by BSGV Quality Assurance
Manual REV-20 10/09/2014

CERTIFIED BY THE QUALITY DEPARTMENT - SIGNATURE ON FILE

MAILING ADDRESS
VINTON STEEL LLC VINTON P.O. BOX 12843
EL PASO, TEXAS 79913-0843 915 886-2000

STREET ADDRESS
I-10 & VINTON ROAD
VINTON, TEXAS 79835-9998

SOLD TO: ~~KATY~~ STEEL
PO BOX 735
KATY, TX 77492-

NUCOR
NUCOR CORPORATION
NUCOR STEEL TEXAS

CERTIFIED MILL TEST REPORT

Page: 1

SHIP TO: KATY STEEL-CUSTOMER PU
N/A
KATY, TX 77492-

Ship from:
MTR #: 0000337724
Nucor Steel - Texas
8812 Hwy 79 W
JEWETT, TX 75846
800-527-6445

Date: 22-May-2018
B.L. Number: 821690
Load Number: 410675

Material Safety Data Sheets are available at www.nucorbar.com or by contacting your inside sales representative.

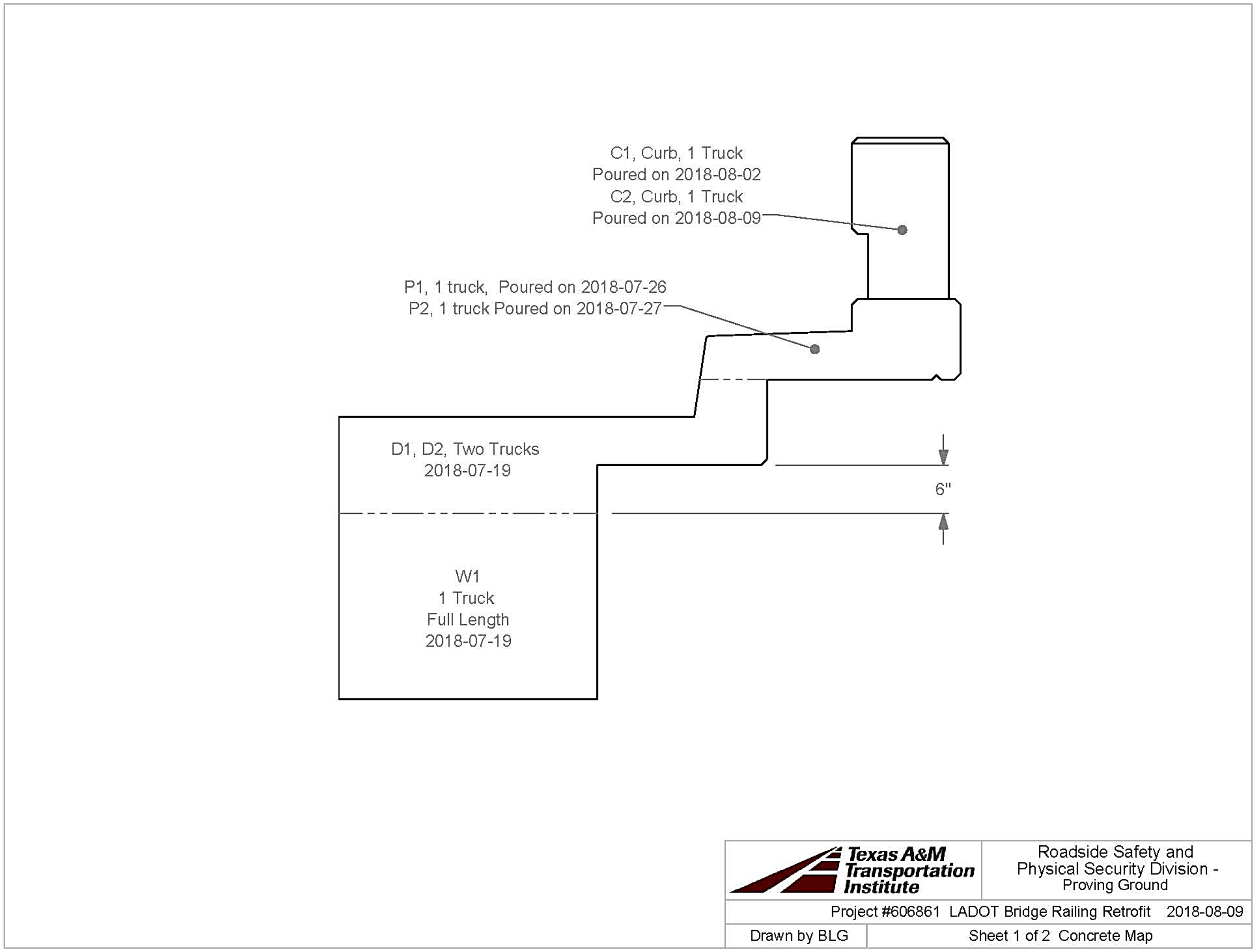
NBMG-08 January 1, 2012

LOT # / HEAT #	DESCRIPTION	PHYSICAL TESTS					CHEMICAL TESTS						
		YIELD P.S.I.	TENSILE P.S.I.	ELONG % IN 8"	BEND	WT% / DEF	C / Ni	Mn / Cr	P / Mo	S / V	Si / Cb	Cu / Sn	C.E.
PO# =>	322637-4												
JW1810405701 JW18104057	Nucor Steel - Texas 16/#5 Rebar 60' A615M GR420 (Gr60) ASTM A615/A615M-16 GR 60 AASHTO M31-15	67,500 465MPa	108,400 747MPa	15.0%	OK		.41 .13	1.02 .16	.012 .048	.031 .004	.22 .002	.28	

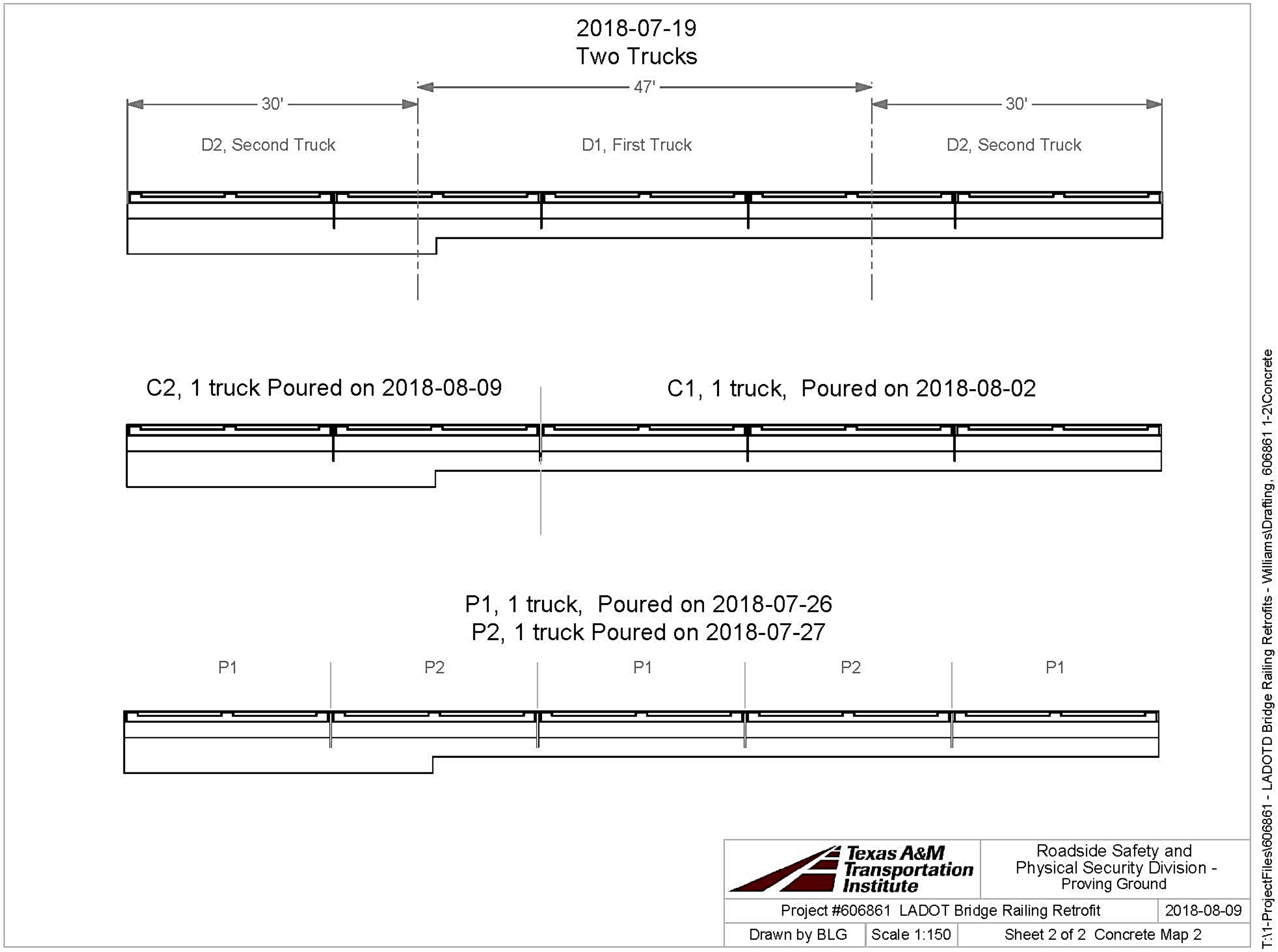
"I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.
1.) Weld repair was not performed on this material
2.) Melted and Manufactured in the United States.
3.) Mercury, Radium, or Alpha source materials in any form

QUALITY

Bela R Vartani



T:\1-ProjectFiles\606861 - LADOTD Bridge Railing Retrofits - Williams\Drafting, 606861 1-2\Concrete


2018-07-19
Two Trucks
30'
47'
30'
D2, Second Truck
D1, First Truck
D2, Second Truck
C2, 1 truck Poured on 2018-08-09
C1, 1 truck, Poured on 2018-08-02
P1, 1 truck, Poured on 2018-07-26
P2, 1 truck Poured on 2018-07-27
P1
P2
P1
P2
P1
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #606861 LADOT Bridge Railing Retrofit
2018-08-09
Drawn by BLG
Scale 1:150
Sheet 2 of 2 Concrete Map 2
T:\1-ProjectFiles\606861 - LADOTD Bridge Railing Retrofits - Williams\Drafting, 606861 1-2\Concrete

Texas A&M Transportation Institute Proving Ground 3100 SH 47, Bldg 7091 Bryan, TX 77807 Texas A&M University College Station, TX 77843 Phone 979-845-6375	5.7.2 **Concrete Sampling**	Doc. No. QPF 5.7.2	Revision Date: 2018-04-17
Quality Policy Form	Revised by: B. L. Griffith Approved by: D. Kuhn	Revision: 6	Page: 1 of 1

Project No: 606861 **Casting Date:** 2018-07-19 **Mix Design (psi):** 3000

Printed Name of Technician taking Sample: GREG FRITZ

Printed Name of Technician breaking Sample: Matt Robinson

Signed Name of Technician taking Sample: [signature]

Signed Name of Technician breaking Sample: [signature]

Load No.	Truck No.	Ticket No.	Location (from concrete map)
W1/T1	7108	4850758	100% of Wall, 6" from Top (TOY)
D1/T2	8162	4850501	Deck for Segment 3 and ½ each way
D2/T3	7211	4850572	Deck for North/South 1 ½ Segment each Side

Load No.	Break Date	Cylinder Age	Total Load (lbs)	Break (psi)	Average
T3	2018-10-02	75 d	4050	114500	|
|	|	|	4085	115500	4008
|	|	|	3891	110000	|
T 2	2018-10-2	75 d	4527	128000	|
|	|	|	4333	122500	4486
|	|	|	4598	130000	|
T ~~3~~ 1 BCG 2018-10-2	2018-10-2	75 d	5359	151500	|
|	|	|	5199	147000	5111
|	|	|	4775	135000	|

CUSTOMER'S COPY

TICKET NO.

4850972

Martin Marietta

1503 LBJ Freeway
Suite 400
Dallas, Tx 75234

LOAD TIME	TO JOB	ARRIVE JOB SITE	BEGIN POUR	FINISH POUR	LEAVE JOB SITE	ARRIVE PLANT
12:19	12:45	11:11	11:15	:	:	:

WATER ADDED ON JOB AT CUSTOMER'S REQUEST 10 GAL.
ALLOWABLE WATER (withheld from batch) ______ GAL.
TEST CYLINDER TAKEN ❑ YES ❑ NO BY ______
CYLINDER TAKEN ❑ BEFORE ❑ AFTER WATER

ADDITIONAL WATER ADDED TO THIS CONCRETE WILL REDUCE ITS STRENGTH. ANY WATER ADDED IN EXCESS OF SPECIFIED SLUMP IS AT CUSTOMER'S RISK.

CUSTOMER SIGNATURE
X

DELIVERY OF THESE MATERIALS IS SUBJECT TO THE TERMS AND CONDITIONS ON THE REVERSE SIDE HEREOF AS ACCEPTED BY SIGNATURE ABOVE.

CUSTOMER NAME AND DELIVERY ADDRESS
BRYAN CONSTRUCTION C
TAMU RIVERSIDE CAMPUS

PLANT	TRUCK	ORDER NO.	SLUMP	P.O. #/JOB/LOT	GRID
617	7211	2024	5.0	292	

DRIVER NAME	DATE
JUAN RAMOS	7/19/18

CUSTOMER NUMBER	PROJECT	CUM. QTY	ORDERED QTY
509195	74925	30.00	30.00

LOAD QUANTITY	PRODUCT CODE	DESCRIPTION	UNIT PRICE	AMOUNT
10.00 CYDS	BDOTCA00	CLASS A		

SPECIAL DELIVERY INSTRUCTIONS
SOUTH 2818, RIGHT LEONARD, RIGHT47, LEFT INTO RELLIS
THEY WILLMEET YOU RIGHT THERE

SALES TAX

TOTAL

DANGER! MAY CAUSE ALKALI BURNS.
SEE WARNINGS ON REVERSE SIDE.

FOR OFFICE USE ONLY **FORM:** 2210013

Truck	Driver	User	Disp Ticket Num	Ticket ID	Time	Date
7211	38554	user	4850972	67604	12:19	7/19/18

Load Size	Mix Code	Returned	Qty	Mix Age	Seq	Load ID
10.00 CYDS	BDOTCA00,				D	68560

Material	Design Qty	Required	Batched	% Var	% Moisture	Actual Wat
157	1931 lb	19407 lb	19440 lb	0.17%	0.50% M	12 gl
10	1374 lb	14268 lb	14280 lb	* 0.08%	3.70% M	63 gl
1	293 lb	2930 lb	2950 lb	0.68%		
8	158 lb	1580 lb	1570 lb	-0.63%		
900	2 oz	22 oz	22 oz	-1.78%		
H20	242 lb	1653 lb	1647 lb	-0.37%		197 gl

Actual Num Batches: 1
Load Total: 39888 lb Design 0.537 Water/Cement 0.535 T Design 290.0 gl Actual 272.3 gl To Add: 17.7 gl
Slump: 5.00 in Water in Truck: 0.0 gl Adjust Water: 0.0 gl / Load Trim Water: -1.7 gl/ CYD Note: Manual feed oc

P80 7 oz 146 oz 148 oz

CUSTOMER'S COPY

TICKET NO. 4850758

Martin Marietta

1503 LBJ Freeway
Suite 400
Dallas, Tx 75234

* 4 8 5 0 7 5 8 *

LOAD TIME	TO JOB	ARRIVE JOB SITE	BEGIN POUR	FINISH POUR	LEAVE JOB SITE	ARRIVE PLANT
11:38	11:50	12:15	12:20	12:25	:	:

WATER ADDED ON JOB AT CUSTOMER'S REQUEST Ø GAL.
ALLOWABLE WATER (withheld from batch) ______ GAL.
TEST CYLINDER TAKEN ❑ YES ☑ NO BY ______
CYLINDER TAKEN ❑ BEFORE ❑ AFTER WATER

ADDITIONAL WATER ADDED TO THIS CONCRETE WILL REDUCE ITS STRENGTH. ANY WATER ADDED IN EXCESS OF SPECIFIED SLUMP IS AT CUSTOMER'S RISK.

CUSTOMER SIGNATURE
X [illegible signature]

DELIVERY OF THESE MATERIALS IS SUBJECT TO THE TERMS AND CONDITIONS ON THE REVERSE SIDE HEREOF AS ACCEPTED BY SIGNATURE ABOVE.

CUSTOMER NAME AND DELIVERY ADDRESS
BRYAN CONSTRUCTION C
TAMU RIVERSIDE CAMPUS

PLANT	TRUCK	ORDER NO.	SLUMP	P.O. #/JOB/LOT	GRID
617	7108	2024	5.0	292	

DRIVER NAME	DATE
VICTOR MARTINEZ	7/19/18

CUSTOMER NUMBER	PROJECT	CUM. QTY	ORDERED QTY
509195	74925	10.00	30.00

LOAD QUANTITY	PRODUCT CODE	DESCRIPTION	UNIT PRICE	AMOUNT
10.00	CYDS BDOTCA00	CLASS A		

SPECIAL DELIVERY INSTRUCTIONS
SOUTH 2818, RIGHT LEONARD, RIGHT47, LEFT INTO RELLIS
THEY WILLMEET YOU RIGHT THERE

SALES TAX

TOTAL

DANGER! MAY CAUSE ALKALI BURNS.
SEE WARNINGS ON REVERSE SIDE.

FOR OFFICE USE ONLY **FORM:** 2210010

Truck	Driver	User	Disp Ticket Num	Ticket ID	Time	Date
7108	923381	user	4850758	67601	11:38	7/19/18

Load Size	Mix Code	Returned Qty	Mix Age	Seq	Load ID
10.00 CYDS	BDOTCA00			D	68557

Material	Design Qty	Required	Batched	% Var	% Moisture	Actual Wat
157	1931 lb	19407 lb	19520 lb	* 0.58%	0.50% M	12 gl
10	1374 lb	14268 lb	14320 lb	0.37%	3.70% M	63 gl
1	293 lb	2930 lb	2940 lb	0.34%		
8	158 lb	1580 lb	1590 lb	* 0.63%		
900	2 oz	20 oz	20 oz	-2.01%		
901	#	oz	oz			
H20	242 lb	1653 lb	1653 lb	0.01%		198 gl
P80	7 oz #	147 oz	146 oz	-0.41%		

Actual Num Batches: 1
Load Total: 40033 lb Design 0.537 Water/Cement 0.534 T Design 290.0 gl Actual 273.3 gl To Add: 16.7 gl
Slump: 5.00 in Water in Truck: 0.0 gl Adjust Water: 0.0 gl / Load Trim Water: -1.7 gl/ CYD

CUSTOMER'S COPY

TICKET NO. 4850901

Martin Marietta

1503 LBJ Freeway
Suite 400
Dallas, Tx 75234

4850901

LOAD TIME	TO JOB	ARRIVE JOB SITE	BEGIN POUR	FINISH POUR	LEAVE JOB SITE	ARRIVE PLANT
12:03	:	:	:	:	:	:

WATER ADDED ON JOB AT CUSTOMER'S REQUEST 16.6 GAL.
ALLOWABLE WATER (withheld from batch) ________ GAL.
TEST CYLINDER TAKEN ❑ YES ❑ NO BY ________
CYLINDER TAKEN ❑ BEFORE ❑ AFTER WATER

ADDITIONAL WATER ADDED TO THIS CONCRETE WILL REDUCE ITS STRENGTH. ANY WATER ADDED IN EXCESS OF SPECIFIED SLUMP IS AT CUSTOMER'S RISK.

CUSTOMER SIGNATURE
X [illegible signature]

DELIVERY OF THESE MATERIALS IS SUBJECT TO THE TERMS AND CONDITIONS ON THE REVERSE SIDE HEREOF AS ACCEPTED BY SIGNATURE ABOVE.

CUSTOMER NAME AND DELIVERY ADDRESS
BRYAN CONSTRUCTION C
TAMU RIVERSIDE CAMPUS

PLANT	TRUCK	ORDER NO.	SLUMP	P.O. #/JOB/LOT	GRID
617	8162	2024	5.0	292	

DRIVER NAME	DATE
CHATHAM, DEXTER	7/19/18

CUSTOMER NUMBER	PROJECT	CUM. QTY	ORDERED QTY
509195	74925	20.00	30.00

LOAD QUANTITY	PRODUCT CODE	DESCRIPTION	UNIT PRICE	AMOUNT
10.00 CYDS	BDOTCA00	CLASS A		

SPECIAL DELIVERY INSTRUCTIONS
SOUTH 2818, RIGHT LEONARD, RIGHT47, LEFT INTO RELLIS
THEY WILLMEET YOU RIGHT THERE

SALES TAX

TOTAL

DANGER! MAY CAUSE ALKALI BURNS.
SEE WARNINGS ON REVERSE SIDE.

FOR OFFICE USE ONLY **FORM:** 2210012

Truck	Driver	User	Disp Ticket Num	Ticket ID	Time	Date
8162	37791	user	4850901	67603	12:03	7/19/18

Load Size	Mix Code	Returned	Qty	Mix Age	Seq	Load ID
10.00 CYDS	BDOTCA00				D	68559

Material	Design Qty	Required	Batched	% Var	% Moisture	Actual Wat
157	1931 lb	19407 lb	19400 lb	-0.04%	0.50% M	12 gl
10	1374 lb	14268 lb	14280 lb	0.08%	3.70% M	63 gl
1	293 lb	2930 lb	2940 lb	0.34%		
8	158 lb	1580 lb	1590 lb	0.63%		
900	2 oz	22 oz	22 oz	-1.78%		
H20	242 lb	1653 lb	1656 lb	0.17%		198 gl
P80	7 oz #	146 oz	146 oz	0.00%		

Actual Num Batches: 1
Load Total: 39876 lb Design 0.537 Water/Cement 0.534 T Design 290.0 gl Actual 273.4 gl To Add: 16.6 gl
Slump: 5.00 in Water in Truck: 0.0 gl Adjust Water: 0.0 gl / Load Trim Water: -1.7 gl/ CYD

Texas A&M Transportation Institute Proving Ground, 3100 SH 47, Bldg 7091, Bryan, TX 77807 Texas A&M University, College Station, TX 77843, Phone 979-845-6375	5.7.2 **Concrete Sampling**	Doc. No. QPF 5.7.2	Revision Date: 2018-04-17
Quality Policy Form	Revised by: B. L. Griffith Approved by: D. Kuhn	Revision: 6	Page: 1 of 1

Project No: 606861 **Casting Date:** 2018-7-26 **Mix Design (psi):** 3000

Printed Name of Technician taking Sample: Greg Fritz

Printed Name of Technician breaking Sample: Matt Robinson

Signed Name of Technician taking Sample: [signature]

Signed Name of Technician breaking Sample: [signature]

Load No.	Truck No.	Ticket No.	Location (from concrete map)
P1	7124	4865630	South, Middle, & North Segments

Load No.	Break Date	Cylinder Age	Total Load (lbs)	Break (psi)	Average
P1	2018-10-2	68 d	5359	151500	
			5359	151500	5235
			4987	141000	

CUSTOMER'S COPY

TICKET NO. 4865630

Martin Marietta

1503 LBJ Freeway
Suite 400
Dallas, Tx 75234

4865630

LOAD TIME	TO JOB	ARRIVE JOB SITE	BEGIN POUR	FINISH POUR	LEAVE JOB SITE	ARRIVE PLANT
8:37	8:41	9:13	9:16	:	:	:

WATER ADDED ON JOB AT CUSTOMER'S REQUEST ____________ GAL.
ALLOWABLE WATER (withheld from batch) ____________ GAL.
TEST CYLINDER TAKEN ❑ YES ❑ NO BY ____________
CYLINDER TAKEN ❑ BEFORE ❑ AFTER WATER

ADDITIONAL WATER ADDED TO THIS CONCRETE WILL REDUCE ITS STRENGTH. ANY WATER ADDED IN EXCESS OF SPECIFIED SLUMP IS AT CUSTOMER'S RISK.

CUSTOMER SIGNATURE
X

DELIVERY OF THESE MATERIALS IS SUBJECT TO THE TERMS AND CONDITIONS ON THE REVERSE SIDE HEREOF AS ACCEPTED BY SIGNATURE ABOVE.

CUSTOMER NAME AND DELIVERY ADDRESS
BRYAN CONSTRUCTION C
TAMU RIVERSIDE CAMPUS

PLANT	TRUCK	ORDER NO.	SLUMP	P.O. #/JOB/LOT	GRID
617	7124	2013	5.0	292	

DRIVER NAME	DATE
ANTHONY WOODS	7/26/18

CUSTOMER NUMBER	PROJECT	CUM. QTY	ORDERED QTY
509195	74925	7.00	7.00

LOAD QUANTITY	PRODUCT CODE	DESCRIPTION		UNIT PRICE	AMOUNT
7.00 CYDS	BDOTCA00	CLASS A			

SPECIAL DELIVERY INSTRUCTIONS
SOUTH 2818, RIGHT LEONARD RD, RIGHT HWY 47, LEFT INTO RELLIS THEY WILL MEET YOU AT THE ENTRANCE

SALES TAX

TOTAL

DANGER! MAY CAUSE ALKALI BURNS.
SEE WARNINGS ON REVERSE SIDE.

FOR OFFICE USE ONLY **FORM:** 2210202

Truck	Driver	User	Disp Ticket Num	Ticket ID	Time	Date
7124	875636	user	4865630	67793	8:37	7/26/18

Load Size	Mix Code	Returned	Qty	Mix Age	Seq	Load ID
7.00 CYDS	BDOTCA00				D	68749

Material	Design Qty		Required	Batched	% Var	% Moisture	Actual Wat
157	1931 lb		13551 lb	13560 lb	0.07%	0.25% M	4 gl
10	1374 lb		9946 lb	9960 lb	* 0.14%	3.30% M	39 gl
1	293 lb		2051 lb	2040 lb	-0.54%		
8	158 lb		1106 lb	1110 lb	0.36%		
900	2 oz		14 oz	14 oz	0.50%		
901		#	oz	oz			
H20	242 lb		1227 lb	1227 lb	0.02%		147 gl
P80	7 oz	#	102 oz	101 oz	-1.38%		

Actual Num Batches: 1
Load Total: 27904 lb Design 0.537 Water/Cement 0.538 T Design 203.0 gl Actual 190.5 gl To Add: 12.5 gl
Slump: 5.00 in Water in Truck: 0.0 gl Adjust Water: 0.0 gl / Load Trim Water: -1.8 gl/ CYD

606861
608861/ p1

Texas A&M Transportation Institute Proving Ground 3100 SH 47, Bldg 7091 Bryan, TX 77807 Texas A&M University College Station, TX 77843 Phone 979-845-6375	5.7.2 Concrete Sampling	Doc. No. QPF 5.7.2	Revision Date: 2018-04-17
Quality Policy Form	Revised by: B. L. Griffith Approved by: D. Kuhn	Revision: 6	Page: 1 of 1

Project No: 606861 **Casting Date:** 2018-7-27 **Mix Design (psi):** 3000

Printed Name of Technician taking Sample: Greg FRITZ

Printed Name of Technician breaking Sample: Matt Robinson

Signed Name of Technician taking Sample: [signature]

Signed Name of Technician breaking Sample: [signature]

Load No.	Truck No.	Ticket No.	Location (from concrete map)
P2	7139	4869236	2 segment, Mid South, Mid North

Load No.	Break Date	Cylinder Age	Total Load (lbs)	Break (psi)	Average
P2	2018-10-2	67	4156	117500	|
P2	|	|	3997	113000	4050
P2			3997	113000	|

CUSTOMER'S COPY

TICKET NO. 4869236

Martin Marietta

1503 LBJ Freeway
Suite 400
Dallas, Tx 75234

* 4 8 6 9 2 3 6 *

LOAD TIME	TO JOB	ARRIVE JOB SITE	BEGIN POUR	FINISH POUR	LEAVE JOB SITE	ARRIVE PLANT
9:03	9:13	:	:	:	:	:

WATER ADDED ON JOB AT CUSTOMER'S REQUEST ________ GAL.
ALLOWABLE WATER (withheld from batch) ____8____ GAL.
TEST CYLINDER TAKEN ❑ YES ❑ NO BY ________
CYLINDER TAKEN ❑ BEFORE ❑ AFTER WATER

ADDITIONAL WATER ADDED TO THIS CONCRETE WILL REDUCE ITS STRENGTH. ANY WATER ADDED IN EXCESS OF SPECIFIED SLUMP IS AT CUSTOMER'S RISK.

CUSTOMER SIGNATURE
X

DELIVERY OF THESE MATERIALS IS SUBJECT TO THE TERMS AND CONDITIONS ON THE REVERSE SIDE HEREOF AS ACCEPTED BY SIGNATURE ABOVE.

CUSTOMER NAME AND DELIVERY ADDRESS
BRYAN CONSTRUCTION C
TAMU RIVERSIDE CAMPUS

PLANT	TRUCK	ORDER NO.	SLUMP	P.O. #/JOB/LOT	GRID
617	7139	2018	5.0	292	

DRIVER NAME	DATE
Rodney Lucas	7/27/18

CUSTOMER NUMBER	PROJECT	CUM. QTY	ORDERED QTY
509195	74925	5.00	5.00

LOAD QUANTITY	PRODUCT CODE	DESCRIPTION		UNIT PRICE	AMOUNT
5.00	CYDS	BDOTCA00	CLASS A		

SPECIAL DELIVERY INSTRUCTIONS
SOUTH 2818, RIGHT LEONARD RD, RIGHT HWY 47, LEFT INTO RELLIS THEY WILL MEET YOU AT THE ENTRANCE

SALES TAX

TOTAL

DANGER! MAY CAUSE ALKALI BURNS.
SEE WARNINGS ON REVERSE SIDE.

FOR OFFICE USE ONLY **FORM:** 2204892

Truck	Driver	User	Disp Ticket Num	Ticket ID	Time	Date
7139	934548	user	4869236	67883	9:03	7/27/18

Load Size	Mix Code	Returned Qty	Mix Age	Seq	Load ID
5.00 CYDS	BDOTCA00			D	68839

Material	Design Qty	Required	Batched	% Var	% Moisture	Actual Wat
157	1931 lb	9679 lb	9720 lb	0.42%	0.25% M	3 gl
10	1374 lb	7104 lb	7160 lb	0.78%	3.30% M	28 gl
1	293 lb	1465 lb	1480 lb	1.02%		
8	158 lb	790 lb	790 lb	0.00%		
900	2 oz	10 oz	10 oz	-4.52%		
901		oz	oz			
H20	242 lb	876 lb	879 lb	0.31%		105 gl
P80	7 oz	73 oz	74 oz	0.95%		

Actual Num Batches: 1
Load Total: 20034 lb Design 0.537 Water/Cement 0.533 T Design 145.0 gl Actual 136.6 gl To Add: 8.4 gl
Slump: 5.00 in Water in Truck: 0.0 gl Adjust Water: 0.0 gl / Load Trim Water: -1.8 gl/ CYD

606861 P2
~~606861~~

Texas A&M Transportation Institute Proving Ground 3100 SH 47, Bldg 7091 Bryan, TX 77807 Texas A&M University College Station, TX 77843 Phone 979-845-6375	5.7.2 Concrete Sampling	Doc. No. QPF 5.7.2	Revision Date: 2018-04-17
Quality Policy Form	Revised by: B. L. Griffith Approved by: D. Kuhn	Revision: 6	Page: 1 of 1

Project No: 606861 **Casting Date:** 2018-08-02 **Mix Design (psi):** 3000 psi

Printed Name of Technician taking Sample: GREG FRITZ
Printed Name of Technician breaking Sample: Matt Robinson

Signed Name of Technician taking Sample: [signature]
Signed Name of Technician breaking Sample: [signature]

Load No.	Truck No.	Ticket No.	Location (from concrete map)
T1	8163	4882854	3 Parapets on Right Side

Load No.	Break Date	Cylinder Age	Total Load (lbs)	Break (psi)	Average
T1	2018-10-2	61 days	4280	121000	|
T1	|	|	3997	113000	4085
T1			3929	112500	|

CUSTOMER'S COPY

TICKET NO. 4882854

Martin Marietta

1503 LBJ Freeway
Suite 400
Dallas, Tx 75234

* 4 8 8 2 8 5 4 *

LOAD TIME	TO JOB	ARRIVE JOB SITE	BEGIN POUR	FINISH POUR	LEAVE JOB SITE	ARRIVE PLANT
1[illegible]:35	1 :43	2 :00	2 :08	:	:	:

WATER ADDED ON JOB AT CUSTOMER'S REQUEST 5 GAL.
ALLOWABLE WATER (withheld from batch) 5.3 GAL.
TEST CYLINDER TAKEN ❑ YES ❑ NO BY
CYLINDER TAKEN ❑ BEFORE ❑ AFTER WATER

ADDITIONAL WATER ADDED TO THIS CONCRETE WILL REDUCE ITS STRENGTH. ANY WATER ADDED IN EXCESS OF SPECIFIED SLUMP IS AT CUSTOMER'S RISK.

CUSTOMER SIGNATURE
X

DELIVERY OF THESE MATERIALS IS SUBJECT TO THE TERMS AN CONDITIONS ON THE REVERSE SIDE HEREOF AS ACCEPTED B SIGNATURE ABOVE .

CUSTOMER NAME AND DELIVERY ADDRESS
BRYAN CONSTRUCTION C
TAMU RIVERSIDE CAMPUS

PLANT	TRUCK	ORDER NO.	SLUMP	P.O. #/JOB/LOT	GRID
617	8163	2033	5.0	292	

DRIVER NAME	DATE
CLARK, GARY	8/2/18

CUSTOMER NUMBER	PROJECT	CUM. QTY	ORDERED QTY
509195	74925	3.00	3.00

LOAD QUANTITY	PRODUCT CODE	DESCRIPTION		UNIT PRICE	AMOUNT
3.00	CYDS	BDOTCA00	CLASS A		

SPECIAL DELIVERY INSTRUCTIONS
HWY 21 WEST, LEFT INTO RELLIS THEY WILL MEET YOU
THERE SITTING IN A SILVER CHEVROLET TRUCK

SALES TAX
TOTAL

DANGER! MAY CAUSE ALKALI BURNS.
SEE WARNINGS ON REVERSE SIDE.

FOR OFFICE USE ONLY **FORM:** 2205141

Truck	Driver	User	Disp Ticket Num	Ticket ID	Time Date
8163	37794	user	4882854	68132	13:35 8/2/18

Load Size	Mix Code	Returned	Qty	Mix Age	Seq	Load ID
3.00 CYDS	BDOTCA00				D	69090

Material	Design Qty		Required	Batched	% Var	% Moisture	Actual Wat
157	1931 lb.		5816 lb	5800 lb	-0.28%	0.40% M	3 gl
10	1374 lb		4294 lb	4320 lb	* 0.61%	4.00% M	21 gl
1	293 lb		879 lb	860 lb	-2.16%		
8	158 lb		474 lb	480 lb	1.27%		
900	2 oz		6 oz	6 oz	0.50%		
901		#	oz	oz			
H2O	242 lb		487 lb	486 lb	-0.24%		58 gl
P80	7 oz	#	38 oz	37 oz	-3.85%		

Actual Num Batches: 1
Load Total: 11949 lb Design 0.537 Water/Cement 0.542 T Design 87.0 gl Actual 81.7 gl To Add: 5.3 gl
Slump: 5.00 in Water in Truck: 0.0 gl Adjust Water: 0.0 gl / Load Trim Water: -1.8 gl/ CYD

Texas A&M Transportation Institute Proving Ground 3100 SH 47, Bldg 7091 Bryan, TX 77807 Texas A&M University College Station, TX 77843 Phone 979-845-6375	5.7.2 Concrete Sampling	Doc. No. QPF 5.7.2	Revision Date: 2018-04-17
Quality Policy Form	Revised by: B. L. Griffith Approved by: D. Kuhn	Revision: 6	Page: 1 of 1

Project No: 606861 **Casting Date:** 2018-08-09 **Mix Design (psi):** 3000

Printed Name of Technician taking Sample: GREG FRITZ
Printed Name of Technician breaking Sample: Matt Robinson

Signed Name of Technician taking Sample: [signature]
Signed Name of Technician breaking Sample: [signature]

BF 2018-08-09

Load No.	Truck No.	Ticket No.	Location (from concrete map)
~~TX~~ C2	8116	4879231	2 remaining Segments (South Side)

Load No.	Break Date	Cylinder Age	Total Load (lbs)	Break (psi)	Average
C2	2018-10-2	47 days	9174	118000	
C2	2018-10-2		9103	116000	4002
C2	2018-10-2		3731	105500	

CUSTOMER'S COPY

TICKET NO. 4899231

Martin Marietta

1503 LBJ Freeway
Suite 400
Dallas, Tx 75234

* 4 8 9 9 2 3 1 *

LOAD TIME	TO JOB	ARRIVE JOB SITE	BEGIN POUR	FINISH POUR	LEAVE JOB SITE	ARRIVE PLANT
12:09	12:19	12:35	12:40	:	:	:

WATER ADDED ON JOB AT CUSTOMER'S REQUEST ________ GAL.
ALLOWABLE WATER (withheld from batch) 6.4 GAL.
TEST CYLINDER TAKEN ❑ YES ❑ NO BY ________
CYLINDER TAKEN ❑ BEFORE ❑ AFTER WATER

ADDITIONAL WATER ADDED TO THIS CONCRETE WILL REDUCE ITS STRENGTH. ANY WATER ADDED IN EXCESS OF SPECIFIED SLUMP IS AT CUSTOMER'S RISK.

CUSTOMER SIGNATURE
X

DELIVERY OF THESE MATERIALS IS SUBJECT TO THE TERMS AND CONDITIONS ON THE REVERSE SIDE HEREOF AS ACCEPTED BY SIGNATURE ABOVE.

CUSTOMER NAME AND DELIVERY ADDRESS
BRYAN CONSTRUCTION C
TAMU RIVERSIDE CAMPUS

PLANT	TRUCK	ORDER NO.	SLUMP	P.O. #/JOB/LOT	GRID
617	8116	2030	5.0	292	

DRIVER NAME	DATE
HOUSE, JOHN	8/9/18

CUSTOMER NUMBER	PROJECT	CUM. QTY	ORDERED QTY
509195	74925	3.00	3.00

LOAD QUANTITY	PRODUCT CODE	DESCRIPTION		UNIT PRICE	AMOUNT
3.00	CYDS	BDOTCA00	CLASS A		

SPECIAL DELIVERY INSTRUCTIONS
HWY 21 WEST, LEFT INTO RELLIS THEY WILL MEET YOU AROUND THERE

SALES TAX

TOTAL

DANGER! MAY CAUSE ALKALI BURNS.
SEE WARNINGS ON REVERSE SIDE.

FOR OFFICE USE ONLY **FORM:** 2205428

Truck	Driver	User	Disp Ticket Num	Ticket ID	Time Date
8116	20640	user	4899231	68419	12:09 8/9/18

Load Size	Mix Code	Returned	Qty	Mix Age	Seq	Load ID
3.00 CYDS	BDOTCA00				D	69383

Material	Design Qty		Required	Batched	% Var	% Moisture	Actual Wat
157	1931 lb		5816 lb	5800 lb	* -0.28%	0.40% M	3 gl
10	1374 lb		4272 lb	4240 lb	-0.74%	3.50% M	18 gl
1	293 lb		879 lb	950 lb	) 8.08%		
8	158 lb		474 lb	460 lb	- -2.95%		
900	2 oz		11 oz	12 oz	1.38%		
901		#	oz	oz			
H20	242 lb		503 lb	501 lb	-0.43%		60 gl
P80	7 oz	#	44 oz	43 oz	-2.23%		

Actual Num Batches: 1
Load Total: 11954 lb Design 0.537 Water/Cement 0.515 T Design 87.0 gl Actual 80.6 gl To Add: 6.4 gl
Slump: 5.00 in Water in Truck: 0.0 gl Adjust Water: 0.0 gl / Load Trim Water: -2.0 gl/ CYD Note: Manual feed oc

Appendix D. MASH Test 3-11 (Crash Test No. 606861-1)

Figure 106. Vehicle properties for Test No. 606861-1

Date: 2018-10-02 Test No.: 606861-1 VIN No.: 1C6RD6GTXCS268732

Year: 2012 Make: RAM Model: 1500

Tire Size: 265/70 R 17 Tire Inflation Pressure: 35 psi

Tread Type: Highway Odometer: 268732

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

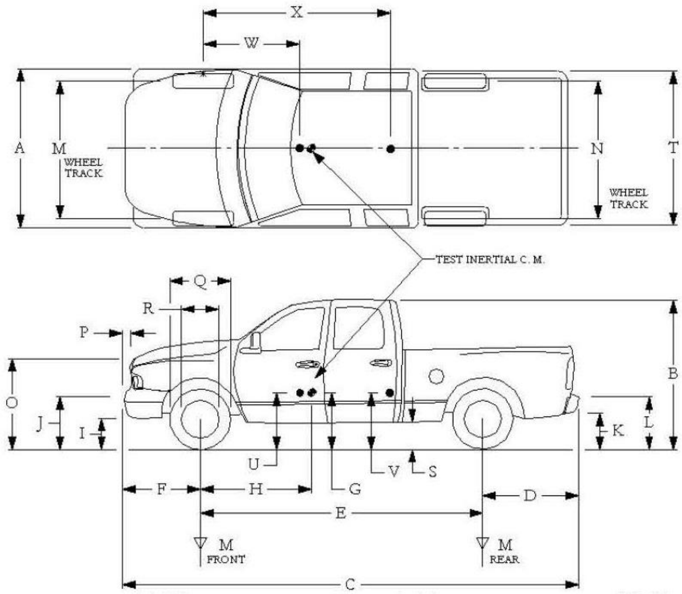
NOTES: None

Engine Type: V-8
Engine CID: 4.7 liter

Transmission Type:
☑ Auto or ☐ Manual
☐ FWD ☑ RWD ☐ 4WD

Optional Equipment:
None

Dummy Data:
Type: 50th percentile male
Mass: 165 lb
Seat Position: Impact side



Geometry: inches

A	78.50	F	40.00	K	20.00	P	3.00	U	26.50
B	74.00	G	28.50	L	30.00	Q	30.50	V	30.25
C	227.50	H	61.30	M	68.50	R	18.00	W	61.30
D	44.00	I	11.75	N	68.00	S	13.00	X	78.00
E	140.50	J	27.00	O	46.00	T	77.00		

Wheel Center Height Front	14.75	Wheel Well Clearance (Front)	6.00	Bottom Frame Height - Front	12.50
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	9.25	Bottom Frame Height - Rear	22.50

RANGE LIMIT: A=78 ±2 inches; C=237 ±13 inches; E=148 ±12 inches; F=39 ±3 inches; G = > 28 inches; H = 63 ±4 inches; O=43 ±4 inches; M+N/2=67 ±1.5 inches

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2930	2826	2911
Back	3900	M_{rear}	2053	2189	2269
Total	6700	M_{Total}	4983	5015	5180

(Allowable Range for TIM and GSM = 5000 lb ±110 lb)

Mass Distribution:
lb LF: 1388 RF: 1438 LR: 1108 RR: 1081

Figure 107. Measurement of vehicle vertical CG for Test No. 606861-1

Date: 2018-10-02 Test No.: 606861-1 VIN: 1C6RD6GTXCS268732

Year: 2012 Make: RAM Model: 1500

Body Style: Quad Cab Mileage: 268732

Engine: 4.7 liter V-8 Transmission: Automatic

Fuel Level: Empty Ballast: 171 (440 lb max)

Tire Pressure: Front: 35 psi Rear: 35 psi Size: 265/70 R 17

Measured Vehicle Weights: (lb)								
LF:	1388		RF:	1438		Front Axle:	2826	
LR:	1108		RR:	1081		Rear Axle:	2189	
Left:	2496		Right:	2519		Total:	5015	
						5000 ±110 lb allowed		
Wheel Base:	140.50	inches	Track: F:	68.50	inches	R:	68.00	inches
	148 ±12 inches allowed			Track = (F+R)/2 = 67 ±1.5 inches allowed				
Center of Gravity, SAE J874 Suspension Method								
X:	61.33	inches	Rear of Front Axle	(63 ±4 inches allowed)				
Y:	0.16	inches	Left - Right +	of Vehicle Centerline				
Z:	28.50	inches	Above Ground	(minumum 28.0 inches allowed)				

Hood Height: 46.00 inches Front Bumper Height: 27.00 inches

43 ±4 inches allowed

Front Overhang: 40.00 inches Rear Bumper Height: 30.00 inches

39 ±3 inches allowed

Overall Length: 227.50 inches

237 ±13 inches allowed

Figure 108. Sequential photographs for Test No. 606861-1 (overhead view).

0.000 s

0.100 s

0.200 s

0.300 s

0.400 s

0.500 s

0.600 s

0.700 s

Figure 109. Sequential photographs for Test No. 606861-1 (frontal view).

0.000 s

0.100 s

0.200 s

0.300 s

0.400 s

0.500 s

0.600 s

0.700 s

Figure 110. Sequential photographs for Test No. 606861-1 (rear view).

0.000 s

0.100 s

0.200 s

0.300 s

0.400 s

0.500 s

0.600 s

0.700 s

Figure 111. Exterior crush measurements for Test No. 606861-1

Date: 2018-10-02 Test No.: 606861-1 VIN No.: 1C6RD6GTXCS268732

Year: 2012 Make: RAM Model: 1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable	
End Damage	**Side Damage**
Undeformed end width ________	Bowing: B1 _____ X1 _____
Corner shift: A1 ________	B2 _____ X2 _____
A2 ________	
End shift at frame (CDC)	Bowing constant
(check one)	$\frac{X1+X2}{2}$ = _______
< 4 inches ________	
≥ 4 inches ________	

Note: Measure C_1 to C_6 from Driver to Passenger Side in Front or Rear Impacts – Rear to Front in Side Impacts.

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	AT FT BUMPER	26	16	34	2	2.5	5	8	12	16	+14
2	ABOVE FT BUMPER	26	15.5	56	2	5	8	10	13.5	15.5	+72
	Measurements recorded										
	☑ **inches** or ☐ **mm**										

[1]Table taken from National Accident Sampling System (NASS).

*Identify the plane at which the C-measurements are taken (e.g., at bumper, above bumper, at sill, above sill, at beltline, etc.) or label adjustments (e.g., free space).

Free space value is defined as the distance between the baseline and the original body contour taken at the individual C locations. This may include the following: bumper lead, bumper taper, side protrusion, side taper, etc. Record the value for each C-measurement and maximum crush.

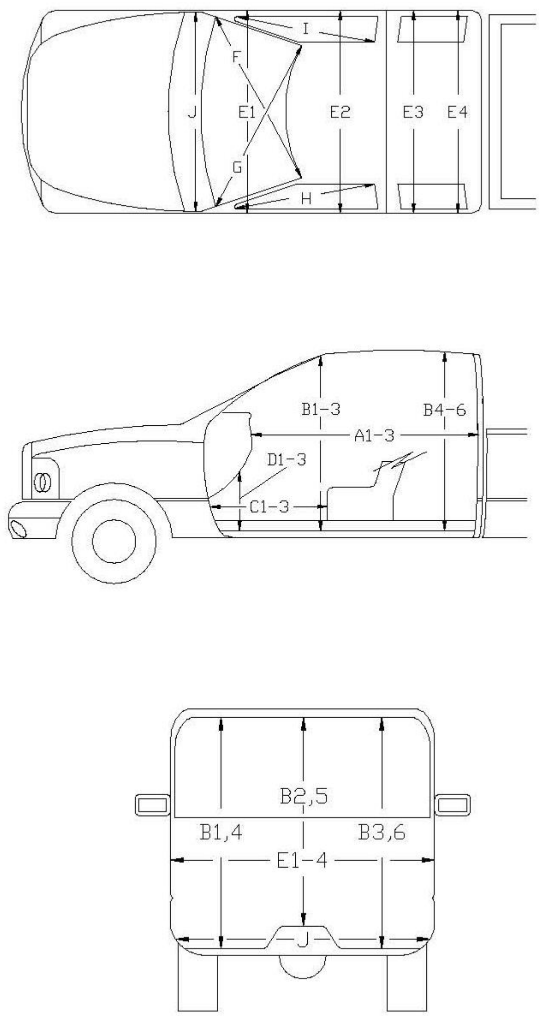
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***Measure and document on the vehicle diagram the location of the maximum crush.

Note: Use as many lines/columns as necessary to describe each damage profile.

Figure 112. Occupant compartment measurements for Test No. 606861-1

Date:	2018-10-02	Test No.:	606861-1	VIN No.:	1C6RD6GTXCS268732
Year:	2012	Make:	RAM	Model:	1500



*Lateral area across the cab from driver's side kickpanel to passenger's side kickpanel.

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	65.00	65.00	0.00
A2	63.00	63.00	0.00
A3	65.50	65.50	0.00
B1	45.00	45.00	0.00
B2	38.00	38.00	0.00
B3	45.00	44.50	-0.50
B4	39.50	39.50	0.00
B5	43.00	43.00	0.00
B6	39.50	39.50	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	24.00	-2.00
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
D3	11.50	11.25	-0.25
E1	58.50	59.00	0.50
E2	63.50	65.75	2.25
E3	63.50	63.50	0.00
E4	63.50	63.50	0.00
F	59.00	59.00	0.00
G	59.00	59.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	25.00	24.00	-1.00

Figure 113. Vehicle angular displacements for Test No. 606861-1

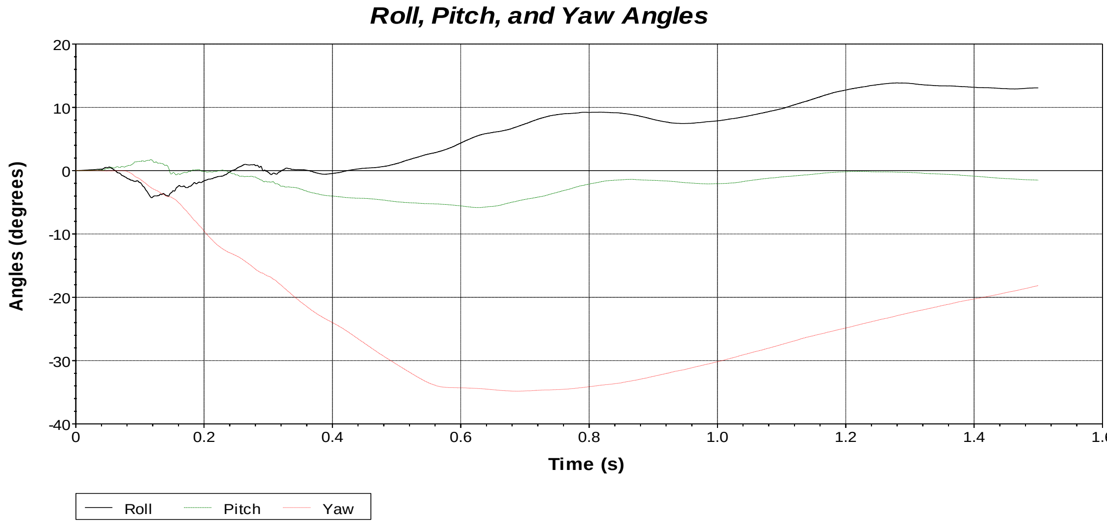


Figure 114. Vehicle longitudinal accelerometer trace for Test No. 606861-1 (accelerometer located at center of gravity)

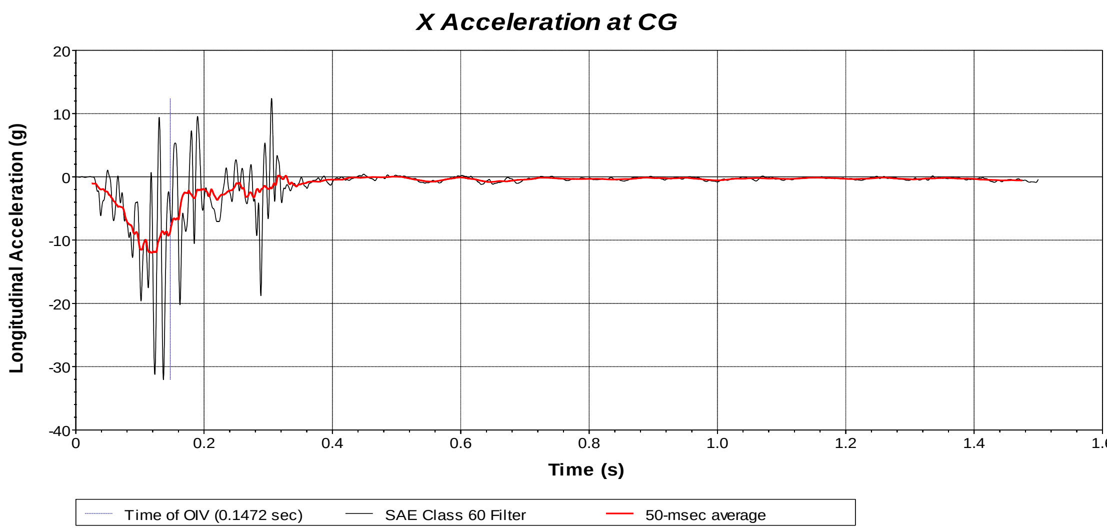


Figure 115. Vehicle lateral accelerometer trace for Test No. 606861-1 (accelerometer located at center of gravity)

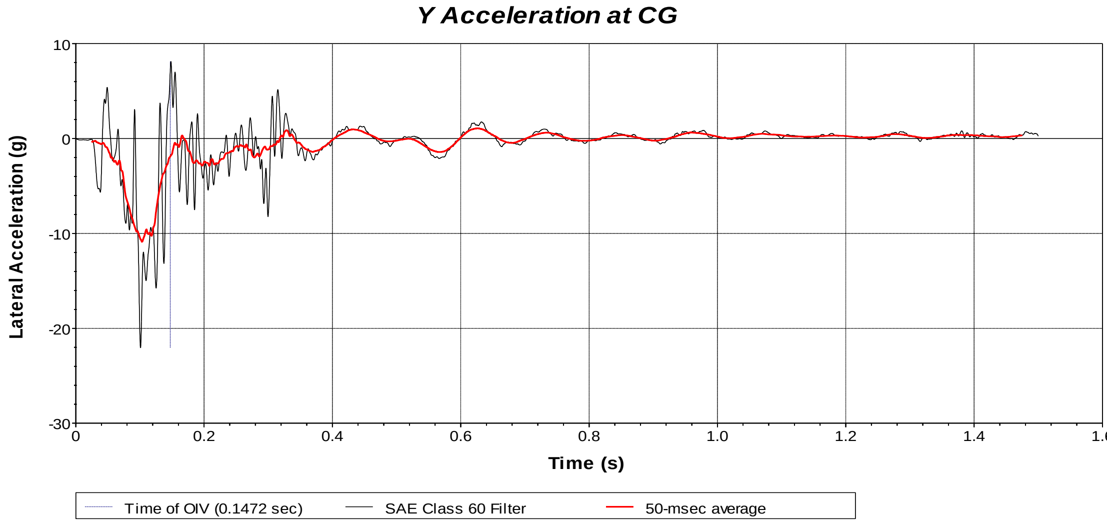
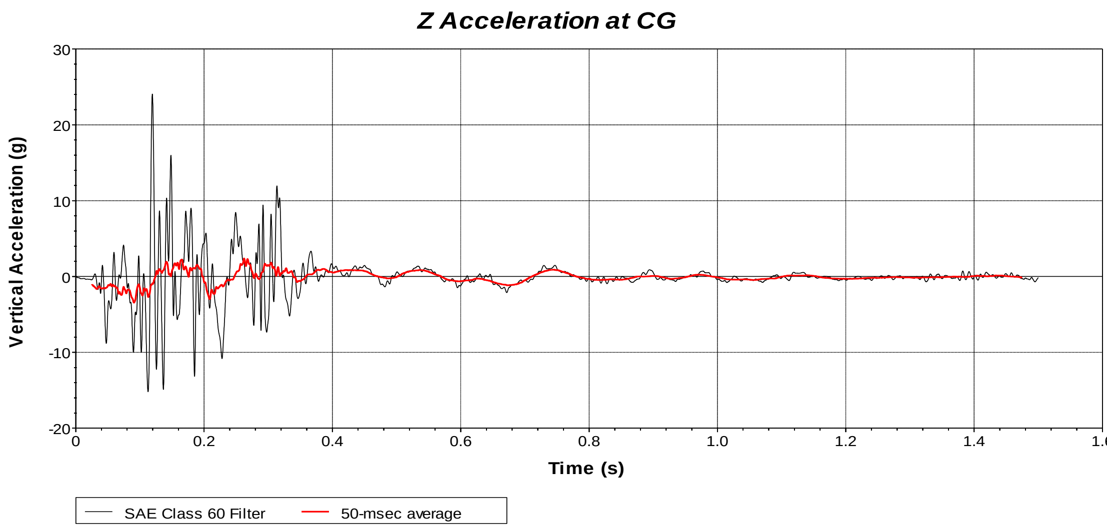


Figure 116. Vehicle vertical accelerometer trace for Test No. 606861-1 (accelerometer located at center of gravity)



Appendix E. MASH Test 3-10 (Crash Test No. 606861-2)

Figure 117. Vehicle properties for Test No. 606861-2

Date: 2020-12-11 Test No.: 606861-4 VIN No.: 3N1CN7APOEL862280

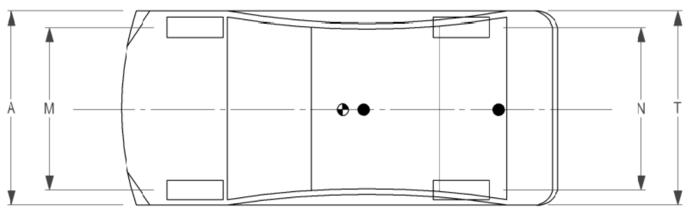
Year: 2014 Make: NISSAN Model: VERSA

Tire Inflation Pressure: 36 PSI Odometer: 91861-4 Tire Size: P185/65R15

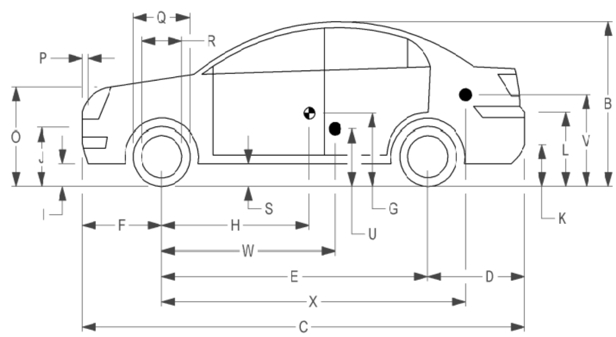
Describe any damage to the vehicle prior to test: None

● Denotes accelerometer location.

NOTES: None



Engine Type: 4 CYL
Engine CID: 1.6 L
Transmission Type:
☐ Auto or ☑ Manual
☑ FWD ☐ RWD ☐ 4WD
Optional Equipment:
None



Dummy Data:
Type: 50th Percentile Male
Mass: 165 lb
Seat Position: IMPACT SIDE

Geometry: inches

A	66.70	F	32.50	K	12.50	P	4.50	U	15.50
B	59.60	G		L	26.00	Q	24.00	V	21.25
C	175.40	H	42.15	M	58.30	R	16.25	W	42.10
D	40.50	I	7.00	N	58.50	S	7.50	X	79.75
E	102.40	J	22.25	O	30.50	T	64.50		

Wheel Center Ht Front 11.50 Wheel Center Ht Rear 11.50 W-H -0.05

RANGE LIMIT: A = 65 ±3 inches; C = 169 ±8 inches; E = 98 ±5 inches; F = 35 ±4 inches; H = 39 ±4 inches; O (Top of Radiator Support) = 28 ±4 inches
(M+N)/2 = 59 ±2 inches; W-H < 2 inches or use MASH Paragraph A4.3.2

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1750	M_{front}	1369	1425	1510
Back	1687	M_{rear}	974	979	1059
Total	3389	M_{Total}	2343	2404	2569

Allowable TIM = 2420 lb ±55 lb | Allowable GSM = 2585 lb ± 55 lb

Mass Distribution:
lb LF: 706 RF: 719 LR: 502 RR: 477

Figure 118. Sequential photographs for Test No. 606861-2 (overhead view).

0.000 s

0.100 s

0.200 s

0.300 s

0.400 s

0.500 s

0.600 s

0.700 s

0.400 s

0.600 s

Figure 119. Sequential photographs for Test No. 606861-2 (frontal view).

0.000 s

0.300 s

0.100 s

0.200 s

0.400 s

0.600 s

0.500 s

0.700 s

Figure 120. Sequential photographs for Test No. 606861-2 (rear view).

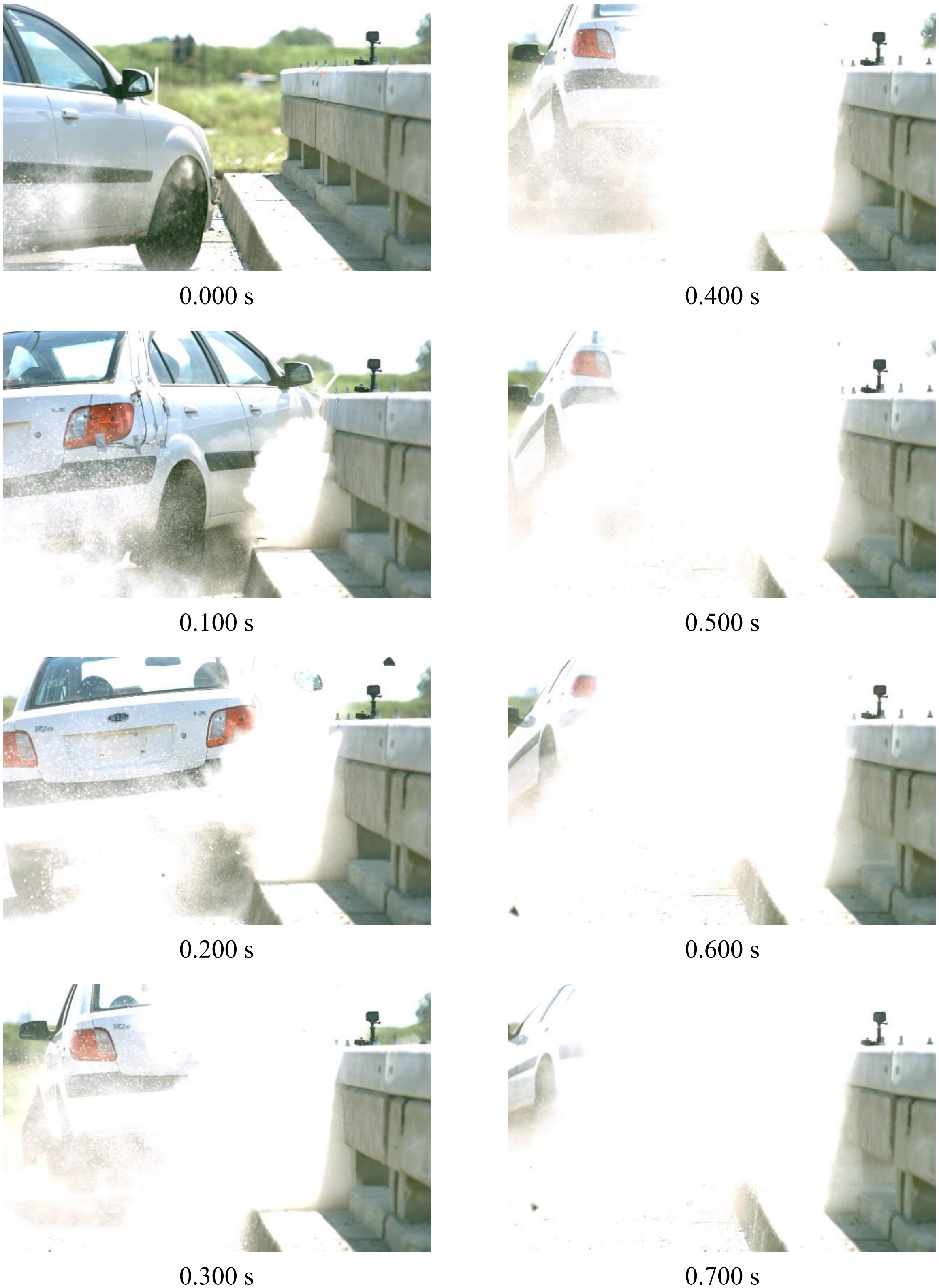


Figure 121. Exterior crush measurements for Test No. 606861-2

Date:	2018-10-03	Test No.:	606861-2	VIN No.:	KNADE223396496067
Year:	2009	Make:	Kia	Model:	Rio

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable	
End Damage	Side Damage
Undeformed end width ________	Bowing: B1 _____ X1 _____
Corner shift: A1 ________	B2 _____ X2 _____
A2 ________	
End shift at frame (CDC)	Bowing constant
(check one)	$\frac{X1+X2}{2}$ = ______
< 4 inches ________	
≥ 4 inches ________	

Note: Measure C_1 to C_6 from Driver to Passenger Side in Front or Rear Impacts – Rear to Front in Side Impacts.

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	AT FT BUMPER	14	8	22	8	6	2	1.5	1	0	+18
2	ABOVE FT BUMPER	14	9	40	0	1	3.25	3.75	6.5	9	+65
	Measurements recorded										
	☑ **inches or** ☐ **mm**										

[1]Table taken from National Accident Sampling System (NASS).

*Identify the plane at which the C-measurements are taken (e.g., at bumper, above bumper, at sill, above sill, at beltline, etc.) or label adjustments (e.g., free space).

Free space value is defined as the distance between the baseline and the original body contour taken at the individual C locations. This may include the following: bumper lead, bumper taper, side protrusion, side taper, etc. Record the value for each C-measurement and maximum crush.

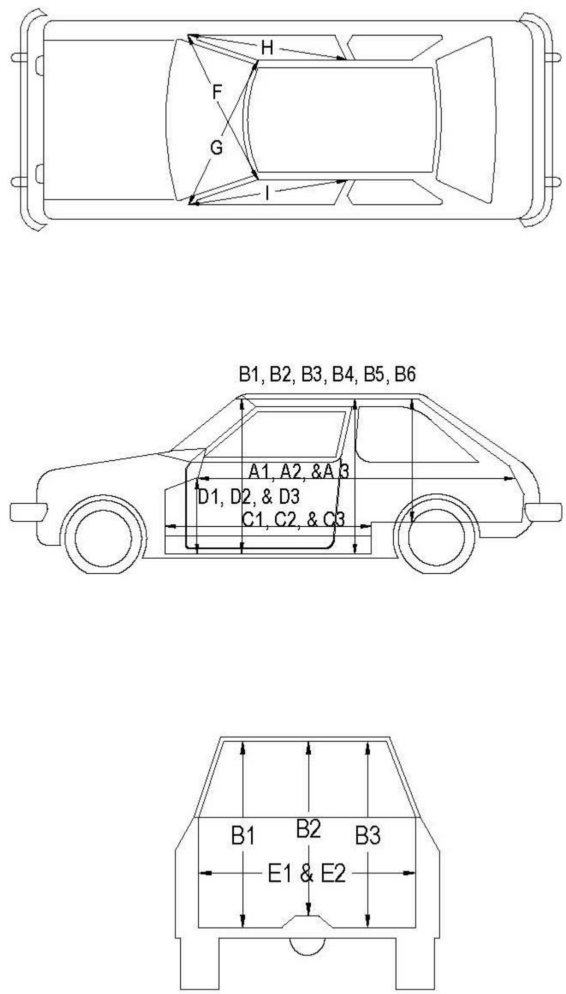
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***Measure and document on the vehicle diagram the location of the maximum crush.

Note: Use as many lines/columns as necessary to describe each damage profile.

Figure 122. Occupant compartment measurements for Test No. 606861-2

Date:	2018-10-03	Test No.:	606861-2	VIN No.:	KNADE223396496067
Year:	2009	Make:	Kia	Model:	Rio



*Lateral area across the cab from
driver's side kick panel to passenger's side kick panel.

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	67.50	67.50	0.00
A2	67.25	67.25	0.00
A3	67.75	67.75	0.00
B1	40.50	40.50	0.00
B2	39.00	39.00	0.00
B3	40.50	40.50	0.00
B4	36.25	36.25	0.00
B5	36.00	36.00	0.00
B6	36.25	36.25	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	24.50	-1.50
D1	9.50	9.50	0.00
D2	0.00	0.00	0.00
D3	9.50	8.50	-1.00
E1	51.50	51.75	0.25
E2	51.00	51.75	0.75
F	51.00	51.00	0.00
G	51.00	51.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	51.00	50.50	-0.50

Figure 123. Vehicle angular displacements for Test No. 606861-2

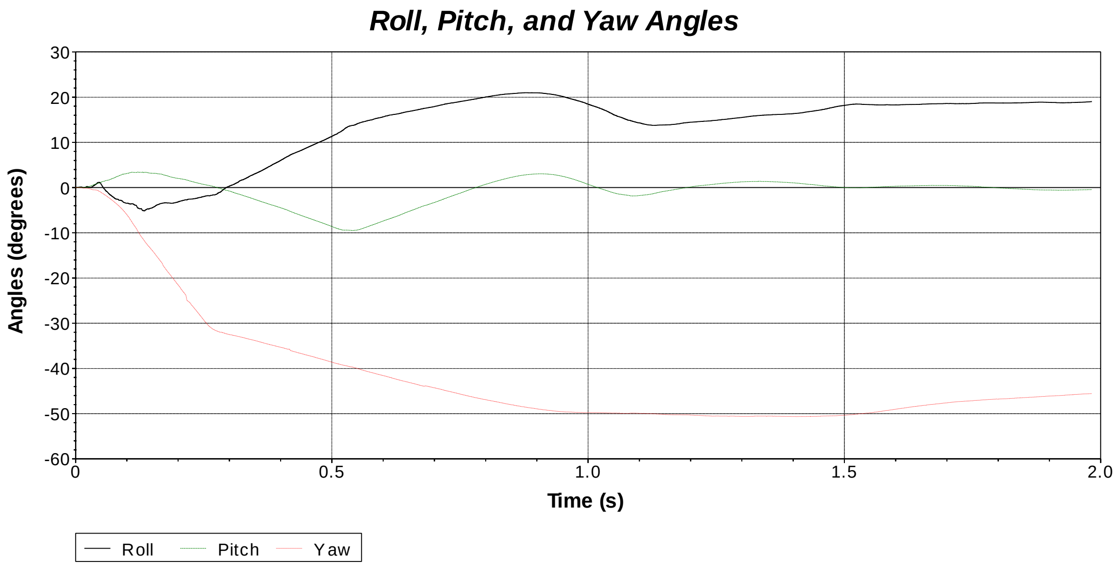


Figure 124. Vehicle longitudinal accelerometer trace for Test No. 606861-2 (accelerometer located at center of gravity)

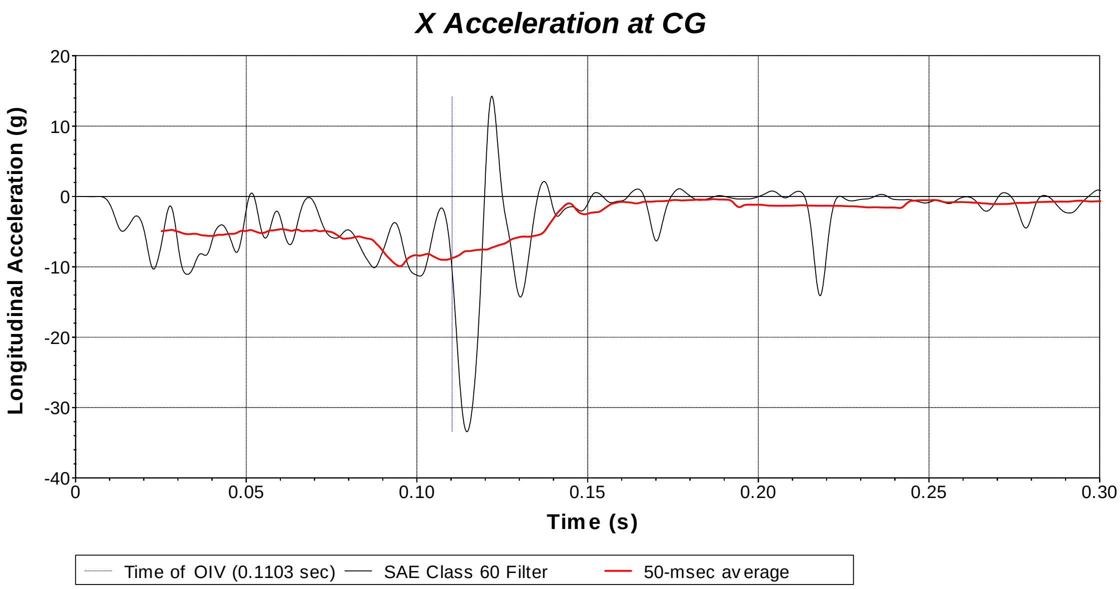


Figure 125. Vehicle lateral accelerometer trace for Test No. 606861-2 (accelerometer located at center of gravity)

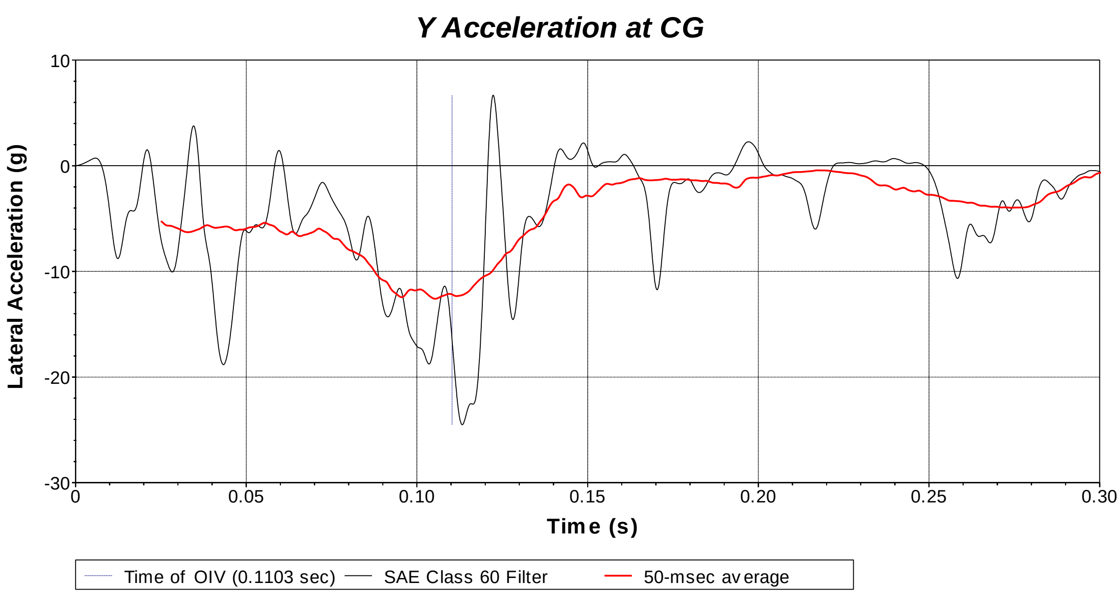
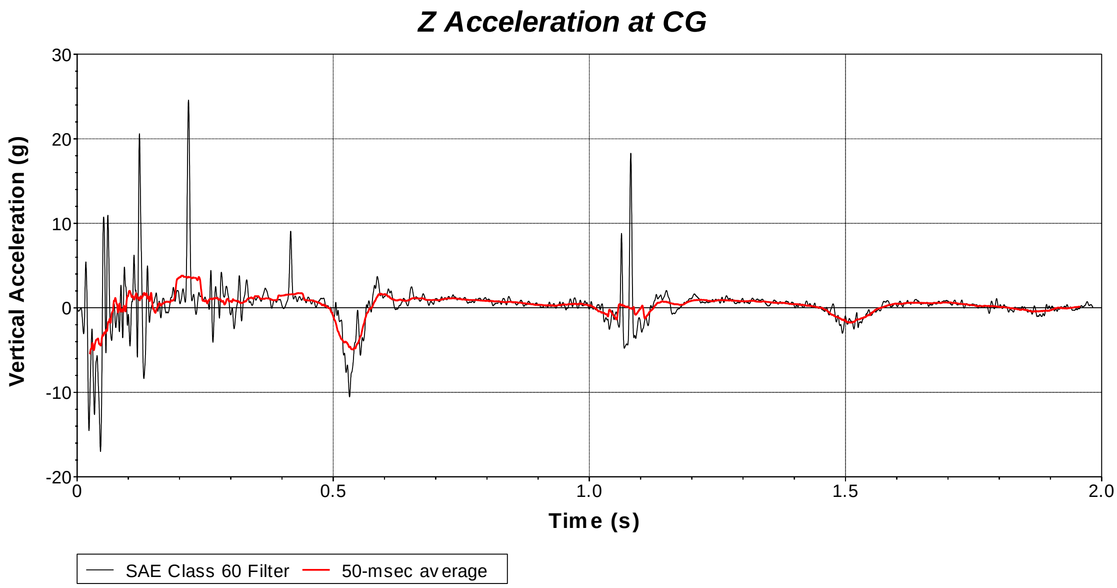


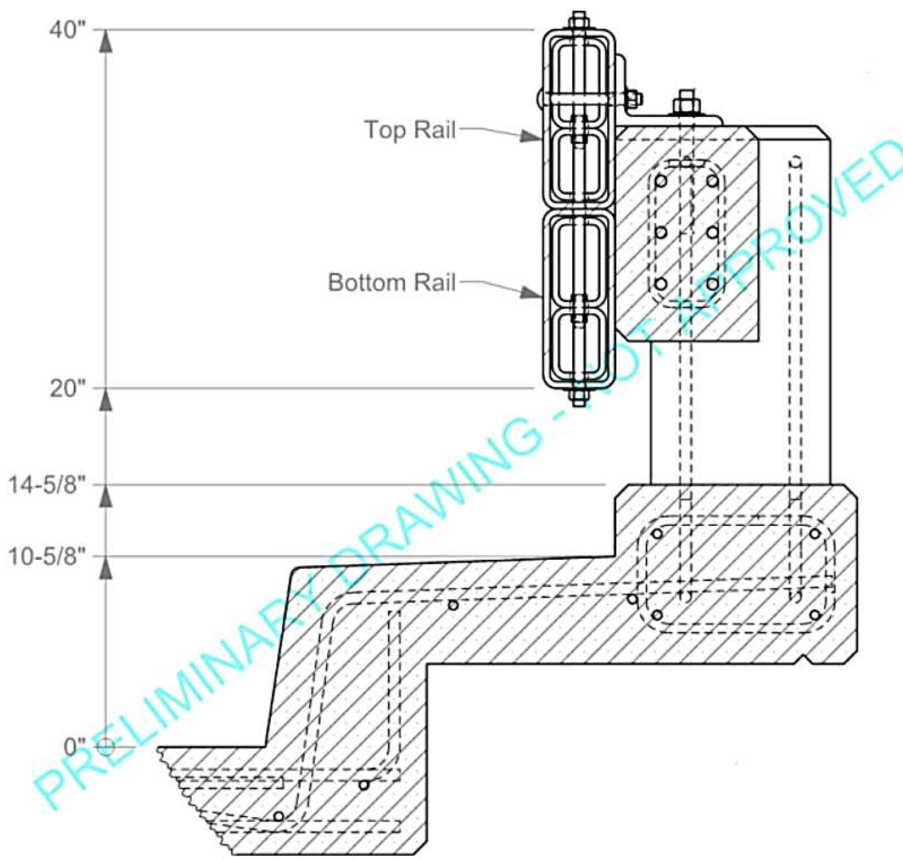
Figure 126. Vehicle vertical accelerometer trace for Test No. 606861-2 (accelerometer located at center of gravity)



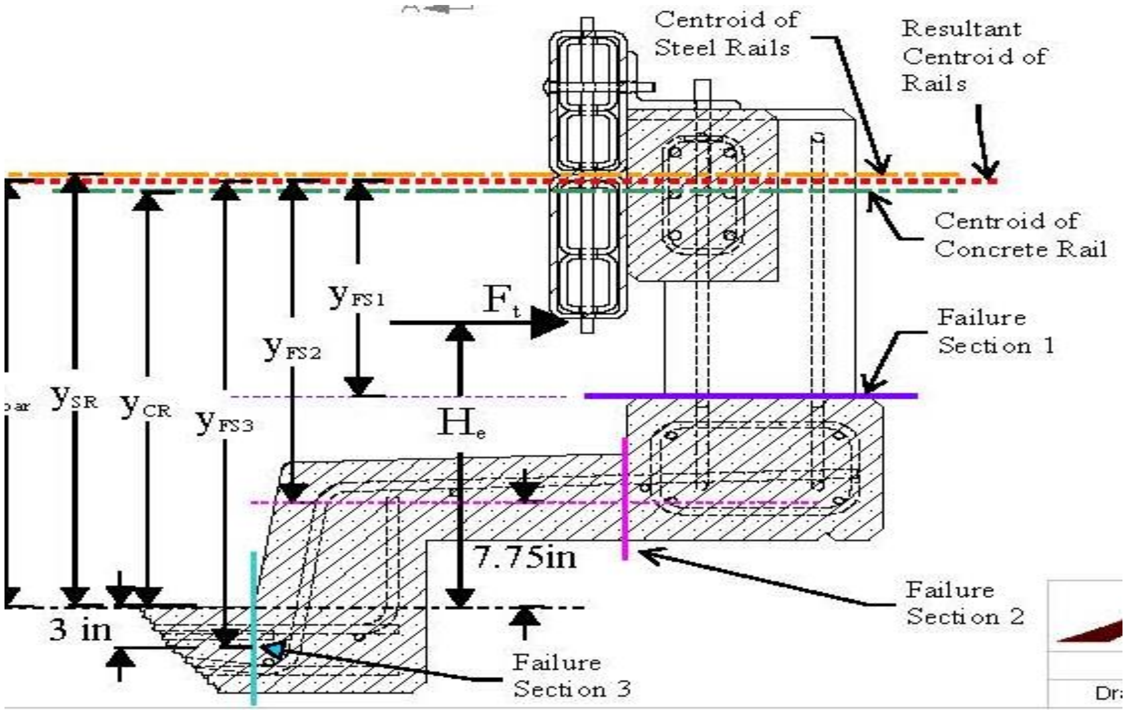
Appendix F. Strength Analysis of DOTD Retrofit Bridge Rail System

Texas A&M Transportation Institute

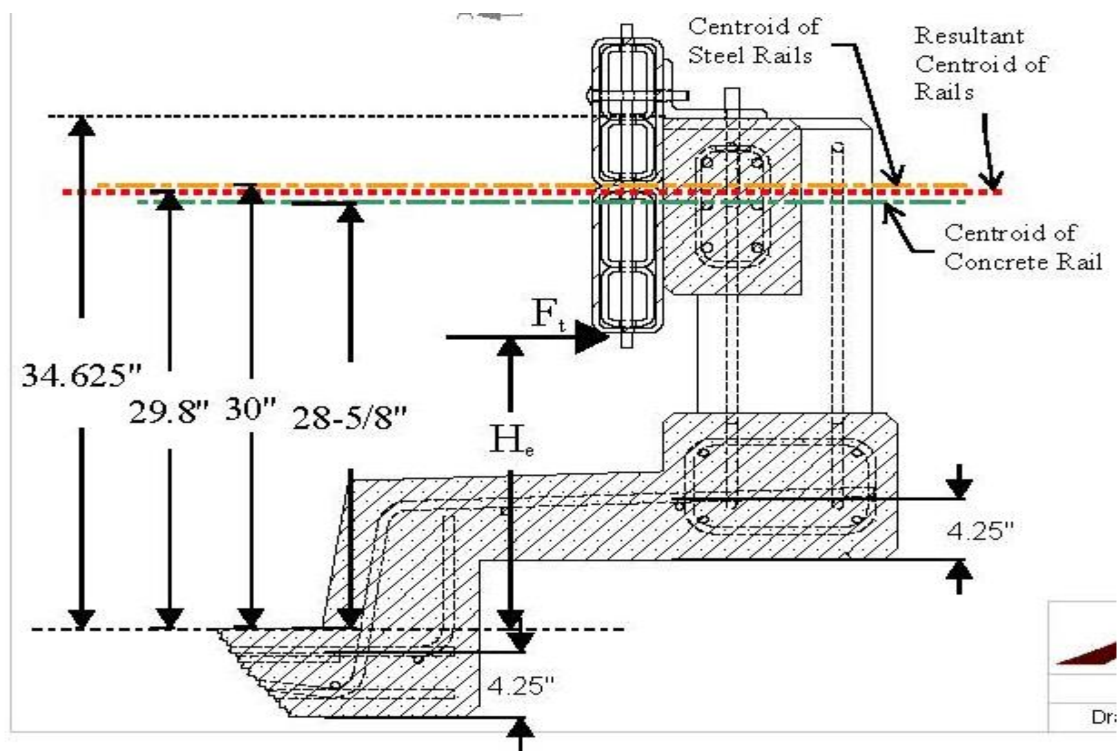
SUBJECT: LADOTD (LTRC 16) HSS Tube Bridge Rail Retrofit LRFD Strength Analysis



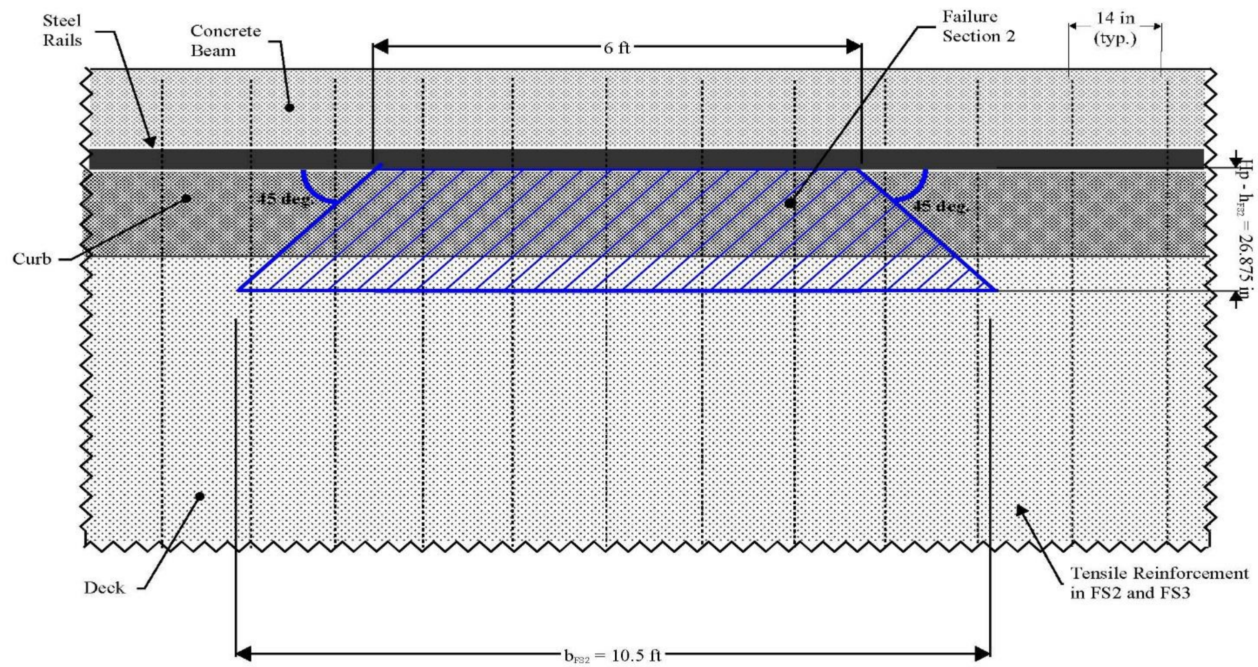
Section View of Bridge Rail Section



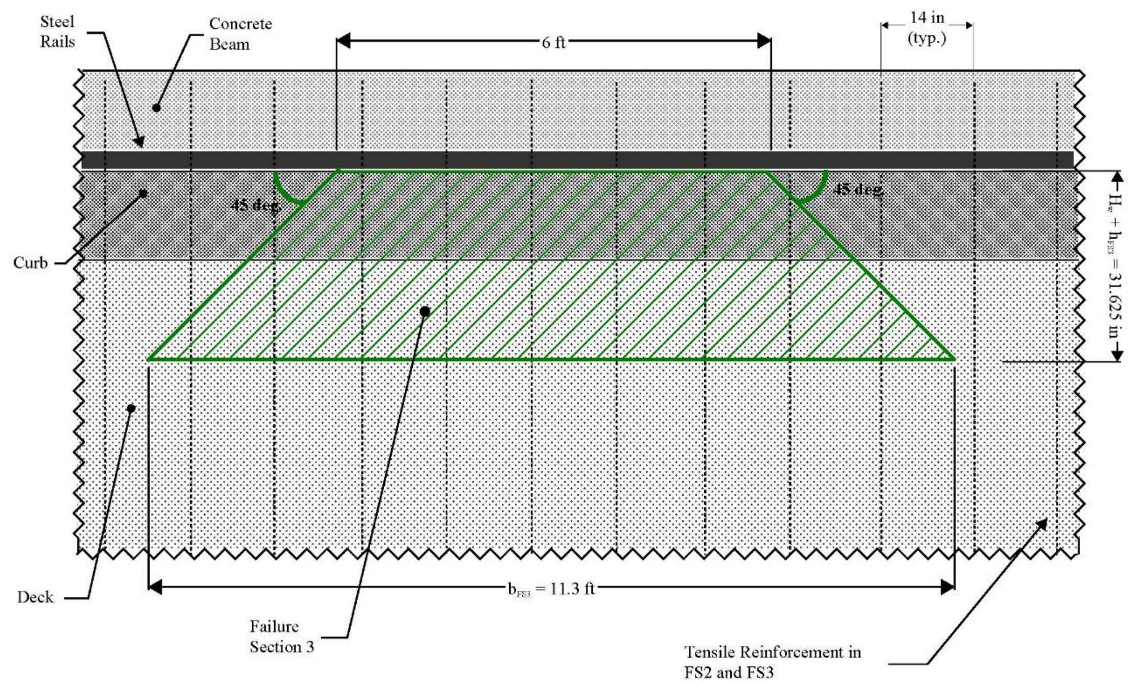
Section View of Bridge Rail System with Variable Notations



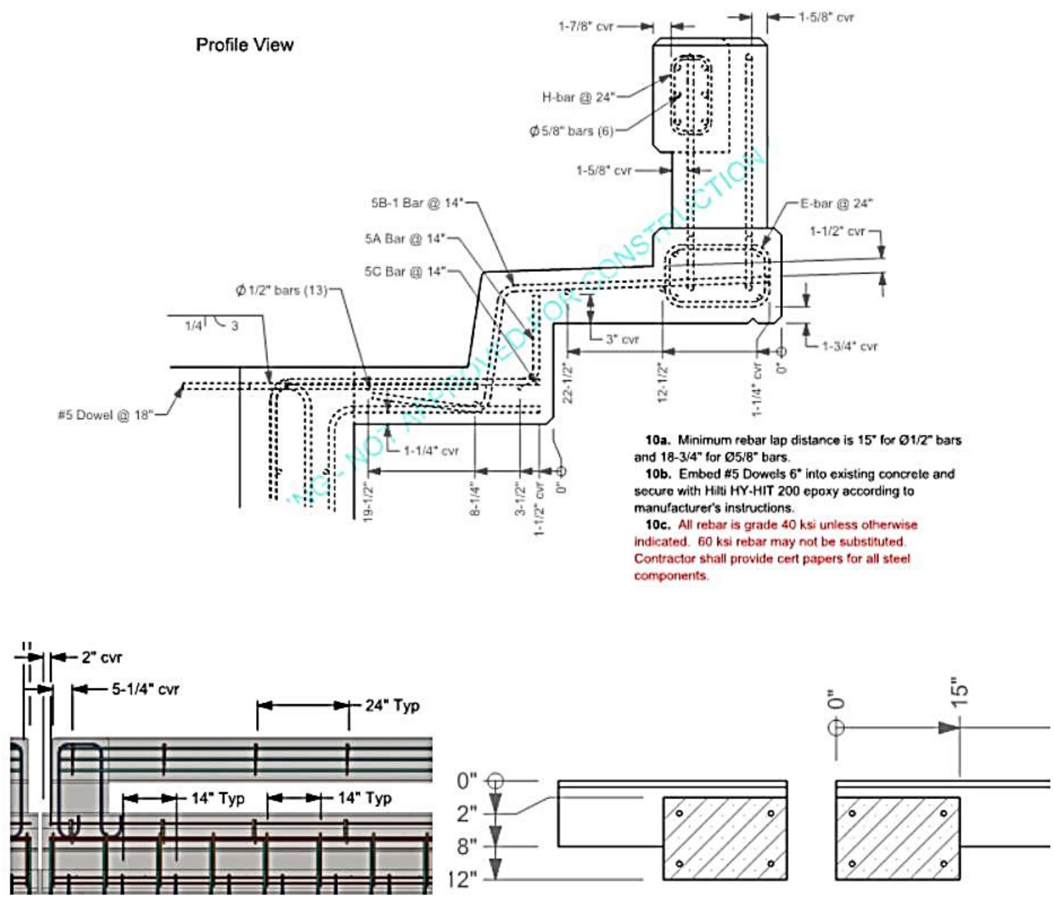
Section View of Bridge Rail System with Key Dimensions



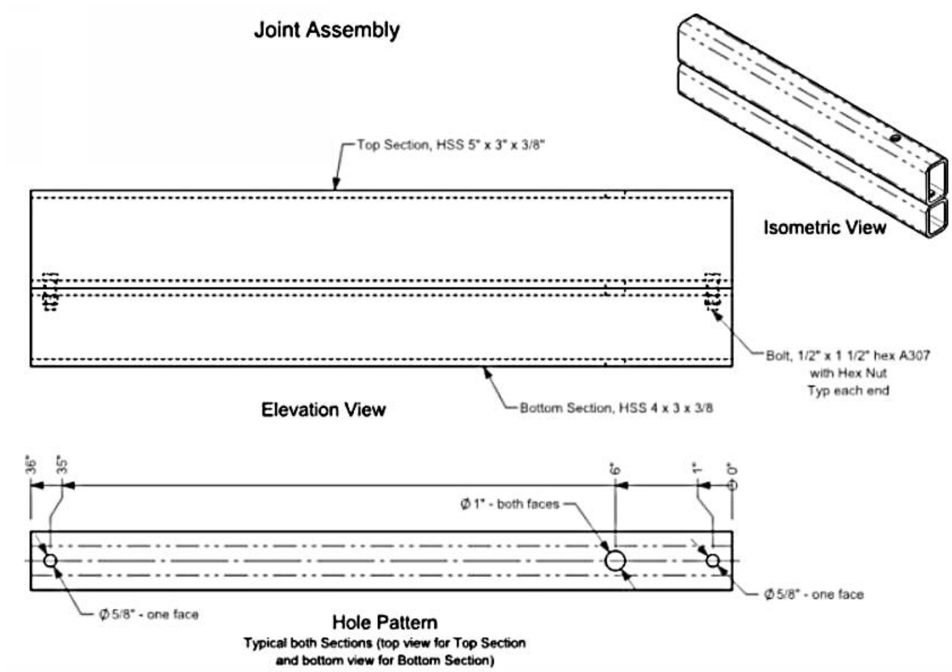
Plan View of Failure Section 2



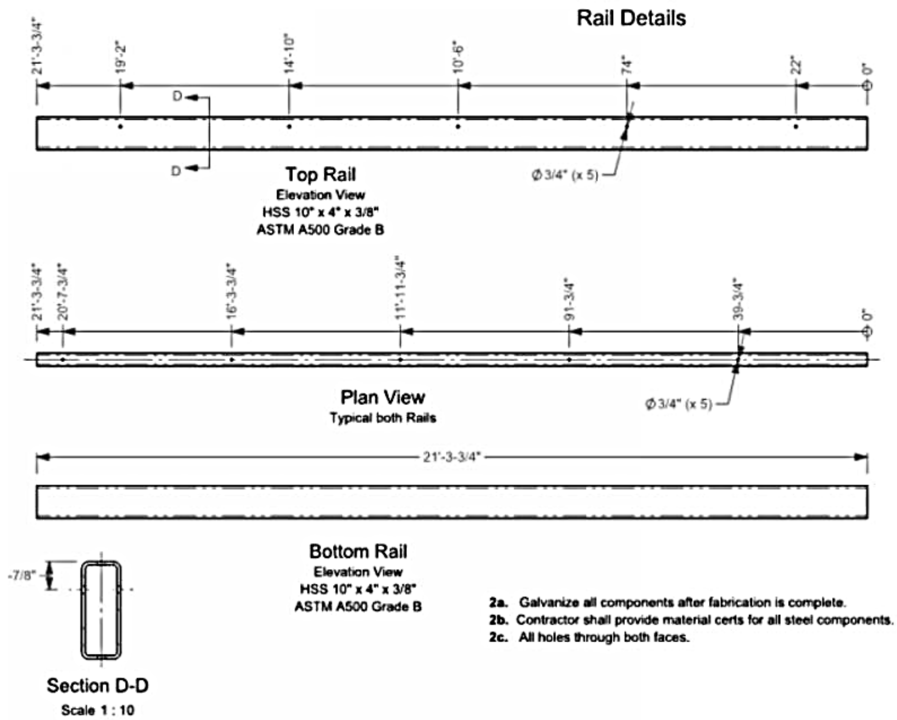
Plan View of Failure Section 3



Details of Concrete and Reinforcement Bars



Detail Views of Splice Details



Detail Views of Steel Rails

SUBJECT: **LADOTD (LTRC 16) HSS Tube Bridge Rail Retrofit LRFD Strength Analysis**

General Information:

- Concrete Parapet Strength, f'c = 4000psi
- Anchor Rods are ϕ3/4" x 8" long, A193 B7 Threaded Anchor: Fu=120ksi
- All concrete reinforcing steel = Grade 40: fy=40ksi
- HSS10x4x3/8 Tube Rails are A500 Grade B Material: Fy=46 ksi
- Reference: AASHTO LRFD Bridge Design Specifications, Section 13, TL-3 Conditions.
- Objective: Calculate the Strength of the Rail based on Worst Case Rail Strength and AASHTO LRFD Section 13 Strength Requirements.

************************* Concrete, Reinforcing Steel & Structural Shape Information *****************************

$f'_c := 4000 \cdot psi$ — Compressive Strength of Concrete (psi)

$F_{yR} := 46ksi$ — Yield Strength of all Steel Rails (ksi)

$f_y := 40ksi$ — Yield Strength of Concrete Reinforcing Steel (ksi)

$b_{rail} := 12in$ — Width of Concrete Rail (in.)

$d_{rail} := 6in$ — Distance to Tensile Reinf. from Compression Face (in.)

$n_{sCR} := 3$ — Number of tensile reinf. bars in Concrete Rail

$A_{sCR} := n_{sCR} \cdot 0.31in^2 = 0.93 \cdot in^2$ — Total Area of Tensile Reinf. (in^2)

*************************************** Anchor Rod Properties ***

$F_{u.rod} := 120ksi$ — Tensile Strength of Anchor Rods (ksi)

$d_{rod} := \frac{3}{4}in$ — Diameter of Anchor Rods (in)

$A_{rod} := \frac{\pi \cdot d_{rod}^2}{4} = 0.442 \cdot in^2$ — Area of a Anchor Rod (in^2)

MASH Design Impact Loads

Test Level	F_t (kip)	F_L (kip)	F_v (kip)	L_t/L_L (ft)	L_v (ft)	H_e (in)	H_{min} (in)
TL 1	13.5	4.5	4.5	4.0	18.0	18.0	18.0
TL 2	27.0	9.0	4.5	4.0	18.0	20.0	18.0
TL 3	71.0	18.0	4.5	4.0	18.0	24.0	29.0
TL 4 (a)	68.0	22.0	38.0	4.0	18.0	25.0	36.0
TL 4 (b)	80.0	27.0	22.0	5.0	18.0	30.0	36.0
TL 5 (a)	160.0	41.0	80.0	10.0	40.0	35.0	42.0
TL 5 (b)	262.0	75.0	160.0	10.0	40.0	43.0	42.0
TL 6	175.0	58.0	80.0	8.0	40.0	56.0	90.0

Note: (a) and (b) denote different TL 4 and TL 5 design force values for bridge rails of different heights.

$TL := 3$ — Test Level

$F_t := 71kip$ — Transverse Impact Force (kip)

$L_t := 4ft$ — Longitudinal Length of Distribution of Transverse Impact Force (ft.)

$L_{t.amp} := 1.5 \cdot L_t = 6\,ft$ — Amplified Longitudinal Length of Distribution of Transverse Impact Force (ft.)
- Note: Amplify Lt by 50% since steel rail retrofit will distribute impact load greater than what typically occurs. 50% amplification is typical of what we've seen in previous similar tests.

$H_e := 19in$ — Height of Transverse Impact Load (in.)

$H_{e.mod} := H_e + 10in = 29 \cdot in$ — Modified Height of Transverse Impact Load (in.)
- Note: Due to curb and deck geometry, the impact load will be applied to the barrier at a greater height than the typical H_e. Adding 10 inches to H_e acounts for the curb height.

$F_v := 4.5kip$ — Vertical Impact Force (kip)

$L_v := 18ft$ — Longitudinal Length of Distribution of Vertical Impact Force (ft.)

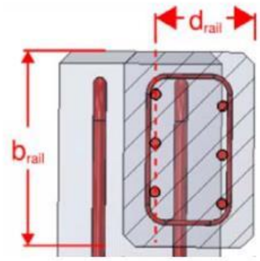
$L_p := 9ft + 9in + \frac{7}{8}in = 117.875 \cdot in$ — Spacing of Posts (in.)

$H_p := 34.625in$ — Height of Concrete Post and Beam (in.)

$H_t := 40in$ — Total height of bridge rail system (in.)

Analysis of Steel and Concrete Rails:

Concrete Rail Properties and Dimensions:
a) Concrete Rail has a width of 12in and a height of 8in
b) #5-Gr.40 Rebar is used for Longitudinal Reinforcement



$A_{sCR} = 0.93 \cdot in^2$ — Total Area of Tensile Reinf. (in2)

$b_{rail} = 12 \cdot in$ — Width of Concrete Rail (in.)

$d_{rail} = 6 \cdot in$ — Distance to Tensile Reinf. from Compression Face (in.)

$f_y = 40 \cdot ksi$ — Yield Stress of Reinf. (ksi)

$f'_c = 4 \cdot ksi$ — Compressive Strength of Concrete (ksi)

$a_{rail} := \frac{A_{sCR} \cdot f_y}{0.85 \cdot f'_c \cdot b_{rail}} = 0.912 \cdot in$ — Whitney Stress Block Depth (in.)

$M_{CR} := A_{sCR} \cdot f_y \cdot \left(d_{rail} - \frac{a_{rail}}{2} \right) = 17.187 \cdot kip \cdot ft$ — Moment Strength of Concrete Rail (k-ft)

$y_{CR} := 28.625in$ — Height of the centroid of the Concrete Rail (in.)

Find Height of Resultant Force of Concrete and Steel Rails: (y_{bar1})

HSS10x4x3/8 Steel Rail Properties and Dimensions:
a) Steel Rails are A500 Gr. B Material, Fy=46ksi
b) Steel Rails bend about the y-axis

$F_{yR} = 46 \cdot ksi$ — Yield Strength of Steel Rail (ksi)

$Z_{SR} := 14in^3$ — Plastic Sectional Modulus of both Steel Rails (in^3)

$M_{SR} := 2Z_{SR} \cdot F_{yR} = 107.333 \cdot kip \cdot ft$ — Total Plastic Moment Strength of both Steel Rails (k-ft)

$y_{SR} := 30in$ — Height of the centroid of the Steel Rails (in.)

$y_{CR} = 28.625 \cdot in$ — Height of the centroid of the Concrete Rail (in.)

$M_{CR} = 17.187 \cdot kip \cdot ft$ — Moment Strength of Concrete Rail (k-ft)

$M_{rail1} := M_{SR} + M_{CR} = 124.52 \cdot kip \cdot ft$ — Total Moment Capacity of Concrete Rail and Steel Rails (k-ft)

$$y_{bar1} := \frac{M_{SR} \cdot y_{SR} + M_{CR} \cdot y_{CR}}{M_{rail1}} = 29.81 \cdot in$$

Height of Resultant Force of Concrete Rail and Steel Rails (in.)

$$F_{rail1} := \frac{M_{rail1}}{y_{bar1}} = 50.125 \cdot kip$$

Total Resistance Force of Concrete Rail and Steel Rails located @ y_{bar1} (kip)

Steel Splice Rail Properties and Dimensions:
a) Steel Splice Rails are A500 Gr. B Material, Fy=46ksi
b) Steel Splice Rails are HSS5x3x3/8 and HSS4x3x3/8 members
b) Steel Splice Rails bend about the y-axis

$F_{yR} = 46 \cdot ksi$	Yield Strength of Steel Splice Rails (ksi)
$Z_{S1} := 5.1 in^3$	Plastic Sectional Modulus of top most Steel Splice Rail (in³)
$M_{S1} := F_{yR} \cdot Z_{S1} = 19.55 \cdot kip \cdot ft$	Plastic Moment Strength of top most Steel Splice Rail (k-ft)
$y_{S1} := 37 in$	Height of the centroid of top most Steel Splice Rail (in.)
$Z_{S2} := 4.18 in^3$	Plastic Sectional Modulus of 2nd from top Steel Splice Rail (in³)
$M_{S2} := F_{yR} \cdot Z_{S2} = 16.023 \cdot kip \cdot ft$	Plastic Moment Strength of 2nd from top Steel Splice Rail (k-ft)
$y_{S2} := 32.5 in$	Height of the centroid of 2nd from top Steel Splice Rail (in.)
$Z_{S3} := 5.1 in^3$	Plastic Sectional Modulus of 3rd from top Steel Splice Rail (in³)
$M_{S3} := F_{yR} \cdot Z_{S3} = 19.55 \cdot kip \cdot ft$	Plastic Moment Strength of 3rd from top Steel Splice Rail (k-ft)
$y_{S3} := 27.25 in$	Height of the centroid of 3rd from top Steel Splice Rail (in.)
$Z_{S4} := 4.18 in^3$	Plastic Sectional Modulus of 4th from top Steel Splice Rail (in³)
$M_{S4} := F_{yR} \cdot Z_{S4} = 16.023 \cdot kip \cdot ft$	Plastic Moment Strength of 4th from top Steel Splice Rail (k-ft)
$y_{S4} := 22.75 in$	Height of the centroid of 4th from top Steel Splice Rail (in.)
$M_S := M_{S1} + M_{S2} + M_{S3} + M_{S4} = 71.147 \cdot kip \cdot ft$	Total Plastic Moment Strength of Steel Splice Rails (k-ft)
$y_S := \dfrac{M_{S1} \cdot y_{S1} + M_{S2} \cdot y_{S2} + M_{S3} \cdot y_{S3} + M_{S4} \cdot y_{S4}}{M_S} = 30.098 \cdot in$	Height of the centroid of the Steel Splice Rails (in.)

Find Height of Resultant Force of Concrete and Steel Splice Rails: (y_{bar2})

$M_{CR} = 17.187 \cdot kip \cdot ft$ — Moment Capacity of Concrete Rail (k-ft)

$y_{CR} = 28.625 \cdot in$ — Height of the centroid of the Concrete Rail (in.)

$M_S = 71.147 \cdot kip \cdot ft$ — Plastic Moment Strength of Steel Splice Rails (k-ft)

$y_S = 30.098 \cdot in$ — Height of the centroid of the Steel Splice Rails (in.)

$M_{rail2} := M_{CR} + M_S = 88.333 \cdot kip \cdot ft$ — Total Moment Capacity of Concrete Rail and Steel Splice Rails (k-ft)

$$y_{bar2} := \frac{M_S \cdot y_S + M_{CR} \cdot y_{CR}}{M_S + M_{CR}} = 29.811 \cdot in$$

Height of the centroid of the Concrete Rail and Steel Splice Rails (in.)

$y_{bar1} = 29.81 \cdot in$ — Height of the centroid of the Concrete Rail and Steel Rails (in.)

$$M_{rail2\_ybar1} := M_{rail2} \cdot \frac{y_{bar2}}{y_{bar1}} = 88.337 \cdot kip \cdot ft$$

Total Moment Capacity of Concrete Rail and Steel Splice Rails @ y_{bar1} (k-ft)

$M_{rail1} = 124.52 \cdot kip \cdot ft$ — Total Moment Capacity of Concrete Rail and Steel Rails (k-ft)

$$M_{rail} := \begin{cases} M_{rail2} & \text{if } M_{rail2\_ybar1} < M_{rail1} \\ M_{rail1} & \text{otherwise} \end{cases} = 88.333 \cdot kip \cdot ft$$

Critical Moment Capacity Rails (k-ft)

$$y_{bar} := \begin{cases} y_{bar2} & \text{if } M_{rail2\_ybar1} < M_{rail1} \\ y_{bar1} & \text{otherwise} \end{cases} = 29.811 \cdot in$$

Critical Height of the centroid of the Rails (in.)

Analysis of Post (Failure Section 1): P_{P1}

Failure Section 1 (FS1) Properties and Dimensions:
a) FS1 has a width of 15in and a height of 10in
b) #6-Gr.40 Rebar is used for Tensile Reinforcement
c) See Figure 6 for more information.

$f_y = 40 \cdot ksi$ $\qquad$ $f'_c = 4 \cdot ksi$

$b_{FS1} := 15in$ — Width of FS1 (in.)

$A_{FS1} := 2 \cdot 0.44in^2 = 0.88 \cdot in^2$ — Area of Tensile Reinforcement in FS1 (in^2)

$d_{FS1} := 7.625in$ — Distance to Tensile Reinf. from Compression Face of FS1 (in.)

$y_{FS1} := y_{bar} - 14.625in = 15.186 \cdot in$ — Height measured from centroid of FS1 to Resultant Force of Rails (in.)

$$a_{FS1} := \frac{A_{FS1} \cdot f_y}{0.85 \cdot f'_c \cdot b_{FS1}}$$ Whitney Stress Block Depth for FS1 (in.)

$$M_{FS1} := A_{FS1} \cdot f_y \cdot \left(d_{FS1} - \frac{a_{FS1}}{2}\right) = 21.354 \cdot kip \cdot ft$$ Moment Strength of Post at FS1 (k-ft)

$$P_{P1} := \frac{M_{FS1}}{y_{FS1}} = 16.874 \cdot kip$$ Strength of Post at FS1 (kip)

Analysis of Post (Failure Section 2): P_{P2}

Failure Section 2 (FS2) Properties and Dimensions:
a) Assuming FS2 is vertical from top to bottom of upper deck at the intersection with the parapet.
b) #5-Gr.40 Rebar is used for Tensile Reinforcement
c) See Figure 4 for more information.

$f_y = 40 \cdot ksi$ $\qquad f'_c = 4 \cdot ksi$

$L_{t.amp} = 6\,ft$ — Amplified Longitudinal Length of Distribution of Transverse Impact Force (ft.)

$h_{FS2} := 7.75in$ — Distance from roadway surface to centroid of FS2 (in.) [See figure 2 for more information]

$H_p = 34.625\,in$ — Height of the Concrete Post and Beam measured from top of roadway surface (in.)

$b_{FS2} := L_{t.amp} + 2 \cdot (H_p - h_{FS2}) = 10.479 \cdot ft$ — Width of FS2 (in.) Note: Width of FS2 is assumed to be the impact force projected outward at a 45 degree angle to the centroid of FS2.

$A_{FS2} := 9 \cdot 0.31in^2 = 2.79 \cdot in^2$ — Area of Tensile Reinforcement in FS2 (in^2) There are 9 bars over b_{FS2}

$d_{FS2} := 4.25in$ — Distance to Tensile Reinf. from Compression Face of FS2 (in.) [See Figure 3 for more information]

$$a_{FS2} := \frac{A_{FS2} \cdot f_y}{0.85 \cdot f'_c \cdot b_{FS2}}$$

Whitney Stress Block Depth for FS2 (in.)

$$M_{FS2} := A_{FS2} \cdot f_y \cdot \left(d_{FS2} - \frac{a_{FS2}}{2} \right) = 38.311 \cdot kip \cdot ft$$

Moment Strength at FS2 about the longitudinal axis (k-ft)

$y_{FS2} := y_{bar} - 7.75in = 22.061 \cdot in$ — Height measured from centroid of FS2 to Resultant Force of Rails (in.)

$$P_{P2} := \frac{M_{FS2}}{y_{FS2}} = 20.839 \cdot kip$$

Strength of Post at FS2 (kip)

Analysis of Post (Failure Section 3): P_{P3}

Failure Section 3 (FS3) Properties and Dimensions:
a) Assuming FS3 is vertical from top to bottom of lower deck at the intersection of the lower deck to curb.
b) #5-Gr.40 Rebar is used for Tensile Reinforcement
c) See Figure 5 for more information.

$f_y = 40 \cdot ksi$ $\quad f'_c = 4 \cdot ksi$

$H_p = 34.625 \cdot in$ — Height of Concrete Post and Beam measured from top of roadway surface (in.)

$L_{t.amp} = 6\,ft$ — Amplified Longitudinal Length of Distribution of Transverse Impact Force (ft.)

$h_{FS3} := 3in$ — Vertical distance from roadway surface to centroid of FS3 (in.) [See Figure 2 for more information]

$b_{FS3} := L_{t.amp} + 2 \cdot (H_p + h_{FS3}) = 12.271 \cdot ft$ — Width of FS3 (ft.) Note: Width of FS3 is assumed to be the impact force projected outward at a 45 degree angle to the centroid of FS3.

$A_{FS3} := 10 \cdot 0.31 in^2 = 3.1 \cdot in^2$ — Area of Tensile Reinforcement in FS3 (in^2) There are 10 bars over b_{FS3}

$d_{FS3} := 4.25in$ — Distance to Tensile Reinf. from Compression Face of FS3 (in.) [See Figure 3 for more information]

$$a_{FS3} := \frac{A_{FS3} \cdot f_y}{0.85 \cdot f'_c \cdot b_{FS3}}$$ Whitney Stress Block Depth for FS3 (in.)

$$M_{FS3} := A_{FS3} \cdot f_y \cdot \left(d_{FS3} - \frac{a_{FS3}}{2}\right) = 42.637 \cdot kip \cdot ft$$ Moment Strength of Post at FS3 (k-ft)

$y_{FS3} := y_{bar} + 3in = 32.811 \cdot in$ — Height measured from centroid of FS3 to Resultant Force of Rails (in.)

$$P_{P3} := \frac{M_{FS3}}{y_{FS3}} = 15.593 \cdot kip$$ Strength of Post at FS3 (kip)

Analysis of Post: P_P

$P_{P1} = 16.874 \cdot kip$ Strength of Post at FS1 (kip)

$P_{P2} = 20.839 \cdot kip$ Strength of Post at FS2 (kip)

$P_{P3} = 15.593 \cdot kip$ Strength of Post at FS3 (kip)

Note: The Limiting ("worst case") Post Strength is taken as P_P

$P_P := \min(P_{P1}, P_{P2}, P_{P3}) = 15.593 \cdot kip$

Total Ultimate Resistance (Nominal Resistance) of Railing: R_R

One Span Failure Mode: $N_1=1$

$P_P = 15.593 \cdot kip$

$N_1 := 1$

$M_{rail} = 88.333 \cdot kip \cdot ft$

$L_p = 9.823 \cdot ft$

$L_t = 4 \cdot ft$

$$R_1 := \frac{16 \cdot M_{rail} + (N_1 - 1) \cdot (N_1 + 1) \cdot P_P \cdot L_p}{2 \cdot N_1 \cdot L_p - L_t} = 90.333 \cdot kip$$

Two Span Failure Mode: $N_2=2$

$P_P = 15.593 \cdot kip$

$N_2 := 2$

$M_{rail} = 88.333 \cdot kip \cdot ft$

$L_p = 9.823 \cdot ft$

$L_t = 4 \cdot ft$

$$R_2 := \frac{16 \cdot M_{rail} + {N_2}^2 \cdot P_P \cdot L_p}{2 \cdot N_2 \cdot L_p - L_t} = 57.408 \cdot kip$$

Total Ultimate Resistance (Nominal Resistance) of Railing: R_R

Three Span Failure Mode: N_3=3

$P_P = 15.593 \cdot kip$

$N_3 := 3$

$M_{rail} = 88.333 \cdot kip \cdot ft$

$L_p = 9.823 \cdot ft$

$L_t = 4 \cdot ft$

$$R_3 := \frac{16 \cdot M_{rail} + (N_3 - 1) \cdot (N_3 + 1) \cdot P_P \cdot L_p}{2 \cdot N_3 \cdot L_p - L_t} = 48.031 \cdot kip$$

Four Span Failure Mode: N_4=4

$P_P = 15.593 \cdot kip$

$N_4 := 4$

$M_{rail} = 88.333 \cdot kip \cdot ft$

$L_p = 9.823 \cdot ft$

$L_t = 4 \cdot ft$

$$R_4 := \frac{16 \cdot M_{rail} + N_4^{\,2} \cdot P_P \cdot L_p}{2 \cdot N_4 \cdot L_p - L_t} = 51.809 \cdot kip$$

Total Ultimate Resistance (Nominal Resistance) of Railing: R_R

Five Span Failure Mode: N_5=5

$P_P = 15.593 \cdot kip$

$N_5 := 5$

$M_{rail} = 88.333 \cdot kip \cdot ft$

$L_p = 9.823 \cdot ft$

$L_t = 4 \cdot ft$

$$R_5 := \frac{16 \cdot M_{rail} + (N_5 - 1) \cdot (N_5 + 1) \cdot P_P \cdot L_p}{2 \cdot N_5 \cdot L_p - L_t} = 54.012 \cdot kip$$

Six Span Failure Mode: N_6=6

$P_P = 15.593 \cdot kip$

$N_6 := 6$

$M_{rail} = 88.333 \cdot kip \cdot ft$

$L_p = 9.823 \cdot ft$

$L_t = 4 \cdot ft$

$$R_6 := \frac{16 \cdot M_{rail} + N_6^{\,2} \cdot P_P \cdot L_p}{2 \cdot N_6 \cdot L_p - L_t} = 60.835 \cdot kip$$

Total Ultimate Resistance (Nominal Resistance) of Railing: R_R

Seven Span Failure Mode: $N_7=7$

$P_P = 15.593 \cdot kip$

$N_7 := 7$

$M_{rail} = 88.333 \cdot kip \cdot ft$

$L_p = 9.823 \cdot ft$

$L_t = 4 \cdot ft$

$$R_7 := \frac{16 \cdot M_{rail} + (N_7 - 1) \cdot (N_7 + 1) \cdot P_P \cdot L_p}{2 \cdot N_7 \cdot L_p - L_t} = 65.65 \cdot kip$$

Eight Span Failure Mode: $N_8=8$

$P_P = 15.593 \cdot kip$

$N_8 := 8$

$M_{rail} = 88.333 \cdot kip \cdot ft$

$L_p = 9.823 \cdot ft$

$L_t = 4 \cdot ft$

$$R_8 := \frac{16 \cdot M_{rail} + N_8^{2} \cdot P_P \cdot L_p}{2 \cdot N_8 \cdot L_p - L_t} = 73.23 \cdot kip$$

Total Ultimate Resistance (Nominal Resistance) of Railing: R_R

Note: The Total Ultimate Resistance of the bridge rail system is the minimum value of R_1 - R_8

$$R_r := \min(R_1, R_2, R_3, R_4, R_5, R_6, R_7, R_8) = 48.031 \cdot kip$$

Total Ultimate Resistance of the bridge rail system @ y_{bar} (kip)

$$H_e = 19 \cdot in$$

Height of Transverse Impact Load (in.)

$$y_{bar} = 29.811 \cdot in$$

Height of Resultant Force (in.)

$$F_t = 71 \cdot kip$$

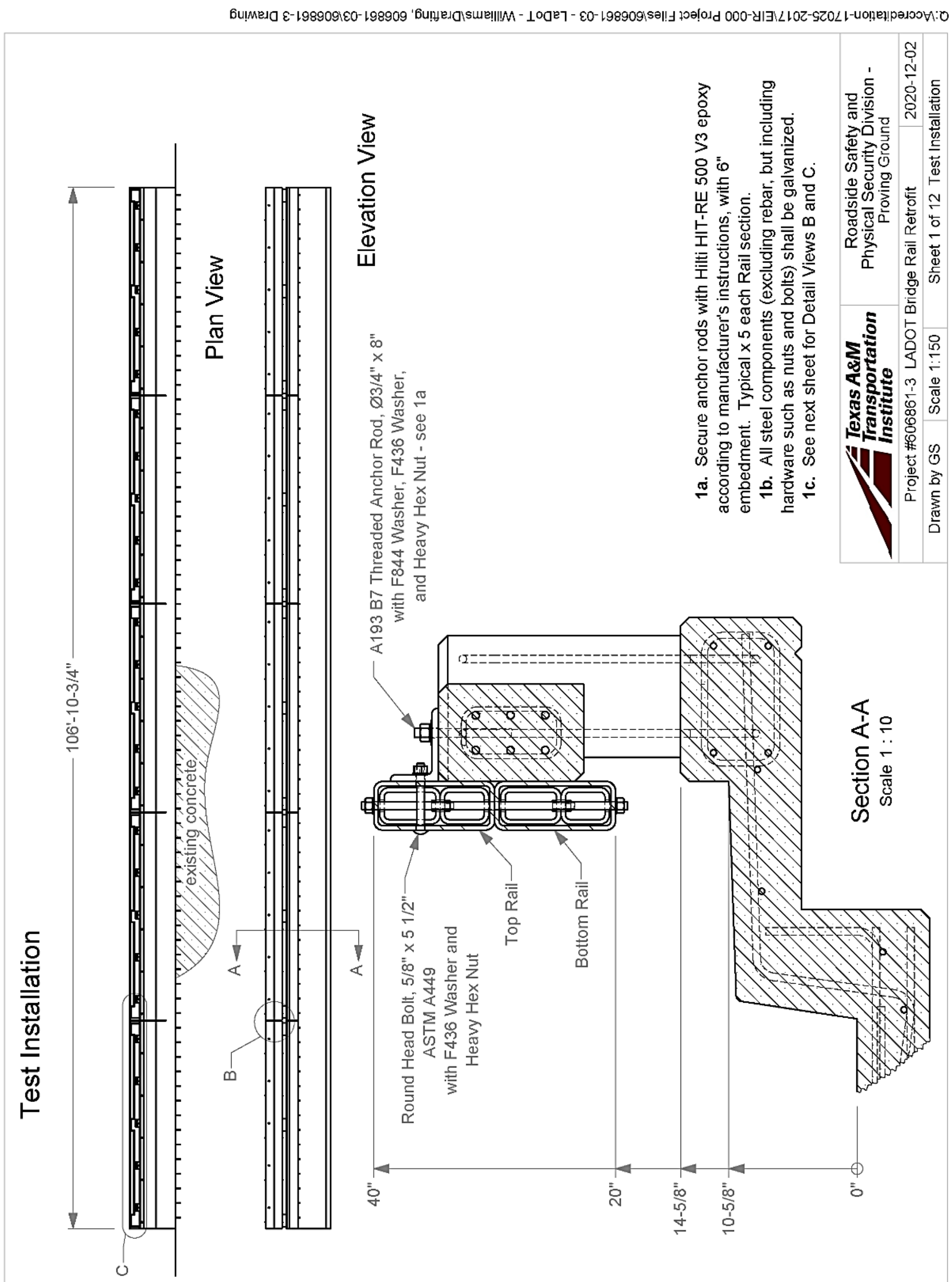
Transverse Impact Force (kip)

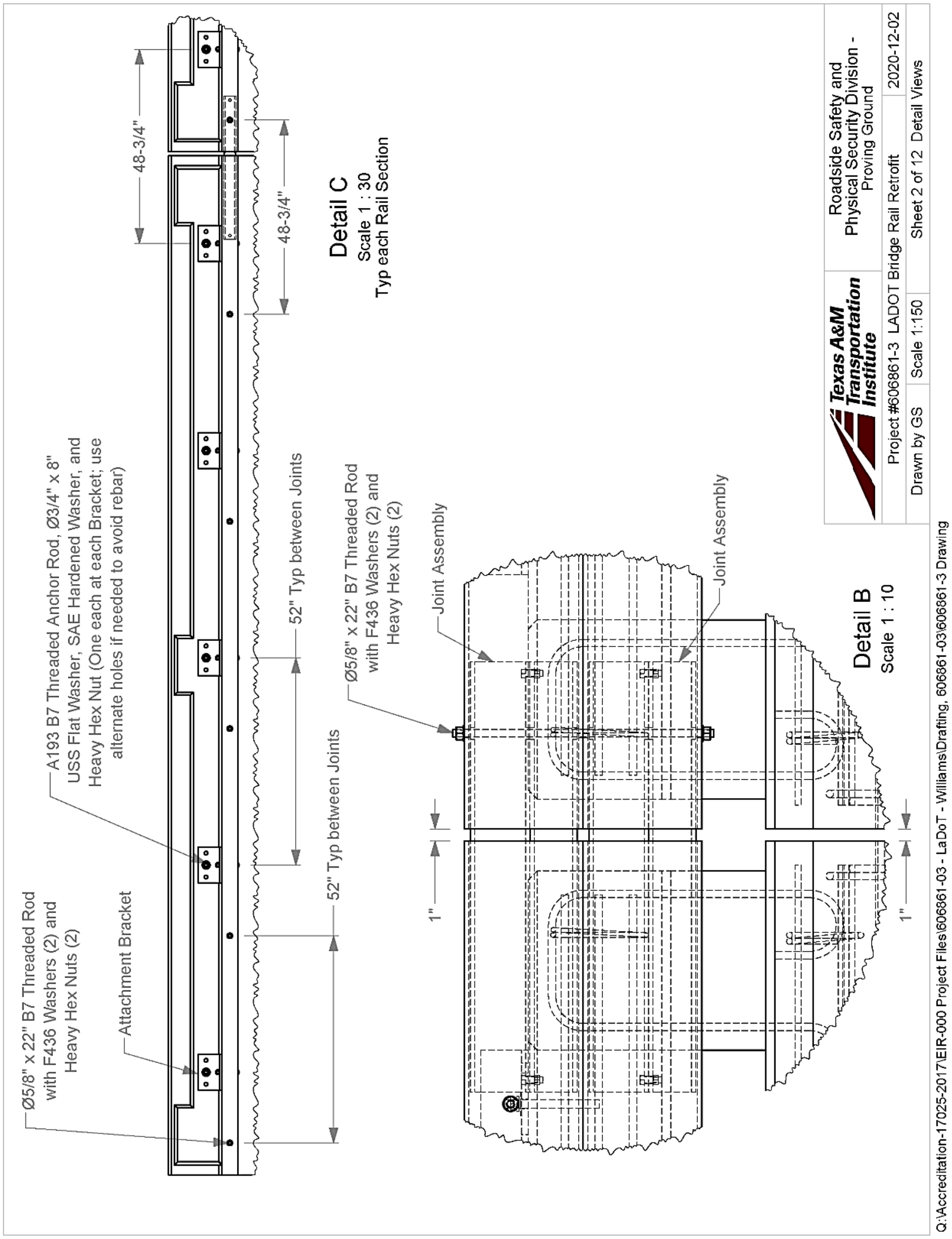
$$R_R := R_r \cdot \left(\frac{y_{bar}}{H_e}\right) = 75.362 \cdot kip$$

Total Ultimate Resistance of the bridge rail system @ H_e (kip)

CHECK= "OK", since R_R = 75.4 kip > F_t = 71 kip

Appendix G. Details of Louisiana Retrofit Post and Beam with Safety Walk Option 2 for Tests 606861-3&4





Ø5/8" x 22" B7 Threaded Rod with F436 Washers (2) and Heavy Hex Nuts (2)
Attachment Bracket
A193 B7 Threaded Anchor Rod, Ø3/4" x 8" USS Flat Washer, SAE Hardened Washer, and Heavy Hex Nut (One each at each Bracket; use alternate holes if needed to avoid rebar)
48-3/4"
48-3/4"
52" Typ between Joints
52" Typ between Joints
Detail C
Scale 1 : 30
Typ each Rail Section
1"
1"
Ø5/8" x 22" B7 Threaded Rod with F436 Washers (2) and Heavy Hex Nuts (2)
Joint Assembly
Joint Assembly
Detail B
Scale 1 : 10
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Roadside Safety and Physical Security Division - Proving Ground
Project #606861-3 LADOT Bridge Rail Retrofit
2020-12-02
Drawn by GS
Scale 1:150
Sheet 2 of 12 Detail Views
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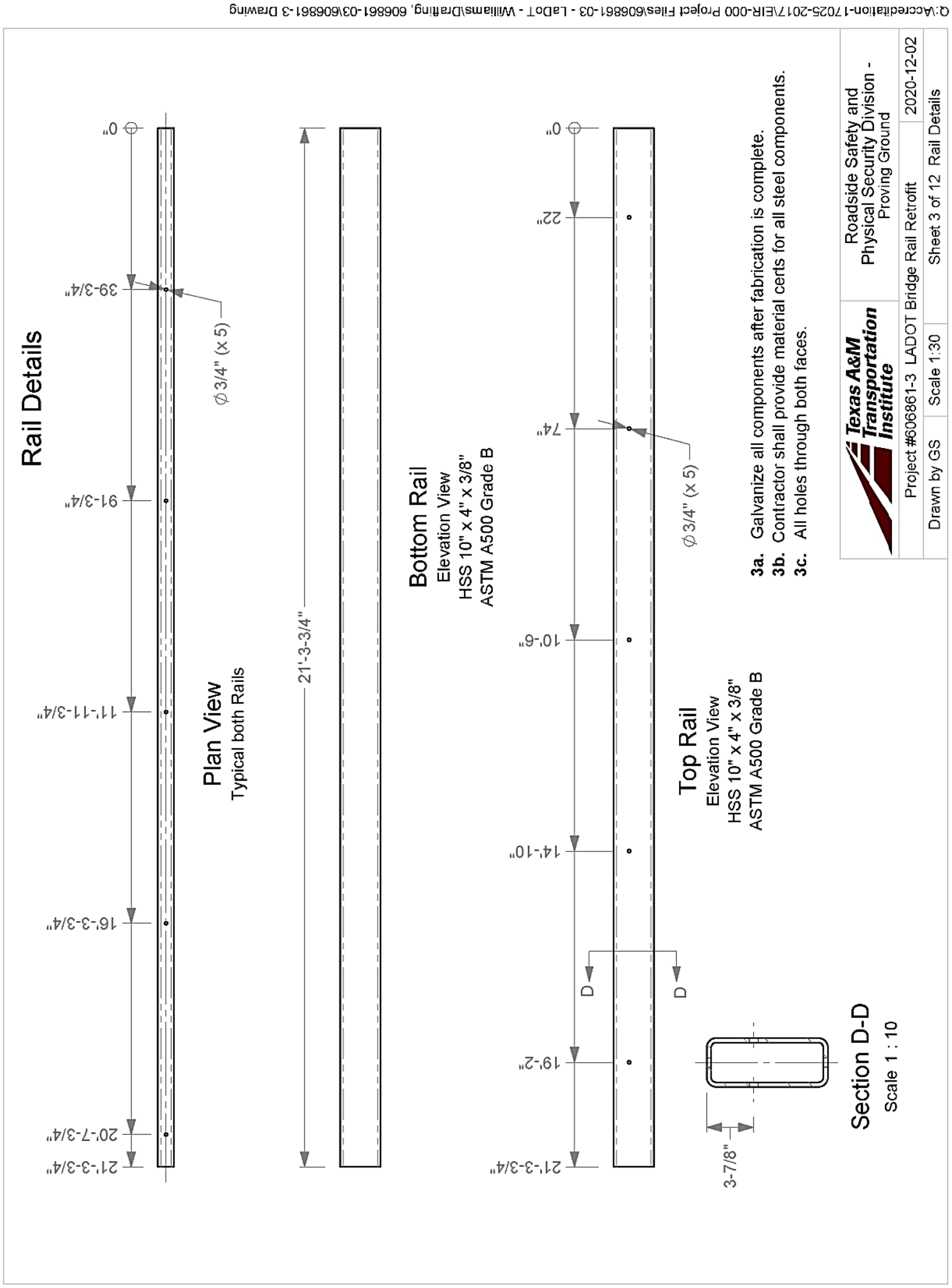
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Rail Details
0"
39-3/4"
91-3/4"
11'-11-3/4"
16'-3-3/4"
20'-7-3/4"
21'-3-3/4"
Ø 3/4" (x 5)
Plan View
Typical both Rails
21'-3-3/4"
Bottom Rail
Elevation View
HSS 10" x 4" x 3/8"
ASTM A500 Grade B
0"
22"
74"
10'-6"
14'-10"
19'-2"
21'-3-3/4"
Ø 3/4" (x 5)
D
D
Top Rail
Elevation View
HSS 10" x 4" x 3/8"
ASTM A500 Grade B
3-7/8"
Section D-D
Scale 1 : 10
3a. Galvanize all components after fabrication is complete.
3b. Contractor shall provide material certs for all steel components.
3c. All holes through both faces.
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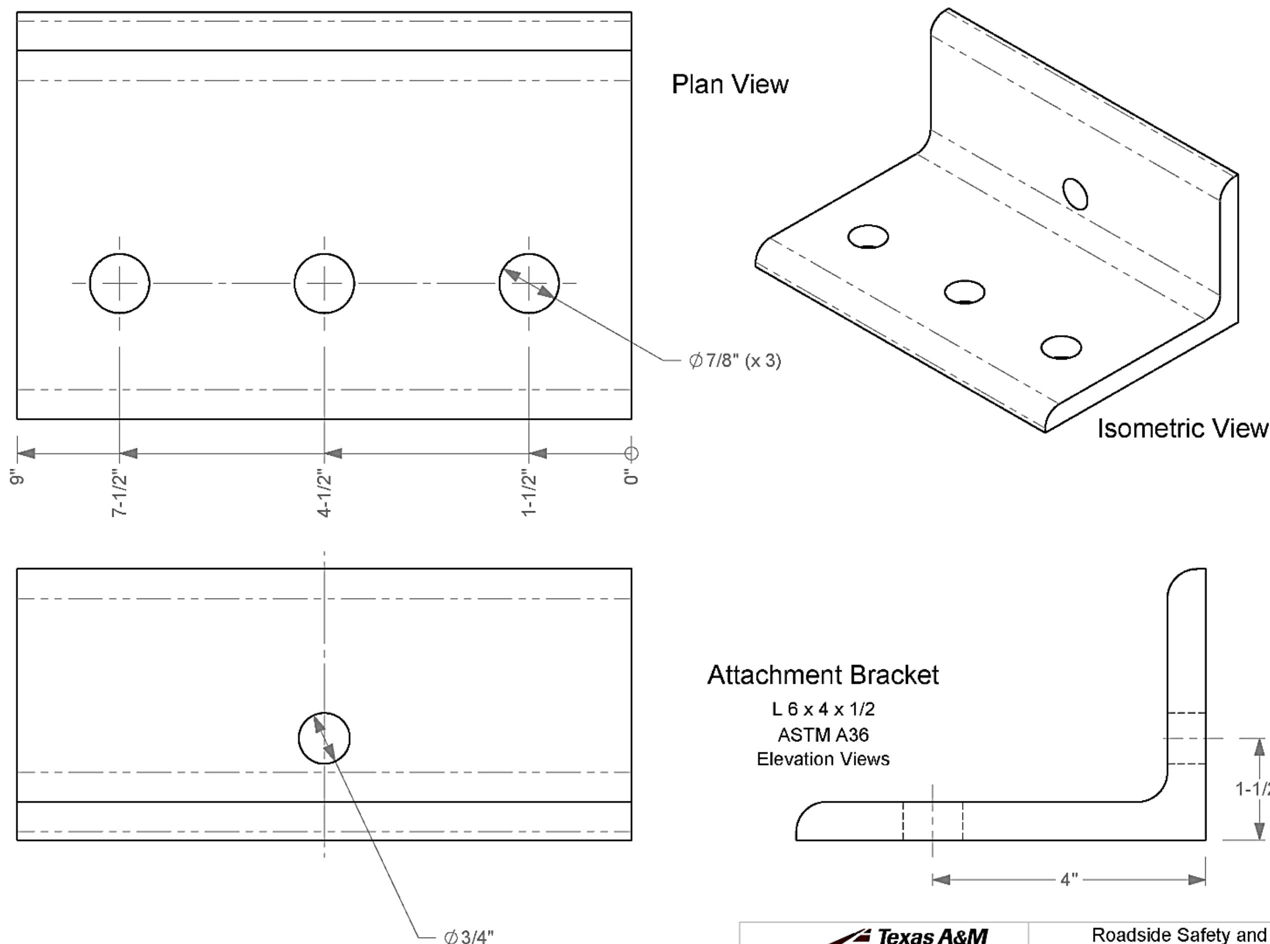
Scale 1:30
Sheet 3 of 12 Rail Details



4a. Contractor shall provide material certs for all steel components.
4b. Galvanize all components after fabrication is complete.

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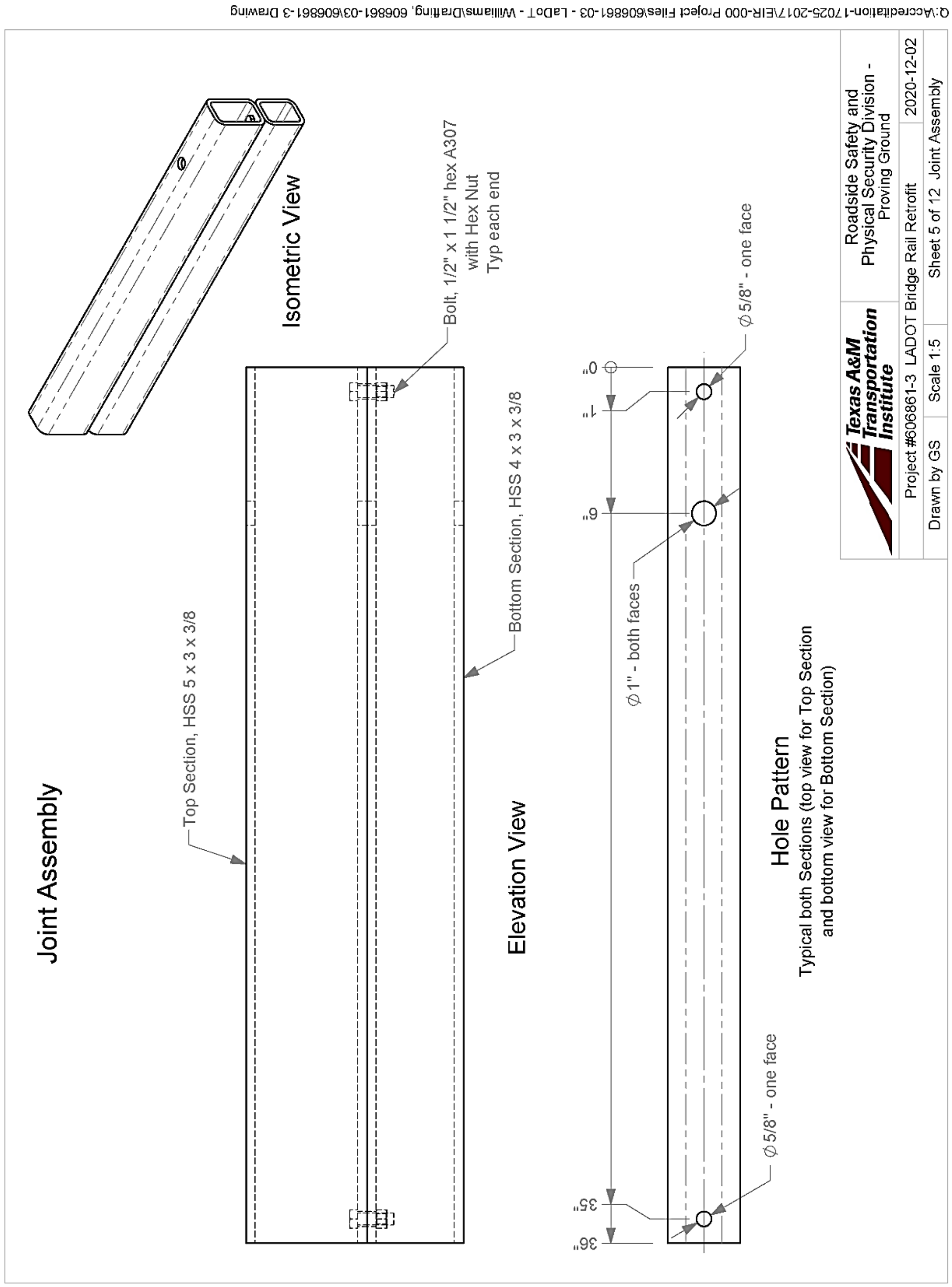
Q:\Accreditation-17025-2017\EIR-000 Project Files\606861-03 - LaDoT - Williams\Drafting, 606861-03\606861-3 Drawing
Joint Assembly
Isometric View
Top Section, HSS 5 x 3 x 3/8
Bolt, 1/2" x 1 1/2" hex A307
with Hex Nut
Typ each end
Bottom Section, HSS 4 x 3 x 3/8
Elevation View
0"
1"
6"
35"
36"
ϕ 5/8" - one face
ϕ 1" - both faces
ϕ 5/8" - one face
Hole Pattern
Typical both Sections (top view for Top Section
and bottom view for Bottom Section)
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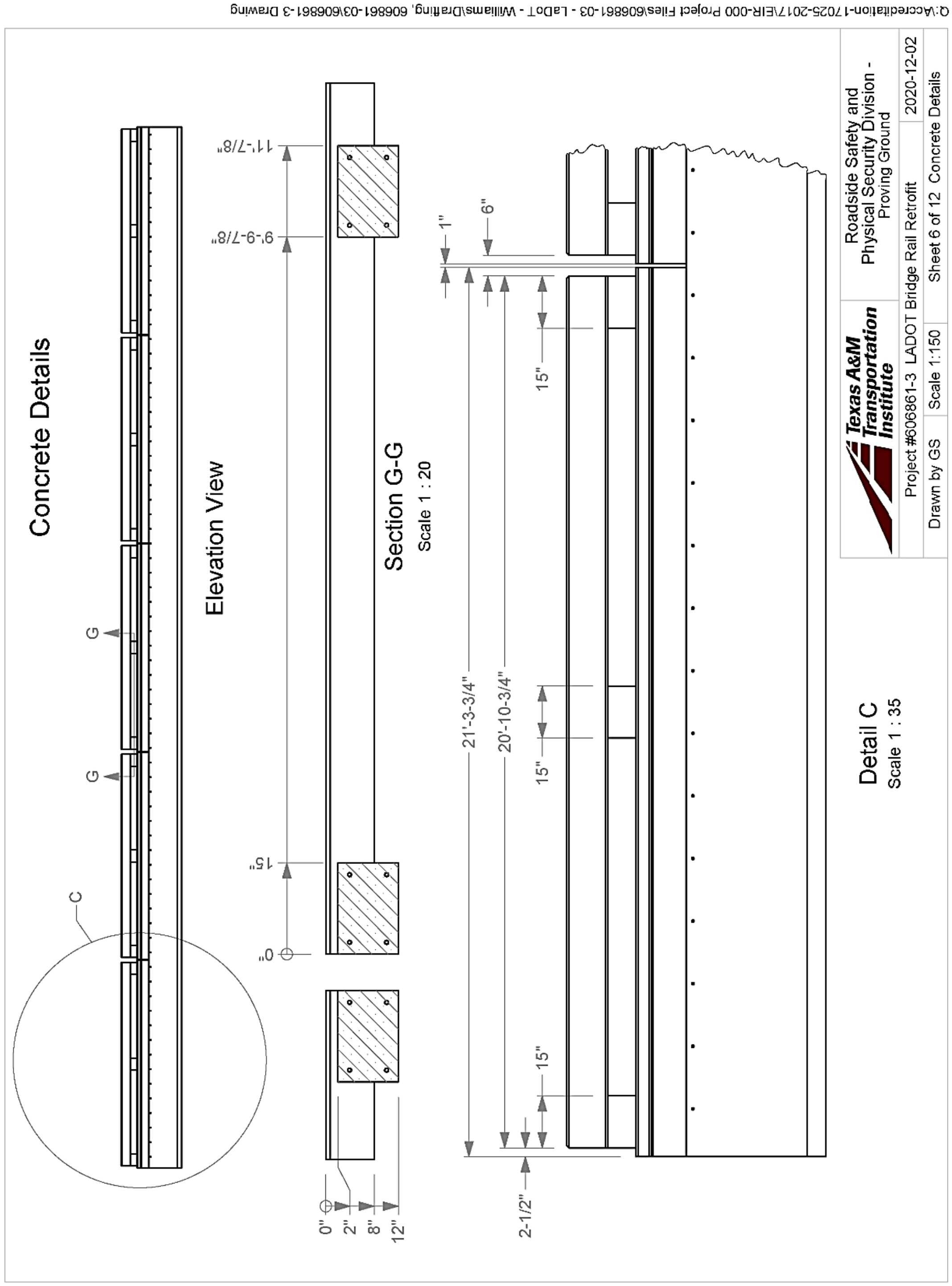
Drawn by GS
Scale 1:5
Sheet 5 of 12 Joint Assembly


Q:\Accreditation-17025-2017\EIR-000 Project Files\606861-03 - LaDoT - Williams\Drafting, 606861 Drawing\606861-3 Drawing
Concrete Details
C
G
G
Elevation View
Section G-G
Scale 1 : 20
0"
15"
9'-9-7/8"
11'-7/8"
0"
2"
8"
12"
2-1/2"
21'-3-3/4"
20'-10-3/4"
15"
15"
15"
1"
6"
Detail C
Scale 1 : 35
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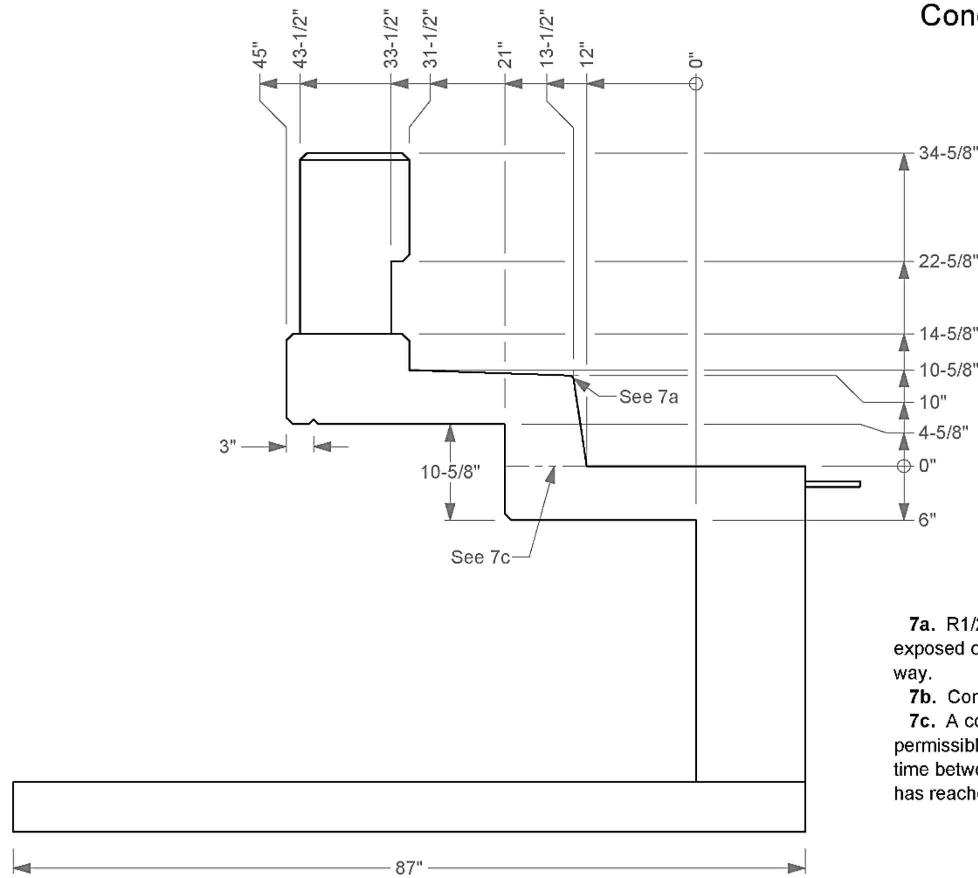
Drawn by GS
Scale 1:150
Sheet 6 of 12 Concrete Details

Concrete Section



7a. R1/2" this edge. Drip Stop and other exposed concrete edges as shown 3/4" each way.

7b. Concrete strength is 3,000 psi.

7c. A cold joint in the concrete is permissible here, with minimum 3 days cure time between pours (or when the first pour has reached 1500 psi compressive strength).

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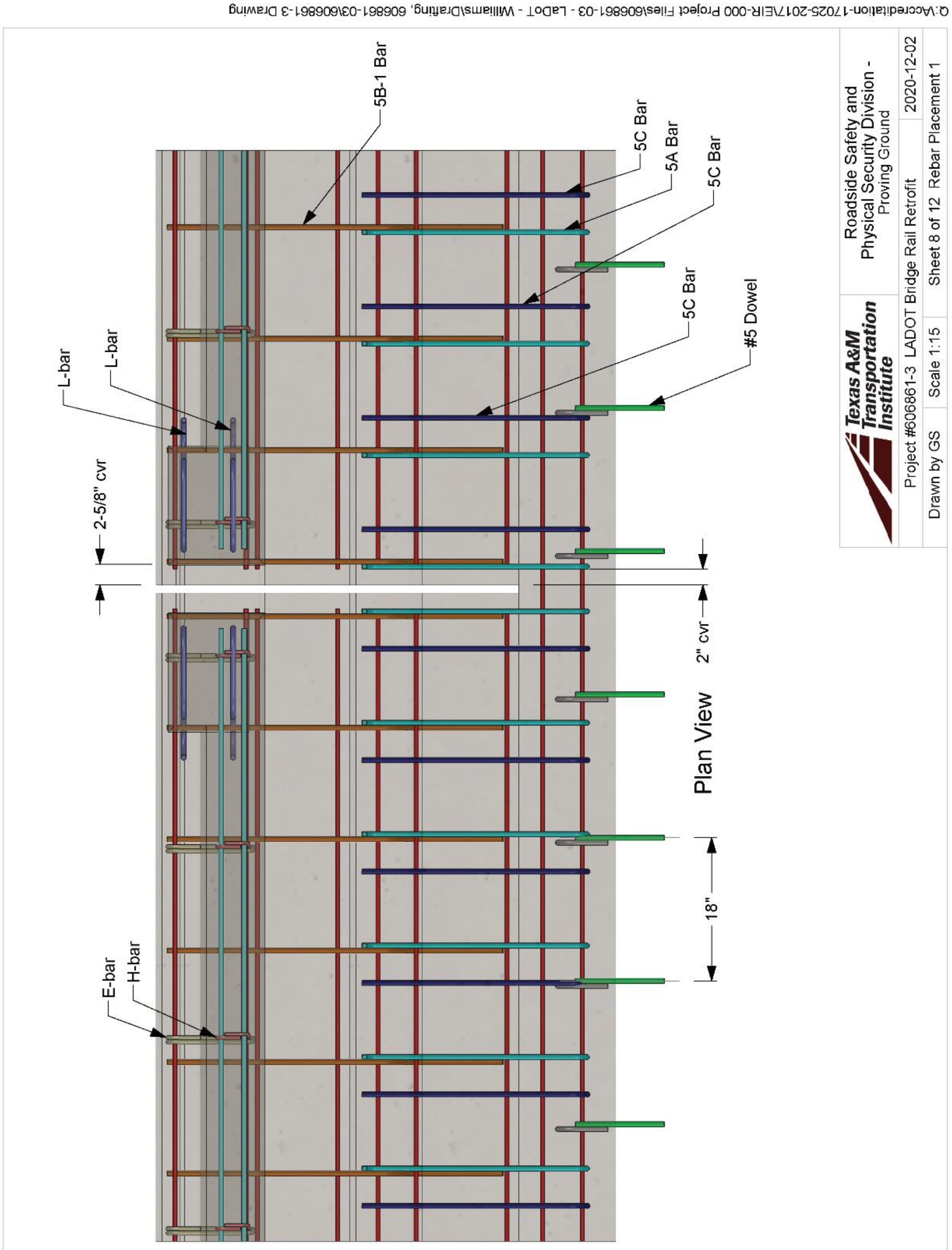
Q:\Accreditation-17025-2017\EIR-000 Project Files\606861-03 - LaDoT - Williams\Drafting, 606861-03\606861-3 Drawing
5B-1 Bar
5C Bar
5A Bar
5C Bar
5C Bar
#5 Dowel
L-bar
L-bar
2-5/8" cvr
2" cvr
Plan View
18"
E-bar
H-bar
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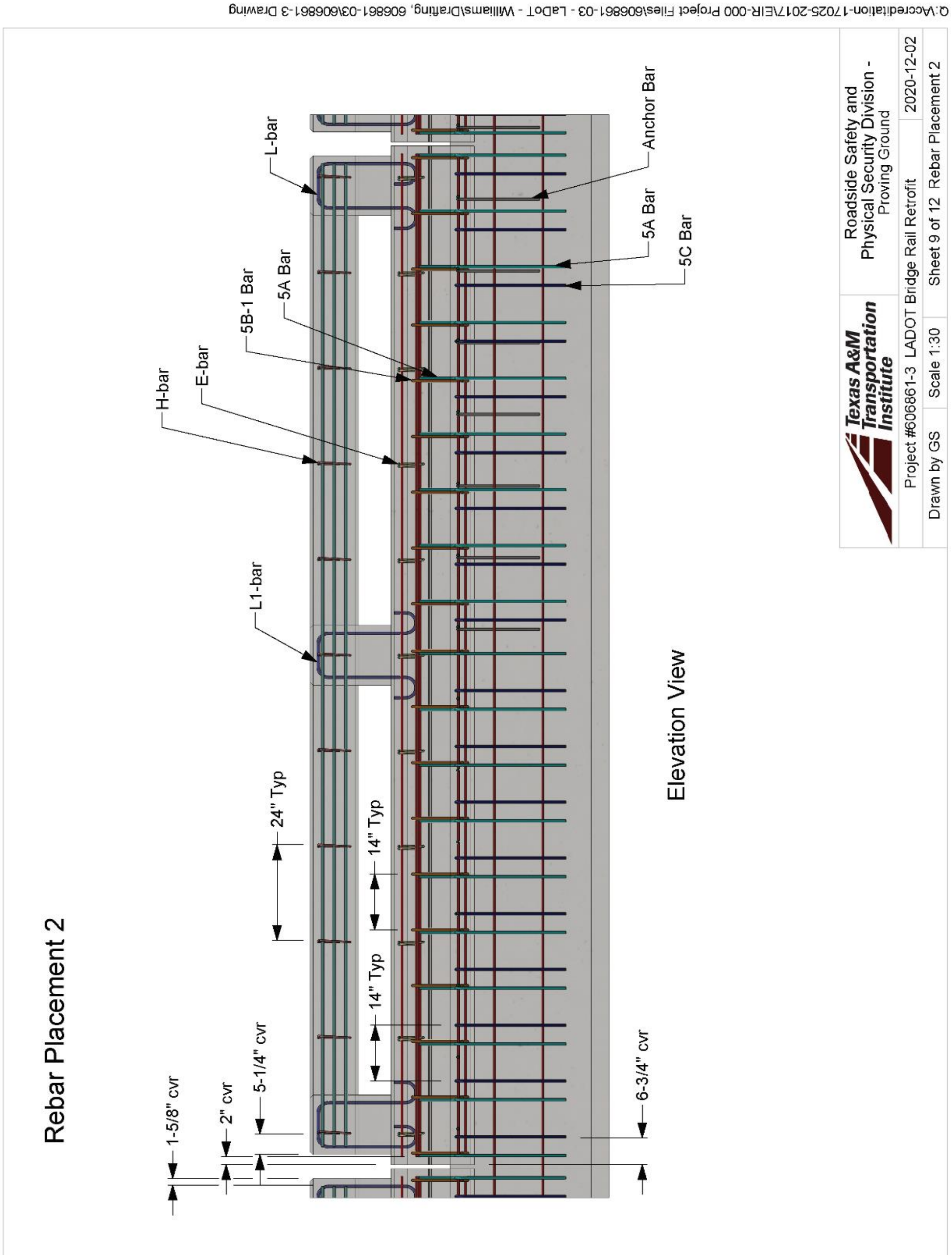
Project #606861-3 LADOT Bridge Rail Retrofit
2020-12-02
Drawn by GS
Scale 1:15
Sheet 8 of 12 Rebar Placement 1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Rebar Placement 2
1-5/8" cvr
2" cvr
5-1/4" cvr
14" Typ
14" Typ
24" Typ
6-3/4" cvr
H-bar
E-bar
5B-1 Bar
5A Bar
L1-bar
L-bar
Anchor Bar
5A Bar
5C Bar
Elevation View
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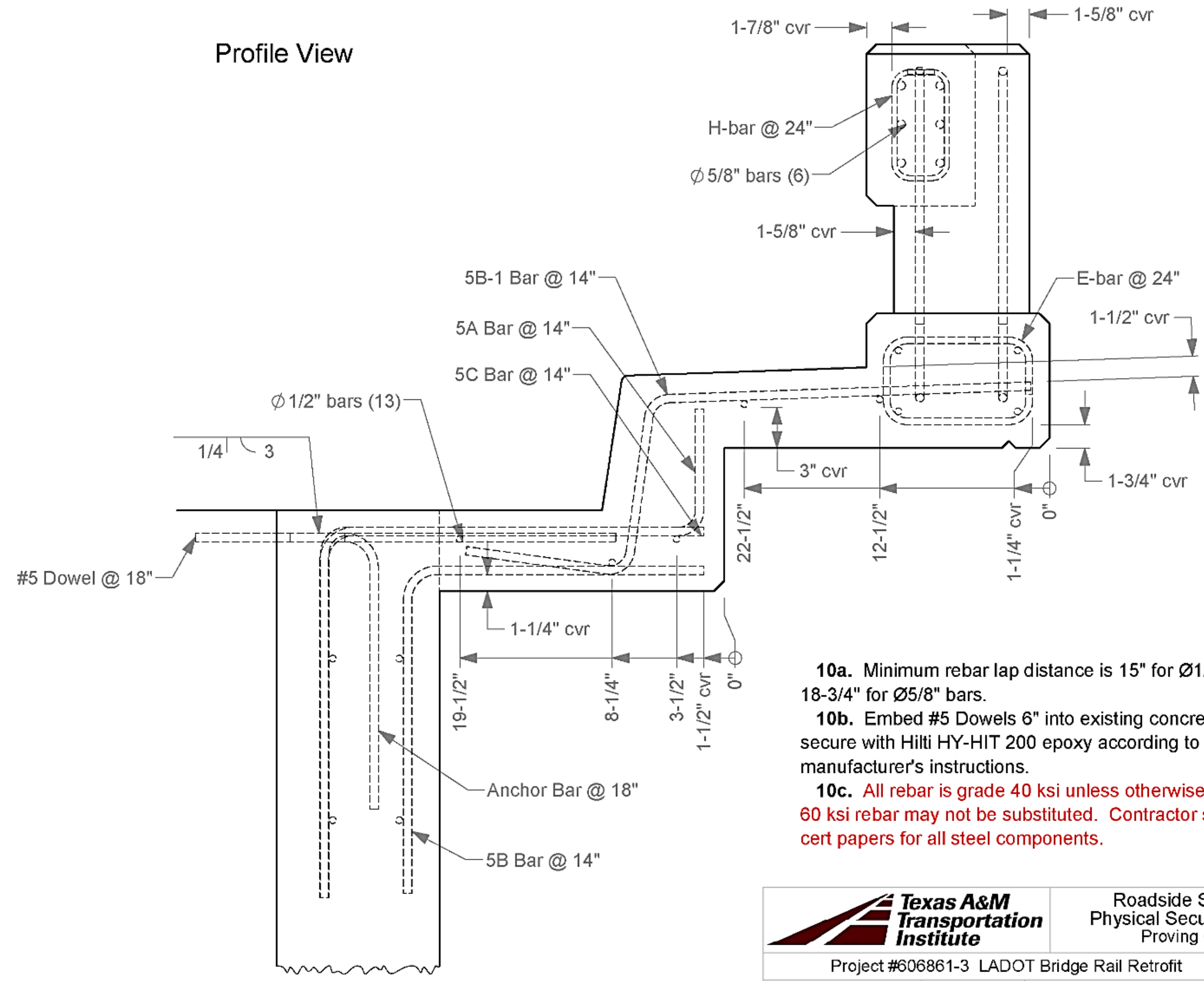
Project #606861-3 LADOT Bridge Rail Retrofit
2020-12-02
Drawn by GS
Scale 1:30
Sheet 9 of 12 Rebar Placement 2

Profile View



10a. Minimum rebar lap distance is 15" for Ø1/2" bars and 18-3/4" for Ø5/8" bars.

10b. Embed #5 Dowels 6" into existing concrete and secure with Hilti HY-HIT 200 epoxy according to manufacturer's instructions.

10c. All rebar is grade 40 ksi unless otherwise indicated. 60 ksi rebar may not be substituted. Contractor shall provide cert papers for all steel components.

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Drawn by GS	Scale 1:10	Sheet 10 of 12 Rebar Placement 3	

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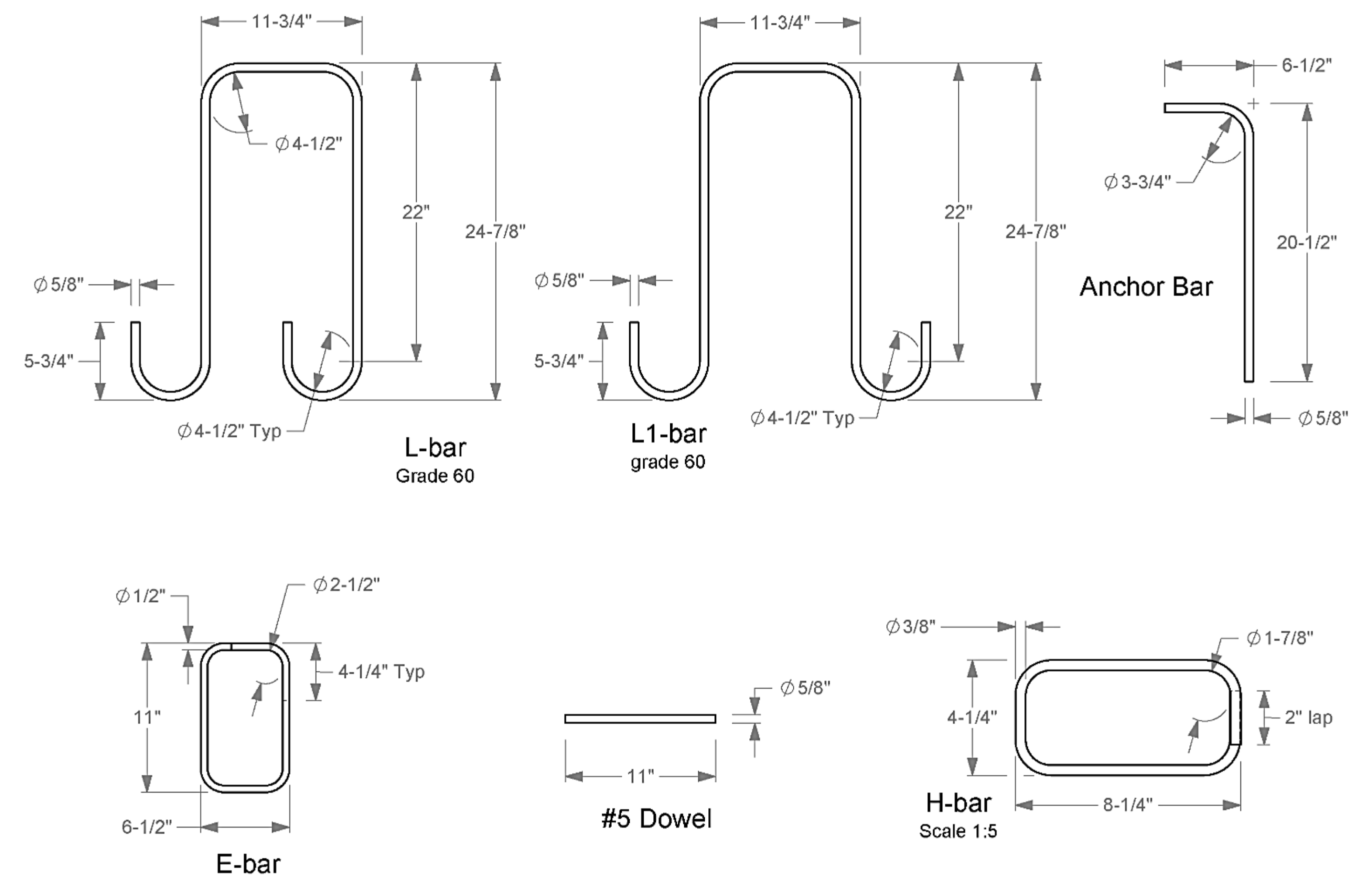

11a. All rebar is grade 40 ksi otherwise indicated. 60 ksi rebar may not be substituted. Contractor shall provide cert papers for all steel components.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #606861-3 LADOT Bridge Rail Retrofit		2020-12-02
Drawn by GS	Scale 1:10	Sheet 11 of 12 Rebar Detail 1

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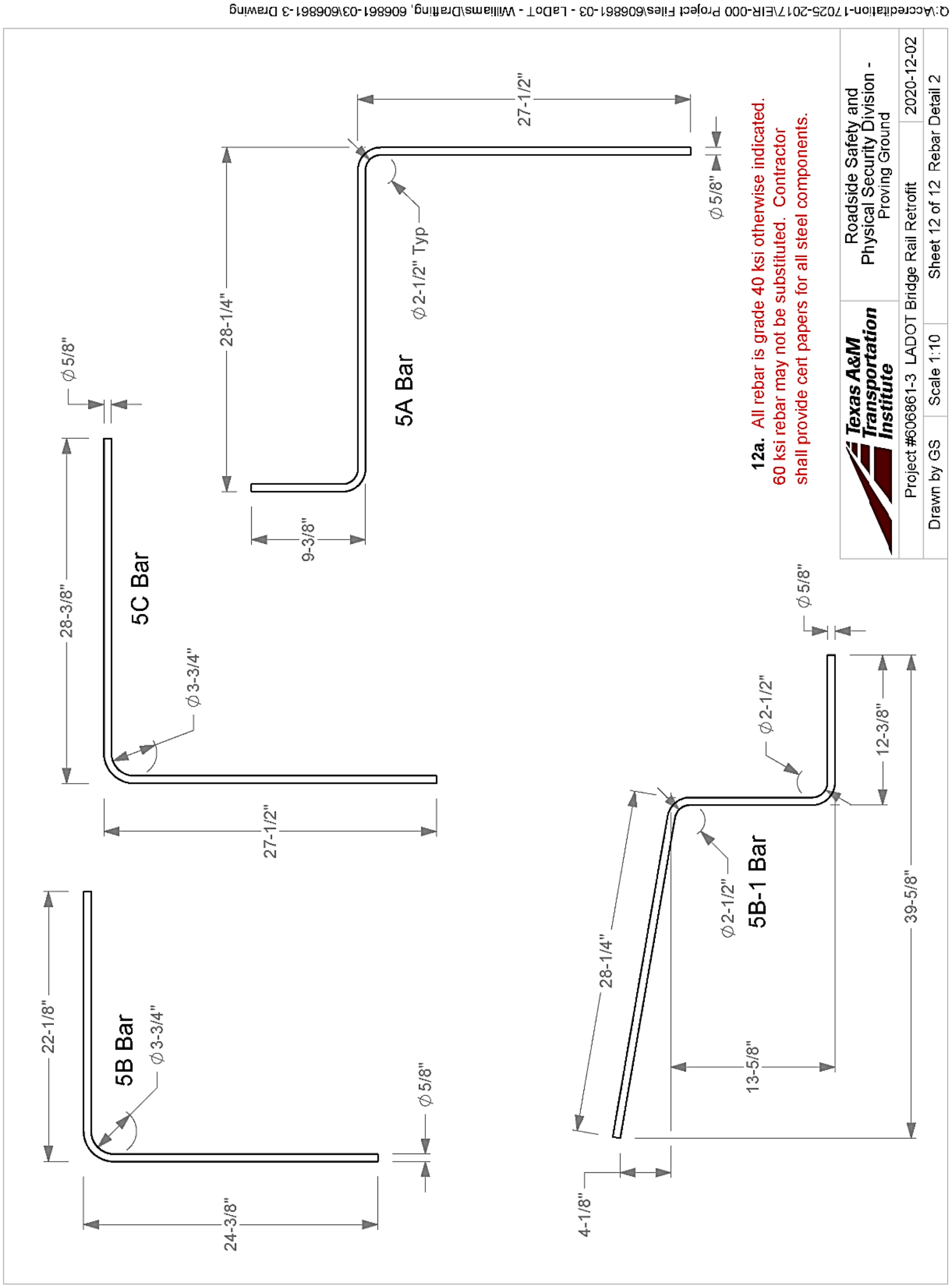
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5A Bar
27-1/2"
28-1/4"
9-3/8"
⌀ 2-1/2" Typ
⌀ 5/8"
5C Bar
28-3/8"
27-1/2"
⌀ 3-3/4"
⌀ 5/8"
5B Bar
22-1/8"
24-3/8"
⌀ 3-3/4"
⌀ 5/8"
5B-1 Bar
28-1/4"
13-5/8"
39-5/8"
12-3/8"
4-1/8"
⌀ 2-1/2"
⌀ 2-1/2"
⌀ 5/8"
12a. All rebar is grade 40 ksi otherwise indicated. 60 ksi rebar may not be substituted. Contractor shall provide cert papers for all steel components.
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #606861-3 LADOT Bridge Rail Retrofit
2020-12-02
Drawn by GS
Scale 1:10
Sheet 12 of 12 Rebar Detail 2

Appendix H. Strength Analysis for Retrofit Bridge Rail Anchored to Solid Concrete Parapet

1.) Given the following Details

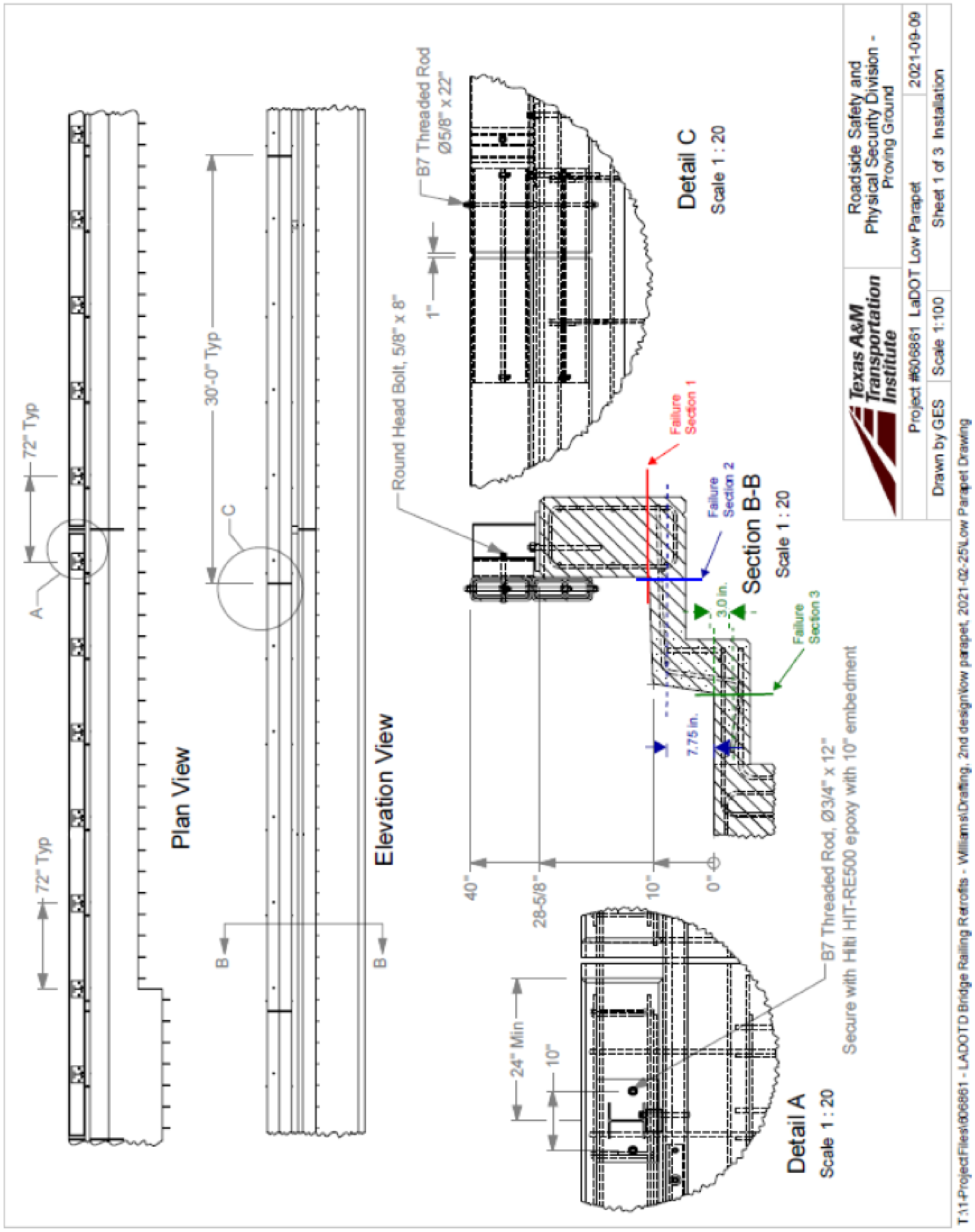


Figure 1. Detailed Views of Bridge Rail System

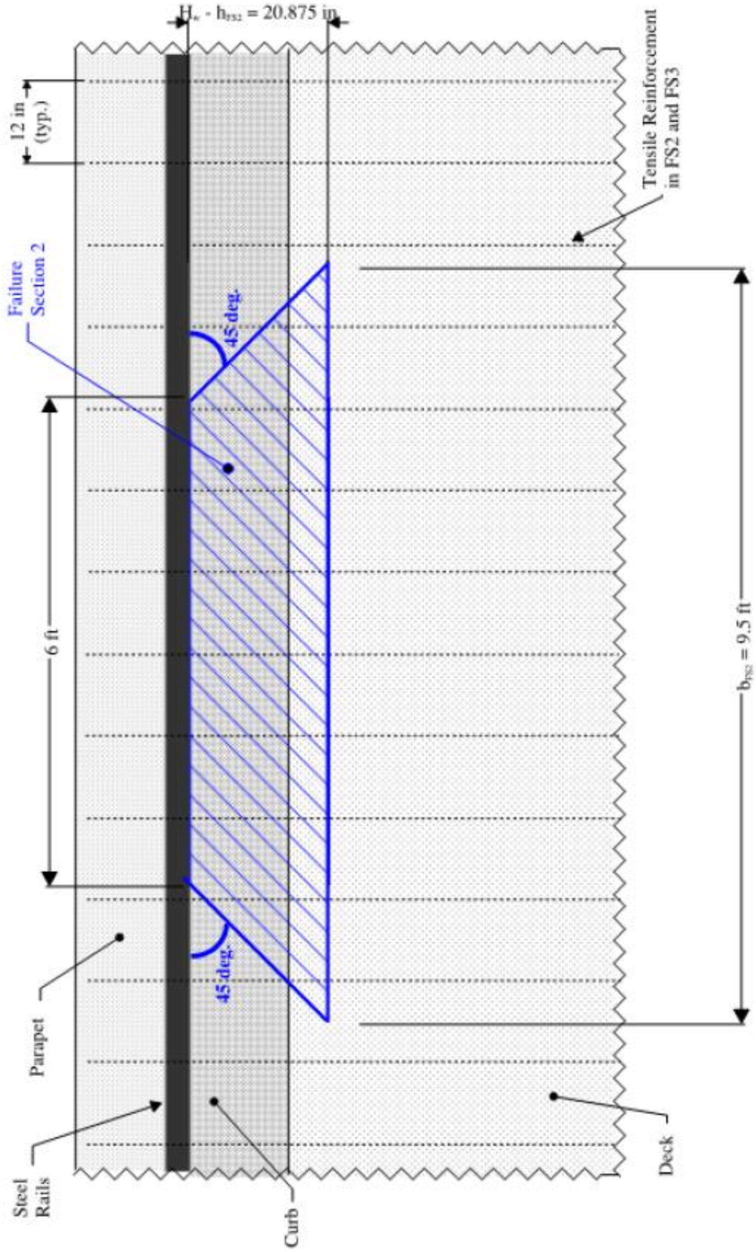


Figure 2. Plan View of Failure Section 2

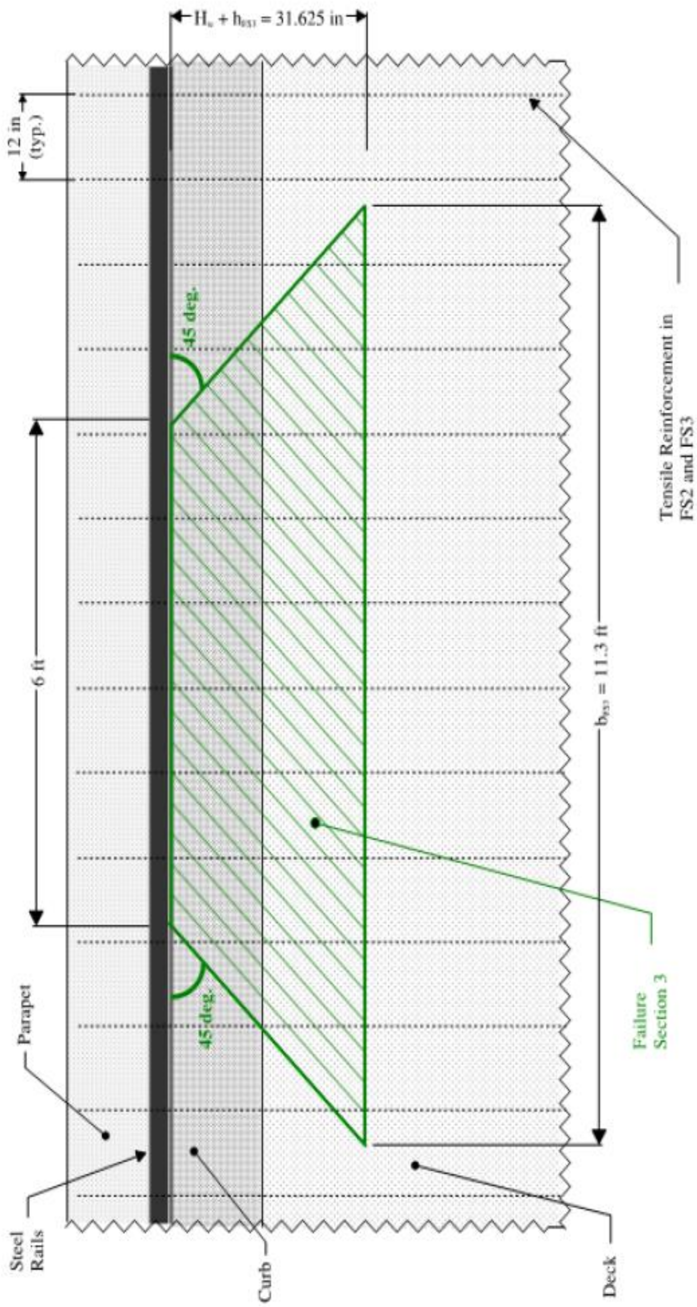


Figure 3. Plan View of Failure Section 3

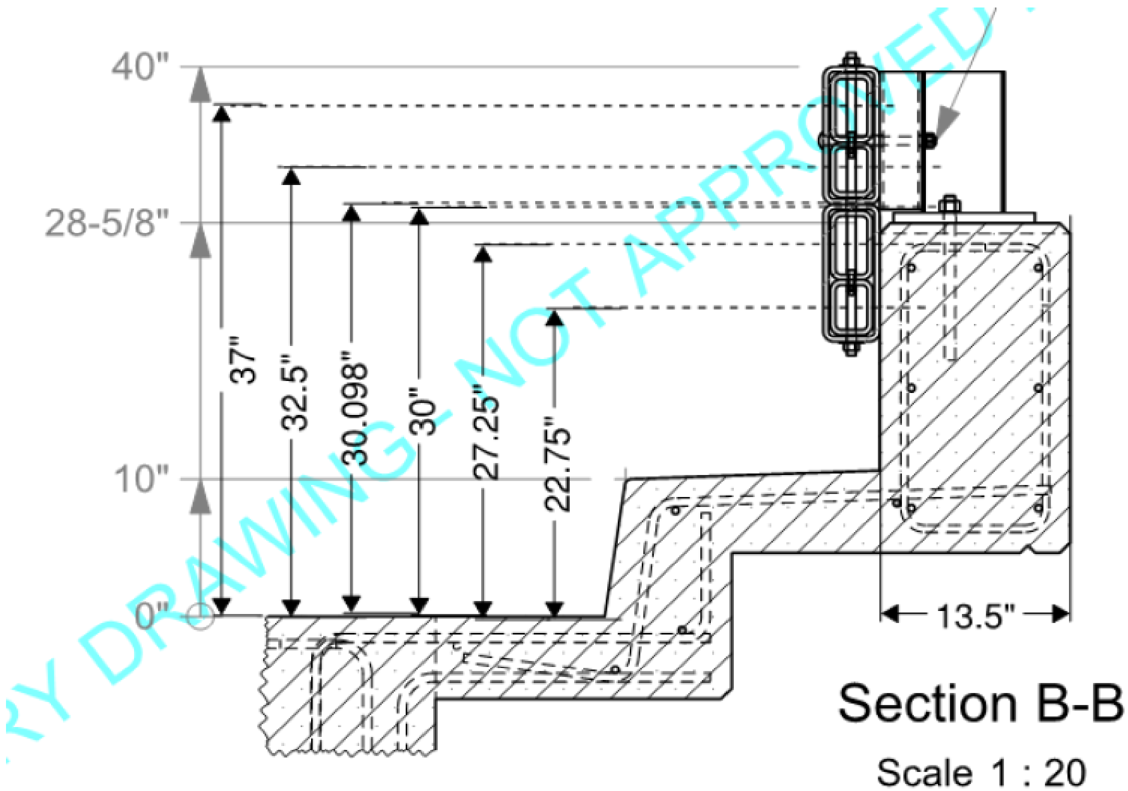
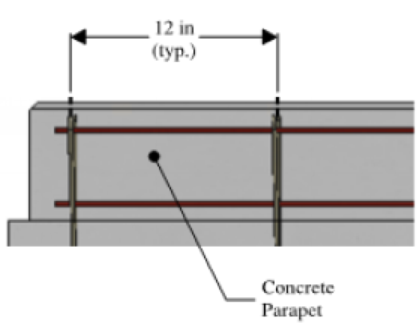


Figure 4. Section View of a Bridge Rail System



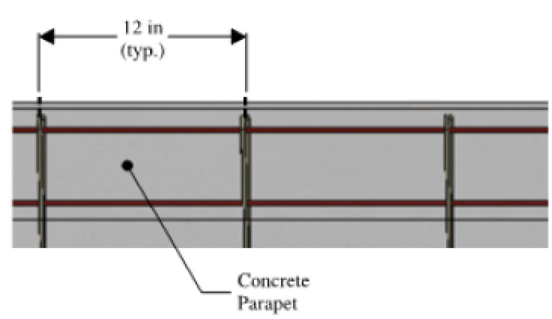


Figure 5a. Elevation View of Bridge Rail System at Ends/Joints

Figure 5b. Elevation View of Bridge Rail System at Midspan

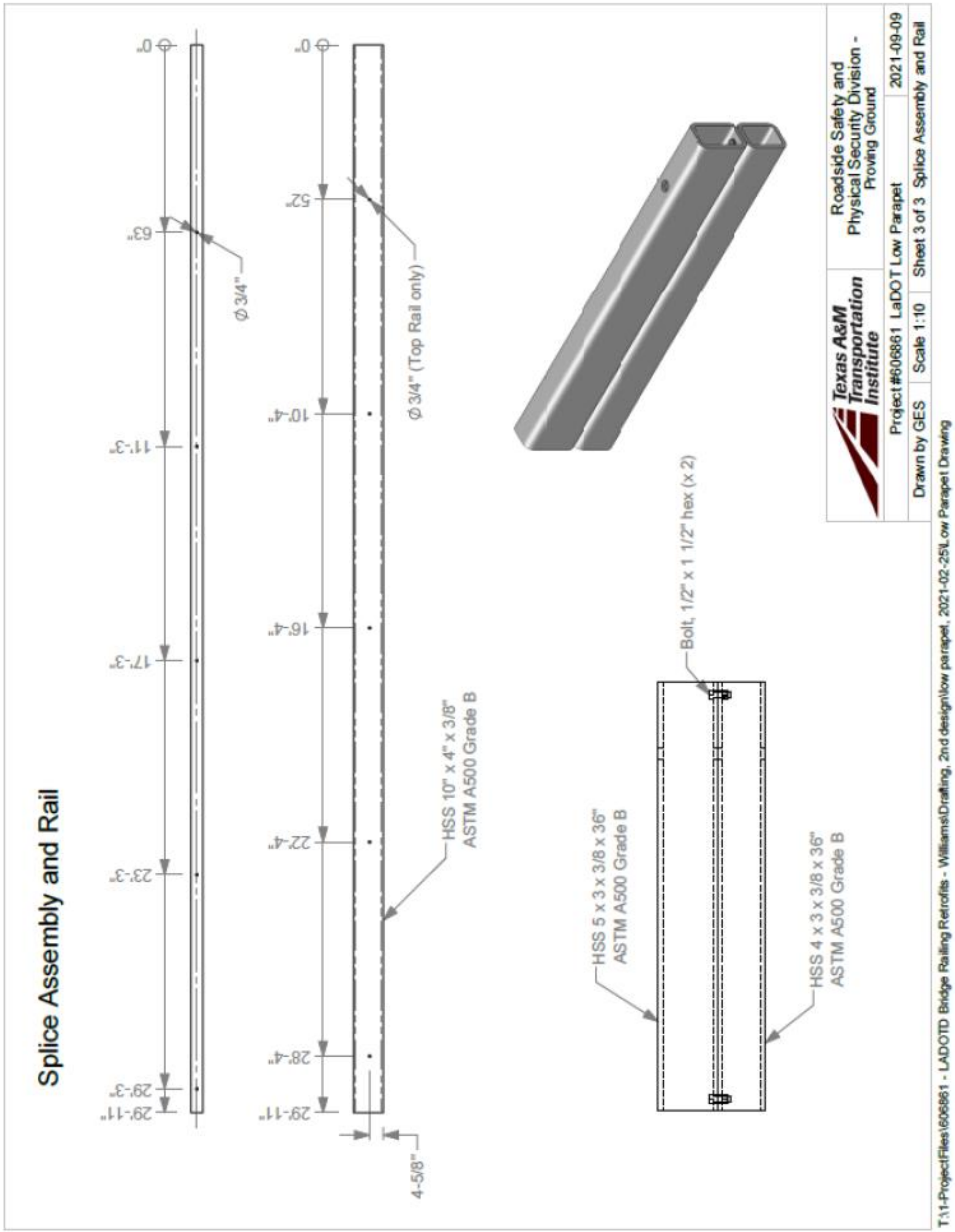


Figure 6. Steel and Rail details

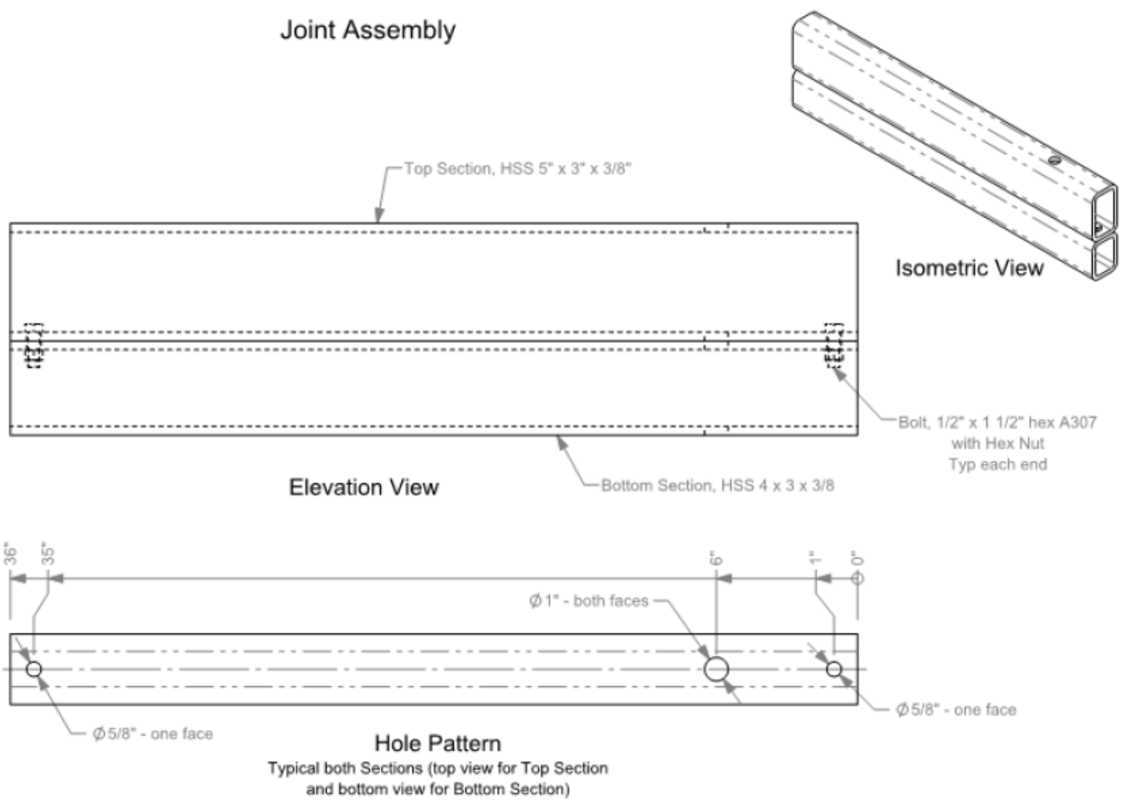


Figure 7. Steel Splice Detail

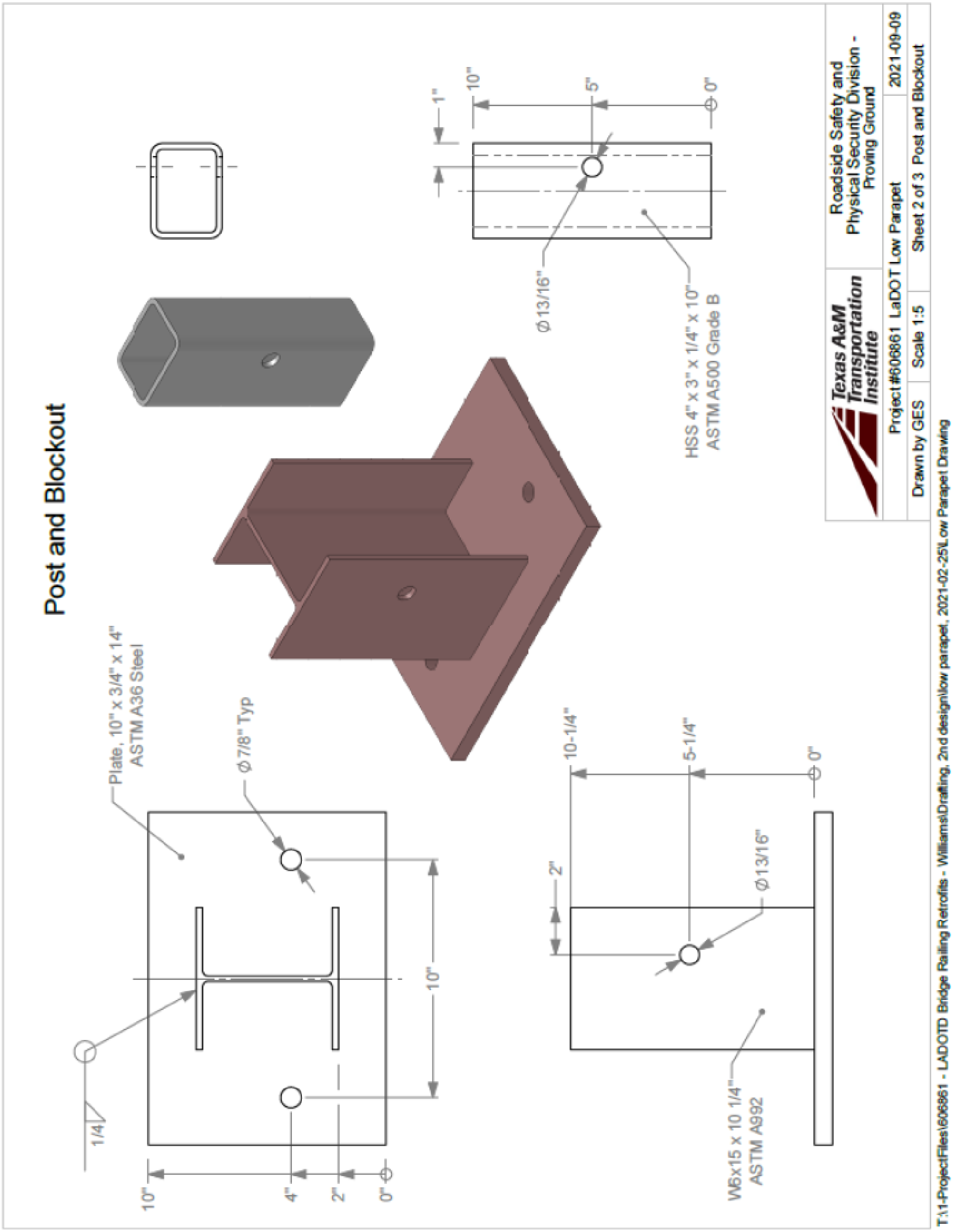


Figure 8. Steel Post and Blockout Details

2.) General Information:

- Concrete Parapet Strength, f'c = 4000psi
- Anchor Rods are ϕ3/4" x 12" long, A193 B7 Threaded Anchor: Fu=120ksi
- All concrete reinforcing steel = Grade 40: fy=40ksi
- HSS10x4x3/8 Tube Rails are A500 Grade B Material: Fy=46 ksi
- Reference: AASHTO LRFD Bridge Design Specifications, Section 13, TL-3 Conditions.
- Objective: Calculate the Strength of the Rail based on Worst Case Rail Strength and AASHTO LRFD Section 13 Strength Requirements.
- Use Hilti RE500 Epoxy with 10" Embedment

$kips \equiv kip$

********************** **Concrete, Reinforcing Steel & Structural Shape Information** **************************

$f'_c := 4000 \cdot psi$ — Compressive Strength of Concrete (psi)

$F_{yR} := 46ksi$ — Yield Strength of all Steel Rails (ksi)

$f_y := 40ksi$ — Yield Strength of Concrete Reinforcing Steel (ksi)

$b_w := 13.5in$ — Width of Concrete Parapet/Wall (in.)

$h_w := 18in$ — Height of Concrete Parapet/Wall (in.)

$H_w := 28.625in$ — Height of Concrete Parapet/Wall measured from roadway surface (in.)

$A_{v1} := 0.2in^2$ — Area of one vertical reinforcement bar in tension zone of the Concrete Parapet/Wall (in²)

$A_{sw1} := 0.2in^2$ — Area of one longitudinal reinforcement bar in tension zone of the Concrete Parapet/Wall (in²)

*********************************** **Anchor Rod Properties** ***********************************

$F_{u.rod} := 120ksi$ — Tensile Strength of Anchor Rods (ksi)

$d_{rod} := \frac{3}{4}in$ — Diameter of Anchor Rods (in)

$A_{rod} := \frac{\pi \cdot d_{rod}^2}{4} = 0.442 \cdot in^2$ — Area of a Anchor Rod (in²)

MASH Design Impact Loads

Test Level	F_t (kip)	F_L (kip)	F_v (kip)	L_t/L_L (ft)	L_v (ft)	H_e (in)	H_{min} (in)
TL 1	13.5	4.5	4.5	4.0	18.0	18.0	18.0
TL 2	27.0	9.0	4.5	4.0	18.0	20.0	18.0
TL 3	71.0	18.0	4.5	4.0	18.0	24.0	29.0
TL 4 (a)	68.0	22.0	38.0	4.0	18.0	25.0	36.0
TL 4 (b)	80.0	27.0	22.0	5.0	18.0	30.0	36.0
TL 5 (a)	160.0	41.0	80.0	10.0	40.0	35.0	42.0
TL 5 (b)	262.0	75.0	160.0	10.0	40.0	43.0	42.0
TL 6	175.0	58.0	80.0	8.0	40.0	56.0	90.0

Note: (a) and (b) denote different TL4 and TL5 design force values for bridge rails of different heights.

$TL := 3$ — Test Level

$F_t := 71kip$ — Transverse Impact Force (kip)

$L_t := 4ft$ — Longitudinal Length of Distribution of Transverse Impact Force (ft.)

$L_{t.amp} := 1.5 \cdot L_t = 6\,ft$ — Amplified Longitudinal Length of Distribution of Transverse Impact Force (ft.)
- Note: Amplify Lt by 50% since steel rail retrofit will distribute impact load greater than what typically occurs. 50% amplification is typical of what we've seen in previous similar tests.

$H_e := 19in$ — Height of Transverse Impact Load (in.)

$H_{e.mod} := H_e + 10in = 29 \cdot in$ — Modified Height of Transverse Impact Load (in.)
- Note: Due to curb and deck geometry, the impact load will be applied to the barrier at a greater height than the typical H_e. Adding 10 inches to H_e acounts for the curb height.

$F_v := 4.5kip$ — Vertical Impact Force (kip)

$L_v := 18ft$ — Longitudinal Length of Distribution of Vertical Impact Force (ft.)

$H_w = 28.625 \cdot in$ — Height of Concrete Parapet measured from the top of the roadway surface (in.)

$H_t := 40in$ — Total height of bridge rail system (in.)

3.) Calculate the Bending Capacity based on Failure Section 1 about the Longitudinal Axis: $M_{c.FS1}$

Note: See Figure 1 for more information

$A_{v1} = 0.2 \cdot in^2$ — Area of one vertical reinforcement leg in tension zone (in^2)

$b_c := 12in$ — Unit Width of Wall (in.)

$s_{v.mid} := 12in$ — Spacing of vertical reinforcement at midspan (in.)

$s_{v.end} := 12in$ — Average Spacing of vertical reinforcement at the end of the parapet/wall or at a joint per the length of the longitudinal distribution of the impact force (in.)

$$A_{v.mid} := \left(\frac{b_c}{s_{v.mid}}\right) \cdot A_{v1} = 0.2 \cdot in^2$$

Total Area of vertical reinforment per unit length of the wall at midspan (in^2)

$$A_{v.end} := \left(\frac{b_c}{s_{v.end}}\right) \cdot A_{v1} = 0.2 \cdot in^2$$

Total Area of vertical reinforment per unit length of the wall at the end of the wall or at a joint (in^2)

$$a_{c.mid} := \frac{A_{v.mid} \cdot f_y}{0.85 \cdot f'_c \cdot b_c} = 0.196 \cdot in$$

Depth of Whitney Stress Block at midspan (in.)

$$a_{c.end} := \frac{A_{v.end} \cdot f_y}{0.85 \cdot f'_c \cdot b_c} = 0.196 \cdot in$$

Depth of Whitney Stress Block at the end of the wall or at a joint (in.)

$b_w = 13.5 \cdot in$ — Width of the Concrete Parapet/Wall (in.)

$d_c := b_w - 1.5in - 0.25in = 11.75 \cdot in$ — Extreme distance of tension vertical reinforcement of the wall (in.) $d_c = b_w$ - stirrup cover - (1/2)*diameter of stirrup

$$M_{cmid.FS1} := \frac{\left[A_{v.mid} \cdot f_y \cdot \left(d_c - \frac{a_{c.mid}}{2}\right)\right]}{b_c} = 7.768 \cdot \frac{kip \cdot ft}{ft}$$

Flexural Resistance of Cantilever Wall specified in Article A13.4.2 at midspan (k-ft/ft)

$$M_{cend.FS1} := \frac{\left[A_{v.end} \cdot f_y \cdot \left(d_c - \frac{a_{c.end}}{2}\right)\right]}{b_c} = 7.768 \cdot \frac{kip \cdot ft}{ft}$$

Flexural Resistance of Cantilever Wall specified in Article A13.4.2 at the end of the wall or at a joint (k-ft/ft)

4.) Calculate the Bending Capacity based on Failure Section 2 about the Longitudinal Axis: $M_{c.FS2}$

Failure Section 2 (FS2) Properties and Dimensions:
a) Assuming FS2 is vertical from top to bottom of upper deck at the intersection with the parapet.
b) #5-Gr.40 Rebar is used for Tensile Reinforcement

$f_y = 40 \cdot ksi$ $\quad$ $f'_c = 4 \cdot ksi$

$H_w = 28.625 \cdot in$ — Height of Concrete Parapet/Wall measured from top of roadway surface (in.)

$L_{t.amp} = 6\,ft$ — Amplified Longitudinal Length of Distribution of Transverse Impact Force (ft.)

$h_{FS2} := 7.75in$ — Distance from roadway surface to centroid of FS2 (in.) [See Figure 1 for more information]

$b_{FS2} := L_{t.amp} + 2 \cdot (H_w - h_{FS2}) = 9.479 \cdot ft$ — Width of FS2 (in.) Note: Width of FS2 is assumed to be the impact force projected outward at a 45 degree angle to the centroid of FS2. [See Figure 2 for more information]

$A_{FS2} := 7 \cdot 0.31in^2 = 2.17 \cdot in^2$ — Area of Tensile Reinforcement in FS2 (in²) [See Figure 2 for more information] There are 9 bars over b_{FS2}

$d_{FS2} := 4.25in$ — Distance to Tensile Reinf. from Compression Face of FS2 (in.) [See Figure 1 for more information]

$$a_{FS2} := \frac{A_{FS2} \cdot f_y}{0.85 \cdot f'_c \cdot b_{FS2}}$$ Whitney Stress Block Depth for FS2 (in.)

$$M_{FS2} := A_{FS2} \cdot f_y \cdot \left(d_{FS2} - \frac{a_{FS2}}{2}\right) = 29.93 \cdot kip \cdot ft$$ Moment Strength at FS2 about the longitudinal axis (k-ft)

$$M_{c.FS2} := \frac{M_{FS2}}{L_{t.amp}} = 4.988 \cdot \frac{kip \cdot ft}{ft}$$ Moment Strength at FS2 about the longitudinal axis per 1 ft segment of barrier (k-ft/ft)

5.) Calculate the Bending Capacity based on Failure Section 3 about the Longitudinal Axis: $M_{c.FS3}$

Failure Section 3 (FS3) Properties and Dimensions:
a) Assuming FS3 is vertical from top to bottom of lower deck at the intersection of the lower deck to curb.
b) #5-Gr.40 Rebar is used for Tensile Reinforcement

$f_y = 40 \cdot ksi$ $\qquad f'_c = 4 \cdot ksi$

$H_w = 28.625 \cdot in$ — Height of Concrete Parapet/Wall measured from top of roadway surface (in.)

$L_{t.amp} = 6\,ft$ — Amplified Longitudinal Length of Distribution of Transverse Impact Force (ft.)

$h_{FS3} := 3in$ — Vertical distance from roadway surface to centroid of FS3 (in.) [See Figure 1 for more information]

$b_{FS3} := L_{t.amp} + 2 \cdot (H_w + h_{FS3}) = 11.271 \cdot ft$ — Width of FS3 (ft.)
Note: Width of FS3 is assumed to be the impact force projected outward at a 45 degree angle to the centroid of FS3.
[See Figure 3 for more information]

$A_{FS3} := 11 \cdot 0.31 in^2 = 3.41 \cdot in^2$ — Area of Tensile Reinforcement in FS3 (in^2)
[See Figure 3 for more information]
There are 11 bars over b_{FS3}

$d_{FS3} := 4.25in$ — Distance to Tensile Reinf. from Compression Face of FS3 (in.) [See Figure 1 for more information]

$$a_{FS3} := \frac{A_{FS3} \cdot f_y}{0.85 \cdot f'_c \cdot b_{FS3}}$$ Whitney Stress Block Depth for FS3 (in.)

$$M_{FS3} := A_{FS3} \cdot f_y \cdot \left(d_{FS3} - \frac{a_{FS3}}{2} \right) = 46.623 \cdot kip \cdot ft$$ Moment Strength of Post at FS3 (k-ft)

$$M_{c.FS3} := \frac{M_{FS3}}{L_{t.amp}} = 7.77 \cdot \frac{kip \cdot ft}{ft}$$ Moment Strength of Post at FS3 per 1 ft segment of barrier (k-ft)

6.) Critical Bending Capacity of the Bridge Rail System about the Longitudinal Axis: M_c

$M_{cmid.FS1} = 7.768 \cdot \frac{kip \cdot ft}{ft}$ — Flexural Resistance of Cantilever Wall specified in Article A13.4.2 at midspan (k-ft/ft)

$M_{cend.FS1} = 7.768 \cdot \frac{kip \cdot ft}{ft}$ — Flexural Resistance of Cantilever Wall specified in Article A13.4.2 at the end of the wall or at a joint (k-ft/ft)

$M_{c.FS2} = 4.988 \cdot \frac{kip \cdot ft}{ft}$ — Moment Strength at FS2 about the longitudinal axis per 1 ft segment of barrier (k-ft/ft)

$M_{c.FS3} = 7.77 \cdot \frac{kip \cdot ft}{ft}$ — Moment Strength of Post at FS3 per 1 ft segment of barrier (k-ft/ft)

$M_c := \min(M_{cmid.FS1}, M_{cend.FS1}, M_{c.FS2}, M_{c.FS3}) = 4.988 \cdot \frac{kip \cdot ft}{ft}$ — Critical Bending Capacity of the Bridge Rail System about the Longitudinal Axis (k-ft/ft)

7.) Calculate the Bending Capacity of the Parapet/Wall about the Vertical Axis: M_w

$A_{sw1} = 0.2 \cdot in^2$ — Area of one Longitudinal bar in tension (in²)

$n_{sw} := 2$ — Number of Longitudinal bars in tension (in²)

$A_{sw} := n_{sw} \cdot A_{sw1} = 0.4 \cdot in^2$ — Total Area of Longitudinal Rebar in tension (in²)

$h_w = 18 \cdot in$ — Total height of the concrete parapet (in.)

$$a_w := \frac{A_{sw} \cdot f_y}{0.85 \cdot f'_c \cdot h_w} = 0.261 \cdot in$$

Depth of the Whitney Stress Block (in.)

$b_w = 13.5 \cdot in$ — Width of the Concrete Parapet/Wall (in.)

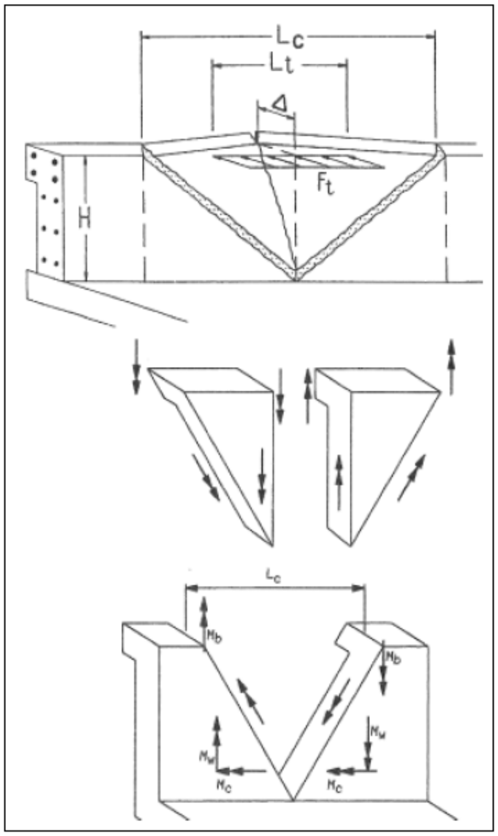
$d_w := b_w - 1.5in - 0.5in - 0.25in = 11.25 \cdot in$

Extreme distance of tension longitudinal reinforcement in wall (in.)
$d_w = b_w$ - cover - diameter of stirrups - (1/2)*diameter of longitudinal bars

$$M_w := A_{sw} \cdot f_y \cdot \left(d_w - \frac{a_w}{2}\right) = 14.826 \cdot kip \cdot ft$$

Flexural Resistance of the Concrete Parapet/Wall about the Vertical Axis(k-ft)

8.) Determine the Ultimate Resistance of the Parapet at Midspan: R_{wmid}



Yield Line Analysis of Concrete Parapet Walls for Impact within Wall Segment.

$h_w = 18 \cdot in$ — Height of the Concrete Parapet/Wall (in.) h_w = H in Figure 2

$M_B := 0 kip \cdot ft$ — No additional beam strength from the concrete

$M_c = 4.988 \cdot \frac{kip \cdot ft}{ft}$ — Flex. Resistance of the Parapet about the Long. Axis (k-ft/ft)

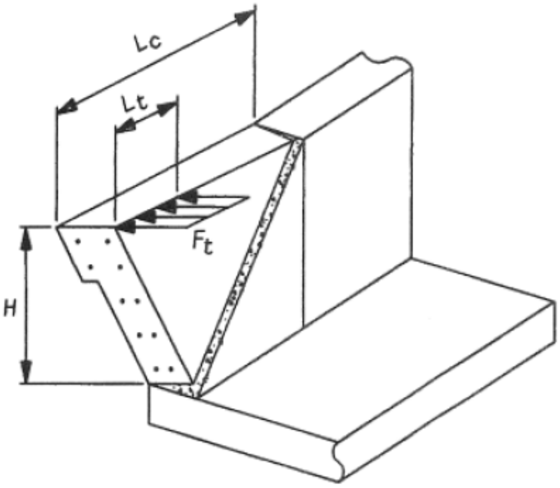
$M_w = 14.826 \cdot kip \cdot ft$ — Flex. Resistance of the Wall about the Vert. Axis (k-ft)

$L_{t.amp} = 6 \cdot ft$ — Amplified Longitudinal length of distribution of impact force (ft.)

$$L_{cmid} := \frac{L_{t.amp}}{2} + \sqrt{\left(\frac{L_{t.amp}}{2}\right)^2 + \frac{\left[8 \cdot h_w \cdot (M_B + M_w)\right]}{M_c}} = 9.683 \cdot ft$$ (AASHTO Equation A13.3.1-2)

$$R_{wmid} := \left[\left(\frac{2}{2 \cdot L_{cmid} - L_{t.amp}}\right)\left[8 \cdot M_B + 8 \cdot M_w + \frac{M_c \cdot (L_{cmid})^2}{h_w}\right]\right] = 64.404 \cdot kip$$ (AASHTO Equation A13.3.1-1)

9.) Determine the Ultimate Resistance of the Parapet at Joints/Ends: R_{wend}



Yield Line Analysis of Concrete Parapet Walls for Impact near End of Wall Segment

$h_w = 18 \cdot in$	Height of the Concrete Parapet/Wall (in.) h_w = H in Figure 3
$M_B = 0$	No additional concrete beam strength
$M_w = 14.826 \cdot kip \cdot ft$	Flex. Resistance of the Wall about the Vert. Axis (k-ft)
$L_{t.amp} = 6\,ft$	Amplified Longitudinal length of distribution of impact force (ft.)
$M_c = 4.988 \cdot \frac{kip \cdot ft}{ft}$	Flexural Resistance of the Wall about the Longitudinal Axis at Joints/Ends specified in Article A13.4.2 (k-ft/ft)

$$L_{cend} := \frac{L_{t.amp}}{2} + \sqrt{\left(\frac{L_{t.amp}}{2}\right)^2 + h_w \cdot \left(\frac{M_B + M_w}{M_c}\right)} = 6.669 \cdot ft \qquad \text{(Equation A13.3.1-4)}$$

$$R_{wend} := \left(\frac{2}{2 \cdot L_{cend} - L_{t.amp}}\right) \cdot \left[M_B + M_w + \frac{\left(M_c \cdot L_{cend}^{\,2}\right)}{h_w}\right] = 44.353 \cdot kip \qquad \text{(Equation A13.3.1-3)}$$

10. Resistance of Steel Rails:

HSS10x4x3/8 Steel Rail Properties and Dimensions:
a) Steel Rails are A500 Gr. B Material, Fy=46ksi
b) Steel Rails bend about the y-axis

$F_{yR} = 46 \cdot ksi$ — Yield Strength of Steel Rail (ksi)

$Z_{SR} := 14in^3$ — Plastic Sectional Modulus of both Steel Rails (in³)

$M_{SR} := 2Z_{SR} \cdot F_{yR} = 107.333 \cdot kip \cdot ft$ — Total Plastic Moment Strength of both Steel Rails (k-ft)

$y_{SR} := 30in$ — Height of the centroid of the Steel Rails measured from the top of the roadway surface (in.)

Steel Splice Rail Properties and Dimensions:
a) Steel Splice Rails are A500 Gr. B Material, Fy=46ksi
b) Steel Splice Rails are HSS5x3x3/8 and HSS4x3x3/8 members
c) Steel Splice Rails bend about the y-axis
d) Note: All heights measured from the top of the roadway surface

$F_{yR} = 46 \cdot ksi$ — Yield Strength of Steel Splice Rails (ksi)

$Z_{S1} := 5.1in^3$ — Plastic Sectional Modulus of top most Steel Splice Rail (in³)

$M_{S1} := F_{yR} \cdot Z_{S1} = 19.55 \cdot kip \cdot ft$ — Plastic Moment Strength of top most Steel Splice Rail (k-ft)

$y_{S1} := 37in$ — Height of the centroid of top most Steel Splice Rail (in.) (See Figure 4)

$Z_{S2} := 4.18in^3$ — Plastic Sectional Modulus of 2nd from top Steel Splice Rail (in³)

$M_{S2} := F_{yR} \cdot Z_{S2} = 16.023 \cdot kip \cdot ft$ — Plastic Moment Strength of 2nd from top Steel Splice Rail (k-ft)

$y_{S2} := 32.5in$ — Height of the centroid of 2nd from top Steel Splice Rail (in.) (See Figure 4)

$Z_{S3} := 5.1in^3$ — Plastic Sectional Modulus of 3rd from top Steel Splice Rail (in³)

$M_{S3} := F_{yR} \cdot Z_{S3} = 19.55 \cdot kip \cdot ft$ — Plastic Moment Strength of 3rd from top Steel Splice Rail (k-ft)

$y_{S3} := 27.25in$ — Height of the centroid of 3rd from top Steel Splice Rail (in.) (See Figure 4)

$Z_{S4} := 4.18 in^3$ — Plastic Sectional Modulus of 4th from top Steel Splice Rail (in³)

$M_{S4} := F_{yR} \cdot Z_{S4} = 16.023 \cdot kip \cdot ft$ — Plastic Moment Strength of 4th from top Steel Splice Rail (k-ft)

$y_{S4} := 22.75 in$ — Height of the centroid of 4th from top Steel Splice Rail (in.) (See Figure 4)

$M_S := M_{S1} + M_{S2} + M_{S3} + M_{S4} = 71.147 \cdot kip \cdot ft$ — Total Plastic Moment Strength of Steel Splice Rails (k-ft)

$$y_S := \frac{M_{S1} \cdot y_{S1} + M_{S2} \cdot y_{S2} + M_{S3} \cdot y_{S3} + M_{S4} \cdot y_{S4}}{M_S} = 30.098 \cdot in$$

Height of the centroid of the Steel Splice Rails (in.)

11.) Find Height of Critical Moment Capacity and Resultant Force of Steel Rails: (M_{rail} & y_{bar})

$M_{SR} = 107.333 \cdot kip \cdot ft$ — Total Plastic Moment Strength of both Steel Rails (k-ft)

$y_{SR} = 30 \cdot in$ — Height of the centroid of the Steel Rails (in.)

$$M_{S\_ySR} := M_S \cdot \left(\frac{y_S}{y_{SR}}\right) = 71.379 \cdot kip \cdot ft$$

Total Plastic Moment Strength of Steel Splice Rails at y_{SR} (k-ft)

$$M_{rail} := \begin{cases} M_S & \text{if } M_{S\_ySR} < M_{SR} \\ M_{SR} & \text{otherwise} \end{cases} = 71.147 \cdot kip \cdot ft$$

Critical Moment Capacity of Rails (k-ft)

$$y_{bar} := \begin{cases} y_S & \text{if } M_{S\_ySR} < M_{SR} \\ y_{SR} & \text{otherwise} \end{cases} = 30.098 \cdot in$$

Critical Height of the centroid of the Rails (in.)

12.) Strength of Post at HR based on Post Yielding Pp1

$Z_{W6x15} := 10.8in^3$ $F_{yA992} := 50ksi$

$F_{Tpost} := 71kip \cdot 0.50$ Consider 1/2 of maximum impact force on top of post (worst cast)

$Ht_{post} := 30in - 27.25in = 2.75 \cdot in$ Use max impact of center of top rail element for TL-3

$M_{postimpact} := Ht_{post} \cdot F_{Tpost} = 8.135 \cdot kip \cdot ft$

$M_{postUltimate} := Z_{W6x15} \cdot F_{yA992} = 45 \cdot kip \cdot ft$

$$P_{p1} := \frac{M_{postUltimate}}{Ht_{post}} = 196.364 \cdot kip$$

13.) Strength of Post based on Adhesive Anchor Strength Pp2

Design Hilti Anchorage System:

$S_{anchors} := 10in$ $C_{anchors} := 5in$ Edge and Anchor Spacing distances (inches)

$F_{vHilti} := 31350lbf \cdot 1.33$ Factored ultimate strength from Table 25, Page 151, Hilti 2016 Technical Guide for RE500V3 Epoxy with dymanic loading for 4000 psi concrete. Comparable for full scale static testing (TTI Project 490026 August 2016)

$f_{AN} := 0.70$ Reduction factor for Spacing .... Table 36, Page 158, 2016 Hilti Technical Guide

$f_{RN} := 0.40$ Reduction factor for Edge Distance .... With reinforcing use 0.40 factor.

$Ecc_{BP} := 6in$ Eccentricty of Anchor Bolts on Baseplate in Tension

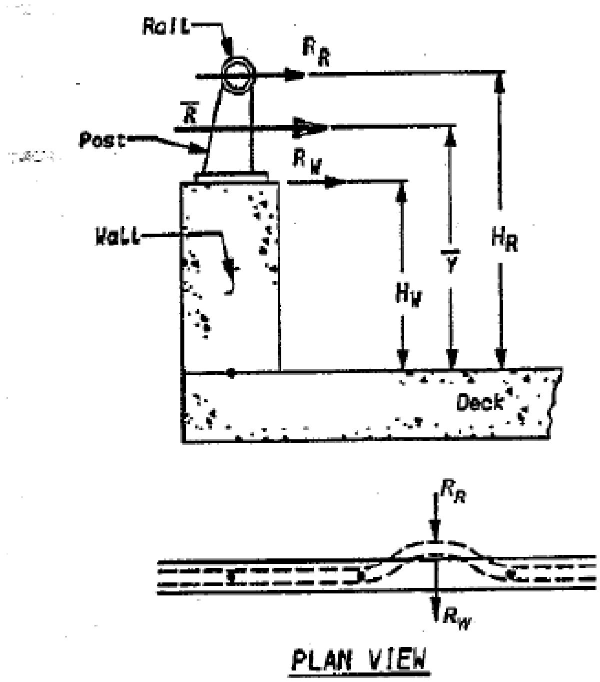
$M_{HiltiAnchors} := F_{vHilti} \cdot f_{AN} \cdot f_{RN} \cdot 2 \cdot Ecc_{BP} = 11.675 \cdot kip \cdot ft$

Use Hilti RE500V3 for A193B7 Threaded Rods, embedded 10 inches minimum

$$P_{p2} := \frac{M_{HiltiAnchors}}{Ht_{post}} = 50.944 \cdot kip$$

$P_p := P_{p2}$ Limiting post strength based on Hilti Adhesive Strength

14.) Calculate the strength of the Steel & Concrete Rail over 1 and 2 Span As per Section A13.3.3



Impact @ Midspan of Steel Rail

$H_R := 30in$ Centroid height to rail elements

$H_w = 28.625 \cdot in$ Height of concrete parapet

$t_{bp} := 0.75in$ Thickness of baseplate

$R_{wmid} = 64.404 \cdot kip$ Strength of the parapet at end Rw kips

$M_{rail} = 71.147 \cdot kip \cdot ft$

$Post_{spa} := 6ft$ Spacing of steel posts (ft.)

$N_1 := 1$ Number of spans for calculations

$N_2 := 2$

$L_t = 4\,ft$

$P_p = 50.944 \cdot kips$ Post strength at H_R

$$R_1 := \frac{16 \cdot M_{rail} + (N_1 - 1) \cdot (N_1 + 1) \cdot P_p \cdot Post_{spa}}{2 \cdot N_1 \cdot Post_{spa} - L_t} \qquad R_1 = 142.293 \cdot kips$$ Strength over 1 span

$$R_2 := \frac{16 \cdot M_{rail} + N_2^{\,2} \cdot P_p \cdot Post_{spa}}{2 \cdot N_2 \cdot Post_{spa} - L_t} \qquad R_2 = 118.051 \cdot kips$$ Strength over 2 spans

$$R_{wreduced} := \frac{R_{wmid} \cdot H_w - P_p \cdot H_R}{H_w} = 11.012 \cdot kips$$ Equation A13.3.3-1 LRFD Section 13

$$R_{bar1} := R_1 + R_{wmid} = 206.697 \cdot kips$$ Strength of the rail 1 span (between posts)

$$Y_{bar1} := \frac{R_1 \cdot H_R + R_{wmid} \cdot H_w}{R_{bar1}} = 29.572 \cdot in$$ Equation A13.3.3-2 LRFD Section 13

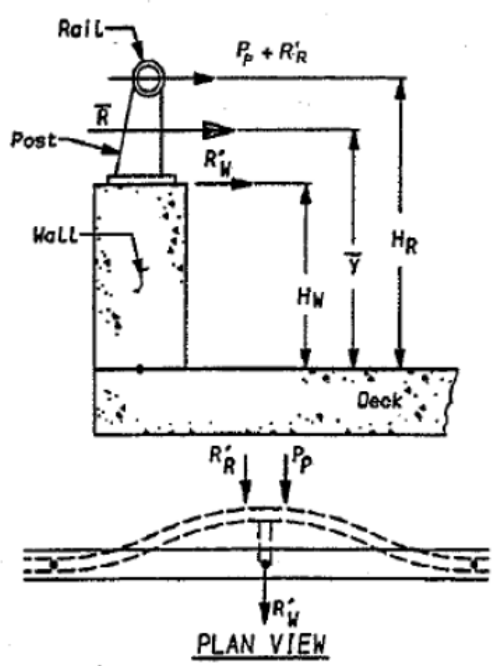


Figure A13.3.3-2 Concrete Wall and Metal Rail Evaluation—Impact at Post.

$R_{bar2} := P_p + R_2 + R_{wreduced} = 180.007 \cdot kips$ Equation A13.3.3-3 LRfd Section 13 Strength OK for 1 and 2 span
Strength of the rail at a post

$$Y_{bar2} := \frac{P_p \cdot H_R + R_2 \cdot H_R + R_{wreduced} \cdot H_w}{R_{bar2}} = 29.916 \cdot in$$ Equation A13.3.3-4 LRFD Section 13

15.) Total Resistance of Bridge Rail System (as continous): R_T

Since the rail retofit bears on top and against the concrete parapet, consider the strength of the retrofit in addition to the concrete parapet
Centroid height of the rails very close to top of concrete parapet, therefore impact load for TL-3 will bear rail on parapet concrete

$R_{wmid} = 64.404 \cdot kip$ Resistance of the Concrete Parapet at midspan (kip)

$R_{wend} = 44.353 \cdot kip$ Resistance of the Concrete Parapet at joints/ends (kip)

Note: Due to steel rail retrofit, the failure mechanism that will occur in the concrete parapet will not occur like a typical joint/end failure.

$R_w := R_{wmid} = 64.404 \cdot kip$ Critical Resistance of the Concrete Parapet (kip)

$H_w = 28.625 \cdot in$ Height of the Concrete Parapet measured from the roadway surface (in.)

$M_{parapet} := R_w \cdot H_w = 153.63 \cdot kip \cdot ft$ Moment Capacity of the Concrete Parapet (k-ft)

$y_{bar} = 30.098 \cdot in$ Height of the Centroid of the Steel Rails measured from the roadway surface (in.) (See Figure 4)

$M_{rail} = 71.147 \cdot kip \cdot ft$ Moment Capacity of Steel Rails (k-ft)
(bending strength at the splices ... This resistance is very conservative due to dynamic strength at impact.

$M_T := M_{parapet} + M_{rail} = 224.777 \cdot kip \cdot ft$ Total Moment Capacity of Bridge Rail System (k-ft)

$$y_T := \frac{M_{parapet} \cdot H_w + M_{rail} \cdot y_{bar}}{M_T} = 29.091 \cdot in$$ Centroid Height of the Total Resistance of the Bridge Rail System measured from the roadway surface (in.)

$$R_T := \frac{M_T}{y_T} = 92.719 \cdot kip$$ Total Resistance of the Bridge Rail System (kip) from item 15 above.

16.) Summary & Conclusions:

$y_T = 29.091 \cdot in$	Centroid Height of the Total Resistance of the Bridge Rail System measured from the roadway surface (in.)
$R_T = 92.719 \cdot kip$	Total Resistance of the Bridge Rail System at the centroid height yt (kip)
$H_{e.mod} = 29 \cdot in$	Modified Height of the Transverse Impact Force, F_t due to curb and deck geometry (in.)
$H_e = 19 \cdot in$	From Full scale crash testing, truck impacts rail @ He
$R_R := R_T \cdot \left(\frac{y_T}{H_e}\right) = 141.964 \cdot kip$	Total Resistance of the Bridge Rail System located at H_e (kip)
$F_t = 71 \cdot kip$	Transverse Impact Force located at H_e (kip)

$Post_{spa} = 6\,ft$

Use W6x15 Post size with 2 ~ Hilti 3/4" Dia. A193 B7 Threaded Rods 12 inches long, embedded 10 inches and anchored with RE500V3

<u>CHECK</u>= "OK", since: R_R = 140.0 kips @ 19 inches height > F_t = 71 kips

Appendix I. Supporting Certification Documents for Test No. 606861-3&4

CERTIFIED MATERIAL TEST REPORT

FOR ASTM A307, GRADE A - HEX BOLTS

FACTORY: ZHEJIANG GOLDEN AUTOMOTIVE FASTENER CO.LTD DATE: MAY.20,2016
ADDRESS: XITANG QIAO HAIYAN ZHEJIANG CHINA

MFG LOT NUMBER 0405006

CUSTOMER:BRIGHTON-BEST INTERNATIONAL(TAIWAN)INC.

PO NUMBER: C11420

SAMPLE SIZE: ACC. TO ASME B18 . 18 -2011 Categories 2
SIZE: 1/2-13X1-1/2" ZP QTY: 48150 PCS PART NO 494086
HEADMARKS: 307A + NDF

STEEL PROPERTIES:
STEEL GRADE: 1008 HEAT NUMBER: 1B-4201965

	C %	Mn%	P %	S %
CHEMISTRY SPEC:	0.29 max	1.20 max	0.04max	0.15max
TEST:	0.05	0.29	0.024	0.023

DIMENSIONAL INSPECTIONS SPECIFICATION: ASME B18.2.1-2012

CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
APPEARANCE	ASTM F788/F788M-13	PASSED	100	0
THREAD	ANSI B1.1-08 2A	PASSED	32	0
WIDTH FLATS	0.750"-0.725"	0.728"-0.748"	8	0
WIDTH A/C	0.866"-0.826"	0.834"-0.855"	8	0
HEAD HEIGHT	0.364"-0.302"	0.308"-0.335"	8	0
BODY DIA.		FULL THREAD	8	0
THREAD LENGTH			8	0
LENGTH	1.54"-1.44"	1.46"-1.47"	8	0

MECHANICAL PROPERTIES: SPECIFICATION: ASTM A307-2014 GR-A

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS :	ASTM E18-14a	69-100 HRB	81-85 HRB	8	0
WEDGE TENSILE :	ASTM F606-14	MIN 60KSI	72-75 KSI	4	0

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
ZINC PLATED	ASTM F1941-15	FE/Zn 3AN	PASS	15	0

ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCR[illegible] IN THE APPLICABLE ASTM SPECIFICATION. WE CERTIFY THAT THIS DATA IS A[illegible]ESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AN[illegible]G LABORATORY.

All parts meet the requirements of FQA and records of compliance

Maker's ISO#CN11/20818

(SIGNATURE OF Q.A. LAB MGR.)
(ZHEJIANG GOLDEN AUTOMOTIVE FASTENER CO.LTD)

Portland Bolt & MANUFACTURING COMPANY

Phone: 800-547-6758 | Fax: 503-227-4634
3441 NW Guam Street, Portland, OR 97210
Web: www.portlandbolt.com | Email: sales@portlandbolt.com

CERTIFICATE OF CONFORMANCE

For: CUSTOM FABRICATORS & REPAIRS
PB Invoice#: 133286
Cust PO#: PO-00408
Date: 8/13/2020
Shipped: 8/13/2020

We certify that the following items were manufactured and tested in accordance with the chemical, mechanical, dimensional and thread fit requirements of the specifications referenced.

Description: 5/8 X 5-1/2 GALV ASTM A449 ROUND HEAD BOLT

Heat#: 3090536 **Base Steel:** 1045 **Diam:** 5/8

Source: COMMERCIAL METALS CO **Proof Load:** 19,200 LBF

C :	.460	**Mn:**	.750	**P :**	.011	**Hardness:**	269 HBN				
S :	.021	**Si:**	.250	**Ni:**	.070	**Tensile:**	35,340 LBF	**RA:**	.00%		
Cr:	.110	**Mo:**	.040	**Cu:**	.280	**Yield:**	0	**Elon:**	.00%		
Pb:	.000	**V :**	.000	**Cb:**	.001	**Sample Length:**	0				
N :	.010			**CE:**	.6057	**Charpy:**		**CVN Temp:**			

LOT#19812

Nuts:
ASTM A563DH HVY HX

Washers:
ASTM F436-1 RND

Coatings:
ITEMS HOT DIP GALVANIZED PER ASTM F2329/A153C

Other:
ALL ITEMS MELTED & MANUFACTURED IN THE USA

By: [signature]
Certification Department Quality Assurance
Dane McKinnon

CMC STEEL TEXAS
1 STEEL MILL DRIVE
SEGUIN TX 78155-7510

CERTIFIED MILL TEST REPORT

For additional copies call
830-372-8771

We hereby certify that the test results presented here are accurate and conform to the reported grade specification

Rolando A Davila
Quality Assurance Manager

HEAT NO.:3090536 SECTION: ROUND 5/8 x 20'0" 1045 GRADE: AISI 1045 ROLL DATE: 09/07/2019 MELT DATE: 08/15/2019 Cert. No.: 83085550 / 090536A032	SOLD TO: Portland Bolt & Mfg 3441 NW Guam St Portland OR US 97210-1613 5032275488 5032274634	SHIP TO: CPU Seguin 1 Steel Mill Dr Seguin TX US 78155-7510 9999999999	Delivery#: 83085550 BOL#: 1925538 CUST PO#: 45869 CUST P/N: DLVRY LBS / HEAT: 4589.000 LB DLVRY PCS / HEAT: 220 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.46%	Bend Test 1	Passed		
Mn	0.75%	Yield Strength test 2	71.2ksi		
P	0.011%	Tensile Strength test 2	111.7ksi		
S	0.021%	Elongation test 2	26%		
Si	0.25%	Elongation Gage Lgth test 2	2IN		
Cu	0.28%	Bend Test Diameter	2.188IN		
Cr	0.11%	BHN @ Surface test 1	228BHN		
Ni	0.07%	Macro Etch Method	ASTM E381		
Mo	0.040%	Macro Surface Rating	1		
V	0.000%	Macro Random Rating	1		
Cb	0.001%	Macro Core Rating	1		
Sn	0.009%				
Al	0.000%				
N	0.0105%				
Yield Strength test 1	71.9ksi				
Tensile Strength test 1	112.4ksi				
Elongation test 1	17%				
Elongation Gage Lgth test 1	8IN				
Reduction of Area test 1	45%				

The Following is true of the material represented by this MTR:
Material is fully killed
**100% melted and rolled in the USA*
**EN10204:2004 3.1 compliant*
**Contains no weld repair*
**Contains no Mercury contamination*
**Manufactured in accordance with the latest version of the plant quality manual*
**Meets the "Buy America" requirements of 23 CFR635.410, 49 CFR 661*
**Warning: This product can expose you to chemicals which are known to the State of California to cause cancer, birth defects or other reproductive harm. For more information go to www.P65Warnings.ca.gov*

REMARKS : ROUND STEEL BAR CARBON GRADE HOT ROLLED

Page 1 OF 1 05/15/2020 16:04:04

UNYTITE INC.
INNOVATIVE FASTENING SYSTEMS

Unytite, Inc.
One Unytite Drive
Peru, IL 61354
Tel 815-224-2221
Fax 815-224-3434

INSPECTION CERTIFICATE

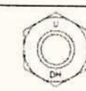
Job No: 32394 | **Job Information** | **Certified Date:** 4/2/20

Customer:
Customer Part No:
Customer PO No:
Lot Number: 32394-6215169002

Ship To:
Shipped Qty:

Part Information

Part No: A563 5/8-11 +0.020 DH HHN HDG BLUE DYE



Description: ASTM A563 HHN, Grade DH, Hot Dipped Galv, Blue Dye

Manufactured Quantity: 153,268

Applicable Specifications

Specification	Amend	Specification	Amend
ASME B1.1	2003	ASME B18.2.2	2015
ASME B18.2.6	2019	ASME B18.2.6M	2012
ASTM A563	2015	ASTM F2329/F2329M	2015
ASTM F606/606M	2019	ASTM F812	2017

Test Results
Test No: 21749 **Test:** A563 DH Mechanical Properties

Description	Hardness (HRC)	Tempering Temp (800 degree F Min)	Proof Load (Pass ASTM Min LBS)	Shape & Dimension ASME B18.2.2	Thread Precision ASME B18.1.1	Visual ASTM F812
Sample Inspection	28.2	1,166	33,900	Pass	Pass	Pass

Certified Chemical Analysis

Heat No	Grade	Manufacturer	Origin	C	Mn	P	S	Si	Cr	Ni	Cu
6215169002	1045	Gerdau Ameristeel	USA	0.4600	0.7700	0.0090	0.0310	0.2000	0.1300	0.0700	0.2200

Notes

All tests are in accordance with the latest revisions of the methods prescribed in the applicable SAE and ASTM Specifications.

The samples tested conform the specifications as described/listed above and were manufactured free of mercury contamination and there is no welding performed in the production of the products. No heats to which Bismuth, Selenium, Tellurium, or Lead was intentionally added have been used to produce products.

The steel was melted and manufactured in the U.S.A. and the product was manufactured and tested in the U.S.A.

We certify that this data is true representation of information provided by the material supplier and our testing laboratory. This certified material test report relates only to the items listed on this document and may not be reproduced except in full.

OFFICIAL SEAL
JEAN E MARGHERIO
NOTARY PUBLIC - STATE OF ILLINOIS
MY COMMISSION EXPIRES 09/18/21

[signature] 4/2/20

Thorsen, Chris - Supervisor, Quality Date

Plex 4/2/20 1:32 PM cthorsen Page 1

4547S - 1

GERDAU

US-ML-ST PAUL
1678 RED ROCK ROAD
SAINT PAUL, MN 55119
USA

CERTIFIED MATERIAL TEST REPORT

Page 1/1

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
UNYTITE INC LASALLE PLANT 325 CIVIC ROAD LA SALLE,IL 61301 USA	UNYTITE INC 1 UNYTITE DR PERU,IL 61354-9710 USA	1045M23FJZN	Round Bar / 7/8"	0000038284
		LENGTH 24'10"	WEIGHT 21,462 LB	HEAT / BATCH 62151690/02
SALES ORDER 8310712/000060	CUSTOMER MATERIAL N° B1045SC0.8750 I	SPECIFICATION / DATE or REVISION ASTM A29-16 ASTM A576-17		

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
P008845	1332-0000077194	01/14/2020

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %	Al %
0.46	0.77	0.009	0.031	0.20	0.22	0.07	0.13	0.018	0.010	0.033	0.000	0.005

METALURGICAL CHARACTERISTICS

FineGr	E381 S	E381 R	E381 C
	1	1	1

HARDENABILITY

DI A255 Inch
1.47

COMMENTS / NOTES

Material 100% melted and rolled in the USA. Manufacturing processes for this steel, which may include scrap melted in an electric arc furnace and hot rolling, have been performed at Gerdau St. Paul Mill, 1678 Red Rock Road, Saint Paul, Minnesota, USA. All product produced from strand cast billets. Silicon killed (deoxidized) steel. No weld repairmen performed. Steel not exposed to mercury or any liquid alloy which is liquid at ambient temperatures during processing or while in Gerdau St. Paul Mills possession. Any modification to this certification as provided by Gerdau-St. Paul Mill without the expressed written consent of Gerdau St. Paul Mill negates the validity of this test report. This report shall not be reproduced except in full, without the expressed written consent of Gerdau St. Paul Mill. Gerdau St. Paul Mill is not responsible for the inability of this material to meet specific applications.
Roll batch 62151690/02 roll date 12/5/2019 Fine Grain (FG 5-8)
Quality Program Manual Rev. 10, Implemented date 11/8/2019
Macro S1 R1 C1 Reduction Ratio: 49.9 (ASTM E381-17 E45-18a)

DEBRA L. KARIESCH
Notary Public-Minnesota
My Commission Expires Jan 31, 2025

Debra L Kariesch

The above figures are certified chemical and physical test records as contained in the permanent records of Company. We certify that these data are correct and in compliance with specified requirements. Weld repair has not been performed on this material. This material, including the billets, was melted USA. CMTR complies with EN 10204 3.1.

Bhaskar — BHASKAR YALAMANCHILI, QUALITY DIRECTOR
Phone: (409) 267-1071 Email: Bhaskar.Yalamanchili@gerdau.com

ALEA BRANDENBURG, QUALITY ASSURANCE MGR.
Phone: (651) 731-5662 Email: Alea.Brandenburg@gerdau.com

Universal Galvanizing, Inc.

510 E South 1ST St.
Wright City, Missouri 63390
Phone:(636)791-2016 Fax:(636)745-0667

Date: 3-27-20

RE: GALVANIZING CERTIFICATE
UNYTITE, INC.
PO# P009098

QTY	PART NUMBER/DESCRIPTION	LOT NUMBER	COATING THICKNESS
153,268	A563 5/8-11+0.020 GRADE DH HEAVY HEX NUT	32394-6215169002	3.5 AVG. MILS
148,064	A563 5/8-11+0.020 GRADE DH HEAVY HEX NUT	32395-6215169002	3.5 AVG. MILS

THIS WILL CERTIFY THAT THE MATERIAL GALVANIZED ON THE ABOVE JOB MEETS ASTM F2329 SPECIFICATIONS. THIS MATERIAL WAS GALVANIZED IN THE USA AT UNIVERSAL GALVANIZING INC IN WRIGHT CITY, MO AT A ZINC BATH TEMPERATURE OF 840° WITH A PLUS MINUS VARIANCE OF 5°. THE MATERIALS ITEMIZED IN THIS SHIPMENT ARE CERTIFIED TO BE IN COMPLIANCE WITH THE APPLICABLE ASTM STANDARDS AND THE IOWA DEPARTMENT OF TRANSPORTATION STANDARD SPECIFICATIONS, IMs AND MEET THE BUY AMERICA REQUIREMENTS AS DESCRIBED IN IM 107 FOR ALL STEEL, IRON PRODUCTS AND COATINGS.

Joseph Jokisch

Joseph Jokisch, Quality/ Shipping & Receiving

TECHNICAL STAMPING TSI EST. 1991

TECHNICAL STAMPING, INC.

50600 E. RUSSELL SCHMIDT BLVD.
CHESTERFIELD TWP., MI 48051
PH(586)948-3285 / FX(586)948-3286

MATERIAL CERTIFICATION

CUSTOMER NAME	CUSTOMER ORDER NUMBER	DATE
Portland Bolt & Mfg Co	45681	5/4/2020

PART NUMBER - CUSTOMER LOT NO.	LOT NUMBER	QUANTITY
5/8" F436 Hdg 16443	1019-282	20,000

STEEL GRADE	HEAT	C	MN	P	S	SI	AL	REVISION
	31938550	.52	.72	.008	.0001	.24	.028	ASTM F-436-10

SPECIFICATION		ACTUAL	GAUGE
O.D -	1.281 - 1.345	1.313 - 1.316	CALIPER
I.D -	.688 - .720	.703 - .706	CALIPER, PIN GAUGE
THICKNESS-	.122 - .177	.123 - .126	MICROMETER
FLAT-	Max .010	.003	CALIPER
HEAT TREAT -	38 - 45HRC	41 - 43	
PLATING-		See Attached Cert	
OTHER		N/A	

WE HEARBY CERTIFY THIS PRODUCT WAS PRODUCED UNDER A ISO-9001 QUALITY ASSURANCE SYSTEM. ISO-9001 CERTIFICATION NUMBER-1265 - DATE OF REGIS. JAN. 3. 2003 ALL MATERIALS ARE MADE AND MELTED IN THE U.S.A. THIS PRODUCT WAS MANUFACTURED IN CHESTERFIELD, MICHIGAN, U.S.A. THIS PRODUCT CONFORMS TO ALL REQUIREMENTS FOR WASHERS AS PRODUCED ACCORDING TO A.S.T.M. F-436-10. THE ABOVE TEST RESULTS APPLY ONLY TO THE ITEMS TESTED. THIS TEST REPORT MUST NOT BE REPRODUCED EXCEPT IN FULL WITHOUT PRIOR WRITTEN APPROVAL.

CERTIFIED ISO 9001:

[signature]
AUTHORIZED SIGNATURE

" MADE AND MANUFACTURED IN THE USA"

Qlty 3008 Rev. 2 11/25/01

45681-2

9350

INDUSTRIAL STEEL TREATING COMPANY, INC

613 Carroll Street Jackson, MI 49202
P.O. Box 98 Jackson MI, 49204
Voice: 517-787-6312 Fax: 517-787-5441

HEAT TREAT CERTIFICATION

Customer:
TECHNICAL STAMPING, INC.
Attn: SHANNON COX
50600 E. RUSSELL SCHMIDT
CHESTERFIELD, MI 48051

Certification Date:
10/29/2019

Page: 1 of 1

Order Details

Part Number:	F0058
Packing Slip:	7259
Purchase Order:	
IST Order Number:	801460-1
Lot Number:	1019-282
Heat Number:	31938550
Blue Print Rev:	1279
Material Type:	1030 - 1050
Quantity:	400,244
Net Weight:	13,128.0
Part Desc:	WASHER
Comments:	9 TUBS#1218,1989,C91,951, 416,921,003,640,655

SPECIFICATIONS

HRC 38 - 45
HEAT TREATED IN THE USA

RESULTS

HRC 41-43
HEAT TREATED IN THE USA

Approval: Tom Levy
Tom Levy - Quality Assurance Supervisor

Contact
Tom Levy - Quality Assurance Supervisor
Voice: 517-780-9043 Fax: 517-787-5441
E-Mail: tolevy@indstl.com

9350

CERTIFICATE OF CONFORMANCE

SABRE STEEL INC.
23680 RESEARCH DRIVE
FARMINGTON HILLS, MI 48335
248-615-0500

SABRE STEEL INC

10/14/2019 1:23:57 PM

Sold To: TECHNICAL STAMPING
50600 E. RUSSELL SCHMIDT BLVD.
CHESTERFIELD TWP., MI 48051

Ship To: TECHNICAL STAMPING
50600 RUSSELL SCHMIDT BLVD.
CHESTERFIELD TWP., MI 48051

Cust PO: S91539 **Ship Date:** 10/15/2019

Sales Order: 77172 **Weight:** 29,710#

CHEMICAL ANALYSIS

Heat Number:		31938550					
C:	.52	Mn:	.72	P:	.008	S:	.0001
Si:	.24	Ti:	.001	Cr:	.04	Mo:	
Cu:	.10	Al:	.028	Cb:		Va:	.002
Ni:	.03	B:		Sn:		N:	

PHYSICAL PROPERTIES

YS:		TS:		E:	
Chemistry:	C1050				

Line: 1 **Item:** .122min X 3.9500 C1050
Grade: HRP&O High Carbon
Cust Part: F0058M

Comment: Tags 065946 A thru H Made & Melted In The USA

WE HEREBY CERTIFY THE ABOVE FIGURES ARE ACCURATELY STATED, MEET YOUR MATERIAL REQUIRMENTS AND ARE TRACEABLE IN OUR RECORDS BACK TO THE PRODUCER AND/OR AN ACCREDITED TEST LABORATORY.

Quality Assurance Manager

9350

Steel Dynamics, Inc.®
Flat Roll Group

4500 County Road 59
Butler, IN 46721 USA
Telephone (260) 868-8000
Fax (260) 868-8955

Metallurgical Certification

Cert # 3360599

Ship To	Voss Industries - T 7925 Beech Daly Road Taylor, MI 48180 United States	Contact Taylor RECEIVING P: 313-291-8535
Sold To	Sabre Steel Inc. 23680 Research Drive Farmington Hills, MI 48335 United States	Contact Bob Alexander P: 847-695-2900 F: 847-695-2950

Length	2,227 ft. / 679 m	Width	50.2500 in. / 1,276 mm	Chem Treat	No
Weight	49,350 lbs / 22,384.77 kg	Gauge	0.1250 in. / 3.18 mm | Min	Oiled	No

Coil #	198448749	Coil Alias	
Order #	663249	Heat #	31938550
Line Item #	4	PO #	65716 - 4
Part #			
Material Spec.	SAE 1050 WITH SILICON		
Product Desc.	Prime Hot Rolled Band		
Cert Comment			
Surface Treatment			

Ladle Chemical Analysis (%)

C	Mn	P	S	Si	Al	Cu	Ni	Cr	Mo	Sn	N	V	Nb	Ti	B	Ca	Pb	Zr
0.52	0.72	0.008	0.000	0.24	0.028	0.10	0.03	0.04	0.02	0.007	0.007	0.002	0.000	0.001	0.0000	0.002	0.000	0.0001

Mechanical Properties (if applicable)

Hiroshi Kimura
Metallurgist

Shipped from Butler, IN, United States.

Melted, thin slab cast and rolled by proud Americans in Butler, IN, USA.

SDI does not weld or repair Prime Hot Rolled Band products.

All tests were performed according to applicable standards and are correct as contained in the records of the company.

Retrieve on : 9/30/2019 8:44:06 PM

Steel Dynamics Rev. Level 1.15 [1560]

Page 1 of 1

AZZ GALVANIZING™ ROCKFORD

January 09, 2020

Technical Stamping
50600 E. Russell Schmidt
Chesterfield TWP, MI 48051

To Whom It May Concern:

This is to certify that the hot dip galvanizing of the following washers on your Purchase Order number 1651 conforms to specification ASTM A-153. The following sizes and lot numbers comply with the coating, workmanship, finish, and appearance requirements of ASTM F2329 specifications. The hot dip galvanizing is ROHS compliant. The galvanizing process was conducted in a temperature range of 830F to 855F.

PIECES	PART# & SIZE	LOT NUMBER	AVERAGE ZINC COATING IN MILS.
90,090	#F0058 5/8" WASHER	1019-282	4.18

This certification in no way implies anything other than the quality of our hot dip galvanizing as it pertains to your order.

This product was galvanized in Rockford, IL USA

Yours very truly,

AZZ Galvanizing Rockford, IL

Peggy Doering

Peggy Doering
Office Manager

PD:ac

Vulcan
THREADED PRODUCTS, INC.

Vulcan Threaded Products
10 Cross Creek Trail
Pelham, AL 35124
Tel (205) 620-5100
Fax (205) 620-5150

JOB MATERIAL CERTIFICATION

Job No: 676043 | **Job Information** | **Certified Date:** 6/8/20

Containers: S17187917

Customer: Interstate Threaded Products

Ship To: 2200 Singleton Blvd
Dallas, TX 75212

Vulcan Part No: ATR B7 5/8x12 HDG

Customer Part No: ATR B7 5/8x12 HDG

Customer PO No: 43237

Shipped Qty: 96 Ft

Order No: 403988

Line No: 3

Note:

Applicable Specifications

Type	Specification	Rev	Amend	Option
-	ASTM F1554 Gd 105 S4	2018		
Heat Treat	ASME SA-193/SA-193M B7	2013		
	ASTM A193 B7	2019		

Test Results

See following pages for tests

Certified Chemical Analysis

Heat No: 20688450 | Origin: USA

C	Mn	P	S	Si	Cr	Mo	Ni	V	Cu
0.42	0.85	0.010	0.003	0.29	0.88	0.15	0.05	0.001	0.14
Al	**Nb**	**Sn**	**Ti**	**N**	**B**	**DI**	**RR**	**G.S.**	**Macro S**
0.029	0.002	0.007	0.001	0.0050	0.0001	4.57	160:1	fine	1
Macro R	**Macro C**	**J1**	**J2**	**J3**	**J4**	**J5**	**J6**	**J7**	**J8**
1	1	57	57	57	57	57	54	53	51
J9	**J10**	**J12**	**J14**	**J16**	**J18**	**J20**	**J24**	**J28**	**J32**
50	48	46	44	41	40	39	37	34	33

Notes

Processed material is Tempered - Stress Free. No weld repair performed on the material. No Mercury used in the production of this material. Melted and Manufactured in the USA.
Grade - 4140
EAF Melted

Plex 6/8/20 11:34 AM vulc.sano Page 1 of 2

Vulcan THREADED PRODUCTS, INC.

Vulcan Threaded Products
10 Cross Creek Trail
Pelham, AL 35124
Tel (205) 620-5100
Fax (205) 620-5150

JOB MATERIAL CERTIFICATION

Job No: 668113 **Job Information** **Certified Date:** 4/8/20

Containers: S17411160

Customer: Winzer Corp

Ship To: 1214 S. Texas Ave
Bryan, TX 77803-4582

Vulcan Part No: ATR B7 3/4x12 HDG

Customer Part No: ATR B7 3/4x12 HDG

Customer PO No: 1103397

Shipped Qty: 1 containers

Order No: 407308

Line No: 1

Note:

Applicable Specifications

Type	Specification	Rev	Amend	Option
-	ASTM F1554 Gd 105 S4	2018		
Heat Treat	ASTM A193 B7	2019		

Test Results

See following pages for tests

Certified Chemical Analysis

Heat No: 10649220 Origin: USA

C	Mn	P	S	Si	Cr	Mo	Ni	V	Cu
0.41	0.87	0.018	0.024	0.27	0.91	0.20	0.06	0.002	0.16
Al	**Nb**	**Sn**	**Ti**	**N**	**B**	**DI**	**RR**	**G.S.**	**Macro S**
0.028	0.001	0.007	0.002	0.0070	0.0001	5.21	54:1	fine	1
Macro R	**Macro C**	**J1**	**J2**	**J3**	**J4**	**J5**	**J6**	**J7**	**J8**
1	1	57	57	57	57	57	57	55	54
J9	**J10**	**J12**	**J14**	**J16**	**J18**	**J20**	**J24**	**J28**	**J32**
53	51	49	47	45	44	43	41	39	37

Notes

Processed material is Tempered - Stress Free. No weld repair performed on the material. No Mercury used in the production of this material. Melted and Manufactured in the USA.
Grade - 4140
EAF Melted

Plex 4/8/20 2:04 PM vulc.sano Page 1 of 2

Vulcan THREADED PRODUCTS, INC.

Vulcan Threaded Products
10 Cross Creek Trail
Pelham, AL 35124
Tel (205) 620-5100
Fax (205) 620-5150

JOB MATERIAL CERTIFICATION

Job No: 668113 **Job Information** **Certified Date:** 4/8/20

Containers: S17411160

Test Results

Part No: BAR B7 .6813x292 HT

Test No: 59660 **Test**: Quench & Temper Information (Lbs)

Description	Austenitizing Temp (F)	Tempering Temp (F)	Run Speed (Ft/min)	Quench Water Temp (F)	Note
Results	1,660	1,346	40	89	

Test No: 59665 **Test**: Partial Decarb Test

Description	Surface Carb.	Partial Surface Decarb.	Note
	Pass	Pass	

Test No: 59666 **Test**: F1554-105 FB Requirements

Description	Tensile (ksi) (ksi)	Yield 0.2% Offset (ksi) (ksi)	Elongation (%)	Elongation Gage Length (8in)	ROA (%)	Note
	138	129	13.1	8in	58.8	tested by external provider

Test No: 59667 **Test**: A193 B7, F1554-105 Requirements

Description	Tensile (ksi)	Yield 0.2% Offset (ksi)	Elongation (%)	Elongation Gage Length	ROA (%)	Midradius Hardness	Surface Hardness	Center Hardness	Hardness Test Type	Note
	139	127	22	4D	61	29	29	29	HRC	
	138	127	21	4D	59	30	30	29	HRC	
	137	125	20	4D	64	28	29	29	HRC	
	137	129	21	4D	61	29	29	29	HRC	
	139	128	19	4D	61	29	29	29	HRC	
	138	125	19	4D	62	29	29	28	HRC	
	137	126	21	4D	61	29	29	29	HRC	
	139	128	20	4D	61	30	30	30	HRC	
	137	126	19	4D	61	29	29	29	HRC	

Test No: 59668 **Test**: F1554 Gd105 S4 Charpy ft/lbs Requirements

Description	Container	Test Temp (F)	Test1 (ft/lbs)	Test2 (ft/lbs)	Test3 (ft/lbs)	Results Avg (ft/lbs)	Note
		-20	81	102	86	90	

The reported test results conform to the specifications listed above.
The reported test results are the actual values measured on the samples taken from the production lot.
Material was manufactured, tested, and inspected as required by the product standard and in accordance with Vulcan"s ISO 9001:2015 Quality Management System registered June 30th, 2017.
Material was tested in accordance with the current revision of ASTM A370, F606, and F2328 test methods.
This test report shall not be reproduced or distributed, except in full, without the written permission of Vulcan Steel Products.
Document is in accordance with EN 10204 - 3.1B of 2004 (3.1).

Sallie Norwood 4/8/20

Norwood, Sallie - Certification Engineer Date

Plex 4/8/20 2:04 PM vulc.sano Page 2 of 2

CERTIFIED MATERIAL TEST REPORT
FOR ASTM A194/A194M-10a GRADE 2H HVY HEX NUTS

FACTORY: NINGBO HAIXIN HARDWARE CO.,LTD.
DATE: AUG.08.2011
ADDRESS: XIJINGTANG,LUOTUO NINGBO ZHEJIANG 315205 CHINA
MFG LOT NUMBER: 1033130006
CUSTOMER: BRIGHTON-BEST INTERNATIONAL (TAIWAN) INC
PO NUMBER: U04584
QNTY SHIPPED: 28.800MPCS
PART NO: 313150
SAMPLE SIZE : ACC. TO ASME B18 . 18 . 1 - 02
SIZE & DESCRIPTION: 5/8-11+0.020"(HDG)

STEEL PROPERTIES:
STEEL GRADE: SWRCH45K SIZE: 25mm HEAT NO: 331105231
CHEMISTRY COMPOSITION:

CHEMIST	C %	Mn %	P %	S %	Si %	Cr %	Ni %	Cu %	Mo %	OTHERS
SPE:	MIN 0.40	MAX 1.00	MAX 0.04	MAX 0.05	MAX 0.40					
TEST:	0.45	0.73	0.009	0.01	0.21					

DIMENSIONAL INSPECTIONS
SPECIFICATION: ASME/ANSI B18 . 2 . 2 - 87(R1999)

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
APPEARANCE	ASTM F812-02		PASSED	100	0
WIDTH A/F	1.031 "-1.062"		1.042"-1.052"	32	0
WIDTH A/C	1.175"-1. 227 "		1.180"-1.221"	32	0
THREAD	ASME B1.1-02		PASSED	8	0
HEIGHT	0.587"-0.631"		0.597"-0.611"	32	0
MARK	2H* LM		PASSED	100	0

MECHANICAL PROPERTIES: TO 1-1/2" in
SPECIFICATION: ASTM A194-10a

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
HARDNESS	ASTM E18-05	24-35HRC	HRC28-30	5	0
PROOF LOAD	ASTM F606-07	39550lbf	39550lbf	5	0
DECARBURIZATION	SAE J121		PASSED	1	0
HARDNESS AFTER 24H AT 540°C ASTM A194 MIN 89 HRB			HRB 92-94	5	0
TEMPERING TEMPERATURE Min455°C			PASSED(520°C)		
MACROETCH	ASTM E381	S1/R1/C1~S4/R4/C4	S2/R2/C2	5	0

PARTS ARE MANUFACTURED AND TESTED IN ACCORDANCE WITH ASTM A194/A194M-10a
ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED SPECIFICATION. WE CERTIFY THAT THIS DAIA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.

All parts meet the requirements of FQA and records of compliance are on file.
Maker's ISO#00109Q10593R0M/3302

TESTING

(SIGNATURE OF Q.A. LAB MGR.)
(NAME OF MANUFACTURER)

NINGBO DONGXIN HIGH-STRENGTH NUT CO.,LTD

TEST CERTIFICATE (EN 10204.3.1)

TEL:0086-574-86531750 FAX:0086-574-86531751 www.d-x.com.cn dongxin@d-x.com.cn

Customer: BRIGHTON-BEST INTERNATIONAL	P/O NO.: B16100374	QTY(MP): 33.75		INVOICE NO: 17075DX228-018
	Product Description: ASTM A194 2H Heavy Hex Nuts			
	Specification: 3/4"-10		T/O: 0.51	Lot#: 1610DX228-0242
	Material: 45K	Surface Finish: HDG		Heat No.: J11604926
	Mark: DX,2HZN		Part Number: 313200	

Chemical Composition

Specification:ASTM A194-16

Element	C	Mn	P	S	Si
Requirement	≥0.40	≤1.00	≤0.04	≤0.05	≤0.40
Result	0.44	0.69	0.019	0.004	0.15

Mechanical Properties

Specification:ASTM A194-16

Test Item	Standard	Results	Sampling	Test method
Hardness after Treatment (540℃ 24h HRB)	MIN89	92-94	5	ASTM E18-14
Hardness HRC	24 - 35	27 - 31	4	ASTM E18-14
Proof loading LBF	58450	58736	3	ASTMA962/A962M-09

Dimensions

Specification:ASTM/ANSI/ASME B18.2.2.10

Test Item	Spec.	Inspection Results	Sampling	Rej	Remark	Test method
Widthacrossflats(mm)	30.78 - 31.75	31.24-31.42	125	0	OK	--------
Widthacrossangle(mm)	35.10 - 36.65	35.80-35.97	125	0	OK	--------
Height(mm)	18.03 - 19.25	18.52-18.72	125	0	OK	--------
Go Gauge	GO	GO	125	0	OK	ASTM B1.1-02
No-Go	NO GO	NO GO	125	0	OK	ASTM B1.1-02
Appearance	OK	OK	125	0	OK	ASTM F812-07

MACROETCH

Division	Surface Condition	Random Condition	Center Segregation	Spec. Of test method
Spec.	S2	R2	C3	ASTM E381
Results	S2	R2	C3	

NOTE: Test Standards:ASTM A194/A194M-2016/ WAF TO DIN934-1987 H=D (HEIGHT=1 DIAMETER) Standard Specification for Carbon and
Alloy Steel nuts.
Quench at 830℃ about 80 minutes, Tempering at 550℃ about 80 minutes
We hereby certify that all the above results are original from our actual testing, and the products have proved to comply with the relevant standards.
Signed on Behalf of Ningbo Dongxin High- Strength Nut Co., Ltd. Date:2017.02.27

(2)

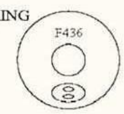
宁波东鑫高强度螺母有限公司
NINGBO DONGXIN HIGH-STRENGTH NUT CO LTD

1/2

HEXICO ENTERPRISE CO., LTD.

NO.355-3,SEC. 3,CHUNG SHAN ROAD,KAU-JEN,TAINAN,TAIWAN,R.O.C.
TEL : 886 - 6 - 2390616 FAX : 886 - 6 - 2308947

MARKING



INSPECTION CERTIFICATE

CUSTOMER	**PORTEOUS FASTENER CO.**		
PART NAME	ASTM F436 - 09 TYPE 1 WASHERS (HOT DIP GALV. PER ASTM A153)		
SIZE	3/4 "	DATE	April 08, 2011
PART NO.	W2A6C6000S6JV	REPORT NO.	1000408-02
CUST. PART NO.	00385-3200-024	SHIPPING NO.	
MATERIAL / DIA.	10B20 / 23 mm	ORDER NO.	10122251
HEAT(COIL) NO.	3B143	LOT NO.	022C6PF41
LOT QTY	72,000 PCS	DOCUMENT NO.	9709015
STANDARD OF SAMPLING SCHEME	ANSI / ASME B18.18.2 M		

DIMENSIONS IN inch

INSPECTION ITEM		SPECIFICATION	INSPECTION RESULTS		REMARKS
			MIN.	MAX.	
1	OUTSIDE DIAMETER	1.4360 - 1.5000	1.4547	1.4681	
2	INSIDE DIAMETER	0.8130 - 0.8450	0.8311	0.8354	
3	THICKNESS	0.1220 - 0.1770	0.1311	0.1394	
4	HARDNESS	HRC 26 - 45	26.1	27.0	
5	COATING	HOT DIP GALV. 43 μm	46.0	75.6	
6	APPEARANCE	VISUAL	OK		

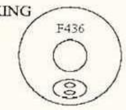
HOT DIP GALV. 43 μm	1	2	3	4	5	6	7	8	9	10
SAMPLE SIZE : 10 PCS	49.1	58.2	62.0	75.6	71.4	49.2	51.4	56.9	66.7	46.0

INSPECTED BY *Yu Tain Lin* CERTIFIED BY *Jing Yeh Tsao*

HEXICO ENTERPRISE CO., LTD.

NO.355-3,SEC. 3,CHUNG SHAN ROAD,KAU-JEN,TAINAN,TAIWAN,R.O.C.
TEL : 886 - 6 - 2390616 FAX : 886 - 6 - 2308947

MARKING



INSPECTION CERTIFICATE

CUSTOMER: PORTEOUS FASTENER CO.

PART NAME: ASTM F436 - 09 TYPE 1 WASHERS (HOT DIP GALV. PER ASTM A153)

SIZE	5/8 "	DATE	April 01, 2011
PART NO.	W2A6C5000S6JV	REPORT NO.	1000401-01
CUST. PART NO.	00385-3000-024	SHIPPING NO.	
MATERIAL / DIA.	10B20 / 20 mm	ORDER NO.	10122251
HEAT(COIL) NO.	1Q961	LOT NO.	022C5PF41
LOT QTY	72,000 PCS	DOCUMENT NO.	9802003

STANDARD OF SAMPLING SCHEME: ANSI / ASME B18.18.2 M

DIMENSIONS IN inch

INSPECTION ITEM		SPECIFICATION	INSPECTION RESULTS		REMARKS
			MIN.	MAX.	
1	OUTSIDE DIAMETER	1.2810 - 1.3450	1.2909	1.3181	
2	INSIDE DIAMETER	0.6880 - 0.7200	0.7134	0.7197	
3	THICKNESS	0.1220 - 0.1770	0.1264	0.1421	
4	HARDNESS	HRC 26 - 45	26.5	31.4	
5	COATING	HOT DIP GALV. 43 μm	46.6	104.0	
6	APPEARANCE	VISUAL	OK		

HOT DIP GALV. 43 μm	1	2	3	4	5	6	7	8	9	10
SAMPLE SIZE : 10 PCS	46.6	50.6	99.2	84.7	81.6	104.0	101.0	88.3	65.1	70.9

INSPECTED BY *Yu Tain Lin* CERTIFIED BY *Jing Yeh Tsao*

Atlas Tube Canada
200 Clark St.
Harrow Ontario Canada
NOR 1G0
Tel: 519-738-3541
Fax: 519-738-3537

Atlas Tube
A DIVISION OF ZEKELMAN INDUSTRIES

REF.B/L: 80954217
Date: 06/01/2020
Customer: 192

MATERIAL TEST REPORT

Sold To
Triple S Steel Supply
PO Box 21119
HOUSTON TX 77026
USA

Shipped To
Intsel Steel Distributors
11310 West Little York
HOUSTON TX 77041
USA

Material: 7.0x5.0x250x40'0"0(2x2). Material No: 70050250 Made in: Canada
Sales Order: 1514677 Purchase Order: WLY-24734 Melted in: Canada

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
797469	0.190	0.780	0.009	0.009	0.014	0.034	0.057	0.004	0.007	0.020	0.034	0.002	0.002	0.0002	0.0040	0.0002

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M101982978	4	057709 Psi	066926 Psi	34.5 %	ASTM A500-18 GRADE B&C	CE: 0.34

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
797469	STELCO	Nanticoke,ON	BOF	36.90%	19.80%	14.40%	100%	1000

Material Note:
Sales Or. Note:

Material: 10.0x6.0x250x48'0"0(2x1). Material No: 100060250 Made in: Canada
Sales Order: 1521362 Purchase Order: WLY-24807 Melted in: Canada

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
796871	0.190	0.810	0.009	0.009	0.017	0.045	0.050	0.005	0.004	0.016	0.041	0.002	0.002	0.0002	0.0040	0.0002

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M201442261	2	063304 Psi	073933 Psi	36.5 %	ASTM A500-18 GRADE B&C	CE: 0.34

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
796871	STELCO	Nanticoke,ON	BOF	36.90%	19.80%	14.40%	100%	1000

Material Note:
Sales Or. Note:

Authorized by Quality Assurance: [signature]

The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements.
CE calculated using the AWS D1.1 method.

Steel Tube Institute OF NORTH AMERICA

Metals Service Center Institute

Atlas Tube Canada
200 Clark St.
Harrow Ontario Canada
N0R 1G0
Tel: 519-738-3541
Fax: 519-738-3537

Atlas *Tube*
A DIVISION OF ZEKELMAN INDUSTRIES

REF.B/L: 80954217
Date: 06/01/2020
Customer: 192

MATERIAL TEST REPORT

Sold To
Triple S Steel Supply
PO Box 21119
HOUSTON TX 77026
USA

Shipped To
Intsel Steel Distributors
11310 West Little York
HOUSTON TX 77041
USA

Material: 10.0x6.0x250x48'0"0(2x2). Material No: 100060250 Made in: Canada
Melted in: Canada
Sales Order: 1521362 Purchase Order: WLY-24807

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
797482	0.200	0.790	0.014	0.009	0.014	0.034	0.048	0.004	0.004	0.017	0.042	0.002	0.002	0.0002	0.0040	0.0002

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M201435080	4	061098 Psi	071252 Psi	32.5 %	ASTM A500-18 GRADE B&C	CE: 0.35

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
797482	STELCO	Nanticoke,ON	BOF	36.90%	19.80%	14.40%	100%	1000

Material Note:
Sales Or. Note:

Material: 10.0x8.0x625x25'0"0(1x1)REC Material No: 100080625 Made in: Canada
Melted in: Canada
Sales Order: 1521862 Purchase Order: WLY-24818

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
842890	0.190	0.800	0.014	0.008	0.016	0.050	0.048	0.005	0.006	0.019	0.051	0.002	0.002	0.0002	0.0040	0.0002

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M201426482	1	059292 Psi	071246 Psi	32.3 %	ASTM A500-18 GRADE B&C	CE: 0.34

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
842890	STELCO	Nanticoke,ON	BOF	36.90%	19.80%	14.40%	100%	1000

Material Note:
Sales Or. Note:

Authorized by Quality Assurance: *Jason Richard*

The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements.
CE calculated using the AWS D1.1 method.

Steel Tube Institute OF NORTH AMERICA

Metals Service Center Institute

Atlas Tube Canada
200 Clark St.
Harrow Ontario Canada
NOR 1G0
Tel: 519-738-3541
Fax: 519-738-3537

Atlas *Tube*
A DIVISION OF ZEKELMAN INDUSTRIES

REF.B/L: 80954217
Date: 06/01/2020
Customer: 192

MATERIAL TEST REPORT

Sold To
Triple S Steel Supply
PO Box 21119
HOUSTON TX 77026
USA

Shipped To
Intsel Steel Distributors
11310 West Little York
HOUSTON TX 77041
USA

Material: 4.0x4.0x313x48'0"0(5x2). Material No: 400403134800 Made in: Canada Melted in: Canada

Sales Order: 1514677 Purchase Order: WLY-24734

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
797410	0.190	0.810	0.012	0.010	0.018	0.048	0.048	0.006	0.004	0.015	0.035	0.002	0.002	0.0002	0.0050	0.0002

CE: 0.34

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification
M101985797	10	067661 Psi	073420 Psi	29.5 %	ASTM A500-18 GRADE B&C

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
797410	STELCO	Nanticoke,ON	BOF	36.90%	19.80%	14.40%	100%	1000

Material Note:
Sales Or. Note:

Material: 8.0x6.0x500x48'0"0(2x2). Material No: 800605004800 Made in: Canada Melted in: Canada

Sales Order: 1521578 Purchase Order: WLY-24813

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
796584	0.200	0.810	0.013	0.007	0.022	0.042	0.058	0.005	0.006	0.023	0.053	0.002	0.002	0.0002	0.0040	0.0002

CE: 0.36

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification
M201431614	4	062920 Psi	074005 Psi	31.0 %	ASTM A500-18 GRADE B&C

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
796584	STELCO	Nanticoke,ON	BOF	36.90%	19.80%	14.40%	100%	1000

Material Note:
Sales Or. Note:

Authorized by Quality Assurance: Jason Richard

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CE calculated using the AWS D1.1 method.

Steel Tube Institute OF NORTH AMERICA

Metals Service Center Institute

Page: 3 of 5

Atlas Tube Canada
200 Clark St.
Harrow Ontario Canada
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Tel: 519-738-3541
Fax: 519-738-3537

Atlas *Tube*
A DIVISION OF ZEKELMAN INDUSTRIES

REF.B/L: 80954217
Date: 06/01/2020
Customer: 192

MATERIAL TEST REPORT

Sold To
Triple S Steel Supply
PO Box 21119
HOUSTON TX 77026
USA

Shipped To
Intsel Steel Distributors
11310 West Little York
HOUSTON TX 77041
USA

Material: 10.0x4.0x250x48'0"0(2x3). Material No: 1000402504800 Made in: Canada Melted in: Canada

Sales Order: 1514677 Purchase Order: WLY-24734

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
797471	0.180	0.750	0.007	0.010	0.012	0.032	0.042	0.004	0.006	0.020	0.034	0.002	0.002	0.0002	0.0030	0.0002

CE: 0.32

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification
M201438465	6	058060 Psi	070681 Psi	35.0 %	ASTM A500-18 GRADE B&C

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
797471	STELCO	Nanticoke,ON	BOF	36.90%	19.80%	14.40%	100%	1000

Material Note:
Sales Or. Note:

Material: 10.0x4.0x375x48'0"0(2x2). Material No: 1000403754800 Made in: Canada Melted in: Canada

Sales Order: 1514677 Purchase Order: WLY-24734

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
797415	0.200	0.800	0.014	0.007	0.016	0.038	0.035	0.005	0.005	0.018	0.042	0.002	0.002	0.0002	0.0030	0.0002

CE: 0.35

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification
M201438379	4	057599 Psi	067269 Psi	35.0 %	ASTM A500-18 GRADE B&C

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
797415	STELCO	Nanticoke,ON	BOF	36.90%	19.80%	14.40%	100%	1000

Material Note:
Sales Or. Note:

Authorized by Quality Assurance: [signature]

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Steel Tube Institute OF NORTH AMERICA

Metals Service Center Institute

Page: 4 of 5

Atlas Tube Canada
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Atlas *Tube*
A DIVISION OF ZEKELMAN INDUSTRIES

REF.B/L: 80954217
Date: 06/01/2020
Customer: 192

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USA

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11310 West Little York
HOUSTON TX 77041
USA

Material: 12.0x8.0x625x48'0"0(2x1). Material No: 1200806254800 Made in: Canada
Melted in: Canada

Sales Order: 1521362 Purchase Order: WLY-24807

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
797462	0.190	0.790	0.012	0.008	0.015	0.034	0.048	0.005	0.004	0.017	0.037	0.002	0.002	0.0002	0.0030	0.0002

CE: 0.34

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification
M201439535	2	058567 Psi	071370 Psi	29.3 %	ASTM A500-18 GRADE B&C

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
797462	STELCO	Nanticoke,ON	BOF	36.90%	19.80%	14.40%	100%	1000

Material Note:
Sales Or. Note:

Authorized by Quality Assurance: [signature]

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Steel Tube Institute OF NORTH AMERICA

Metals Service Center Institute

Page: 5 of 5

Atlas Tube Corp. Chicago
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Atlas Tube
A DIVISION OF ZEKELMAN INDUSTRIES

REF.B/L: 80940403
Date: 03/10/2020
Customer: 192

MATERIAL TEST REPORT

Sold To
Triple S Steel Supply
PO Box 21119
HOUSTON TX 77026
USA

Shipped To
Intsel Steel Distributors
11310 West Little York
HOUSTON TX 77041
USA

Material: 8.0x4.0x500x40'0"0(3x1)PB **Material No:** 80040500

Sales Order: 1498356 **Purchase Order:** WLY-24524

Made in: USA
Melted in: USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
Y05692	0.200	0.770	0.010	0.007	0.014	0.045	0.020	0.004	0.006	0.010	0.040	0.001	0.001	0.0001	0.0050	0.0000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification
M800931466	3	065915 Psi	075380 Psi	33 %	ASTM A500-18 GRADE B&C

CE: 0.34

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
Y05692	USSTEEL	GARY,IN	BOF	36.90%	19.80%	14.40%	100%	500

Material Note:
Sales Or. Note:

Material: 4.0x3.0x375x40'0"0(4x3). **Material No:** 400303754000

Sales Order: 1492004 **Purchase Order:** WLY-24410

Made in: USA
Melted in: USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
D83893	0.210	0.760	0.019	0.010	0.018	0.050	0.030	0.003	0.004	0.010	0.050	0.002	0.001	0.0001	0.0040	0.0000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification
M800931772	3	061002 Psi	081030 Psi	32 %	ASTM A500-18 GRADE B&C

CE: 0.35

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
D83893	USSTEEL	GARY,IN	BOF	36.90%	19.80%	14.40%	100%	500

Material Note:
Sales Or. Note:

Authorized by Quality Assurance: Jason Richard

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Steel Tube Institute OF NORTH AMERICA

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Atlas *Tube*
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REF.B/L: 80940403
Date: 03/10/2020
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11310 West Little York
HOUSTON TX 77041
USA

Material: 4.0x3.0x375x40'0"0(4x3). **Material No:** 400303754000 **Made in:** USA
Sales Order: 1492004 **Purchase Order:** WLY-24410 **Melted in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
D83894	0.190	0.780	0.014	0.007	0.014	0.047	0.030	0.003	0.004	0.010	0.040	0.001	0.001	0.0001	0.0040	0.0000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M800931772	9	063360 Psi	077169 Psi	31 %	ASTM A500-18 GRADE B&C	CE: 0.33

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
D83894	USSTEEL	GARY,IN	BOF	36.90%	19.80%	14.40%	100%	500

Material Note:
Sales Or. Note:

Material: 7.0x5.0x500x40'0"0(3x1). **Material No:** 700505004000 **Made in:** USA
Sales Order: 1485177 **Purchase Order:** WLY-24291 **Melted in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
Y05253	0.190	0.800	0.013	0.008	0.018	0.044	0.020	0.004	0.003	0.010	0.050	0.001	0.001	0.0000	0.0060	0.0000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M800931582	3	066337 Psi	079066 Psi	36 %	ASTM A500-18 GRADE B&C	CE: 0.34

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
Y05253	USSTEEL	GARY,IN	BOF	36.90%	19.80%	14.40%	100%	500

Material Note:
Sales Or. Note:

Authorized by Quality Assurance: [signature]

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Steel Tube Institute OF NORTH AMERICA

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Atlas *Tube*
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REF.B/L: 80940403
Date: 03/10/2020
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11310 West Little York
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USA

Material: 7.0x5.0x500x40'0"0(3x1). **Material No:** 700505004000 **Made in:** USA

Sales Order: 1485177 **Purchase Order:** WLY-24291 **Melted in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
Y05253	0.190	0.800	0.013	0.008	0.018	0.044	0.020	0.004	0.003	0.010	0.050	0.001	0.001	0.0000	0.0060	0.0000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M800931583	3	066337 Psi	079066 Psi	36 %	ASTM A500-18 GRADE B&C	CE: 0.34

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
Y05253	USSTEEL	GARY,IN	BOF	36.90%	19.80%	14.40%	100%	500

Material Note:
Sales Or. Note:

Material: 8.0x8.0x500x48'0"0(2x2). **Material No:** 800805004800 **Made in:** USA

Sales Order: 1498356 **Purchase Order:** WLY-24524 **Melted in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
M87505	0.180	0.780	0.010	0.005	0.010	0.042	0.030	0.003	0.005	0.010	0.030	0.001	0.001	0.0001	0.0050	0.0000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M901119365	2	060302 Psi	071291 Psi	34 %	ASTM A500-18 GRADE B&C	CE: 0.32

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
M87505	USSTEEL	GARY,IN	BOF	36.90%	19.80%	14.40%	100%	500

Material Note:
Sales Or. Note:

Authorized by Quality Assurance: [signature]

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Shipped To
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USA

Material: 8.0x8.0x500x48'0"0(2x2). **Material No:** 800805004800 **Made in:** USA
Sales Order: 1498356 **Purchase Order:** WLY-24524 **Melted in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
Y05507	0.200	0.790	0.009	0.008	0.004	0.050	0.020	0.004	0.005	0.010	0.040	0.002	0.001	0.0001	0.0040	0.0000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M901119365	2	059317 Psi	071270 Psi	38 %	ASTM A500-18 GRADE B&C	CE: 0.34

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
Y05507	USSTEEL	GARY,IN	BOF	36.90%	19.80%	14.40%	100%	500

Material Note:
Sales Or. Note:

Material: 8.0x8.0x500x48'0"0(2x2). **Material No:** 800805004800 **Made in:** USA
Sales Order: 1498356 **Purchase Order:** WLY-24524 **Melted in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
D83797	0.190	0.780	0.007	0.006	0.012	0.049	0.030	0.004	0.005	0.010	0.030	0.001	0.001	0.0001	0.0060	0.0000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M901114557	2	056430 Psi	078625 Psi	34 %	ASTM A500-18 GRADE B&C	CE: 0.33

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
D83797	USSTEEL	GARY,IN	BOF	36.90%	19.80%	14.40%	100%	500

Material Note:
Sales Or. Note:

Authorized by Quality Assurance: Jason Richard

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USA

Material: 8.0x8.0x500x48'0"0(2x2). **Material No:** 800805004800 **Made in:** USA
Sales Order: 1498356 **Purchase Order:** WLY-24524 **Melted in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
T01125	0.180	0.770	0.006	0.008	0.012	0.056	0.030	0.004	0.005	0.010	0.040	0.001	0.001	0.0001	0.0050	0.0000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M901114557	2	065336 Psi	077781 Psi	36 %	ASTM A500-18 GRADE B&C	CE: 0.32

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
T01125	USSTEEL	GARY,IN	BOF	36.90%	19.80%	14.40%	100%	500

Material Note:
Sales Or. Note:

Material: 12.0x12.0x250x40'0"0(2x2). **Material No:** 1201202504000 **Made in:** USA
Sales Order: 1494355 **Purchase Order:** WLY-24454 **Melted in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
C93111	0.200	0.830	0.013	0.004	0.030	0.030	0.170	0.003	0.020	0.050	0.070	0.003	0.002	0.0003	0.0060	0.0017

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M901118368	4	057441 Psi	075486 Psi	28 %	ASTM A500-18 GRADE B&C	CE: 0.38

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
C93111	GALLATIN	Ghent,KY	EAF	60.60%	21.70%	39.00%	100%	500

Material Note:
Sales Or. Note:

Authorized by Quality Assurance: *Jason Richard*

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Steel Tube Institute OF NORTH AMERICA

Metals Service Center Institute

Page: 5 of 5

Atlas Tube Corp. Chicago
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Atlas *Tube*
A DIVISION OF ZEKELMAN INDUSTRIES

REF.B/L: 80934498
Date: 02/10/2020
Customer: 192

MATERIAL TEST REPORT

Sold To
Triple S Steel Supply
PO Box 21119
HOUSTON TX 77026
USA

Shipped To
Intsel Steel Distributors
11310 West Little York
HOUSTON TX 77041
USA

Material: 5.0x2.0x250x48'0"0(4x3). **Material No:** 50020250 **Made in:** USA
Sales Order: 1472390 **Purchase Order:** WLY-24050 **Melted in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
M87395	0.200	0.800	0.009	0.007	0.012	0.045	0.020	0.004	0.008	0.010	0.030	0.001	0.001	0.0001	0.0050	0.0000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M800923834	12	057589 Psi	076143 Psi	28 %	ASTM A500-18 GRADE B&C	CE: 0.35

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
M87395	USSTEEL	GARY,IN	BOF	36.90%	19.80%	14.40%	100%	500

Material Note:
Sales Or. Note:

Material: 5.0x3.0x375x40'0"0(1x8)PB **Material No:** 50030375 **Made in:** USA
Sales Order: 1485177 **Purchase Order:** WLY-24291 **Melted in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
E84426	0.200	0.780	0.010	0.007	0.008	0.039	0.030	0.005	0.008	0.010	0.030	0.001	0.001	0.0001	0.0060	0.0000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M800913733	2	069108 Psi	081026 Psi	29 %	ASTM A500-18 GRADE B&C	CE: 0.34

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
E84426	USSTEEL	GARY,IN	BOF	36.90%	19.80%	14.40%	100%	500

Material Note:
Sales Or. Note:

Authorized by Quality Assurance: Jason Richard

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Steel Tube Institute OF NORTH AMERICA

Metals Service Center Institute

Atlas Tube Corp. Chicago
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Atlas Tube
A DIVISION OF ZEKELMAN INDUSTRIES

REF.B/L: 80934498
Date: 02/10/2020
Customer: 192

MATERIAL TEST REPORT

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PO Box 21119
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USA

Shipped To
Intsel Steel Distributors
11310 West Little York
HOUSTON TX 77041
USA

Material: 5.0x3.0x375x40'0"0(1x8)PB | **Material No:** 50030375 | **Made in:** USA
Sales Order: 1485177 | **Purchase Order:** WLY-24291 | **Melted in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
M87383	0.180	0.750	0.010	0.006	0.008	0.048	0.020	0.006	0.003	0.010	0.030	0.001	0.001	0.0001	0.0040	0.0000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	
M800913733	6	068651 Psi	080685 Psi	29 %	ASTM A500-18 GRADE B&C	CE: 0.32

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
M87383	USSTEEL	GARY,IN	BOF	36.90%	19.80%	14.40%	100%	500

Material Note:
Sales Or. Note:

Material: 12.0x6.0x313x48'0"0(2x2). | **Material No:** 1200603134800 | **Made in:** USA
Sales Order: 1472390 | **Purchase Order:** WLY-24050 | **Melted in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
W86982	0.200	0.770	0.008	0.008	0.013	0.052	0.010	0.005	0.005	0.010	0.030	0.001	0.001	0.0001	0.0040	0.0000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	
M901114292	4	060722 Psi	077505 Psi	29 %	ASTM A500-18 GRADE B&C	CE: 0.34

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
W86982	USSTEEL	GARY,IN	BOF	36.90%	19.80%	14.40%	100%	500

Material Note:
Sales Or. Note:

Authorized by Quality Assurance: Jason Richard

The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements.
CE calculated using the AWS D1.1 method.

Steel Tube Institute OF NORTH AMERICA

Metals Service Center Institute

Atlas Tube Corp. Chicago
1855 East 122nd Street
Chicago Illinois USA
60633
Tel: 773-646-4500
Fax: 773-646-6128

Atlas Tube
A DIVISION OF ZEKELMAN INDUSTRIES

REF.B/L: 80934498
Date: 02/10/2020
Customer: 192

MATERIAL TEST REPORT

Sold To
Triple S Steel Supply
PO Box 21119
HOUSTON TX 77026
USA

Shipped To
Intsel Steel Distributors
11310 West Little York
HOUSTON TX 77041
USA

Material: 12.0x6.0x375x40'0"0(2x2). **Material No:** 1200603754000 **Made in:** USA
Sales Order: 1485177 **Purchase Order:** WLY-24291 **Melted in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
D00023	0.200	0.800	0.013	0.011	0.020	0.042	0.050	0.001	0.008	0.020	0.080	0.001	0.001	0.0000	0.0000	0.0010

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M901114268	4	059674 Psi	072705 Psi	32 %	ASTM A500-18 GRADE B&C	CE: 0.36

Material Note:
Sales Or. Note:

Material: 14.0x4.0x500x40'0"0(1x4). **Material No:** 1400405004000 **Made in:** USA
Sales Order: 1485177 **Purchase Order:** WLY-24291 **Melted in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
T01126	0.190	0.770	0.009	0.008	0.022	0.050	0.030	0.005	0.006	0.010	0.040	0.001	0.001	0.0001	0.0040	0.0000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M901114122	4	061481 Psi	074158 Psi	33 %	ASTM A500-18 GRADE B&C	CE: 0.33

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
T01126	USSTEEL	GARY,IN	BOF	36.90%	19.80%	14.40%	100%	500

Material Note:
Sales Or. Note:

Authorized by Quality Assurance: Jason Richard

The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements.
CE calculated using the AWS D1.1 method.

Steel Tube Institute OF NORTH AMERICA

Metals Service Center Institute

Page: 3 of 4

Atlas Tube Corp. Chicago
1855 East 122nd Street
Chicago Illinois USA
60633
Tel: 773-646-4500
Fax: 773-646-6128

Atlas *Tube*
A DIVISION OF ZEKELMAN INDUSTRIES

REF.B/L: 80934498
Date: 02/10/2020
Customer: 192

MATERIAL TEST REPORT

Sold To
Triple S Steel Supply
PO Box 21119
HOUSTON TX 77026
USA

Shipped To
Intsel Steel Distributors
11310 West Little York
HOUSTON TX 77041
USA

Material: 14.0x6.0x375x48'0"0(1x3). **Material No:** 1400603754800 **Made in:** USA
Sales Order: 1487345 **Purchase Order:** WLY-24338 **Melted in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
D83794	0.200	0.760	0.011	0.010	0.009	0.047	0.020	0.003	0.008	0.010	0.040	0.001	0.001	0.0001	0.0060	0.0000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	
M901113006	3	062369 Psi	076088 Psi	33 %	ASTM A500-18 GRADE B&C	CE: 0.34

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
D83794	USSTEEL	GARY,IN	BOF	36.90%	19.80%	14.40%	100%	500

Material Note:
Sales Or. Note:

Material: 16.0x8.0x313x40'0"0(1x3). **Material No:** 1600803134000 **Made in:** USA
Sales Order: 1487345 **Purchase Order:** WLY-24338 **Melted in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
D83392	0.160	0.460	0.015	0.013	0.008	0.051	0.030	0.004	0.007	0.020	0.060	0.002	0.001	0.0001	0.0070	0.0000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	
M901107193	3	061671 Psi	074921 Psi	30 %	ASTM A500-18 GRADE B&C	CE: 0.26

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
D83392	USSTEEL	GARY,IN	BOF	36.90%	19.80%	14.40%	100%	500

Material Note:
Sales Or. Note:

Authorized by Quality Assurance: Jason Richard

The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements.
CE calculated using the AWS D1.1 method.

Steel Tube Institute OF NORTH AMERICA

Metals Service Center Institute

Page: 4 of 4

GERDAU

US-ML-CARTERSVILLE
384 OLD GRASSDALE ROAD NE
CARTERSVILLE, GA 30121
USA

CERTIFIED MATERIAL TEST REPORT

Page 1/1

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE		DOCUMENT ID:
INTSEL STEEL DISTRIBUTORS LP 11310 W LITTLE YORK RD HOUSTON,TX 77041-4917 USA	INTSEL STEEL DISTRIBUTORS LP HOUSTON,TX 77226-1119 USA	GGMULTI	Angle / 6X4X1/2		0000245874
		LENGTH 40'00"	WEIGHT 19,440 LB	HEAT / BATCH 55061469/02	
SALES ORDER 7833203/000010	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION ASTM A529-14, A572-15 ASTM A6-17,A36-14, ASME SA-36 ASTM A709-17, AASHTO M270-15 CSA G40.20-13/G40.21-13			

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
WLY-23175	1323-0000135212	06/03/2019

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	V %	Nb %	N %	Pb %
0.15	1.00	0.015	0.021	0.20	0.32	0.11	0.11	0.025	0.001	0.009	0.0100	0.0040

CHEMICAL COMPOSITION

Sn %
0.011

MECHANICAL PROPERTIES

Elong. %	G/L Inch	UTS PSI	UTS MPa	YS 0.2% PSI	YS MPa
26.20	8.000	77800	536	53400	368
25.40	8.000	78000	538	53700	370

COMMENTS / NOTES

This grade meets the requirements for the following grades:
ASTM Grades: A36; A529-50; A572-50; A709-36; A709-50
CSA Grades: 44W; 50W
AASHTO Grades: M270-36; M270-50
ASME Grades: SA36

The above figures are certified chemical and physical test records as contained in the permanent records of company. We certify that these data are correct and in compliance with specified requirements. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 267-1071 Email: Bhaskar.Yalamanchili@gerdau.com

YAN WANG
QUALITY ASSURANCE MGR.
Phone: (770) 387 5718 Email: yan.wang@gerdau.com

Heat#: A96500* Tag: C03071520 ... Line#: 1 PO#: PO-00404 Part: T1000403748* Qty: 2

NUCOR
TUBULAR PRODUCTS

6226 W. 74TH STREET
CHICAGO, IL 60638
Tel: 708-496-0380
Fax: 708-563-1950

https://www.nucortubular.com
https://www.ntpportal.com
Certificate Number: MAR 341996

SSW 7/22/2020 MTRs AG 119611

Sold By:
NUCOR TUBULAR PRODUCTS INC.
MARSEILLES DIVISION
1201 E. BROADWAY
MARSEILLES, IL 61341
Tel: 815 795-4400
Fax: 815 795-4449

Purchase Order No: SSW112611
Sales Order No: MAR 394124 - 1
Bill of Lading No: MAR 232863 - 4
Invoice No:

Shipped: 5/29/2020
Invoiced:

Sold To:
2734 - SERVICE STEEL WAREHOUSE CO., L.P.
PO BOX 9607
HOUSTON, TX 77213

Ship To:
1 - SERVICE STEEL WAREHOUSE CO.
8415 CLINTON DRIVE
HOUSTON, TX 77029

CERTIFICATE of ANALYSIS and TESTS

Customer Part No:

Certificate No: MAR 341996
Test Date: 5/27/2020

TUBING A500 GRADE B(C)
10" X 4" X 3/8" X 48'

* DOMESTIC STEEL M&M *

Total Pieces	Total Weight Lbs
12	18,766

Bundle Tag	Mill	Heat	Specs	Y/T Ratio	Pieces	Weight Lbs
400062	13N	A96500	YLD=52500/TEN=67580/ELG=34.8	0.7769	6	9,383
400063	13N	A96500	YLD=52500/TEN=67580/ELG=34.8	0.7769	6	9,383

Mill #: 13N Heat #: A96500 Carbon Eq: 0.1534 Heat Src Origin: MELTED AND MANUFACTURED IN THE USA

C	Mn	P	S	Si	Al	Cu	Cr	Mo	V	Ni	Nb	Sn
0.0600	0.4100	0.0080	0.0030	0.0200	0.0440	0.1100	0.0500	0.0200	0.0020	0.0500	0.0120	0.0040

N	B	Ti	Ca
0.0061	0.0001	0.0010	0.0019

LEED Information (based on the most recent LEED information from the producing mill)

Method	Location	Recycled Content	Post Consumer	Post Industrial
EAF	Ghent, KY	66.9%	28.2%	38.8%

Certification:

I certify that the above results are a true and correct copy of records prepared and maintained by NUCOR TUBULAR PRODUCTS INC. Sworn this day, 5/27/2020.

THE SPECIFICATIONS LISTED BELOW REPRESENT THE CURRENT ISSUED DATES OF THESE STANDARDS. THIS DOES NOT INDICATE THAT THE MATERIAL ABOVE CONFORMS TO EACH OR ALL OF THE STANDARDS. WE CERTIFY THE MATERIAL ABOVE TO THE SPECIFICATION LISTED IN THE LINE DESCRIPTION.

Chris Allen

Chris Allen, ASQ CMQ/OE
Quality Systems Supervisor

CURRENT STANDARDS:
A252-19
A500/A500M-18
A513/A513M-19
ASTM A53/A53M-18| ASME SA-53/SA-53M-18
A847/A847M-14
A1085/A1085M-15
IN COMPLIANCE WITH EN 10204 SECTION 4.1
INSPECTION CERTIFICATE TYPE 3.1

CMC STEEL TEXAS
1 STEEL MILL DRIVE
SEGUIN TX 78155-7510

CERTIFIED MILL TEST REPORT

For additional copies call
830-372-8771

We hereby certify that the test results presented here
are accurate and conform to the reported grade specification

Rolando A Davila
Quality Assurance Manager

HEAT NO.:3099966 SECTION: REBAR 10MM (#3) 20'0" 300/40 GRADE: ASTM A615-20 Grade 300/40 ROLL DATE: 09/25/2020 MELT DATE: 09/13/2020 Cert. No.: 83224860 / 099966A357	SOLD TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	SHIP TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	Delivery#: 83224860 BOL#: 73793087 CUST PO#: 862925 CUST P/N: DLVRY LBS / HEAT: 2106.000 LB DLVRY PCS / HEAT: 280 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.10%				
Mn	0.74%				
P	0.012%				
S	0.048%				
Si	0.19%				
Cu	0.31%				
Cr	0.10%				
Ni	0.12%				
Mo	0.059%				
V	0.000%				
Cb	0.000%				
Sn	0.013%				
Al	0.000%				
Yield Strength test 1	47.8ksi				
Tensile Strength test 1	66.1ksi				
Elongation test 1	26%				
Elongation Gage Lgth test 1	8IN				
Bend Test 1	Passed				
Bend Test Diameter	1.313IN				

The Following is true of the material represented by this MTR:

**Material is fully killed*
**100% melted and rolled in the USA*
**EN10204:2004 3.1 compliant*
**Contains no weld repair*
**Contains no Mercury contamination*
**Manufactured in accordance with the latest version of the plant quality manual*
**Meets the "Buy America" requirements of 23 CFR635.410, 49 CFR 661*
**Warning: This product can expose you to chemicals which are known to the State of California to cause cancer, birth defects or other reproductive harm. For more information go to www.P65Warnings.ca.gov*

REMARKS :

CMC STEEL TEXAS
1 STEEL MILL DRIVE
SEGUIN TX 78155-7510

CERTIFIED MILL TEST REPORT

For additional copies call
830-372-8771

We hereby certify that the test results presented here are accurate and conform to the reported grade specification

Rolando A Davila
Quality Assurance Manager

HEAT NO.:3099959 SECTION: REBAR 13MM (#4) 20'0" 300/40 GRADE: ASTM A615-20 Grade 300/40 ROLL DATE: 09/17/2020 MELT DATE: 09/13/2020 Cert. No.: 83224860 / 099959A293	SOLD TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	SHIP TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	Delivery#: 83224860 BOL#: 73793087 CUST PO#: 862925 CUST P/N: DLVRY LBS / HEAT: 2191.000 LB DLVRY PCS / HEAT: 164 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.11%				
Mn	0.81%				
P	0.013%				
S	0.048%				
Si	0.17%				
Cu	0.30%				
Cr	0.14%				
Ni	0.13%				
Mo	0.058%				
V	0.000%				
Cb	0.001%				
Sn	0.012%				
Al	0.000%				
Yield Strength test 1	47.0ksi				
Tensile Strength test 1	64.4ksi				
Elongation test 1	26%				
Elongation Gage Lgth test 1	8IN				
Bend Test 1	Passed				
Bend Test Diameter	1.750IN				

The Following is true of the material represented by this MTR:

**Material is fully killed*
**100% melted and rolled in the USA*
**EN10204:2004 3.1 compliant*
**Contains no weld repair*
**Contains no Mercury contamination*
**Manufactured in accordance with the latest version of the plant quality manual*
**Meets the "Buy America" requirements of 23 CFR635.410, 49 CFR 661*
**Warning: This product can expose you to chemicals which are known to the State of California to cause cancer, birth defects or other reproductive harm. For more information go to www.P65Warnings.ca.gov*

REMARKS :

Page 1 OF 1 09/25/2020 16:24:57

CMC STEEL TEXAS
1 STEEL MILL DRIVE
SEGUIN TX 78155-7510

CERTIFIED MILL TEST REPORT

For additional copies call
830-372-8771

We hereby certify that the test results presented here are accurate and conform to the reported grade specification

Rolando A Davila
Quality Assurance Manager

HEAT NO.:3099508 SECTION: REBAR 16MM (#5) 20'0" 300/40 GRADE: ASTM A615-20 Grade 300/40 ROLL DATE: 08/28/2020 MELT DATE: 08/25/2020 Cert. No.: 83224860 / 099508A138	SOLD TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	SHIP TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	Delivery#: 83224860 BOL#: 73793087 CUST PO#: 862925 CUST P/N: DLVRY LBS / HEAT: 4380.000 LB DLVRY PCS / HEAT: 210 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.20%				
Mn	0.75%				
P	0.010%				
S	0.049%				
Si	0.18%				
Cu	0.33%				
Cr	0.11%				
Ni	0.11%				
Mo	0.043%				
V	0.000%				
Cb	0.001%				
Sn	0.014%				
Al	0.001%				
Yield Strength test 1	48.6ksi				
Tensile Strength test 1	71.6ksi				
Elongation test 1	24%				
Elongation Gage Lgth test 1	8IN				
Bend Test 1	Passed				
Bend Test Diameter	2.188IN				

The Following is true of the material represented by this MTR:

- *Material is fully killed*
- *100% melted and rolled in the USA*
- *EN10204:2004 3.1 compliant*
- *Contains no weld repair*
- *Contains no Mercury contamination*
- *Manufactured in accordance with the latest version of the plant quality manual*
- *Meets the "Buy America" requirements of 23 CFR635.410, 49 CFR 661*
- *Warning: This product can expose you to chemicals which are known to the State of California to cause cancer, birth defects or other reproductive harm. For more information go to www.P65Warnings.ca.gov*

REMARKS :

Page 1 OF 1 09/25/2020 16:24:57

Project No: 606861-03 **Casting Date:** 10/30/2020 **Mix Design (psi):** 3000 psi

Name of Technician Taking Sample: Terracon
Name of Technician Breaking Sample: Terracon

Signature of Technician Taking Sample: Terracon
Signature of Technician Breaking Sample: Terracon

Load No.	Truck No.	Ticket No.	Location (from concrete map)
T1	Tucker	1027	South half of wall and deck
T2	Tucker	1357	Northern Half of Wall and deck

Load No.	Break Date	Cylinder Age	Total Load (lbs)	Break (psi)	Average
See attached Reports from Terracon					

TUCKER CONCRETE
8930 LACY WELL RD CS
979-777-6749 VM1802

Job # TUCKER
LA DOT TTI
TICKET # 1027
START DATE: 10/30/2020 TIME: 08:56:02
STOP DATE: 10/30/2020 TIME: 09:17:14

MIX DESIGN B1350
RAW CEMENT COUNTS____________ 5949
RAW CONVEYOR COUNTS__________ 4419

TOTAL YARDS 10.05

MATERIAL	RATE SETTING	TOTAL
CAPTYPE[illegible]	4[illegible]7.4LBPM__	4725.8LBS
LRMSAND	[illegible].5 GATE_	13949.7LBS
RGBLEND	[illegible]7.8 GATE_	19266.2LBS
WATER	21.1GPM__	262.7GAL
SIKA686	__ 1.2GPM__	12.1GAL
NC4	__ 0.8GPM__	8.0OZ

NAME______________________________
NOTES:

TUCKER_concrete
9797776749
1904
TUCKER_CONST
LA_DOT_TTI

TICKET # 1357

START DATE: 2020-10-30 TIME: 10:20:38
STOP DATE: 2020-10-30 TIME: 10:34:59

MIX DESIGN: B1350

RAW CEMENT COUNTS: 3736
RAW CONVEYOR COUNTS: 127042
CONVEYOR SPEED: 45
TOTAL YARDS 6.75

MATERIAL	RATE SETTING	TOTAL
CEMENT	8.45924LBS/	3081.079
SAND	5.781536 GA	9100.307
ADJUSTED:		
STONE	7.619714 GA	12568.65
ADJUSTED:		
WATER	27.59709GAL	168.0812
ADMIX #1	0.0OZ/MIN	0.0OZ
ADMIX #2	167.385OZ/M	0.0OZ
ADMIX #3	0.0OZ/MIN	0.0OZ

ASTM DATA AVAILABLE UPON REQ

Name ____________________
NOTES:

LADOTD

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0151
Service Date: 10/30/20
Report Date: 10/30/20
Task: 606861-3 (LADOT)

Terracon
6198 Imperial Loop
College Station, TX 77845-5765
979-846-3767 Reg No: F-3272

Client

Texas Transportation Institute
Attn: Gary Gerke
TTI Business Office
3135 TAMU
College Station, TX 77843-3135

Project

Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1171057

Material Information

Specified Strength: 3,000 psi @ 28 days

Mix ID: B1350
Supplier: Tucker
Batch Time: 1000 **Plant:**
Truck No.: **Ticket No.:** 1027

Sample Information

Sample Date: 10/30/20 **Sample Time:** 1008
Sampled By: Cullen Turney
Weather Conditions: Clear, no wind
Accumulative Yards: 10/20 **Batch Size (cy):** 10
Placement Method: Direct Discharge
Water Added Before (gal): 0
Water Added After (gal): 0
Sample Location: South east end
Placement Location: 606861-3(LADOT)

Field Test Data

Test	Result	Specification
Slump (in):	7 1/2	Max 8
Air Content (%):	1.8	
Concrete Temp. (F):	68	40 - 95
Ambient Temp. (F):	55	40 - 95
Plastic Unit Wt. (pcf):	146.2	Not Specified
Yield (Cu. Yds.):		

Laboratory Test Data

Set No.	Specimen ID	Avg Diam. (in)	Area (sq in)	Date Received	Date Tested	Age at Test (days)	Maximum Load (lbs)	Compressive Strength (psi)	Fracture Type	Tested By
1	A	6.00	28.27		12/10/20	41 F	132,160	4,670	1	SLS
1	B	6.00	28.27		12/10/20	41 F	128,080	4,530	2	SLS
1	C	6.00	28.27		12/10/20	41 F	124,660	4,410	1	SLS
1	D					Hold				

Initial Cure: Outside **Final Cure:** Field Cured
Comments: **F = Field Cured**

Samples Made By: Terracon
Services: Obtain samples of fresh concrete at the placement locations (ASTM C 172), perform required field tests and cast, cure, and test compressive strength samples (ASTM C 31, C 39, C 1231).
Terracon Rep.: Cullen Turney **Start/Stop:** 0815-1400
Reported To:
Contractor:
Report Distribution:
(1) Texas Transportation Institute, Gary Gerke (1) Terracon Consultants, Inc., Alex Dunigan, P.E.
(1) Texas Transportation Institute, Bill Griffith

Test Methods: ASTM C 31, ASTM C143, ASTM C231, ASTM C1064

The tests were performed in general accordance with applicable ASTM, AASHTO, or DOT test methods. This report is exclusively for the use of the client indicated above and shall not be reproduced except in full without the written consent of our company. Test results transmitted herein are only applicable to the actual samples tested at the location(s) referenced and are not necessarily indicative of the properties of other apparently similar or identical materials.

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0151
Service Date: 10/30/20
Report Date: 10/30/20
Task: 606861-3 (LADOT)

Terracon
6198 Imperial Loop
College Station, TX 77845-5765
979-846-3767 Reg No: F-3272

Client

Texas Transportation Institute
Attn: Gary Gerke
TTI Business Office
3135 TAMU
College Station, TX 77843-3135

Project

Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1171057

Material Information

Specified Strength: 3,000 psi @ 28 days

Mix ID: B1350
Supplier: Tucker
Batch Time: 1030 **Plant:**
Truck No.: **Ticket No.:** 1357

Sample Information

Sample Date: 10/30/20 **Sample Time:** 1035
Sampled By: Cullen Turney
Weather Conditions: Clear, no wind
Accumulative Yards: 20/20 **Batch Size (cy):** 10
Placement Method: Direct Discharge
Water Added Before (gal): 0
Water Added After (gal): 0
Sample Location: North west end
Placement Location: 606861-3(LADOT

Field Test Data

Test	Result	Specification
Slump (in):	7 1/4	Max 8
Air Content (%):	1.9	
Concrete Temp. (F):	68	40 - 95
Ambient Temp. (F):	57	40 - 95
Plastic Unit Wt. (pcf):	146.4	Not Specified
Yield (Cu. Yds.):		

Laboratory Test Data

Set No.	Specimen ID	Avg Diam. (in)	Area (sq in)	Date Received	Date Tested	Age at Test (days)	Maximum Load (lbs)	Compressive Strength (psi)	Fracture Type	Tested By
2	A	6.00	28.27		12/10/20	41 F	124,320	4,400	1	SLS
2	B	6.00	28.27		12/10/20	41 F	121,970	4,310	1	SLS
2	C	6.00	28.27		12/10/20	41 F	123,700	4,370	1	SLS
2	D					Hold				

Initial Cure: Outside **Final Cure:** See Comments

Comments: **F = Field Cured**

Samples Made By: Terracon
Services: Obtain samples of fresh concrete at the placement locations (ASTM C 172), perform required field tests and cast, cure, and test compressive strength samples (ASTM C 31, C 39, C 1231).
Terracon Rep.: Cullen Turney **Start/Stop:** 0815-1400
Reported To:
Contractor:
Report Distribution:
(1) Texas Transportation Institute, Gary Gerke (1) Terracon Consultants, Inc., Alex Dunigan, P.E.
(1) Texas Transportation Institute, Bill Griffith

Reviewed By:
Alexander Dunigan
Project Manager

Test Methods: ASTM C 31, ASTM C143, ASTM C231, ASTM C1064

Project No: 606861-03 **Casting Date:** 11/5/2020 **Mix Design (psi):** 3000 psi

Name of Technician Taking Sample: Terracon

Name of Technician Breaking Sample: Terracon

Signature of Technician Taking Sample: Terracon

Signature of Technician Breaking Sample: Terracon

Load No.	Truck No.	Ticket No.	Location (from concrete map)
T1	Tucker	292	100% of Curb

Load No.	Break Date	Cylinder Age	Total Load (lbs)	Break (psi)	Average
See attached Reports from Terracon					

TUCKER_concrete
979-777-6749
TRUCK_#4
TUCKER_CONSTRUCTION
TTI_LA_DOT

TICKET # 292

START DATE: 2020-11-05 TIME: 08:59:55
STOP DATE: 2020-11-05 TIME: 09:25:51

MIX DESIGN: B1350

RAW CEMENT COUNTS: 4751
RAW CONVEYOR COUNTS: 161573
CONVEYOR SPEED: 50
TOTAL YARDS 8.286

MATERIAL	RATE SETTING	TOTAL
CEMENT	9.343309LBS	3894.87L
SAND	6.013903 GA	11505.07
ADJUSTED:		
STONE	7.916514 GA	15889.93
ADJUSTED:		
WATER	27.58288GAL	193.7082
ADMIX #1	0.0OZ/MIN	0.0OZ
ADMIX #2	0.0OZ/MIN	0.0OZ
ADMIX #3	0.0OZ/MIN	0.0OZ

TOTAL SAND MOISTURE: 0.0
TOTAL STONE MOISTURE: 0.0

Name____________________________________
NOTES:

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0154
Service Date: 11/05/20
Report Date: 11/06/20
Task: 606861-3 (LADOT)

Terracon
6198 Imperial Loop
College Station, TX 77845-5765
979-846-3767 Reg No: F-3272

Client

Texas Transportation Institute
Attn: Gary Gerke
TTI Business Office
3135 TAMU
College Station, TX 77843-3135

Project

Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1171057

Material Information

Specified Strength: 3,000 psi @ 28 days

Mix ID: B1350
Supplier: Tucker Concrete
Batch Time: 0800 **Plant:**
Truck No.: 4 **Ticket No.:** 292

Sample Information

Sample Date: 11/05/20 **Sample Time:** 0820
Sampled By: Matcek, James
Weather Conditions: Partly cloudy
Accumulative Yards: 8.28 **Batch Size (cy):** 8.28
Placement Method: Direct Discharge
Water Added Before (gal): 0
Water Added After (gal): 0
Sample Location: 20' West of Southeast end
Placement Location: Curb

Field Test Data

Test	Result	Specification
Slump (in):	4 3/4	
Air Content (%):	1.2	
Concrete Temp. (F):	74	
Ambient Temp. (F):	63	
Plastic Unit Wt. (pcf):	147.2	
Yield (Cu. Yds.):		

Laboratory Test Data

Set No.	Specimen ID	Avg Diam. (in)	Area (sq in)	Date Received	Date Tested	Age at Test (days)	Maximum Load (lbs)	Compressive Strength (psi)	Fracture Type	Tested By
1	A	6.00	28.27	11/06/20	12/10/20	35 F	133,780	4,730	1	SLS
1	B	6.00	28.27	11/06/20	12/10/20	35 F	125,810	4,450	1	SLS
1	C	6.00	28.27	11/06/20	12/10/20	35 F	127,600	4,510	1	SLS
1	D			11/06/20		Hold				

Initial Cure: Outside **Final Cure:** Field Cured
Comments: **F = Field Cured**

Samples Made By: Terracon
Services: Obtain samples of fresh concrete at the placement locations (ASTM C 172), perform required field tests and cast, cure, and test compressive strength samples (ASTM C 31, C 39, C 1231).
Terracon Rep.: Matcek, James **Start/Stop:** 0715-0915
Reported To:
Contractor:
Report Distribution:
(1) Texas Transportation Institute, Gary Gerke (1) Terracon Consultants, Inc., Alex Dunigan, P.E.
(1) Texas Transportation Institute, Bill Griffith

Reviewed By: Alexander Dunigan
Project Manager

Test Methods: ASTM C 31, ASTM C143, ASTM C231, ASTM C1064

Project No: 606861-03 **Casting Date:** 11/19/2020 **Mix Design (psi):** 3000 psi

Name of Technician Taking Sample: Terracon

Name of Technician Breaking Sample: Terracon

Signature of Technician Taking Sample: Terracon

Signature of Technician Breaking Sample: Terracon

Load No.	Truck No.	Ticket No.	Location (from concrete map)
T1	Tucker	340	Parapet

Load No.	Break Date	Cylinder Age	Total Load (lbs)	Break (psi)	Average
See attached Reports from Terracon					

TUCKER_concrete
979-777-6749
TRUCK_#4
TUCKER_CONSTRUCTION
LA_DOT_TTI

TICKET # 340

START DATE: 2020-11-19 TIME: 07:57:42
STOP DATE: 2020-11-19 TIME: 08:41:15

MIX DESIGN: B1350

RAW CEMENT COUNTS: 2227
RAW CONVEYOR COUNTS: 83512
CONVEYOR SPEED: 50
TOTAL YARDS 3.884

MATERIAL	RATE SETTING	TOTAL
CEMENT	9.343309LBS	1825.695
SAND	6.013903 GA	5946.61L
ADJUSTED:		
STONE	7.916514 GA	8213.006
ADJUSTED:		
WATER	23.58288GAL	92.5162G
ADMIX #1	0.0OZ/MIN	0.0OZ
ADMIX #2	0.0OZ/MIN	0.0OZ
ADMIX #3	268.3716OZ/	909.8145

TOTAL SAND MOISTURE: 0.0
TOTAL STONE MOISTURE: 0.0

Name ________________________
NOTES:

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0155
Service Date: 11/19/20
Report Date: 11/19/20
Task: 606861-3 (LADOT)

Terracon
6198 Imperial Loop
College Station, TX 77845-5765
979-846-3767 Reg No: F-3272

Client

Texas Transportation Institute
Attn: Gary Gerke
TTI Business Office
3135 TAMU
College Station, TX 77843-3135

Project

Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1171057

Material Information

Specified Strength: 3,000 psi @ 28 days

Mix ID: B1350
Supplier: Tucker
Batch Time: 0700 **Plant:**
Truck No.: 4 **Ticket No.:** 340

Sample Information

Sample Date: 11/19/20 **Sample Time:** 0712
Sampled By: Cullen Turney
Weather Conditions: Cloudy, no wind
Accumulative Yards: 10/10 **Batch Size (cy):** 10
Placement Method: Direct Discharge
Water Added Before (gal): 0
Water Added After (gal): 0
Sample Location: 10' west of Southeast end
Placement Location: 606861-3 half wall

Field Test Data

Test	Result	Specification
Slump (in):	6 3/4	
Air Content (%):	2.5	
Concrete Temp. (F):	69	
Ambient Temp. (F):	54	
Plastic Unit Wt. (pcf):	145.8	
Yield (Cu. Yds.):		

Laboratory Test Data

Set No.	Specimen ID	Avg Diam. (in)	Area (sq in)	Date Received	Date Tested	Age at Test (days)	Maximum Load (lbs)	Compressive Strength (psi)	Fracture Type	Tested By
1	A	6.00	28.27	11/19/20	12/10/20	21 F	113,160	4,000	2	SLS
1	B	6.00	28.27	11/19/20	12/10/20	21 F	111,410	3,940	1	SLS
1	C	6.00	28.27	11/19/20	12/10/20	21 F	117,530	4,160	2	SLS
1	D			11/19/20		Hold				

Initial Cure: Outside **Final Cure:** Field Cured

Comments: **F = Field Cured**

Samples Made By: Terracon
Services: Obtain samples of fresh concrete at the placement locations (ASTM C 172), perform required field tests and cast, cure, and test compressive strength samples (ASTM C 31, C 39, C 1231).
Terracon Rep.: Cullen Turney **Start/Stop:** 0600-1000
Reported To:
Contractor:
Report Distribution:
(1) Texas Transportation Institute, Gary Gerke (1) Terracon Consultants, Inc., Alex Dunigan, P.E.
(1) Texas Transportation Institute, Bill Griffith

Reviewed By:
Alexander Dunigan
Project Manager

Test Methods: ASTM C 31, ASTM C143, ASTM C231, ASTM C1064

Appendix J. MASH Test 3-11 (Crash Test No. 606861-3)

Figure 127. Vehicle properties for Test No. 606861-3

Date: 2020-12-14 Test No.: 606861-3 VIN No.: 1C6RR6GT0ES287150

Year: 2014 Make: RAM Model:

Tire Size: 265/70 R 17 Tire Inflation Pressure: 35 psi

Tread Type: Highway Odometer: 118074

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

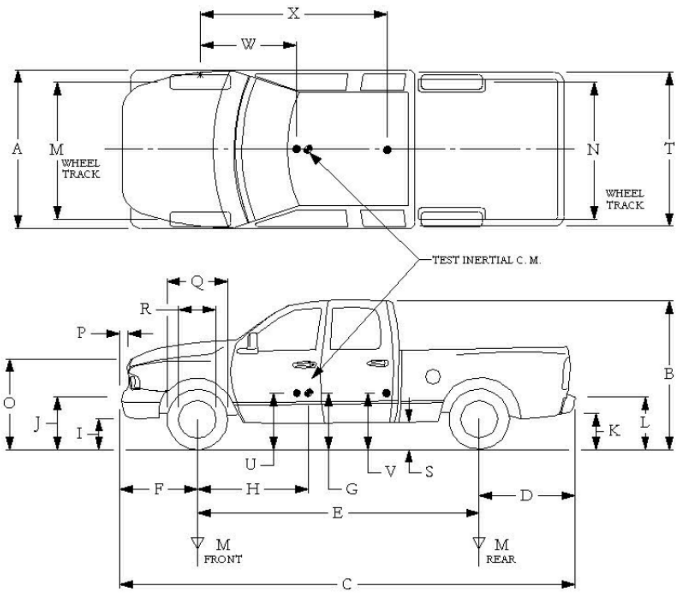
NOTES: None

Engine Type: V-8
Engine CID: 5.7L

Transmission Type:
☑ Auto or ☐ Manual
☐ FWD ☑ RWD ☐ 4WD

Optional Equipment:
None

Dummy Data:
Type: 50th percentile male
Mass: 165 lb
Seat Position: IMPACT SIDE



Geometry: inches

A	78.50	F	40.00	K	20.00	P	3.00	U	26.75
B	74.00	G	28.50	L	30.00	Q	30.50	V	30.25
C	227.50	H	61.46	M	68.50	R	18.00	W	61.40
D	44.00	I	11.75	N	68.00	S	13.00	X	79.00
E	140.50	J	27.00	O	46.00	T	77.00		

Wheel Center Height Front	14.75	Wheel Well Clearance (Front)	6.00	Bottom Frame Height - Front	12.50
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	9.25	Bottom Frame Height - Rear	22.50

RANGE LIMIT: A=78 ±2 inches; C=237 ±13 inches; E=148 ±12 inches; F=39 ±3 inches; G = > 28 inches; H = 63 ±4 inches; O=43 ±4 inches; (M+N)/2=67 ±1.5 inches

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2925	2844	2929
Back	3900	M_{rear}	2131	2212	2292
Total	6700	M_{Total}	5056	5056	5221

(Allowable Range for TIM and GSM = 5000 lb ±110 lb)

Mass Distribution:
lb LF: 1430 RF: 1414 LR: 1154 RR: 1058

Figure 128. Measurement of vehicle vertical CG for Test No. 606861-3

Date: 2020-12-14 Test No.: 606861-3 VIN: 1C6RR6GT0ES287150

Year: 2014 Make: RAM Model: 1500

Body Style: Quad Cab Mileage: 118074

Engine: 5.7L V-8 Transmission: Automatic

Fuel Level: Empty Ballast: 140 (440 lb max)

Tire Pressure: Front: 35 psi Rear: 35 psi Size: 265/70 R 17

Measured Vehicle Weights: (lb)							
LF:	1430		RF:	1414		Front Axle:	2844
LR:	1154		RR:	1058		Rear Axle:	2212
Left:	2584		Right:	2472		Total:	5056
							5000 ±110 lb allowed
Wheel Base:	140.50	inches	Track: F:	68.50	inches	R:	68.00 inches
	148 ±12 inches allowed			Track = (F+R)/2 = 67 ±1.5 inches allowed			

Center of Gravity, SAE J874 Suspension Method					
X:	61.47	inches	Rear of Front Axle		(63 ±4 inches allowed)
Y:	-0.76	inches	Left -	Right +	of Vehicle Centerline
Z:	28.5	inches	Above Ground		(minumum 28.0 inches allowed)

Hood Height: 46.00 inches
43 ±4 inches allowed

Front Bumper Height: 27.00 inches

Front Overhang: 40.00 inches
39 ±3 inches allowed

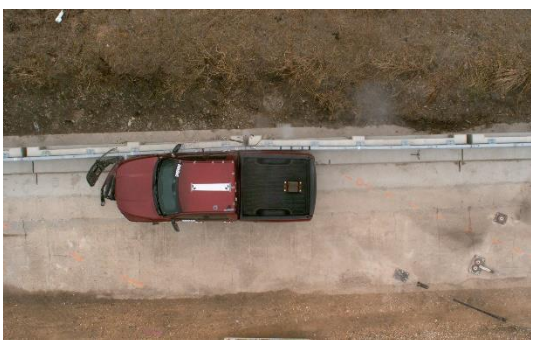
Rear Bumper Height: 30.00 inches

Overall Length: 227.50 inches
237 ±13 inches allowed

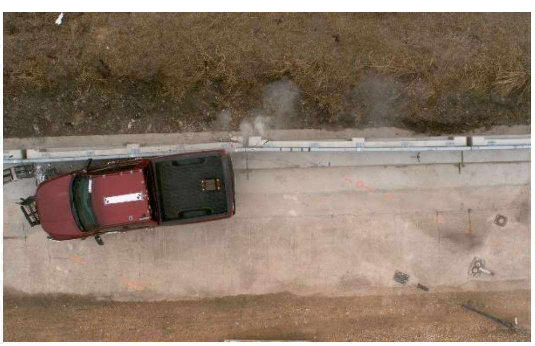
Figure 129. Sequential photographs for Test No. 606861-3 (overhead view).

0.000 s

0.100 s



0.200 s



0.300 s

0.400 s

0.500 s

0.600 s

0.700 s

Figure 130. Sequential photographs for Test No. 606861-3 (frontal view).

0.000 s

0.100 s

0.200 s

0.300 s

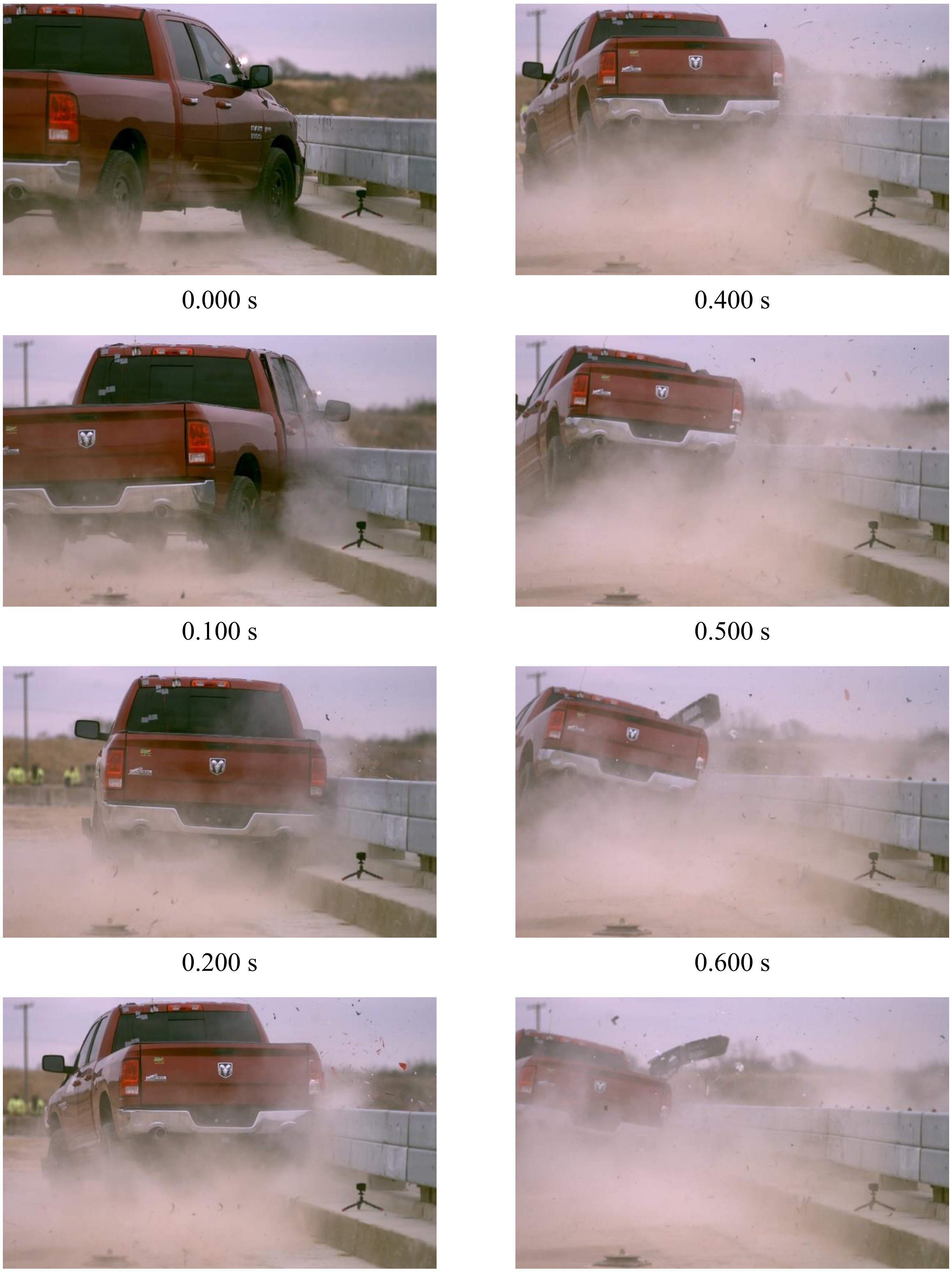
0.400 s

0.500 s

0.600 s

0.700 s

Figure 131. Sequential photographs for Test No. 606861-3 (rear view).



0.000 s

0.100 s

0.200 s

0.300 s

0.400 s

0.500 s

0.600 s

0.700 s

Figure 132. Exterior crush measurements for Test No. 606861-3

Date:	2020-12-14	Test No.:	606861-3	VIN No.:	1C6RR6GT0ES287150
Year:	2014	Make:	RAM	Model:	1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

<table>
<tr><td colspan="2">Complete When Applicable</td></tr>
<tr><td>End Damage</td><td>Side Damage</td></tr>
<tr><td>Undeformed end width ________
Corner shift: A1 ________
A2 ________
End shift at frame (CDC)
(check one)
< 4 inches ________
≥ 4 inches ________</td><td>Bowing: B1 _____ X1 _____
B2 _____ X2 _____
Bowing constant
$\frac{X1+X2}{2}$ = _______</td></tr>
</table>

Note: Measure C_1 to C_6 from Driver to Passenger Side in Front or Rear Impacts – Rear to Front in Side Impacts.

Specific Impact Number	Plane* of C-Measurements	Direct Damage		Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width** (CDC)	Max*** Crush								
1	Front plane at bmp ht	16	11.0	40	-	-	-	-	-	-	18
2	Side plane at bmp ht	16	9.0	56	-	-	-	-	-	-	78
	Measurements recorded										
	☑ **inches** **or** ☐ **mm**										

[1]Table taken from National Accident Sampling System (NASS).

*Identify the plane at which the C-measurements are taken (e.g., at bumper, above bumper, at sill, above sill, at beltline, etc.) or label adjustments (e.g., free space).

Free space value is defined as the distance between the baseline and the original body contour taken at the individual C locations. This may include the following: bumper lead, bumper taper, side protrusion, side taper, etc. Record the value for each C-measurement and maximum crush.

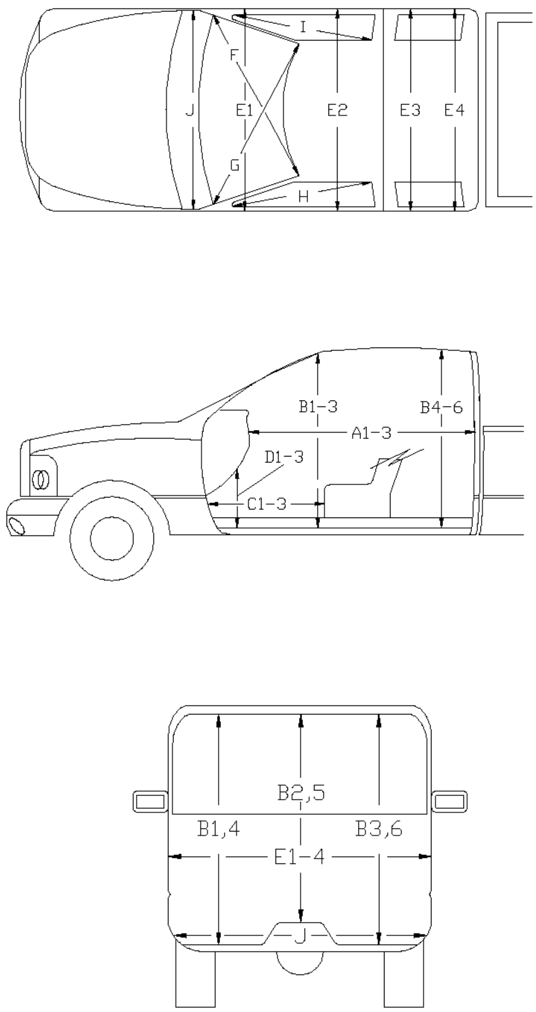
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***Measure and document on the vehicle diagram the location of the maximum crush.

Note: Use as many lines/columns as necessary to describe each damage profile.

Figure 133. Occupant compartment measurements for Test No. 606861-3

Date:	2020-12-14	Test No.:	606861-3	VIN No.:	1C6RR6GT0ES287150
Year:	2014	Make:	RAM	Model:	1500



*Lateral area across the cab from driver's side kickpanel to passenger's side kickpanel.

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	65.00	65.00	0.00
A2	63.00	63.00	0.00
A3	65.50	65.50	0.00
B1	45.00	45.00	0.00
B2	38.00	38.00	0.00
B3	45.00	45.00	0.00
B4	39.50	39.50	0.00
B5	43.00	43.00	0.00
B6	39.50	39.50	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	26.00	0.00
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
D3	11.50	11.50	0.00
E1	58.50	58.50	0.00
E2	63.50	63.50	0.00
E3	63.50	63.50	0.00
E4	63.50	63.50	0.00
F	59.00	59.00	0.00
G	59.00	59.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	25.00	25.00	0.00

Figure 134. Vehicle angular displacements for Test No. 606861-3

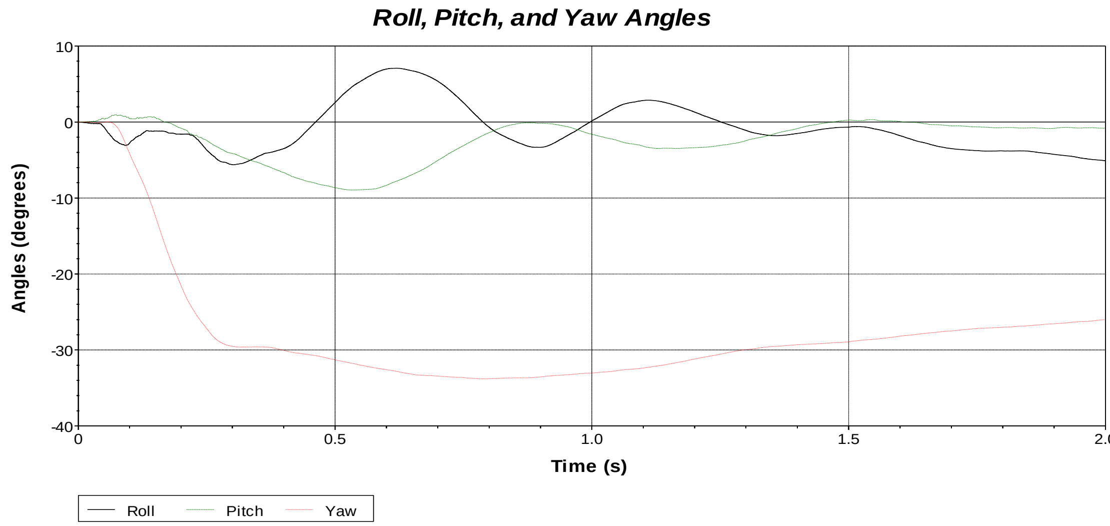


Figure 135. Vehicle longitudinal accelerometer trace for Test No. 606861-3 (accelerometer located at center of gravity)

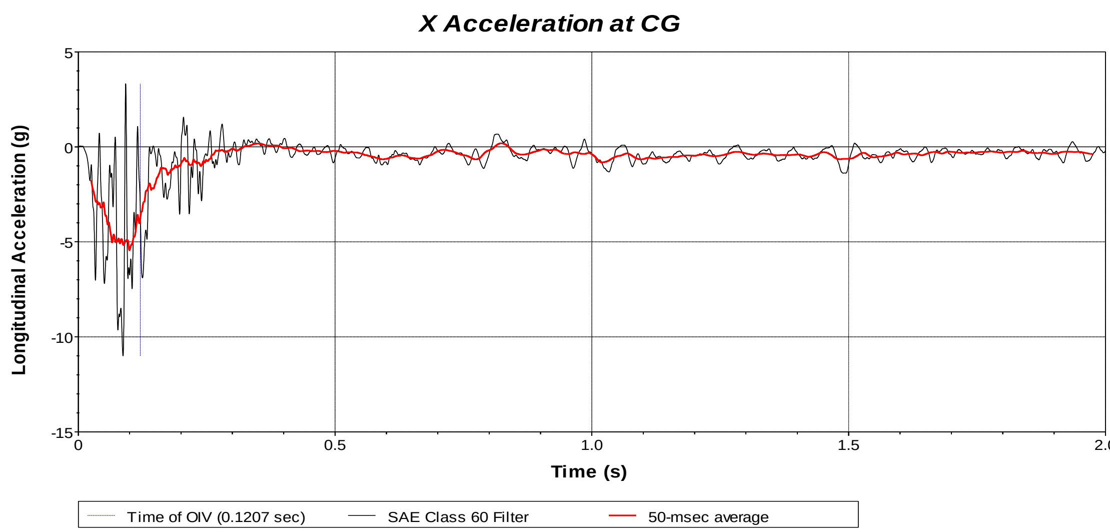


Figure 136. Vehicle lateral accelerometer trace for Test No. 606861-3 (accelerometer located at center of gravity)

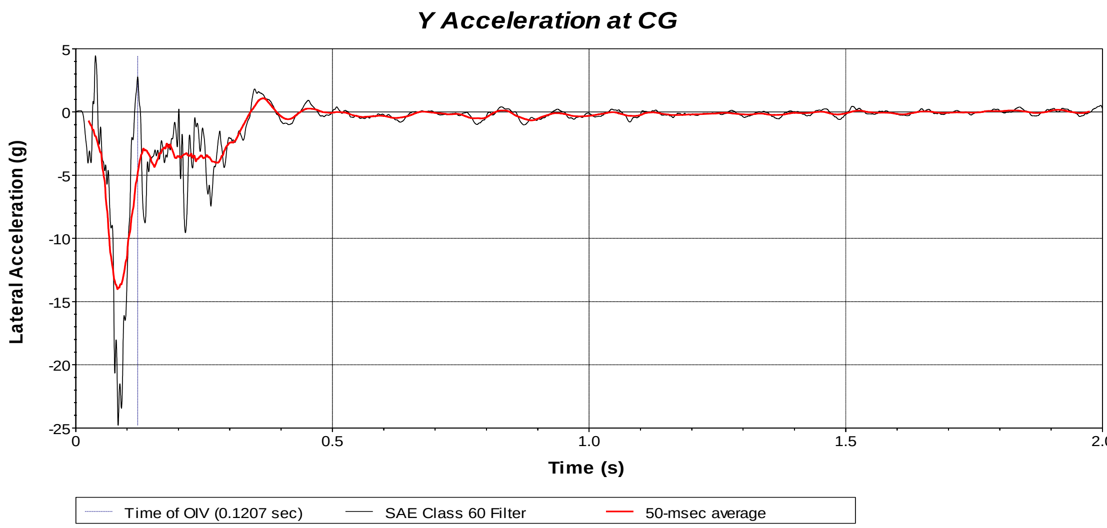
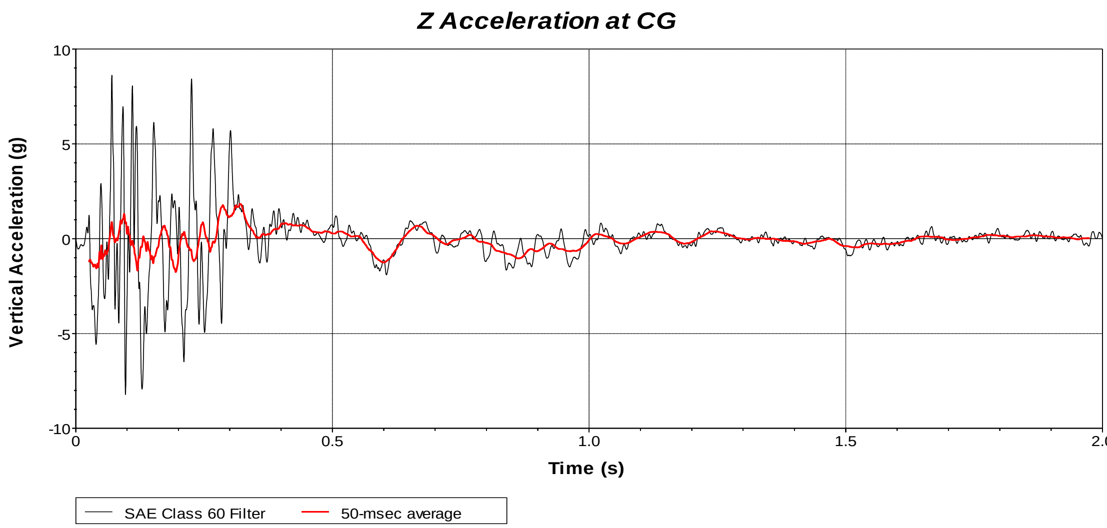


Figure 137. Vehicle vertical accelerometer trace for Test No. 606861-3 (accelerometer located at center of gravity)



Appendix K. MASH Test 3-10 (Crash Test No. 606861-4)

Figure 138. Vehicle properties for Test No. 606861-4

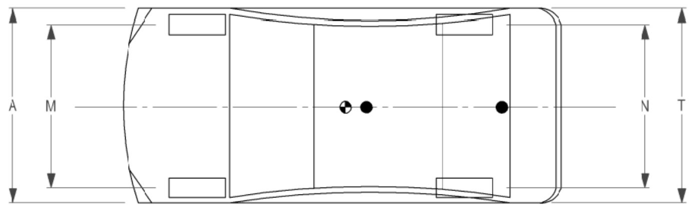
Date: 2020-12-11 Test No.: 606861-4 VIN No.: 3N1CN7APOEL862280

Year: 2014 Make: NISSAN Model: VERSA

Tire Inflation Pressure: 36 PSI Odometer: 91861-4 Tire Size: P185/65R15

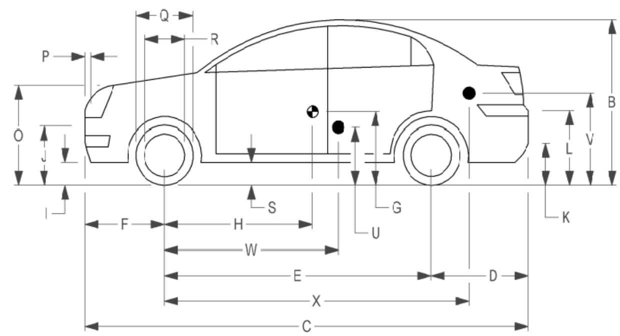
Describe any damage to the vehicle prior to test: None

● Denotes accelerometer location.



NOTES: None

Engine Type: 4 CYL
Engine CID: 1.6 L
Transmission Type:
☐ Auto or ☑ Manual
☑ FWD ☐ RWD ☐ 4WD
Optional Equipment:
None



Dummy Data:
Type: 50th Percentile Male
Mass: 165 lb
Seat Position: IMPACT SIDE

Geometry: inches

A	66.70	F	32.50	K	12.50	P	4.50	U	15.50
B	59.60	G		L	26.00	Q	24.00	V	21.25
C	175.40	H	42.15	M	58.30	R	16.25	W	42.10
D	40.50	I	7.00	N	58.50	S	7.50	X	79.75
E	102.40	J	22.25	O	30.50	T	64.50		

Wheel Center Ht Front 11.50 Wheel Center Ht Rear 11.50 W-H -0.05

RANGE LIMIT: A = 65 ±3 inches; C = 169 ±8 inches; E = 98 ±5 inches; F = 35 ±4 inches; H = 39 ±4 inches; O (Top of Radiator Support) = 28 ±4 inches
(M+N)/2 = 59 ±2 inches; W-H < 2 inches or use MASH Paragraph A4.3.2

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1750	M_{front}	1369	1425	1510
Back	1687	M_{rear}	974	979	1077
Total	3389	M_{Total}	2343	2404	2587

Allowable TIM = 2420 lb ±55 lb | Allowable GSM = 2585 lb ± 55 lb

Mass Distribution:
lb LF: 706 RF: 719 LR: 502 RR: 477

Figure 139. Sequential photographs for Test No. 606861-4 (overhead view).

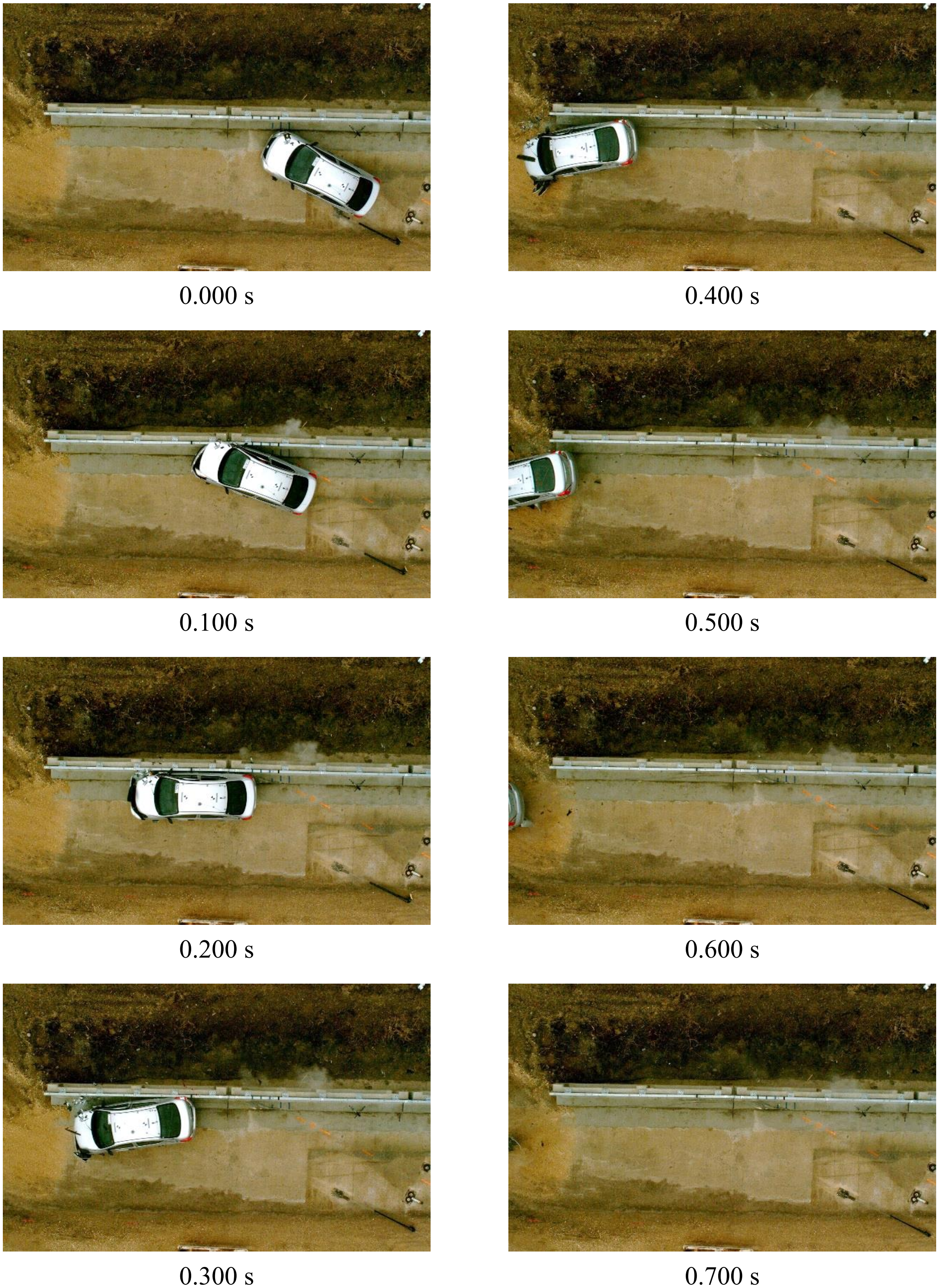


Figure 140. Sequential photographs for Test No. 606861-4 (frontal view).

0.000 s

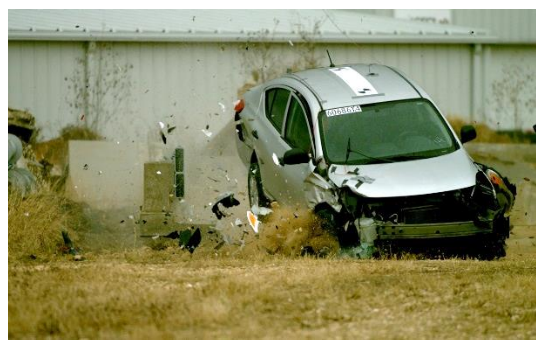
0.100 s

0.200 s

0.300 s

0.400 s

0.500 s



0.600 s

0.700 s

Figure 141. Sequential photographs for Test No. 606861-4 (rear view).

0.000 s

0.100 s

0.200 s

0.300 s

0.400 s

0.500 s

0.600 s

0.700 s

Figure 142. Exterior crush measurements for Test No. 606861-4

Date:	2020-12-11	Test No.:	606861-4	VIN No.:	3N1CN7APOEL862280
Year:	2014	Make:	NISSAN	Model:	VERSA

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable	
End Damage	Side Damage
Undeformed end width ________	Bowing: B1 _____ X1 _____
Corner shift: A1 ________	B2 _____ X2 _____
A2 ________	
End shift at frame (CDC)	Bowing constant
(check one)	$\frac{X1+X2}{2}$ = ______
< 4 inches ________	
≥ 4 inches ________	

Note: Measure C_1 to C_6 from Driver to Passenger Side in Front or Rear Impacts – Rear to Front in Side Impacts.

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	Front plane at bumper ht	14	9.0	30	-	-	-	-	-	-	11
2	Side plane at bumper ht	14	6.0	44	-	-	-	-	-	-	60
	Measurements recorded										
	☑ **inches** or ☐ **mm**										

[1]Table taken from National Accident Sampling System (NASS).

*Identify the plane at which the C-measurements are taken (e.g., at bumper, above bumper, at sill, above sill, at beltline, etc.) or label adjustments (e.g., free space).

Free space value is defined as the distance between the baseline and the original body contour taken at the individual C locations. This may include the following: bumper lead, bumper taper, side protrusion, side taper, etc. Record the value for each C-measurement and maximum crush.

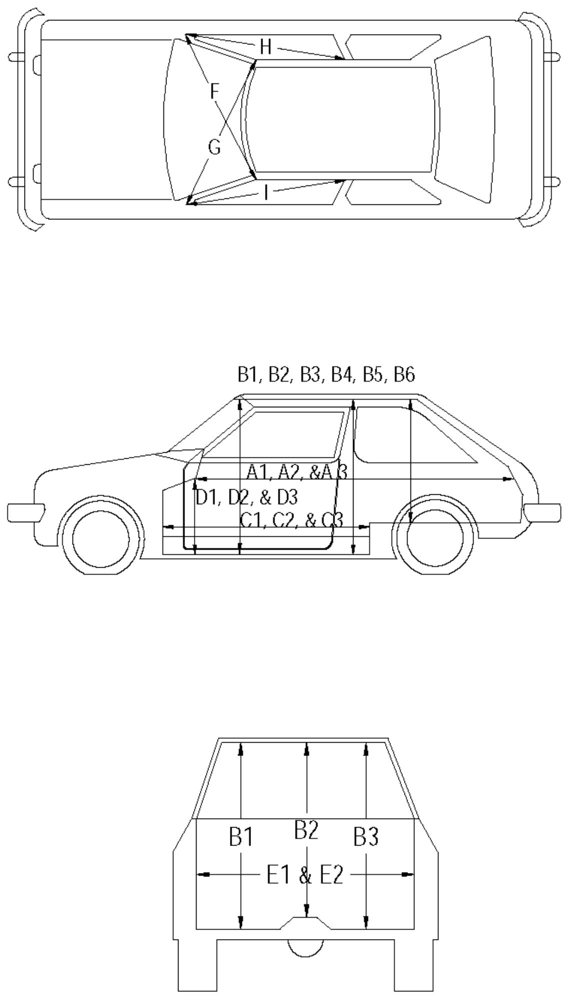
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***Measure and document on the vehicle diagram the location of the maximum crush.

Note: Use as many lines/columns as necessary to describe each damage profile.

Figure 143. Occupant compartment measurements for Test No. 606861-4

Date:	2020-12-11	Test No.:	606861-4	VIN No.:	3N1CN7APOEL862280
Year:	2014	Make:	NISSAN	Model:	VERSA



*Lateral area across the cab from
driver's side kick panel to passenger's side kick panel.

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	75.00	75.00	0.00
A2	74.00	74.00	0.00
A3	74.00	74.00	0.00
B1	43.00	43.00	0.00
B2	37.00	37.00	0.00
B3	43.00	43.00	0.00
B4	46.50	46.50	0.00
B5	42.50	42.50	0.00
B6	46.50	46.50	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	26.00	0.00
D1	12.50	12.50	0.00
D2	0.00	0.00	0.00
D3	10.00	9.50	-0.50
E1	45.00	45.00	0.00
E2	48.75	48.75	0.00
F	47.50	47.50	0.00
G	47.50	47.50	0.00
H	39.00	39.00	0.00
I	39.00	39.00	0.00
J*	48.50	48.00	-0.50

Figure 144. Vehicle angular displacements for Test No. 606861-4

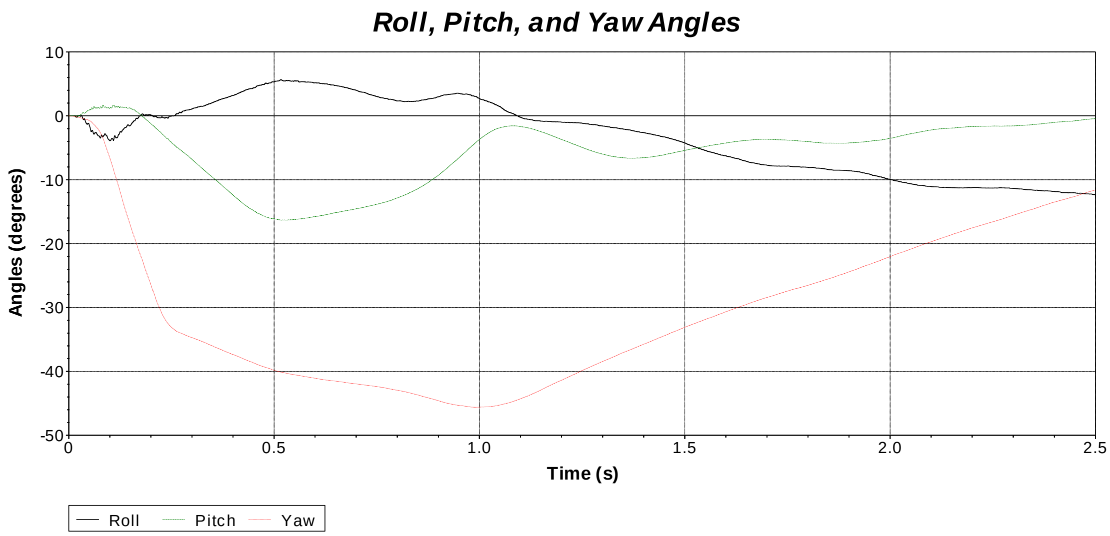


Figure 145. Vehicle longitudinal accelerometer trace for Test No. 606861-4 (accelerometer located at center of gravity)

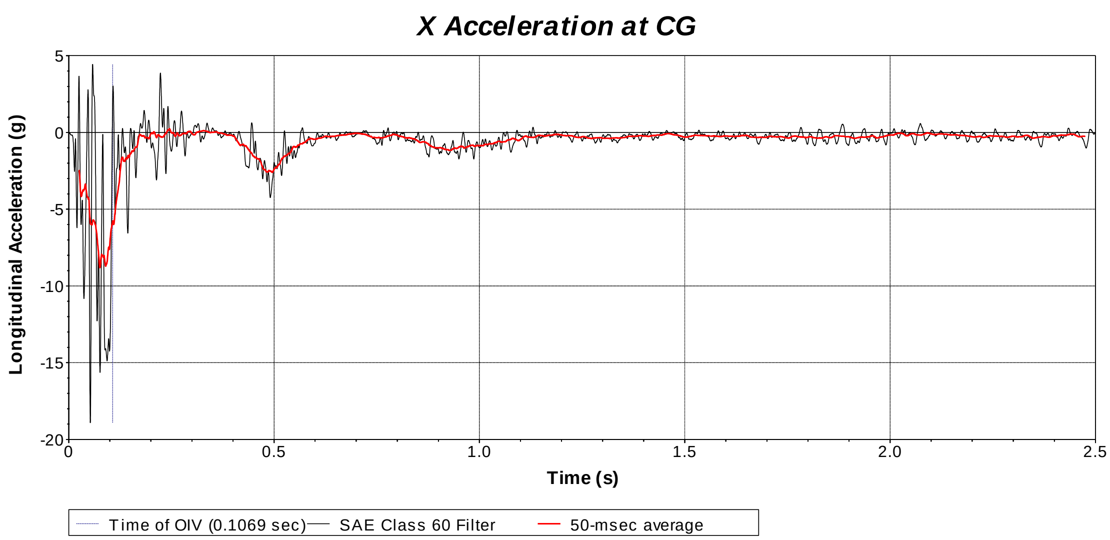


Figure 146. Vehicle lateral accelerometer trace for Test No. 606861-4 (accelerometer located at center of gravity)

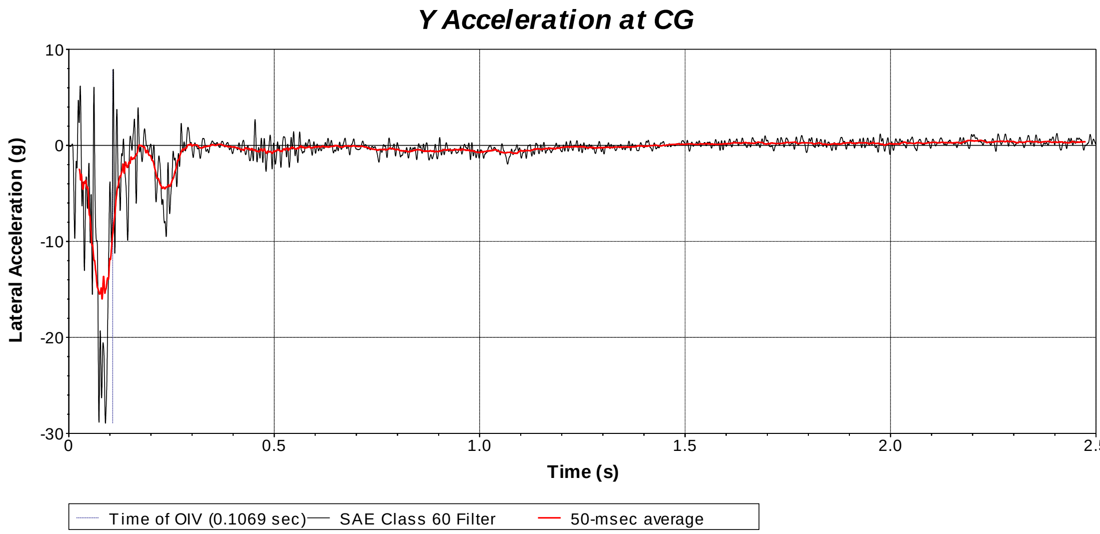
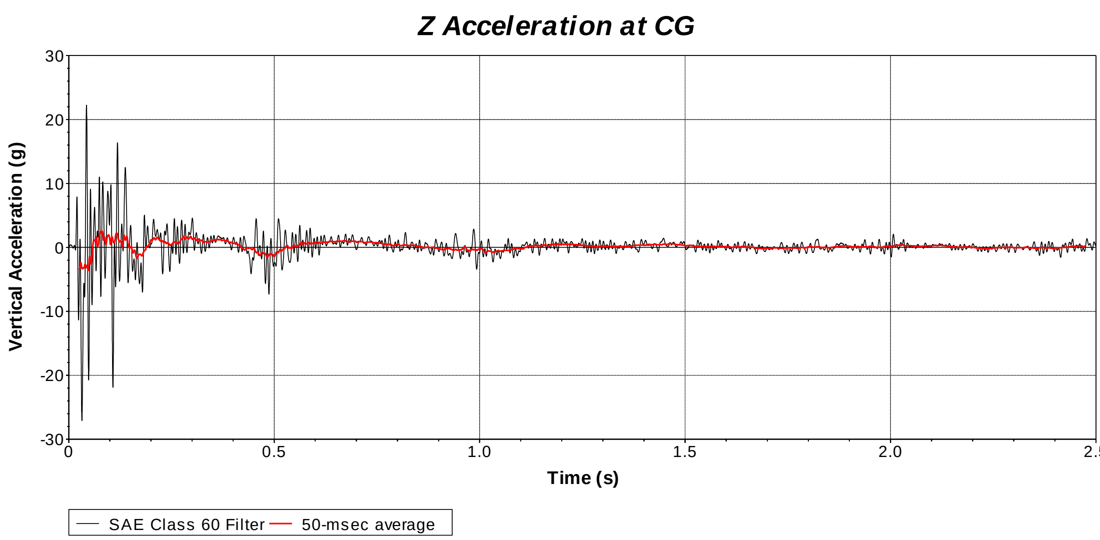


Figure 147. Vehicle vertical accelerometer trace for Test No. 606861-4 (accelerometer located at center of gravity)



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