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Retrofit of Existing Statewide Louisiana Safety Walk Bridge Barrier Railing Systems

by

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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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The contents of this report reflect the views of the author/principal investigator, who is responsible for the facts and the accuracy of the data presented herein.

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January 2022

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Implementation Statement¹

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

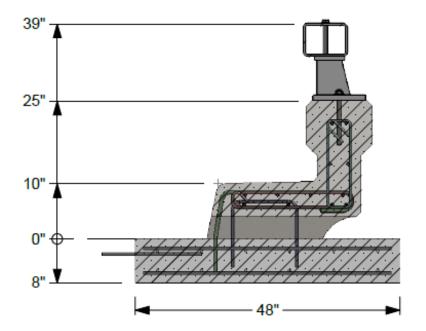


Figure 3. Photos of full-scale test installation



(a) Traffic face of bridge rail



(b) Steel post



(c) Joint

(d) Field side of bridge rail

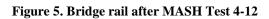
Three crash tests were required to evaluate the bridge rail's performance for TL-4 of MASH [1]. These tests involved a 10000S vehicle (22,000-lb. single unit truck), a 2270P vehicle (a 5000-lb. (½-ton) quad cab pickup), and a smaller 1100C vehicle (2420-lb. small car). Figure 4 through Figure 12 show 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





(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



(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

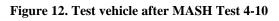


(b) Impact point



(c) Joint







(a) Damage to front of test vehicle

(b) Damage to left front tire

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. No occupant compartment deformation or intrusion	Pass
	G.	was observed. The 10000S vehicle remained upright during and after	
		the collision event.	

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

² See Table 9 for details of respective evaluation criteria.

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.	-
		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

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

³ See Table 9 for details of respective evaluation criteria.

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

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

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.-6³/₄ in. long double steel rail on a concrete parapet comprised of four 40-ft. long rail segments with 2¹/₄-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 2¹/₄-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

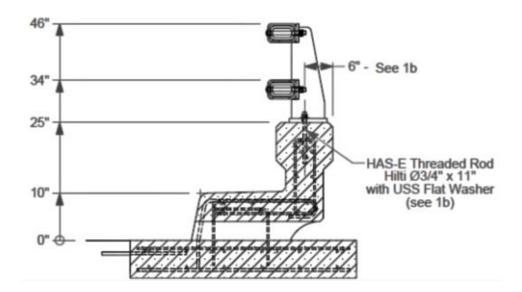


Figure 14. Design Option B1 before testing



(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





(a) Traffic side

(b) Field side

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



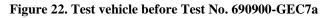
⁽a) Traffic side



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



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





(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





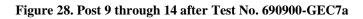


Figure 27. Post 8 after Test No. 690900-GEC7a



(a) Traffic side

(b) Field side





(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

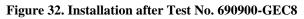
(b) 1100C test vehicle

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



(a) Traffic side

(b) Parallel with bridge rail





(a) Traffic face of bridge rail





(c) Field side of bridge rail



(d) Crack in concrete curb





(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

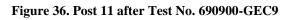
(b) 2270P test vehicle





(a) Traffic side

(b) Along traffic face of bridge rail





(a) Traffic side



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



(a) Traffic side impact area damage test

(b) Field side damage



(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 38. Photos after Test No. 690900-GEC9

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 OptionB1 Bridge Rail

Evaluation Factors	Evaluation ⁵ Criteria	Test Results	Assessment
Structural Adequacy	А.	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 D. Risk		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 OptionB1 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 D. Risk		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 OptionB1 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 D. Risk		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. Maximum occupant compartment deformation was	Pass
		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 OptionB1 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 D. Risk		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. Maximum occupant compartment deformation was	Pass
	F.	1.0 in. in the right front kickpanel area.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 <u>Bridge Curbed Barrier Retrofit Project</u>. 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 <u>Bridge Curbed Barrier Retrofit Project</u>. 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.

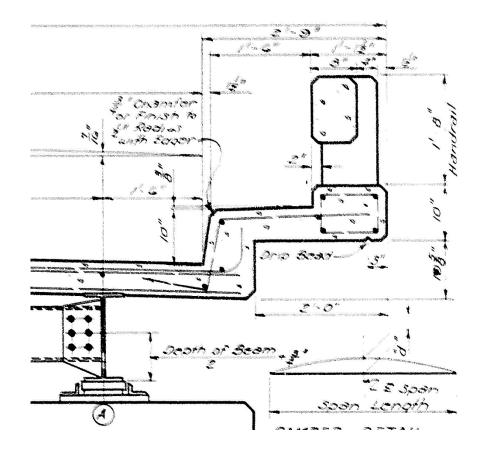
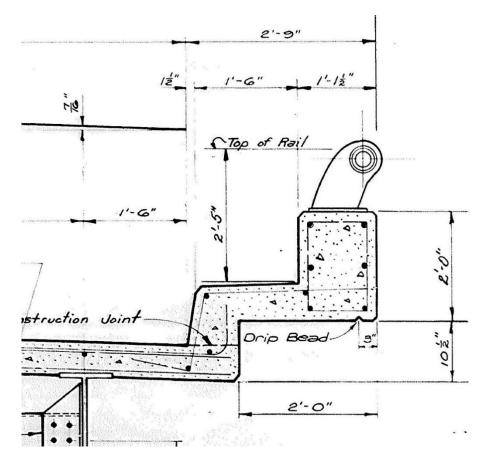


Figure 41. Details from drawing SCJ5C-90-24P concrete post and beam

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.

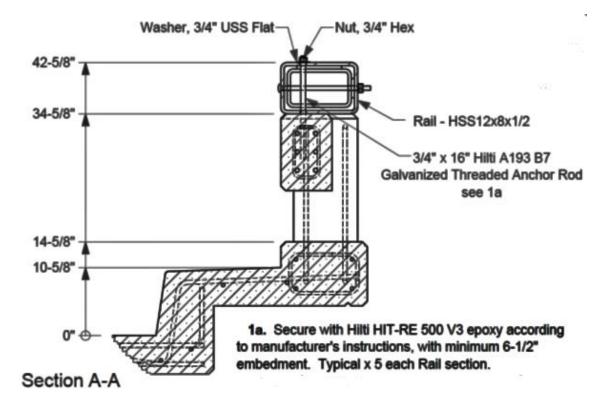


Figure 43. Retrofit bridge rail Option 1 cross section details

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. \pm 55 lb. impacting the critical impact point (CIP) of the bridge barrier at an impact speed of 62 mi/h \pm 2.5 mi/h and an angle of 25 degrees \pm 1.5 degrees. MASH Test 3-11 involves a 2270P vehicle weighing 5000 lb. \pm 110 lb. impacting the CIP of the bridge barrier at an impact speed of 62 mi/h \pm 2.5 mi/h and an angle of 25 degrees \pm 1.5 degrees. \pm 1.5 degrees.

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
Longitudinal Barrier	3-11	2270P	62 mi/h	25°	A, D, F, H, I

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

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 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. 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. 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. 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. 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

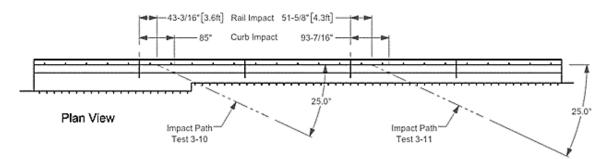


Figure 45. Target CIPs for MASH Test 3-10 on redesigned Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk

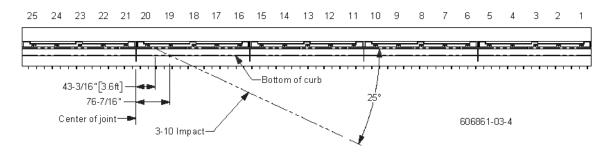
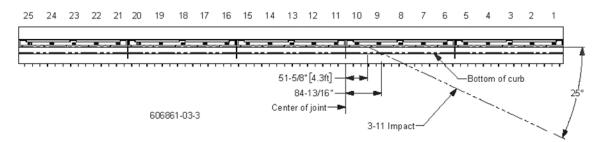


Figure 46. Target CIP for MASH Test 3-11 on redesigned Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk



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.

Evaluation Factors		Evaluation Criteria		
Structural Adequacy	А.	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.		
	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.		
Occupant Risk	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.		

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

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 jointedconcrete 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 ENDEVCOTM 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 42⁵/₈ 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.-10³/₄ 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.-3³/₄ 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 ³/₄-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

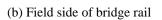
The specified compressive strength of the concrete used in the wall, deck, curb, and parapet was 3000 psi. On October 2, 2018, the average compressive strengths of the concrete were as follows:

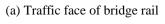
- Average concrete strength for the wall and deck: 4535 psi at 75 days of age.
- Average concrete strength for the curb: 4643 psi at 66 and 67 days of age (2 pours).
- Average concrete strength for the parapet: 4044 psi at 54 and 61 days of age (2 pours).

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





(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 \pm 110 lbs impacting the CIP of the bridge barrier at an impact speed of 62 mi/h \pm 2.5 mi/h and an angle of 25 degrees \pm 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. \pm 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

(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.

⁽a) Right side of 2270P test vehicle

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

Table 10. Events during Test No. 606861-1

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 width⁹ 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





(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





(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.

Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV)		
Longitudinal	28.9 ft/s	
Lateral	21.7 ft/s	at 0.1472 s on right side of interior
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

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

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



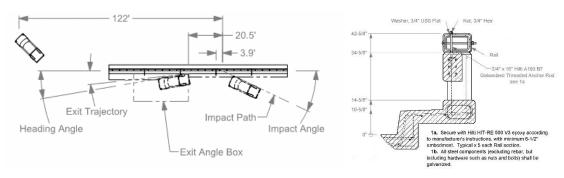
(a) 0.000 s





(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			
Туре	Longitudinal Barrier—Bridge Rail		
Name	Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk		
Installation Length	106 ft10¾ 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		

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
СDС	01FREW5
Max Exterior Deformation	16.0 in.
OCDI	FR0010000
Max Occupant Compartment Deformation	2.0 in.

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

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 Rio¹⁰ 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.

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.

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	

Table 14. Events during Test No. 606861-2

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 width¹¹ 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

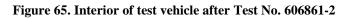
Damage to Test Vehicle

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.



(a) Front of 1100C test vehicle after test

(b) Right front of 1100C test vehicle





(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.

Occupant Risk Factor	Value	Time
OIV		
Longitudinal	18.4 ft/s	at 0,1102 a an eight side of interior
Lateral	24.3 ft/s	at 0.1103 s on right side of interior
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

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

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



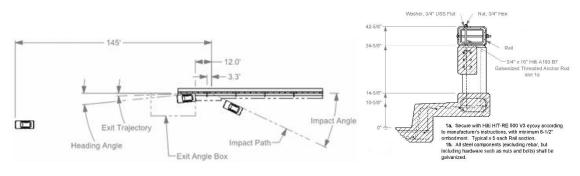
(a) 0.000 s





(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	e 2018-10-03	
Test Article		
Туре	Longitudinal Barrier—Bridge Rail	
Name	Louisiana Retrofit Post and Beam Bridge Rail with Safety Walk	
Installation Length	106 ft10¾ 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	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		

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
СДС	01FREW5
Max Exterior Deformation	9.0 in.
OCDI	RF0010000
Max Occupant Compartment Deformation	1.5 in.

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

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</u> <u>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.

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 D. Risk		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). Maximum occupant compartment deformation was	Pass
	F.	2.0 in. in the right firewall area.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

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

¹² See Table 9 for details of respective evaluation criteria.

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 D. Risk		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. Maximum occupant compartment deformation was	Pass
	F.	1.5 in. in the right firewall area.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

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

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.

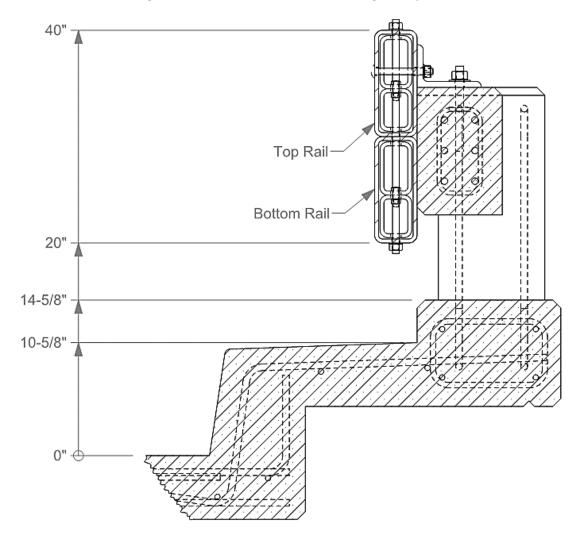


Figure 67. Section view of retrofitted bridge rail system

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).

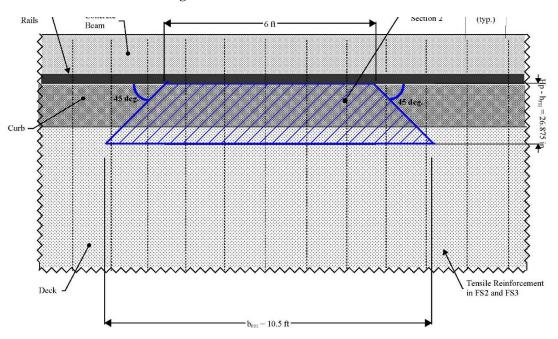
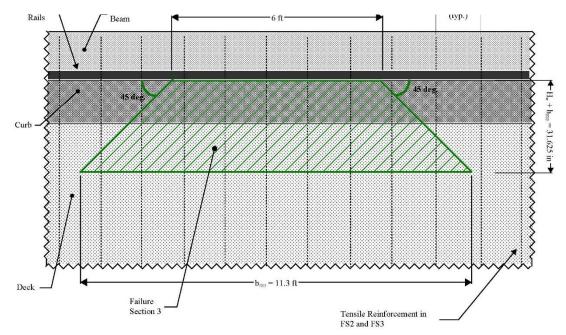


Figure 68. Plan view of failure section 2





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

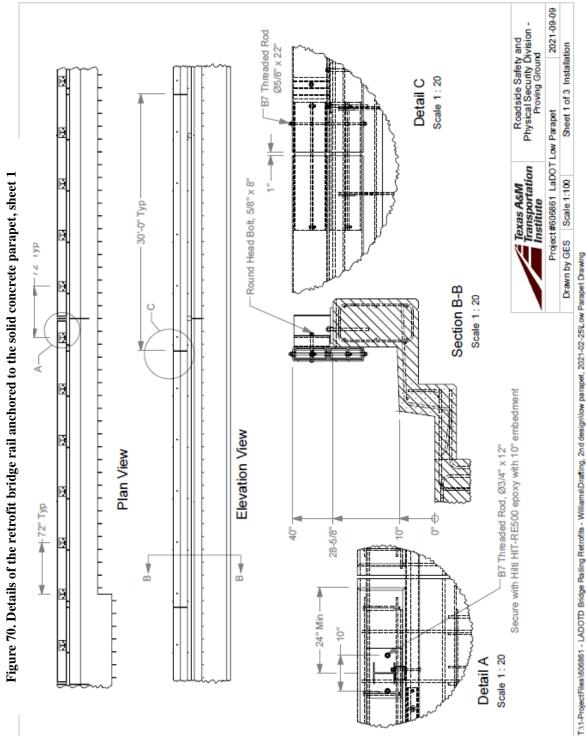
N = Number of railing spans.

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 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 of the new retrofit bridge rail please refer to 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.

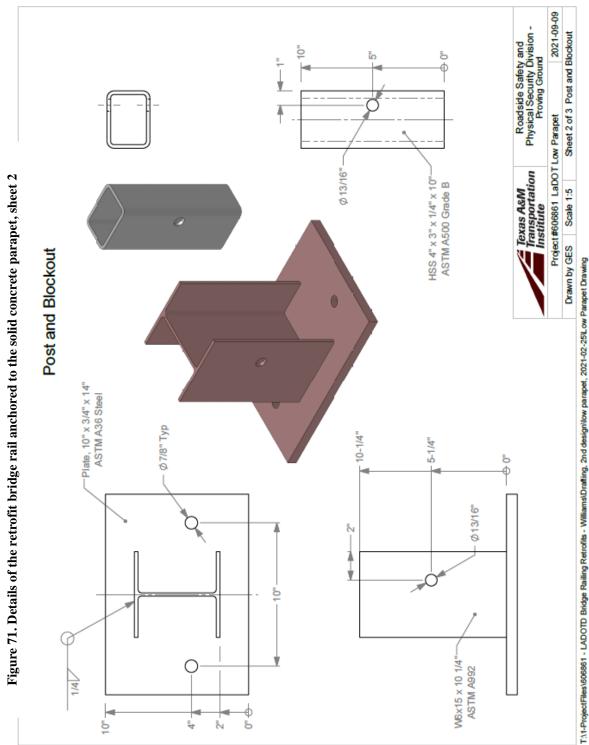
Based on the results of the structural analysis, the new retrofit bridge rail design as shown herein meets the strength requirements for MASH TL-3. This new design improves the strength of the existing concrete bridge rail and still allows some access to the existing safety sidewalk. This design was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

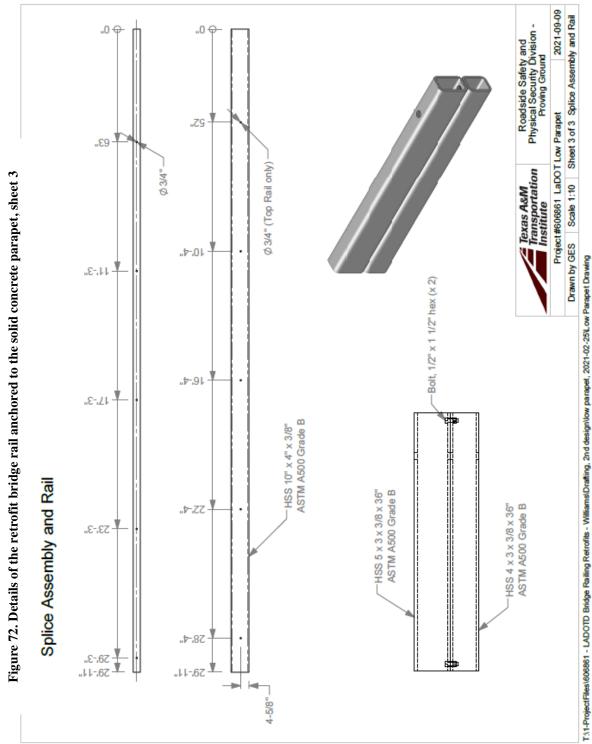
It was recommended that this design be full-scale crash tested as per the MASH specifications for TL-3. Two full-scale crash tests were planned. MASH Test 3-10 (small car) was performed on December 11, 2020. MASH Test 3-11 (pickup truck) was planned for December 14, 2020.

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.











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.-10³/₄ 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.-3³/₄ 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 $L6 \times 4 \times 1/4$ in. angle brackets that were anchored to the concrete beam with $\frac{3}{4}$ -in. diameter \times 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 $\frac{5}{8}$ -in. diameter \times 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 \pm 110 lbs impacting the CIP of the bridge barrier at an impact speed of 62 mi/h \pm 2.5 mi/h and an angle of 25 degrees \pm 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. Figure129 through Figure 131 in Appendix J present sequential photographs during the test.

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	

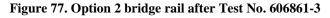
Table 20. Events during Test No. 606861-3

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 width¹⁴ 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.





(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

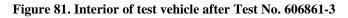
Figure 80 shows the damage sustained by the vehicle. The front bumper, grill, hood, radiator and support, right front fender, right front tire and rim, right front and rear doors, right rear cab corner, right rear exterior bed, right rear tire, and rear bumper were damaged. Maximum exterior crush to 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





(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.

Occupant Risk Factor	Value	Time
OIV		
Longitudinal	13.1 ft/s	
Lateral	24.6 ft/s	at 0.1207 s on right side of interior
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

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

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



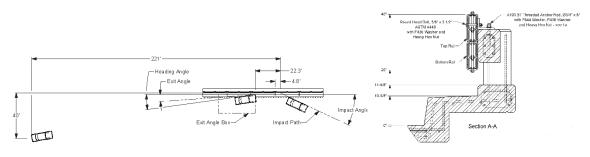
(a) 0.000 s





(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	ate 2020-12-14	
Test Article		
Туре	Longitudinal Barrier—Bridge Rail	
Name	Louisiana Retrofit post and beam bridge rail with safety walk Option 2	
Installation Length	106 ft10¾ in.	
Material or Key Elements	ts 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	n 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		

Occupant Risk Values	
	12.1.5/
Longitudinal OIV	
Lateral OIV	210105
Longitudinal Ridedown	
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
СДС	01FREW4
Max Exterior Deformation	11.0 in.
OCDI	RF000000
Max Occupant Compartment Deformation	None

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

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
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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 width¹⁵ 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.

Occupant Risk Factor	Value	Time
OIV		
Longitudinal	19.7 ft/s	
Lateral	31.2 ft/s	at 0.1069 s on right side of interior
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

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

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



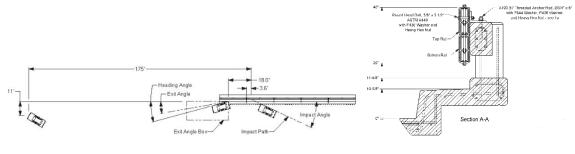
(a) 0.000 s





(c) 0.400 s

(d) 0.600 s



(e) Impact summary

(f) Cross-section of bridge rail

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	
Туре	Longitudinal Barrier—Bridge Rail
Name	Louisiana Retrofit post and beam bridge rail with safety walk
	Option 2
Installation Length	106 ft10¾ 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 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

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.

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

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.

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

Table 28. Performance evaluation summary forTest 3-11 on Louisiana Retrofit Post and BeamBridge Rail with Safety Walk Option 2

¹⁶ See Table 9 for details of respective evaluation criteria.

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

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

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 $L6 \times 4 \times \frac{1}{2}$ angle. These holes can be used if rebar is encountered in the drilling operation using the center hole in the angle.



Figure 94. Installed L6×4×1⁄2 angle support bracket with 3⁄4-in. A193 B7 galvanized threaded rod with Hilti RE500-V3 adhesive

4. Install/connect the top HSS10×4×³/₈ rail to the L6×4×¹/₂ 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 ¹/₂ in. long bolt. Some temporary shoring support might be required to bolt this top rail element to the L6×4×¹/₂ 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× $\frac{3}{8}$ rail element by connecting lower element to top rail element using $\frac{5}{8}$ -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 HSS10×4×3% rail and bolting to top rail with 5%-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 ³/₄-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.
- HSS10×4×3/8 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, HSS5×3×3/8 and HSS4×3×3/8 ASTM A500 grade B material, hot dipped galvanized.
- Rail attachment bolts, round head bolt, ⁵/₈-in. diameter × 5¹/₂ in. long attaching rail to L6×4×¹/₂ bracket angles ASTM A449 with F436 washer and heavy hex nut, hot dipped galvanized.
- Rail connecting bolts, ⁵/₈-in. diameter × 22 in. long bolts connecting HSS10×4×³/₈ tubes A193 B7 threaded rods, with F436 washers (2) and heavy hex nuts (2), hot-dipped galvanized.
- $L6 \times 4 \times \frac{1}{2}$ attachment bracket ASTM A36 material, hot-dipped galvanized.
- Splice connection bolts, ¹/₂-in. diameter × 1¹/₂-in. long ASTM A307 material, hotdipped 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.

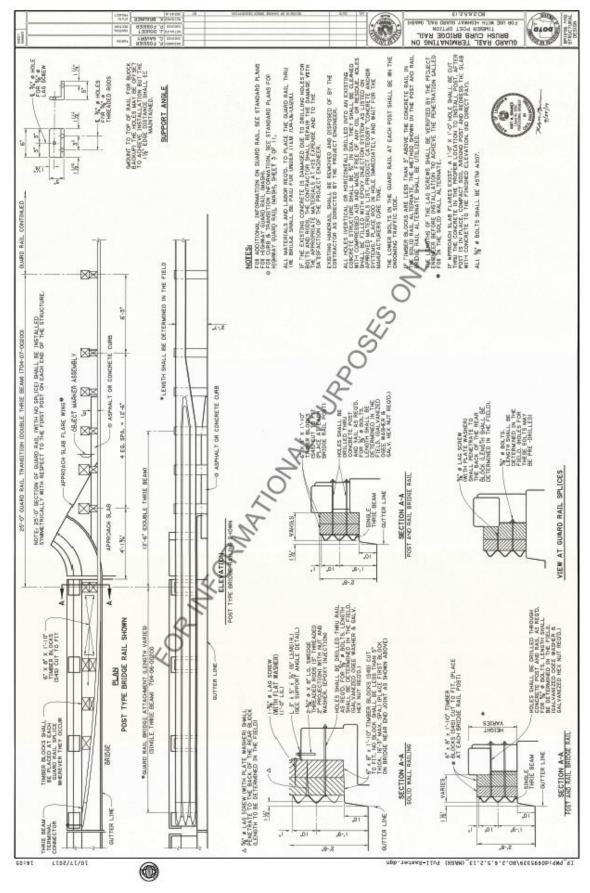
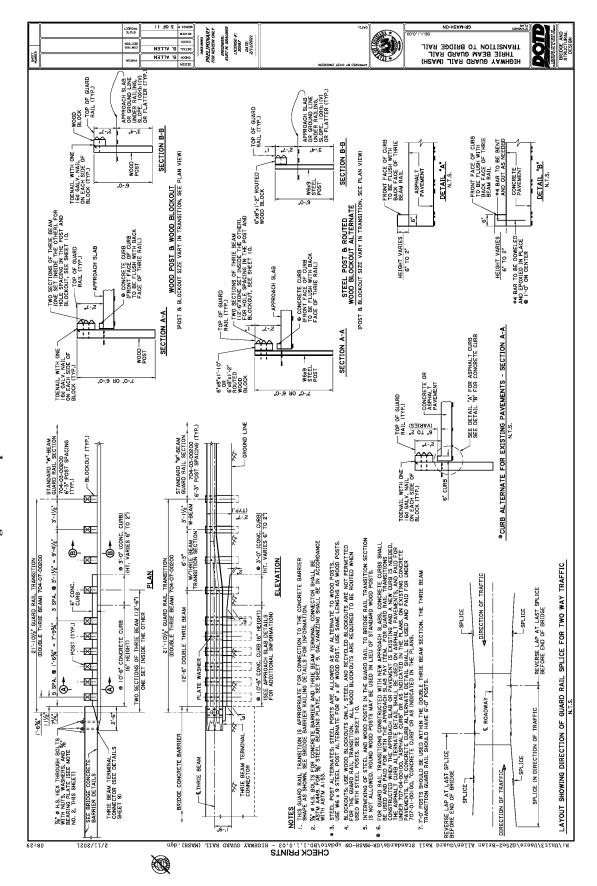
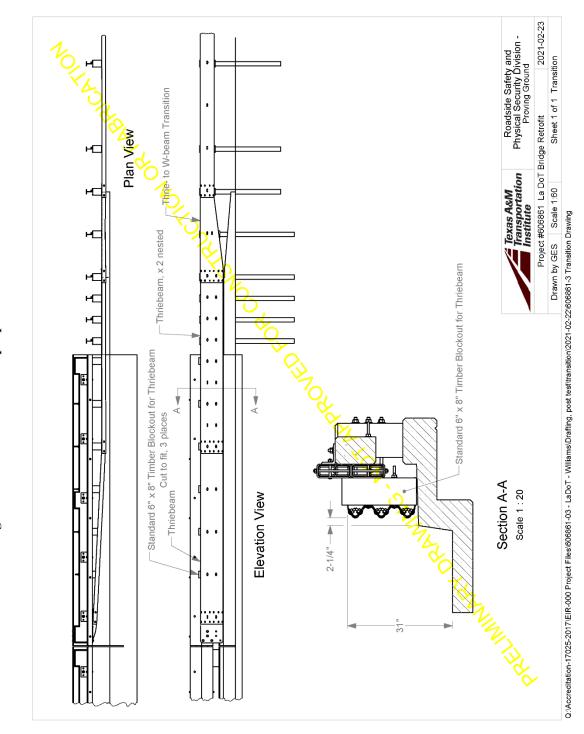


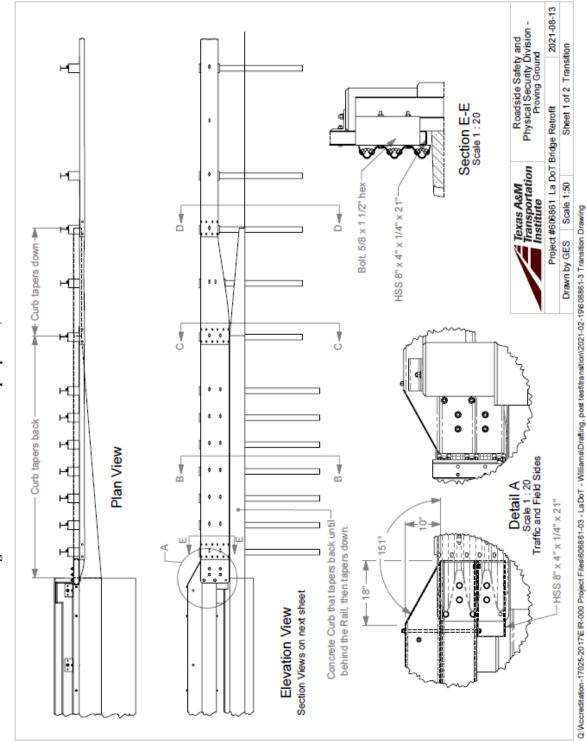
Figure 101. Current retrofit transition for safety walk barriers received from DOTD



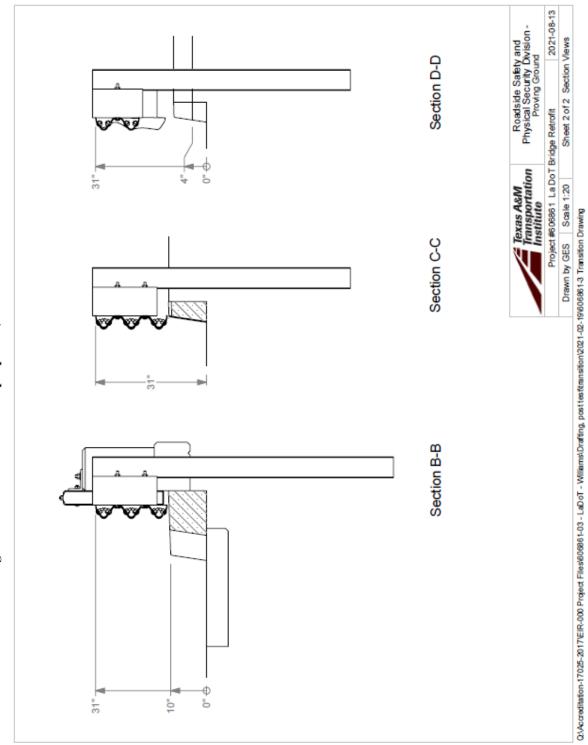














Conclusions

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.

Evaluation Factors	Evaluation Criteria	Test No. 606861-1	Test No. 606861-2
Structural Adequacy	А.	S	S
Occupant Risk	D.	S	S
	F.	S	S
	Н.	S	S
	I.	S	U
	Test No.	MASH Test 3-11	MASH Test 3-10
	Pass/Fail	Pass	Fail
		S = Satisfactor U = Unsatisfactor	•

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

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.

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

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

S = Satisfactory U = Unsatisfactory

Recommendations¹⁸

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 $L6 \times 4 \times \frac{1}{2}$ angle brackets is lower than the as tested height of 40 in., short steel baseplated posts shall be used instead of the $L6 \times 4 \times \frac{1}{2}$ 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 L6x4x1/2angle 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.

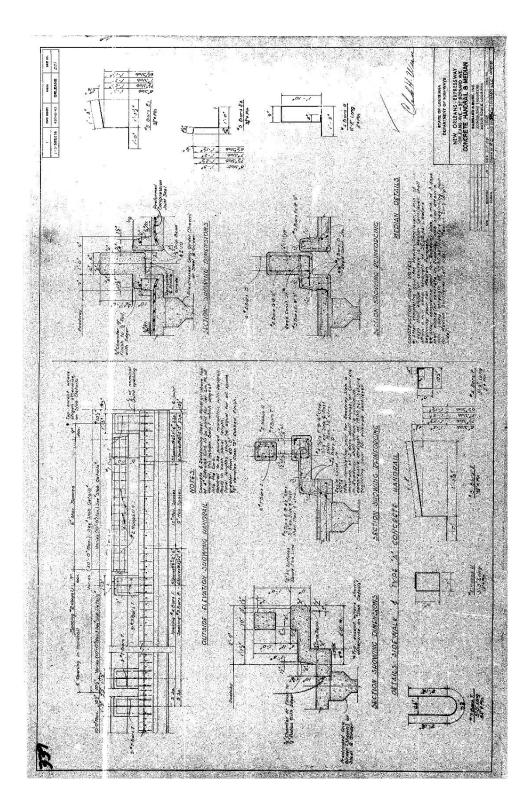
Acronyms, Abbreviations, and Symbols

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

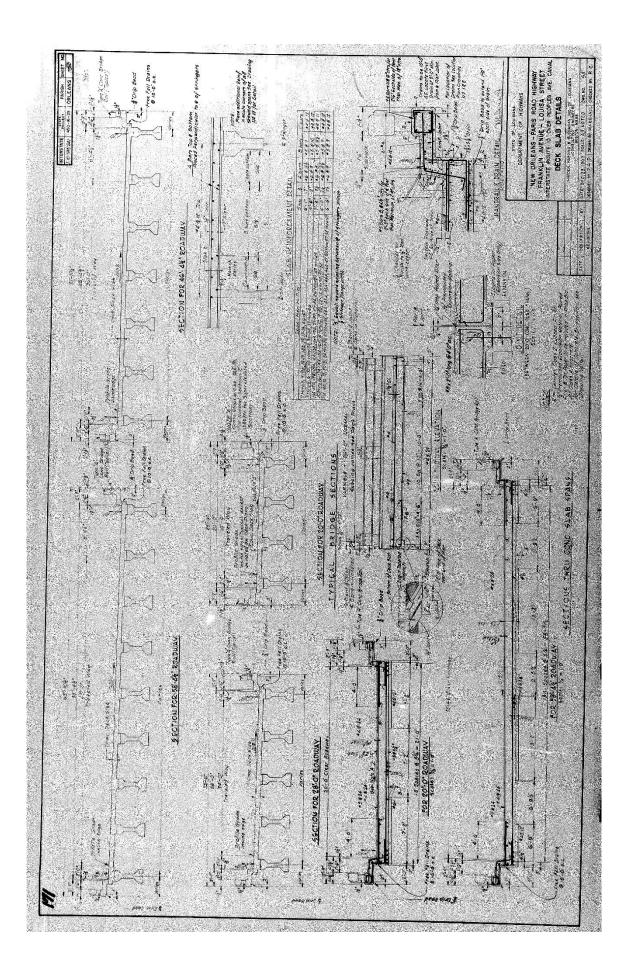
Term	Description
NCHRP	National Cooperative Highway Research Program
NIST	National Institute of Standards Technology
OCDI	NCHRP Report 350 Appendix E: Occupant Compartment Deformation
	Index
OIV	Occupant Impact Velocity
psi	pound(s) per square inch
S	second(s)
SAE	Society of Automotive Engineers
TDAS	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

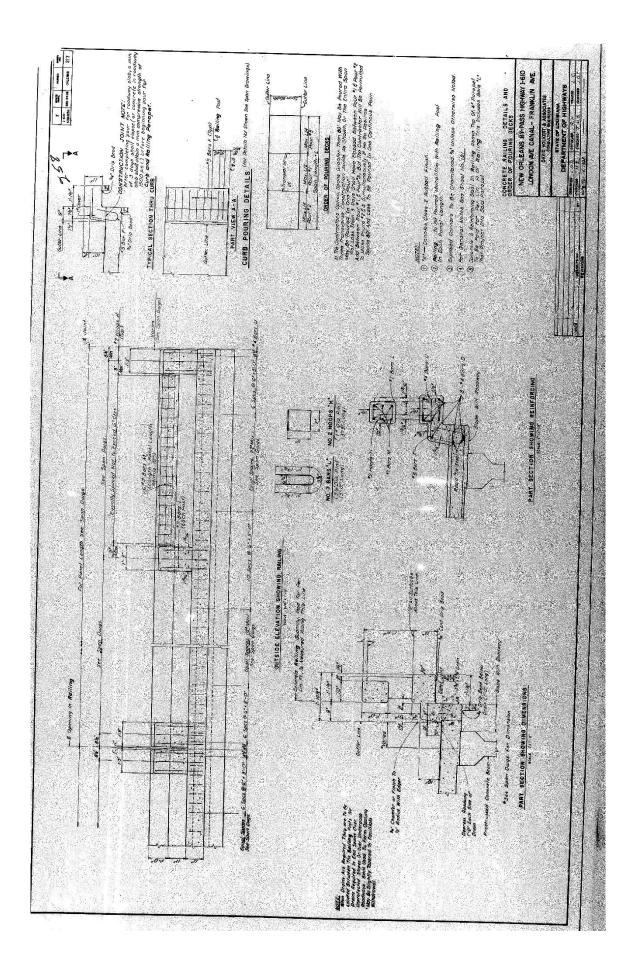
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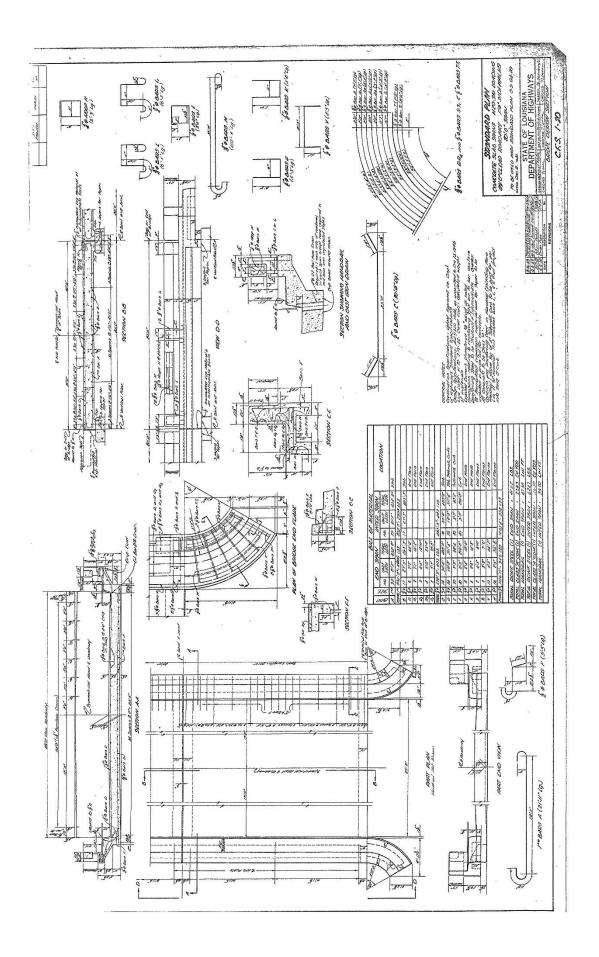
- 1. AASHTO. *Manual for Assessing Roadside Safety Hardware, Second Edition.* American Association of State Highway and Transportation Officials, Washington, DC, 2016.
- W. F. Williams, "4.3. Design & Full Scale Testing of Retrofit Bridge Rail for 24.8 Miles Long Southbound Causeway Bridge, New Orleans,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

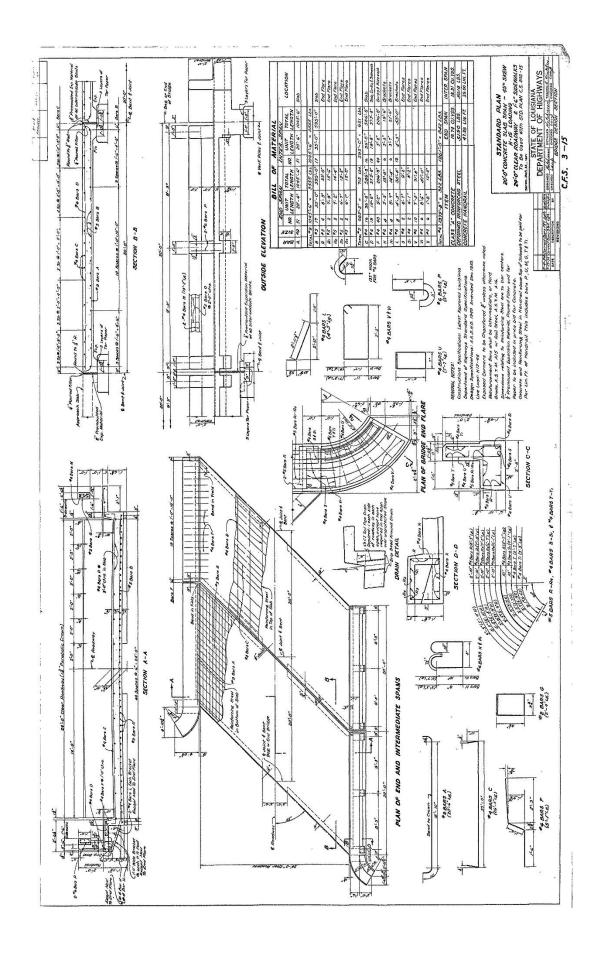


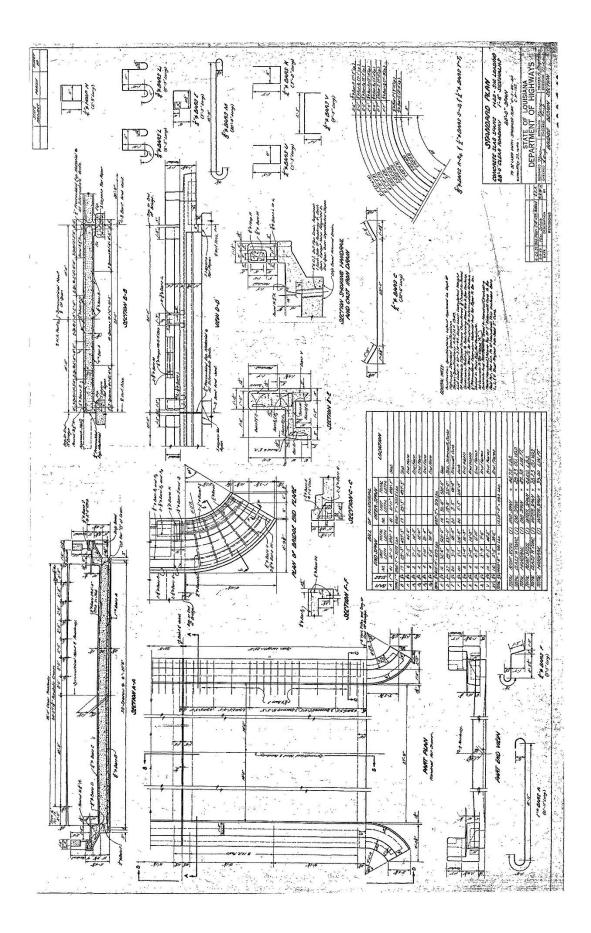
Appendix A. DOTD Bridge Rails

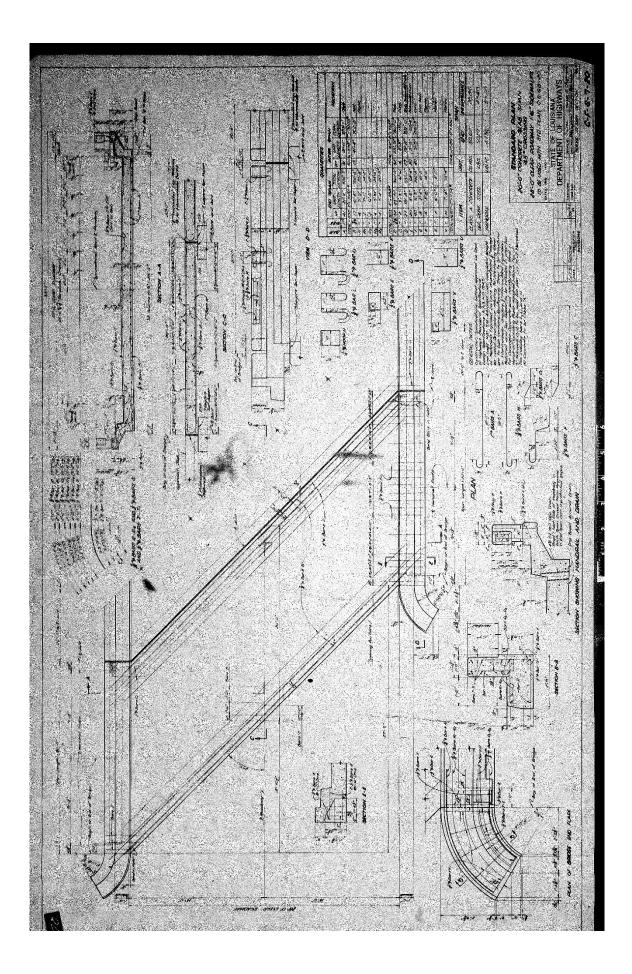


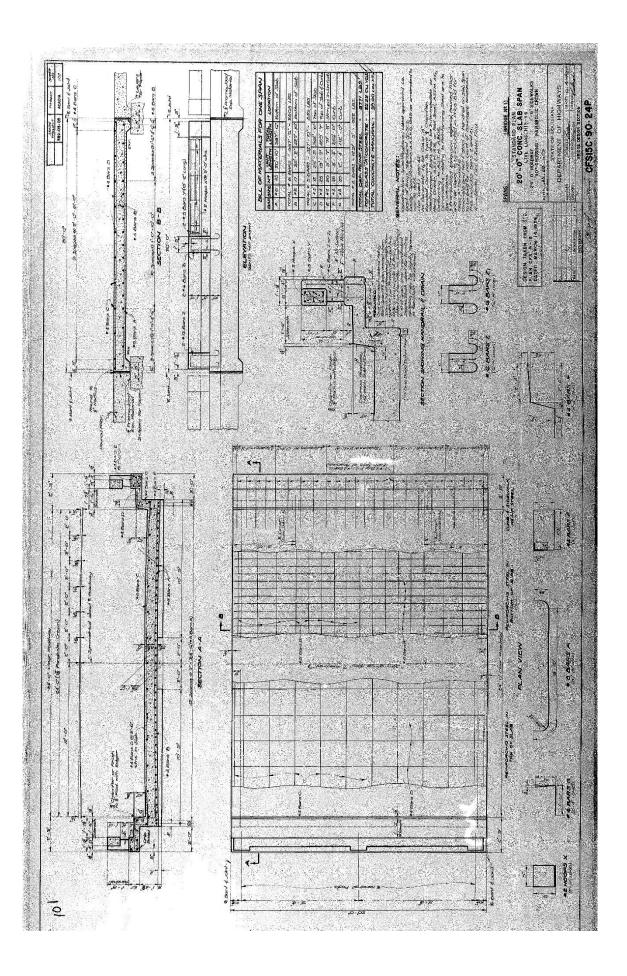


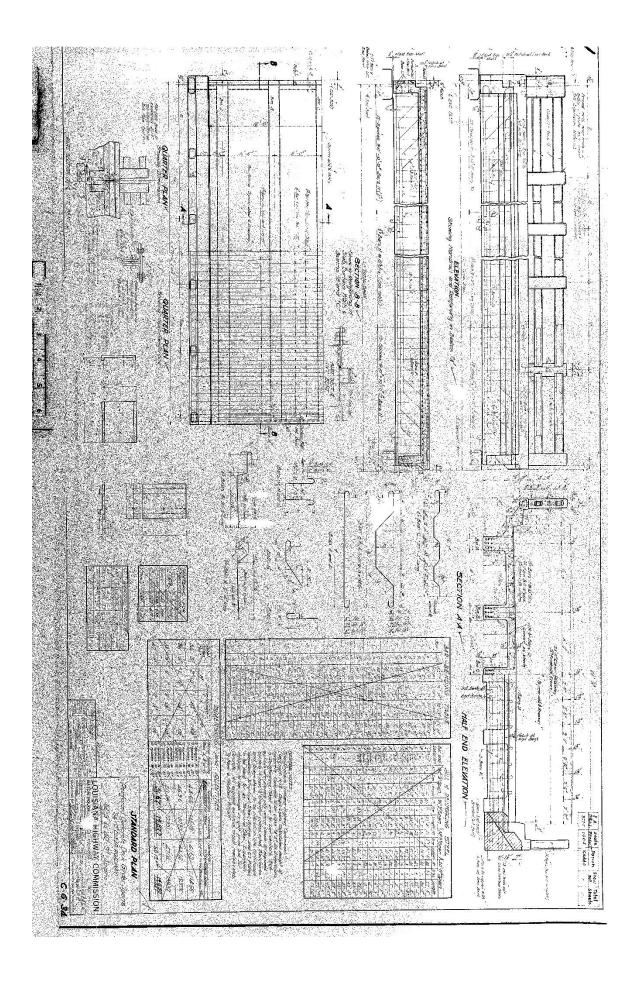


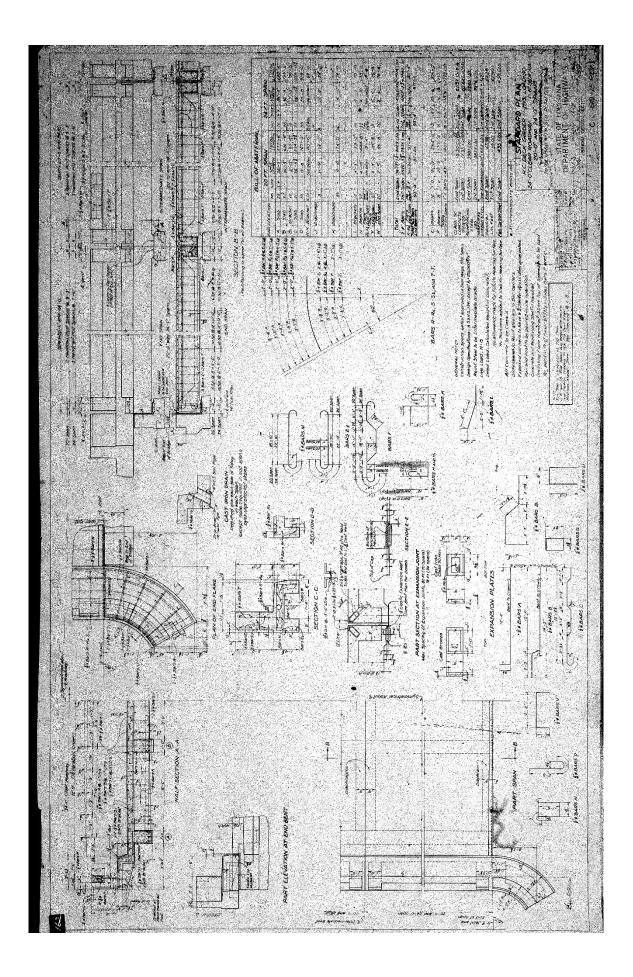


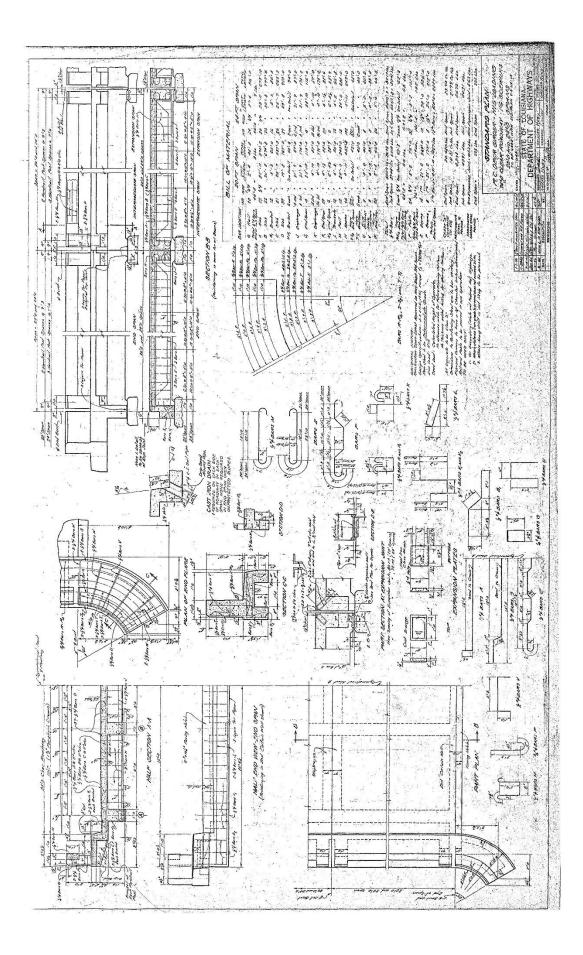


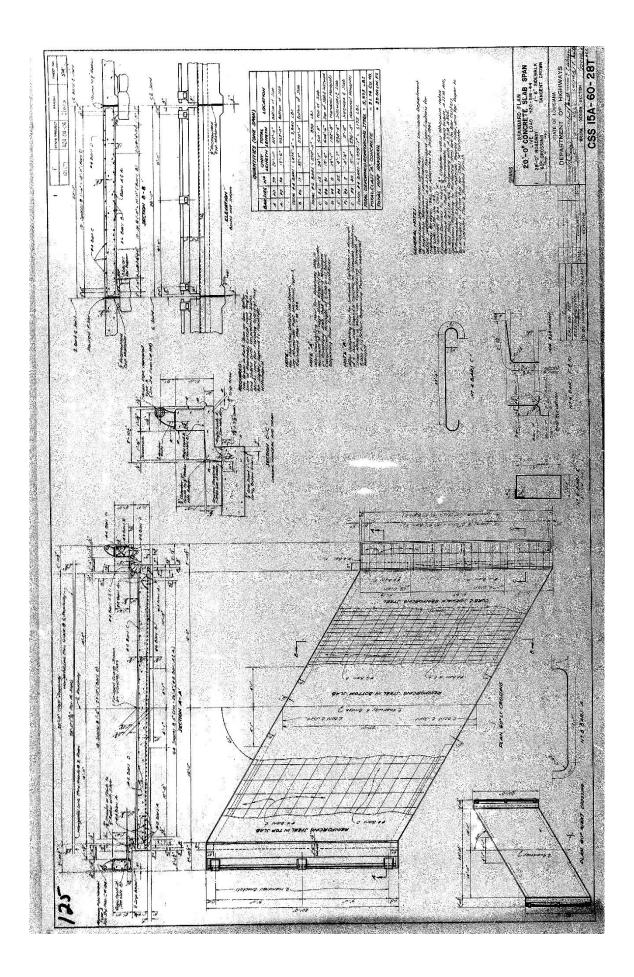


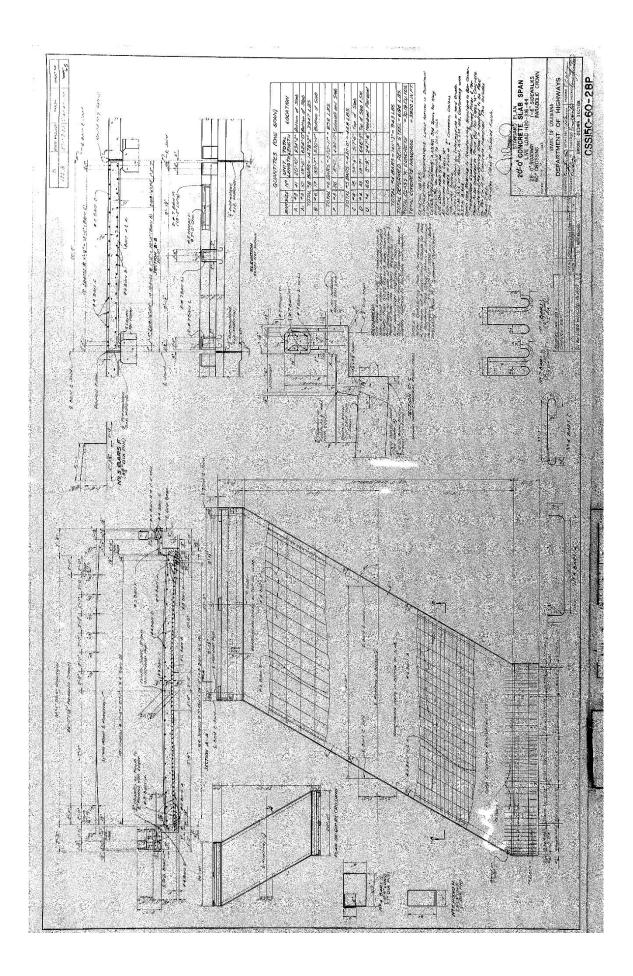


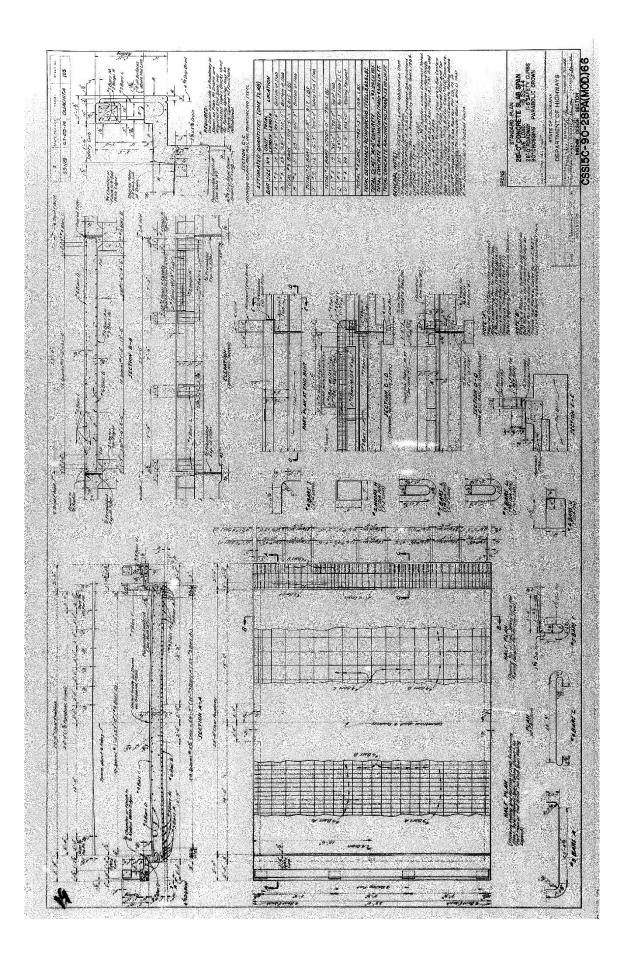


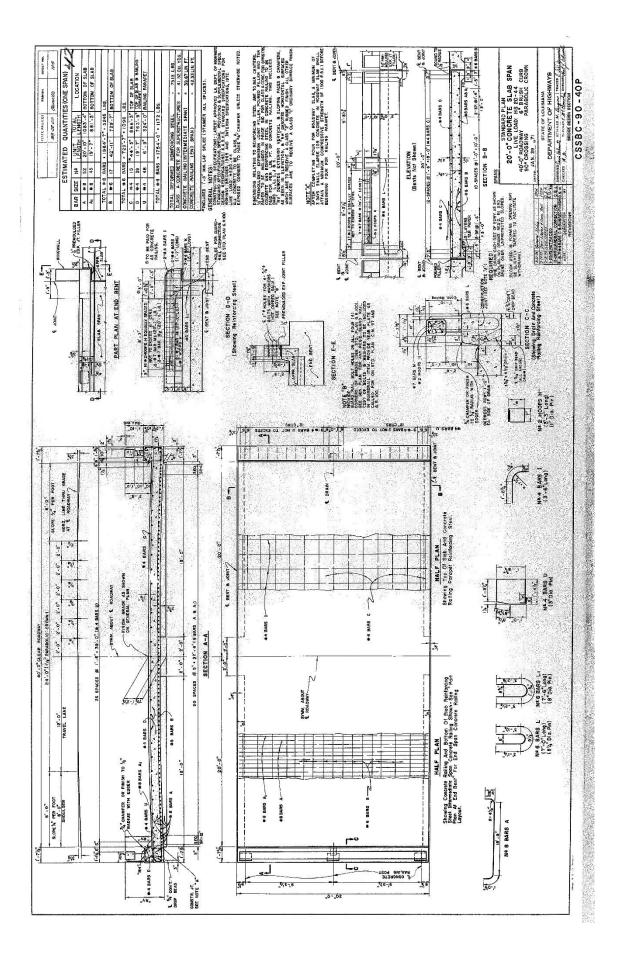


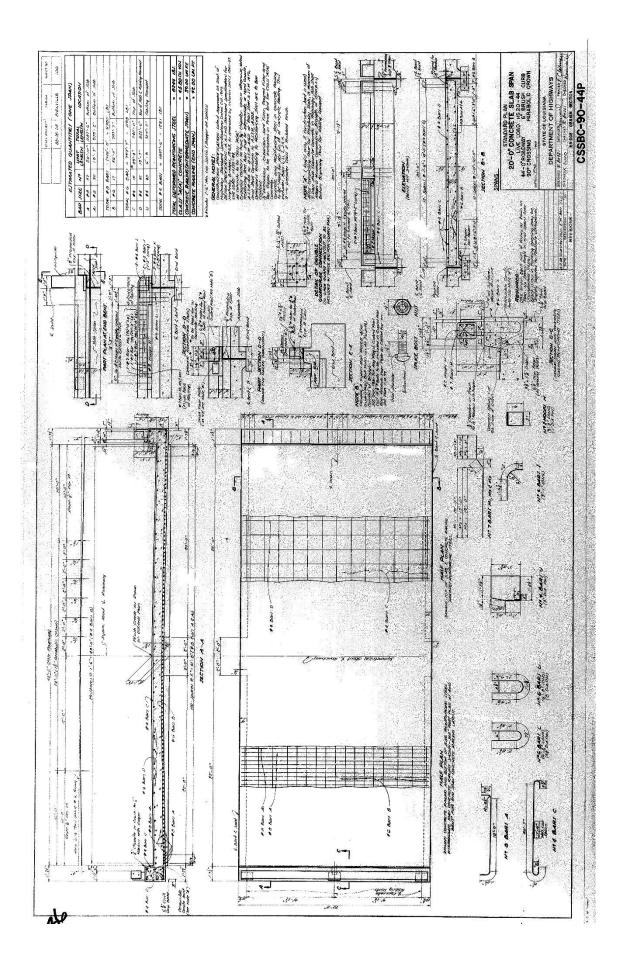


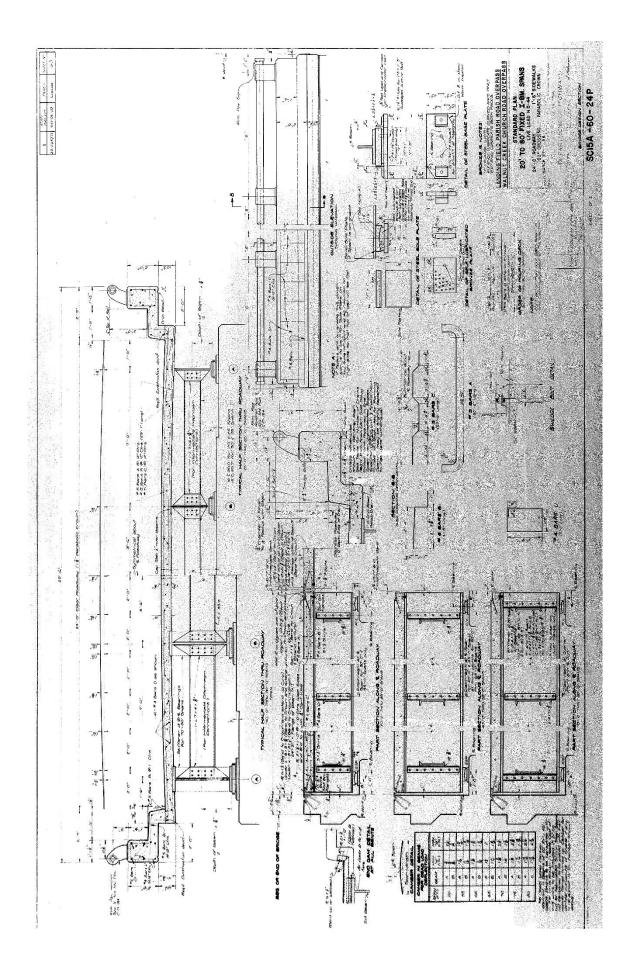


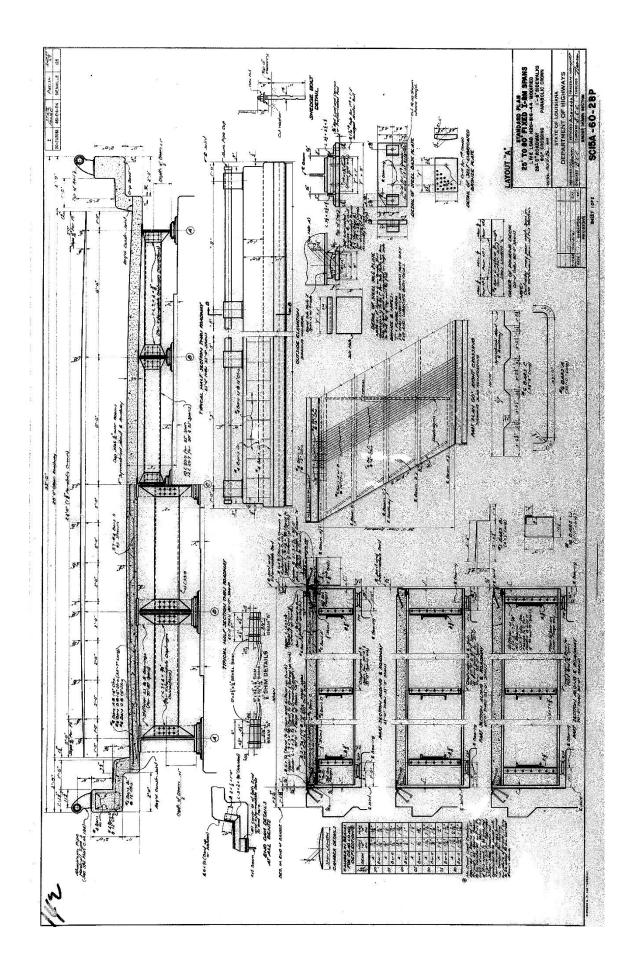


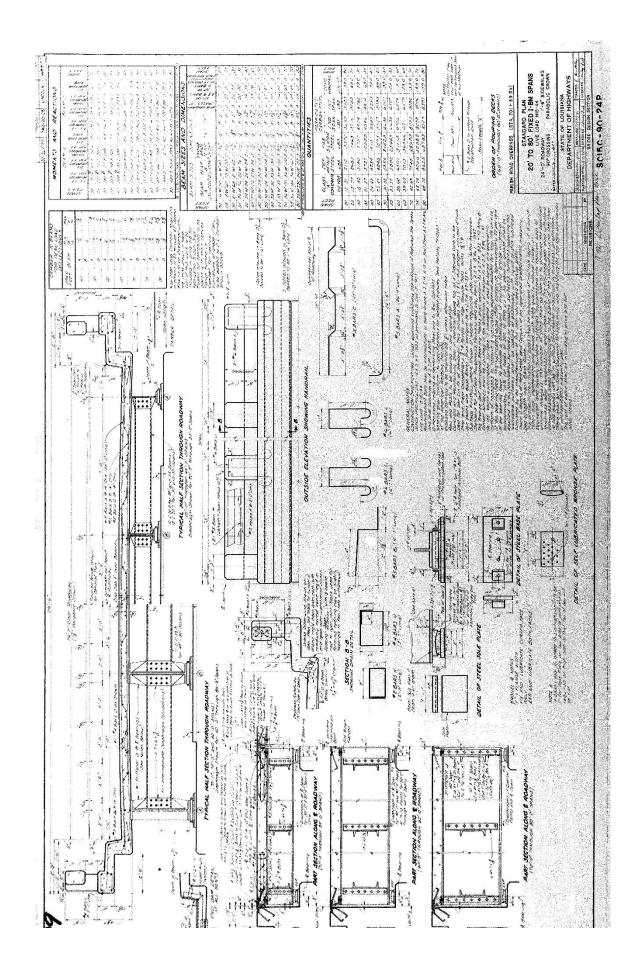


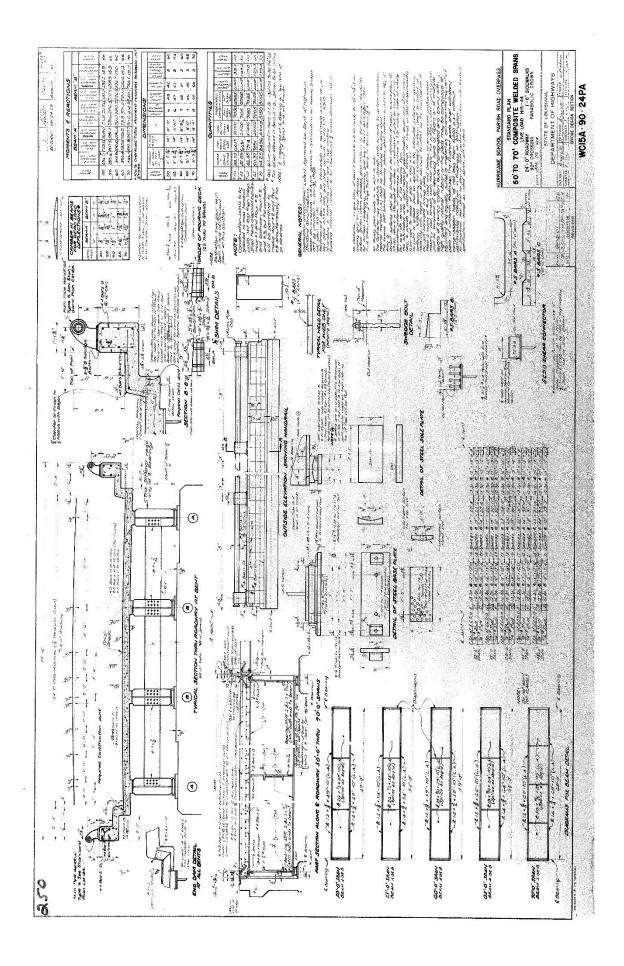


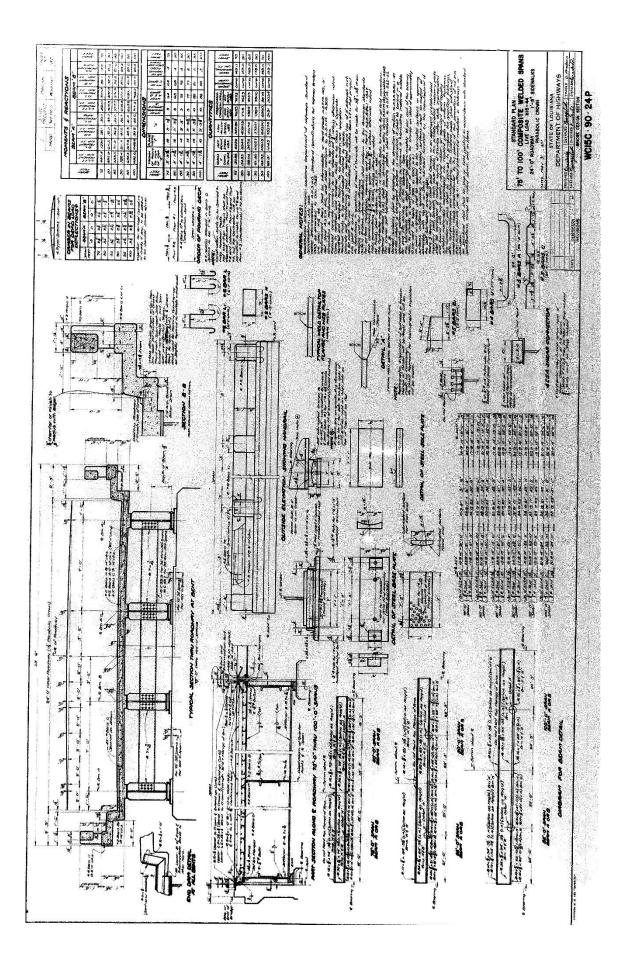




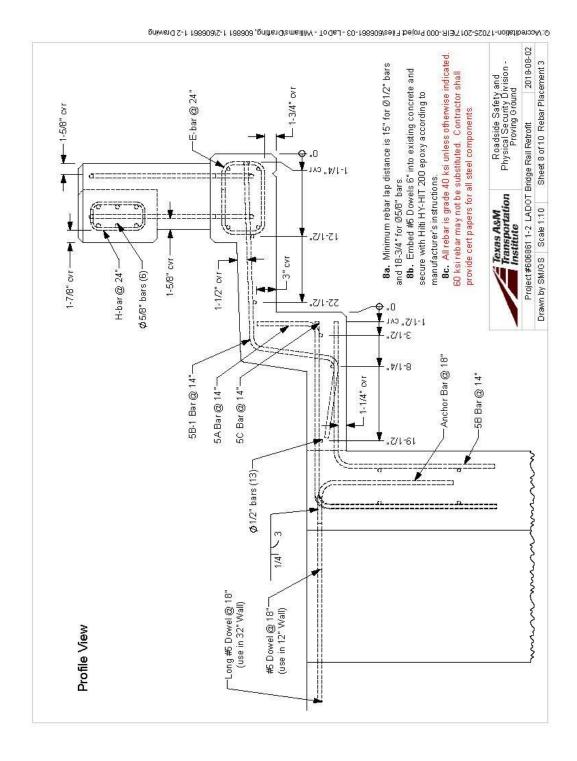


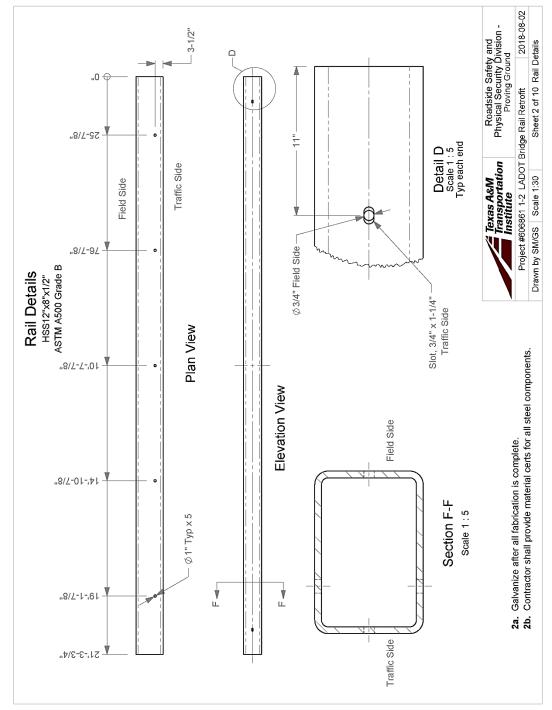




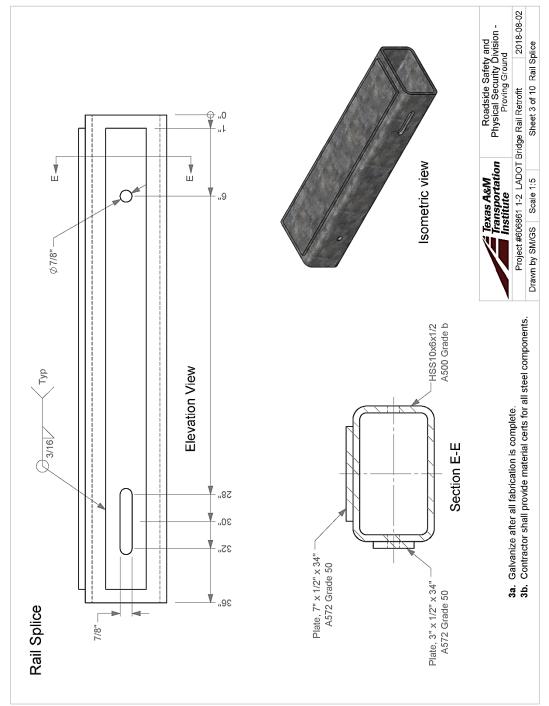


Appendix B. Details of Louisiana Retrofit Post and Beam with Safety Walk for Tests 606861-1&2

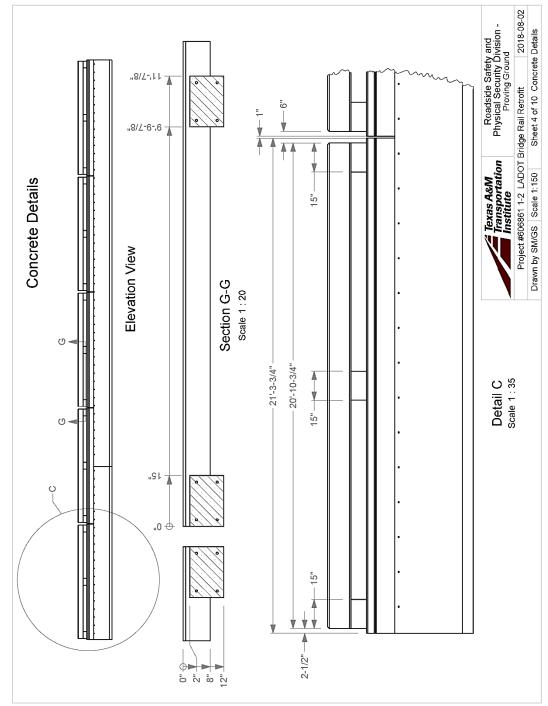




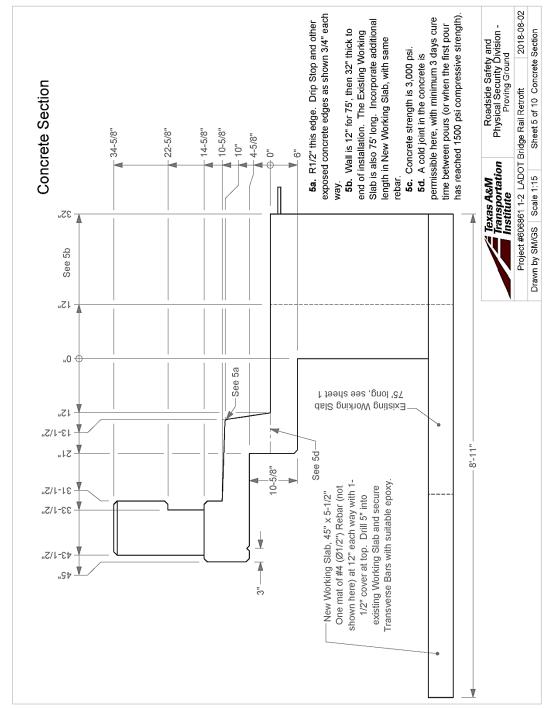
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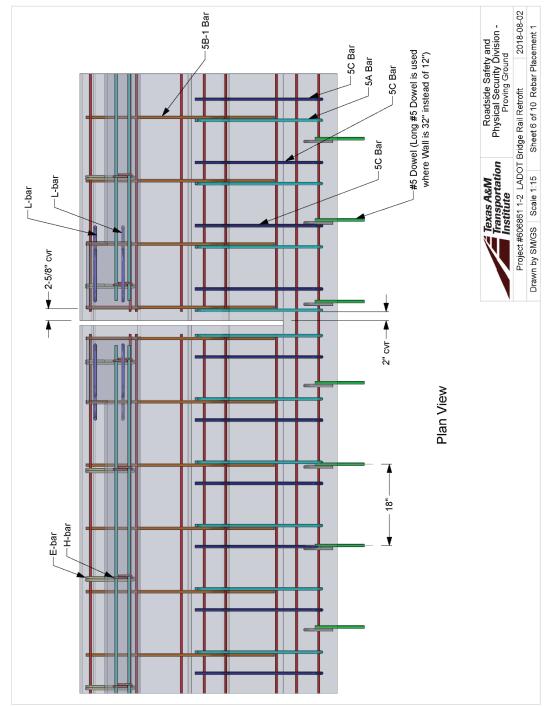
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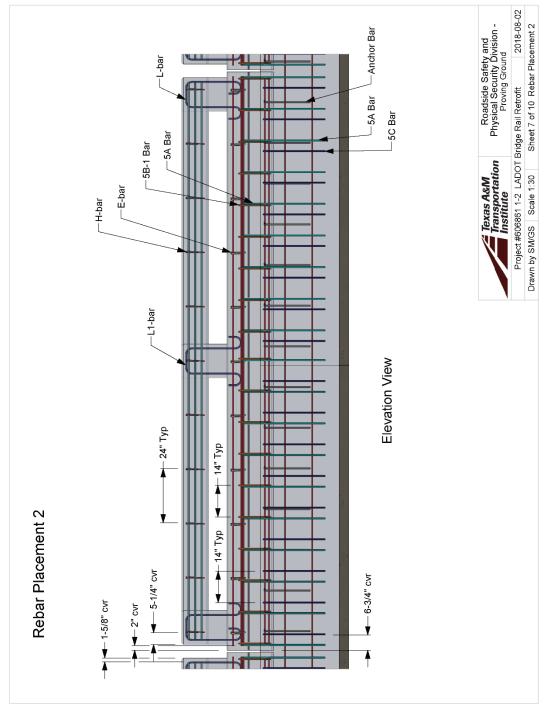
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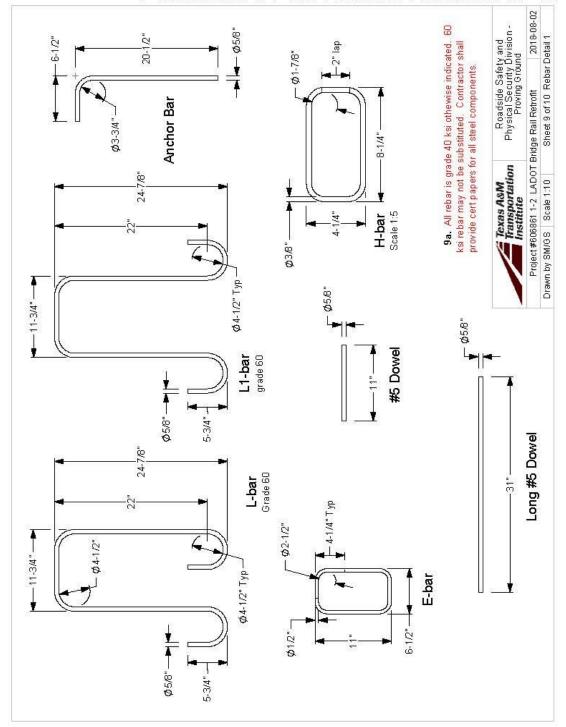
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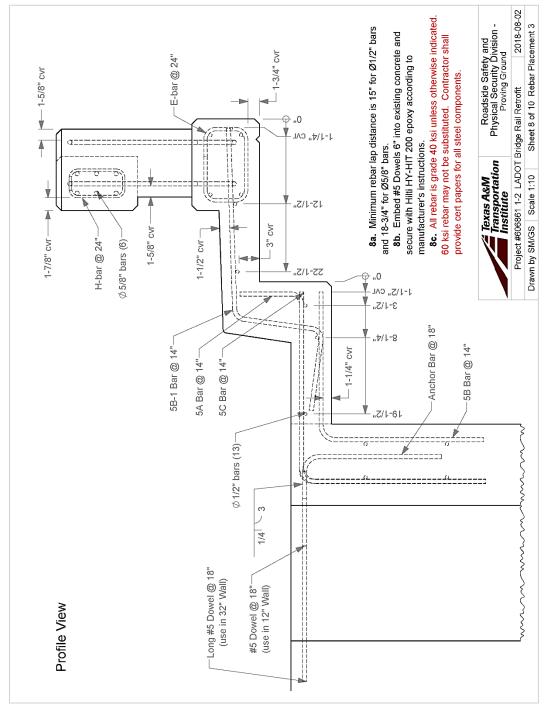
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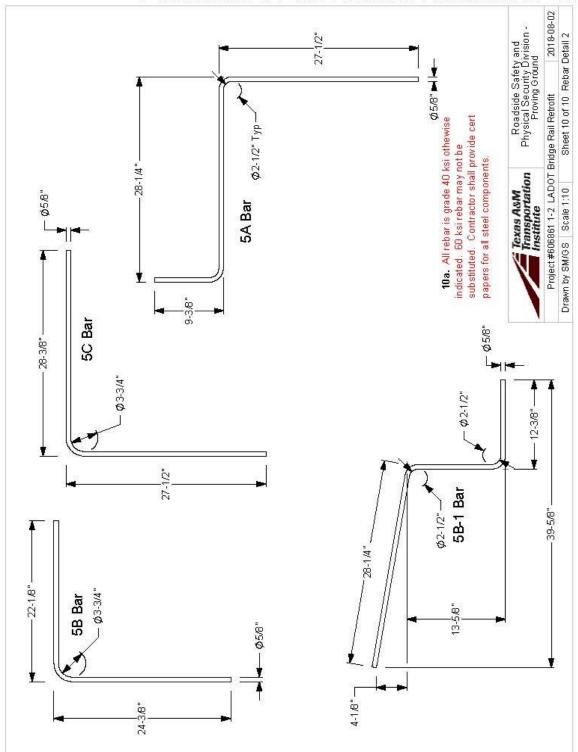
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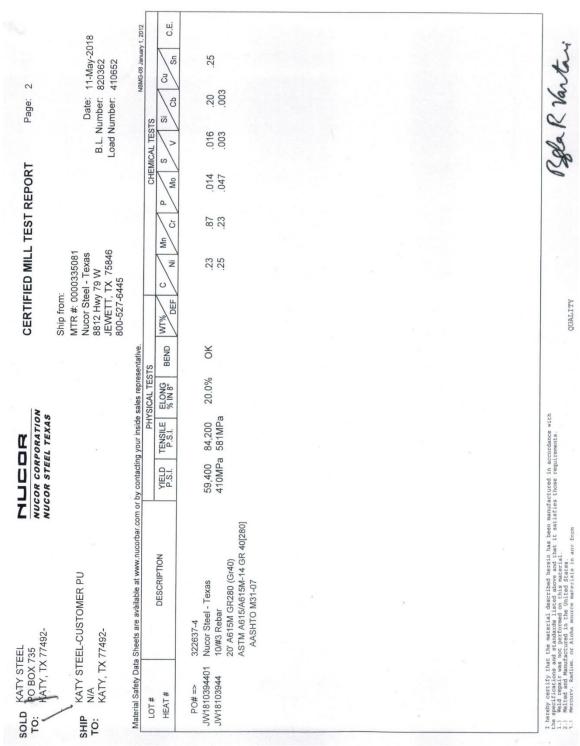
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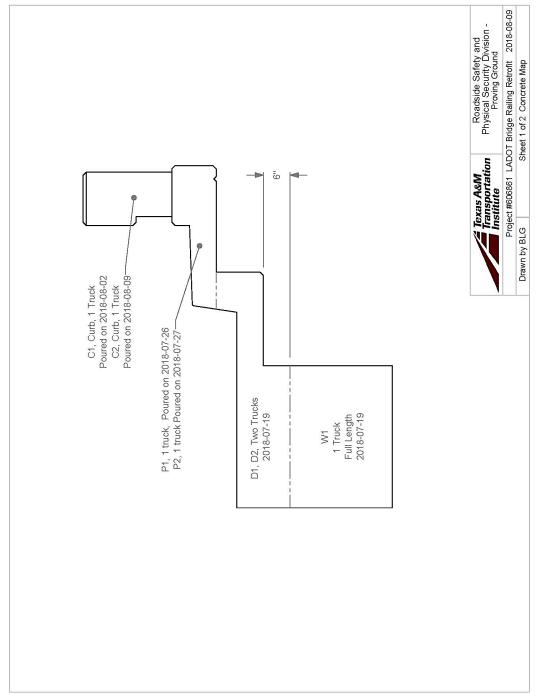


Appendix C. Supporting Certification Documents for Test No. 606861-1&2

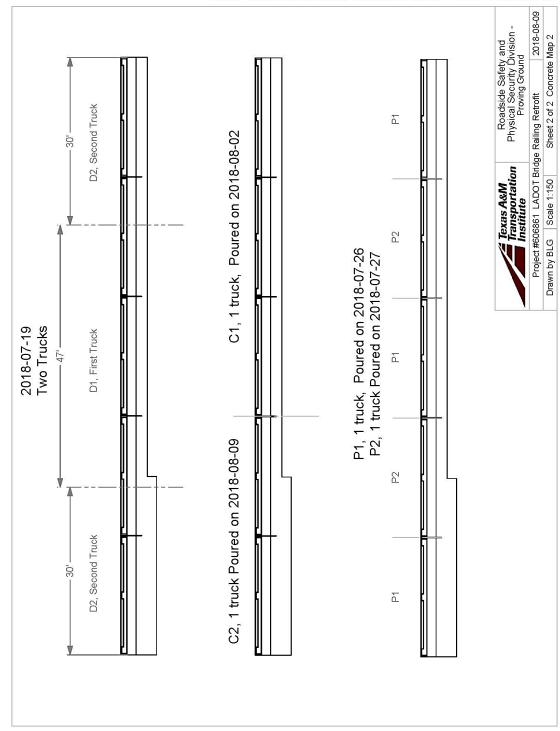
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	Y STEEL COMF BOX 735 Y TX 77492 Y STEEL COMF 1 HW 90 1 HW 90 1 0040B17PA #5 1 NUMBER: 417 8 NUMBER: 417		0	ITION	Mn %	0.5971	HAT THE A CTURED IN all the requi lity Assura	MAILING ADDRESS VINTON STEEL LLC VINTON P.O. BOX 121
	KATY STEEL COMPANY, INC. P. O. BOX 735 KATY TX 77492 KATY STEEL COMPANY 28011 HW 90 KATY TX 77494 KATY TX 77494 Ster NUMBER: 417207 MGR NUMBER: 417207	1 07	48000	COMPOSITION	U %	0.2775	ERTIFY TI MANUFAC steel meets ISGV Qual 20 10/09/20	DRESS EL LLC VI
	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: RV 16040B17PA #5 X 20' GRADE 40 (ASTM A615) (ASTM A615/A615M) DELIVERY LIST NUMBER: P.O. CUSTOMER NUMBER: 417207	HEAT	1820222	CHEMICAL	HEAT NUMBER	1820222	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	WAILING ADDRESS VINTON STEEL LLC VINTON P.O. BOX 12843

The Mart STEEL CUSTOMER PU Marcon STEEL TEXAS WICON STEEL CUSTOMER PU Marcin Street are available at www.nucortar.com or by contacting your inside safes representative. Marcial Safety Data Sheets are available at www.nucortar.com or by contacting your inside safes representative. TeXT # DESCRIPTION PSS. PSS. PSS. PSS. PSS. PSS. PSS. PSS	
KATY, TX 77492- KATY, STEEL-CUSTOMER PU NIA KATY, TX 77492- KATY, TX 77492- ISafety Data Sheets are available at www.nucorbar.com o # 10405701 Nucor Steel - Texas 10405701 Nucor Steel - Texas 10405701 Nucor Steel - Texas 10405701 Nucor Steel - Texas 1040570 16/#5 Rebar 0.031-15 0.031-15 0.031-15	



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





Proving Graun 3100 5H 47, B Brvan, TX 778	d tdg 7091 College Station. TX 77 Phone 979-845-6375	tion	Concrete Samplin	g QPF 5.7.2	Revision Date: 2018-04-17
	ality Policy Form	Pauland have E	3. L. Griffith : D. Kuhn	Revision: 1 6	Page: 1 of 1
Project No:	606261	Casting Date:	2018-07-19	Mix Design (psi):	3000
Printed Name of Technician taking Sample	Cont to	152	Printed Name of Technician breaking Sample	Mitt	Kobinso
Signed Name of Fechnician taking Sample	111	5/20	Signed Name of Technician breaking Sample	L	nL
Load No.	Truck No.	Ticket No.	Locati	on (from concrete	e map)
WI/TI	7108	4850758	100% of	Wall, 6"	from Top
DITZ	8162	4850501	Deck for \$	coment 3 and	1 1/k each way
D2/53	7211	4850572	Deck for No	which fort 1/2 Seg	ment each Sid
Load No.	Break Date	Cylinder Age	Total Load (lbs)	Break (psi)	Average
73	2018-10-02	75 d	4050	114500	•
1	1	,	4025	115500	4008
((3891	110600	1
T2	2010-10-3	751	4527	128000	1 18
	1	1	4772	122500	4486
			4588	120000	1
B 2015-10-2	2018-10-2	250	5359	151500	
i	1	1	5199	147000	5111
			4275	135000	/

			TICK	ET NO.
Marietta Suit	Marie J Freeway e 400 Tx 75234			0972
			National States of the states	And a second sec
LOAD TIME TO JOB ARRIVE JOB SITE BEGIN	POUR	FINISH POUR	LEAVE JOB SITE	ARRIVE PLANT
in the Helle Th	.15	and a serie		
18:19 12 75 11 11 11		• •	•	
WATER ADDED ON JOB AT CUSTOMER'S REQUESTGAL	CUSTOMER	SIGNATURE		
ALLOWABLE WATER (withheld from batch)GAL	X			
TEST CYLINDER TAKEN YES NO BY	_ DELIVER	Y OF THESE M	TERIALS IS SUBJEC	T TO THE TERMS AN
CYLINDER TAKEN BEFORE AFTER WATER		IONS ON THE F JRE ABOVE .	EVERSE SIDE HERI	EOF AS ACCEPTED B
ADDITIONAL WATER ADDED TO THIS CONCRETE WILL REDUCE ITS STRENGTH. ANY WATER ADDED IN EXCESS OF SPECIFIED SLUMP IS AT CUSTOMER'S RISK.				
CUSTOMER NAME AND DELIVERY ADDRESS	PLANT 617	TRUCK ORDER	NO. SLUMP P.	0. #/JOB/LOT GRID
BRYAN CONSTRUCTION C TAMU RIVERSIDE CAMPUS	DRIVER NAM		- Contain the second second second	DATE
		N RAMOS	7/1	
	CUSTOMER M	UMBER PROJE		ORDERED OTY
	509	195 7	1985 - 30.	00 30.00
SPECIAL DELIVERY INSTRUCTIONS SOUTH 2818, RIGHT LEONARD, RIGHT47, I THEV WILL MEET VOL PIGHT THERE	LEFT INT	O RELLIS	ALES TAX	
SPECIAL DELIVERY INSTRUCTIONS SOUTH 2818, RIGHT LEONARD, RIGHT47, THEY WILLMEET YOU RIGHT THERE	LEFT INT	O RELLIS	ales tax total	
SOUTH 2818, RIGHT LEONARD, RIGHT47, I	_EFT INT	O RELLIS		2210013
SOUTH 2818, RIGHT LEONARD, RIGHT47, I THEY WILLMEET YOU RIGHT THERE DANGER! MAY CAUSE ALKALI BURNS. SEE WARNINGS ON REVERSE SIDE. Truck Driver User Disp 7211 38554 user 4850 Load Size Mix Code Returned D 10.00 CYDS BDOTCA00	Ticket 972 ty	FOR OFFICE L FOR OFFICE L Num Tick 6760 Mix Age	TOTAL SE ONLY FORM: et ID Time 4 12:19 Seq Load D 6856	Date 7/19/18 1 ID
SOUTH 2818, RIGHT LEONARD, RIGHT47, I THEY WILLMEET YOU RIGHT THERE DANGERI MAY CAUSE ALKALI BURNS. SEE WARNINGS ON REVERSE SIDE. Truck Driver User Disp 7211 38554 user 4850 Load Size Mix Code Returned D	Ticket 972 ty % 0,50% % 3.70% %	FOR OFFICE L Num Tick 6760 Mix Age store Actual M M 12 M 53 1 M 53 1	TOTAL SE ONLY FORM: at ID Time 4 12:19 Seq Load D 6856 at 1	Date 7/19/18 1 ID 50

AB50758 Freeway 400 x 75234 POUR FINISH POUR LEAVE JOB SITE ARRIVE PLANT 20 12 : 2 : :
FX 75234 POUR FINISH POUR LEAVE JOB SITE ARRIVE PLANT 20 12 2 2 CUSTOMER SIGNATURE X 2 3
POUR FINISH POUR LEAVE JOB SITE ARRIVE PLANT
20 12:25 : ::
x Antique
x Antique
DELIVERY OF THESE MATERIALS IS SUBJECT TO THE TERMS AND CONDITIONS ON THE REVERSE SIDE HEREOF AS ACCEPTED BY SIGNATURE ABOVE .
PLANT TRUCK ORDER NO. SLUMP P.O. #JOB/LOT GRID
DRIVER NAME DATE
VICTOR MARTINEZ 7/19/18
509195 74985 10.00 .30.00
FT INTO RELLIS SALES TAX
FOR OFFICE USE ONLY FORM: 2210010
icket Num Ticket ID Time Date 8 .167601 11:38 7/19/18 Mix Age Seq Load ID D 68557 X Moistore Actual Wat 8.50x M 12 g1 3.70x M 63 g1 *

CUSTOM	ER'S COPY	TICKE	T NO.
Martin Marietta Marietta Marietta Martin M 1503 LBJ Suite Dallas, T	Freeway 400	4850	901
LOAD TIME TO JOB ARRIVE JOB SITE BEGIN P	VUR FINISH POUR	LEAVE JOB SITE	ARRIVE PLANT
18:03	73 :	:	: -
WATER ADDED ON JOB AT CUSTOMER'S REQUESTGAL. ALLOWABLE WATER (withheld from batch)GAL.	CUSTOMER SIGNATURE	Rodnia	4. G
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.	DELIVERY OF THESE M CONDITIONS ON THE SIGNATURE ABOVE .		
CUSTOMER NAME AND DELIVERY ADDRESS	PLANT TRUCK ORDER		#/JOB/LOT GRID
TAMU RIVERSIDE CAMPUS -	DRIVER NAME		DATE
	CHATHAM, DEX CUSTOMER NUMBER PROJE		ORDERED OTY
LOAD QUANTITY PRODUCT CODE DESCRIPTION	509195 7	4925 20.0	0 30.00
SPECIAL DELIVERY INSTRUCTIONS BOUTH 2818, RIGHT LEONARD, RIGHT47, LE	FT INTO RELLIS	SALES TAX	
THEY WILLMEET YOU RIGHT THERE	IT INTO RELETO	TOTAL	a line and
DANGER! MAY CAUSE ALKALI BURNS. SEE WARNINGS ON REVERSE SIDE.	FOR OFFICE U	SE ONLY FORM: 2	210012
			·····
0162 37791 user 485090 Load Size Mix Code Returned Gty 10.00 CYDS BDOTCA00 I Material Design Bty Required Batched X Var 157 1931 1b 19407 1b 19408 1b -0,004 10 1376 1b 19407 1b 19408 1b -0,004		3 12:03 ¹ 7 Seq Load D 68559 at	
1 293 16 2930 16 2940 16 6.344 8 158 15 1580 16 1590 16 6.345 900 202 20 2 22 02 22 02 -1.785 H20 242 16 1653 16 1655 16 6.178 P80 7 02 # 146 02 146 02 0.003 Actual Num Batches: 1 Load Total: 39875 16 Design 0.537 Water/Cement 0.534 T Slump: 5.00 in Water in Truck: 0.0 gl Adjust Water: 0.			To Add: 16.6 gl

Proving Gri 3100 SH 4 Brvan TX 3	And 7, Bidg 7091 7807 7807 7807 7807 7807 7807 7807 780	ation	5.7.2	Concrete Samplir		Revision Date: 2018-04-17
Quality Policy Form			Revised by: I Approved by	3. L. Griffith : D. Kuhn	Revision: 6	Page: 1 of 1
Project N	o: 606861	Ca	sting Date	2018-7-26	Mix Design (psi	3000
Printed Name Technician takin Samp Signed Name Technician takin	ng Gregs Fri	72 5-6		Printed Name of Technician breaking Sample Signed Name of Technician breaking	mai	ta Robi
Samp	Truck No.	Tie	ket No.	Sample	on (from concre	te man)
P/	7/2 4		5630			th Segments
Load No.	Break Date	Cylii	nder Age	Total Load (lbs)	Break (psi)	Average
PI	2018-10-2	68	2	5055	151500	1
1	1			5355	151500	5235
				4987	14/000)

Martin Marietta	CUSTOM Martin M 1503 LBJ Suite Dallas, T	Arietta Freeway 400	4865	E 30
LOAD TIME TO JOB ARRIVE JO	B SITE BEGIN P	OUR FINISH POUR	LEAVE JOB SITE	ARRIVE PLANT
8:37 8:4 9:	13 9:	16 :	:	:
WATER ADDED ON JOB AT CUSTOMER'S REQUEST	GAL.	CUSTOMER SIGNATURE		-
ALLOWABLE WATER (withheld from batch) TEST CYLINDER TAKEN YES NO BY CYLINDER TAKEN BEFORE AFTER WATE ADDITIONAL WATER ADDED TO THIS CONCRE ITS STRENGTH. ANY WATER ADDED IN EXCE SLUMP IS AT CUSTOMER'S RISK.	TE WILL REDUCE	LX DELIVERY OF THESE MATI CONDITIONS ON THE REV SIGNATURE ABOVE .	ERIALS IS SUBJECT /ERSE SIDE HEREO	TO THE TERMS ANI F AS ACCEPTED B'
CUSTOMER NAME AND DELIVERY ADDRESS		PLANT TRUCK ORDER NO.	SLUMP P.O. #	JOB/LOT GRID
TAMU RIVERSIDE CAMPUS		DRIVER NAME		DATE
		ANTHONY WOODS CUSTOMER NUMBER PROJECT	7/26 CUM. QTY	
LOAD QUANTITY PRODUCT CODE DESCRIPTION		5091951 749	25 7.0	0 7.00/
SPECIAL DELIVERY INSTRUCTIONS SOUTH 2818, RIGHT LEONARD R RELLIS THEY WILL MEET YOU	D, RIGHT HWY AT THE ENTRA	47, LEFT INTO J	S TAX	
	and the second second second			
DANGER! MAY CAUSE ALKALI BURNS. SEE WARNINGS ON REVERSE SIDE.		FOR OFFICE USE	ONLY FORM: 2	210202
DANGER: MAY CAUSE ALKALI BURNS. SEE WARNINGS ON REVERSE SIDE.		FOR OFFICE USE	ONLY FORM: 2	210202

Proving Gro 3100 SH 47 Brvan, TX 7	And Bisdg 7091 7807 Rest Add Linversit College Station, TX - Phone 979-845-8375	ation	Concrete Samplin		Revision Date: 2018-04-17
	ality Policy For	Revised	by: B. L. Griffith d by: D. Kuhn	Revision: 6	Page: 1 of 1
Project No Printed Name o Technician takin Signed Name o Technician takin Samp	g Gres FRI		ate: <u>2018-7-22</u> Printed Name of Technician breaking Sample Signed Name of Technician breaking Sample	max.	
Load No.	Truck No.	Ticket No.	Locat	ion (from concret	e map)
P2	7139	4869230	5 2 segment,	Mid Sark,	M.d North
Load No.	Break Date	Cylinder Ag	e Total Load (lbs)	Break (psi)	Average
PZ	2018-10-2	67	4156	117500	
P2	1	1	3997	113000	4050
122			3557	113000	

	14 al			CUSTOM	ER'S COF	ΡY			FICKET NO.	
	Martin Marietta	N	15	tin N 503 LBJ Suite Dallas, T>	Freewa 400	ay	Touristing and the second seco	A contraction A cont		
LOAD TIME	TO JOB	ARRIVE JOB	SITE	BEGIN PO	DUR	FINISH	POUR	LEAVE JOB S	ITE AR	RIVE PLANT
9:03	9:13	:		:			:	:		:
ALLOWABLE WATE TEST CYLINDER TA CYLINDER TAKEN ADDITIONAL WA	BEFORE D TER ADDED TO TH ANY WATER ADDE	D BY AFTER WATER IS CONCRETI			X DELIVE CONDIT	RY OF TH TIONS ON TURE ABO	IESE MATE N THE REV	RIALS IS SUB Erse side h	JECT TO THE	E TERMS AN CCEPTED B
	D DELIVERY ADDRESS				PLANT 6.1		ORDER NO. 9 20	SLUMP 18 5.0		GRID
		1			CUSTOMER		UC ars PROJECT	CUM. OTY	DATE	REDOTY
			N				7498			5,00
SPECIAL DELIVERY INS SOUTH 28 RELLIS T	TRUCTIONS 18, RIGHT LE HEY WILL MEE	ONARD RD T YOU A	, RIG T THE	HT HWY ENTRAI	47, 1 NCE	EFT I	NTO SALES			
DANGER! MAY CAU SEE WARNINGS OF						FOR O	FFICE USE (2204	892
										*
5.00 CY Naterial I 157 10 8 900 900	1931 1b 967 1374 1b 710 293 1b 146 158 1b 79 2 oz 1	uired Ba 9 1b 9 4 1b 7 5 1b 1 8 1b 1 8 2 9 9 2	rned 1729 lb 160 lb 480 lb 190 lb 19 oz	4859230 Gty X lar 6,42% 0.78% 1.62% 0.98% -4.52%		Mix A sture A	67863 ge 5 I tual Wat 3 gi 28 gi	ID Time 9:03 Seq Lo) 68	7/27/1 ad ID 839	B BUP
H20 P90 Actual Load Total: Slump: 5.00	242 1b 87 7 oz 8 7 Nue Batches: 1 20034 1b Desi in Water in T	3 0Z	879 15 74 oz	0.31% 0.95% 0.533 T Water: 0.0) gl / L	sign 145.0 pad Tris	105 gl gl Water: -1.	Actual 136.6 8 gl/ CYD	70000	7

Proving Gro 3100 SH 42 Brvan TX 2	ound 7, Bidg 7091 7, Bidg 7, Bid	ation	5.7.2 0	Concrete Sampli		Revision Date: 2018-04-17
	uality Policy For		Revised by: B Approved by:	. L. Griffith D. Kuhn	Revision: 6	Page: 1 of 1
Project No	o: 606361	Cas	ting Date:	2018-02-02	Mix Design (ps	ii): <u>3000 psi</u>
Printed Name Fechnician takin Samp Signed Name	ng GREG	FRI	T2 -1	Printed Name of Technician breaking Sample Signed Name of	mat	t Robir
Fechnician takir Samp	ng	rk	hy	Technician breaking Sample		91 m
Load No.	Truck No.	Tic	ket No.	Locat	tion (from conc	ete map)
T/	8163	4882	854	3 Parapel	ts on Ris.	ht Side
Load No.	Break Date	Cylin	der Age	Total Load (lbs)	Break (psi)	Average
T/	2012-10-2	61	days	4280	121000	1
TI	1		1	3997	113000	4025
71			1	3929	112500	(
			-			

CUSTON	MER'S COPY
Marietta 1503 LB. Suite	Warietta 4882854 J Freeway 4882854 e 400 7x 75234
LOAD TIME TO JOB ARRIVE JOB SITE BEGIN	POUR FINISH POUR LEAVE JOB SITE ARRIVE PLANT
13:35 1:43 2:00 2:	
WATER ADDED ON JOB AT CUSTOMER'S REQUEST	X DELIVERY OF THESE MATERIALS IS SUBJECT TO THE TERMS AN
CYLINDER TAKEN DEFORE 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.	CONDITIONS ON THE REVERSE SIDE HEREOF AS ACCEPTED E Signature above .
CUSTOMER NAME AND DELIVERY ADDRESS BRYAN CONSTRUCTION C	PLANT TRUCK ORDER NO. SLUMP P.O. #/JOB/LOT GRID 617 8163 2033 5,0 292
TAMU RIVERSIDE CAMPUS	DRIVER NAME DATE
	CLARK, BARY 8/2/18 CUSTOMER NUMBER PROJECT CUM. GTY ORDERED GTY
LOAD QUANTITY PRODUCT CODE DESCRIPTION	509195 74925 3.00 3.00 UNITPRICE AMOUNT
SPECIAL DELIVERY INSTRUCTIONS HWY 21 WEST, LEFT INTO RELLIS THEY WILL THERE SITTING IN A SILVER CHEVROLET TO	- MEET YOU RUCK TOTAL
DANGER! MAY CAUSE ALKALI BURNS.	0005111
SEE WARNINGS ON REVERSE SIDE.	FOR OFFICE USE ONLY FORM: 2205141
8163 37794 user 488285	Mix Age Seq Load ID D 69090 % Moisture Actual Hat 0.40% M 2i gl 58 gl

		ality Policy Form	Revised by: B Approved by:	D. Kuhn	Revision: 6	Revision Date: 2018-04-17 Page: 1 of 1
	Project No: Printed Name of Technician taking Sampled Signed Name of Technician taking Sample	GREG	Casting Date: FRIT2 The	Dill-08-09 Printed Name of Technician breaking Sample Signed Name of Technician breaking Sample	Mix Design (psi	ta Robinson
No No-Order	Load No.	Truck No.	Ticket No. 4879231) ·	on (from concre	16 161
	······································	£116		d femsian	· /	(South S. d.)
F	Load No.	Break Date	Cylinder Age	Total Load (lbs) リアリ	Break (psi)	Average 1
-	$\frac{c}{c}$	2018-10-2	47 kgys	4103	118000 116000	4002
F	$\overline{\zeta}$	2012-10-2	1	373/	105500	
ŀ	, ind	AUTO A		<u> </u>	/////	
	-					
· -						
-				; 		
-						
		`				
. –		•				
F						
F						

CUSTOM	ER'S COPY	TICKI	ET NO.
Martin Marietta Marietta Marietta Martin M 1503 LBJ Suite Dallas, Tr	Freeway 400	4899	9231 R#1
LOAD TIME TO JOB ARRIVE JOB SITE BEGIN P	i A	LEAVE JOB SITE	ARRIVE PLANT
12:09 12:19 16:35 16:	40 .	:	:
WATER ADDED ON JOB AT CUSTOMER'S REQUESTGAL.			
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.		MATERIALS IS SUBJEC Reverse side here	
CUSTOMER NAME AND DELIVERY ADDRESS BRYAN CONSTRUCTION C	PLANT TRUCK ORDE		, #/JOB/LOT GRID
TAMU RIVERSIDE CAMPUS	DRIVER NAME		DATE
THE TREATES STUDIES A			/18
THE TAXY DECIMAL TO BE SETTING TO THE SECOND	HOUSE, JOHN CUSTOMER NUMBER PRO	JECT CUM. QTY	ORDERED QTY
LOAD QUANTITY PRODUCT CODE DESCRIPTION 3.00 CYDS BDDTCA00 CLASS A	CUSTOMER NUMBER PRO		
LOAD QUANTITY PRODUCT CODE DESCRIPTION	CUSTOMER NUMBER PRO. 509195	иест сим. ату 74925 3. I	3.00
LOAD QUANTITY PRODUCT CODE DESCRIPTION 3,00 CYDS BDUTCA00 CLASS A SPECIAL DELIVERY INSTRUCTIONS HWY 21 WEST, LEFT INTO RELLIS THEY WILL ARCIUND THERE	CUSTOMER NUMBER PRO. 509195	JECT CUM. OTY 74925 3. I UNITPRICE SALES TAX TOTAL	and 3.00
LOAD QUANTITY PRODUCT CODE DESCRIPTION 3.00 CYDS BDUTCA00 CLASS A SPECIAL DELIVERY INSTRUCTIONS HWY 21 WEST, LEFT INTO RELLIS THEY WILL	CUSTOMER NUMBER PRO. 509195	JECT CUM. OTY 74925 3. 1 UNIT PRICE SALES TAX	anount

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

Date: 20)18-10-02	Test No.:	606861	-1	VIN No.:	1C6	RD6GT>	KCS26	8732
Year:	2012	Make:	RAM		Model:		150	00	
Tire Size:	265/70 R 17			Tire I	nflation Pre	ssure:	;	35 ps	
Tread Type:	Highway				Odo	meter: 2	268732		
Note any dam	age to the ve	hicle prior to te	est: None						
 Denotes ac 	celerometer	ocation.		[<	-			
NOTES: Nor	ne		1		TIT		<u> </u>	<u> </u>	•
				(
Engine Type: Engine CID:	V-8 4.7 liter		A M -						N T
Transmission	-	1					-TEST INERTIAL	LC.M.	
↓ Auto ↓ FWD	or L	Manual		R PQ					
Optional Equij None	oment:						°		B
Dummy Data: Type: Mass: Seat Positior	50th perc	entile male 35 lb de	Ţ 1 <u></u> 1₹	F F	U- H- M		-HO) -S		FK. L
Geometry:	inches]: •	FRONT	- C	READ	R.	
A78.5	50 F	40.00	К	20.00	P _	3.0	0	υ	26.50
B74.0		28.50	L	30.00	Q	30.5		V	30.25
C227.5		61.30	Μ	68.50	- R	18.0		W	61.30
D44.0		11.75	N	68.00	S	13.0		X	78.00
E 140.5 Wheel Cent	er	27.00 14.75 Clea	O Wheel Well	46.00	_ Т 6.00	77.C Bottom	Frame		12.50
Height Fro Wheel Cent			arance (Front) - Wheel Well			Bottom	- Front		March
Height Re		14.75 Clea 13 inches; E=148 ±12 ir	arance (Rear) _		9.25	-	- Rear	(2=67 ±1 6	22.50
GVWR Rating		Mass: Ib	Curb	es, G = 2 20 II		nertial		Gross	
	700	Mfront		930	1651	2826	2	01055	2911
	900	Mrear	-	053	-	2189	-		2269
	700	MTotal	1	983		5015	-		5180
Mass Distrib					Range for TIM and			4	
lb	LF:	1388	RF:1	438	LR:	1108	_ RR:		081

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

Date: 2018-	10-02 T	est No.: _	60686	1-1	VIN:	1C6RD6G	TXCS26873	32
Year:20*	12	Make:	RAN	1	Model:	1	1500	
Body Style: _C	ad Cab				Mileage:	268732		
Engine: <u>4.7 lit</u>	er '	V-8		Tran	smission:	Automatic		
Fuel Level: E	mpty	Ball	last: _171				(440) Ib max)
Tire Pressure:	Front:	35 ps	i Rea	ar: <u>35</u>	psi S	Size: _265/70 R	17	
Measured Vel	nicle Wei	ghts: (I	b)					
LF:	1388		RF:	1438		Front Axle	: 2826	
LR:	1108		RR:	1081		Rear Axle	: 2189	
Left:	2496	_	Right:	2519		Total	: 5015	
						5000 ±	110 lb allowed	
VV h	eel Base:	140.50	inches	Track: F:	68.50	inches R	: 68.00	inches
	148 ±12 inch	es allowed			Track = (F+F	R)/2 = 67 ±1.5 inche	s allowed	
Center of Gra	vity, SAE	J874 Sus	pension M	ethod	-			
X:	61.33	inches	Rear of F	ront Axle	(63 ±4 inche	s allowed)		
Y:	0.16	inches	Left -	Right +	of Vehicle	e Centerline		
Z:	28.50	inches	Above Gr	ound	(minumum 2	8.0 inches allowed)		
Hood Heig	ıht:	46.00	inches	Front	Bumper H	eight:	27.00 i	nches
	1	nches allowed				U		
Front Overha	ng:	40.00	inches	Rear	Bumper H	eight:	30.00 i	inches
	39 ±3 i	nches allowed						

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

Overall Length: <u>227.50</u> inches 237 ±13 inches allowed Figure 108. Sequential photographs for Test No. 606861-1 (overhead view).



0.000 s



0.100 s



0.400 s



0.500 s



0.200 s



0.300 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







0.400 s



0.500 s



0.600 s



0.700 s

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



0.000 s



0.400 s



0.100 s



0.500 s



0.200 s



0.600 s



0.300 s



0.700 s

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

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

VEHICLE CRUSH MEASUREMENT SHEET¹

Complete Wh	en 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)	X1+X2
< 4 inches	2
\geq 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.

G		Direct Damage									
Specific Impact Number	Plane* of C-Measurements	Width*** (CDC)	Max*** Crush	Field L**	C_1	C ₂	C_3	C4	C5	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							-			

¹Table 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.

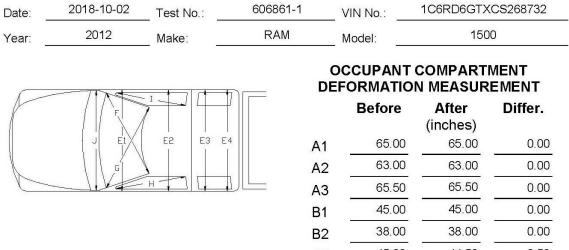
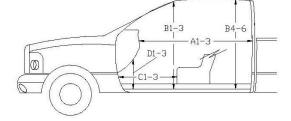
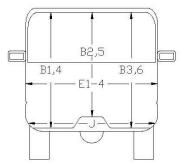


Figure 112. Occupant compartment measurements for Test No. 606861-1

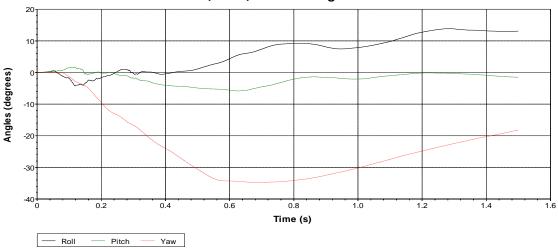




*Lateral area across the cab from driver's side kickpanel to passenger's side kickpanel.

DEF	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							
Н	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



Roll, Pitch, and Yaw Angles

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

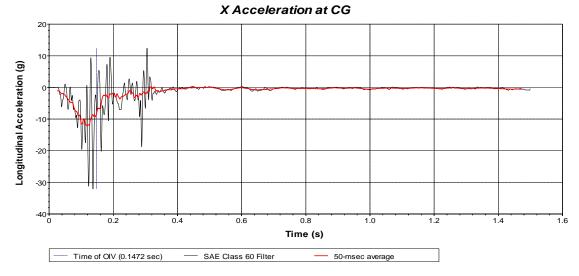


Figure 115. Vehicle lateral accelerometer trace for Test No. 606861-1 (accelerometer located at center of gravity)

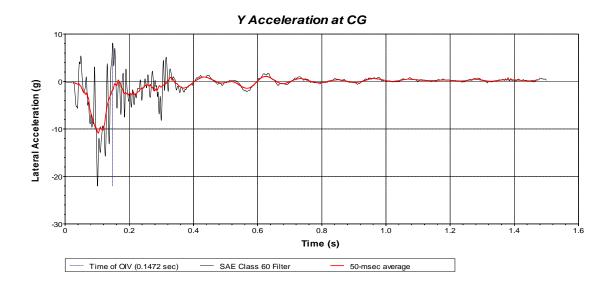
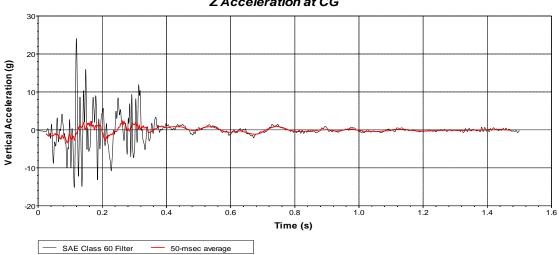


Figure 116. Vehicle vertical accelerometer trace for Test No. 606861-1 (accelerometer located at center of gravity)



Z Acceleration at CG

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

Date:	2020-12-11	_ Test No.:	606861-4	VIN No.:	3N1CN7APOEL862280
Year:	2014	Make:	NISSAN	Model:	VERSA
Tire Inf	lation Pressure: <u>36</u>) PSI	Odometer: <u>91861-4</u>		Tire Size: <u>P185/65R15</u>
Descrit	be any damage to th	ne vehicle prio	r to test: <u>None</u>		
Deno NOTES		location.			
Engine Transm	CID: <u>1.6 L</u> nission Type: Auto or <u>✓</u> FWD <u>□</u> RWD al Equipment:] 4WD		R	
Dummy Type: Mass: Seat F	50th Perce	entile Male		H_S WE	
Geome	etry: inches				-
A <u>66.7</u>	<u>70 </u>	2.50	K <u>12.50</u>	P <u>4.50</u>	U <u>15.50</u>
B <u>59.6</u>	<u> </u>		L <u>26.00</u>	Q <u>24.0</u>	0 V <u>21.25</u>
C <u>175</u>	. <u>40 H 42</u>	2.15	M <u>58.30</u>	R <u>16.2</u>	5 W <u>42.10</u>
D <u>40.5</u>			N <u>58.50</u>	S <u>7.50</u>	
E <u>102</u>			O <u>30.50</u>	T <u>64.5</u>	
	eel Center Ht Front	C = 169 ±8 inches; E =	Wheel Center Ht = 98 ±5 inches; F = 35 ±4 inches; H = inches; W-H < 2 inches or use MASH I	: 39 ±4 inches; O (D W-H -0.05 Top of Radiator Support) = 28 ±4 inches
GVWR	Ratings:	Mass: Ib	Curb	Test I	nertial Gross Static
Front	1750	Mfront	1369	1425	1510
Back	1687	M _{rear}	974	979	
Total	3389	MTotal	2343	2404	2569
Mass I Ib	Distribution:	706	Allowable TIM = 242 RF: <u>719</u>	0 lb ±55 lb Allow LR: <u>502</u>	able GSM = 2585 lb ± 55 lb RR: <u>477</u>

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

0.000 s



0.100 s



0.400 s



0.500 s



0.200 s



0.300 s



0.600 s



0.700 s

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



0.000 s



0.300 s



0.100 s



0.200 s

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



0.400 s



0.600 s



0.500 s



0.700 s

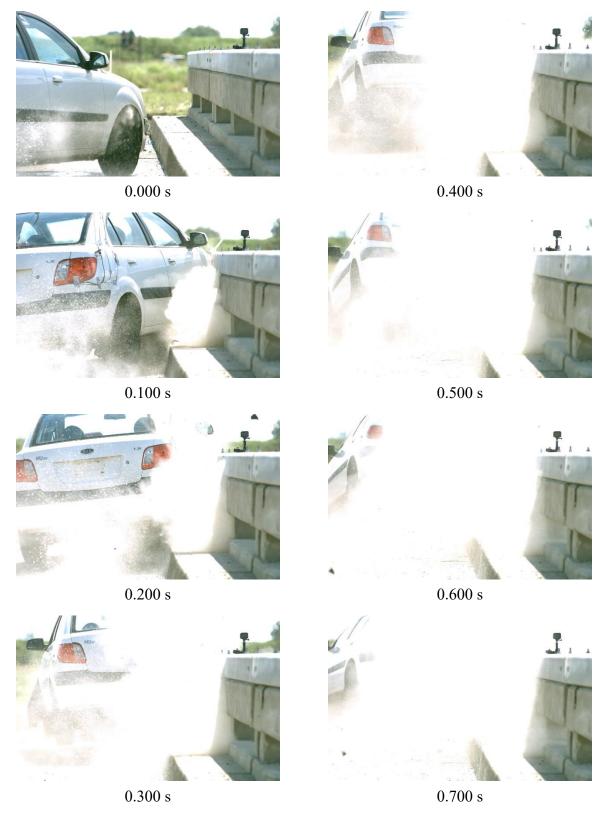


Figure 120. Sequential photographs for Test No. 606861-2 (rear view).

Date:	2018-10-03	Test No.:	606861-2	VIN No.:	KNADE223396496067
Year:	2009	_ Make:	Kia	Model:	Rio
	·,	VEHICLE CRU	JSH MEASURE	MENT SHEET	71
		Cor	nplete When Applic	able	
	End Da	Side	Damage		
	Undeformed	d end width		Bowing: B1	X1
	Corn	er shift: A1		B2	X2

Bowing constant

 $\frac{X1+X2}{2}$

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

Note: Measure C₁ to C₆ from Driver to Passenger Side in Front or Rear Impacts – Rear to Front in Side Impacts.

a :a		Direct I	Damage								
Specific Impact Number	Plane* of C-Measurements	Width** (CDC)	Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C5	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										

¹Table 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.

A2

 \leq 4 inches \geq 4 inches

End shift at frame (CDC)

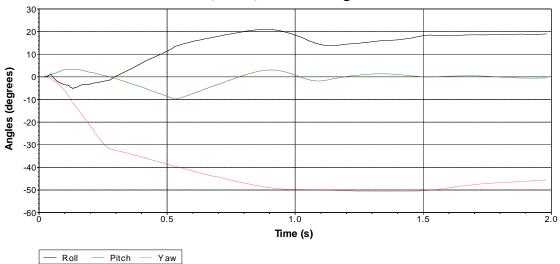
(check one)

Date:2018-10-03Test No.:606	861-2	VIN No.:	KNADE223396496067		
Year: 2009 Make:	Kia	Model:	Ric	1	
H		CCUPANT FORMATIO			
F		Before	After (inches)	Differ.	
G	A1	67.50	67.50	0.00	
	A2	67.25	67.25	0.00	
9	A3	67.75	67.75	0.00	
	B1	40.50	40.50	0.00	
	B2	39.00	39.00	0.00	
B1, B2, B3, B4, B5, B6	B3	40.50	40.50	0.00	
	B4	36.25	36.25	0.00	
A1, A2, &A B	B5	36.00	36.00	0.00	
D1, D2, & D3 C1, C2, & C3	□ 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	
B1 B2 B3	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	
	Н	37.50	37.50	0.00	
	I	37.50	37.50	0.00	
Lateral area across the cab from	J*	51.00	50.50	-0.50	

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

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

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



Roll, Pitch, and Yaw Angles

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

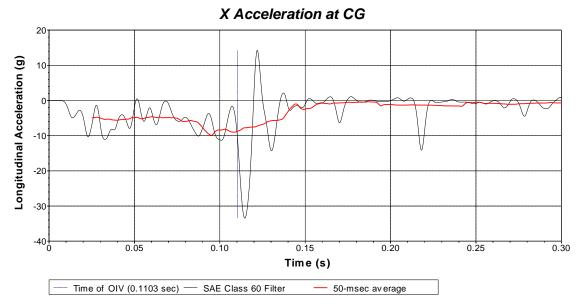
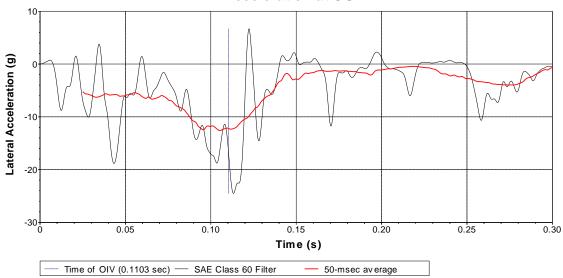
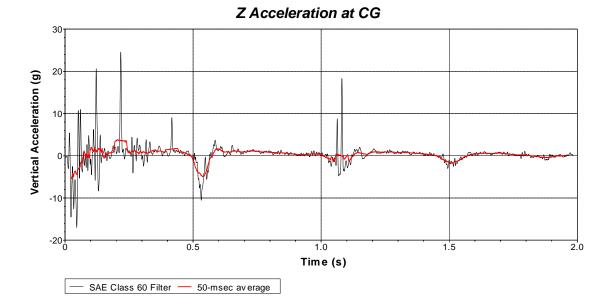


Figure 125. Vehicle lateral accelerometer trace for Test No. 606861-2 (accelerometer located at center of gravity)



Y Acceleration at CG

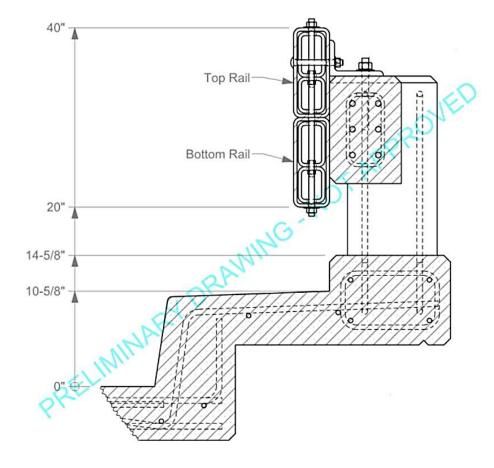
Figure 126. Vehicle vertical accelerometer trace for Test No. 606861-2 (accelerometer located at center of gravity)



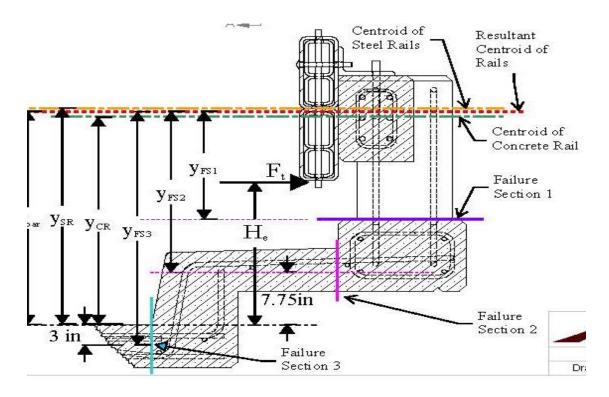
Appendix F. Strength Analysis of DOTD Retrofit Bridge Rail System



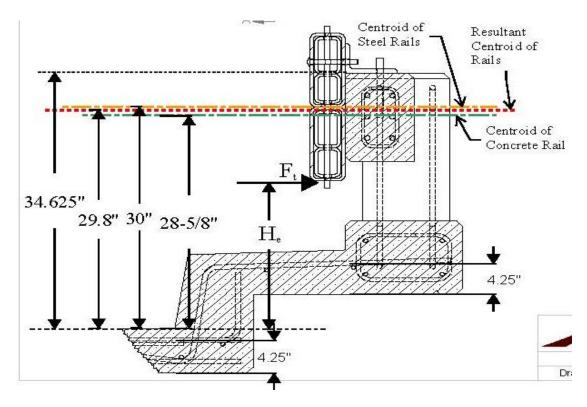
SUBJECT: LADOTD (LTRC 16) HSS Tube Bridge Rail Retrofit LRFD Strength Analysis



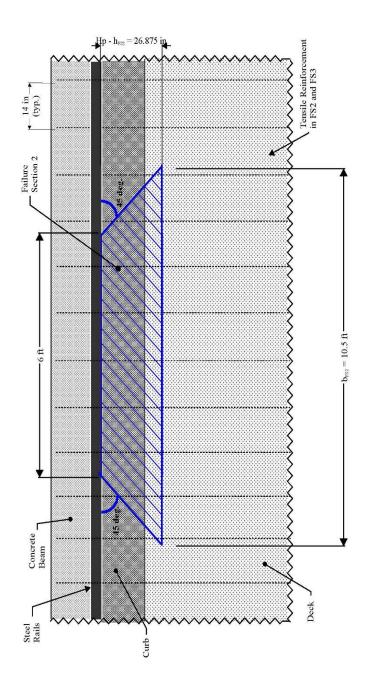
Section View of Bridge Rail Section



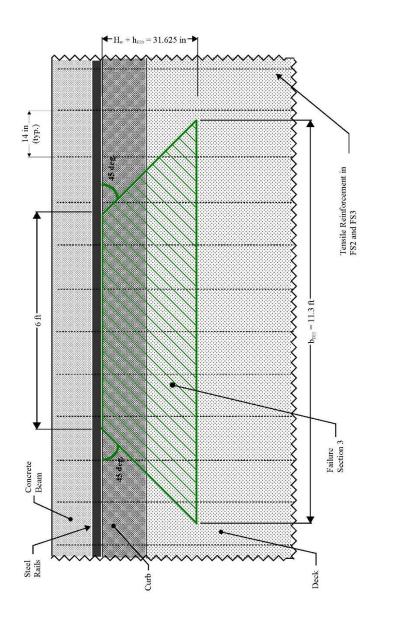
Section View of Bridge Rail System with Variable Notations



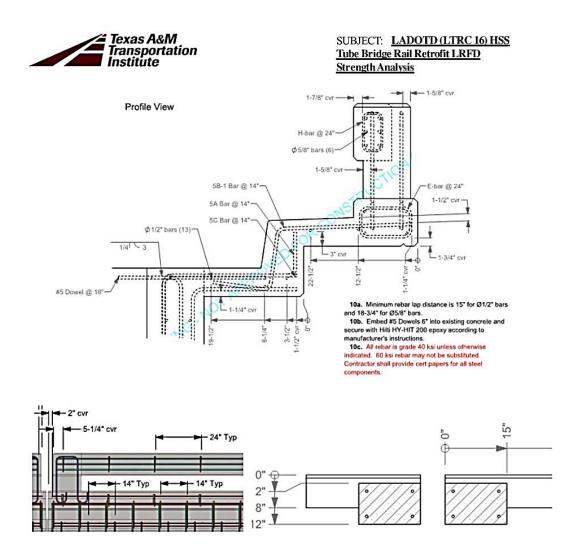
Section View of Bridge Rail System with Key Dimensions



Plan View of Failure Section 2



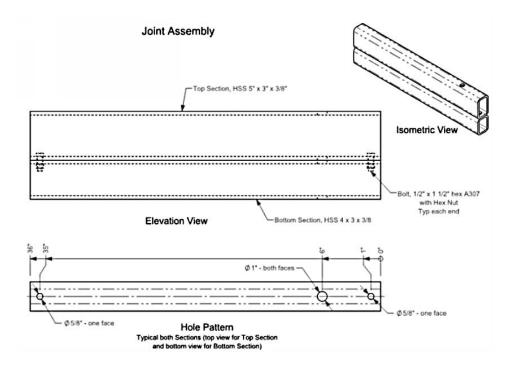
Plan View of Failure Section 3



Details of Concrete and Reinforcement Bars



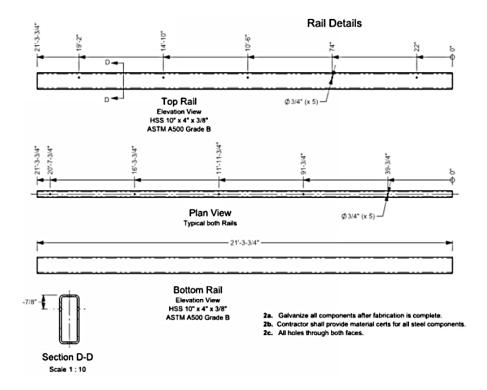
SUBJECT: LADOTD (LTRC 16) HSS Tube Bridge Rail Retrofit LRFD Strength Analysis



Detail Views of Splice Details



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



Detail Views of Steel Rails



General Information:

- Concrete Parapet Strength, fc = 4000psi •
- •
- .
- .
- Anchor Rods are \$3/4" 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.

f' _c := 4000 · 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
$A_{sCR} := n_{sCR} \cdot 0.31 in^2 = 0.93 \cdot in^2$	Total Area of Tensile Reinf. (in ²)

$F_{u,rod} := 120ksi$	
$\mathbf{d_{rod}} \coloneqq \frac{3}{4}$ in	
2	

 $\mathbf{A}_{rod} \coloneqq \frac{\boldsymbol{\pi} \cdot \mathbf{d}_{rod}^2}{4} = 0.442 \cdot \mathrm{in}^2$

Tensile Strength of Anchor Rods (ksi)

Diameter of Anchor Rods (in)

Area of a Anchor Rod (in2)



Test Level	Ft (kip)	FL (kip)	Fv (kip)	L_{t}/L_{L} (ft)	L _v (ft)	H _e (in)	Hmin (in)
TL1	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

MASH Design Impact Loads

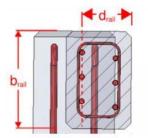
Note: (a) and (b) denote different TL4 and TL 5 design force values for bridge rails of different heights.

TL := 3	Test Level
F _t := 71kip	Transverse Impact Force (kip)
$\mathbf{L}_{\mathbf{f}} \coloneqq 4\mathbf{f}\mathbf{t}$	Longitudinal Length of Distribution of Transverse Impact Force (ft.)
$\mathbf{L}_{t.amp} := 1.5 \cdot \mathbf{L}_t = 6 \mathrm{ft}$	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.)
$\mathbf{H}_{e,mod} \coloneqq \mathbf{H}_{e} + 10in = 29 \cdot in$	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:

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



 $\mathbf{A_{sCR}}=0.93\cdot\text{in}^2$ Total Area of Tensile Reinf. (in2) Width of Concrete Rail (in.) $b_{rail} = 12 \cdot in$ d_{rail} = 6∙in Distance to Tensile Reinf. from Compression Face (in.) $f_v = 40 \cdot ksi$ Yield Stress of Reinf. (ksi) $f'_c = 4 \cdot ksi$ Compressive Strength of Concrete (ksi)

$$a_{rail} := \frac{A_{sCR} \cdot f_y}{0.85 \cdot f'_{c} \cdot b_{rail}} = 0.912 \cdot in$$

 $\mathbf{M}_{CR} \coloneqq \mathbf{A}_{sCR} \cdot \mathbf{f}_{y} \cdot \left(\mathbf{d}_{rail} - \frac{\mathbf{a}_{rail}}{2} \right) = 17.187 \cdot \mathbf{kip} \cdot \mathbf{ft}$

Moment Strength of Concrete Rail (k-ft)

y_{CR} := 28.625in

Height of the centroid of the Concrete Rail (in.)

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

Strength Analysis

Whitney Stress Block Depth (in.)



Find Height of Resultant Force of Concrete and Steel Rails: (ybar1) 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) $\mathbf{M}_{SR} \coloneqq \mathbf{2Z}_{SR} \cdot \mathbf{F}_{yR} = \mathbf{107.333} \cdot \mathbf{kip} \cdot \mathbf{ft}$ Total Plastic Moment Strength of both Steel Rails (k-ft) Height of the centroid of the Steel Rails (in.) $y_{SR} := 30in$ Height of the centroid of the Concrete Rail (in.) $y_{CR} = 28.625 \cdot in$ $M_{CR} = 17.187 \cdot kip \cdot ft$ 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) $\mathbf{y_{bar1}} \coloneqq \frac{\mathbf{M_{SR}} \cdot \mathbf{y_{SR}} + \mathbf{M_{CR}} \cdot \mathbf{y_{CR}}}{\mathbf{M_{rail1}}} = 29.81 \cdot \text{in}$ 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 @ ybar1 (kip)



<u>Steel Splice Rail Properties and Dimensions;</u> 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 (in ³)
$\mathbf{M}_{S1} := \mathbf{F}_{yR} \cdot \mathbf{Z}_{S1} = 19.55 \cdot \mathbf{kip} \cdot \mathbf{ft}$	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.)
Z _{S2} := 4.18in ³	Plastic Sectional Modulus of 2nd from top Steel Splice Rail (in ³)
$M_{S2} := F_{yR} \cdot Z_{S2} = 16.023 \cdot kip \cdot ft$	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.)
$Z_{S3} := 5.1 \text{ in}^3$	Plastic Sectional Modulus of 3rd from top Steel Splice Rail (in ³)
$\mathbf{M}_{S3} := \mathbf{F}_{yR} \cdot \mathbf{Z}_{S3} = 19.55 \cdot \text{kip} \cdot \text{ft}$	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.)
Z _{S4} := 4.18in ³	Plastic Sectional Modulus of 4th from top Steel Splice Rail (in ³)
$\mathbf{M}_{S4} := \mathbf{F}_{yR} \cdot \mathbf{Z}_{S4} = 16.023 \cdot \mathbf{kip} \cdot \mathbf{ft}$	Plastic Moment Strength of 4th from top Steel Splice Rail (k-ft)
y _{S4} := 22.75in	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)
$y_{S} \coloneqq \frac{M_{S1} \cdot y_{S1} + M_{S2} \cdot y_{S2} + M_{S3} \cdot y_{S3} + M_{S4} \cdot y_{S4}}{M_{S}} = 30.098 \cdot \text{in}$	Height of the centroid of the Steel Splice Rails (in.)



Find Height of Resultant Force of Concrete and Steel Splice Rails: (ybar2)

$M_{CR} = 17.187 \cdot kip \cdot ft$	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)	
$\mathbf{y_{bar2}} \coloneqq \frac{\mathbf{M_S} \cdot \mathbf{y_S} + \mathbf{M_{CR}} \cdot \mathbf{y_{CR}}}{\mathbf{M_S} + \mathbf{M_{CR}}} = 29.811 \cdot \mathrm{in}$	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 @ $y_{\rm barl}~(k{\mbox{-}ft})$	
$M_{rail1} = 124.52 \cdot kip \cdot ft$	Total Moment Capacity of Concrete Rail and Steel Rails (k-ft)	
$y_{bar} := \begin{vmatrix} y_{bar2} & \text{if } M_{rail2_ybar1} < M_{rail1} &= 29.811 \\ y_{bar1} & \text{otherwise} \end{vmatrix}$	in Critical Height of the centroid of the Rails (in.)	



Analysis of Post (Failure Section 1): PP1

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.

 $f_v = 40 \cdot ksi$ $f'_c = 4 \cdot ksi$

 $\mathbf{b_{FS1}} \coloneqq 15$ in

$$A_{FS1} := 2 \cdot 0.44 in^2 = 0.88 \cdot in^2$$

 $\mathbf{d_{FS1}}\coloneqq 7.625 \text{in}$

 $y_{FS1} := y_{bar} - 14.625 in = 15.186 \cdot in$

 $\mathbf{a_{FS1}} \coloneqq \frac{\mathbf{A_{FS1}} \cdot \mathbf{f_y}}{\mathbf{0.85} \cdot \mathbf{f'_c} \cdot \mathbf{b_{FS1}}}$

$$\mathbf{M}_{FS1} := \mathbf{A}_{FS1} \cdot \mathbf{f}_{\mathbf{y}} \cdot \left(\mathbf{d}_{FS1} - \frac{\mathbf{a}_{FS1}}{2} \right) = 21.354 \cdot \mathbf{kip} \cdot \mathbf{ft}$$

 $P_{P1} := \frac{M_{FS1}}{y_{FS1}} = 16.874 \cdot kip$

Width of FS1 (in.)

Area of Tensile Reinforcement in FS1 (in2)

Distance to Tensile Reinf. from Compression Face of FS1 (in.)

Height measured from centroid of FS1 to Resultant Force of Rails (in.)

Whitney Stress Block Depth for FS1 (in.)

Moment Strength of Post at FS1 (k-ft)

Strength of Post at FS1 (kip)



Analysis of Post (Failure Section 2): PP2

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 · ksi $f'_c = 4 \cdot ksi$ Amplified Longitudinal Length of Distribution of Transverse Impact $L_{t.amp} = 6 ft$ Force (ft.) $h_{FS2} := 7.75$ in Distance from roadway surface to centroid of FS2 (in.) [See figure 2 for more information] Height of the Concrete Post and Beam measured from top of $H_p = 34.625$ in roadway surface (in.) Width of FS2 (in.) $\mathbf{b}_{FS2} \coloneqq \mathbf{L}_{t,amp} + 2 \cdot \left(\mathbf{H}_p - \mathbf{h}_{FS2}\right) = 10.479 \cdot \text{ft}$ Note: Width of FS2 is assumed to be the impact force projected outward at a 45 degree angle to the centroid of FS2. $A_{FS2} := 9.0.31 in^2 = 2.79 in^2$ Area of Tensile Reinforcement in FS2 (in2) There are 9 bars over b_{FS2} $d_{FS2} := 4.25 in$ Distance to Tensile Reinf. from Compression Face of FS2 (in.) [See Figure 3 for more information] $\mathbf{a}_{FS2} \coloneqq \frac{\mathbf{A}_{FS2} \cdot \mathbf{f}_y}{\mathbf{0.85} \cdot \mathbf{f}_c \cdot \mathbf{b}_{FS2}}$ Whitney Stress Block Depth for FS2 (in.) $\mathbf{M}_{FS2} \coloneqq \mathbf{A}_{FS2} \cdot \mathbf{f}_y \cdot \left(\mathbf{d}_{FS2} - \frac{\mathbf{a}_{FS2}}{2} \right) = 38.311 \cdot \mathbf{kip} \cdot \mathbf{ft}$ Moment Strength at FS2 about the longitudinal axis (k-ft) $y_{FS2} := y_{bar} - 7.75 in = 22.061 \cdot in$ 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): PP3

<u>Failure Section 3 (FS3) Properties and Dimensions:</u> 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.		
$f_y = 40 \cdot ksi$ $f'_c = 4 \cdot ksi$		
$H_p = 34.625 \cdot in$	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 (fl.)	
$h_{\overline{FS3}} := 3in$	Vertical distance from roadway surface to centroid of FS3 (in.) [See Figure 2 for more information]	
$\mathbf{b}_{FS3} \coloneqq \mathbf{L}_{t,amp} + 2 \cdot \left(\mathbf{H}_p + \mathbf{h}_{FS3}\right) = 12.271 \cdot ft$	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.	
$A_{FS3} := 10.0.31 \text{ in}^2 = 3.1 \text{ in}^2$	Area of Tensile Reinforcement in FS3 (in ²) There are 10 bars over b_{FS3}	
$d_{FS3} := 4.25$ in	Distance to Tensile Reinf. from Compression Face of FS3 (in.) [See Figure 3 for more information]	
$\mathbf{a_{FS3}} \coloneqq \frac{\mathbf{A_{FS3}} \cdot \mathbf{f_y}}{0.85 \cdot \mathbf{f_c} \cdot \mathbf{b_{FS3}}}$	Whitney Stress Block Depth for FS3 (in.)	
$\mathbf{M}_{FS3} \coloneqq \mathbf{A}_{FS3} \cdot \mathbf{f}_{y} \cdot \left(\mathbf{d}_{FS3} - \frac{\mathbf{a}_{FS3}}{2} \right) = 42.637 \cdot \mathbf{kip} \cdot \mathbf{ft}$	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: PP

$\mathbf{P_{P1}} = 16.874 \cdot kip$	Strength of Post at FS1 (kip)	
$P_{P2} = 20.839 \text{ kip}$	Strength of Post at FS2 (kip)	
$P_{P3} = 15.593 \text{ kip}$	Strength of Post at FS3 (kip)	

 $\underline{Note}:$ The Limiting ("worst case") Post Strength is taken as $P_{\rm p}$

 $P_{P} \coloneqq \min\left(P_{P1}, P_{P2}, P_{P3}\right) = 15.593 \cdot kip$



Total Ultimate Resistance (Nominal Resistance) of Railing: R_R

$$\begin{array}{l} \underline{One \; Span \; Failure \; Mode} \colon N_1 = 1 \\ P_p = 15.593 \cdot kip \\ N_1 := \; 1 \\ \\ M_{rail} = 88.333 \cdot kip \cdot ft \\ \\ L_p = 9.823 \cdot ft \\ \\ L_t = 4 \cdot ft \\ \\ R_1 := \; \frac{16 \cdot M_{rail} + \left(N_1 - 1\right) \cdot \left(N_1 + 1\right) \cdot P_P \cdot L_p}{2 \cdot N_1 \cdot L_p - L_t} = 90.333 \cdot kip \end{array}$$

$$2 \cdot N_1 \cdot L_p - L$$

Two Span Failure Mode: N2=2

 $P_P = 15.593 \cdot kip$

N₂ := 2

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

 $L_p = 9.823 \cdot ft$

 $L_t = 4 \cdot ft$

$$\mathbf{R}_{2} := \frac{\mathbf{16} \cdot \mathbf{M}_{rail} + \mathbf{N}_{2}^{-2} \cdot \mathbf{P}_{p} \cdot \mathbf{L}_{p}}{2 \cdot \mathbf{N}_{2} \cdot \mathbf{L}_{p} - \mathbf{L}_{t}} = 57.408 \cdot kip$$



Total Ultimate Resistance (Nominal Resistance) of Railing: R_R

$$\begin{array}{l} \underline{\mbox{Three Span Failure Mode}} : N_3 = 3 \\ P_p = 15.593 \cdot kip \\ N_3 := 3 \\ M_{rail} = 88.333 \cdot kip \cdot ft \\ L_p = 9.823 \cdot ft \\ L_t = 4 \cdot ft \\ R_3 := \frac{16 \cdot M_{rail} + \left(N_3 - 1\right) \cdot \left(N_3 + 1\right) \cdot P_P \cdot L_p}{2 \cdot N_3 \cdot L_p - L_t} = 48.031 \cdot kip \end{array}$$

Four Span Failure Mode: N4=4

 $P_P = 15.593 \cdot kip$

N₄ := 4

M_{rail} = 88.333 · kip · ft

 $L_p = 9.823 \cdot ft$

 $L_t = 4 \cdot ft$

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



Total Ultimate Resistance (Nominal Resistance) of Railing: R_R

$$\begin{split} & \underline{Five \; Span \; Failure \; Mode} : N_5 = 5 \\ & \mathbf{P_P} = 15.593 \cdot kip \\ & N_5 := 5 \\ & \mathbf{M_{rail}} = 88.333 \cdot kip \cdot ft \\ & \mathbf{L_p} = 9.823 \cdot ft \\ & \mathbf{L_t} = 4 \cdot ft \\ & \mathbf{R_5} := \frac{16 \cdot \mathbf{M_{rail}} + \left(N_5 - 1\right) \cdot \left(N_5 + 1\right) \cdot \mathbf{P_P} \cdot \mathbf{L_p}}{2 \cdot N_5 \cdot \mathbf{L_p} - \mathbf{L_t}} = 54.012 \cdot kip \end{split}$$

Six Span Failure Mode: $N_6=6$ $P_p = 15.593 \cdot kip$ $N_6 := 6$ $M_{rail} = 88.333 \cdot kip \cdot ft$ $L_p = 9.823 \cdot ft$ $L_t = 4 \cdot ft$

$$\mathbf{R}_{6} \coloneqq \frac{\mathbf{16} \cdot \mathbf{M}_{rail} + \mathbf{N}_{6}^{2} \cdot \mathbf{P}_{P} \cdot \mathbf{L}_{p}}{2 \cdot \mathbf{N}_{6} \cdot \mathbf{L}_{p} - \mathbf{L}_{t}} = 60.835 \cdot kip$$



Total Ultimate Resistance (Nominal Resistance) of Railing: R_R

Seven Span Failure Mode: N₇=7
P_P = 15.593 · kip
N₇ := 7
M_{rail} = 88.333 · kip · ft
L_p = 9.823 · ft
L_t = 4 · ft
R₇ :=
$$\frac{16 \cdot M_{rail} + (N_7 - 1) \cdot (N_7 + 1) \cdot P_P \cdot L_p}{2 \cdot N_7 \cdot L_p - L_t} = 65.65 \cdot kip$$

Eight Span Failure Mode: N₈=8

 $P_P = 15.593 \cdot kip$

N₈ := 8

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

 $L_p = 9.823 \cdot ft$

 $L_t = 4 \cdot ft$

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



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

Total Ultimate Resistance (Nominal Resistance) of Railing: RR

<u>Note</u>: The Total Ultimate Resistance of the bridge rail system is the minimum value of $R_1 - R_8$

 $\mathbf{R}_r \coloneqq min \left(\mathbf{R}_1\,, \mathbf{R}_2\,, \mathbf{R}_3\,, \mathbf{R}_4\,, \mathbf{R}_5\,, \mathbf{R}_6\,, \mathbf{R}_7\,, \mathbf{R}_8\right) = 48.031 \cdot kip$

 $H_e = 19 \cdot in$

Height of Transverse Impact Load (in.)

 $y_{bar} = 29.811 \cdot in$

Height of Resultant Force (in.)

 $F_t = 71 \cdot kip$

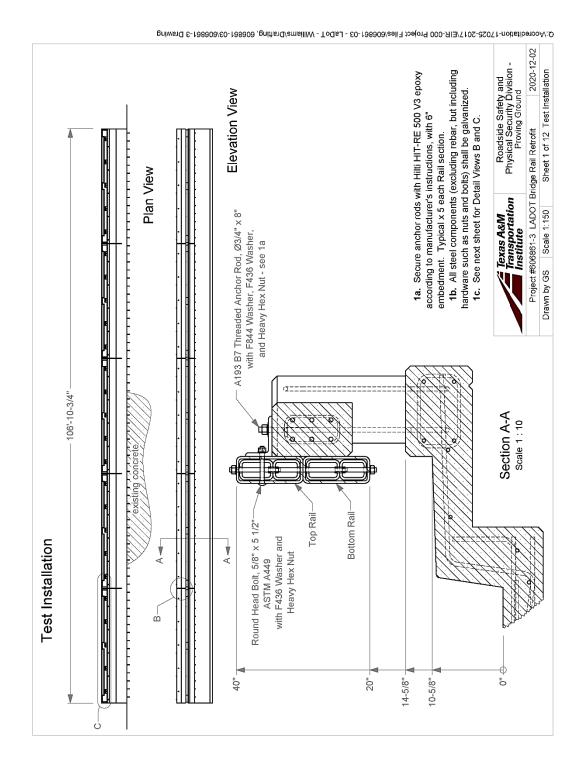
Transverse Impact Force (kip)

 $\mathbf{R}_{\mathbf{R}} := \mathbf{R}_{\mathbf{r}} \cdot \left(\frac{\mathbf{y}_{bar}}{\mathbf{H}_{e}} \right) = 75.362 \cdot kip$

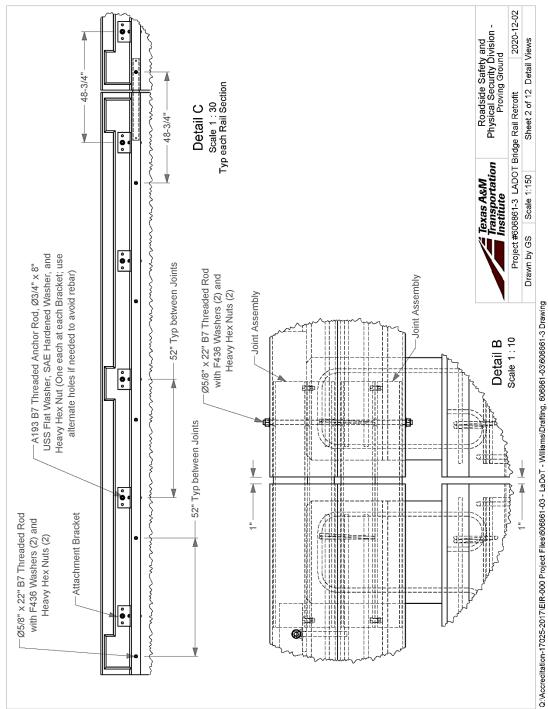
Total Ultimate Resistance of the bridge rail system @ He (kip)

<u>CHECK</u>= "OK", since $R_R = 75.4$ kip > $F_t = 71$ kip

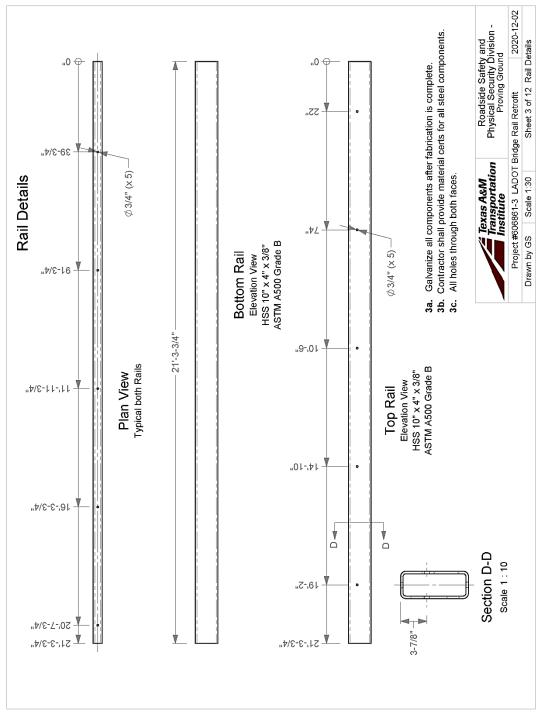
Appendix G. Details of Louisiana Retrofit Post and Beam with Safety Walk Option 2 for Tests 606861-3&4



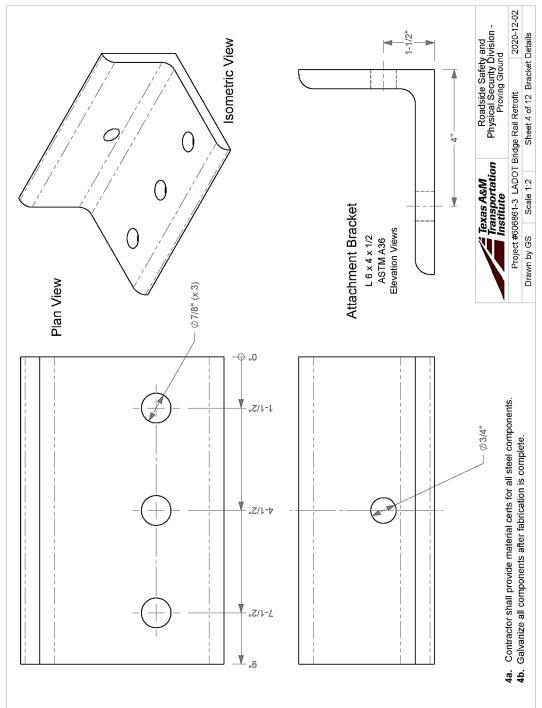
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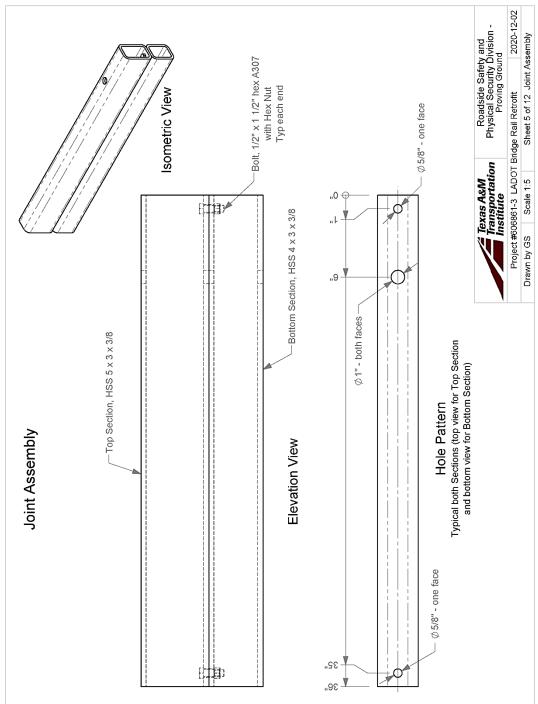




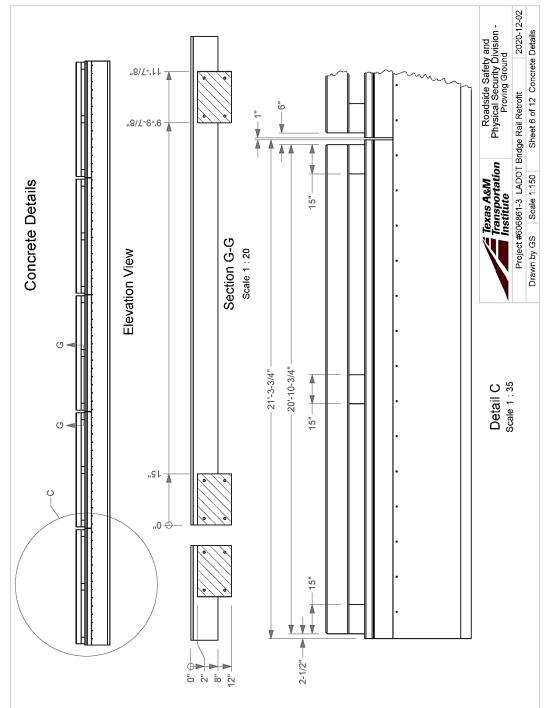
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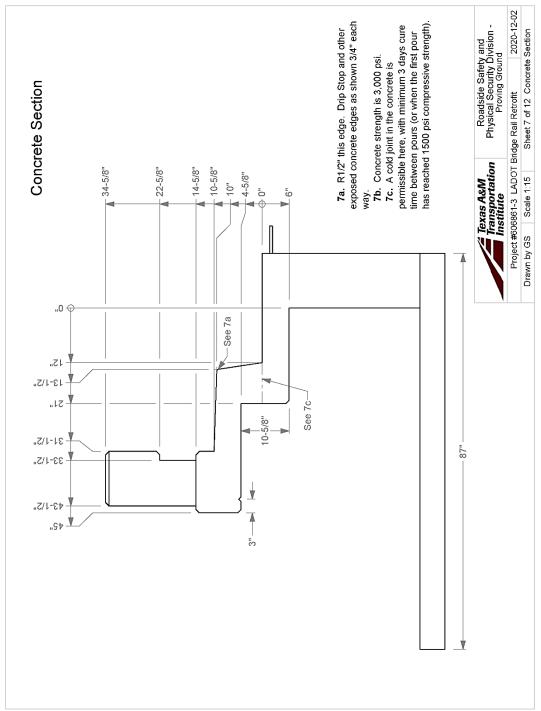
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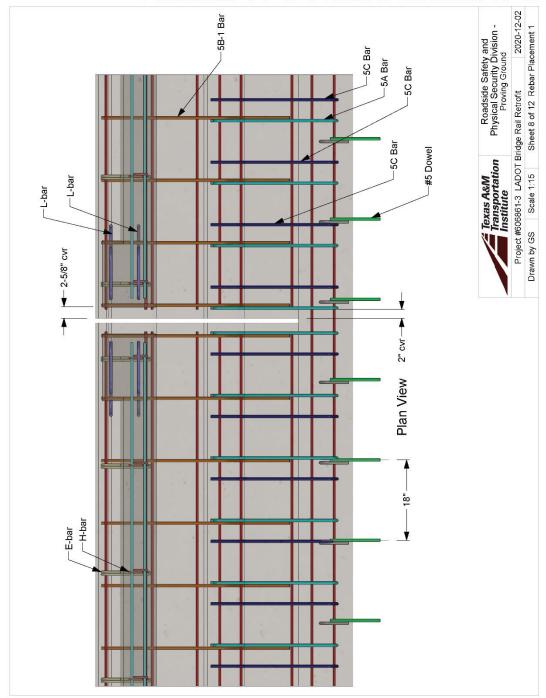


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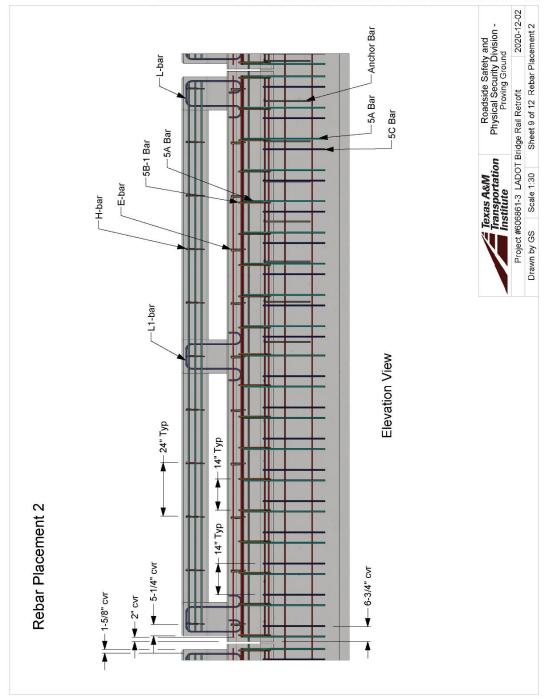


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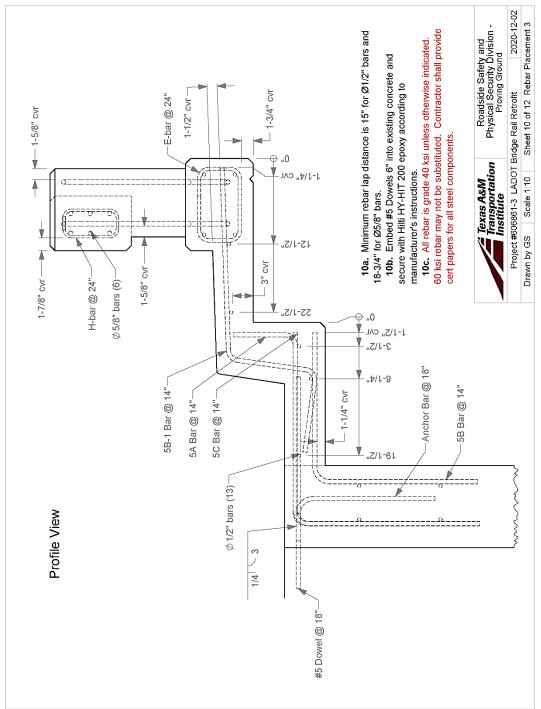




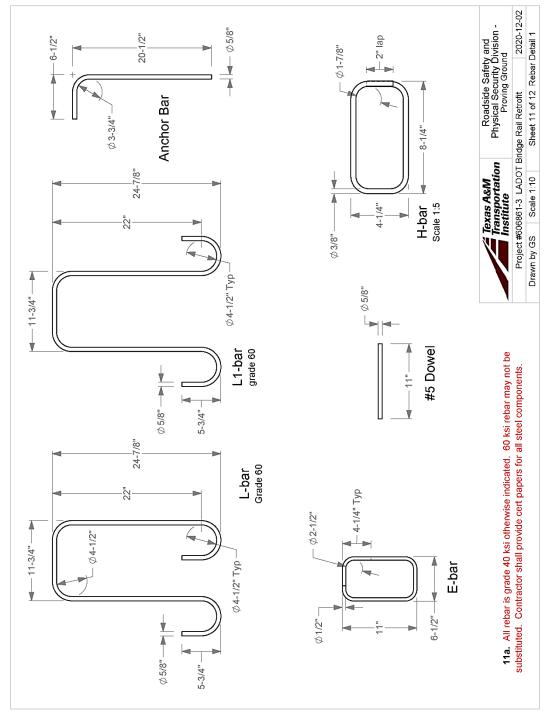
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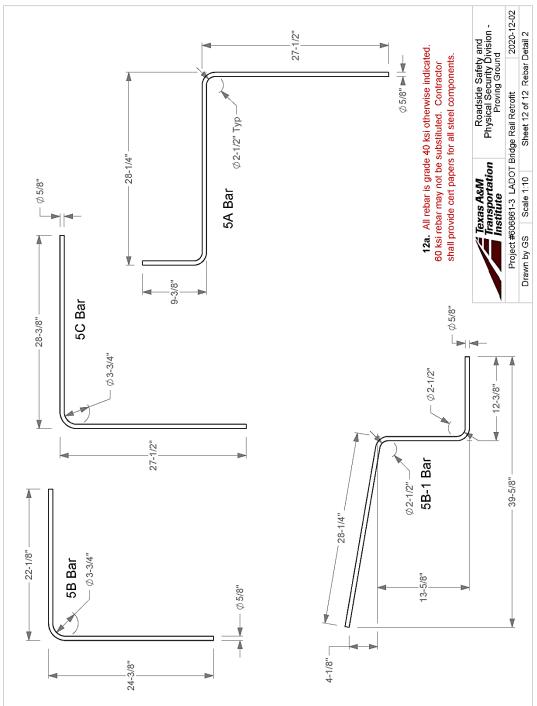
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Appendix H. Strength Analysis for Retrofit Bridge Rail Anchored to Solid Concrete Parapet



1.) Given the following Details

SUBJECT: <u>LADOTD (LTRC 16) HS</u> <u>Tube Bridge Rail Retrofit LRFD</u> <u>Strength Analysis</u>

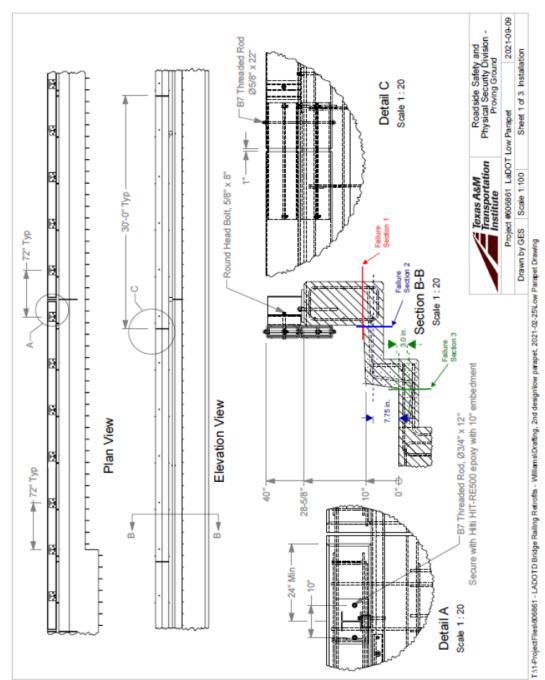
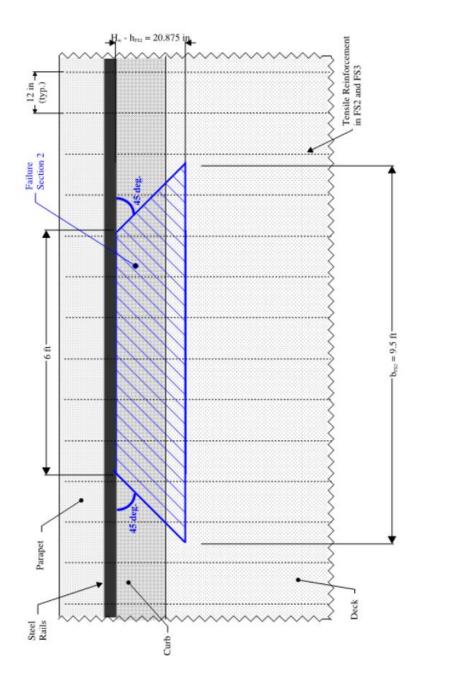


Figure 1. Detailed Views of Bridge Rail System









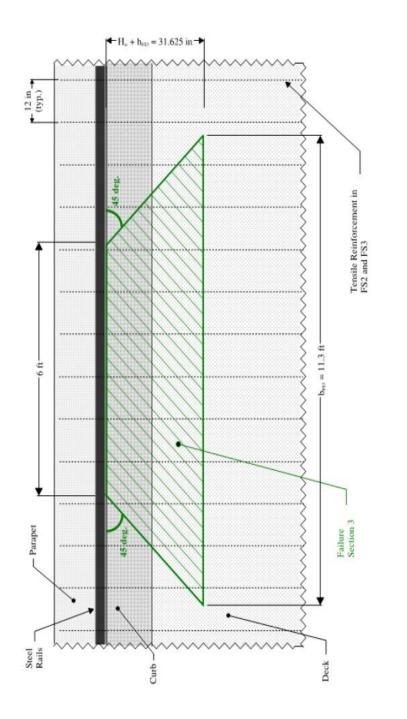
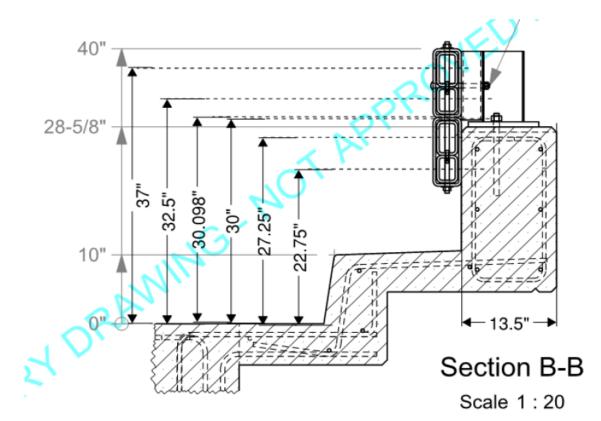
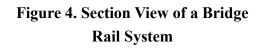
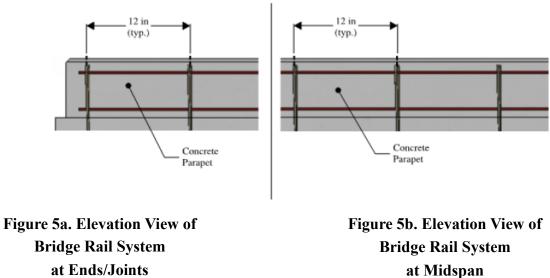


Figure 3. Plan View of Failure Section 3



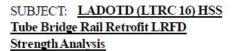






at Ends/Joints





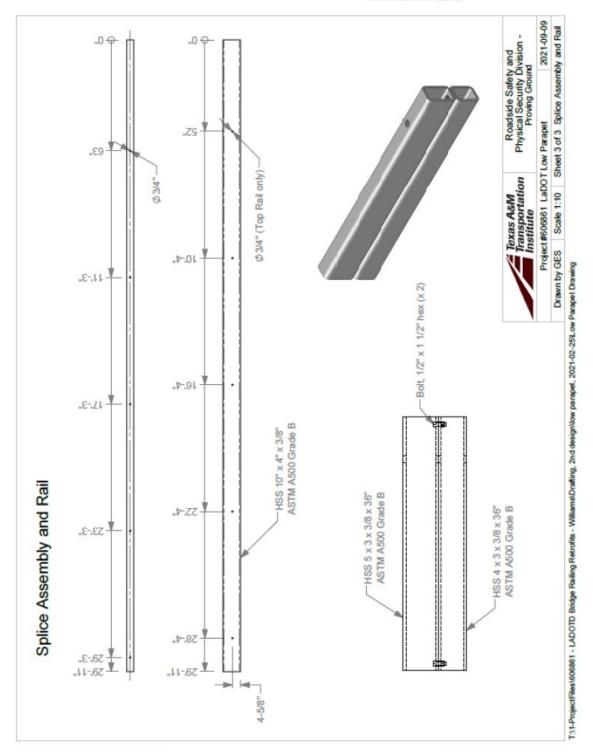


Figure 6. Steel and Rail details



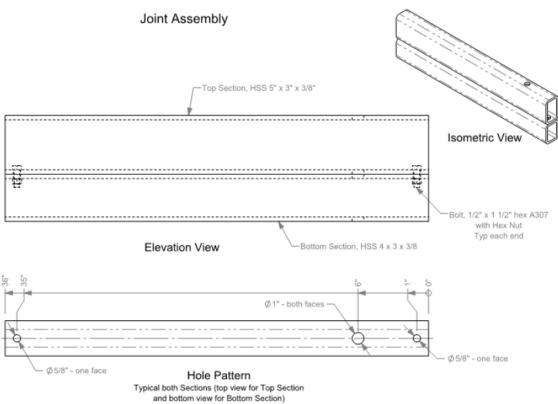
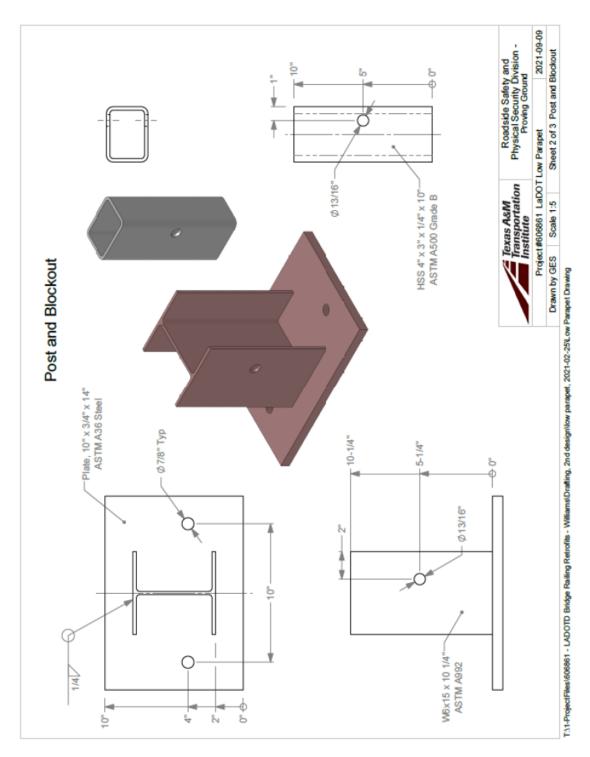
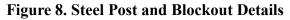


Figure 7. Steel Splice Detail









SUBJECT: <u>LADOTD (LTRC 16) HSS</u> <u>Tube Bridge Rail Retrofit LRFD</u> <u>Strength Analysis</u>

kips ≡ kip

2.) General Information:

- Concrete Parapet Strength, fc = 4000psi
- Anchor Rods are \$\phi3/4" 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
 DED Control 12 Contro
- LRFD Section 13 Strength Requirements.
- Use Hilti RE500 Epoxy with 10" Embedment

************************* Concrete, Reinforcing Steel & Structural Shape Information **************************		
f'c := 4000·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 (in ²)	
$A_{sw1} := 0.2 in^2$	Area of one longitudinal reinforcement bar in tension zone of the Concrete Parapet/Wall (in ²)	

$F_{u.rod} := 120ksi$	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)



Test Level	Ft (kip)	F _L (kip)	F _v (kip)	L_t/L_L (ft)	L _v (ft)	H _e (in)	H _{min} (in)
TL1	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

MASH Design Impact Loads

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

TL := 3	Test Level
$\mathbf{F}_t \coloneqq 71 \mathrm{kip}$	Transverse Impact Force (kip)
$\mathbf{L}_{\mathbf{t}} := 4\mathbf{ft}$	Longitudinal Length of Distribution of Transverse Impact Force (ft.)
$\mathbf{L}_{t.\text{amp}} := 1.5 \cdot \mathbf{L}_t = 6 \text{ ft}$	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.)
$\mathbf{H}_{e.mod} := \mathbf{H}_{e} + 10in = 29 \cdot in$	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.
$F_v := 4.5 kip$	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.)
$\mathbf{H}_{\mathbf{t}} := 40 \mathbf{i} \mathbf{n}$	Total height of bridge rail system (in.)



SUBJECT: <u>LADOTD (LTRC 16) HSS</u> <u>Tube Bridge Rail Retrofit LRFD</u> <u>Strength Analysis</u>

3.) Calculate the Bending Capacity based on Failure Section 1 about the Longitudinal Axis: M_{c.FS1} Note: See Figure 1 for more information

$$A_{v1} = 0.2 \text{ in}^2$$
Area of one vertical reinforcement leg in tension zone (in?) $b_c := 12\text{in}$ Unit Width of Wall (in.) $v_{vnild} := 12\text{in}$ Spacing of vertical reinforcement at midspan (in.) $v_{vnild} := 12\text{in}$ Average Spacing of vertical reinforcement at the end of the properties at a joint per the length of the longitudinal distribution of the impact force (in.) $A_{v,mild} := \left(\frac{b_c}{s_{v,mid}}\right) \cdot A_{v1} = 0.2 \text{ in}^2$ Total Area of vertical reinforment per unit length of the wall at midspan (in?) $A_{v,mild} := \left(\frac{b_c}{s_{v,mid}}\right) \cdot A_{v1} = 0.2 \text{ in}^2$ Total Area of vertical reinforment per unit length of the wall at the end of the wall at the end of the wall at the end of the wall or at a joint (in?) $A_{v,end} := \left(\frac{b_c}{0.85 \cdot f_c \cdot b_c} = 0.196 \text{ in}$ Depth of Whitney Stress Block at midspan (in.) $a_{c,end} := \frac{A_{v,end} \cdot f_v}{0.85 \cdot f_c \cdot b_c} = 0.196 \text{ in}$ Depth of Whitney Stress Block at the end of the wall or at a joint (in.) $b_w = 13.5 \text{ in}$ Width of the Concrete Parapet/Wall (in.) $d_c := b_w - 1.5\text{ in} - 0.25\text{ in} = 11.75 \text{ in}$ Externe distance of tension vertical reinforcement of the wall (in.) $d_c := b_w - 1.5\text{ in} - 0.25\text{ in} = 11.75 \text{ in}$ Externe distance of tension vertical reinforcement of the wall (in.) $d_c := b_w - 1.5\text{ in} - 0.25\text{ in} = 11.75 \text{ in}$ Externe distance of tension vertical reinforcement of the wall (in.) $d_c := b_w - 1.5\text{ in} - 0.25\text{ in} = 11.75 \text{ in}$ Externe distance of tension vertical reinforcement of the wall (in.) $d_c := b_w - 1.5\text{ in} - 0.25\text{ in} = 11.75 \text{ in}$ Externe distance of tension vertical reinforcement of the wall (in.) $d_c := b_w - 1.5\text{ in} - 0.$



4.) Calculate the Bending Capacity based on Failure Section 2 about the Longitudinal Axis: McFS2

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-Gr40 Rebar is used for Tensile Reinforcement

$f_y = 40 \cdot ksi$	$r_c = 4 \cdot ksi$	
H _W = 28.625 ⋅ in	Height of Concrete Parapet/Wall measur from top of roadway surface (in.)	ed
$L_{t,amp} = 6 ft$	Amplified Longitudinal Length of Distri Force (ft.)	bution of Transverse Impact
$\mathbf{h}_{FS2} := 7.75 \mathbf{in}$	Distance from roadway surface to centro [See Figure 1 for more information]	vid of FS2 (in.)
$\mathbf{b}_{FS2} := \mathbf{L}_{t.amp} + 2 \cdot \left(\mathbf{H}_{W} - \mathbf{h}_{FS2} \right) = 9.479 \cdot ft$	Width of FS2 (in.) Note: Width of FS2 is assumed to be the projected outward at a 45 degree angle to [See Figure 2 for more information]	
$A_{FS2} := 7.0.31 \text{in}^2 = 2.17 \cdot \text{in}^2$	Area of Tensile Reinforcement in FS2 (i [See Figure 2 for more information] Th are 9 bars over b _{FS2}	-
d _{FS2} := 4.25in	Distance to Tensile Reinf. from Compre [See Figure 1 for more information]	ssion Face of FS2 (in.)
$\mathbf{a}_{FS2} := \frac{\mathbf{A}_{FS2} \cdot \mathbf{f}_y}{0.85 \cdot \mathbf{f}_c \cdot \mathbf{b}_{FS2}}$	Whitney Stress Block Depth for FS2 (in	r)
$\mathbf{M}_{FS2} := \mathbf{A}_{FS2} \cdot \mathbf{f}_{y} \cdot \left(\mathbf{d}_{FS2} - \frac{\mathbf{a}_{FS2}}{2} \right) = 29.93 \cdot \mathbf{kip}$	ft Moment Strength at FS2 about the longi	tudinal 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 longi segment of barrier (k-ft/ft)	tudinal axis per 1 ft



5.) Calculate the Bending Capacity based on Failure Section 3 about the Longitudinal Axis: Mc.FS3

<u>Failure Section 3 (FS3) Properties and Dimensions:</u> 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

$f_y = 40 \cdot ksi$	$\mathbf{f'}_{\mathbf{c}} = 4 \cdot \mathbf{ksi}$	
H _W = 28.625 ⋅ 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]
$\mathbf{b}_{FS3} := \mathbf{L}_{t,amp} + 2 \cdot \left(\mathbf{H}_{W} + \mathbf{h}_{FS3}\right)$	$) = 11.271 \cdot ft$	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]
$A_{FS3} := 11.0.31 \text{ in}^2 = 3.41. \text{ in}^2$		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]
$\mathbf{a}_{FS3} := \frac{\mathbf{A}_{FS3} \cdot \mathbf{f}_{y}}{0.85 \cdot \mathbf{f}_{c} \cdot \mathbf{b}_{FS3}}$		Whitney Stress Block Depth for FS3 (in.)
$\mathbf{M}_{\mathbf{FS3}} := \mathbf{A}_{\mathbf{FS3}} \cdot \mathbf{f}_{\mathbf{y}} \cdot \left(\mathbf{d}_{\mathbf{FS3}} - \frac{\mathbf{a}_{\mathbf{FS}}}{2} \right)$	$\left(\frac{63}{6}\right) = 46.623 \cdot \text{kip} \cdot \text{ft}$	Moment Strength of Post at FS3 (k-ft)
$\mathbf{M}_{c,FS3} := \frac{\mathbf{M}_{FS3}}{\mathbf{L}_{t,amp}} = 7.77 \cdot \frac{\mathrm{kip} \cdot \mathbf{f}_{t}}{\mathrm{ft}}$	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: Mc

$M_{cmid.FS1} = 7.768 \cdot \frac{kip \cdot ft}{ft}$	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)
$\mathbf{M}_{c.FS3} = 7.77 \cdot \frac{\mathrm{kip} \cdot \mathrm{ft}}{\mathrm{ft}}$	Moment Strength of Post at FS3 per 1 ft segment of barrier (k-ft/ft)

 $\mathbf{M}_{\mathbf{c}} := \min \left(\mathbf{M}_{\mathbf{cmid},\mathbf{FS1}}, \mathbf{M}_{\mathbf{cend},\mathbf{FS1}}, \mathbf{M}_{\mathbf{c},\mathbf{FS2}}, \mathbf{M}_{\mathbf{c},\mathbf{FS3}} \right) = 4.988 \cdot \frac{\mathbf{kip} \cdot \mathbf{ft}}{\mathbf{ft}}$ 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: Mw

 $n_{_{SW}} := 2$ Number of Longitudinal bars in tension (m²)

 $\mathbf{A}_{sw} \coloneqq \mathbf{n}_{sw} \cdot \mathbf{A}_{sw1} = 0.4 \cdot \mathbf{in}^2$

 $h_w = 18 \cdot in$

$$\mathbf{a}_{\mathbf{W}} := \frac{\mathbf{A}_{\mathbf{SW}} \cdot \mathbf{f}_{\mathbf{y}}}{\mathbf{0.85} \cdot \mathbf{f}_{\mathbf{C}} \cdot \mathbf{h}_{\mathbf{W}}} = \mathbf{0.261} \cdot \mathbf{in}$$

 $b_w = 13.5 \cdot in$

Depth of the Whitney Stress Block (in.)

Total height of the concrete parapet (in.)

Total Area of Longitudinal Rebar in tension (in2)

Width of the Concrete Parapet/Wall (in.)

$$d_{W} := b_{W} - 1.5in - 0.5in - 0.25in = 11.25 \cdot in$$

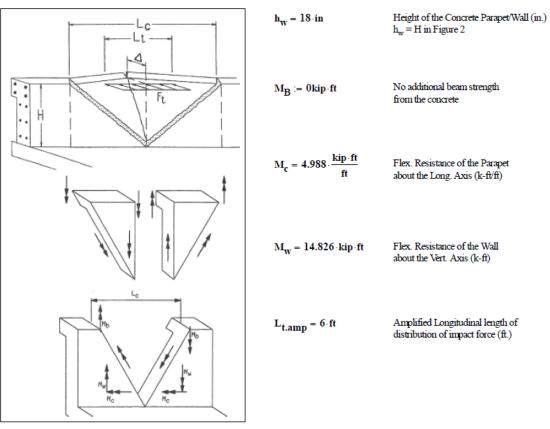
Extreme distance of tension longitudinal reinforcement in wall (in.) $d_w = b_w$ - cover - diameter of stirrups - (1/2)*diameter of longitudinal bars

$$\mathbf{M}_{\mathbf{W}} := \mathbf{A}_{\mathbf{SW}} \cdot \mathbf{f}_{\mathbf{Y}} \cdot \left(\mathbf{d}_{\mathbf{W}} - \frac{\mathbf{a}_{\mathbf{W}}}{2} \right) = 14.826 \cdot \mathbf{kip} \cdot \mathbf{ft}$$

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}

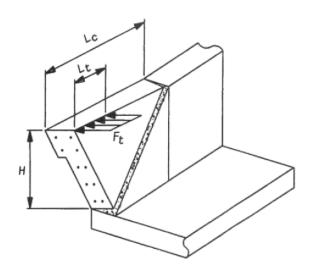


Yield Line Analysis of Concrete Parapet Walls for Impact within Wall Segment.

$$\mathbf{L}_{cmid} := \frac{\mathbf{L}_{t.amp}}{2} + \sqrt{\left(\frac{\mathbf{L}_{t.amp}}{2}\right)^2 + \frac{\left[8 \cdot \mathbf{h}_w \cdot \left(\mathbf{M}_B + \mathbf{M}_w\right)\right]}{\mathbf{M}_c}} = 9.683 \cdot \text{ft}$$
(AASHTO Equation A13.3.1-2)
$$\mathbf{R}_{wmid} := \left[\left(\frac{2}{2 \cdot \mathbf{L}_{cmid} - \mathbf{L}_{t.amp}}\right) \cdot \left[8 \cdot \mathbf{M}_B + 8 \cdot \mathbf{M}_w + \frac{\mathbf{M}_c \cdot \left(\mathbf{L}_{cmid}\right)^2}{\mathbf{h}_w}\right]\right] = 64.404 \cdot \text{kip}$$
(AASHTO Equation A13.3.1-1)



9.) Determine the Ultimate Resistance of the Parapet at Joints/Ends: Rwend



Yield Line Analysis of Concrete Parapet Walls for Impact near End of Wall Segment

$\mathbf{h}_{W} = 18 \cdot \mathbf{in}$	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 f	orce (ft.)
$M_{c} = 4.988 \cdot \frac{kip \cdot ft}{ft}$	Flexural Resistance of the Wall about the Longitudinal A: specified in Article A13.4.2 (k-ft/ft)	xis at Joints/Ends
$\mathbf{L}_{cend} := \frac{\mathbf{L}_{t.amp}}{2} + \sqrt{\left(\frac{\mathbf{L}_{t.amp}}{2}\right)^2 + 1}$	$\mathbf{h}_{\mathbf{W}} \cdot \left(\frac{\mathbf{M}_{\mathbf{B}} + \mathbf{M}_{\mathbf{W}}}{\mathbf{M}_{\mathbf{C}}}\right) = 6.669 \cdot \mathbf{ft}$	(Equation A13.3.1-4)
$\mathbf{R}_{wend} := \left(\frac{2}{2 \cdot \mathbf{L}_{cend} - \mathbf{L}_{t.amp}}\right) \left[\mathbf{M}_{B}\right]$	$+ \mathbf{M}_{W} + \frac{\left(\mathbf{M}_{c} \cdot \mathbf{L}_{cend}^{2}\right)}{\mathbf{h}_{W}} = 44.353 \cdot \mathrm{kip}$	(Equation A13.3.1-3)



10. Resistance of Steel Rails:

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

<u>HSS10x4x3/8 Steel Rail Properties and Dimensions:</u> 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 measured from the top of the roadway surface (in.)
<u>Steel Splice Rail Properties and Dimensions:</u> a) Steel Splice Rails are A500 Gr. B Material, Fy=46ksi b) Steel Splice Rails are HSS5x3x3/8 and HSS4x3x3/8 memb c) Steel Splice Rails bend about the y-axis d) Note: All heights measured from the top of the roadway sur-	
$F_{yR} = 46 \cdot ksi$	Yield Strength of Steel Splice Rails (ksi)
$Z_{S1} := 5.1 \text{ im}^3$	Plastic Sectional Modulus of top most Steel Splice Rail (\mbox{in}^3)
$\mathbf{M}_{S1} \coloneqq \mathbf{F}_{yR} \cdot \mathbf{Z}_{S1} = 19.55 \ \text{kip} \ \text{ft}$	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)
$Z_{S2} := 4.18 \text{ in}^3$	Plastic Sectional Modulus of 2nd from top Steel Splice Rail (in ³)
$\mathbf{M}_{S2} \coloneqq \mathbf{F}_{yR} \cdot \mathbf{Z}_{S2} = 16.023 \cdot \mathbf{kip} \cdot \mathbf{ft}$	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)
$Z_{S3} := 5.1 \text{im}^3$	Plastic Sectional Modulus of 3rd from top Steel Splice Rail (in^3)
$\mathbf{M}_{S3} := \mathbf{F}_{yR} \cdot \mathbf{Z}_{S3} = 19.55 \cdot \mathbf{kip} \cdot \mathbf{ft}$	Plastic Moment Strength of 3rd from top Steel Splice Rail (k-ft)
y _{\$3} := 27.25in	Height of the centroid of 3rd from top Steel Splice Rail (in.) (See Figure 4)

SUBJECT:LADOTD (LTRC 16) HSS
Tube Bridge Rail Retrofit LRFD
Strength Analysis
$$Z_{54} := 4.18 \text{ in}^3$$
Plastic Sectional Modulus of 4th from top Steel Splice Rail (in³) $M_{54} := F_{yR} \cdot Z_{54} = 16.023 \cdot \text{kip} \cdot \text{ft}$ Plastic Sectional Modulus of 4th from top Steel Splice Rail (k-ft) $y_{54} := 22.75 \text{ in}$ Height of the centroid of 4th from top Steel Splice Rail (in.)
(See Figure 4) $M_{5} := M_{51} + M_{52} + M_{53} + M_{54} = 71.147 \cdot \text{kip} \cdot \text{ft}$ Total Plastic Moment Strength of Steel Splice Rails (k-ft) $y_{5} := \frac{M_{51} \cdot y_{51} + M_{52} \cdot y_{52} + M_{53} \cdot y_{53} + M_{54} \cdot y_{54}}{M_5} = 30.098 \cdot \text{in}$ Height of the centroid of the Steel Splice Rails (in.)**L1.) Find Height of Critical Moment Capacity and Resultant Force of Steel Rails:** $(M_{rail} & \$ y_{bar})$

$$\mathbf{M}_{\mathbf{SR}} = 107.333 \cdot \mathbf{kip} \cdot \mathbf{ft}$$

Total Plastic Moment Strength of both Steel Rails (k-ft)

 $y_{SR} = 30 \cdot in$

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

 $\mathbf{M}_{\underline{S}_\underline{ySR}} \coloneqq \mathbf{M}_{\underline{S}} \cdot \left(\frac{\mathbf{y}_{\underline{S}}}{\mathbf{y}_{\underline{SR}}} \right) = 71.379 \cdot \mathbf{kip} \cdot \mathbf{ft}$

Total Plastic Moment Strength of Steel Splice Rails at y_{SR} (k-ft)



12.) Strength of Post at HR based on Post Yielding Pp1

$$\begin{split} & Z_{W6x15} \coloneqq 10.8 in^3 \qquad F_{yA992} \coloneqq 50 ksi \\ & F_{Tpost} \coloneqq 71 kip \cdot 0.50 \quad \text{Consider } 1/2 \text{ of maximum impact force on top of post (worst cast)} \\ & Ht_{post} \coloneqq 30 in - 27.25 in = 2.75 \cdot in \qquad \text{Use max impact of center of top rail element for } TL-3 \\ & M_{postimpact} \coloneqq Ht_{post} \cdot F_{Tpost} = 8.135 \cdot kip \cdot ft \\ & M_{postUltimate} \coloneqq Z_{W6x15} \cdot F_{yA992} = 45 \cdot kip \cdot ft \end{split}$$

 $P_{p1} := \frac{M_{postUltimate}}{Ht_{post}} = 196.364 \cdot kip$

13.) Strength of Post based on Adhesive Anchor Strength Pp2

Design Hilti Anchorage System:

$S_{anchors} := 10in$ $C_{anchors} := 5in$		C _{anchors} := 5in	Edge and Anchor Spacing distances (inches)
		dymanic loading for 40	gth from Table 25, Page 151, Hilti 2016 Technical Guide for RE500V3 Epoxy with 000 psi concrete. Comparable for full scale static testing (TTI Project 490026
$f_{AN} := 0.70$	Reduct	ion 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.			ace With reinforcing use 0.40 factor.
Ecc _{BP} := 6in	Eccentric	cty of Anchor Bolts on E	Baseplate in Tension

$\mathbf{M}_{HiltiAnchors} := \mathbf{F}_{vHilti} \cdot \mathbf{f}_{AN} \cdot \mathbf{f}_{RN} \cdot 2 \cdot \mathbf{Ecc}_{BP} = 11.675 \cdot kip \cdot ft$

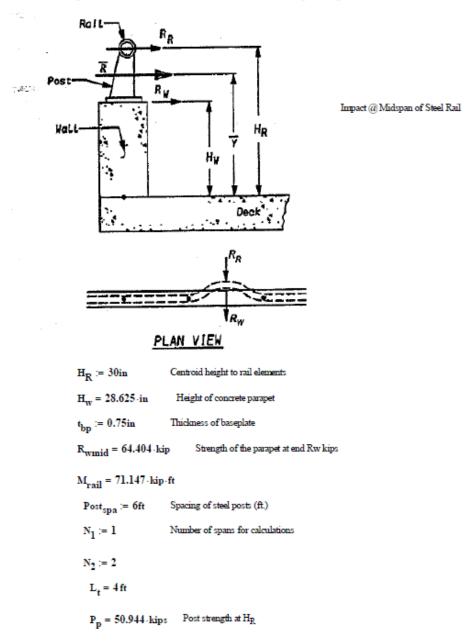
Use Hilti RE500V3 for A193B7 Threaded Rods, embedded 10 inches minimum

$$P_{p2} := \frac{M_{HiltiAnchors}}{Ht_{post}} = 50.944 \text{ kip}$$

 $P_p := P_{p2}$ 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





$$\mathbf{R}_{1} := \frac{\mathbf{16} \cdot \mathbf{M}_{rail} + (\mathbf{N}_{1} - 1) \cdot (\mathbf{N}_{1} + 1) \cdot \mathbf{P}_{p} \cdot \mathbf{Post}_{spa}}{2 \cdot \mathbf{N}_{1} \cdot \mathbf{Post}_{spa} - \mathbf{L}_{t}}$$

$$\mathbf{R}_{2} := \frac{\mathbf{16} \cdot \mathbf{M}_{rail} + \mathbf{N}_{2}^{2} \cdot \mathbf{P}_{p} \cdot \mathbf{Post}_{spa}}{2 \cdot \mathbf{N}_{2} \cdot \mathbf{Post}_{spa} - \mathbf{L}_{t}}$$

R₂ = 118.051 · kips Strength over 2 spans

$$R_{wreduced} := \frac{R_{wrid} \cdot H_w - P_p \cdot H_R}{H_w} = 11.012 \cdot kips$$

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

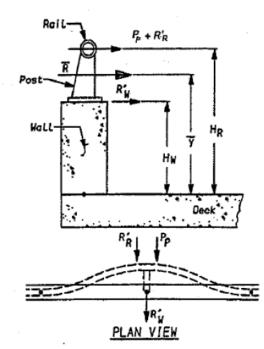


Figure A13.3.3-2 Concrete Wall and Metal Rail Evaluation---Impact at Post.



$R_{bar2} := P_p + R_2 + R_{wreduced} = 180.007 \cdot kips$	equation A13.3.3-3 LRfd Section 13 Strength of the rail at a post	Strength OK for 1 and 2 span
$\mathbf{Y}_{bar2} := \frac{\mathbf{P}_{\mathbf{p}} \cdot \mathbf{H}_{\mathbf{R}} + \mathbf{R}_{2} \cdot \mathbf{H}_{\mathbf{R}} + \mathbf{R}_{wreduced} \cdot \mathbf{H}_{w}}{\mathbf{R}_{bar2}} =$	29.916 in Equation A13.3.3-4 LRF	D Section 13
15.) Total Resistance of Bridge Rail System (as conti	<u>10us):</u> R _T	
Since the rail retofit bears on top and against the concrete parapet, con Centroid height of the rails very close to top of concrete parapet, ther		
R _{wmid} = 64.404 · 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 ty	pical joint/end failure.
$\mathbf{R}_{\mathbf{W}} := \mathbf{R}_{\mathbf{Wmid}} = 64.404 \cdot \mathbf{kip}$	Critical Resistance of the Concrete Parapet ((kip)
$H_{W} = 28.625 \cdot in$	Height of the Concrete Parapet measured fr	om the roadway surface (in.)
$\mathbf{M}_{parapet} := \mathbf{R}_{W} \cdot \mathbf{H}_{W} = 153.63 \cdot kip \cdot ft$	Moment Capacity of the Concrete Parapet ()	k-ft)
y _{bar} = 30.098 in	Height of the Centroid of the Steel Rails me surface (in.) (See Figure 4)	asured from the roadway
$M_{rail} = 71.147 \cdot kip \cdot ft$	Moment Capacity of Steel Rails (k-ft) (bending strength at the splices This resis conservative due to dynamic strength at imp	

 $\mathbf{M}_{\mathbf{T}} := \mathbf{M}_{parapet} + \mathbf{M}_{rail} = 224.777 \cdot kip \cdot ft$

$$y_{T} := \frac{M_{parapet} \cdot H_{w} + M_{rail} \cdot y_{bar}}{M_{T}} = 29.091 \cdot in$$

$$\mathbf{R}_{\mathbf{T}} := \frac{\mathbf{M}_{\mathbf{T}}}{\mathbf{y}_{\mathbf{T}}} = 92.719 \cdot \mathbf{kip}$$

Centroid Height of the Total Resistance of the Bridge Rail System measured from the roadway surface (in.)

Total Resistance of the Bridge Rail System (kip) from item 15 above.

Total Moment Capacity of Bridge Rail System (k-ft)

Texas A&M Transportation Institute	SUBJECT: <u>LADOTD (LTRC 16) HSS</u> <u>Tube Bridge Rail Retrofit LRFD</u> <u>Strength Analysis</u>
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, \mathbf{F}_{t} due to curb and deck geometry (in.)
$H_e = 19 \cdot in$	From Full scale crash testing, truck impacts rail $@$ He
$\mathbf{R}_{\mathbf{R}} := \mathbf{R}_{\mathbf{T}} \cdot \left(\frac{\mathbf{y}_{\mathbf{T}}}{\mathbf{H}_{\mathbf{e}}} \right) = 141.964 \cdot \mathbf{kip}$	Total Resistance of the Bridge Rail System located at $\rm H_{e}$ (kip)
$\mathbf{F}_{t} = 71 \cdot \mathbf{kip}$	Transverse Impact Force located at $\rm H_{e}$ (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 REPORTFORASTM A307, GRADE A - HEX BOLTS

FACTORY: ZHEJIANG ADDRESS: XITANG (DATE: MAY.20,2016					
1001000.10110.00	MFG LOT NUMBEF0405006					
CUSTOMER: BRIGHTON	N-BEST INTERNATIONA	L(TAIWAN)INC.				
			PO NUM	BER:	C11420	
SAMPLE SIZE: ACC. T	O ASME B18. 18-2011	Categories 2				
SIZE: 1/2-13X1-1.	/2" ZP QTY:	48150 PCS	PART NO	9494086 2		
HEADMARKS: 307A +	NDF					
STEEL PROPERTIES:						
STEEL GRADE: 1008			HEAT N	JMBER :	1B-42019	6 5
CHEMISTRY SPEC:	1 · · · · · · · · · · · ·	2% S% 0.04max 0.15max]			
TEST:	0.25 1122 1.20 1122 0.29	0.024 0.021	3			
DIMENSIONAL INSPE	CTIONS	SPECIFIC	CATION: A	SME B18.2.	1-2012	
CHARACTERISTICS	SPECI	FIED	ACTUA	AL RESULT	ACC.	REJ.
****	*****	*******	****	****	******	******
APPEARANCE	ASTM F78	8/F788M-13	PASSED		100	0
THREAD	ANSI B1.1-	08 2A	PASSED		32	0
WIDTH FLATS	0.750"-0.72:	5"	0.728"-0.1	748"	8	0
WIDTH A/C	0.866"-0.82	6"	0.834"-0.8	355"	8	0
HEAD HEIGHT	0.364"-0.30	2"	0.308"-0.3	335"	8	0
BODY DIA.			FULL TH	IREAD	8	0
THREAD LENGTH					8	0
LENGTH	1.54"-1.44"		1.46"-1.47	7"	8	0
MECHANICAL PROPE	RTIES:	SPECIFIC	CATION: A	ASTM A307	-2014 GR-J	A
CHARACTERISTICS	TEST METHOD	SPECIFIED		L RESULI		REJ.
CORE HARDNESS :	ASTM E18-14a	69-100 HRB		HRB	8	0
WEDGE TENSILE :	ASTM F606-14	MIN 60KSI	72-75		4	Ő
CHARACTERISTICS	TEST METHOD	SPECIFIED		RESULT	ACC.	REJ
****	****	***	****	****	****	*****
ZINC PLATED	ASTM F1941-15	FE/Zn 3AN	PASS		15	0
ALL TESTS IN ACC	CORDANCE WITH TH	HE METHODS PR	ESCE	THE	APPLICA	BLE
ASTM SPECIFICATIO	N. WE CERTIFY TH	LAT THIS DALA I	S ISTER	ES	ENTATIO	N OF
INFORMATION PROV	IDED BY THE MATE	RIAL SUPPLIER A	N K	TAR G	LABORAT	FORY.
All parts meet the requ	irements of FQA and ree	cords of compliance	e 1. 41 192	mi		
Maker's ISO#CN11/20	818		BC MM	書牌 *		
	-		TEST	INC CONT	•	
		(SIGNATURE (DF Q.A. L	AB MGR.)	

(ZHEJIANG GOLDEN AUTOMOTIVE FASTENER CO.LTD)



3441 NW Guam Street, Portland, OR 97210 Web: www.portlandbolt.com | Email: sales@portlandbolt.com

Phone: 800-547-6758 | Fax: 503-227-4634

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 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 Tensile: 35,340 LBF Ni: .070 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 Certification Department Quality Assurance Dane McKinnon

S Portland Bolt & Mfg S CPU Seguin 0 0 3441 NW Guam St H H 1 2441 NW Guam St H H Seguin TX 1 939310-1613 1 1 Seguin TX 1 15 032274634 0 1 999999999 1 5032274634 0 1 999999999999999999999999999999999999	CO" Totand Bolt & Mfg S CPU Seguin CO" 0 Portland Bolt & Mfg S CPU Seguin D Portland OR US 73155-7510 D Portland OR US 78155-7510 D Soziote1613 D Seguin TX D536A032 T 592210-1613 T Seguin TX D5355A032 T 592210-1613 T Seguin TX D5355A032 T 592210-1613 T Seguin TX D5355A032 T 592210-1613 T T Seguin TX D532275463 T 592210-1613 T T Seguin TX D 0.17% Bend Test T T Seguin TX Mn 0.21% Elongation test 2 T Seguin TX Si 0.25% Elongation test 2 T Seguin TX Si 0.01% Bend Tes	CPU Seguin	S Portland Bolt & Mfg 0 0 3441 NW Guam St L 3441 NW Guam St 0 D Portland OR 0 U 97210-1613 1 1 50322755488 0 3032274634 0 5032274634 alue .15% 0
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test 1 17% test 1 81N test 1 45%	test 1 17% test 1 18% test 1 45%	of the plant quality manual	toet 1
ess 1 17%	test 1 1/% test 1 8/N test 1 45%	"Meets the "Buy America" requirements of 23 CFR6	1 1001
test 1 45%	test 1 45%	*Warning- This product can expose you to chemical	t test 1
		known to the State of California to cause cancer, t	t per 1
		or other reproductive harm. For more information gr 10 www.P65Wamings. ca.gov	1001

Page 1 OF 1 05/15/2020 16:04:04

	32394	Job Information	Certified	Date: 4/2/20	
Customer:				Ship To:	
Customer Part No:					9
Customer PO No:				Shipped Qty:	8
Lot Number:	32394-6215169002			-	
		Part Information			
					-
Part No:	A563 5/8-11 +0.020 DH I	HHN HDG BLUE DYE			(\bigcirc)
					A
Description:	ASTM A563 HHN, Grade Dye	DH, Hot Dipped Galv, Blue			
Manufactured Quantity:					
	100,200				
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Specificatio	The second	mend	Specification		Amend
ASME B18.2.6	2003 2019	ASME B18.2.2		2015	- a meanad
ASTM A563	2015	ASME B18.2.6N ASTM F2329/F2		2012	
ASTM F606/606M	2019	ASTM F812	102 9141	2015 2017	88 B
est Results				2017	
Test No: 21749 Test: A563 DH					_
Description Hardness (HR	degree F Min)	Min LBS)	Shape & Dimension ASME B18.2.2	Thread Precision ASME B18.1.1	Visual ASTM F812
Inspection 28.2	1,166	33,900	Pass	Pass	Pass
Heat No Grade Manu	facturer Origin C	Certified Chemical Analy	sis si	Cr NI	Cu
6215169002 1045 Ge	erdau USA 0.460		0 0310 0 2000	0 1300 0.0700	0 2200
Il teste ara in anordana a il u	he latest as fat	Notes hods prescribed in the applicable			-
roducts. he steel was melted and manuf	actured in the U.S.A. and the	sted above and were manufactu h Bismuth, Selenium, Tellurium, product was manufactured and rovided by the material supplier be reproduced execution in full.	or Lead was intentionally a tested in the U.S.A.	added have been used to	o produce
OFFICIAL SEAL	ors 21		Churt Ans.		4/2/20
JEAN E MARGHERIO HOTARY PUBLIC - STATE OF ILLIN MY COMMISSION EXPIRES.OR 10	~~~~5				
NOTARY PUBLIC - STATE OF ILLIN	5		Thorsen, Chris - Supervisor	, Quality	Date

GERDAU UNTITIE INCLARALE PLANT UNTITIE INC UNTITIE INCLARALE PLANT UNTITIE INC	US-ML-ST PAUL USA ULE.IL 61301 PERU.IL 61384-9710 USA RED ROCK ROAD USA	SAILT PAUL, MN 55119 SALES ORDER CUSTOMER MATERIAL N° 8310712/000060 B1045SC0.8750 I B1045SC0.8750 I	CUSTOMER PURCHASE ORDER NUMBER BILL OF LADING DATE P008345 1332-0000071194 01/14/2020	CHEMICAL COMPOSITION CHEMICAL COMPOSITION CHEMICAL COMPOSITION 0.46 0.77 0.09 0.031 0.20 0.22 0.07 0.15 0.15		and bot rolling, have been performed at Carcia Manufortung processes for this steel, which may include scrap melted in an electric are furnace and hot rolling, have been performed at Carcia St. Paul Mill. 1678 Red Kost Rad, Stan Paul, Minnerson, USA. All product produced from strand cast billets. Silicon Nileci (geordized) seet. No well repirations for exposed to mercury or any liquid any which is provided by Carcia-Silicon Nill without the repressed written consent of Gerdau St. Paul Mill. posts report and treport shall not be reproduced except in full, without the expressed written consent of Gerdau St. Paul Mill without the expressed written consent of Gerdau St. Paul Mill without the expressed written consent of Gerdau St. Paul Mill without the expressed written consent of Gerdau St. Paul Mill. Gerdau St. Paul Mill without the expressed written consent of Gerdau St. Paul Mill without the expressed written consent of Gerdau St. Paul Mill. Gerdau St. Paul Mill without the expressed written consent of Gerdau St. Paul Mill. Gerdau St. Paul Mill without the expressed written consent of Gerdau St. Paul Mill. Gerdau St. Paul Mill without the expressed written consent of Gerdau St. Paul Mill. Gerdau St. Paul Mill without the expressed written consent of Gerdau St. Paul Mill. Gerdau St. Paul Mill is not Real basch St. 2016 JEne Can (FG S-3) Outly Program Manual Rev. 10. Implemented date 11/8/2019 Macro SI R1 CI Reduction Ratio. 49.9 (ASTM E381-17 EdS-18) Macro SI R1 CI Reduction Ratio. 49.9 (ASTM E381-17 EdS-18)		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 presented 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.	Machay BHASAR YALMARCHEL
GRADE SHAPE / SIZE 1045M23FJZN Round Bar / 7/8*	LENGTH WEIGHT 24'10' 21,462 LB	SPECIFICATION / DATE or REVISION	ASTM A576-17	Mo 200	600'A 418'A	lectric arc furnace ar produced from strand v bhich is arion as report. This Mill is not	DEBRAL, KARIESCH NOENPL, KARIESCH Noemmen tenn inn i 200	f Company. We certify that these data are correct i, including the billets, was melted USA. CMTR or	M 2 ALEA BRANDENBURG
1/8* DOCUMENT 10: 0000035284	HEAT 6215	_		₩ N			KARIESCH eMinnesch am Jan 1, 2023	nd in Inplies	

Universal Galvanizing, Inc. 510 E South 1st St. Wright City, Missouri 63390 Phone:(636)791-2016 Fax:(636)745-0667

Date: 3-27-20

1

RE: GALVANIZING CERTIFICATE UNYTITE, INC. PO# P009098

QTY 53,268	PART NUMBER/DESCRIPTION A563 5/8-11+0.020 GRADE DH HEAVY HEX NUT	LOT NUMBER 32394-6215169002	COATH 3.5	N <u>G THICKNESS</u> AVG. MILS	
48,064	A563 5/8-11+0.020 GRADE DH	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

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

350

10/29/2019

Certification Date:

Page: 1 of 1

Order Details

Part Number.	F0058	Blue Print Rev	1279
Packing Slip:	7259	Material Type	1030 - 1050
Purchase Order.		Quantity:	400,244
IST Order Numb	er. 801460-1	Net Weight:	13,128.0
Lot Number.	1019-282	Part Desc:	WASHER
Heat Number.	31938550	Comments	9 TUBS#121

SPECIFICATIONS

HRC 38 - 45 HEAT TREATED IN THE USA

RESULTS

HRC 41-43 HEAT TREATED IN THE USA

9 TUBS#1218,1989,C91,951,

416,921,003,640,655

Approval: Jom Leny

Tom Levy - Quality Assurance Supervisor

Tom Levy - Quality Assurance Supervisor

Voice: 517-780-9043 Fax: 517-787-5441 E-Mail: tolevy@indst.com

This Certification cannot be reproduced except in full, without written authorization from Industrial Steel Treating Company, LLC.

Contact

248-615	IGTO -0500	ARCH DRIV N HILLS, MI	E 48335	SAL	BRE ST	1 79.1 6		10/14/2019 1:23:57 PM
Sold To:		TECHNICA 50600 E. RI CHESTERF	L STAMPIN USSELL SC TIELD TWP.,	HMIDT BLVD		Ship To:	50600 1	IICAL STAMPING RUSSELL SCHMIDT BLVD. ERFIELD TWP., MI 48051
Cust PO:			S91539		Ship Date	: 10/15/2019		
Sales Or	der:		77172		Weight:	29,710#		
				C	HEMICAL ANA	LYSIS	1.46	
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):	.52		31938550 Mn:	.72	P:	.008	0.	-
Si:	.24		Ti:	.001	Cr:	.008	S: Mo:	.0001
Cu: li:	.10		AI:	.028	Cb:		Va:	.002
11: 1976-1976)	.03	Star Daring	B:		Sn:		N:	
1919103.4	7. F	an the off		PH	SICAL PROP	ERTIES		
'S: hemistry		C1050	TS:		E:			
ine:		1	ltem: Grade: Cust Part:	.122min X 3.1 HRP&O High E0058M	9500 C1050 Carbon			
omment		Tags 065946		Made & Melted	In The USA			
/E HER EQUIRI EST LA	EBY C MENT BORA	SANDARE	IE ABOVE TRACEAE		CORD'S BA		, MEET Y PRODUC	OUR MATERIAL ER AND/OR AN ACCREDITED
			-6	Qualit	Assurance	Manager		

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 0.0001</t Metallurgical Certification Page 1 of 1 SDI does not weld or repair Prime Hot Rolled Band All tests were performed according to applicable standards and are correct as contained in the records of the company. Heat # 31938550 PO# 65716 - 4 How were the Melted, thin slab cast and rolled by proud Americans in Butler, IN, USA. Shipped from Butler, IN, United States. **Coil Alias** Cert # 3360599 Hiroshl Kimura Metallurgist Material Spec. SAE 1050 WITH SILICON Product Desc. Prime Hot Rolled Band Porola Coil # 198448749 Order # 663249 products. Line Item # 4 Part # Surface Treatment Cert Comment Steel Dynamics Rev. Level 1.15 [1560] Width 50.2500 in. / 1,276 mm Chem Treat No Oiled No 4500 County Road 59 Butler , IN 46721 USA Telephone (260) 868-8000 Fax (260) 868-8955 Contact Taylor RECEIVING P: 847-695-2900 F: 847-695-2950 P: 313-291-8535 Contact Bob Alexander 0.1250 in. / 3.18 mm | Min Flat Roll Group Gauge Mechanical Properties (if applicable) Farmington Hills, MI 48335 United States 49,350 lbs / 22,384.77 kg Voss Industries - T 7925 Beech Daly Road Retrieve on : 9/30/2019 8:44:06 PM Sabre Steel Inc. 23680 Research Drive 2,227 ft. / 679 m Ladle Chemical Analysis (%) Taylor, MI 48180 United States Length Weight 105 Ship To Sold To



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

 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

Geros Doering

Peggy Doering Office Manager

PD:ac

		10 Cross C Pelham, A Tel (205) 6	L 35124 20-5100	s	JOB	MATE	RIAL CE	RTIFIC	ATION
	Job No:	676043		Job Info	rmation	Ce	ertified Date:	6/8/20	
	Containers:	S17187917							
	Customer:	Interstate Thr	readed Produ	cts	ił.		Ship To:	2200 Singlet Dallas, TX 7	
Vul	can Part No:	ATR B7 5/8x	12 HDG						
Custo	mer Part No:	ATR B7 5/8x	12 HDG						
Cust	omer PO No:	43237					Shipped Qty:	96 Ft	
	Order No:	403988					Line No:	3	
	Note:								
		- 1.1.40		Applicable S	pecifications			•	
Ty Heat			ASTM F1 ASME SA-	cification 554 Gd 105 S4 193/SA-193M M A193 B7		Re 20 20 20	18 13	nend	Option
st Results									
e following	pages for test	is							
				Certified Cher	nical Analysis	3			
	a a state and the set	eat No: 206884					Origin: USA	41 12 14.4 14 14 14	
C 0.42	Mn 0.85	P 0.010	S 0.003	1 Si 0.29	Cr 0.88	Mo 0.15	0.05	0.001	Cu 0.14
0.42 Al	Nb	0.010 Sn	Ti	0.29 N	0.00 B	0.15 D1	0.05 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	JG	J7	J8
1	1	57	57	57	57	57	54	53	51
J9	J10	J12	J14	J16	J18	J20	jJ24	j28	J32
50	48	46	44	41	40	39	37	34	33
				No	tes				

Plex 6/8/20 11:34 AM vulc.sano Page 1 of 2

	PRODUCTS, I	10 Cross Pelham, A Tel (205) (20-5100	ts	JO	B MATER		ERTIFIC	ATION
	Job No	668113		Job Info	ormation	Certi	fied Date:	4/8/20	
	Containers	: S17411160							
	Custome	r: Winzer Corp					Ship To:	1214 S. Tex Bryan, TX 7	
Vi	lcan Part No	: ATR B7 3/4x	2 HDG					500 • 7 6 10 • 12 2 8 6 10	
Custo	omer Part No	: ATR B7 3/4x	2 HDG						
Cus	tomer PO No	1103397				C 1	inned Ohu		
545		: 407308				Sr		1 container:	5
							Line No:	1	
	Note	2:					-		
				Applicable S	pecifications				
Т	/pe			ification		Rev	Ame	nd	Option
-		ASTM F1554 (2018			
Heat Treat		ASTM A193 B				2019			
Test Results									
See following	pages for te	ests							
1.2.2		and the second second		Certified Cher	nical Analysis				
		Heat No: 106492	20			C	rigin: USA		
С	Mn	Р	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
AI	Nb	Sn	Ti	N	В	DI	RR	G.S.	Macro S
0.028 Macro R	0.001 Macro C	0.007	0.002	0.0070	0.0001	5.21	54:1	fine	1
Macro R	Macro C	J1 57	J2	J3	J4	J5	J6	J7	J8
19	J10	5/ J12	57 J14	57 J16	57	57	57	55	54
53	51	49	J14 47	J16 45	J18 44	J20	J24	J28	J32
00	51	43	4/			43	41	39	37
		- Makerin III III		No	tes				

Plex 4/8/20 2:04 PM vulc.sano Page 1 of 2

THREADED	PRODUC	Te	elham, AL 351 el (205) 620-5 ax (205) 620-	100		JC		RIAL CE	KIIFIC/	AUON	
	Jol	b No: 6681 ⁻	13	Jot	o Infor	mation	Ce	rtified Date: 4	/8/20		
	Contai	ners: S174	11160								
Test Results	5										
Part No: BA	R B7 .68	13x292 HT									
Test No: 596	60 Test	Quench & Ter	nper Informa	tion (Lbs)							
Description	1	tenitizing Te		Tempering Temp	(F)	Run Spee	ed (Ft/min)	Quench Water	Temp (F)	Note	
Results		1,660		1,346		New Second Street Street	40	89			
Test No: 596	65 Test	Partial Decarb	Test								
Des	cription		Surf	ace Carb.			Partial Surfa	ce Decarb.		Note	
			2.11	Pass Pass							
Test No: 506	66 Test	F1554-105 FE	Requiremon				10				
				Offset (ksi) (ksi)	Flore	ation (%)	Elemention C		DOA (61)		
Description	Tenane	138	11610 0.276	129		13.1	Elongation G	age Length (8in) 8in	ROA (%)	Note tested by external	
Teat Na: 506	7 Test	4402 D7 F45	54 405 D	••						provider	
	Tensile	A193 B7, F15 Yield 0.2%			ROA	Midradi	us Surface	Center	Hardness		
Description	(ksi)	Offset (ks		Gage Length	(%)	Hardnes			Fardness Fest 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		
	139 138	128	19	4D 4D	61 62	29 29	29 29	29 28	HRC		
	137	125	21	4D 4D	61	29	29	28	HRC		
	139	128	20	4D	61	30	30	30	HRC		
	137	126	19	4D	61	29	29	29	HRC		
Test No: 5966	38 Test:	F1554 Gd105	S4 Charpy ft	/lbs Requirements							
Description			Temp (F)	Test1 (ft/lbs)	Test	2 (ft/lbs)	Test3 (ft/lbs) Results Av	(ft/lbs)	Note	
	1000000		-20	81		102	86	90		Hote	
The reported t taken from the Material was n product standa Management S Material was to F606, and F23	est results productio nanufactu ard and in System reg ested in a 28 test me	a are the actua in lot. red, tested, ar accordance w gistered June 3 ccordance wit ethods.	I values mea ad inspected a ith Vulcan''s 30th, 2017. h the current	ons listed above. sured on the sample as required by the ISO 9001:2015 Qual revision of ASTM A ed, except in full, with	ity 370,	-	Sallie M	`orwood		4/8/20	
This test repor	mission o	f Vulcan Steel	Products.				The second second second	ertification Enginee		Date	
	accordar	nce with FN 10									

CERTIFIED MATERIAL TEST REPORT FOR ASTM A194/A194M-10a GRADE 2H HVY HEX NUTS

FACTORY:	NINGBC	HAIXIN HARDWARE CO., LTD.
ADDRESS:	XIJINGT	ANG,LUOTUO NINGBO ZHEJIANG 315205
	<u>CHINA</u>	
CUSTOMER:	BRIGHT	ON-BEST INTERNATIONAL (TAIWAN) INC
QNTY SHIPP	ED:	28.800MPCS
SAMPLE SIZE	E:	ACC. TO ASME B18 . 18 . 1 - 02
SIZE & DESC	RIPTION:	5/8-11+0.020"(HDG)

DATE: AUG.08.2011

MFG LOT NUMBER: <u>1033130006</u> PO NUMBER: <u>U04584</u> PART NO: <u>313150</u>

STEEL GRAD		SWRCH ITION:	<u>145K</u>	SIZE:	<u>25mm</u>			HEAT NO:	<u>33</u> 1	105231
CHEMIST	С%	Mn %	Р%	S%	Si %	Cr %	Ni %	Cu %	Mo %	OTHERS
SPE:	MIN	MAX	MAX	MAX	MAX			Curt	1010 70	OTHERS
	0.40	1.00	0.04	0.05	0.40					
TEST:	0.45	0.73	0.009	0.01	0.21					
DIMENSIONA CHARACTER	ISTICS	CTIONS	TEST ME	THOD	SPECIFI SPECI	CATION		SI B18.2	. 2 - 87(R1 ACC	999) REJ.
*****			******	******	******	******		*****	******	NLJ. *****
APPEARANC	E		ASTM I	7812-02			PA	SSED	100	0
WIDTH A/F			1.031 "	-1.062"			1.042	-1.052"	32	0
WIDTH A/C	4		1.175"-	1. 227 "			1.180	-1.221"	32	0
THREAD			ASME	B1.1-02			PAS	SSED	8	0
HEIGHT			0.587"-	0.631"			0.597	-0.611"	32	ů
MARK			2H*	LM			PAS	SSED	100	0
MECHANICA	PROPER	TIES:	TO 1-1/2	' in		SPECIE	ICATION:	ASTM A19	10-	
CHARACTER			TEST ME		SPECI *******		ACTUAL	RESULT	ACC.	REJ.
ARDNESS			ASTM I	E18-05	24-35H	IRC	HRC	28-30	5	0
ROOF LOAD			ASTM F	606-07	3955	0lbf		50lbf	5	0
DECARBURIZ			SAE.	121				SED	1	0
ARDNESS A	FTER 24H	AT 540	CASTM	A194 MIN	89 HRB			3 92-94	5	0
EMPERING 1	EMPERA	TURE N	4in455 ^o C				PASSET	D(520°C)		0
MACROETCH			ASTM E3		SI/R1/C1~			(520 C)		

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

Aanbeed

(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

	P/O NO.: B1610	00374	QTY(MP): 33.75		INVOICE	NO: 17075DX228-018
Customer.	Product Descriptio		luts			
	Specification:	3/4"-10		T/O: 0.51	Lot#: 161	0DX228-0242
	Material:	45K	Surface Finish: HDG		Heat No.:	J11604926
	Mark:	DX,2HZN		Part Number:	3132	200

Specification: ASTM A194-16

Element	C	Mn	D	e	C :	-
Element	v	N/III	F	5	51	
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°C 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

Test Item	Spec.	Inspection Results	Sampling	Rej	Remark	Test method
Widthacrossflats(mm)	30.78 - 31.75	31.24-31.42	125	0	ок	
Widthacrossangle(mm)	35.10 - 36.65	35.80-35.97	125	0	ОК	
Height(mm)	18.03 - 19.25	18.52-18.72	125	0	ОК	
Go Gauge	GO	GO	125	0	ОК	ASTM 81.1-02
No-Go	NO GO	NO GO	125	0	ОК	ASTM 81.1-02
Appearance	OK	ОК	125	0	ок	ASTM F812-07

MACROETCH

Random Condition Surface Condition Center Segregation Spec. Of test method Spec. S2 R2 C3 ASTM E381 Results S2 R2 СЗ NOTE

Division

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°C about 80 minutes, Tempering at 550°C 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

宁波东鑫高强度 NNGBD DONGXIN HIGH 9 KB

(2)

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

INSPECTION CERTIFICATE



CUSTOMER	PORTEOUS FASTE	NER CO.	
PART NAME	ASTM F436 - 09 TYP	E 1 WASHERS (HOT DIP GAI	LV. 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	

DEMONDER	N RESULTS	INSPECTIO	NON	CIFICAT	C DE/	INSPECTION ITEM	
REMARKS	MAX.	MIN.	ION	JIFICAI	SPEC	INSPECTION TIEM	
-	1.4681	1.4547	1.5000	14	1.4360	OUTSIDE DIAMETER	1
	0.8354	0.8311	0.8450	-	0.8130	INSIDE DIAMETER	2
	0.1394	0.1311	0.1770	-	0.1220	THICKNESS	3
	27.0	26.1	- 45	26	HRC	HARDNESS	4
	75.6	46.0	43 μm	GALV.	HOT DIP	COATING	5
	K	0		VISUAL		APPEARANCE	6

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

PDF created with pdfFactory trial version www.pdffactory.com

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

INSPECTION CERTIFICATE



CUSTOMER	PORTEOUS FASTE	NER CO.	
PART NAME	ASTM F436 - 09 TYP	E 1 WASHERS (HOT DIP GAL	V. PER ASTM A153)
SIZE	5/8 "	DATE	April 01, 2011
PART NO.	W2A6C5000S6JV	REPORT NO.	1000401-01
CUST. PART NO	0. 00385-3000-024	SHIPPING NO.	
MATERIAL / DIA	. <u>10B20 / 20 mm</u>	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	

	INSPECTION ITEM	SDE	CIFICAT	CION	INSPECTIO	N RESULTS	DEMONSTR
	INDIFICIENT ITEM	5115	CIFICA	ION	MIN.	MAX.	REMARKS
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		C	DK	

HOT DIP GALV. 43 µm		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

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Call Material No: 7050250 ATTINIAL TEST REPORT Material No: 7050250 Anterial No: 7050250 Naterial No: P S P No 0.0009 0.0014 0.037 0.007 0.000 0.0009 0.0014 0.0014 0.004 0.001 0.0010 0.0014 0.005 0.004 0.001 0.0010 0.0014 0.005 0.004 0.016 0.0010 0.0014 0.005 0.004 0.016 0.0010 0.0014 0.005 0.006 0.006 0.0010 0.011 0.005 0.006 0.016 0.0010 0.011 0.005 0.005 0.016 0 0.0010 0.011 0.005 0.006 0.016 0 0.0010 0.0017 0.016 0 0 0 0.0010 0.0017 0.005 0.005 0.016 0 0.0010 0.0017 0.005 0.0016 0 0 0.0011 0.0017 0.005 0.0016 0 0 0.0010 0.0017 0.005 0.005 0.0016 0 0.0010 0.0016	REF.B/L: 80954217 Date: 06/01/2020 Customer: 192	Shipped To Intsel Steel Distributors 11310 West Little York HOUSTON TX 77041 USA	Made in: Canada Melted in: Canada	Cr V Ti B N 0.034 0.002 0.002 0.0002 0.0002	0.002 0.002	Made in: Canada Nelted in: Canada		41 0.002 0.002 0.0040 CE: 0.34	ustrial) <u>% Harvested</u> Writhin Miles of Location 100% 1000	applicable specification and contract requiremen Metals Service Center Institute
Image: Second	TUDE MAN INDUSTRIES	PORT		Mo Ni 0.007 0.020	tification TM A500-18 on onsumer (Post 0%	0 1	Mo Ni	0.004 0.016 0.0 <u>Certification</u> <u>ASTM A500.18 GBA</u> T	Pre-Consumer (Post Industrial) 14.40%	e full compliance with all app
4 4 47 4 47 4 47 4 47 4 47 4 48 0.003 49 0.003 40 0.003 41 0.003 42 0.003 43 0.003 60 0.014 190 0.780 0.003 0.003 190 0.780 190 0.780 191 0.003 192 1 193 0.003 194 0.003 195 1 196 1 197 1 198 1 199 0.810 0.801 0.81 190 0.810 191 0.033 192 1 193 1 194 1 195 1 196 1 197 1 198 1 199 1 190 1 191 1 192 1 193 1 193 1	XLAS DIVISION OF ZEKEL	aterial test ri		21	Post Con 19.80%					I furnished and indicat
a 41 42 43 44 45 65 65 65 65 65 65 65 65 65 6		W	Material		926	Material Purchase		36.		fibutes of the materia
a 41 42 41 42 65 65 65 65 65 65 65 65 65 65			2x2).		57709 Psi Me N	(2x1).		0.0	BO	face literation
Artlas Tube Canada Actas Tube Canada Nor 160 Nor 15 Nor 15 N	nada	<u>Sold To</u> Triple S Steel Supply PO BOX 21119 HOUSTON TX 77026 USA	7.0x5.0x250x40'0"0(3 1514477	C Mn 0.190 0.780	PCs 4 Manticoke, (10.0x6.0x250x48 ⁺ 0"0(1521362		PCs 2	Mill Locati Nanticoke,	Authorized by Quality Assurance: The results reported on this report reported the Aws D1.1 me Calculated using the Aws D1.1 me Steel Tub D1 MB CALL

At las Tube Canada At las Tube Canada Harrow On Canada NOR 160 A DIVISION OI Fact: 519-738-3547 Fact: 519-738-3547	ty	10.0x6.0x250x48'0"0(2x2).	1521362 Purchase Order:	C Mn P S Si Al Cu	0.200 0.790 0.014 0.009 0.014 0.034 0.048	PCs Yield Tensile Eln.2in 4 061098 071252 Psi 32.5 %	Method Recycled Content BOF 36.90%	10.0x8.0x625x25'0"0(1x1)REC	1521862 Purchase Order:	C Mn P S Si Al Cu	0.800 0.014 0.008 0.016	PCs <u>Yield Tensile Eln.2in</u> 1 059292 Psi 071246 Psi 32.3 %	MILL Mill Location Method Recycled Content Post Co STELCO Nanticoke, ON BOF 36.90% 19.80% ste:	Authorized by Quality Assurance: 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. C calculated using the AWS D1.1 method.
AUBS TUDE A DIVISION OF ZEKELMAN INDUSTRIES	I DIVISION OF ZEKELMAN INDUSTRIES MATERIAL TEST REPORT	100060250	WLY-24807	Cb Mo Ni	0.004 0.004 0.017	Certification ASTM A500-18 GRADE B&C	nsumer 1	100080625	WLY-24818	Mo	0.005 0.006 0.019	Certification ASTM A500-18 GRADE B&C	Post Consumer Pre-Consumer (Post Industrial) 19.80% 14.40%	ind indicate full compliance with a
REF.B/L: Date: Customer:	Shipp Intee 11310 HOUSA USA	Made in:	Melted in:	Cr v Ti	0.042 0.002 0.002	SRADE B&C	Industrial) % Harvested 100%	Made in: Melted in:		Cr V Ti	0.051 0.002 0.002	BRADE B&C	Industrial) % Harvested 100%	vith all applicable specification and contract requirement
/L: 80954217 06/01/2020 mer: 192	<u>Shipped To</u> Inteel Steel Distributors 11370 West Little York HOUSTON TX 77041 USA	Canada	Canada	B N Ca	2 0.0002 0.0040 0.0002	CE: 0.35	Within Miles of Location 1000	Canada Canada		B N Ca		CE: 0.34	sted Wrthin Miles of Location 1000	d contract requirements. Enter institute

		4.0x4.0x313x48'0"0(5x2).	Purchase Order:	Mn P S Si Al Cu	0.010 0.018 <u>Tensile</u>	067661 Psi 073420 Psi 29.5 % Location Method Recycled Content ticoke, ON BOF 36.90%	2	8.0x6.0x500x48'0"0(2x2).	Purchase Order:	AI	0.013 0.0	tent	Authorized by Quality Assurance:	Steel Tube Institute	
Atlas Tube a division of zekelman industries	I DIVISION OF ZEKELMAN INDUSI KIES MATERIAL TEST REPORT	AL TEST REPO		MLY-24734	СÞ	48 0.006	Post Consumer 19.80%		800605004800	3		58 0.005	Post Consumer 19.80%	furnished and indicate	
		400403134800			0.004 0.015 0.035 (<u>Certification</u>	Pre-Consumer (Post Industrial) 14.40%		200			0.006 0.023 Certification	ASTM A500-18 GRADE B&C Pre-Consumer (Post Industrial) 14.40%	e full compliance with	0	
			Ma			0.035 0.002	st Industrial)		M.			0.0	s GRADE B&C	all applicable si	O Metals
REF.B/L: Date: Customer:	shinned To	Intsel Ste 11310 West HOUSTON TX USA	Made in: Melted in:			0.002	% Harvested 100%		Made in: Melted in:	ş	11 0000	400.0	% Harvested 100%	pecification and c	Service Cen
80954217 06/01/2020 192	Shipped To Intsel Steel Distributors (1310 West Little York HOUSTON TX 77041 USA		Canada Canada			0.0002 U.UGU CE: 0.34	Within Miles of Location 1000		Canada Canada	2	0000		Within Miles of Location 1000	ontract requirements.	Metals Service Center Institute

REF.B/L: 80954217 Date: 06/01/2020 Customer: 192	Shipped To Intest Steel Distributors 11310 West Little York HOUSTOW TX 77041 USA	Made in: Canada Netted in: Canada V Ti B N Ca O 0.002 0.0030 0.0002 0.002 0.0030 0.0002 0.0002 0.002 0.0030 0.0002 0.0002 0.003 0.0030 0.0002 0.0002 0.004 0.004 Mithin Miles of Location 100% 1000 1000 1000	with all applicable specification and contract requirements.
DOD ALASS TUDE DOD A DIVISION OF ZEKELMAN INDUSTRIES	MATERIAL TEST REPORT	Material No: 1200806254800 Purchase Order:: VLY-24807 Purchase Order:: VLY-24807 Curchase Order:: VLY-24807 S Si Al Cu Cb Mo Ni Cr I2 0.008 0.015 0.034 0.017 0.037 0.037 0.037 Pail Tensile Eln.2in Associal Rabote Bac Astimise Pail Pre-Consumer (Post Industrial) Pail Discosi 19.80% 14.40% 14.40%	Authorized by Quality Assurance: Authorized by Quality Assurance with all applicable specification and contract requirements. The results report represent the actual attributes of the material furrished and indicate full compliance with all applicable specification and contract requirements. The results report representation and contract requirements. The results report representation and contract requirements. The results report representation actual attributes of the material furrished and indicate full compliance with all applicable specification and contract requirements. The results report representation actual attributes of the material furrished and indicate full compliance with all applicable specification and contract requirements. The results report representation actual attributes of the material furrished and indicate full compliance with all applicable specification and contract requirements. The results report representation actual attributes of the material furrished and indicate full compliance with all applicable specification and contract requirements. The results report representation actual attributes of the material function actual attributes o
Atlas Tube Canada 200 Clark St. Harrow Ontario Canada NOR 100 rai. 519-736-3541	Fax: 519-738-3537 Sold To Triple S steel Supply PO Bax 27119 PO Bax 27119 PO Bax 27119 PO Bax 27119	Material: 12.0x8.0x625x48'0"0(2x1). Sales order: 1521362 Heat No C Mn 797462 0.190 0.090 0.0 Bundle No C 0.190 0.0190 0.0 MILL 0.190 0.790 0.0 0.0 Hast No C 0.190 0.00 0.0 Multice No Mill Location Material Note: Material Note: Sales Or. Note:	Authorized by Quality Assurance: The results reported on this report entropy CE calculated using the AWS D1.1 met CE calculated using the AWS D1.1 met

C REF.B/L: 80940403 Date: 03/10/2020 USTRIES	Shipped To Intsel Steel Distributors 11310 West Little York HOUSTON IX 77041	Made in: USA Mefted in: USA	Io Ni Cr V Ti B N Ca 006 0.010 0.040 0.001 0.0001 0.0050 0.0000 Certification CE: 0.34 0.001 0.0050 0.0000 ASTM AS00-16 GRADE B&C CE: 0.34 CE: 0.34 Pre-Consumer (Post Industrial) 26 Harvested Within Miles of Location 14.40% 500 500 500 500 500 500	00 Made in: USA Metted in: USA Metted in: USA USA 0. Ni Cr V Ti B N Ca 0.4 0.010 0.050 0.002 0.001 0.0040 0.0000 0.0000 0.0000 ASTM A500-18 GRADE B&C CE: 0.35 0.001 0.00000 0.00000 0.00000 0.0000 0.0000 0.	e with all applicable specification and contract requirements.
Atlas Tube Advision of Zekelman industries	MATERIAL TEST REPORT	Material No: 8 Purchase Order: V	NI OIO7 OI CU Cb M 10 0.007 0.014 0.045 0.020 0.004 0 1 Tensile EIn.2in 0.023 0.004 0 0 5 Psi 075380 Psi 33 % 1 Post Consumer 19.80% BOF 36.90% 19.80% 19.80% 19.80% 1	Material No: 4003037540 Purchase Order: VLY-24410 S Si Al Cu Cb N 0 0.010 0.018 0.050 0.003 0 <td>Authorized by Quality Assurance: A full compliance with all applicable specification and contract requirements. The results report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements. So the material furnished and indicate full compliance with all applicable specification and contract requirements. So the material furnished and indicate full compliance with all applicable specification and contract requirements. So the material furnished and indicate full compliance with all applicable specification and contract requirements. So the material function of the material furnished and indicate full compliance with all applicable specification and contract requirements.</td>	Authorized by Quality Assurance: A full compliance with all applicable specification and contract requirements. The results report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements. So the material furnished and indicate full compliance with all applicable specification and contract requirements. So the material furnished and indicate full compliance with all applicable specification and contract requirements. So the material furnished and indicate full compliance with all applicable specification and contract requirements. So the material function of the material furnished and indicate full compliance with all applicable specification and contract requirements.
Atlas Tube Corp. Chicago 1855 East 122nd Street Chicago Illinois USA 60633 Tel: 773-646-4500 Fax: 773-646-6128	Sold To Triple S Steel Supply PO Box 21119 HOUSTON TX 77026 USA	Material: 8.0x4.0x500x400°0(3x1)PB Sales Order: 1498356 Heat No C Mn P	atic 0	Material: 4.0x3.0x375x400°0(4x3). Sales Order: 1492004 m p Plaet No C Mn p D33833 0.210 0.790 0.019 Bundle No 0.790 0.019 p Bundle No 0.210 0.790 0.019 Bundle No 0.210 0.790 0.019 Bundle No 9.210 0.790 0.019 Bundle No 0.210 0.790 0.019 Bundle No 9.210 0.790 0.019 Material No 9.210 0.0100 Material Notes: Salee Or. Note: Sales Or. Note: 0.100 0.100	Authorized by Quality Assurance: The results reported on this report report CE calculated using the AWS D1.1 method. CE calculated using the AWS D1.1 method.

REF.B/L: 80940403 Date: 03/10/2020 Customer: 192		Shipped To Intsel Steel Distributors 11310 West Little York HOUSTON TX 77041 USA		Melted in: USA		001 0.001 0.0001 0.0040		26 Harvested Writhin Miles of Location 100% 500		Melted in: USA	Ti B N Ca	0060		26 Harvested Within Miles of Location 100% 500	all applicable specification and contract requirements. Metals Service Center Institute
RIES					Ni Cr	10 0.040	Certification ASTM A500-18 GRADE B&C	<u>Pre-Consumer (Post Industrial)</u> 14.40%			Ni Cr V	0.010 0.050 0	Certification ASTM A500-18 GRADE B&C	Pre-Consumer (Post Industrial) 14.40%	with all applicable spec
Atlas Tube a division of zekelman industries	T REPORT		400303754000	WLY-24410	b Mo	0.003 0.004			700505004000	WLY-24291	Mo	0.004 0.003 0			cate fuil compliance
	MATERIAL TEST REPORT		Material No: 40	Purchase Order: WI	Cu Cb	0.030		ttent Post Consumer 19.80%	Material No: 700	Purchase Order: WL	Cu Cb	0.020		tent Post Consumer 19.80%	I furnished and indi
	2		Mater	Purch	Si Al	.014	<u>Tensile</u> <u>Eln.2in</u> 077169 Psi 31 %	Recycled Content 36.90%	Mater	Purch	Si Al	018	<u>Tensile Eln.2in</u> 079066 Psi 36 %	Recycled Content 36.90%	A utes of the materia
			(4×3).		٩ ۵	14 0.00	<u>Vield</u> 063360 Psi 0771	BOF	3x1).		S	013 0.0	Yield Ten: 066337 Psi 0790	Method BOF	Annel Charles
Atlas Tube Corp. Chicago 1855 East 122nd Street Chicago Illinois USA 60633 Tel: 773-846-4500 Fax: 773-846-4500	Sold To	Triple Steel Supply PO Box 21119 HOUSTON TX 77026 USA	Material: 4.0x3.0x375x40'0"0(4x3).	Sales Order: 1492004	Heat No C Mn	0.190 0.780	<u>116 NO</u> 931772 9	Heat MILL Mill Location D83894 USSTEEL GARY,IN Material Note: Sales Or. Note:	Material: 7.0x5.0x500x40'0"0(3x1).	Sales Order: 1485177	c Mn	0.190 0.800	116 NO PCS 931582 3	Heat MILL Mill Location Y05253 USSTEEL GARY,IN Material Note: Sales Or. Note:	Authorized by Quality Assurance:

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80940403 03/10/2020 192	ors prk			2	0 0060	0000	<u>Within Miles of Location</u> 500			2	0.0050		S00 Miles of Location		ute
	Shipped To Intsel Steel Distributors 11310 West Little York HOUSTON TX 77041 USA	USA	NSA	α	0 0000	CE: 0.34	500	USA	USA	α	0.0001	CE: 0.32	With 500		Metals Service Center Institute
REF.B/L: Date: Customer:	Shipped To Intsel Steel C 11310 West HOUSTON T USA			μ	0.001		<u>% Harvested</u> 100%				101	CE	<u>%</u> Harvested 100%		Centel
200	0 7 - I J	Made in:	Melted in:	-	0.001 0		<u>% Har</u> 100%	Made in:	Melted in:	Ϊ			<u>% Har</u> 100%		ervice
				>	0.0	S	trial)	2	S	>	0.001	U,	rial)		als S
				ŗ	0.050	Certification ASTM A500-18 GRADE B&C	Pre-Consumer (Post Industrial) 14.40%			ŗ	0:030	Certification ASTM A500-18 GRADE B&C	Pre-Consumer (Post Industrial) 14.40%	andicahlo	Met
STRIES				ĩ	0.010	Certification ASTM A500-18	Insumer (F			Ni	0.010	Certification ASTM A500-18 (Isumer (P	lie diw a	80
UDNI NE	ORT	4000	10	Mo	0.003	Cert	Pre-Col 14.40%	4800	ক	Mo	0.005	Certi	<u>Pre-Cor</u> 14.40%	complianc	
Atlas Tube A DIVISION OF ZEKELMAN INDUSTRIES	MATERIAL TEST REPORT	700505004000	WLY-24291	Cb	0.004		usumer	800805004800	WLY-24524	Cb	0.003		Isumer	dicate full	
	RIAL TE			Cu	0.020		Post Consumer 19.80%			Сц	0.030		Post Consumer 19.80%	hed and in	
ADIVI	MATE	Material No:	Purchase Order:	AI	**	Zin	Content	Material No:	Purchase Order:			<u>ri</u>	Content	rial furnis	
		Ma	Pu	A		<u>Eln.2in</u> 36 %	Recycled Content 36.90%	Mat	Pur	AI		<u>Eln.2in</u> 34 %	Recycled Content 36.90%	the mate	
				Si	0.018	Tensile 079066 Psi				ŝ	0.010	<u>Tensile</u> 071291 Psi	36. 36.	v utes of	
				s	0.008	<u>Ter</u> 079	<u>Method</u> BOF			s	0.005	0712	BOF	Creckone stual attrik	
)(3x1).		۵.	0.013	Yield 066337 Psi		(2x2).		٩	0.010	<u>Vield</u> 060302 Psi		france b	
0		7.0x5.0x500x40'0"0(3x1).		Mn	800		Mill Location GARY, IN	8.0x8.0x500x48'0"0(2x2).		Mn	780		MIII LOCAUON GARY,IN	urance:	Steel Tub Institute
o. Chica Id Street USA \$500 \$128	pply 7026	X5.0x5	1485177	1	0.190	3 BCs		x8.0x5(38356		0.180	2 PCS		lity Ass	iceel Stitt
lbe Corr ast 122n 1llinois 73-646-4	Steel Su 21119 N TX 7	7.0		U			MILL USSTEEL ote: lote:	8.0	er: 149	υ	0		MILL USSTEEL ote: ote:	by Qua	E S
Attas Tube Corp. Chicago 1855 East 122nd Street Chicago Illinois USA 60633 Tel: 773-646-4500 Fax: 773-646-6128	Sold To Triple S steel Supply PO Box 21119 HOUSTON TX 77026 USA	Material:	Sales Order:	Heat No	Y05253	Bundle No M800931583	<u>Heat</u> <u>MIL</u> Y05253 US\$ Material Note: Sales Or. Note:	Material:	Sales Order: 1498356	Heat No	M87505	119365	Material Note: Sales Or. Note:	Authorized by Quality Assurance:	

REF-B/L: 80940403 Date: 03/10/2020 Customer: 192	Shipped To Intel Steel Distributors 11310 West Little York HOUSTON TX 77041 USA	Made in: USA Melted in: USA	н И И И И И И И	002 0.001 0.0001 0.0000	CE: 0.34	2. Harvested Writhin Miles of Location 100% 500		Melted in: USA	V Ti B N Ga	0001 0.0060		<u>% Harvested</u> Within Miles of Location 100% 500		cification and contract requirements.	S Metals Service Genter Institute	
Addas <i>Tube</i> <i>a division of Zekelman industries</i> MATERIAL TEST REPORT). Material No: 800805004800 Purchase Order: WI Y.24524	S Si Al Cu	0.008 0.004 0.050 0.020 0.004 0.005 0.010	Tensile Eln.2in Certification 071270 Psi 38 % ASTM A500-18 GR	Method Recycled Content Post Consumer Pre-Consumer (Post Industrial) BOF 36.90% 19.80% 14.40%	Material No: 800805004800	Purchase Order: WLY-24524	S Si Al Cu Cb Mo Ni Cr	0.006 0.012 0.049 0.030 0.004 0.005 0.010 0.030	<u>Tensile Eln.2in</u> 078625 Psi 34 %	Method Recruied Content Post Consumer Pre-Consumer (Post Industrial) BOF 36.90% 19.80% 14.40%	melichael	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.	S Metals	Page: 4 of 5
Attas Tube Corp. Chicago 1855 East 122nd Street Chicago Illinois USA 60633 Tel: 773-646-6128 Sold To	21111 ON TJ	Material: 8.0x8.0x500x48'0"0(2x2) Sales Order: 1498356	C Mn	0.200 0.790	<u>dle No</u> 119365	Heat MILL Mill Location Y05507 USSTEEL GARY,IN Material Note: Sales Or, Note:	Material: 8.0x8.0x500x48'0"0(2x2)	Sales Order: 1498356	C	0.190 0.780	<u>114557</u>	Heat MILL Mill Location DB377 USSTEEL GARY,IN Material Note: Sales Or. Note:	Authorized by Quality Assurance:	The results reported on this report represent CE calculated using the AWS D1.1 method.	Steel Tube	OF NORTH AMERICA

Page: 4 of 5

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REF.B/L: 80934498 Date: 02/10/2020 Customer: 192	Shipped To Intsel Steel Distributors 11310 West Little York HOUSTON TX 77041 USA	Made in: USA Meited in: USA	V Ti B N Ca	0.001 0.001 0.0001 0.0050 0.0000 CE: 0.35	0 26 Harvested Writhin Miles of Location 100% 500	Made in: USA	Melted in: USA	V Ti B N Ca	0060	26 Harvested Within Miles of Location 100% 500	eclification and contract requirements.	Some the service Center Institute	
Atlas Tube a division of zekelman industries	MATERIAL TEST REPORT	x3). Material No: 5002050 Purchase Order: VVLY-24050	Mo	9 Psi 076143 Psi 28 %	Method Recycled Content Post Consumer Pre-Consumer (Post Industrial) BOF 36.90% 19.80% 14.40%	K8)PB Material No: 50030375	Purchase Order: WLY-24291	S Si Al Cu Cb Mo Ni Cr	10 0.007 0.008 0.039 0.030 0.005 0.008 0.010 0.030 <u>Tensile EIn.2in</u> Psi 081026 Psi 29 % ASTIM ASIN31 GENANE DS C	Method Recycled Content Post Consumer Pre-Consumer (Post Industrial) BOF 36.90% 19.80% 14.40%	Authorized by Quality Assurance: Amended and the material furnished and indicate full compliance with all applicable specification and contract requirements.	So Metals	Page: 1 of 4
Atlas Tube Corp. Chicago 1855 East 122nd Street Chicago Illinois USA 60633 Tel: 773-646-4500 Fax: 773-646-6128	Sold To Triple S Steel Supply PO Box 21119 HOUSTON TX 77026 USA	al: 5 Drder: 1	Heat No C Mn M87395 0.200 0.800	<u>lle No</u> 323834 12	Heat MILL Mill Location M87395 USSTEEL GARY,IN Material Note: Sales Or. Note:	Material: 5.0x3.0x375x40'0"0(1x8)PB	Drder: 1485177	Wn	Lo U.200 U.780 Jle No PCs 2 913733 2 2	Heat MILL Mill Location E84426 USSTEEL GARY,IN Material Note: Sales Or. Note:	Authorized by Quality Assurance: The results reported on this report repres CE calculated using the AWS D1.1 methor	Steel Tube	

REF.B/L: 80934498 Date: 02/10/2020 Customer: 192	Shipped To Infsel Steel Distributors 11310 West Little York HOUSTON TX 77041 USA	Made in: USA Meited in: USA	V TI B N Ca 0.001 0.0001 0.0040 0.0000 CE: 0.32	26 Harvested Within Miles of Location 100% 500	Made in: USA Melted in: USA	V Ti B N Ca 0.001 0.001 0.0001 0.0000 0.0000 CE: 0.34 0.0040 0.0000 ²⁶ Harvested Within Miles of Location 100% 500	all applicable specification and contract requirements.	
Addas Tube a division of zekelman industries	MATERIAL TEST REPORT	1x8)PB Material No: 50030375 Purchase Order: VVLY-24291	S Si Al Cu Cb Mo Ni Cr 10 0.006 0.008 0.048 0.020 0.005 0.010 0.030 Tensile EIn.2in Certification Certification 1Psi 000685 29 % ASTM AGAINADORATION ASTM AGAINADORATION	Content Post Consumer P. 14.80% 14.80%	Material No: 1200603134800 Purchase Order: WLY-24050	03 0.013 0.005 0.010 0.005 0.010 0.005 03 0.055 0.010 0.005 0.010 0.030 Tensile In.2in Certification 0.030 0.010 0.030 1Psi Tensile In.2in Certification 0.030 0.010 0.030 Method Recycled Content Post Consumer Pre-Consumer (Post Industrial) BCF 36.90% 14.40%	Authorized by Quality Assurance:	Page: 2 of 4
Atlas Tube Corp. Chicago 1855 East 122nd Street Chicago Illinois USA 60633 Tel: 773-646-6128 Fax: 773-646-6128	Sold To Triple S Steel Supply PO Box 21119 HOUSTON TX 77026 USA	Material: 5.0x3.0x375x40'0'0(1x8)PB Sales Order: 1485177	Heat No C Mn P M87383 0.180 0.750 0.0 Bundle No PCS Yield M800913733 6 068651	Heat MILL Mill Location M87383 USSTEEL GARY,IN Material Note: Sales Or. Note:	Material: 12.0x6.0x313x48'0"0(2x2) Sales Order: 1472390 Heat No C Mn P	0 200 0.770 No 0.200 0.770 232 4 Mill Locatic USSTEEL GARY,IN INOte:	Authorized by Quality Assurance: The results reported on this report nepres CE calculated using the AWS D1.1 method STOCEI TUDO STOCEI TUDO OF NORTH AMBRICA	

Page: 2 of 4

DE REF.B/L: 80934498 Date: 02/10/2020 Customer: 192 0/STRIES	Shipped To Intsel Steel Distributors 11310 West Little York HOUSTON TX 77041 USA	Made in:	Melted in: USA	Ni Cr V Ti B N	0.020 0.080 0.001 0.001 0.0000 0.0000	Certification ASTM A500-18 GRADE B&C	Made in:	Metted In: USA	Ni Cr V Ti B N Ca	0.010 0.040 0.001 0.001 0.0001 0.0040		Pre-Consumer (Post Industrial) 2// Harvested Within Miles of Location 14.40% 500	ance with all applicable specification and contract someones	Service Center Institute
ATAS TUDE A DIVISION OF ZEKELMAN INDUSTRIES	MATERIAL TEST REPORT	(2x2). Material No: 1200603754000	Purchase Order: WLY-24291	P S Si Al Cu Cb Mo	113 0.011 0.020 0.042 0.050 0.001 0.00	L <u>ensile Ein.Zin</u> 1 Psi 072705 Psi 32 %	(1x4). Material No: 1400405004000	Purchase Order: WLY-24291	P S Si Al Cu Cb Mo	0.009 0.008 0.022 0.050 0.030 0.005 0.006	<u>Tensile Eln.2in</u> I Psi 074158 Psi 33 %	Method Recycled Content Post Consumer Pre-Co. BCF 36.90% 19.80% 14.40%	Authorized by Quality Assurance:	Page: 3 of 4
Atlas Tube Corp. Chicago 1855 East 122nd Street Chicago Illinois USA 60633 60633 101: 773-646-4500 Fax: 773-646-6128	Sold To Triple S Steel Supply PO Box 21119 HOUSTON TX 77026 USA	Material: 12.0x6.0x375x40'0"0(2x2)	Sales Order: 1485177	Heat No C Mn	.800	ote: 4	Material: 14.0x4.0x500x40'0'0(1x4).	Sales Order: 1485177	Wu	0.190 0.770	<u>dle No</u> 114122 4	Heat MILL Mill Location T01126 USSTEEL GARY,IN Material Note: Sales Or. Note:	Authorized by Quality Assurance:	Steel Tube

REF.B/L: 80934498 Date: 02/10/2020 Customer: 192	Shipped To Intsel Steel Distributors 11310 West Little York HOUSTON TX 77041 USA	Made in: USA Metted in: USA	V Ti B N Ca 0.001 0.001 0.0050 0.0000 CE: 0.34 0.000 1.0000 100% 500 500 500	Made in: USA Melted in: USA V Ti B N Ca 0.002 0.001 0.0000 0.0000	<u>%</u> Harveste 100%	vall applicable specification and contract requirements.
Atlas Tube a division of zekelman industrates	MATERIAL TEST REPORT	0(1x3). Material No: 1400603754800 Purchase Order: VVLY-24338	Ŭ %	Material No: 1600803134000 Purchase Order: VLY-24338 Purchase Order: VLY-24338 S AI Cu Cb Mo Ni Cr 0.013 0.008 0.031 0.030 0.004 0.007 0.020 0.060 Tensile EIn.2in Certification Certification	061671 Psi 074921 Psi 30 % ASTM A500-18 GRADE B&C Dn Method Recycled Content Post Consumer Pre-Consumer (Post Industrial) BOF 36.90% 19.80% 14.40%	Authorized by Quality Assurance: Authorized by Quality Assurance: Authorized by Quality Assurance: Authorized on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements. So the material furnished and indicate full compliance with all applicable specification and contract requirements. So the material furnished and indicate full compliance with all applicable specification and contract requirements. So the material furnished and indicate full compliance with all applicable specification and contract requirements. So the material function of the material furnished and indicate full compliance with all applicable specification and contract requirements. So the material function of the material furnished and indicate full compliance with all applicable specification and contract requirements. So the material function of the material furnished and indicate full compliance with all applicable specification and contract requirements. So the material function of the materi
Atlas Tube Corp. Chicago 1855 East 122nd Street Chicago Illinois USA 60633 Tel: 773-646-6128 Fax: 773-646-6128	Sold To Triple S Steel Supply PO Box 21119 HOUSTON TX 77026 USA	Material: 14.0x6.0x375x48'0"0(1x3) Sales Order: 1487345	Heat No C Mn D83794 0.200 0.760 Bundle No 0.200 0.760 Bundle No 0.0 Meat MILL MILL Location D83794 USSTEEL GARY,IN Material Note: Sales Or. Note:	16.0x8.0x313x40 [,] er: 1487345 c Mn 0.160 0.460 <u>PCs</u>	M901107193 3 005 Heat MILL MIII Location B83392 UNSSTEEL GARY,IN Material Note: Sales Or. Note:	Authorized by Quality Assurance: The results reported on this report represents report represents calculated using the AWS D1.1 methods CE calculated using the AWS D1.1 methods CE calculated using the AWS D1.1 methods OF NORTH AMERICA

			CERTIFI	ED MATER	CERTIFIED MATERIAL TEST REPORT	DPT -					
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US-ML-CARTERSVILLE 384 OLD GRASSDALE ROAD NE	HOUSTON, USA	IX 77041-4917		HOUSTON,TX 77226-1119 USA	7226-1119	<u> 18</u>	LENGTH 40'00"		WEIGHT 19,440 LB	HEAT / BATCH 55061469/02	-
CARTERSVILLE, GA 30121 USA	SALES ORDER 7833203/000010	DER 010	0	USTOMER	CUSTOMER MATERIAL N°	A ⁵	SPECIFICATION / DATE or REVISION ASTM A529-14, A572-15	DATE or REVIS	NOI		
CUSTOMER PURCHASE ORDER NUMBER WLY-23175		BILL OF LADING 1323-0000135212	0ING 212	DA' 06/0	DATE 06/03/2019	2 2 2	ASTM A6-17,A36-14, ASME SA-36 ASTM A709-17, AASHTO M270-15 CSA G40.20-13/G40.21-13	NSME SA-36 TO M270-15 -13			
CHEMICAL COMPOSITION	\$ 0.021	Si 0.20	Си 0.32	i%0	ۍ 0.11	Mo 0.025	۲ %000000000000000000000000000000000000	4% % 000:0	N 001000	문 문 0.0040	
CHEMICAL COMPOSITION											
ERTIES	G/L Inch 8.000 8.000	UTS 17800 778000 778000	6.99		UTS MPa 536 538	Y SO	YS 0.2% 53400 53700	~Zww	MPa 368 370		
CoMMENTS NOTES CLOMMENTS NOTES ASTM grade meets the requirements for the following grades: ASTM Grades: A36, A579-50, A572-50, A709-36, A709-30 Cades: A249-50W AASHTO Grades: M270-36, M270-50 ASME Grades: SA36 ASME Grades: SA36	; A709-50										
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 complise with EN 10204 31.	fied chemical an is material, inclu	d physical test recoiding the billets, was	rds as contained s melted and ma	l in the perma mufactured in	ment records of con the USA. CMTR	npany. We cert	ify that these data at 2N 10204 3.1.	te correct and in	compliance with		
Machay	BHAS DUAL	BHASKAR YALAMANCHILI QUALITY DIRECTOR					2 yan we	YAN WANG	DN		
Phone: (409) 267-1071 Email: Bhaskar. Yalamanchili@gerdau.com	nail: Bhaskar.Yala	manchili@gerdau.com	1			£	Phone: (770) 387 5718	QUALITY ASSURANCE Email: van wone@eerdon.com	QUALITY ASSURANCE MGR.		

שרו	at#: A90000" Tag: C03071520		0#: PU-00404 Part: T1000403748* Qt
1 i a	NUCOR TUBULAR PRODUCTS	6226 W. 74TH STREET CHICAGO, IL 60638 Tel: 708-496-0380 Fax: 708-563-1950	https://www.nucortubular.cor https://www.ntpportal.cor Certificate Number: MAR 34199
10 miles	Sold By: NUCOR TUBULAR PRODUCTS INC. MARSEILLES DIVISION 1201 E. BROADWAY MARSEILLES, IL 61341 Tel: 815 795-4400 Fax: 815 795-4449 Sold To:	Purchase Order No: SSW11261 Sales Order No: MAR 394124 - Bill of Lading No: MAR 232863 - Involce No:	1
162/2020 MILLAS ALO	2734 - SERVICE STEEL WAREHOUSE CO., L.P. PO BOX 9607 HOUSTON, TX 77213	Ship To: 1 - SERVICE STEEL WAREHOL 8415 CLINTON DRIVE HOUSTON, TX 77029	JSE CO.
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	CERTIFICATE of ANALYSIS and TES Customer Part No:	STS	Certificate No: MAR 341996
11	TUBING A500 GRADE B(C) 10" X 4" X 3/8" X 48'		Test Date: 5/27/2020 Total Pieces Total Weight Lbs
1	* DOMESTIC STEEL M&M *		12 18,766
201	Bundle Tag         Mill         Heat         Specs           400062         13N         A96500         YLD=52500/TEI           400063         13N         A96500         YLD=52500/TEI	V=67580/ELG=34.8 0.7769 N=67580/ELG=34.8 0.7769	6 9,383
C	Mill #: 13N Heat #: A96500 Carbon Eq: 0.1534 H	eat Src Origin: MELTED AND MANUFA	CTURED IN THE USA
2/0	C         Mn         P         S         Si           0.0600         0.4100         0.0080         0.0030         0.0200         0.0           N         B         Ti         Co         Co	Al Cu Cr Mo	V Ni Nb Sn 020 0.0500 0.0120 0.0040
1	N         B         Ti         Ca           0.0061         0.0001         0.0010         0.0019		
~	LEED Information (based on the most recent LEED in Method		
~	EAF Ghent, KY	Recycled Content Post Consu 66.9%	
-	Certification:	00.070	28.2% 38.8%
)	I certify that the above results are a true and correct or PRODUCTS INC. Sworn this day, 5/27/2020.	ppy of records prepared and maintained	by NUCOR TUBULAR
	THE SPECIFICATIONS LISTED BELOW REPRESEN CURRENT ISSUED DATES OF THESE STANDARDS DOES NOT INDICATE THAT THE MATERIAL ABOVE TO EACH OR ALL OF THE STANDARDS. WE CERTII MATERIAL ABOVE TO THE SPECIFICATION LISTED	CONFORMS	Brie Allon
	ENCLOSER FION.		AVUE AVUE
	CURRENT STANDARDS: A252-19 A500/A500M-18 A513/A513M-19	Chris A Quality	Allen, ASQ CMQ/OE Systems Supervisor
	ASTM A53/A53M-18  ASME SA-53/SA-53M-18 A847/A847M-14 A1085/A1085M-15		
1	N COMPLIANCE WITH EN 10204 SECTION 4.1 NSPECTION CERTIFICATE TYPE 3.1		

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For additional copies call 830-372-8771 Rolendo A Davila Rolendo A Davila Quality Assurance Manager	⊢		10650 State Hwy 30	×	US 77845-7950	T 979 774 5900 DLVRY PCS / HEAT: 280 EA	Characteristic Value Characteristic Value						5			The Following is true of the material represented by this MTR:				Contains no weld repair *Contains no Manutur containing	• 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 andust san expose you to chemicals which are	known to the State of California to cause cancer, birth defects	er ekker fanneline hann. En en en en er ekker fanneline hann	or outer reproductive right of more information go to www.P65Warnings.ca.gov	
CERT	S CMC Construction Svcs College Stati	0		D College Station TX	_	T 979 774 5900 0				12%	88%	%(	8	Sec. 10 Sec. 10 Sec. 960	%	<b>66%</b>	%00	%00	3%	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~			KSI				3IN	
CMC STEEL TEXAS 1 STEEL MILL DRIVE SEGUIN TX 78155-7510	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	Characteristic Value	C 0.10%	Mn 0.74%	P 0.012%		Si 0.19%							-	AI 0.000%	Viold Commeth tast 1 17 81ei	- ,	Lensue Surengun lest 7 00.1K		Elongation Gage Lgtn test 1 Bin		Bend Lest Diameter 1.313IN	

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"Meets the "Buy America" requirements of 23 CFR635.410, 49 CFR 661 are accurate and conform to the reported grade specification We hereby certify that the test results presented here *Warning: This product can expose you to chemicals which are known to the State of California to cause cancer, birth defects DLVRY LBS / HEAT: 2191.000 LB Page 1 OF 1 09/25/2020 16:24:57 The Following is true of the material represented by this MTR: DLVRY PCS / HEAT: 164 EA or other reproductive harm. For more information go Manufactured in accordance with the latest version Rotando A Davila H and Delivery#: 83224860 CUST PO#: 862925 BOL#: 73793087 Contains no Mercury contamination * 100% melted and rolled in the USA Characteristic Value CUST P/N: **Quality Assurance Manager** EN10204:2004 3.1 compliant to www.P55Warnings.ca.gov of the plant quality manual Contains no weld repair *Material is fully killed S CMC Construction Svcs College Stati H 1 10650 State Hwy 30 P College Station TX College Station TX US 77845-7950 979 774 5900 **CERTIFIED MILL TEST REPORT** For additional copies call 830-372-8771 Characteristic Value ۲ 0 CMC Construction Svcs College Stati 10650-State Hwy 30 College Station TX US 77845-7950 979 774 5900 SEGUIN TX 78155-7510 ŝ - 0 ⊢ 0 **1 STEEL MILL DRIVE** CMC STEEL TEXAS 0.13% 0.058% SECTION: REBAR 13MM (#4) 20'0" 300/40 0.013% 0.048% 0.000% 0.001% 0.012% 0.000% 47.0ksi 64.4ksi 1.750IN 0.81% 0.30% 0.14% Passed 0.17% 0.11% Value 26% 8IN GRADE: ASTM A615-20 Grade 300/40 Cert. No.: 83224860 / 099959A293 A S B < 8 I S C S S A υ Mn Yield Strength test 1 Bend Test 1 Characteristic Tensile Strength test 1 Elongation test 1 Elongation Gage Lgth test 1 **Bend Test Diameter** ROLL DATE: 09/17/2020 MELT DATE: 09/13/2020 HEAT NO.:3099959 REMARKS :

| 0140         S         CMC Construction Svcs College Stati         S         CMC Construction Svcs College Stati         S         CMC Construction Svcs College Station TX           1         10650 State Hwy 30         1         10650 State Hwy 30         1         10650 State Hwy 30           1         10550 State Hwy 30         1         1         10650 State Hwy 30         1           1         0.5         College Station TX         1         1050 State Hwy 30         1           1         10550 State Hwy 30         1         1         10650 State Hwy 30         1           1         1057 R45-7950         77845-7950         0         0         77845-7950           1         979 774 5900         0         0         979 774 5900         0           100%         0         0         979 774 5900         0         0           110%         110%         1         979 774 5900         0           110%         110%         0         0         0         0           11%         11%         11%         1         1         1           11%         11%         1         1         1         1           64si         64si         64si <t< th=""><th>0140         S         CMC Construction Sves College Stati         S         CMC Construction Sves College Stati         S         CMC Construction Sves College Stati         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         <th< th=""><th>0140         S         CMC Construction Sves College Stati         S         CMC Construction Sves College Station TX         P         College Station TX         D         Us         77845-7950         T         P         College Station TX         D         Us         77845-7950         T         P         College Station TX         D         Us         77845-7950         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D</th><th>1.3099508       S       CMC Construction Sves College Statin<br/>Filth 10MM (#5) 20°° 300/40       S       CMC Construction Sves College Statin<br/>ASTM A615-20 Grade 300/40       I       10650 State Hwy 30         ASTM A615-20 Grade 300/40       L       10650 State Hwy 30       I       10650 State Hwy 30         ASTM A615-20 Grade 300/40       L       College Station TX       P       College Station TX         TE: 08/25/2020       L       D       College Station TX       P       College Station TX         TE: 08/25/2020       L       D       College Station TX       P       College Station TX         TE: 08/25/2020       L       D       College Station TX       P       College Station TX         TE: 08/25/2020       L       D       College Station TX       P       College Station TX         TE: 08/25/2020       L       D       College Station TX       P       College Station TX         TE: 08/25/2020       L       D       D       College Station TX       D       D         S       0       D       D       College Station TX       D       D       D       D         S       0.010%       D       D       D       D       D       D       D       D       D       D       <t< th=""><th>1.3099508       S. CMC Construction Sves College Stati Invition Sves College State Hvy 30       1       10650 State Hvy 30         1.5109503       L       10650 State Hvy 30       1       10650 State Hvy 30         1.5109503       L       10650 State Hvy 30       1       10650 State Hvy 30         1.510912       L       10650 State Hvy 30       1       10650 State Hvy 30         1.510912       L       10650 State Hvy 30       1       10650 State Hvy 30         1.510912       US 77845-7950       1       77845-7950         1.510912       US 77845-7950       1       779 774 5900         1.510912       US 77845-7950       1       7979 774 5900         1.510912       US 774 5900       0       0       979 774 5900         1.510912       US 774 5900       US 774 5900       1       979 774 5900         1.510912       US 774 5900       US 774 5900       0       0         1.510912       US 774 5900       US 774 5900       0       0         1.510912&lt;</th><th>1.3099508       \$       CMC Construction Sves College Statin<br/>FieldsAn Tekink (#5) 20°° 300/40       \$       CMC Construction Sves College Statin<br/>ASTM A615-20 Grade 300/40       \$       CMC Construction Sves College Statin<br/>Fields26       \$       CMC Construction Sves College Statin<br/>Fields26       \$       CMC Construction Sves College Statin<br/>Fields26       \$       CMC Construction Sves College Station<br/>Fields26       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C</th><th>3099503       S       CMC Construction Sves College Stati       S       CMC Construction Sves College Stati       S       CMC Construction Sves College Stati       S       CMC Construction Sves College Station TX        1      1       10650 State Hwy 30       1       10650 State Hwy 30       1       10650 State Hwy 30        1         10650 State Hwy 30       1       1       10650 State Hwy 30                                                                             </th><th>3099508       S       CMC Construction Sves College Stati I       S       CMC Construction Sves College Station TX        ERBAR 16MM (#5) 20'0" 300/40       D       10650 State Hwy 30       1       10650 State Hwy 30         ASTM A615-20       D       10650 State Hwy 30       1       10650 State Hwy 30         ASTM A615-20       D       D       10650 State Hwy 30       1       10650 State Hwy 30         TE: 08/25/2020       D       D       US       77845-7950       1       1050 State Hwy 30         TE: 08/25/2020       D       D       US       77845-7950       1       1050 T/4 5900         R: 0.010%       D       D       979 774 5900       T       1       979 774 5900         R: 0.010%       D       D       D       D       1       979 774 5900       1         R: 0.010%       D       D       D       D       P       College Station TX       US 77845-7950         R: 0.010%       D       D       D       D       P       College Station TX       US 77845-7950         R: 0.010%       D       D       D       D       D       D       D       D       D       D       D       D       D       D       D</th><th>3099503       S       CMC Construction Sves College Stati I       S       CMC Construction Sves College Stati I       S       CMC Construction Sves College Stati I       S       CMC Construction Sves College Station TX         SEMAN 16MM (#5) 20'0" 300/40       D       10650 State Hwy 30       1       10650 State Hwy 30       1       10650 State Hwy 30         TE: 00/25/2020       D       D College Station TX       P       College Station TX       1       10550 State Hwy 30         TE: 00/25/2020       D       D State Station TX       P       College Station TX       1       10550 State Hwy 30         TE: 00/25/2020       D       D State Station TX       P       College Station TX       1       10560 State Hwy 30         TE: 00/25/2020       TE: 00/25/2020       T       T       979 774 5900       0       979 774 5900         S       0.019%       M       0.11%       M       0.11%       0       0       979 774 5900       0         S       0.019%       E       0.014%       M       M       0.014%       M       0.014%       M       0.</th><th>1.3099503       S       CMC Construction Sves College Stati       S       CMC Construction Sves College Station 1X         STR A815-20140       D       College Station 1X       10550 State Hwy 30       1       10550 State Hwy 30         TE: 08/25/2020       D       College Station 1X       US 77445-7950       1       979 774 5900         TE: 08/25/2020       TE: 08/25/2020       T       979 774 5900       0       77845-7950         TE: 08/25/2020       T       979 774 5900       0       1       979 774 5900         S       0.0175%       No       0.115%       0       0       979 774 5900         Mo       0.11%       No       0.013%       1       979 774 5900       0         S       0.013%       S       0.013%       S       0.013%       1       1         Mo       0.11%       No       0.013%       S       0.013%       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1      
1</th><th>.:3099503     S     CMC Construction Sves College Stati     S     CMC Construction Sves College Stati     A       STER.AM 15.00 Crede 30040     C     10650 State Hwy 30     1     10650 State Hwy 30       STER.AM 15.00 Crede 30040     D     College Station TX     1     10650 State Hwy 30       TE: 08/25/2020     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     D     College Station TX     D     D       S     College Station TX     D     D     D     D       M     D     D     D     D     D     D       M     D     D     D     D     D     D       M     D     D     D</th><th>.:3099503     S     CMC Construction Sves College Stati     S     CMC Construction Sves College Stati     S     CMC Construction Sves College Stati     N       NSTM A515.00 Crede 300400     1     10650 State Hwy 30     1     10650 State Hwy 30       NSTM A515.00 Crede 300400     1     10650 State Hwy 30     1     10650 State Hwy 30       TE: 08/25/2020     1     10650 State Hwy 30     1     10650 State Hwy 30       TE: 08/25/2020     1     10650 State Hwy 30     1     10650 State Hwy 30       TE: 08/25/2020     1     10550 State Hwy 30     1     10650 State Hwy 30       TE: 08/25/2020     1     10550 State Hwy 30     1     10650 State Hwy 30       TE: 08/25/2020     1     10550 State Hwy 30     1     10650 State Hwy 30       TE: 08/25/2020     1     10550 State Hwy 30     1     10550 State Hwy 30       TE: 08/25/2020     1     1399 774 55000     0     1     10550 State Hwy 30       Min     0.73%     0     0.13%     1     1979 745 5500       Min     0.73%     0.014%     Min     0.014%       Min     0.11%     Min     0.11%     1       Min     0.11%     Min     1.16%     1       Min     0.11%     Min     1.16%</th><th>3099503     S     CMC Construction Sves College Stati     S     CMC Construction Sves College Stati     S     CMC Construction Sves College Stati     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     <td< th=""><th>0140         S         CMC Construction Svcs College Stati         S         CMC Construction Svcs College Stati         S         CMC Construction Svcs College Stati         N           0140         L         10650 State Hwy 30         1         10650 State Hwy 30         1         10650 State Hwy 30           D         College Station TX         P         College Station TX         US         77845-7950           1         979 774 5900         7         979 774 5900         0         7         979 774 5900           0         7         979 774 5900         0         7         979 774 5900         0           10%         77845-7950         7         1         979 774 5900         0         0           10%         1         979 774 5900         0         0         0         0         0           110%         1         1         979 774 5900         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0</th><th>ully truu</th></td<></th></t<></th></th<></th></t<> | 0140         S         CMC Construction Sves College Stati         S         CMC Construction Sves College Stati         S         CMC Construction Sves College Stati         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N         N <th< th=""><th>0140         S         CMC Construction Sves College Stati         S         CMC Construction Sves College Station TX         P         College Station TX         D         Us         77845-7950         T         P         College Station TX         D         Us         77845-7950         T         P         College Station TX         D         Us         77845-7950         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D</th><th>1.3099508       S       CMC Construction Sves College Statin<br/>Filth 10MM (#5) 20°° 300/40       S       CMC Construction Sves College Statin<br/>ASTM A615-20 Grade 300/40       I       10650 State Hwy 30         ASTM A615-20 Grade 300/40       L       10650 State Hwy 30       I       10650 State Hwy 30         ASTM A615-20 Grade 300/40       L       College Station TX       P       College Station TX         TE: 08/25/2020       L       D       College Station TX       P       College Station TX         TE: 08/25/2020       L       D       College Station TX       P       College Station TX         TE: 08/25/2020       L       D       College Station TX       P       College Station TX         TE: 08/25/2020       L       D       College Station TX       P       College Station TX         TE: 08/25/2020       L       D       College Station TX       P       College Station TX         TE: 08/25/2020       L       D       D       College Station TX       D       D         S       0       D       D       College Station TX       D       D       D       D         S       0.010%       D       D       D       D       D       D       D       D       D       D       <t< th=""><th>1.3099508       S. CMC Construction Sves College Stati Invition Sves College State Hvy 30       1       10650 State Hvy 30         1.5109503       L       10650 State Hvy 30       1       10650 State Hvy 30         1.5109503       L       10650 State Hvy 30       1       10650 State Hvy 30         1.510912       L       10650 State Hvy 30       1       10650 State Hvy 30         1.510912       L       10650 State Hvy 30       1       10650 State Hvy 30         1.510912       US 77845-7950       1       77845-7950         1.510912       US 77845-7950       1       779 774 5900         1.510912       US 77845-7950       1       7979 774 5900         1.510912       US 774 5900       0       0       979 774 5900         1.510912       US 774 5900       US 774 5900       1       979 774 5900         1.510912       US 774 5900       US 774 5900       0       0         1.510912       US 774 5900       US 774 5900       0       0         1.510912&lt;</th><th>1.3099508       \$       CMC Construction Sves College Statin<br/>FieldsAn Tekink (#5) 20°° 300/40       \$       CMC Construction Sves College Statin<br/>ASTM A615-20 Grade 300/40       \$       CMC Construction Sves College Statin<br/>Fields26       \$       CMC Construction Sves College Statin<br/>Fields26       \$       CMC Construction Sves College Statin<br/>Fields26       \$       CMC Construction Sves College Station<br/>Fields26       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C</th><th>3099503       S       CMC Construction Sves College Stati       S       CMC Construction Sves College Stati       S       CMC Construction Sves College Stati       S       CMC Construction Sves College Station TX        1      1       10650 State Hwy 30       1       10650 State Hwy 30       1       10650 State Hwy 30        1         10650 State Hwy 30       1       1       10650 State Hwy 30                                                  
                          </th><th>3099508       S       CMC Construction Sves College Stati I       S       CMC Construction Sves College Station TX        ERBAR 16MM (#5) 20'0" 300/40       D       10650 State Hwy 30       1       10650 State Hwy 30         ASTM A615-20       D       10650 State Hwy 30       1       10650 State Hwy 30         ASTM A615-20       D       D       10650 State Hwy 30       1       10650 State Hwy 30         TE: 08/25/2020       D       D       US       77845-7950       1       1050 State Hwy 30         TE: 08/25/2020       D       D       US       77845-7950       1       1050 T/4 5900         R: 0.010%       D       D       979 774 5900       T       1       979 774 5900         R: 0.010%       D       D       D       D       1       979 774 5900       1         R: 0.010%       D       D       D       D       P       College Station TX       US 77845-7950         R: 0.010%       D       D       D       D       P       College Station TX       US 77845-7950         R: 0.010%       D       D       D       D       D       D       D       D       D       D       D       D       D       D       D</th><th>3099503       S       CMC Construction Sves College Stati I       S       CMC Construction Sves College Stati I       S       CMC Construction Sves College Stati I       S       CMC Construction Sves College Station TX         SEMAN 16MM (#5) 20'0" 300/40       D       10650 State Hwy 30       1       10650 State Hwy 30       1       10650 State Hwy 30         TE: 00/25/2020       D       D College Station TX       P       College Station TX       1       10550 State Hwy 30         TE: 00/25/2020       D       D State Station TX       P       College Station TX       1       10550 State Hwy 30         TE: 00/25/2020       D       D State Station TX       P       College Station TX       1       10560 State Hwy 30         TE: 00/25/2020       TE: 00/25/2020       T       T       979 774 5900       0       979 774 5900         S       0.019%       M       0.11%       M       0.11%       0       0       979 774 5900       0         S       0.019%       E       0.014%       M       M       0.014%       M       0.014%       M       0.</th><th>1.3099503       S       CMC Construction Sves College Stati       S       CMC Construction Sves College Station 1X         STR A815-20140       D       College Station 1X       10550 State Hwy 30       1       10550 State Hwy 30         TE: 08/25/2020       D       College Station 1X       US 77445-7950       1       979 774 5900         TE: 08/25/2020       TE: 08/25/2020       T       979 774 5900       0       77845-7950         TE: 08/25/2020       T       979 774 5900       0       1       979 774 5900         S       0.0175%       No       0.115%       0       0       979 774 5900         Mo       0.11%       No       0.013%       1       979 774 5900       0         S       0.013%       S       0.013%       S       0.013%       1       1         Mo       0.11%       No       0.013%       S       0.013%       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1</th><th>.:3099503     S     CMC Construction Sves College Stati     S     CMC Construction Sves College Stati     A       STER.AM 15.00 Crede 30040     C     10650 State Hwy 30     1     10650 State Hwy 30       STER.AM 15.00 Crede 30040     D     College Station TX     1     10650 State Hwy 30       TE: 08/25/2020     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     D     College Station TX     D     D       S     College Station TX     D     D     D     D       M     D     D     D     D     D     D       M     D     D     D     D     D     D       M     D     D     D</th><th>.:3099503     S     CMC Construction Sves College Stati     S     CMC Construction Sves College Stati     S     CMC Construction Sves College Stati     N       NSTM A515.00 Crede 300400     1     10650 State Hwy 30     1     10650 State Hwy 30       NSTM A515.00 Crede 300400     1     10650 State Hwy 30     1     10650 State Hwy 30       TE: 08/25/2020     1     10650 State Hwy 30     1     10650 State Hwy 30       TE: 08/25/2020     1     10650 State Hwy 30     1     10650 State Hwy 30       TE: 08/25/2020     1     10550 State Hwy 30     1     10650 State Hwy 30       TE: 08/25/2020     1     10550 State Hwy 30     1     10650 State Hwy 30       TE: 08/25/2020     1     10550 State Hwy 30     1     10650 State Hwy 30       TE: 08/25/2020     1     10550 State Hwy 30     1     10550 State Hwy 30       TE: 08/25/2020     1     1399 774 55000     0     1     10550 State Hwy 30       Min     0.73%     0     0.13%     1     1979 745 5500       Min     0.73%     0.014%     Min     0.014%       Min     0.11%     Min     0.11%     1       Min     0.11%     Min     1.16%     1       Min     0.11%     Min     1.16%</th><th>3099503     S     CMC Construction Sves College Stati     S     CMC Construction Sves College Stati     S     CMC Construction Sves College Stati     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     <td< th=""><th>0140         S         CMC Construction Svcs College Stati         S         CMC Construction Svcs College Stati         S         CMC Construction Svcs College Stati         N           0140         L         10650 State Hwy 30         1         10650 State Hwy 30         1         10650 State Hwy 30           D         College Station TX         P         College Station TX         US         77845-7950           1         979 774 5900         7         979 774 5900         0         7         979 774 5900           0         7         979 774 5900         0         7         979 774 5900         0           10%         77845-7950         7         1         979 774 5900         0         0           10%         1         979 774 5900         0         0         0         0         0           110%         1         1         979 774 5900         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0</th><th>ully truu</th></td<></th></t<></th></th<> | 0140         S         CMC Construction Sves College Stati         S         CMC Construction Sves College Station TX         P         College Station TX         D         Us         77845-7950         T         P         College Station TX         D         Us         77845-7950         T         P         College Station TX         D         Us         77845-7950         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D         D                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 1.3099508       S       CMC Construction Sves College
Statin<br>Filth 10MM (#5) 20°° 300/40       S       CMC Construction Sves College Statin<br>ASTM A615-20 Grade 300/40       I       10650 State Hwy 30         ASTM A615-20 Grade 300/40       L       10650 State Hwy 30       I       10650 State Hwy 30         ASTM A615-20 Grade 300/40       L       College Station TX       P       College Station TX         TE: 08/25/2020       L       D       College Station TX       P       College Station TX         TE: 08/25/2020       L       D       College Station TX       P       College Station TX         TE: 08/25/2020       L       D       College Station TX       P       College Station TX         TE: 08/25/2020       L       D       College Station TX       P       College Station TX         TE: 08/25/2020       L       D       College Station TX       P       College Station TX         TE: 08/25/2020       L       D       D       College Station TX       D       D         S       0       D       D       College Station TX       D       D       D       D         S       0.010%       D       D       D       D       D       D       D       D       D       D <t< th=""><th>1.3099508       S. CMC Construction Sves College Stati Invition Sves College State Hvy 30       1       10650 State Hvy 30         1.5109503       L       10650 State Hvy 30       1       10650 State Hvy 30         1.5109503       L       10650 State Hvy 30       1       10650 State Hvy 30         1.510912       L       10650 State Hvy 30       1       10650 State Hvy 30         1.510912       L       10650 State Hvy 30       1       10650 State Hvy 30         1.510912       US 77845-7950       1       77845-7950         1.510912       US 77845-7950       1       779 774 5900         1.510912       US 77845-7950       1       7979 774 5900         1.510912       US 774 5900       0       0       979 774 5900         1.510912       US 774 5900       US 774 5900       1       979 774 5900         1.510912       US 774 5900       US 774 5900       0       0         1.510912       US 774 5900       US 774 5900       0       0         1.510912&lt;</th><th>1.3099508       \$       CMC Construction Sves College Statin<br/>FieldsAn Tekink (#5) 20°° 300/40       \$       CMC Construction Sves College Statin<br/>ASTM A615-20 Grade 300/40       \$       CMC Construction Sves College Statin<br/>Fields26       \$       CMC Construction Sves College Statin<br/>Fields26       \$       CMC Construction Sves College Statin<br/>Fields26       \$       CMC Construction Sves College Station<br/>Fields26       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C</th><th>3099503       S       CMC Construction Sves College Stati       S       CMC Construction Sves College Stati       S       CMC Construction Sves College Stati       S       CMC Construction Sves College Station TX        1      1       10650 State Hwy 30       1       10650 State Hwy 30       1       10650 State Hwy 30        1         10650 State Hwy 30       1       1       10650 State Hwy 30                                                                             </th><th>3099508       S       CMC Construction Sves College Stati I       S       CMC Construction Sves College Station TX        ERBAR 16MM (#5) 20'0" 300/40       D       10650 State Hwy 30       1       10650 State Hwy 30         ASTM A615-20       D       10650 State Hwy 30       1       10650 State Hwy 30         ASTM A615-20       D       D       10650 State Hwy 30       1       10650 State Hwy 30         TE: 08/25/2020       D       D       US       77845-7950       1       1050 State Hwy 30         TE: 08/25/2020       D       D       US       77845-7950       1       1050 T/4 5900         R: 0.010%       D       D       979 774 5900       T       1       979 774 5900         R: 0.010%       D       D       D       D       1       979 774 5900       1         R: 0.010%       D       D       D       D       P       College Station TX       US 77845-7950         R: 0.010%       D       D       D       D       P       College Station TX       US 77845-7950         R: 0.010%       D       D       D       D       D       D       D       D       D       D       D       D       D       D       D</th><th>3099503       S       CMC Construction Sves College Stati I       S       CMC Construction Sves College Stati I       S       CMC Construction Sves College Stati I       S       CMC Construction Sves College Station TX         SEMAN 16MM (#5) 20'0" 300/40       D       10650 State Hwy 30       1       10650 State Hwy 30       1       10650 State Hwy 30         TE: 00/25/2020       D       D College Station TX       P       College Station TX       1       10550 State Hwy 30         TE: 00/25/2020       D       D State Station TX       P       College Station TX       1       10550 State Hwy 30         TE: 00/25/2020       D       D State Station TX       P       College Station TX       1       10560 State Hwy 30         TE: 00/25/2020       TE: 00/25/2020       T       T       979 774 5900       0       979 774 5900         S       0.019%       M       0.11%       M       0.11%       0       0       979 774 5900       0         S       0.019%       E       0.014%       M       M       0.014%       M       0.014%       M       0.</th><th>1.3099503       S       CMC Construction Sves College Stati       S       CMC Construction Sves College Station 1X         STR A815-20140       D       College Station 1X       10550 State Hwy 30       1       10550 State Hwy 30         TE: 08/25/2020       D       College Station 1X       US 77445-7950       1       979 774 5900         TE: 08/25/2020       TE: 08/25/2020       T       979 774 5900       0       77845-7950         TE: 08/25/2020       T       979 774 5900       0       1       979 774 5900         S       0.0175%       No       0.115%       0       0       979 774 5900         Mo       0.11%       No       0.013%       1       979 774 5900       0         S       0.013%       S       0.013%       S       0.013%       1       1         Mo       0.11%       No       0.013%       S       0.013%       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1</th><th>.:3099503     S     CMC Construction Sves College Stati     S     CMC Construction Sves College Stati     A       STER.AM 15.00 Crede 30040     C     10650 State Hwy 30     1     10650 State Hwy 30       STER.AM 15.00 Crede 30040     D     College Station TX     1     10650 State Hwy 30       TE: 08/25/2020     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     D     College Station TX     D     D       S     College Station TX     D     D     D     D       M     D     D     D     D     D     D       M     D     D     D     D     D     D       M     D     D     D</th><th>.:3099503     S     CMC Construction Sves College Stati     S     CMC Construction Sves College Stati     S     CMC Construction Sves College Stati     N       NSTM A515.00 Crede 300400     1     10650 State Hwy 30     1     10650 State Hwy 30       NSTM A515.00 Crede 300400     1     10650 State Hwy 30     1     10650 State Hwy 30       TE: 08/25/2020     1     10650 State Hwy 30     1     10650 State Hwy 30       TE: 08/25/2020     1     10650 State Hwy 30     1     10650 State Hwy 30       TE: 08/25/2020     1     10550 State Hwy 30     1     10650 State Hwy 30       TE: 08/25/2020     1     10550 State Hwy 30     1     10650 State Hwy 30       TE: 08/25/2020     1     10550 State Hwy 30     1     10650 State Hwy 30       TE: 08/25/2020     1     10550 State Hwy 30     1     10550 State Hwy 30       TE: 08/25/2020     1     1399 774 55000     0     1     10550 State Hwy 30       Min     0.73%     0     0.13%     1     1979 745 5500       Min     0.73%     0.014%     Min     0.014%       Min     0.11%     Min     0.11%     1       Min     0.11%     Min     1.16%     1       Min     0.11%     Min     1.16%</th><th>3099503     S     CMC Construction Sves College Stati     S     CMC Construction Sves College Stati     S     CMC Construction Sves College Stati     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     <td< th=""><th>0140         S         CMC Construction Svcs College Stati         S         CMC Construction Svcs College Stati         S        
CMC Construction Svcs College Stati         N           0140         L         10650 State Hwy 30         1         10650 State Hwy 30         1         10650 State Hwy 30           D         College Station TX         P         College Station TX         US         77845-7950           1         979 774 5900         7         979 774 5900         0         7         979 774 5900           0         7         979 774 5900         0         7         979 774 5900         0           10%         77845-7950         7         1         979 774 5900         0         0           10%         1         979 774 5900         0         0         0         0         0           110%         1         1         979 774 5900         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0</th><th>ully truu</th></td<></th></t<> | 1.3099508       S. CMC Construction Sves College Stati Invition Sves College State Hvy 30       1       10650 State Hvy 30         1.5109503       L       10650 State Hvy 30       1       10650 State Hvy 30         1.5109503       L       10650 State Hvy 30       1       10650 State Hvy 30         1.510912       L       10650 State Hvy 30       1       10650 State Hvy 30         1.510912       L       10650 State Hvy 30       1       10650 State Hvy 30         1.510912       US 77845-7950       1       77845-7950         1.510912       US 77845-7950       1       779 774 5900         1.510912       US 77845-7950       1       7979 774 5900         1.510912       US 774 5900       0       0       979 774 5900         1.510912       US 774 5900       US 774 5900       1       979 774 5900         1.510912       US 774 5900       US 774 5900       0       0         1.510912       US 774 5900       US 774 5900       0       0         1.510912<                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1.3099508       \$       CMC Construction Sves College Statin<br>FieldsAn Tekink (#5) 20°° 300/40       \$       CMC Construction Sves College Statin<br>ASTM A615-20 Grade 300/40       \$       CMC Construction Sves College Statin<br>Fields26       \$       CMC Construction Sves College Statin<br>Fields26       \$       CMC Construction Sves College Statin<br>Fields26       \$       CMC Construction Sves College Station<br>Fields26       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C       C                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 3099503       S       CMC Construction Sves College Stati       S       CMC Construction Sves College Stati       S       CMC Construction Sves College Stati       S       CMC Construction Sves College Station TX        1      1       10650 State Hwy 30       1       10650 State Hwy 30       1       10650 State Hwy 30        1         10650 State Hwy 30       1       1       10650 State Hwy 30                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 3099508       S       CMC Construction Sves College Stati I       S       CMC Construction Sves College Station TX        ERBAR 16MM (#5) 20'0" 300/40       D       10650 State Hwy 30       1       10650 State Hwy 30         ASTM A615-20       D       10650 State Hwy 30       1       10650 State Hwy 30         ASTM A615-20       D       D       10650 State Hwy 30       1       10650 State Hwy 30         TE: 08/25/2020       D       D       US       77845-7950       1       1050 State Hwy 30         TE: 08/25/2020       D       D       US       77845-7950       1       1050 T/4 5900         R: 0.010%       D       D       979 774 5900       T       1       979 774 5900         R: 0.010%       D       D       D       D       1       979 774 5900       1         R: 0.010%       D       D       D       D       P       College Station TX       US 77845-7950         R: 0.010%       D       D       D       D       P       College Station TX       US 77845-7950         R: 0.010%       D       D       D       D       D       D       D       D       D       D       D       D       D       D       D                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                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Construction Sves College Stati I       S       CMC Construction Sves College Stati I       S       CMC Construction Sves College Stati I       S       CMC Construction Sves College Station TX         SEMAN 16MM (#5) 20'0" 300/40       D       10650 State Hwy 30       1       10650 State Hwy 30       1       10650 State Hwy 30         TE: 00/25/2020       D       D College Station TX       P       College Station TX       1       10550 State Hwy 30         TE: 00/25/2020       D       D State Station TX       P       College Station TX       1       10550 State Hwy 30         TE: 00/25/2020       D       D State Station TX       P       College Station TX       1       10560 State Hwy 30         TE: 00/25/2020       TE: 00/25/2020       T       T       979 774 5900       0       979 774 5900         S       0.019%       M       0.11%       M       0.11%       0       0       979 774 5900       0         S       0.019%       E       0.014%       M       M       0.014%       M       0.014%       M       0.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 1.3099503       S       CMC Construction Sves College Stati       S       CMC Construction Sves College Station 1X         STR A815-20140       D       College Station 1X       10550 State Hwy 30       1       10550 State Hwy 30         TE: 08/25/2020       D       College Station 1X       US 77445-7950       1       979 774 5900         TE: 08/25/2020       TE: 08/25/2020       T       979 774 5900       0       77845-7950         TE: 08/25/2020       T       979 774 5900       0       1       979 774 5900         S       0.0175%       No       0.115%       0       0       979 774 5900         Mo       0.11%       No       0.013%       1       979 774 5900       0         S       0.013%       S       0.013%       S       0.013%       1       1         Mo       0.11%       No       0.013%       S       0.013%       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | .:3099503     S     CMC Construction Sves College Stati     S     CMC Construction Sves College Stati     A       STER.AM 15.00 Crede 30040     C     10650 State Hwy 30     1     10650 State Hwy 30       STER.AM 15.00 Crede 30040     D     College Station TX     1     10650 State Hwy 30       TE: 08/25/2020     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     D     College Station TX     P     College Station TX       TE: 08/25/2020     D     D     College Station TX     D     D       S     College Station TX     D     D     D     D       M     D     D     D     D     D     D       M     D     D     D     D     D     D       M     D     D     D                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | .:3099503     S     CMC Construction Sves College Stati     S     CMC Construction Sves College Stati     S     CMC Construction Sves College Stati     N       NSTM A515.00 Crede 300400     1     10650 State Hwy 30     1     10650 State Hwy 30       NSTM A515.00 Crede 300400     1     10650 State Hwy 30     1     10650 State Hwy 30       TE: 08/25/2020     1     10650 State Hwy 30     1     10650 State Hwy 30       TE: 08/25/2020     1     10650 State Hwy 30     1     10650 State Hwy 30       TE: 08/25/2020     1     10550 State Hwy 30     1     10650 State Hwy 30       TE: 08/25/2020     1     10550 State Hwy 30     1     10650 State Hwy 30       TE: 08/25/2020     1     10550 State Hwy 30     1     10650 State Hwy 30       TE: 08/25/2020     1     10550 State Hwy 30     1     10550 State Hwy 30       TE: 08/25/2020     1     1399 774 55000     0     1     10550 State Hwy 30       Min     0.73%     0     0.13%     1     1979 745 5500       Min     0.73%     0.014%     Min     0.014%       Min     0.11%     Min     0.11%     1       Min     0.11%     Min     1.16%     1       Min     0.11%     Min     1.16%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   
                                                                                                                                                                                                                                                                                                                                                                                                 | 3099503     S     CMC Construction Sves College Stati     S     CMC Construction Sves College Stati     S     CMC Construction Sves College Stati     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N     N <td< th=""><th>0140         S         CMC Construction Svcs College Stati         S         CMC Construction Svcs College Stati         S         CMC Construction Svcs College Stati         N           0140         L         10650 State Hwy 30         1         10650 State Hwy 30         1         10650 State Hwy 30           D         College Station TX         P         College Station TX         US         77845-7950           1         979 774 5900         7         979 774 5900         0         7         979 774 5900           0         7         979 774 5900         0         7         979 774 5900         0           10%         77845-7950         7         1         979 774 5900         0         0           10%         1         979 774 5900         0         0         0         0         0           110%         1         1         979 774 5900         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0</th><th>ully truu</th></td<>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 0140         S         CMC Construction Svcs College Stati         S         CMC Construction Svcs College Stati         S         CMC Construction Svcs College Stati         N           0140         L         10650 State Hwy 30         1         10650 State Hwy 30         1         10650 State Hwy 30           D         College Station TX         P         College Station TX         US         77845-7950           1         979 774 5900         7         979 774 5900         0         7         979 774 5900           0         7         979 774 5900         0         7         979 774 5900         0           10%         77845-7950         7         1         979 774 5900         0         0           10%         1         979 774 5900         0         0         0         0         0           110%         1         1         979 774 5900         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     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c         Value         Characteristic         Value           C         0.20%         Characteristic         Value           P         0.010%         Characteristic         Value           P         0.010%         Characteristic         Value           P         0.010%         Characteristic         Value           P         0.011%         Characteristic         Value           P         0.11%         Characteristic         Value           P         0.001%         Characteristic         Value           P         1         48.6ksi         Passed         Passed           P         2.188IN         2.188IN         Passed         Passed		
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      1         48.6ksi         Characteristic           P         2.188IN         C         2.188IN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Characteristic         Value         Characteristic         Value           C         0.20%         M         0.72%         P           R         0.015%         P         0.010%         S           R         0.010%         S         0.049%         S           S         0.049%         S         0.011%           No         0.11%         N         N         N           Cu         0.33%         Cu         0.33%         S           Cu         0.33%         Cu         0.014%         N           No         0.011%         N         N         N           Yield Strength test 1         48.6ksi         S         0.001%           Sin         0.001%         S         S         0.001%           Al         0.001%         S         S         S           Sinel Strength test 1         24%         S         S         S           Gangation test 1         24%         S         S         S         S           Bend Test 1         Passed         Bend Test 1         Passed         Bend Test 1         S         S                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Characteristic     Value     Characteristic     Value       C     0.20%     C     0.15%       Mn     0.75%     P     Outlow       S     0.0010%     S     0.010%       S     0.010%     S     0.010%       S     0.011%     No     0.11%       Nield Strength test 1     21%     Al     0.014%       Yield Strength test 1     71.6ksi     Elongation test 1     21.6ksi       Bend Test Diameter     2.188IN     21.88IN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Characteristic         Value         Characteristic         Value           C         0.20%         C         0.20%         C           C         0.010%         0.010%         S         0.010%           F         0.010%         S         0.049%         S           S         0.049%         S         0.011%         C           No         0.11%         No         0.043%         S           C         0.11%         No         0.043%         S           No         0.014%         No         0.043%         S           Al         0.001%         Al         0.001%         S           S         0.001%         S         0.001%         S           Al         0.001%         S         S         0.001%           S         0.001%         S         S         S           Al         0.001%         S         S         S           S         0.001%         S         S         S           Al         0.001%         S         S         S           Al         0.001%         S         S         S           S         0.001%         S <th>Characteristic         Value         Characteristic         Value           C         0.250%         Min         0.755%         P           Min         0.755%         P         0.010%         S           S         0.010%         S         0.013%         C           S         0.11%         Min         0.11%         Min           Ni         0.11%         Min         0.11%         Min           V         0.000%         C         0.013%         S           Vield Strength test 1         48.6ksi         Tensile Strength test 1         11.6ksi           Floragation test 1         24%         Sin         0.001%         S           Gardion feet 1         Passed         Band Test Diameter         2.1881N</th> <th>Characteristic         Value         Characteristic         Value           C         0.20%         Mn         0.155%         P           Mn         0.155%         P         0.0105%         S           S         0.049%         S         0.049%         S           S         0.11%         Mn         0.11%         Mn           Mi         0.11%         Mi         0.11%         Mn           Mo         0.043%         S         0.043%         S           Mi         0.11%         Mi         0.11%         Mn           Mo         0.043%         S         0.001%         S           Mo         0.043%         Mo         0.043%         Mn           Yield Strength test         1         48.6ksi         S         0.001%           S         0.001%         A         0.001%         A         0.001%         B           Passed         Bend Test         1         24.6ksi         B         21.881N         B         B         21.881N         B         21.881N         B         21.881N         B         21.881N         B         21.881N         B         21.81%         B         21.81%</th> <th>Characteristic         Value         Characteristic         Value         Characteristic         Value           C         0.20%         Mn         0.75%         P         0.010%         S         0.010%         S         0.010%         S         0.010%         S         0.011%         Mn         0.11%         Mn         0.013%         S         0.011%         S         0.011%         S         S         0.011%         S         S         0.014%         S         S         0.014%         S         S         0.014%         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S    
    S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         &lt;</th> <th>Characteristic         Value         Characteristic         Value           C         0.25%         Mn         0.75%         Mn           Min         0.75%         Mn         0.75%         Mn           Min         0.71%         S         0.010%         S           S         0.010%         S         0.011%         Mn           Min         0.11%         Mn         0.013%         S           Cr         0.11%         Mn         0.0043%         S           Ni         0.11%         Mn         0.014%         S           An         0.001%         S         Nn         0.014%           Mn         0.11%         Mn         0.001%         S           Yield Strength test         1         71.6ksi         Elongation test         24%           Band Test 1         81N         Band Test 1         Band Test 1         Band Test 1         S           Band Test Diameter         2.1381N         S         S         S         S         S</th> <th>Characteristic         Value         Characteristic         Value         Characteristic         Value           C         0.25%         Mn         0.75%         Mn         0.010%         Mn         0.11%         Mn         0.011%         Mn         0.014%         Mn<!--</th--><th>Characteristic         Value         Characteristic         Value           n         0.750%         Mn         0.750%           m         0.750%         P         0.010%           m         0.750%         P         0.010%           m         0.750%         P         0.010%           m         0.713%         C         0.013%           m         0.11%         Ni         0.11%           n         0.11%         Ni         0.11%           Ni         0.11%         Ni         0.11%           Ni         0.11%         Ni         0.014%           Ni         0.014%         Ai         0.001%           Yriald Strength test 1         148.6ksi         Elongation test 1         24%           Elongation test 1         24%         Bend Test 1         Band           Bend Test Diameter         2.1881N         Bend Test Diameter         2.1881N</th><th>Characteristic         Value         Characteristic         Value           C         0.25%         Mn         0.75%         Characteristic         Value           Mn         0.75%         Mn         0.75%         Characteristic         Value           P         0.010%         S         0.010%         S         Characteristic         Value           P         0.011%         Mn         0.11%         Mn         Cu         Characteristic         Value           Ni         0.11%         Mn         0.013%         Cr         Cn         Cn</th><th>C         Value         Characteristic         Value           C         0.20%         Characteristic         Value           P         0.010%         Characteristic         Value           P         0.010%         Characteristic         Value           P         0.010%         Characteristic         Value           P         0.010%         Characteristic         Value           P         0.014%         Characteristic         Value           P         1         2.16         Characteristic         Value           P         2.16         2.18         Characteristic         Value</th><th>Characteristic Value<br/>The Following is true of the material represented by this MTR:<br/>Material is fully killed<br/>*100% method and rolled in the USA<br/>*110204:2004:31 compliant</th></th> | Characteristic         Value         Characteristic         Value           C         0.250%         Min         0.755%         P           Min         0.755%         P         0.010%         S           S         0.010%         S         0.013%         C           S         0.11%         Min         0.11%         Min           Ni         0.11%         Min         0.11%         Min           V         0.000%         C         0.013%         S           Vield Strength test 1         48.6ksi         Tensile Strength test 1         11.6ksi           Floragation test 1         24%         Sin         0.001%         S           Gardion feet 1         Passed         Band Test Diameter         2.1881N                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Characteristic         Value         Characteristic         Value           C         0.20%         Mn         0.155%         P           Mn         0.155%         P         0.0105%         S           S         0.049%         S         0.049%         S           S         0.11%         Mn         0.11%         Mn           Mi         0.11%         Mi         0.11%         Mn           Mo         0.043%         S         0.043%         S           Mi         0.11%         Mi         0.11%         Mn           Mo         0.043%         S         0.001%         S           Mo         0.043%         Mo         0.043%         Mn           Yield Strength test         1         48.6ksi         S         0.001%           S         0.001%         A         0.001%         A         0.001%         B           Passed         Bend Test         1         24.6ksi         B         21.881N         B         B         21.881N         B         21.881N         B         21.881N         B         21.881N         B         21.881N         B         21.81%         B         21.81%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Characteristic         Value         Characteristic         Value         Characteristic         Value           C         0.20%         Mn         0.75%         P         0.010%         S         0.010%         S         0.010%         S         0.010%         S         0.011%         Mn         0.11%         Mn         0.013%         S         0.011%         S         0.011%         S         S         0.011%         S         S         0.014%         S         S         0.014%         S         S         0.014%         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S        
S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         S         <                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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       Mn         0.75%         Mn           Min         0.75%         Mn         0.75%         Mn           Min         0.71%         S         0.010%         S           S         0.010%         S         0.011%         Mn           Min         0.11%         Mn         0.013%         S           Cr         0.11%         Mn         0.0043%         S           Ni         0.11%         Mn         0.014%         S           An         0.001%         S         Nn         0.014%           Mn         0.11%         Mn         0.001%         S           Yield Strength test         1         71.6ksi         Elongation test         24%           Band Test 1         81N         Band Test 1         Band Test 1         Band Test 1         S           Band Test Diameter         2.1381N         S         S         S         S         S                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Characteristic         Value         Characteristic         Value         Characteristic         Value           C         0.25%         Mn         0.75%         Mn         0.010%         Mn         0.11%         Mn         0.011%         Mn         0.014%         Mn </th <th>Characteristic         Value         Characteristic         Value           n         0.750%         Mn         0.750%           m         0.750%         P         0.010%           m         0.750%         P         0.010%           m         0.750%         P         0.010%           m         0.713%         C         0.013%           m         0.11%         Ni         0.11%           n         0.11%         Ni         0.11%           Ni         0.11%         Ni         0.11%           Ni         0.11%         Ni         0.014%           Ni         0.014%         Ai         0.001%           Yriald Strength test 1         148.6ksi         Elongation test 1         24%           Elongation test 1         24%         Bend Test 1         Band           Bend Test Diameter         2.1881N         Bend Test Diameter         2.1881N</th> <th>Characteristic         Value         Characteristic         Value           C         0.25%         Mn         0.75%         Characteristic         Value           Mn         0.75%         Mn         0.75%         Characteristic         Value      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fully killed<br/>*100% method and rolled in the USA<br/>*110204:2004:31 compliant</th> | Characteristic         Value         Characteristic         Value           n         0.750%         Mn         0.750%           m         0.750%         P         0.010%           m         0.750%         P         0.010%           m         0.750%         P         0.010%           m         0.713%         C         0.013%           m         0.11%         Ni         0.11%           n         0.11%         Ni         0.11%           Ni         0.11%         Ni         0.11%           Ni         0.11%         Ni         0.014%           Ni         0.014%         Ai         0.001%           Yriald Strength test 1         148.6ksi         Elongation test 1         24%           Elongation test 1         24%         Bend Test 1         Band           Bend Test Diameter         2.1881N         Bend Test Diameter         2.1881N                                                                            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killed<br>• 100% melted and rolled in the USA<br>• EN10204:2004 31 compliant                    |
| C 0.20%<br>P 0.010%<br>S 0.049%<br>S 0.049%<br>D 0.011%<br>P 0.11%<br>P 0.11%<br>P 0.11%<br>P 0.014%<br>P 0.001%<br>P 0.001%<br>P 0.001%<br>P 1.6ksi<br>P 2.188IN<br>P 2.188IN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         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| C 0.20%<br>P 0.010%<br>S 0.049%<br>S 0.049%<br>D 0.011%<br>P 0.11%<br>P 0.11%<br>P 0.11%<br>P 0.014%<br>P 0.001%<br>P 0.001%<br>P 0.001%<br>P 1.6ksi<br>P 2.188IN<br>P 2.188IN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         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| C 0.20%<br>P 0.18%<br>S 0.049%<br>O 0.18%<br>U 0.33%<br>P 0.11%<br>N 0.11%<br>N 0.017%<br>N 0.001%<br>N 0.001%<br>N 0.001%<br>N 0.001%<br>N 0.001%<br>S 0.001%<br>N 0.000%<br>N 0.000%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 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               | The Following is true of the material represented by this MTR:<br>•Material is fully killed<br>• 100% materia and rolled in the USA<br>• EV10204:204 31 compliant                     |
| P 0.010%<br>S 0.049%<br>D 0.010%<br>P 0.11%<br>P 0.11%<br>P 0.11%<br>P 0.014%<br>P 0.001%<br>P 0.001%<br>P 0.001%<br>P 0.001%<br>P 2.188IN<br>P 2.188IN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                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The Following is true of the material represented by this MTR:<br>•Material is fully killed<br>• 100% meted and rolled in the USA<br>• Enrin204:204:31 compliant                      |
| P 0.010%<br>S 0.049%<br>P 0.11%<br>P 0.11%<br>P 0.11%<br>P 0.11%<br>P 0.001%<br>P 0.001%<br>P 0.001%<br>P 0.001%<br>P 1.6ksi<br>P 2.1381N<br>P 2.1381N<br>P 2.1381N                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    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| S 0.049%<br>Si 0.18%<br>r 0.11%<br>n 0.11%<br>o 0.043%<br>o 0.043%<br>o 0.01%<br>h 0.014%<br>n 0.014%<br>n 0.014%<br>n 0.014%<br>si 2.188IN<br>2.188IN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 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| S 0.049%<br>10.11%<br>10.11%<br>10.11%<br>10.11%<br>10.013%<br>10.001%<br>11.48.6ksi<br>11.24%<br>12.188IN<br>2.188IN<br>2.188IN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       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0.18%<br>Cr 0.11%<br>No 0.11%<br>No 0.11%<br>No 0.11%<br>No 0.00%<br>Cb 0.001%<br>Cb 0.001%<br>Sn 0.014%<br>Al 0.001%<br>Al 0.001%<br>Al 0.001%<br>Al 0.001%<br>Al 0.001%<br>Al 2.138IN<br>Bend Test 1 24%<br>Bend Test Diameter 2.138IN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 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0.0001%<br>Cb 0.001%<br>Cb 0.001%                                                                   | Si 0.18%<br>Cr 0.11%<br>No 0.043%<br>No 0.043%<br>V 0.000%<br>Cb 0.014%<br>Sn 0.014%<br>Al 0.001%<br>Sn 0.014%<br>Al 0.001%<br>Al 0.001%<br>Al 0.001%<br>Sn 0.014%<br>Al 0.001%<br>Sn 0.014%<br>Al 0.001%<br>Sn 0.014%<br>Sn 0.014%<br>Al 0.001%<br>Sn 0.014%<br>Sn 0.014%                                                                  | Si 0.18%<br>Cr 0.11%<br>No 0.11%<br>Mo 0.043%<br>V 0.000%<br>Cb 0.001%<br>Cb 0.001%<br>Sn 0.014%<br>Al 0.001%<br>Al 0.001%<br>Al 0.001%<br>Al 0.001%<br>Al 0.001%<br>Al 0.001%<br>Sn 0.014%<br>Sn 0.014%<br>Al 24%<br>Sn 0.014%<br>Al 24%<br>Sn 0.014%<br>Al 24%<br>Sn 0.001%<br>Al 24%<br>Sn 0.001%<br>Al 24%<br>Sn 0.001%<br>Al 24%<br>Sn 0.001%<br>Al 24%<br>Sn 0.001%<br>Al 24%<br>Sn 0.001%<br>Sn 0.001%<br>Al 24%<br>Sn 0.001%<br>Al 2.4%<br>Sn 0.001%<br>Sn 0.001%                                                                                                            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2.0000%<br>Al 2.001%<br>Al 2.001%  | ii 0.18%<br>ii 0.11%<br>ii 0.11%<br>ii 0.11%<br>o 0.043%<br>o 0.013%<br>b 0.001%<br>ii 24%<br>ii 2.188IN<br>2.188IN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | The Following is true of the material represented by this MTR:<br>•Material is fully killed<br>• 100% meted and rolled in the USA<br>• EV10204:2004 31 compliant                      |
| 0.013%<br>1.0.11%<br>0.11%<br>0.013%<br>0.001%<br>0.001%<br>0.001%<br>1.48.6ksi<br>1.24%<br>1.24%<br>1.24%<br>2.1381N<br>2.1381N                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       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| u 0.33%<br>r 0.11%<br>n 0.11%<br>o 0.043%<br>v 0.000%<br>h 0.014%<br>n 0.014%<br>n 0.014%<br>n 0.014%<br>r 2.188IN<br>z 2.188IN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        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| r 0.11%<br>ii 0.11%<br>o 0.043%<br>V 0.000%<br>b 0.001%<br>n 0.014%<br>n 0.001%<br>1 48.6ksi<br>1 71.6ksi<br>2.188IN<br>2.188IN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        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                                                                                       | The Following is true of the material represented by this MTR:<br>• Material is fully killed<br>• 100% moted and rolled in the USA<br>• EV10204:2004 3.1 compliant                    |
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Proving-Ground¶ 3100-SH-47, Bilds-709 Bryan, TX-77807	Texas A&M Transportatio Institute Teyes-A&M-UniversityII College Station.77:-77843I Phone:979-845-63761		.3-01∵Concret Sampling¤	Q1 7.5-012	Issue Date: ↔ C
• Qua	ality ·Form¤		Wanda L. Menges¶ Darrell L. Kuhn¤	Revision:⊶ 6¤	Page:¶ C 1 of 1¤
The information con	tained in this document is cor 606861-03	nfidential to TTI Proving (	Ground.	Mix Design (psi):	3000 psi
Name of Technician Taking Sample	Terrac	con	Name of Technician Breaking Sample	Terra	con
Signature of Technician Taking Sample	Terrac		Signature of Technician Breaking Sample	Terra	con
Load No.	Truck No.	Ticket No.	Locat	ion (from concrete	map)
⊤1	Tucker	1027	Sou	th half of wall and d	eck
Τ2	⊤ucker	1357	North	ern Half of Wall and	deck
Load No.	Break Date	Cylinder Age	Total Load (lbs)	Break (psi)	Average
	s	See attached Repo	orts from Terracon		

	WELL RD	CS	EIE	
START DATE:	I CKET # 10/30/20	20 TIME	: 08:5	6:02
STOP DATE:	10/30/20 C DESIGN	20 TIME B1350	: 09:1	7:14
TOTAL	YARDS	;	10.0	5
MATERIA CAPTYPE LRMSAND RGBLEND WATER SIKA686 NC4	RATE SETT 4 7.4LB 5.5 GA 7.8 GA 2 1.1GP 1.2GP 0.8GP	M	262.7GA	L
N A M E				
	•			

# 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 SOURTS: 5.781536 GA

 ADJUSTED: ADJUSTED: ADJUSTED:

 NATER

 ADJUSTED: ADJUSTED: ADJUSTED:

 WATER 0.002/MIN

 ADMIX #1

 ADMIX #2

 O.002/MIN

 ADMIX #3

LADOTO

ASTM DATA AVAILABLE UPON REQ

Name NOTES:

## CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0151 Service Date: 10/30/20 Report Date: 10/30/20



Client			Project			
Texas Transportation Institut Attn: Gary Gerke TTI Business Office	le		Riverside Campus Riverside Campus Bryan, TX			
3135 TAMU			bijuli, tre			
College Station, TX 77843-3	3135		Project Number: A1171057			
Material Information			Sample Information			
Specified Strength: 3,000 Mix ID: B1350	psi @ 2	8 days	Sample Date: Sampled By: Weather Conditions:	10/30/20 Cullen Turr Clear, no w	*	100
Supplier: Tucker			Accumulative Yards:	10/20	Batch Size (cy):	10
Batch Time: 1000	Plant:		Placement Method:	Direct Disc	harge	
Truck No.:	Ticket No.:	1027	Water Added Before (gal):			
Field Test Data			Water Added After (gal): Sample Location:	0 South cast	end	
Test	Result	Specification	Placement Location:	606861-3(I		
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. (pef): Yield (Cu. Yds.):	146.2	Not Specified				

Labu	ratory re-	SLDala				Age at	Maximum	Compressive		
Set	Specimen	Avg Diam.	Area	Date	Date	Test	Load	Strength	Fracture	Tested
No.	1D	(in)	(sq in)	Received	Tested	(days)	(lbs)	(psi)	Туре	By
l	Λ	6.00	28.27		12/10/20	41 F	132,160	4,670		SLS
1	в	6.00	28.27		12/10/20	41 F	128,080	4,530	2	SLS
L	С	6.00	28.27		12/10/20	41 F	124,660	4,410	I	SLS
1	D					Hold				
Initial	Cure: Outsi	ide		Final C	ure: Field Cu	red				

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).

Start/Stop: 0815-1400

Terracon Rep.: Cullen Turney Reported To:

Contractor:

**Report Distribution:** 

 Texas Transportation Institute, Gary Gerke
 Texas Transportation Institute, Bill Griffith (1) Terracon Consultants, Inc., Alex Dunigan, P.E.

#### 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.

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## CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0151 Service Date: 10/30/20 **Report Date:** 10/30/20 606861-3 (LADOT) Task



Task: 606861-3	(LADOT)		979-846-3767 Reg No: F-3272								
Client			Project								
Texas Transportation Institut	te		Riverside Campus								
Attn: Gary Gerke			Riverside Campus								
TTI Business Office			Bryan, TX								
3135 TAMU	2125										
College Station, TX 77843-3	3135		Project Number: A1171057								
Material Information			Sample Information								
Specified Strength: 3,000	) psi @ 2	8 days	Sample Date:	10/30/20	Sample Time:	1035					
			Sampled By:	Cullen Turi	ney						
Mix ID: B1350			Weather Conditions:	Clear, no w	rind						
Supplier: Tucker			Accumulative Yards:	20/20	Batch Size (cy):	10					
Batch Time: 1030	Plant:		Placement Method:	Direct Disc	harge						
Truck No.:	Ticket No.:	1357	Water Added Before (gal):								
Field Test Data			Water Added After (gal): Sample Location:	0 North west	end						
Test	Result	Specification	Placement Location:	606861-3(I							
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			Age at Maximum	Compress	ive						
					-						

Set No.	Specimen ID	Avg Diam. (in)	Area (sq in)	Date Received	Date Tested	Age at Test (days)	Load (lbs)	Strength	Fracture Type	Tested By
2	A	6.00	28.27		12/10/20	41 F	124,320	4,400	1	SLS
2	В	6.00	28.27		12/10/20	41 F	121,970	4,310	1	SLS
2	С	6.00	28.27		12/10/20	41 F	123,700	4,370	1	SLS
2	D					Hold				
Initial	Cure: Outsi	ide		Final Cu	ire: See Com	ments				

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 **Reported To:** 

Contractor:

**Report Distribution:** (1) Terracon Consultants, Inc., Alex Dunigan, P.E.

Texas Transportation Institute, Gary Gerke
 Texas Transportation Institute, Bill Griffith

**Reviewed By:** 

Start/Stop: 0815-1400 1 1h Alexander Dunigan

Project Manager

#### 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.

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Page 2 of 2

Project No:	606861-03	Casting Date:	11/5/2020	Mix Design (psi):	3000 psi
Name of Technician Taking Sample	Terr	acon	Name of Technician Breaking Sample		acon
Signature of Technician Taking Sample	Terr	acon	Signature of Technician Breaking Sample		acon
Load No.	Truck No.	Ticket No.	Locat	ion (from concrete	e map)
Τ1	Tucker	292		100% of Curb	
Load No.	Break Date	Cylinder Age	Total Load (lbs)	Break (psi)	Average
		See attached Rep	orts 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
ADJUSTI	ED:	
STONE	7.916514 GA	15889.93
ADJUSTE	ED:	
WATER	27.58288GAL	193,7082
ADMIX #1	0.00Z/MIN	0.00Z
ADMIX #2	0.00Z/MIN	0.00Z
ADMIX #3	0.00Z/MIN	0.00Z
TOTAL SAND	MOISTURE: 0.0	
TOTAL STON		

Name___ NOTES:

## CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0154 Service Date: 11/05/20 **Report Date:** 11/06/20 606861-3 (LADOT) Task:



Task: 000801-3	(LADOT)					/9-840-3/0/	Reg No: F-3272	
Client				Project				
Texas Transportation Institu	ite			Riverside Car	mpus			
Attn: Gary Gerke				Riverside Car	mpus			
TTI Business Office				Bryan, TX				
3135 TAMU				-				
College Station, TX 77843-	3135			Project Numb	per: A1171057			
<b>Material Information</b>			:	Sample Inf	ormation			
Specified Strength: 3,000	) psi @ _ 28	days		Sample Date	:	11/05/20	Sample Time:	0820
				Sampled By:		Matcek, Jan	nes	
Mix ID: B1350				Weather Cor	iditions:	Partly cloud	ly	
Supplier: Tucker Conc	rete			Accumulativ	e Yards:	8.28	Batch Size (cy):	8.28
Batch Time: 0800	Plant:			Placement M	lethod:	Direct Discl	harge	
Truck No.: 4	Ticket No.:	292		Water Addeo	i Before (gal):	0		
Field Test Data				Water Addeo	i After (gal):	0		
field fest Data				Sample Loca	ition:	20' West of	Southeast end	
Test	Result	Specificat	tion	Placement L	ocation:	Curb		
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.):								
_aboratory Test Data	L			Age at	Maximum	Compressi	ve	
Set Specimen Avg Dia	am. Area	Date	Date	Test	Load	Strength		Teste

	Set	Specimen	Avg Diam.	Area	Date	Date	lest	Load	Strength	Fracture	Tested
	No.	ID	(in)	(sq in)	Received	Tested	(days)	(lbs)	(psi)	Туре	By
	1	A	6.00	28.27	11/06/20	12/10/20	35 F	133,780	4,730	1	SLS
	1	в	6.00	28.27	11/06/20	12/10/20	35 F	125,810	4,450	1	SLS
	1	С	6.00	28.27	11/06/20	12/10/20	35 F	127,600	4,510	1	SLS
	1	D			11/06/20		Hold				
l	Initial	Cure: Outsi	ide		Final C	ure: Field Cur	red				

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 **Reported To:** 

Contractor:

**Report Distribution:** 

 Texas Transportation Institute, Gary Gerke
 Texas Transportation Institute, Bill Griffith (1) Terracon Consultants, Inc., Alex Dunigan, P.E.

**Reviewed By:** 

Start/Stop: 0715-0915 1 1h Alexander Dunigan

Project Manager

#### 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.

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Page 1 of 1

Project No:	606861-03	Casting Date:	11/19/2020	Mix Design (psi):	3000 psi
Name of Technician Taking Sample	Terr	acon	Name of Technician Breaking Sample	Terr	acon
Signature of Technician Taking Sample	Terr	acon	Signature of Technician Breaking Sample	Terr	acon
Load No.	Truck No.	Ticket No.	Locat	ion (from concrete	e map)
Τ1	Tucker	340		Parapet	
Load No.	Break Date	Cylinder Age	Total Load (lbs)	Break (psi)	Average
		See attached Repo	orts 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	
ADJUSTED		5946.61L
STONE	7.916514 GA	8213.006
ADJUSTED		0213.006
WATER	23.58288GAL	92.5162G
ADMIX #1	0.00Z/MIN	
ADMIX #2	0.00Z/MIN	0.00Z
ADMIX #3	268.37160Z/	0.00Z
	IOISTURE: 0.0	909.8145
TOTAL STONE		

Name____ NOTES:

## CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0155 Service Date: 11/19/20 **Report Date:** 11/19/20 606861-3 (LADOT) Task



Task:	(	506861-3 (L.	ADOT)				9	79-846-3767	Reg No: F-3272	
Client	t					Project				
Attn: ( TTI B	Transportati Gary Gerke usiness Offic TAMU					Riverside Car Riverside Car Bryan, TX				
	ge Station, T	X 77843-313	35			Project Numb	er: A1171057			
Mater	rial Inform	nation			;	Sample Inf	ormation			
Specif Mix II	fied Strengt		osi @ 28	days		Sample Date Sampled By: Weather Cor		11/19/20 Cullen Turney Cloudy, no w	·	0712
Truck	<b>Time:</b> 070 <b>No.:</b> 4	00 <b>1</b> 1	Plant: Ficket No.:	340		Accumulativ Placement M Water Addec Water Addec	lethod: 1 Before (gal):	• ·	Batch Size (cy):	10
Field	Test Data	a		~		Sample Loca		10' west of So		
Concr Ambie Plastie	Test p (in): ontent (%): rete Temp. ( ent Temp. (l c Unit Wt. ( (Cu. Yds.):	F): F):	Result         6         3/4         2.5         69         54         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8         145.8	Specificat	<u>non</u>	Placement L		606861-3 hal	т waii	
Laboi	ratory Te	st Data				Age at	Maximum	Compressiv	P	
Set No.	Specimen ID	Avg Diam. (in)	. Area (sq in)	Date Received	Date Tested	Test (days)	Load (lbs)	Strength (psi)	Fracture Type	Tested By
1	A	6.00	28.27	11/19/20	12/10/20		113.160	4.000		SLS

Set	specimen	Avg Diam.	Alta	Date	Date	rest	Loau	Strength	Fracture	resteu
No.	ID	(in)	(sq in)	Received	Tested	(days)	(lbs)	(psi)	Туре	By
1	A	6.00	28.27	11/19/20	12/10/20	21 F	113,160	4,000	2	SLS
1	в	6.00	28.27	11/19/20	12/10/20	21 F	111,410	3,940	1	SLS
1	С	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: Outsi	ide		Final C	ure: Field Cu	red				

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 **Reported To:** 

Contractor:

**Report Distribution:** (1) Terracon Consultants, Inc., Alex Dunigan, P.E.

Texas Transportation Institute, Gary Gerke
 Texas Transportation Institute, Bill Griffith

**Reviewed By:** 

Start/Stop: 0600-1000 1 1h Alexander Dunigan

Project Manager

#### 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.

CR0001, 11-16-12, Rev.6

Page 1 of 1

# Appendix J. MASH Test 3-11 (Crash Test No. 606861-3)

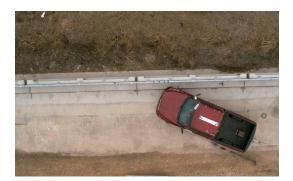
Date: 2	020-12-14	Test No.:	606861	1-3	VIN No.:	1C	6RR6GT	0ES28	37150
Year:	2014	Make:	RAN	1	Model:				
Tire Size:	265/70 R 17			Tire I	nflation Pre	ssure:		35 ря	si
Tread Type:	Highway				Odo	meter:	118074		
Note any dan	nage to the ve	hicle prior to te	est: <u>None</u>						
<ul> <li>Denotes ad</li> </ul>	celerometer la	ocation.			▲X —	-			
NOTES: No	ne		1		T			)	
NOTEO. <u></u>				(					T I
Engine Type:	V-8		A M -		+		<u> </u>		- N T
Engine CID:	5.7L								WHEEL TRACK
Transmission	Туре:	_	<b>y</b>		JAP	-102	-TEST INERT	IALC M	
Auto FWD		Manual		_ <b>F</b> Q	•		/		
	RWD		P —						t t
Optional Equ None	ipment:		•	6			0		B
						╉ <u></u> ╉		Pi	
Dummy Data Type:	: 50th perce	entile male			U		Y	/	
Mass:	16	-		<b>◄</b> — F <b>→</b> ■	⊷H►	LG	-5	— D —	•
Seat Positio	n: IMPACT SID	E		↓ ↓	M	- E		м	
Geometry:	inches				FRONT	— C ———	RE	CAR.	
A78.	50 F	40.00	К	20.00	P _	3.	00	υ	26.75
B74.	0 _	28.50	L	30.00	Q	30.5		V _	30.25
C227.		61.46	Μ	68.50	- R_	18.0		W _	61.40
D <u>44</u> .		11.75	N	68.00	_ s _	13.0		× _	79.00
E 140. Wheel Cer		27.00	O Wheel Well	46.00	- ^T -	77.0	00 n Frame	_	
Height Fr	ont	14.75 Clea	rance (Front)		6.00	Heigh	t - Front		12.50
Wheel Cer Height R		14.75 Clea	Wheel Well arance (Rear)		9.25		n Frame nt - Rear _		22.50
		3 inches; E=148 ±12 in	iches; F=39 ±3 inch	es; G = > 28 in	nches; H = 63 ±4 ii	nches; O=43 ±	±4 inches; (M·	+N)/2=67 ±	1.5 inches
GVWR Ratin		Mass: Ib	<u>Curb</u>		<u>Test</u>	Inertial		<u>Gross</u>	<u>Static</u>
	3700	Mfront		925		2844	-		2929
	3900	M _{rear}		131		2212	-		2292
Total 6	5700	M _{Total}	5	056 (Allowable F	Range for TIM and	5056 GSM = 5000	lb±110 lb) -		5221
Mass Distrib		1 / 20	<i>,</i>						059
lb	LF:	1430	RF:	1414	LR:	1154	_ RR	:i	058

Figure 127. Vehicle properties for Test No. 606861-3

Date:202	20-12-	14 T	est No.: _	60686	1-3	VIN:	10	C6RR6G	F0ES28715	50
Year:	2014		Make:	RAN	1	Model:		15	500	
Body Style:	Qua	d Cab				Mileage:	11	8074		
Engine: 5.7	L	١	√-8		Tran	smission:	Automa	atic		
Fuel Level:									(44)	) lb max)
Tire Pressu					ar: 35	nsi 9	Siza: 2	65/70 R 1		<u> </u>
Measured \					a. <u>55</u>		<u> </u>			
			<b>9.</b>							
L	.F:	1430		RF:	1414		Fro	nt Axle:	2844	
L	R:	1154		RR:	1058		Re	ar Axle:	2212	
	<b>a</b> .	05.0.4		Disht	0.470			Tatalı	5050	
Le	eft:	2084		Right	2472				5056 10 lb allowed	<u> </u>
1	Whee	I Base:	140.50	inches	Track: F:	68.50	inches	<b>R</b> :	68.00	inches
	148	3 ±12 inch	es allowed			Track = (F+F	R)/2 = 67 :	±1.5 inches	allowed	
Center of G	iravit	y, SAE	J874 Sus	pension M	ethod					
		-								
	<b>X</b> :	61.47	inches	Rear of F	ront Axle	(63 ±4 inche	s allowed)	)		
	Y:	-0.76	inches	Left -	Right +	of Vehicle	e Cente	erline		
	Z:	28.5	inches	Above Gr	ound	(minumum 2	8.0 inche	s allowed)		
Hood H	eight:		46.00	inches	Front	Bumper H	leight:		27.00 i	inches
		43 ±4 i	nches allowed							
Front Over	hana:		40.00	inches	Rear	Bumper H	leiaht:		30.00 i	inches
	3.		nches allowed	-			<b>U</b> .			-
Quarall	nath:		227.50	inchos						
	ngui.		3 inches allow	-						

# Figure 128. Measurement of vehicle vertical CG for Test No. 606861-3

Figure 129. Sequential photographs for Test No. 606861-3 (overhead view).



0.000 s



0.400 s



0.100 s



0.500 s



0.200 s







0.300 s



0.700 s

Figure 130. Sequential photographs for Test No. 606861-3 (frontal view).



0.000 s



0.100 s



0.400 s



0.500 s



0.200 s



0.300 s



0.600 s



0.700 s

Figure 131. Sequential photographs for Test No. 606861-3 (rear view).



0.000 s



0.400 s



0.100 s



0.500 s







0.300 s



0.600 s



0.700 s

Date:	2020-12-14	Test No.:	606861-3	VIN No.:	1C6RR6GT0ES287150
Year:	2014	Make:	RAM	Model:	1500

# Figure 132. Exterior crush measurements for Test No. 606861-3

# VEHICLE CRUSH MEASUREMENT SHEET¹

Complete What	en 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)	$X1+X2$ _
< 4 inches	2
$\geq$ 4 inches	

# Note: Measure C₁ to C₆ from Driver to Passenger Side in Front or Rear Impacts – Rear to Front in Side Impacts.

Guide		Direct I	Direct Damage								
Specific Impact Number	Plane* of C-Measurements	Width** (CDC)	Max*** Crush	Field L**	$C_1$	$C_2$	$C_3$	$C_4$	$C_5$	$C_6$	±D
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										

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

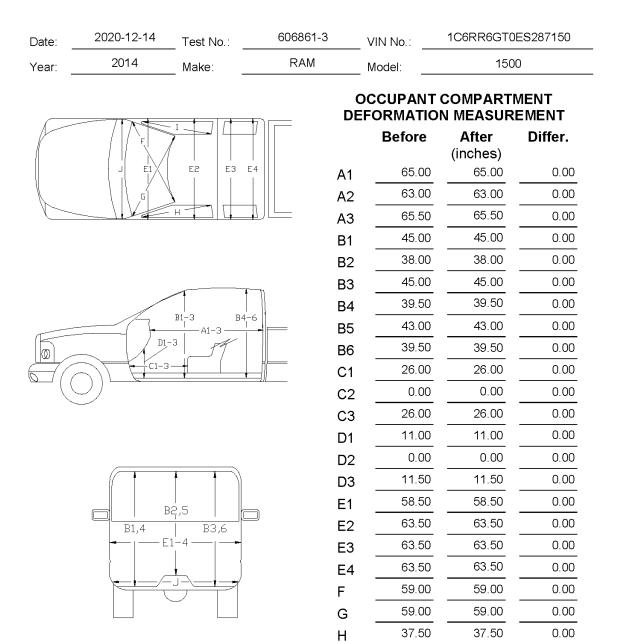
*Identify the plane at which the C-measurements are taken (e.g., at bumper, above bumper, at sill, above sill, at beltline, etc.) or label adjustments (e.g., free space).

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

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

L

J*

37.50

25.00

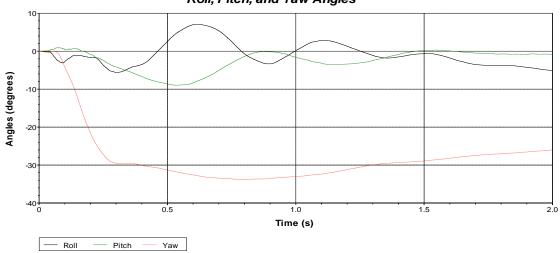
37.50

25.00

0.00

0.00

Figure 134. Vehicle angular displacements for Test No. 606861-3



Roll, Pitch, and Yaw Angles

Figure 135. Vehicle longitudinal accelerometer trace for Test No. 606861-3 (accelerometer located at center of gravity)

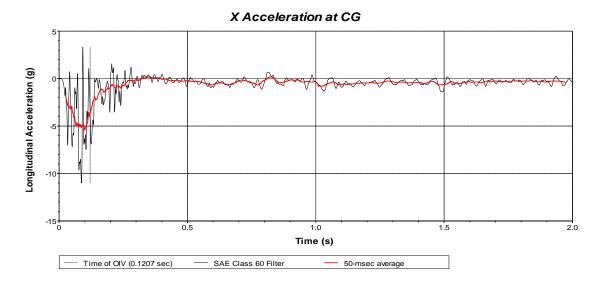


Figure 136. Vehicle lateral accelerometer trace for Test No. 606861-3 (accelerometer located at center of gravity)

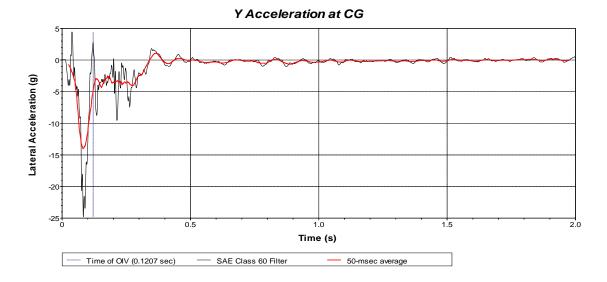
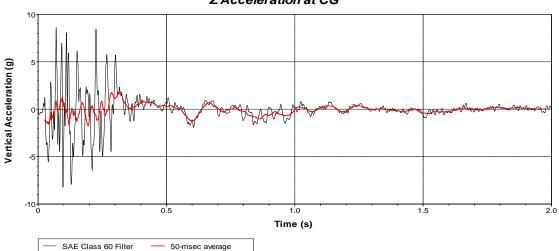


Figure 137. Vehicle vertical accelerometer trace for Test No. 606861-3 (accelerometer located at center of gravity)



Z Acceleration at CG

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

		-			
Date:	2020-12-11	Test No.:	606861-4	VIN No.: <u>3N1CN7</u>	APOEL862280
Year:	2014	Make:	NISSAN	Model: <u>VERSA</u>	
Tire Inf	lation Pressure:	36 PSI	_ Odometer: <u>918</u>	61-4 Tire Size	e: <u>P185/65R15</u>
Descril	oe any damage to	the vehicle pric	or to test: <u>None</u>		
NOTE:	otes acceleromete S: <u>None</u>	er location.		~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~	
	CID: <u>1.6 L</u> nission Type: Auto or FWD <u></u> RW al Equipment:	<mark>∕/</mark> Manual /D <u> </u> 4WD			
Type: Mass		ercentile Male			
Geom	etry: inches			0	
A <u>66.7</u>	7 <u>0</u> F	32.50	K <u>12.50</u>	P <u>4.50</u>	U <u>15.50</u>
B <u>59.6</u>	<u>30</u> G		L <u>26.00</u>	Q <u>24.00</u>	V <u>21.25</u>
C <u>175</u>	. <u>40</u> H	42.15	M <u>58.30</u>	R <u>16.25</u>	W <u>42.10</u>
D <u>40.</u>	50 <u> </u>	7.00	N <u>58.50</u>	S <u>7.50</u>	X <u>79.75</u>
E <u>102</u>	. <u>40</u> J	22.25	O <u>30.50</u>	T <u>64.50</u>	
	eel Center Ht Fror			er Ht Rear <u>11.50</u>	W-H0.05
RA	ANGE LIMIT: A = 65 ±3 inch		= 98 ±5 inches; F = 35 ±4 inc inches; W-H < 2 inches or us	shes; H = 39 ±4 inches; O (Top of Radiato e MASH Paragraph A4.3.2	r Support) = 28 ±4 inches
GVWR	Ratings:	Mass: Ib	<u>Curb</u>	<u>Test Inertial</u>	<u>Gross Static</u>
Front	1750	Mfront	1369	1425	1510
Back	1687	M _{rear}	974	979	1077
Total	3389	М⊤otal	2343	2404	2587
Mace I	Distribution:		Allowable T	IM = 2420 lb ±55 lb   Allowable GSM = 25	35 lb ± 55 lb
lviass i lb		_F: <u>706</u>		LR: <u>502</u>	RR: <u>477</u>

# Figure 138. Vehicle properties for Test No. 606861-4

Figure 139. Sequential photographs for Test No. 606861-4 (overhead view).



0.000 s



0.400 s



0.100 s



0.500 s



0.200 s







0.300 s



0.700 s

Figure 140. Sequential photographs for Test No. 606861-4 (frontal view).



0.000 s



0.100 s



0.400 s



0.500 s



0.200 s



0.300 s



0.600 s



0.700 s

Figure 141. Sequential photographs for Test No. 606861-4 (rear view).



0.000 s



0.100 s



0.400 s



0.500 s



0.200 s



0.300 s



0.600 s



0.700 s

Date:	2020-12-11	Test No.:	606861-4	VIN No.:	3N1CN7APOEL862280
Year:	2014	Make:	NISSAN	Model:	VERSA

# Figure 142. Exterior crush measurements for Test No. 606861-4

# VEHICLE CRUSH MEASUREMENT SHEET¹

Complete Wh	en 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)	$X1+X2$ _
< 4 inches	2
≥ 4 inches	

# Note: Measure C₁ to C₆ from Driver to Passenger Side in Front or Rear Impacts – Rear to Front in Side Impacts.

		Direct Damage									
Specific Impact Number	Plane* of C-Measurements	Width** (CDC)	Max*** Crush	Field L**	$C_1$	$C_2$	$C_3$	C4	C5	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										

¹Table 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.

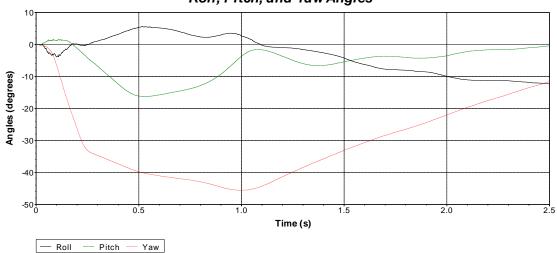
Note: Use as many lines/columns as necessary to describe each damage profile.

Date:2020-12-11 Test No.:606861	-4	VIN No.:	3N1CN7APOEL862280					
/ear:2014Make:NISSAN		Model:	VERSA					
		OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT						
F		Before	After (inches)	Differ.				
Ġ	A1	75.00	75.00	0.00				
	A2	74.00	74.00	0.00				
\$ <i>\</i>	A3	74.00	74.00	0.00				
	B1	43.00	43.00	0.00				
	B2	37.00	37.00	0.00				
B1, B2, B3, B4, B5, B6	B3	43.00	43.00	0.00				
	B4	46.50	46.50	0.00				
A1, A2, 8AB	B5	42.50	42.50	0.00				
D1, D2, & D3 C1, C2, & C3	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				
B1 B2 B3	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				
	Н	39.00	39.00	0.00				
	I	39.00	39.00	0.00				
Lateral area across the cab from	J*	48.50	48.00	-0.50				

# Figure 143. Occupant compartment measurements for Test No. 606861-4

*Li driver's side kick panel to passenger's side kick panel.

Figure 144. Vehicle angular displacements for Test No. 606861-4



Roll, Pitch, and Yaw Angles

Figure 145. Vehicle longitudinal accelerometer trace for Test No. 606861-4 (accelerometer located at center of gravity)

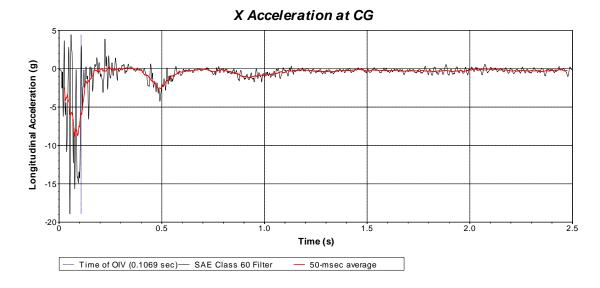


Figure 146. Vehicle lateral accelerometer trace for Test No. 606861-4 (accelerometer located at center of gravity)

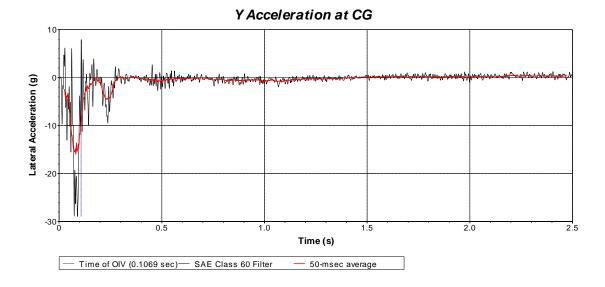
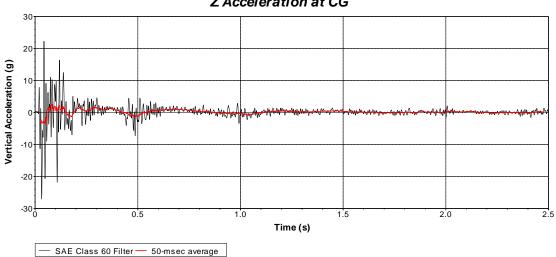


Figure 147. Vehicle vertical accelerometer trace for Test No. 606861-4 (accelerometer located at center of gravity)



Z Acceleration at CG

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