Texas A&M Transportation Institute
Proving Ground

Texas A&M Transportation Institute
3135 TAMU
College Station, TX 77843-3135

979-317-2274
Fax: 979-267-7940
http://tti.tamu.edu/crashtesting

TECHNICAL MEMORANDUM

Contract No.:	**1807207**
Test Report No.:	**610461-2**
Project Name:	**Thrie/W-Beam/Tubular Barrier Gap Rail for MASH TL-3**
Sponsor:	**Roadside Safety Research Pooled Fund**

DATE: **December 17, 2019**

TO: **Michael Elle, P.E.**
Design Standards Engineer, Minnesota Department of Transportation

COPY TO: **Mary Levien**, TTI RDO
D. L. Bullard, Jr., Head, TTI Roadside Safety & Physical Security Division
Rebecca Heck, TTI Roadside Safety & Physical Security Division

FROM: **William F. Williams**, P.E., Associate Research Engineer, TTI Roadside Safety & Physical Security Division

PREPARED BY: **Wanda L. Menges**, Research Specialist, TTI Proving Ground
Glenn E. Schroeder, Research Specialist, TTI Proving Ground
Darrell L. Kuhn, Research Specialist, TTI Proving Ground

FOR MORE INFORMATION:
Name: William F. Williams, P.E.
Phone: 979-317-2707
Email: w-williams@tti.tamu.edu

SUMMARY REPORT

American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*) Test 3-10 was performed on the Tubular Barrier Gap Rail as reported herein. (*1*) The test was not successful with respect to the *MASH* Test 3-10 criteria. Therefore, the design is not acceptable with respect to *MASH* specifications.

DISCLAIMER

The contents of this report reflect the views of the authors, who are solely responsible for the facts and accuracy of the data, findings and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Roadside Safety Research Pooled Fund, Texas A&M University System, or Texas A&M Transportation Institute (TTI). This report does not constitute a standard, specification, or regulation. In addition, the above listed company/agencies assume no liability for its contents or use thereof. The names of specific products or manufacturers listed herein do not imply endorsement of those products or manufacturers. The results reported herein apply only to the article being tested. The test was performed according to TTI Proving Ground quality procedures and according to AASHTO) *MASH*.

INTRODUCTION

The objective of this research was to design a tubular barrier gap rail system for use on a 36-inch high single slope barrier. This barrier gap rail is needed in instances where manholes and other features located along the barrier alignment need to be accessed. Therefore, the gap rail designed for this project was designed to be removable to allow access to these features. Thrie-beam, W-beam, and tubular rail elements were considered for the barrier rail design. The maximum open gap used for the design was 8 ft. The new design was tested to *MASH* TL-3. TTI received the preliminary barrier details that were considered for this design from Minnesota Department of Transportation (MnDOT). The TTI research team incorporated much of this information into the initial design concepts.

The purpose of the test reported herein was to assess the performance of the barrier gap design according to the safety-performance evaluation guidelines in the AASHTO *MASH*. The crash test was performed in accordance with *MASH* Test 3-10, which involves an 1100C vehicle impacting the barrier gap device at a target impact speed of 62 mi/h and impact angle of 25°.

TEST ARTICLE DESIGN AND CONSTRUCTION

The test installation consisted of two 30-ft long single slope reinforced concrete barrier sections, with an 8-ft gap between them. The barriers were keyed into a 4-inch thick lift of asphalt and 6 inches of grade B crushed limestone road base (10-inch thickness). An assembly consisting of rectangular steel tubes, welded to a flat plate on each end, spanned this opening on the traffic and field sides. These plates were secured to the traffic and field side faces of the concrete barrier. On the day of the test, the compressive concrete strength for the downstream and upstream barriers averaged 6137 psi at 58 days age and 5912 psi at 48 days age, respectively. For additional information, please refer to the Test Article Details in Attachment A.

TEST DESIGNATION AND ACTUAL TEST CONDITIONS

MASH Test 3-10 involves an 1100C vehicle weighing 2420 lb ±55 lb and impacting the barrier gap design at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 25° ±1.5°. The target impact point was 3.6 ft upstream of the end of the connection mounting plate. The 2007 Kia Rio[*] used in the test weighed 2434 lb, and the actual impact speed and angle were 61.4 mi/h and 24.8°. The actual impact point was 3.8 ft upstream of the end of the connection mounting plate. The minimum target impact severity (IS) was 51 kip-ft, and the actual IS was 54 kip-ft.

TEST VEHICLE

Test inertia weight of the test vehicle was 2434 lb, and its gross static weight was 2599 lb. The height to the lower edge of the vehicle front bumper was 7.75 inches, and the height to the upper edge of the front bumper was 21.5 inches.

[*] The 2007 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 2007 model vehicle met the *MASH* requirements.

Figure 1. Barrier Gap Design before Test No. 610461-2.

WEATHER CONDITIONS

The crash test was performed on the morning of October 9, 2019. Weather conditions at the time of testing were: Wind speed: 9 mi/h; wind direction: 178° (magnetic heading 335°); temperature: 82°F; relative humidity: 70 percent.

TEST DESCRIPTION

The test vehicle was traveling at an impact speed of 61.4 mi/h when it contacted the barrier gap design 3.8 ft upstream of the end of the connection mounting plate at an impact angle of 24.8°. Table 1 lists events that occurred during Test No. 610461-2.

After loss of contact with the barrier, the vehicle came to rest upright 165 ft downstream of the impact point and 45 ft towards the field side. However, the vehicle rolled over during the event.

TEST ARTICLE/COMPONENT DAMAGE

Figure 2 shows damage to the barrier gap design. No damage was observed other than cosmetic damage in the form of vehicle scuffs and scrapes. No dynamic deflection was observed during the test, and there was no measurable permanent deformation after the test. Working width* was 31.0 inches at a height of 5.5 inches.

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* 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.

Table 1. Events during Test No. 610461-2.

TIME (s)	EVENTS
0.0000	Vehicle contacts barrier
0.0120	Left front tire leaves the pavement
0.0240	Vehicle begins to redirect
0.0630	Right front tire leaves the pavement
0.0680	Right rear tire leaves the pavement
0.1270	Vehicle traveling parallel with barrier
0.1670	Left rear of vehicle contacts barrier
0.2810	Vehicle loses contact with barrier while traveling at 49.9 mi/h, with a heading of 20.7°, and a trajectory of 6.0°.
0.7150	Vehicle on left side, rolling counterclockwise
1.4950	Vehicle on its roof continues to roll counterclockwise

Figure 2. Barrier Gap Rail after Test No. 610461-2.

TEST VEHICLE DAMAGE

Figure 3 shows damage to the test vehicle after the test. The 1100C vehicle rolled one revolution and came to rest upright. Maximum occupant compartment deformation was 5.5 inches in the windshield/roof area.

Figure 3. Vehicle after Test No. 610461-2.

OCCUPANT RISK VALUES

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk, and results are reported in Table 2. These data and other pertinent information from the test are summarized in Figure 4.

Table 2. Occupant Risk Factors for Test No. 610461-2.

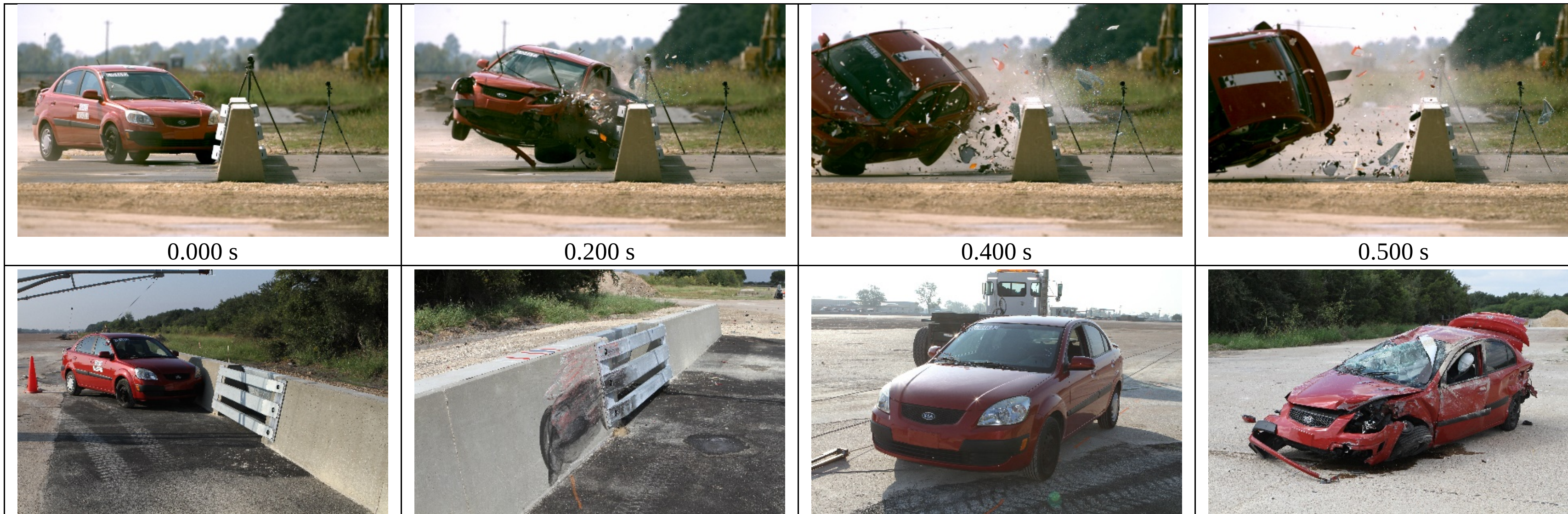
Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV)		
Longitudinal	**26.9 ft/s**	0.0696 s on left side interior
Lateral	**35.4 ft/s**	
10-ms Occupant Ridedown Accelerations		
Longitudinal	**7.1 g**	0.0696 s – 0.0796 s
Lateral	**14.4 g**	0.1709 – 0.1809 s
Theoretical Head Impact Velocity (THIV)	**13.3 m/s**	0.0679 s on left side interior
Acceleration Severity Index (ASI)	**2.9**	0.0427 – 0-0927 s
Maximum 50-ms Moving Average		
Longitudinal	**-15.7 g**	0.0227 – 0.0727 s
Lateral	**21.5 g**	0.0204 – 0.0704 s
Vertical	**-6.6 g**	2.9323 – 2.9823 s
Maximum Roll, Pitch, and Yaw Angles		
Roll	**370°**	3.1816 s
Pitch	**16°**	1.7508 s
Yaw	**173°**	3.5069 s

SUMMARY AND CONCLUSIONS

Due to vehicle rollover, the barrier gap rail did not perform acceptably for *MASH* Test 3-10, as shown in Table 3.

REFERENCES

1. AASHTO. *Manual for Assessing Roadside Safety Hardware, Second Edition.* American Association of State Highway and Transportation Officials: Washington, DC, 2016.



0.000 s | 0.200 s | 0.400 s | 0.500 s

Barrier prior to Test | Barrier after Test | Test Vehicle before Test | Test Vehicle after Test

General Information

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	MASH Test 3-10
TTI Test No.	610461-2
Date	2019-10-09
Test Article	
Type	Longitudinal Barrier
Name	Barrier Gap
Installation Length	68 ft
Material or Key Elements	Two 30-ft long single slope reinforced concrete barriers with 8 ft gap covered by steel rectangular 3-tube assembly
Soil Type and Condition	Placed on Native Soil and Keyed in 10 inches with 6 inches Crushed Limestone plus 4 inches Asphalt
Test Vehicle	
Type/Designation	1100C
Make and Model	2007 Kia Rio
Curb	2457 lb
Test Inertial	2434 lb
Dummy	165 lb
Gross Static	2599 lb

Impact Conditions

Speed	61.4 mi/h
Angle	24.8°
Location/Orientation	3.8 ft upstream of plate
Impact Severity	54 kip-ft
Exit Conditions	
Speed	49.9 mi/h
Trajectory/Heading Angle	6.0° / 20.7°
Occupant Risk Values	
Longitudinal OIV	26.9 ft/s
Lateral OIV	35.4 ft/s
Longitudinal Ridedown	7.1 g
Lateral Ridedown	14.4 g
THIV	13.3 m/s
ASI	2.88
Max. 0.050-s Average	
Longitudinal	-15.7 g
Lateral	21.5 g
Vertical	-6.6 g

Post-Impact Trajectory

Stopping Distance	165 ft downstream 45 ft twd field side
Vehicle Stability	
Maximum Yaw Angle	173°
Maximum Pitch Angle	16°
Maximum Roll Angle	370°
Vehicle Snagging	No
Vehicle Pocketing	No
Test Article Deflections	
Dynamic	None
Permanent	None
Working Width	31.0 inches
Height of Working Width	5.5 inches
Vehicle Damage	
VDS	Undetermined
CDC	Undetermined
Max. Exterior Deformation	Roll over
OCDI	Undetermined
Max. Occupant Compartment Deformation	5.5 inches

Figure 4. Summary of Results for *MASH* Test 3-10 on Barrier Gap Design.

Table 3. Performance Evaluation Summary for *MASH* Test 3-10 on Barrier Gap Design.

Test Agency: Texas A&M Transportation Institute | Test No.: 610461-2 | Test Date: 2019-10-09

***MASH* Test 3-10 Evaluation Criteria**	**Test Results**	**Assessment**
<u>Structural Adequacy</u> *A. Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable*	The Barrier Gap Design contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the installation. No dynamic deflection was observed during the test, and there was no measurable permanent deformation after the test.	Pass
<u>Occupant Risk</u> *D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	No detached element, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present hazard to others in the area.	Fail
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	Maximum occupant compartment deformation was 5.5 inches in the windshield/roof area.	
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The 1100C vehicle rolled over.	Fail
H. Longitudinal and lateral occupant impact velocities should fall below the preferred value of 30 ft/s, or at least below the maximum allowable value of 40 ft/s.	Longitudinal OIV was 26.9 ft/s, and lateral OIV was 35.4 ft/s.	Pass
I. Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15.0 Gs, or at least below the maximum allowable value of 20.49 Gs.	Longitudinal occupant ridedown acceleration was 7.1 g, and lateral occupant ridedown acceleration was 14.4 g.	Pass

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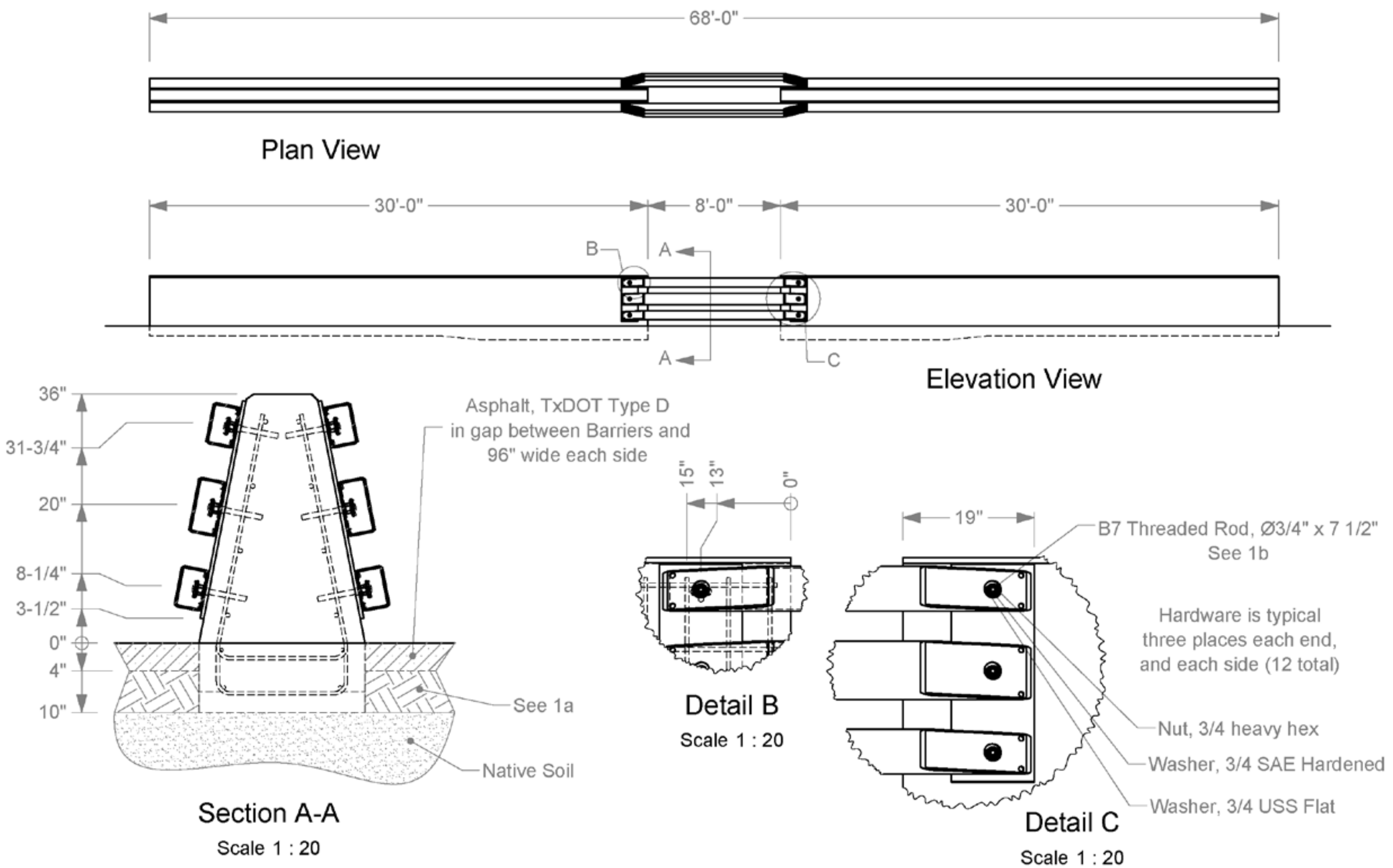
ATTACHMENT A: TEST ARTICLE DETAILS

Test Installation



1a. Backfill with AASHTO M147-65(2004), grade B crushed limestone road base, compacted to 95% of standard proctor density.

1b. Install centered in slots, with 5-1/2" embedment. Secure with Hilti HIT-RE 500 V3 epoxy according to manufacturer's instructions. Tighten to snug fit only after epoxy has cured.

1c. Threaded Rods and all connecting hardware shall be galvanized.

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Project #610461 Barrier Gap		2019-05-06
Drawn by GES	Scale 1:100	Sheet 1 of 6 Test Installation

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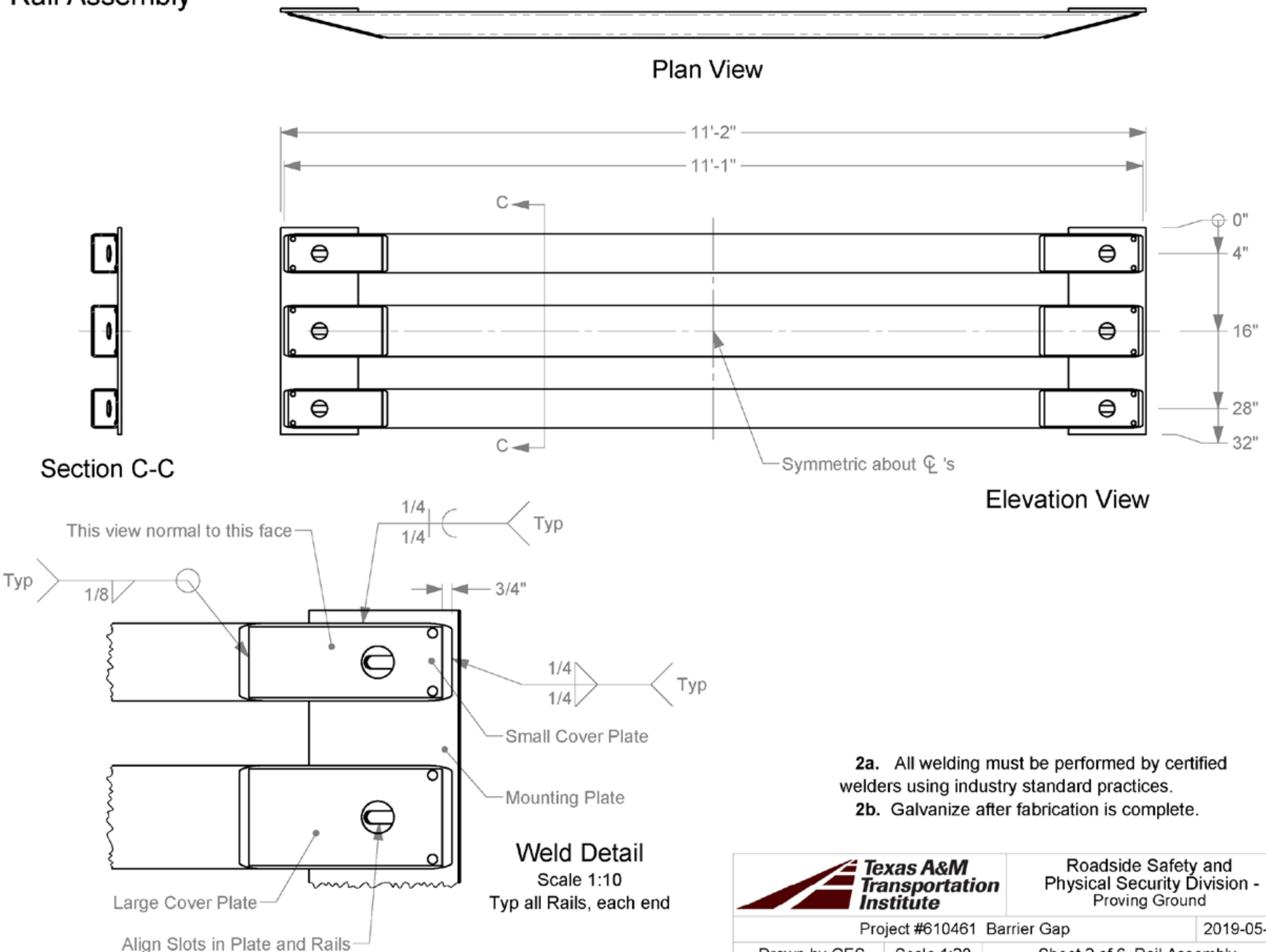
Rail Assembly



2a. All welding must be performed by certified welders using industry standard practices.
2b. Galvanize after fabrication is complete.

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Drawn by GES	Scale 1:20	Sheet 2 of 6 Rail Assembly

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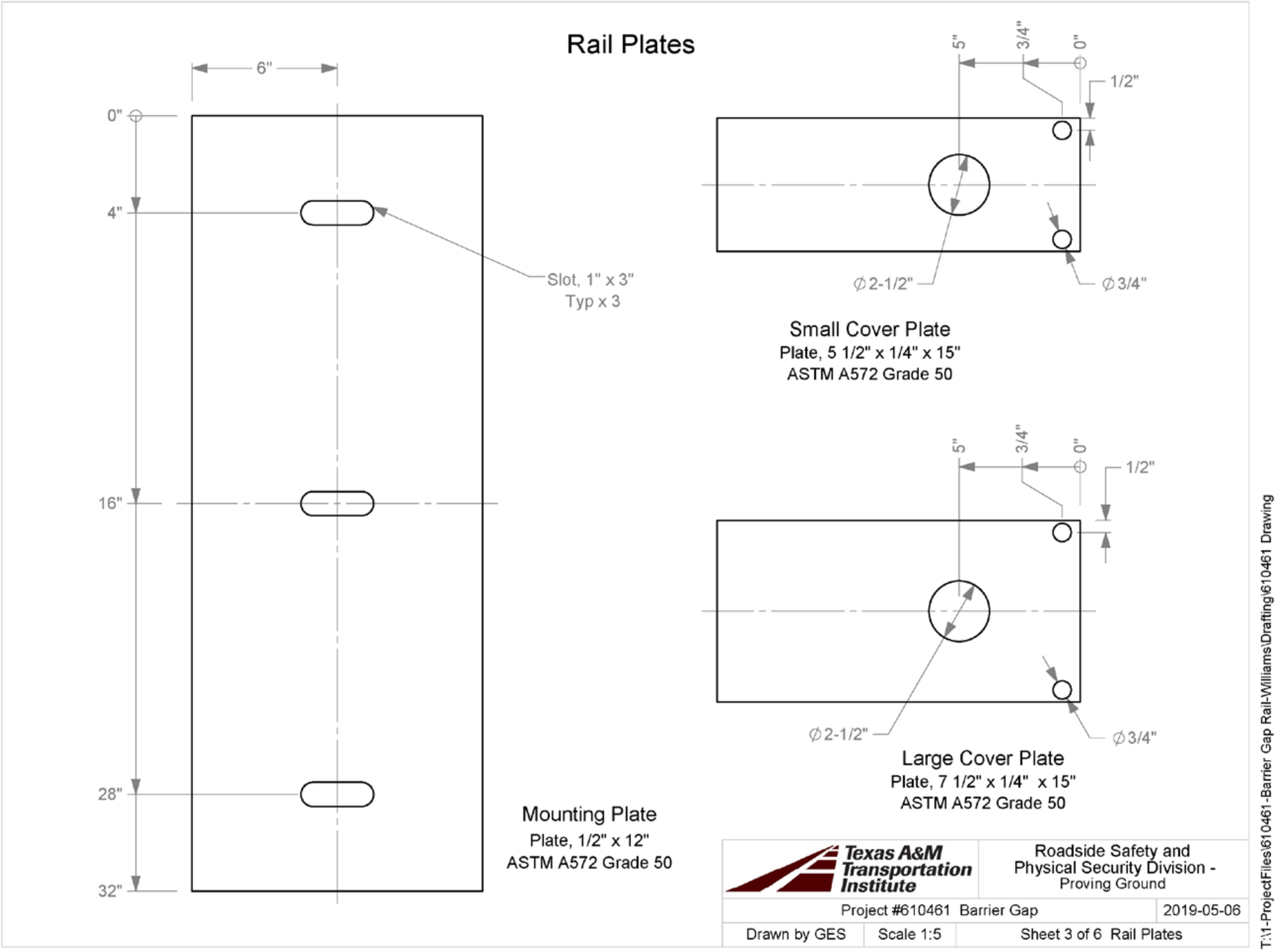
Rail Plates
6"
0"
4"
16"
28"
32"
Slot, 1" x 3"
Typ x 3
Mounting Plate
Plate, 1/2" x 12"
ASTM A572 Grade 50
5"
3/4"
0"
1/2"
∅ 2-1/2"
∅ 3/4"
Small Cover Plate
Plate, 5 1/2" x 1/4" x 15"
ASTM A572 Grade 50
5"
3/4"
0"
1/2"
∅ 2-1/2"
∅ 3/4"
Large Cover Plate
Plate, 7 1/2" x 1/4" x 15"
ASTM A572 Grade 50
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #610461 Barrier Gap
2019-05-06
Drawn by GES
Scale 1:5
Sheet 3 of 6 Rail Plates
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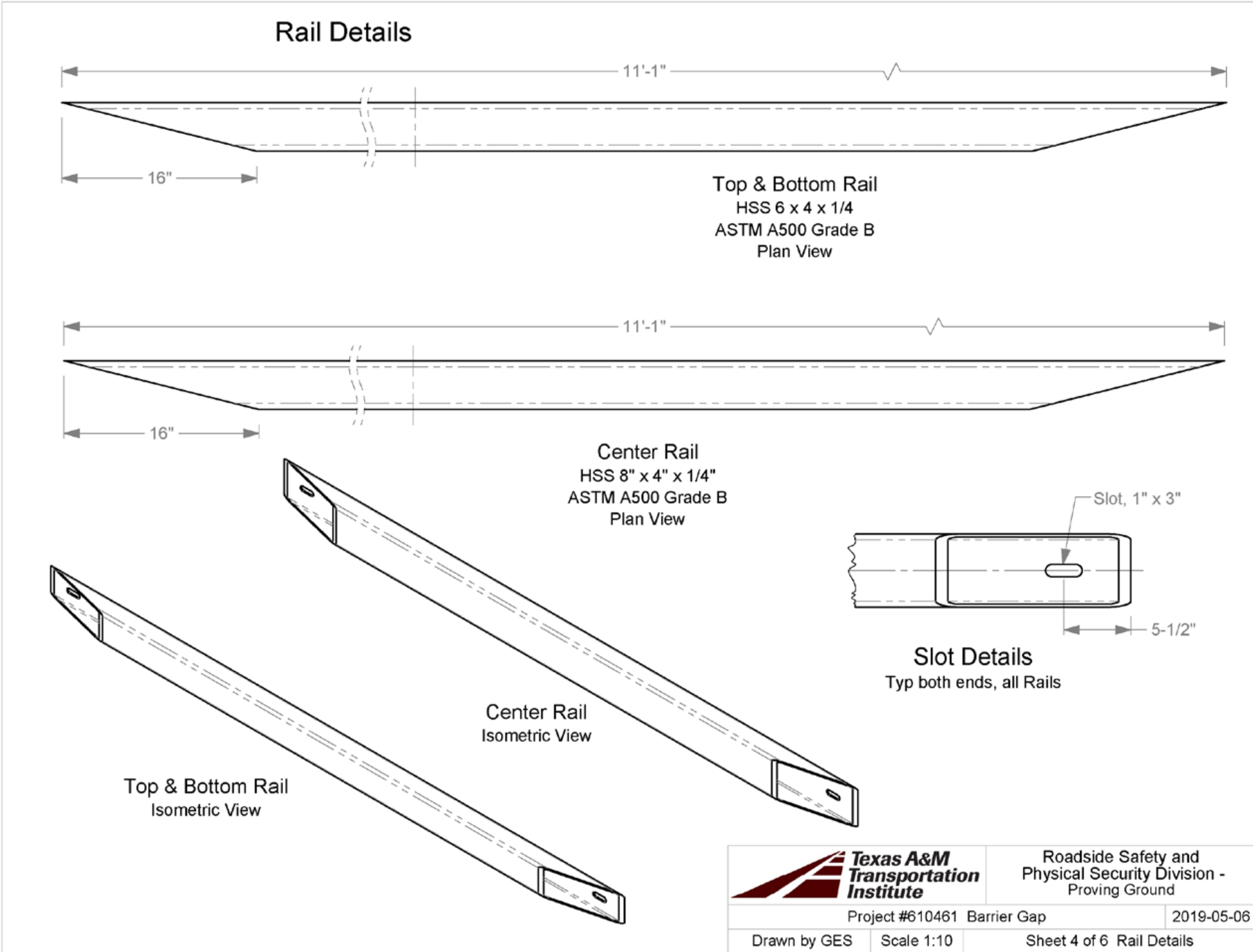

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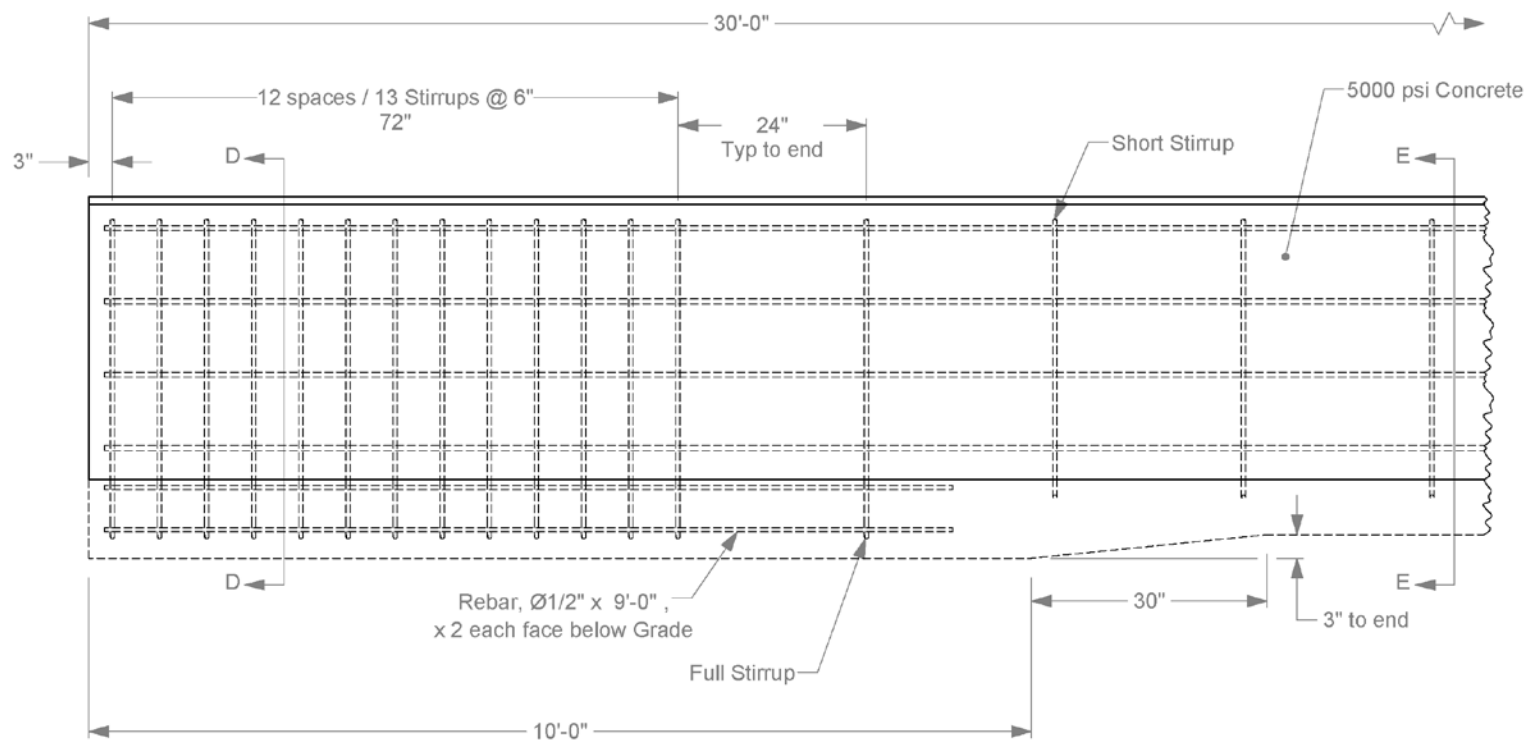
Concrete and Rebar Details

See next sheet for Section Views



5a. All rebar is grade 60, and epoxy coated.
5b. Chamfer exposed edges, 3/4" each way.
5c. All rebar dimensions are to center of bar unless otherwise indicated by "cvr" (cover).

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Drawn by GES	Scale 1:20	Sheet 5 of 6 Concrete and Rebar Details

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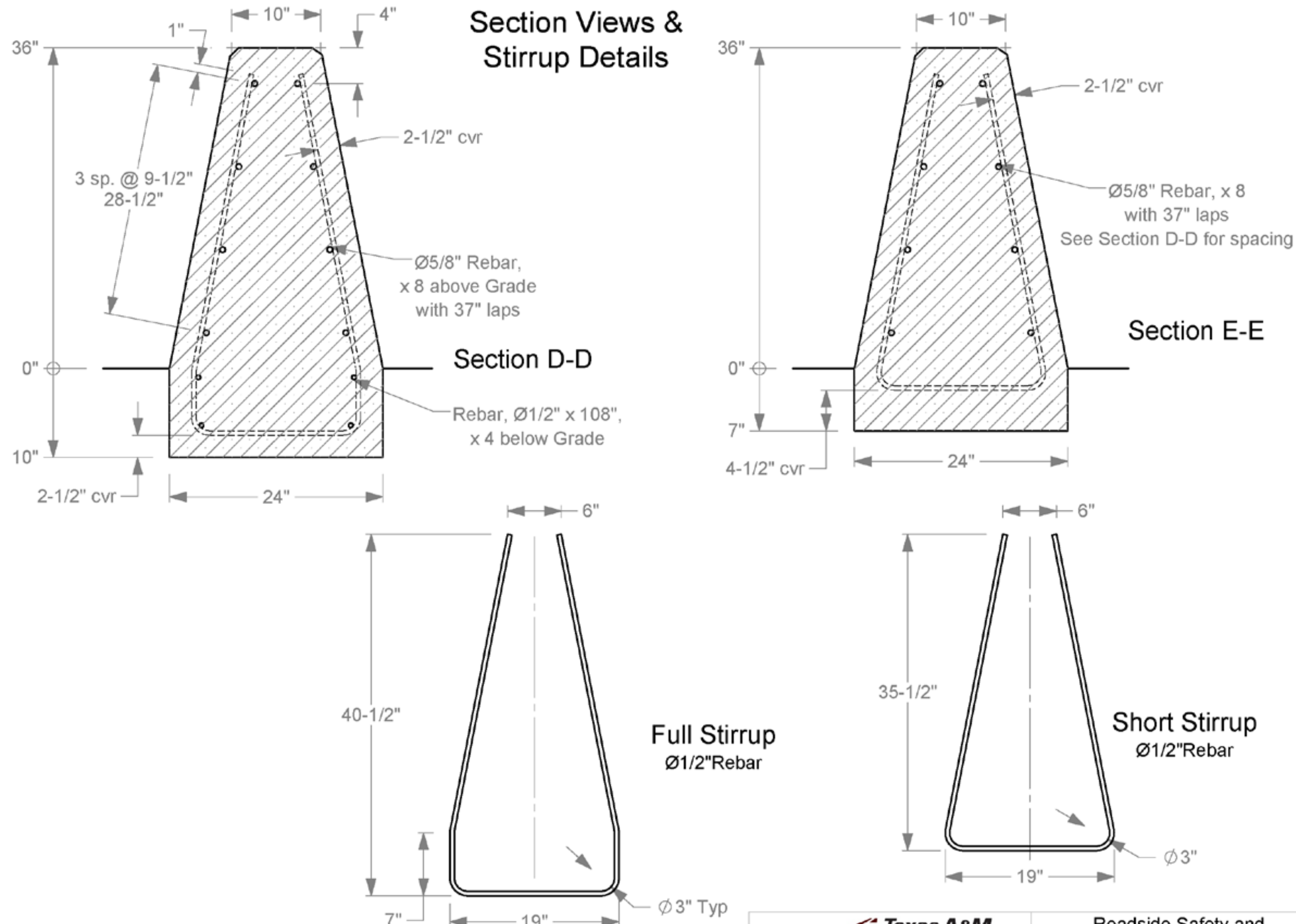
Section Views & Stirrup Details



6a. All rebar is grade 60, and epoxy coated.
6b. Chamfer exposed edges, 3/4" each way.
6c. All rebar dimensions are to center of bar unless otherwise indicated by "cvr" (cover).

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Project #610461 Barrier Gap		2019-05-06
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