Texas A&M Transportation Institute
Proving Ground

Test Report No. 618981-01-1

MASH TEST LEVEL 3 EVALUATION OF A SHORTER THRIE-BEAM APPROACH TRANSITION

Sponsored by
Washington State Department of Transportation

TEXAS A&M TRANSPORTATION INSTITUTE PROVING GROUND
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16. Abstract

The purpose of the tests reported herein was to assess the performance of the Shortened Transition according to the safety-performance evaluation guidelines included in the second edition of the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*) (*1*). The crash test was performed in accordance with *MASH* Test Level 3 (TL-3):

1. ***MASH* Test 3-21:** A 2270P vehicle weighing 5000 lb impacting the Longitudinal Barrier at 25 degrees while travelling at 62 mi/h.

This report provides details on the Shortened Transition, the crash tests and results, and the performance assessment of the Shortened Transition for *MASH* TL-3 Longitudinal Barrier evaluation criteria.

The Shortened Transition met the performance criteria for *MASH* TL-3 Longitudinal Barrier.

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The results reported herein apply only to the article tested. The full-scale crash test was performed according to TTI Proving Ground quality procedures and American Association of State Highway and Transportation Officials (AASHTO) Manual for Assessing Safety Hardware, Second Edition (*MASH*) guidelines and standards.

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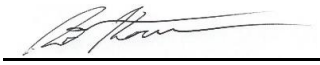

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
	NOTE: volumes greater than 1000L shall be shown in m^3			
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5(F-32)/9 or (F-32)/1.8	Celsius	°C
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	Square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lb/in^2

*SI is the symbol for the International System of Units

Chapter 1. INTRODUCTION

The purpose of the test reported herein was to assess the performance of the Sponsor's Shortened Transition according to the safety-performance evaluation guidelines included in the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*), Second Edition (*1*). The crash test was performed in accordance with *MASH* Test Level 3 (TL-3), (as discussed in Chapter 3).

Chapter 2. BACKGROUND

When roadways intersect with restrictive features such as a bridge rail, it becomes difficult to fit a transition system with proper length. For this project, American Association of State Highway and Transportation (AASHTO) Manual for Assessing Safety Hardware (MASH) Test Level 3 (TL-3) W beam transitions with shorter length are desired to be tested (1). These systems are used when State Departments of Transportation (DOTs) need to implement a shorter transition without compromising the integrity of the guardrail system.

The objective of this study was to model and crash test shorter W-beam transition systems for MASH TL-3 compliance. A MASH compliant transition with shorter length would provide the members of the Roadside Safety Pooled Fund with a valuable option in restrictive conditions against roadside hazards.

Figure 2.1 shows a similar transition design that was used for the installation constructed during this project. The objective was to reduce the 25-ft transition length. For this purpose, the TTI research team first performed an engineering review of available transition systems and their design variables to shortlist a set of candidates for modeling and evaluation. The researchers conducted a series of simulations of the candidate set. The final design was then crash tested for MASH TL-3 compliance.

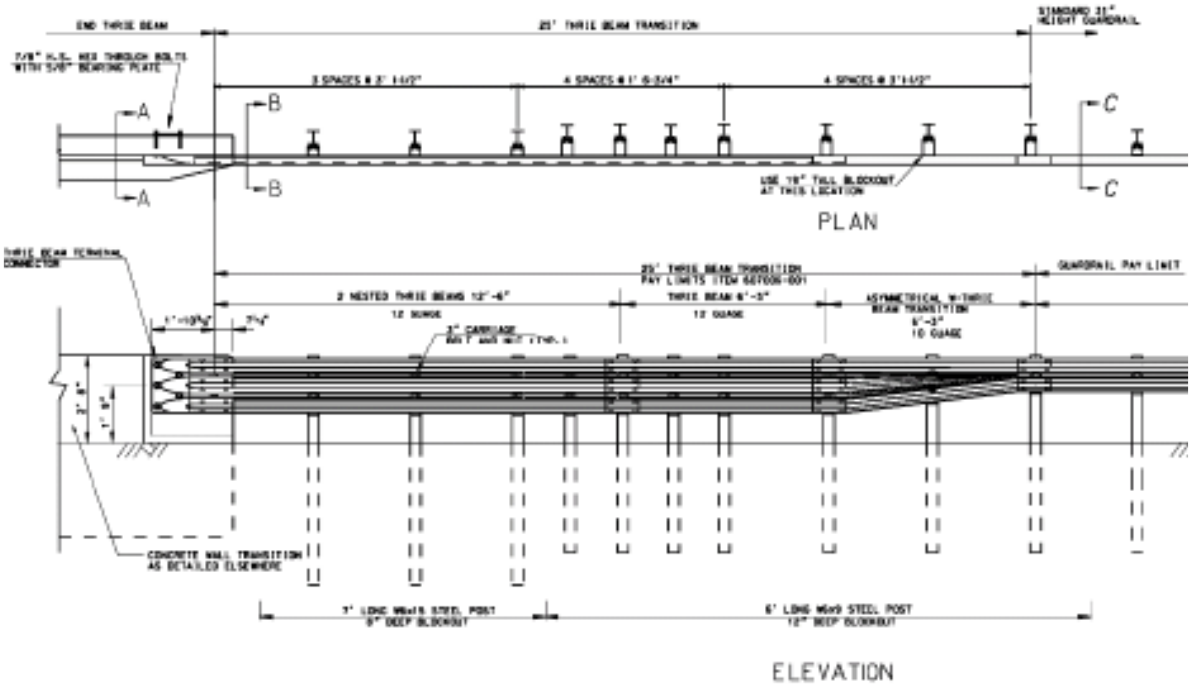


Figure 2.1– Thrie Beam Guardrail Bridge Transition and Connection (WVDOT Standard Drawing, 2016)

Chapter 3. SYSTEM DETAILS

3.1. TEST ARTICLE AND INSTALLATION DETAILS

The installation was 99 feet and 8 inches long from post 1 to the end of the concrete parapet. The top of the rail was 31 inches above grade. The rails were supported by W6x8.5 wide-flange posts and timber blockouts. The rail was anchored with a Steel Post Terminal. Posts 3 through 10 spanned 50 feet, and consisted of galvanized steel W-beam railing, with the posts spaced at 75 inches. . The W-beam extended to post 14, with posts 11 – 14 spaced at 37-1/2 inches. An Asymmetric Thrie-beam to W-beam rail extended from post 14 to post 18, and two nested Thrie-beams, spanning 75 inches, extended from post 18 to the terminal connector. Posts 14 – 21 were spaced at 18-3/4 inches.

The terminal connector was secured to a vertical reinforced concrete parapet that was 32 inches tall, 16 feet long, and 12 inches tall at top. A rub rail attached to the field side of post 13,and extended along the traffic side of posts 14 – 21, attaching at

alternate posts, and was attached to a bracket at the parapet.

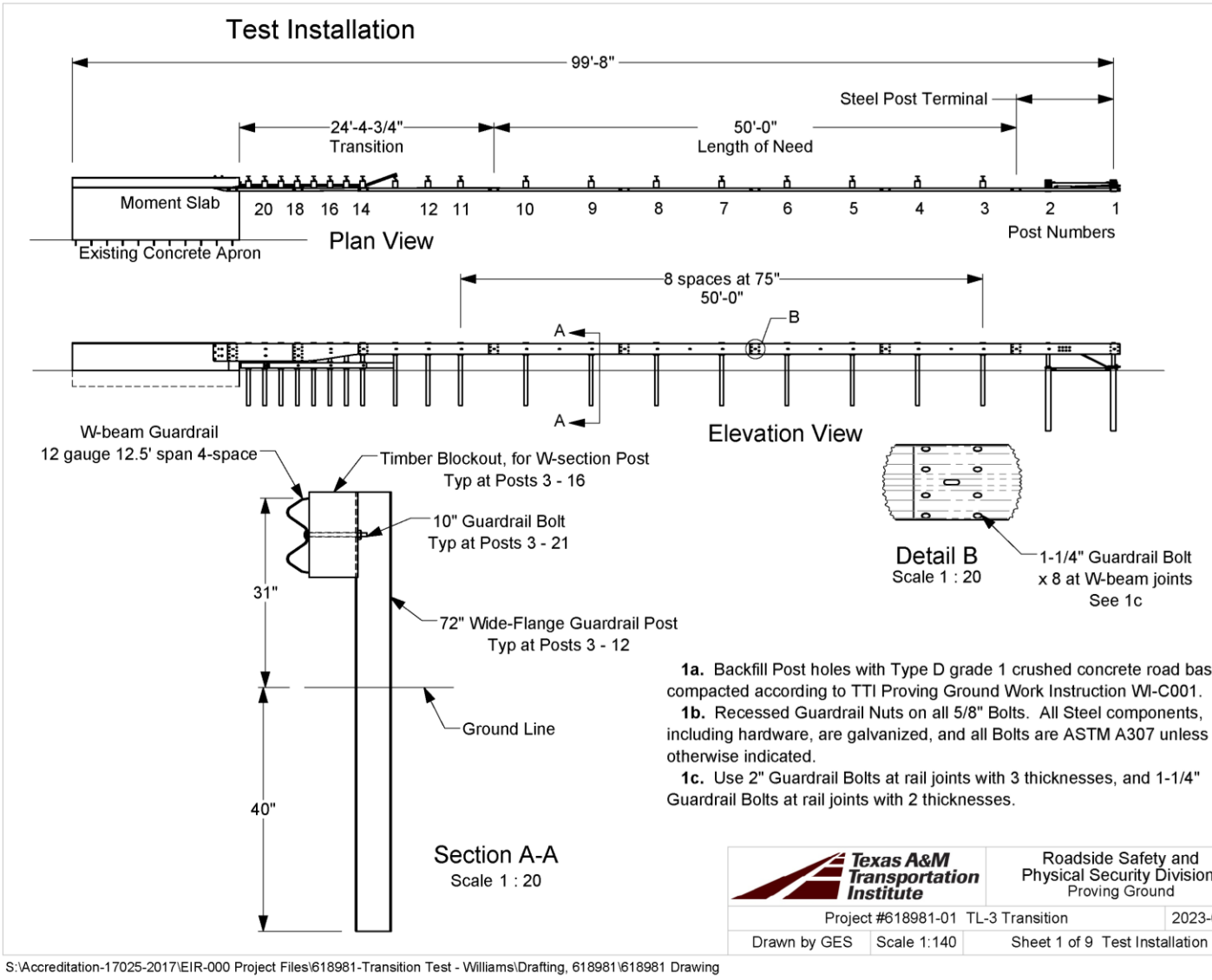


Figure 3.1 presents the overall information on the Shortened Transition, and Figure 3.2 thru Figure 3.7 provide photographs of the installation. Appendix A provides further details on the Shortened Transition. Drawings were provided by the Texas A&M Transportation Institute (TTI) Proving Ground, and construction was performed by TTI Proving Ground personnel.

3.2. DESIGN MODIFICATIONS DURING TESTS

No modifications were made to the installation during the testing phase.

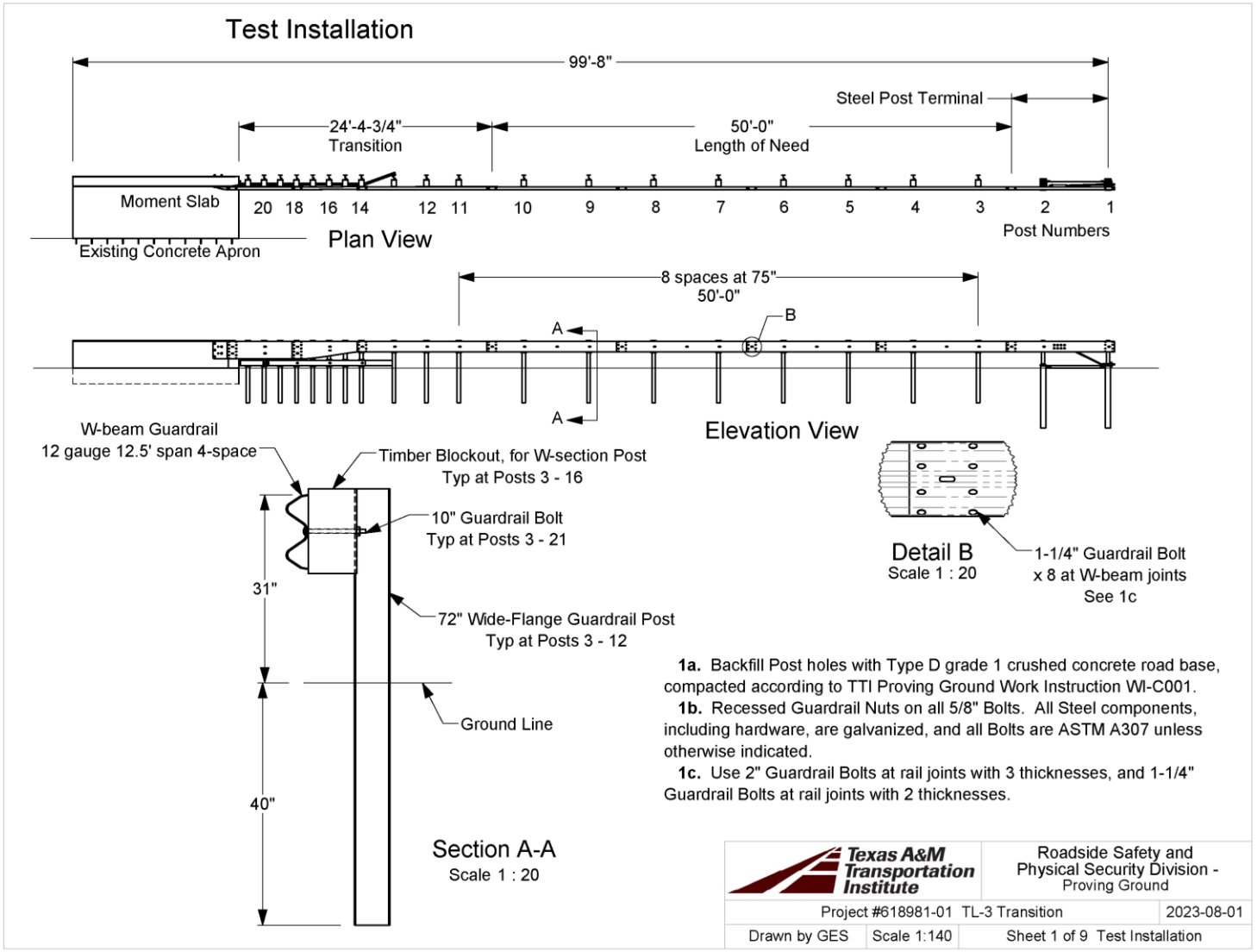


Figure 3.1. Details of Shortened Transition.

Figure 3.2. Shortened Transition prior to Testing.

Figure 3.3. In-Line View of Shortened Transition prior to Testing.

Figure 3.4. View of Shortened Transition from Downstream prior to Testing.

Figure 3.5. View of Shortened Transition from Downstream prior to Testing.

Figure 3.6. Traffic Side View of Shortened Transition at Thrie-beam Asymmetric Transition prior to Testing.

Figure 3.7. Field Side View of Shortened Transition prior to Testing.

3.3. MATERIAL SPECIFICATIONS

Appendix B provides material certification documents for the materials used to install/construct the Shortened Transition. Table 3.1 shows the average compressive strengths of the concrete on the day of the test 2023-09-21.

Table 3.1. Concrete Strength.

Location	Design Strength (psi)	Avg. Strength (psi)	Age (days)	Detailed Location
Barrier	3600	3937	44	100% of barrier

3.4. SOIL CONDITIONS

The test installation was installed in standard soil meeting Type 1 Grade D of AASHTO standard specification M147-17 “Materials for Aggregate and Soil Aggregate Subbase, Base, and Surface Courses.”

In accordance with Appendix B of *MASH*, soil strength was measured the day of the crash test. During installation of the Shortened Transition for full-scale crash testing, two 6-ft long W6×16 posts were installed in the immediate vicinity of the Shortened Transition using the same fill materials and installation procedures used in the test installation and the standard dynamic test.

On the day of Test 3-21, 2023-09-21, loads on the post at deflections were as follows: the backfill material in which the Shortened Transition was installed met/did not meet minimum *MASH* requirements for soil strength.

Table 3.2. Soil Strength for 618981-01-1.

Displacement (in)	Minimum Load (lb)	Actual Load (lb)
5	4420	8300
10	4981	9909
15	5282	10,879

Chapter 4. TEST REQUIREMENTS AND EVALUATION CRITERIA

4.1. CRASH TEST PERFORMED/MATRIX

Table 4.1 shows the test conditions and evaluation criteria for *MASH* TL-3 for Longitudinal Barrier. The target critical impact point (CIPs) for the test was determined using the information provided in *MASH* Section 2.2.1 and Section 2.3.2 Figure 4.1 shows the target CIP for the *MASH* TL-3 test on the Shortened Transition.

Table 4.1. Test Conditions and Evaluation Criteria Specified for *MASH* TL-3 Longitudinal Barrier.

Test Designation	Test Vehicle	Impact Speed	Impact Angle	Evaluation Criteria
3-21	2270P	62 mi/h	25º	A, D, F, H, I

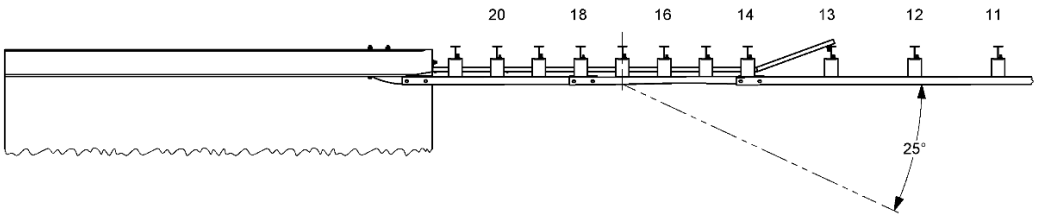


Figure 4.1. Target CIP for *MASH* TL-3 Tests on Shortened Transition.

The crash tests and data analysis procedures were in accordance with guidelines presented in *MASH*. Chapter 4 presents brief descriptions of these procedures.

4.2. EVALUATION CRITERIA

The appropriate safety evaluation criteria from Tables 2-2 and 5-1 of *MASH* were used to evaluate the crash test reported herein. Table 4.1 lists the test conditions and evaluation criteria required for *MASH* TL-3, and Table 4.2 provides detailed information on the evaluation criteria.

Table 4.2. Evaluation Criteria Required for *MASH* Testing.

Evaluation Factors	Evaluation Criteria
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.
D.	Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of *MASH*.
F.	The vehicle should remain upright during and after collision. 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.
I.	The occupant ridedown accelerations should satisfy the following: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.

Chapter 5. TEST CONDITIONS

5.1. TEST FACILITY

The full-scale crash test reported herein was performed at the 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 test was performed according to TTI Proving Ground quality procedures, as well as *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 mi 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, highway pavement durability and efficacy, and roadside safety hardware and perimeter protective device evaluation. The sites selected for construction and testing are along the edge of an out-of-service apron/runway. The apron/runway consists of an unreinforced jointed-concrete pavement in 12.5-ft × 15-ft blocks nominally 6 inches deep. The aprons were built in 1942, and the joints have some displacement but are otherwise flat and level.

5.2. VEHICLE TOW AND GUIDANCE SYSTEM

For the testing utilizing the 2270P vehicles, each 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 and 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. Just prior to impact with the installation, the test vehicle was released and ran unrestrained. The vehicle remained freewheeling (i.e., no steering or braking inputs) until it cleared the immediate area of the test site.

5.3. DATA ACQUISITION SYSTEMS

5.3.1. Vehicle Instrumentation and Data Processing

The test vehicle was instrumented with a self-contained onboard data acquisition system. The signal conditioning and acquisition system is a multi-channel data acquisition system (DAS) 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 data acquisition hardware and software conform to the latest SAE J211, Instrumentation for Impact Test. Each of the 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 samples per second with a resolution of one part in 65,536. Once data are recorded, internal batteries back these up inside the unit in case the primary battery cable is severed. Initial contact of the pressure switch on the vehicle bumper provides a time zero mark and initiates the recording process. After each test, the data are downloaded from the DAS 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 DAS is returned to the factory annually for complete recalibration and to ensure that all instrumentation used in the vehicle conforms to the specifications outlined by SAE J211. All accelerometers are calibrated annually by means of an ENDEVCO® 2901 precision primary vibration standard. This standard and its support instruments are checked annually and receive a National Institute of Standards Technology (NIST) traceable calibration. The rate transducers used in the data acquisition system receive 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 anytime data are suspect. Acceleration data are measured with an expanded uncertainty of ±1.7 percent at a confidence factor of 95 percent (k = 2).

TRAP uses the DAS-captured data to compute the occupant/compartment impact velocities, time of occupant/compartment impact after vehicle impact, and 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 an SAE Class 180-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, and 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 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).

5.3.2. Anthropomorphic Dummy Instrumentation

According to *MASH*, use of a dummy in the 2270P vehicle is optional, and no dummy was used in the test.

5.3.3. Photographic Instrumentation Data Processing

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

- One placed overhead with a field of view perpendicular to the ground and directly over the impact point. One placed with a field of view parallel to and aligned with the installation at the downstream end.
- One placed at an oblique angle upstream from the installation on the field side.

A flashbulb on the impacting vehicle was activated by a pressure-sensitive tape switch to indicate the instant of contact with the Shortened Transition. 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.

Chapter 6. *MASH* TEST 3-21 (CRASH TEST 618981-01-1)

6.1. TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

See Table 6.1 for details of *MASH* impact conditions for this test and Table 6.2 for the exit parameters. Figure 6.1 and Figure 6.2 depict the target impact setup.

Table 6.1. Impact Conditions for *MASH TEST 3-21,* Crash Test 618981-01-1.

Test Parameter	Specification	Tolerance	Measured
Impact Speed (mi/h)	62	±2.5 mi/h	63.2
Impact Angle (deg)	25	±1.5°	25.1
Impact Severity (kip-ft)	106	≥106 kip-ft	120.9
Impact Location	Centerline of post 17 on the traffic side face of rail	±12 inches	1.5 inches upstream of centerline of post 17 on the traffic side face of rail

Table 6.2. Exit Parameters for *MASH TEST 3-21,* Crash Test 618981-01-1.

Exit Parameter	Measured
Speed (mi/h)	48.2
Trajectory (deg)	6.3
Heading (deg)	10.7
Brakes applied post impact (s)	1.1
Vehicle at rest position	246 ft downstream of impact point 12 ft to the traffic side Vehicle positioned 15° right relative to the installation
Comments:	The vehicle had a maximum roll of 59.5° but was able to right itself and come to a controlled stop in the upright position. Vehicle crossed the exit box[a] 55 ft downstream from loss of contact.

[a] Not less than 32.8 ft downstream from loss of contact for cars and pickups is optimal.

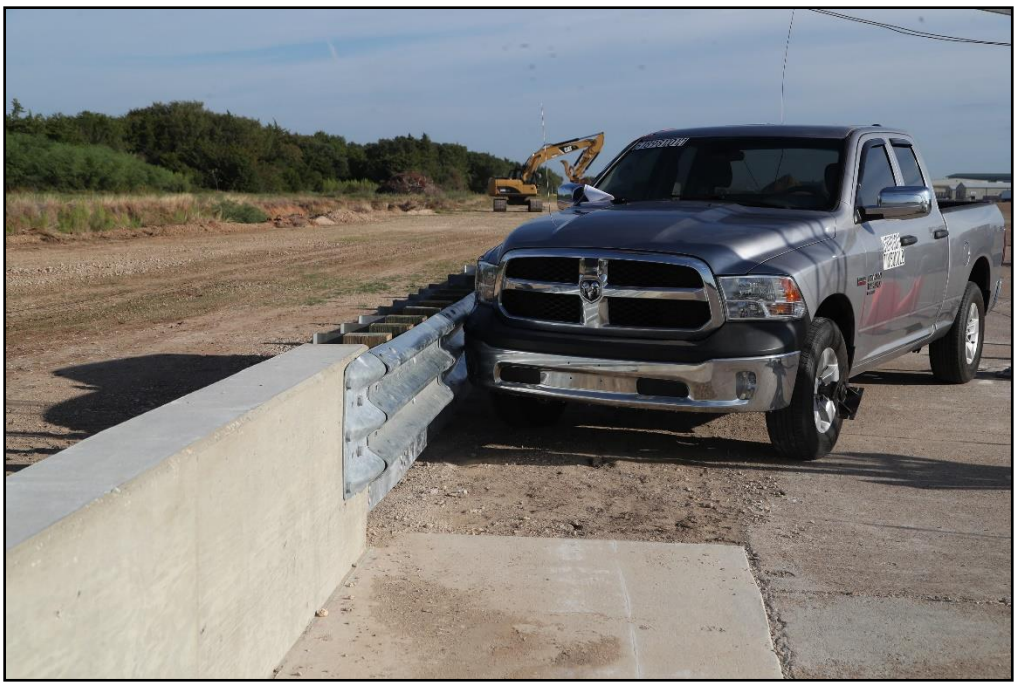


Figure 6.1. Shortened Transition Test Vehicle Geometrics for Test 618981-01-1.

Figure 6.2. Shortened Transition/Test Vehicle Impact Location 618981-01-1.

6.2. WEATHER CONDITIONS

Table 6.3 provides the weather conditions for 618981-01-1.

Table 6.3. Weather Conditions 618981-01-1.

Date of Test	2023-09-21
Wind Speed (mi/h)	4
Wind Direction (deg)	182
Temperature (°F)	87
Relative Humidity (%)	77
Vehicle Traveling (deg)	195

6.3. TEST VEHICLE

Figure 6.3 and Figure 6.4 show the 2019 RAM 1500 used for the crash test. Table 6.4 shows the vehicle measurements. Figure C.1 in Appendix C.1 gives additional dimensions and information on the vehicle.

Figure 6.3. Impact Side of Test Vehicle before Test 618981-01-1.

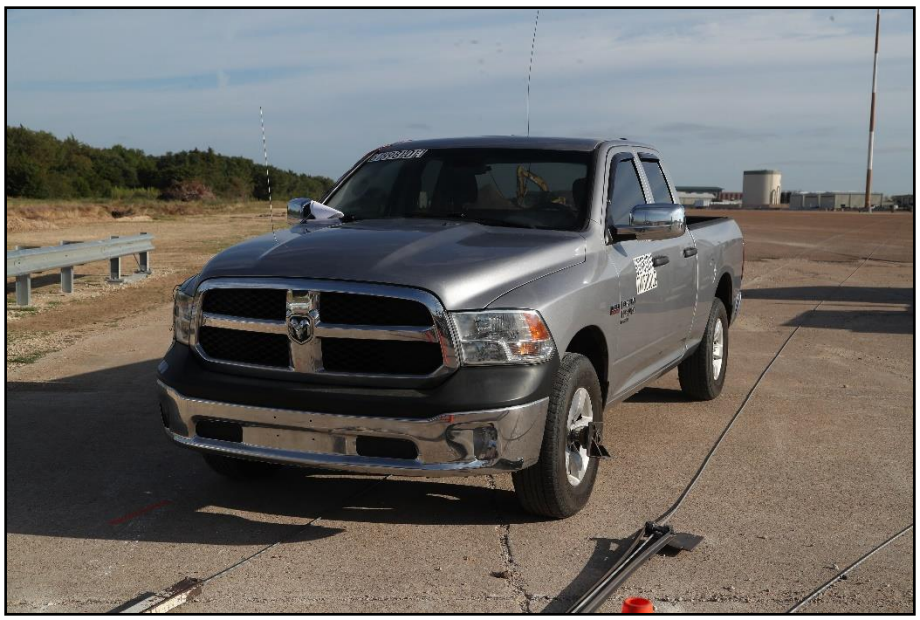


Figure 6.4. Opposite Impact Side of Test Vehicle before Test 618981-01-1.

Table 6.4. Vehicle Measurements for Test 618981-01-1.

Test Parameter	Specification	Tolerance	Measured
Dummy (if applicable)[a] (lb)	165	N/A	N/A
Inertial Weight (lb)	5000	±110	5031
Gross Static[a] (lb)	5000	±110	5031
Wheelbase (inches)	148	±12	140.5
Front Overhang (inches)	39	±3	40
Overall Length (inches)	237	±13	227.5
Overall Width (inches)	78	±2	78.5
Hood Height (inches)	43	±4	46
Track Width[b] (inches)	67	±1.5	68.3
CG aft of Front Axle[c] (inches)	63	±4	61.5
CG above Ground[c,d] (inches)	28	28	28.6

Note: N/A = not applicable; CG = center of gravity.

[a] If a dummy is used, the gross static vehicle mass should be increased by the mass of the dummy.

[b] Average of front and rear axles.

[c] For test inertial mass.

[d] 2270P vehicle must meet minimum CG height requirement.

6.4. TEST DESCRIPTION

Table 6.5 lists events that occurred during Test 618981-01-1. Figures C.4, C.5, and C.6 in Appendix C.2 present sequential photographs during the test.

Table 6.5. Events during Test 618981-01-1.

Time (s)	Events
0.0000	Vehicle impacted the installation
0.0130	Posts 16, 17, and 18 began to lean toward field side
0.0170	Posts 19 and 20 began to lean toward field side
0.0290	Post 20 began to lean downstream and toward field side
0.0350	Vehicle began to redirect
0.0980	Crack began to form on backside of concrete barrier
0.1920	Vehicle was parallel with installation
0.2000	Passenger side rear bumper impacted the rail
0.3350	Vehicle exited the installation at 48.2mi/h with a heading of 10.7 degrees and a trajectory of 6.3 degrees

6.5. DAMAGE TO TEST INSTALLATION

Table 6.6 describes the deflection and working width of the Shortened Transition. Figure 6.5 and Figure 6.6 show the damage to the Shortened Transition.

Table 6.6. Deflection and Working Width of the Shortened Transition for Test 618981-01-1.

Test Parameter	Measured
Permanent Deflection/Location	11.9 inches toward field side, at the rail at post 20
Dynamic Deflection	12.2 inches toward field side, at the rail at post 20
Working Width [a] and Height	31.3 inches, at a height of 31 inches, at the top of post 21

[a] 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 6.5. Shortened Transition at Impact Location after Test 618981-01-1.

Figure 6.6.Field Side View of Shortened Transition of Concrete Parapet after Test 618981-01-1.

6.6. DAMAGE TO TEST VEHICLE

Figure 6.7 and Figure 6.8 show the damage sustained by the vehicle. Figure 6.9 and Figure 6.10 show the interior of the test vehicle. Table 6.7 and Table 6.8 provide details on the occupant compartment deformation and exterior vehicle damage. Figures C.2 and C.3 in Appendix C.1 provide exterior crush and occupant compartment measurements.

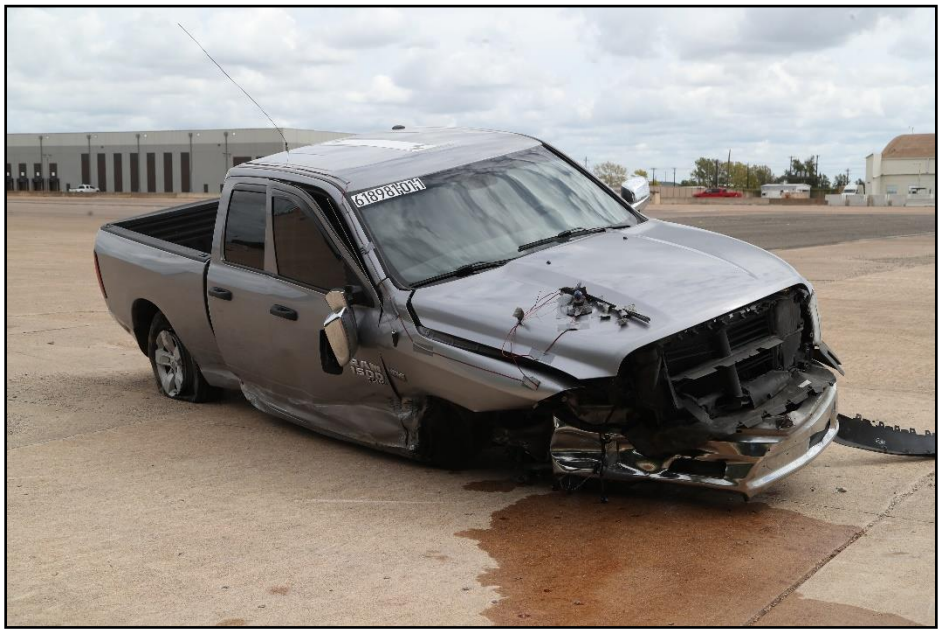


Figure 6.7. Impact Side of Test Vehicle after Test 618981-01-1.

Figure 6.8. Rear Impact Side of Test Vehicle after Test 618981-01-1.

Figure 6.9. Overall Interior of Test Vehicle after Test 618981-01-1.

Figure 6.10. Interior of Test Vehicle on Impact Side after Test 618981-01-1.

Table 6.7. Occupant Compartment Deformation 618981-01-1.

Test Parameter	**Specification** (inches)	**Measured** (inches)
Roof	≤4.0	0.0
Windshield	≤3.0	0.0
A and B Pillars	≤5.0 overall/≤3.0 lateral	0.0
Foot Well/Toe Pan	≤9.0	1
Floor Pan/Transmission Tunnel	≤12.0	1
Side Front Panel	≤12.0	0.8
Front Door (above Seat)	≤9.0	0.0
Front Door (below Seat)	≤12.0	0.0

Table 6.8. Exterior Vehicle Damage 618981-01-1.

Side Windows	Side windows remained intact
Maximum Exterior Deformation	24 inches of the front bumper
VDS	01FRQ5
CDC	01FREW8
Fuel Tank Damage	None
Description of Damage to Vehicle:	The bumper, grill, radiator, and support were severely deformed. The right headlight was broken and the right front fender was dented. There were dents and scratches all down the lower portion of the right hand side. The right rear wheel busted and the right rear tire was blown out. There was a 4-inch gap at the top of the right front door and a .5-inch gap at the top of the right rear door. The right rear bumper was dented.

6.7. OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 6.9. Figure C.7 in Appendix C.3 shows the vehicle angular displacements, and Figures C.8 through C.10 in Appendix C.4 show acceleration versus time traces.

Table 6.9. Occupant Risk Factors for Test 618981-01-1.

Test Parameter	Specification [a]	Measured	Time
OIV, Longitudinal (ft/s)	≤40.0 *30.0*	22.8	0.1114 seconds on right side of interior
OIV, Lateral (ft/s)	≤40.0 *30.0*	26.4	0.1114 seconds on right side of interior
Ridedown, Longitudinal (g)	≤20.49 *15.0*	11.7	0.1418 - 0.1518 seconds
Ridedown, Lateral (g)	≤20.49 *15.0*	12.5	0.2552 - 0.2652 seconds
Theoretical Head Impact Velocity (THIV) (m/s)	N/A	10.1	0.1084 seconds on right side of interior
Acceleration Severity Index (ASI)	N/A	1.6	0.1038 - 0.1538 seconds
50-ms Moving Avg. Accelerations (MA) Longitudinal (g)	N/A	-9.6	0.0826 - 0.1326 seconds
50-ms MA Lateral (g)	N/A	-12.1	0.0843 - 0.1343 seconds
50-ms MA Vertical (g)	N/A	-3.9	0.0494 - 0.0994 seconds
Roll (deg)	≤75	59.5	1.0002 seconds
Pitch (deg)	≤75	14.4	0.5982 seconds
Yaw (deg)	N/A	39.0	0.7118 seconds

[a.] *Values in italics are the preferred MASH values*

6.8. TEST SUMMARY

Figure 6.11 summarizes the results of *MASH* Test 618981-01-1.

0.000 s

0.200 s

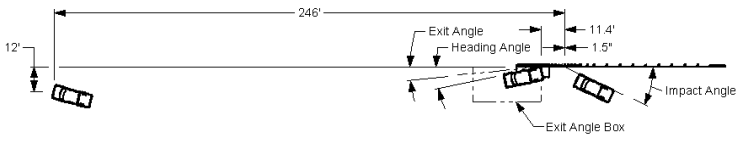
0.400 s

0.600 s

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.	*MASH* 2016, Test 3-21
TTI Project No.	618981-01-1
Test Date	2023-09-21
TEST ARTICLE	
Type	Longitudinal Barrier
Name	Shortened Transition
Length	99 feet and 8 inches
Key Materials	Galvanized steel rubrail, timber blockouts, concrete parapet, Hilti HT-RE 500 V3 epoxy
Soil Type and Condition	concrete, crushed concrete, wet
TEST VEHICLE	
Type/Designation	2270P
Year, Make and Model	2019 RAM 1500
Inertial Weight (lb)	5031
Dummy (lb)	N/A
Gross Static (lb)	5031
IMPACT CONDITIONS	
Impact Speed (mi/h)	63.2
Impact Angle (deg)	25.1
Impact Location	1.5 inches upstream of centerline of post 17
Impact Severity (kip-ft)	120.9
EXIT CONDITIONS	
Exit Speed (mi/h)	48.2
Trajectory/Heading Angle (deg)	6.3 / 10.7
Exit Box Criteria	Vehicle crossed the exit box 55 ft downstream from loss of contact.
Stopping Distance	246 ft downstream 12 ft to the traffic side
TEST ARTICLE DEFLECTIONS	
Dynamic (inches)	12.2
Permanent (inches)	11.9
Working Width / Height (inches)	31.3 / 31
VEHICLE DAMAGE	
VDS	01FRQ5
CDC	01FREW8
Max. Ext. Deformation (inches)	24
Max Occupant Compartment Deformation	1 inch into the floorpan

OCCUPANT RISK VALUES

Long. OIV (ft/s)	22.8	Long. Ridedown (g)	11.7	Max 50-ms Long. (g)	-9.6	Max Roll (deg)	59.5
Lat. OIV (ft/s)	26.4	Lat. Ridedown (g)	12.5	Max 50-ms Lat. (g)	-12.1	Max Pitch (deg)	14.4
THIV (m/s)	10.1	ASI	1.6	Max 50-ms Vert. (g)	-3.9	Max Yaw (deg)	39.0



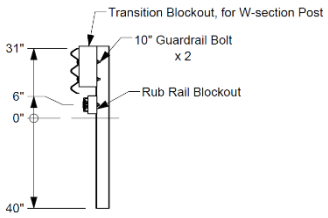


Figure 6.11. Summary of Results for *MASH* Test 3-21 on Shortened Transition.

Chapter 7. SUMMARY AND CONCLUSIONS

7.1. ASSESSMENT OF TEST RESULTS AND CONCLUSIONS

The crash test reported herein was performed in accordance with *MASH* TL-3, on the Shortened Transition.

Table 7.1 shows that the Shortened Transition met the performance criteria for *MASH* TL-3 Longitudinal Barrier.

Table 7.1. Assessment Summary for *MASH* TL-3 Tests on Shortened Transition.

Evaluation Criteria	Description	Test 618981-01-1
A	Contain, Redirect, or Controlled Stop	S
D	No Penetration into Occupant Compartment	S
F	Roll and Pitch Limit	S
H	OIV Threshold	S
I	Ridedown Threshold	S
Overall	Evaluation	Pass

Note: S = Satisfactory; N/A = Not Applicable.
[1] See Table 4.2 for details

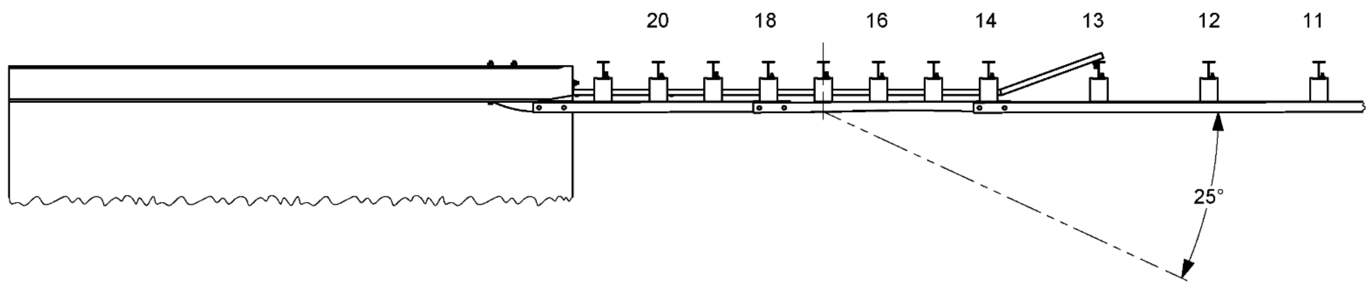
Chapter 8. IMPLEMENTATION

Based on the results of this successful MASH Test 3-21, this transition design as tested herein, is recommended for use on all projects requiring a shorter transition. Based on previous testing (TXDOT Project 469549 (*2*)), it was concluded that MASH Test 3-20 (small car) was not needed or required in the immediate transition area. Therefore, based on this testing, this design, as tested herein, meets the performance requirements of MASH Test Level 3.

Chapter 9. REFERENCES

1. AASHTO. *Manual for Assessing Safety Hardware*, Second Edition. American Association of State Highway and Transportation Officials, Washington, DC, 2016.
2. Williams, William F., Akram Y. Abu-Odeh, Maysam Kiani, Melissa Martinez, Sana Moran, Wanda L. Menges, Glenn E. Schroeder, and Bill L. Griffith. *MASH TL-3 Evaluation of Guardrail to Rigid Barrier Transition Attached to Bridge or Culvert Structure.* Test Report No. 0-6954-R1. Texas A&M Transportation Institute, College Station, TX, 2019

APPENDIX A. DETAILS OF SHORTENED TRANSITION



Texas A&M Transportation Institute

Roadside Safety and Physical Security Division - Proving Ground

Project #618981

Drawn by GES

Sheet 1 of 1 Impact

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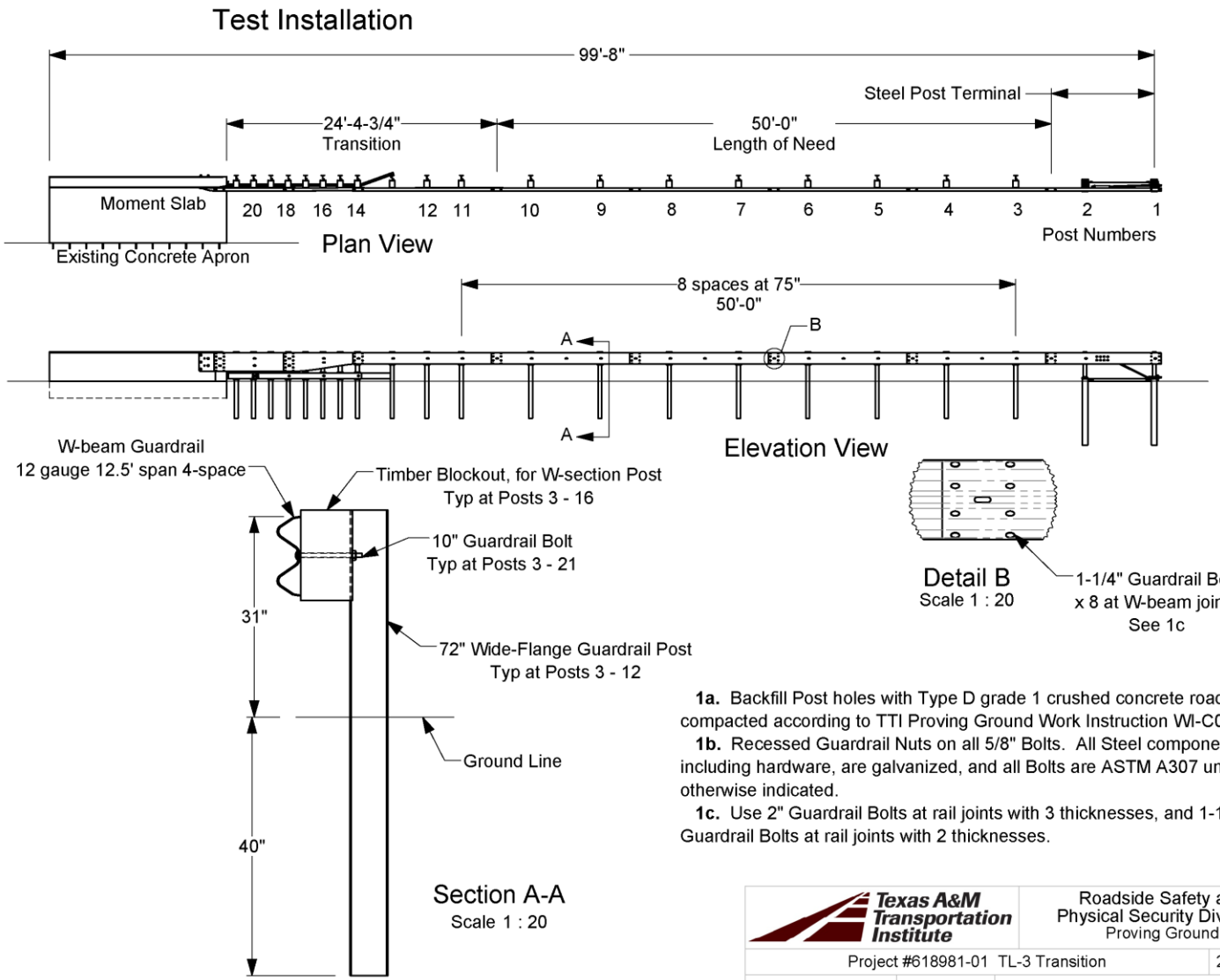

1a. Backfill Post holes with Type D grade 1 crushed concrete road base, compacted according to TTI Proving Ground Work Instruction WI-C001.

1b. Recessed Guardrail Nuts on all 5/8" Bolts. All Steel components, including hardware, are galvanized, and all Bolts are ASTM A307 unless otherwise indicated.

1c. Use 2" Guardrail Bolts at rail joints with 3 thicknesses, and 1-1/4" Guardrail Bolts at rail joints with 2 thicknesses.

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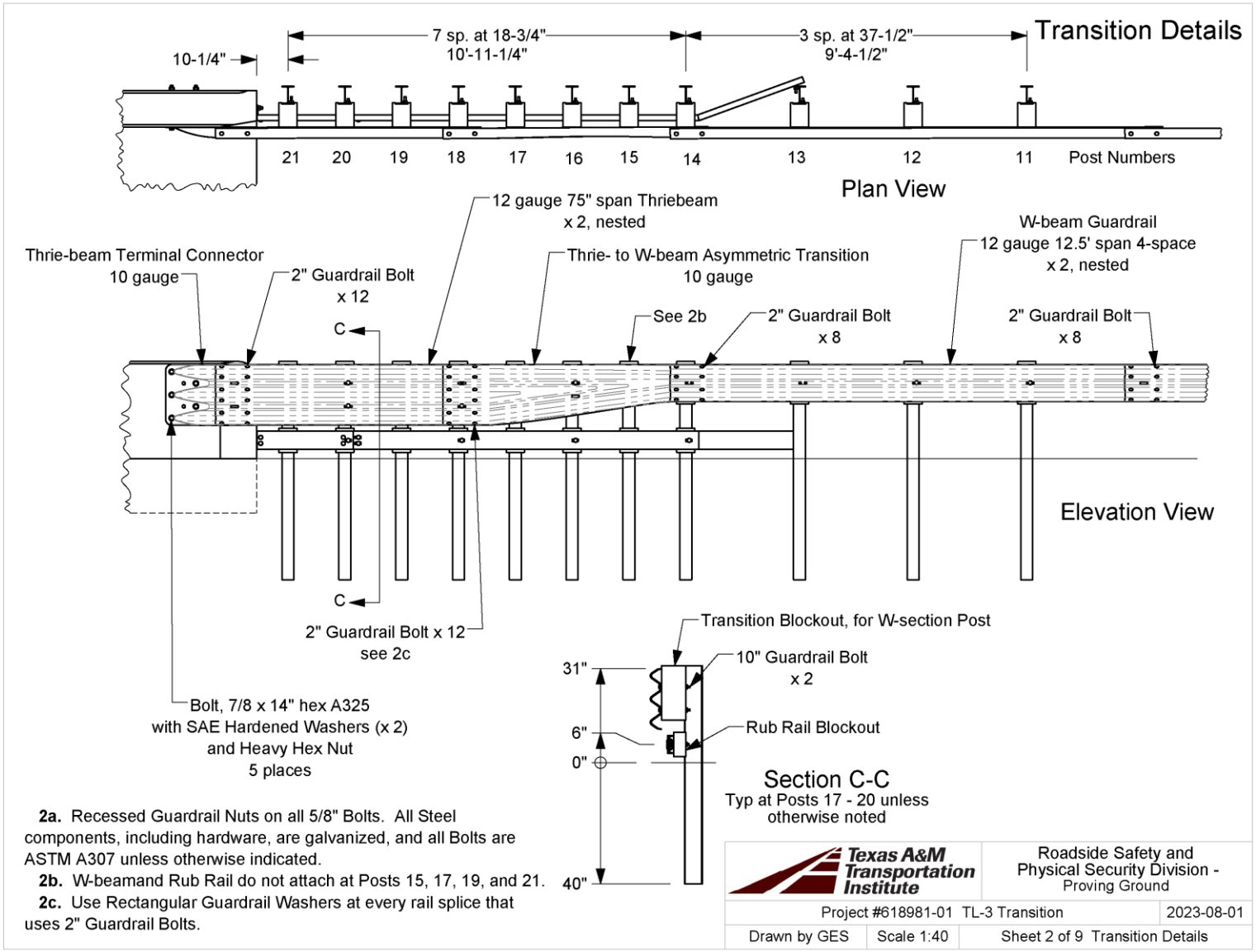

2a. Recessed Guardrail Nuts on all 5/8" Bolts. All Steel components, including hardware, are galvanized, and all Bolts are ASTM A307 unless otherwise indicated.

2b. W-beamand Rub Rail do not attach at Posts 15, 17, 19, and 21.

2c. Use Rectangular Guardrail Washers at every rail splice that uses 2" Guardrail Bolts.

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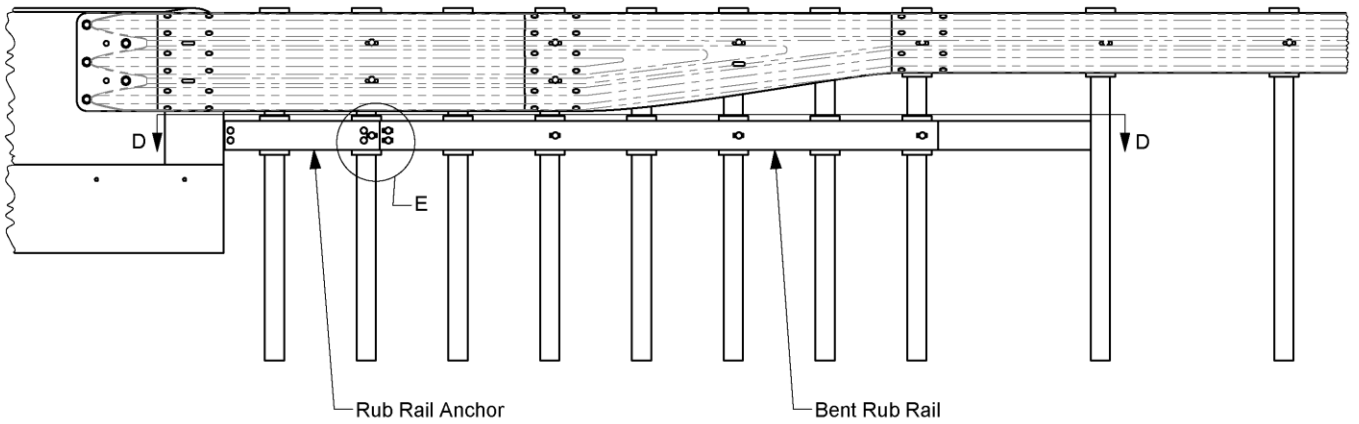
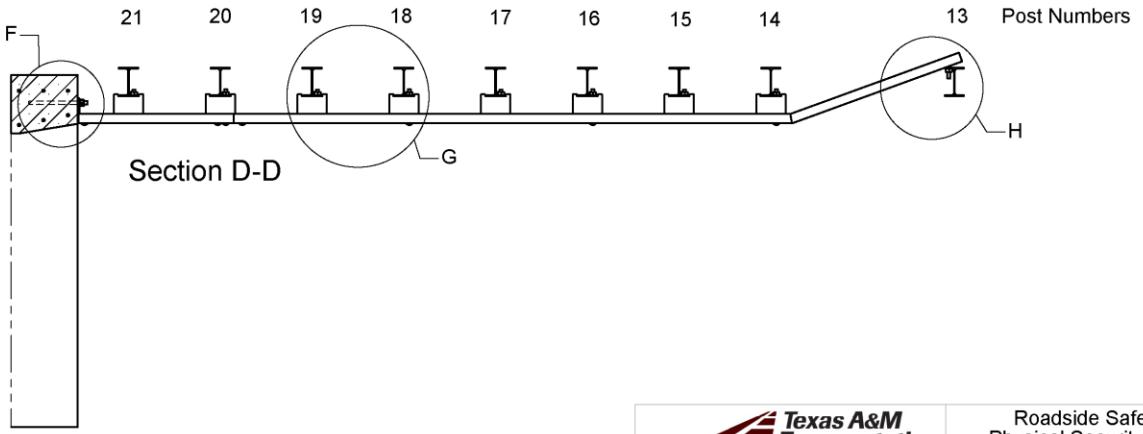
Rub Rail Connections

Detail Views on next sheet





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Project #618981-01 TL-3 Transition			2023-08-01
Drawn by GES	Scale 1:30	Sheet 3 of 9 Rub Rail Connections	

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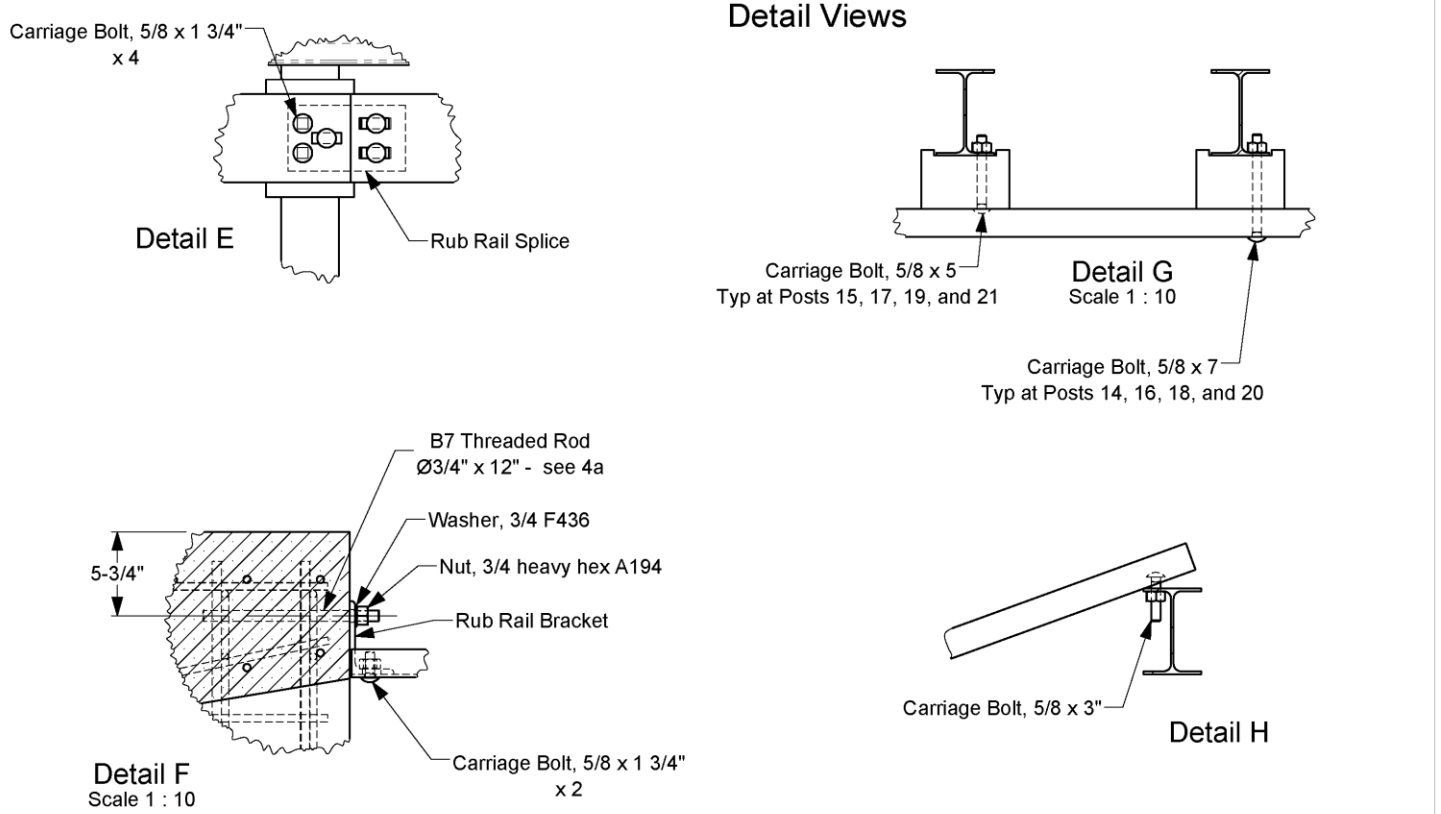

4a. Secure with Hilti HIT-RE 500 V3 epoxy according to manufacturer's instructions, with 10" embedment.

4b. Recessed Guardrail Nuts on all 5/8" Bolts. All Steel components, including hardware, are galvanized, and all Bolts are ASTM A307 unless otherwise indicated.

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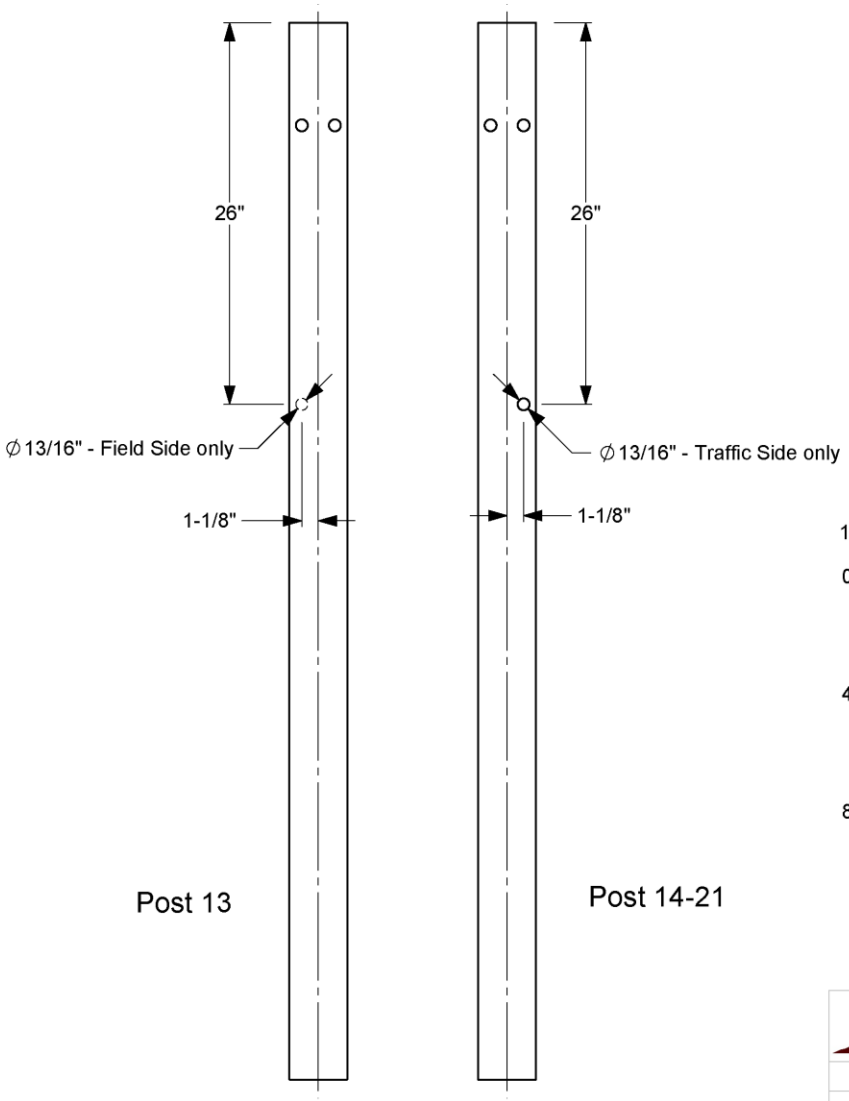
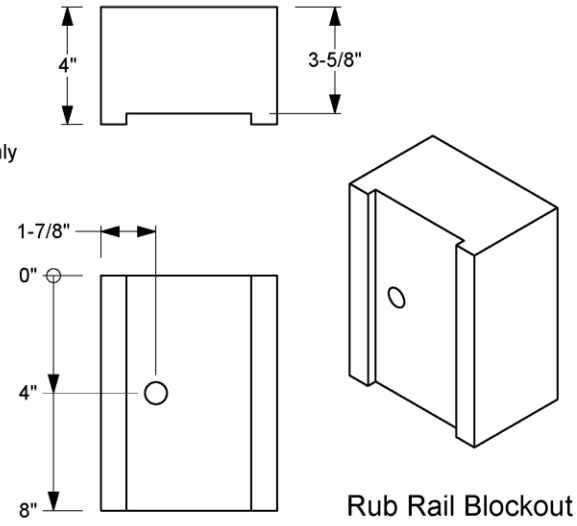
Post and Blockout Details

See *72" Wide Flange Guardrail Post for Thrie-beam* drawing sheet for Post details not shown here. See *Timber Blockout for W-section Post* drawing sheet for Blockout details not shown here.





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Project #618981-01 TL-3 Transition		2023-08-01
Drawn by GES	Scale 1:10	Sheet 5 of 9 Post and Blockout Details

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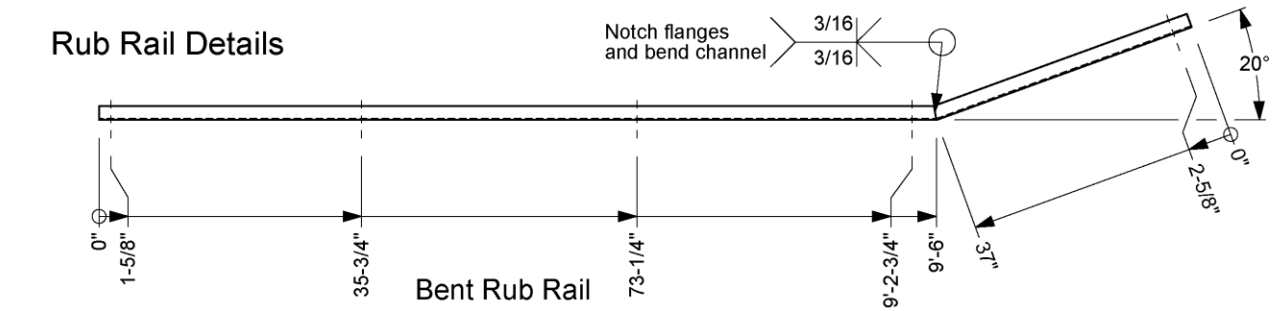
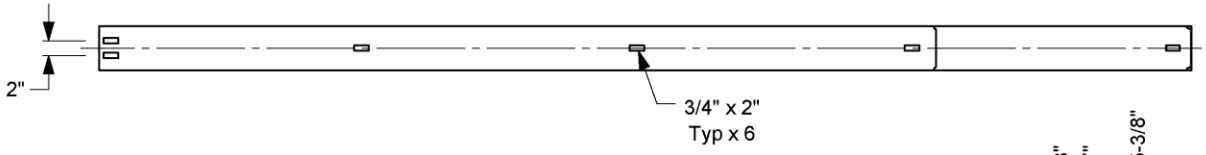
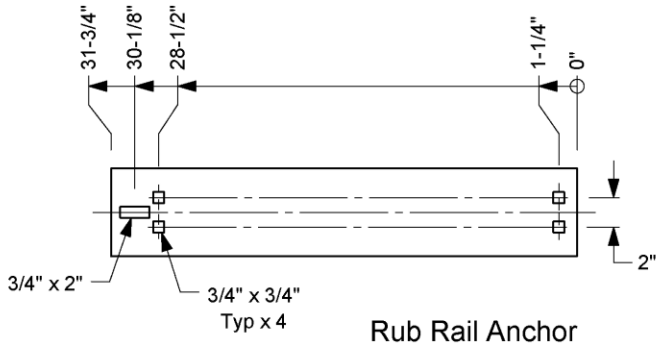
Rub Rail Details



Bent Rub Rail

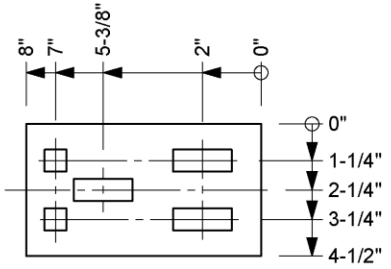
C 6 x 8.2 - ASTM A36
Plan and Elevation Views





Rub Rail Anchor

C 6 x 8.2 - ASTM A36
Scale 1:10



Rub Rail Splice

Plate, 4 1/2" x 3/8" - ASTM A36
Scale 1:5
See Rub Rail Anchor detail, this sheet, for hole sizes

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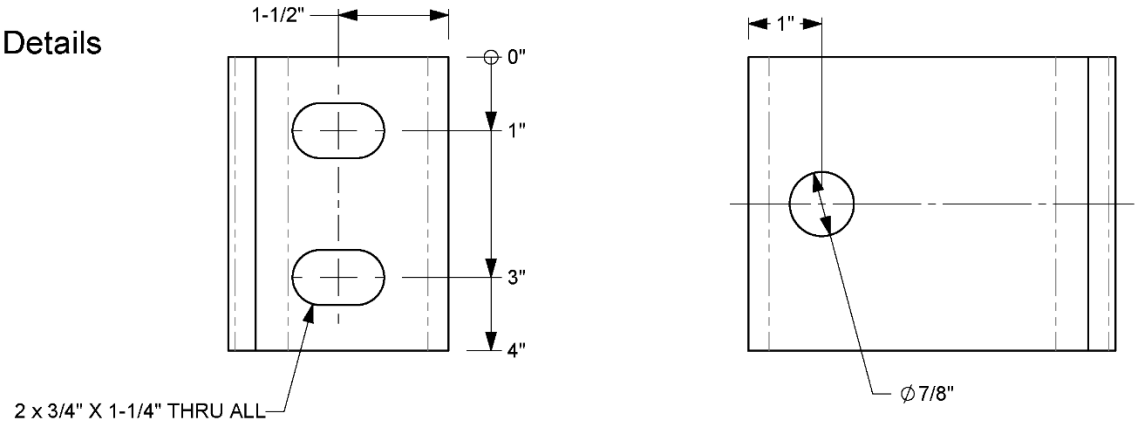
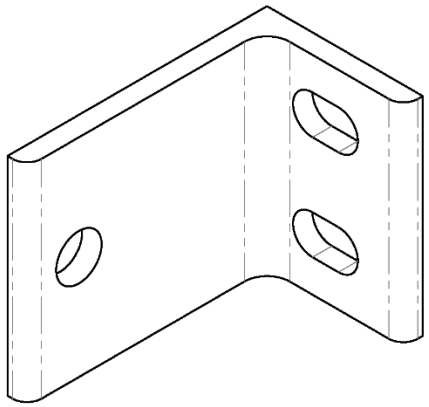
Bracket Details



Rub Rail Bracket

L 5" x 3" x 3/8" - ASTM A36



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Project #618981-01 TL-3 Transition			2023-08-01
Drawn by GES	Scale 1:2	Sheet 7 of 9 Bracket Details	

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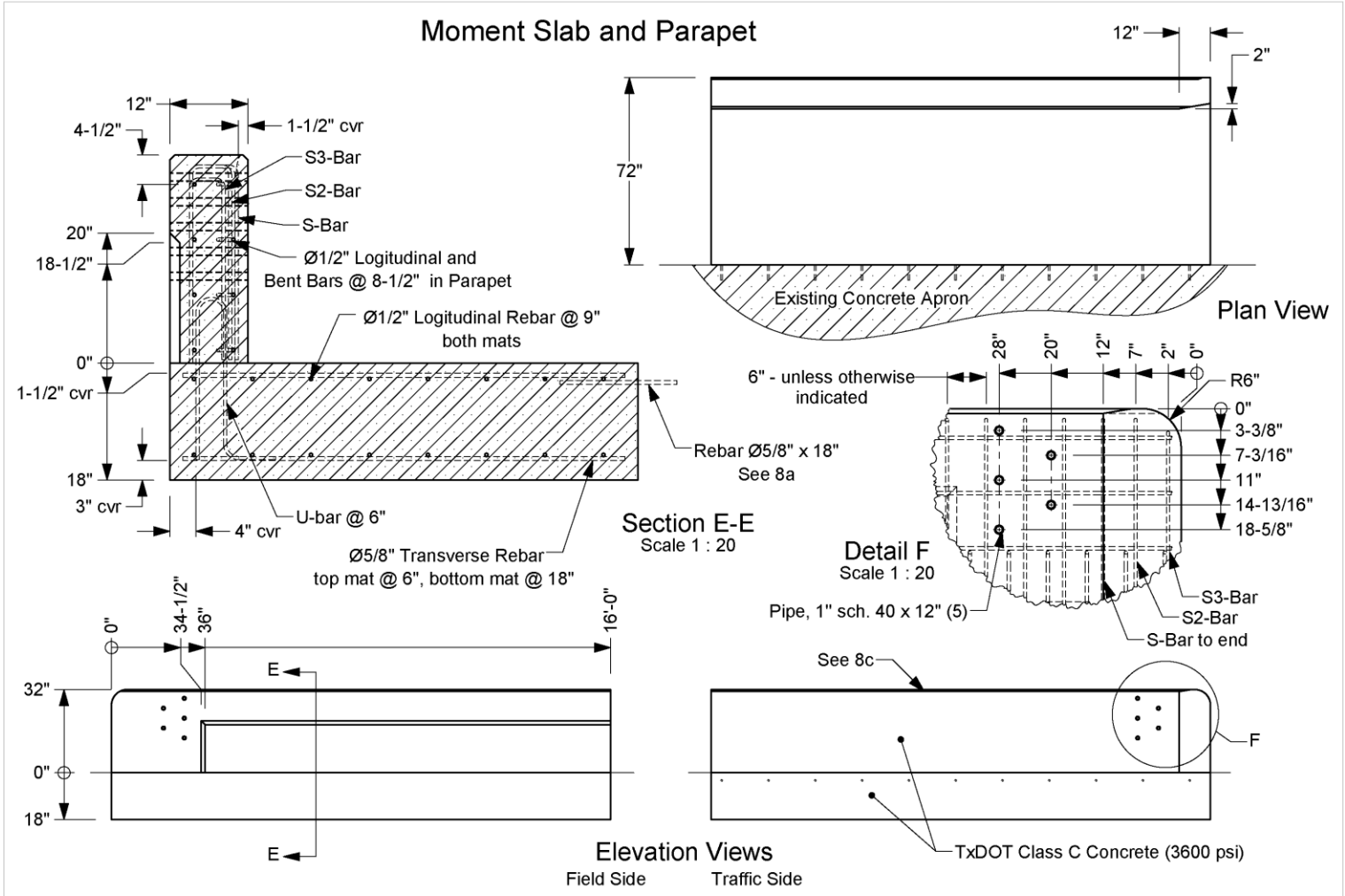

8a. Secure in existing concrete apron with Hilti HIT-RE 500 V3 epoxy according to manufacturer's instructions, with 6" embedment at 18" spacing.

8b. All rebar dimensions are to center unless otherwise indicated by "cvr" (cover).

8c. 1" chamfer (3/4" each way) exposed edges of parapet as shown.

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Project #618981-01 TL-3 Transition		2023-08-01
Drawn by GES	Scale 1:50	Sheet 8 of 9 Moment Slab and Parapet

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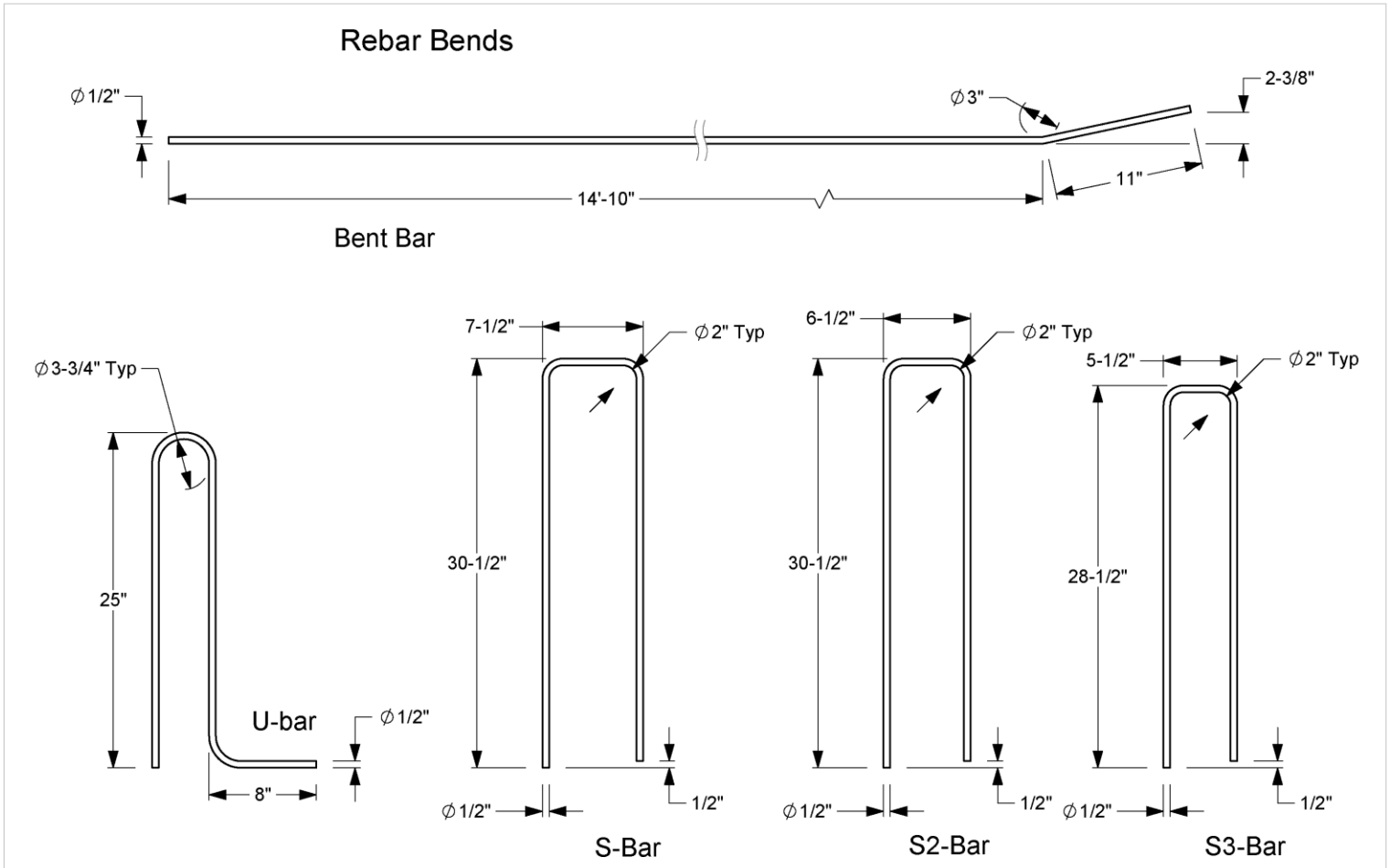

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #618981-01 TL-3 Transition		2023-08-01
Drawn by GES	Scale 1:10	Sheet 9 of 9 Rebar Bends

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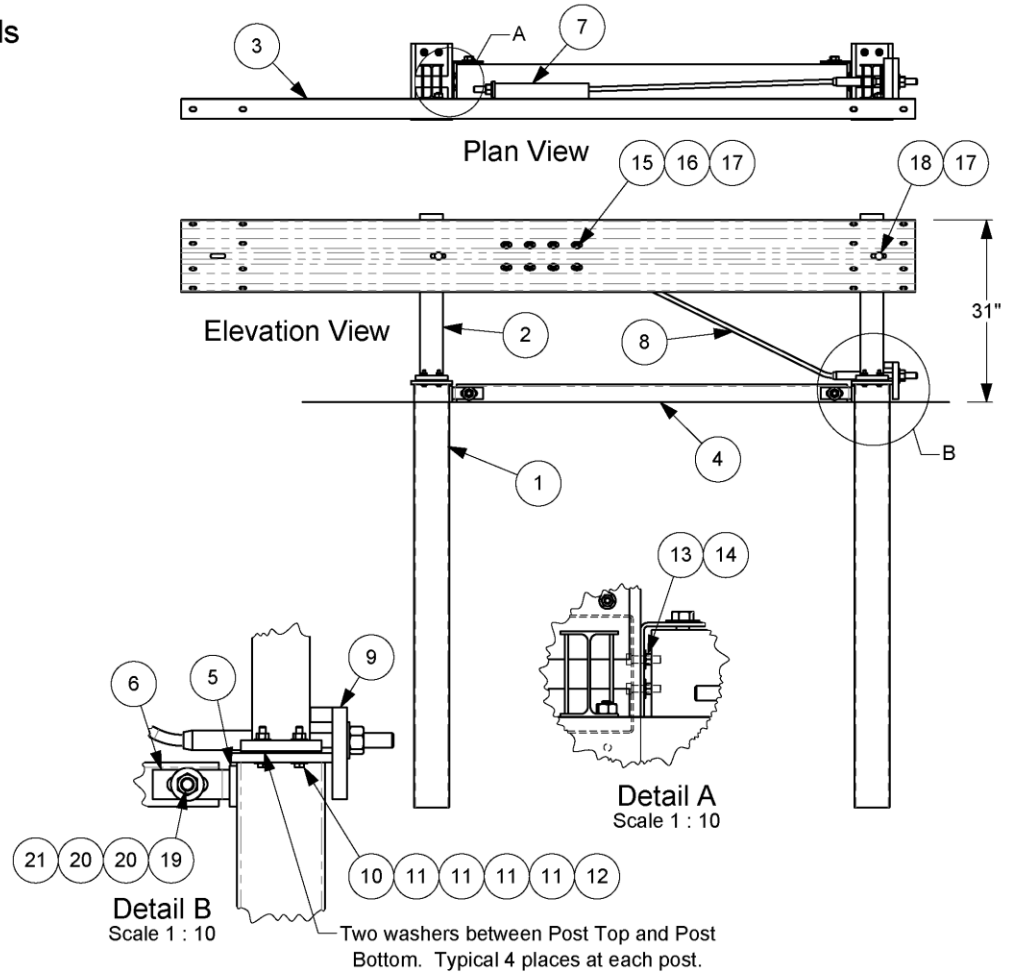
Steel Post Terminal Details

#	Part Name	QTY.
1	Post Bottom	2
2	Post Top	2
3	9'-4-1/2" span Terminal Rail	1
4	Strut	1
5	Strut Spacer	2
6	Strut Bracket	2
7	Guardrail Anchor Bracket	1
8	Anchor Cable Assembly	1
9	Bearing Plate	1
10	Bolt, 7/16 x 2 1/2" hex	8
11	Washer, 7/16 F844	32
12	Nut, 7/16 heavy hex	8
13	Nut, 1/2 hex	4
14	Washer, 1/2 F844	4
15	Bolt, 5/8 x 1 1/2" hex	8
16	Washer, 5/8 F844	8
17	Recessed Guardrail Nut	10
18	1-1/4" Guardrail Bolt	2
19	Bolt, 7/8 x 8 1/2" hex	2
20	Washer, 7/8 F844	4
21	Nut, 7/8 hex	2



1a. 7/16" x 2-1/2" Bolts are ASTM A449. All other Bolts are ASTM A307. All Nuts (except Recessed Guardrail Nuts) are ASTM A563A unless otherwise indicated.

1b. All steel parts shall be galvanized.

1c. This specific terminal configuration has not been tested. It is used as a barrier anchorage device for crash testing purposes.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project # Terminal		2023-02-08
Drawn by GES	Scale 1:25	Sheet 1 of 6 Terminal Details

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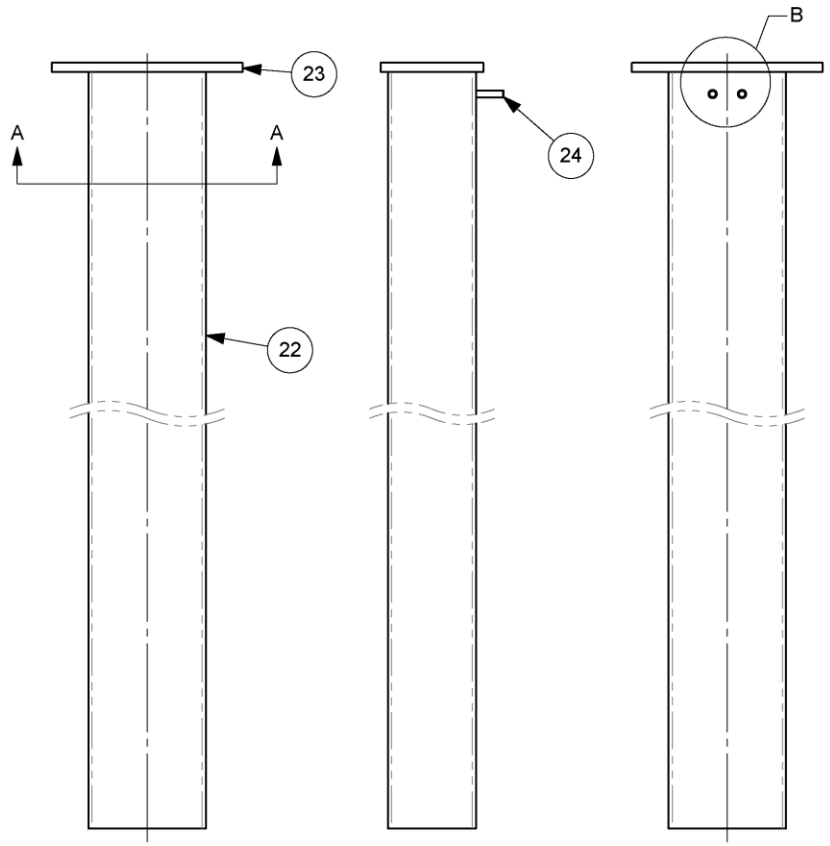
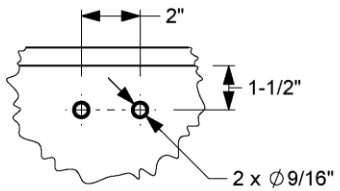
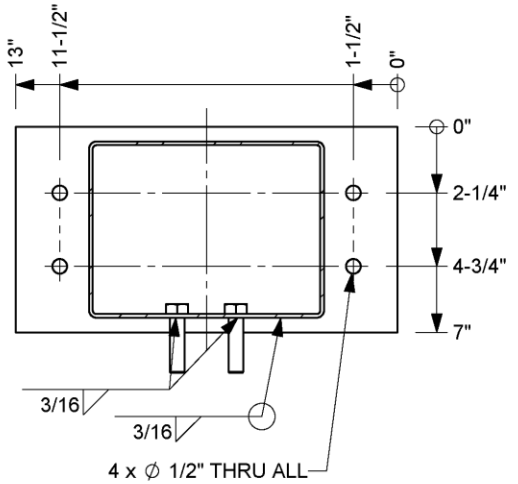


Elevation Views

Post Bottom



Detail B
Scale 1 : 5



Section A-A
Scale 1 : 5

#	Description	Length	Material	Qty
22	HSS 8" x 6" x 1/8"	72"	ASTM A500 Grade B	1
23	Plate, 7" x 5/8"	13"	ASTM A36	1
24	Bolt, 1/2 x 2 hex		ASTM A307	2

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project # Terminal		2023-02-08
Drawn by GES	Scale 1:10	Sheet 2 of 6 Post Bottom

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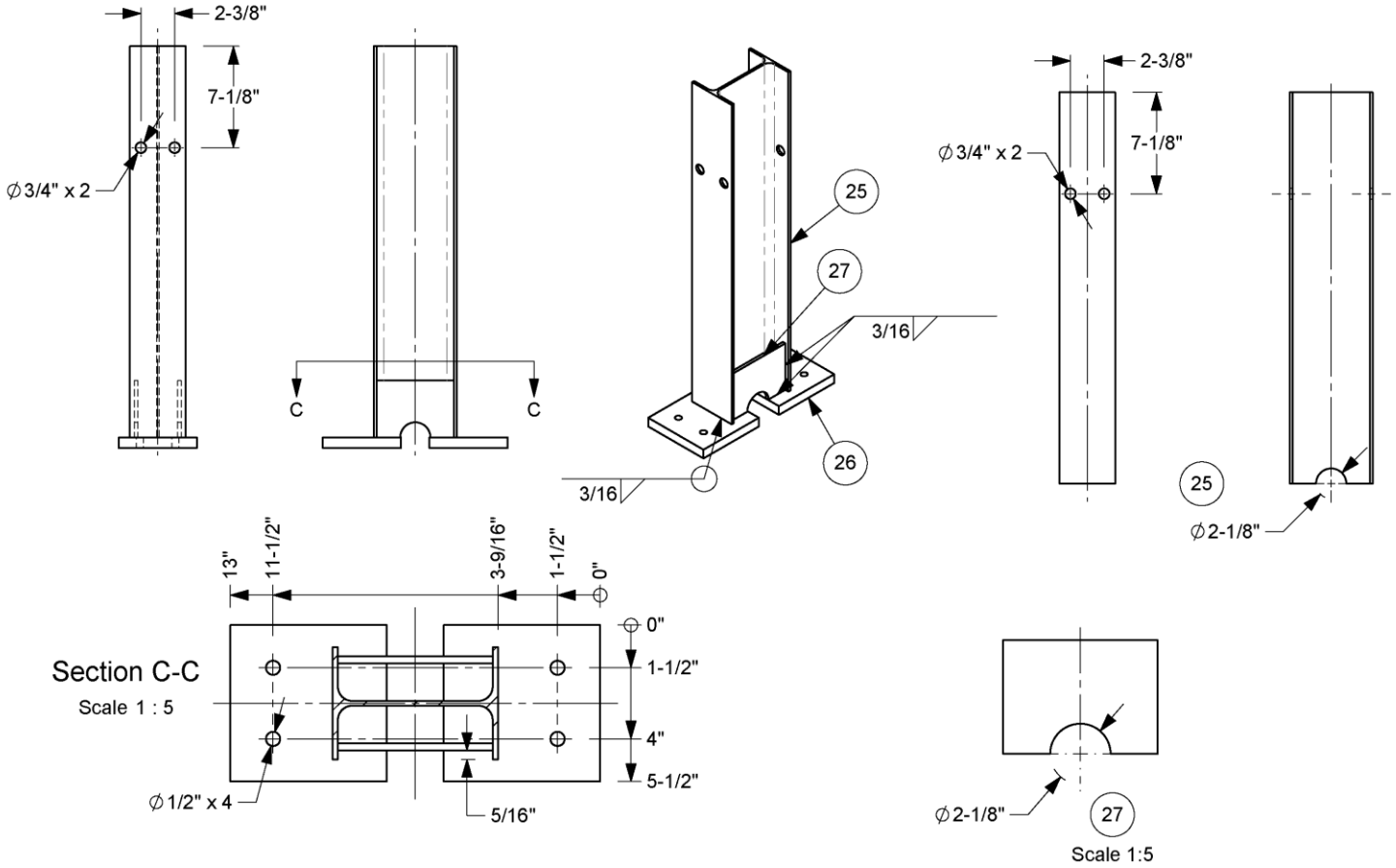

#	Description	Length	Material	Qty
25	W6x8.5	27 1/2"	ASTM A992	1
26	Plate, 5 1/2" x 3/4"	5 1/2"	ASTM A36	2
27	Plate, 5 7/16" x 1/4"	4"	ASTM A36	2

Texas A&M Transportation Institute

Roadside Safety and Physical Security Division - Proving Ground

Project # Terminal		2023-02-08
Drawn by GES	Scale 1:10	Sheet 3 of 6 Post Top

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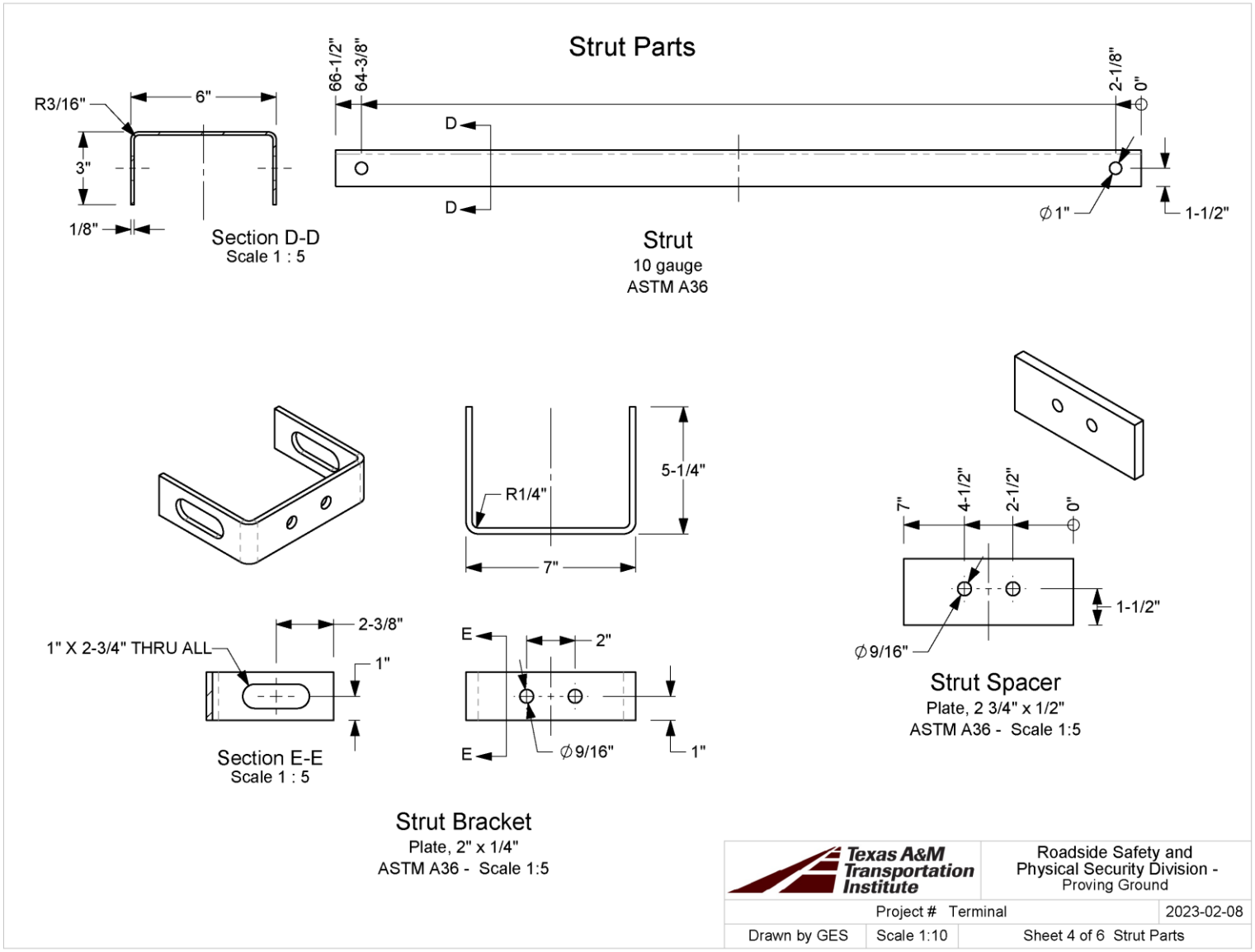
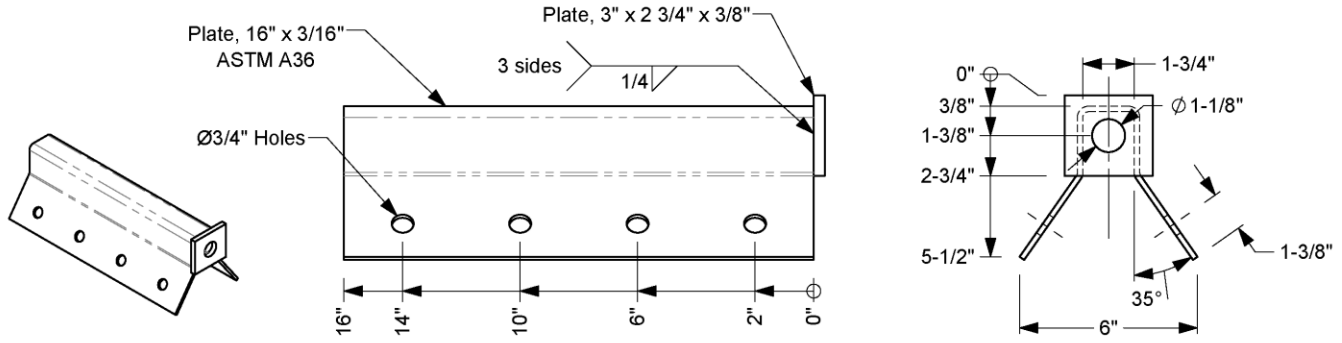
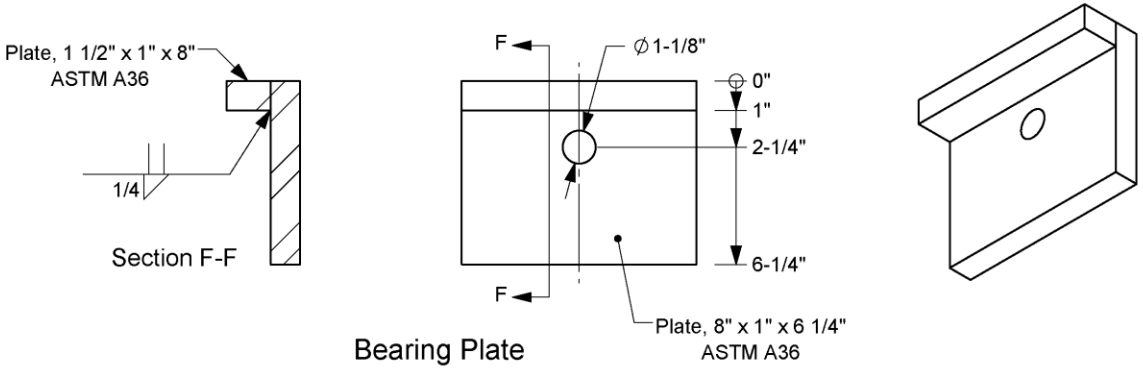


Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
	Project # Terminal	2023-02-08
Drawn by GES	Scale 1:10	Sheet 4 of 6 Strut Parts

S:\engrfact\Drafting Department\Solidworks\Standard Parts\Guardrail Parts and Subs\Guardrail Drawings\Steel Post Terminal



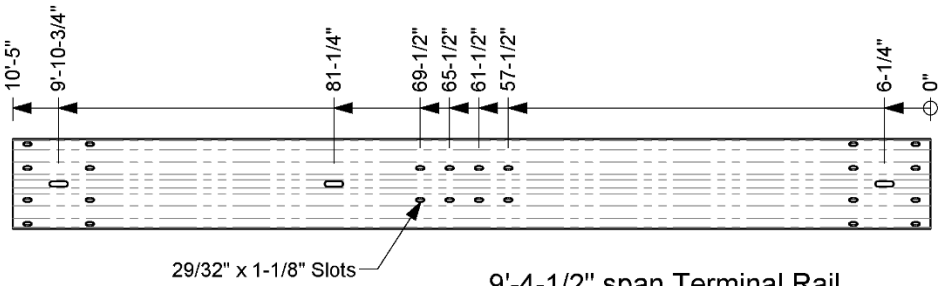
Guardrail Anchor Bracket



Bearing Plate

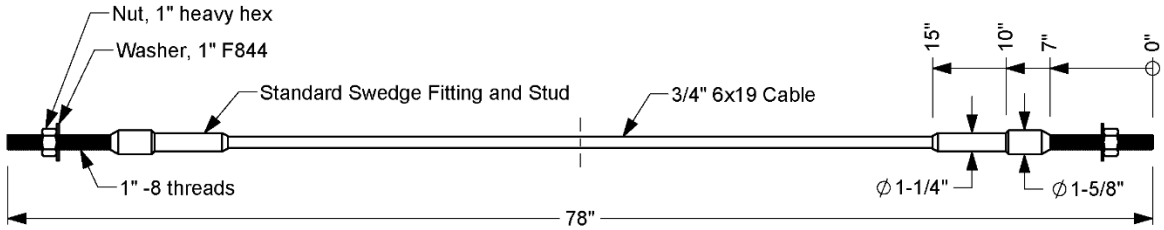
Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
	Project # Terminal	2023-02-08
Drawn by GES	Scale 1:5	Sheet 5 of 6 Assorted Parts A

S:\engrfact\Drafting Department\Solidworks\Standard Parts\Guardrail Parts and Subs\Guardrail Drawings\Steel Post Terminal



9'-4-1/2" span Terminal Rail

Scale 1:20 - See 4-space W-beam Guardrail drawing for cross-section and other dimensions.



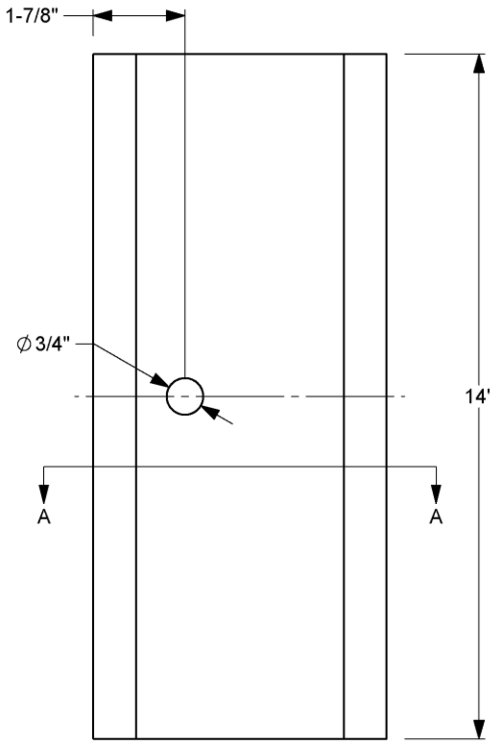
Anchor Cable Assembly

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Project # Terminal			2023-02-08
Drawn by GES	Scale 1:5	Sheet 6 of 6 Assorted Parts B	

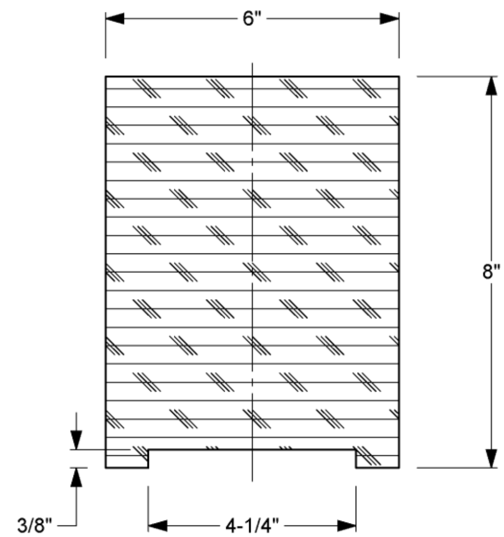
S:\engrfact\Drafting Department\Solidworks\Standard Parts\Guardrail Parts and Subs\Guardrail Drawings\Steel Post Terminal

Timber Blockout for W-section Post

All dimensions except hole diameter are nominal



Elevation View



Section A-A

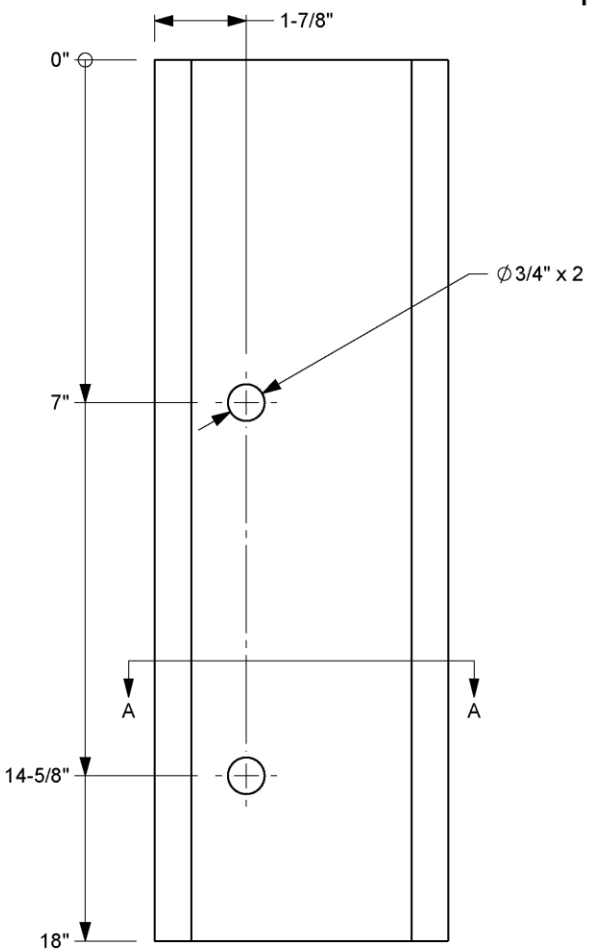
1a. Timber blockouts are treated with a preservative in accordance with AASHTO M 133 after all cutting and drilling.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Timber Blockout, for W-section Post		2022-12-16
Drawn by GES	Scale 1:3	Sheet 1 of 1

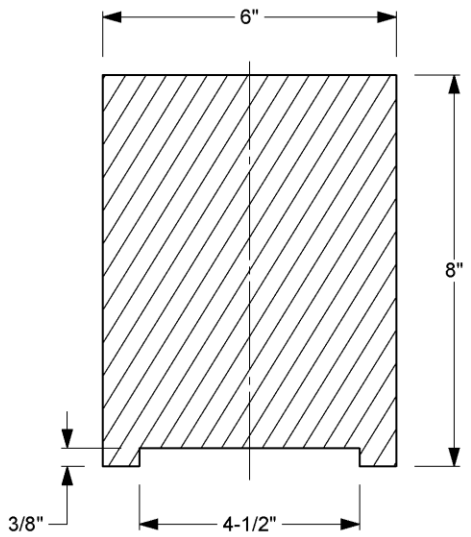
T:\Drafting Department\Solidworks\Standard Parts\Guardrail Parts and Subs\Guardrail Drawings\Timber Blockout for W-section Post

Transition Blockout for W-section Post

All dimensions except hole diameter are nominal



Elevation View

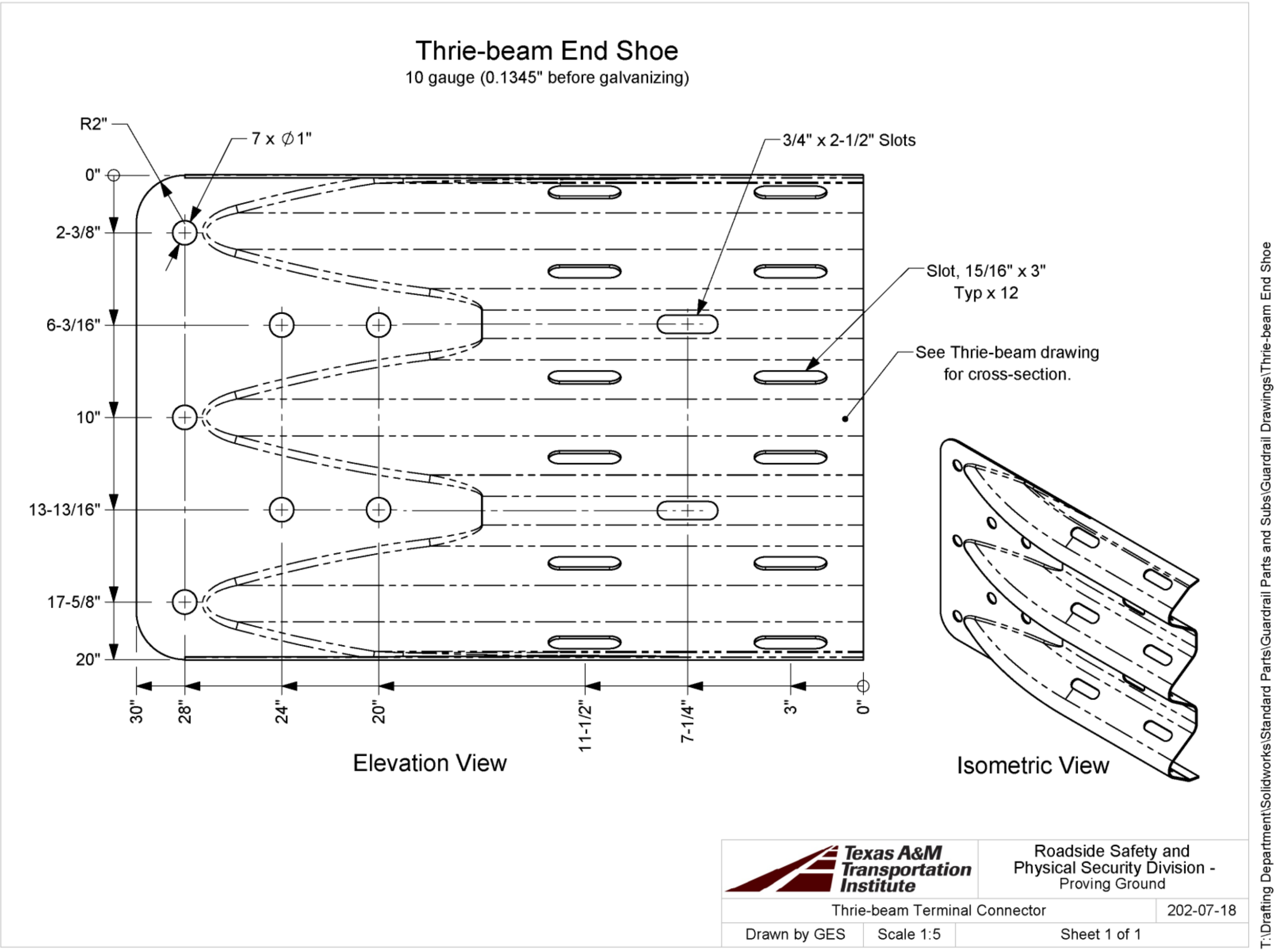


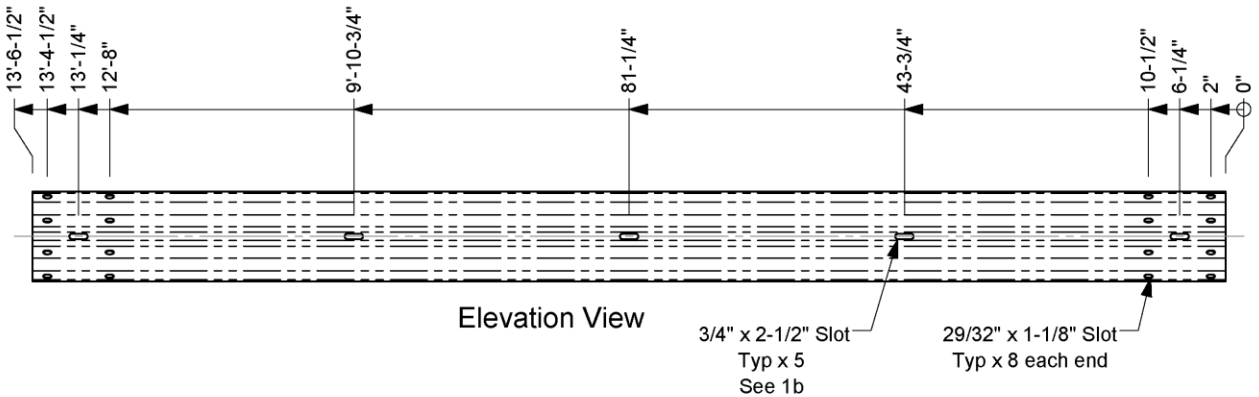
Section A-A

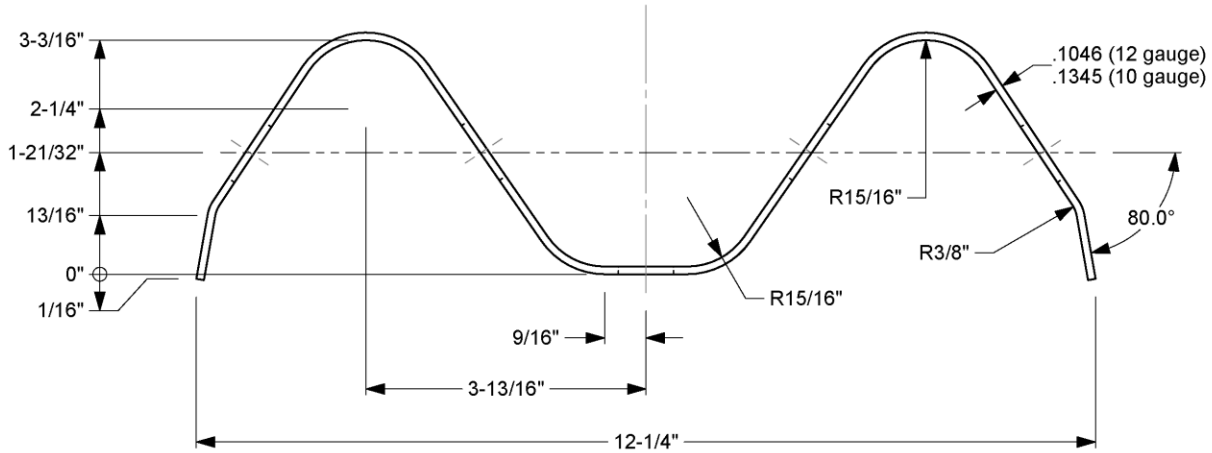
1a. Timber blockouts are treated with a preservative in accordance with AASHTO M 133 after all cutting and drilling.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Transition Blockout, for W-section Post		2022-10-25
Drawn by GES	Scale 1:3	Sheet 1 of 1

T:\Drafting Department\Solidworks\Standard Parts\Guardrail Parts and Subs\Guardrail Drawings\Transition Blockout for W-section Post


Thrie-beam End Shoe
10 gauge (0.1345" before galvanizing)
R2"
7 x ∅1"
3/4" x 2-1/2" Slots
Slot, 15/16" x 3"
Typ x 12
See Thrie-beam drawing
for cross-section.
0"
2-3/8"
6-3/16"
10"
13-13/16"
17-5/8"
20"
30"
28"
24"
20"
11-1/2"
7-1/4"
3"
0"
Elevation View
Isometric View
Texas A&M Transportation Institute
Roadside Safety and
Physical Security Division -
Proving Ground
Thrie-beam Terminal Connector
202-07-18
Drawn by GES
Scale 1:5
Sheet 1 of 1
T:\Drafting Department\Solidworks\Standard Parts\Guardrail Parts and Subs\Guardrail Drawings\Thrie-beam End Shoe

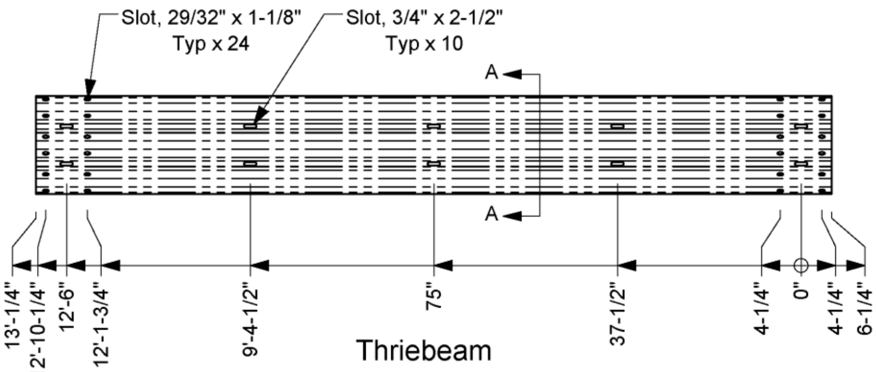




1a. Manufacture per AASHTO M180 specifications.
1b. 4-space Guardrail is shown. Slots typical x 3 for 2-space W-beam spaced at 75", and typical x 9 for 8-space W-beam spaced at 18-3/4". Slots are typical x 4 at 37-1/2" for 9'-4-1/2" span W-beam.

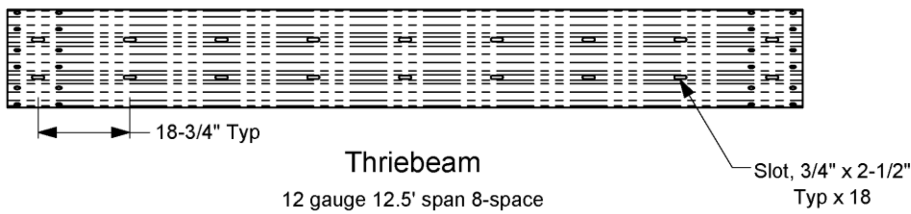
Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
W-beam Guardrail		2022-07-13
Drawn by GES	Scale 1:20	Sheet 1 of 1

T:\Drafting Department\Solidworks\Standard Parts\Guardrail Parts and Subs\Guardrail Drawings\W-Beam Guardrail



Thriebeam

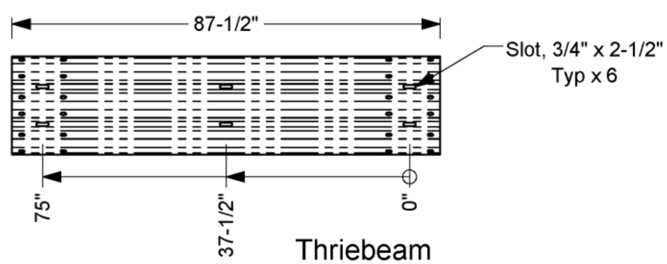
12 gauge 12.5' span 4-space



Thriebeam

12 gauge 12.5' span 8-space

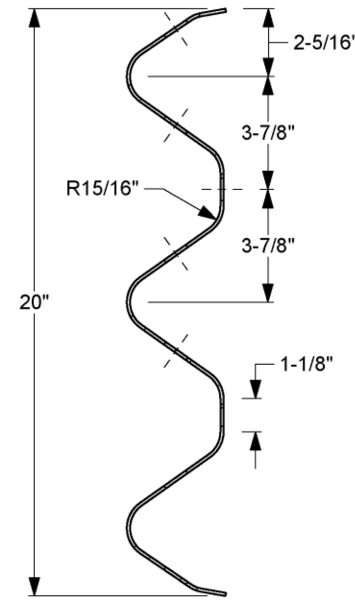
Dimensions not shown here same as 4-space Thriebeam



Thriebeam

12 gauge 75" span

Dimensions not shown here same as 4-space Thriebeam



Section A-A

Scale 1 : 5

Typical all Thriebeams

1a. 12 gauge is 0.1046" before galvanizing and 0.1084" after, and 10 gauge is 0.1345" before galvanizing and 0.1382" after.

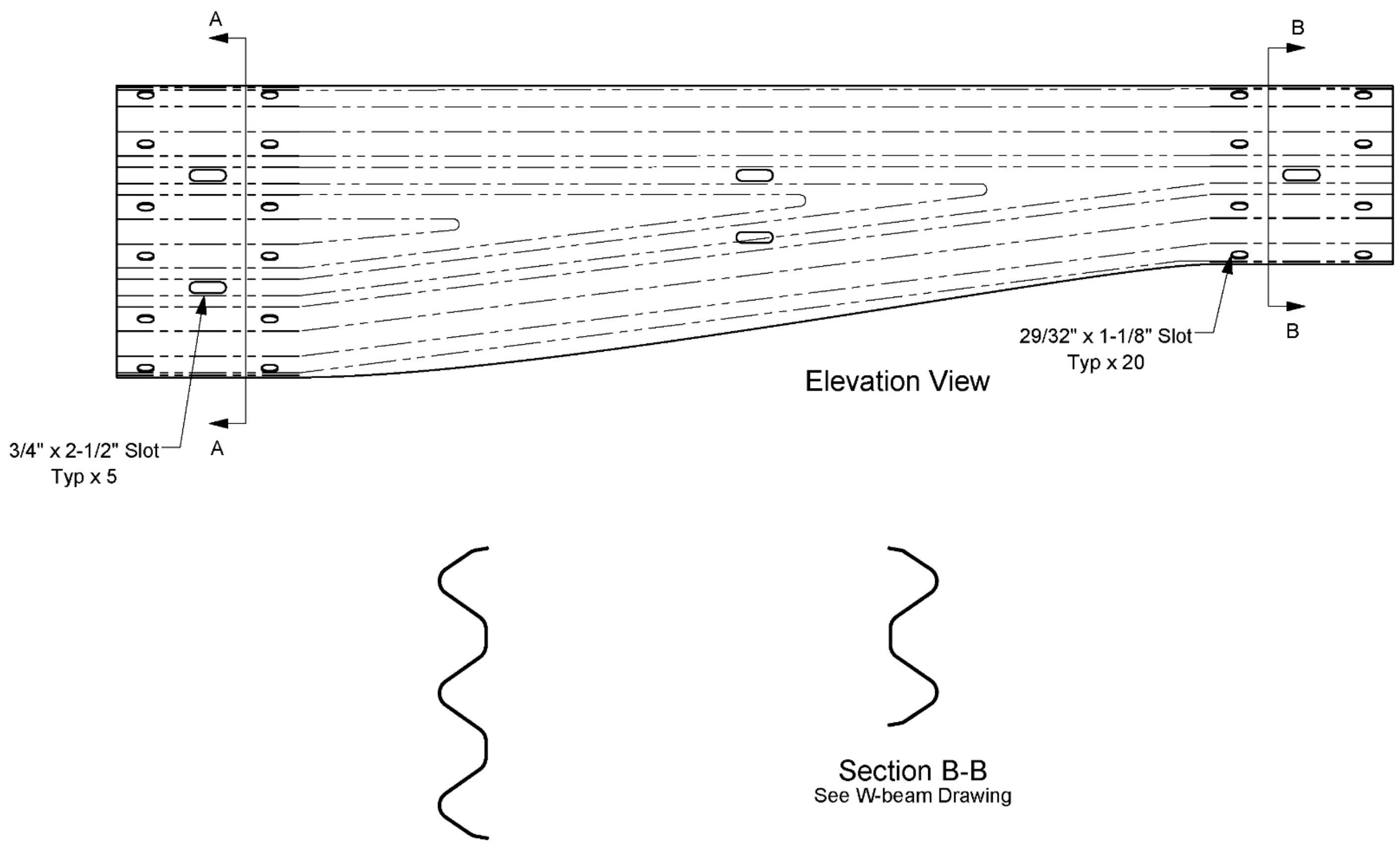
1b. Not all versions shown here used in all installations.

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Thrie-beam			2022-07-18
Drawn by GES	Scale 1:30	Sheet 1 of 1	

T:\Drafting Department\Solidworks\Standard Parts\Guardrail Parts and Subs\Guardrail Drawings\Thrie-Beam

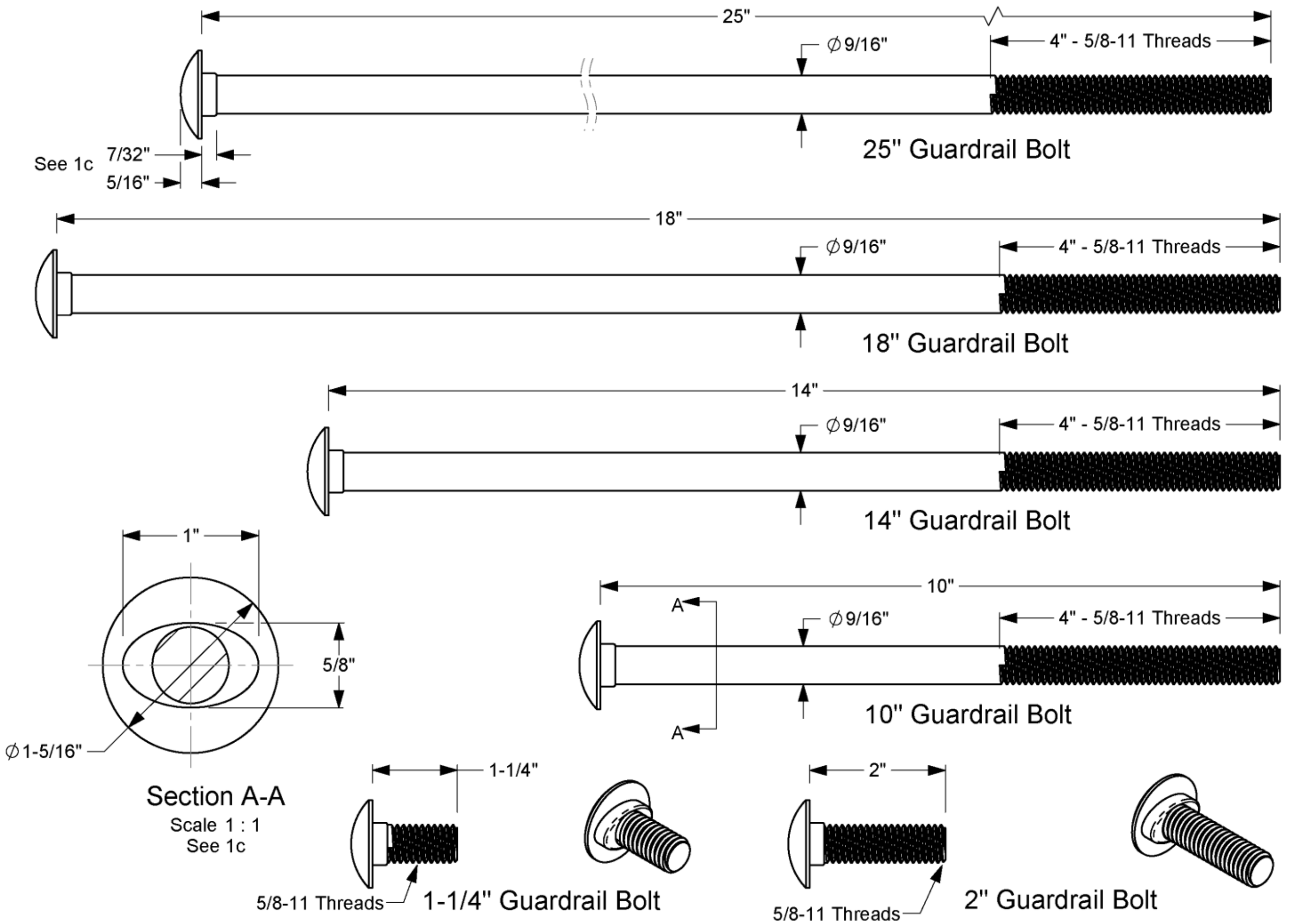
Thrie to W-Beam, asymmetric

10 gauge



Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Thrie- to W-beam Asymmetric Transition			2022-07-18
Drawn by GES	Scale 1:10	Sheet 1 of 1	

T:\Drafting Department\Solidworks\Standard Parts\Guardrail Parts and Subs\Guardrail Drawings\Thrie to W-Beam, asymmetric



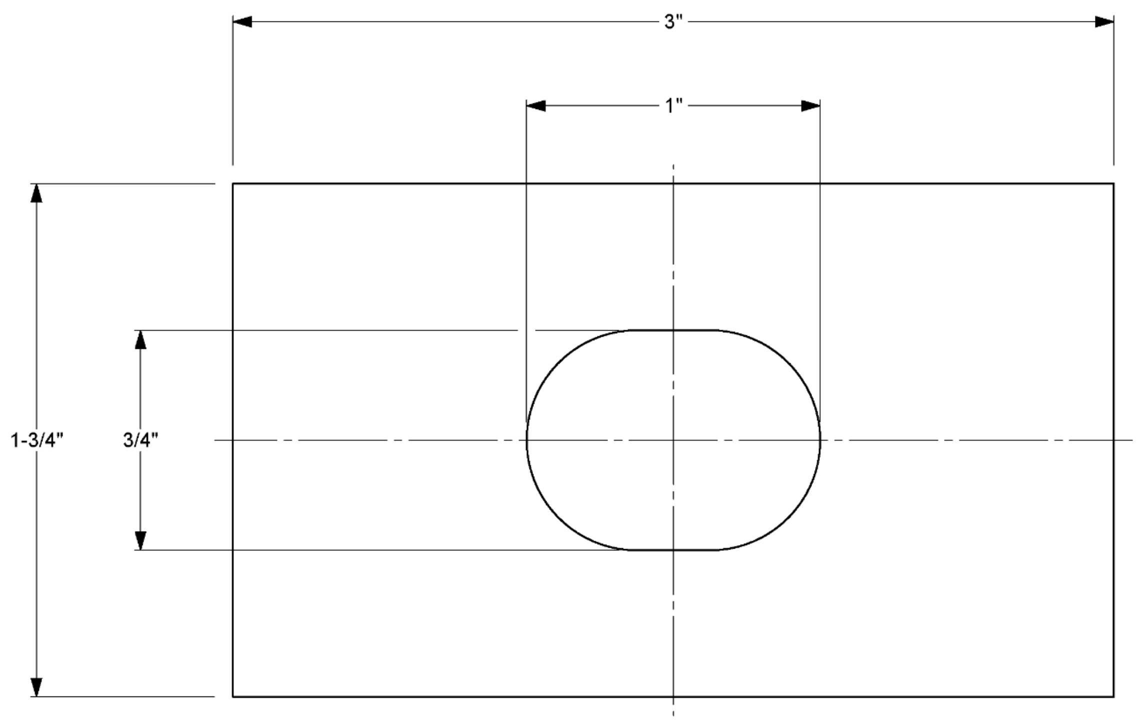
1a. Material is ASTM A307.
1b. All bolt sizes not used in all projects. See system drawing.
1c. Head and shoulder dimensions typical all lengths.

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Guardrail Bolt			2020-07-08
Drawn by GES/WS	Scale 1:2	Sheet 1 of 1	

T:\Drafting Department\Solidworks\Standard Parts\Guardrail Parts and Subs\Guardrail Drawings\Guardrail Bolt

Rectangular Guardrail Washer

0.20" thick



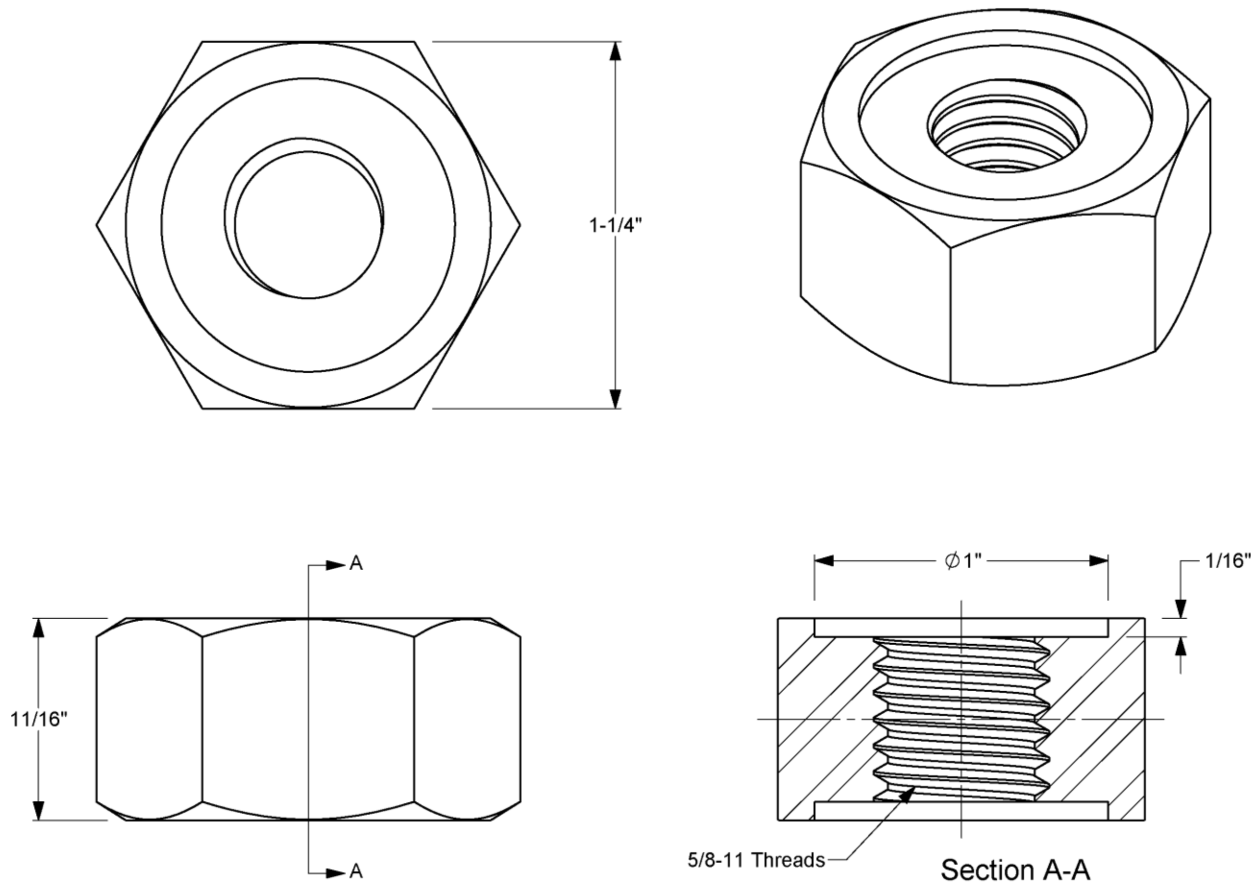
Texas A&M Transportation Institute

Roadside Safety and Physical Security Division - Proving Ground

Rectangular Guardrail Washer		2022-07-08
Drawn by GES	Scale 2:1	Sheet 1 of 1

T:\Drafting Department\Solidworks\Standard Parts\Guardrail Parts and Subs\Guardrail Drawings\Washer, rect.

Recessed Guardrail Nut

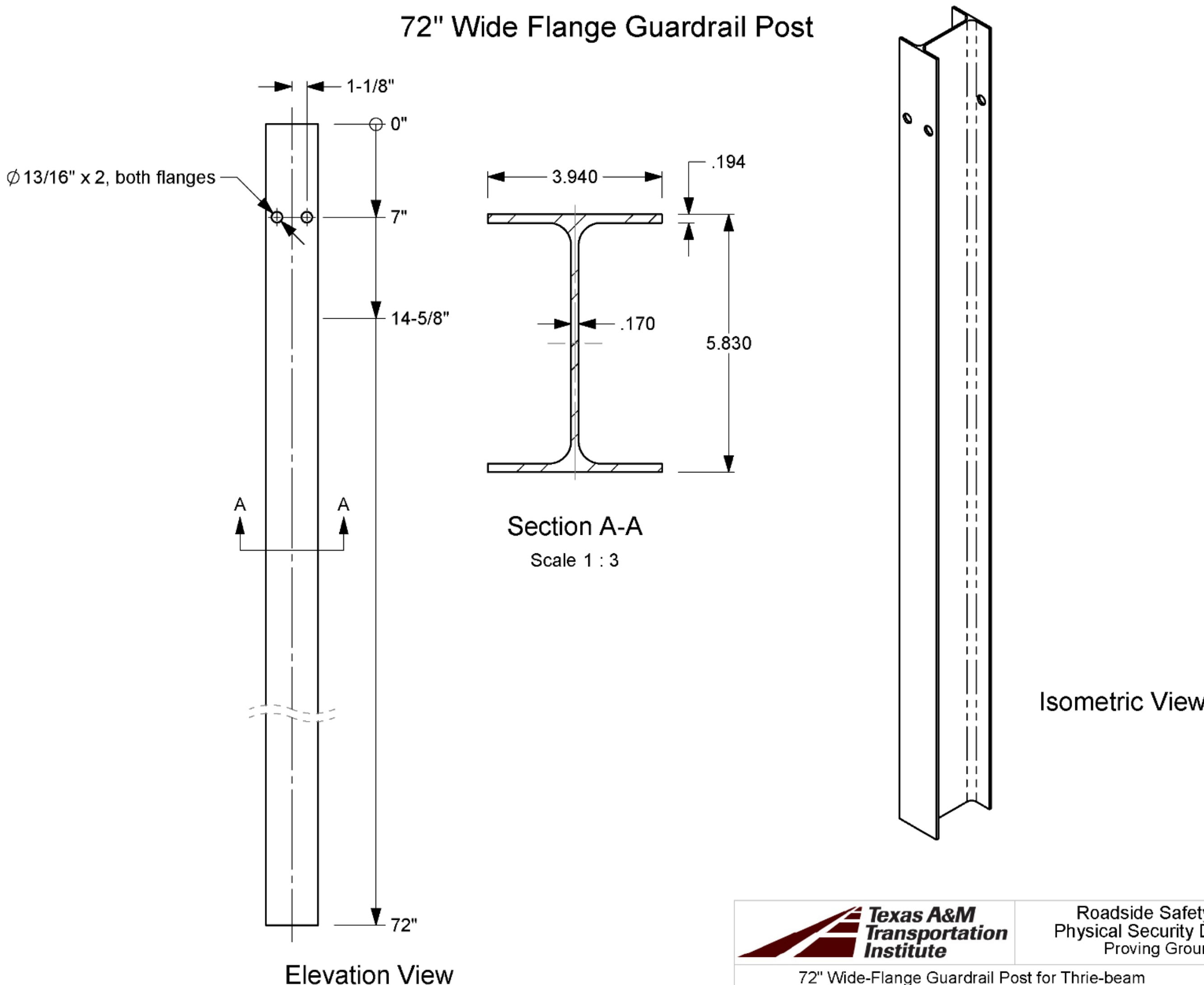


1a. Material is ASTM A 563 Grade A.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Recessed Guardrail Nut		2022-07-18
Drawn by GES	Scale 2:1	Sheet 1 of 1

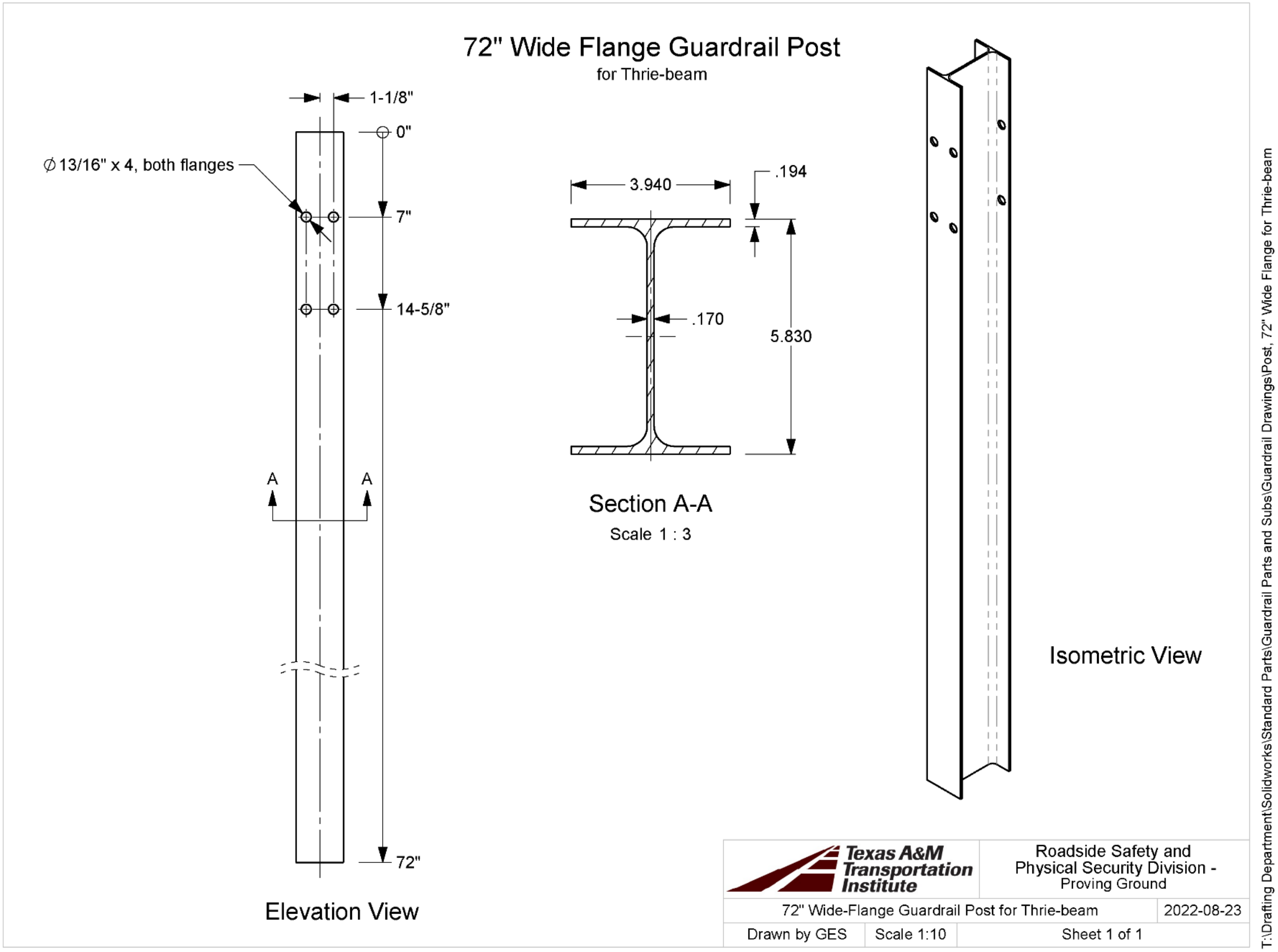
T:\Drafting Department\Solidworks\Standard Parts\Guardrail Parts and Subs\Guardrail Drawings\Nut, Recessed Guardrail

72" Wide Flange Guardrail Post



Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
72" Wide-Flange Guardrail Post for Thrie-beam			2022-07-08
Drawn by GES	Scale 1:10	Sheet 1 of 1	

T:\Drafting Department\Solidworks\Standard Parts\Guardrail Parts and Subs\Guardrail Drawings\Post, 72" Wide Flange for W-beam


72" Wide Flange Guardrail Post
for Thrie-beam
1-1/8"
0"
∅ 13/16" x 4, both flanges
7"
14-5/8"
A
A
72"
Elevation View
3.940
.194
.170
5.830
Section A-A
Scale 1 : 3
Isometric View
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
72" Wide-Flange Guardrail Post for Thrie-beam
2022-08-23
Drawn by GES
Scale 1:10
Sheet 1 of 1
T:\Drafting Department\Solidworks\Standard Parts\Guardrail Parts and Subs\Guardrail Drawings\Post, 72" Wide Flange for Thrie-beam

APPENDIX B. SUPPORTING CERTIFICATION DOCUMENTS

TR No. 618981-01-1

60

2024-02-27

CMC STEEL TEXAS
1 STEEL MILL DRIVE
SEGUIN TX 78155-7510

CERTIFIED MILL TEST REPORT

For additional copies call
830-372-8771

We hereby certify that the test results presented here are accurate and conform to the reported grade specification

Rolando A Davila
Quality Assurance Manager

HEAT NO.:3108472 SECTION: REBAR 16MM (#5) 20'0" 420/60 GRADE: ASTM A615-20 Gr 420/60 ROLL DATE: 08/30/2021 MELT DATE: 08/27/2021 Cert. No.: 83605619 / 108472A371	SOLD TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	SHIP TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	Delivery#: 83605619 BOL#: 74392050 CUST PO#: 896487 CUST P/N: DLVRY LBS / HEAT: 48072.000 LB DLVRY PCS / HEAT: 2304 EA

Characteristic	Value
C	0.45%
Mn	0.92%
P	0.010%
S	0.048%
Si	0.19%
Cu	0.29%
Cr	0.11%
Ni	0.16%
Mo	0.061%
V	0.000%
Cb	0.000%
Sn	0.009%
Al	0.001%
Yield Strength test 1	70.1ksi
Tensile Strength test 1	109.6ksi
Elongation test 1	14%
Elongation Gage Lgth test 1	8IN
Tensile to Yield ratio test1	1.56
Bend Test 1	Passed

Characteristic	Value
Bend Test Diameter	2.188IN

Characteristic Value

The Following is true of the material represented by this MTR:

**Material is fully killed*
**100% melted and rolled in the USA*
**EN10204:2004 3.1 compliant*
**Contains no weld repair*
**Contains no Mercury contamination*
**Manufactured in accordance with the latest version of the plant quality manual*
**Meets the "Buy America" requirements of 23 CFR635.410, 49 CFR 661*
**Warning: This product can expose you to chemicals which are known to the State of California to cause cancer, birth defects or other reproductive harm. For more information go to www.P65Warnings.ca.gov*

REMARKS :

CMC STEEL TEXAS
1 STEEL MILL DRIVE
SEGUIN TX 78155-7510

CERTIFIED MILL TEST REPORT

For additional copies call
830-372-8771

We hereby certify that the test results presented here are accurate and conform to the reported grade specification

Rolando A Davila
Quality Assurance Manager

HEAT NO.:3111183 SECTION: REBAR 13MM (#4) 20'0" 420/60 GRADE: ASTM A615-20 Gr 420/60 ROLL DATE: 12/19/2021 MELT DATE: 12/08/2021 Cert. No.: 83693955 / 111183A130	SOLD TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	SHIP TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	Delivery#: 83693955 BOL#: 74533988 CUST PO#: 904440 CUST P/N: DLVRY LBS / HEAT: 15337.000 LB DLVRY PCS / HEAT: 1148 EA

Characteristic	Value
C	0.43%
Mn	0.83%
P	0.011%
S	0.039%
Si	0.16%
Cu	0.36%
Cr	0.12%
Ni	0.18%
Mo	0.056%
V	0.000%
Cb	0.001%
Sn	0.014%
Al	0.002%
Yield Strength test 1	64.4ksi
Tensile Strength test 1	102.6ksi
Elongation test 1	15%
Elongation Gage Lgth test 1	8IN
Tensile to Yield ratio test1	1.59
Bend Test 1	Passed

Characteristic	Value
Bend Test Diameter	1.750IN

Characteristic	Value

The Following is true of the material represented by this MTR:

**Material is fully killed*
**100% melted and rolled in the USA*
**EN10204:2004 3.1 compliant*
**Contains no weld repair*
**Contains no Mercury contamination*
**Manufactured in accordance with the latest version of the plant quality manual*
**Meets the "Buy America" requirements of 23 CFR635.410, 49 CFR 661*
**Warning: This product can expose you to chemicals which are known to the State of California to cause cancer, birth defects or other reproductive harm. For more information go to www.P65Warnings.ca.gov*

REMARKS :

CONCRETE SAMPLING REPORT

Report Number: A1171057.0277
Service Date: 08/07/23
Report Date: 09/20/23
Task: PO# 618981

6198 Imperial Loop
College Station, TX 77845-5765
979-846-3767 Reg No: F-3272

Client

Texas Transportation Institute
Attn: Bill Griffith
TTI Business Office
3135 TAMU
College Station, TX 77843-3135

Project

Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1171057

General Information

Bill w/ TTI requested Terracon to be on site for concrete sampling for the following members: safety barrier. These member(s) are being constructed by TTI. The results of observation(s) for today were reported to Bill at TTI. The Terracon representative arrived on site at 0720 and departed at 0900.

Reinforcing Steel

Reinforcing steel was not previously inspected because n/a.

Concrete Placement

Terracon performed concrete sampling for the following:

Element	Location	Yardage	Supplier	Mix ID	Mix Description
Other	Safety Barrier	2	Texcrete	TXC3600	Normal Weight, 3600-psi, air-entrained concrete

Placement Method: Direct Discharge

Tests Performed

The following tests were performed and were in accordance with project specifications: Slump, Air Content, Temperature, Unit Weight.
A total of 4 compressive strength specimens [1 Sets] for lab curing were fabricated. 4 compressive strength specimens (Set No(s) 1) for field curing were fabricated.

Additional Comments

Compliance

Compliance Statement

Based on our observations, cast-in-place concrete construction activities at the above-referenced locations appeared to be completed in general accordance with the project plans and specifications.

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: Bill at TTI
Contractor: TTI
Start/Stop: 0700-0945

Report Distribution:
(1) Texas Transportation Institute, Bill Griffith
(1) Texas Transportation Institute, Adam Mayer

Reviewed By:
Alexander Dunigan, P.E.
Project Manager

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0277
Service Date: 08/07/23
Report Date: 09/20/23
Task: PO# 618981

Terracon
6198 Imperial Loop
College Station, TX 77845-5765
979-846-3767 Reg No: F-3272

Client
Texas Transportation Institute
Attn: Bill Griffith
TTI Business Office
3135 TAMU
College Station, TX 77843-3135

Project - A1171057
Riverside Campus
Riverside Campus
Bryan, TX

Permit No.: N/A

Material Information

Specified Strength: 3,600 psi @ 28 days

Mix ID: TXC 3600
Supplier: Texcrete
Batch Time: 0756 **Plant:** Bryan
Truck No.: 115 **Ticket No.:** 81131

Sample Information

Sample Date: 08/07/23 **Sample Time:** 0845
Sampled By: Matcek, James
Weather Conditions: Cloudy
Accumulative Yards: 2.0 **Batch Size (cy):** 2
Placement Method: Direct Discharge
Water Added Before (gal): 5
Water Added After (gal): 0
Sample Location: Safety Barrier
Placement Location: Safety Barrier
Sample Description: 6-inch diameter cylinders

Field Test Data

Test	Result	Specification
Slump (in):	4 1/2	
Air Content (%):	2.4	
Concrete Temp. (F):	89	
Ambient Temp. (F):	83	
Plastic Unit Wt. (pcf):	148.3	
Yield (Cu. Yds.):		

Laboratory Test Data

Set No.	Spec ID	Cyl. Cond.	Avg Diam. (in)	Area (sq in)	Date Received	Date Tested	Age at Test (days)	Max Load (lbs)	Comp Strength (psi)	Frac Type	Tested By
1	A	Good	6.00	28.27		09/20/23	44 F	103,540	3,660	2	DD
1	B	Good	6.00	28.27		09/20/23	44 F	120,510	4,260	2	DD
1	C	Good	6.00	28.27		09/20/23	44 F	109,900	3,890	2	DD
1	D						Hold				

Initial Cure: Outside in shade **Final Cure:** Field Cured

Comments: **F = Field Cured**
Note: Reported air content does not include Aggregate Correction Factor (ACF).

Samples Made By: Terracon

Services: Obtain samples of fresh concrete at the placement locations (ASTM C 172), perform required field tests and cast, cure, and test compressive strength samples (ASTM C 31, C 39, C 1231).

Terracon Rep.: Matcek, James
Start/Stop: 0700-0945
Reported To: Bill at TTI
Contractor: TTI
Report Distribution:
(1) Texas Transportation Institute, Bill Griffith (1) Texas Transportation Institute, Adam Mayer

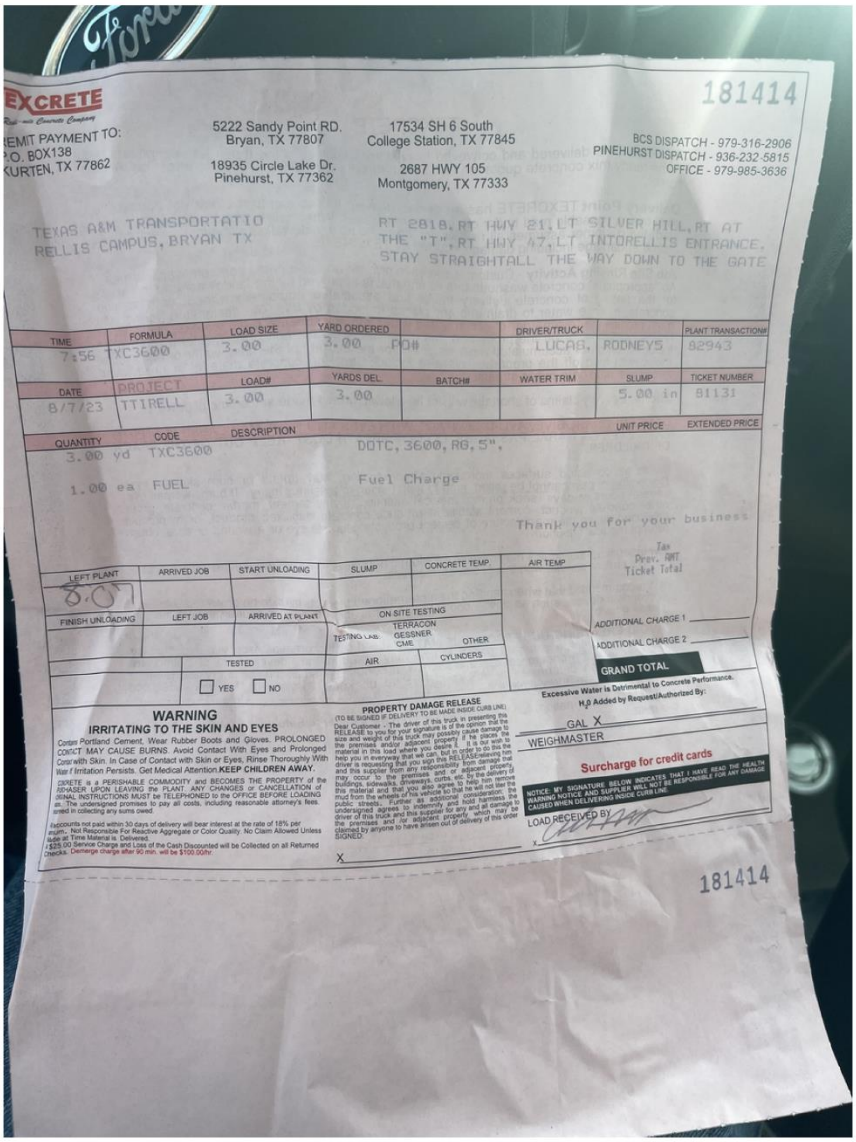
Reviewed By: Alexander Dunigan, P.E.
Project Manager

Test Methods: ASTM C 31, ASTM C143, ASTM C231, ASTM C1064

Photo Log

Report Number: A1171057.0277
Service Date: 08/07/23
Report Date: 09/20/23
Task: PO# 618981

Terracon
6198 Imperial Loop
College Station, TX 77845-5765
979-846-3767 Reg No: F-3272



EXCRETE

181414

REMIT PAYMENT TO:
P.O. BOX138
KURTEN, TX 77862

5222 Sandy Point RD.
Bryan, TX 77807

18935 Circle Lake Dr.
Pinehurst, TX 77362

17534 SH 6 South
College Station, TX 77845

2687 HWY 105
Montgomery, TX 77333

BCS DISPATCH - 979-316-2906
PINEHURST DISPATCH - 936-232-5815
OFFICE - 979-985-3636

TEXAS A&M TRANSPORTATIO
RELLIS CAMPUS, BRYAN TX

RT 2818, RT HWY 21, LT SILVER HILL, RT AT THE "T", RT HWY 47, LT INTORELLIS ENTRANCE. STAY STRAIGHTALL THE WAY DOWN TO THE GATE

TIME	FORMULA	LOAD SIZE	YARD ORDERED		DRIVER/TRUCK		PLANT TRANSACTION#
7:56	TXC3600	3.00	3.00 PO#		LUCAS,	RODNEY5	82943
DATE	PROJECT	LOAD#	YARDS DEL.	BATCH#	WATER TRIM	SLUMP	TICKET NUMBER
8/7/23	TTIRELL	3.00	3.00			5.00 in	81131

QUANTITY	CODE	DESCRIPTION	UNIT PRICE	EXTENDED PRICE
3.00 yd	TXC3600	DOTC, 3600, RG, 5",		
1.00 ea	FUEL	Fuel Charge		

Thank you for your business

LEFT PLANT	ARRIVED JOB	START UNLOADING	SLUMP	CONCRETE TEMP.	AIR TEMP
8:07					
FINISH UNLOADING	LEFT JOB	ARRIVED AT PLANT	ON SITE TESTING		
			TESTING LAB: TERRACON GIESSNER CMS OTHER		
TESTED			AIR	CYLINDERS	
☐ YES ☐ NO					

Tax
Prev. Amt.
Ticket Total
ADDITIONAL CHARGE 1
ADDITIONAL CHARGE 2
GRAND TOTAL

Excessive Water is Detrimental to Concrete Performance.
H2O Added by Request/Authorized By:
GAL X
WEIGHMASTER

Surcharge for credit cards

NOTICE: MY SIGNATURE BELOW INDICATES THAT I HAVE READ THE HEALTH WARNING NOTICE AND SUPPLIER WILL NOT BE RESPONSIBLE FOR ANY DAMAGE CAUSED WHEN DELIVERING INSIDE CURB LINE.

LOAD RECEIVED BY

WARNING
IRRITATING TO THE SKIN AND EYES
Contain Portland Cement. Wear Rubber Boots and Gloves. PROLONGED CONTACT MAY CAUSE BURNS. Avoid Contact With Eyes and Prolonged Contact with Skin. In Case of Contact with Skin or Eyes, Rinse Thoroughly With Water. If Irritation Persists, Get Medical Attention. **KEEP CHILDREN AWAY.**

CONCRETE is a PERISHABLE COMMODITY and BECOMES THE PROPERTY of the PURCHASER UPON LEAVING the PLANT. ANY CHANGES or CANCELLATION of ORIGINAL INSTRUCTIONS MUST be TELEPHONED to the OFFICE BEFORE LOADING as. The undersigned promises to pay all costs, including reasonable attorney's fees. avoid in collecting any sums owed.

Accounts not paid within 30 days of delivery will bear interest at the rate of 18% per annum. Not Responsible For Reactive Aggregate or Color Quality. No Claim Allowed Unless Made at Time Material is Delivered.
A $25.00 Service Charge and Loss of the Cash Discounted will be Collected on all Returned Checks. Demerge charge after 90 min. will be $100.00/hr.

PROPERTY DAMAGE RELEASE
(TO BE SIGNED IF DELIVERY TO BE MADE INSIDE CURB LINE)

Dear Customer - The driver of this truck in presenting this RELEASE to you for your signature is of the opinion that the size and weight of this truck may possibly cause damage to the premises and/or adjacent property if he is ask to material in this load where you desire it put, but in order to do this help you in everyway that we can, but we insist this RELEASE relieving him driver is requesting that you sign this RELEASE relieving him and this supplier from any responsibility from damage that may occur to the premises and/or adjacent property by the delivery of this material and that you also agree to help him remove buildings, sidewalks, driveways, curbs, etc., caused by the delivery mud from the wheels of his vehicle(s). In consideration, the public streets. Further as additional considerations, the undersigned agrees to indemnify and hold harmless the driver of this truck and this supplier for any and all damage to the premises and /or adjacent property which may be claimed by anyone to have arisen out of delivery of this order SIGNED

X

181414

(P1) Batch Ticket

Texas A&M Transportation Institute	QF 7.3-01 Concrete Sampling	Doc. No. QF 7.3-01	Revision Date: 2020-07-29
Quality Form	Revised by: B.L. Griffith Approved by: D. L. Kuhn	Revision: 7	Page: 1 of 1

Project No: 618981 **Casting Date:** 8/7/2023 **Mix Design (psi):** 3600

Name of Technician Taking Sample: Terracon

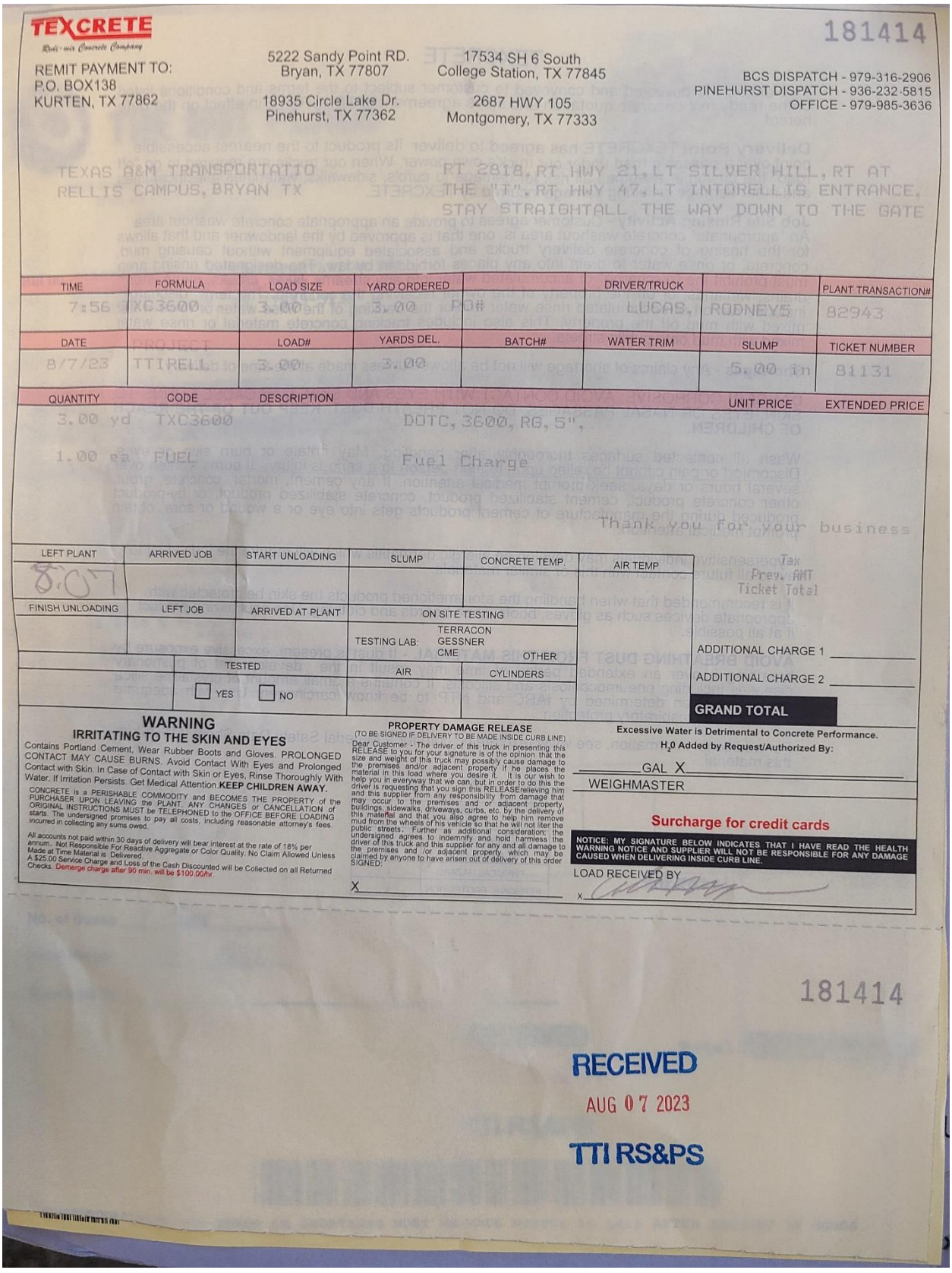
Name of Technician Breaking Sample: Terracon

Signature of Technician Taking Sample: Terracon

Signature of Technician Breaking Sample: Terracon

Load No.	Truck No.	Ticket No.	Location (from concrete map)
T1	Lucas Rodney5	81131	100% of barrier

Load No.	Break Date	Cylinder Age	Total Load (lbs)	Break (psi)	Average



TEXCRETE
Ready-mix Concrete Company

181414

REMIT PAYMENT TO:
P.O. BOX138
KURTEN, TX 77862

5222 Sandy Point RD.
Bryan, TX 77807

18935 Circle Lake Dr.
Pinehurst, TX 77362

17534 SH 6 South
College Station, TX 77845

2687 HWY 105
Montgomery, TX 77333

BCS DISPATCH - 979-316-2906
PINEHURST DISPATCH - 936-232-5815
OFFICE - 979-985-3636

TEXAS A&M TRANSPORTATIO
RELLIS CAMPUS, BRYAN TX

RT 2818, RT HWY 21, LT SILVER HILL, RT AT
THE "T", RT HWY 47, LT INTORELLIS ENTRANCE,
STAY STRAIGHTALL THE WAY DOWN TO THE GATE

TIME	FORMULA	LOAD SIZE	YARD ORDERED		DRIVER/TRUCK		PLANT TRANSACTION#
7:56	TXC3600	3.00	3.00	PO#	LUCAS,	RODNEY5	82943
DATE	**PROJECT**	**LOAD#**	**YARDS DEL.**	**BATCH#**	**WATER TRIM**	**SLUMP**	**TICKET NUMBER**
8/7/23	TTIRELL	3.00	3.00			5.00 in	81131

QUANTITY	CODE	DESCRIPTION	UNIT PRICE	EXTENDED PRICE
3.00 yd	TXC3600	DOTC, 3600, RG, 5",		
1.00 ea	FUEL	Fuel Charge		

Thank you for your business

Tax
Prev. AMT
Ticket Total

LEFT PLANT	ARRIVED JOB	START UNLOADING	SLUMP	CONCRETE TEMP.	AIR TEMP
8:07					
FINISH UNLOADING	**LEFT JOB**	**ARRIVED AT PLANT**	**ON SITE TESTING**		
			TESTING LAB: TERRACON GESSNER CME OTHER		
TESTED			**AIR**	**CYLINDERS**	
☐ YES ☐ NO					

ADDITIONAL CHARGE 1 _____

ADDITIONAL CHARGE 2 _____

GRAND TOTAL

WARNING
IRRITATING TO THE SKIN AND EYES

Contains Portland Cement. Wear Rubber Boots and Gloves. PROLONGED CONTACT MAY CAUSE BURNS. Avoid Contact With Eyes and Prolonged Contact with Skin. In Case of Contact with Skin or Eyes, Rinse Thoroughly With Water. If Irritation Persists, Get Medical Attention. **KEEP CHILDREN AWAY.**

CONCRETE is a PERISHABLE COMMODITY and BECOMES THE PROPERTY of the PURCHASER UPON LEAVING the PLANT. ANY CHANGES or CANCELLATION of ORIGINAL INSTRUCTIONS MUST be TELEPHONED to the OFFICE BEFORE LOADING starts. The undersigned promises to pay all costs, including reasonable attorney's fees, incurred in collecting any sums owed.

All accounts not paid within 30 days of delivery will bear interest at the rate of 18% per annum. Not Responsible For Reactive Aggregate or Color Quality. No Claim Allowed Unless Made at Time Material is Delivered.
A $25.00 Service Charge and Loss of the Cash Discounted will be Collected on all Returned Checks. Demerge charge after 90 min. will be $100.00/hr.

PROPERTY DAMAGE RELEASE
(TO BE SIGNED IF DELIVERY TO BE MADE INSIDE CURB LINE)

Dear Customer - The driver of this truck in presenting this RELEASE to you for your signature is of the opinion that the size and weight of this truck may possibly cause damage to the premises and/or adjacent property if he places the material in this load where you desire it. It is our wish to help you in everyway that we can, but in order to do this the driver is requesting that you sign this RELEASEreleiving him and this supplier from any responsibility from damage that may occur to the premises and or adjacent property, buildings, sidewalks, driveways, curbs, etc. by the delivery of this material and that you also agree to help him remove mud from the wheels of his vehicle so that he will not liter the public streets. Further as additional consideration: the undersigned agrees to indemnify and hold harmless the driver of this truck and this supplier for any and all damage to the premises and /or adjacent property which may be claimed by anyone to have arisen out of delivery of this order SIGNED.

X _____

Excessive Water is Detrimental to Concrete Performance.
H_2O Added by Request/Authorized By:

_____GAL X _____
WEIGHMASTER

Surcharge for credit cards

NOTICE: MY SIGNATURE BELOW INDICATES THAT I HAVE READ THE HEALTH WARNING NOTICE AND SUPPLIER WILL NOT BE RESPONSIBLE FOR ANY DAMAGE CAUSED WHEN DELIVERING INSIDE CURB LINE.

LOAD RECEIVED BY

X _____

181414

RECEIVED
AUG 07 2023
TTI RS&PS

CONCRETE SAMPLING REPORT

Report Number: A1171057.0277
Service Date: 08/07/23
Report Date: 09/20/23
Task: PO# 618981

6198 Imperial Loop
College Station, TX 77845-5765
979-846-3767 Reg No: F-3272

Client

Texas Transportation Institute
Attn: Bill Griffith
TTI Business Office
3135 TAMU
College Station, TX 77843-3135

Project

Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1171057

General Information

Bill w/ TTI requested Terracon to be on site for concrete sampling for the following members: safety barrier. These member(s) are being constructed by TTI. The results of observation(s) for today were reported to Bill at TTI. The Terracon representative arrived on site at 0720 and departed at 0900.

Reinforcing Steel

Reinforcing steel was not previously inspected because n/a.

Concrete Placement

Terracon performed concrete sampling for the following:

Element	Location	Yardage	Supplier	Mix ID	Mix Description
Other	Safety Barrier	2	Texcrete	TXC3600	Normal Weight, 3600-psi, air-entrained concrete

Placement Method: Direct Discharge

Tests Performed

The following tests were performed and were in accordance with project specifications: Slump, Air Content, Temperature, Unit Weight.
A total of 4 compressive strength specimens [1 Sets] for lab curing were fabricated. 4 compressive strength specimens (Set No(s) 1) for field curing were fabricated.

Additional Comments

Compliance

Compliance Statement

Based on our observations, cast-in-place concrete construction activities at the above-referenced locations appeared to be completed in general accordance with the project plans and specifications.

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: Bill at TTI
Contractor: TTI
Start/Stop: 0700-0945

Report Distribution:
(1) Texas Transportation Institute, Bill Griffith
(1) Texas Transportation Institute, Adam Mayer

Reviewed By:
Alexander Dunigan, P.E.
Project Manager

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0277
Service Date: 08/07/23
Report Date: 09/20/23
Task: PO# 618981

Terracon
6198 Imperial Loop
College Station, TX 77845-5765
979-846-3767 Reg No: F-3272

Client
Texas Transportation Institute
Attn: Bill Griffith
TTI Business Office
3135 TAMU
College Station, TX 77843-3135

Project - A1171057
Riverside Campus
Riverside Campus
Bryan, TX

Permit No.: N/A

Material Information
Specified Strength: 3,600 psi @ 28 days

Mix ID: TXC 3600
Supplier: Texcrete
Batch Time: 0756 **Plant:** Bryan
Truck No.: 115 **Ticket No.:** 81131

Sample Information
Sample Date: 08/07/23 **Sample Time:** 0845
Sampled By: Matcek, James
Weather Conditions: Cloudy
Accumulative Yards: 2.0 **Batch Size (cy):** 2
Placement Method: Direct Discharge
Water Added Before (gal): 5
Water Added After (gal): 0
Sample Location: Safety Barrier
Placement Location: Safety Barrier
Sample Description: 6-inch diameter cylinders

Field Test Data

Test	Result	Specification
Slump (in):	4 1/2	
Air Content (%):	2.4	
Concrete Temp. (F):	89	
Ambient Temp. (F):	83	
Plastic Unit Wt. (pcf):	148.3	
Yield (Cu. Yds.):		

Laboratory Test Data

Set No.	Spec ID	Cyl. Cond.	Avg Diam. (in)	Area (sq in)	Date Received	Date Tested	Age at Test (days)	Max Load (lbs)	Comp Strength (psi)	Frac Type	Tested By
1	A	Good	6.00	28.27		09/20/23	44 F	103,540	3,660	2	DD
1	B	Good	6.00	28.27		09/20/23	44 F	120,510	4,260	2	DD
1	C	Good	6.00	28.27		09/20/23	44 F	109,900	3,890	2	DD
1	D						Hold				

Initial Cure: Outside in shade **Final Cure:** Field Cured

Comments: **F = Field Cured**
Note: Reported air content does not include Aggregate Correction Factor (ACF).

Samples Made By: Terracon
Services: Obtain samples of fresh concrete at the placement locations (ASTM C 172), perform required field tests and cast, cure, and test compressive strength samples (ASTM C 31, C 39, C 1231).

Terracon Rep.: Matcek, James
Start/Stop: 0700-0945
Reported To: Bill at TTI
Contractor: TTI
Report Distribution:
(1) Texas Transportation Institute, Bill Griffith (1) Texas Transportation Institute, Adam Mayer

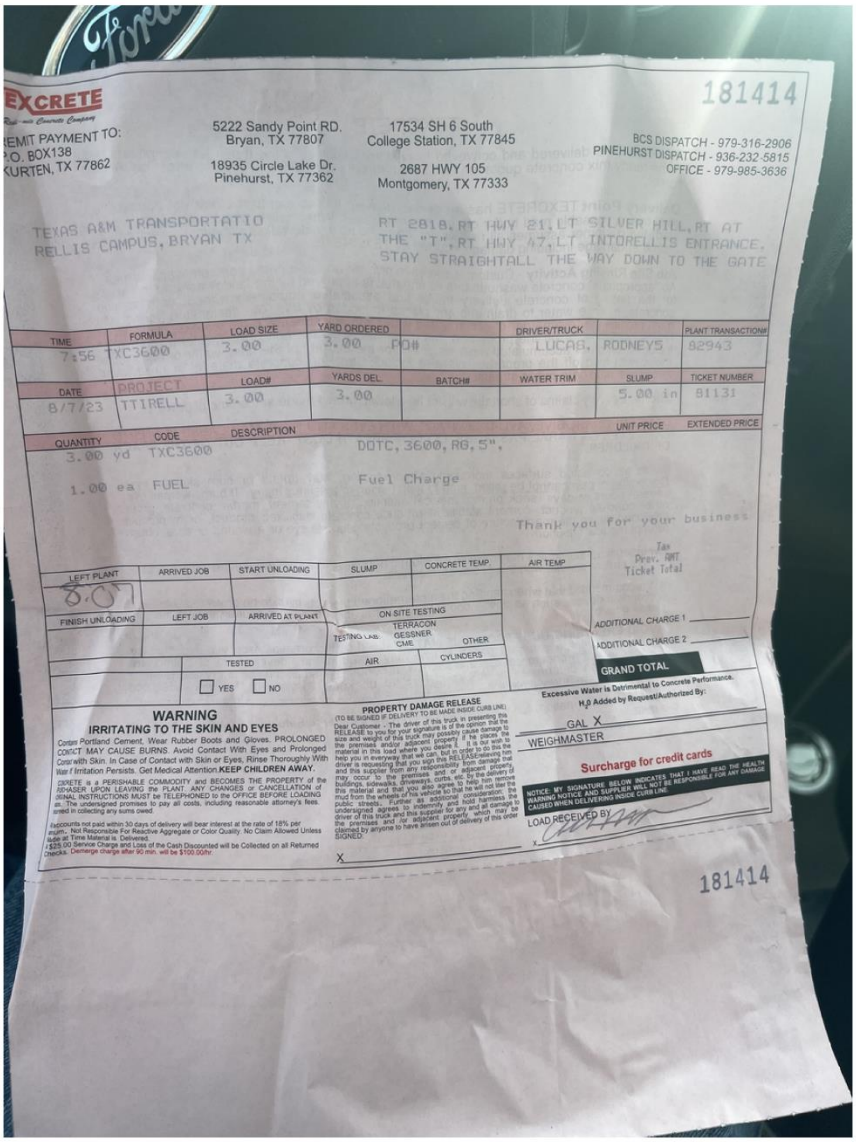
Reviewed By: Alexander Dunigan, P.E.
Project Manager

Test Methods: ASTM C 31, ASTM C143, ASTM C231, ASTM C1064

Photo Log

Report Number: A1171057.0277
Service Date: 08/07/23
Report Date: 09/20/23
Task: PO# 618981

Terracon
6198 Imperial Loop
College Station, TX 77845-5765
979-846-3767 Reg No: F-3272



EXCRETE

181414

REMIT PAYMENT TO:
P.O. BOX138
KURTEN, TX 77862

5222 Sandy Point RD.
Bryan, TX 77807

18935 Circle Lake Dr.
Pinehurst, TX 77362

17534 SH 6 South
College Station, TX 77845

2687 HWY 105
Montgomery, TX 77333

BCS DISPATCH - 979-316-2906
PINEHURST DISPATCH - 936-232-5815
OFFICE - 979-985-3636

TEXAS A&M TRANSPORTATIO
RELLIS CAMPUS, BRYAN TX

RT 2818, RT HWY 21, LT SILVER HILL, RT AT THE "T", RT HWY 47, LT INTORELLIS ENTRANCE. STAY STRAIGHTALL THE WAY DOWN TO THE GATE

TIME	FORMULA	LOAD SIZE	YARD ORDERED		DRIVER/TRUCK		PLANT TRANSACTION#
7:56	TXC3600	3.00	3.00 PO#		LUCAS,	RODNEY5	82943
DATE	PROJECT	LOAD#	YARDS DEL.	BATCH#	WATER TRIM	SLUMP	TICKET NUMBER
8/7/23	TTIRELL	3.00	3.00			5.00 in	81131

QUANTITY	CODE	DESCRIPTION	UNIT PRICE	EXTENDED PRICE
3.00 yd	TXC3600	DOTC, 3600, RG, 5",		
1.00 ea	FUEL	Fuel Charge		

Thank you for your business

LEFT PLANT	ARRIVED JOB	START UNLOADING	SLUMP	CONCRETE TEMP.	AIR TEMP
8:07					
FINISH UNLOADING	LEFT JOB	ARRIVED AT PLANT	ON SITE TESTING		
			TESTING LAB: TERRACON GIESSNER CMS OTHER		
TESTED			AIR	CYLINDERS	
☐ YES ☐ NO					

Tax
Prev. RMT
Ticket Total
ADDITIONAL CHARGE 1
ADDITIONAL CHARGE 2
GRAND TOTAL

Excessive Water is Detrimental to Concrete Performance.
H2O Added by Request/Authorized By:
GAL X
WEIGHMASTER

Surcharge for credit cards

NOTICE: MY SIGNATURE BELOW INDICATES THAT I HAVE READ THE HEALTH WARNING NOTICE AND SUPPLIER WILL NOT BE RESPONSIBLE FOR ANY DAMAGE CAUSED WHEN DELIVERING INSIDE CURB LINE.

LOAD RECEIVED BY

WARNING
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X

181414

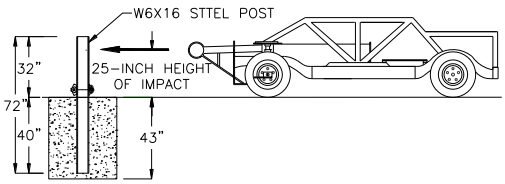
(P1) Batch Ticket

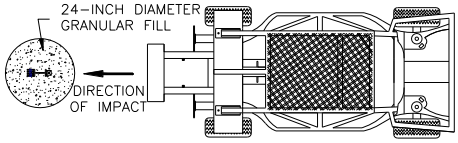
Dynamic Test Setup

Post-Test Photo of post

Static Load Test

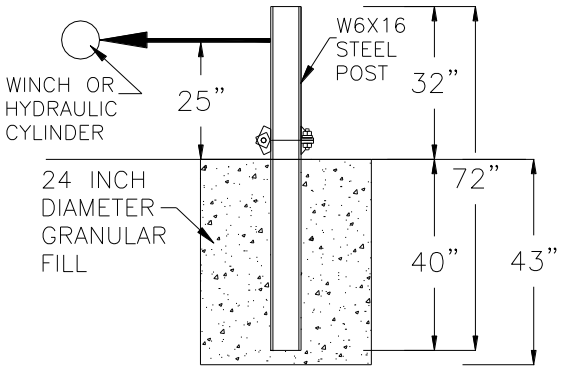
Post-Test Photo





Dynamic Test Installation Details

Comparison of Load vs. Displacement



Static Load Test Installation Details

Date	2020-02-02
Test Facility and Site Location	TTI Proving Ground, 3100 SH 47, Bryan, TX 77807
In Situ Soil Description (ASTM D2487)	Sandy gravel with silty fines
Fill Material Description (ASTM D2487) and sieve analysis	Type 1 Grade D Crushed Concrete Road Base
Description of Fill Placement Procedure	12-inch lifts tamped with a pneumatic compactor for 20 sec
Bogie Weight	2020 lb
Impact Velocity	19.2 mph

Texas A&M Transportation Institute	LF-SST1 Crushed Concrete Soil Strength Performance Test Record	Doc. No. LF-SST2	Revision Date: 2021-04-05
Laboratory Form	Revised by: B.L.Griffith Approved by: D. L. Kuhn	Revision: 0	Page: 1 of 1

Crushed Concrete Soil Strength Performance Test

MASH, Appendix B

Project Number: 618981-01-1

Date of Crash Test: 2023-09-21

Post No. 1 of 1 Fill Moisture: n/a % Native Moisture: n/a %

Temperature: 81 ° F Humidity: 89%

File Name: Soil Strength_54.ASC

Displacement (in.)	*Pull Force (Lbf)	Minimum Force (Lbf)	Pass / Fail
5	8,300	4420	P
10	9,909	4981	P
15	10,879	5282	P

*Do not exceed 10,000 lbf

Test Post Location:	15	ft	☒ South	☐ North	of terminal post
		ft	☐ East	☒ West	of terminal post

APPENDIX C. MASH TEST 3-21 (CRASH TEST 618981-01-1)

C.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2023-09-21 Test No.: 618981-01-1 VIN No.: 1C6RRFT2KS742190

Year: 2019 Make: RAM Model: 1500

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

Tread Type: Highway Odometer: 104522

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

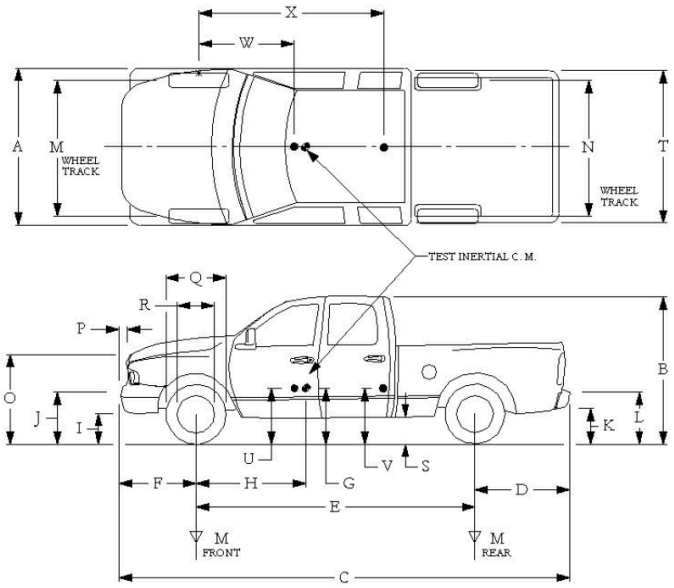
NOTES: None

Engine Type: V-8
Engine CID: 5.7 liter

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

Optional Equipment:
None

Dummy Data:
Type:
Mass:
Seat Position:



Geometry: inches

A	78.50	F	40.00	K	20.00	P	3.00	U	26.75
B	74.00	G	28.62	L	30.00	Q	30.50	V	30.25
C	227.50	H	61.49	M	68.50	R	18.00	W	61.50
D	44.00	I	11.75	N	68.00	S	13.00	X	79.00
E	140.50	J	27.00	O	46.00	T	77.00		

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

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

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2918	2829	2829
Back	3900	M_{rear}	2055	2202	2202
Total	6700	M_{Total}	4973	5031	5031

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

Mass Distribution:
lb LF: 1426 RF: 1403 LR: 1115 RR: 1087

Figure C.1. Vehicle Properties for Test 618981-01-1.

Date:	2023-09-21	Test No.:	618981-01-1	VIN No.:	1C6RRFT2KS742190
Year:	2019	Make:	RAM	Model:	1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage		Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width** (CDC)	Max*** Crush								
1	AT FRONT BUMPER	16	24	40	-	-	-	-	-	-	+13
2	ABOVE FT BUMPER	18	9	57	-	-	-	-	-	-	68
	Measurements recorded										
	☑ **inches or** ☐ **mm**										

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

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

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

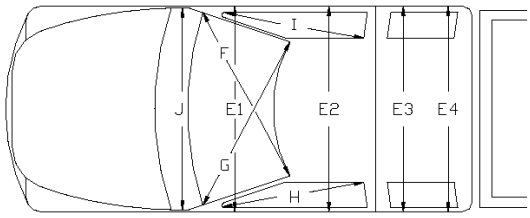
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

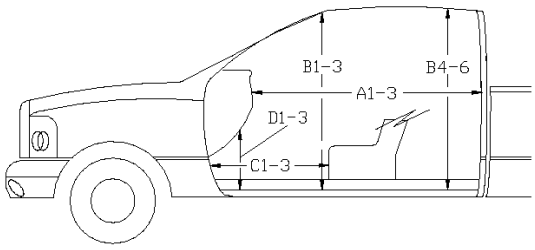
***Measure and document on the vehicle diagram the location of the maximum crush.

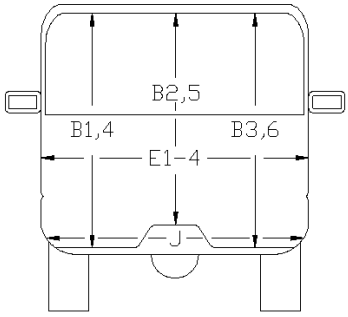
Note: Use as many lines/columns as necessary to describe each damage profile.

Figure C.2. Exterior Crush Measurements for Test 618981-01-1.

Date:	2023-09-21	Test No.:	618981-01-1	VIN No.:	1C6RRFT2KS742190
Year:	2019	Make:	RAM	Model:	1500







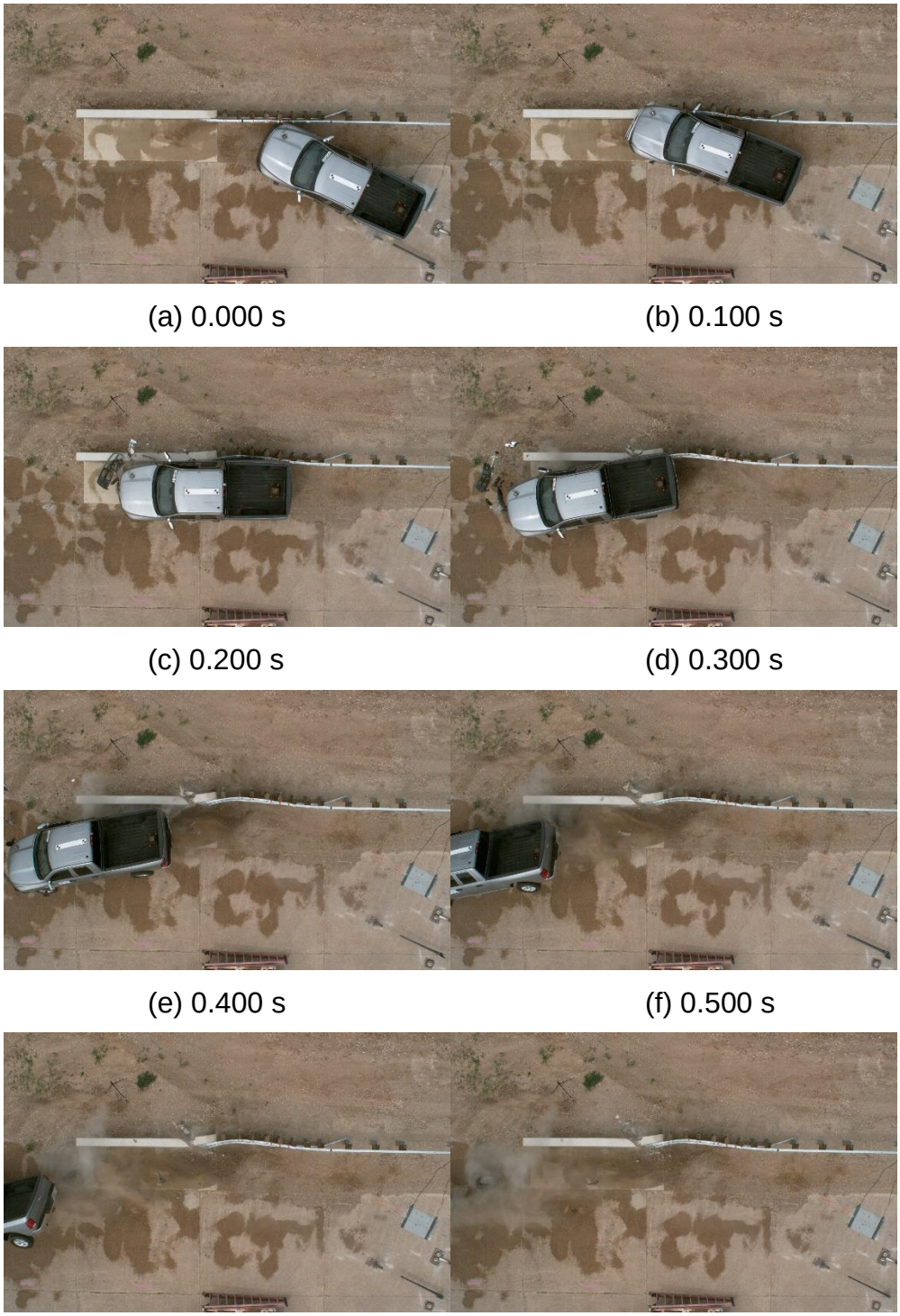
*Lateral area across the cab from driver's side kickpanel to passenger's side kickpanel.

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	65.00	65.00	0.00
A2	63.00	63.00	0.00
A3	65.50	65.50	0.00
B1	45.00	45.00	0.00
B2	38.00	38.00	0.00
B3	45.00	45.00	0.00
B4	39.50	39.50	0.00
B5	43.00	43.00	0.00
B6	39.50	39.50	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	25.00	-1.00
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
D3	11.50	10.50	-1.00
E1	58.50	59.25	0.75
E2	63.50	64.00	0.50
E3	63.50	63.50	0.00
E4	63.50	63.50	0.00
F	59.00	59.00	0.00
G	59.00	59.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	25.00	24.25	-0.75

Figure C.3. Occupant Compartment Measurements for Test 618981-01-1.

C.2. SEQUENTIAL PHOTOGRAPHS



(a) 0.000 s (b) 0.100 s

(c) 0.200 s (d) 0.300 s

(e) 0.400 s (f) 0.500 s

(g) 0.600 s (h) 0.700 s

Figure C.4. Sequential Photographs for Test 618981-01-1 (Overhead Views).

(a) 0.000 s (b) 0.100 s

(c) 0.200 s (d) 0.300 s

(e) 0.400 s (f) 0.500 s

(g) 0.600 s (h) 0.700 s

Figure C.5. Sequential Photographs for Test 618981-01-1 (Frontal Views).

(a) 0.000 s (b) 0.100 s

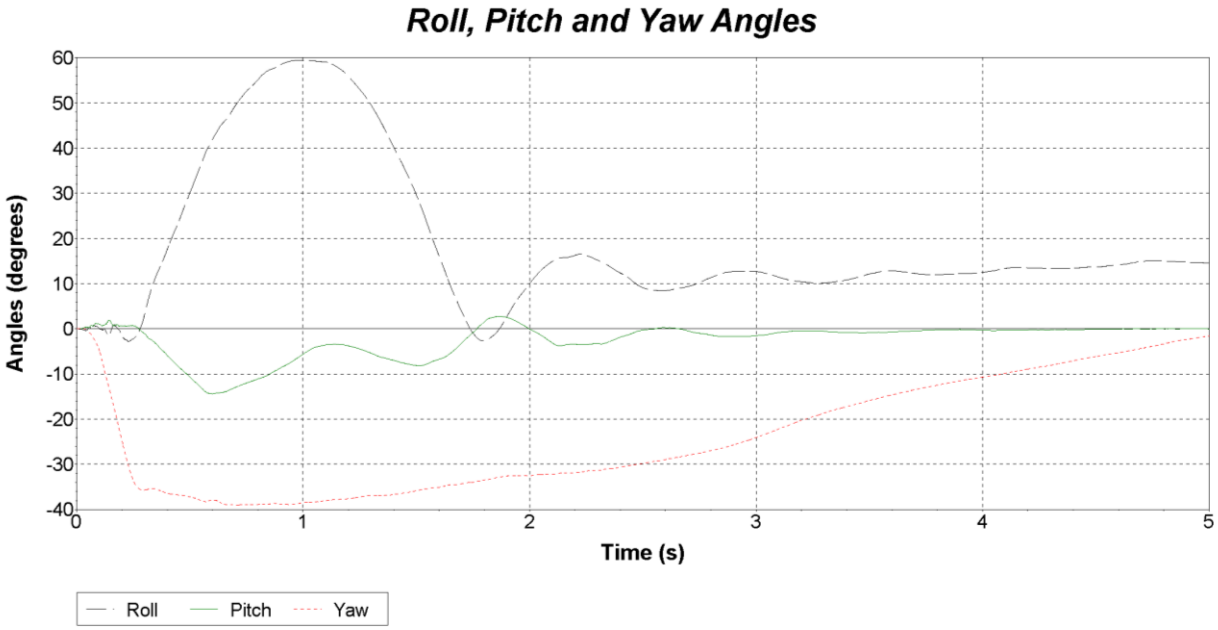
(c) 0.200 s (d) 0.300 s

(e) 0.400 s (f) 0.500 s

(g) 0.600 s (h) 0.700 s

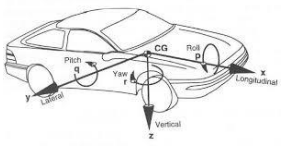
Figure C.6. Sequential Photographs for Test 618981-01-1 (Rear Views).

C.3. VEHICLE ANGULAR DISPLACEMENTS



Axes are vehicle-fixed.
Sequence for determining orientation:

1. Yaw.
2. Pitch.
3. Roll.



Test Number: 618981-01-1
Test Standard Test Number: *MASH* Test 3-21
Test Article: Shortened Transition
Test Vehicle: 2019 RAM 1500
Inertial Mass: 5031lbs
Gross Mass: 5031 lbs
Impact Speed: 63.2 mi/h
Impact Angle: 25.1°

Figure C.7. Vehicle Angular Displacements for Test 618981-01-1.

C.4. VEHICLE ACCELERATIONS

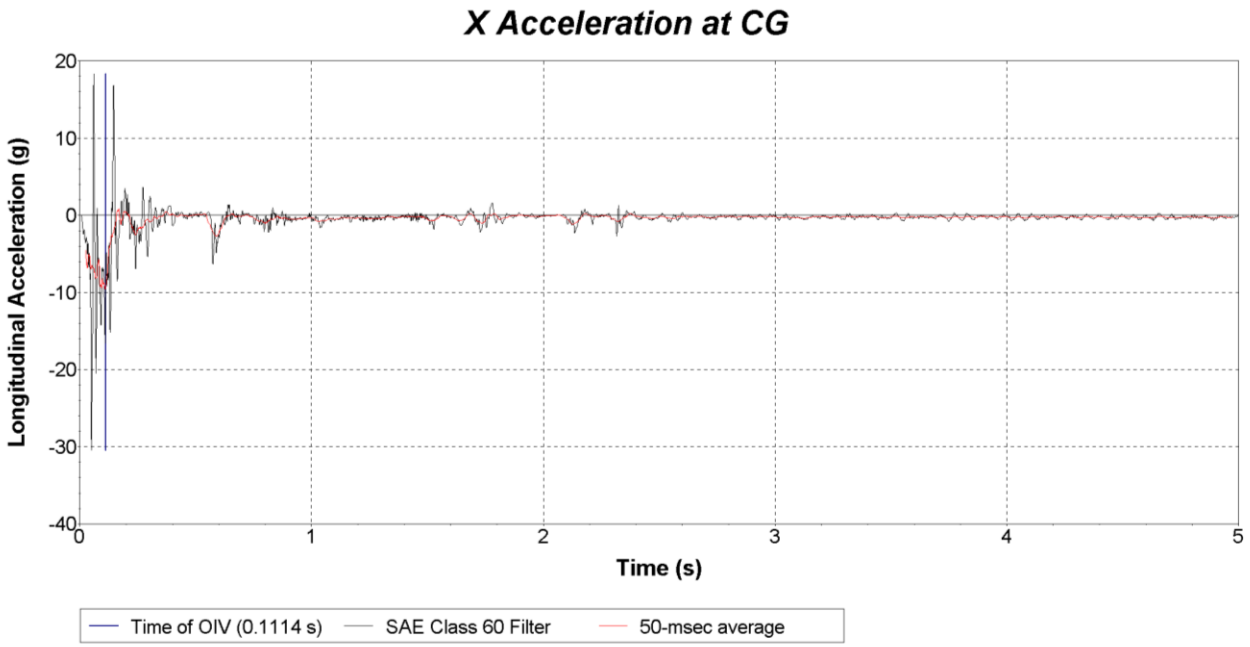


Figure C.8. Vehicle Longitudinal Accelerometer Trace for Test 618981-01-1 (Accelerometer Located at Center of Gravity).

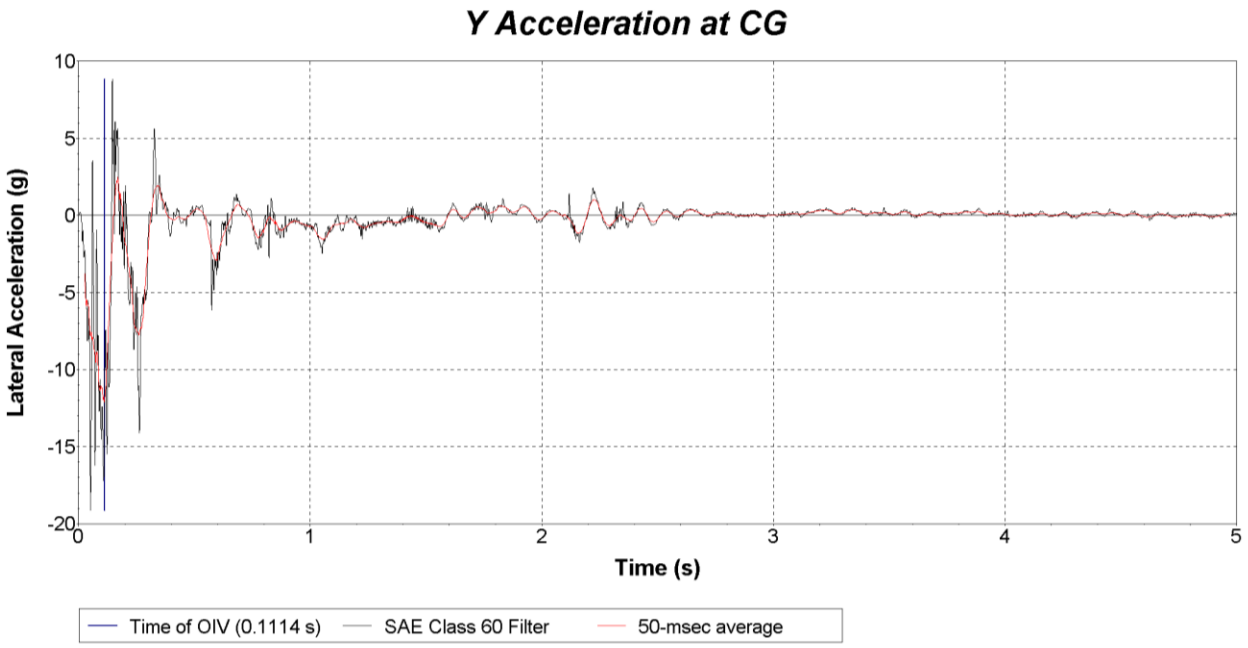


Figure C.9. Vehicle Lateral Accelerometer Trace for Test 618981-01-1 (Accelerometer Located at Center of Gravity).

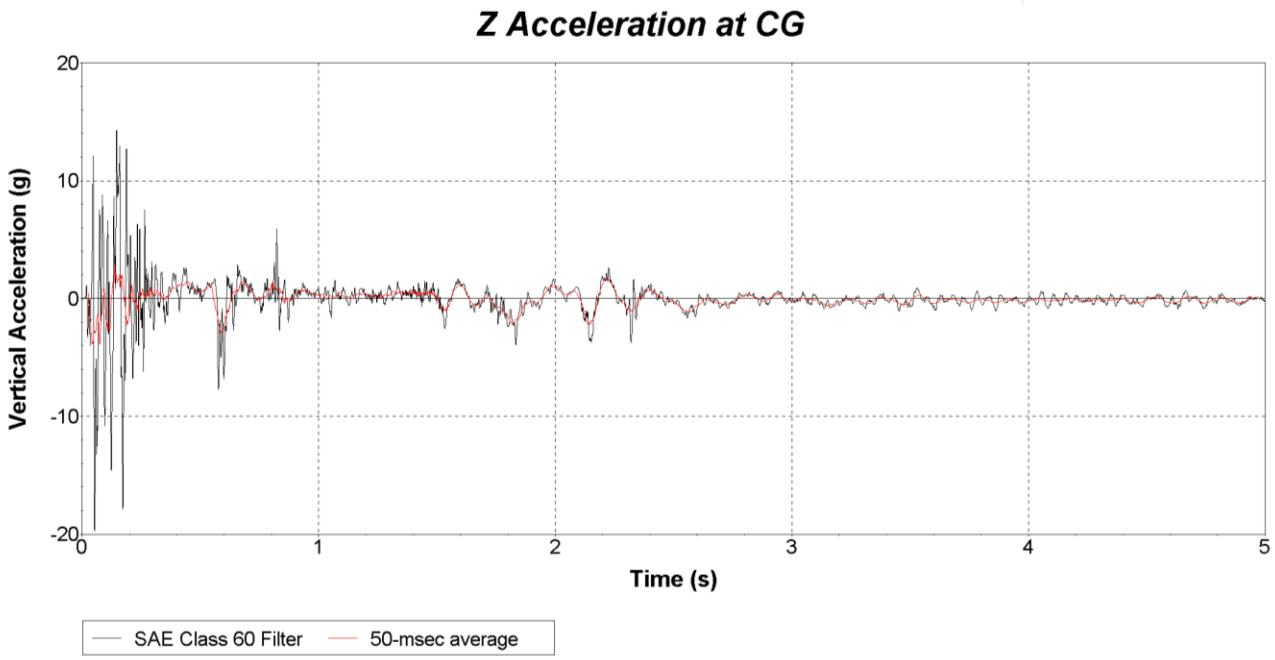


Figure C.10. Vehicle Vertical Accelerometer Trace for Test 618981-01-1 (Accelerometer Located at Center of Gravity)