Texas A&M Transportation Institute
Proving Ground

Test Report No. 9-1531-R2B

EVALUATION OF LOWER AND UPPER RAIL ELEMENTS WITH MIDWEST GUARDRAIL SYSTEM TO ADDRESS MOTORCYCLE SAFETY

Sponsored by the

Motorcycle Safety Pooled Fund
and the
Texas Department of Transportation

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ACCREDITED
ISO 17025 Laboratory
Testing Certificate # 2821.01

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-24/9-1531-R2B		

4. Title and Subtitle	5. Report Date
EVALUATION OF LOWER AND UPPER RAIL ELEMENTS WITH MIDWEST GUARDRAIL SYSTEM TO ADDRESS MOTORCYCLE SAFETY	Submitted: December 2023
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Nathan D. Schulz, Roger Bligh, and Brianna Bastin	Test Report No. 9-1531-R2B
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Texas A&M Transportation Institute Proving Ground The Texas A&M University System College Station, Texas 77843-3135	11. Contract or Grant No. Contract 9-1531
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Texas Department of Transportation Research and Technology Implementation Office 125 E. 11th Street Austin, TX 78701-2483	Technical Report: September 2023–November 2023
	14. Sponsoring Agency Code

15. Supplementary Notes

Project sponsored by the Texas Department of Transportation and the Federal Highway Administration.

Project Title: Development and Evaluation of Roadside Safety Systems for Motorcyclists

16. Abstract

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

1. ***MASH* Test 3-10:** An 1100C vehicle weighing 2420 lb impacting the longitudinal barriers at 25 degrees while traveling at 62 mi/h.
2. ***MASH* Test 3-11:** A 2270P vehicle weighing 5000 lb impacting the longitudinal barriers at 25 degrees while traveling at 62 mi/h.

This report provides details on the Enhanced Motorcycle MGS, the crash tests and results, and the performance assessment of the Enhanced Motorcycle MGS for *MASH* TL-3 longitudinal barriers evaluation criteria.

The Enhanced Motorcycle MGS met the performance criteria for *MASH* TL-3 longitudinal barriers.

17. Key Words	18. Distribution Statement
Guardrail, *MASH*, Motorcycle, Crash Test, Steel Post	No restrictions. This document is available to the public through NTIS: National Technical Information Service Alexandria, Virginia https://www.ntis.gov

19. Security Classification. (of this report)	20. Security Classification. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	108	

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Report No. 9-1531-R2B
Contract No.: 9-1531

Sponsored by the

Motorcycle Safety Pooled Fund

and the

Texas Department of Transportation

Submitted: December 2023

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

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ACKNOWLEDGEMENTS

This research project was performed under a pooled fund program, TPF-5(482), between the following States and Agencies. The authors acknowledge and appreciate their guidance and assistance.

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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 tests reported herein was to assess the performance of the Enhanced Motorcycle MGS 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 tests were performed in accordance with *MASH* Test Level 3 (TL-3), which requires two crash tests (as discussed in Chapter 3).

1.1. BACKGROUND

A guardrail system with lower and upper rail elements was previously developed to address motorcycle safety (*2*). The system consisted of a MGS with round wood posts, steel rub rail, and steel cap rail. Figure 1.1 shows the system prior to testing.

Figure 1.1. Wood Post MGS with Motorcycle Rail Elements. (*2*)

The system was evaluated through full-scale crash testing with motorcyclist and vehicle impacts. Sliding ATD impacts and an upright motorcyclist were conducted to evaluate the performance for different motorcyclist impact scenarios. The system indicated the ability to prevent interaction with discrete elements of the guardrail during the sliding and upright impacts. The system showed satisfactory performance for MASH TL-3.

1.2. OBJECTIVE

The goal of this project was to evaluate a steel post MGS with lower and upper rail elements according to MASH TL-3.

Chapter 2. SYSTEM DETAILS

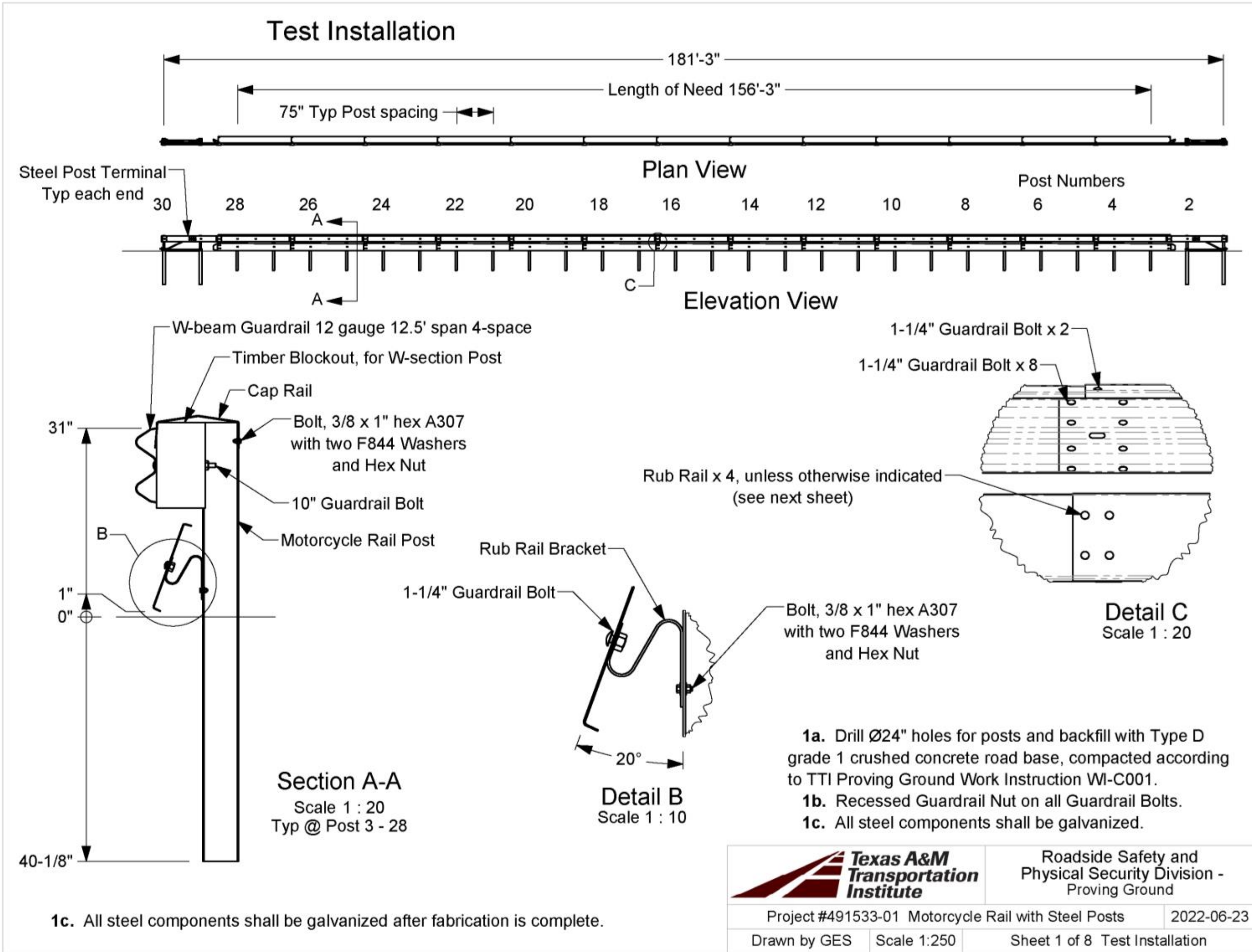
2.1. TEST ARTICLE AND INSTALLATION DETAILS

The installation consisted of a guardrail system with a standard four-space W-beam guardrail secured to the top of the rail 31 inches above grade by steel 72-inch W6×8.5 posts and wood blockouts. A series of 12-ft 10-inch-long, 14¾-inch-wide rub rails were located just below the W-beam such that the bottom was 1 inch from grade and were held away from the posts by a rub rail bracket at a 20-degree angle. A series of 12-ft 10-inch-long and 15-inch-wide cap rails were placed over the top of the guardrail posts and blockouts. The posts were evenly spaced at 75 inches, with a consistent embedment of 36⅛ inches, and the W-beam and both rails ran the entire length of need of 156 ft 3 inches. The installation was capped on both ends by a steel post terminal system, for a total installation length of 181 ft 3 inches.

Figure 2.1 presents the overall information on the Enhanced Motorcycle MGS, and Figure 2.2 through Figure 2.7 provide photographs of the installation. Appendix A provides further details on the Enhanced Motorcycle MGS. Drawings were provided by the Texas A&M Transportation Institute (TTI) Proving Ground, and construction was performed by TTI Proving Ground personnel and DMA Contractors.

2.2. DESIGN MODIFICATIONS DURING TESTS

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



S:\Accreditation-17025-2017\EIR-000 Project Files\491533-TxDOT Pooled Fund Guardrail-Schulz\-01-1&2 Motorcycle Rubrail for Steel-Post Guardrail\Drafting, 491533-01\491533-01-1 Drawing

Figure 2.1. Details of Enhanced Motorcycle MGS.

Figure 2.2. Overall View of the Enhanced Motorcycle MGS prior to Testing.

Figure 2.3. Upstream In-Line View of the Enhanced Motorcycle MGS prior to Testing.

Figure 2.4. Enhanced Motorcycle MGS at Impact prior to Testing.

Figure 2.5. Oblique Field-Side View of Enhanced Motorcycle MGS prior to Testing.

Figure 2.6. Focus on Post 1 without Rub Rail of the Enhanced Motorcycle MGS prior to Testing.

Figure 2.7. Oblique Upstream View of Enhanced Motorcycle MGS prior to Testing.

2.3. MATERIAL SPECIFICATIONS

Appendix B provides material certification documents for the materials used to install/construct the Enhanced Motorcycle MGS.

2.4. 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 Enhanced Motorcycle MGS for full-scale crash testing, two 6-ft-long W6×16 posts were installed in the immediate vicinity of the Enhanced Motorcycle MGS using the same fill materials and installation procedures used in the test installation and the standard dynamic test.

On the day of Test 3-10, September 19, 2023, loads on the post at deflections were as shown in Table 2.1. The backfill material in which the Enhanced Motorcycle MGS was installed met minimum *MASH* requirements for soil strength.

Table 2.1. Soil Strength for 491534-01-1.

Displacement (in)	Minimum Load (lb)	Actual Load (lb)
5	3940	9300
10	5500	9800
15	6540	9600

On the day of Test 3-11, October 6, 2023, loads on the post at deflections were as shown in Table 2.2. The backfill material in which the Enhanced Motorcycle MGS was installed met minimum *MASH* requirements for soil strength.

Table 2.2. Soil Strength for 491534-01-2.

Displacement (in)	Minimum Load (lb)	Actual Load (lb)
5	3940	7400
10	5500	8800
15	6540	10,000

Chapter 3. TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1. CRASH TEST PERFORMED/MATRIX

Table 3.1 shows the test conditions and evaluation criteria for *MASH* TL-3 for longitudinal barriers. The target critical impact points (CIPs) for each test were determined using the information provided in *MASH* Section 2.2.1 and Section 2.3.2. Figure 3.1 shows the target CIP for *MASH* TL-3 tests on the Enhanced Motorcycle MGS.

Table 3.1. Test Conditions and Evaluation Criteria Specified for *MASH* TL-3 Longitudinal Barriers.

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

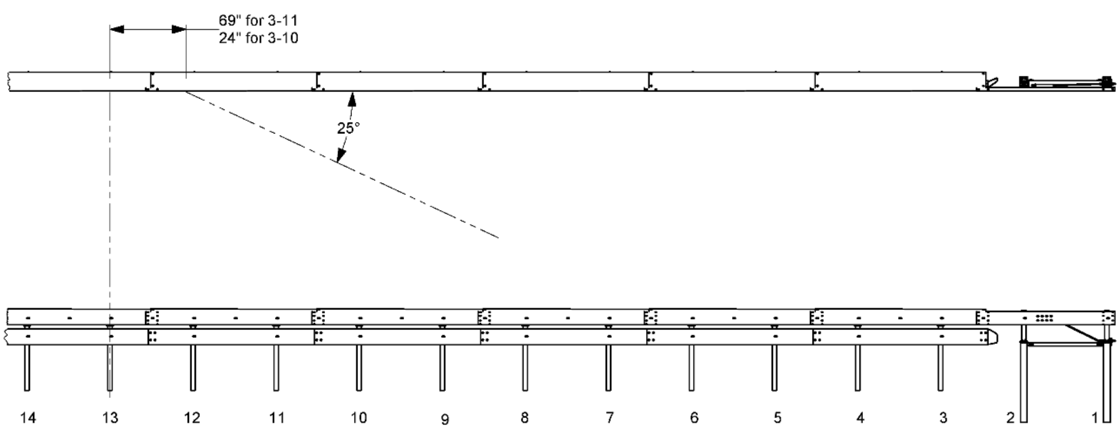


Figure 3.1. Target CIP for *MASH* TL-3 Tests on Enhanced Motorcycle MGS.

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

3.2. EVALUATION CRITERIA

The appropriate safety evaluation criteria from Tables 2-5 and 5-1 of *MASH* were used to evaluate the crash tests reported herein. Table 3.1 lists the test conditions and evaluation criteria required for *MASH* TL-3, and Table 3.2 provides detailed information on the evaluation criteria.

Table 3.2. 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 10 ft/s, or maximum allowable value of 16 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 4. TEST CONDITIONS

4.1. TEST FACILITY

The full-scale crash tests reported herein were 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 tests were 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.

4.2. VEHICLE TOW AND GUIDANCE SYSTEM

For the testing utilizing the 1100C and 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.

4.3. DATA ACQUISITION SYSTEMS

4.3.1. Vehicle Instrumentation and Data Processing

Each 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).

4.3.2. Anthropomorphic Dummy Instrumentation

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

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

4.3.3. Photographic Instrumentation Data Processing

Photographic coverage of each 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 Enhanced Motorcycle MGS. 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 5. *MASH* TEST 3-10 (CRASH TEST 491534-01-1)

5.1. TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

See Table 5.1 for the *MASH* impact conditions and Table 5.2 for the exit parameters for Test 491534-01-1. Figure 5.1 and Figure 5.2 depict the target impact setup.

Table 5.1. Impact Conditions for *MASH* Test 3-10, Crash Test 491534-01-1.

Test Parameter	Specification	Tolerance	Measured
Impact Speed (mi/h)	62	±2.5 mi/h	61.2
Impact Angle (deg)	25	±1.5°	25.4
Impact Severity (kip-ft)	51	≥51 kip-ft	56.3
Impact Location	24 inches upstream from the centerline of post 13	±12 inches	23.1 inches upstream from the centerline of post 13

Table 5.2. Exit Parameters for *MASH* Test 3-10, Crash Test 491534-01-1.

Exit Parameter	Measured
Speed (mi/h)	43.1
Trajectory (deg)	14.9
Heading (deg)	11.4
Brakes applied post impact (s)	2.7
Vehicle at rest position	148 ft downstream of impact point 102 ft to the traffic side Vehicle positioned 90° left relative to the installation
Comments:	Vehicle remained upright and stable. Vehicle met the exit box[a] criteria by crossing the exit box 33 ft downstream from loss of contact.

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

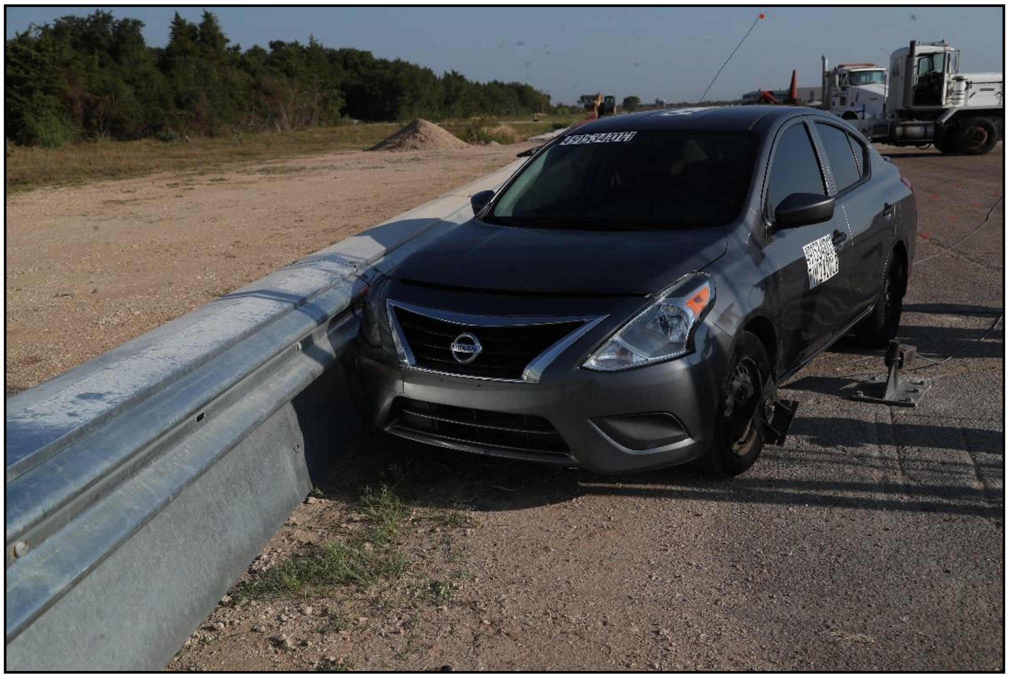


Figure 5.1. Enhanced Motorcycle MGS/Test Vehicle Geometrics for Test 491534-01-1.

Figure 5.2. Enhanced Motorcycle MGS/Test Vehicle Impact Location for Test 491534-01-1.

5.2. WEATHER CONDITIONS

Table 5.3 provides the weather conditions for Test 491534-01-1.

Table 5.3. Weather Conditions for Test 491534-01-1.

Date of Test	2023-09-19
Wind Speed (mi/h)	8
Wind Direction (deg)	180
Temperature (°F)	87
Relative Humidity (%)	58
Vehicle Traveling (deg)	195

5.3. TEST VEHICLE

Figure 5.3 and Figure 5.4 show the 2018 Nissan Versa used for the crash test. Table 5.4 shows the vehicle measurements. Figure C.1 in Appendix C.1 gives additional dimensions and information on the vehicle.

Figure 5.3. Impact Side of Test Vehicle before Test 491534-01-1.

Figure 5.4. Opposite Impact Side of Test Vehicle before Test 491534-01-1.

Table 5.4. Vehicle Measurements for Test 491534-01-1.

Test Parameter	Specification	Tolerance	Measured
Dummy (if applicable)[a] (lb)	165	N/A	165
Inertial Weight (lb)	2420	±55	2443
Gross Static[a] (lb)	2585	±55	2608
Wheelbase (inches)	98	±5	102.4
Front Overhang (inches)	35	±4	32.5
Overall Length (inches)	169	±8	175.4
Overall Width (inches)	65	±3	66.7
Hood Height (inches)	28	±4	30.5
Track Width[b] (inches)	59	±2	58.4
CG aft of Front Axle[c] (inches)	39	±4	41.2
CG above Ground[c,d] (inches)	N/A	N/A	N/A

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.

5.4. TEST DESCRIPTION

Table 5.5 lists events that occurred during Test 491534-01-1. Figures C.4, C.5, and C.6 in Appendix C.2 present sequential photographs during the test.

Table 5.5. Events during Test 491534-01-1.

Time (s)	Events
0.0000	Vehicle impacted the installation
0.0170	Post 13 began to lean toward field side
0.0220	Post 12 and post 14 began to lean toward field side
0.0390	Vehicle began to redirect
0.0450	Top cap rail began to come off
0.0910	Post 15 began to lean toward field side
0.1750	Vehicle passenger-side rear bumper contacted the rail at post 13
0.1810	Vehicle was parallel with installation
0.3400	Vehicle exited the installation at 43.1 mi/h with a heading of 11.4 degrees and a trajectory of 14.9 degrees

5.5. DAMAGE TO TEST INSTALLATION

The system was scuffed and deformed, and the cap rail released from posts 7 through 14. The top of the rail and the rub rail were deformed. The flanges of posts 12 through 15 were bent below 90 degrees toward the field side.

Table 5.6 describes the damage to the Enhanced Motorcycle MGS. Table 5.7 describes the deflection and working width of the Enhanced Motorcycle MGS. Figure 5.5 and Figure 5.6 show the damage to the Enhanced Motorcycle MGS.

Table 5.6. Damage to the Enhanced Motorcycle MGS for Test 491534-01-1.

Post Number	Soil Gap (inches)	Post Lean from Vertical (degrees)
12	0.3 t/s	0.8 f/s
13	2.8 t/s, 0.5 f/s	8.7 f/s
14	2.0 t/s, 1.3 f/s	10.5 f/s
15	0.5 t/s, 0.1 f/s	1.8 f/s

Note: t/s = traffic side; f/s = field side.

Table 5.7. Deflection and Working Width of the Enhanced Motorcycle MGS for Test 491534-01-1.

Test Parameter	Measured
Permanent Deflection/Location	9.8 inches toward field side, 20 inches upstream of post 14
Dynamic Deflection	13.8 inches toward field side, top cover between posts 12 and 13
Working Width[a] and Height	33.5 inches, at a height of 38.8 inches

[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 5.5. Enhanced Motorcycle MGS at Impact Location after Test 491534-01-1.

Figure 5.6. Downstream View of Enhanced Motorcycle MGS after Test 491534-01-1.

5.6. DAMAGE TO TEST VEHICLE

Figure 5.7 and Figure 5.8 show the damage sustained by the vehicle. Figure 5.9 and Figure 5.10 show the interior of the test vehicle. Table 5.8 and Table 5.9 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.

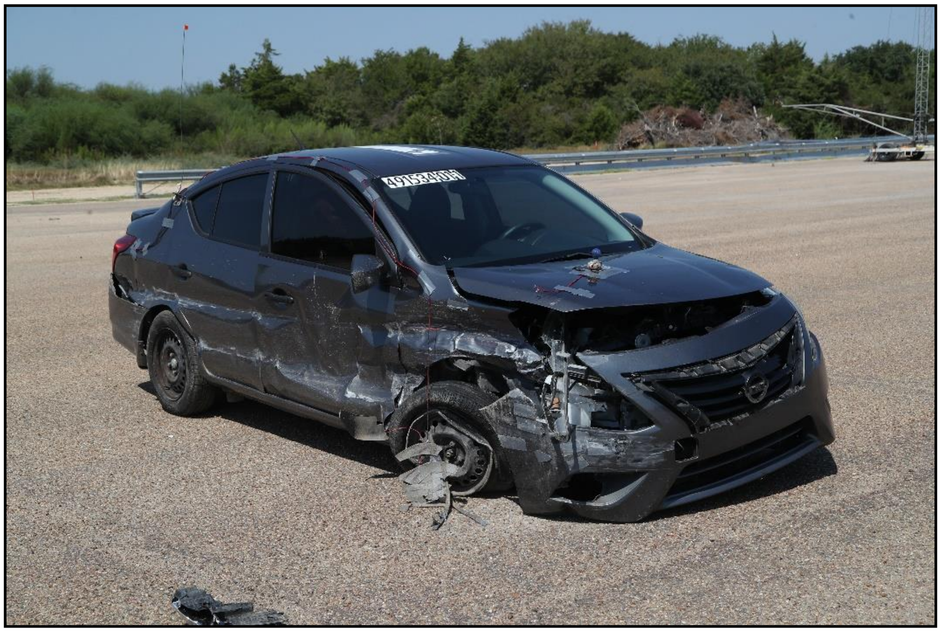


Figure 5.7. Impact Side of Test Vehicle after Test 491534-01-1.

Figure 5.8. Rear Impact Side of Test Vehicle after Test 491534-01-1.

Figure 5.9. Overall Interior of Test Vehicle after Test 491534-01-1.

Figure 5.10. Interior of Test Vehicle on Impact Side after Test 491534-01-1.

Table 5.8. Occupant Compartment Deformation for Test 491534-01-1.

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	0.0
Floor Pan/Transmission Tunnel	≤12.0	0.5
Side Front Panel	≤12.0	0.3
Front Door (above Seat)	≤9.0	0.3
Front Door (below Seat)	≤12.0	0.0

Table 5.9. Exterior Vehicle Damage for Test 491534-01-1.

Side Windows	Side windows remained intact
Maximum Exterior Deformation	10 inches above the front bumper
VDS	01RFQ4
CDC	01FREW6
Fuel Tank Damage	None
Description of Damage to Vehicle:	The bumper, grill, radiator, and support were dented. The right front headlight was busted. The right front frame rail and the right front wheel were bent, with the right front tire being flat. The whole passenger side of the vehicle was dented and scratched. There was a 3-inch gap at the top of the right front door. The right rear bumper was scratched up.

5.7. OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 5.10. 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 5.10. Occupant Risk Factors for Test 491534-01-1.

Test Parameter	Specification[a]	Measured	Time
OIV, Longitudinal (ft/s)	≤40.0 *30.0*	19.4	0.1043 seconds on right side of interior
OIV, Lateral (ft/s)	≤40.0 *30.0*	23.3	0.1043 seconds on right side of interior
Ridedown, Longitudinal (g)	≤20.49 *15.0*	9.7	0.1113–0.1213 seconds
Ridedown, Lateral (g)	≤20.49 *15.0*	13.6	0.1121–0.1221 seconds
Theoretical Head Impact Velocity (THIV) (m/s)	N/A	9.1	0.1012 seconds on right side of interior
Acceleration Severity Index (ASI)	N/A	1.3	0.1023–0.1523 seconds
50-ms Moving Avg. Accelerations (MA) Longitudinal (g)	N/A	−8.8	0.0804–0.1304 seconds
50-ms MA Lateral (g)	N/A	−9.6	0.0808–0.1308 seconds
50-ms MA Vertical (g)	N/A	−2.3	0.1699–0.2199 seconds
Roll (deg)	≤75	18.5	2.4909 seconds
Pitch (deg)	≤75	3.7	2.4858 seconds
Yaw (deg)	N/A	67.8	2.4999 seconds

Note: N/A = not applicable.
[a] Values in italics are the preferred *MASH* values.

5.8. TEST SUMMARY

Figure 5.11 summarizes the results of *MASH* Test 491534-01-1.

0.000 s

0.200 s

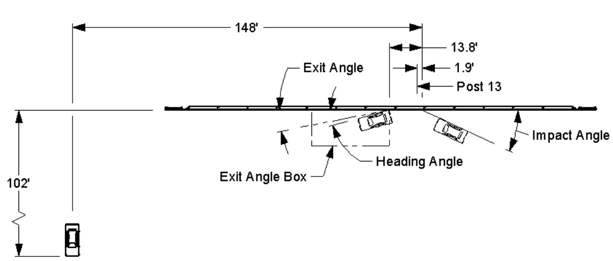
0.400 s

0.600 s

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.	*MASH* 2016, Test 3-10
TTI Project No.	491534-01-1
Test Date	2023-09-19
TEST ARTICLE	
Type	Longitudinal barriers
Name	Enhanced Motorcycle MGS
Length	181 ft 3 inches
Key Materials	Galvanized steel posts and rails, timber wood blockouts
Soil Type and Condition	AASHTO M147-65(2004), Type 1, Grade D crushed concrete
TEST VEHICLE	
Type/Designation	1100C
Year, Make and Model	2018 Nissan Versa
Inertial Weight (lb)	2443
Dummy (lb)	165
Gross Static (lb)	2608
IMPACT CONDITIONS	
Impact Speed (mi/h)	61.2
Impact Angle (deg)	25.4
Impact Location	23.1 inches upstream of centerline of post 13
Impact Severity (kip-ft)	56.3
EXIT CONDITIONS	
Exit Speed (mi/h)	43.1
Trajectory/Heading Angle (deg)	14.9/11.4
Exit Box Criteria	Vehicle met the exit box criteria
Stopping Distance	148 ft downstream 102 ft to the traffic side
TEST ARTICLE DEFLECTIONS	
Dynamic (inches)	13.8
Permanent (inches)	9.8 inches
Working Width/Height (inches)	33.5/38.8
VEHICLE DAMAGE	
VDS	01RFQ4
CDC	01FREW6
Max. Ext. Deformation (inches)	10
Max Occupant Compartment Deformation	0.5 inch into the floor pan

OCCUPANT RISK VALUES

Long. OIV (ft/s)	19.4	Long. Ridedown (g)	9.7	Max 50-ms Long. (g)	−8.8	Max Roll (deg)	18.5
Lat. OIV (ft/s)	23.3	Lat. Ridedown (g)	13.6	Max 50-ms Lat. (g)	−9.6	Max Pitch (deg)	3.7
THIV (m/s)	9.1	ASI	1.3	Max 50-ms Vert. (g)	−2.3	Max Yaw (deg)	67.8



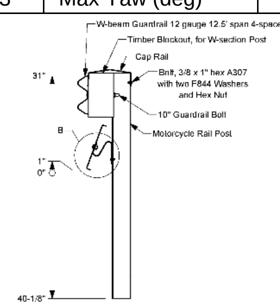


Figure 5.11. Summary of Results for *MASH* Test 3-10 on Enhanced Motorcycle MGS.

Chapter 6. *MASH* TEST 3-11 (CRASH TEST 491534-01-2)

6.1. TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

See Table 6.1 for the impact conditions and Table 6.2 for the exit parameters for Test 491534-01-2. Figure 6.1 and Figure 6.2 depict the target impact setup.

Table 6.1. Impact Conditions for *MASH* Test 3-11, Crash Test 491534-01-2.

Test Parameter	Specification	Tolerance	Measured
Impact Speed (mi/h)	62	±2.5 mi/h	63.1
Impact Angle (deg)	25	±1.5°	25.5
Impact Severity (kip-ft)	106	≥106 kip-ft	123.9
Impact Location	69 inches upstream from the centerline of post 13	±12 inches	67.8 inches upstream from the centerline of post 13

Table 6.2. Exit Parameters for *MASH* Test 3-11, Crash Test 491534-01-2.

Exit Parameter	Measured
Speed (mi/h)	46.7
Trajectory (deg)	9.8
Heading (deg)	15.7
Brakes applied post impact (s)	1.8
Vehicle at rest position	285 ft downstream of impact point 9 ft to the traffic side Vehicle positioned 2° right relative to the installation
Comments:	Vehicle remained upright and stable. Vehicle met the exit box[a] criteria by crossing the exit box 42 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. Enhanced Motorcycle MGS/Test Vehicle Geometrics for Test 491534-01-2.

Figure 6.2. Enhanced Motorcycle MGS/Test Vehicle Impact Location for Test 491534-01-2.

6.2. WEATHER CONDITIONS

Table 6.3 provides the weather conditions for Test 491534-01-2.

Table 6.3. Weather Conditions for Test 491534-01-2.

Date of Test	2023-10-06
Wind Speed (mi/h)	8
Wind Direction (deg)	11
Temperature (°F)	78
Relative Humidity (%)	77
Vehicle Traveling (deg)	195

6.3. TEST VEHICLE

Figure 6.3 and Figure 6.4 show the 2018 RAM 1500 used for the crash test. Table 6.4 shows the vehicle measurements. Figure D.1 in Appendix D.1 gives additional dimensions and information on the vehicle.

Figure 6.3. Impact Side of Test Vehicle before Test 491534-01-2.

Figure 6.4. Opposite Impact Side of Test Vehicle before Test 491534-01-2.

Table 6.4. Vehicle Measurements for Test 491534-01-2.

Test Parameter	Specification	Tolerance	Measured
Dummy (if applicable)[a] (lb)	165	N/A	N/A
Inertial Weight (lb)	5000	±110	5024
Gross Static[a] (lb)	5000	±110	5024
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	46.0
Track Width[b] (inches)	67	±1.5	68.3
CG aft of Front Axle[c] (inches)	63	±4	61.1
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 491534-01-2. Figures D.4, D.5, and D.6 in Appendix D.2 present sequential photographs during the test.

Table 6.5. Events during Test 491534-01-2.

Time (s)	Events
0	Vehicle impacted the installation
0.014	Post 12 began to lean toward field side
0.017	Post 13 began to lean toward field side
0.038	Vehicle began to redirect
0.043	Post 14 began to lean toward field side
0.063	Cap rail separated from system at post 12
0.084	Front passenger-side tire impacted post 13
0.175	Vehicle passenger-side rear bumper contacted the rail at post 13
0.248	Vehicle was parallel with installation
0.527	Vehicle exited the installation at 46.7 mi/h with a heading of 15.7 degrees and a trajectory of 9.8 degrees

6.5. DAMAGE TO TEST INSTALLATION

The rail was scuffed and deformed. The cap rail released from posts 5 through 19, and the W-beam was released from posts 13 through 15. The bolt slipped through the joint of the rub rail between posts 12 and 13. The cap rail joint of 12 and 13 had a bolt fail on the field side and an 80 percent pull through on the traffic side. Posts 12 through 14 had severe soil disturbance. Post 15 was twisted counterclockwise.

Table 6.6 describes the damage to the Enhanced Motorcycle MGS. Table 6.7 describes the deflection and working width of the Enhanced Motorcycle MGS. Figure 6.5 and Figure 6.6 show the damage to the Enhanced Motorcycle MGS.

Table 6.6. Damage to the Enhanced Motorcycle MGS for Test 491534-01-2.

Post Number	Soil Gap (inches)	Post Lean from Vertical (degrees)
1	0.1 u/s	0.0
12	1.5 t/s, 1.3 f/s	4.0 f/s
13	Soil blown out	47.0 d/s
14	Soil blown out	41.0 f/s
15	3.0 t/s, 0.8 f/s	17.0 f/s, post twisted counterclockwise
16	0.3 f/s	0.0

Note: u/s = upstream; t/s = traffic side; f/s = field side; d/s = downstream.

Table 6.7. Deflection and Working Width of the Enhanced Motorcycle MGS for Test 491534-01-2.

Test Parameter	Measured
Permanent Deflection/Location	18.5 inches toward field side, at post 14
Dynamic Deflection	29.1 inches toward field side, top cover between posts 12 and 13
Working Width[a] and Height	59.9 inches, at a height of 20 inches, on the field side of the top cover at the joint between posts 12 and 13

[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. Enhanced Motorcycle MGS at Impact Location after Test 491534-01-2.

Figure 6.6. Downstream View of Enhanced Motorcycle MGS after Test 491534-01-2.

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 6.8 and Table 6.9 provide details on the occupant compartment deformation and exterior vehicle damage. Figures D.2 and D.3 in Appendix D.1 provide exterior crush and occupant compartment measurements.

Figure 6.7. Impact Side of Test Vehicle after Test 491534-01-2.

Figure 6.8. Rear Impact Side of Test Vehicle after Test 491534-01-2.

Figure 6.9. Overall Interior of Test Vehicle after Test 491534-01-2.

Figure 6.10. Interior of Test Vehicle on Impact Side after Test 491534-01-2.

Table 6.8. Occupant Compartment Deformation for Test 491534-01-2.

Test Parameter	Specification	Measured
Roof	≤4.0 inches	0 inches
Windshield	≤3.0 inches	0 inches
A and B Pillars	≤5.0 overall/≤3.0 inches lateral	0 inches
Foot Well/Toe Pan	≤9.0 inches	0 inches
Floor Pan/Transmission Tunnel	≤12.0 inches	0 inches
Side Front Panel	≤12.0 inches	0 inches
Front Door (above Seat)	≤9.0 inches	0 inches
Front Door (below Seat)	≤12.0 inches	0 inches

Table 6.9. Exterior Vehicle Damage for Test 491534-01-2.

Side Windows	Side windows remained intact
Maximum Exterior Deformation	12 inches in the front bumper
VDS	01RFQ4
CDC	01FREW5
Fuel Tank Damage	None
Description of Damage to Vehicle:	On the right front, the headlight was gone, the frame was bent, the control arm was ripped off, and the fender and door were dented. The door had a 1-inch gap at the top. The front bumper, grill, and radiator were dented. The right rear door had small dents and scrapes. The right rear quarter fender and rear bumper were dented.

6.7. OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 6.10. Figure D.7 in Appendix D.3 shows the vehicle angular displacements, and Figures D.8 through D.10 in Appendix D.4 show acceleration versus time traces.

Table 6.10. Occupant Risk Factors for Test 491534-01-2.

Test Parameter	Specification[a]	Measured	Time
OIV, Longitudinal (ft/s)	≤40.0 *30.0*	19.7	0.1334 seconds on right side of interior
OIV, Lateral (ft/s)	≤40.0 *30.0*	17.4	0.1334 seconds on right side of interior
Ridedown, Longitudinal (g)	≤20.49 *15.0*	7.1	0.1486–0.1586 seconds
Ridedown, Lateral (g)	≤20.49 *15.0*	7.6	0.1743–0.1843 seconds
THIV (m/s)	N/A	7.8	0.1284 seconds on right side of interior
ASI	N/A	0.8	0.0706–0.1206 seconds
50-ms MA Longitudinal (g)	N/A	−6.7	0.0581–0.1081 seconds
50-ms MA Lateral (g)	N/A	−6.6	0.0596–0.1096 seconds
50-ms MA Vertical (g)	N/A	−2.7	0.5902–0.6402 seconds
Roll (deg)	≤75	11.2	0.8747 seconds
Pitch (deg)	≤75	10.5	0.6176 seconds
Yaw (deg)	N/A	49.8	0.9539 seconds

Note: N/A = not applicable.
[a] Values in italics are the preferred *MASH* values.

6.8. TEST SUMMARY

Figure 6.11 summarizes the results of *MASH* Test 491534-01-2.

0.000 s

0.200 s

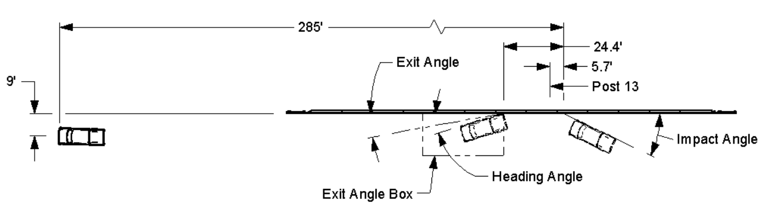
0.400 s

0.600 s

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.	*MASH* 2016, Test 3-11
TTI Project No.	491534-01-2
Test Date	2023-10-06
TEST ARTICLE	
Type	Longitudinal barriers
Name	Enhanced Motorcycle MGS
Length	181 ft 3 inches
Key Materials	Galvanized steel posts and rails, timber wood blockouts
Soil Type and Condition	AASHTO M147-65(2004), Type 1, Grade D crushed concrete
TEST VEHICLE	
Type/Designation	2270P
Year, Make and Model	2018 RAM 1500
Inertial Weight (lb)	5024
Dummy (lb)	N/A
Gross Static (lb)	5024
IMPACT CONDITIONS	
Impact Speed (mi/h)	63.1
Impact Angle (deg)	25.5
Impact Location	67.8 inches upstream of centerline of post 13
Impact Severity (kip-ft)	123.9
EXIT CONDITIONS	
Exit Speed (mi/h)	46.7
Trajectory/Heading Angle (deg)	9.8/15.7
Exit Box Criteria	Vehicle met the exit box criteria
Stopping Distance	285 ft downstream 9 ft to the traffic side
TEST ARTICLE DEFLECTIONS	
Dynamic (inches)	29.1
Permanent (inches)	18.5
Working Width/Height (inches)	59.9/20
VEHICLE DAMAGE	
VDS	01RFQ4
CDC	01FREW5
Max. Ext. Deformation (inches)	12
Max Occupant Compartment Deformation	No occupant compartment deformation

OCCUPANT RISK VALUES

Long. OIV (ft/s)	19.7	Long. Ridedown (g)	7.1	Max 50-ms Long. (g)	−6.7	Max Roll (deg)	11.2
Lat. OIV (ft/s)	17.4	Lat. Ridedown (g)	7.6	Max 50-ms Lat. (g)	−6.6	Max Pitch (deg)	10.5
THIV (m/s)	7.8	ASI	0.8	Max 50-ms Vert. (g)	−2.7	Max Yaw (deg)	49.8



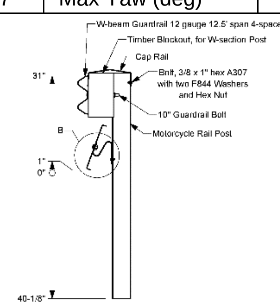


Figure 6.11. Summary of Results for *MASH* Test 3-11 on Enhanced Motorcycle MGS.

Chapter 7. SUMMARY AND CONCLUSIONS

The crash tests reported herein were performed in accordance with *MASH* TL-3, which involves two tests, on the Enhanced Motorcycle MGS.

Table 7.1 shows that the Enhanced Motorcycle MGS met the performance criteria for *MASH* TL-3 longitudinal barriers.

Table 7.1. Assessment Summary for *MASH* TL-3 Tests on Enhanced Motorcycle MGS.

Evaluation Criteria[a]	Description	Test 491534-01-1	Test 491534-01-2
A	Contain, Redirect, or Controlled Stop	S	S
D	No Penetration into Occupant Compartment	S	S
F	Roll and Pitch Limit	S	S
H	OIV Threshold	S	S
I	Ridedown Threshold	S	S
Overall	Evaluation	Pass	Pass

Note: S = Satisfactory.
[a] See Table 3.2 for details.

Chapter 8. IMPLEMENTATION*

The Enhanced Motorcycle MGS was evaluated through full-scale crash testing. This system is ready for implementation as a MASH TL-3 longitudinal barrier system. Additionally, this system can be considered for implementation as a longitudinal barrier system designed to reduce injury and fatality risk for motorcyclists.

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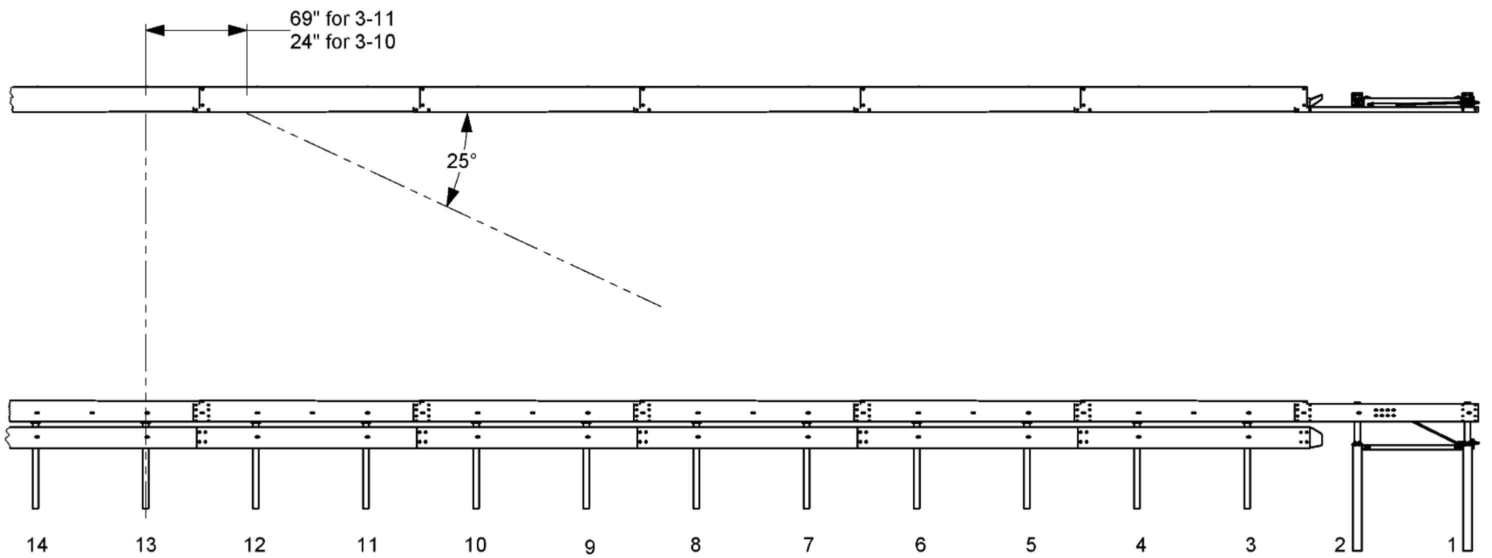
* *The opinions/interpretations identified/expressed in this section of the report are outside the scope of TTI Proving Ground's A2LA Accreditation.*

REFERENCES

1. AASHTO. *Manual for Assessing Safety Hardware*, Second Edition. American Association of State Highway and Transportation Officials, Washington, DC, 2016.
2. Schulz, N., Bligh, R., Dadashova, B., Silvestri Dobrovolny, C., and Schroeder, W. *Develop a Retrofit Design for Guard Fence System to Enhance Motorcycle Safety*. Report No. 0-6994-R1. Texas A&M Transportation Institute, College Station, TX, 2023.

APPENDIX A. DETAILS OF ENHANCED MOTORCYCLE MGS



Texas A&M Transportation Institute

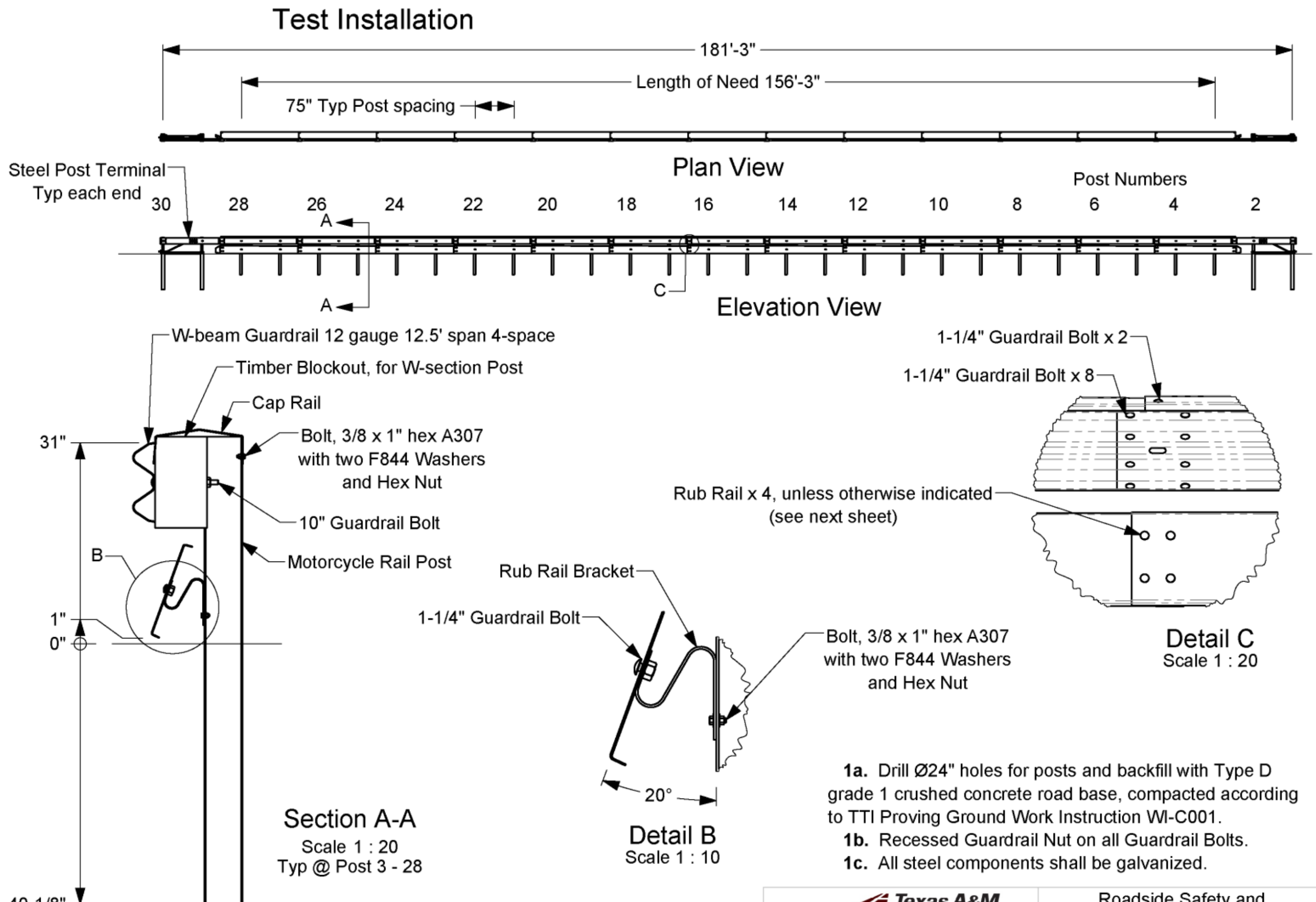
Roadside Safety and Physical Security Division - Proving Ground

Project #491533-1

Drawn by GES

Sheet 1 of 1 Impact

S:\Accreditation-17025-2017\EIR-000 Project Files\491533-TxDOT Pooled Fund Guardrail-Schulz\-01-1&2 Motorcycle Rubrail for Steel-Post Guardrail\Drafting, 491533-01\491533-01 Impacts and Summaries



1a. Drill Ø24" holes for posts and backfill with Type D grade 1 crushed concrete road base, compacted according to TTI Proving Ground Work Instruction WI-C001.
1b. Recessed Guardrail Nut on all Guardrail Bolts.
1c. All steel components shall be galvanized.

1c. All steel components shall be galvanized after fabrication is complete.

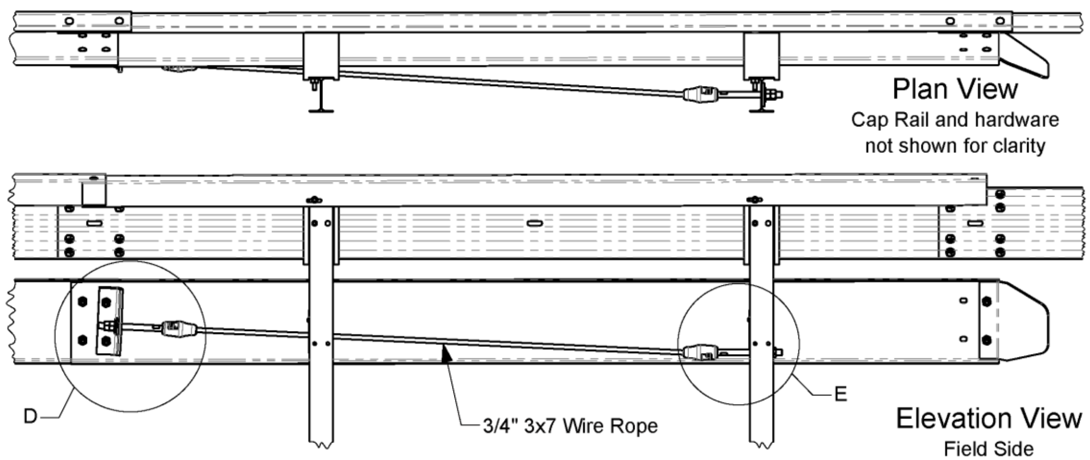
Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #491533-01 Motorcycle Rail with Steel Posts		2022-06-23
Drawn by GES	Scale 1:250	Sheet 1 of 8 Test Installation

S:\Accreditation-17025-2017\EIR-000 Project Files\491533-TxDOT Pooled Fund Guardrail-Schulz\-01-1&2 Motorcycle Rubrail for Steel-Post Guardrail\Drafting, 491533-01\491533-01-1 Drawing

Rub Rail Anchor Details

Typ each end of Rail

Traffic Direction



Plan View

Cap Rail and hardware not shown for clarity

D

E

3/4" 3x7 Wire Rope

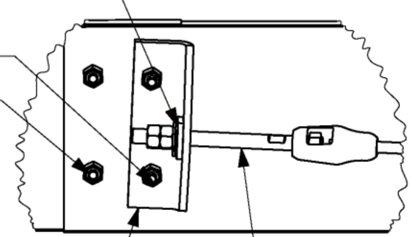
Elevation View

Field Side

Plate Washer, 2 1/2" x 3/8" x 2 1/2" with Ø7/8" hole at center (this end of Cable only)

2" Guardrail Bolt x 2

1-1/4" Guardrail Bolt x 2



Detail D

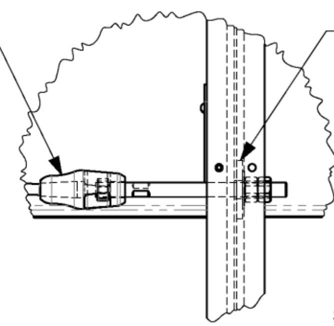
Scale 1 : 10

Rub Rail Anchor Bracket

Field-applied 1" Terminal Fitting

Field-applied 1" Terminal Fitting

Plate Washer, 4" x 3/8" x 4" with Ø1 1/4" hole at center (this end of Cable only)

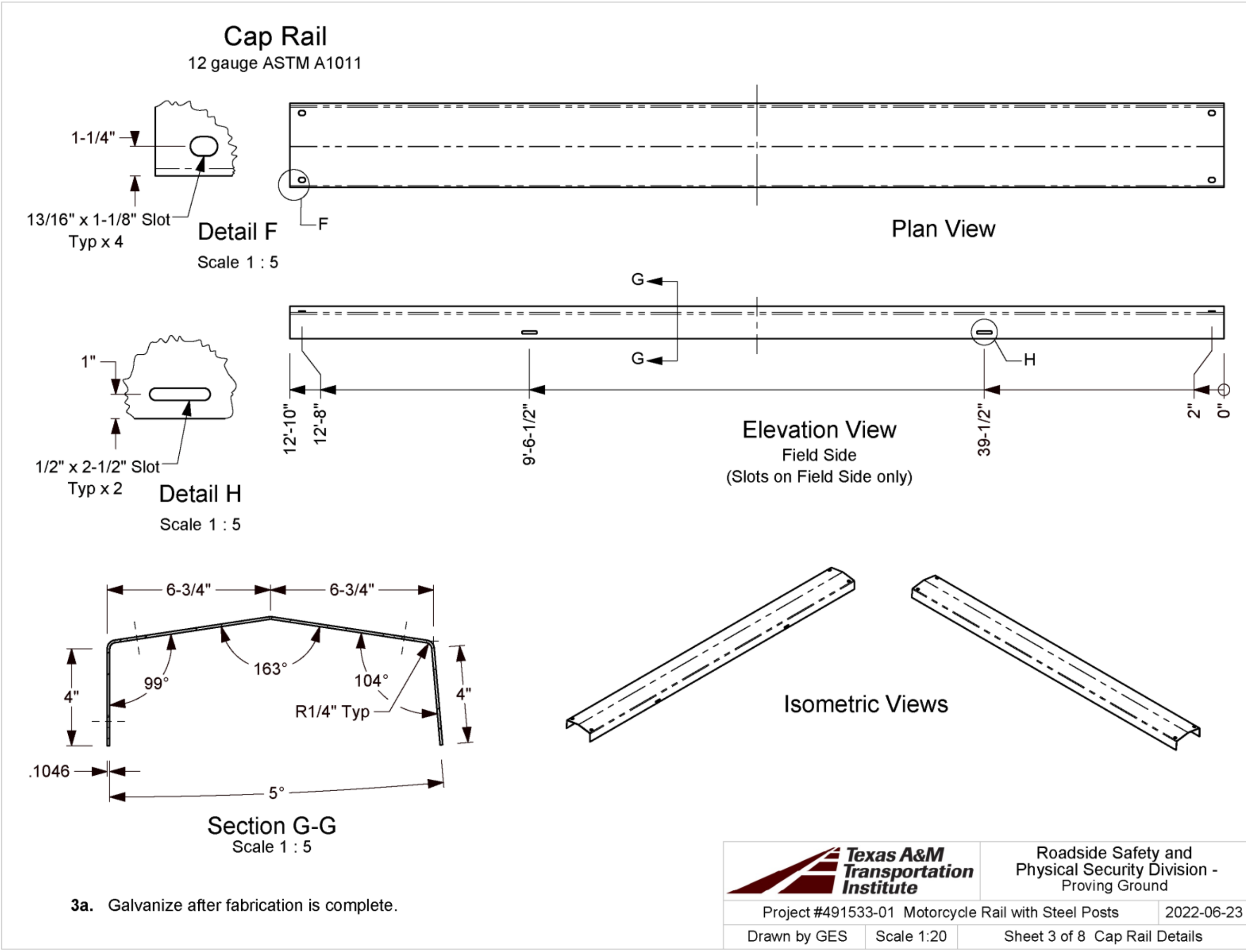


Detail E

Scale 1 : 10

2a. Rub Rail Anchor Cap is placed on field side of Rub Rail in this location. It will be on the traffic side on the upstream end of the installation to minimize snagging potential.

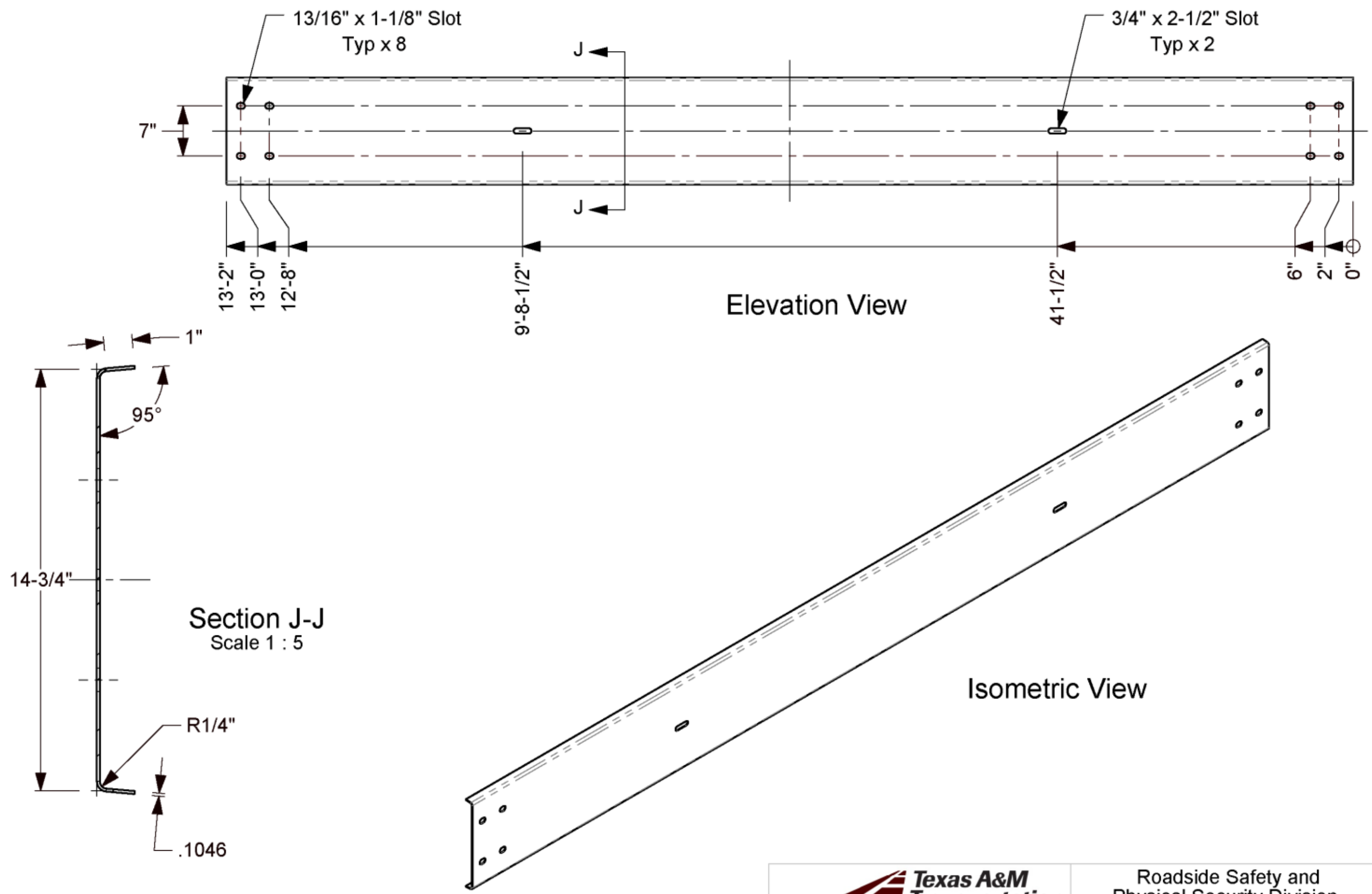
Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #491533-01 Motorcycle Rail with Steel Posts		2022-06-23
Drawn by GES	Scale 1:25	Sheet 2 of 8 Rub Rail Anchor Details



S:\Accreditation-17025-2017\EIR-000 Project Files\491533-TxDOT Pooled Fund Guardrail-Schulz\-01-1&2 Motorcycle Rubrail for Steel-Post Guardrail\Drafting, 491533-01\491533-01-1 Drawing

Rub Rail

12 gauge ASTM A1011



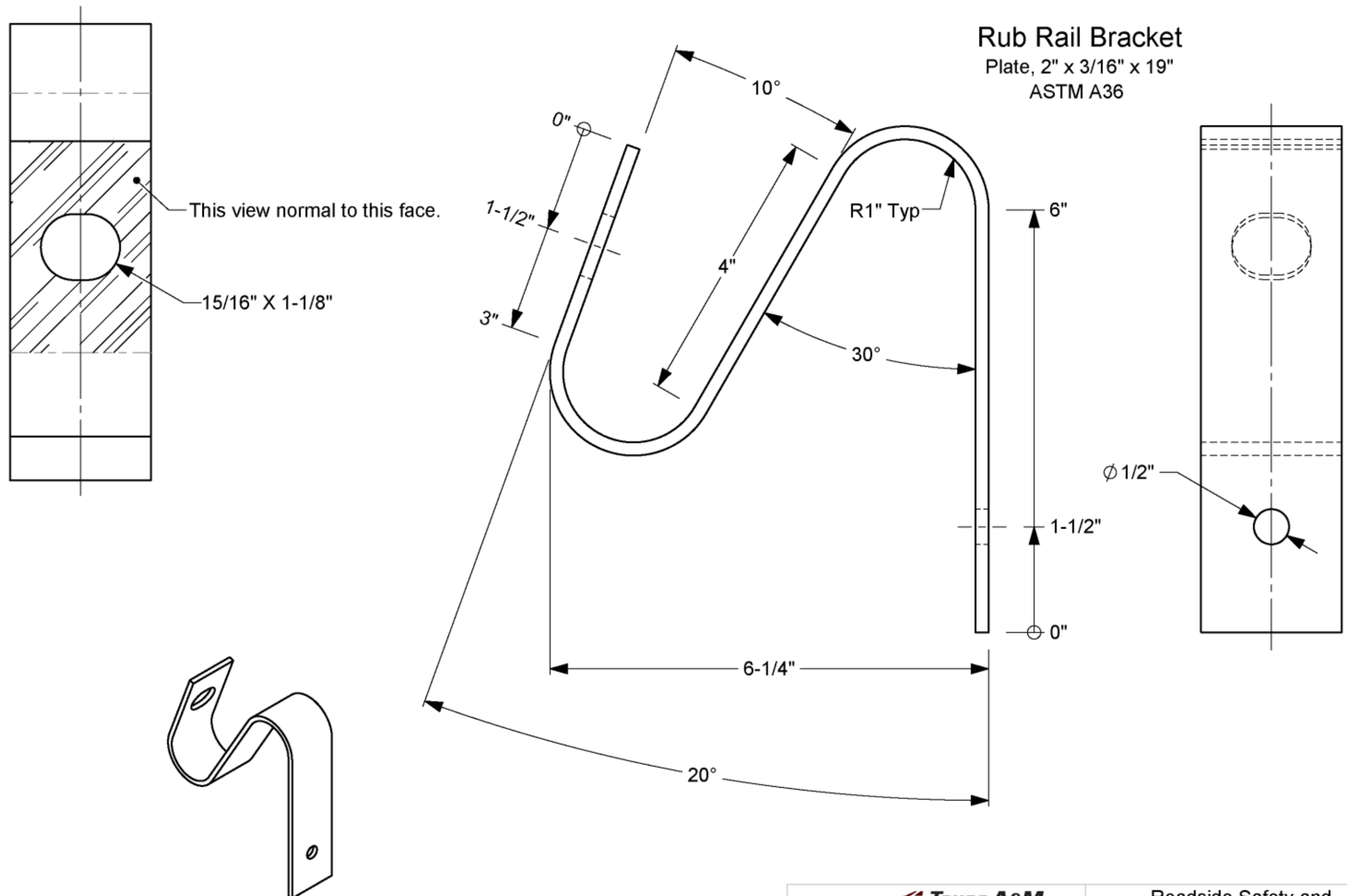
4a. Galvanize after fabrication is complete.

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground
Project #491533-01 Motorcycle Rail with Steel Posts		2022-06-23
Drawn by GES	Scale 1:20	Sheet 4 of 8 Rub Rail Details

S:\Accreditation-17025-2017\EIR-000 Project Files\491533-TxDOT Pooled Fund Guardrail-Schulz\-01-1&2 Motorcycle Rubrail for Steel-Post Guardrail\Drafting, 491533-01\491533-01-1 Drawing

Rub Rail Bracket

Plate, 2" x 3/16" x 19"
ASTM A36

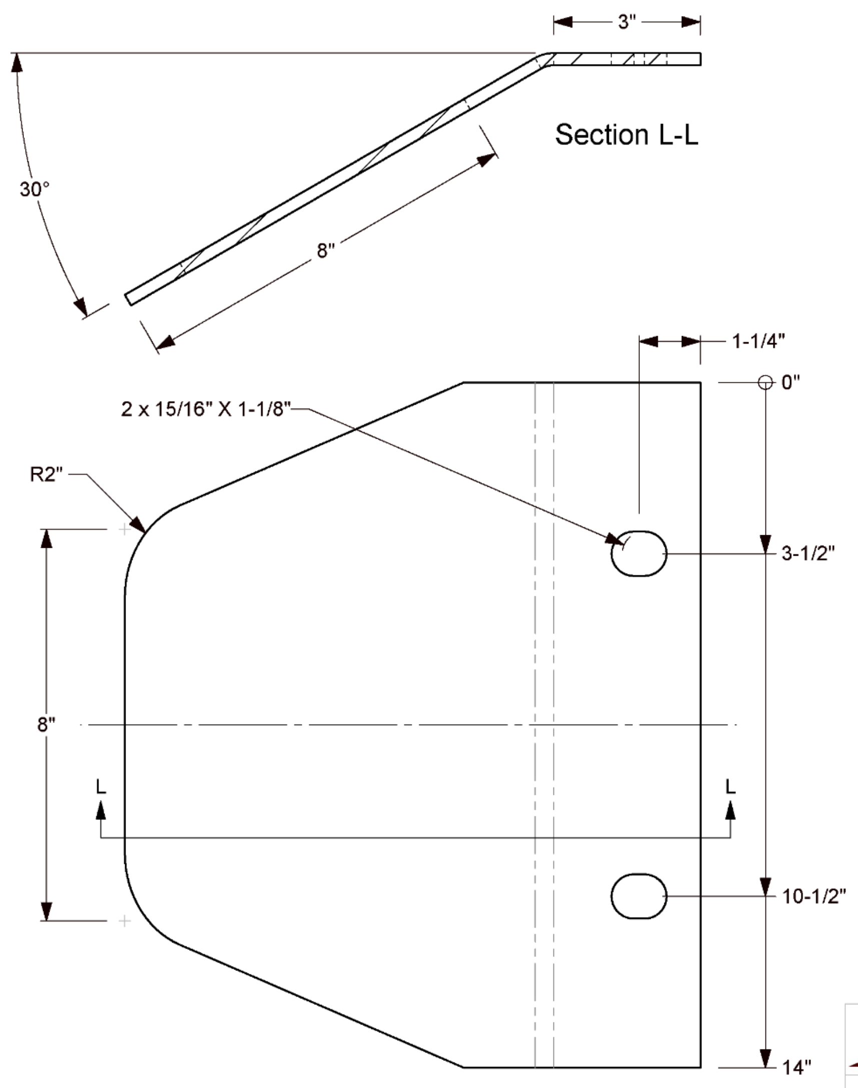


Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #491533-01 Motorcycle Rail with Steel Posts		2022-06-23
Drawn by GES	Scale 1:2	Sheet 5 of 8 Rub Rail Bracket

TRNo. 9-1531-R2B

52

2023-12-18



Rub Rail Anchor Cap

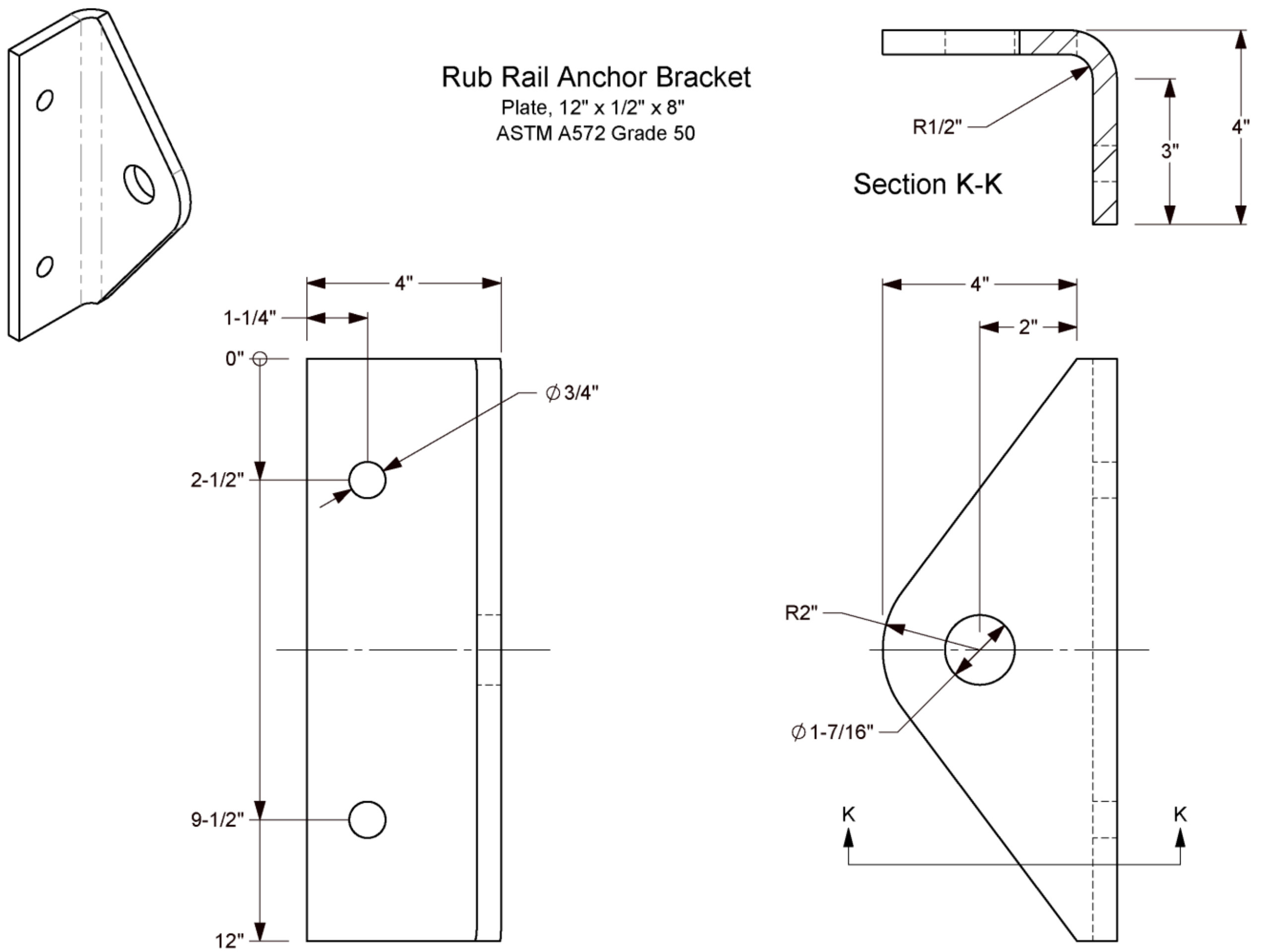
Plate, 14" x 1/4" x 13"
ASTM A572 Grade 50

Texas A&M Transportation Institute

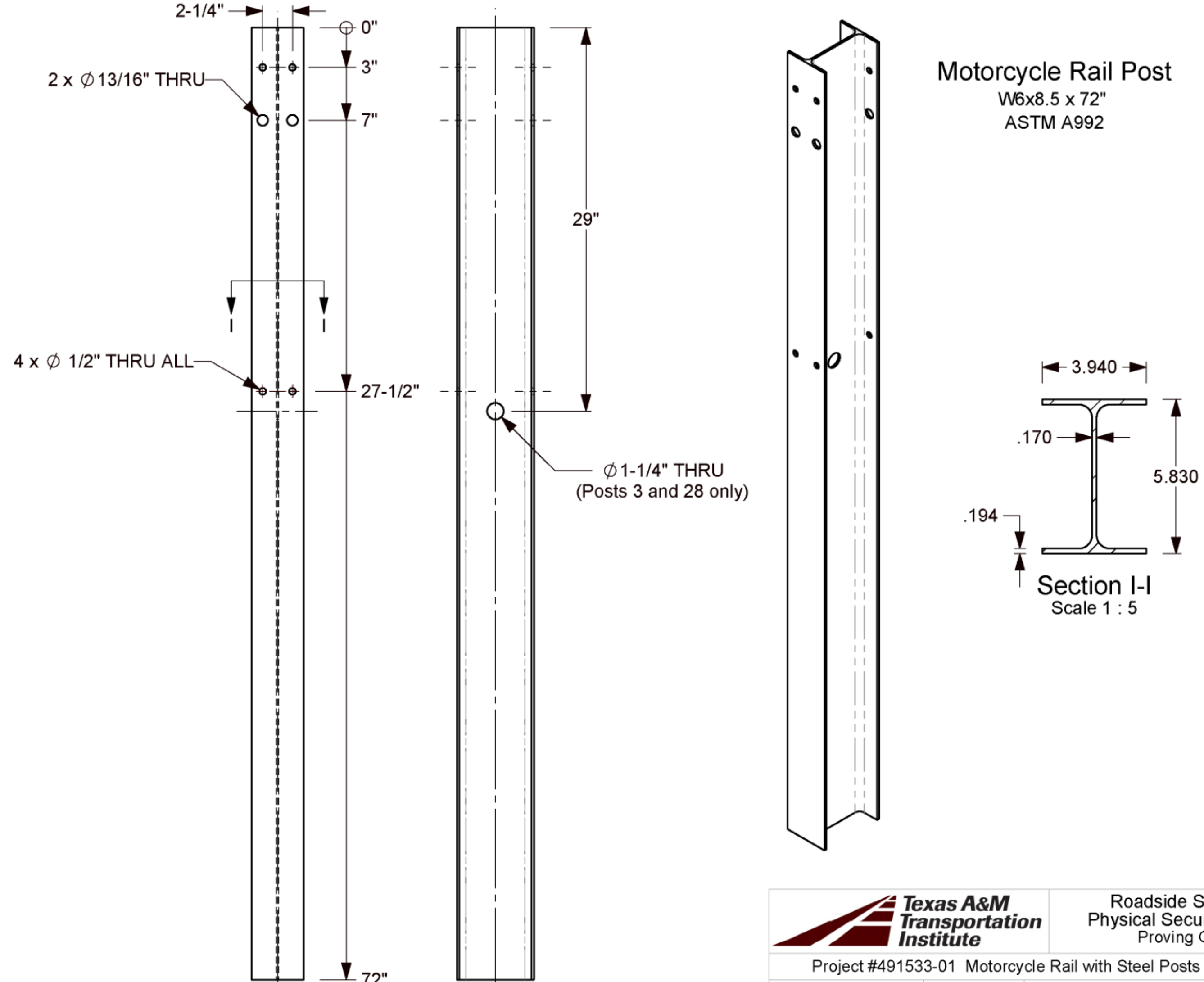
Roadside Safety and Physical Security Division - Proving Ground

Project #491533-01 Motorcycle Rail with Steel Posts		2022-06-23
Drawn by GES	Scale 1:3	Sheet 6 of 8 Rub Rail Anchor Cap

S:\Accreditation-17025-2017\EIR-000 Project Files\491533-TxDOT Pooled Fund Guardrail-Schulz\-01-1&2 Motorcycle Rubrail for Steel-Post Guardrail\Drafting, 491533-01\491533-01-1 Drawing



Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #491533-01 Motorcycle Rail with Steel Posts		2022-06-23
Drawn by GES	Scale 1:3	Sheet 7 of 8 Anchor Bracket

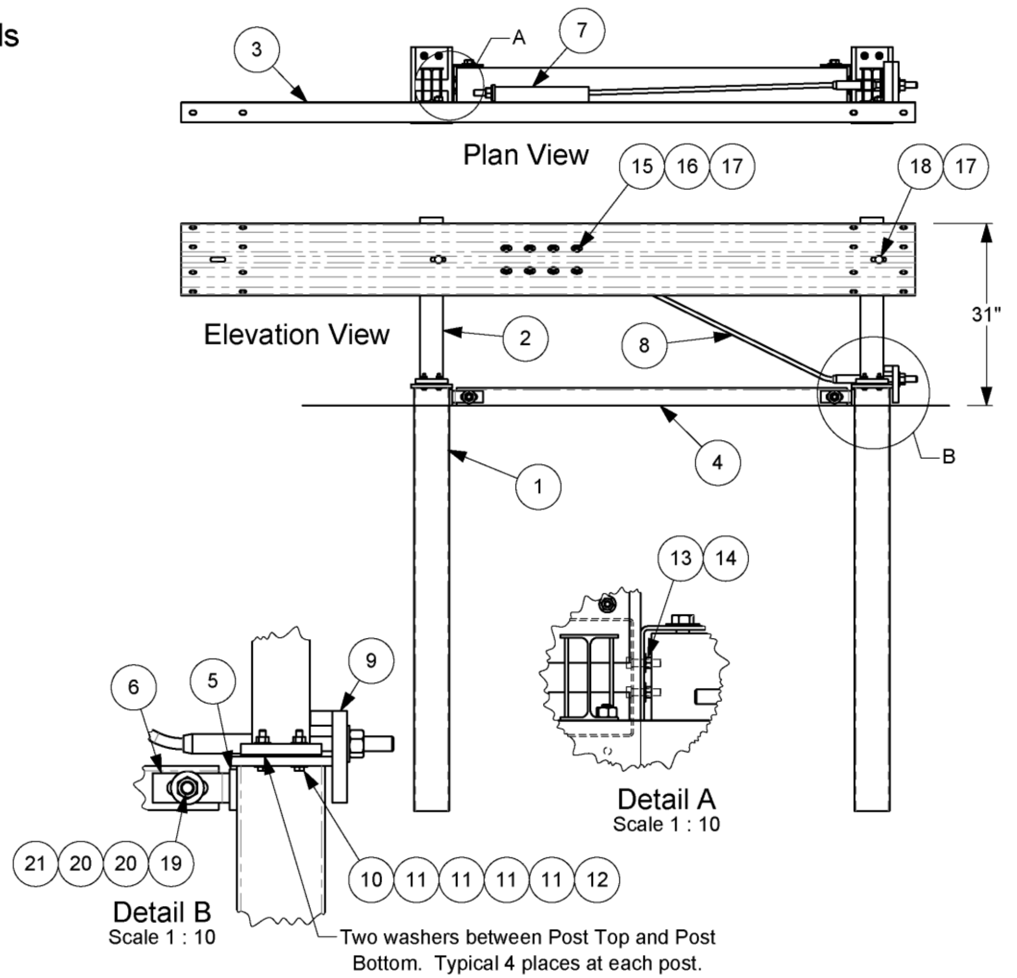


Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #491533-01 Motorcycle Rail with Steel Posts		2022-06-23
Drawn by GES	Scale 1:10	Sheet 8 of 8 Post Details

S:\Accreditation-17025-2017\EIR-000 Project Files\491533-TxDOT Pooled Fund Guardrail-Schulz\-01-1&2 Motorcycle Rubrail for Steel-Post Guardrail\Drafting, 491533-01\491533-01-1 Drawing

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

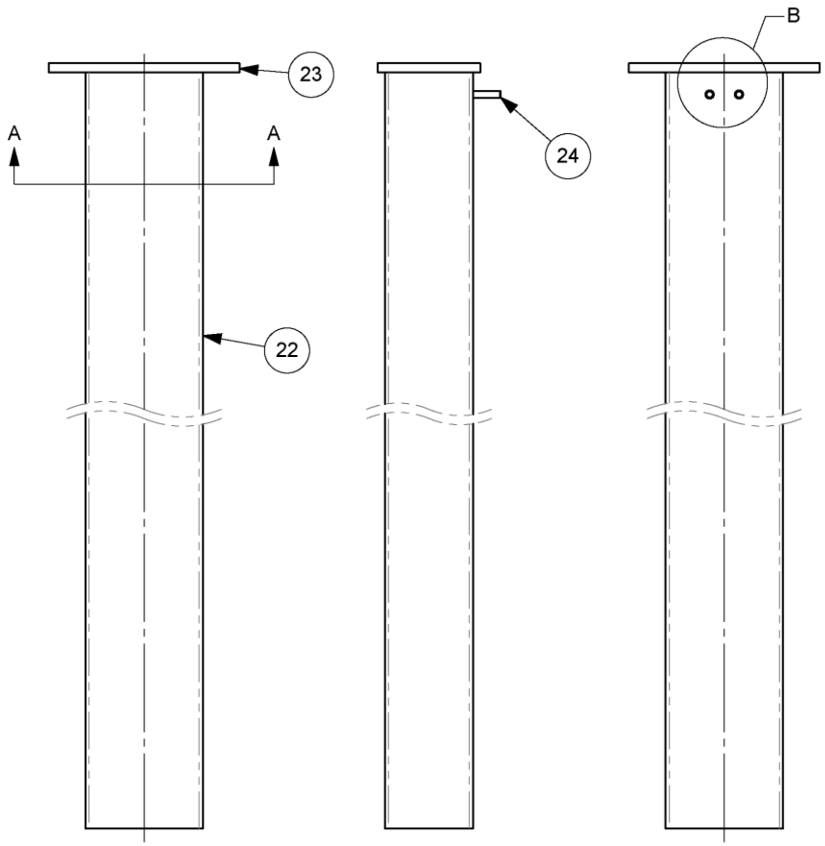
Roadside Safety and Physical Security Division - Proving Ground

Project # Terminal 2023-02-08

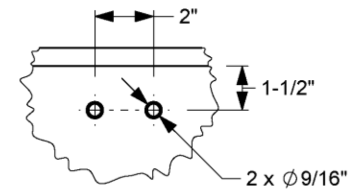
Drawn by GES | Scale 1:25 | Sheet 1 of 6 Terminal Details

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

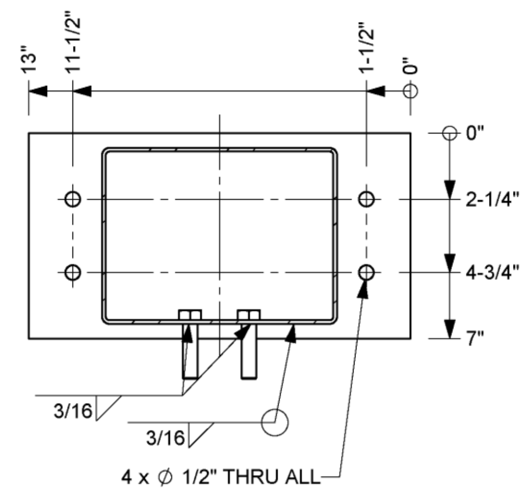
Post Bottom



Elevation Views



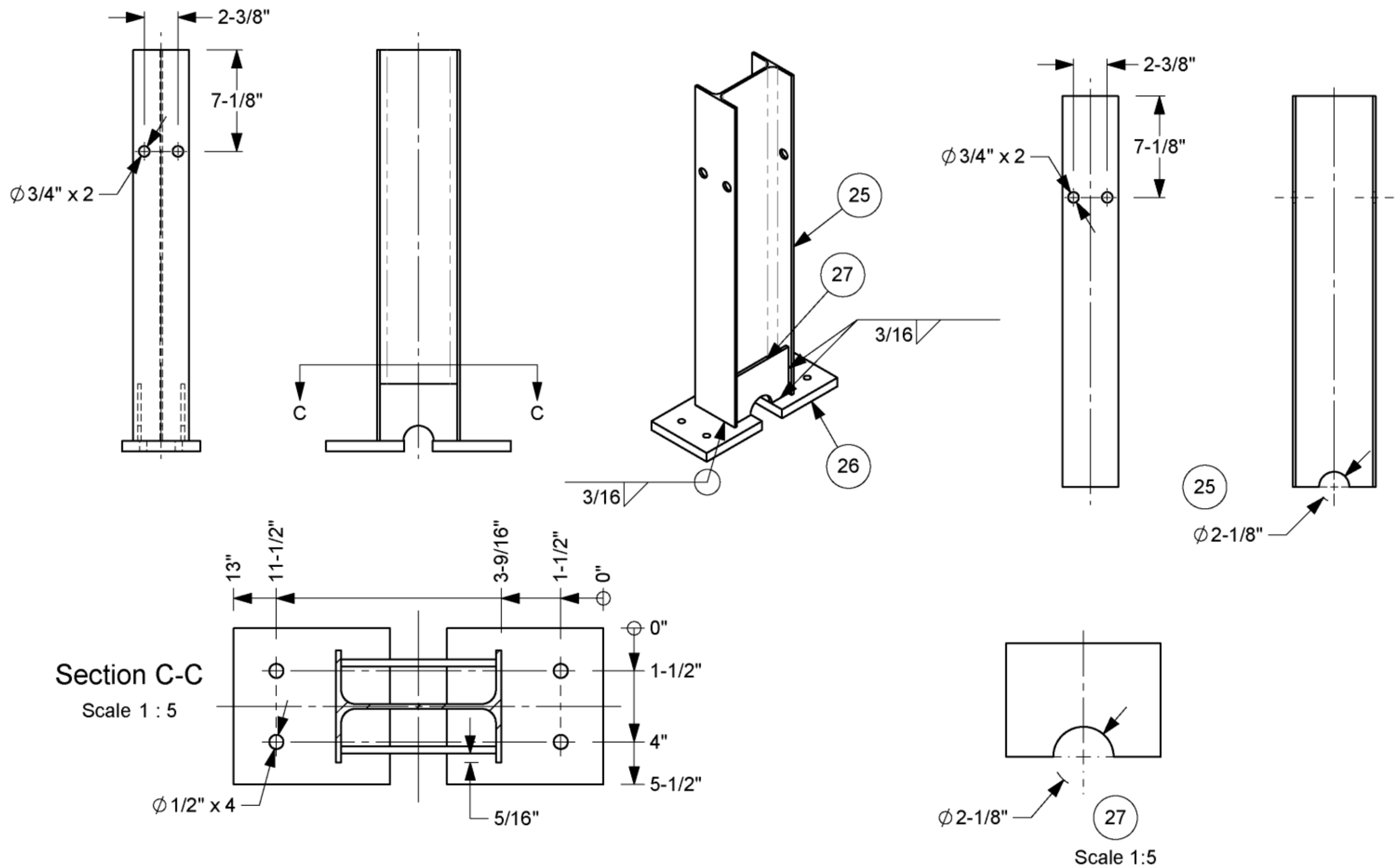
Detail B
Scale 1 : 5



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



#	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

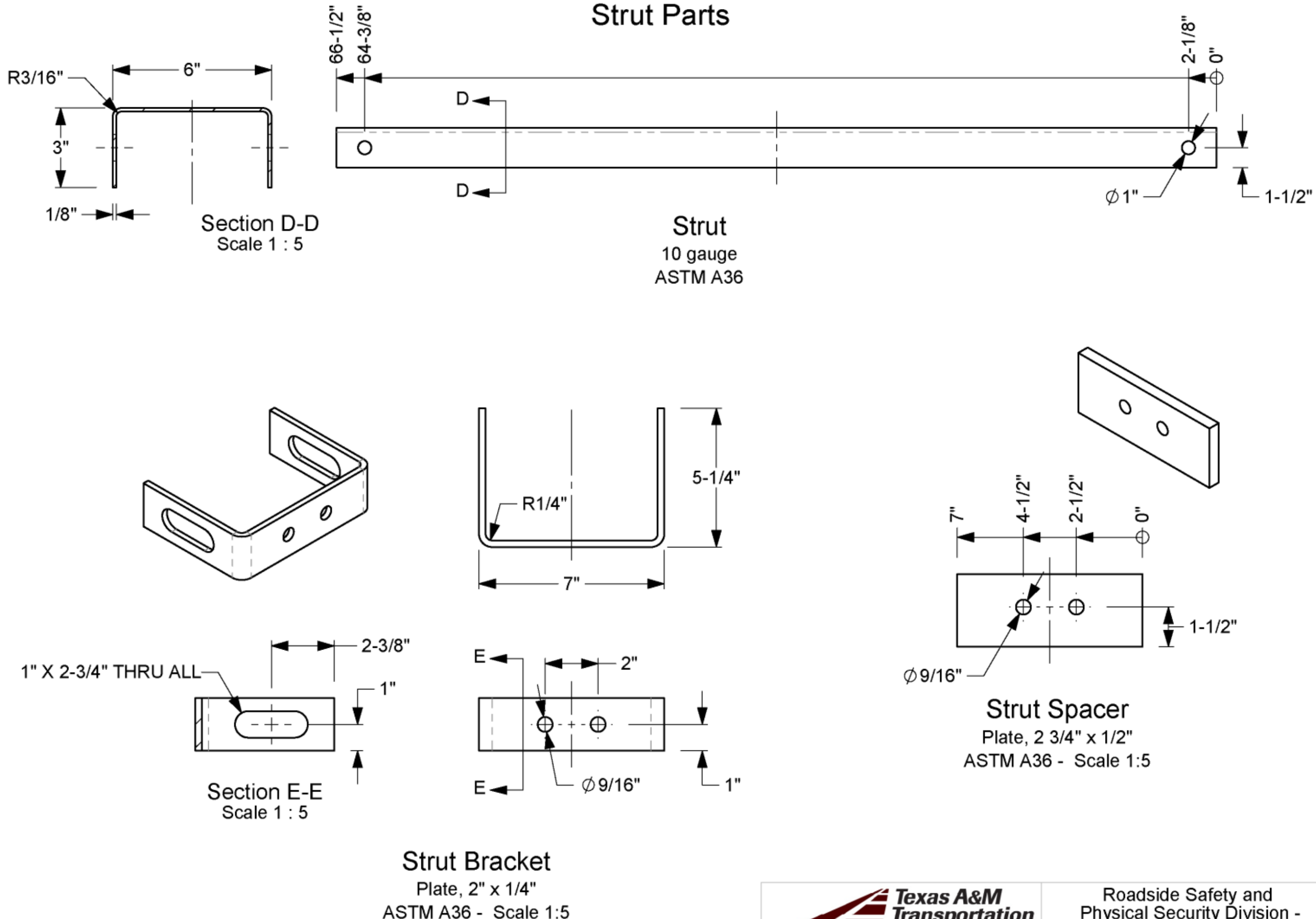
Roadside Safety and Physical Security Division - Proving Ground

Project # Terminal | 2023-02-08

Drawn by GES | Scale 1:10 | Sheet 3 of 6 Post Top

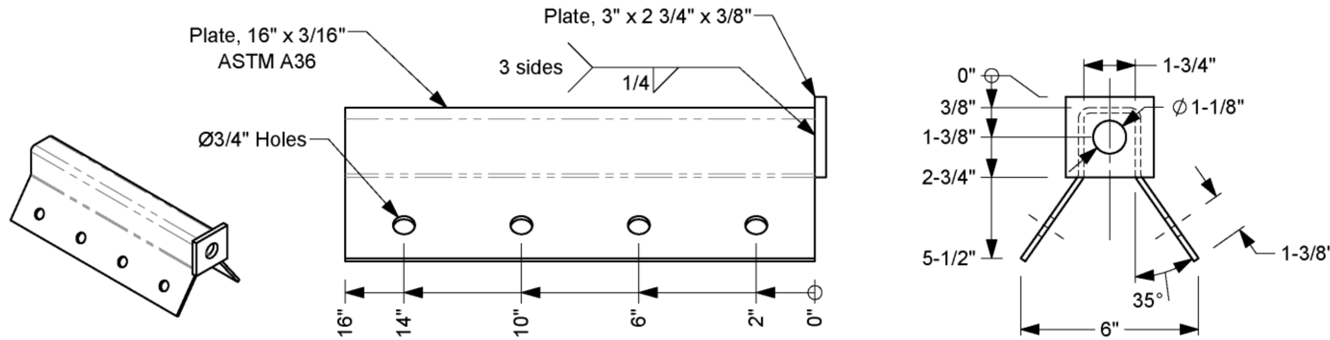
S:\engrfact\Drafting Department\Solidworks\Standard Parts\Guardrail Parts and Subs\Guardrail Drawings\Steel Post Terminal

Strut Parts

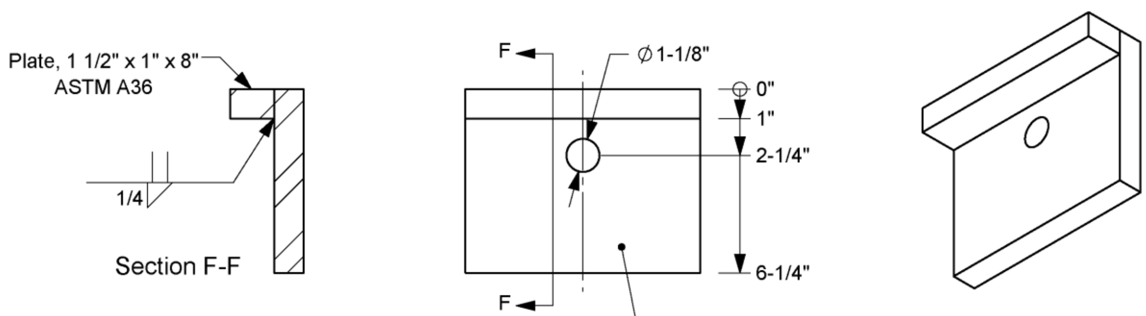


Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project # Terminal		2023-02-08
Drawn by GES	Scale 1:10	Sheet 4 of 6 Strut Parts

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



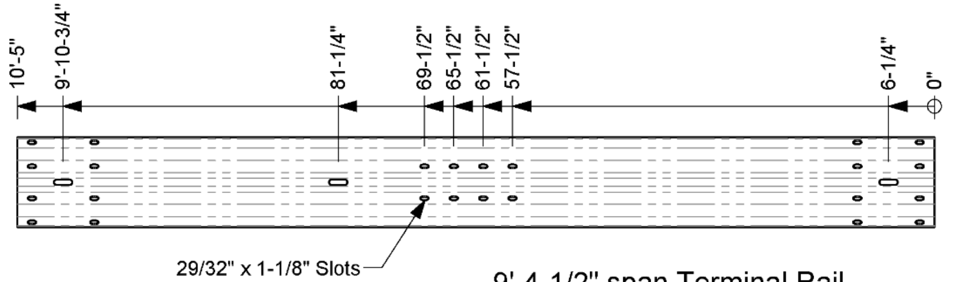
Guardrail Anchor Bracket



Bearing Plate

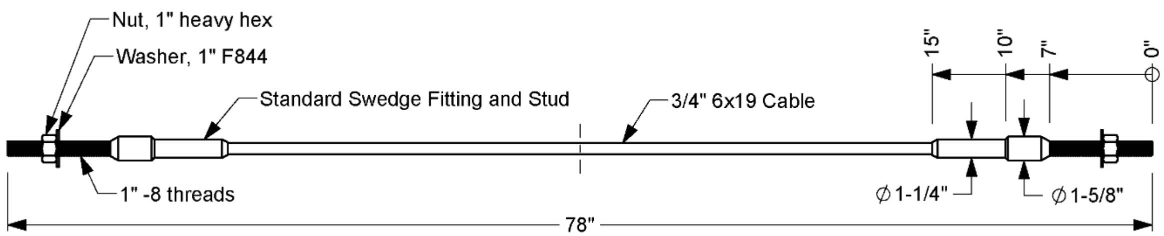
Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
	Project # Terminal		2023-02-08
Drawn by GES	Scale 1:5	Sheet 5 of 6 Assorted Parts A	

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.



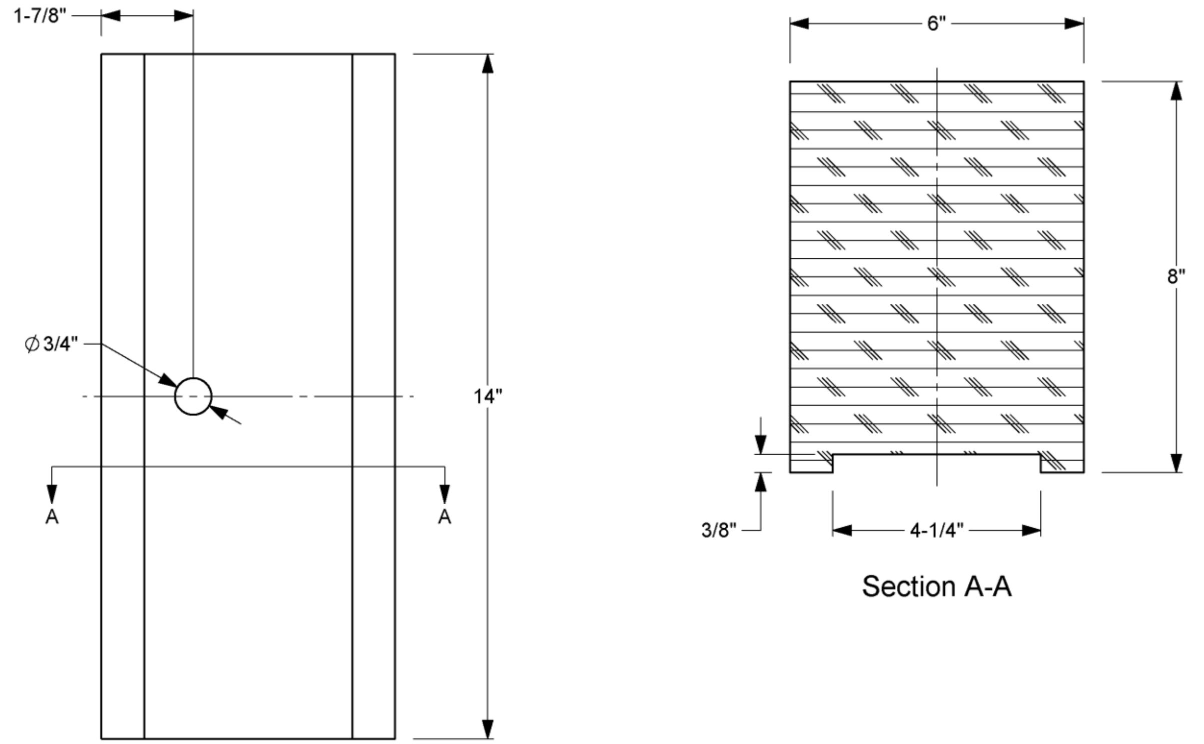
Anchor Cable Assembly

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



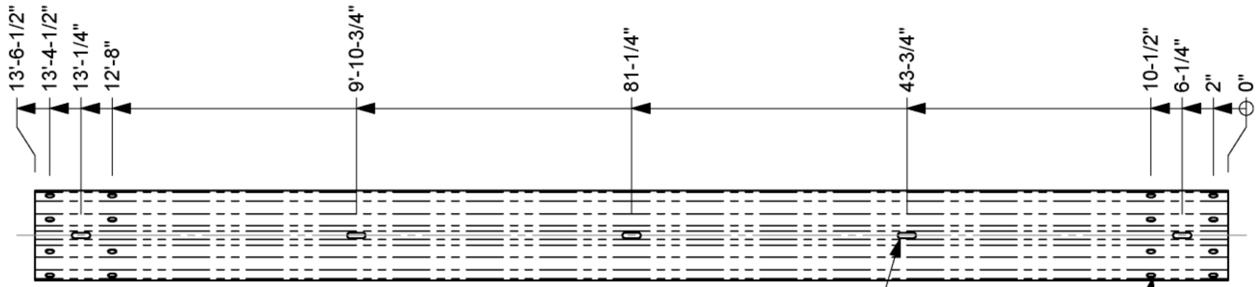
Elevation View

Section A-A

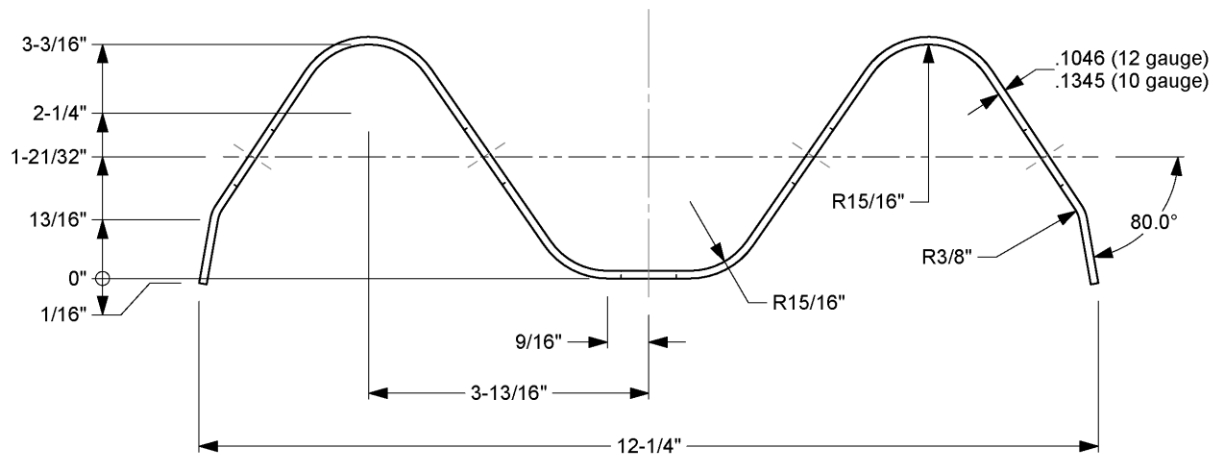
1a. Timber blockouts are treated with a preservative in accordance with AASHTO M 133 after all cutting and drilling.

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



Elevation View



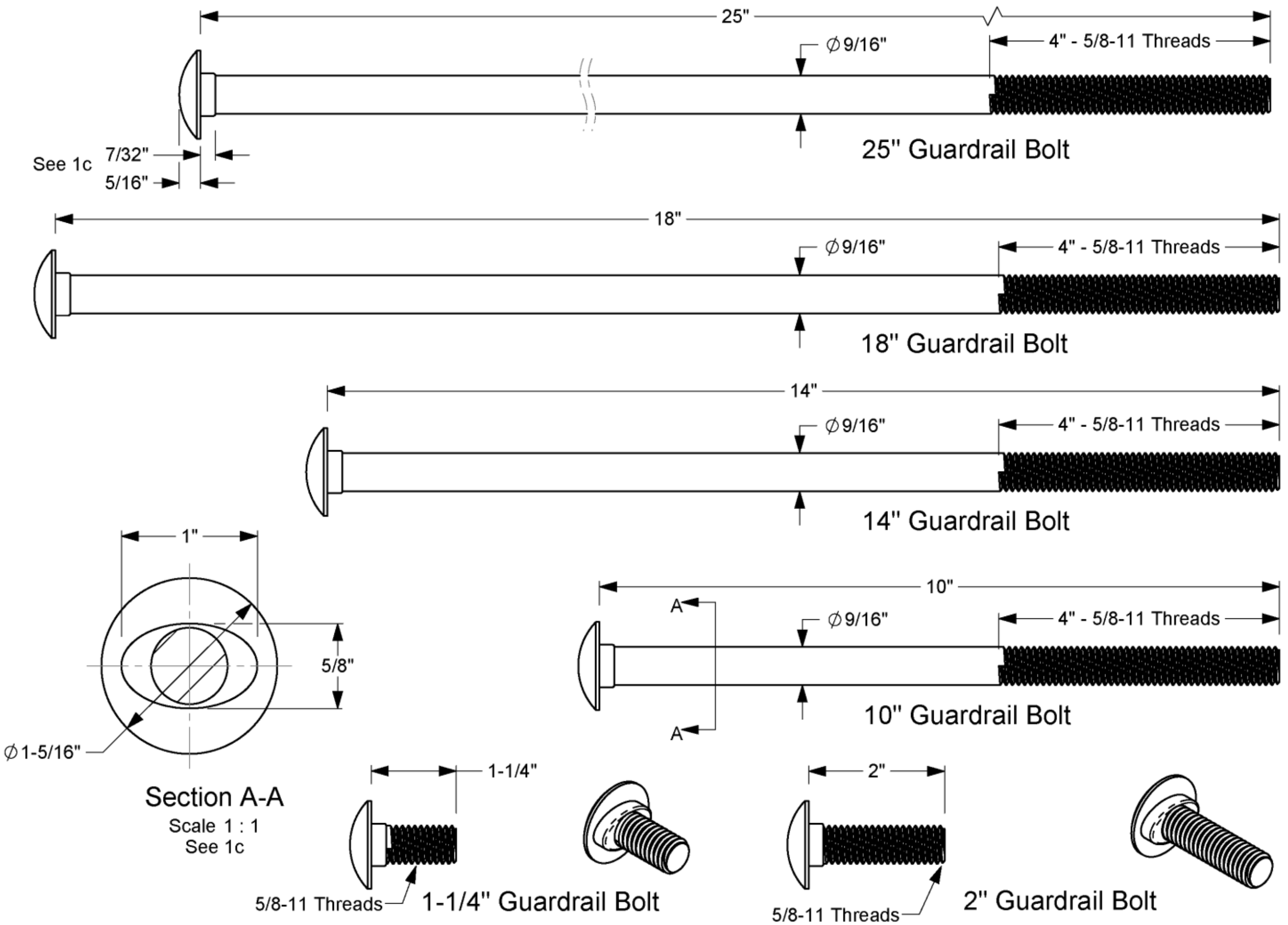
Section View

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

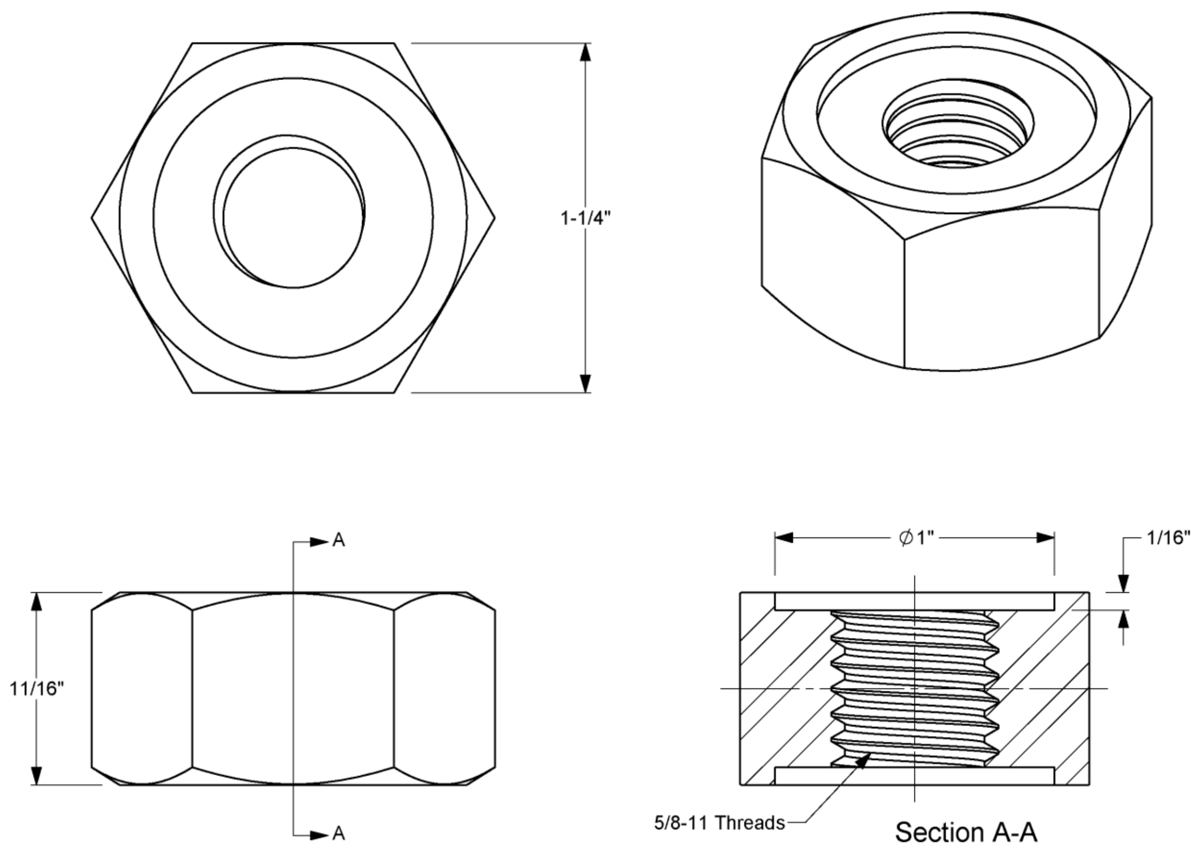


1a. Material is ASTM A307.
1b. All bolt sizes not used in all projects. See system drawing.
1c. Head and shoulder dimensions typical all lengths.

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

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

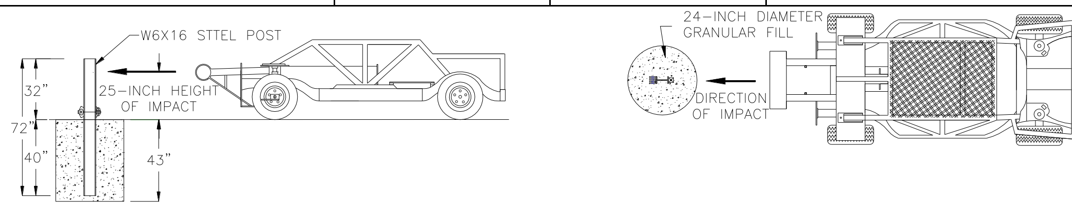
APPENDIX B. SUPPORTING CERTIFICATION DOCUMENTS

Dynamic Test Setup

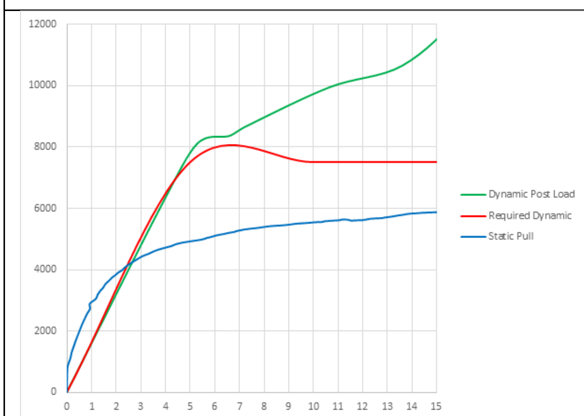
Post-Test Photo of Post

Static Load Test

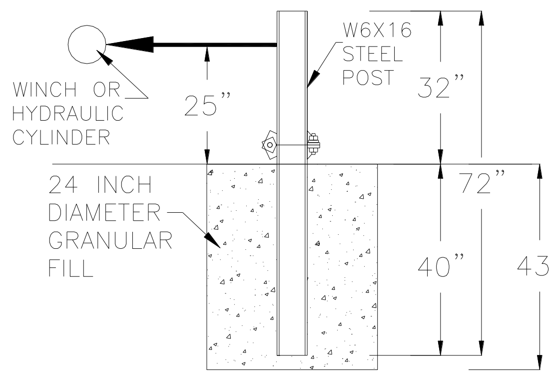
Post-Test Photo



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 s
Bogie Weight	2020 lb
Impact Velocity	19.2 mi/h

Soil Strength Performance Test

MASH, Appendix B

Project Number: 491534-01-1

Date of Crash Test: 2023-09-19

Post No. 1 of 2 Fill Moisture: NA% Native Moisture: NA%

Temperature: 77 ° F Humidity: 78%

File Name: -52

Displacement (in.)	*Pull Force (Lbf)	Minimum Force (Lbf)	Pass / Fail
5	9300	3940	P
10	9800	5500	P
15	9600	6540	P

*Do not exceed 10,000 lbf

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

Performed by: Ed, Matt, Ken Date: 2023-09-19

Soil Strength Performance Test

***MASH*, Appendix B**

Project Number: 491534-01-2

Date of Crash Test: 2023-10-06

Post No. 1 of 2 Fill Moisture: NA% Native Moisture: NA%

Temperature: 73 ° F Humidity: 82%

File Name: SoilStrength_58.ASC

Displacement (in.)	*Pull Force (Lbf)	Minimum Force (Lbf)	Pass / Fail
5	7400	3940	P
10	8800	5500	P
15	10,000	6540	P

*Do not exceed 10,000 lbf

Test Post Location: 1 ft ☐ South ☒ North of terminal post
33 ft ☐ East ☐ West of terminal post

Performed by: Brackin, Kochman, Robinson Date: 2023-10-06

491553

Certified Analysis

VALTIR

Valtir, LLC
2548 N.E. 28th St.
Ft Worth (THP), TX 76111 Phn:(817) 665-1499

Customer: TEXAS A&M TRANSPORTATION INSTI
ROADSIDE SAFETY & PHYSICA
BUSINESS OFFICE
3135 TAMU
COLLEGE STATION, TX 77843-3135

Project: STOCK

Order Number: 1358214 Prod Ln Grp: 0-OE2.0
Customer PO: 491553
BOL Number: 91111 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 5/24/23

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn
15	11G	12/12'6/3'1.5/S			2	F11823												
			M-180	A	2	AA8107	59,700	86,800	21.0	0.210	0.490	0.007	0.001	0.020	0.013	0.000	0.090	0.002
			M-180	A	2	AA8108	56,700	80,000	24.0	0.210	0.480	0.007	0.002	0.020	0.120	0.001	0.090	0.002
			M-180	A	2	AA8110	62,400	86,800	20.0	0.230	0.470	0.008	0.002	0.020	0.110	0.000	0.090	0.002
			M-180	A	2	AA8112	62,800	84,400	23.0	0.210	0.480	0.006	0.002	0.030	0.120	0.000	0.080	0.003
	11G				2	F13122												
			M-180	A	2	277506	65,000	84,374	24.3	0.200	0.790	0.016	0.004	0.010	0.120	0.000	0.080	0.001
			M-180	A	2	277540	59,744	76,903	26.9	0.180	0.740	0.010	0.004	0.010	0.100	0.001	0.050	0.002
			M-180	A	2	277541	61,280	79,207	25.9	0.190	0.730	0.010	0.002	0.020	0.100	0.001	0.040	0.001
	11G				2	F13222												
			M-180	A	2	2122871	58,100	81,100	23.0	0.210	0.750	0.009	0.003	0.020	0.070	0.002	0.040	0.003
			M-180	A	2	2122872	50,800	74,300	26.0	0.220	0.790	0.009	0.002	0.030	0.080	0.001	0.040	0.003
			M-180	A	2	2122872	61,000	83,300	,999.0	0.220	0.790	0.009	0.002	0.030	0.080	0.000	0.040	0.003
			M-180	A	2	277506	65,000	84,374	24.3	0.200	0.790	0.016	0.004	0.010	0.120	0.000	0.080	0.001
			M-180	A	2	277540	59,744	76,903	26.9	0.180	0.740	0.010	0.004	0.010	0.100	0.001	0.050	0.002
			M-180	A	2	277541	61,280	79,207	25.9	0.190	0.730	0.010	0.002	0.020	0.100	0.001	0.040	0.001
			M-180	A	2	277542	61,872	79,516	25.8	0.200	0.760	0.009	0.005	0.010	0.100	0.000	0.050	0.001
30	533G	6'0 POST/8.5/DDR/7	A-36			1114803	54,500	67,500	28.3	0.070	0.840	0.007	0.022	0.230	0.130	0.015	0.040	0.002
	533G		A-36			2104723	54,000	66,200	26.0	0.070	80.000	0.013	0.020	0.200	0.100	0.014	0.040	0.002
	533G					VF1923B												
			A-709			59110729	58,770	71,691	22.7	0.070	0.840	0.011	0.031	0.220	0.260	0.013	0.014	0.001
			A-709			59110730	59,045	72,898	23.3	0.090	0.860	0.012	0.024	0.220	0.250	0.013	0.150	0.001
			A-709			59110732	58,972	73,363	23.3	0.080	0.950	0.013	0.021	0.220	0.029	0.011	0.150	0.001
30	3340G	5/8" GR HEX NUT	FAST			23-35-001												

Certified Analysis

VALTIR

Valtir, LLC
2548 N.E. 28th St.
Ft Worth (THP), TX 76111 Phn:(817) 665-1499
Customer: TEXAS A&M TRANSPORTATION INSTI
ROADSIDE SAFETY & PHYSICA
BUSINESS OFFICE
3135 TAMU
COLLEGE STATION, TX 77843-3135
Project: STOCK

Order Number: 1358214 Prod Ln Grp: 0-OE2.0
Customer PO: 491553
BOL Number: 91111 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 5/24/23

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn
30	3500G	5/8"X10" GR BOLT A307	A307-3500G			A20068-6												
30	4075B	WD BLK 6X8X14	WOOD			22--924												

Upon delivery, all materials subject to Valtir, LLC Storage Stain Policy QMS-LQ-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT, 23 CFR 635.410.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36 UNLESS OTHERWISE STATED.

ALL COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT", 23 CFR 635.410.
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 (US DOMESTIC SHIPMENTS)
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 & ISO 1461 (INTERNATIONAL SHIPMENTS)

FINISHED GOOD PART NUMBERS ENDING IN SUFFIX B,P, OR S, ARE UNCOATED

BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.

NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
WASHERS COMPLY WITH ASTM F-436 SPECIFICATION AND/OR F-844 AND ARE GALVANIZED IN ACCORDANCE WITH ASTM F-2329, UNLESS OTHERWISE STATED.
3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH – 46000 LB

State of Texas, County of Tarrant. Sworn and subscribed before me this 24th day of May, 2023 .

Notary Public:
Commission Expires: /

MARIANA GISELA SALINAS
Notary Public, State of Texas
Comm. Expires 03-16-2027
Notary ID 134256660

Certified By: Valtir, LLC
Quality Assurance

2 of 3

Certified Analysis

VALTIR

Valtir, LLC
2548 N.E. 28th St.
Ft Worth (THP), TX 76111 Phn:(817) 665-1499

Customer: TEXAS A&M TRANSPORTATION INSTI
ROADSIDE SAFETY & PHYSICA
BUSINESS OFFICE
3135 TAMU
COLLEGE STATION, TX 77843-3135

Project: STOCK

Order Number: 1358214 Prod Ln Grp: 0-OE2.0
Customer PO: 491553
BOL Number: 91111 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 5/24/23

APPENDIX C. *MASH* TEST 3-10 (CRASH TEST 491534-01-1)

C.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2023-09-19 Test No.: 491534-01-1 VIN No.: 13NCN7APOJL814904

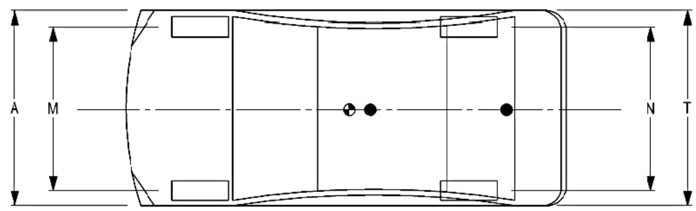
Year: 2018 Make: Nissan Model: Versa

Tire Inflation Pressure: 36 PSI Odometer: 122162 Tire Size: P185/65R15

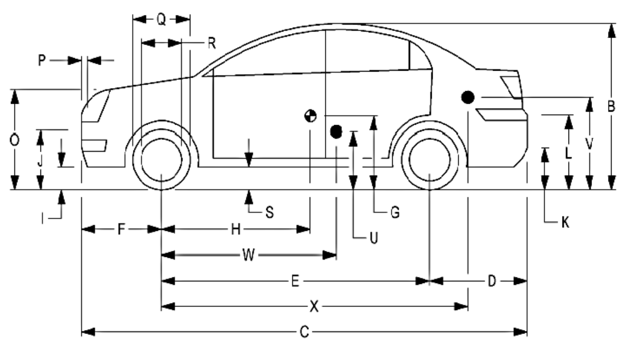
Describe any damage to the vehicle prior to test: None

● Denotes accelerometer location.

NOTES: None



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



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

Geometry: inches

A	66.70	F	32.50	K	12.50	P	4.50	U	15.50
B	59.60	G	0.00	L	26.00	Q	24.00	V	21.25
C	175.40	H	41.24	M	58.30	R	16.25	W	41.00
D	40.50	I	7.00	N	58.50	S	7.50	X	79.75
E	102.40	J	22.50	O	30.50	T	64.50		

Wheel Center Ht Front 11.50 Wheel Center Ht Rear 11.50 W-H -0.24

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

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1750	M_{front}	1440	1459	1544
Back	1687	M_{rear}	778	984	1064
Total	3389	M_{Total}	2218	2443	2608

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

Mass Distribution:
lb LF: 740 RF: 719 LR: 482 RR: 502

Figure C.1. Vehicle Properties for Test 491534-01-1.

Date:	2023-09-19	Test No.:	491534-01-1	VIN No.:	3N1CN7APOJL814904
Year:	2018	Make:	Nissan	Model:	Versa

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	AT FRONT BUMPER	9	6	24	-	-	-	-	-	-	+16
2	ABOVE FT BUMPER	22	10	46	-	-	-	-	-	-	52
	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.

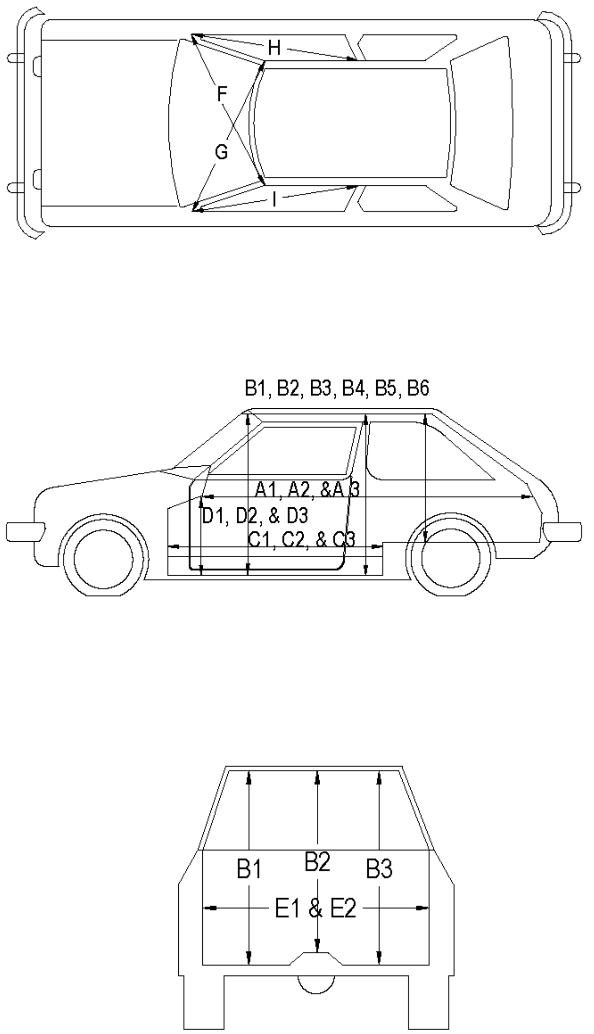
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***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 491534-01-1.

Date:	2023-09-19	Test No.:	491534-01-1	VIN No.:	3N1CN7APOJL814904
Year:	2018	Make:	Nissan	Model:	Versa



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

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	67.50	67.50	0.00
A2	67.25	67.25	0.00
A3	67.75	67.75	0.00
B1	40.50	40.50	0.00
B2	39.00	39.00	0.00
B3	40.50	40.50	0.00
B4	36.25	36.25	0.00
B5	36.00	36.00	0.00
B6	36.25	36.25	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	26.00	0.00
D1	9.50	9.50	0.00
D2	0.00	0.00	0.00
D3	9.50	9.00	-0.50
E1	51.50	51.25	-0.25
E2	51.00	51.00	0.00
F	51.00	51.00	0.00
G	51.00	51.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	51.00	50.75	-0.25

Figure C.3. Occupant Compartment Measurements for Test 491534-01-1.

C.2. SEQUENTIAL PHOTOGRAPHS

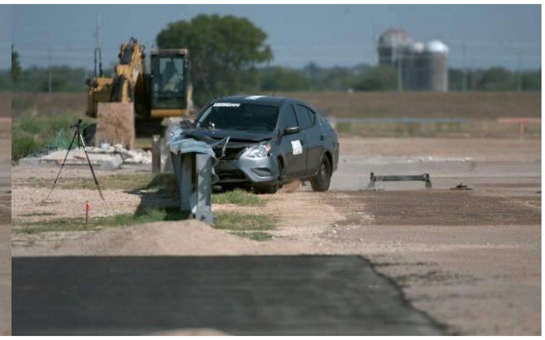
(a) 0.000 s (b) 0.100 s

(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 491534-01-1 (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 491534-01-1 (Frontal Views).

(a) 0.000 s

(b) 0.100 s

(c) 0.200 s

(d) 0.300 s

(e) 0.400 s

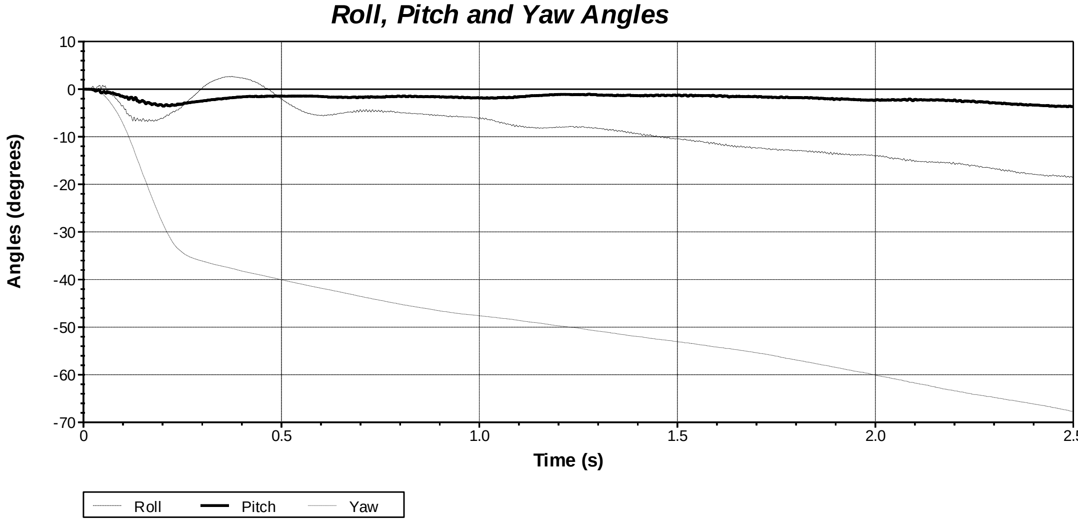
(f) 0.500 s

(g) 0.600 s

(h) 0.700 s

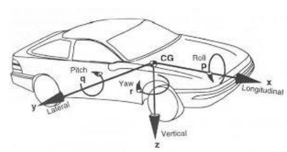
Figure C.6. Sequential Photographs for Test 491534-01-1 (Rear Views).

C.3. VEHICLE ANGULAR DISPLACEMENTS



Axes are vehicle-fixed.
Sequence for determining orientation:

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



Test Number: 491534-01-1
Test Standard Test Number: *MASH* Test 3-10
Test Article: Enhanced Motorcycle MGS
Test Vehicle: 2018 Nissan Versa
Inertial Mass: 2443 lb
Gross Mass: 2608 lb
Impact Speed: 61.2 mi/h
Impact Angle: 25.5°

Figure C.7. Vehicle Angular Displacements for Test 491534-01-1.

C.4. VEHICLE ACCELERATIONS

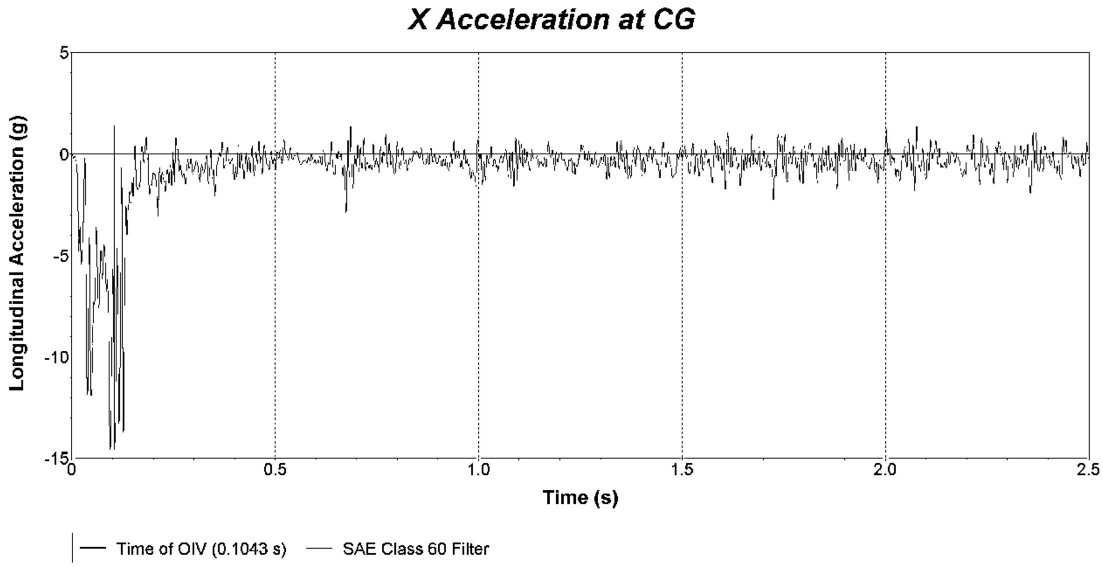


Figure C.8. Vehicle Longitudinal Accelerometer Trace for Test 491534-01-1 (Accelerometer Located at Center of Gravity).

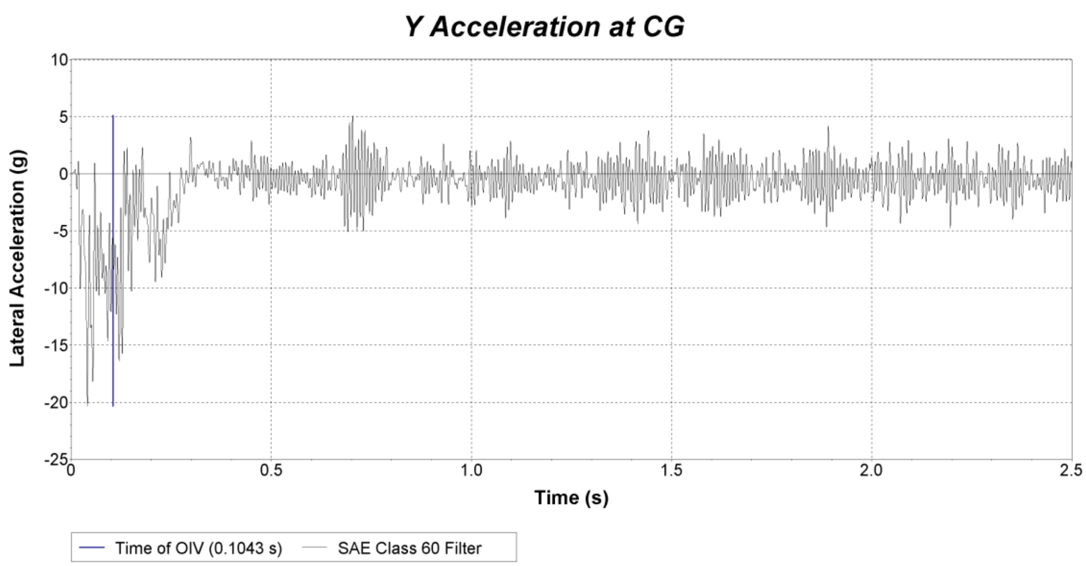


Figure C.9. Vehicle Lateral Accelerometer Trace for Test 491534-01-1 (Accelerometer Located at Center of Gravity).

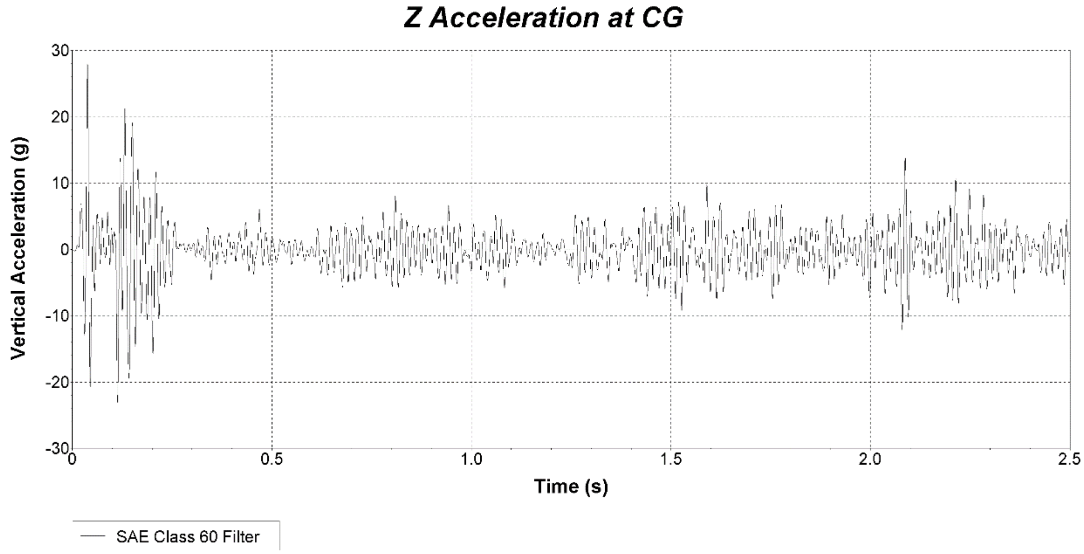


Figure C.10. Vehicle Vertical Accelerometer Trace for Test 491534-01-1 (Accelerometer Located at Center of Gravity).

APPENDIX D. *MASH* TEST 3-11 (CRASH TEST 491534-01-2)

D.1. VEHICLE PROPERTIES AND INFORMATION

Date:	2023-10-06	Test No.:	491534-01-2	VIN No.:	1C6RR6FT4JS313051
Year:	2018	Make:	RAM	Model:	1500

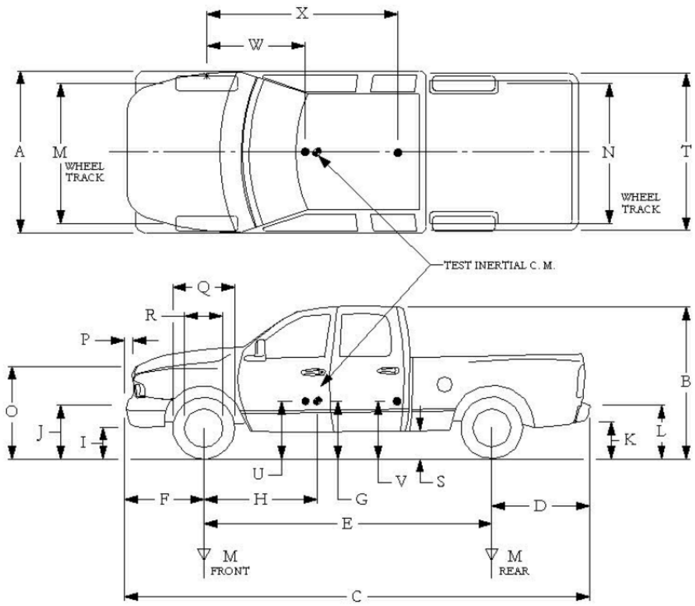
Tire Size: 265/70 R 17 Tire Inflation Pressure: 35 psi

Tread Type: Highway Odometer: 114689

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	61.13	M	68.50	R	18.00	W	61.00
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}	2921	2838	2838
Back	3900	M_{rear}	2054	2186	2186
Total	6700	M_{Total}	4975	5024	5024

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

Mass Distribution:
lb LF: 1391 RF: 1447 LR: 1128 RR: 1058

Figure D.1. Vehicle Properties for Test 491534-01-2.

Date:	2023-10-06	Test No.:	491534-01-2	VIN No.:	1C6RR6FT4JS313051
Year:	2018	Make:	RAM	Model:	1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	AT FRONT BUMPER	18	12	32	-	-	-	-	-	-	+14
2	SAME	18	11	62	-	-	-	-	-	-	73
	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.

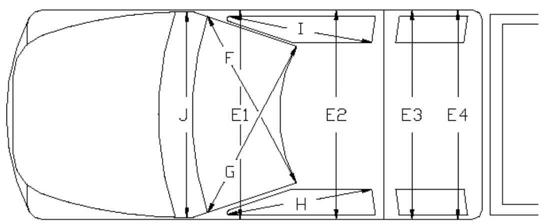
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

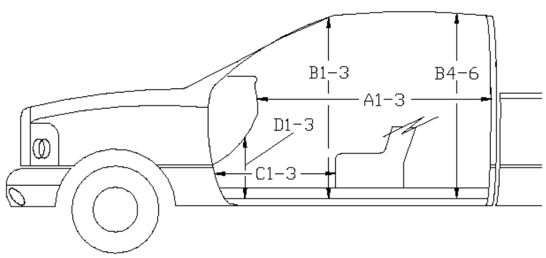
***Measure and document on the vehicle diagram the location of the maximum crush.

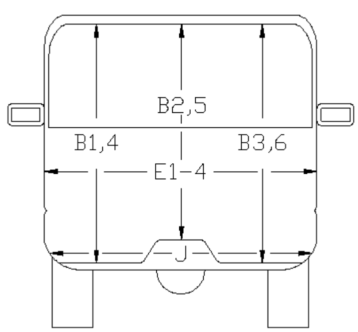
Note: Use as many lines/columns as necessary to describe each damage profile.

Figure D.2. Exterior Crush Measurements for Test 491534-01-2.

Date:	2023-10-06	Test No.:	491534-01-2	VIN No.:	1C6RR6FT4JS313051
Year:	2018	Make:	RAM	Model:	1500







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

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

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

Figure D.3. Occupant Compartment Measurements for Test 491534-01-2.

D.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

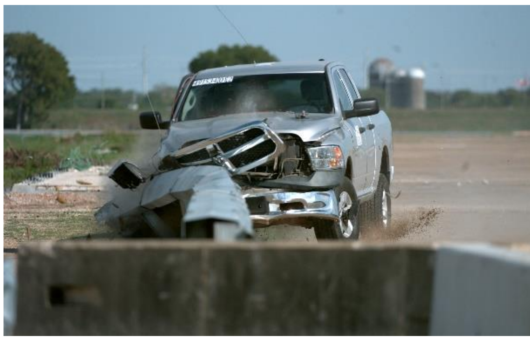

(g) 0.600 s


(h) 0.700 s

Figure D.4. Sequential Photographs for Test 491534-01-2 (Overhead Views).

(a) 0.000 s

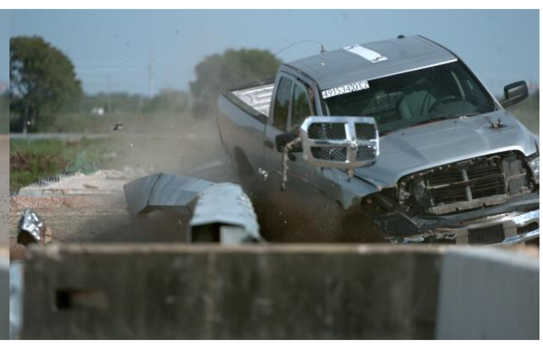
(b) 0.100 s



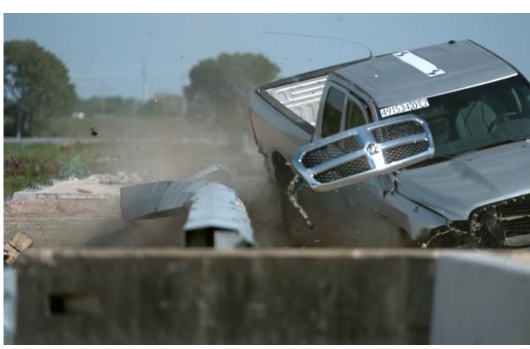
(c) 0.200 s

(d) 0.300 s

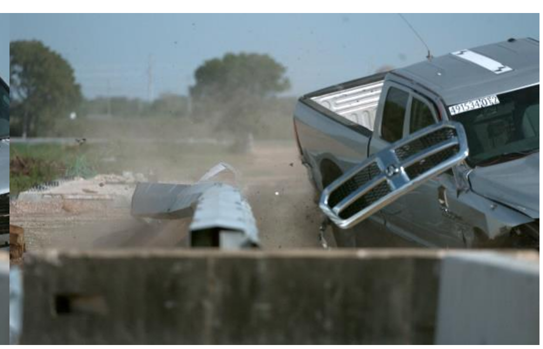
(e) 0.400 s



(f) 0.500 s



(g) 0.600 s



(h) 0.700 s

Figure D.5. Sequential Photographs for Test 491534-01-2 (Frontal Views).


(a) 0.000 s (b) 0.100 s

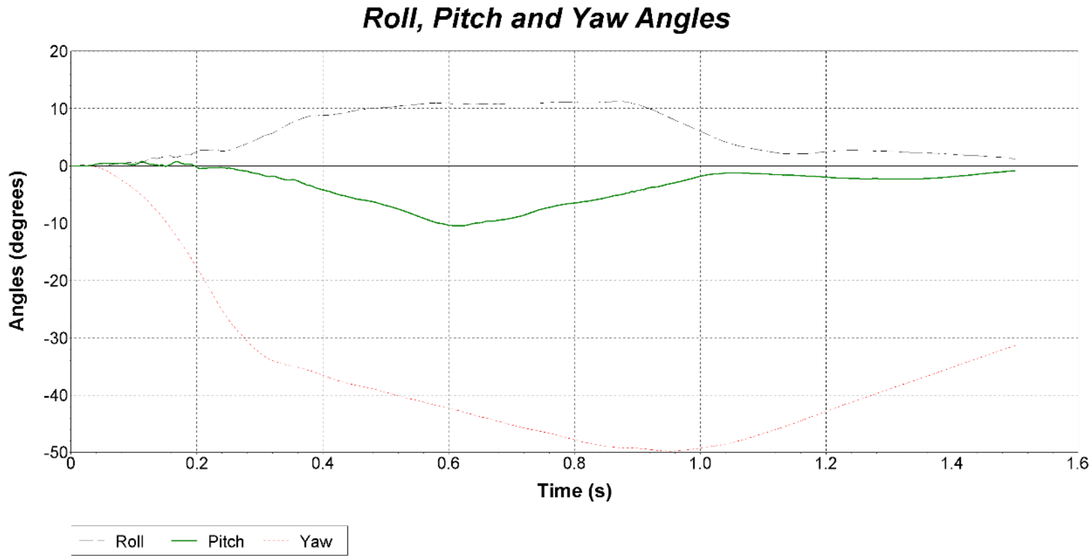

(c) 0.200 s (d) 0.300 s


(e) 0.400 s (f) 0.500 s


(g) 0.600 s (h) 0.700 s

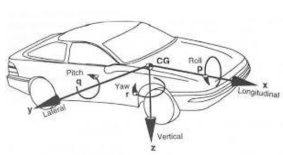
Figure D.6. Sequential Photographs for Test 491534-01-2 (Rear Views).

D.3. VEHICLE ANGULAR DISPLACEMENTS



Axes are vehicle-fixed.
Sequence for determining orientation:

4. Yaw.
5. Pitch.
6. Roll.



Test Number: 491534-01-2
Test Standard Test Number: *MASH* Test 3-11
Test Article: Enhanced Motorcycle MGS Test
Vehicle: 2018 RAM 1500
Inertial Mass: 5024 lb
Gross Mass: 5024 lb
Impact Speed: 63.1 mi/h
Impact Angle: 25.5°

Figure D.7. Vehicle Angular Displacements for Test 491534-01-2.

D.4. VEHICLE ACCELERATIONS

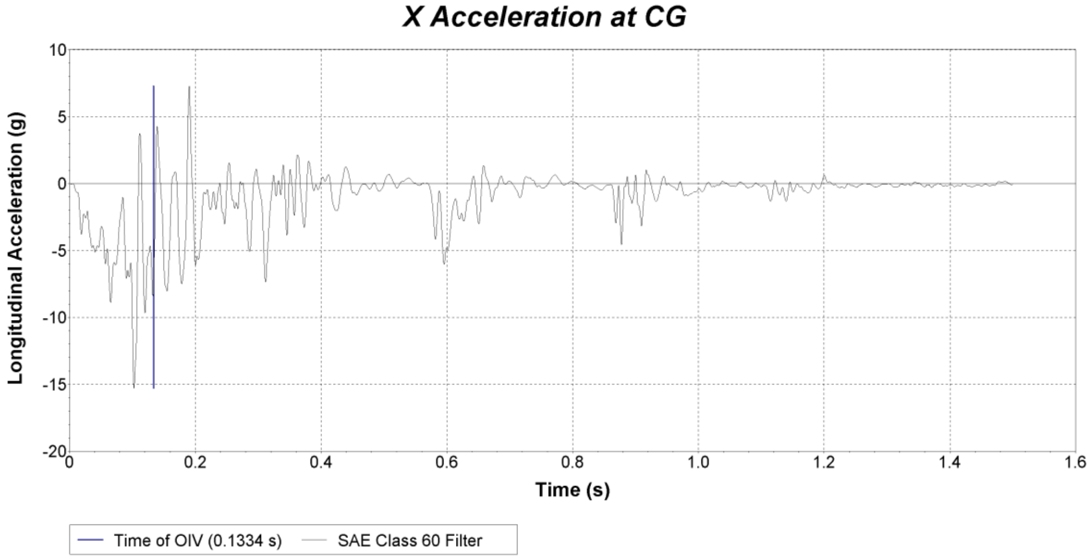


Figure D.8. Vehicle Longitudinal Accelerometer Trace for Test 491534-01-2 (Accelerometer Located at Center of Gravity).

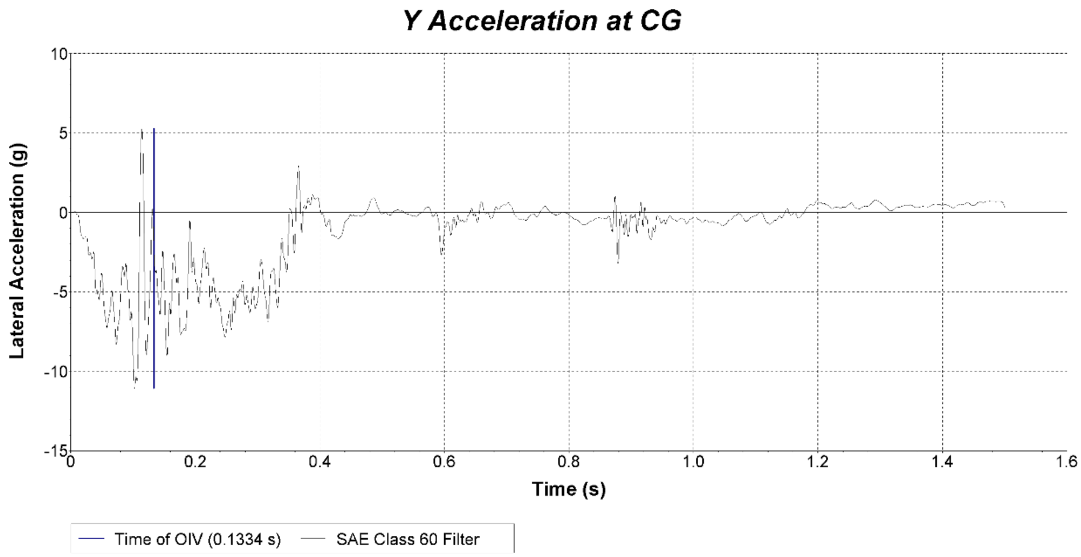


Figure D.9. Vehicle Lateral Accelerometer Trace for Test 491534-01-2 (Accelerometer Located at Center of Gravity).

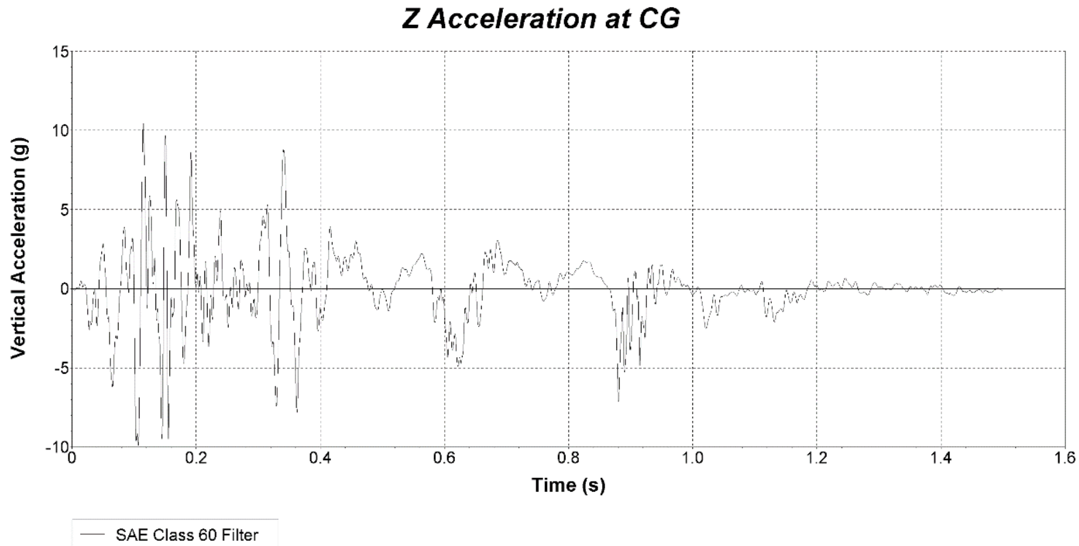


Figure D.10. Vehicle Vertical Accelerometer Trace for Test 491534-01-2 (Accelerometer Located at Center of Gravity).