



MASH TEST 3-11 EVALUATION OF TXDOT W-BEAM GUARDRAIL WITH 7½-INCH DIAMETER ROUND WOOD POSTS IN CONCRETE MOW STRIP



Crash testing performed at:
TTI Proving Ground
3100 SH 47, Building 7091
Bryan, TX 77807

Test Report 0-6968-R2

Cooperative Research Program

TEXAS A&M TRANSPORTATION INSTITUTE

COLLEGE STATION, TEXAS

TEXAS DEPARTMENT OF TRANSPORTATION

in cooperation with the
Federal Highway Administration and the
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16. Abstract <p>The purpose of the testing reported herein was to assess the performance of the Texas Department of Transportation (TxDOT) W-beam guardrail with 7½-inch diameter round wood posts in concrete mow strip according to the safety-performance evaluation guidelines included in the American Association of Safety Highway and Transportation Officials <i>Manual for Assessing Safety Hardware (MASH)</i> for Test Level Three (TL-3) longitudinal barriers. The crash test performed was in accordance with <i>MASH</i> Test 3-11, which involves a 2270P vehicle impacting the TxDOT W-beam guardrail with 7½-inch diameter round wood posts in concrete mow strip at a target impact speed and impact angle of 62 mi/h and 25°, respectively.</p> <p>The TxDOT W-beam guardrail with 7½-inch diameter round wood posts in concrete mow strip performed acceptably for <i>MASH</i> Test 3-11.</p>					
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by

Sana M. Moran
Assistant Transportation Researcher
Texas A&M Transportation Institute

Roger P. Bligh, Ph.D., P.E.
Senior Research Engineer
Texas A&M Transportation Institute

Wanda L. Menges
Research Specialist
Texas A&M Transportation Institute

Glenn E. Schroeder
Research Specialist
Texas A&M Transportation Institute

and

Darrell L. Kuhn, P.E.
Research Specialist
Texas A&M Transportation Institute

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College Station, Texas 77843-3135

DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation.

This report is not intended for construction, bidding, or permit purposes. The engineer in charge of the project was Roger P. Bligh, Ph.D., P.E., TX #78550.

The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

TTI PROVING GROUND DISCLAIMER

The results of the crash testing reported herein apply only to the article tested.

REPORT AUTHORIZATION

Bill L. Griffith, Research Specialist
Deputy Quality Manager

Darrell L. Kuhn, P.E., Research Specialist
Quality Manager

Matthew N. Robinson, Research Specialist
Test Facility Manager & Technical Manager

Sana M. Moran
Assistant Transportation Researcher

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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

1.1 PROBLEM

In July 2018, the Texas Department of Transportation (TxDOT) Round Wood Post Guardrail System in soil with 36-inch embedment performed acceptably in the *Manual for Assessing Safety Hardware (MASH)* Test 3-11 (1, 2). This system was then evaluated in a concrete mow strip application and did not perform acceptably in *MASH* Test 3-11 (3). Following the failed test, dynamic bogie impact tests were performed to evaluate different post alternatives (4). Based on the dynamic bogie impact tests, a 7½-inch diameter post was selected for testing.

1.2 OBJECTIVE/SCOPE OF RESEARCH

The purpose of the testing reported herein was to assess the performance of the TxDOT W-beam guardrail with 7½-inch diameter round wood posts in concrete mow strip according to the safety-performance evaluation guidelines included in the American Association of State Highway and Transportation Officials (AASHTO) *MASH* for Test Level Three (TL-3) longitudinal barriers. The crash test was performed in accordance with *MASH* Test 3-11, which involves a 2270P vehicle impacting the TxDOT W-beam guardrail with 7½-inch diameter round wood posts in concrete mow strip at a target impact speed and impact angle of 62 mi/h and 25°, respectively.

CHAPTER 2: SYSTEM DETAILS

2.1 TEST ARTICLE AND INSTALLATION DETAILS

The TxDOT W-beam guardrail with 7½-inch diameter round wood posts in concrete mow strip had a total length of 181 ft-3 inches. This consisted of 162 ft-6 inches of 12-gauge W-beam guardrail attached to 7½ inch diameter wood posts with a TxDOT downstream anchor terminal (DAT) [GF (31) DAT-14] on each end. The top of the rail was located 31 inches above grade, the posts were spaced 75 inches center-to-center, and the guardrail splices were located mid-span between every other post. Standard 12-gauge W-beam guardrail (type RWM04a) was used in the system. Each TxDOT GF (31) DAT-14 terminal was 9 ft-4½ inches long as measured from their anchor posts to the W-beam splice between posts 2 and 3 and posts 28 and 29, respectively.

Guardrail posts 3 through 28 were 6 ft long (including a rounded top) round wood guardrail line posts. The posts were installed 36 inches deep in drilled holes, using 18-inch long guardrail bolts, USS flat washers, and recessed guardrail nuts. The holes were backfilled and compacted with soil meeting Grading B of AASHTO standard specification M147-65(2004) “Materials for Aggregate and Soil Aggregate Subbase, Base and Surface Courses.” The modified round wood posts nominally measured 14 inches tall × 6 inches wide × 8 inches deep, including a routed ¾-inch radius on the post side.

Guardrail posts 8 through 23 were placed in 19-inch square voids (leaveouts) cast into the 4-inch thick × 42-inch wide × 100-ft long concrete mow strip. The soil backfill at these post locations stopped at the bottom of the mow strip. The top 4 inches (inside the voids) was filled with low strength grout after the posts were installed.

Figure 2.1 presents overall information on the TxDOT W-beam guardrail with 7½-inch diameter round wood posts in concrete mow strip, and Figure 2.2 provides photographs of the installation. Appendix A provides further details of the TxDOT W-beam guardrail with 7½-inch diameter round wood posts in concrete mow strip.

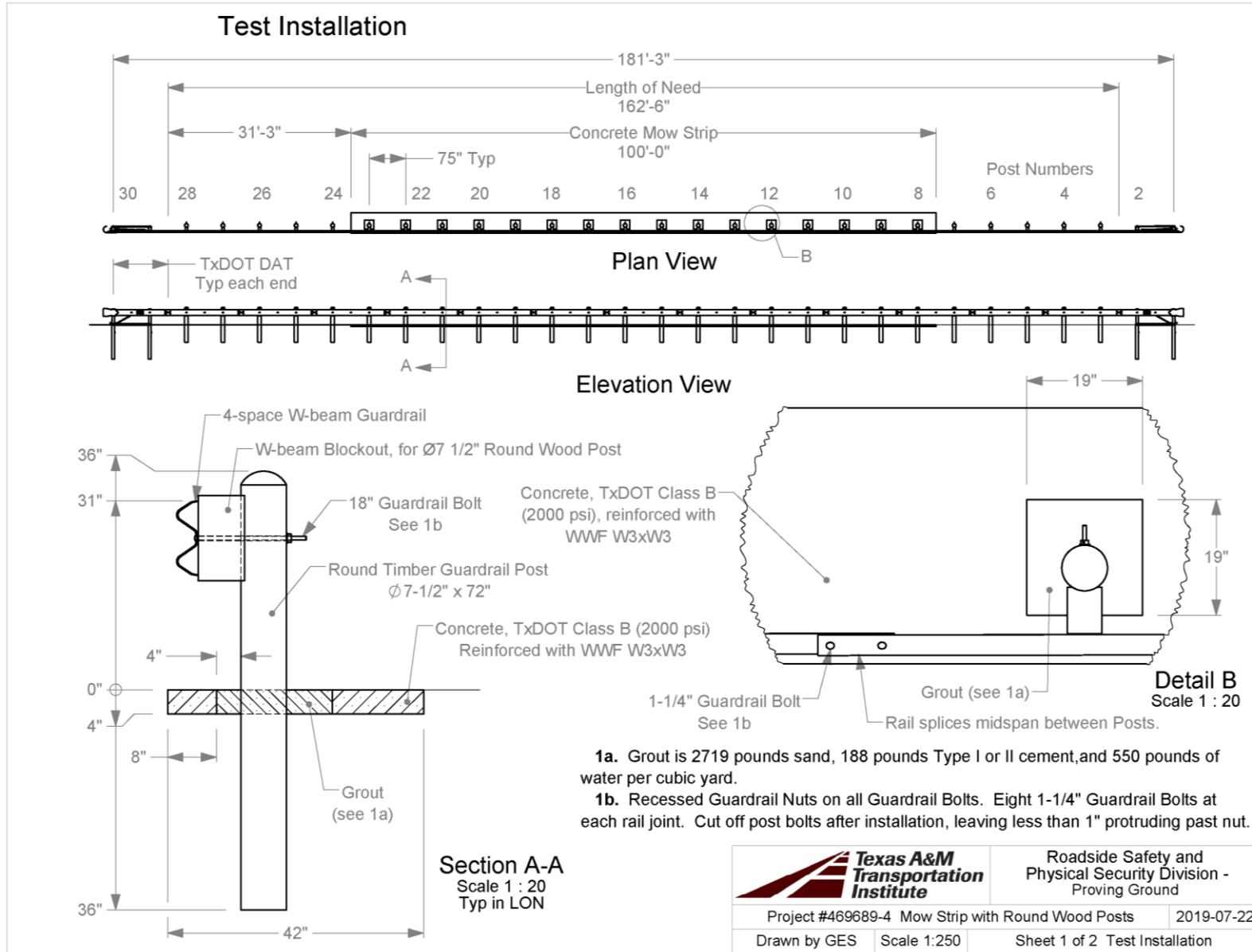
2.2 DESIGN MODIFICATIONS DURING TESTS

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

2.3 MATERIAL SPECIFICATIONS

The specified concrete strength for the mow strip for this test was 2000 psi. Concrete strength measured 3040 psi on 2017-10-09 at 17 days of age.

The low-strength grout mix used in the leave-outs was comprised of 188 lb of Type I or II cement, 2719 lb of sand, and 550 lb of water per cubic yard of grout. Grout compressive strength measured 230 psi on 2019-08-16 (on the day of the test) at 21 days of age.



T:\1-ProjectFiles\469689-TxDOT\4 Mow Strip with Round Wood Posts\Drafting_469469-4\469689-4 Drawing

Figure 2.1. Overall Details of TxDOT W-Beam Guardrail with 7 1/2-Inch Diameter Round Wood Posts in Concrete Mow Strip.



Figure 2.2. TxDOT W-Beam Guardrail with 7½-inch Diameter Round Wood Posts in Concrete Mow Strip prior to Testing.

Appendix A.2 provides material certification documents for the materials used to install/construct the TxDOT W-beam guardrail with 7½-inch diameter round wood posts in concrete mow strip.

2.4 SOIL CONDITIONS

The test installation was installed in standard soil meeting AASHTO standard specifications for “Materials for Aggregate and Soil Aggregate Subbase, Base and Surface Courses,” designated M147-65(2004), grading B.

In accordance with Appendix B of *MASH*, soil strength was measured the day of the crash test. During installation of the TxDOT W-beam guardrail with 7½-inch diameter round wood posts in concrete mow strip for full-scale crash testing, two standard W6×16 posts were installed in the immediate vicinity of the installation, using the same fill materials and installation procedures used in the standard dynamic test performed (see Table C.1 in Appendix C for establishment minimum soil strength properties in the dynamic test performed in accordance with *MASH* Appendix B).

As determined in the tests shown in Appendix C, Table C.1, the minimum post load required for deflections at 5 inches, 10 inches, and 15 inches, measured at a height of 25 inches, is 3940 lb, 5500 lb, and 6540 lb, respectively (90 percent of static load for the initial standard installation). On the day of the test, August 16, 2019, load on the post at deflections of 5 inches, 10 inches, and 15 inches was 11,290 lbf, 11,428 lbf, and 11,049 lbf, respectively. In Appendix C, Table C.2 shows the strength of the backfill material in which the TxDOT W-beam guardrail with 7½-inch diameter round wood posts in concrete mow strip was installed met minimum requirements.

CHAPTER 3: TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1 CRASH TEST MATRIX

Table 3.1 shows the test conditions and evaluation criteria for *MASH* TL-3 for longitudinal barriers. *MASH* Test 3-11 involves a 2270P vehicle weighing 5000 lb \pm 110 lb and impacting the critical impact point (CIP) of the TxDOT W-beam guardrail with 7½-inch diameter round wood posts in concrete mow strip at an impact speed of 62 mi/h \pm 2.5 mi/h and an angle of 25° \pm 1.5°. The target CIP, shown in Figure 3.1, was determined using the information provided in *MASH* Section 2.2.1, Section 2.3.2, and Figure 2-1. The target CIP was 11.75 ft upstream of the center of post 15 (equivalent to 9 inches downstream of the center of post 13).

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

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

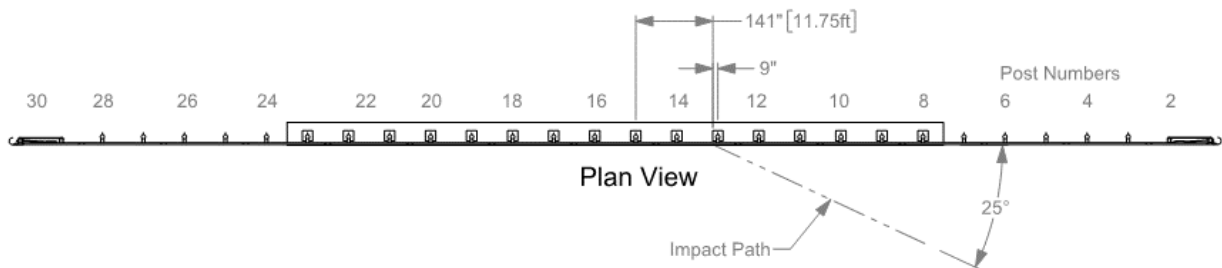


Figure 3.1. Target CIP for *MASH* Test 3-11 on the TxDOT W-Beam Guardrail with 7½-inch Diameter Round Wood Posts in Concrete Mow Strip.

MASH Test 3-10 was not performed on the TxDOT W-beam guardrail with 7½-inch diameter round wood posts in concrete mow strip. However, *MASH* Test 3-10 was successfully performed on the guardrail in concrete mow strip with both W6×8.5 steel posts and 6-inch × 8-inch rectangular wood posts (5). The geometries of the steel and rectangular wood posts are considered more critical in terms of vehicle snagging and deceleration compared to the round wood post. Therefore, since both the steel and rectangular wood posts in concrete mow strip meet *MASH* Test 3-10 criteria, this test was not performed on the TxDOT W-beam guardrail with 7½-inch diameter round wood posts in concrete mow strip.

The crash test 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 2-2 and 5-1 of *MASH* were used to evaluate the crash test(s) reported herein. The test conditions and evaluation criteria required for *MASH* Test 3-11 are listed in Table 3.1, and the substance of the evaluation criteria in Table 3.2. An evaluation of the crash test results is presented in detail under the section Assessment of Test Results.

Table 3.2. Evaluation Criteria Required for *MASH* Test 3-11.

Evaluation Factors	Evaluation Criteria
Structural Adequacy	A. <i>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.</i>
Occupant Risk	D. <i>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.</i>
	F. <i>The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</i>
	H. <i>Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 30 ft/s, or maximum allowable value of 40 ft/s.</i>
	I. <i>The occupant ridedown accelerations should satisfy the following: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.</i>

CHAPTER 4: TEST CONDITIONS

4.1 TEST FACILITY

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

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

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

4.3 DATA ACQUISITION SYSTEMS

4.3.1 Vehicle Instrumentation and Data Processing

The test vehicle was instrumented with a self-contained, on-board data acquisition system. The signal conditioning and acquisition system is a 16-channel, Tiny Data Acquisition System (TDAS) Pro produced by Diversified Technical Systems, Inc. The accelerometers, which measure the x, y, and z axis of vehicle acceleration, are strain gauge type with linear millivolt output proportional to acceleration. Angular rate sensors, measuring vehicle roll, pitch, and yaw rates,

are ultra-small, solid state units designed for crash test service. The TDAS Pro hardware and software conform to the latest SAE J211, Instrumentation for Impact Test. Each of the 16 channels is capable of providing precision amplification, scaling, and filtering based on transducer specifications and calibrations. During the test, data are recorded from each channel at a rate of 10,000 values per second with a resolution of one part in 65,536. Once data are recorded, internal batteries back these up inside the unit should the primary battery cable be severed. Initial contact of the pressure switch on the vehicle bumper provides a time zero mark and initiates the recording process. After each test, the data are downloaded from the TDAS Pro unit into a laptop computer at the test site. The Test Risk Assessment Program (TRAP) software then processes the raw data to produce detailed reports of the test results.

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

TRAP uses the data from the TDAS Pro to compute occupant/compartment impact velocities, time of occupant/compartment impact after vehicle impact, and the highest 10-millisecond (ms) average ridedown acceleration. TRAP calculates change in vehicle velocity at the end of a given impulse period. In addition, maximum average accelerations over 50-ms intervals in each of the three directions are computed. For reporting purposes, the data from the vehicle-mounted accelerometers are filtered with a 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, then plots yaw, pitch, and roll versus time. These displacements are in reference to the vehicle-fixed coordinate system with the initial position and orientation of the vehicle-fixed coordinate systems being initial impact. Rate of rotation data is measured with an expanded uncertainty of ± 0.7 percent at a confidence factor of 95 percent ($k=2$).

4.3.2 Anthropomorphic Dummy Instrumentation

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

4.3.3 Photographic Instrumentation and Data Processing

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

- One overhead with a field of view perpendicular to the ground and directly over the impact point;
- One placed behind the installation at an angle; and
- A third placed to have a field of view parallel to and aligned with the installation at the downstream end.

A flashbulb on the impacting vehicle was activated by a pressure-sensitive tape switch to indicate the instant of contact with the installation. 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 3-11 (CRASH TEST NO. 469689-4-1)

5.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

MASH Test 3-11 involves a 2270P vehicle weighing 5000 lb \pm 110 lb impacting the CIP of the test article at an impact speed of 62 mi/h \pm 2.5 mi/h and an angle of 25° \pm 1.5°. The CIP for *MASH* Test 3-11 on the TxDOT W-beam guardrail with 7½-inch diameter round wood posts in concrete mow strip was 11.75 ft \pm 1 ft upstream of the center of post 15 (equivalent to 9 inches \pm 1 ft downstream of the center of post 13).

The 2013 RAM 1500 pickup truck used in the test weighed 5017 lb, and the actual impact speed and angle were 63.7 mi/h and 25.1°. The actual impact point was 9 inches downstream of the center of post 13. Minimum target impact severity (IS) was 106 kip-ft, and actual IS was 123 kip-ft.

5.2 WEATHER CONDITIONS

The test was performed on the morning of August 16, 2019. Weather conditions at the time of testing were as follows: wind speed: 3 mi/h; wind direction: 254° (vehicle was traveling at magnetic heading of 205°); temperature: 90°F; relative humidity: 70 percent.

5.3 TEST VEHICLE

Figures 5.1 and 5.2 show the 2013 RAM 1500 pickup truck used for the crash test. The vehicle's test inertia weight was 5017 lb, and its gross static weight was 5017 lb. The height to the lower edge of the vehicle bumper was 11.75 inches, and height to the upper edge of the bumper was 27.0 inches. The height to the vehicle's center of gravity was 28.0 inches. Tables D.1 and D.2 in Appendix D1 give additional dimensions and information on the vehicle. It was directed into the installation using the cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.



Figure 5.1. Test Installation/Test Vehicle Geometrics for Test No. 469689-4-1.



Figure 5.2. Test Vehicle before Test No. 469689-4-1.

5.4 TEST DESCRIPTION

The test vehicle was traveling at an impact speed of 63.7 mi/h when it contacted TxDOT W-beam guardrail with 7½-inch diameter round wood posts in concrete mow strip 9 inches downstream of the center of post 13 at an impact angle of 25.1°. Table 5.1 lists events that occurred during Test No. 469689-4-1. Figures D.1 and D.2 in Appendix D2 present sequential photographs during the test.

Table 5.1. Events during Test No. 469689-4-1.

TIME (s)	EVENTS
0.0000	Vehicle contacts guardrail
0.0030	Post 13 begins to rotate clockwise and deflect toward field side
0.0120	Post 14 begins to rotate counterclockwise and deflect toward field side
0.0340	Vehicle begins to redirect
0.0460	Post 15 begins to rotate counterclockwise and deflect toward field side
0.0820	Front right tire begins to run over broken post 14
0.1900	Right rear corner of vehicle contacts rail
0.2690	Vehicle traveling parallel with original rail position
0.5660	Right rear corner of vehicle contacts post 15; the vehicle began to yaw clockwise
0.5950	Vehicle loses contact with guardrail while traveling at 26.7 mi/h, with a trajectory of 19.5° and a heading of 15.6°

It is desirable that the vehicle redirects and exits longitudinal barriers within the exit box criteria (not less than 32.8 ft downstream from loss of contact for cars and pickups). The test vehicle exited within the exit box criteria defined in *MASH*. After loss of contact with the barrier, the vehicle came to rest 56 ft downstream of the impact and 11.7 ft toward traffic lanes.

5.5 DAMAGE TO TEST INSTALLATION

Figures 5.3 and 5.4 show the damage to the TxDOT W-beam guardrail with 7½-inch diameter round wood posts in concrete mow strip. The rail released from posts 1 through 16, and 18. There was a ¾-inch gap in the soil on the upstream side of post 1, and ½-inch gaps on the downstream side of posts 1 and 2. The blockouts rotated clockwise at posts 3 through 11. The blockout rotated clockwise and cracked at post 12. Post 13 had 1½-inch gaps in the grout on the traffic side and ½-inch on the field side, and it was leaning toward the field side at 86°. Post 14 broke off at grade, and the grout cracked near the post. Post 15 also broke off at grade, and had a 2½-inch gap in the grout on the traffic and field sides. Post 16 fractured and broke off at 6 inches above grade, and had a 2-inch gap in the grout on the traffic side and a 4-inch gap on the field side. There was a 1-inch gap in the grout on the traffic side and a 2-inch gap on the field side of post 17, it was leaning back at 83°, and the blockout was broken and detached. There was no apparent damage or post movement from posts 19 through 30. Working width* was 50.9 inches, and height of working width was 54.4 inches. Maximum dynamic deflection during the test was 43.4 inches.

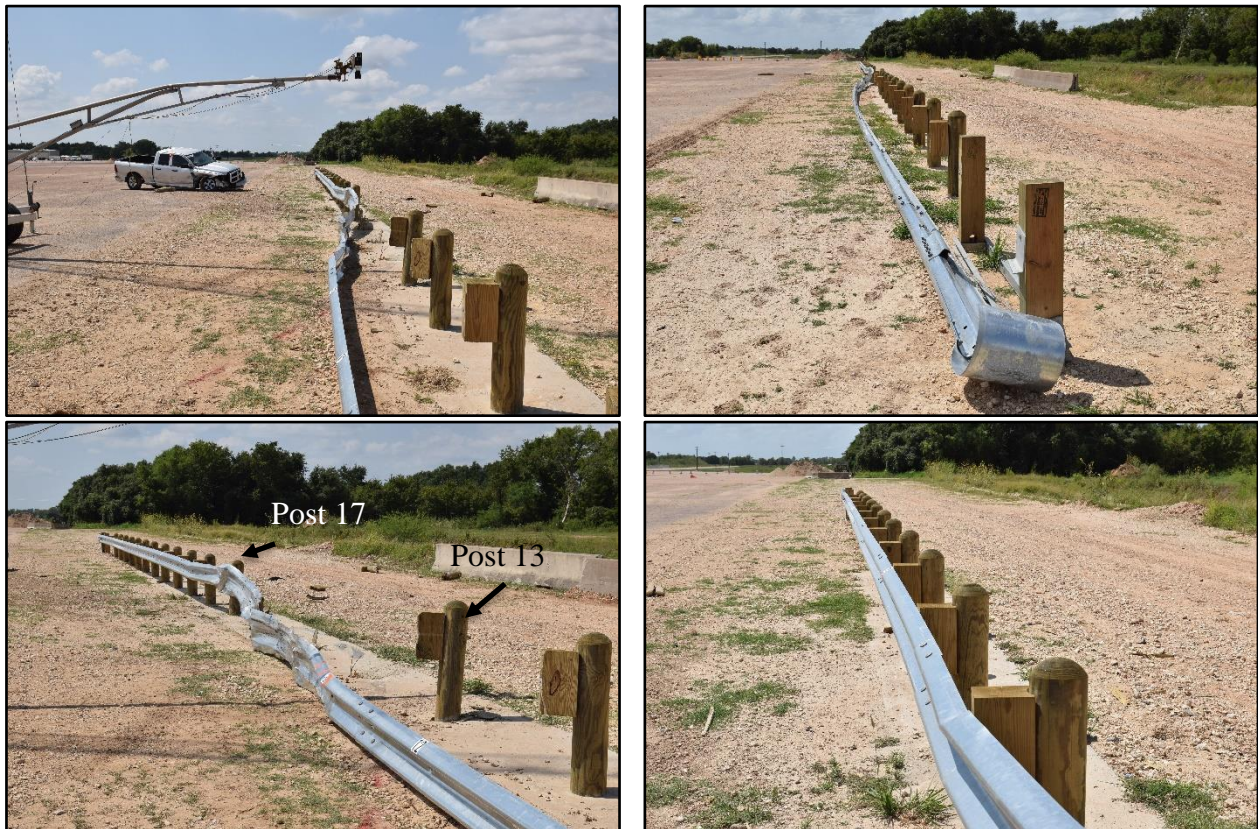


Figure 5.3. TxDOT W-Beam Guardrail with 7½-inch Diameter Round Wood Posts in Concrete Mow Strip after Test No. 469689-4-1.

* Working width is defined as the distance between the traffic face of the barrier before impact and the maximum lateral position of any major part of the barrier or the vehicle after impact.

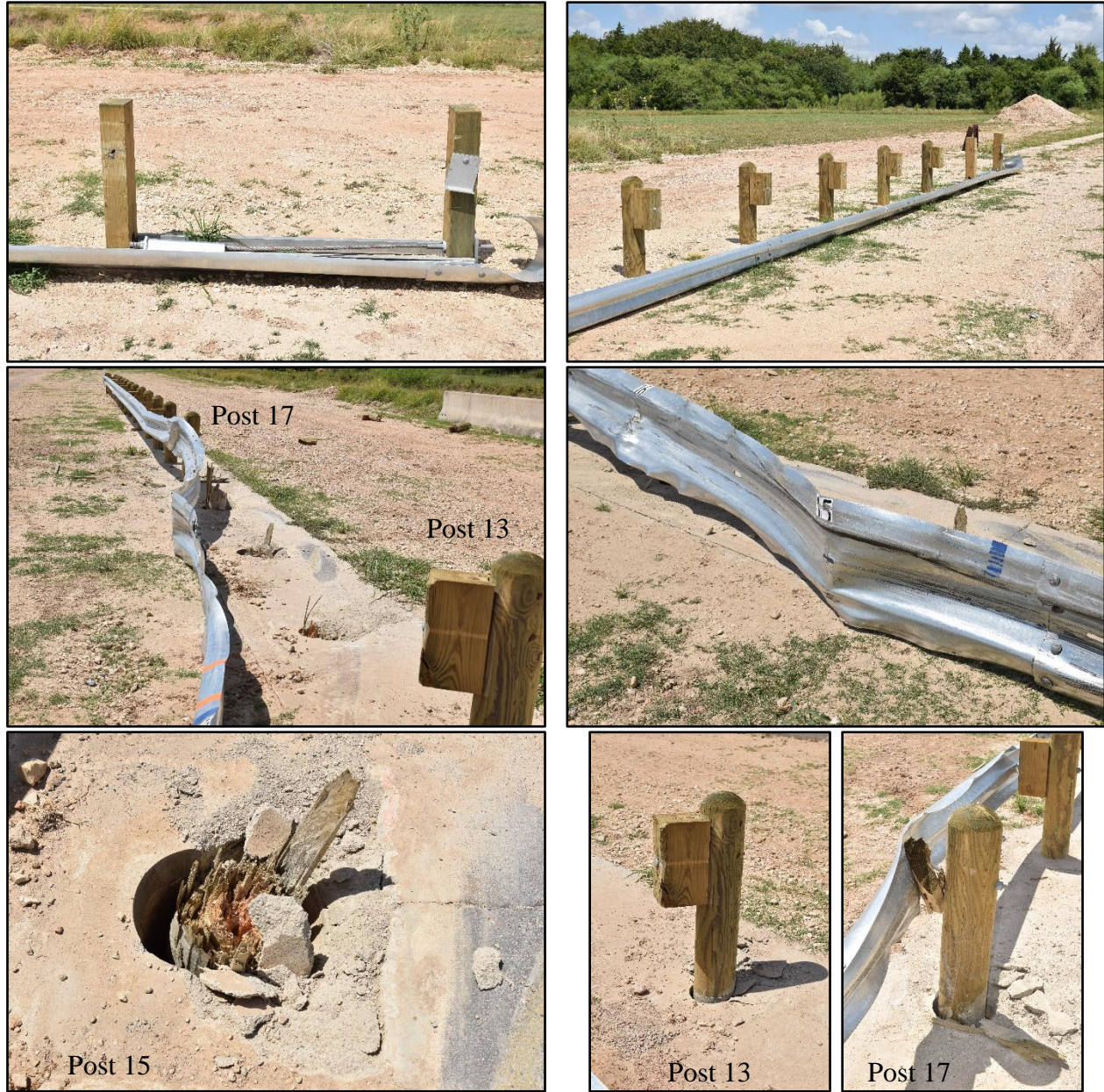


Figure 5.4. Damage to Installation after Test No. 469689-4-1.

5.6 DAMAGE TO TEST VEHICLE

Figure 5.5 shows the damage sustained by the vehicle. The front bumper, grill, radiator support, right front fender, right frame rail, right upper and lower A-arms, right front tire and rim, right front and rear doors, right cab corner, right rear exterior bed, right rear spring and trailing arm, and rear bumper were damaged. Maximum exterior crush to the vehicle was 10.0 inches in the front plane at the right front corner at bumper height. Maximum occupant compartment deformation was 1.5 inches in the right front floor pan. Figure 5.6 shows the

interior of the vehicle. Tables D.3 and D.4 in Appendix D1 provide exterior crush and occupant compartment measurements.



Figure 5.5. Test Vehicle after Test No. 469689-4-1.



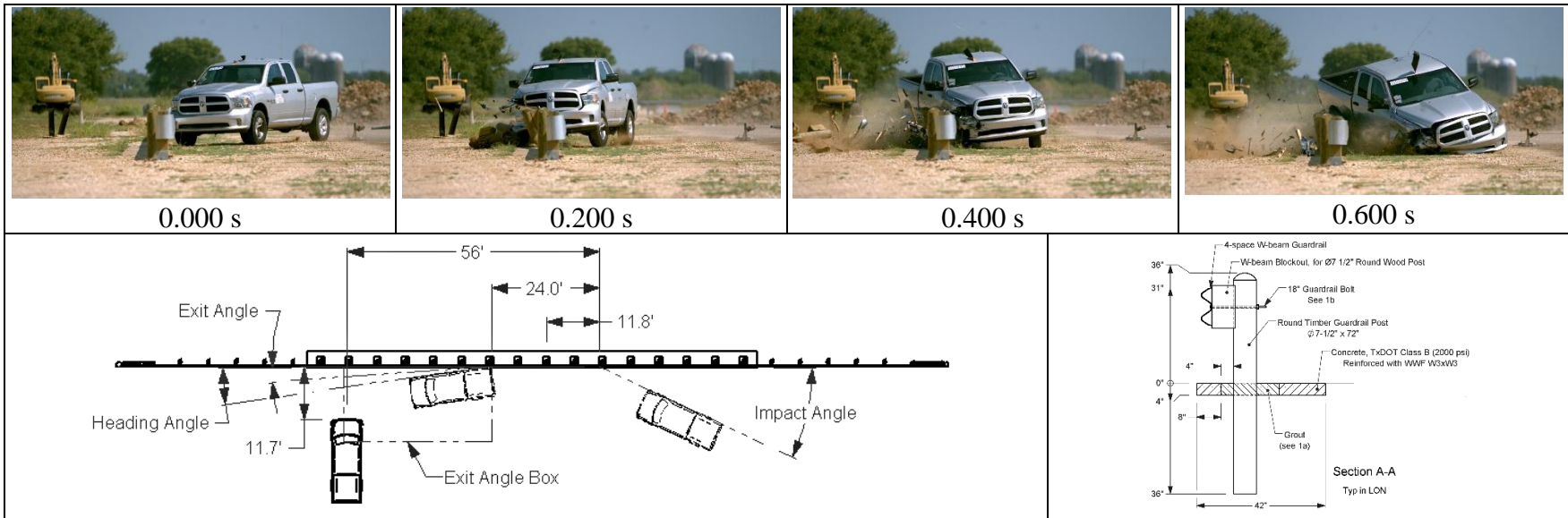
Figure 5.6. Interior of Test Vehicle after Test No. 469689-4-1.

5.7 OCCUPANT RISK FACTORS

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk and results are shown in Table 5.2. Figure 5.7 summarizes these data and other pertinent information from the test. Figure D.3 in Appendix D3 shows the vehicle angular displacements, and Figures D.4 through D.9 in Appendix D4 show acceleration versus time traces.

Table 5.2. Occupant Risk Factors for Test No. 469689-4-1.

Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV) Longitudinal Lateral	20.0 ft/s 15.7 ft/s	at 0.1485 s on right side of interior
Ridedown Accelerations Longitudinal Lateral	8.7 g 8.4 g	0.5583–0.5683 s 0.2642–0.2742 s
Theoretical Head Impact Velocity (THIV)	27.8 km/h 7.7 m/s	at 0.1426 s on right side of interior
Post Head Deceleration (PHD)	10.1 g	0.5552–0.5652 s
Acceleration Severity Index (ASI)	0.86	0.1050–0.1550 s
Maximum 50-ms Moving Average Longitudinal Lateral Vertical	-7.0 g -6.1 g -3.8 g	0.0704–0.1204 s 0.2344–0.2844 s 1.8254–1.8754 s
Maximum Roll, Pitch, and Yaw Angles Roll Pitch Yaw	19° 12° 58°	0.8646 s 2.0000 s 2.0000 s



General Information

Test Agency..... Texas A&M Transportation Institute (TTI)
 Test Standard Test No..... MASH Test 3-11
 TTI Test No. 469689-4-1
 Test Date..... 2019-08-16

Test Article

Type Longitudinal Barrier - Guardrail
 Name..... TxDOT W-beam guardrail with 7½-inch diameter round wood posts in concrete mow strip
 Installation Length..... 181 ft-3 inches w/100 ft mow strip incl.
 Material or Key Elements... 31-inch tall W-beam guardrail with 7½-inch diameter round wood posts at 6 ft-3 inch spacing embedded 36 in

Soil Type and Condition

..... 4 inch thick concrete mow strip with grout-filled leaveouts. AASHTO M147-65(2004), grading B Soil (crushed limestone), Damp

Test Vehicle

Type/Designation..... 2270P
 Make and Model 2013 RAM 1500 Pickup
 Curb..... 4947 lb
 Test Inertial..... 5017 lb
 Dummy No Dummy
 Gross Static 5017 lb

Impact Conditions

Speed 63.7 mi/h
 Angle 25.1°
 Location/Orientation 11.75 ft upstrm of center of post 15

Impact Severity

..... 123 kip-ft

Exit Conditions

Speed 26.7 mi/h
 Trajectory/Heading Angle... 19.5° / 15.6°

Occupant Risk Values

Longitudinal OIV 20.0 ft/s
 Lateral OIV..... 15.7 ft/s
 Longitudinal Ridedown 8.7 g
 Lateral Ridedown 8.4 g
 THIV 27.8 km/h
 PHD..... 10.1 g
 ASI..... 0.86
 Max. 0.050-s Average
 Longitudinal -7.0 g
 Lateral..... -6.1 g
 Vertical..... -3.8 g

Post-Impact Trajectory

Stopping Distance..... 56 ft downstream
 11.7 ft twd traffic

Vehicle Stability

Maximum Yaw Angle 58°
 Maximum Pitch Angle 12°
 Maximum Roll Angle 19°
 Vehicle Snagging No
 Vehicle Pocketing No

Test Article Deflections

Dynamic..... 43.4 inches
 Permanent Rail released from downstream posts
 Working Width..... 50.9 inches
 Height of Working Width 54.4 inches

Vehicle Damage

VDS 01RFQ5
 CDC..... 01FREW4
 Max. Exterior Deformation..... 10.0 inches
 OCDI..... RF0010000
 Max. Occupant Compartment Deformation 1.5 inches

Figure 5.7. Summary of Results for MASH Test 3-11 on TxDOT W-Beam Guardrail with 7½-inch Diameter Round Wood Posts in Concrete Mow Strip.

CHAPTER 6: SUMMARY AND CONCLUSIONS

6.1 SUMMARY OF RESULTS

Table 6.1 provides an assessment of the test based on the applicable safety evaluation criteria for *MASH* Test 3-11 on the TxDOT W-beam guardrail with 7½-inch diameter round wood posts in concrete mow strip. The installation contained and redirected the 2270P vehicle. The vehicle did not penetrate, underide, or override the guardrail. Maximum dynamic deflection during the test was 43.4 inches, and working width was 50.9 inches. Three posts fractured at ground line but did not penetrate or show potential for penetrating the occupant compartment, or present undue hazard to others in the area. Maximum occupant compartment deformation was 1.5 inches in the right front floor pan. The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 19° and 12°, respectively. Occupant risk factors were within the preferred limits of *MASH*.

6.2 CONCLUSIONS

The TxDOT W-beam guardrail with 7½-inch diameter round wood posts in concrete mow strip performed acceptably for *MASH* Test 3-11.

Table 6.1. Performance Evaluation Summary for MASH Test 3-11 on TxDOT W-Beam Guardrail with 7½-inch Diameter Round Wood Posts in Concrete Mow Strip.

Test Agency: Texas A&M Transportation Institute

Test No.: 469689-4-1

Test Date: 2019-08-16

MASH Test Evaluation Criteria	Test Results	Assessment
<p><u>Structural Adequacy</u></p> <p>A. <i>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</i></p>	<p>The TxDOT W-beam guardrail with 7½-inch diameter round wood posts in concrete mow strip contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the guardrail. Maximum dynamic deflection during the test was 43.4 inches.</p>	<p>Pass</p>
<p><u>Occupant Risk</u></p> <p>D. <i>Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.</i></p>	<p>Three posts fractured at ground line but did not penetrate or show potential for penetrating the occupant compartment, or present undue hazard to others in the area.</p>	<p>Pass</p>
<p><i>Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.</i></p>	<p>Maximum occupant compartment deformation was 1.5 inches in the right front floor pan.</p>	
<p>F. <i>The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</i></p>	<p>The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 19° and 12°, respectively.</p>	<p>Pass</p>
<p>H. <i>Longitudinal and lateral occupant impact velocities should fall below the preferred value of 30 ft/s, or at least below the maximum allowable value of 40 ft/s.</i></p>	<p>Longitudinal OIV was 20.0 ft/s, and lateral OIV was 15.7 ft/s.</p>	<p>Pass</p>
<p>I. <i>Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15.0 Gs, or at least below the maximum allowable value of 20.49 Gs.</i></p>	<p>Maximum longitudinal occupant ridedown acceleration was 8.7 g, and maximum lateral occupant ridedown was 8.4 g.</p>	<p>Pass</p>

CHAPTER 7: IMPLEMENTATION*

The testing and evaluation reported herein shows the TxDOT W-beam guardrail with 7½-inch diameter round wood posts in concrete mow strip successfully met all requirements for *MASH* Test 3-11, which primarily evaluates the strength of the guardrail system and stability of the 2270P vehicle. The other test considered under *MASH* TL-3, *MASH* Test 3-10, primarily evaluates occupant risk.

MASH Test 3-10 was not performed on the TxDOT W-beam guardrail with 7½-inch diameter round wood posts in concrete mow strip. However, *MASH* Test 3-10 was successfully performed on guardrail in concrete mow strip with both W6×8.5 steel posts and 6-inch × 8-inch rectangular wood posts (5). The geometries of the steel and rectangular wood posts are considered more critical in terms of vehicle snagging and deceleration compared to the round wood post. Therefore, since both the steel and rectangular wood posts in concrete mow strip meet *MASH* Test 3-10, this test was not considered necessary for the evaluation of the TxDOT W-beam guardrail with 7½-inch diameter round wood posts in concrete mow strip.

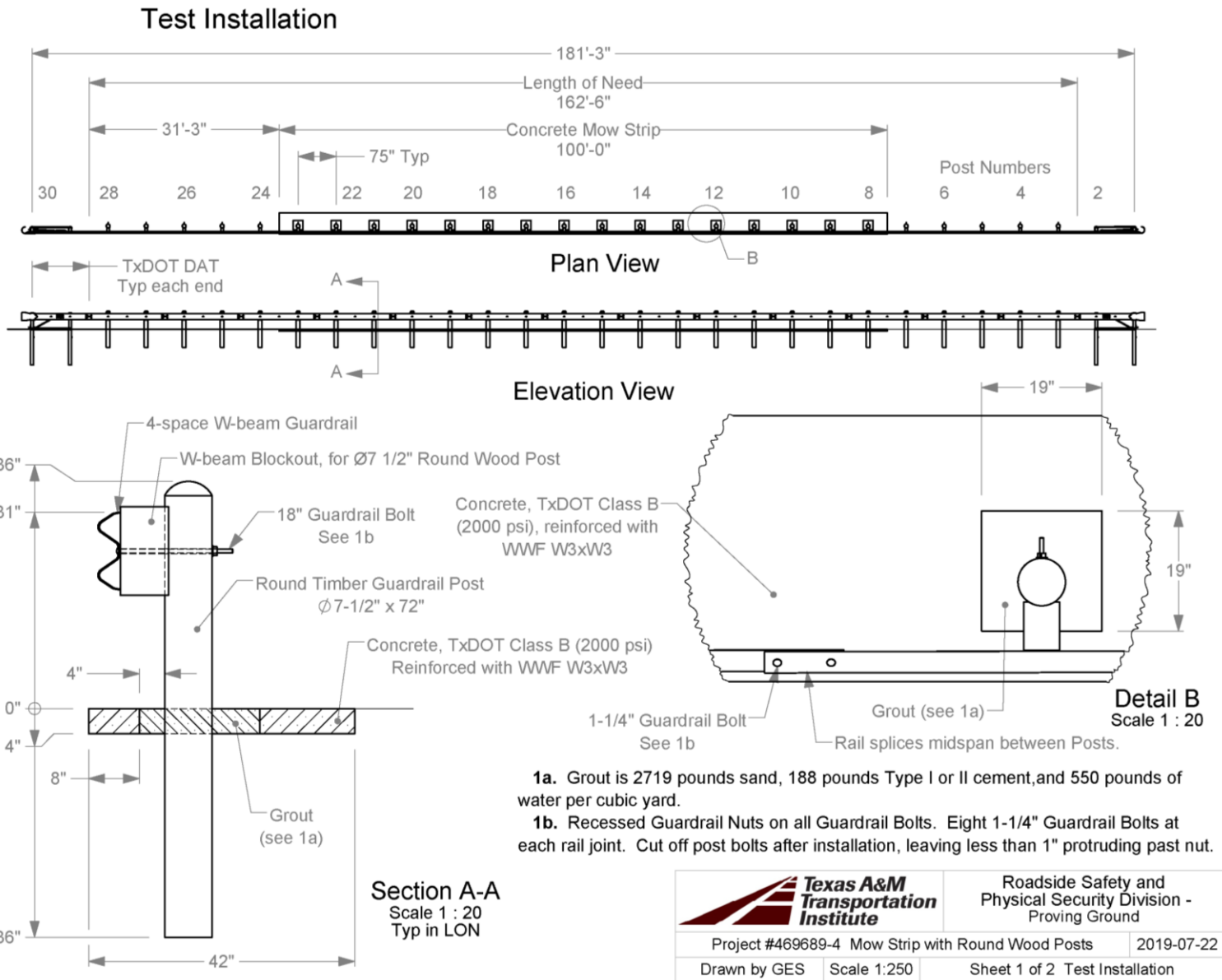
Based on the results of the testing and evaluation reported herein, the TxDOT W-beam guardrail with 7½-inch diameter round wood posts in concrete mow strip is considered suitable for implementation as a *MASH* TL-3 longitudinal barrier. The guardrail system had a dynamic deflection of 43.4 inches for the pickup truck impact.

Statewide implementation of this barrier can be achieved by TxDOT's Design Division through the development and issuance of a revised standard detail sheet. The guardrail details provided in Appendix A can be used for this purpose.

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

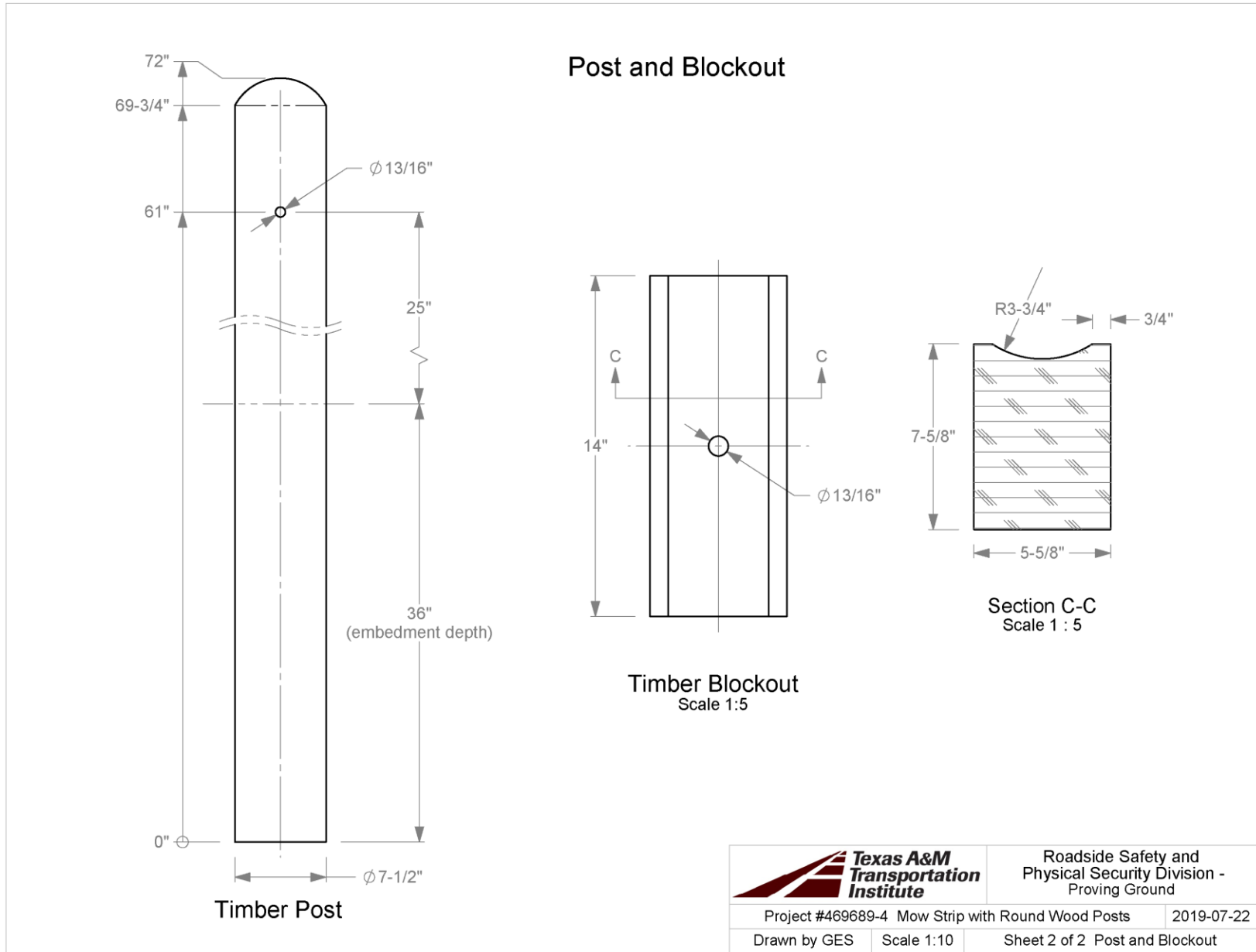
REFERENCES

1. AASHTO. *Manual for Assessing Roadside Safety Hardware*. Second Edition, 2016, American Association of State Highway and Transportation Officials: Washington, D.C.
2. James C. Kovar, Roger P. Bligh, Bill L. Griffith, Darrell L. Kuhn, and Glenn E. Schroeder, *MASH Test 3-11 Evaluation of Modified TxDOT Round Wood Post Guardrail System*. Test Report No. 0-6968-R4, Texas A&M Transportation Institute, College Station, Tx, June 2019.
3. Roger P. Bligh, Bill L. Griffith, Glenn E. Schroeder, and Darrell L. Kuhn, *MASH Evaluation of TxDOT Roadside Safety Features – Phase III*. Test Report No. 0-6946-R3 (Test No. 469469-11), Texas A&M Transportation Institute, College Station, Tx, not yet published.
4. Sana M. Moran and Wanda L. Menges, *Various Round Wood Posts in Mow Strip*. Technical Memo No. 690900-AFP B1-B4-B5-B6, Texas A&M Transportation Institute, College Station, TX, August 2019.
5. Nauman M. Sheikh, Wanda L. Menges, and Darrell L. Kuhn. *MASH TL-3 Evaluation of 31-inch W-Beam Guardrail with Wood and Steel Posts in Concrete Mow Strip*. Test Report No. 608551-1-4, Texas A&M Transportation Institute, College Station, Tx, April 2019.



T:\11-ProjectFiles\469689-TxDOT\4 Mow Strip with Round Wood Posts\Drafting_469469-4\469689-4 Drawing

APPENDIX A. DETAILS OF TEST INSTALLATION

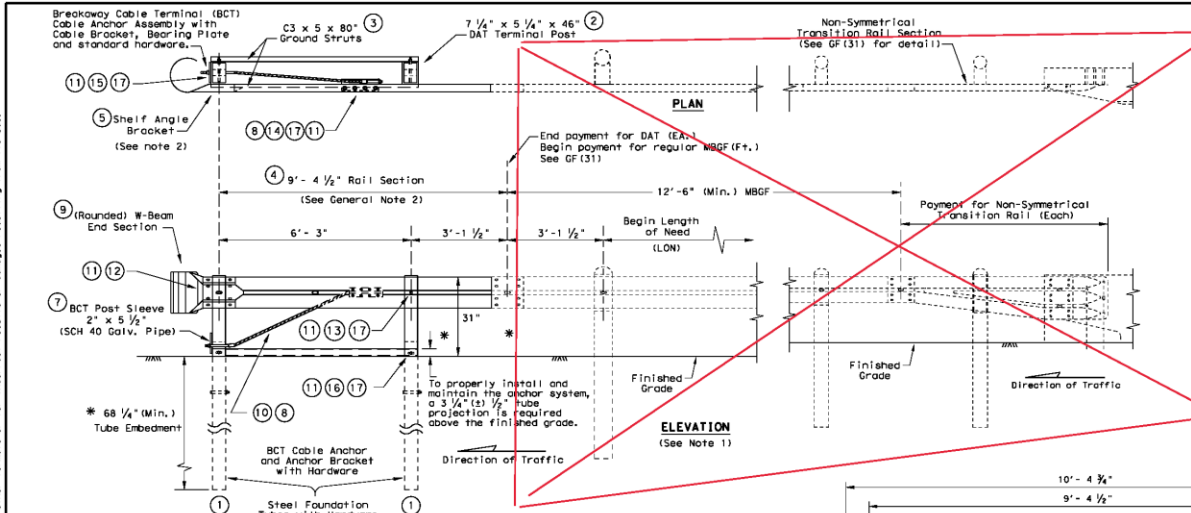


Roadside Safety and
Physical Security Division -
Proving Ground

Project #469689-4 Mow Strip with Round Wood Posts 2019-07-22

Drawn by GES Scale 1:10 Sheet 2 of 2 Post and Blockout

DISC: This standard is governed by the Texas Engineering Practice Act. No warranty of any kind is made by the Texas Department of Transportation for the use of this standard in any project. The user is responsible for the proper application of this standard.

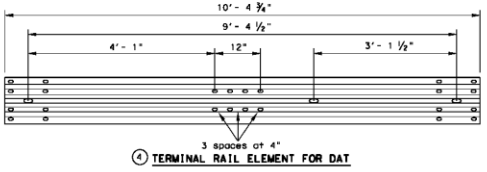


- GENERAL NOTES**
1. The detail shown is the minimum Length of Need (LON) for a DAT connected to a concrete rail.
 2. The rail section at the end post is supported by the Shelf Angle Bracket. The rail element is not attached to the end post.
 3. The foundation tubes shall not project more than 3 1/4" above the finished grade.
 4. All hardware for DAT shall be ASTM A307 unless otherwise shown.
 5. Refer to GF(31) sheet for terminal connection details.

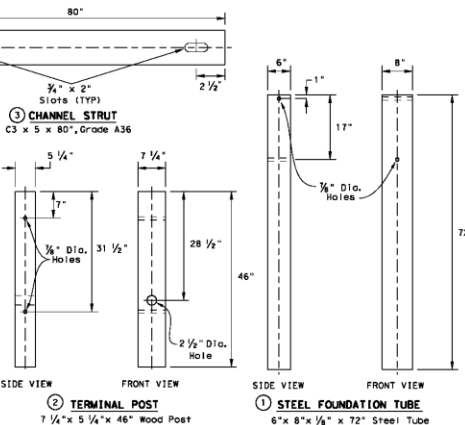
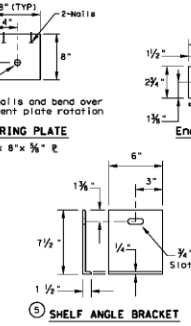
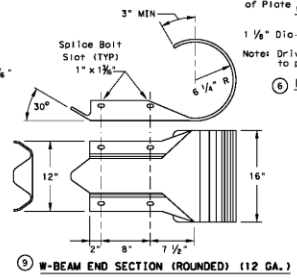
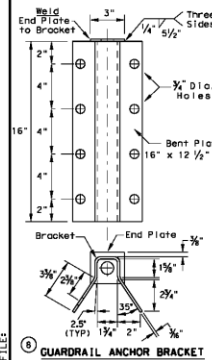
MOW STRIP INSTALLATION

If a mow strip is required with the DAT installation the leave-out area around the steel foundation tubes and the two channel struts may be omitted. This will require a full pour of the foundation tubes.

DOWNSTREAM ANCHOR TERMINAL (DAT)
 Only for downstream use, when located outside the horizontal clearance area of opposing traffic.



#	(DAT) PARTS LIST	QTY
1	Steel Foundation Tube	2
2	DAT Terminal Post	2
3	Channel Strut	2
4	Terminal Rail Element	1
5	Shelf Angle Bracket	1
6	BCT Bearing Plate	1
7	BCT Post Sleeve	1
8	Guardrail Anchor Bracket	1
9	(Rounded) W-Beam End Section	1
10	BCT Cable Anchor	1
11	Recessed Nut, Guardrail	20
12	1 1/4" Button Head Bolt	4
13	10" Button Head Bolt	2
14	3/8" x 2" Hex Head Bolt	8
15	3/8" x 8" Hex Head Bolt	4
16	3/8" x 10" Hex Head Bolt	2
17	3/8" Flat Washer	18

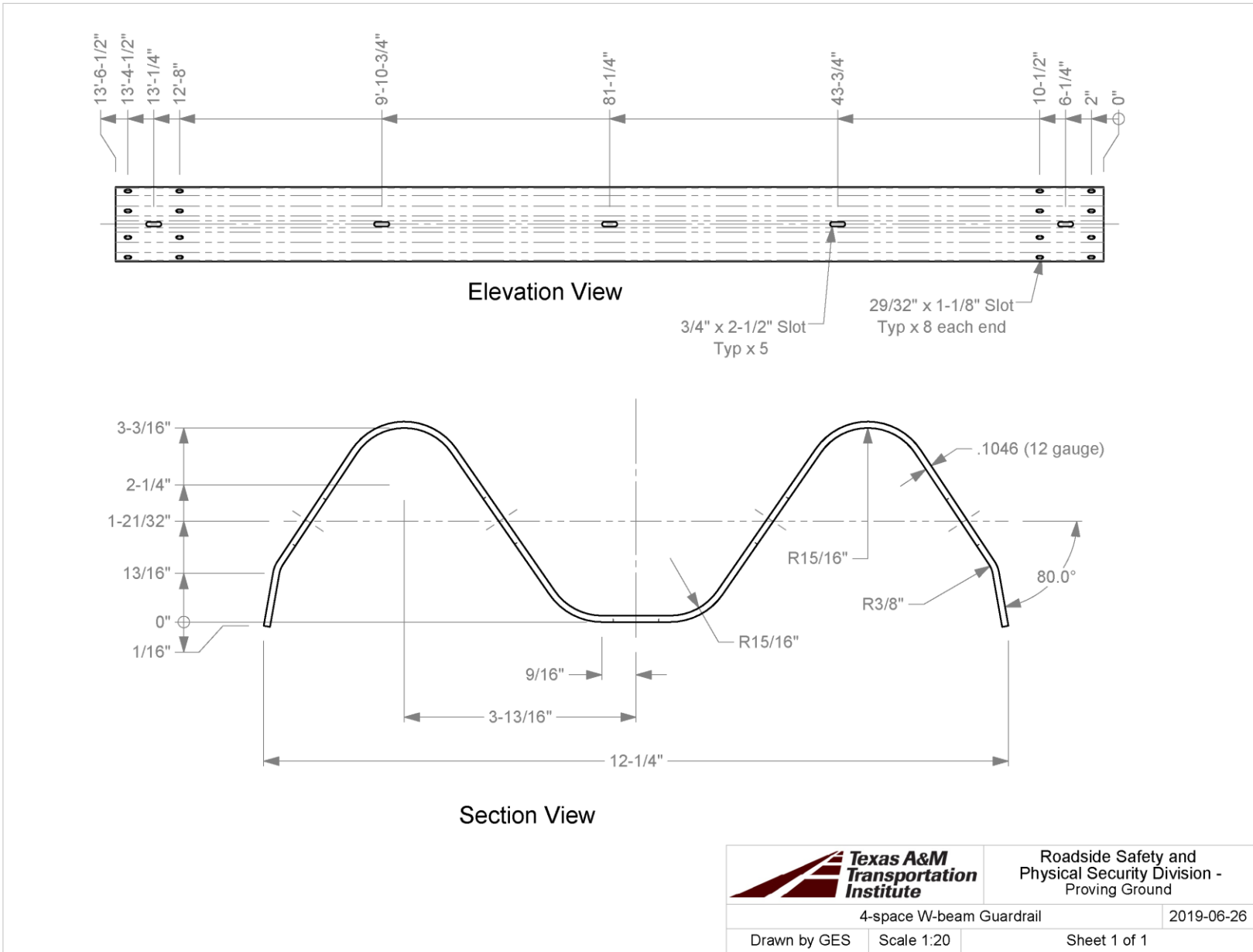


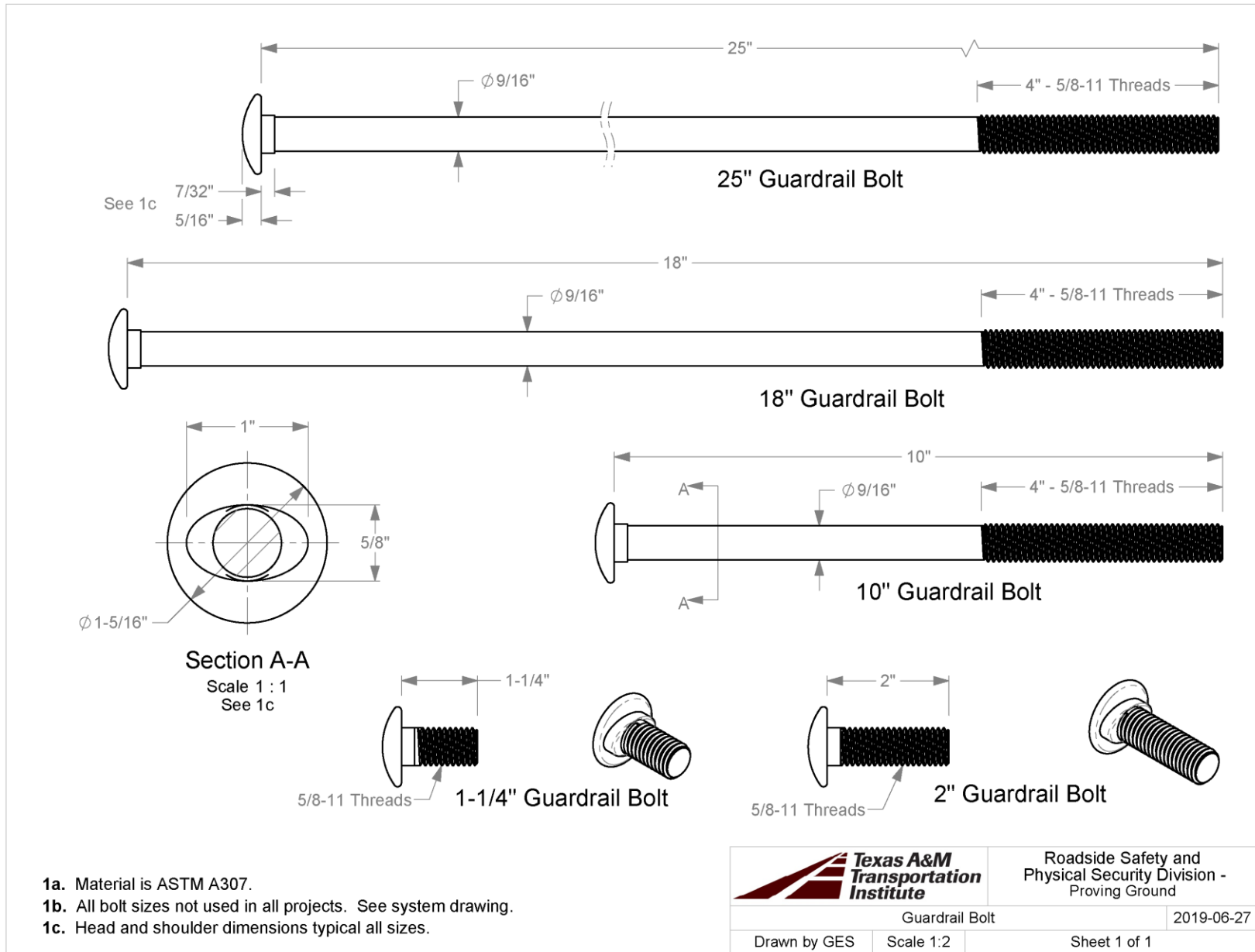
Texas Department of Transportation Design Division Standard

METAL BEAM GUARD FENCE (Downstream Anchor Terminal)

GF (31) DAT-14

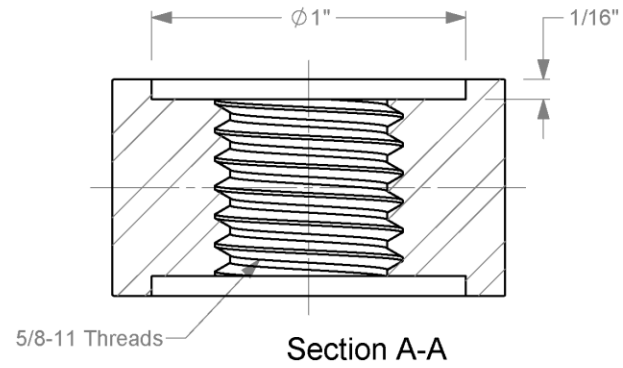
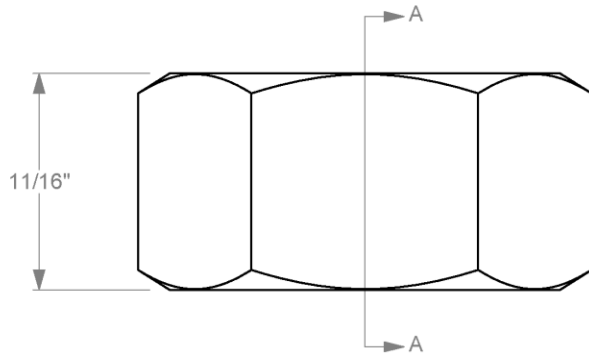
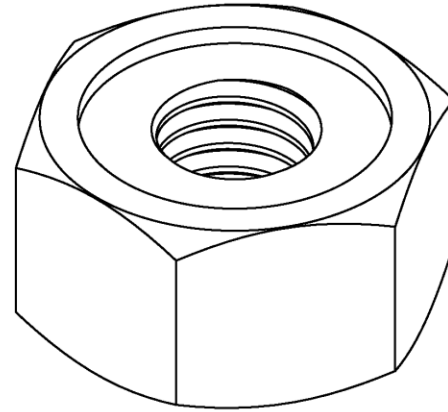
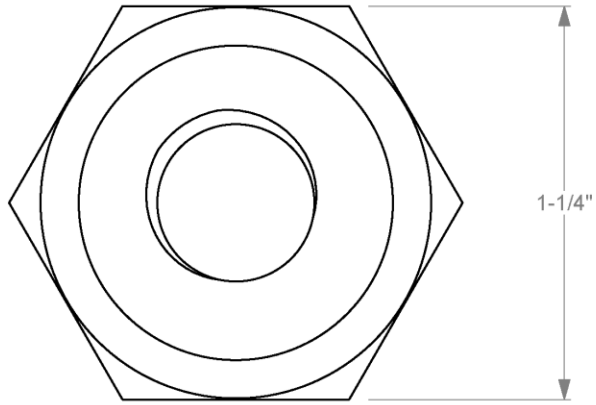
FILE: gf31(14).dgn	DATE: 12/01/01	BY: JMB	CHK: JVP	APP: COL
© TxDOT, December 2011	CON: SEC	JOB	REVISION	
REV: 1				
		COUNTY		SHEET NO.





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

Recessed Guardrail Nut



1a. Material is ASTM A 563 Grade A.



Roadside Safety and
Physical Security Division -
Proving Ground

Recessed Guardrail Nut		2019-06-27
Drawn by GES	Scale 2:1	Sheet 1 of 1



Martin Marietta

1503 LBJ Freeway
Suite 400
Dallas, Tx 75234

TICKET NO.

5554007



* 5 5 5 4 0 0 7 *

LOAD TIME	TO JOB	ARRIVE JOB SITE	BEGIN POUR	FINISH POUR	LEAVE JOB SITE	ARRIVE PLANT
10:23	10	10:50	10:53	:	:	:

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

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

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

CUSTOMER NAME AND DELIVERY ADDRESS	PLANT	TRUCK	ORDER NO.	SLUMP	P.O. #/JOB/LOT	GRID
TEXAS A & M UNIVERSI TTI-Riverside Campus	617	7130	2034	10	469689-4	
	DRIVER NAME	DATE				
	Billy Lomuscio	7/26/19				
	CUSTOMER NUMBER	PROJECT	CUM. QTY	ORDERED QTY		
	783659	79546	5.00	5.00		

LOAD QUANTITY	PRODUCT CODE	DESCRIPTION	UNIT PRICE	AMOUNT
5.00	CYDS	EFLOW15	1.55K FLOW FILL	
1.00	es	12987	FREIGHT CHARGE	

*Growt
465865-4*

SPECIAL DELIVERY INSTRUCTIONS: 2818-RT ON LEONARD RT ON HWY-47-LFT INTO RELLIS CAMPUS WILL MEET AT GATE
 SALES TAX
 TOTAL

DANGER! MAY CAUSE ALKALI BURNS. SEE WARNINGS ON REVERSE SIDE. FOR OFFICE USE ONLY FORM: 2679626

Truck	Driver	User	Disp	Ticket Num	Ticket ID	Time	Date
7130	943816	user	5554007	77920	77920	10:23	7/26/19
Load Size	Mix Code	Returned	Qty	Mix Age	Seq	Load ID	
5.00	CYDS EFLOW15				D	78957	
Material	Design Qty	Required	Batched	% Var	% Moisture	Actual Wat	
SAND-1	2719 lb	14044 lb	14040 lb	-0.03%	3.20% M	54 gl	
CHT-1/II	180 lb	940 lb	940 lb	0.00%			
H2O	550 lb	2217 lb	2214 lb	-0.14%		265 gl	
Actual	Num Batches: 1						
Load Total:	17194 lb	Design 2.926	Water/Cement 2.926 T	Design 329.5 gl	Actual 319.1 gl	To Add: 10.4	
Slump:	10.00 in	Water in Truck: 0.0 gl	Adjust Water: 0.0 gl	/ Load	Triv Water: -2.0 gl/ CYD		

GROUT COMPRESSIVE STRENGTH TEST REPORT



Report Number: A1171057.0057
Service Date: 07/26/19
Report Date: 08/16/19 Revision 2 - 21 day breaks
Task: PO #469689

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

Client

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

Project

Riverside Campus
 Riverside Campus
 Bryan, TX

Project Number: A1171057

Material Information

Specified Strength: 1,500 psi @
Mix ID: EFLOW15
Supplier: Martin Marietta
Batch Time: 1023 **Plant:**
Truck No.: 7130 **Ticket No.:** 5554007

Sample Information

Sample Date: 07/26/19 **Sample Time:** 1110
Sampled By: David Carpio
Weather Conditions: Clear, light wind
Accumulative Yards: 5/5 **Batch Size:** 5
Sample Size:
Sample Location: Leave outs
Placement Location: Guard rail posts
Form Material: Cardboard Form **No. Units:** 12
Samples Plumb: Yes
Temperature Range: 70 - 102

Field Test Data

Test	Result	Specification
Slump (in):		Not Specified
Grout Temp. (F):	88	40 - 95
Ambient Temp. (F):	87	40 - 95

Laboratory Test Data

Set No.	Specimen ID	Date Received	Date Tested	Age (days)	Area (sq in)	Maximum Load (lbs)	Compressive Strength (psi)	Tested By
1	A	07/30/19	08/14/19	19	11.22	2,660	240	DRH
1	B	07/30/19	08/14/19	19	10.40	2,440	230	DRH
1	C	07/30/19	08/14/19	19	10.24	1,990	190	DRH
Average (19 days)							220	
1	D	07/30/19	08/16/19	21	10.56	2,767	260	
1	E	07/30/19	08/16/19	21	10.56	2,214	210	
1	F	07/30/19	08/16/19	21	10.56	2,324	220	
Average (21 days)							230	
1	G	07/30/19	08/23/19	28				
1	H	07/30/19	08/23/19	28				
1	I	07/30/19	08/23/19	28				

Initial Cure: Onsite Cooler **Final Cure:** Cure Box

Comments:

Samples Made By: Terracon

Services: Obtain sample of grout at the placement location and cast specimens for compressive strength determination.

Terracon Rep.: David Carpio

Start/Stop: 0900-1200

Reported To:

Contractor:

Report Distribution:

(1) Texas Transportation Institute, Gary Gerke (1) Terracon Consultants, Inc., Andrea Allen

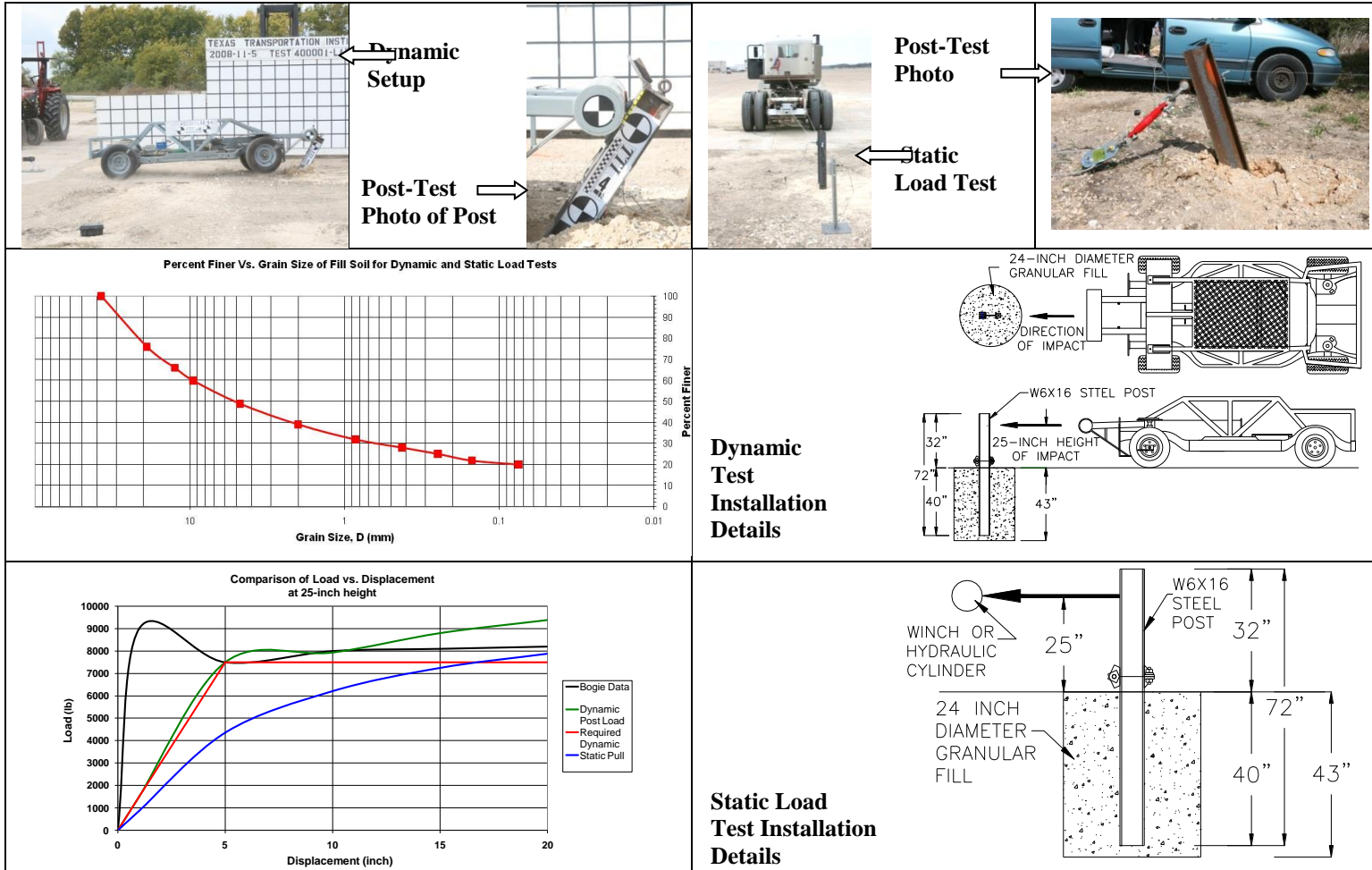
Reviewed By:

Andrea Allen
 Project Manager

Test Methods: ASTM C109, ASTM C1019

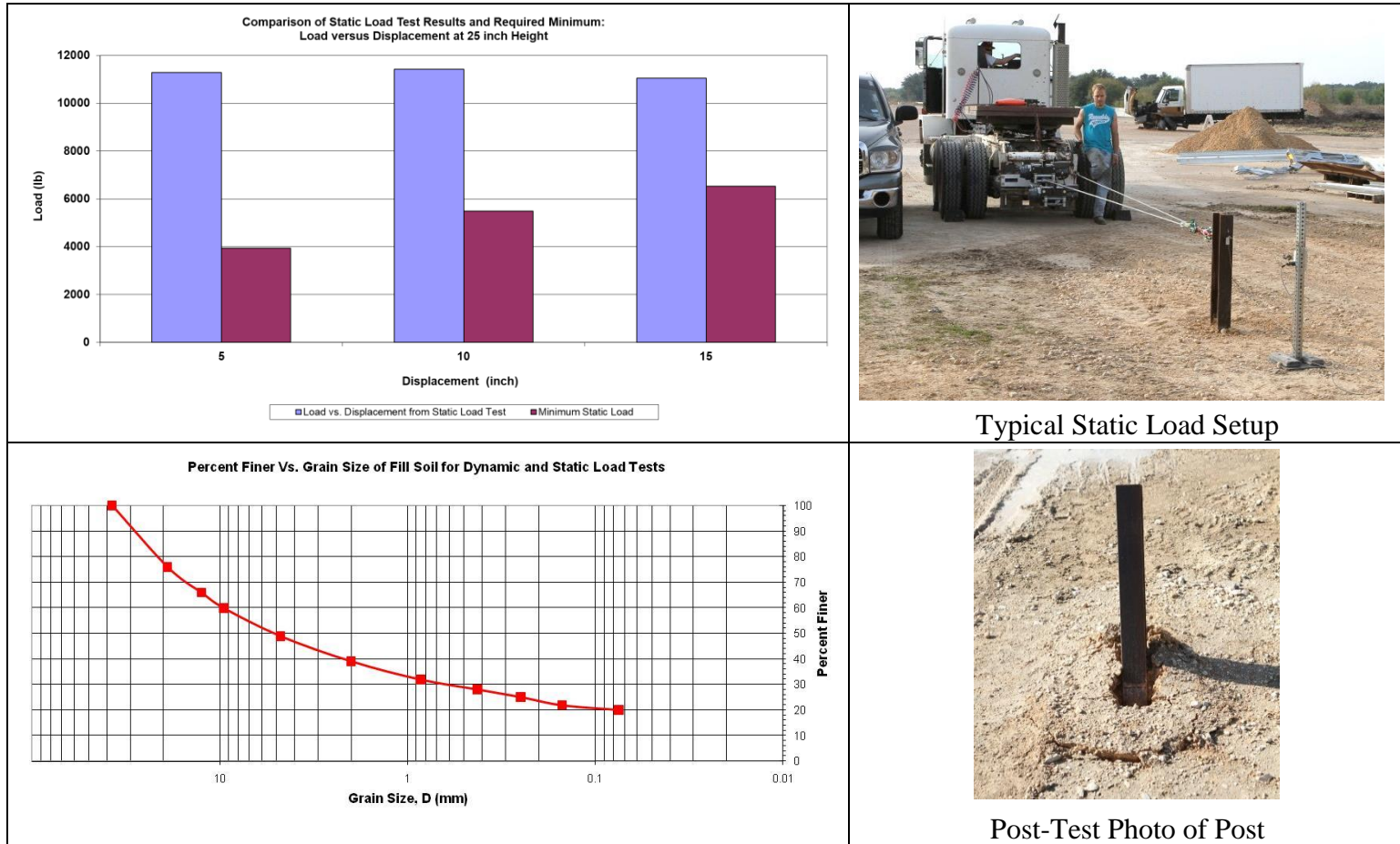
The tests were performed in general accordance with applicable ASTM, AASHTO, or DOT test methods. This report is exclusively for the use of the client indicated above and shall not be reproduced except in full without the written consent of our company. Test results transmitted herein are only applicable to the actual samples tested at the location(s) referenced and are not necessarily indicative of the properties of other apparently similar or identical materials.

Table C.1. Summary of Strong Soil Test Results for Establishing Installation Procedure.



Date	2008-11-05
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	AASHTO Grade B Soil-Aggregate (see sieve analysis above)
Description of Fill Placement Procedure	6-inch lifts tamped with a pneumatic compactor
Bogie Weight	5009 lb
Impact Velocity	20.5 mph

Table C.2. Test Day Static Soil Strength Documentation for Test No. 469689-4-1.



Date.....	<u>2019-08-16</u>
Test Facility and Site Location	<u>TTI Proving Ground – 3100 SH 47, Bryan, Tx</u>
In Situ Soil Description (ASTM D2487)	<u>Sandy gravel with silty fines</u>
Fill Material Description (ASTM D2487) and sieve analysis ..	<u>AASHTO Grade B Soil-Aggregate (see sieve analysis)</u>
Description of Fill Placement Procedure	<u>6-inch lifts tamped with a pneumatic compactor</u>

APPENDIX D. MASH TEST 3-11 (CRASH TEST NO. 469689-4-1)

D.1 VEHICLE PROPERTIES AND INFORMATION

Table D.1. Vehicle Properties for Test No. 469689-4-1.

Date: 2019-08-16 Test No.: 469689-4 VIN No.: 1C6RR6FT8DS686274
 Year: 2013 Make: RAM Model: 1500
 Tire Size: 265/70 R 17 Tire Inflation Pressure: 35 psi
 Tread Type: Highway Odometer: 128862
 Note any damage to the vehicle prior to test: None

• Denotes accelerometer location.

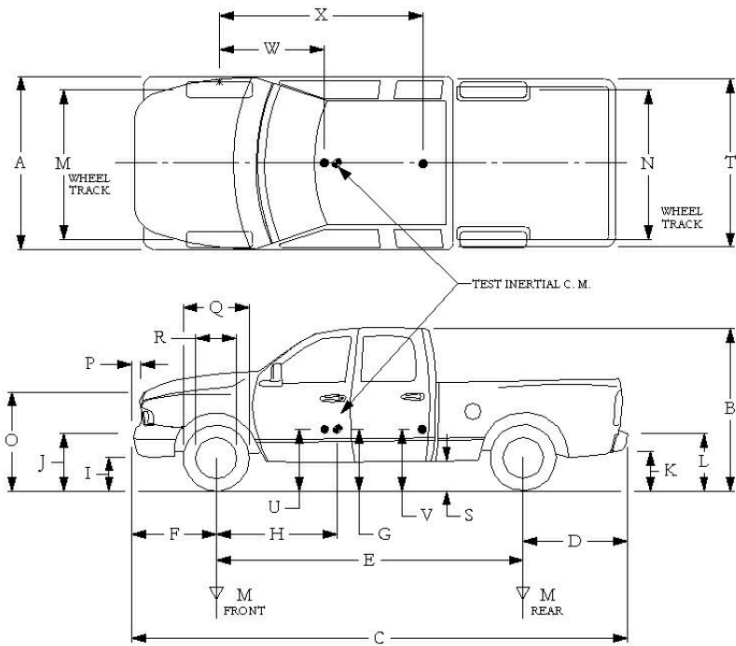
NOTES: None

Engine Type: V-8
 Engine CID: 5.7 liter

Transmission Type:
 Auto or Manual
 FWD RWD 4WD

Optional Equipment:
None

Dummy Data:
 Type: NONE
 Mass: 0 lb
 Seat Position: NA



Geometry: inches

A	78.50	F	40.00	K	20.00	P	3.00	U	26.75
B	74.00	G	28.00	L	30.00	Q	30.50	V	30.25
C	227.50	H	61.21	M	68.50	R	18.00	W	61.20
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}	2874	2831
Back	3900	M _{rear}	2073	2186
Total	6700	M _{Total}	4947	5017

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

Mass Distribution:

lb	LF: <u>1393</u>	RF: <u>1438</u>	LR: <u>1140</u>	RR: <u>1046</u>
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Table D.2. Measurements of Vehicle Vertical CG for Test No. 469689-4-1.

Date: 2019-08-16 Test No.: 469689-4 VIN: 1C6RR6FT8DS686274
 Year: 2013 Make: RAM Model: 1500
 Body Style: Quad Cab Mileage: 128862
 Engine: 5.7 liter V-8 Transmission: Automatic
 Fuel Level: Empty Ballast: 100 (440 lb max)
 Tire Pressure: Front: 35 psi Rear: 35 psi Size: 265/70 R 17

Measured Vehicle Weights: (lb)							
LF:	1393		RF:	1438	Front Axle:	2831	
LR:	1140		RR:	1046	Rear Axle:	2186	
Left:	2533		Right:	2484	Total:	5017	
						5000 ±110 lb allowed	
Wheel Base:	140.50	inches	Track: F:	68.50	inches	R:	68.00 inches
	148 ±12	inches allowed		Track = (F+R)/2 = 67 ±1.5			inches allowed
Center of Gravity, SAE J874 Suspension Method							
X:	61.22	inches	Rear of Front Axle	(63 ±4 inches allowed)			
Y:	-0.33	inches	Left -	Right +	of Vehicle Centerline		
Z:	28.00	inches	Above Ground	(minimum 28.0 inches allowed)			

Hood Height: 46.00 inches Front Bumper Height: 27.00 inches
 43 ±4 inches allowed

Front Overhang: 40.00 inches Rear Bumper Height: 30.00 inches
 39 ±3 inches allowed

Overall Length: 227.50 inches
 237 ±13 inches allowed

Table D.3. Exterior Crush Measurements of Vehicle for Test No. 469689-4-1.

Date: 2019-08-16 Test No.: 469689-4 VIN No.: 1C6RR6FT8DS686274
 Year: 2013 Make: RAM Model: 1500

VEHICLE CRUSH MEASUREMENT SHEET¹

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 $\frac{X1 + X2}{2} = \underline{\hspace{2cm}}$

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage		Field L**	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	±D
		Width*** (CDC)	Max**** Crush								
1	Front plane at bmpr ht	18	10	50	1	2	4	7	8	10	-15
2	Side plane at bmpr ht	18	10	60	1	2	-	-	8	10	+18
	Measurements recorded										
	<input checked="" type="checkbox"/> inches or <input type="checkbox"/> mm										

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

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

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

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

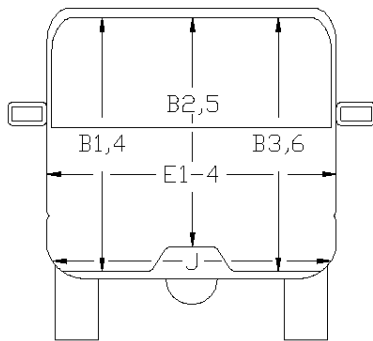
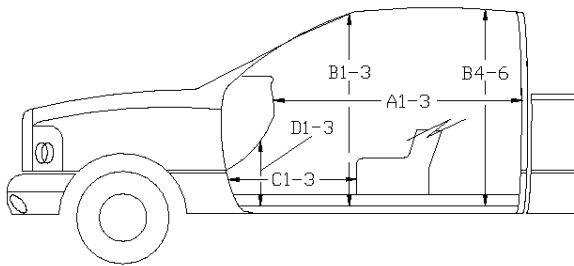
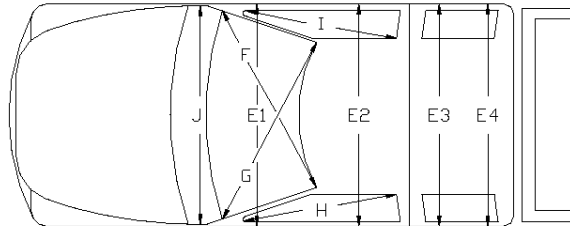
***Measure and document on the vehicle diagram the location of the maximum crush.

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

Table D.4. Occupant Compartment Measurements of Vehicle for Test No. 469689-4-1.

Date: 2019-08-16 Test No.: 469689-4 VIN No.: 1C6RR6FT8DS686274
 Year: 2013 Make: RAM Model: 1500

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT



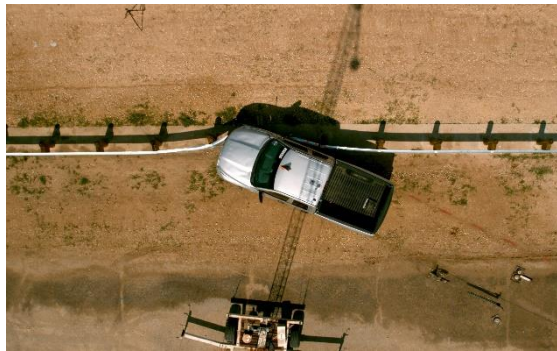
*Lateral area across the cab from driver's side kickpanel to passenger's side kickpanel.

	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	24.50	-1.50
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

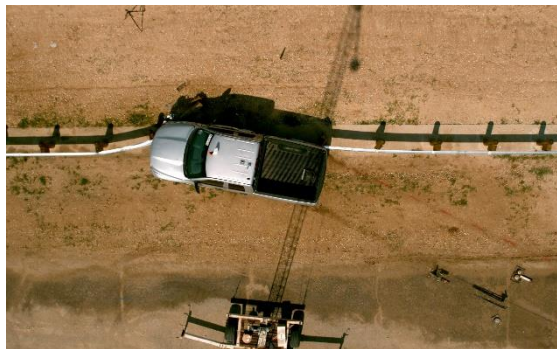
D.2 SEQUENTIAL PHOTOGRAPHS



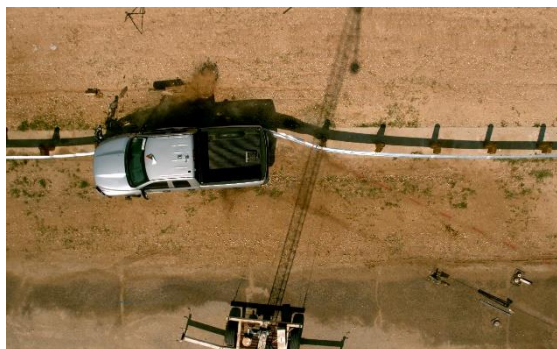
0.000 s



0.100 s



0.200 s



0.300 s



Figure D.1. Sequential Photographs for Test No. 469689-4-1 (Overhead and Frontal Views).



0.400 s



0.500 s



0.600 s



0.700 s



Figure D.1. Sequential Photographs for Test No. 469689-4-1 (Overhead and Frontal Views) (Continued).



0.000 s



0.400 s



0.100 s



0.500 s



0.200 s



0.600 s



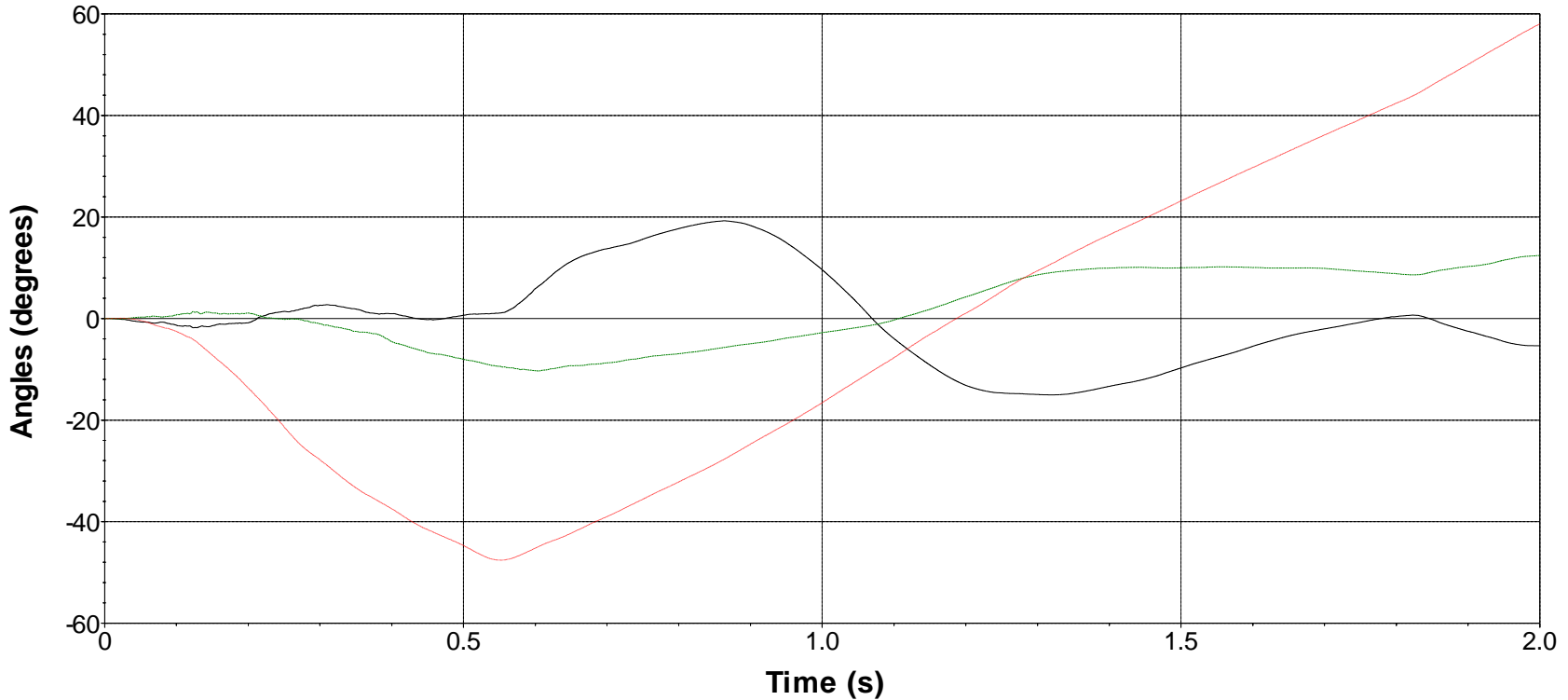
0.300 s



0.700 s

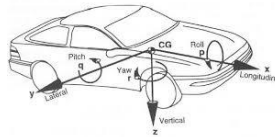
Figure D.2. Sequential Photographs for Test No. 469689-4-1 (Rear View).

Roll, Pitch, and Yaw Angles



— Roll - - - Pitch - - - Yaw

- Sequence for determining orientation:
1. Yaw.
 2. Pitch.
 3. Roll.

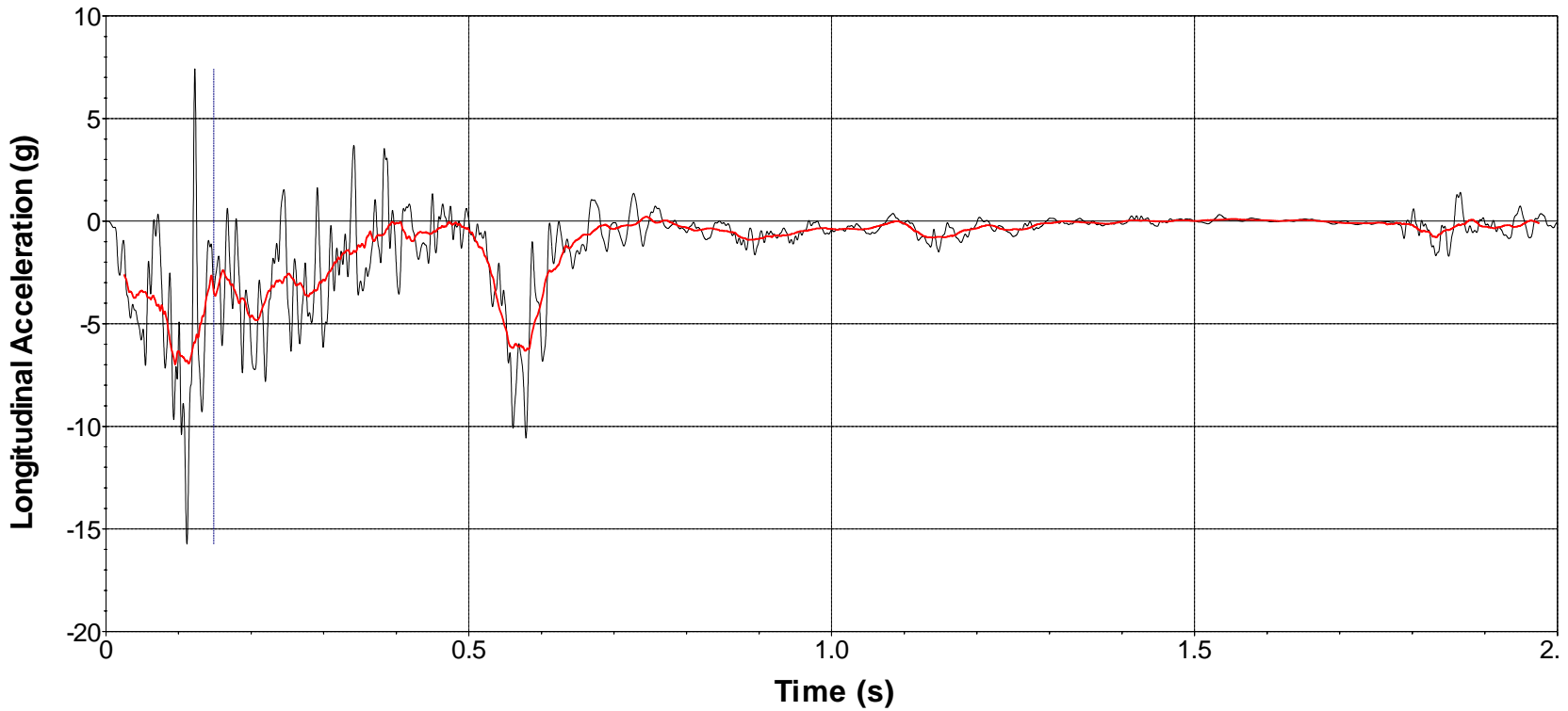


Test Number: 469689-4-1
 Test Standard Test Number: MASH Test 3-11
 Test Article: Mowstrip with Round Wood Posts
 Test Vehicle: 2013 RAM 1500 Pickup
 Inertial Mass: 5017 lb
 Gross Mass: 5017 lb
 Impact Speed: 63.7 mi/h
 Impact Angle: 25.1°

Figure D.3. Vehicle Angular Displacements for Test No. 469689-4-1.

X Acceleration at CG

D.4 VEHICLE ACCELERATIONS

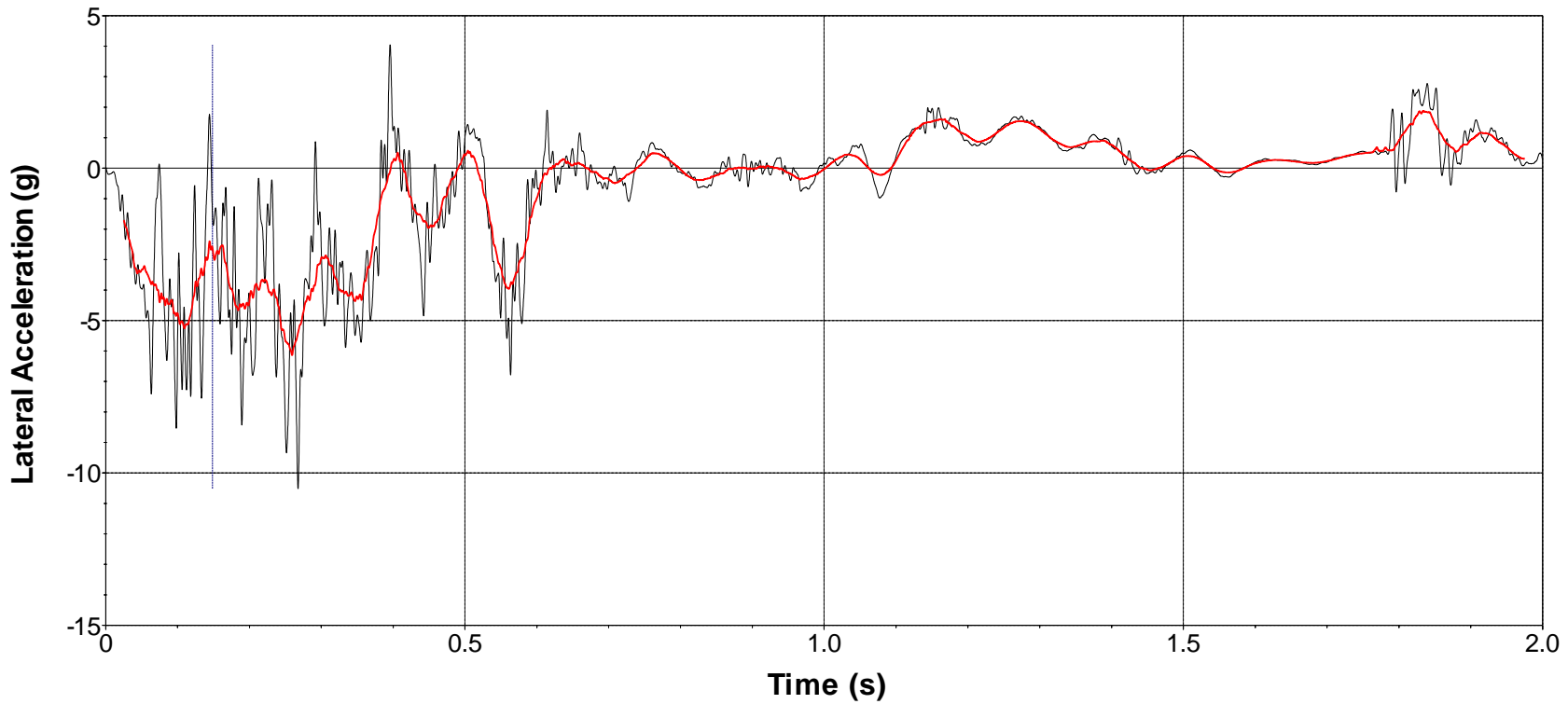


— Time of OIV (0.1485 sec) — SAE Class 60 Filter — 50-msec average

Test Number: 469689-4-1
Test Standard Test Number: MASH Test 3-11
Test Article: Mowstrip with Round Wood Posts
Test Vehicle: 2013 RAM 1500 Pickup
Inertial Mass: 5017 lb
Gross Mass: 5017 lb
Impact Speed: 63.7 mi/h
Impact Angle: 25.1°

**Figure D.4. Vehicle Longitudinal Accelerometer Trace for Test No. 469689-4-1
(Accelerometer Located at Center of Gravity).**

Y Acceleration at CG

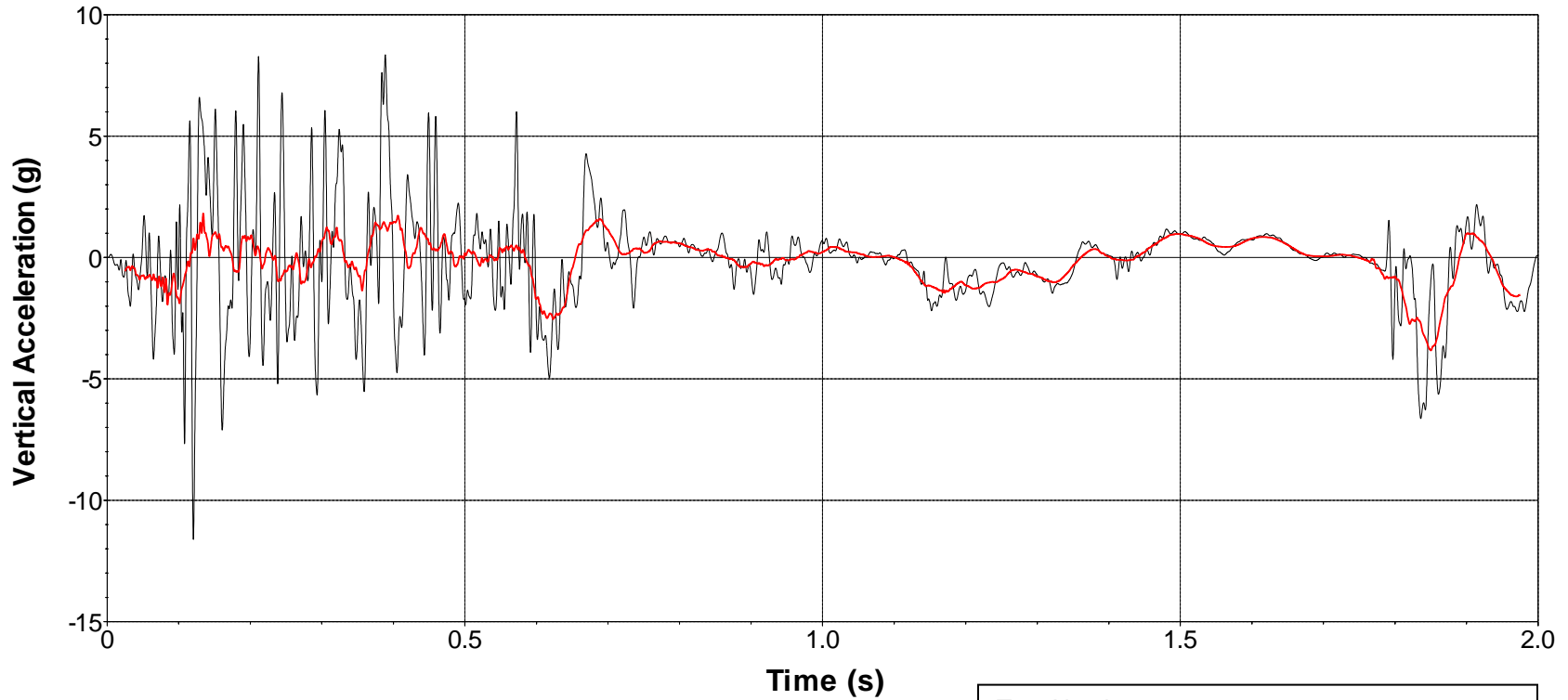


Time of OIV (0.1485 sec) SAE Class 60 Filter 50-msec average

Test Number: 469689-4-1
Test Standard Test Number: MASH Test 3-11
Test Article: Mowstrip with Round Wood Posts
Test Vehicle: 2013 RAM 1500 Pickup
Inertial Mass: 5017 lb
Gross Mass: 5017 lb
Impact Speed: 63.7 mi/h
Impact Angle: 25.1°

Figure D.5. Vehicle Lateral Accelerometer Trace for Test No. 469689-4-1 (Accelerometer Located at Center of Gravity).

Z Acceleration at CG



— SAE Class 60 Filter — 50-msec average

Test Number: 469689-4-1
 Test Standard Test Number: MASH Test 3-11
 Test Article: Mowstrip with Round Wood Posts
 Test Vehicle: 2013 RAM 1500 Pickup
 Inertial Mass: 5017 lb
 Gross Mass: 5017 lb
 Impact Speed: 63.7 mi/h
 Impact Angle: 25.1°

**Figure D.6. Vehicle Vertical Accelerometer Trace for Test No. 469689-4-1
 (Accelerometer Located at Center of Gravity).**

