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MASH TL-3 EVALUATION OF W-BEAM MEDIAN BARRIER WITH RUB RAIL

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16. Abstract

The objective of this research was to evaluate the impact performance of W-beam median barrier with rub rail according to the safety evaluation criteria of *MASH* Test Level 3 (TL-3). This evaluation involved performing two crash tests, one with an 1100C small passenger car, and one with a 2270P pickup truck. The target impact speed and angle were 62 mi/h and 25° for both tests.

This report provides details of the W-beam median barrier with rub rail, detailed documentation of the crash tests and results, and an assessment of the performance of the median barrier for *MASH* TL-3 evaluation criteria.

The W-beam median barrier with rub rail performed acceptably for *MASH* TL-3 evaluation criteria for longitudinal barriers.

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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

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Chapter 1. INTRODUCTION

1.1 PROBLEM STATEMENT

Currently used W-beam median barrier with rub rail attached to the posts has not been evaluated under the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*) testing criteria (*1*). In 2013, TTI tested a W-beam median barrier system in accordance with *MASH* Test Level 3 (TL-3) evaluation criteria (*3*). Both *MASH* Test 3-10 with the small passenger car and *MASH* Test 3-11 with the pickup truck were performed and were successful. This median guardrail system did not have a rub rail attached. Due to prevalent use of the rub rail with W-beam median barriers in Florida, Florida Department of Transportation (FDOT) desires to perform *MASH* testing of this system.

1.2 OBJECTIVE

The objective of this research was to evaluate the impact performance of W-beam median barrier with rub rail in accordance with *MASH* TL-3 criteria for evaluating longitudinal barriers, which involves two crash tests:

- *MASH* Test 3-10, which involves an 1100C impacting the critical impact point (CIP) of the longitudinal barrier at a target impact speed and impact angle of 62 mi/h and 25°.
- *MASH* Test 3-11, which involves a 2270P vehicle impacting the CIP of the longitudinal barrier at a target impact speed and impact angle of 62 mi/h and 25°.

This report provides details of the W-beam median barrier with rub rail, detailed documentation of the crash tests and results, and an assessment of the performance of the median guardrail for *MASH* TL-3 evaluation criteria.

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Chapter 2. SYSTEM DETAILS

2.1. TEST ARTICLE AND INSTALLATION DETAILS

The test installation was 184 ft long and consisted of standard 12-gauge W-beam guardrail sections mounted on each side of a single row of 6 ft-6 inch long W6×8.5 posts. The guardrail on each side was offset from the posts with 6-inch × 8-inch (nominal) × 14-inch timber blockouts. A rub rail fabricated from bent plate was attached to the posts on the impact side. The top edge of the W-beam guardrail was 31 inches above grade, and the top edge of the rub rail was 16 inches above grade. A Florida DOT Double Face Trailing Anchorage Type II End Treatment was installed on each end of the guardrail.

Figure 2.1 presents overall information on the test installation, and Figure 2.2 provides photographs of the installation. Appendix A provides further details of the W-beam median barrier with rub rail.

2.2. DESIGN MODIFICATIONS DURING TESTS

No modification was made to the installation during the testing phase.

2.3. MATERIAL SPECIFICATIONS

Appendix B provides material certification documents for the materials used to construct the W-beam median barrier with rub rail.

2.4. SOIL CONDITIONS

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

Soil strength was measured on the day of each crash test in accordance with Appendix B of *MASH*. Two 6 ft long W6×16 posts were installed in the immediate vicinity of the test installation during the installation of the guardrail. These posts were installed with same fill materials and by following the same installation procedures as were used in installing the posts of the test installation.

Table C.1 in Appendix C presents minimum soil strength properties established through standard dynamic testing performed in accordance with *MASH* Appendix B. As determined by the tests summarized in Appendix C, Table C.1, the minimum post loads required for deflections at 5 inches, 10 inches, and 15 inches, measured at a height of 25 inches, are 3940 lb, 5500 lb, and 6540 lb, respectively (90 percent of static load for the initial standard installation).

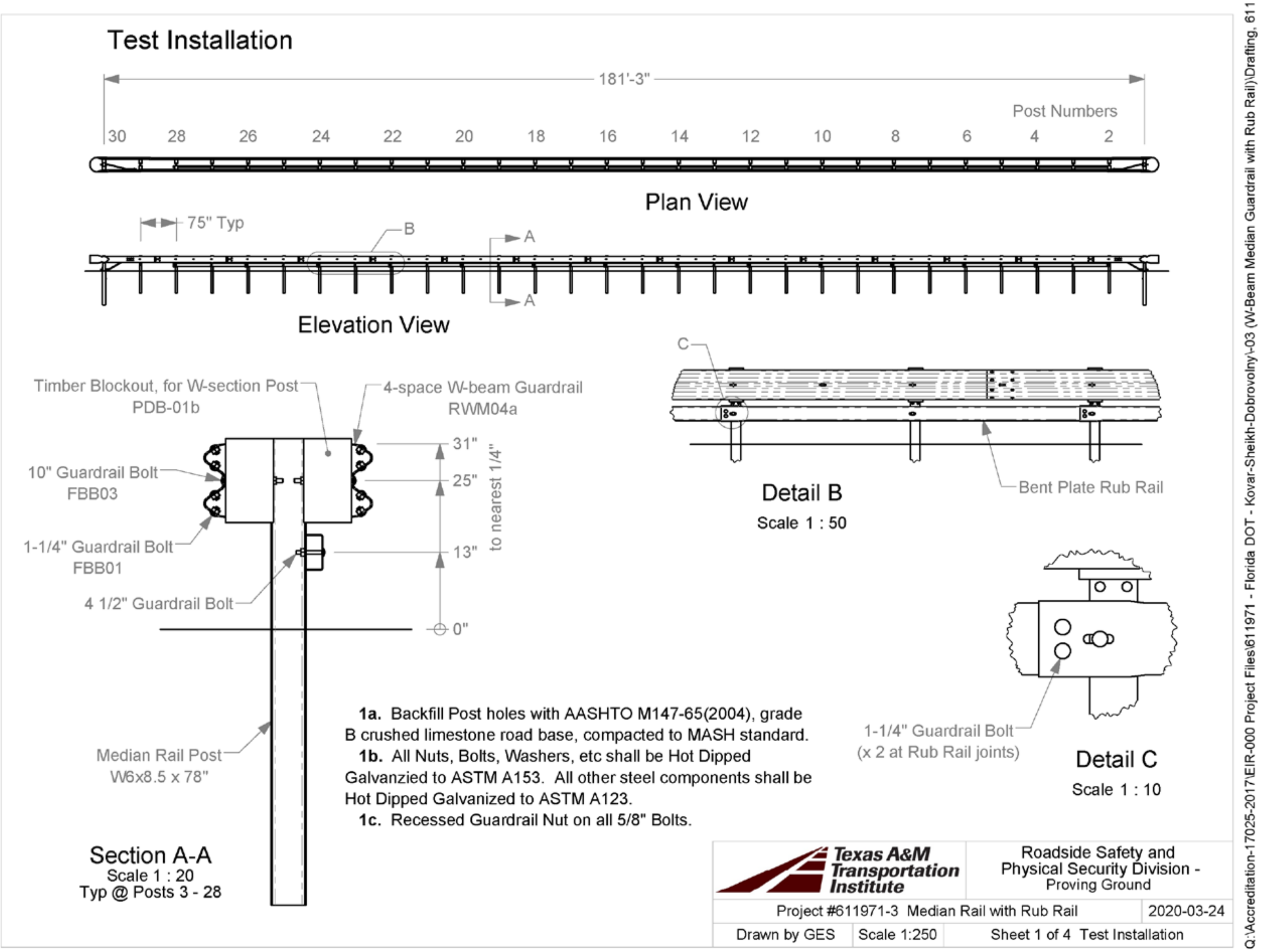

Figure 2.1. Details of W-Beam Median Barrier with Rub Rail.

Figure 2.2. W-Beam Median Barrier with Rub Rail Prior to Testing.

On the day of the first test, September 11, 2019, loads on the post at deflections of 5 inches, 10 inches, and 15 inches were 9397 lbf, 8777 lbf, and 7986 lbf, respectively. Table C.2 in Appendix C shows the strength of the backfill material for this test met minimum *MASH* requirements.

On the day of the second test, September 17, 2019, loads on the post at deflections of 5 inches, 10 inches, and 15 inches were 7814 lbf, 7538 lbf, and 6850 lbf, respectively. Table C.3 in Appendix C shows the strength of the backfill material for this test met minimum *MASH* requirements.

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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), shown in Figure 3.1, were determined using the information provided in Section 2.2.1, Section 2.3.2, and Figure 2-1 of *MASH*. For *MASH* Test 3-10, the CIP was 8.0 ft ±1 ft upstream of the centerline of post 9. The CIP for *MASH* Test 3-11 was 11.1 ft ±1 ft upstream of the centerline of post 13.

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

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

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

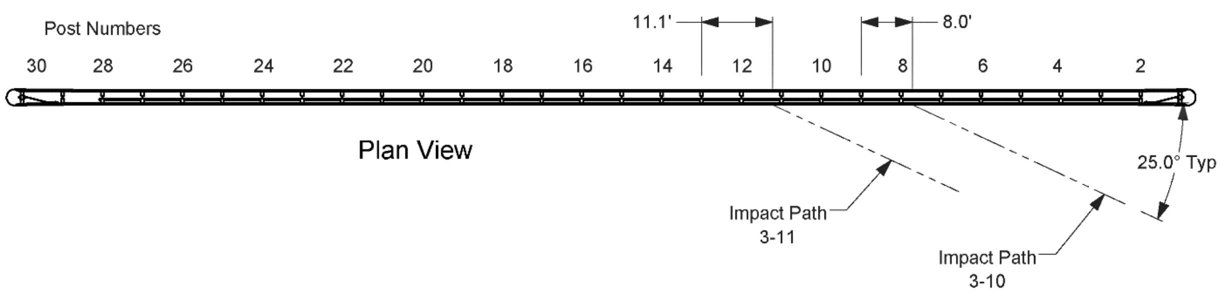

Figure 3.1. Target CIPs for *MASH* TL-3 Tests on W-Beam Median Barrier with Rub Rail.

3.2. EVALUATION CRITERIA

The appropriate safety evaluation criteria from Tables 2-2 and 5-1 of *MASH* were used to evaluate the crash tests reported herein. The test conditions and evaluation criteria required for *MASH* TL-3 longitudinal barriers are listed in Table 3.1. The substance of the evaluation criteria is presented in Table 3.2.

Table 3.2. Evaluation Criteria Required for *MASH* TL-3 Longitudinal Barriers.

Evaluation Factors	Evaluation Criteria	
Structural Adequacy	*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.*
Occupant Risk	*D.*	*Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present undue hazard to other traffic, pedestrians, or personnel in a work zone.* *Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH.*
	F.	*The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.*
	H.	*Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 30 ft/s, or maximum allowable value of 40 ft/s.*
	I.	*The occupant ridedown accelerations should satisfy the following: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.*

Chapter 4. TEST CONDITIONS

4.1. TEST FACILITY

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

The test facilities of the TTI Proving Ground are located on the Texas A&M University System RELLIS Campus, which consists of a 2000-acre complex of research and training facilities situated 10 miles northwest of the flagship campus of Texas A&M University. The site, formerly a United States Army Air Corps base, has large expanses of concrete runways and parking aprons well suited for experimental research and testing in the areas of vehicle performance and handling, vehicle-roadway interaction, durability and efficacy of highway pavements, and evaluation of roadside safety hardware and perimeter protective devices. The site selected for construction and testing of the W-beam median barrier with rub rail 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

Each test vehicle was towed into the test installation using a steel cable guidance and reverse tow system. A steel cable for guiding the test vehicle was tensioned along the path, anchored at each end, and threaded through an attachment to the front wheel of the test vehicle. An additional steel cable was connected to the test vehicle, passed around a pulley near the impact point, through a pulley on the tow vehicle, and then anchored to the ground such that the tow vehicle moved away from the test site. A 2:1 speed ratio between the test and tow vehicle existed with this system. 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, 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

Each test vehicle was instrumented with a self-contained, on-board data acquisition system. The signal conditioning and acquisition system is a 16-channel, Tiny Data Acquisition System (TDAS) Pro produced by Diversified Technical Systems, Inc. The accelerometers, which measure the x, y, and z axis of vehicle acceleration, are strain gauge type with linear millivolt output proportional to acceleration. Angular rate sensors, measuring vehicle roll, pitch, and yaw rates, are ultra-small, solid state units designed for crash test service. The TDAS Pro hardware and software conform to the latest SAE J211, Instrumentation for Impact Test. Each of the 16 channels is capable of providing precision amplification, scaling, and filtering based on transducer specifications and calibrations. During the test, data are recorded from each channel at a rate of 10,000 samples 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 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, 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

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 overhead with a field of view perpendicular to the ground and directly over the impact point;
- One placed upstream of impact on the traffic side; 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 W-beam median barrier with rub rail. The flashbulb was visible from each camera. The video files from these digital high-speed cameras were analyzed to observe phenomena occurring during the collision and to obtain time-event, displacement, and angular data. A digital camera recorded and documented conditions of each test vehicle and the installation before and after the test.

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Chapter 5. *MASH* TEST 3-10 (CRASH TEST NO. 611971-03-1)

5.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

MASH Test 3-10 involves an 1100C vehicle weighing 2425 lb ±55 lb impacting the CIP of the barrier at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 25° ±1.5°. The CIP for *MASH* Test 3-10 on the W-beam median barrier with rub rail was 8.0 ft ±1 ft upstream of the centerline of post 9.

The 2009 Kia Rio[*] used in the test weighed 2438 lb, and the actual impact speed and angle were 60.9 mi/h and 25.1°. The actual impact point was 8.3 ft upstream of the centerline of post 9. Minimum target impact severity (IS) was 51 kip-ft, and actual IS was 54 kip-ft.

5.2 WEATHER CONDITIONS

The test was performed on the morning of September 11, 2019. Weather conditions at the time of testing were as follows: wind speed: 6 mi/h; wind direction: 146° (vehicle was traveling at magnetic heading of 205°); temperature: 88°F; relative humidity: 71 percent.

5.3 TEST VEHICLE

Figures 5.1 and 5.2 show the 2009 Kia Rio used for the crash test. The vehicle's test inertia weight was 2438 lb, and its gross static weight was 2603 lb. The height to the lower edge of the vehicle front bumper was 7.75 inches, and height to the upper edge of the bumper was 21.5 inches. Table D.1 in Appendix D1 gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system and was released to be freewheeling and unrestrained just prior to impact.

Figure 5.1. Median Barrier/Test Vehicle Geometrics for Test No. 611971-03-1.

[*] The 2009 model vehicle used is older than the 6-year age noted in *MASH* and was selected based upon availability. An older model vehicle is permitted by AASHTO as long as it is otherwise *MASH* compliant. Other than the vehicle's year model, this 2009 model vehicle met the *MASH* requirements.

Figure 5.2. Test Vehicle before Test No. 611971-03-1.

5.4 TEST DESCRIPTION

The test vehicle was traveling at an impact speed of 60.9 mi/h when it contacted the median barrier 8.3 ft upstream of the centerline of post 9 at an impact angle of 25.1°. Table 5.1 lists events that occurred during Test No. 611971-03-1. Figures D.1 and D.2 in Appendix D2 present sequential photographs during the test.

Table 5.1. Events during Test No. 611971-03-1.

TIME (s)	EVENTS
0.0000	Vehicle contacts median barrier
0.0430	Vehicle begins to redirect
0.0150	Post 8 begins to deflect toward field side
0.0300	Posts 9 and 7 begin to rotate counterclockwise and deflect toward field side
0.0700	Post 10 begins to move toward field side
0.0890	Blockout on post 9 contacted by the vehicle and begins to break apart
0.0910	Field side W-beam rail element detaches from post 10 blockout
0.1120	Field side W-beam rail element detaches from post 11 blockout
0.1470	Field side W-beam rail element detaches from post 12 blockout
0.1860	Vehicle is parallel with median barrier
0.3620	Vehicle loses contact with median barrier while traveling at 41.3 mi/h with trajectory of 16.6° and heading of 16.1°

For longitudinal barriers, it is desirable that the vehicle redirects and exits the barrier within the exit box criteria (not less than 32.8 ft downstream from loss of contact for cars and pickups). The test vehicle exited within the exit box criteria defined in *MASH*. Brakes on the vehicle were applied at 2.0 s after impact. The vehicle came to rest 199 ft downstream of the impact point and 36 ft toward traffic lanes.

5.5 DAMAGE TO TEST INSTALLATION

Figures 5.3 through 5.7 show the damage to the W-beam median barrier with rub rail. There was minimal soil disturbance at post 1, but no visible post movement. Post 9 was twisted and deformed. The field side blockout at post 9 was split, with one portion landing 10 ft behind the rail. See Table 5.2 for movement of posts 7, 8, and 10.

Table 5.2. Movement at Posts 7, 8, and 10.

Post #	Lean to Field Side	Traffic Side Gap	Field Side Gap
7	88.2°	¾ inches	0
8	83.8°	filled with soil	1 inch
10	89.8°	filled with soil	½ inch

There was no post movement observed past post 10. The W-beam rail on the field side released from posts 10, 11, and 12. The rub rail and traffic side W-beam were deformed and scuffed in the impact area.

Working width* was 41.5 inches, and height of working width was 31.0 inches. Maximum dynamic deflection during the test was 21.7 inches, and maximum permanent deformation was 11.5 inches.

5.6 VEHICLE DAMAGE

Figure 5.8 shows the damage sustained by the vehicle. The front bumper, hood, right front fender, right front tire and rim, right front and rear doors, right rear quarter panel, and rear bumper were damaged. Maximum exterior crush to the vehicle was 10.0 inches in the side plane at the right front corner at bumper height. No occupant compartment deformation or intrusion was observed. Figure 5.9 shows the interior of the vehicle. Tables D.2 and D.3 in Appendix D1 provide exterior crush and occupant compartment measurements.

5.7 OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 5.3. 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. Figure 5.10 summarizes pertinent information from the test.

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* Working width is defined as the total barrier width plus the maximum intrusion of any portion of the barrier or test vehicle past the field side edge of the barrier.

Figure 5.3. Median Barrier after Test No. 611971-03-1.

Figure 5.4. Post 8 after Test No. 611971-03-1.

Figure 5.5. Post 9 after Test No. 611971-03-1.

Figure 5.6. Post 10 after Test No. 611971-03-1.

Figure 5.7. Field Side of Median Barrier after Test No. 611971-03-1.

Figure 5.8. Test Vehicle after Test No. 611971-03-1.

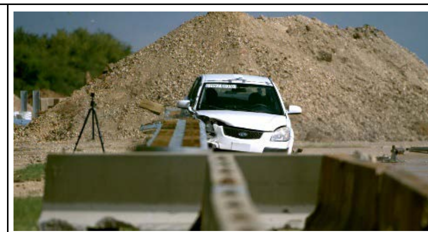
Figure 5.9. Interior of Test Vehicle after Test No. 611971-03-1.

Table 5.3. Occupant Risk Factors for Test No. 611971-03-1.

Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV)		
Longitudinal	**19.4 ft/s**	at 0.1047 s on right side of interior
Lateral	**22.6 ft/s**	
Occupant Ridedown Accelerations		
Longitudinal	**13.5 g**	0.1260 - 0.1360 s
Lateral	**9.3 g**	0.1431 - 0.1531 s
Theoretical Head Impact Velocity (THIV)	**8.8 m/s**	at 0.1016 s on right side of interior
Acceleration Severity Index (ASI)	**1.2**	0.0852 - 0.1352 s
Maximum 50-ms Moving Average		
Longitudinal	**-8.8 g**	0.0861 - 0.1361 s
Lateral	**-9.2 g**	0.0497 - 0.0997 s
Vertical	**2.9 g**	0.1419 - 0.1919 s
Maximum Roll, Pitch, and Yaw Angles		
Roll	**5**	0.1760 s
Pitch	**5°**	0.2942 s
Yaw	**44°**	0.6605 s

0.000 s

400



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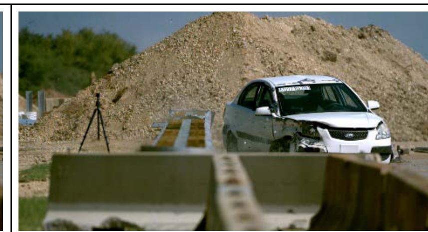

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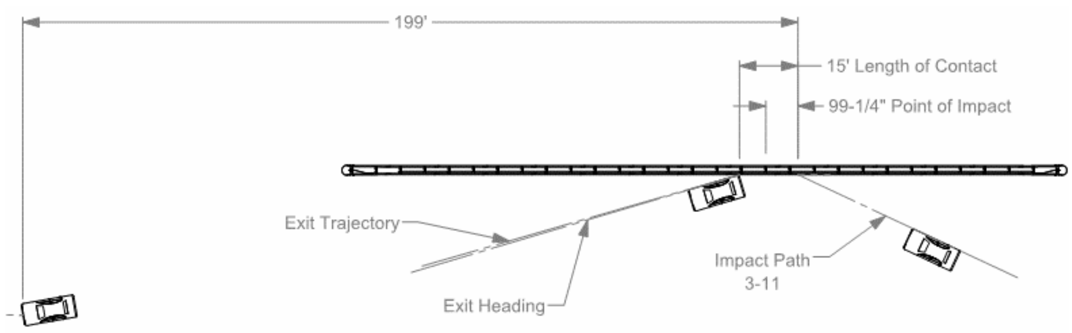

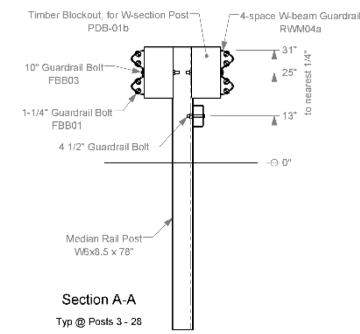

General Information

Test Agency....................... Texas A&M Transportation Institute (TTI)
Test Standard Test No....... MASH Test 3-10
TTI Test No. 611971-03-1
Test Date 2019-09-11

Test Article

Type .... Longitudinal Barrier – Median Barrier
Name................................ W-beam median barrier with rub rail
184 ft
Installation Length............. 12-gauge W-Beam mounted on each side
Material or Key Elements... of single row of W6×8.5 posts with 6-inch × 8-inch (nominal) × 14-inch timber blockouts and bent plate rub rail
AASHTO M147-65(2004), grading B Soil
Soil Type and Condition ..... (crushed limestone), Damp

Test Vehicle 1100C
Type/Designation............... 2009 Kia Rio
Make and Model .... 2487 lb
Curb................................. 2438 lb
Test Inertial....................... 165 lb
Dummy .... 2603 lb
Gross Static ....

Impact Conditions

Speed .... 60.9 mi/h
Angle .... 25.1°
Location/Orientation .... 8.3 ft upstream of centerline of post 9

Impact Severity.................... 54 kip-ft

Exit Conditions

Speed .... 41.3 mi/y
Trajectory/Heading Angle... 16.6° / 16.1°

Occupant Risk Values

Longitudinal OIV .... 19.4 ft/s
Lateral OIV......................... 22.6 ft/s
Longitudinal Ridedown....... 13.5 g
Lateral Ridedown .... 9.3 g
THIV .... 8.8 m/s
ASI.................................... 1.2

Max. 0.050-s Average
Longitudinal .... -8.8 g
Lateral............................. -9.2 g
Vertical............................ 2.9 g

Post-Impact Trajectory

Stopping Distance.................... 199 ft downstream
36 ft toward traffic

Vehicle Stability

Maximum Yaw Angle .... 44°
Maximum Pitch Angle .... 5°
Maximum Roll Angle .... 5°
Vehicle Snagging...................... No
Vehicle Pocketing .... No

Test Article Deflections

Dynamic................................... 21.7 inches
Permanent .... 11.5 inches
Working Width.......................... 41.5 inches
Height of Working Width .... 31.0 inches

Vehicle Damage

VDS 01RFQ5
CDC... 01FREW4
Max. Exterior Deformation......... 10.0 inches
OCDI.. FR0000000
Max. Occupant Compartment Deformation........................... None

Figure 5.10. Summary of Results for *MASH* Test 3-10 on W-Beam Median Barrier with Rub Rail.

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Chapter 6. *MASH* TEST 3-11 (CRASH TEST NO. 611971-03-2)

6.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

MASH Test 3-11 involves a 2270P vehicle weighing 5000 lb ±110 lb impacting the CIP of the barrier at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 25° ±1.5°. The CIP for *MASH* Test 3-11 on the W-beam median barrier with rub rail was 11.1 ft ±1 ft upstream of the centerline of post 13.

The 2016 RAM 1500 pickup truck used in the test weighed 5041 lb, and the actual impact speed and angle were 61.3 mi/h and 25.1°, respectively. The actual impact point was 11.1 ft upstream of the centerline of post 13. Minimum target IS was 106 kip-ft, and actual IS was 114 kip-ft.

6.2 WEATHER CONDITIONS

The test was performed on the morning of September 17, 2019. Weather conditions at the time of testing were as follows: wind speed: 5 mi/h; wind direction: 67° (vehicle was traveling at magnetic heading of 205°); temperature: 83°F; relative humidity: 81 percent.

6.3 TEST VEHICLE

Figures 6.1 and 6.2 show the 2016 RAM 1500 pickup truck used for the crash test. The vehicle's test inertia weight was 5041 lb, and its gross static weight was 5041 lb. The height to the lower edge of the vehicle front 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 28.5 inches. Tables E.1 and E.2 in Appendix D1 give additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system and was released to be freewheeling and unrestrained just prior to impact.

Figure 6.1. Median Barrier/Test Vehicle Geometrics for Test No. 611971-03-2.

Figure 6.2. Test Vehicle before Test No. 611971-03-2.

6.4 TEST DESCRIPTION

The test vehicle was traveling at an impact speed of 61.3 mi/h when it contacted the barrier 11.1 ft upstream of the centerline of post 13 at an impact angle of 25.1°. Table 6.1 lists events that occurred during Test No. 611971-03-2. Figures E.1 and E.2 in Appendix E2 present sequential photographs during the test.

Table 6.1. Events during Test No. 611971-03-2.

TIME (s)	EVENTS
0.0000	Vehicle contacts barrier
0.0640	Vehicle begins to redirect
0.0240	Post 12 begins to deflect toward field side
0.0520	Post 13 begins to rotate counterclockwise and deflect toward field side
0.0730	Field side rail element detaches from post 13 blockout
0.0830	Field side rail element detaches from post 11 blockout
0.0860	Field side rail element detaches from post 14 blockout
0.0940	Field side rail element detaches from post 10 blockout
0.1080	Field side rail element detaches from post 15 blockout
0.1170	Field side rail element detaches from post 9 blockout
0.1350	Field side rail element detaches from post 16 blockout
0.1860	Field side rail element detaches from post 17 blockout
0.1900	Rear right side of the truck bed contacts barrier
0.2300	Vehicle traveling parallel with barrier
0.4900	Vehicle loses contact with barrier while traveling at 46.2 mi/h, exit trajectory of 13.1°, and heading of 15.0°

For longitudinal barriers, it is desirable that the vehicle redirects and exits the barrier within the exit box criteria (not less than 32.8 ft downstream from loss of contact for cars and pickups). The test vehicle exited within the exit box criteria defined in *MASH*. Brakes on the vehicle were applied at 2.0 s after impact, and the vehicle subsequently came to rest 205 ft downstream of the impact, 8 ft toward traffic lanes.

6.5 DAMAGE TO TEST INSTALLATION

Figures 6.3 through 6.9 show the damage to the test installation. There was minimal soil disturbance at post 1, and a ⅛-inch gap between the soil and post on the upstream side. Posts 12 through 14 were rotated and deformed. See Table 6.2 for more information on post movement.

There was no post movement observed past post 15. The W-beam rail released from posts 7 through 18 on the field side and posts 12 through 14 on the traffic side. The rub rail and traffic side W-beam were deformed and scuffed in the impact area.

Working width* was 52.6 inches, and height of working width was 31.0 inches. Maximum dynamic deflection during the test was 28.1 inches, and maximum permanent deformation was 20.25 inches.

Figure 6.3. Median Barrier after Test No. 611971-03-2.

* Working width is defined as the total barrier width plus the maximum intrusion of any portion of the barrier or test vehicle past the field side edge of the barrier.

Figure 6.4. Post 11 after Test No. 611971-03-2.

Figure 6.5. Post 12 after Test No. 611971-03-2.

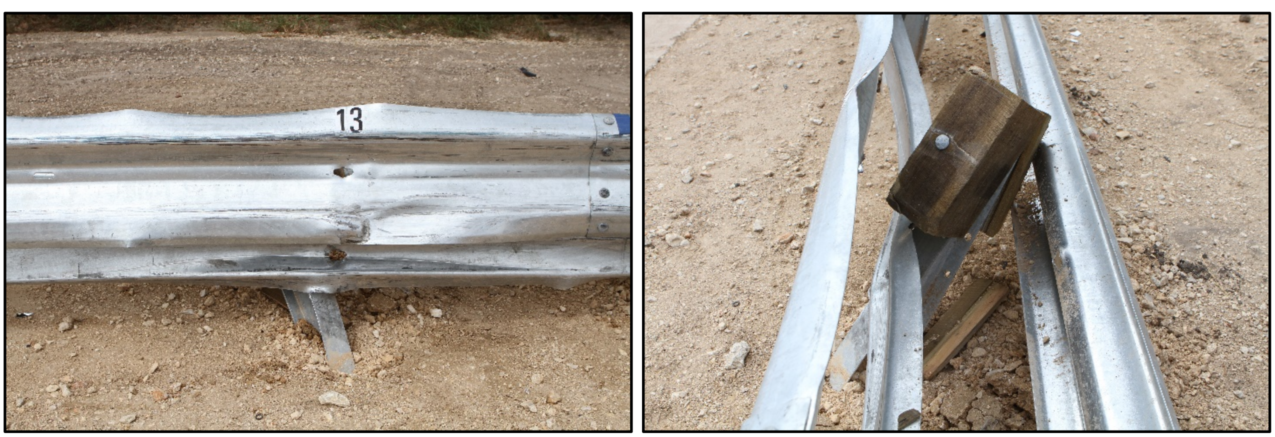


Figure 6.6. Post 13 after Test No. 611971-03-2.

Figure 6.7. Median Barrier after Test No. 611971-03-2.

Figure 6.8. Median Barrier after Test No. 611971-03-2.

Figure 6.9. Posts 14-16 after Test No. 611971-03-2.

Table 6.2. Movement at Posts 10 through 15.

Post #	Lean to Field Side	Traffic Side Gap	Field Side Gap
10	-	0	⅛-inch
11	87.0°	¼-inch	1 inch
13	50.0°	filled with soil	filled with soil
14	70.0°	3 inches	1 inch
15	-	¼-inch	⅛-inch

6.6 VEHICLE DAMAGE

Figure 6.10 shows the damage sustained by the vehicle. The front bumper, radiator and support, right front fender, right front tire and rim, right front and rear doors, right rear cab corner, right rear exterior bed, and rear bumper were damaged. Maximum exterior crush to the vehicle was 11.0 inches in the front and side planes at the right front corner at bumper height. No occupant compartment deformation or intrusion was observed. Figure 6.11 shows the interior of the vehicle. Tables E.3 and E.4 in Appendix E1 provide exterior crush and occupant compartment measurements.

Figure 6.10. Test Vehicle after Test No. 611971-03-2.

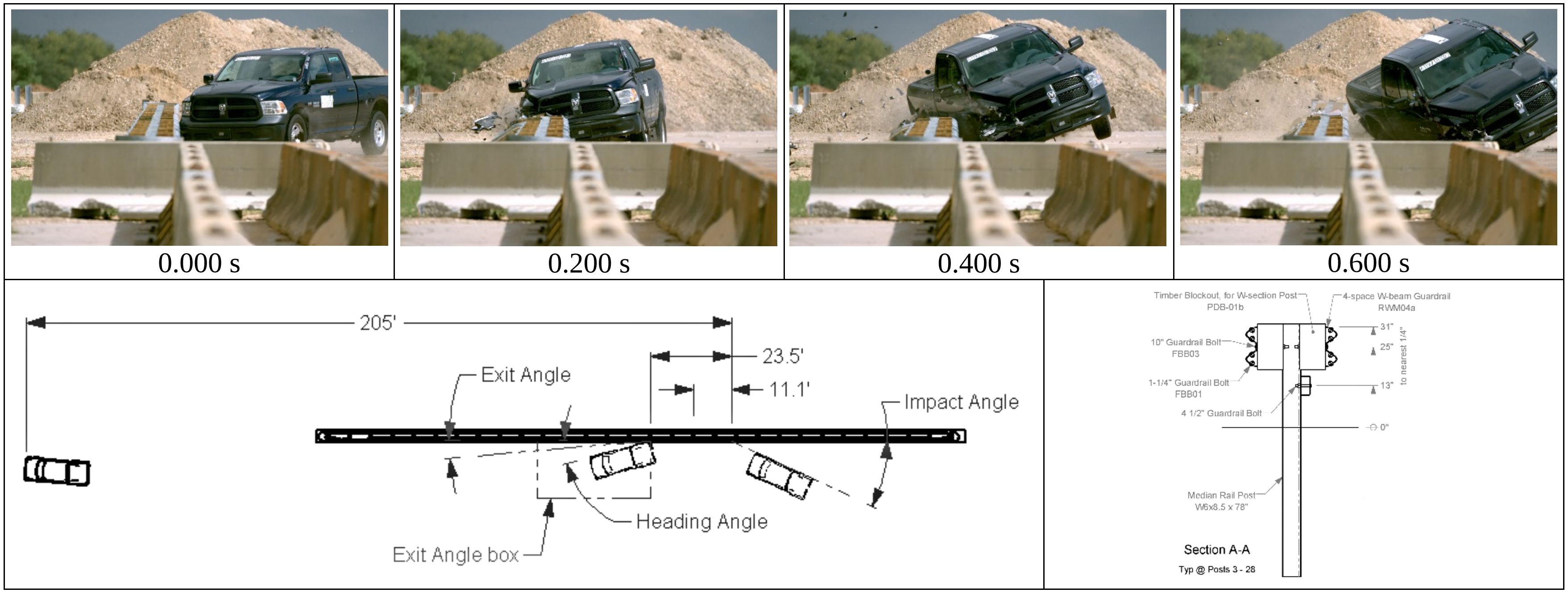
Figure 6.11. Interior of Test Vehicle after Test No. 611971-03-2.

6.7 OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 6.3. Figure E.3 in Appendix E3 shows the vehicle angular displacements, and Figures E.4 through E.9 in Appendix E4 show acceleration versus time traces. Figure 6.12 summarizes pertinent information from the test.

Table 6.3. Occupant Risk Factors for Test No. 611971-03-2.

Occupant Risk Factor	Value	Time
OIV		
Longitudinal	**15.4 ft/s**	at 0.1383 s on right side of interior
Lateral	**17.7 ft/s**	
Occupant Ridedown Accelerations		
Longitudinal	**5.1 g**	0.1401 - 0.1501 s
Lateral	**10.6 g**	0.2318 - 0.2418 s
THIV	**7.1 m/s**	at 0.1333 s on right side of interior
ASI	**0.9**	0.2314 - 0.2814 s
Maximum 50-ms Moving Average		
Longitudinal	**-4.9 g**	0.0557 - 0.1057 s
Lateral	**-7.0 g**	0.2012 - 0.2512 s
Vertical	**1.9 g**	0.2356 - 0.2856 s
Maximum Roll, Pitch, and Yaw Angles		
Roll	**24°**	0.6004 s
Pitch	**6°**	0.7936 s
Yaw	**43°**	0.7055 s



General Information
Test Agency...................... Texas A&M Transportation Institute (TTI)
Test Standard Test No....... MASH Test 3-11
TTI Test No. 611971-03-2
Test Date.......................... 2019-09-17
Test Article
Type .... Longitudinal Barrier – Median Barrier
Name................................ W-beam median barrier with rub rail
184 ft
Installation Length............. 12-gauge W-Beam mounted on each side
Material or Key Elements... of single row of W6×8.5 posts with 6-inch × 8-inch (nominal) × 14-inch timber blockouts and bent plate rub rail
AASHTO M147-65(2004), grading B Soil
Soil Type and Condition ..... (crushed limestone), Damp

Test Vehicle 2270P
Type/Designation............... 2016 RAM 1500 pickup truck
Make and Model .... 5002 lb
Curb................................. 5041 lb
Test Inertial....................... No Dummy
Dummy .... 5041 lb
Gross Static ....

Impact Conditions
Speed .... 61.3 mi/h
Angle .... 25.1°
Location/Orientation........... 11.1 ft upstream of post 13
Impact Severity.................... 114 kip-ft
Exit Conditions
Speed .... 46.3 mi/h
Trajectory/Heading Angle... 13.1° / 15.0°
Occupant Risk Values
Longitudinal OIV .... 15.4 ft/s
Lateral OIV........................ 17.7 ft/s
Longitudinal Ridedown....... 5.1 g
Lateral Ridedown .... 10.6 g
THIV .... 7.1 m/s
ASI.................................... 0.9
Max. 0.050-s Average
Longitudinal .... -4.9 g
Lateral............................ -7.0 g
Vertical........................... 1.9 g

Post-Impact Trajectory
Stopping Distance.................... 205 ft downstream
8 ft toward traffic
Vehicle Stability
Maximum Yaw Angle .... 43°
Maximum Pitch Angle .... 6°
Maximum Roll Angle .... 24°
Vehicle Snagging...................... No
Vehicle Pocketing .... No
Test Article Deflections
Dynamic.................................. 28.1 inches
Permanent .... 20.25 inches
Working Width.......................... 52.6 inches
Height of Working Width .... 31.0 inches
Vehicle Damage
VDS 01RFQ4
CDC.. 01FREW3
Max. Exterior Deformation......... 11.0 inches
OCDI....................................... RF0000000
Max. Occupant Compartment Deformation.......................... None

Figure 6.12. Summary of Results for *MASH* Test 3-11 on W-Beam Median Barrier with Rub Rail.

Chapter 7. SUMMARY AND CONCLUSIONS

7.1 ASSESSMENT OF TEST RESULTS

The crash tests reported herein were performed on the W-beam median barrier with rub rail in accordance with *MASH* TL-3, which involves the following two crash tests.

7.1.1 *MASH* Test 3-10 (Crash Test No. 611971-03-1)

Table 7.1 provides an assessment of *MASH* Test 3-10 on the W-beam median barrier with rub rail. The median barrier contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 21.7 inches. One blockout fractured, however this debris did not penetrate or show potential for penetrating the occupant compartment, or present undue hazard to others in the area. No other debris was observed. No occupant compartment deformation or intrusion was observed. The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 5° each. Occupant risk factors were within the preferred limits of *MASH*.

7.1.2 *MASH* Test 3-11 (Crash Test No. 611971-03-2)

Table 7.2 provides an assessment of *MASH* Test 3-11 on the W-beam median barrier with rub rail. The median barrier contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 28.1 inches. No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or present undue hazard to others in the area. No other debris was observed. No occupant compartment deformation or intrusion was observed. The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 24° and 6°, respectively. Occupant risk factors were within the preferred limits of *MASH*.

7.2 CONCLUSIONS

Table 7.3 shows the W-beam median barrier with rub rail performed acceptably for *MASH* TL-3 longitudinal barriers.

Table 7.1. Performance Evaluation Summary for *MASH* Test 3-10 on W-Beam Median Barrier with Rub Rail.

Test Agency: Texas A&M Transportation Institute | Test No.: 611971-03-1 | Test Date: 2019-09-11

MASH Test x-xx Evaluation Criteria	Test Results	Assessment
Structural Adequacy		
A. Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.	The W-beam median barrier with rub rail contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 21.7 inches.	Pass
Occupant Risk		
D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.	One blockout fractured, however this debris did not penetrate or show potential for penetrating the occupant compartment, or present undue hazard to others in the area. No other debris was observed.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH.	No occupant compartment deformation or intrusion was observed.	
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 5° each.	Pass
H. Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 30 ft/s, or maximum allowable value of 40 ft/s.	Longitudinal OIV was 19.4 ft/s, and lateral OIV was 22.6 ft/s.	Pass
I. The occupant ridedown accelerations should satisfy the following limits: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	Longitudinal occupant ridedown acceleration was 13.5 g, and lateral occupant ridedown acceleration was 9.3 g.	Pass
Vehicle Trajectory		
For redirective devices, it is preferable that the vehicle be smoothly redirected and leave the barrier within the "exit box" criteria (not less than 32.8 ft for the 1100C and 2270P vehicles) and should be documented.	The 1100C vehicle exited within the exit box criteria.	Documentation only

Table 7.2. Performance Evaluation Summary for *MASH* Test 3-11 on W-Beam Median Barrier with Rub Rail.

Test Agency: Texas A&M Transportation Institute | Test No.: 611971-03-2 | Test Date: 2019-09-17

MASH Test x-xx Evaluation Criteria	Test Results	Assessment
Structural Adequacy		
A. Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.	The W-beam median barrier with rub rail contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 28.1 inches.	Pass
Occupant Risk		
D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.	No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or present undue hazard to others in the area. No other debris was observed.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH.	No occupant compartment deformation or intrusion was observed.	
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 24° and 6°, respectively.	Pass
H. Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 30 ft/s, or maximum allowable value of 40 ft/s.	Longitudinal OIV was 15.4 ft/s, and lateral OIV was 17.7 ft/s.	Pass
I. The occupant ridedown accelerations should satisfy the following limits: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	Longitudinal occupant ridedown acceleration was 5.1 g, and lateral occupant ridedown acceleration was 10.6 g.	Pass
Vehicle Trajectory		
For redirective devices, it is preferable that the vehicle be smoothly redirected and leave the barrier within the "exit box" criteria (not less than 32.8 ft for the 1100C and 2270P vehicles) and should be documented.	The 2270P vehicle exited within the exit box criteria.	Documentation only

Table 7.3. Assessment Summary for *MASH* TL-3 Tests on W-Beam Median Barrier with Rub Rail.

Evaluation Factors	Evaluation Criteria	Test No. 611971-03-1	Test No. 611971-03-2
Structural Adequacy	A	S	S
Occupant Risk	D	S	S
	F	S	S
	H	S	S
	I	S	S
	Test No.	***MASH* Test 3-10**	***MASH* Test 3-11**
	Pass/Fail	Pass	Pass

S = Satisfactory
U = Unsatisfactory

REFERENCES

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

2. A. Y. Abu-Odeh, R. P. Bligh, M. L. Mason, and W. L. Menges. "Development and Evaluation of a *MASH* TL-3 31-inch W-Beam Median Barrier." Report 9-1002-12-8, Texas A&M Transportation Institute, College Station, Texas, 2013.

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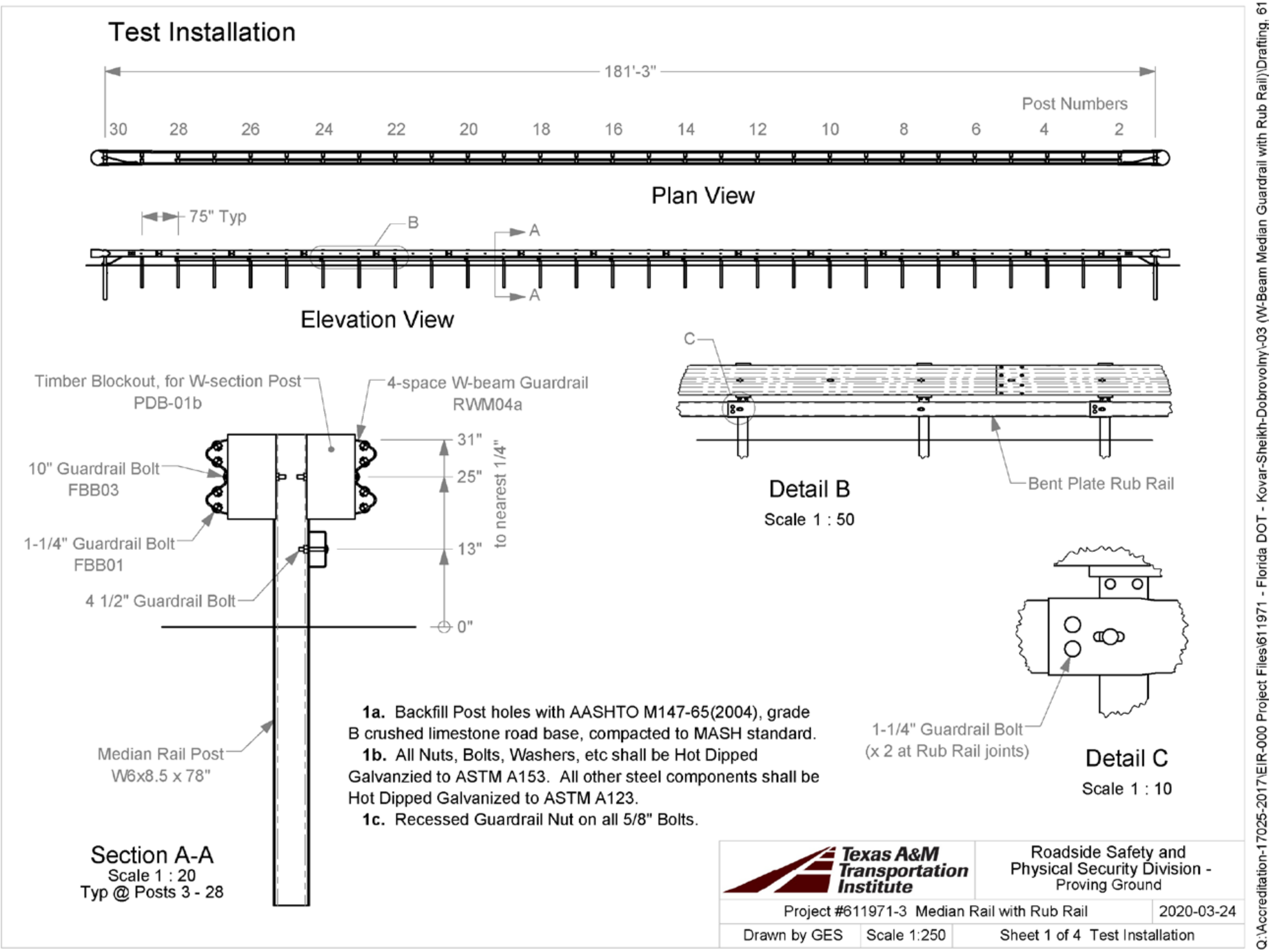
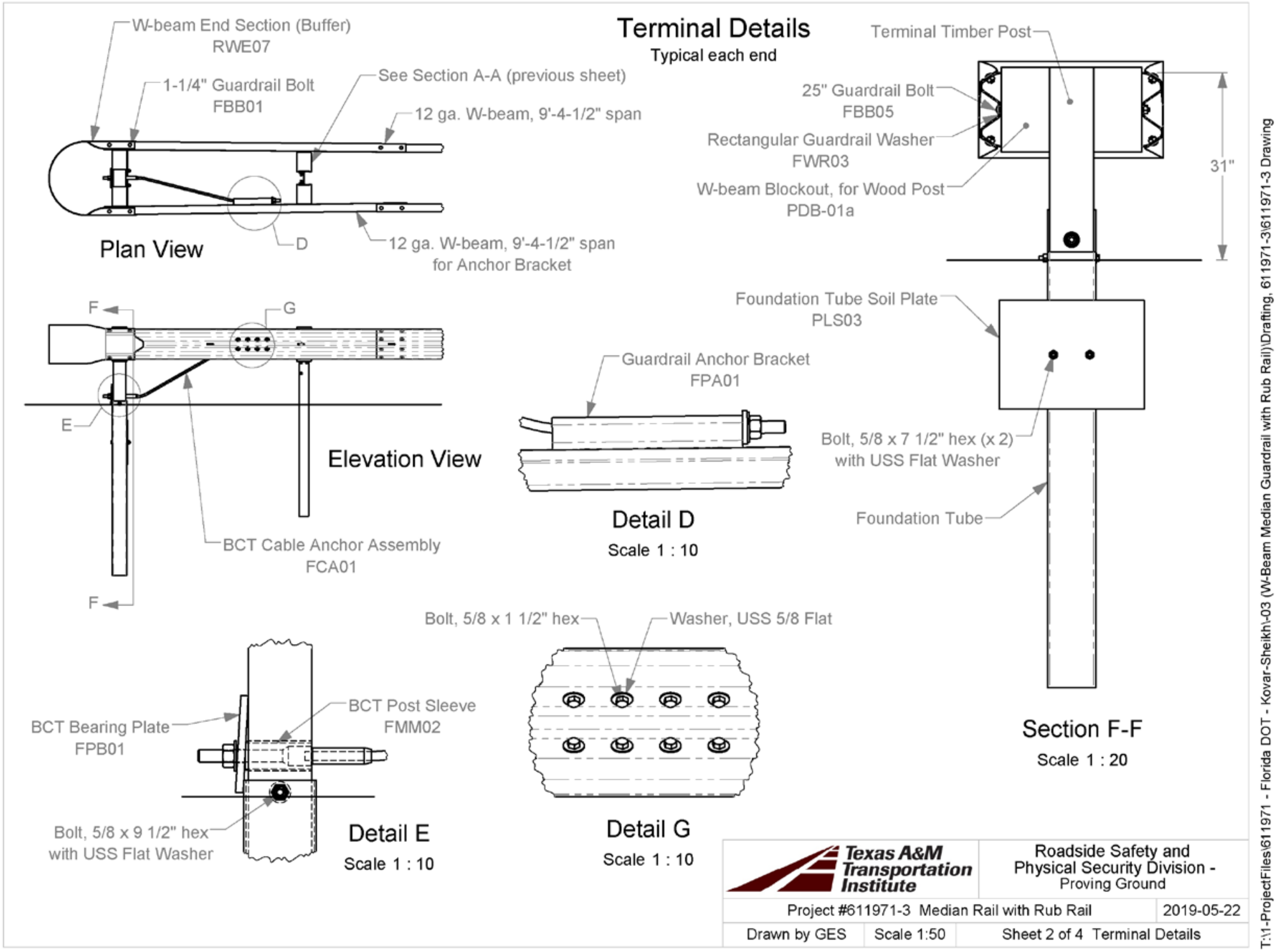
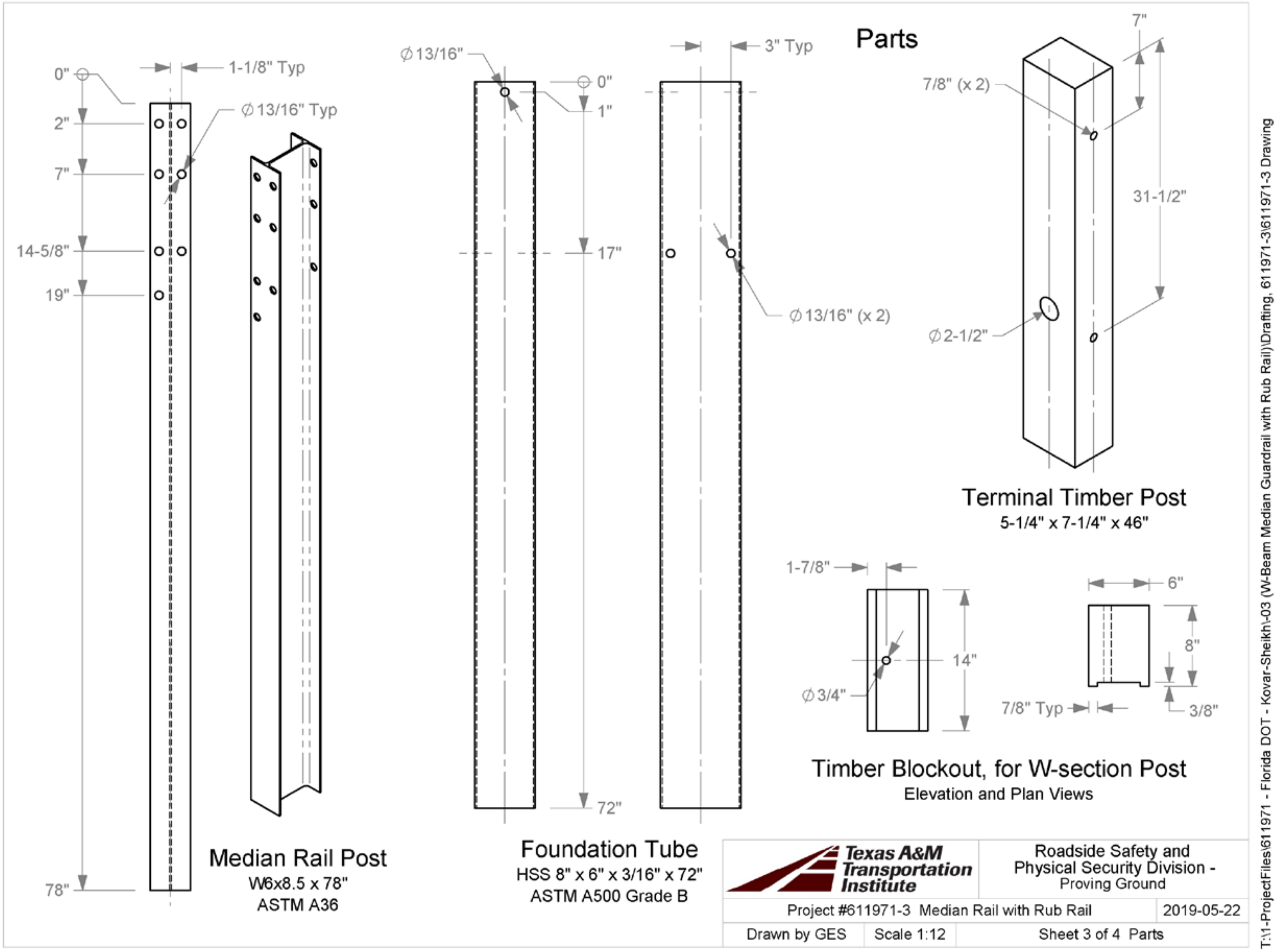
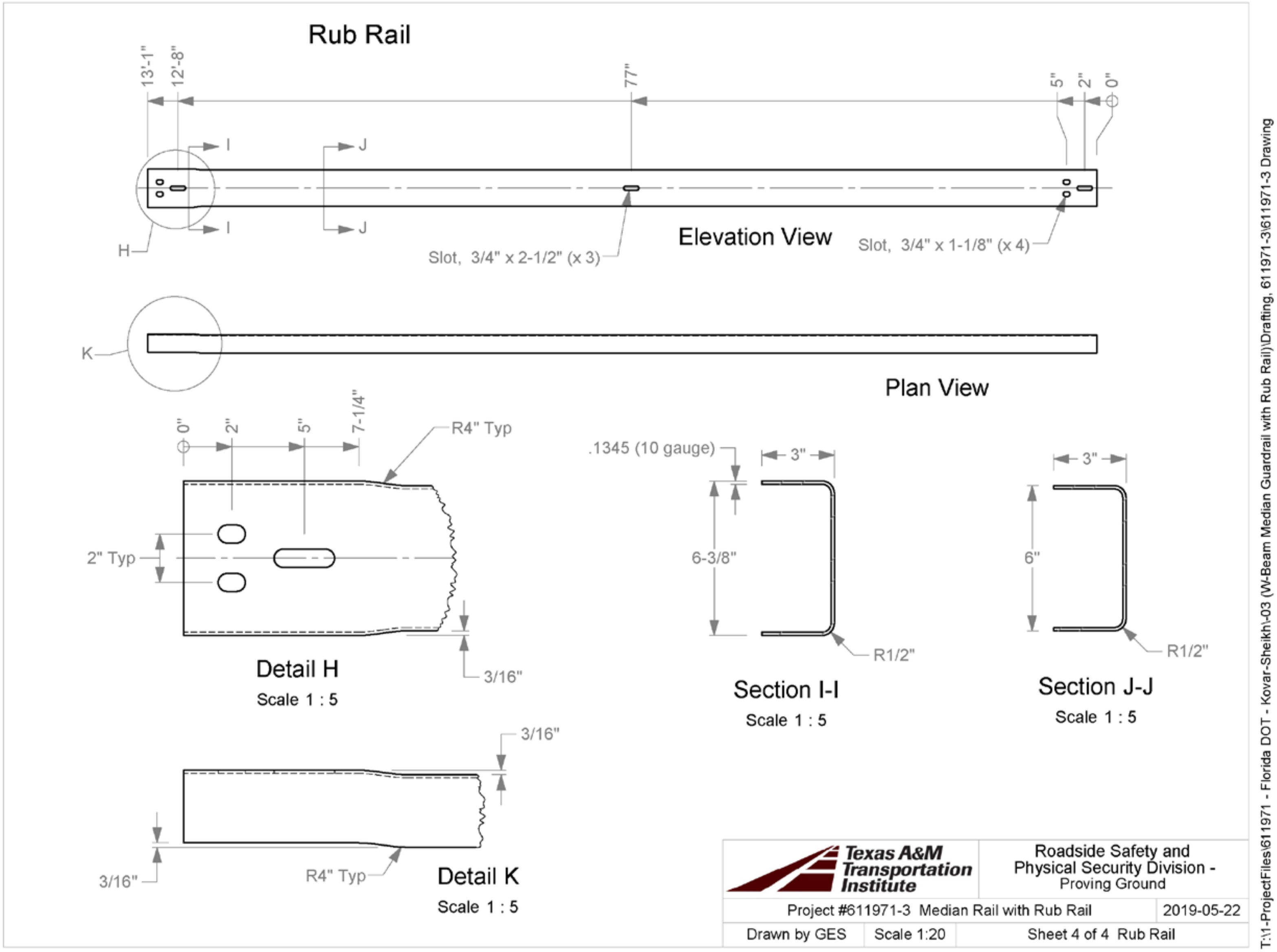
APPENDIX A. DETAILS OF THE W-BEAM MEDIAN BARRIER WITH RUB RAIL




Terminal Details
Typical each end
W-beam End Section (Buffer)
RWE07
1-1/4" Guardrail Bolt
FBB01
See Section A-A (previous sheet)
12 ga. W-beam, 9'-4-1/2" span
Plan View
D
12 ga. W-beam, 9'-4-1/2" span
for Anchor Bracket
F
G
E
Elevation View
BCT Cable Anchor Assembly
FCA01
F
Guardrail Anchor Bracket
FPA01
Detail D
Scale 1 : 10
Terminal Timber Post
25" Guardrail Bolt
FBB05
Rectangular Guardrail Washer
FWR03
W-beam Blockout, for Wood Post
PDB-01a
31"
Foundation Tube Soil Plate
PLS03
Bolt, 5/8 x 7 1/2" hex (x 2)
with USS Flat Washer
Foundation Tube
Section F-F
Scale 1 : 20
Bolt, 5/8 x 1 1/2" hex
Washer, USS 5/8 Flat
BCT Bearing Plate
FPB01
BCT Post Sleeve
FMM02
Bolt, 5/8 x 9 1/2" hex
with USS Flat Washer
Detail E
Scale 1 : 10
Detail G
Scale 1 : 10
Texas A&M Transportation Institute
Roadside Safety and
Physical Security Division -
Proving Ground
Project #611971-3 Median Rail with Rub Rail
2019-05-22
Drawn by GES
Scale 1:50
Sheet 2 of 4 Terminal Details
T:\1-ProjectFiles\611971 - Florida DOT - Kovar-Sheikh\-03 (W-Beam Median Guardrail with Rub Rail)\Drafting, 611971-3\611971-3 Drawing


Parts
0"
2"
7"
14-5/8"
19"
78"
1-1/8" Typ
∅13/16" Typ
Median Rail Post
W6x8.5 x 78"
ASTM A36
∅13/16"
0"
1"
17"
72"
3" Typ
∅13/16" (x 2)
Foundation Tube
HSS 8" x 6" x 3/16" x 72"
ASTM A500 Grade B
7"
7/8" (x 2)
31-1/2"
∅2-1/2"
Terminal Timber Post
5-1/4" x 7-1/4" x 46"
1-7/8"
∅3/4"
14"
6"
8"
7/8" Typ
3/8"
Timber Blockout, for W-section Post
Elevation and Plan Views
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #611971-3 Median Rail with Rub Rail
2019-05-22
Drawn by GES
Scale 1:12
Sheet 3 of 4 Parts
T:\1-ProjectFiles\611971 - Florida DOT - Kovar-Sheikh\-03 (W-Beam Median Guardrail with Rub Rail)\Drafting, 611971-3\611971-3 Drawing


Rub Rail
13'-1"
12'-8"
77"
5"
2"
0"
I
J
H
Slot, 3/4" x 2-1/2" (x 3)
Elevation View
Slot, 3/4" x 1-1/8" (x 4)
K
Plan View
0"
2"
5"
7-1/4"
R4" Typ
2" Typ
3/16"
Detail H
Scale 1 : 5
.1345 (10 gauge)
3"
6-3/8"
R1/2"
Section I-I
Scale 1 : 5
3"
6"
R1/2"
Section J-J
Scale 1 : 5
3/16"
3/16"
R4" Typ
Detail K
Scale 1 : 5
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #611971-3 Median Rail with Rub Rail
2019-05-22
Drawn by GES
Scale 1:20
Sheet 4 of 4 Rub Rail
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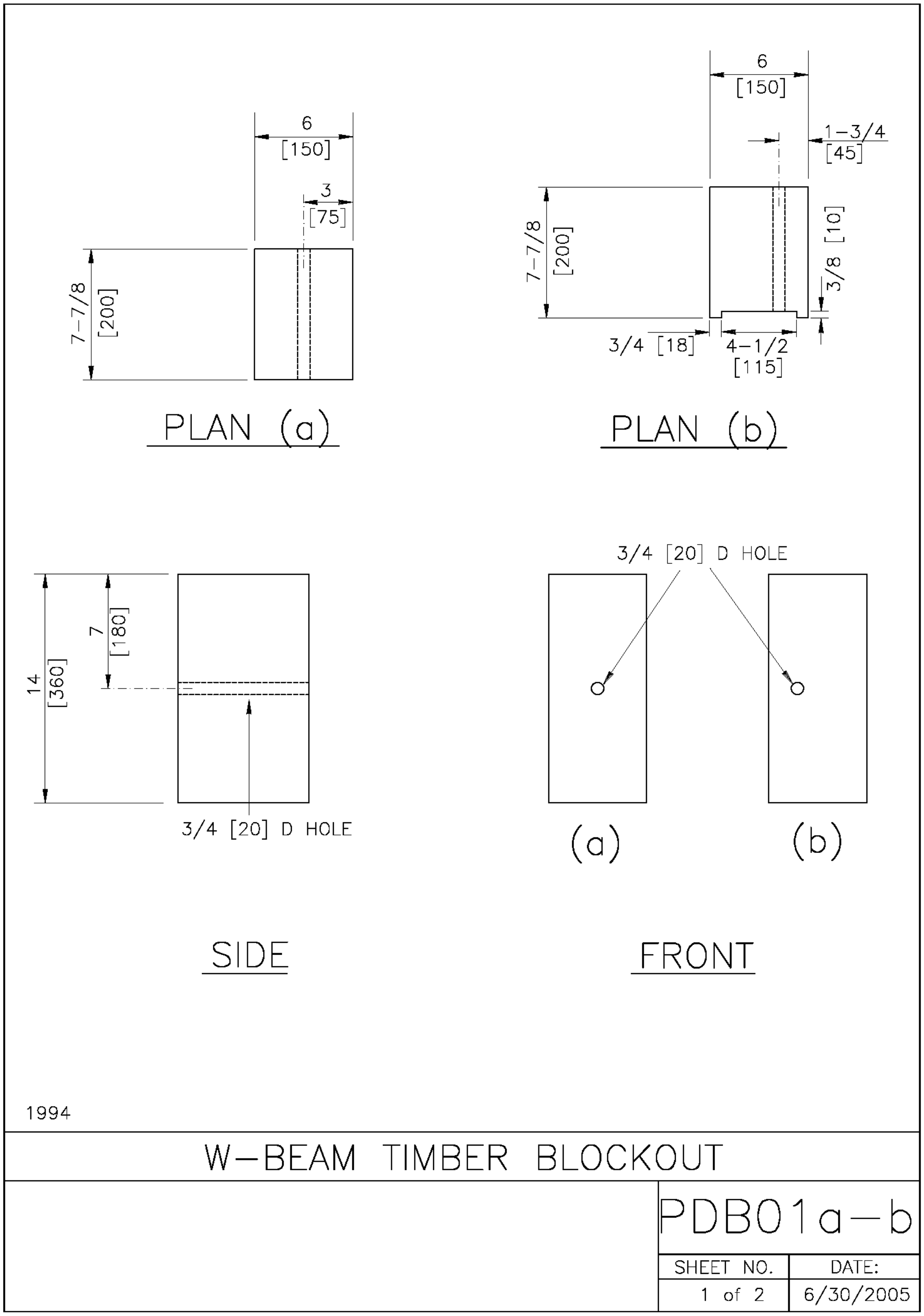

6
[150]
3
[75]
7-7/8
[200]
PLAN (a)
6
[150]
1-3/4
[45]
7-7/8
[200]
[10]
3/8
3/4 [18]
4-1/2
[115]
PLAN (b)
14
[360]
7
[180]
3/4 [20] D HOLE
SIDE
3/4 [20] D HOLE
(a)
(b)
FRONT
1994
W-BEAM TIMBER BLOCKOUT
PDB01a-b
SHEET NO.
1 of 2
DATE:
6/30/2005

SPECIFICATIONS

Blockouts shall be made of timber with a stress grade of at least 1160 psi [8 MPa]. Grading shall be in accordance with the rules of the West Coast Lumber Inspection Bureau, Southern Pine Inspection Bureau, or other appropriate timber association. Timber for blockouts shall be either rough-sawn (unplaned) or S4S (surfaced four sides) with nominal dimensions indicated. The variation in size of blockouts in the direction parallel to the axis of the bolt holes shall not be more than ± ¼ inch [6 mm]. Only one type of surface finish shall be used for posts and blockouts in any one continuous length of guardrail.

All timber shall receive a preservation treatment in accordance with AASHTO M 133 after all end cuts are made and holes are drilled.

Dimensional tolerances not shown or implied are intended to be those consistent with the proper functioning of the part, including its appearance and accepted manufacturing practices.

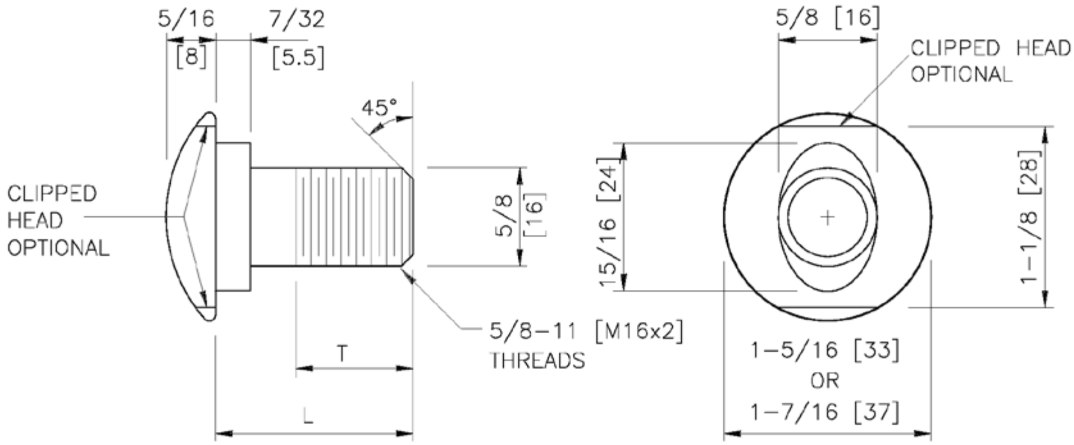
INTENDED USE

Blockout PDB01a is used with wood post PDE01 or PDE02 in the SGR04b strong-post W-beam guardrail and the SGM04b median barrier. Blockout PDB01b is routed to be used with steel post PWE01 or PWE02 in the SGR04c guardrail and the SGM04a median barrier.

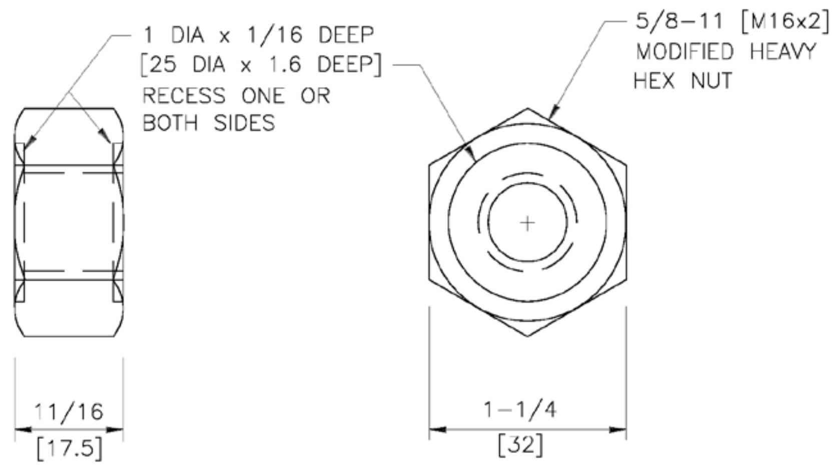
W-BEAM TIMBER BLOCKOUT

PDB01a-b	
SHEET NO.	DATE
2 of 2	7/06/2005

NOTES: 1. ALL FILLETS SHALL HAVE A MINIMUM RADIUS OF 1/16 [2].
2. IF THE BOLT EXTENDS MORE THAN 1/4 [6] FROM THE NUT THE BOLT SHOULD BE TRIMMED BACK.



DESIGNATOR	L	T (MIN)
FBB01	1-1/4 [32]	1-1/8 [28]
FBB02	2 [51]	1-3/4 [44]
FBB03	10 [254]	4 [102]
FBB04	18 [457]	4 [102]
FBB05	25 [635]	4 [102]



GUARDRAIL BOLT AND RECESSED NUT

FBB01-05

SHEET NO.	DATE:
1 of 2	5/2/2018

SPECIFICATIONS

The geometry and material specifications for this oval shoulder button-headed bolt and hex nut are found in AASHTO M 180. The bolt shall have 5/8-11 [M16x2] threads as defined in ANSI B1.1 [ANSI B1.13M] for Class 2A [6g] tolerances. Bolt material shall conform to ASTM A307 Grade A [ASTM F 568M Class 4.6], with a tensile strength of 60 ksi [400 MPa] and yield strength of 36 ksi [240 MPa]. Material for corrosion-resistant bolts shall conform to ASTM A325 Type 3 [ASTM F 568M Class 8.8.3], with tensile strength of 120 ksi [830 MPa] and yield strength of 92 ksi [660 MPa]. This bolt material has corrosion resistance comparable to ASTM A588 steels. Metric zinc-coated bolt heads shall be marked as specified in ASTM F 568 Section 9 with the symbol "4.6."

Nuts shall have ANSI B1.1 Class 2B [ANSI B1.13M Class 6h] 5/8-11 [M16x2] threads. The geometry of the nuts, with the exception of the recess shown in the drawing, shall conform to ANSI B18.2.2 [ANSI B18.2.4.1M Style 1] for zinc-coated hex nuts (shown in drawing) and ANSI B18.2.2 [ANSI B18.2.4.6M] for heavy hex corrosion-resistant nuts (not shown in drawing). Material for zinc-coated nuts shall conform to the requirements of AASHTO M 291 (ASTM A 563) Grade A [AASHTO M 291M (ASTM A 563M) Class 5], and material for corrosion-resistant nuts shall conform to the requirements of AASHTO M 291 (ASTM A 563) Grade C3 [AASHTO M 291M (ASTM A 563M) Class 8S3].

When zinc-coated bolts and nuts are required, the coating shall conform to either AASHTO M 232 (ASTM A 153/A 153M) for Class C or AASHTO M 298 (ASTM B 695) for Class 50. Zinc-coated nuts shall be tapped over-size as specified in AASHTO M 291 (ASTM A 563) [AASHTO M 291M (ASTM A 563M)], except that a diametrical allowance of 0.020 inch [0.510 mm] shall be used instead of 0.016 inches [0.420 mm].

Designator	Stress Area of Threaded Bolt Shank (in^2 [mm^2])	Min. Bolt Tensile Strength (kips [kN])
FBB01-05	0.226 [157.0]	13.6 [62.8]

Dimensional tolerances not shown or implied are intended to be those consistent with the proper functioning of the part, including its appearance and accepted manufacturing practices.

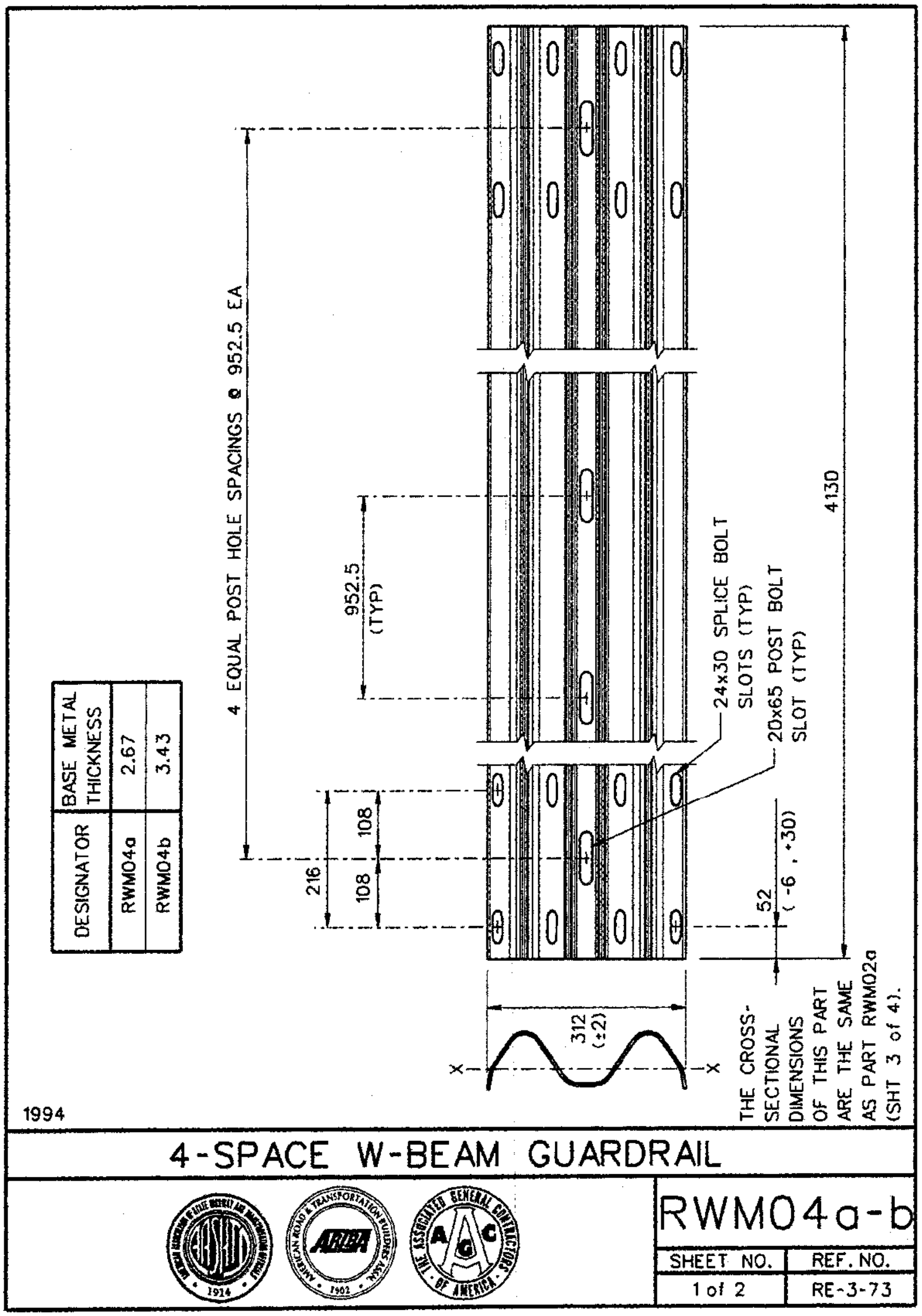
INTENDED USE

These bolts and nuts are used in numerous guardrail and median barrier designs.

GUARDRAIL BOLT AND RECESSED NUT

FBB01-05	
SHEET NO.	DATE
2 of 2	5/2/2018

TF 13


4 EQUAL POST HOLE SPACINGS @ 952.5 EA
952.5
(TYP)
4130
24x30 SPLICE BOLT
SLOTS (TYP)
20x65 POST BOLT
SLOT (TYP)
216
108
108
52
(-6 , +30)
312
(±2)
THE CROSS-
SECTIONAL
DIMENSIONS
OF THIS PART
ARE THE SAME
AS PART RWM02a
(SHT 3 of 4).
DESIGNATOR
BASE METAL THICKNESS
RWM04a
2.67
RWM04b
3.43
1994
4-SPACE W-BEAM GUARDRAIL
RWM04a-b
SHEET NO.
1 of 2
REF. NO.
RE-3-73

SPECIFICATIONS

Corrugated sheet steel beams shall conform to the current requirements of AASHTO M180. The section shall be manufactured from sheets with a nominal width of 483 mm. Guardrail RWM04a shall conform to AASHTO M180 Class A and RWM04b shall conform to Class B. Corrosion protection may be either Type II (zinc-coated) or Type IV (corrosion resistant steel). Corrosion resistant steel should conform to ASTM A606 for Type IV material and shall not be zinc-coated, painted or otherwise treated. Inertial properties are calculated for the whole cross-section without a reduction for the splice bolt holes.

Designator	Area (10^3 mm^2)	I_x (10^6 mm^4)	I_y (10^6 mm^4)	S_x (10^3 mm^3)	S_y (10^3 mm^3)
RWM04a-b	1.3	1.0	--	23	--

Dimensional tolerances not shown or implied are intended to be those consistent with the proper functioning of the part, including its appearance and accepted manufacturing practices.

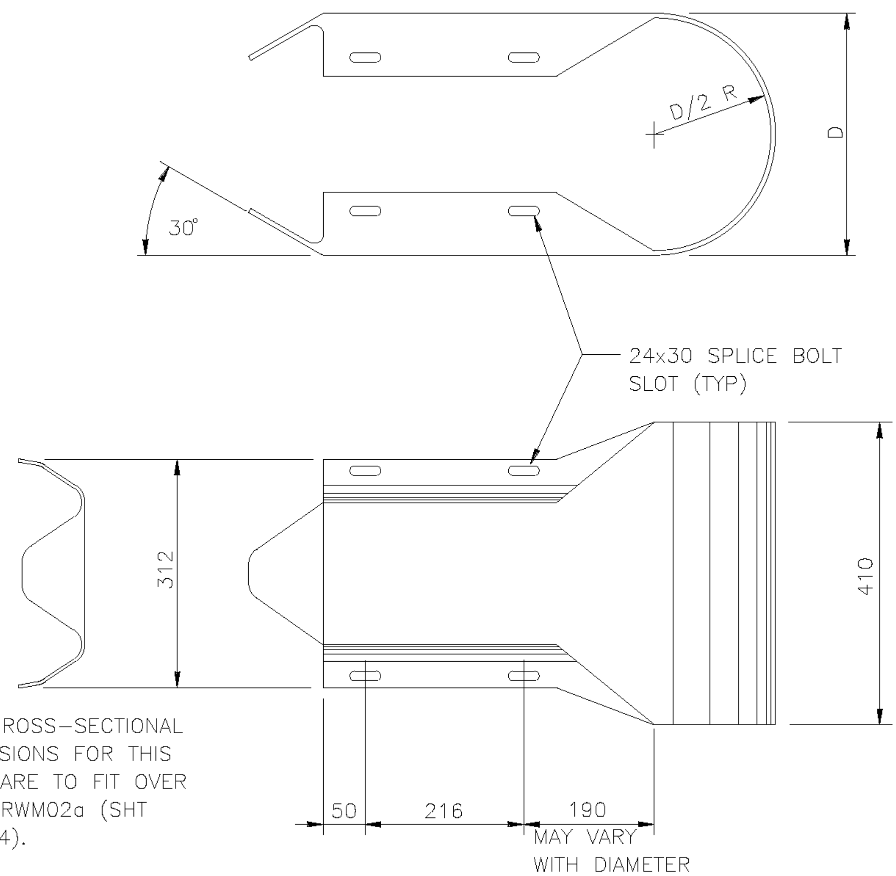
INTENDED USE

This corrugated sheet steel beam is used as a rail element in transition systems STB02 and STB03 or when a reduced post spacing is desired in the SGR02, SGR04a-b, SGM02, and SGM04a-b.

4-SPACE W-BEAM GUARDRAIL

RWM04a-b

SHEET NO.	DATE
2 of 2	04-01-95



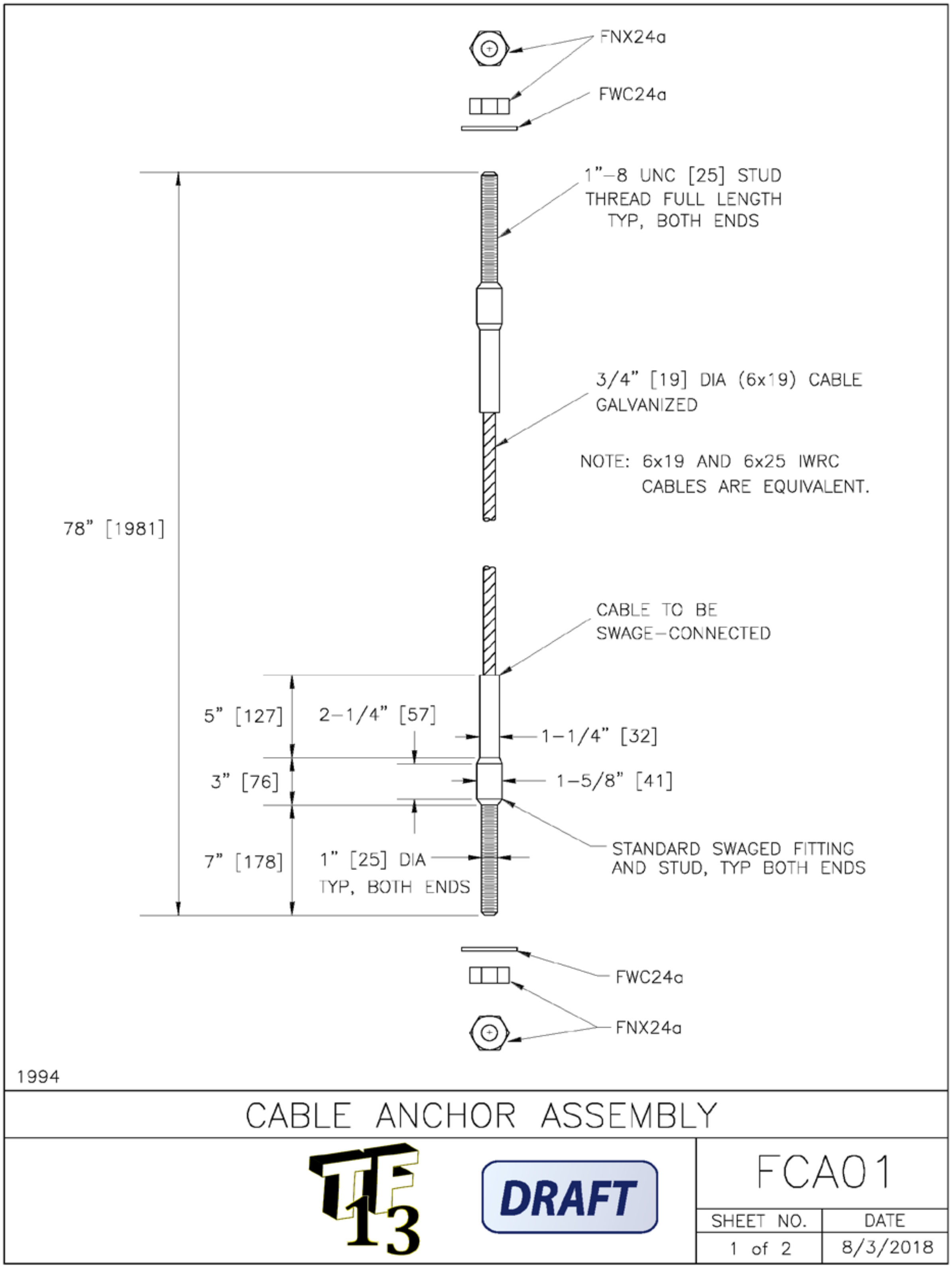
DESIGNATOR	BASE METAL THICKNESS	D
RWE05a	2.67	540
RWE05b	3.43	540
RWE06a	2.67	610
RWE06b	3.43	610
RWE07a	2.67	760
RWE07b	3.43	760

1994

W-BEAM END SECTION (BUFFER)

RWE05a-07b

SHEET NO.	REF. NO.
1 of 2	RE-7-79


FNX24a
FWC24a
1"–8 UNC [25] STUD
THREAD FULL LENGTH
TYP, BOTH ENDS
3/4" [19] DIA (6x19) CABLE
GALVANIZED
NOTE: 6x19 AND 6x25 IWRC
CABLES ARE EQUIVALENT.
78" [1981]
CABLE TO BE
SWAGE–CONNECTED
5" [127]
2–1/4" [57]
1–1/4" [32]
3" [76]
1–5/8" [41]
STANDARD SWAGED FITTING
AND STUD, TYP BOTH ENDS
7" [178]
1" [25] DIA
TYP, BOTH ENDS
FWC24a
FNX24a
1994
CABLE ANCHOR ASSEMBLY
DRAFT
FCA01
SHEET NO.
1 of 2
DATE
8/3/2018

SPECIFICATIONS

The swaged fittings shall be machined from hot-rolled carbon steel conforming to ASTM A576, Grade 1035 and zinc-coated according to AASHTO M111 (ASTM A123) before swaging. The material shall be annealed suitably for cold swaging. A lock pin hole to accommodate a ¼" [6] plated spring-steel pin shall be drilled through the head of the swaged fitting to retain the stud in the proper position.

Threads shall conform to 1"-8 UNC.

The cable shall be ¾" [19] diameter, 6x19 wire-strand core or independent wire rope core (IWRC), zinc-coated, right regular lay wire rope conforming to AASHTO M30. The wire rope steel shall be improved steel with a minimum breaking strength of 42.8 kips [190 kN]. The swaged fitting, stud and nut shall develop the full breaking strength of the wire rope.

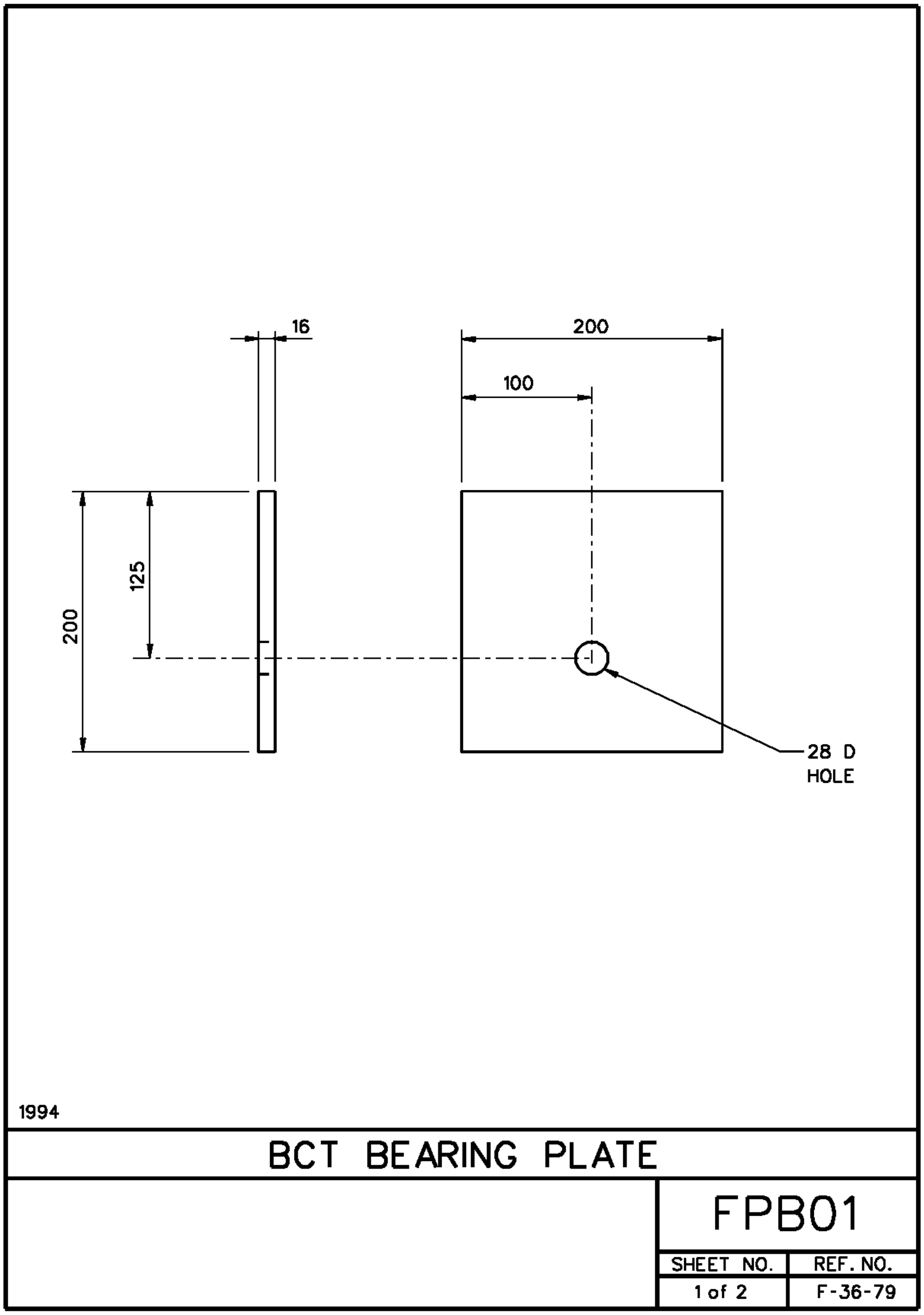
Dimensional tolerances not shown or implied are intended to be those consistent with the proper functioning of the part, including its appearance and accepted manufacturing practices.

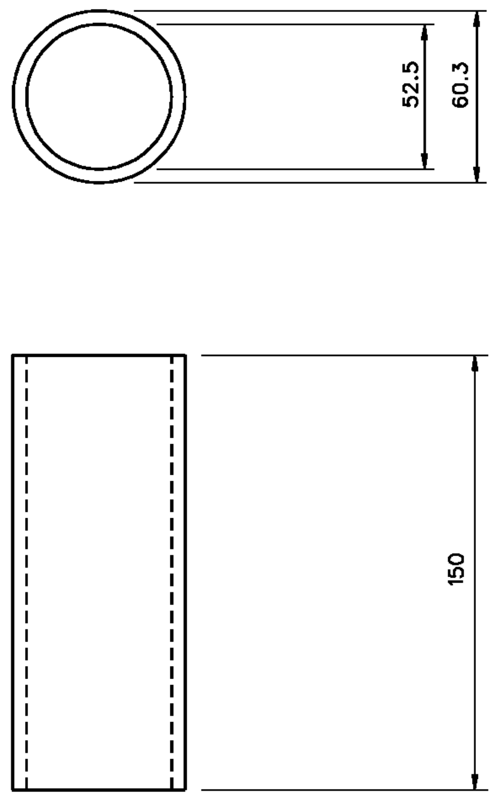
INTENDED USE

The FCA01 Cable Anchor Assembly is used in the following Systems:

- SEW31, Trailing-End Anchorage for 31" Guardrail.

CABLE ANCHOR ASSEMBLY		
FCA01		DRAFT
SHEET NO.	DATE	
2 of 2	8/3/2018	

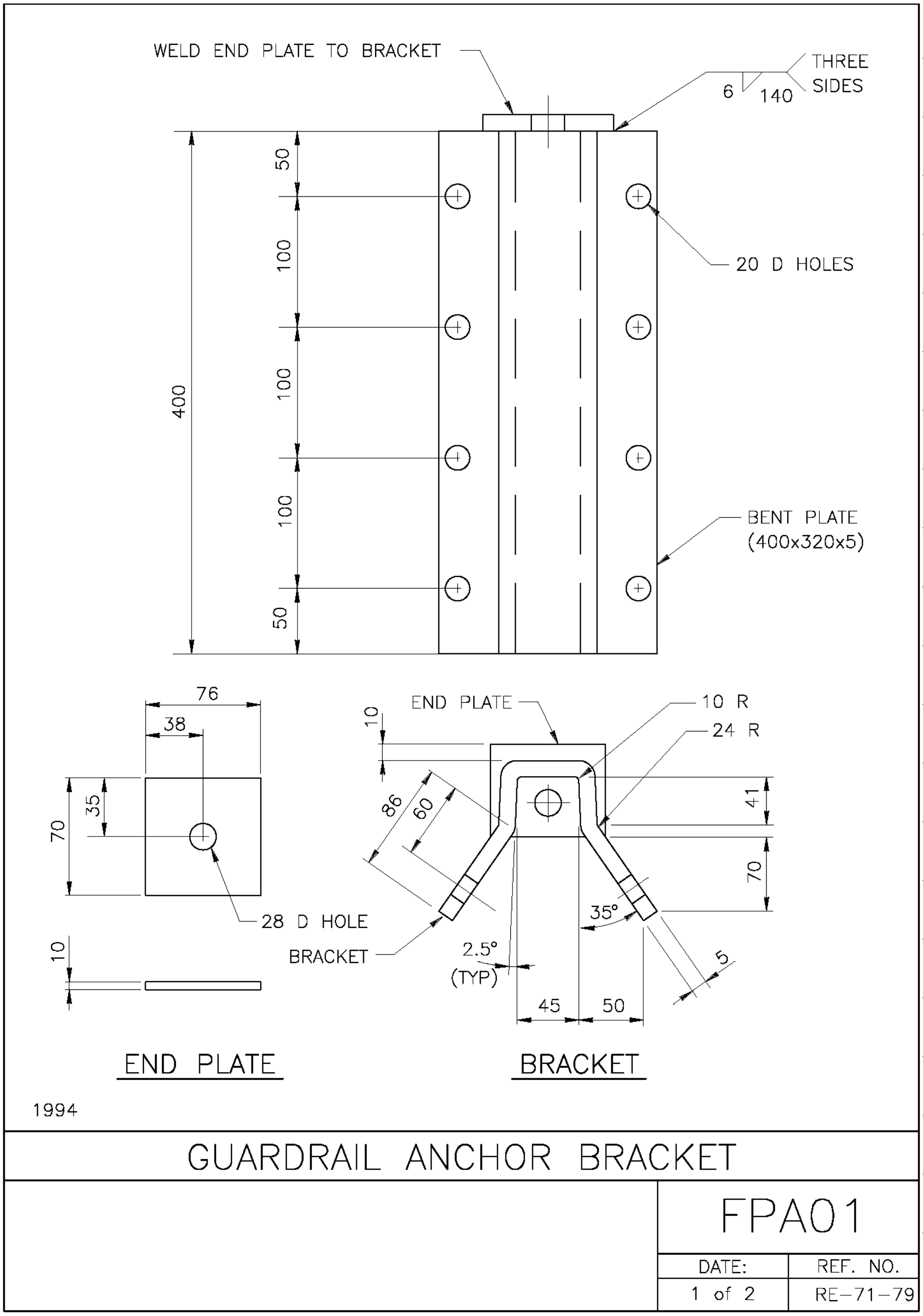

16
200
100
125
200
28 D
HOLE
1994
BCT BEARING PLATE
FPB01
SHEET NO.
REF. NO.
1 of 2
F-36-79



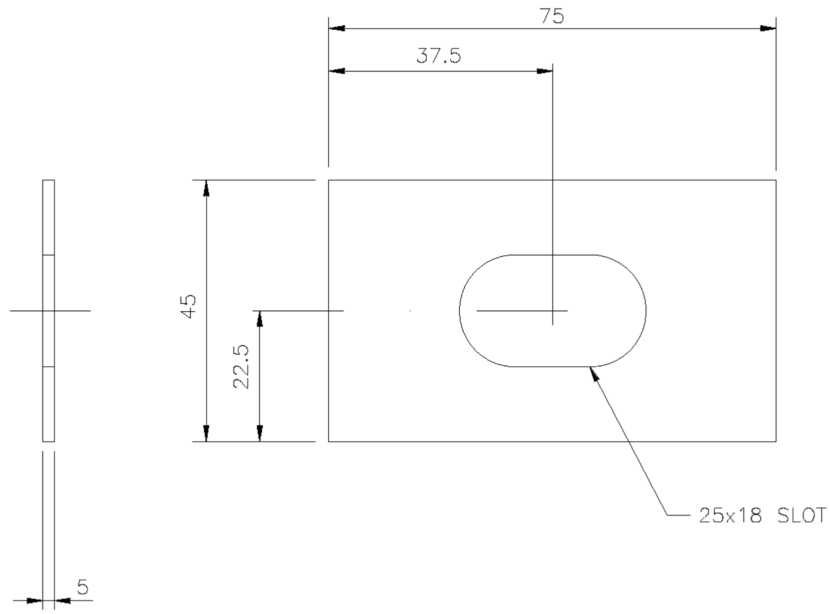
1994

BCT POST SLEEVE

	FMM02	
	SHEET NO.	REF. NO.
	1 of 2	F-34-76



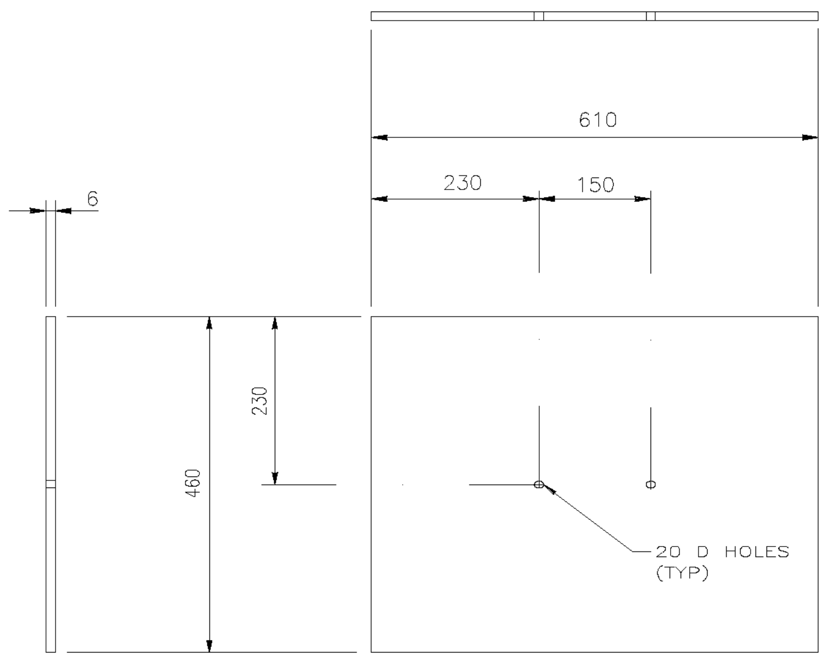
WELD END PLATE TO BRACKET
6
140
THREE
SIDES
50
100
100
100
50
400
20 D HOLES
BENT PLATE
(400x320x5)
76
38
35
70
28 D HOLE
10
END PLATE
10
86
60
10 R
24 R
41
70
35°
5
BRACKET
2.5°
(TYP)
45
50
END PLATE
BRACKET
1994
GUARDRAIL ANCHOR BRACKET
FPA01
DATE:
REF. NO.
1 of 2
RE–71–79



1994

RECTANGULAR GUARDRAIL PLATE WASHER

	FWR03	
	SHEET NO.	REF. NO.
	1 of 2	F-12-73



1994

FOUNDATION TUBE SOIL PLATE

	PLS03	
	SHEET NO.	REF. NO.
	1 of 2	

APPENDIX B. SUPPORTING CERTIFICATION DOCUMENTS

Load List

TRINITY HIGHWAY PRODUCTS, LLC
PACKING LIST

SALES ORDER # 1310739

LOAD # 92 DROP # 1

Ship From: Trinity Highway
Plant 55
550 East Robb Ave.
Lima , OH 45801
United States
(419) 227-1296

Ship To : SAMPLES, TESTING MATERIALS
3100 STATE HWY 47
BLDG 7090

BRYAN ,TX 77807
Contact :GARY GERKE
936-825-4661

PI #	Qty Ordered	UOM	PI Product Code	Description
1	2	EACH	99TESTMATERIA	TEST MATERIAL

Part No	Qty On Load	Description
700A	2	3/16X12.5X16 CAB ANC BRKT
706G	2	2" ID X 6" PIPE
749G	4	TS 8X6X3/16X6'-0" SLEEVE
765G	2	1/4 X18 X24 SOIL PL 2 HOL
782G	2	5/8"X8"X8" BEAR PL/OF HOL
953G	2	12/BUFFER/ROLLED/92"
3000G	2	CBL 3/4X6'6/DBL SWG/NOHWD
3300G	28	WASHER,FLAT,5/8 R,TY B,G
3320G	2	3/16"X1.75"X3" WASHER
3340G	78	5/8" GR HEX NUT
3360G	48	5/8"X1.25" GR BOLT
3380G	16	5/8"X1.5" HEX BOLT A307
3478G	8	5/8" X7.5" HEX BOLT A307
3497G	4	5/8"X9.5" HEX BOLT A307
3500G	4	5/8"X10" GR BOLT A307
3650G	2	5/8"X25" GR BOLT A307
3900G	4	1" ROUND WASHER F844
3910G	4	1" HEX NUT A563
4075B	4	WD BLK 6X8X14
4076B	4	WD BLK RTD 6X8X14
10967G	2	12/9'4.5/3'1.5/S
20207G	2	12/9'4.5/8-HOLE ANCH/S
130593G	2	6'6"POST/W6X8.5#W/RUBHOL
626079B	2	WD 3'10 POST 5.25X7.25CRT

PI #	Qty Ordered	UOM	PI Product Code	Description
2	26	LF	99TESTMATERIA	TEST MATERIAL

Part No	Qty On Load	Description
11G	26	12/12'6/3'1.5/S
865G	13	10/13'1/6'3 FORM CHAN
3340G	268	5/8" GR HEX NUT
3360G	216	5/8"X1.25" GR BOLT
3433G	33	5/8"X3" CARR BOLT A307
3500G	52	5/8"X10" GR BOLT A307
4076B	52	WD BLK RTD 6X8X14
130593G	26	6'6"POST/W6X8.5#W/RUBHOL

Date: 6/6/19
Plant: 55
Load: 92

rfheatherp 6/5/2019 2:10:45PM

This Memorandum is an acknowledgement that a Bill of Lading has been issued and is not the original Bill of Lading, nor a copy or duplicate, covering the property named herein, and is intended solely for filing or record.

55-108880

Carrier: Trinity Highway Products, LLC 3

Shipper's No.

S/O No. 1310739

RECEIVED, subject to the classifications and tariffs in effect on the date of receipt by the carrier of the property described in the Original Bill of Lading,

at 6-6-19 20, from

the property described below, in apparent good order, except as noted (contents and condition of contents of packages unknown) marked, consigned and destined as shown below, which said company (the word company being understood throughout this contract as meaning any person or corporation in possession of the property under the contract) agrees to carry to its usual place of delivery at said destination, if on its own railroad, water line, highway route or routes, or within the territory of its highway operations, otherwise to deliver to another carrier on the route to said destination. It is mutually agreed, as to each carrier of all or any of said property over all or any portion of said route to destination, and as to each party at any time interested in all or any of said property, that every service to be performed hereunder shall be subject to all the conditions not prohibited by law, whether printed or written, herein contained, including the conditions on back hereof, which are hereby agreed to by the shipper and accepted for himself and his assigns.

Subject to Section 7 of Conditions of applicable Bill of Lading, if this shipment is to be delivered to the consignee without recourse on the consignor, the consignor shall sign the following statement:
The carrier shall not make delivery of this shipment without payment of freight and all other lawful charges.

TRINITY HIGHWAY PRODUCTS, LLC

Per Trinity Highway Products, L

(Signature of Consignor)

If charges are to be prepaid, write or stamp here, "To be Prepaid." TO BE PREPAID

Received $ ______ to apply in prepayment of the charges on the property described hereon.

Agent or Cashier

Per ______ (The signature here acknowledges only the amount prepaid.)

Charges advanced:

Consigned to: SAMPLES, TESTING MATERIALS
Cust. P.O. TTI - 611971-3
Load No.: 92-1

Destination: 3100 STATE HWY 47
BLDG 7090

Total Weight: 7,237.72

City: BRYAN State: TX Zip: 77807

Ship: 6/6/2019

Arrive: 6/7/19 8:00:00AM

563182

Contact: GARY GERKE Phone: 936-825-4661

Delivering Carrier: ADD Vehicle or Car Initial: ______ No. ______

Collect On Delivery:
$ ______ **and remit to:** ______

C.O.D. charge to be paid by Shipper ☐ Consignee ☐

______ **Street** ______ **City** ______ **State**

No. Pkgs.	Piece Count	Description of Articles	*Wt.	Class or Rate	✓ Col.
		Upon delivery, all materials subject to Trinity Highway Products, LLC Storage Stain Policy No. OMS-LG-002.			
		Project Info: FDOT PROJECT 611971-3			
		LD Comments:			
	26	11G 12/12'6/3'1.5/S			
	2	700A 3/16X12.5X16 CAB ANC BRKT			
	2	706G 2" ID X 6" PIPE			
	4	749G TS 8X6X3/16X6'-0" SLEEVE			
	2	765G 1/4 X18 X24 SOIL PL 2 HOL			
	2	782G 5/8"X8"X8" BEAR PL/OF HOL			
	13	865G 10/13'1/6'3 FORM CHAN			
	2	953G 12/BUFFER/ROLLED/92"			
	2	3000G CBL 3/4X6'6/DBL SWG/NOHWD			
	28	3300G WASHER,FLAT,5/8 R,TY B,G			
	2	3320G 3/16"X1.75"X3" WASHER			
	346	3340G 5/8" GR HEX NUT			
	264	3360G 5/8"X1.25" GR BOLT			
	16	3380G 5/8"X1.5" HEX BOLT A307			
	33	3433G 5/8"X3" CARR BOLT A307			
	8	3478G 5/8" X7.5" HEX BOLT A307			
	4	3497G 5/8"X9.5" HEX BOLT A307			
	56	3500G 5/9"X10" GR BOLT A307			
	2	3650G 5/8"X25" GR BOLT A307			
	4	3900G 1" ROUND WASHER F844			
	4	3910G 1" HEX NUT A563			
	4	4075B WD BLK 6X8X14			
	56	4076B WD BLK RTD 6X8X14			
	2	10967G 12/9'4.5/3'1.5/S			
	2	20207G 12/9'4.5/8-HOLE ANCH/S			
	28	130593G 6'6"POST/W6X8.5#W/RUBHOL			
	2	626079B WD 3'10 POST 5.25X7.25CRT			

No. Pkgs.	Piece Count	Description of Articles	*Wt.	Class or Rate	✓ Col.

SPECIAL INSTRUCTIONS:

55-108880

SHIPPER LOAD - CONSIGNEE UNLOAD

Total Weight 3

*If the shipment moves between two ports by a carrier by water, the law requires that the bill of lading shall state whether it is "carrier's or shipper's weight."
NOTE - Where the rate is dependent on value, shippers are required to state specifically in writing the agreed or declared value of the property.
The agreed or declared value of the property is hereby specifically stated by the shipper to be not exceeding ______ per ______

ORIGIN — SHIPPER OR AGENT: I hereby authorize this shipment and make the declaration of values (if any) and agree to the contract terms and conditions hereof.
SIGN HERE: Derick Kavereen DATE 6-6-19
AGENT OR DRIVER: This shipment received subject to exceptions as noted and according to the terms and conditions hereof.
(SIGN HERE) [signature] DATE

DESTINATION — CONSIGNEE OR AGENT: Received the above described property in good condition except as noted on the back hereof and agree to the foregoing contract terms and conditions.
SIGN HERE ______ DATE / / TIME A.M. P.M.
DRIVER ______ NO

Permanent post-office address of shipper,

TRI 609-RF (R 10/93)

(This Bill of Lading is to be signed by the shipper and agent of the carrier issuing same.)

CONSIGNEE/CUSTOMER COPY

Certified Analysis

Trinity Highway Products LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296
Customer: SAMPLES, TESTING MATERIALS
2525 STEMMONS FRWY

DALLAS, TX 75207
Project: FDOT PROJECT 611971-3

Order Number: 1310739 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: TTI - 611971-3
BOL Number: 108880 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 6/6/19

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
26	11G	12/12'6/3'1.5/S			2	L21619													
			M-180	A	2	237554	61,450	79,890	26.6	0.190	0.730	0.013	0.004	0.020	0.150	0.000	0.070	0.002	4
			M-180	A	2	237555	60,150	77,940	28.2	0.190	0.730	0.016	0.004	0.020	0.130	0.000	0.070	0.001	4
			M-180	A	2	237556	60,630	81,840	23.3	0.190	0.730	0.014	0.003	0.020	0.070	0.000	0.070	0.002	4
			M-180	A	2	237557	62,780	80,860	24.5	0.190	0.730	0.014	0.003	0.020	0.150	0.000	0.060	0.001	4
			M-180	A	2	237558	61,370	78,960	27.5	0.190	0.730	0.012	0.004	0.020	0.130	0.000	0.060	0.002	4
	11G				2	L21919													
			M-180	A	2	224116	62,690	81,820	45.6	0.190	0.730	0.010	0.004	0.020	0.120	0.000	0.060	0.001	4
			M-180	A	2	237553	65,000	83,270	24.3	0.190	0.730	0.015	0.030	0.010	0.130	0.000	0.070	0.001	4
			M-180	A	2	237923	61,070	79,110	27.9	0.190	0.730	0.009	0.004	0.020	0.120	0.000	0.060	0.000	4
			M-180	A	2	238622	61,950	81,070	23.2	0.180	0.720	0.011	0.004	0.020	0.140	0.000	0.070	0.002	4
			M-180	A	2	238623	63,640	81,270	26.4	0.190	0.730	0.013	0.003	0.020	0.130	0.000	0.080	0.001	4
			M-180	A	2	238624	61,390	80,200	26.1	0.190	0.730	0.013	0.002	0.020	0.160	0.000	0.070	0.002	4
			M-180	A	2	238625	61,150	79,980	26.5	0.200	0.730	0.011	0.004	0.020	0.130	0.000	0.080	0.001	4
			M-180	A	2	238626	59,870	78,870	26.3	0.190	0.730	0.010	0.004	0.020	0.170	0.000	0.060	0.002	4
			M-180	A	2	238627	61,630	80,850	25.5	0.190	0.720	0.011	0.004	0.020	0.130	0.000	0.070	0.001	4
			M-180	A	2	235966	60,030	77,640	25.9	0.190	0.740	0.006	0.004	0.010	0.080	0.000	0.040	0.000	4
			M-180	A	2	235967	63,090	80,420	24.6	0.190	0.710	0.006	0.003	0.010	0.070	0.000	0.050	0.002	4
			M-180	A	2	237921	62,280	80,280	27.2	0.190	0.730	0.008	0.004	0.020	0.110	0.000	0.070	0.002	4
			M-180	A	2	237922	63,040	81,090	24.4	0.190	0.730	0.008	0.005	0.010	0.130	0.000	0.060	0.002	4
	11G				2	L21219													
			M-180	A	2	235969	61,800	78,900	26.4	0.190	0.730	0.009	0.001	0.020	0.100	0.000	0.060	0.002	4
			M-180	A	2	236244	62,620	81,700	22.1	0.190	0.730	0.013	0.006	0.010	0.120	0.000	0.060	0.000	4
			M-180	A	2	236245	60,190	79,330	24.8	0.190	0.720	0.012	0.005	0.010	0.130	0.000	0.050	0.002	4
			M-180	A	2	236471	65,000	83,480	23.4	0.190	0.720	0.012	0.001	0.030	0.110	0.000	0.080	0.002	4
			M-180	A	2	236472	64,070	83,800	21.4	0.190	0.720	0.012	0.003	0.020	0.100	0.000	0.060	0.000	4

Certified Analysis

Trinity Highway Products LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296
Customer: SAMPLES, TESTING MATERIALS
2525 STEMMONS FRWY

DALLAS, TX 75207
Project: FDOT PROJECT 611971-3

Order Number: 1310739 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: TTI - 611971-3
BOL Number: 108880 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 6/6/19

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
			M-180	A	2	236474	61,800	81,510	22.3	0.180	0.720	0.011	0.005	0.010	0.120	0.000	0.060	0.000	4
			M-180	A	2	236901	62,260	80,750	25.1	0.190	0.740	0.012	0.005	0.010	0.120	0.000	0.050	0.001	4
			M-180	A	2	237554	61,450	79,890	26.6	0.190	0.730	0.013	0.004	0.020	0.150	0.000	0.070	0.002	4
			M-180	A	2	235964	57,330	77,750	28.5	0.190	0.720	0.007	0.004	0.010	0.050	0.000	0.050	0.001	4
	11G				2	L11619													
			M-180	A	2	237923	61,070	79,110	27.9	0.190	0.730	0.009	0.004	0.020	0.120	0.000	0.060	0.000	4
			M-180	A	2	237924	600,100	78,270	26.4	0.180	0.740	0.008	0.004	0.020	0.120	0.000	0.060	0.001	4
			M-180	A	2	238622	61,950	81,070	23.2	0.180	0.720	0.011	0.004	0.020	0.140	0.000	0.070	0.002	4
2	700A	3/16X12.5X16 CAB ANC	A-36			JM3688	54,000	76,000	25.0	0.150	1.020	0.010	0.021	0.230	0.260	0.001	0.100	0.019	4
	700A		A-36			4174233	48,700	68,700	34.0	0.200	0.400	0.011	0.010	0.010	0.040	0.001	0.050	0.001	4
	700A		A-36			Q5142A	61,000	79,500	29.0	0.180	0.630	0.014	0.007	0.032	0.130	0.003	0.011	0.004	4
2	706G	2" ID X 6" PIPE	A-500			2817844	63,600	73,600	24.0	0.210	0.830	0.010	0.003	0.030	0.090	0.000	0.040	0.004	4
4	749G	TS 8X6X3/16X6'-0" SLEEVE	A-500			A712224	79,860	80,000	25.8	0.050	0.810	0.008	0.002	0.030	0.090	0.000	0.050	0.003	4
2	765G	1/4 X18 X24 SOIL PL 2 HOL	A-36			4125205	48,000	69,200	33.0	0.210	0.400	0.012	0.008	0.010	0.040	0.001	0.050	0.001	4
2	782G	5/8"X8"X8" BEAR PL/OF	A-36			55049020	56,000	79,800	23.4	0.160	0.920	0.017	0.018	0.210	0.330	0.001	0.130	0.018	4
13	865G	10/13'1/6'3 FORM CHAN	A-36			229326	56,480	71,950	30.6	0.190	0.540	0.009	0.002	0.020	0.100	0.000	0.060	0.000	4
2	953G	12/BUFFER/ROLLED/92"	A-36			31847970	48,400	62,300	35.0	0.060	0.450	0.015	0.001	0.030	0.090	0.001	0.070	0.002	4
2	3000G	CBL 3/4X6'6/DBL	WIRE			133778													4

Certified Analysis

Trinity Highway Products LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296
Customer: SAMPLES, TESTING MATERIALS
2525 STEMMONS FRWY

DALLAS, TX 75207
Project: FDOT PROJECT 611971-3

Order Number: 1310739 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: TTI - 611971-3
BOL Number: 108880 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 6/6/19

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
28	3300G	WASHER,FLAT,5/8 R,TY	HW			P38498 R70030-02													
2	3320G	3/16"X1.75"X3" WASHER	MISC-1			72899													4
346	3340G	5/8" GR HEX NUT	HW			19-42-001													
264	3360G	5/8"X1.25" GR BOLT	HW			93169													
16	3380G	5/8"X1.5" HEX BOLT A307	HW			85798													
33	3433G	5/8"X3" CARR BOLT A307	HW			p38458													
8	3478G	5/8" X7.5" HEX BOLT A307	A307-3478			31846													4
4	3497G	5/8"X9.5" HEX BOLT A307	HW			31621													
56	3500G	5/8"X10" GR BOLT A307	HW			31791-B													
2	3650G	5/8"X25" GR BOLT A307	HW			31682													
4	3900G	1" ROUND WASHER F844	HW			P38368 R69176-01													
4	3910G	1" HEX NUT A563	HW			P38562 R70589-01													
4	4075B	WD BLK 6X8X14	WOOD			5330													
56	4076B	WD BLK RTD 6X8X14	WOOD			271													

Certified Analysis

Trinity Highway Products LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296
Customer: SAMPLES, TESTING MATERIALS
2525 STEMMONS FRWY

DALLAS, TX 75207
Project: FDOT PROJECT 611971-3

Order Number: 1310739 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: TTI - 611971-3
BOL Number: 108880 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 6/6/19

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
2	10967G	12/9'4.5/3'1.5/S	RHC		2	L10518													4
			M-180	A	2	221964	62,660	81,850	26.0	0.200	0.720	0.011	0.004	0.020	0.130	0.000	0.070	0.000	4
			M-180	A	2	221967	60,810	79,990	26.5	0.180	0.760	0.012	0.004	0.020	0.120	0.000	0.070	0.002	4
			M-180	A	2	222039	61,590	79,770	24.0	0.190	0.720	0.011	0.003	0.020	0.110	0.000	0.060	0.002	4
			M-180	A	2	222040	63,720	83,580	23.6	0.200	0.740	0.013	0.005	0.020	0.100	0.001	0.060	0.000	4
			M-180	A	2	222041	61,320	80,430	22.8	0.190	0.720	0.011	0.006	0.010	0.120	0.000	0.060	0.000	4
			M-180	A	2	221964	62,660	81,850	26.0	0.200	0.720	0.011	0.004	0.020	0.130	0.000	0.070	0.000	4
			M-180	A	2	221967	60,810	79,990	26.5	0.180	0.760	0.012	0.004	0.020	0.120	0.000	0.070	0.002	4
			M-180	A	2	222039	61,590	79,770	24.0	0.190	0.720	0.011	0.003	0.020	0.110	0.000	0.060	0.002	4
			M-180	A	2	222040	63,720	83,580	23.6	0.200	0.740	0.013	0.005	0.020	0.100	0.001	0.060	0.000	4
			M-180	A	2	222041	61,320	80,430	22.8	0.190	0.720	0.011	0.006	0.010	0.120	0.000	0.060	0.000	4
2	20207G	12/9'4.5/8-HOLE ANCH/S	RHC		2	L13818													4
			M-180	A	2	230046	62,830	81,430	27.2	0.200	0.750	0.009	0.002	0.020	0.140	0.000	0.050	0.002	4
			M-180	A	2	230050	62,160	80,260	26.9	0.190	0.720	0.014	0.004	0.010	0.120	0.000	0.070	0.001	4
			M-180	A	2	231186	57,040	77,590	26.9	0.180	0.720	0.010	0.004	0.020	0.110	0.000	0.060	0.002	4
			M-180	A	2	231187	55,080	78,060	25.3	0.180	0.720	0.014	0.004	0.010	0.110	0.000	0.070	0.008	4
			M-180	A	2	231188	59,830	82,260	22.6	0.190	0.740	0.010	0.002	0.020	0.120	0.000	0.050	0.002	4
			M-180	A	2	231189	59,500	81,190	23.6	0.190	0.700	0.014	0.004	0.010	0.110	0.000	0.060	0.002	4
			M-180	A	2	A89864	64,500	86,000	19.7	0.200	0.720	0.015	0.002	0.030	0.050	0.001	0.060	0.001	4
			M-180	A	2	C87743	60,600	83,000	22.1	0.200	0.680	0.008	0.003	0.030	0.060	0.001	0.050	0.001	4
			M-180	B	2	228145	56,880	76,080	28.9	0.190	0.730	0.013	0.004	0.020	0.120	0.000	0.060	0.008	4
			M-180	B	2	229086	62,200	79,510	28.2	0.190	0.730	0.012	0.004	0.020	0.100	0.000	0.070	0.000	4
			M-180	A	2	230046	62,830	81,430	27.2	0.200	0.750	0.009	0.002	0.020	0.140	0.000	0.050	0.002	4
			M-180	A	2	230050	62,160	80,260	26.9	0.190	0.720	0.014	0.004	0.010	0.120	0.000	0.070	0.001	4
			M-180	A	2	231186	57,040	77,590	26.9	0.180	0.720	0.010	0.004	0.020	0.110	0.000	0.060	0.002	4

Certified Analysis

Trinity Highway Products LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296

Customer: SAMPLES, TESTING MATERIALS
2525 STEMMONS FRWY

DALLAS, TX 75207

Project: FDOT PROJECT 611971-3

Order Number: 1310739 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: TTI - 611971-3
BOL Number: 108880 Ship Date:
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Shipped To: TX
Use State: TX

As of: 6/6/19

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
			M-180	A	2	231187	55,080	78,060	25.3	0.180	0.720	0.014	0.004	0.010	0.110	0.000	0.070	0.008	4
			M-180	A	2	231188	59,830	82,260	22.6	0.190	0.740	0.010	0.002	0.020	0.120	0.000	0.050	0.002	4
			M-180	A	2	231189	59,500	81,190	23.6	0.190	0.700	0.014	0.004	0.010	0.110	0.000	0.060	0.002	4
			M-180	A	2	A89864	64,500	86,000	19.7	0.200	0.720	0.015	0.002	0.030	0.050	0.001	0.060	0.001	4
			M-180	A	2	C87743	60,600	83,000	22.1	0.200	0.680	0.008	0.003	0.030	0.060	0.001	0.050	0.001	4
			M-180	B	2	228145	56,880	76,080	28.9	0.190	0.730	0.013	0.004	0.020	0.120	0.000	0.060	0.008	4
			M-180	B	2	229086	62,200	79,510	28.2	0.190	0.730	0.012	0.004	0.020	0.100	0.000	0.070	0.000	4
28	130593G	6'6"POST/W6X8.5#W/RUBH	A-36			2810029	56,800	68,800	27.0	0.060	0.870	0.005	0.018	0.230	0.080	0.014	0.030	0.004	4
2	626079B	WD 3'10 POST	WOOD			329													

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy QMS-LG-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

Certified Analysis

Trinity Highway Products LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296
Customer: SAMPLES, TESTING MATERIALS
2525 STEMMONS FRWY

DALLAS, TX 75207
Project: FDOT PROJECT 611971-3

Order Number: 1310739 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: TTI - 611971-3
BOL Number: 108880 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 6/6/19

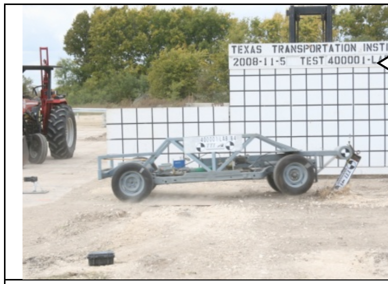
State of Ohio, County of Allen. Sworn and subscribed before me this 6th day of June, 2019 .

Notary Public: Jamie L Davis
Commission Expires 3/22/2021

NOTARIAL SEAL STATE OF OHIO
JAMIE L DAVIS
Notary Public, State of Ohio
My Commission Expires
March 22, 2021

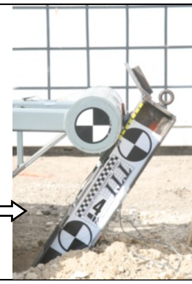
Trinity Highway Products LLC
Certified By: Heather L. Painter
Quality Assurance

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



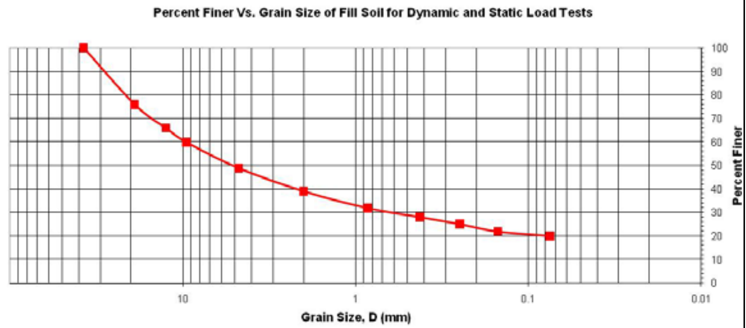
Dynamic Setup

Post-Test Photo of post

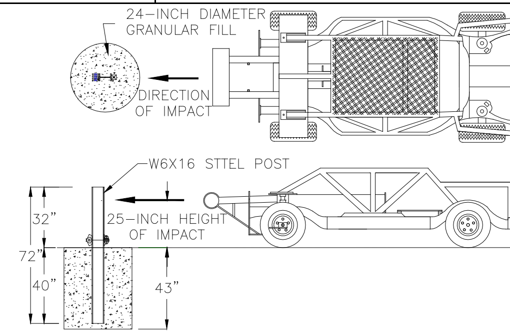


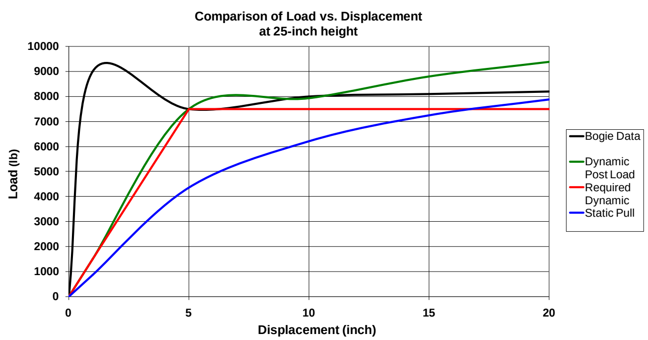
Post-Test Photo

Static Load Test

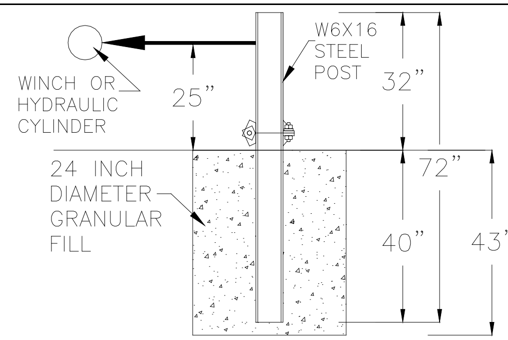


Dynamic Test Installation Details



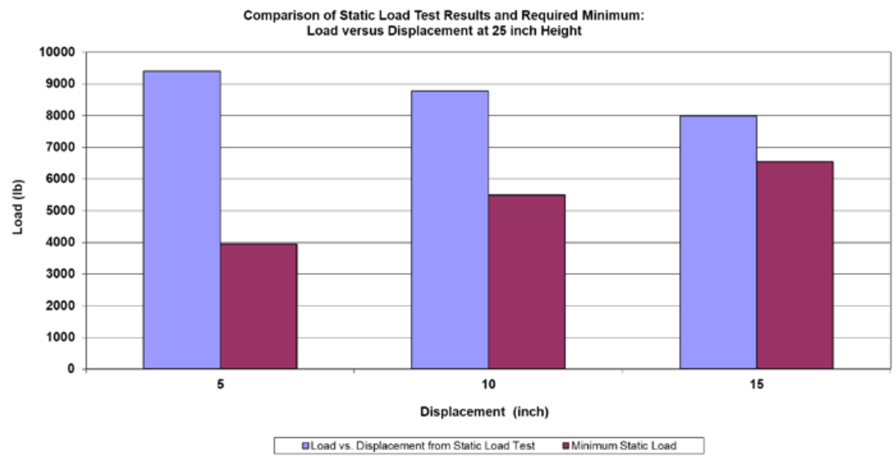


Static Load Test Installation Details

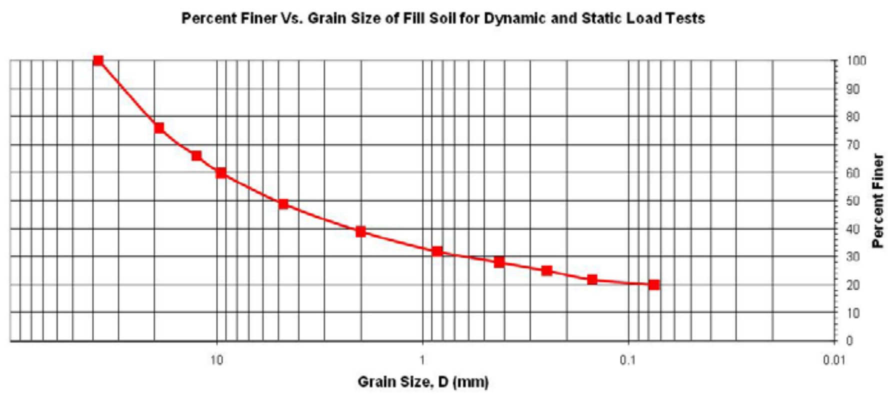


Date	2008-11-05
Test Facility and Site Location	TTI Proving Ground, 3100 SH 47, Bryan, TX 77807
In Situ Soil Description (ASTM D2487)	Sandy gravel with silty fines
Fill Material Description (ASTM D2487) and sieve analysis	AASHTO Grade B Soil-Aggregate (see sieve analysis above)
Description of Fill Placement 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. 611971-03-1.



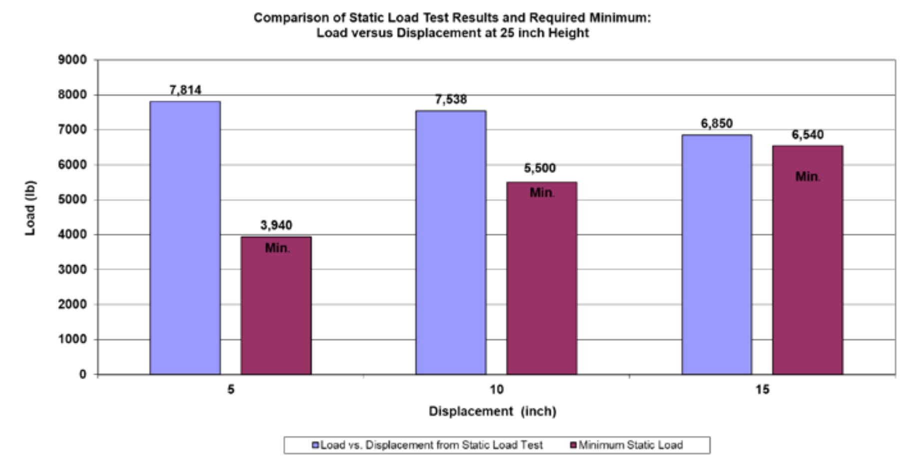
Typical Static Load Setup



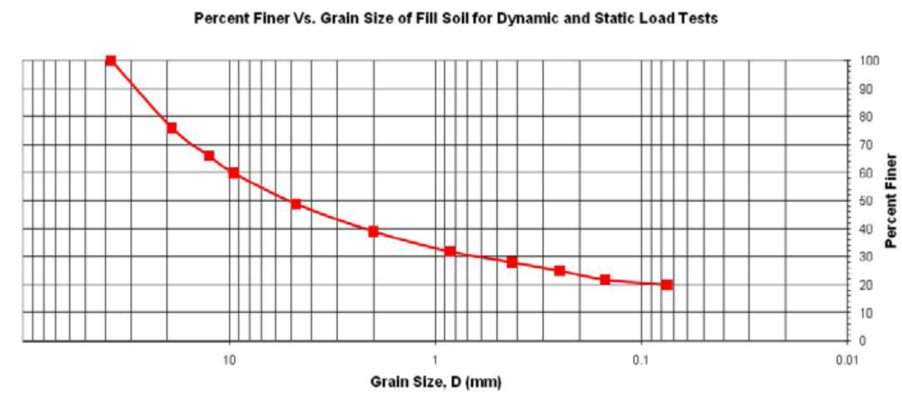
Post-Test Photo of Post

Date	2019-09-11
Test Facility and Site Location	TTI Proving Ground – 3100 SH 47, Bryan, Tx
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)
Description of Fill Placement Procedure	6-inch lifts tamped with a pneumatic compactor

Table C.3. Test Day Static Soil Strength Documentation for Test No. 611971-03-2.



Typical Static Load Setup



Post-Test Photo of Post

Date	2019-09-17
Test Facility and Site Location	TTI Proving Ground – 3100 SH 47, Bryan, Tx
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)
Description of Fill Placement Procedure	6-inch lifts tamped with a pneumatic compactor

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APPENIDX D. *MASH* TEST 3-10 (CRASH TEST NO. 611971-03-1)

D1 VEHICLE PROPERTIES AND INFORMATION

Table D.1. Vehicle Properties for Test No. 611971-03-1.

Date: 2019-09-11 Test No.: 611971-03-1 VIN No.: KNADE2235964462616

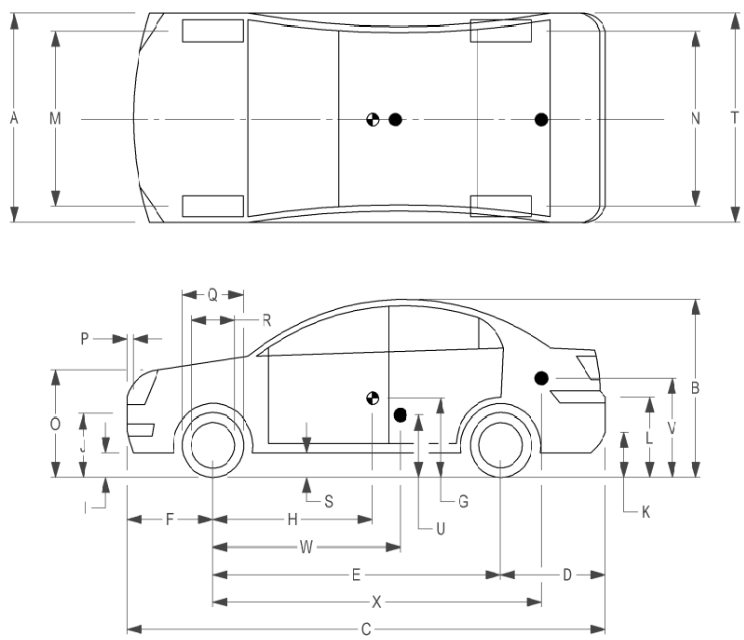
Year: 2009 Make: Kia Model: Rio

Tire Inflation Pressure: 32 PSI Odometer: 220921 Tire Size: 185/65R14

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	66.38	F	33.00	K	12.25	P	4.12	U	14.75
B	51.50	G		L	25.25	Q	22.50	V	20.75
C	165.75	H	35.11	M	57.75	R	15.50	W	35.10
D	34.00	I	7.75	N	57.70	S	8.25	X	71.50
E	98.75	J	21.50	O	27.00	T	66.20		

Wheel Center Ht Front 11.00 Wheel Center Ht Rear 11.00 W-H 0.00

RANGE LIMIT: A = 65 ±3 inches; C = 169 ±8 inches; E = 98 ±5 inches; F = 35 ±4 inches; H = 39 ±4 inches; O (Bottom of Hood Lip) = 24 ±4 inches
TOP OF RADIATOR SUPPORT = 28.25 inches; (M+N)/2 = 56 ±2 inches; W-H < 2 inches or use MASH Paragraph A4.3.2

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1718	M_{front}	1590	1571	1656
Back	1874	M_{rear}	897	867	947
Total	3638	M_{Total}	2487	2438	2603

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

Mass Distribution:
lb LF: 766 RF: 805 LR: 417 RR: 450

Table D.2. Exterior Crush Measurements for Test No. 611971-03-1.

Date:	2019-09-11	Test No.:	611971-03-1	VIN No.:	KNADE2235964462616
Year:	2009	Make:	Kia	Model:	Rio

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage		Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width** (CDC)	Max*** Crush								
1	Front plane at bumper ht	16	8	16	8	6	4	-	-	-	+23
2	Side plane at bumper ht	16	10	28	2	3	4	5	8	10	+59
	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.

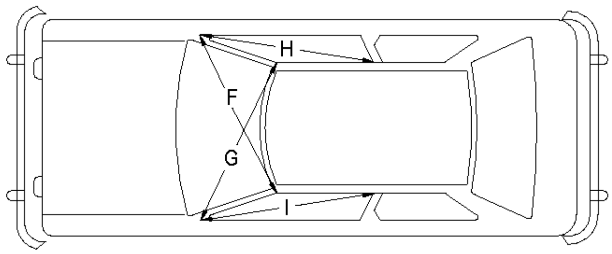
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

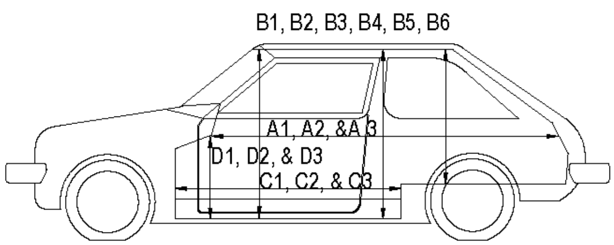
***Measure and document on the vehicle diagram the location of the maximum crush.

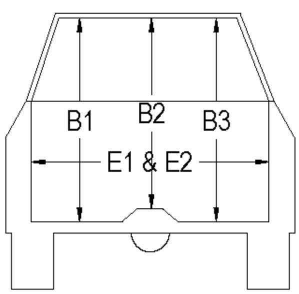
Note: Use as many lines/columns as necessary to describe each damage profile.

Table D.3. Occupant Compartment Measurements for Test No. 611971-03-1.

Date:	2019-09-11	Test No.:	611971-03-1	VIN No.:	KNADE2235964462616
Year:	2009	Make:	Kia	Model:	Rio







*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	9.50	0.00
E1	51.50	51.50	0.00
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	51.00	0.00

D2 SEQUENTIAL PHOTOGRAPHS

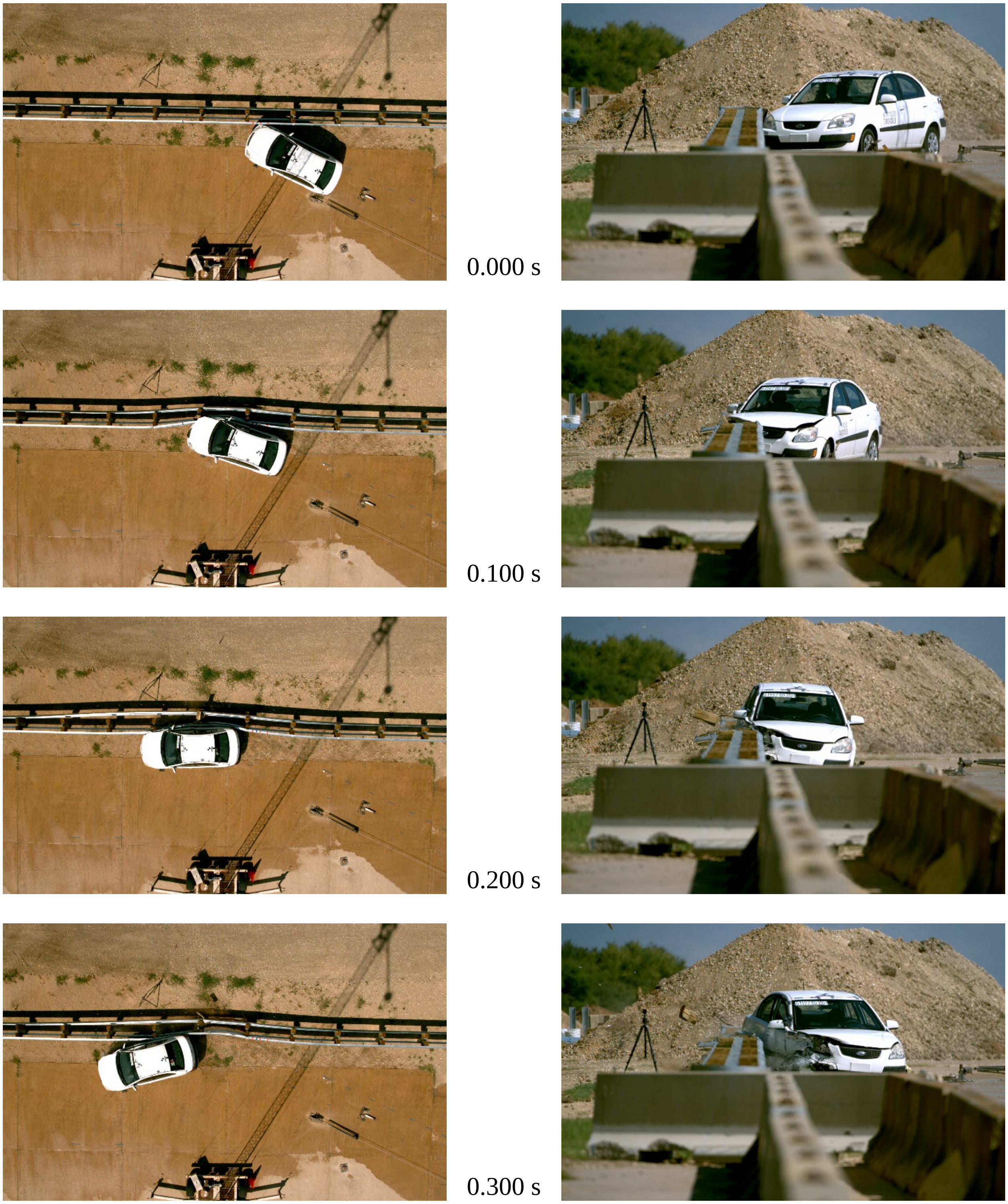


Figure D.1. Sequential Photographs for Test No. 611971-03-1 (Overhead and Frontal Views).

0.400 s

0.500 s

0.600 s

0.700 s

Figure D.1. Sequential Photographs for Test No. 611971-03-1 (Overhead and Frontal Views) (Continued).

0.000 s

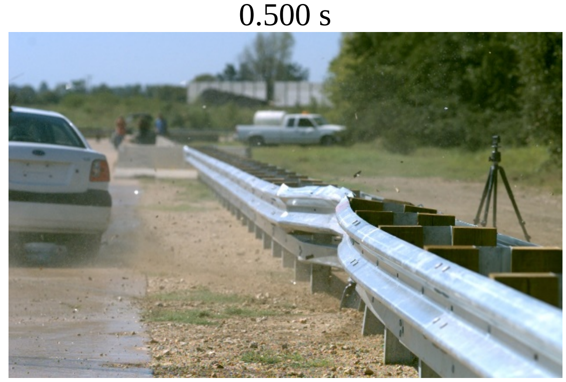
0.100 s

0.200 s

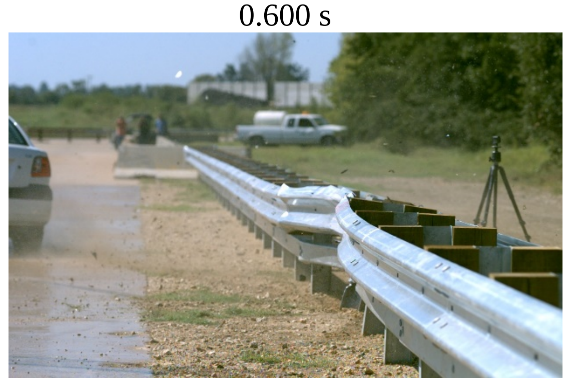
0.300 s

0.400 s

0.500 s



0.600 s



0.700 s

Figure D.2. Sequential Photographs for Test No. 611971-03-1 (Rear View).

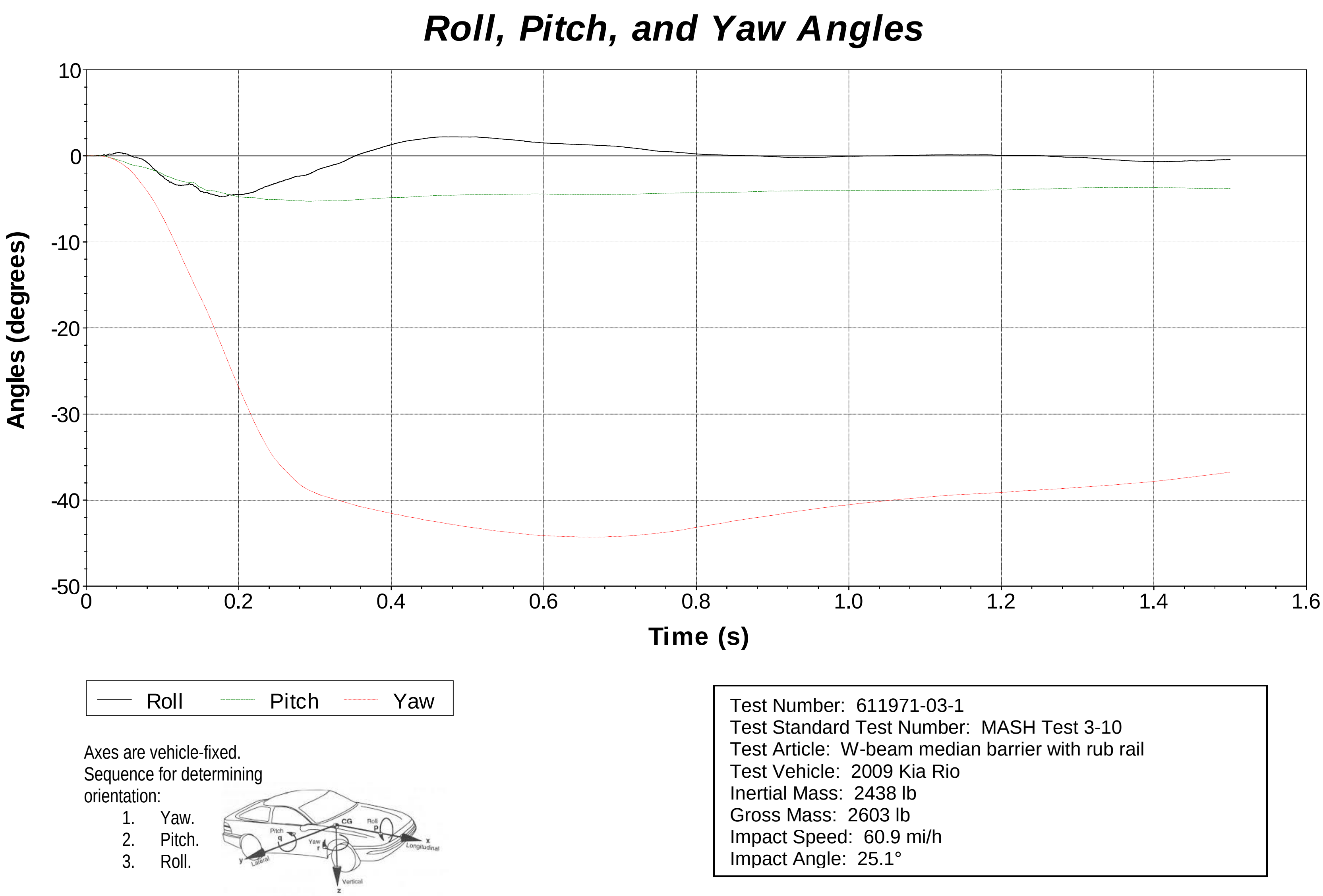


Figure D.3. Vehicle Angular Displacements for Test No. 611971-03-1.

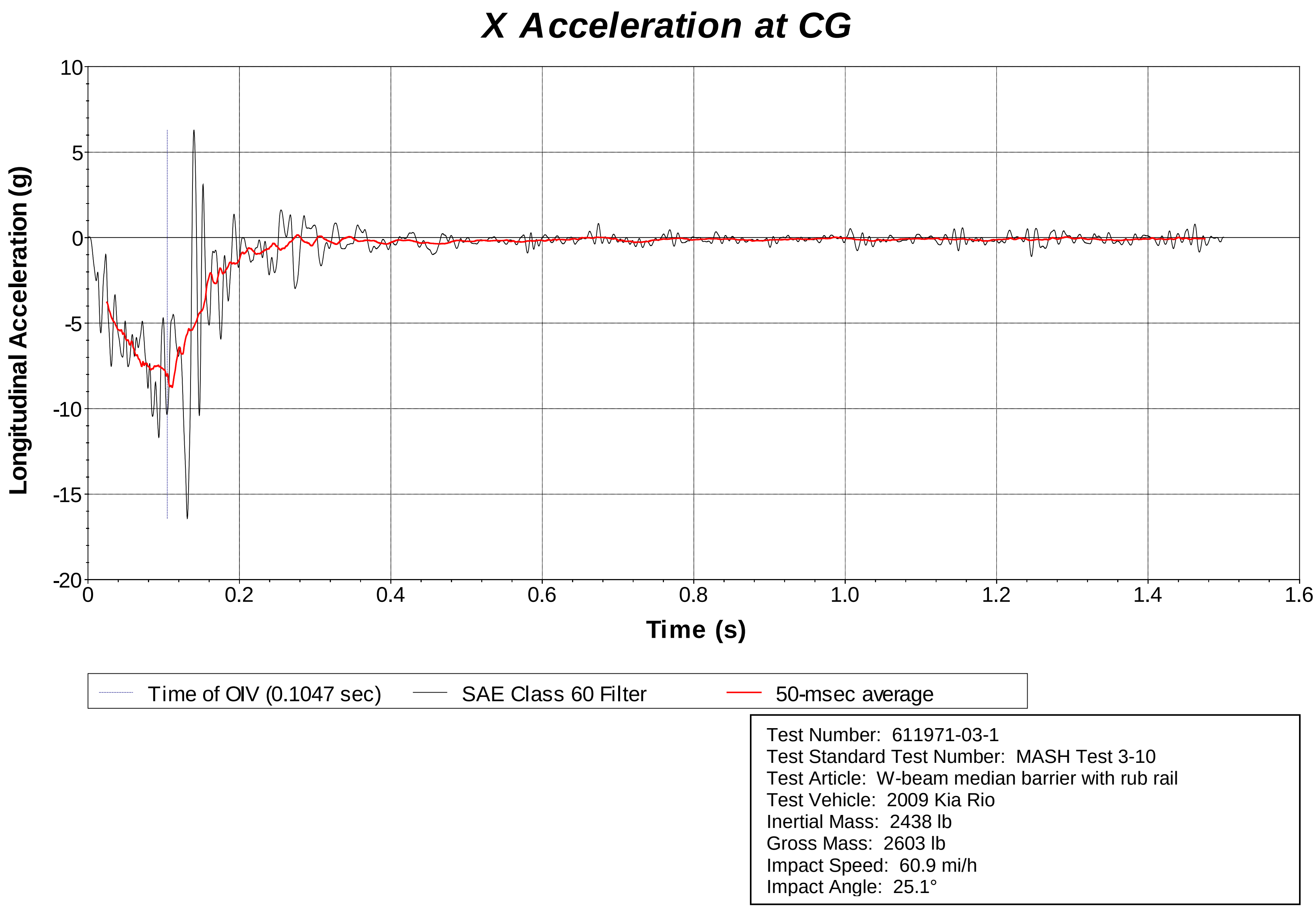
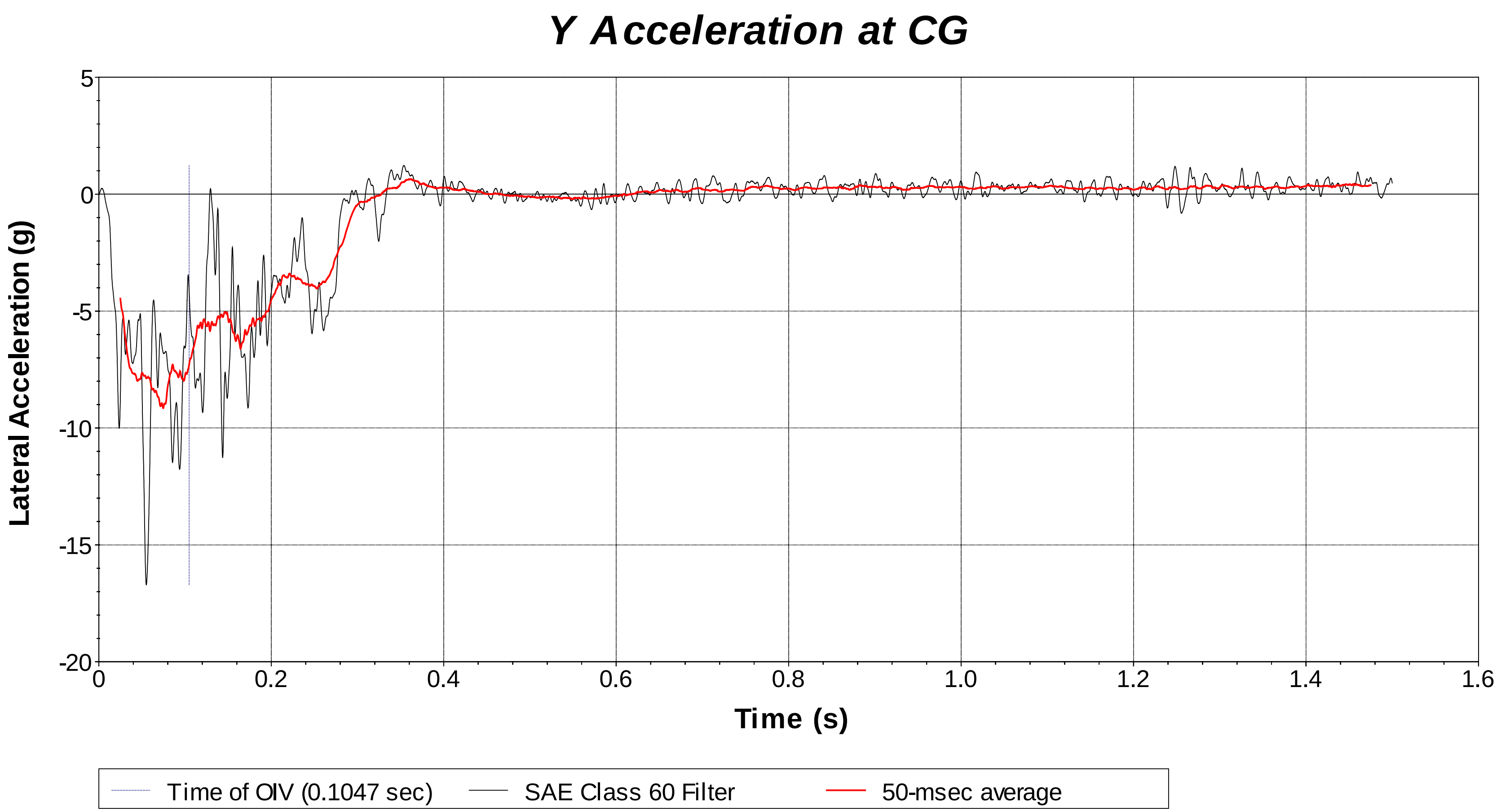


Figure D.4. Vehicle Longitudinal Accelerometer Trace for Test No. 611971-03-1 (Accelerometer Located at Center of Gravity).



Test Number: 611971-03-1
Test Standard Test Number: MASH Test 3-10
Test Article: W-beam median barrier with rub rail
Test Vehicle: 2009 Kia Rio
Inertial Mass: 2438 lb
Gross Mass: 2603 lb
Impact Speed: 60.9 mi/h
Impact Angle: 25.1°

Figure D.5. Vehicle Lateral Accelerometer Trace for Test No. 611971-03-1 (Accelerometer Located at Center of Gravity).

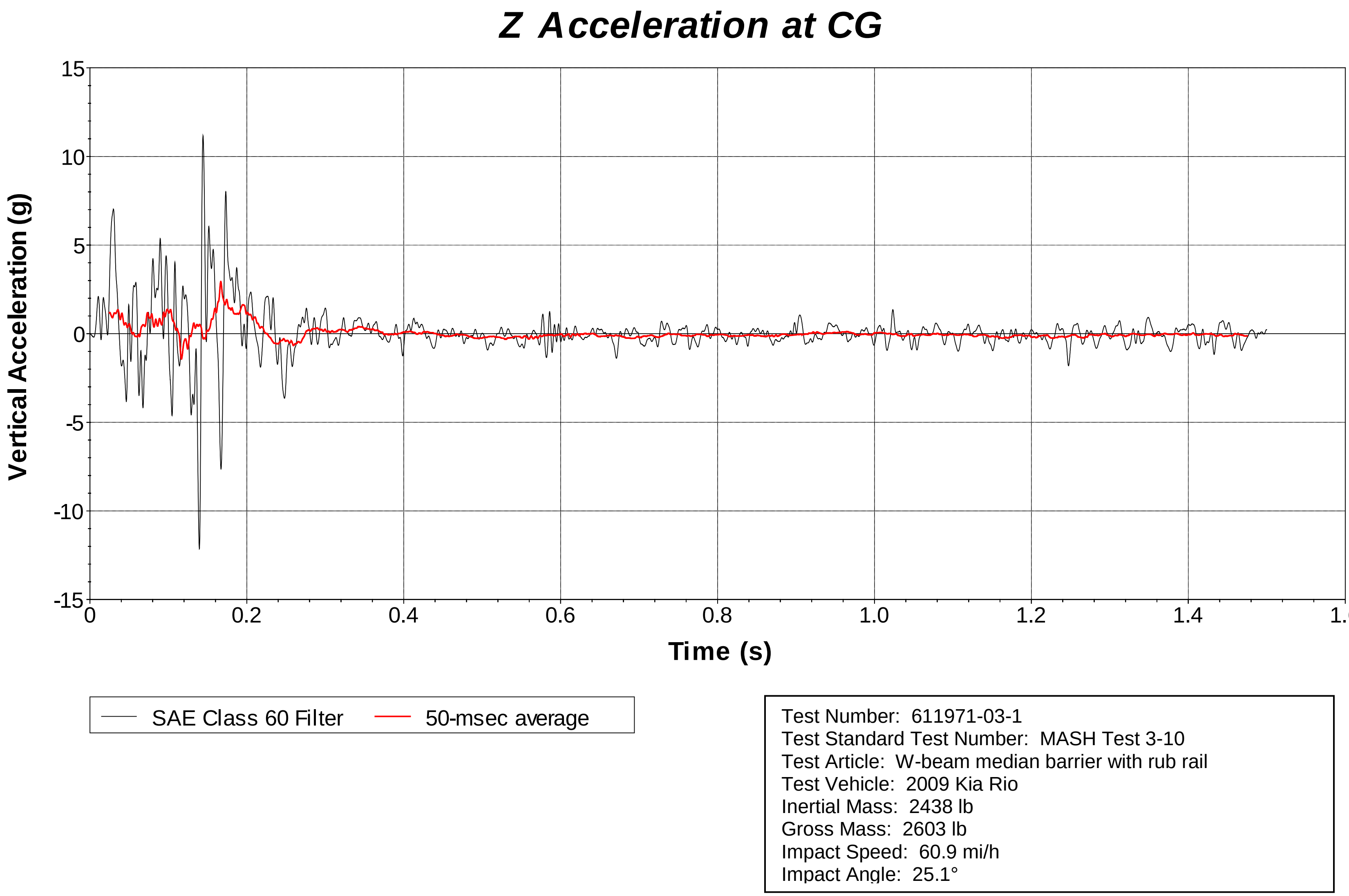


Figure D.6. Vehicle Vertical Accelerometer Trace for Test No. 611971-03-1 (Accelerometer Located at Center of Gravity).

APPENIDX E. *MASH* TEST 3-11 (CRASH TEST NO. 611971-03-2)

E1 VEHICLE PROPERTIES AND INFORMATION

Table E.1. Vehicle Properties for Test No. 611971-03-2.

Date:	2019-09-17	Test No.:	611971-03-02	VIN No.:	1C6RR6FT2GS375508
Year:	2016	Make:	RAM	Model:	1500

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

Tread Type: Highway Odometer: 106813

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

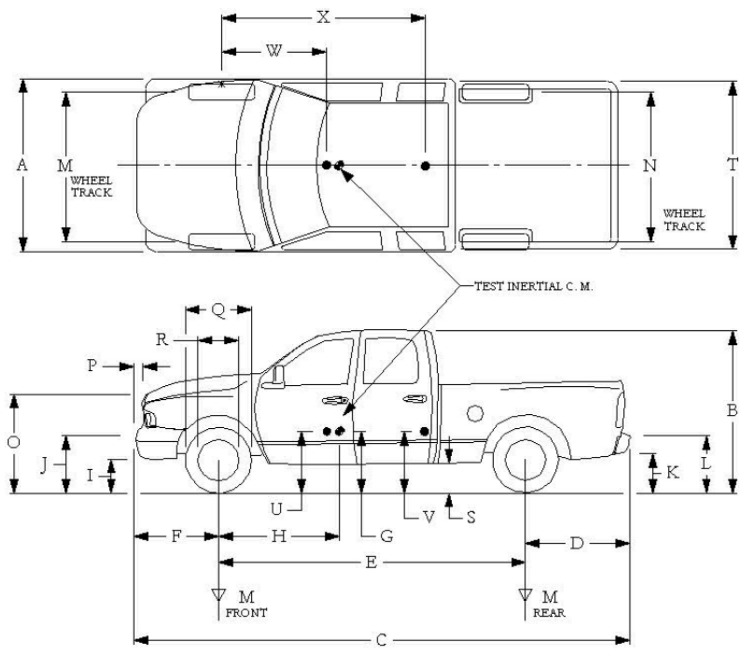
NOTES: None

Engine Type: V-8
Engine CID: 4.7 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	28.50	L	30.00	Q	30.50	V	30.25
C	227.50	H	59.61	M	68.50	R	18.00	W	59.60
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}	2945	2902	2902
Back	3900	M_{rear}	2057	2139	2139
Total	6700	M_{Total}	5002	5041	5041

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

Mass Distribution:
lb LF: 1463 RF: 1439 LR: 1071 RR: 1068

Table E.2. Measurements of Vehicle Vertical CG for Test No. 611971-03-2.

Date: 2019-09-17 Test No.: 611971-03-02 VIN: 1C6RR6FT2GS375508

Year: 2016 Make: RAM Model: 1500

Body Style: Quad Cab Mileage: 106813

Engine: 4.7 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:	1463	RF:	1439		Front Axle:	2902	
LR:	1071	RR:	1068		Rear Axle:	2139	
Left:	2534	Right:	2507		Total:	5041	
						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:	59.62	inches	Rear of Front Axle	(63 ±4 inches allowed)			
Y:	-0.18	inches	Left -	Right +	of Vehicle Centerline		
Z:	28.50	inches	Above Ground	(minumum 28.0 inches allowed)			

Hood Height: 46.00 inches
43 ±4 inches allowed

Front Bumper Height: 27.00 inches

Front Overhang: 40.00 inches
39 ±3 inches allowed

Rear Bumper Height: 30.00 inches

Overall Length: 227.50 inches
237 ±13 inches allowed

Table E.3. Exterior Crush Measurements for Test No. 611971-03-2.

Date:	2019-09-17	Test No.:	611971-03-02	VIN No.:	1C6RR6FT2GS375508
Year:	2016	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	Front plane at bmpr ht	18	11	36	1	2	4	8	10	11	+18
2	Side plane at bmpr ht	18	11	52	1	3	-	-	-	11	+70
	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.

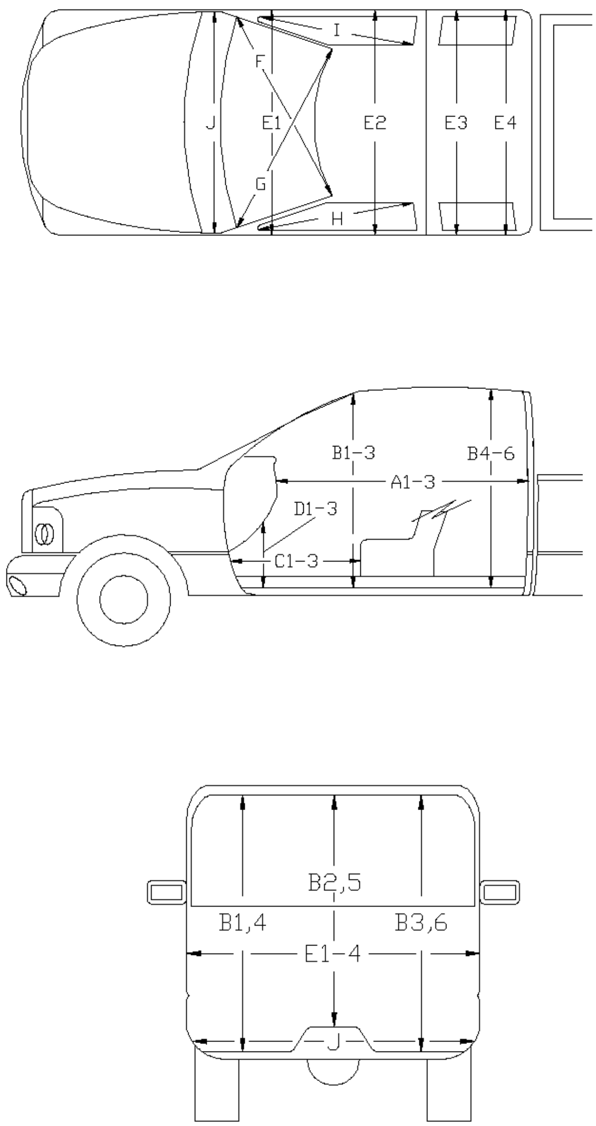
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***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.

Table E.4. Occupant Compartment Measurements for Test No. 611971-03-2.

Date:	2019-09-17	Test No.:	611971-03-02	VIN No.:	1C6RR6FT2GS375508
Year:	2016	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

E2 SEQUENTIAL PHOTOGRAPHS

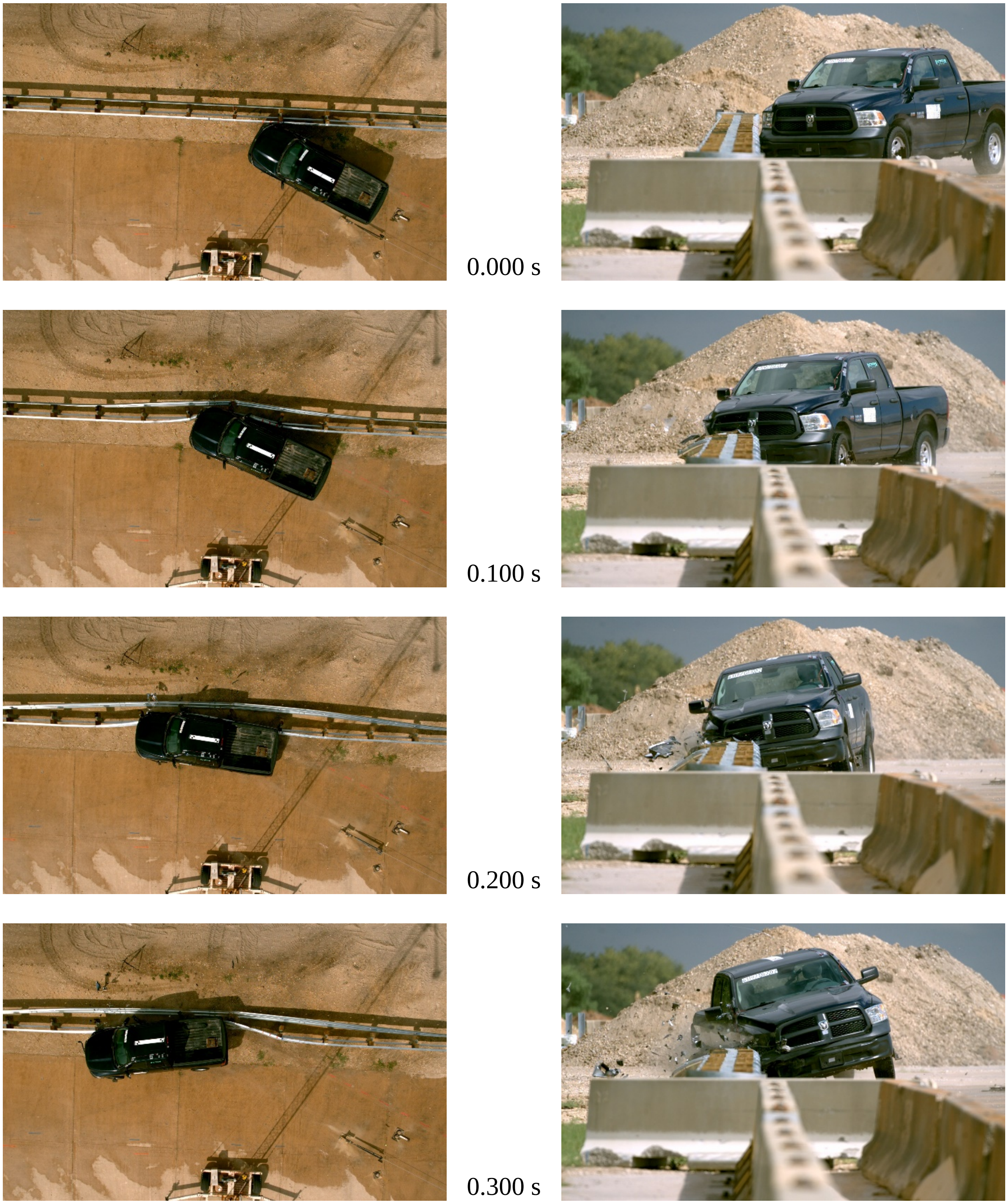


Figure E.1. Sequential Photographs for Test No. 611971-03-2 (Overhead and Frontal Views).

0.400 s

0.500 s

0.600 s

0.700 s

Figure E.1. Sequential Photographs for Test No. 611971-03-2 (Overhead and Frontal Views) (Continued).

0.000 s

0.100 s

0.200 s

0.300 s

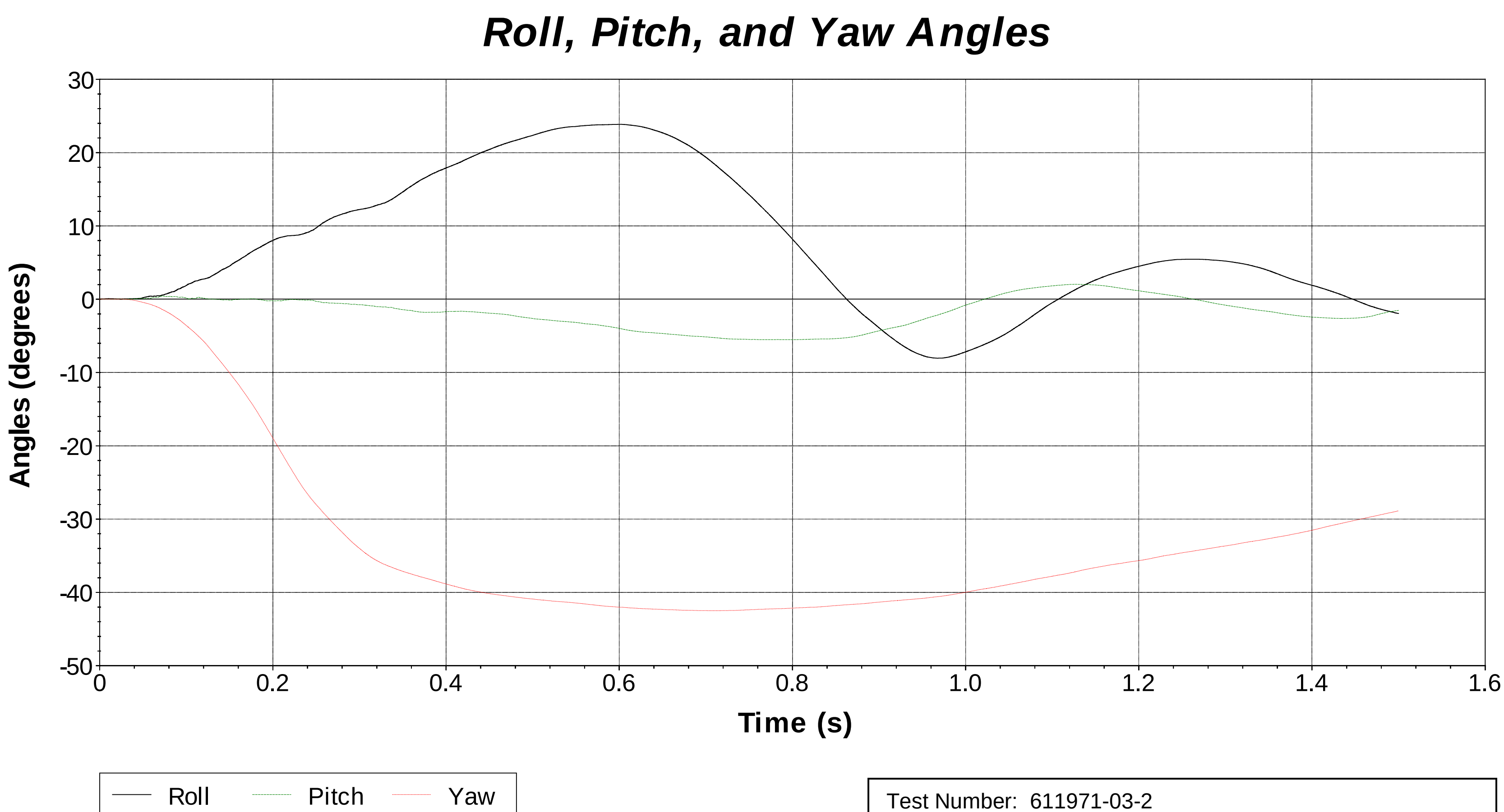
0.400 s

0.500 s

0.600 s

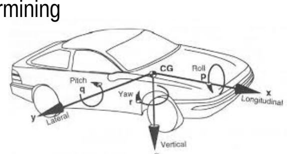
0.700 s

Figure E.2. Sequential Photographs for Test No. 611971-03-2 (Rear View).



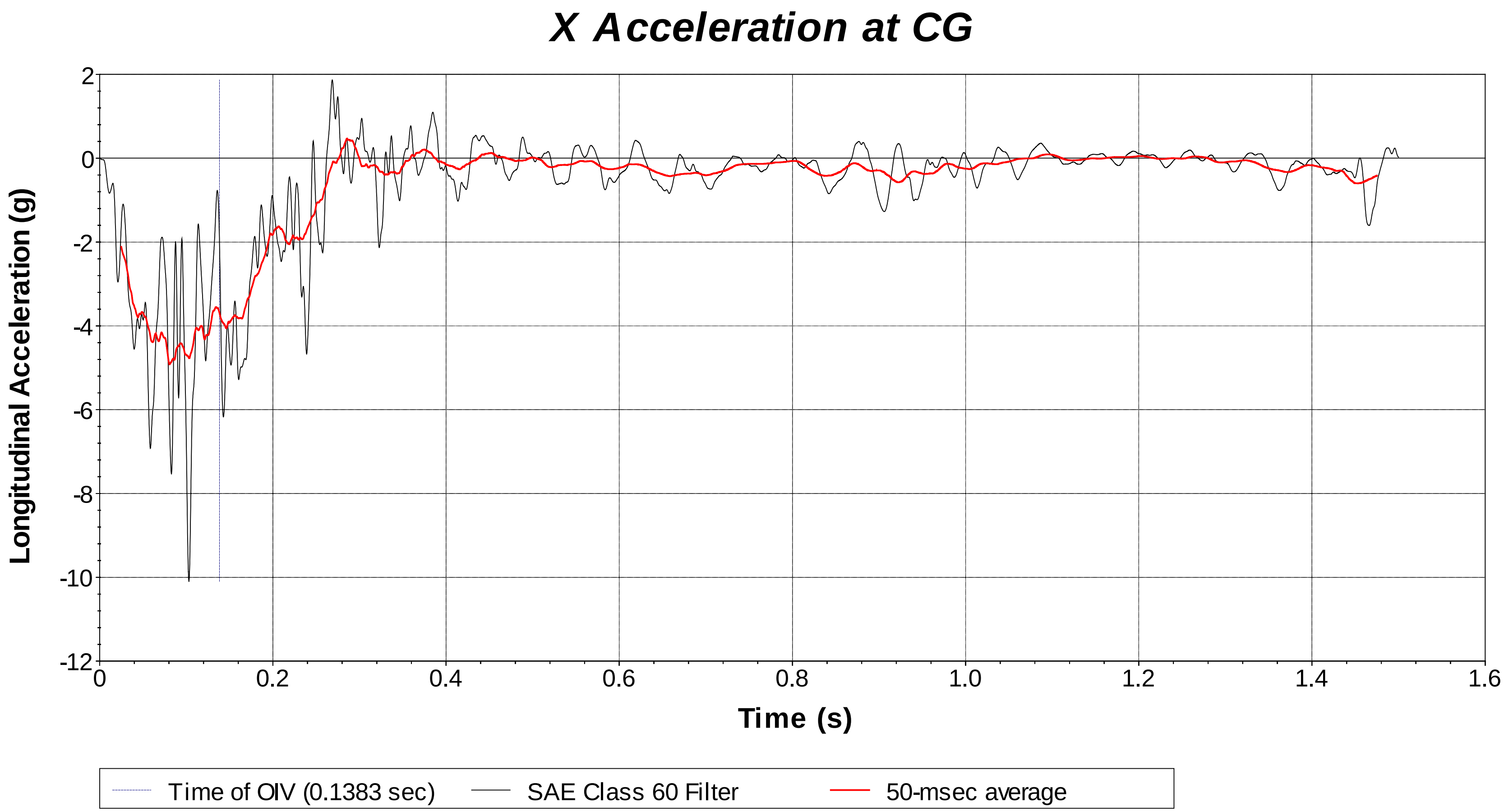
Axes are vehicle-fixed.
Sequence for determining orientation:

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



Test Number: 611971-03-2
Test Standard Test Number: MASH Test 3-11
Test Article: W-beam median barrier with rub rail
Test Vehicle: 2016 RAM 1500 Pickup Truck
Inertial Mass: 5041 lb
Gross Mass: 5041 lb
Impact Speed: 61.3 mi/h
Impact Angle: 25.1°

Figure E.3. Vehicle Angular Displacements for Test No. 611971-03-2.



Test Number: 611971-03-2
Test Standard Test Number: MASH Test 3-11
Test Article: W-beam median barrier with rub rail
Test Vehicle: 2016 RAM 1500 Pickup Truck
Inertial Mass: 5041 lb
Gross Mass: 5041 lb
Impact Speed: 61.3 mi/h
Impact Angle: 25.1°

Figure E.4. Vehicle Longitudinal Accelerometer Trace for Test No. 611971-03-2 (Accelerometer Located at Center of Gravity).

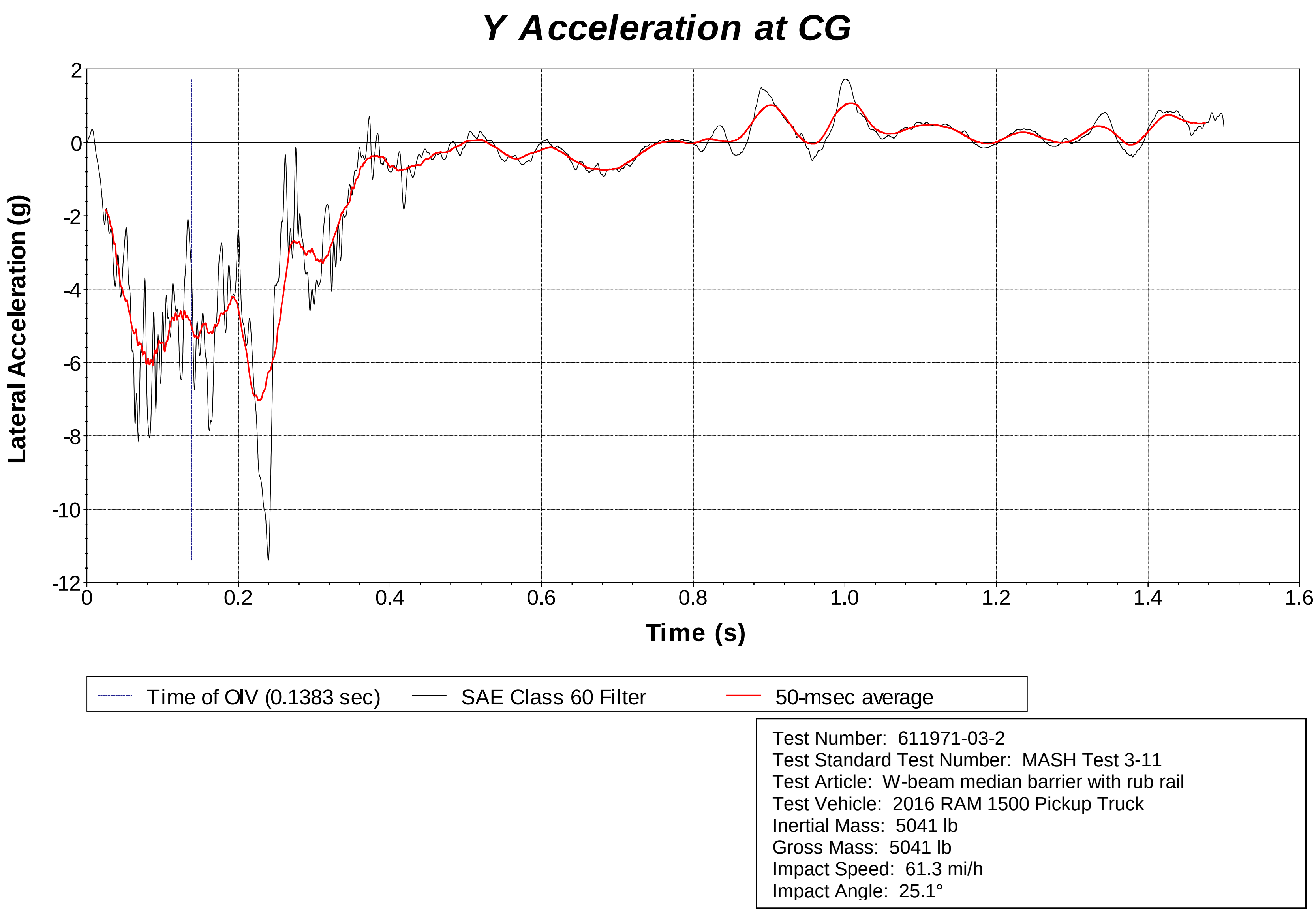
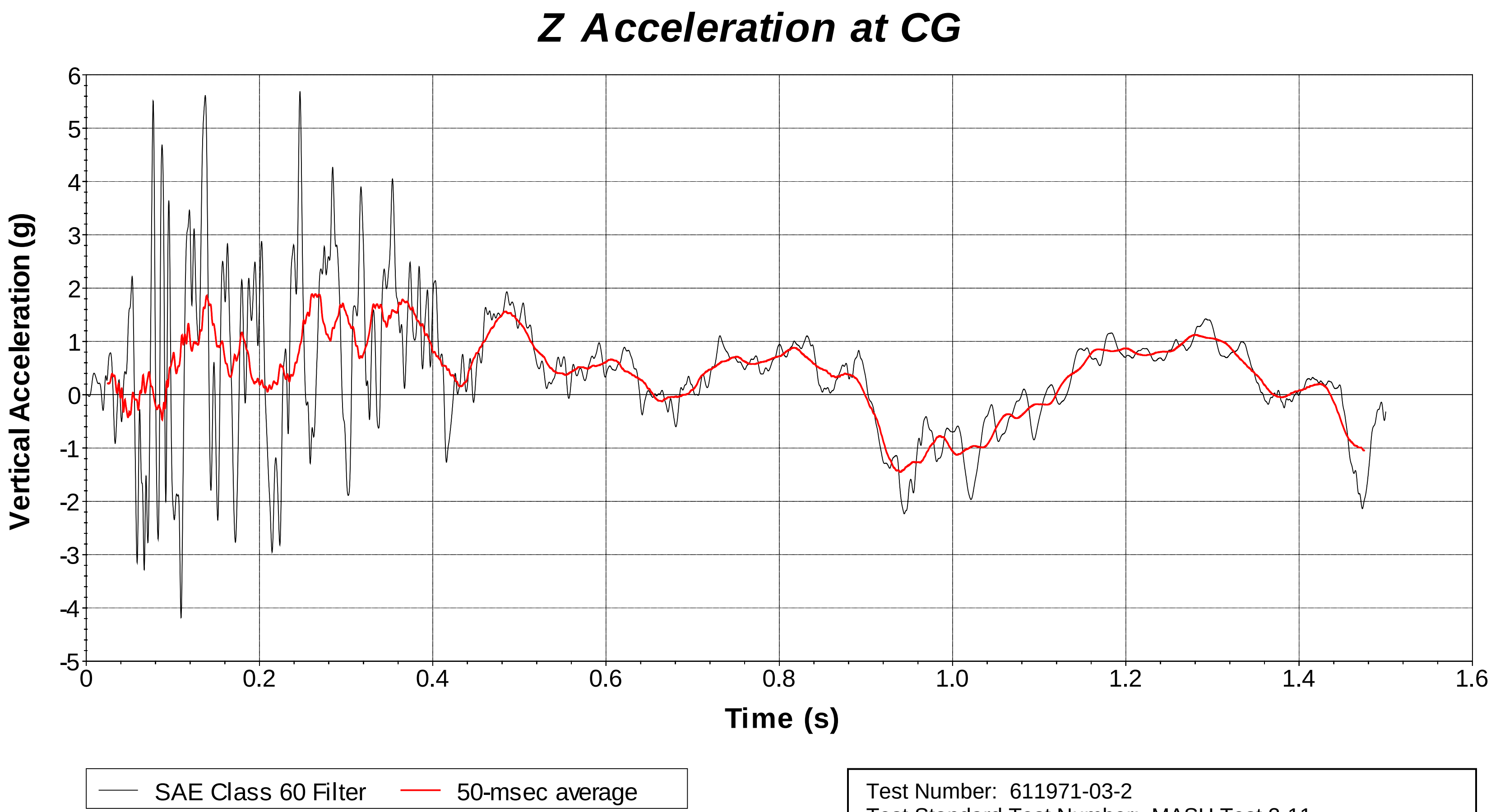


Figure E.5. Vehicle Lateral Accelerometer Trace for Test No. 611971-03-2 (Accelerometer Located at Center of Gravity).



Test Number: 611971-03-2
Test Standard Test Number: MASH Test 3-11
Test Article: W-beam median barrier with rub rail
Test Vehicle: 2016 RAM 1500 Pickup Truck
Inertial Mass: 5041 lb
Gross Mass: 5041 lb
Impact Speed: 61.3 mi/h
Impact Angle: 25.1°

Figure E.6. Vehicle Vertical Accelerometer Trace for Test No. 611971-03-2 (Accelerometer Located at Center of Gravity).