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MASH TEST 3-11 ON F-SHAPE PORTABLE CONCRETE BARRIER PINNED TO CONCRETE

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16. Abstract

The objective of this research was to evaluate the *MASH* Test Level 3 (TL-3) performance of an F-shape Portable Concrete Barrier (PCB) pinned to concrete. The barrier was installed with a 9-inch offset from the edge of an 8-inch thick unreinforced concrete pavement.

This report provides details of the F-shape PCB pinned to concrete, detailed documentation of the crash test results, and an assessment of the performance of the PCB per *MASH* Test 3-11 evaluation criteria.

The *MASH* Test 3-11 was performed with a 2270P test vehicle impacting the barrier at a target impact speed and angle of 62 mi/h and 25°, respectively. The F-shape PCB pinned to the 8-inch thick unreinforced concrete pavement, with a 9-inch offset from the edge of the pavement, performed acceptably for *MASH* Test 3-11 for longitudinal barriers.

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

*SI is the symbol for the International System of Units

Chapter 1. INTRODUCTION

1.1 BACKGROUND

In 2008, the Texas A&M Transportation Institute (TTI) developed an F-shape portable concrete barrier (PCB) design that was restrained by pinning the barrier segments to the underlying unreinforced concrete pavement. This system was developed through the Roadside Safety Pooled Fund Program and was tested under the National Cooperative Highway Research Program (NCHRP) *Report 350* testing criteria *(1, 2)*.

It was then desired to evaluate the pinned F-shape portable concrete barrier in accordance with the *MASH* testing criteria. In 2017, the barrier was retested in accordance with the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*) testing criteria *(3, 4)*. The barrier failed *MASH* Test 3-11 due to failure of the concrete pavement around the anchoring pins, causing the impacted barrier segments to become unrestrained and topple over the edge of the pavement. In this test, the barrier was installed at the edge of the concrete pavement without any lateral offset from the edge.

It is expected that by allowing some lateral offset of the barrier from the edge of the concrete pavement, the failure of pavement concrete around the anchoring pins can be prevented and the pinned barrier can successfully pass the *MASH* testing criteria.

1.2 OBJECTIVE

The objective of this research was to test the F-shape PCB pinned to concrete pavement with a suitable offset from the edge of the pavement that would lead to successful *MASH* test level 3 performance. The barrier was to be tested using *MASH* Test 3-11 criteria with a pickup truck vehicle.

Using results of the previous unsuccessful crash test, the failure of the concrete around the anchoring pins was evaluated to determine that a 9-inch offset of the barrier from the edge of the concrete pavement is likely to prevent the concrete failure. The *MASH* Test 3-11 was thus performed with a 9-inch offset.

This report provides details of the F-shape PCB pinned to concrete, detailed documentation of the crash test results, and an assessment of the performance of the F-shape PCB pinned to concrete per *MASH* Test 3-11 evaluation criteria.

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Chapter 2. SYSTEM DETAILS

2.1. TEST ARTICLE AND INSTALLATION DETAILS

The test installation was comprised of eight pre-cast concrete barrier segments for a total length of approximately 100 ft-7 inches. The segments were each 12.5 ft long and 32 inches tall, and were set and pinned to an 8-inch thick unreinforced concrete slab. Vertical connecting pins, dropped down through loops cast into the segments, connected adjoining barrier segments. Each segment was secured to the concrete slab with two steel pins inserted through inclined elongated holes in the barrier segments and into holes drilled into the underlying concrete slab. The field side edge of the toe of the barrier installation was 9 inches from the edge of the concrete slab. A ditch, approximately 18 inches deep, 88 ft long, and 24 inches wide, was created behind the slab on the field side.

Figure 2.1 presents overall information on the PCB pinned to concrete, and Figure 2.2 provides photographs of the installation. Appendix A provides further details of the PCB pinned to concrete.

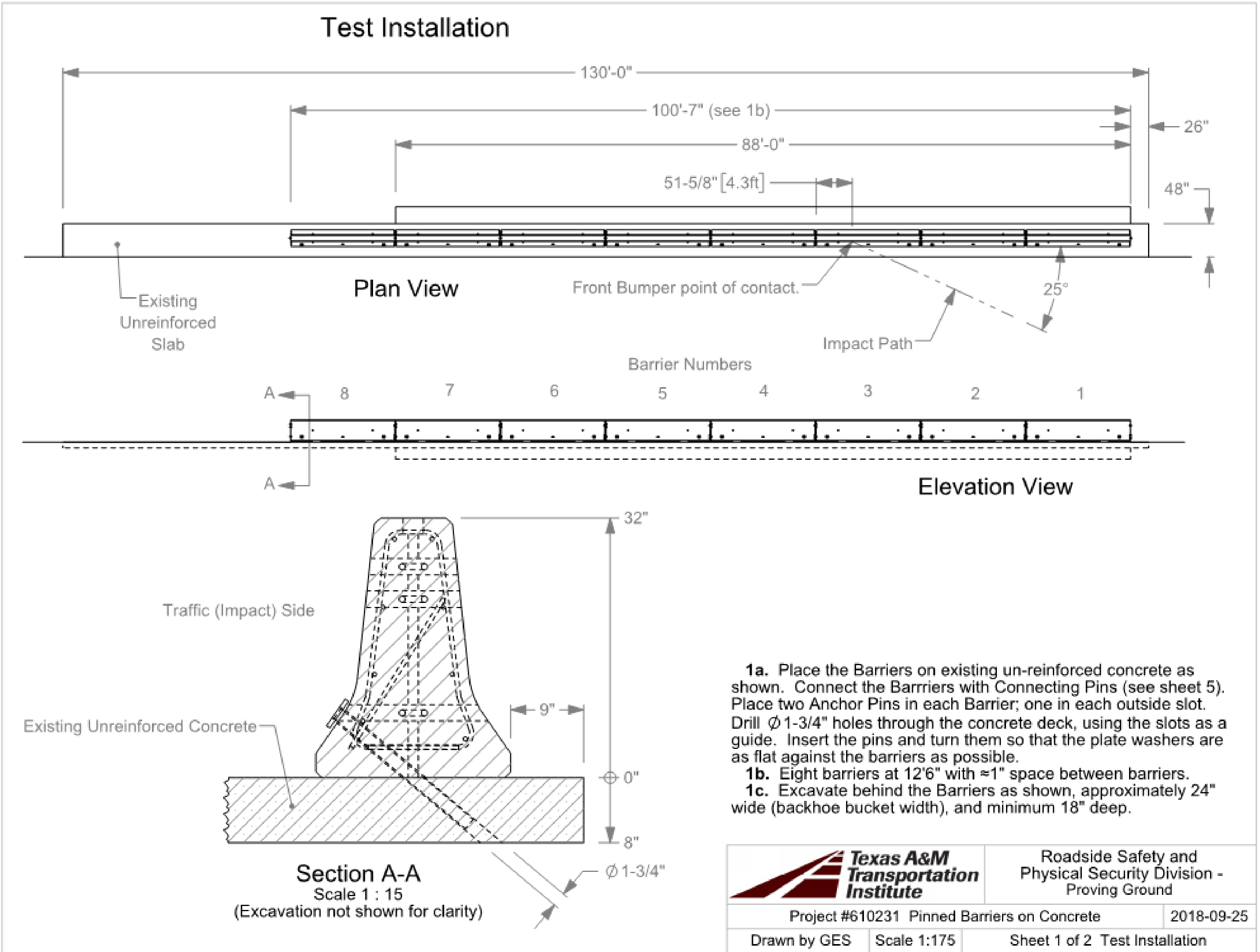

Figure 2.1. Details of the F-shape PCB Pinned to Concrete.

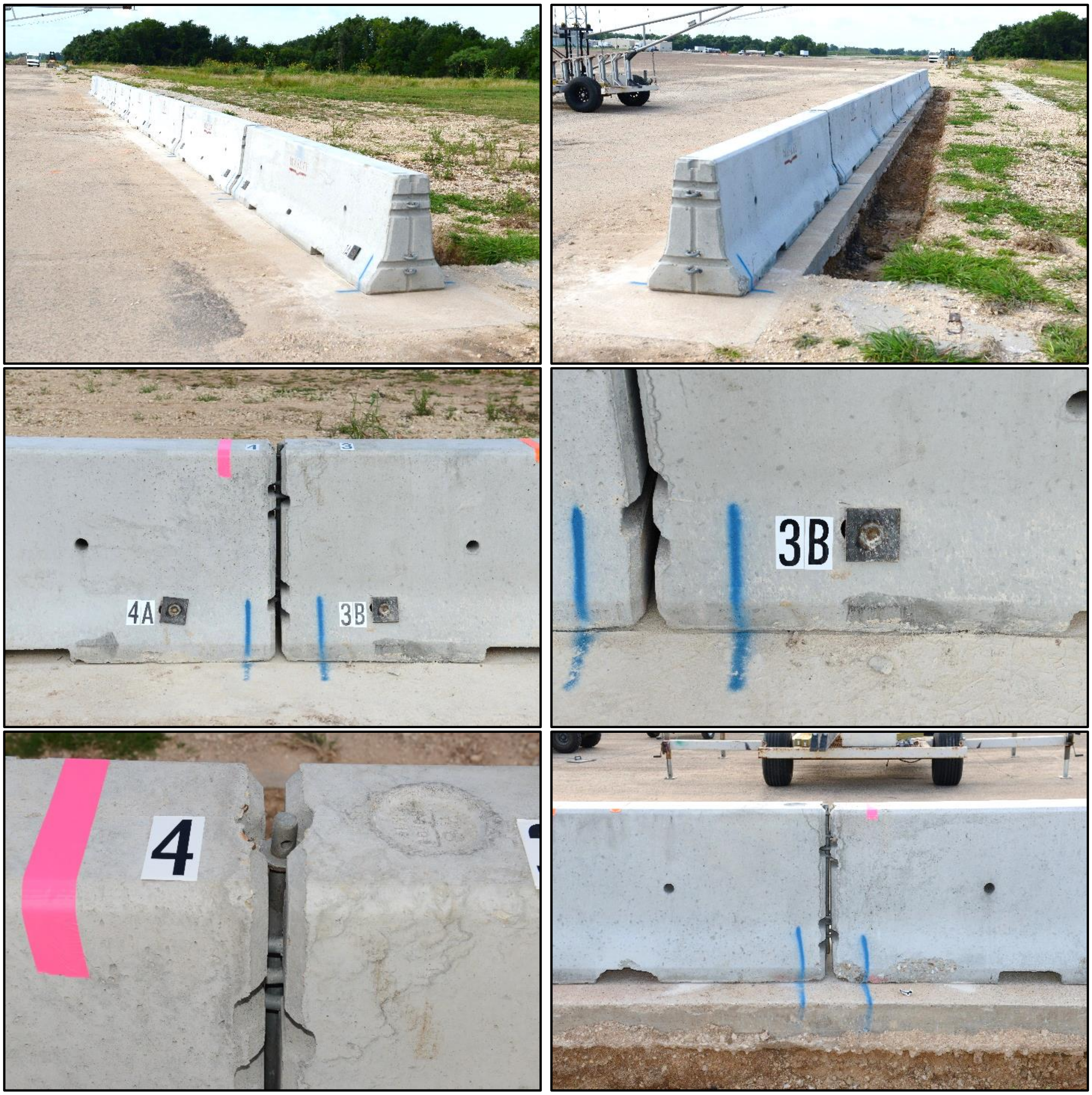

Figure 2.2. F-shape PCB Pinned to Concrete prior to Testing.

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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. *MASH* Test 3-11 involves a 2270P vehicle weighing 5000 lb (±110 lb) impacting the critical impact point (CIP) of the PCB pinned to concrete at a speed of 62 mi/h (±2.5 mi/h) and an angle of 25° (±1.5°). The target CIP was determined to be 4.3 ft upstream of the joint between segments 3 and 4 using the information provided in *MASH* Section 2.2.1, Section 2.3.2, and Figure 2-1.

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

As listed in Table 3.1, *MASH* also requires performing Test 3-10 with an 1100C small passenger car. Compared to the 2270P pickup truck of Test 3-11, the lighter passenger car of Test 3-10 will not impart greater load on the barrier's lateral restraint design or the barrier connections. Thus, the small car test is not critical from the perspective of impact load on the barrier. Furthermore, previous small car tests with permanent New Jersey barrier profile and single slope barrier profile have successfully passed *MASH* Test 3-10 criteria *(5, 6)*. From the occupant risk and vehicle stability perspective, the performance of the F-shape profile is generally considered to be bracketed between the New Jersey and the single slope profiles. For these reasons, Test 3-10 was not considered critical for the pinned F-shape PCB and only *MASH* Test 3-11 was performed. The crash test and data analysis procedures for Test 3-11 were in accordance with guidelines presented in *MASH*. Chapter 4 presents brief descriptions of these procedures.

3.2. EVALUATION CRITERIA

The appropriate safety evaluation criteria from Tables 2-2A and 5-1 of *MASH* were used to evaluate the crash test reported herein. The test conditions and evaluation criteria required for *MASH* Test 3-11 are listed in Table 3.1. The substance of the evaluation criteria is listed in Table 3.2. Evaluation of the crash test results is presented in detail under the section Assessment of Test Results.

Table 3.2. Evaluation Criteria Required for *MASH* Test 3-11 for 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 test reported herein was performed at Texas A&M Transportation Institute (TTI) Proving Ground, an International Standards Organization (ISO)/International Electrotechnical Commission (IEC) 17025-accredited laboratory with American Association for Laboratory Accreditation (A2LA) Mechanical Testing Certificate 2821.01. The full-scale crash test was performed according to TTI Proving Ground quality procedures, and according to the *MASH* guidelines and standards.

The test facilities of the TTI Proving Ground are located on the Texas A&M University 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 F-shape PCB pinned to concrete was along the edge of an out-of-service apron. The apron consists of an unreinforced jointed-concrete pavement in 12.5-ft × 15-ft blocks nominally 6 inches deep. The aprons were built in 1942, and the joints have some displacement, but are otherwise flat and level.

4.2 VEHICLE TOW AND GUIDANCE SYSTEM

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

4.3 DATA ACQUISITION SYSTEMS

4.3.1 Vehicle Instrumentation and Data Processing

The test vehicle was instrumented with a self-contained, on-board data acquisition system. The signal conditioning and acquisition system is a 16-channel, Tiny Data Acquisition System (TDAS) Pro produced by Diversified Technical Systems, Inc. The accelerometers, which measure the x, y, and z axis of vehicle acceleration, are strain gauge type with linear millivolt output proportional to acceleration. Angular rate sensors, measuring vehicle roll, pitch, and yaw rates, are ultra-small, solid state units designed for crash test service. The TDAS Pro hardware and software conform to the latest SAE J211, Instrumentation for Impact Test. Each of the 16 channels is capable of providing precision amplification, scaling, and filtering based on transducer specifications and calibrations. During the test, data are recorded from each channel at a rate of 10,000 values per second with a resolution of one part in 65,536. Once data are recorded, internal batteries back these up inside the unit should the primary battery cable be severed. Initial contact of the pressure switch on the vehicle bumper provides a time zero mark as well as 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 is measured with an expanded uncertainty of ±1.7 percent at a confidence factor of 95 percent (k=2).

TRAP uses the data from the TDAS Pro to compute occupant/compartment impact velocities, time of occupant/compartment impact after vehicle impact, and the highest 10-millisecond (ms) average ridedown acceleration. TRAP calculates change in vehicle velocity at the end of a given impulse period. In addition, maximum average accelerations over 50-ms intervals in each of the three directions are computed. For reporting purposes, the data from the vehicle-mounted accelerometers are filtered with a 60-Hz low-pass digital filter, and acceleration versus time curves for the longitudinal, lateral, and vertical directions are plotted using TRAP.

TRAP uses the data from the yaw, pitch, and roll rate transducers to compute angular displacement in degrees at 0.0001-s intervals, then plots yaw, pitch, and roll versus time. These displacements are in reference to the vehicle-fixed coordinate system with the initial position and orientation of the vehicle-fixed coordinate systems being initial impact. Rate of rotation data is measured with an expanded uncertainty of ±0.7 percent at a confidence factor of 95 percent (k=2).

4.3.2 Anthropomorphic Dummy Instrumentation

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

4.3.3 Photographic Instrumentation Data Processing

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

- One overhead with a field of view perpendicular to the ground and directly over the impact point;

- One placed behind the installation at an angle; and
- A third placed to have a field of view parallel to and aligned with the installation at the downstream end.

A flashbulb on the impacting vehicle was activated by a pressure-sensitive tape switch to indicate the instant of contact with the F-shape PCB Pinned to Concrete. 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 3-11 (CRASH TEST NO. 610231-01-1)

5.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

MASH Test 3-11 involves a 2270P vehicle weighing 5000 lb ±110 lb impacting the CIP of the F-shape PCB pinned to concrete at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 25° ±1.5°. The target CIP for *MASH* Test 3-11 on the pinned PCB was 4.3 ft ±1 ft upstream of the joint between segments 3 and 4.

The 2014 RAM 1500 pickup used in the test weighed 5090 lb, and the actual impact speed and angle were 63.6 mi/h and 25.5°, respectively. The actual impact point was 4.8 ft upstream of the joint between segments 3 and 4. Minimum target impact severity (IS) was 106 kip-ft, and actual IS was 128 kip-ft.

5.2 WEATHER CONDITIONS

The test was performed on the morning of July 12, 2018. Weather conditions at the time of testing were as follows: wind speed: 4 mi/h; wind direction: 202 degrees (vehicle was traveling in a southwesterly direction); temperature: 86°F; relative humidity: 76 percent.

5.3 TEST VEHICLE

Figures 5.1 and 5.2 show the 2014 RAM 1500 pickup used for the crash test. The vehicle's test inertia weight was 5090 lb, and its gross static weight was 5090 lb. The height to the lower edge of the vehicle bumper was 11.8 inches, and height to the upper edge of the bumper was 27.0 inches. The height to the vehicle's center of gravity was 28.0 inches. Tables B.1 and B.2 in Appendix B1 give additional dimensions and information on the vehicle. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

Figure 5.1. F-shape PCB Pinned to Concrete/Test Vehicle Geometrics for Test No. 610231-01-1.

Figure 5.2. Test Vehicle before Test No. 610231-01-1.

5.4 TEST DESCRIPTION

The test vehicle was traveling at an impact speed of 63.6 mi/h when the vehicle contacted the pinned F-shape PCB 4.8 ft upstream of the joint between segments 3 and 4 at an impact angle of 25.5°. Table 5.1 lists events that occurred during the test. Figures B.1 and B.2 in Appendix B2 present sequential photographs during the test.

Table 5.1. Events during Test No. 610231-01-1.

TIME (s)	EVENTS
0.034	Downstream end of segment 3 begins to deflect toward field side
0.039	Vehicle bumper reaches joint 3-4 & segment 4 begins to deflect toward field side
0.045	Vehicle begins to redirect
0.094	Top upstream end of segment 5 begins to rotate toward field side
0.113	Top downstream end of segment 5 begins to rotate toward field side
0.149	Upstream end of segment 5 begins to deflect toward field side
0.179	Top upstream end of segment 6 begins to rotate toward field side
0.196	Vehicle bumper reaches joint 4-5
0.218	Vehicle becomes parallel to the barrier
0.245	Rear of vehicle contacts barrier
0.488	Vehicle loses contact with barrier while traveling at 52.5 mi/h

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*. After loss of contact with the barrier, the vehicle came to rest 195 ft downstream of the impact point. Brakes on the test vehicle were applied at 2.5 s after impact.

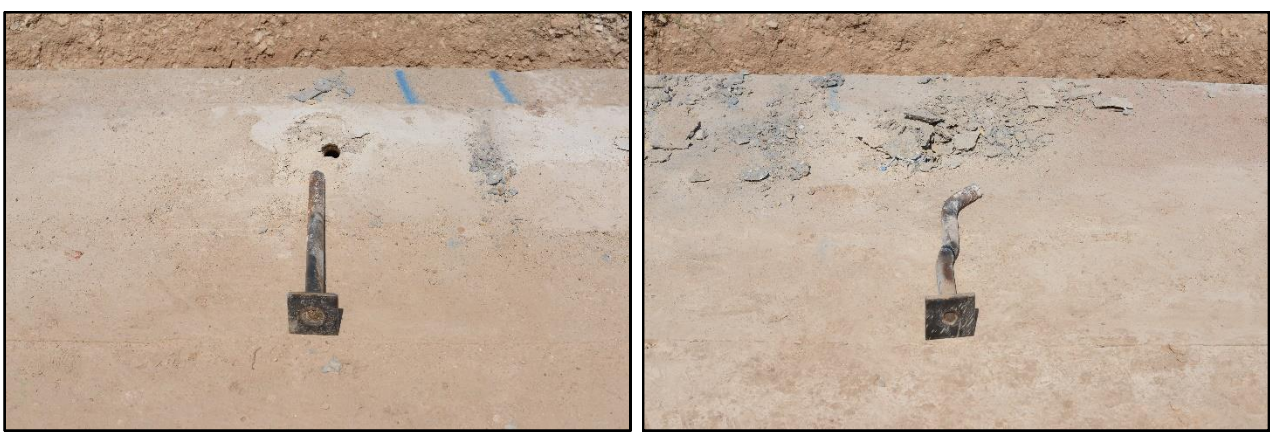
5.5 DAMAGE TO TEST INSTALLATION

Figure 5.3 through 5.7 show the damage to the F-shape PCB pinned to concrete. Movement of the segments and anchor pin pull-out distance are noted in Table 5.2. Working width was 30.7 inches at a height of 32.0 inches. Maximum dynamic deflection of the barrier during the test was 22.1 inches, and maximum permanent deflection was 9.0 inches.

Figure 5.3. F-shape PCB Pinned to Concrete after Test No. 610231-01-1.

Figure 5.4. Rear of Barrier after Test No. 610231-01-1.

Figure 5.5. Pins at Joint 3-4 after Test No. 610231-01-1.



Upstream End Downstream End

Figure 5.6. Pins and Holes for Barrier 3 after Test No. 610231-01-1.

Upstream End

Downstream End

Figure 5.7. Pins and Holes for Barrier 4 after Test No. 610231-01-1.

Table 5.2. Damage to Barrier after Test No. 610231-01-1.

Joint	Barrier Movement	Pin Pull-Out
1-2	No movement	No movement
3A	1.0 inch downstream	1.5 inches
3B	9.0 inches toward field side	4.0 inches
4A	9.0 inches toward field side	5.0 inches, deformed, head off
4B	1.75 inches toward field side	2.75 inches
5A	1.0 inch toward field side	2.5 inches
5B	0.5 inch toward field side	No movement
6-8	No movement	No movement

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 frame rail, right front and rear doors, right rear cab corner, right rear exterior bed, right rear tire and rim, and rear bumper were damaged. The windshield sustained stress cracks radiating from the right lower corner of the A-pillar. Maximum exterior crush to the vehicle was 12.0 inches in the side plane at the right front corner at bumper height. Maximum occupant compartment deformation was 3.5 inches in the right-side firewall/toe pan area. Figure 5.9 shows the interior of the vehicle.

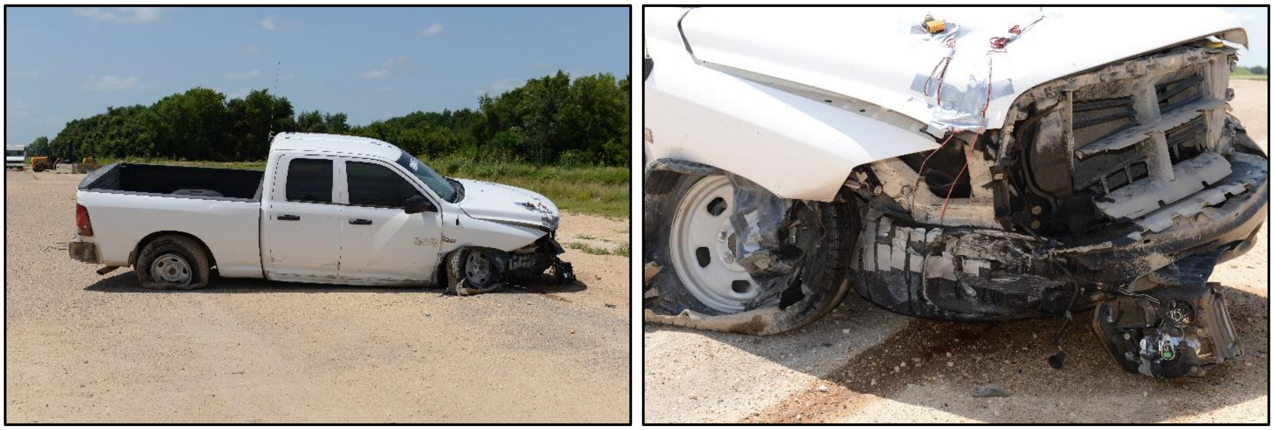


Figure 5.8. Test Vehicle after Test No. 610231-01-1.

Before Test **After Test**

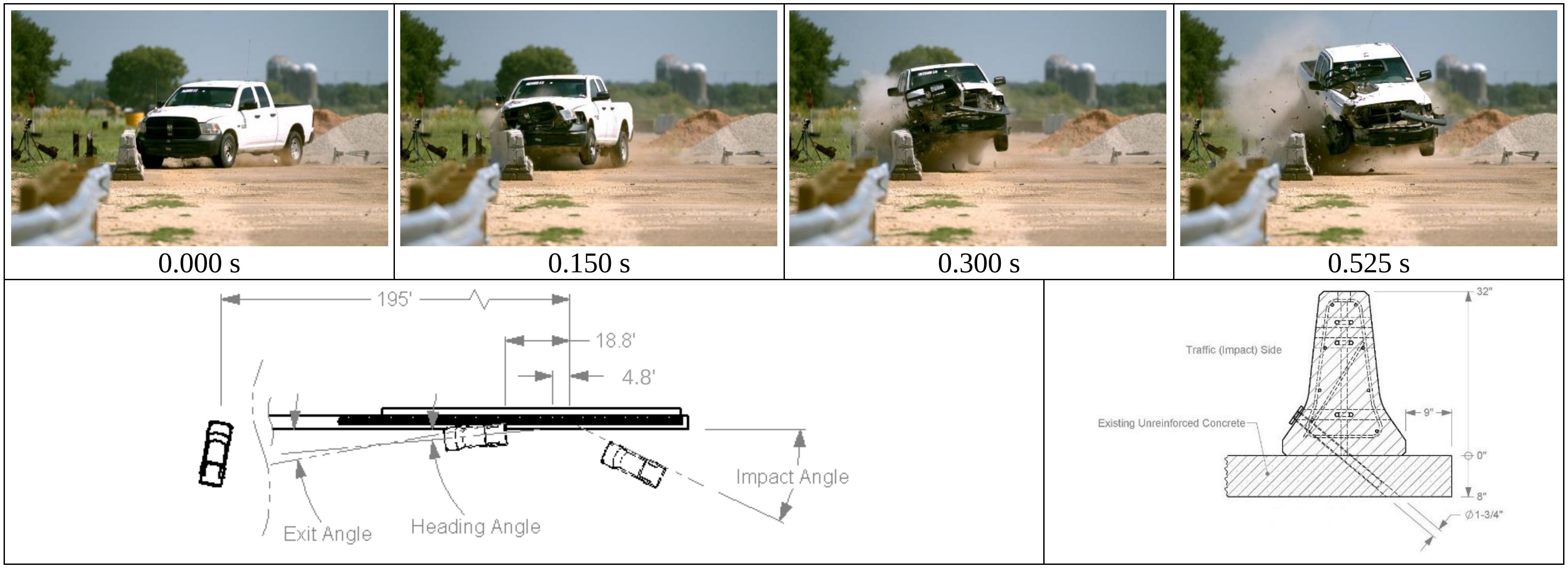
Figure 5.9. Interior of Test Vehicle for Test No. 610231-01-1.

5.7 OCCUPANT RISK FACTORS

Data from the accelerometer, located at the vehicle's center of gravity, were digitized for evaluation of occupant risk and are shown in Table 5.3. Figure 5.10 summarizes these data and other pertinent information from the test. Figure B.3 in Appendix B3 shows the vehicle angular displacements, and Figures B.4 through B.9 in Appendix B4 show accelerations versus time traces.

Table 5.3. Occupant Risk Factors for Test No. 610231-01-1.

Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV)		at 0.1039 s on right side of interior
Longitudinal	**17.1 ft/s**	
Lateral	**19.7 ft/s**	
Occupant Ridedown Accelerations		
Longitudinal	**6.5 g**	(0.1069 - 0.1169 s)
Lateral	**10.3 g**	(0.2360 - 0.2460 s)
Theoretical Head Impact Velocity (THIV)	**28.3 km/h** **7.9 m/s**	at 0.1005 s on right side of interior
Post Head Deceleration (PHD)	**10.4 g**	(0.2360 - 0.2460 s)
Acceleration Severity Index (ASI)	**1.48**	(0.0551 - 0.1051 s)
Maximum 50-ms Moving Average		
Longitudinal	**-8.8 g**	(0.0341 - 0.0841 s)
Lateral	**-11.2 g**	(0.0317 - 0.0817 s)
Vertical	**-4.4 g**	(0.7594 - 0.8094 s)
Maximum Roll, Pitch, and Yaw Angles		
Roll	**12°**	(1.0896 s)
Pitch	**12°**	(0.7605 s)
Yaw	**42°**	(1.2049 s)



General Information

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	MASH Test 3-11
TTI Test No.	610231-01-1
Test Date	2018-07-12

Test Article

Type	Longitudinal Barrier
Name	F-shape PCB Pinned to Concrete
Installation Length	100.6 ft
Material or Key Elements	32 inches tall, 12.5 ft long F-shape portable concrete barrier pinned to concrete surface
Soil Type and Condition	Concrete Pavement, Damp

Test Vehicle

Type/Designation	2270P
Make and Model	2014 RAM 1500 Pickup
Curb	5129 lb
Test Inertial	5090 lb
Dummy	No dummy
Gross Static	5090 lb

Impact Conditions

Speed	63.6 mi/h
Angle	25.5°
Location/Orientation	4.8 ft upstream of joint 3-4
Impact Severity	128 kip-ft

Exit Conditions

Speed	52.5 mi/h
Exit Heading Angle	8.1°
Exit Trajectory Angle	6.4°

Occupant Risk Values

Longitudinal OIV	17.1 ft/s
Lateral OIV	19.7 ft/s
Longitudinal Ridedown	6.5 g
Lateral Ridedown	10.3 g
THIV	28.3 km/h
PHD	10.4 g
ASI	1.48
Max. 0.050-s Average	
Longitudinal	-8.8 g
Lateral	-11.2 g
Vertical	-4.4 g

Post-Impact Trajectory

Stopping Distance	195 ft downstream

Vehicle Stability

Maximum Yaw Angle	42°
Maximum Pitch Angle	12°
Maximum Roll Angle	12°
Vehicle Snagging	No
Vehicle Pocketing	No

Test Article Deflections

Dynamic	22.1 inches
Permanent	9.0 inches
Working Width	30.7 inches
Height of Working Width	32.0 inches

Vehicle Damage

VDS	01RFQ3
CDC	01FREW3
Max. Exterior Deformation	12.0 inches
OCDI	RF0020000
Max. Occupant Compartment Deformation	3.5 inches

Figure 5.10. Summary of Results for *MASH* Test 3-11 on F-shape PCB Pinned to Concrete.

Chapter 6. SUMMARY AND CONCLUSIONS

6.1. ASSESSMENT OF TEST RESULTS

The crash test reported herein was performed in accordance with *MASH* Test 3-11, which involves a 2270P vehicle impacting the F-shape PCB pinned to concrete at a target impact speed and impact angle of 62 mi/h and 25°, respectively. An assessment of the test based on the applicable safety evaluation criteria for *MASH* Test 3-11 for longitudinal barriers is provided in Table 6.1.

6.2 CONCLUSIONS

The F-shape PCB, pinned to 8-inch thick unreinforced concrete pavement, with a 9-inch offset from the edge of the pavement, performed acceptably for *MASH* Test 3-11 for longitudinal barriers.

Table 6.1. Performance Evaluation Summary for *MASH* Test 3-11 on F-shape PCB Pinned to Concrete.

Test Agency: Texas A&M Transportation Institute | Test No.: 610231-01-1 | Test Date: 2018-07-12

MASH Test 3-11 Evaluation Criteria	Test Results	Assessment
<u>Structural Adequacy</u>		
A. *Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.*	The F-shape PCB Pinned to Concrete contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 22.1 inches.	Pass
<u>Occupant Risk</u>		
D. *Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present undue hazard to others in the area.	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.	Maximum occupant compartment deformation was 3.5 inches in the right firewall/toe pan area.	Pass
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 12° and 12°, 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 17.1 ft/s, and lateral OIV was 19.7 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.*	Maximum occupant ridedown acceleration were 6.5 g in the longitudinal direction and 10.3 g in the lateral direction.	Pass
<u>Vehicle Trajectory</u>		
For redirective devices, it is desirable that the vehicle be smoothly redirected and exit the barrier within the “exit box” criteria (not less than 32.8 ft), and should be documented.	Vehicle exited within the exit box.	Documentation only

REFERENCES

1. Sheikh, N.M., Bligh, R.P., and Menges, W.L. (2008). "Crash Testing and Evaluation of the 12 ft Pinned F-shape Temporary Barrier." Texas A&M Transportation Institute, College Station, Texas.

2. Ross, Jr., H.E.; Sicking, D.L.; Zimmer, R.A.; and Michie, J.D. (1993). *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, National Cooperative Highway Research Program Report 350, Transportation Research Board, National Research Council, Washington, D.C.

3. Sheikh, N.M., Menges, W.L., and Kuhn, D.L. (2017). "MASH Testing of Portable Concrete Barrier Pinned on concrete Pavement." Technical Memorandum 607911-3, Texas A&M Transportation Institute, College Station, Texas.

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

5. Lechtenberg, K., Faller, R., Sicking, D., Rohde, J., Bielenberg, B., Reid, J., and Coon, B. (2006). "Performance Evaluation of the Permanent New Jersey Safety Shape Barrier - Update to NCHRP 350 Test No. 3-10 (2214NJ-1)," Report TRP-03-177-06, Midwest Roadside Safety Facility, Lincoln, Nebraska.

6. Whitesel, D., Jewell, J., and Meline, R. (2018). "Compliance Crash Testing of the Type 60 Median Barrier, Test 140MASH3C16-04." Roadside Safety Research Group, California Department of the Transportation, Sacramento, California.

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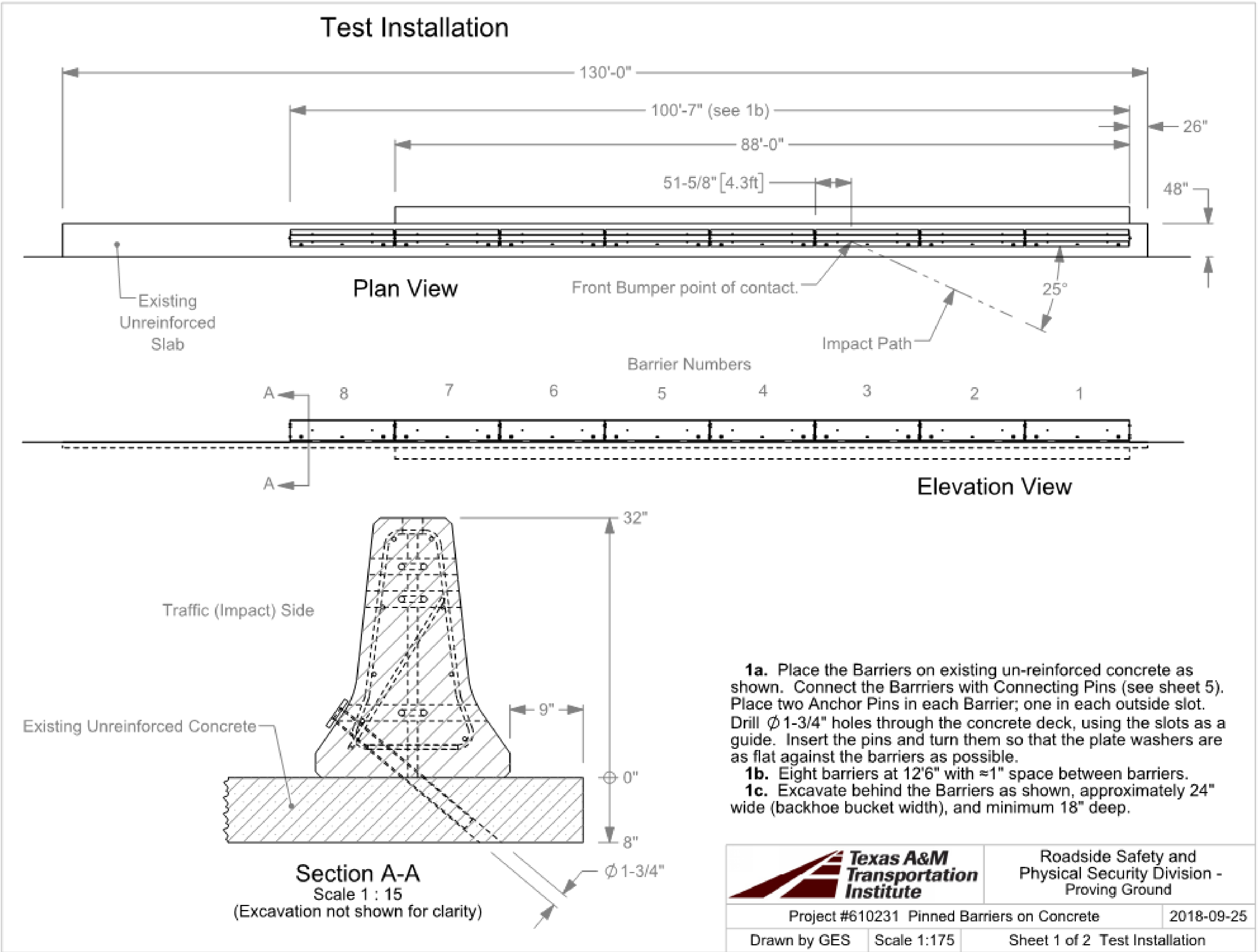
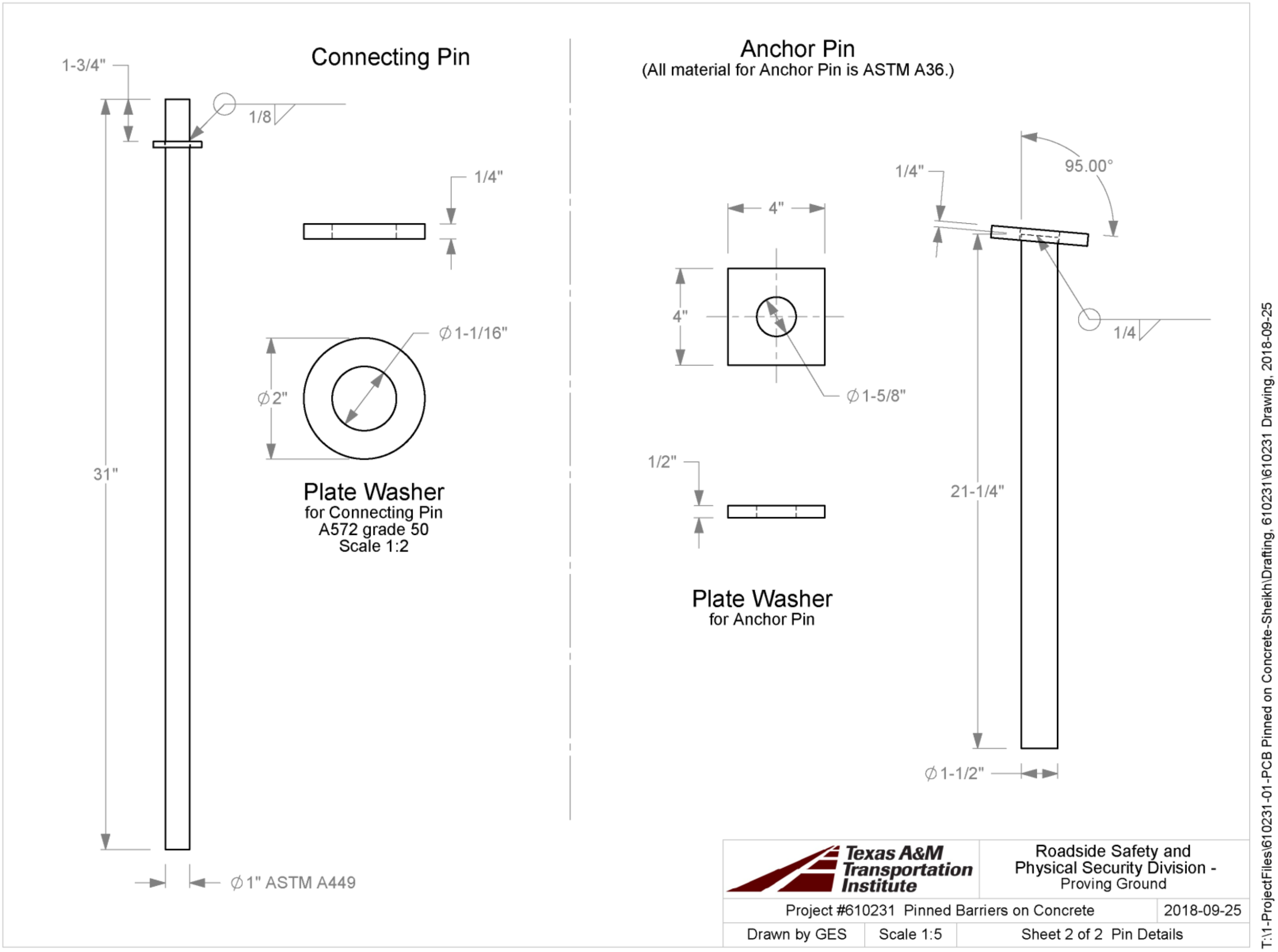
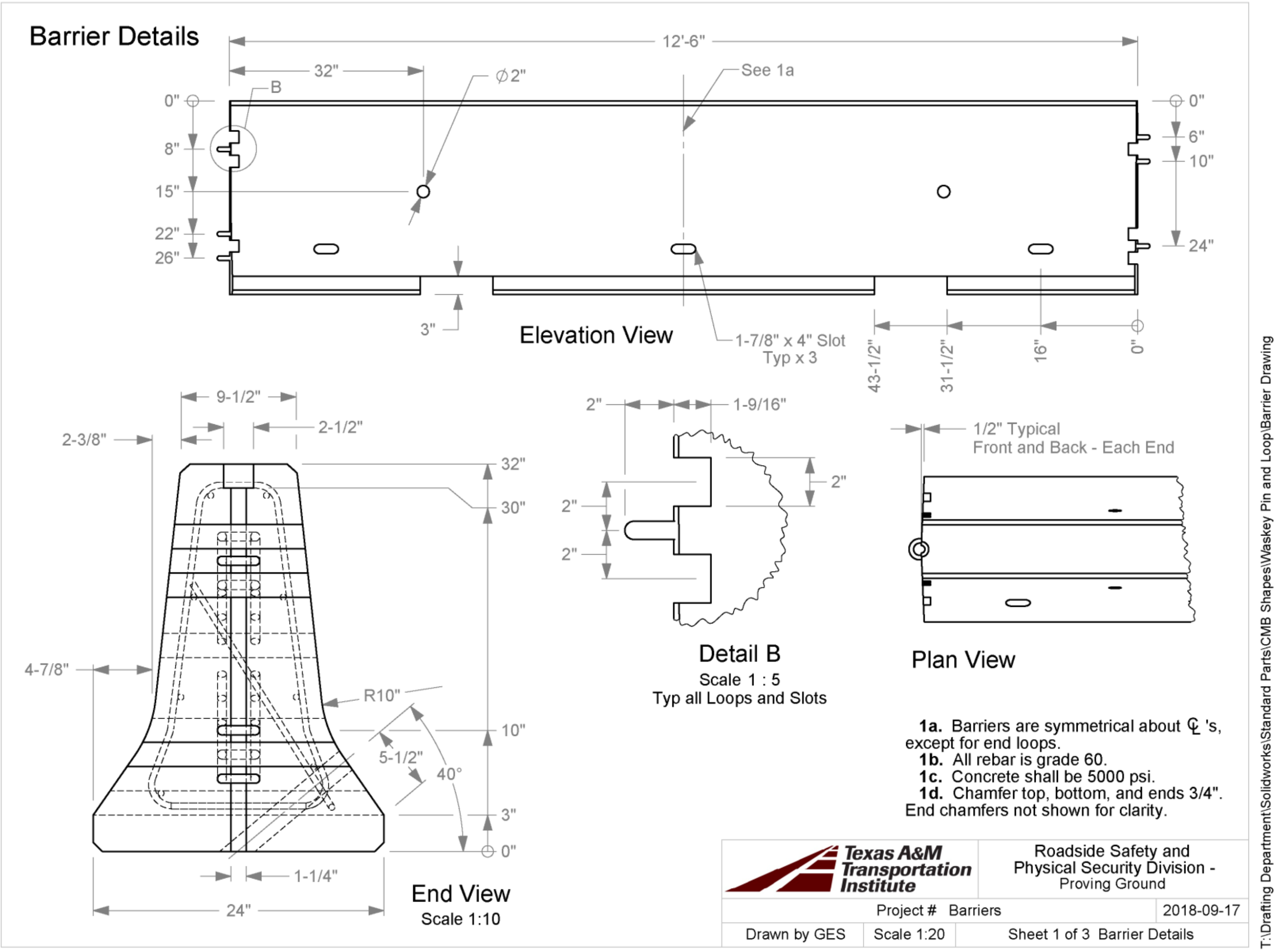
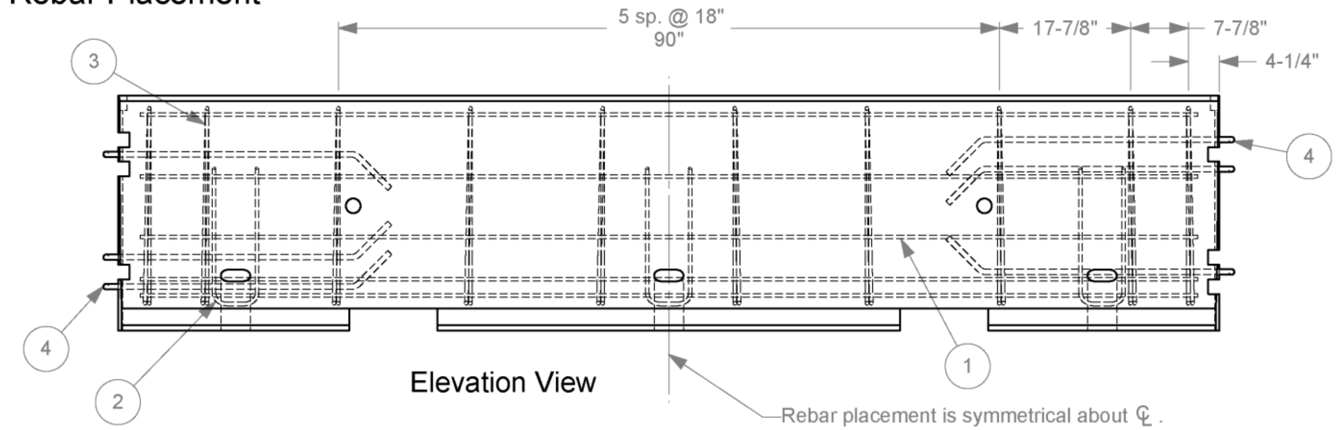
APPENDIX A. DETAILS OF THE F-SHAPED PCB PINNED TO CONCRETE



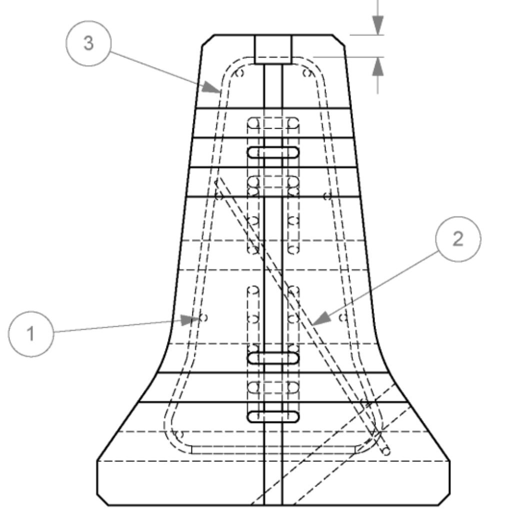

Connecting Pin
1-3/4"
1/8
1/4"
31"
ϕ1-1/16"
ϕ2"
Plate Washer
for Connecting Pin
A572 grade 50
Scale 1:2
ϕ1" ASTM A449
Anchor Pin
(All material for Anchor Pin is ASTM A36.)
95.00°
1/4"
4"
4"
ϕ1-5/8"
1/4
1/2"
21-1/4"
Plate Washer
for Anchor Pin
ϕ1-1/2"
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #610231 Pinned Barriers on Concrete
2018-09-25
Drawn by GES
Scale 1:5
Sheet 2 of 2 Pin Details
T:\1-ProjectFiles\610231-01-PCB Pinned on Concrete-Sheikh\Drafting, 610231\610231 Drawing, 2018-09-25


Barrier Details
12'-6"
32"
⌀2"
See 1a
B
0"
8"
15"
22"
26"
6"
10"
24"
3"
Elevation View
1-7/8" x 4" Slot
Typ x 3
43-1/2"
31-1/2"
16"
9-1/2"
2-1/2"
2-3/8"
32"
30"
4-7/8"
R10"
5-1/2"
40°
10"
3"
1-1/4"
24"
End View
Scale 1:10
2"
1-9/16"
Detail B
Scale 1 : 5
Typ all Loops and Slots
1/2" Typical
Front and Back - Each End
Plan View
1a. Barriers are symmetrical about ℄ 's, except for end loops.
1b. All rebar is grade 60.
1c. Concrete shall be 5000 psi.
1d. Chamfer top, bottom, and ends 3/4". End chamfers not shown for clarity.
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project # Barriers
2018-09-17
Drawn by GES
Scale 1:20
Sheet 1 of 3 Barrier Details
T:\Drafting Department\Solidworks\Standard Parts\CMB Shapes\Waskey Pin and Loop\Barrier Drawing

Rebar Placement



Elevation View



End View

Scale 1:10

#	Part Name	Qty.
1	Rebar, #4 x 144"	8
2	403 Bar	3
3	Stirrup	10
4	End Loops	6

Texas A&M Transportation Institute

Roadside Safety and Physical Security Division - Proving Ground

Project # Barriers | 2018-09-17

Drawn by GES | Scale 1:20 | Sheet 2 of 3 Rebar Placement

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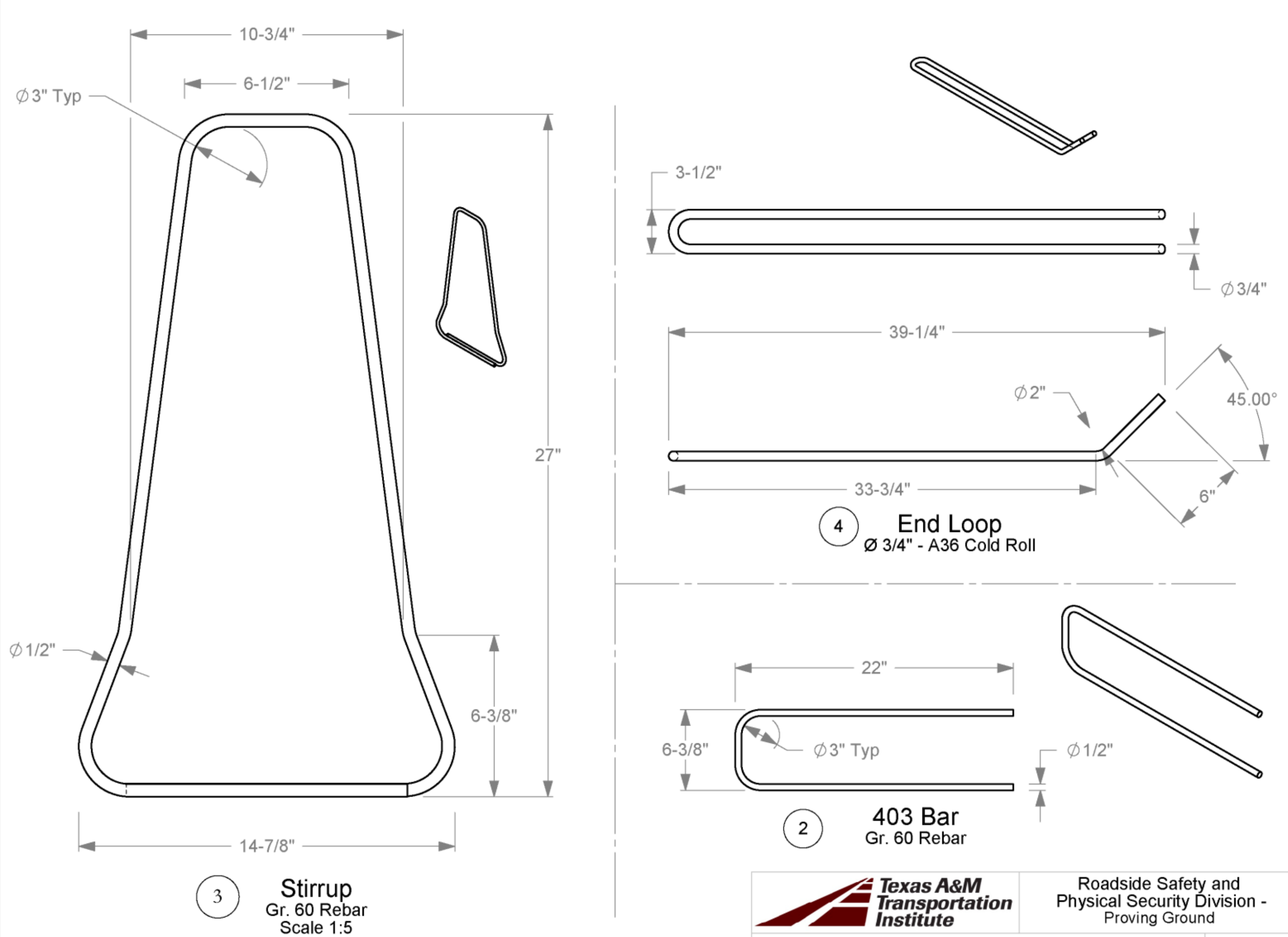

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
	Project # Barriers	2018-09-17
Drawn by GES	Scale 1:10	Sheet 3 of 3 Barrier Parts

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APPENIDX B. *MASH* TEST 3-11 (CRASH TEST NO. 610231-01-1)

B1 VEHICLE PROPERTIES AND INFORMATION

Table B.1. Vehicle Properties for Test No. 610231-01-1.

Date:	2018-07-12	Test No.:	610231-01-1	VIN No.:	1C6RR6FT8ES265026
Year:	2014	Make:	RAM	Model:	1500

Tire Size: 265/70 R 17 — Tire Inflation Pressure: 35 PSI

Tread Type: HIGHWAY — Odometer: 166434

Note any damage to the vehicle prior to test: NONE

● Denotes accelerometer location.

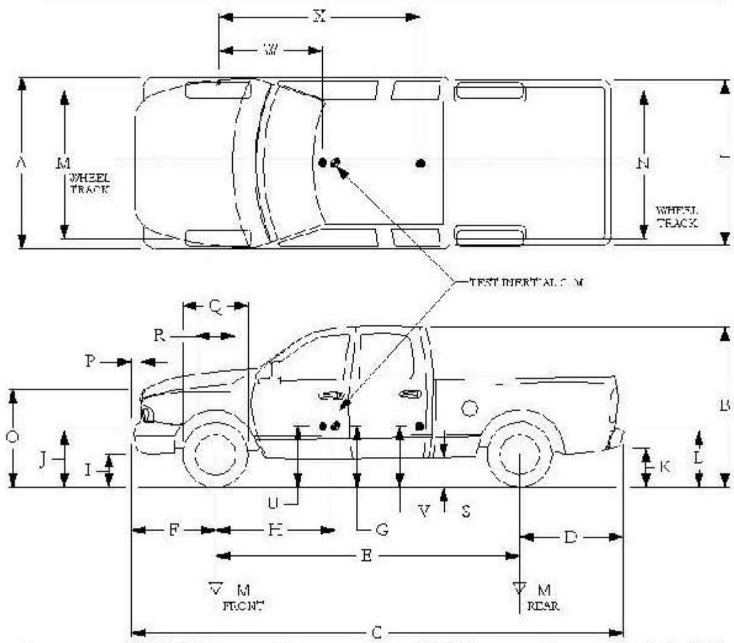
NOTES:

Engine Type: V-8
Engine CID: 4.7 L

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

Optional Equipment:
NONE

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



Geometry: inches

A	78.50	F	40.00	K	20.00	P	3.00	U	26.75
B	74.00	G	28.00	L	30.00	Q	30.50	V	30.75
C	227.50	H	59.30	M	68.50	R	18.00	W	59.30
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	12.00
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	9.25	Bottom Frame Height - Rear	25.50

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}	2979	2940	
Back	3900	M_{rear}	2150	2150	
Total	6700	M_{Total}	5129	5090	

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

Mass Distribution:
lb LF: 1470 RF: 1470 LR: 1120 RR: 1030

Table B.2. Measurements of Vehicle Vertical CG for Test No. 610231-01-1.

Date: 2018-07-12 Test No.: 610231-01-1 VIN: 1C6RR6FT8ES265026

Year: 2014 Make: RAM Model: 1500

Body Style: QUAD CAB Mileage: 166434

Engine: 4.7L V-8 Transmission: AUTO

Fuel Level: EMPTY Ballast: 114 LB (440 lb max)

Tire Pressure: Front: 35 psi Rear: 35 psi Size: 265/70 R 17

Measured Vehicle Weights: (lb)					
LF:	1470	RF:	1470	Front Axle:	2940
LR:	1120	RR:	1030	Rear Axle:	2150
Left:	2590	Right:	2500	Total:	5090
					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:	59.35 inches	Rear of Front Axle	(63 ±4 inches allowed)
Y:	-0.61 inches	Left - Right +	of Vehicle Centerline
Z:	28.00 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 B.3. Exterior Crush Measurements for Test No. 610231-01-1.

Date:	2018-07-12	Test No.:	610231-01-1	VIN No.:	1C6RR6FT8ES265026
Year:	2014	Make:	RAM	Model:	1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	AT FT BUMPER	18	10	34	0	1	3	6	8	10	+12
2	SAME	18	12	48	1	2.5	-	-	10	12	+70
	inches										

[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.

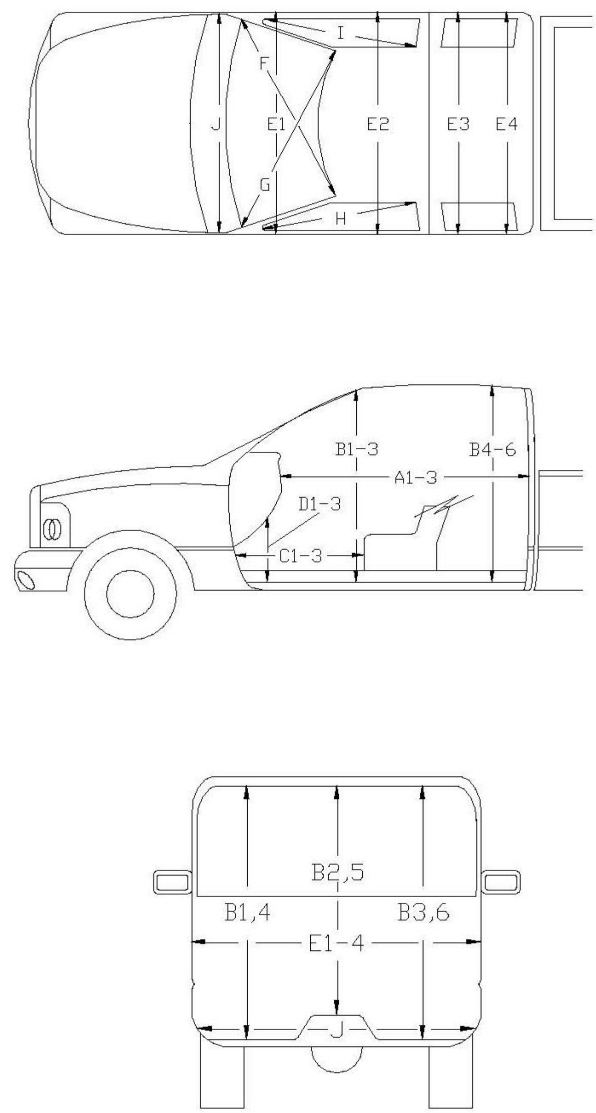
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***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 B.4. Occupant Compartment Measurements for Test No. 610231-01-1.

Date:	2018-07-12	Test No.:	610231-01-1	VIN No.:	1C6RR6FT8ES265026
Year:	2014	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	Differ.
		inches	
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	45.50	0.50
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	22.50	-3.50
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
D3	11.50	12.25	0.75
E1	58.50	59.00	0.50
E2	63.50	63.75	0.25
E3	63.50	63.50	0.00
E4	63.50	63.50	0.00
F	59.00	59.00	0.00
G	59.00	59.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	25.00	24.50	-0.50

B2 SEQUENTIAL PHOTOGRAPHS

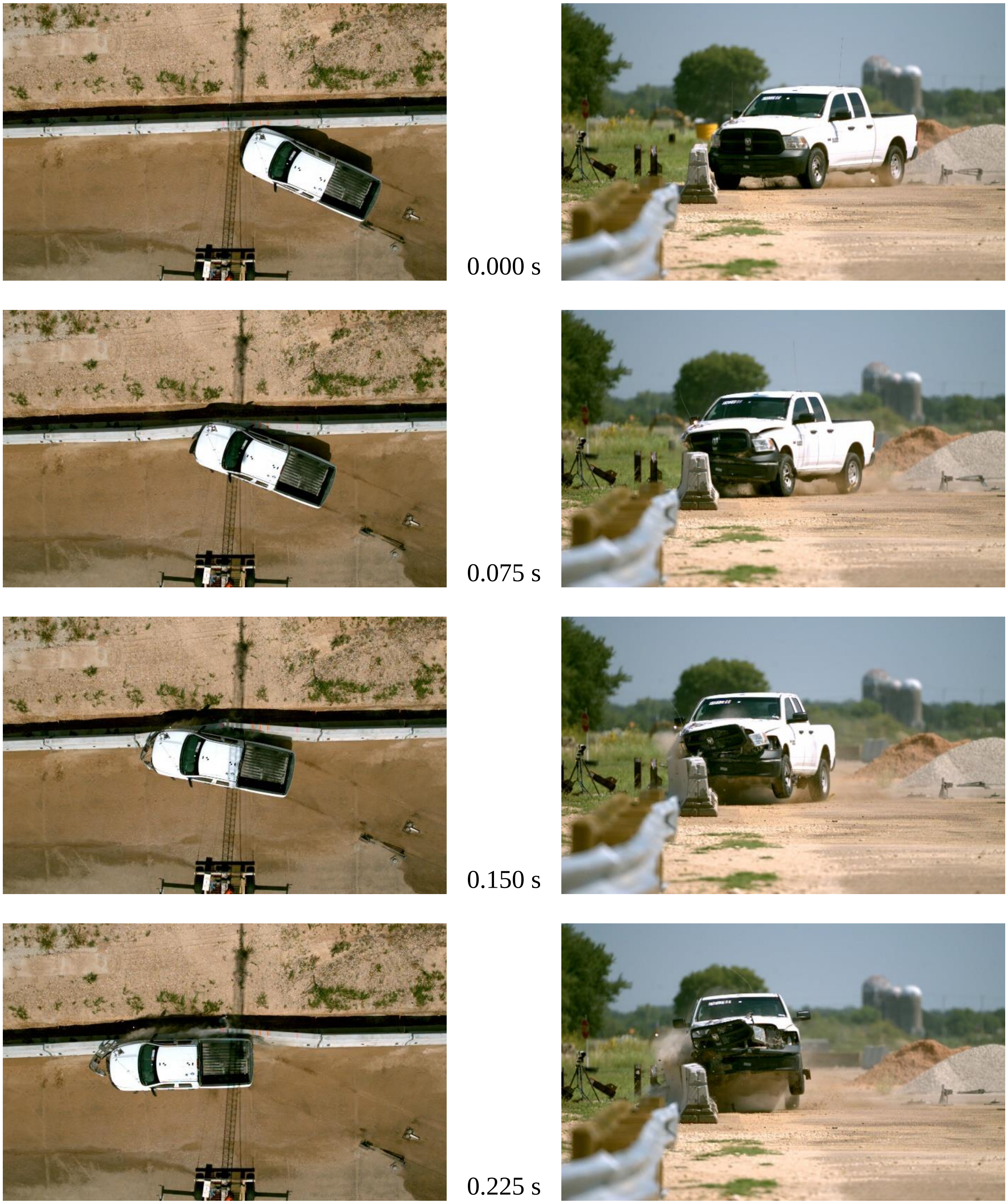
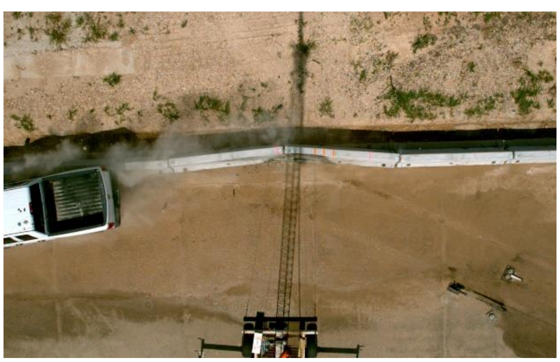


Figure B.1. Sequential Photographs for Test No. 610231-01-1 (Overhead and Frontal Views).

0.300 s

0.375 s

0.450 s



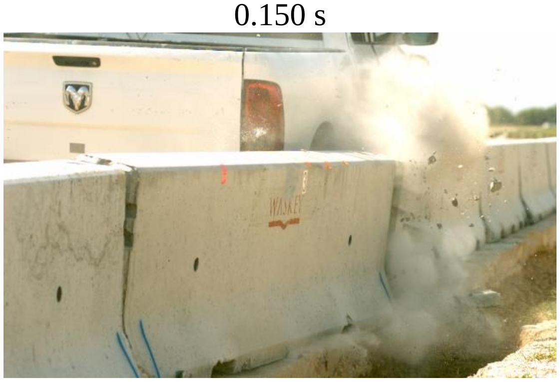
0.525 s

Figure B.1. Sequential Photographs for Test No. 610231-01-1 (Overhead and Frontal Views) (Continued).

0.000 s

0.075 s

0.150 s

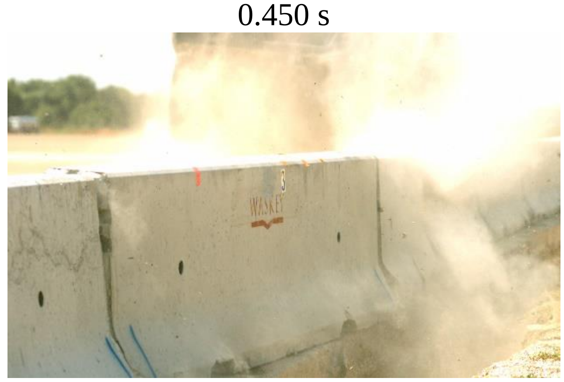


0.225 s

0.300 s

0.375 s

0.450 s



0.525 s

Figure B.2. Sequential Photographs for Test No. 610231-01-1 (Rear View).

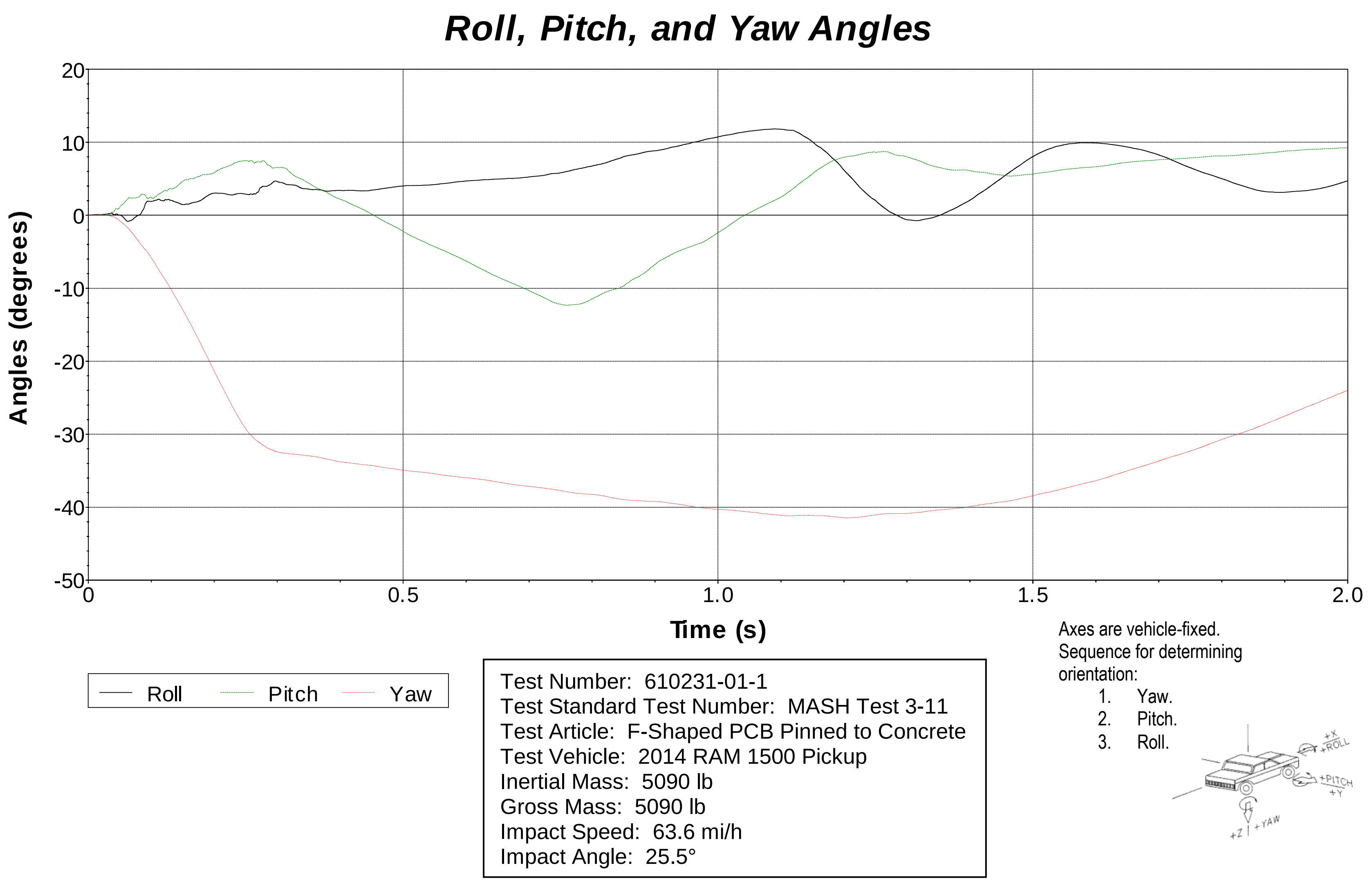


Figure B.3. Vehicle Angular Displacements for Test No. 610231-01-1.

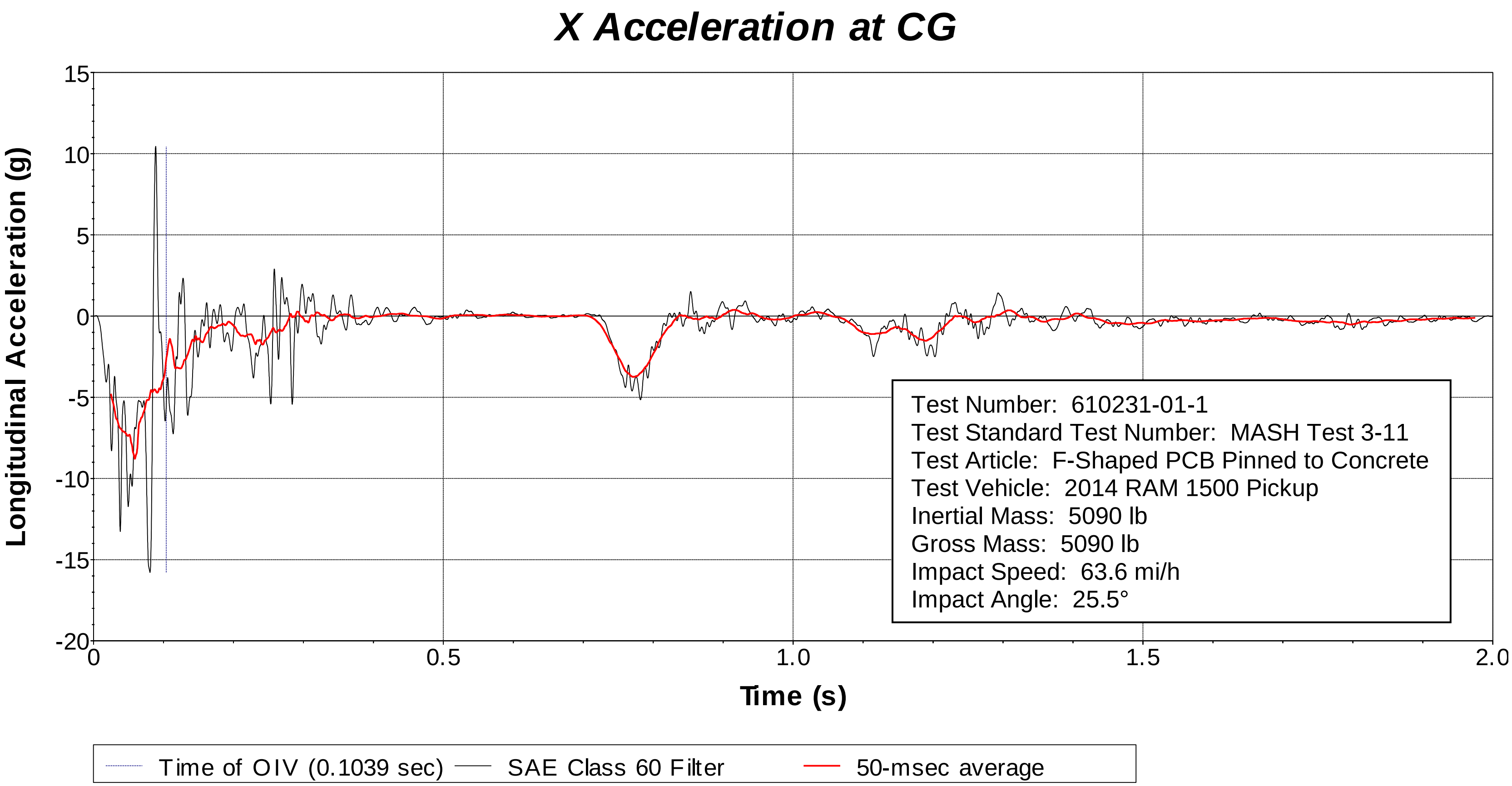


Figure B.4. Vehicle Longitudinal Accelerometer Trace for Test No. 610231-01-1 (Accelerometer Located at Center of Gravity).

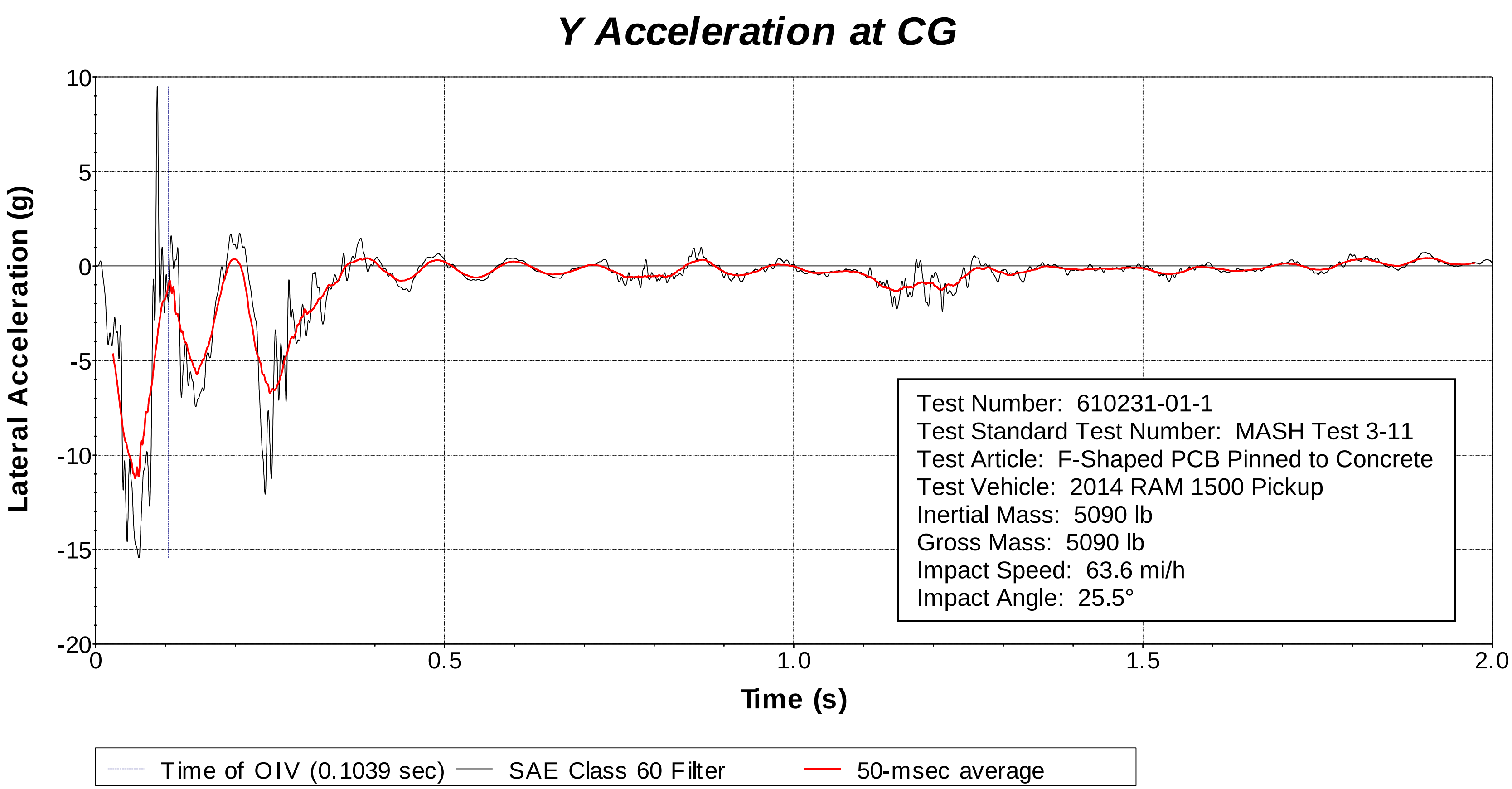


Figure B.5. Vehicle Lateral Accelerometer Trace for Test No. 610231-01-1 (Accelerometer Located at Center of Gravity).

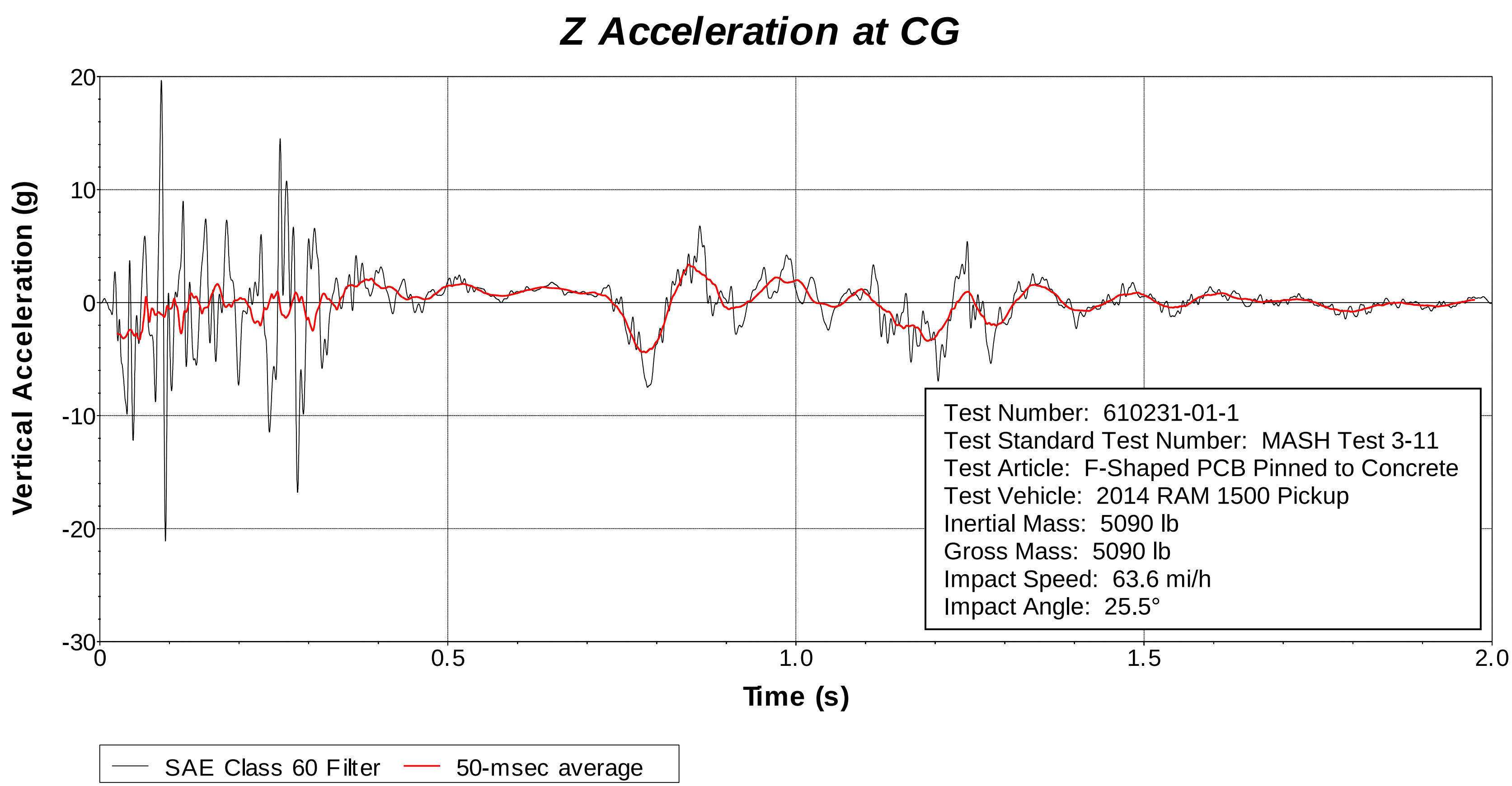


Figure B.6. Vehicle Vertical Accelerometer Trace for Test No. 610231-01-1 (Accelerometer Located at Center of Gravity).

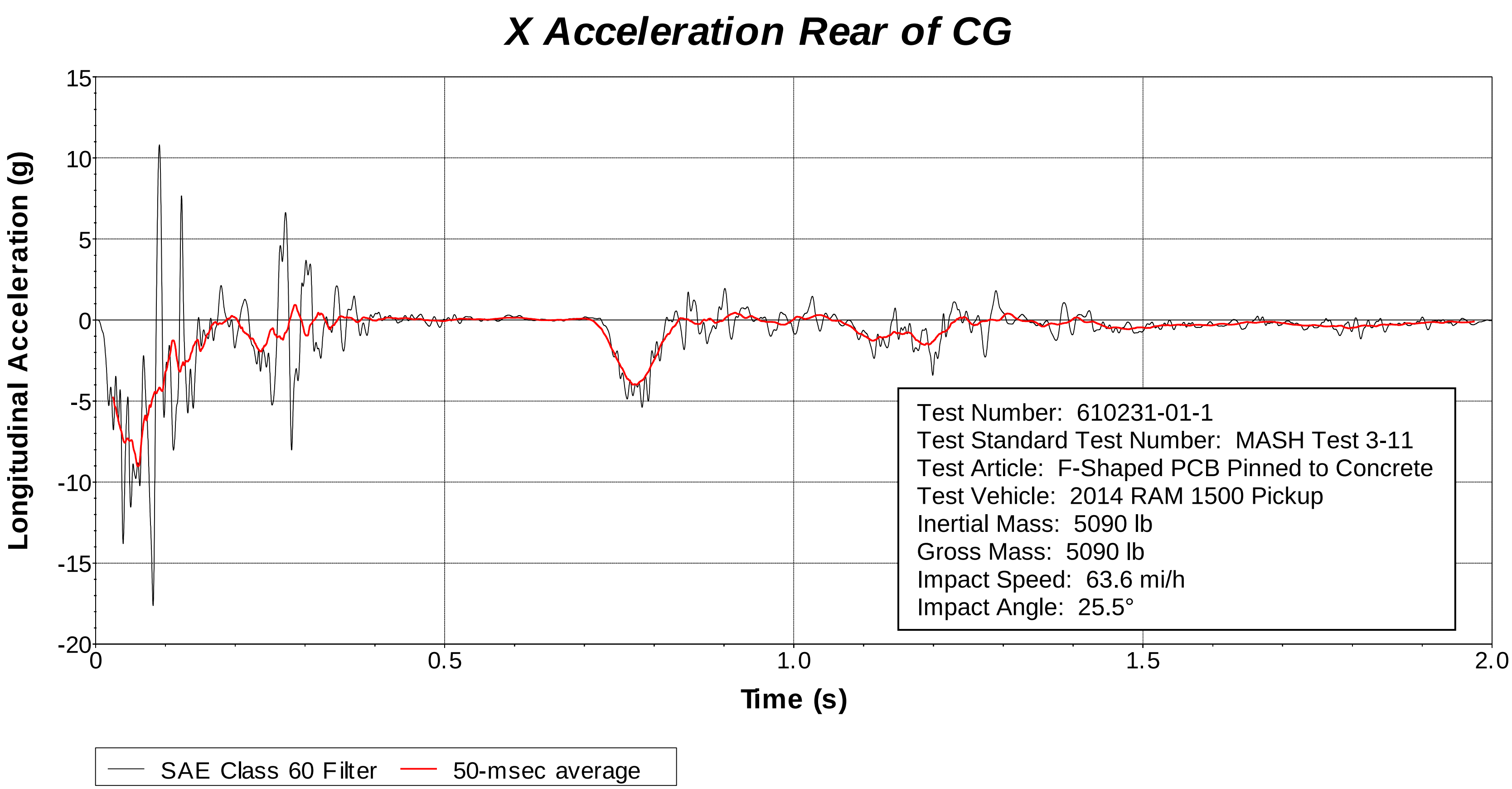


Figure B.7. Vehicle Longitudinal Accelerometer Trace for Test No. 610231-01-1 (Accelerometer Located Rear of Center of Gravity).

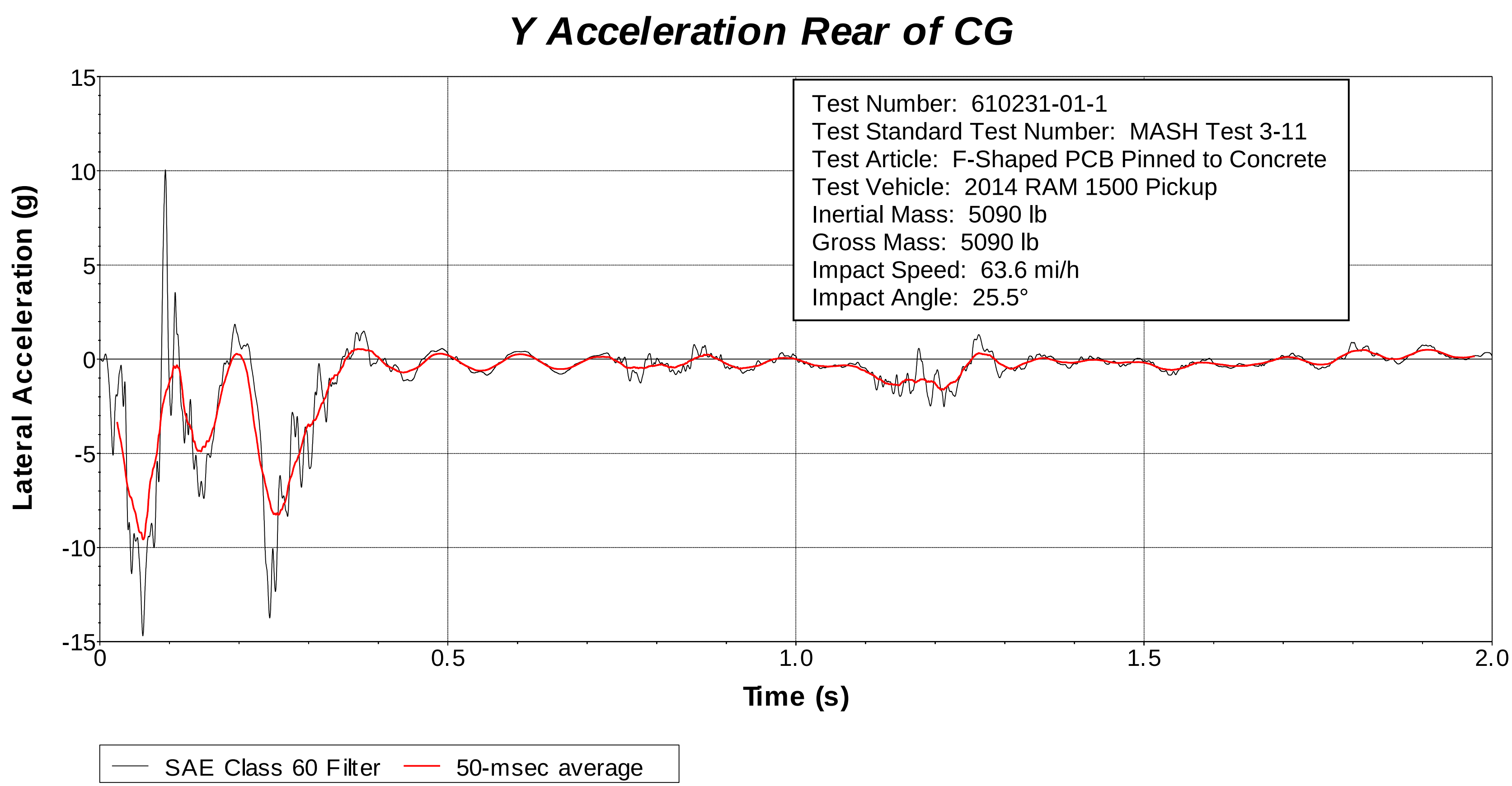


Figure B.8. Vehicle Lateral Accelerometer Trace for Test No. 610231-01-1 (Accelerometer Located Rear of Center of Gravity).

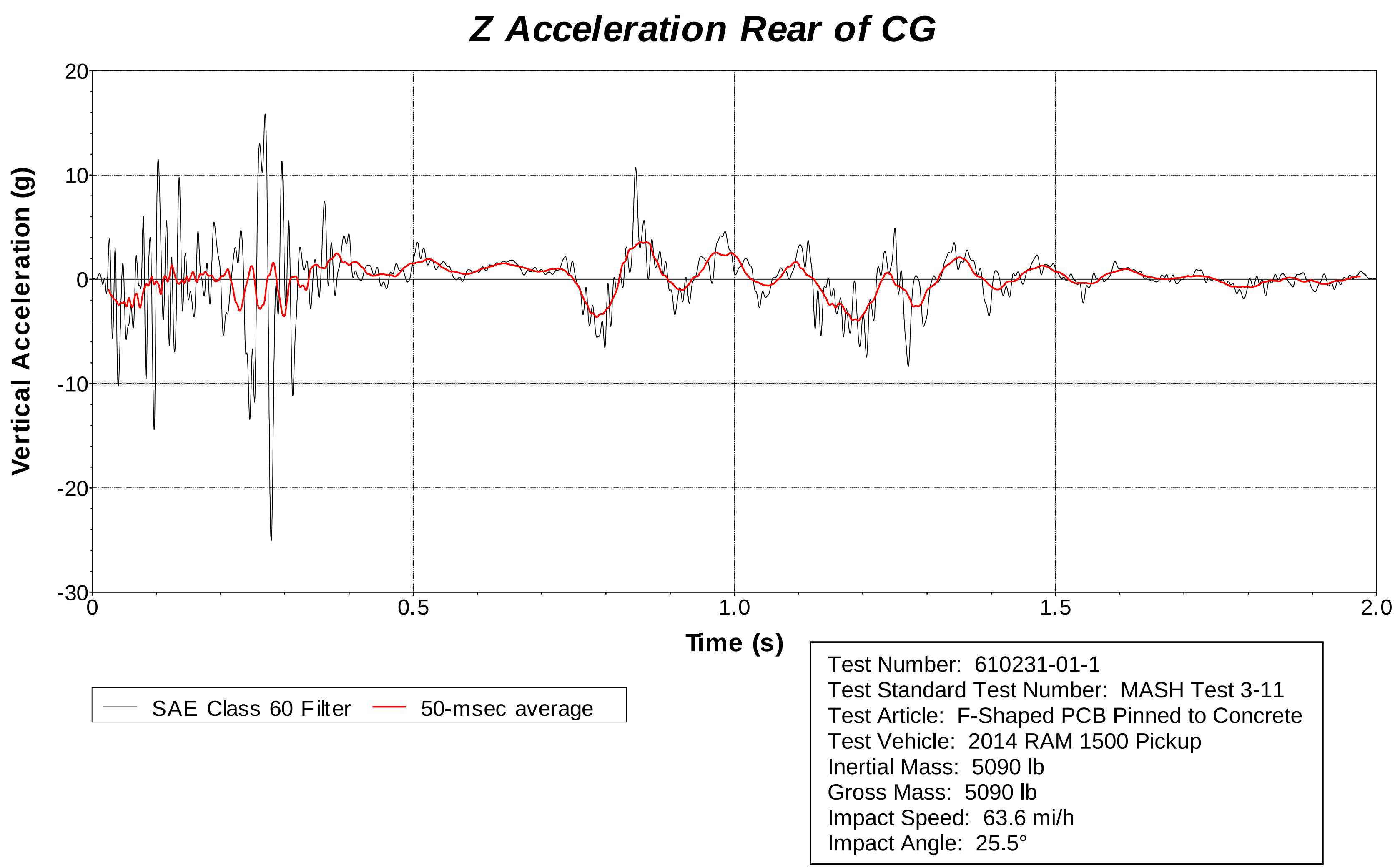


Figure B.9. Vehicle Vertical Accelerometer Trace for Test No. 610231-01-1 (Accelerometer Located Rear of Center of Gravity)