Test Report No. 612051-4
Test Report Date: March 2020

MASH TL-3 FULL SCALE CRASH TESTING AND EVALUATION OF TRANSITION FROM 32-INCH TALL WEAK POST GUARDRAIL SYSTEM TO MGS STRONG POST SYSTEM

by

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Contract No.: 1900856
Test No.: 612051-03-1 & 612051-02-1
Test Date: 2019-10-07 & 2019-11-05

Sponsored by
Roadside Safety Research Program Pooled Fund
Study No. TPF-5(114)

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle *MASH* TL-3 FULL SCALE CRASH TESTING AND EVALUATION OF TRANSITION FROM 32-INCH TALL WEAK POST GUARDRAIL SYSTEM TO MGS STRONG POST SYSTEM		5. Report Date March 2020 6. Performing Organization Code
7. Author(s) Chiara Silvestri Dobrovolny, Nathan D. Schulz, Roger P. Bligh, Wanda L. Menges, Glenn E. Schroeder, and Darrell L. Kuhn		8. Performing Organization Report No. Test Report No. 612051-4
9. Performing Organization Name and Address Texas A&M Transportation Institute Proving Ground 3135 TAMU College Station, Texas 77843-3135		10. Work Unit No. (TRAIS) 11. Contract or Grant No. 1900856
12. Sponsoring Agency Name and Address Washington State Department of Transportation Transportation Building, MS: 47372 Olympia, WA 98504-7372		13. Type of Report and Period Covered Technical Report: October 2018 – February 2020 14. Sponsoring Agency Code

15. Supplementary Notes
Project Title: MASH Full Scale Crash Testing of the Transition from the MGS Weak Post System to the Strong Post MGS System
Name of Contacting Representative: David Kilpatrick, State of Connecticut Department of Transportation

16. Abstract

With the adoption of the AASHTO/FHWA Joint Implementation Agreement for *Manual for Assessing Safety Hardware* (*MASH*) in 2015, originally all transition systems for projects on the National Highway System advertised for construction after December 31, 2019 must have been evaluated using the 2016 edition of *MASH*. At a later date, the original agreement was modified to allow States to specify *MASH* 2009-compliance of *NCHRP Report 350*-compliant devices for cases where the State is awaiting completion of *MASH*-2016 testing for a specific device, among other limited situations.Those transitions that have not been evaluated in accordance with *MASH* by that time will not be allowed for use on the NHS. In order to comply with this requirement, Connecticut Department of Transportation (CTDOT) proposed to review and crash test a guardrail transition from a 32-inch weak post guardrail system to the 31-inch strong post MGS (with 8-inch blockouts) according to the new *MASH* requirements.

The research objectives were to:

1. Develop a design for a guardrail transition from a 32-inch weak post guardrail system to the 31-inch strong post MGS (with 8-inch wood blockouts),
2. Perform full-scale *MASH* Tests 3-21 and 3-20 on the proposed transition system, and
3. Evaluate the performance of the proposed transition system per required *MASH* evaluation criteria.

This report provides details of a guardrail transition from a 32-inch MGS weak post system to the MGS strong post system, detailed documentation of the crash tests and results, and an assessment of the performance of the transition for *MASH* Test Level 3 (TL-3) transition evaluation criteria.

The guardrail transition from a 32-inch MGS weak post system to the MGS strong post system met the performance criteria for a *MASH* TL-3 transition.

17. Key Words	18. Distribution Statement
Longitudinal barrier, transition, guardrail, strong post, weak post, crash testing, roadside safety, MASH, Test Level 3	Copyrighted. Not to be copied or reprinted without consent from the Roadside Safety Research Pooled Fund.

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	106	

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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

ACKNOWLEDGMENTS

This research project was performed under a pooled fund program between the following States and Agencies. The authors acknowledge and appreciate their guidance and assistance.

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1.1 PROBLEM

With the adoption of the American Association of State Highway Transportation Officials (AASHTO)/Federal Highway Administration (FHWA) Joint Implementation Agreement for *Manual for Assessing Safety Hardware* (*MASH*) in 2015, originally all transition systems for projects on the National Highway system (NHS) advertised for construction after December 31, 2019 must have been evaluated using the 2016 edition of *MASH*. *(1, 2)* At a later date, the original agreement was modified to allow States to specify *MASH* 2009-compliance of National Cooperative Highway Research Program (NCHRP) *Report 350*-compliant devices for cases where the State is awaiting completion of *MASH*-2016 testing for a specific device, among other limited situations. In order to comply with this requirement, Connecticut Department of Transportation (CTDOT) proposed to review and crash test a guardrail transition from a 32-inch weak post guardrail system to the 31-inch strong post MGS (with 8-inch blockouts) according to the new *MASH* requirements.

1.2 BACKGROUND

The Pennsylvania DOT (PennDOT) G2 weak post W-Beam guardrail system was tested in 2009 with *MASH* Test 3-11 (2270P test), and in 2017 with *MASH* 2016 Test 3-10 (1100C test). (*3*, *4*) The system was comprised of a 32-inch tall W-beam guardrail system utilizing PennDOT Type 2-W S3×5.7 guardrail posts, each 63 inches in length, with a ¼–inch × 8-inch × 24-inch soil plate on posts within the length of need (LON). Posts within the LON were equally spaced at 12 ft-6 inches. Standard 12-gauge W-beam guardrail was used in the system.

The PennDOT G2 weak post W-Beam system met the crash test and evaluation criteria of the AASHTO's *MASH* and was issued FHWA Eligibility Letter B-305, based on the review of the crash test results and certifications submitted.

CTDOT was interested in including this guardrail system within its standards as an available roadside safety system. The CTDOT's safety engineers have been encouraging deployment of flexible roadside safety devices to reduce the crash severity level of injuries. However, prior to adding this system to the CTDOT standards, it was necessary to have a *MASH* compliant transition system from the MGS weak post system to the MGS strong post (with 8-inch deep wood blockouts) guardrail.

When implemented in field, all W-beam end terminals and bridge transitions attach to a strong post MGS guardrail system. Therefore, any time a weak post guardrail system is installed it will need to transition to a strong post system. Therefore, there was an urgent need to develop and evaluate a *MASH*-approved transition guardrail system that would safely allow transitioning from a weak post MGS system to a strong post MGS system.

CTDOT already has details for a guardrail system to transition from a 32-inch weak post to a 28-inch strong post guardrail system. However, CTDOT proposed to conduct a research and testing study to review and update system details to allow for MGS compatibility and guardrail height preferences.

1.3 OBJECTIVE

The research objectives were to

1. Develop a design for a guardrail transition from a 32-inch weak post guardrail system to the 31-inch strong post MGS (with 8-inch wood blockouts),
2. Perform full-scale *MASH* Tests 3-21 and 3-20 on the proposed transition system, and
3. Evaluate the performance of the proposed transition system per required *MASH* evaluation criteria.

This report provides details of a guardrail transition from the 32-inch tall MGS weak post system to the MGS strong post system, detailed documentation of the crash tests and results, and an assessment of the performance of the transition for *MASH* Test Level 3 (TL-3) transition evaluation criteria.

Chapter 2. SYSTEM DETAILS

2.1. TEST ARTICLE AND INSTALLATION DETAILS

The test installation consisted of a weak post section, a strong post section, a transition section between the weak and strong post sections, and a terminal on each end. Posts in the weak post section (posts 3 through 14) were 32 inches to the top of the W-beam. Posts in the strong post section (posts 21 through 32) were 31 inches to the top of the W-beam. The transition section of the guardrail was between posts 14 and 21.

Posts 3 through 19 were 5-ft 5-inch long S3×5.7 weak posts (PSE03), embedded 33 inches deep into the soil.

Posts 20 through 32 were 6-ft long W6×8.5 strong posts (PWE01), embedded 40 inches deep into the soil. Nominally 8-inch deep timber blockouts (PDB-01b) were installed using 10-inch long guardrail bolts and recessed guardrail nuts (FBB03).

A Texas Department of Transportation (TxDOT) downstream anchor terminal (DAT) [GF (31) DAT-14], 9 ft-4½ inches long, was installed on each end (i.e. Posts 1 and 2 and Posts 33 and 34)

The total installation length was 265 ft-7½ inches. Post spacing was as follows: Posts 3 to 14 at 12 ft-6 inches (150 inches); Posts 14-15-16 at 75 inches; Posts 16 to 20 at 37½ inches; and Posts 20 to 32 at 75 inches.

Standard 12-gauge, 2-space W-beam guardrail (type RWM02a) was connected to posts 3 through 13. A section of standard 12-gauge W-beam guardrail measuring 9 ft-4½ inches long was connected to post 14. Standard 12-gauge, 4-space W-beam guardrail (type RWM04a) was connected to posts 15 through 32. W-beam rail joints were between posts, with the exception of post 17.

The posts were installed in drilled holes that were backfilled and compacted with soil meeting Grading B of AASHTO standard specification M147-65(2004) "*Materials for Aggregate and Soil Aggregate Subbase, Base and Surface Courses*" (see Section 2.4).

Figure 2.1 presents overall information on the guardrail transition from the 32-inch tall weak post guardrail system to the MGS strong post system, and Figures 2.2 through 2.4 provide photographs of the installation. Appendix A provides further details of the transition section.

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 install/construct the guardrail transition from a 32-inch tall weak post guardrail system to the MGS strong post system.

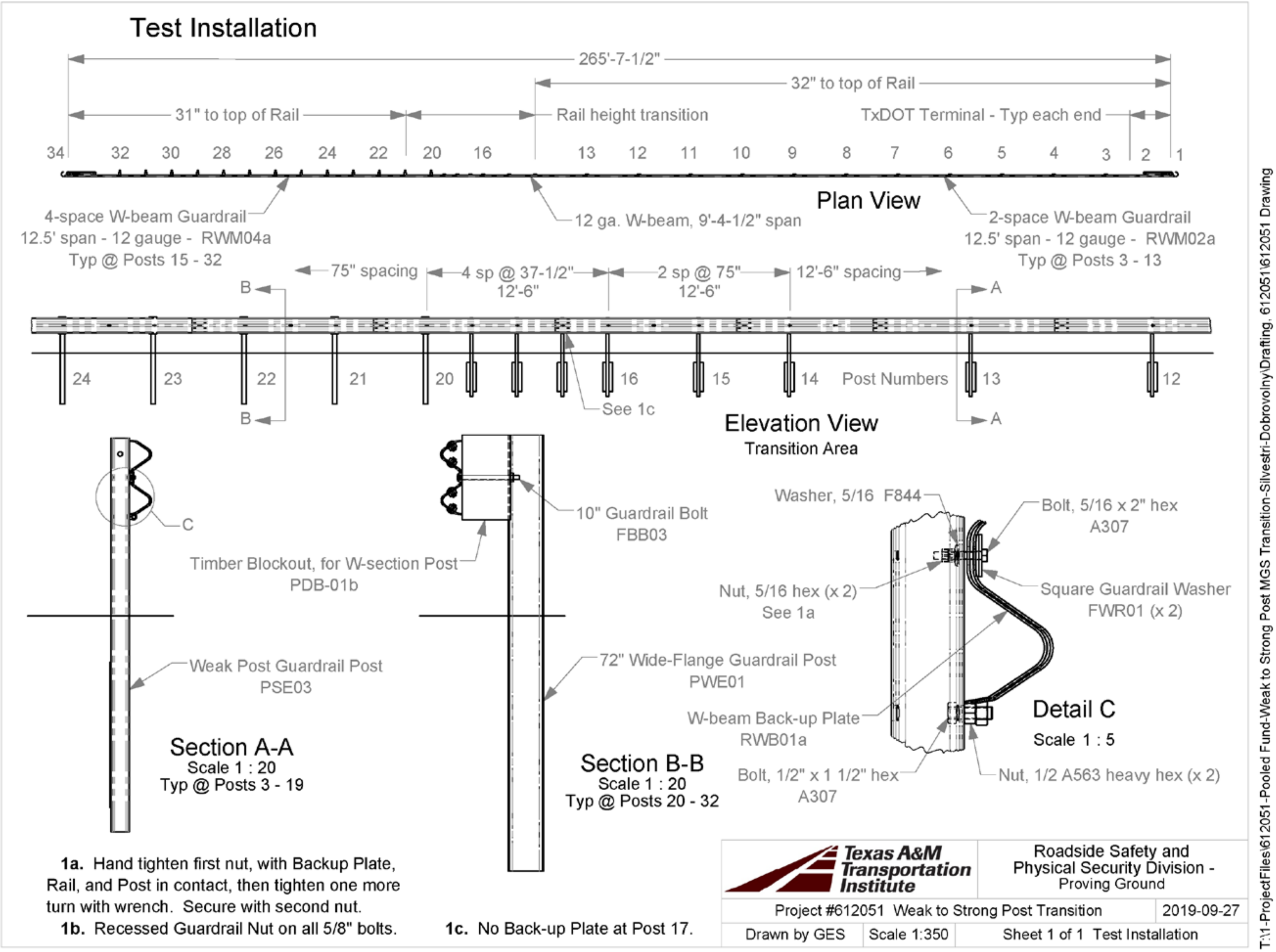

Figure 2.1. Details of Guardrail Transition from 32-inch Tall MGS Weak Post System to MGS Strong Post System.

Figure 2.2. Guardrail Transition from 32-inch Tall MGS Weak Post System to MGS Strong Post System prior to Testing.

Figure 2.3. Transition prior to Testing.

Figure 2.4. MGS Strong Post System prior to Testing.

2.4. SOIL CONDITIONS

In accordance with Appendix B of *MASH*, soil strength was measured the day of the crash test. During installation of the transition for full-scale crash testing, two 6-ft long W6×16 posts were installed in the immediate vicinity of the transition using the same fill materials and installation procedures used in the test installation and the standard dynamic test. Table C.1 in Appendix C presents minimum soil strength properties established through the dynamic testing performed in accordance with *MASH* Appendix B (*2*).

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 (90 percent of static load for the initial standard installation).

On the day of the first test (612051-03-1), October 7, 2019, measured loads on the post at deflections of 5 inches, 10 inches, and 15 inches were 10,499 lbf, 9569 lbf, and 8674 lbf. On the day of the second test (612051-02-1), November 5, 2019, loads on the post at deflections of 5 inches, 10 inches, and 15 inches were 10,567 lbf, 10,877 lbf, and 10,808 lbf.

Tables C.2 and C.3 in Appendix C show that the strength of the backfill material, in which the transition was installed, met minimum *MASH* requirements.

Chapter 3. TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1. CRASH TEST PERFORMED / MATRIX

Table 3.1 shows the test conditions and evaluation criteria required by *MASH* TL-3 for transitions. The critical impact points (CIPs) of the transition were determined using BARRIER VII simulations. BARRIER VII is a program developed for predicting deflections of barriers. Computer simulations were performed with BARRIER VII by varying impact locations along the barrier for the 1100C impact and 2270P impact. The selected CIPs were the impact locations that resulted in the highest deflection of the barrier and the highest tension in the barrier rail. Figures 3.1 and 3.2 show the proposed target CIPs for each test.

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

Test Article	Test Designation	Test Vehicle	Impact Conditions		Evaluation Criteria
			Speed	Angle	
Transition	3-20 (optional test)	1100C	62 mi/h	25°	A, D, F, H, I (see Table 3.3)
	3-21	2270P	62 mi/h	25°	A, D, F, H, I (see Table 3.3)

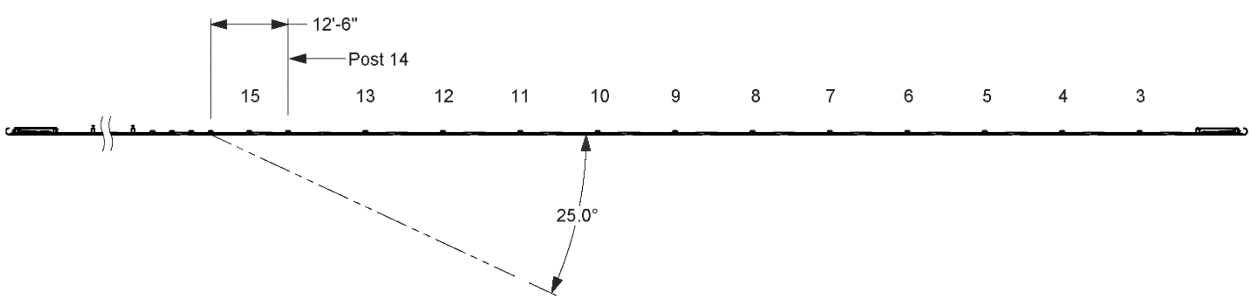

Figure 3.1. Target CIP for *MASH* Test 3-20 on Guardrail Transition from 32-inch tall MGS Weak Post Guardrail System to MGS Strong Post System.

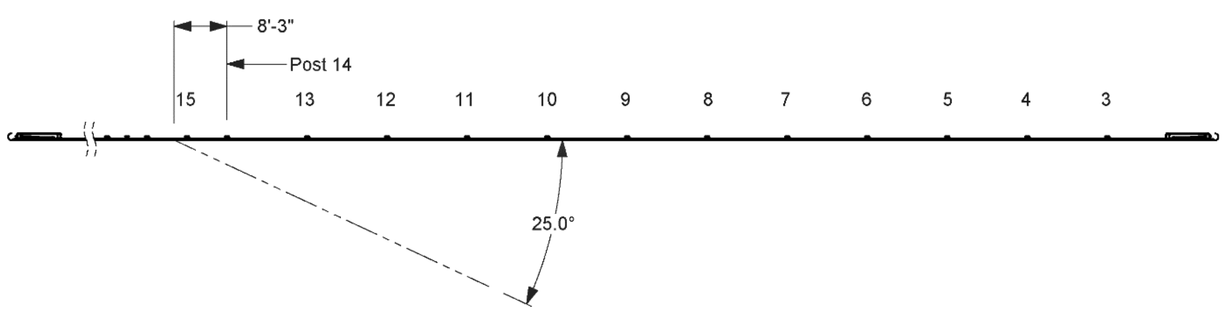

Figure 3.2. Target CIP for *MASH* Test 3-21 on Guardrail Transition from 32-inch tall MGS Weak Post System to MGS Strong Post System.

Consideration was also given to the reverse direction impact. The worst-case scenario impact for Tests 3-10 and 3-11 were compared for the impact direction shown in Figures 3.1 and 3.2 and the reverse direction impact. Table 3.2 compares the maximum deflection, rail tension, and vehicle pocketing values from the critical computer simulations. Based on the results observed in the computer simulations, the reverse direction impact was determined to be non-critical and crash tests were not needed to evaluate the system in the opposite impact direction.

Table 3.2. Barrier VII Computer Simulation Primary and Reverse Direction Comparison.

	Maximum Deflection (inches)	Maximum Tension (kips)	Vehicle Pocketing Angle (rad.)
Primary Impact Direction			
Test 3-10	38.1	74.5	0.18
Test 3-11	62.4	89.8	0.17
Reverse Direction			
Test 3-10	33.4	73.8	0.17
Test 3-11	48.9	89.7	0.17

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

3.2. EVALUATION CRITERIA

The appropriate safety evaluation criteria from Tables 2-2 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 transitions are listed in Table 3.1, and the substance of the evaluation criteria in Table 3.3. An evaluation of the crash test results is presented in detail under the section Assessment of Test Results.

Table 3.3. Evaluation Criteria Required for *MASH* TL-3 Transitions.

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.

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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 transition 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 (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

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 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 transition. The flashbulb was visible from each camera. The video files from these digital high-speed cameras were analyzed to observe phenomena occurring during the collision and to obtain time-event, displacement, and angular data. A digital camera recorded and documented conditions of each test vehicle and the installation before and after the test.

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Chapter 5. *MASH* TEST 3-21 (CRASH TEST NO. 612051-02-1)

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 transition at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 25° ±1.5°. The CIP for *MASH* Test 3-21 on the guardrail transition from the 32-inch tall MGS weak post system to the MGS strong post system was 8.3 ft ±1 ft downstream of post 14 (see Figures 3.2 and 5.1).

Figure 5.1. Transition/Test Vehicle Geometrics for Test No. 612051-02-1.

The 2014 RAM 1500 pickup truck used in the test weighed 5005 lb, and the actual impact speed and angle were 63.2 mi/h and 25.3°. The actual impact point was 8.3 ft downstream of post 14. Minimum target IS was 106 kip-ft, and actual IS was 122 kip-ft.

5.2 WEATHER CONDITIONS

The test was performed on the morning of November 5, 2019. Weather conditions at the time of testing were as follows: wind speed: 1 mi/h; wind direction: 175° (vehicle was traveling at magnetic heading of 205°); temperature: 75°F; relative humidity: 87 percent.

5.3 TEST VEHICLE

Figure 5.2 shows the 2014 RAM 1500 pickup truck used for the crash test. The vehicle's test inertia weight was 5005 lb, and its gross static weight was 5005 lb. The height to the lower edge of the vehicle bumper was 11.75 inches, and height to the upper edge of the bumper was 27.0 inches. The height to the vehicle's center of gravity was 28.1 inches. Tables D.1 and D.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 5.2. Test Vehicle before Test No. 612051-02-1.

5.4 TEST DESCRIPTION

Table 6.1 lists events that occurred during Test No. 612051-02-1. Figures D.1 and D.2 in Appendix D2 present sequential photographs during the test.

Table 5.1. Events during Test No. 612051-02-1.

TIME (s)	EVENTS
0.000	Vehicle contacts transition traveling at 63.2 mi/h and 25.3°
0.016	Post 15 and 16 begin to deflect toward field side
0.029	Post 17 begins to deflect toward field side
0.035	Post 18 begins to deflect toward field side
0.062	Vehicle begins to redirect
0.241	Rail element releases from post 15
0.266	Vehicle traveling parallel with transition barrier
0.279	Rail element released form post 14
0.724	Vehicle loses contact with transition barrier while traveling at 35.5 mi/h with a heading of 12.3° and a trajectory of 19.5°

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 2.3 s after impact, and the vehicle subsequently came to rest 193 ft downstream of the impact and 37 ft toward traffic lanes.

5.5 DAMAGE TO TEST INSTALLATION

Figures 5.3 through 5.7 show the damage to the transition. There was a ½ inch gap in the soil at the upstream side of post 1 and the rail was pulled down 3 inches from its original height. The soil was disturbed around post 2 and the rail was released from the post. Posts 3 through 6 were leaning downstream 87° from vertical. Posts 7 and 8 were leaning downstream 86° from vertical. Posts 9, 10, 11, and 12 were leaning 85° downstream from vertical. Post 13 was leaning at 77° downstream and 80° toward the field side from vertical. Post 14 was leaning 65° downstream and back toward the field side from vertical. Post 15 was leaning 56° downstream and rotated toward the field side from vertical. Posts 16 through 22 were leaning downstream and toward the field side at 24° from vertical. There was slight soil disturbance at post 34. The rail released from posts 10 through 23. The rail element had a partial tear on the field side of the splice between posts 20 and 21.

Working width* was 65.5 inches, and height of working width was 54.2 inches. Maximum dynamic deflection during the test was 57.2 inches, and maximum permanent deformation was 31.0 inches.

Figure 5.3. Transition after Test No. 612051-02-1.

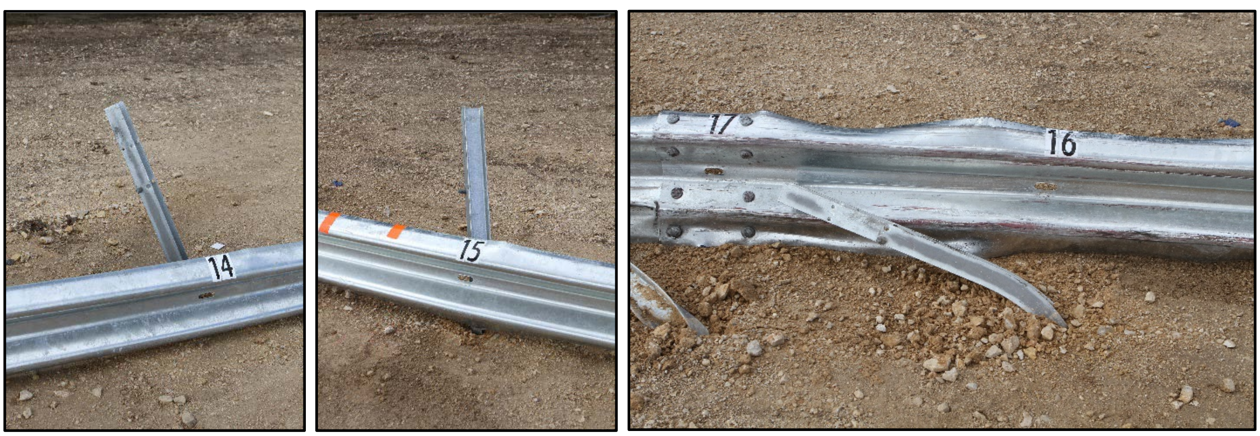


Figure 5.4. Posts 14 through 16 after Test No. 612051-02-1.

* Working width is measured from the pre-impact traffic-side face of the barrier. It includes the total barrier width plus the maximum intrusion of any significant portion of the barrier or test vehicle past the field side edge of the barrier.

Figure 5.5. Posts 17 and 18 after Test No. 612051-02-1.

Figure 5.6. Posts 19 through 25 after Test No. 612051-02-1.

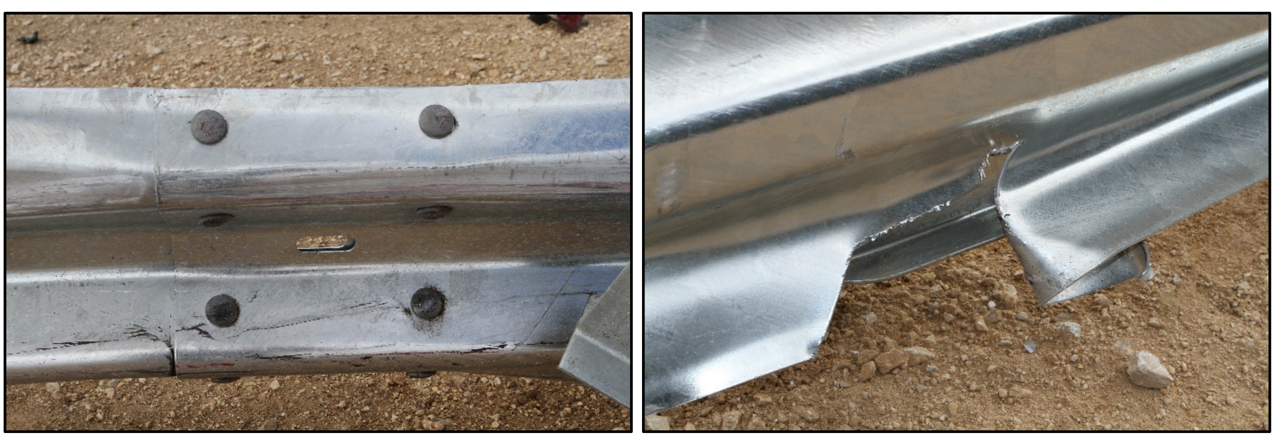


Figure 5.7. Partial Tear of Rail Element after Test No. 612051-02-1.

5.6 VEHICLE DAMAGE

Figure 5.8 shows the damage sustained by the vehicle. The front bumper, grill, right front tire, right front fender, right front and rear doors, right lower cab corner, right rear exterior bed, and rear bumper were damaged. No fuel tank damage was observed. Maximum exterior crush to the vehicle was 9.0 inches in the front and side planes at the right front corner at bumper height. No occupant compartment deformation or intrusion was observed. Figure 5.9 shows the interior of the vehicle. Tables D.3 and D.4 in Appendix D1 provide exterior crush and occupant compartment measurements.

Figure 5.8. Test Vehicle after Test No. 612051-02-1.

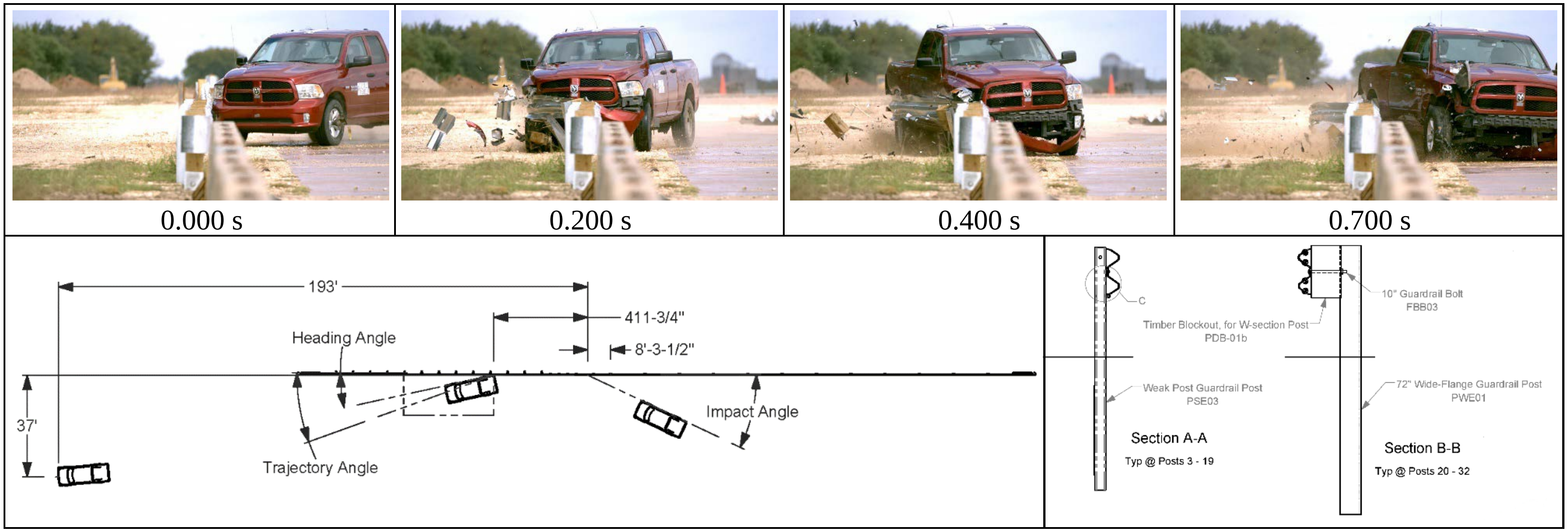
Figure 5.9. Interior of Test Vehicle after Test No. 612051-02-1.

5.7 OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 5.2. Figure D.3 in Appendix D3 shows the vehicle angular displacements, and Figures D.4 through D.6 in Appendix D4 show acceleration versus time traces. Figure 6.10 summarizes pertinent information from the test.

Table 5.2. Occupant Risk Factors for Test No. 612051-02-1.

Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV)		
Longitudinal	**15.7 ft/s**	at 0.1638 s on right side of interior
Lateral	**15.4 ft/s**	
Occupant Ridedown Accelerations		
Longitudinal	**6.1 g**	0.4128 - 0.4228 s
Lateral	**6.5 g**	0.2710 - 0.2810 s
Theoretical Head Impact Velocity (THIV)	**23.4 km/h**	at 0.1568 s on right side of interior
Acceleration Severity Index (ASI)	**0.65**	0.2827 - 0.3327 s
Maximum 50-ms Moving Average		
Longitudinal	**-4.1 g**	0.1108 - 0.1608 s
Lateral	**-5.5 g**	0.2533 - 0.3033 s
Vertical	**1.5 g**	0.4248 - 0.4748 s
Maximum Roll, Pitch, and Yaw Angles		
Roll	**5°**	0.6906 s
Pitch	**2°**	0.4455 s
Yaw	**41°**	0.4990 s



General Information
- Test Agency: Texas A&M Transportation Institute (TTI)
- Test Standard Test No.: MASH Test 3-21
- TTI Test No.: 612051-02-1
- Test Date: 2019-11-05

Test Article
- Type: Transition
- Name: Transition from 32-inch weak post MGS to strong post MGS system
- Installation Length: 265 ft-7 ½ inches
- Material or Key Elements: W-Beam guardrail with posts 3 through 19 5-ft-5-inch, S3×5.7 weak post guardrail posts 33 inches deep and posts 20 through 32 6-ft W6×8.5 guardrail posts 41 inches deep

Soil Type and Condition: AASHTO M147-65(2004), grading B Soil (crushed limestone), Dry

Test Vehicle
- Type/Designation: 2270P
- Make and Model: 2014 RAM 1500 pickup
- Curb: 4958 lb
- Test Inertial: 5005 lb
- Dummy: No dummy
- Gross Static: 5005 lb

Impact Conditions
- Speed: 63.2 mi/h
- Angle: 25.3°
- Location/Orientation: 8.3 ft upstream of post 14

Impact Severity: 122 kip-ft

Exit Conditions
- Speed: 35.5 mi/h
- Trajectory/Heading Angle: 19.5° / 12.3°

Occupant Risk Values
- Longitudinal OIV: 15.7 ft/s
- Lateral OIV: 15.4 ft/s
- Longitudinal Ridedown: 6.1 g
- Lateral Ridedown: 6.5 g
- THIV: 23.4 km/h
- ASI: 0.65
- Max. 0.050-s Average
  - Longitudinal: -4.1 g
  - Lateral: -5.5 g
  - Vertical: 1.5 g

Post-Impact Trajectory
- Stopping Distance: 193 ft downstream, 37 ft twd traffic lanes

Vehicle Stability
- Maximum Yaw Angle: 41°
- Maximum Pitch Angle: 2°
- Maximum Roll Angle: 5°
- Vehicle Snagging: No
- Vehicle Pocketing: No

Test Article Deflections
- Dynamic: 57.2 inches
- Permanent: 31.0 inches
- Working Width: 65.5 inches
- Height of Working Width: 54.2 inches

Vehicle Damage
- VDS: 01RFQ3
- CDC: 01FREW3
- Max. Exterior Deformation: 9.0 inches
- OCDI: FR0000000
- Max. Occupant Compartment Deformation: None

Figure 5.10. Summary of Results for *MASH* Test 3-21 on Guardrail Transition from 32-inch Tall MGS Weak Post System to the MGS Strong Post System.

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Chapter 6. *MASH* TEST 3-20 (CRASH TEST NO. 612051-03-1)

6.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

MASH Test 3-20 involves an 1100C vehicle weighing 2420 lb ±55 lb impacting the CIP of the transition at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 25° ±1.5°. The CIP for *MASH* Test 3-20 on the guardrail transition from the 32-inch tall MGS weak post system to the MGS strong post system was 12.5 ft ±1 ft downstream of post 14 (see Figures 3.1 and 6.1).

Figure 6.1. Transition/Test Vehicle Geometrics for Test No. 612051-03-1.

The 2009 Kia Rio[*] used in the test weighed 2426 lb, and the actual impact speed and angle were 62.6 mi/h and 25.0°. The actual impact point was 12.3 ft downstream of post 14. Minimum target impact severity (IS) was 51 kip-ft, and actual IS was 57 kip-ft.

6.2 WEATHER CONDITIONS

The test was performed on the morning of October 7, 2019. Weather conditions at the time of testing were as follows: wind speed: 8 mi/h; wind direction: 346° (vehicle was traveling at magnetic heading of 205°); temperature: 72°F; relative humidity: 71 percent.

6.3 TEST VEHICLE

Figure 6.1 shows the 2009 Kia Rio used for the crash test. The vehicle's test inertia weight was 2426 lb, and its gross static weight was 2591 lb. The height to the lower edge of the vehicle bumper was 7.75 inches, and height to the upper edge of the bumper was 21.5 inches. Table E.1 in Appendix E1 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.

[*] 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 6.2. Test Vehicle before Test No. 612051-03-1.

6.4 TEST DESCRIPTION

Table 6.1 lists events that occurred during Test No. 612051-03-1. Figures E.1 and E.2 in Appendix E2 present sequential photographs during the test.

Table 6.1. Events during Test No. 612051-03-1.

TIME (s)	EVENTS
0.0000	Vehicle contacts transition traveling at 62.6 mi/h and 25.0°
0.0070	Post 16 and 17 begin to deflect toward field side
0.0150	Right front tire contacts post 16
0.0190	Post 15 and 18 begin to deflect toward field side
0.0340	Post 19 begins to rotate and deflect toward field side
0.0400	Vehicle begins to redirect
0.0460	Post 20 begins to rotate and deflect toward field side
0.1230	Right front tire leaves the ground
0.1780	Right rear tire leaves the ground
0.2720	Vehicle traveling parallel with test article
0.5110	Vehicle loses contact with transition barrier while traveling 28.9 mi/h, trajectory of 16.5°, and heading of 11.3°

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 not applied until the vehicle exited the test side. The vehicle subsequently came to rest 155 ft downstream of the impact and 92 ft toward traffic lanes.

6.5 DAMAGE TO TEST INSTALLATION

Figure 6.3 shows the damage to the transition. The soil was disturbed around post 1, and it was pulled downstream 0.125 inches at ground level. The rail sustained a partial tear at the bolt at post 2. The rail element released from posts 15 through 21, and the blockouts released from posts 20 and 21. Posts 7 through 14 were leaning downstream between 86 and 88.6°. Post 15 was leaning toward the field side at 83.7°, posts 16 through 21 were leaning toward the field side at approximately 5° and downstream approximately 20°, and post 22 was leaning toward the downstream at 86.6°. Working width[*] was 37.9 inches, and height of working width was 40.0 inches. Maximum dynamic deflection during the test was 34.9 inches, and maximum permanent deformation was 27.0 inches.

Figure 6.3. Transition after Test No. 612051-03-1.

[*] Working width is measured from the pre-impact traffic-side face of the barrier. It includes the total barrier width plus the maximum intrusion of any significant portion of the barrier or test vehicle past the field side edge of the barrier.

6.6 VEHICLE DAMAGE

Figure 6.4 shows the damage sustained by the vehicle. The front bumper, radiator and support, right front tire and rim, right front floor pan, right front strut and tower, right front fender, right front and rear doors, and right rear quarter panel were damaged. No fuel tank damage was observed. Maximum exterior crush to the vehicle was 10.0 inches in the front plane at the right front corner at bumper height. Maximum occupant compartment deformation was 1.0 inch in the right front toe pan. Figure 6.5 shows the interior of the vehicle. Tables E.3 and E.4 in Appendix E1 provide exterior crush and occupant compartment measurements.

6.7 OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 6.2. Figure E.3 in Appendix E3 shows the vehicle angular displacements, and Figures E.4 through E.6 in Appendix E4 show acceleration versus time traces. Figure 5.6 summarizes pertinent information from the test.

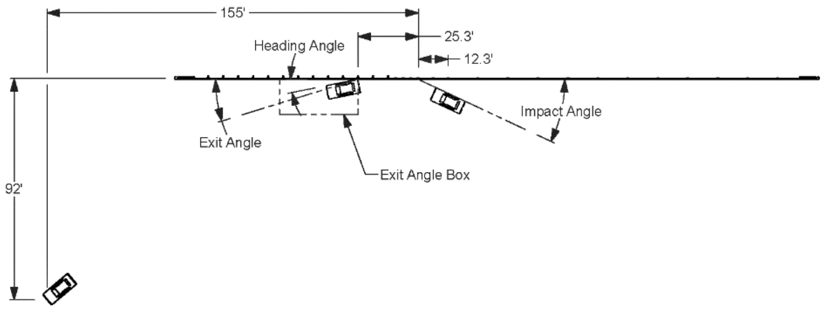
Figure 6.4. Test Vehicle after Test No. 612051-03-1.

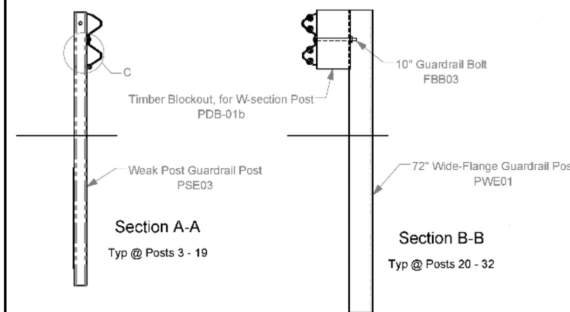
Figure 6.5. Interior of Test Vehicle after Test No. 612051-03-1.

Table 6.2. Occupant Risk Factors for Test No. 612051-03-1.

Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV)		
Longitudinal	**22.3 ft/s**	at 0.1342 s on right side of interior
Lateral	**16.7 ft/s**	
Occupant Ridedown Accelerations		
Longitudinal	**9.7 g**	0.1703 - 0.1803 s
Lateral	**7.9 g**	0.2562 - 0.2662 s
Theoretical Head Impact Velocity (THIV)	**8.0 m/s**	at 0.1288 s on right side of interior
Acceleration Severity Index (ASI)	**0.77**	0.1131 - 0.1631 s
Maximum 50-ms Moving Average		
Longitudinal	**-6.7 g**	0.0917 - 0.1417 s
Lateral	**-5.5 g**	0.1674 - 0.2174 s
Vertical	**-3.3 g**	0.1950 - 0.2450 s
Maximum Roll, Pitch, and Yaw Angles		
Roll	**12°**	0.2457 s
Pitch	**5°**	0.4377 s
Yaw	**52°**	1.5000 s

0.000 s | 0.200 s | 0.400 s | 0.600 s





General Information
Test Agency .... Texas A&M Transportation Institute (TTI)
Test Standard Test No. .... MASH Test 3-20
TTI Test No. 612051-03-1
Test Date 2019-10-07

Test Article
Type .... Transition
Name .... Transition from 32- inch tall weak post MGS to strong post MGS System
Installation Length .... 265 ft-7 ½ inches
Material or Key Elements .... W-Beam guardrail with posts 3 through 19 5-ft- 5-inch, S3×5.7 weak post guardrail posts 33 inches deep and posts 20 through 32 6-ft W6×8.5 guardrail posts 41 inches deep

Soil Type and Condition .... AASHTO M147-65(2004), grading B Soil (crushed limestone), Dry

Test Vehicle
Type/Designation 1100C
Make and Model .... 2009 Kia Rio
Curb .... 2460 lb
Test Inertial .... 2426 lb
Dummy .... 165 lb
Gross Static .... 2591 lb

Impact Conditions
Speed .... 62.6 mi/h
Angle .... 25.0°
Location/Orientation .... 12.3 ft downstream of post 14

Impact Severity .... 57 kip-ft

Exit Conditions
Speed .... 28.9 mi/h
Trajectory/Heading Angle ... 16.5° / 11.3°

Occupant Risk Values
Longitudinal OIV .... 22.3 ft/s
Lateral OIV .... 16.7 ft/s
Longitudinal Ridedown .... 9.7 g
Lateral Ridedown .... 7.9 g
THIV .... 8.0 m/s
ASI 0.77
Max. 0.050-s Average
Longitudinal .... -6.7 g
Lateral .... -5.5 g
Vertical .... -3.3 g

Post-Impact Trajectory
Stopping Distance .... 155 ft downstream 92 ft twd traffic lanes

Vehicle Stability
Maximum Yaw Angle .... 52°
Maximum Pitch Angle .... 5°
Maximum Roll Angle .... 12°
Vehicle Snagging .... No
Vehicle Pocketing .... No

Test Article Deflections
Dynamic .... 34.9 inches
Permanent .... 27.0 inches
Working Width .... 37.9 inches
Height of Working Width .... 40.0 inches

Vehicle Damage
VDS 01RFQ5
CDC 01FREW4
Max. Exterior Deformation .... 10.0 inches
OCDI FR0001000
Max. Occupant Compartment Deformation .... 1.0 inch

Figure 6.6. Summary of Results for *MASH* Test 3-20 on Guardrail Transition from 32-inch tall MGS Weak Post System to the MGS Strong Post System.

Chapter 7. SUMMARY AND CONCLUSIONS

7.1 ASSESSMENT OF TEST RESULTS

An assessment of each test based on the applicable safety evaluation criteria for *MASH* TL-3 transitions is provided below and in Tables 7.1 and 7.2.

7.1.1 *MASH* Test 3-20 (Crash Test No. 612051-03-1)

The transition contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection of the transition during the test was 34.9 inches. No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present hazard to others in the area. Maximum occupant compartment deformation was 1.0 inch in the right front toe pan area. The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 12° and 5°. Occupant risk factors were within the preferred limits of *MASH*.

7.1.2 *MASH* Test 3-21 (Crash Test No. 612051-02-1)

The transition contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection of the transition during the test was 57.2 inches. No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present hazard to others in the area. No occupant compartment deformation or intrusion was observed. The 2270P vehicle remained upright during and after the collision period. Maximum roll and pitch angles were 5° and 2°. Occupant risk factors were within the preferred limits of *MASH*.

7.2 CONCLUSIONS

The guardrail transition from the 32-inch tall weak post guardrail system to the 31-inch tall MGS strong post system met the performance criteria for a *MASH* TL-3 transition, as shown in Table 7.3.

Although the system was evaluated with use of 8-inch deep blockouts, it is the opinion of the researchers that use of 12-inch deep blockouts would not significantly alter the system crashworthiness behavior. *

Testing of the transition system from the 31-inch tall MGS strong post to the 32-inch tall weak post was not considered critical. *MASH* Section 2.2.1.1 indicates that transitions should be evaluated by impacting upstream of the stiffer barrier system such as tested herein. When impacts occur in the opposite direction upstream of the more flexible system, the chances for vehicle pocketing, vehicle rollover, and rail rupture are all reduced. Therefore, impacting the transition system going from the 31-inch tall MGS strong post system to the 32-inch tall weak post system is less critical.

* The opinions/interpretations identified/expressed in this paragraph and the next two paragraphs of the report are outside the scope of TTI Proving Ground's A2LA Accreditation.

Table 7.1. Performance Evaluation Summary for *MASH* Test 3-20 on Guardrail Transition from 32-inch Tall MGS Weak Post System to the MGS Strong Post System.

Test Agency: Texas A&M Transportation Institute | Test No.: 612051-03-1 | Test Date: 2019-10-07

***MASH* Test 3-20 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 transition contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection of the transition during the test was 34.9 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 to present 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 1.0 inch in the right front toe pan area.	
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 12° and 5°.	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 22.3 ft/s, and lateral OIV was 16.7 g.	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 9.7 g, and lateral occupant ridedown acceleration was 7.9 g.	Pass

Table 7.2. Performance Evaluation Summary for *MASH* Test 3-21 on Guardrail Transition from 32-inch Tall MGS Weak Post System to the MGS Strong Post System.

Test Agency: Texas A&M Transportation Institute | Test No.: 612051-02-1 | Test Date: 2019-11-05

***MASH* Test 3-21 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 transition contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection of the transition during the test was 57.2 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 to present 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.	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 period. Maximum roll and pitch angles were 5° and 2°.	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 15.7 ft/s, and lateral OIV was 15.4 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 6.1 g and lateral occupant ridedown acceleration was 6.5 g.	Pass

Table 7.3. Assessment Summary for *MASH* TL-3 Tests on Guardrail Transition from 32-inch Tall MGS Weak Post System to MGS Strong Post System.

Evaluation Factors	Evaluation Criteria	Test No. 612051-03-1 1100C	Test No. 612051-02-1 2270P
Structural Adequacy	A	S	S
Occupant Risk	D	S	S
	F	S	S
	H	S	S
	I	S	S
	Test No.	***MASH* Test 3-20**	***MASH* Test 3-21**
	Pass/Fail	Pass	Pass

S = Satisfactory
U = Unsatisfactory
N/A = Not Applicable

For the reasons explained above and based on the successful performance of the conducted full-scale crash tests, the proposed transition system between the 31-inch tall MGS strong post to the 32-inch tall weak post is considered *MASH* compliant and suitable for implementation on the NHS.

REFERENCES

1. AASHTO/FHWA Joint Implementation Agreement for *Manual for Assessing Safety Hardware* (*MASH*), January 7, 2016.
2. AASHTO. *Manual for Assessing Roadside Safety Hardware, Second Edition*. 2016, American Association of State Highway and Transportation Officials: Washington, D.C.
3. D. Lance Bullard, Jr., Roger P. Bligh, Wanda L. Menges, and Rebecca R. Haug. "Evaluation of Existing Roadside Safety Hardware Using Updated Criteria – Technical Report." *NCHRP Web-Only Document 157*. NCHRP Project 22-14(03), National Cooperative Highway Research Program, Washington, DC, March 2010.
4. D. Lance Bullard, Jr., Wanda L. Menges, and Darrell L. Kuhn. *MASH Test 3-10 of PennDOT G2 Weak Post W-Beam Guardrail*. Test Report No. 608221-1. Texas A&M Transportation Institute, Texas A&M University, College Station, TX, September 2017.

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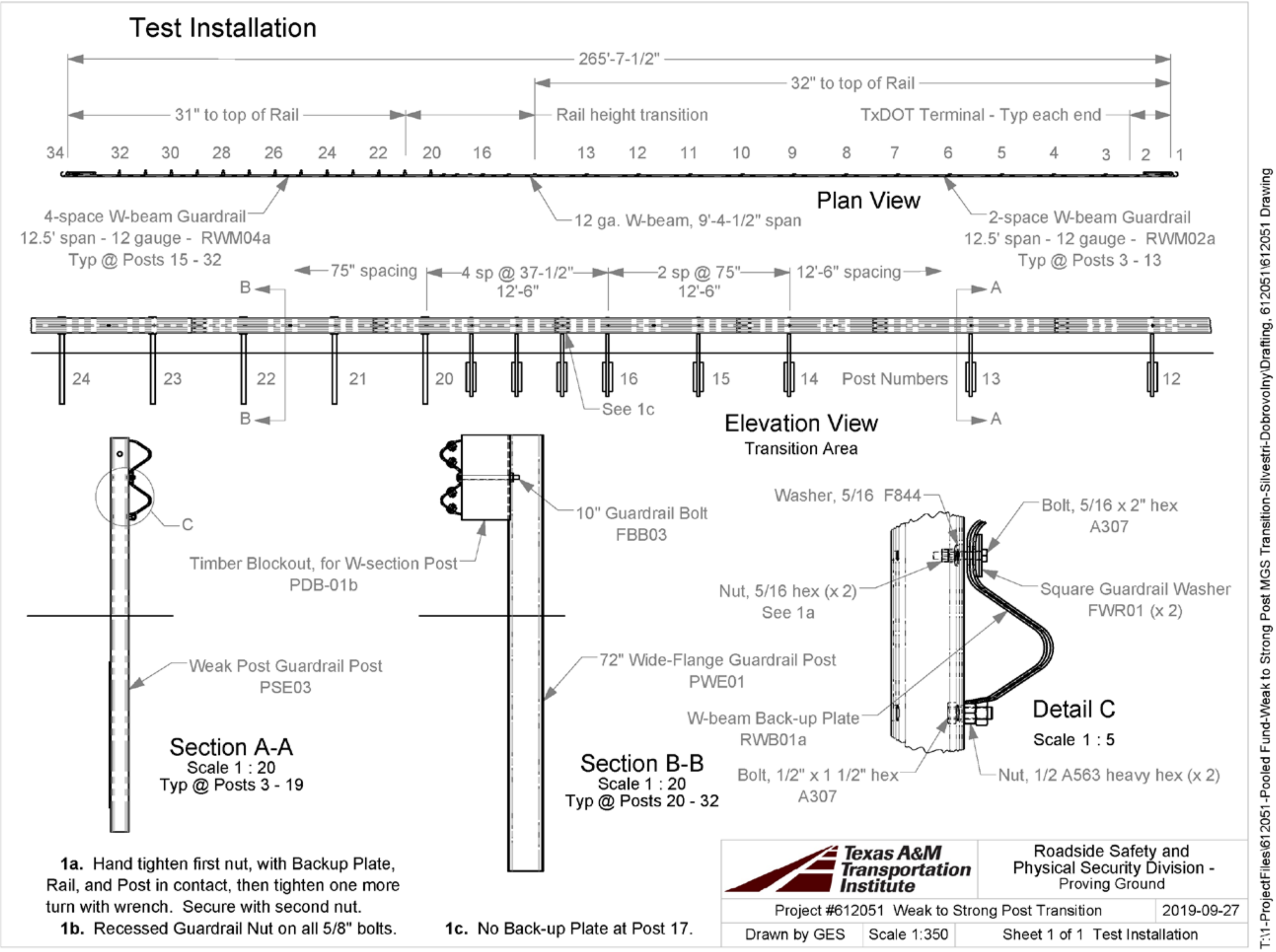
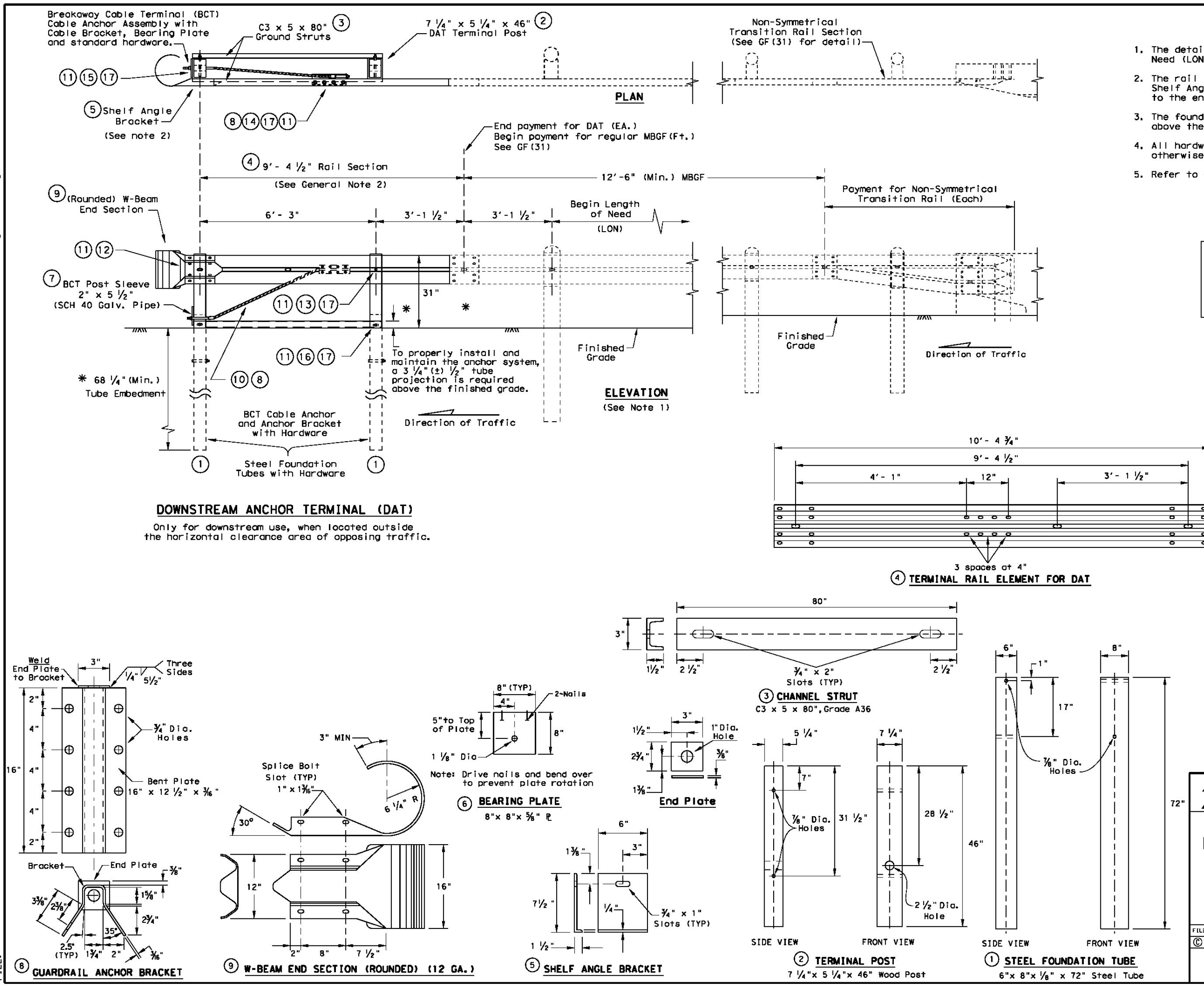
APPENDIX A. DETAILS OF THE TRANSITION





GENERAL NOTES

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

MOW STRIP INSTALLATION

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

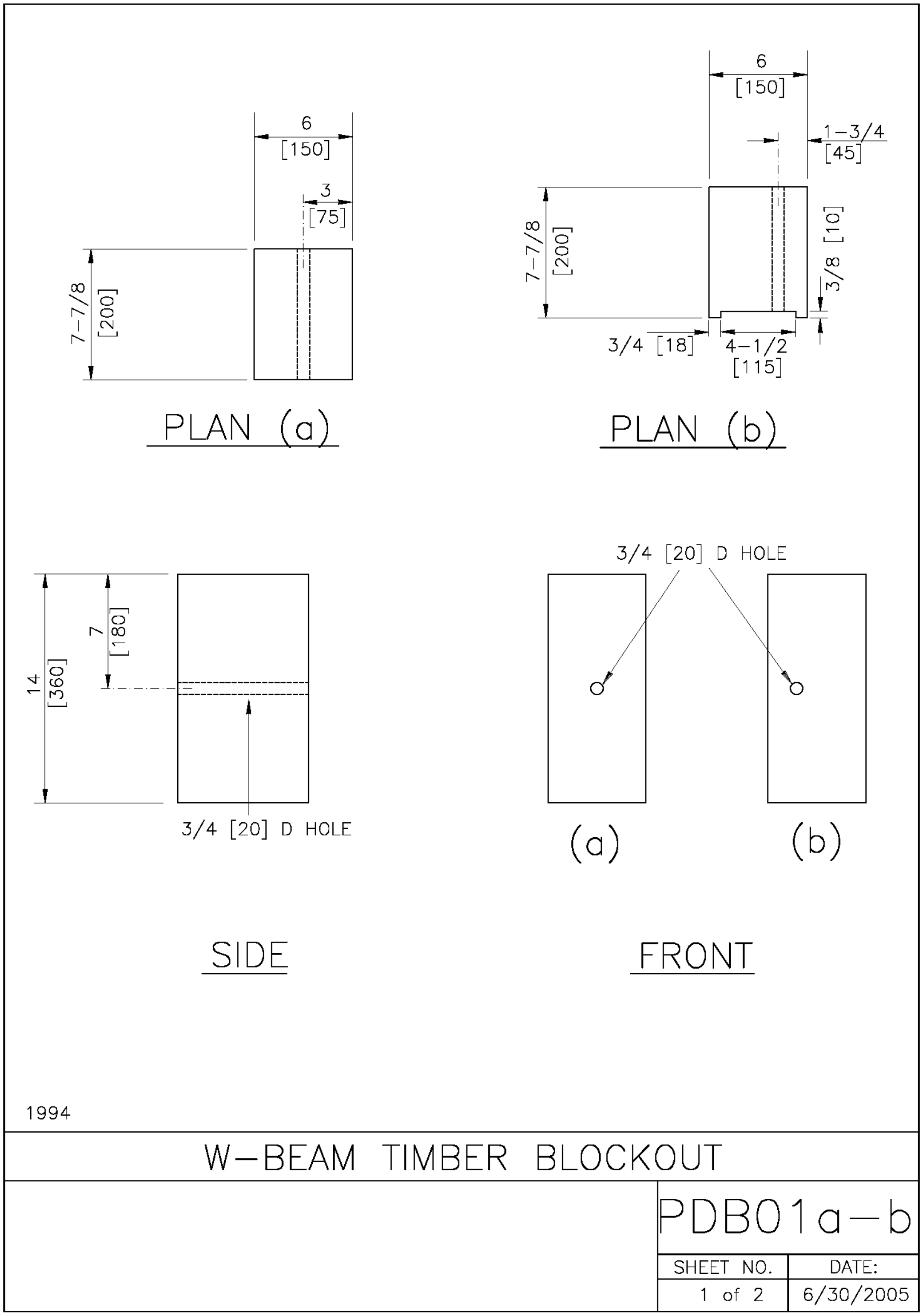
#	(DAT) PARTS LIST	QTY
1	Steel Foundation Tube	2
2	DAT Terminal Post	2
3	Channel Strut	2
4	Terminal Rail Element	1
5	Shelf Angle Bracket	1
6	BCT Bearing Plate	1
7	BCT Post Sleeve	1
8	Guardrail Anchor Bracket	1
9	(Rounded) W-Beam End Section	1
10	BCT Cable Anchor	1
11	Recessed Nut, Guardrail	20
12	1 1/4"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

Texas Department of Transportation — Design Division Standard

METAL BEAM GUARD FENCE
(Downstream Anchor Terminal)
GF(31)DAT-14

FILE: gf31dt14.dgn | DN: TxDOT | CK: AM | DW: VP | CK: CCL
© TxDOT: December 2011 | CONT | SECT | JOB | HIGHWAY
REVISIONS | DIST | COUNTY | SHEET NO.

DATE:
FILE:


6
[150]
3
[75]
7-7/8
[200]
PLAN (a)
6
[150]
1-3/4
[45]
7-7/8
[200]
3/8 [10]
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.

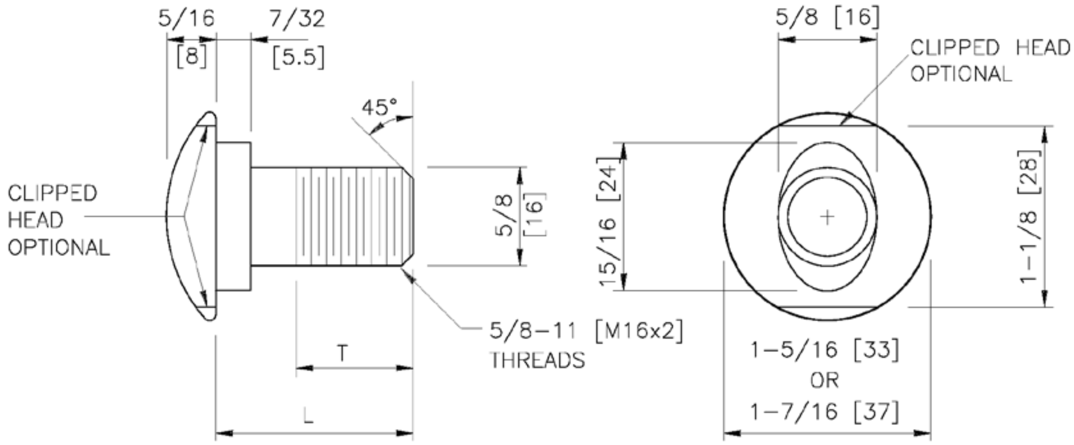
INTENDED USE

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.

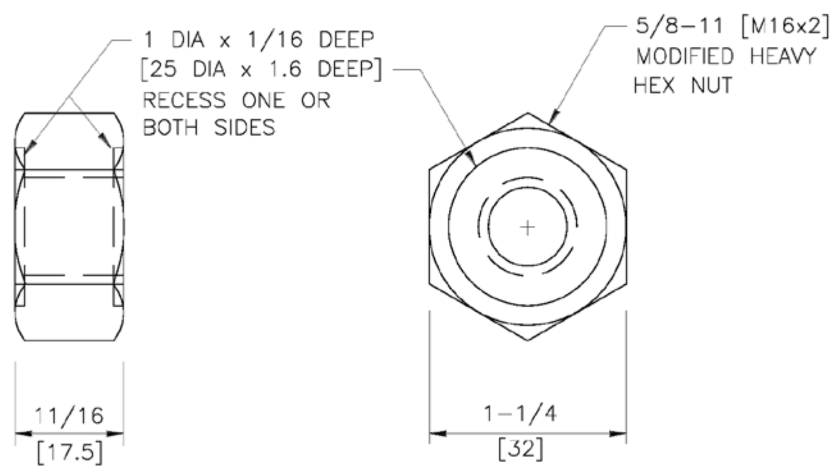
W-BEAM TIMBER BLOCKOUT

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.

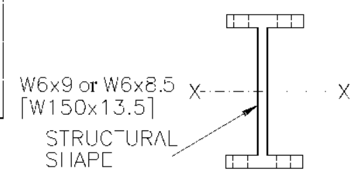
GUARDRAIL BOLT AND RECESSED NUT

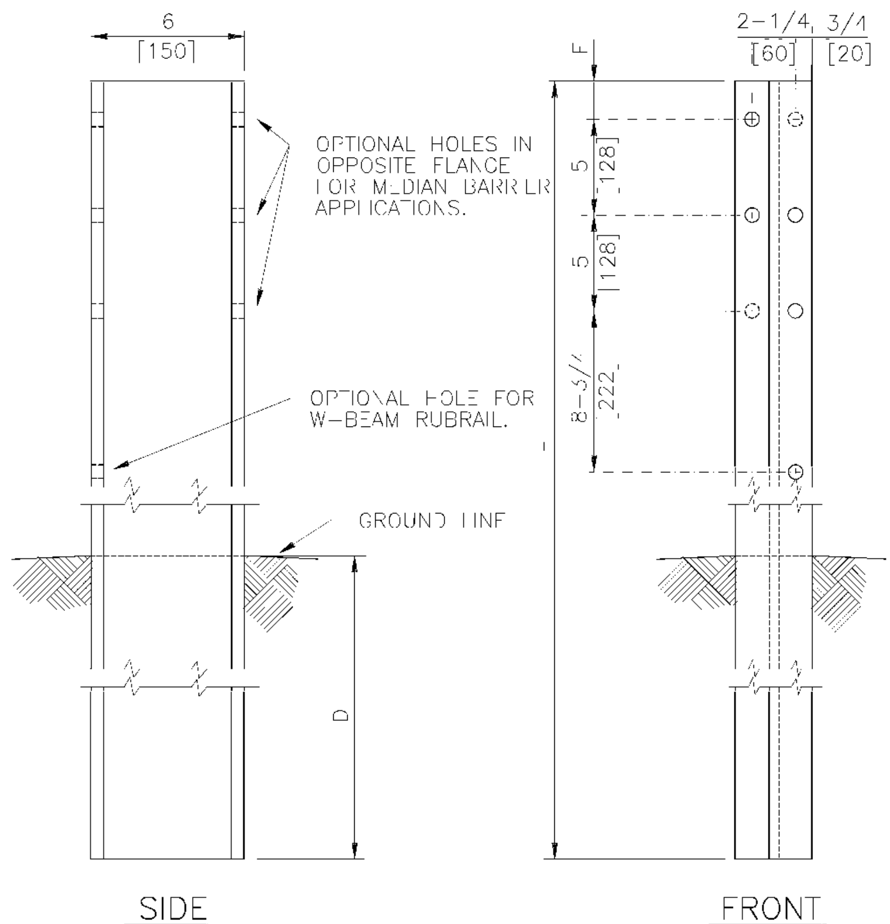
FBB01-05

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

NOTE: ALL HOLES ARE 3/4 [20] D.

DESIGNATOR	L	D	E
PWE01	72 [1830]	43-1/4 [1100]	2 [52]
PWE02	78 [1980]	49-1/4 [1250]	2 [52]
PWE03	78 [1980]	45-3/8 [1153]	5-7/8 [149]
PWE04	81 [2060]	46-1/8 [1173]	5-7/8 [149]





SIDE

FRONT

1994

WIDE-FLANGE GUARDRAIL POST

PWE01-04

SHEET NO.	DATE:
1 of 2	7/27/2005

SPECIFICATIONS

W-beam and thrie-beam guardrail posts shall be manufactured using AASHTO M 270 / M 270M (ASTM A 709 / A 709M) Grade 36 [250] steel unless corrosion-resistant steel is required, in which case the post shall be manufactured from AASHTO M 270 / M 270M (ASTM A 709 / A 709M) Grade 50W [345W] steel. The dimensions of the cross-section shall conform to a W6x9 [W150x13.5] section as defined in AASHTO M 160 / M 160M (ASTM A 6 / A 6M). [W150x12.6] wide flange posts are an acceptable alternative that is considered equivalent to the [W150x13.5].

After the section is cut and all holes are drilled or punched, the component should be zinc-coated according to AASHTO M 111 (ASTM A 123) unless corrosion-resistant steel is used. When corrosion-resistant steel is used, the portion of the post to be embedded in soil shall be zinc-coated according to AASHTO M 111 (ASTM A 123) and the portion above the soil shall not be zinc-coated, painted or otherwise treated.

Designator	Area in^2 [10^3 mm^2]	I_x in^4 [10^6 mm^4]	I_y in^4 [10^6 mm^4]	S_x in^3 [10^3 mm^3]	S_y in^3 [10^3 mm^3]
PWE01-04	2.63 [1.7]	16.43 [6.84]	2.19 [0.91]	5.57 [91.2]	1.11 [18.2]

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

Posts PWE01 and PWE02 are used with the SGR04a and SGR04c guardrails and the SGM04a median barrier. Blockouts like PWB01 (steel) or PDB01 (wood) are attached to each post.

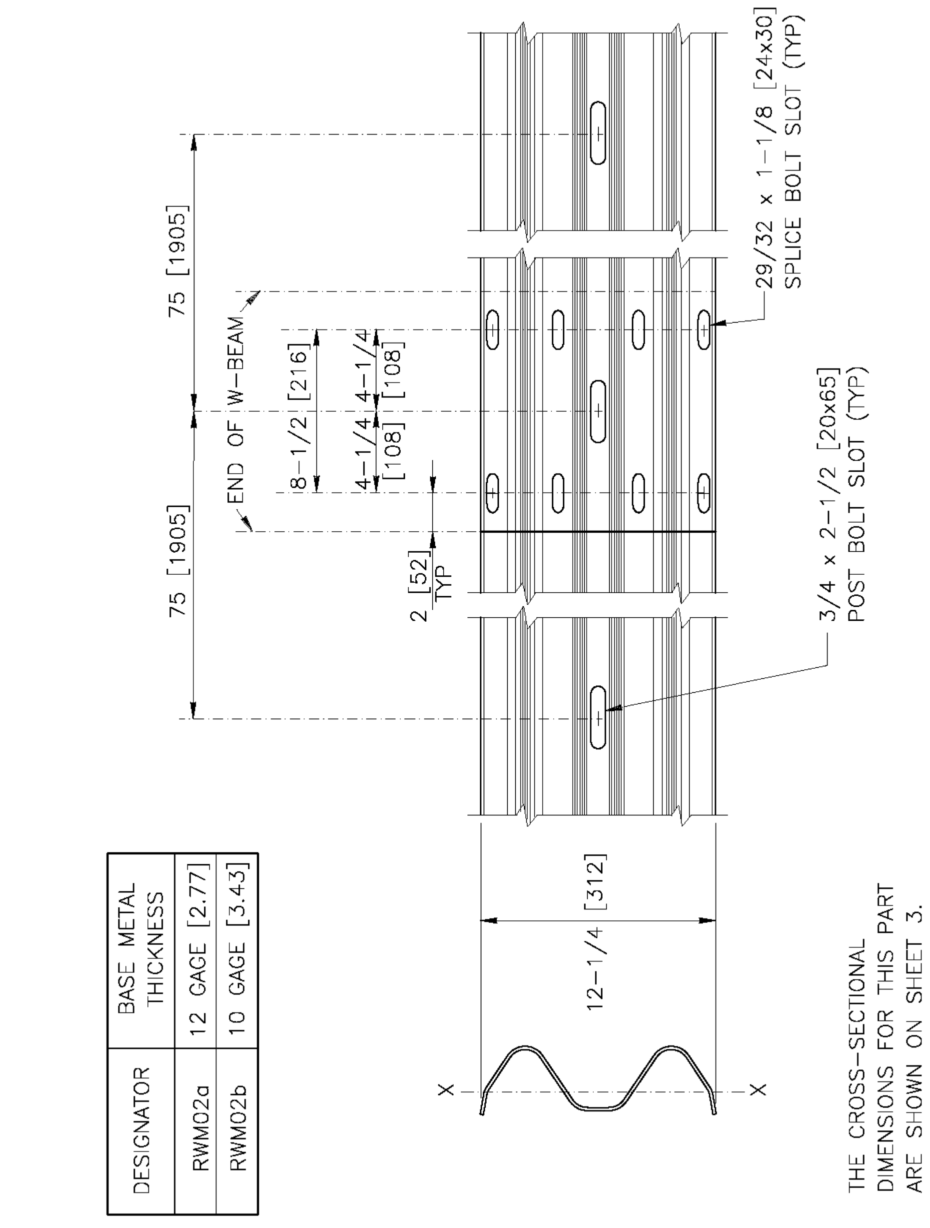
Post PWE03 is used with the SGR09a guardrail and the SGM09a median barrier. Wood or plastic blockouts like the PWB02 are attached to each post with FBB03 bolts and FWC16a washers under the nuts.

Post PWE04 is used with the SGR09b guardrail and the SGM09b median barrier. A modified steel blockout PWB03 is attached to each post with at least two 1.5-inch [40 mm] long FBX16a bolts and nuts.

WIDE-FLANGE GUARDRAIL POST

PWE01-04

SHEET NO.	DATE
2 of 2	7/06/2005



DESIGNATOR	BASE METAL THICKNESS
RWM02a	12 GAGE [2.77]
RWM02b	10 GAGE [3.43]

1994

2-SPACE W-BEAM GUARDRAIL

RWM02a-b	
SHEET NO.	DATE:
1 of 4	6/09/2005

SPECIFICATIONS

Corrugated sheet steel beams shall conform to the current requirements of AASHTO M 180. The section shall be manufactured from sheets with a nominal width of 19 inches [483 mm]. Guardrail RWM02a shall conform to AASHTO M 180 Class A, and RWM02b shall conform to Class B. Corrosion protection may be either Type II (galvanized) or Type IV (corrosion-resistant steel). Type IV connectors shall be manufactured using AASHTO M 222/M 222M (ASTM A 588/A 588 M) and shall not be galvanized, painted or otherwise coated.

Inertial properties shown below are based on the gross cross-section dimensions without a reduction for the splice and bolt holes.

Designator	Area in^2 [10^3 mm^2]	I_x in^4 [10^6 mm^4]	S_x in^3 [10^3 mm^3]
RWM02a	2.01 [1.3]	2.40 [1.0]	1.40 [23]
RWM02b	2.63 [1.7]	3.12 [1.3]	1.77 [29]

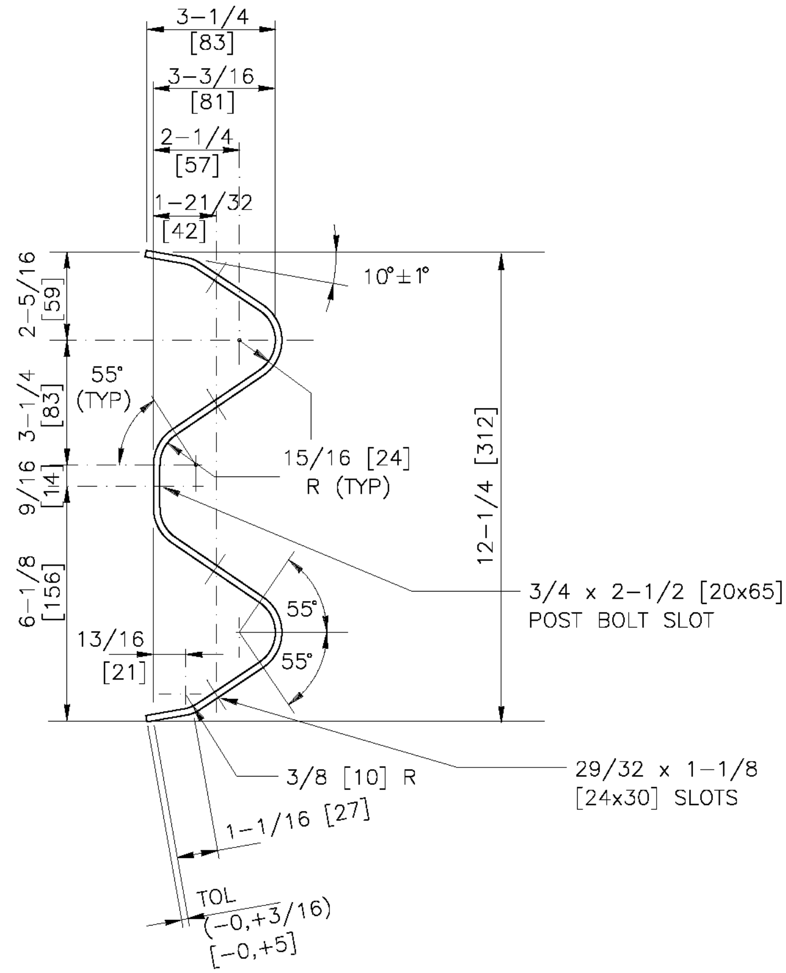
Dimensional tolerances not shown or implied are intended to be those consistent with the proper functioning of the part, including its appearance and accepted manufacturing practices.

INTENDED USE

This corrugated sheet steel beam is used as a rail element in barrier designs SGR02a-b, SGR04a-c, SGM02a-b, and SGM04a-b.

2-SPACE W-BEAM GUARDRAIL

RWM02a-b	
SHEET NO.	DATE
2 of 4	7/13/2005



1994

2-SPACE W-BEAM GUARDRAIL

	RWM02a-b	
	SHEET NO.	DATE:
	3 of 4	6/09/2005

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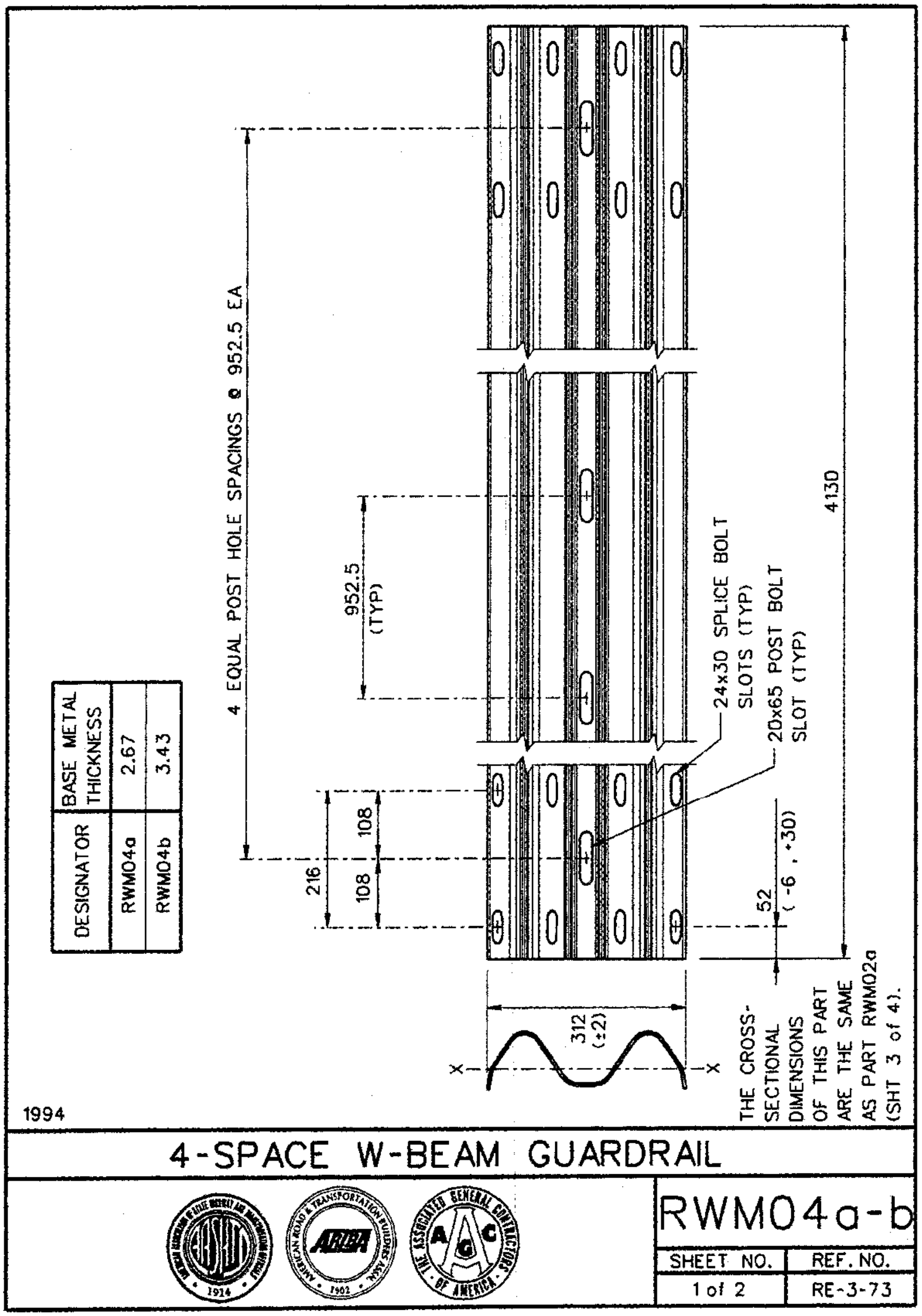
2-SPACE W-BEAM GUARDRAIL		
RWM02a-b		
SHEET NO.	DATE	
4 of 4	6/27/2005	



DESIGNATOR
BASE METAL THICKNESS
RWM04a
2.67
RWM04b
3.43
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).
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.

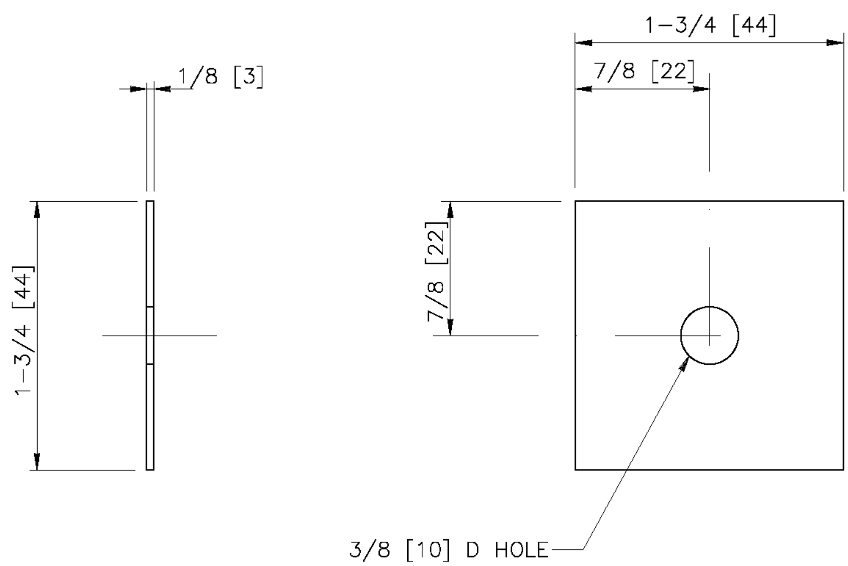
INTENDED USE

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



1994

SQUARE GUARDRAIL WASHER

	FWR01	
	SHEET NO.	DATE:
	1 of 2	6/08/2005

SPECIFICATIONS

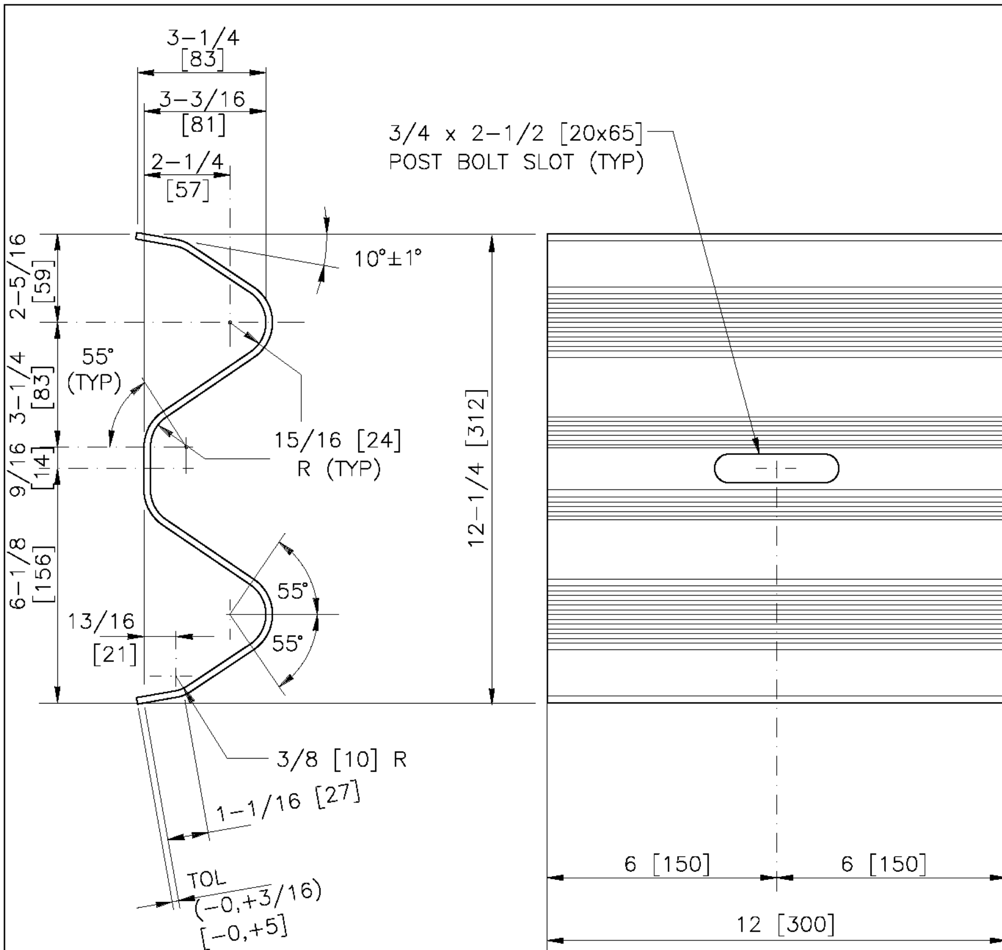
The square guardrail washer shall be manufactured from AASHTO M 183/M 183M (ASTM A 36/ A 36M) steel plate except when corrosion-resistant steel is required, in which case AASHTO M 222/M 222M (ASTM A 588/A 588M) steel shall be used. After stamping or punching, galvanized plates shall be finished according to AASHTO M 111 (ASTM A 123).

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 washer is used in the weak-post W-beam guardrails and median barriers (SGR02 and SGM02) to provide a bearing surface between the rail-to-post bolt and W-beam rail (RWM02a-b).

SQUARE GUARDRAIL WASHER	
FWR01	
SHEET NO.	DATE
2 of 2	7/13/2005



DESIGNATOR	BASE METAL THICKNESS
RWB01a	12 GAGE [2.77]
RWB01b	10 GAGE [3.43]

1994

W-BEAM BACK-UP PLATE

RWB01a-b

SHEET NO.	DATE:
1 of 2	6/09/2005

SPECIFICATIONS

Back-up plates shall conform to the current requirements of AASHTO M 180. The section shall be manufactured from sheets with a nominal width of 19 inches [483 mm]. RWB01a shall conform to AASHTO M 180 Class A, and RWB01b shall conform to Class B. Corrosion protection shall be either Type II (galvanized) or Type IV (corrosion-resistant steel). Type IV material shall conform to ASTM A 588/A 588 M and shall not be galvanized, painted or otherwise coated.

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.

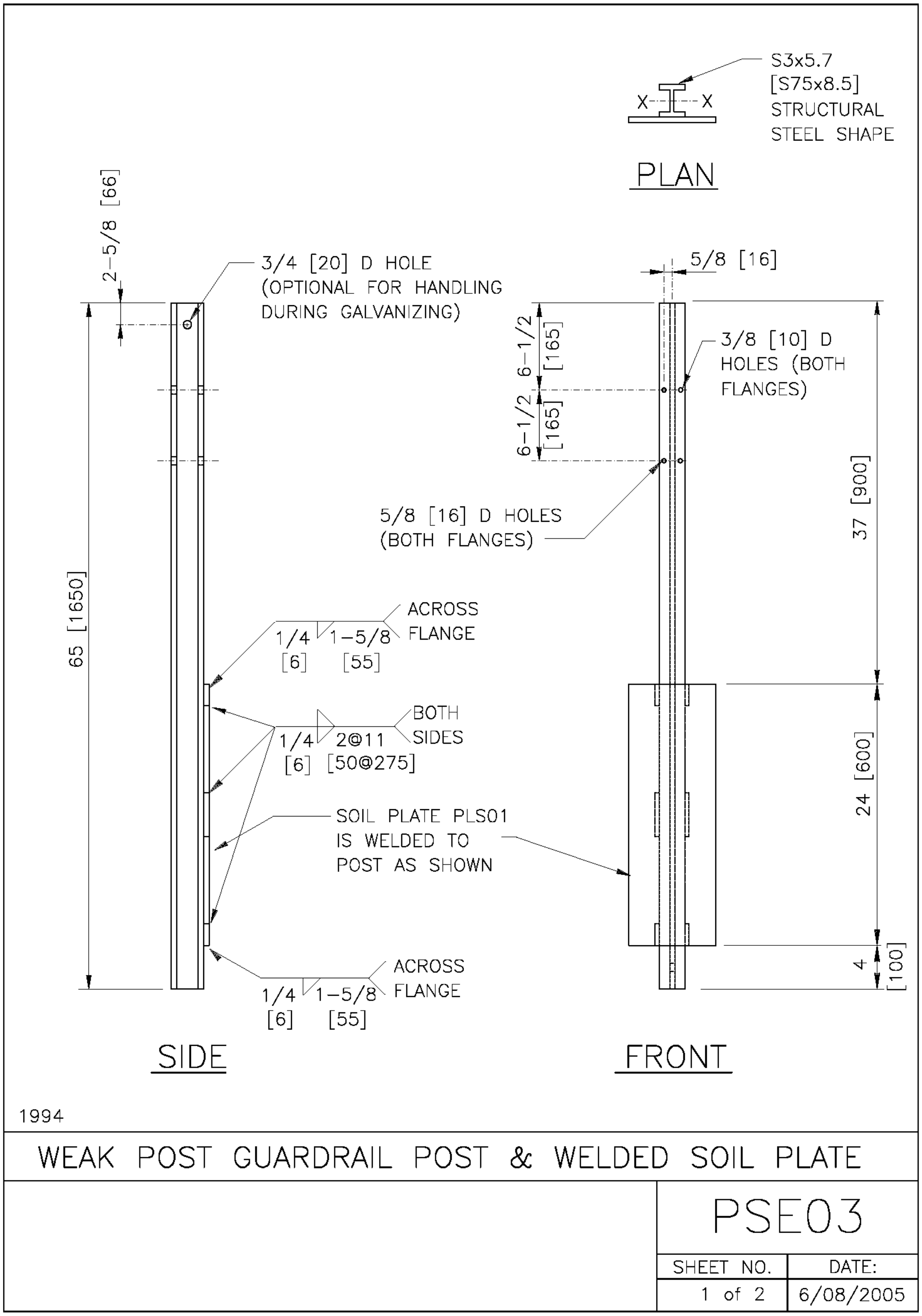
INTENDED USE

This back-up plate is placed behind W-beam guardrail elements (RWM02a-b) at intermediate steel posts (non-splice posts) in the SGR04a W-beam guardrail.

W-BEAM BACK-UP PLATE

RWB01a-b

SHEET NO.	DATE
2 of 2	7/06/2005


S3x5.7
[S75x8.5]
STRUCTURAL
STEEL SHAPE
PLAN
2-5/8 [66]
3/4 [20] D HOLE
(OPTIONAL FOR HANDLING
DURING GALVANIZING)
5/8 [16]
6-1/2 [165]
6-1/2 [165]
3/8 [10] D
HOLES (BOTH
FLANGES)
37 [900]
5/8 [16] D HOLES
(BOTH FLANGES)
65 [1650]
1/4 1-5/8
[6] [55]
ACROSS
FLANGE
1/4 2@11
[6] [50@275]
BOTH
SIDES
24 [600]
SOIL PLATE PLS01
IS WELDED TO
POST AS SHOWN
4 [100]
1/4 1-5/8
[6] [55]
ACROSS
FLANGE
SIDE
FRONT
1994
WEAK POST GUARDRAIL POST & WELDED SOIL PLATE
PSE03
SHEET NO.
1 of 2
DATE:
6/08/2005

SPECIFICATIONS

This post shall be manufactured using steel conforming to AASHTO M 183/M 183M (ASTM A 36/A 36M). The section shall be manufactured such that it conforms to the geometry and tolerances of AASHTO M 160/M 160M (ASTM A 6/A 6M) for a S3x5.7 [S75x8.5] S-section. After all punching, drilling, stamping and welding is complete, the section shall be galvanized according to AASHTO M 111 (ASTM A 123). If corrosion-resistant hardware is required, AASHTO M 222/ M 222M (ASTM A 588/A 588M) steel shall be used and the embedded portion of the post shall be galvanized according to AASHTO M 111 (ASTM A 123). All holes shall be punched through both flanges (in-line). All welding shall conform to ANSI/AASHTO/AWS D1.5.

Designator	Area (in^2) [10^3 mm^2]	I_x (in^4) [10^6 mm^4]	I_y (in^4) [10^6 mm^4]	S_x (in^3) [10^3 mm^3]	S_y (in^3) [10^3 mm^3]
PSE03	1.67 [1.1]	2.52 [1.1]	0.455 [0.2]	1.68 [28]	0.39 [6]

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.

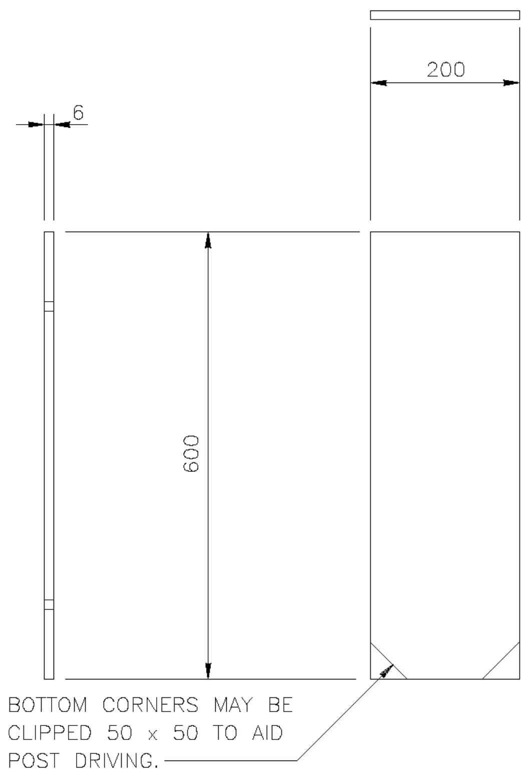
INTENDED USE

This post is used in the SGR02 weak-post guardrail system and the SGM02 weak-post median barrier. The RWM02a W-beam guardrail is bolted to this post using a 1.5-inch [40 mm] long FBX08a bolt and two nuts with two FWR01 square washers and one round washer, and a FBX14a support bolt with two nuts.

WEAK-POST GUARDRAIL POST & WELDED SOIL PLATE

PSE03

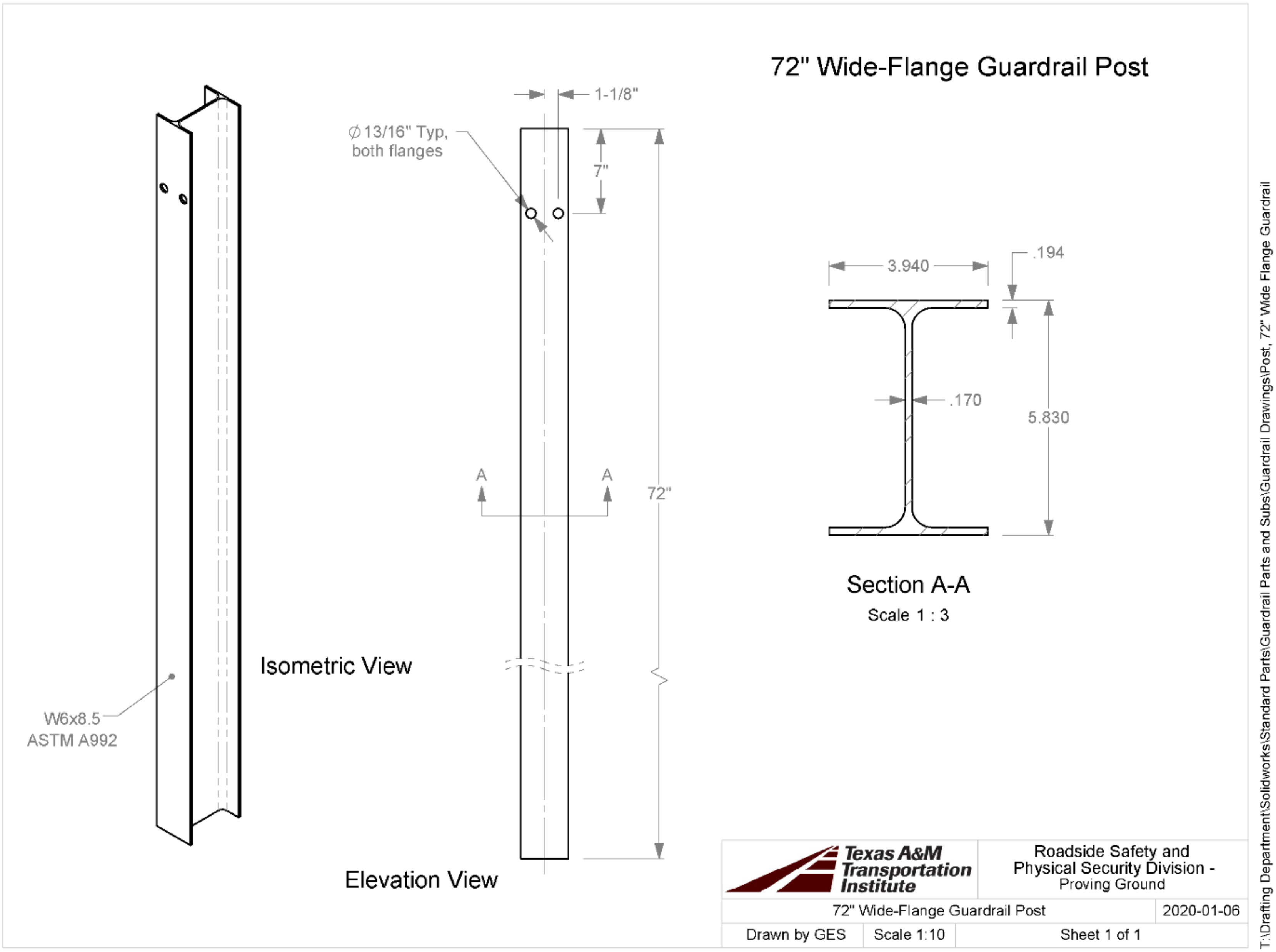
SHEET NO.	DATE
2 of 2	7/13/2005



1994

WEAK POST SOIL PLATE

	PLS01	
	SHEET NO.	REF. NO.
	1 of 2	P-4-76


72" Wide-Flange Guardrail Post
W6x8.5
ASTM A992
Isometric View
1-1/8"
∅13/16" Typ,
both flanges
7"
A
A
72"
Elevation View
3.940
.194
.170
5.830
Section A-A
Scale 1 : 3
Texas A&M Transportation Institute
Roadside Safety and
Physical Security Division -
Proving Ground
72" Wide-Flange Guardrail Post
2020-01-06
Drawn by GES
Scale 1:10
Sheet 1 of 1
T:\Drafting Department\Solidworks\Standard Parts\Guardrail Parts and Subs\Guardrail Drawings\Post, 72" Wide Flange Guardrail

APPENDIX B. SUPPORTING CERTIFICATION DOCUMENTS

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.

Shipper's No. 55-109584

S/O No. 1313267

Carrier: Trinity Highway Products,LLC 3

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 Lima, OH 8-7-19 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.

Consigned to: SAMPLES, TESTING MATERIALS Cust. P.O. WEAK POST TRANS Load No.: 1-1
Destination: 3100 STATE HWY 47
BLDG 7090
Total Weight: 9,948.57

City: BRYAN State: TX Zip: 77807
Ship: 8/7/2019
Arrive: 8/9/19 8:00:00AM

Contact: GARY GERKE Phone: 936-825-4661 567508

Delivering Carrier: Mercer Vehicle or Car Initial: No.

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:

Collect On Delivery:
$ **and remit to:**
Street **City** **State**

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

Upon delivery, all materials subject to Trinity Highway Products,LLC Storage Stain Policy No. QMS-LG-002.
Project Info: PROJ#612051 WEAK TO STRONG POST TRANSITION
LD Comments:

No. Pkgs.	Piece Count	Description of Articles	*Wt.	Class or Rate	✓ Col.
	36	3G 12/12"/BACKUP			
	42	11G 12/12'6/3'1.5/S			
	26	533G 6'0 POST/8.5/DDR			
	8	724G 6'0 TUBE SL/.125X8X6			
	4	850G 12/BUFFER/ROLLED			
	4	3000G CBL 3/4X6'6/DBL SWG/NOHWD			
	36	3240G WASHER,FLAT,5/16 N,TY A,G			
	72	3245G 5/16" HEX NUT A563			
	4	3300G WASHER,FLAT,5/8 R,TY B,G			
	72	3319G 1/8"X1.75"X1.75" WSHR PL			
	62	3340G 5/8" GR HEX NUT			
	336	3360G 5/8"X1.25" GR BOLT			
	26	3500G 5/8"X10" GR BOLT A307			
	36	4076B WD BLK RTD 6X8X14			
	8	4140B WD 4'0.25 POST 5.5X7.5			
	72	4303G 1/2" HEX NUT A563 GR A			
	36	4308G 1/2"X1.5" HEX BOLT A307			
	36	6267G 5/16"X2.375"HXBLT A307 FT			
	8	19481G C3X5#X6'-8" RUBRAIL			
	4	20207G 12/9'4.5/8-HOLE ANCH/S			
	36	24586A 5'5 POST/5.7#GD RL/.25PL			
	4	36120A DAT-31-TX-HDW-CAN			

612051

SPECIAL INSTRUCTIONS:
SHIPPER LOAD - CONSIGNEE UNLOAD

55-109584

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 Heather Painter DATE 8-7-19
AGENT OR DRIVER — This shipment received subject to exceptions as noted and according to the terms and conditions hereof.
(SIGN HERE) DATE 8-7-19

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 A.M. P.M. TIME
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

CONSIGNEE/CUSTOMER COPY

Load List

TRINITY HIGHWAY PRODUCTS, LLC
PACKING LIST

SALES ORDER # 1313267

LOAD # 1 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	36	EACH	99TESTMATERIA	TEST MATERIAL

Part No	Qty On Load	Description
3G	36	12/12"/BACKUP
11G	42	12/12'6/3'1.5/S
533G	26	6'0 POST/8.5/DDR
3240G	36	WASHER,FLAT,5/16 N,TY A,G
3245G	72	5/16" HEX NUT A563
3319G	72	1/8"X1.75"X1.75" WSHR PL
3340G	62	5/8" GR HEX NUT
3360G	336	5/8"X1.25" GR BOLT
3500G	26	5/8"X10" GR BOLT A307
4076B	26	WD BLK RTD 6X8X14
4303G	72	1/2" HEX NUT A563 GR A
4308G	36	1/2"X1.5" HEX BOLT A307
6267G	36	5/16"X2.375"HXBLT A307 FT
24586A	36	5'5 POST/5.7#/GD RL/.25PL

PI #	Qty Ordered	UOM	PI Product Code	Description
2	8	EACH	99TESTMATERIA	TEST MATERIAL

Part No	Qty On Load	Description
724G	8	6'0 TUBE SL/.125X8X6
850G	4	12/BUFFER/ROLLED
3000G	4	CBL 3/4X6'6/DBL SWG/NOHWD
3300G	4	WASHER,FLAT,5/8 R,TY B,G
4140B	8	WD 4'0.25 POST 5.5X7.5
19481G	8	C3X5#X6'-8" RUBRAIL
20207G	4	12/9'4.5/8-HOLE ANCH/S
36120A	4	DAT-31-TX-HDW-CAN

Date: 8/7/19
Plant: 55
Load: 1

rfheatherp 8/6/2019 2:14:05PM

Certified Analysis

Trinity Highway Products, LLC

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

Order Number: 1313267 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: WEAK POST TRA
BOL Number: 109584 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 8/7/19

Project: PROJ# 612051 WEAK TO STRONG POST TRANSITION

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
36	3G	12/12"/BACKUP	M-180	A		195412	62,850	80,260	25.7	0.180	0.710	0.014	0.005	0.010	0.120	0.000	0.050	0.000	4
42	11G	12/12'6/3'1.5/S			2	L12519													
			M-180	A	2	239384	54,800	73,070	31.1	0.200	0.730	0.013	0.002	0.020	0.090	0.000	0.050	0.001	4
			M-180	A	2	239385	58,590	76,490	28.7	0.190	0.730	0.014	0.004	0.020	0.100	0.000	0.060	0.001	4
			M-180	A	2	240027	64,200	82,340	23.8	0.190	0.730	0.012	0.003	0.020	0.120	0.000	0.070	0.001	4
			M-180	A	2	240028	64,000	82,300	24.4	0.200	0.740	0.012	0.003	0.020	0.120	0.000	0.060	0.001	4
			M-180	A	2	240029	59,320	77,690	25.8	0.180	0.710	0.012	0.003	0.020	0.140	0.000	0.070	0.001	4
			M-180	A	2	240030	64,360	82,430	24.2	0.190	0.720	0.012	0.004	0.020	0.120	0.000	0.070	0.001	4
			M-180	A	2	240678	60,840	78,860	26.7	0.190	0.730	0.008	0.004	0.010	0.110	0.000	0.060	0.000	4
			M-180	B	2	240199	61,710	80,240	24.7	0.190	0.730	0.011	0.004	0.010	0.130	0.000	0.050	0.001	4
	11G				2	L22419													
			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	239161	60,130	80,610	25.2	0.190	0.720	0.013	0.004	0.010	0.120	0.000	0.060	0.001	4
			M-180	A	2	239383	63,360	82,800	23.6	0.200	0.720	0.012	0.003	0.020	0.090	0.000	0.060	0.001	4
			M-180	A	2	239385	58,590	76,490	28.7	0.190	0.730	0.014	0.004	0.020	0.100	0.000	0.060	0.001	4
			M-180	A	2	239386	63,060	81,300	27.6	0.200	0.730	0.013	0.003	0.020	0.100	0.000	0.050	0.000	4
			M-180	A	2	239387	61,850	79,720	27.4	0.200	0.740	0.010	0.004	0.020	0.080	0.000	0.050	0.001	4
			M-180	A	2	239388	61,700	80,740	26.6	0.190	0.730	0.012	0.003	0.020	0.100	0.000	0.050	0.000	4
			M-180	A	2	240025	62,670	80,290	26.9	0.200	0.740	0.012	0.003	0.020	0.110	0.000	0.070	0.002	4
			M-180	A	2	240026	62,330	81,120	25.6	0.190	0.720	0.011	0.003	0.020	0.130	0.000	0.060	0.000	4
	11G				2	L13019													
			M-180	A	2	240027	64,200	82,340	23.8	0.190	0.730	0.012	0.003	0.020	0.120	0.000	0.070	0.001	4
			M-180	A	2	240029	59,320	77,690	25.8	0.180	0.710	0.012	0.003	0.020	0.140	0.000	0.070	0.001	4
			M-180	A	2	241193	64,430	83,900	26.5	0.190	0.710	0.011	0.002	0.020	0.100	0.000	0.070	0.001	4
			M-180	A	2	241194	60,960	77,840	25.1	0.190	0.730	0.012	0.002	0.020	0.100	0.000	0.090	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

Order Number: 1313267 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: WEAK POST TRA
BOL Number: 109584 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 8/7/19

Project: PROJ# 612051 WEAK TO STRONG POST TRANSITION

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	241195	62,130	81,280	26.6	0.190	0.720	0.012	0.002	0.020	0.110	0.000	0.070	0.000	4
			M-180	A	2	241196	61,060	79,430	26.7	0.190	0.730	0.011	0.003	0.020	0.100	0.000	0.070	0.002	4
			M-180	A	2	241197	61,510	82,330	26.2	0.210	0.740	0.011	0.004	0.010	0.100	0.000	0.060	0.001	4
	11G				2	L22019													
			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	239161	60,130	80,610	25.2	0.190	0.720	0.013	0.004	0.010	0.120	0.000	0.060	0.001	4
			M-180	A	2	239383	63,360	82,800	23.6	0.200	0.720	0.012	0.003	0.020	0.090	0.000	0.060	0.001	4
	11G				2	L22119													
			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	239161	60,130	80,610	25.2	0.190	0.720	0.013	0.004	0.010	0.120	0.000	0.060	0.001	4
			M-180	A	2	239383	63,360	82,800	23.6	0.200	0.720	0.012	0.003	0.020	0.090	0.000	0.060	0.001	4
			M-180	A	2	239384	54,800	73,070	31.1	0.200	0.730	0.013	0.002	0.020	0.090	0.000	0.050	0.001	4
26	533G	6'0 POST/8.5/DDR	A-36			2909185	56,400	69,800	30.0	0.070	0.800	0.008	0.027	0.210	0.120	0.013	0.040	0.004	4
	533G		A-36			1715509	58,600	70,400	27.6	0.070	0.890	0.009	0.030	0.210	0.270	0.014	0.050	0.003	4
8	724G	6'0 TUBE SL/.125X8X6	A-500			A83576	70,400	90,800	28.8	0.200	0.480	0.009	0.001	0.030	0.090	0.001	0.060	0.001	4
4	850G	12/BUFFER/ROLLED	M-180	A		216690	65,000	83,340	22.8	0.190	0.730	0.012	0.003	0.020	0.100	0.000	0.070	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

Order Number: 1313267 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: WEAK POST TRA
BOL Number: 109584 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 8/7/19

Project: PROJ# 612051 WEAK TO STRONG POST TRANSITION

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
4	3000G	CBL 3/4X6'6/DBL	WIRE			134352													4
36	3240G	WASHER,FLAT,5/16 N,TY	F436 -3240			P38754 R71028-01													4
72	3245G	5/16" HEX NUT A563	A563-3245			P38401 R70400-01													4
4	3300G	WASHER,FLAT,5/8 R,TY	F844-3300			P38729 R70883-02													4
72	3319G	1/8"X1.75"X1.75" WSHR PL	HW			P35672													
62	3340G	5/8" GR HEX NUT	FAST			19-35-003													4
336	3360G	5/8"X1.25" GR BOLT	A307-3360			0116968													4
26	3500G	5/8"X10" GR BOLT A307	A307-3500			32099													4
26	4076B	WD BLK RTD 6X8X14	WOOD			5372													
8	4140B	WD 4'0.25 POST 5.5X7.5	HW			5294													
72	4303G	1/2" HEX NUT A563 GR A	HW			P37736													
36	4308G	1/2"X1.5" HEX BOLT A307	HW			P35642													
36	6267G	5/16"X2.375"HXBLT A307	HW			42162													
8	19481G	C3X5#X6'-8" RUBRAIL	A-36			2073540	57,700	78,700	29.0	0.150	0.650	0.014	0.022	0.210	0.350	0.015	0.140	0.000	4

Certified Analysis

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Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
4	20207G	12/9'4.5/8-HOLE ANCH/S			2	L14718													
			M-180	A	2	A90778	65,800	86,800	20.7	0.210	0.680	0.012	0.003	0.030	0.120	0.000	0.060	0.001	4
			M-180	A	2	A90779	55,100	78,200	20.6	0.190	0.660	0.010	0.002	0.020	0.120	0.000	0.070	0.001	4
			M-180	A	2	C88581	59,000	79,100	16.3	0.210	0.690	0.009	0.002	0.030	0.110	0.000	0.060	0.001	4
36	24586A	5'5 POST/5.7#/GD RL/.25PL	A-36			28873	47,000	68,000	24.8	0.140	0.590	0.019	0.030	0.210	0.290	0.001	0.210	0.004	4
4	36120A	DAT-31-TX-HDW-CAN	FAST			19-35-003													4
	36120A		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
	36120A		F844-3300			P38729 R70883-02													4
	36120A		A307-3360			0116968													4
	36120A		A307-3403			P38421 R69871-01													4
	36120A		A307-3500			32099													4
	36120A		HW			P38729 R71181-01													
	36120A		A563-3910			P38562 R70614													4
	36120A		HW			30666													
	36120A		A307-4500			31433													4
	36120A		A-36			B8P3311	48,000	69,200	32.1	0.200	0.870	0.010	0.004	0.030	0.120	0.003	0.070	0.004	4

Certified Analysis

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

DALLAS, TX 75207
Project: PROJ# 612051 WEAK TO STRONG POST TRANSITION

Order Number: 1313267 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: WEAK POST TRA
BOL Number: 109584 Ship Date:
Document #: 1
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Use State: TX

As of: 8/7/19

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
	36120A		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
	36120A		A-36			DL19103077	56,000	75,000	26.0	0.120	0.800	0.011	0.021	0.190	0.420	0.000	0.150	0.005	4
	36120A		A-36			1059343	62,600	77,700	24.0	0.150	0.720	0.014	0.018	0.180	0.330	0.015	0.160	0.004	4
	36120A		HW			028536													
	36120A		HW			025689													
	36120A		A-500			SJ2270	63,400	72,800	25.0	0.200	0.870	0.004	0.002	0.019	0.080	0.000	0.040	0.004	4

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

Certified Analysis

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

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Use State: TX

As of: 8/7/19

Project: PROJ# 612051 WEAK TO STRONG POST TRANSITION

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

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

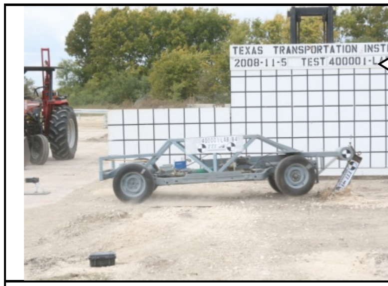
State of Ohio, County of Allen. Sworn and subscribed before me this 7th day of August, 2019 .

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

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

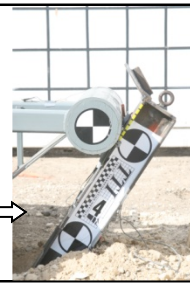
NOTARIAL SEAL STATE OF OHIO
JAMIE L DAVIS
Notary Public, State of Ohio
My Commission Expires
March 22, 2021

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



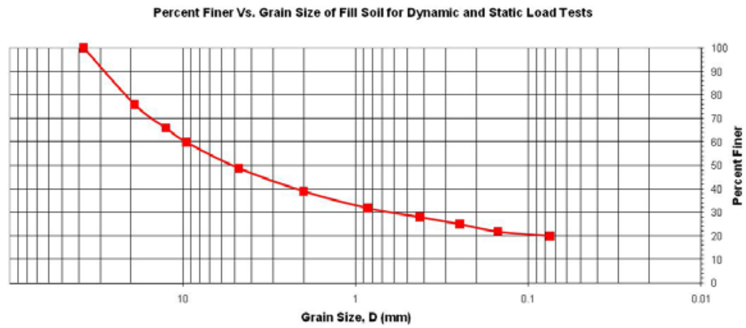
Dynamic Setup

Post-Test Photo of post

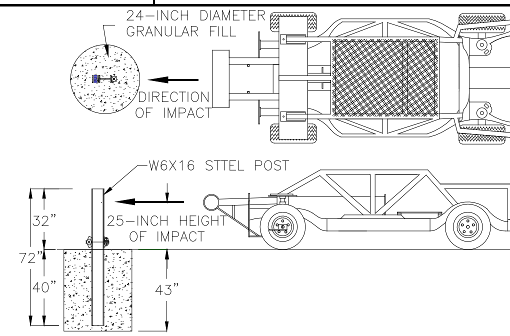


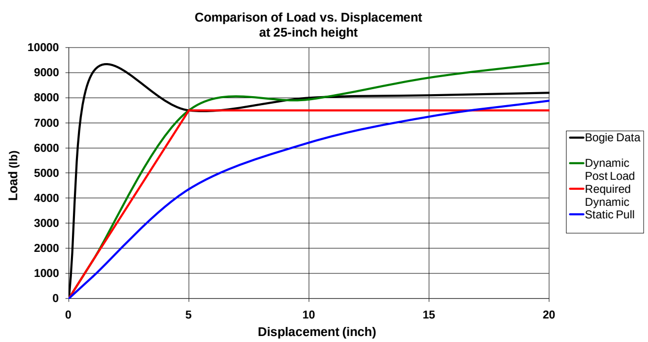
Post-Test Photo

Static Load Test

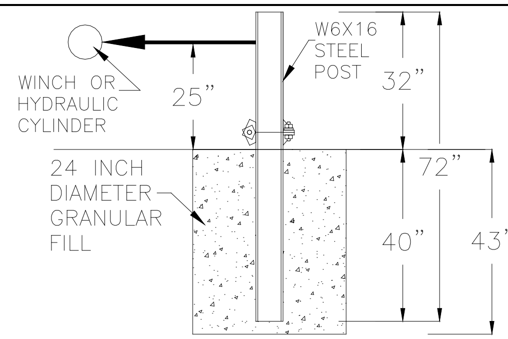


Dynamic Test Installation Details



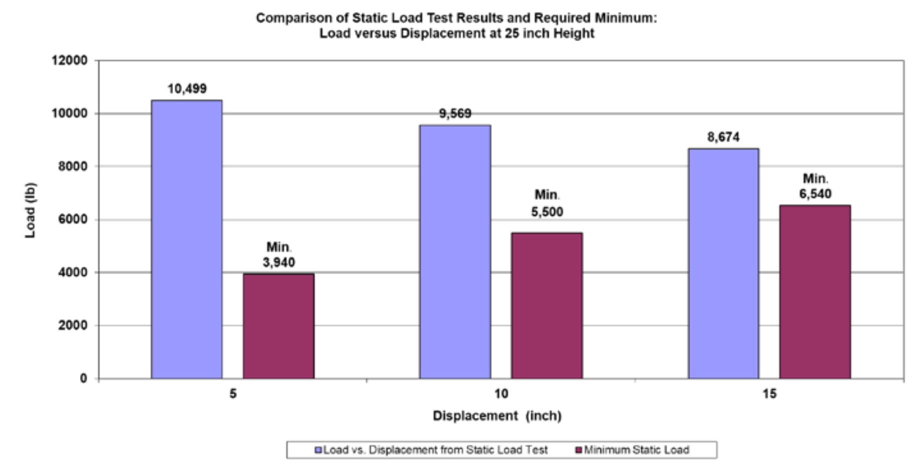


Static Load Test Installation Details

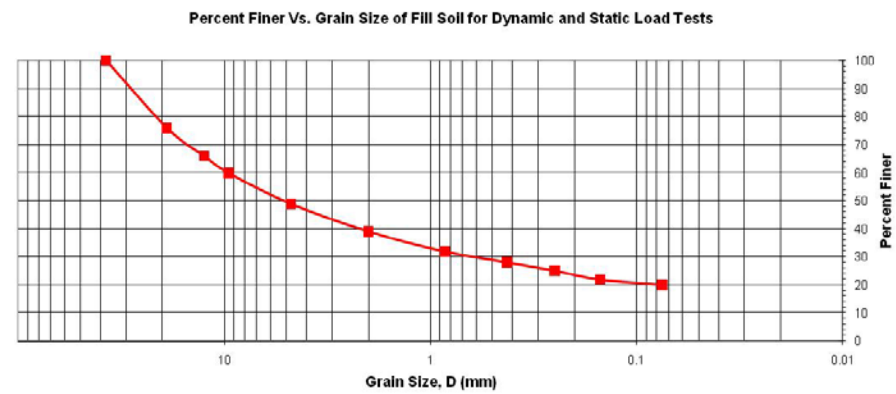


Date	2008-11-05
Test Facility and Site Location	TTI Proving Ground, 3100 SH 47, Bryan, TX 77807
In Situ Soil Description (ASTM D2487)	Sandy gravel with silty fines
Fill Material Description (ASTM D2487) and sieve analysis	AASHTO Grade B Soil-Aggregate (see sieve analysis above)
Description of Fill Placement 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. 612051-03-1.



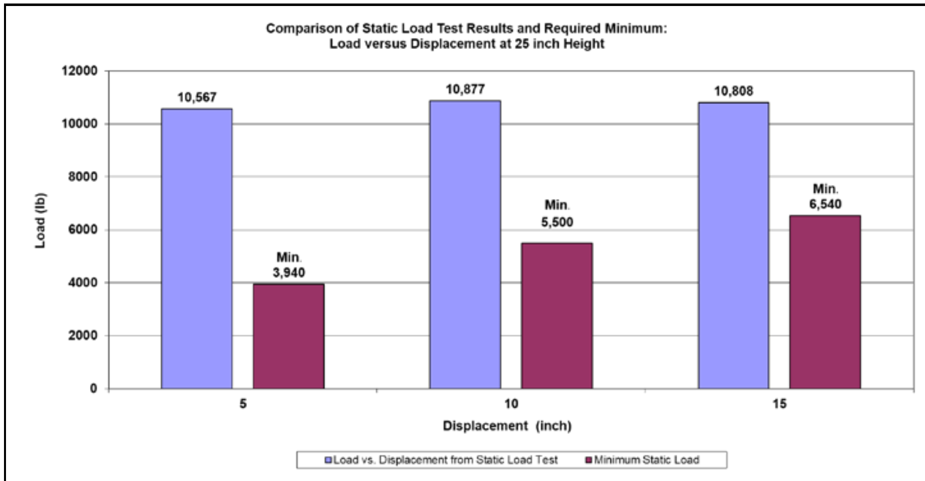
Typical Static Load Setup



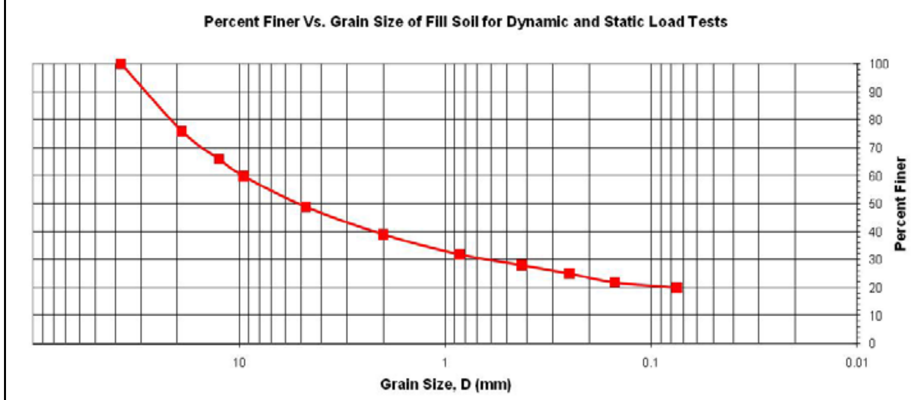
Post-Test Photo of Post

Date	2019-10-07
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. 612051-02-1.



Typical Static Load Setup



Post-Test Photo of Post

Date	2019-11-05
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 3-21 (CRASH TEST NO. 612051-02-1)

D1 VEHICLE PROPERTIES AND INFORMATION

Table D.1. Vehicle Properties for Test No. 612051-02-1.

Date:	2019-11-05	Test No.:	612051-02-1	VIN No.:	1C6RR6FT4ES233643
Year:	2014	Make:	RAM	Model:	1500

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

Tread Type: Highway Odometer: 173058

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

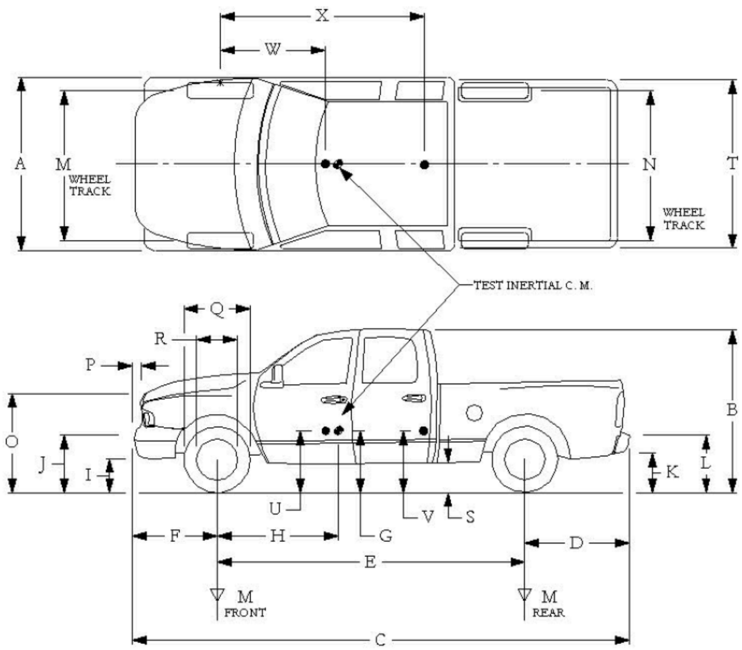
NOTES: None

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	28.12	L	30.00	Q	30.50	V	30.25
C	227.50	H	61.39	M	68.50	R	18.00	W	61.30
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	12.50
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}	2865	2818	2818
Back	3900	M_{rear}	2093	2187	2187
Total	6700	M_{Total}	4958	5005	5005

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

Mass Distribution:
lb LF: 1388 RF: 1430 LR: 1137 RR: 1050

Table D.2. Measurements of Vehicle Vertical CG for Test No. 612051-02-1.

Date: 2019-11-05 Test No.: 612051-02-1 VIN: 1C6RR6FT4ES233643

Year: 2014 Make: RAM Model: 1500

Body Style: Quad Cab Mileage: 173058

Engine: 4.7 liter V-8 Transmission: Automatic

Fuel Level: Empty Ballast: 130 (440 lb max)

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

Measured Vehicle Weights: (lb)								
LF:	1388		RF:	1430		Front Axle:	2818	
LR:	1137		RR:	1050		Rear Axle:	2187	
Left:	2525		Right:	2480		Total:	5005	
							5000 ±110 lb allowed	
Wheel Base:	140.50	inches	Track: F:	68.50	inches	R:	68.00	inches
	148 ±12 inches allowed			Track = (F+R)/2 = 67 ±1.5 inches allowed				
Center of Gravity, SAE J874 Suspension Method								
X:	61.39	inches	Rear of Front Axle	(63 ±4 inches allowed)				
Y:	-0.31	inches	Left -	Right +	of Vehicle Centerline			
Z:	28.12	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 D.3. Exterior Crush Measurements for Test No. 612051-02-1.

Date:	2019-11-05	Test No.:	612051-02-1	VIN No.:	1C6RR6FT4ES233643
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	Front plane @bumper	12	9	20	1	3	9	-	-	-	27
2	Side plane @bumper	12	9	50	1	2	-	-	7	9	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.

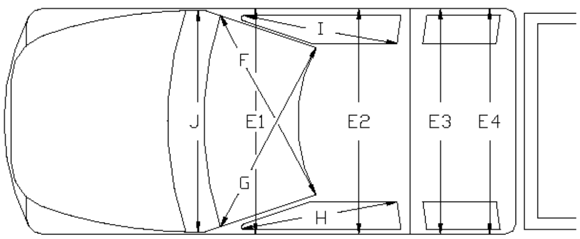
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

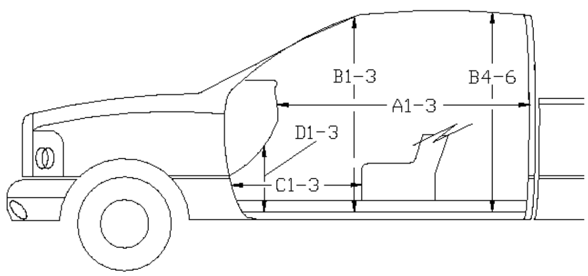
***Measure and document on the vehicle diagram the location of the maximum crush.

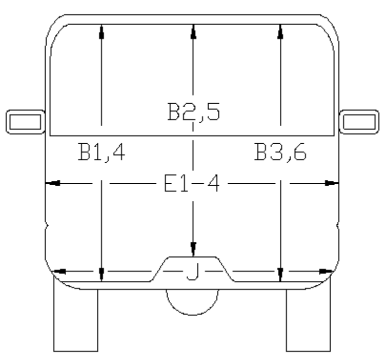
Note: Use as many lines/columns as necessary to describe each damage profile.

Table D.4. Occupant Compartment Measurements for Test No. 612051-02-1.

Date:	2019-11-05	Test No.:	612051-02-1	VIN No.:	1C6RR6FT4ES233643
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 (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

D2 SEQUENTIAL PHOTOGRAPHS

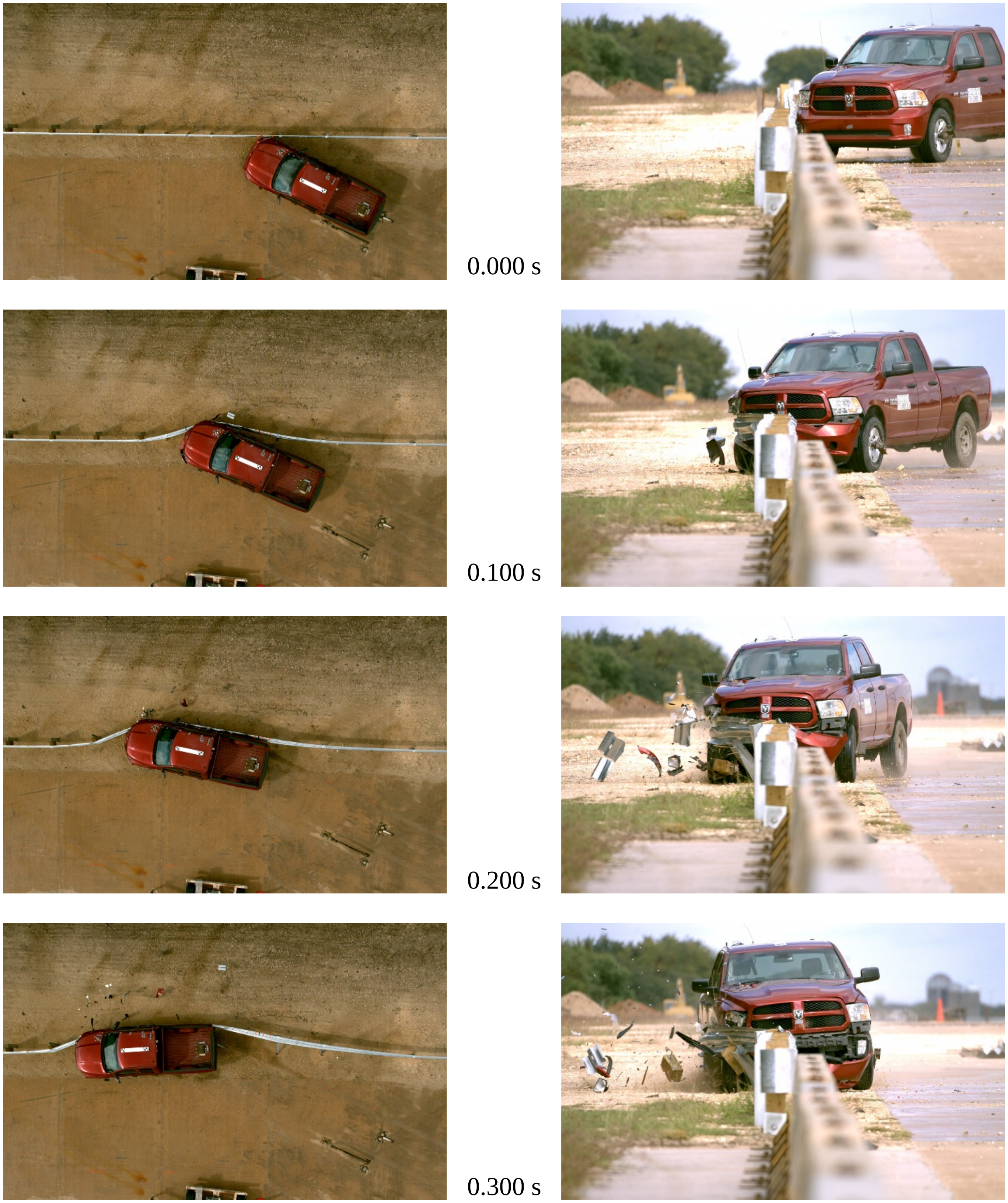
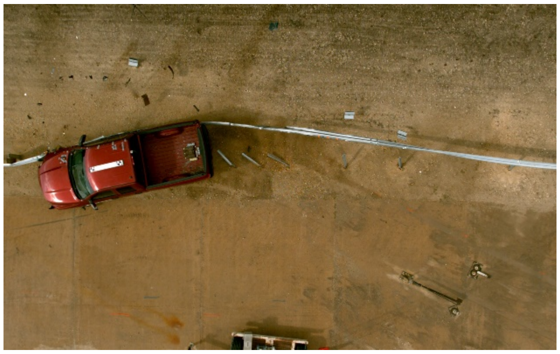


Figure D.1. Sequential Photographs for Test No. 612051-02-1 (Overhead and Frontal Views).



0.400 s

0.500 s

0.600 s

0.700 s

Figure D.1. Sequential Photographs for Test No. 612051-02-1 (Overhead and Frontal Views) (Continued).

0.000 s

0.100 s

0.200 s

0.300 s

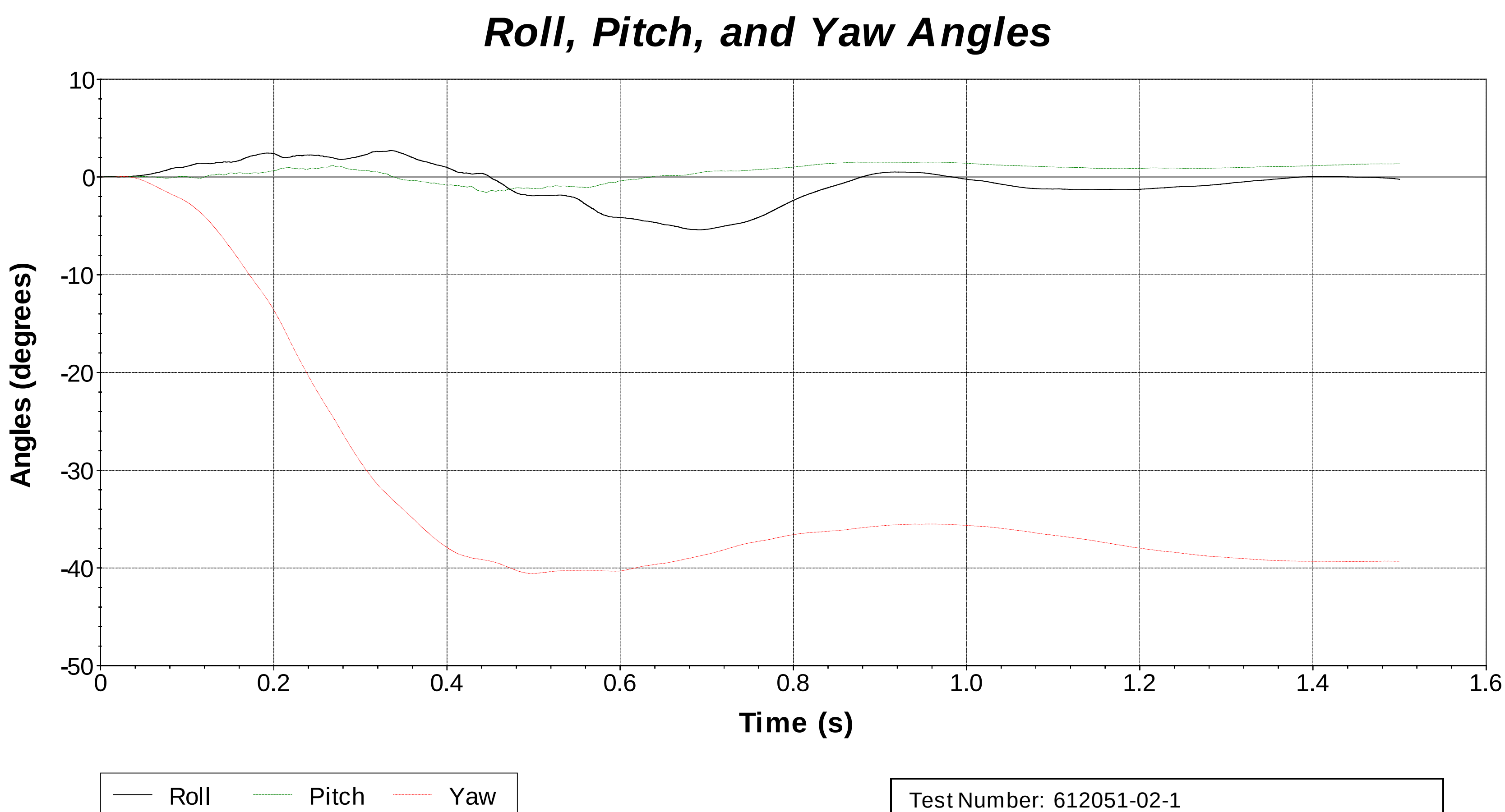
0.400 s

0.500 s

0.600 s

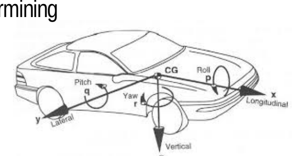
0.700 s

Figure D.2. Sequential Photographs for Test No. 612051-02-1 (Rear View).



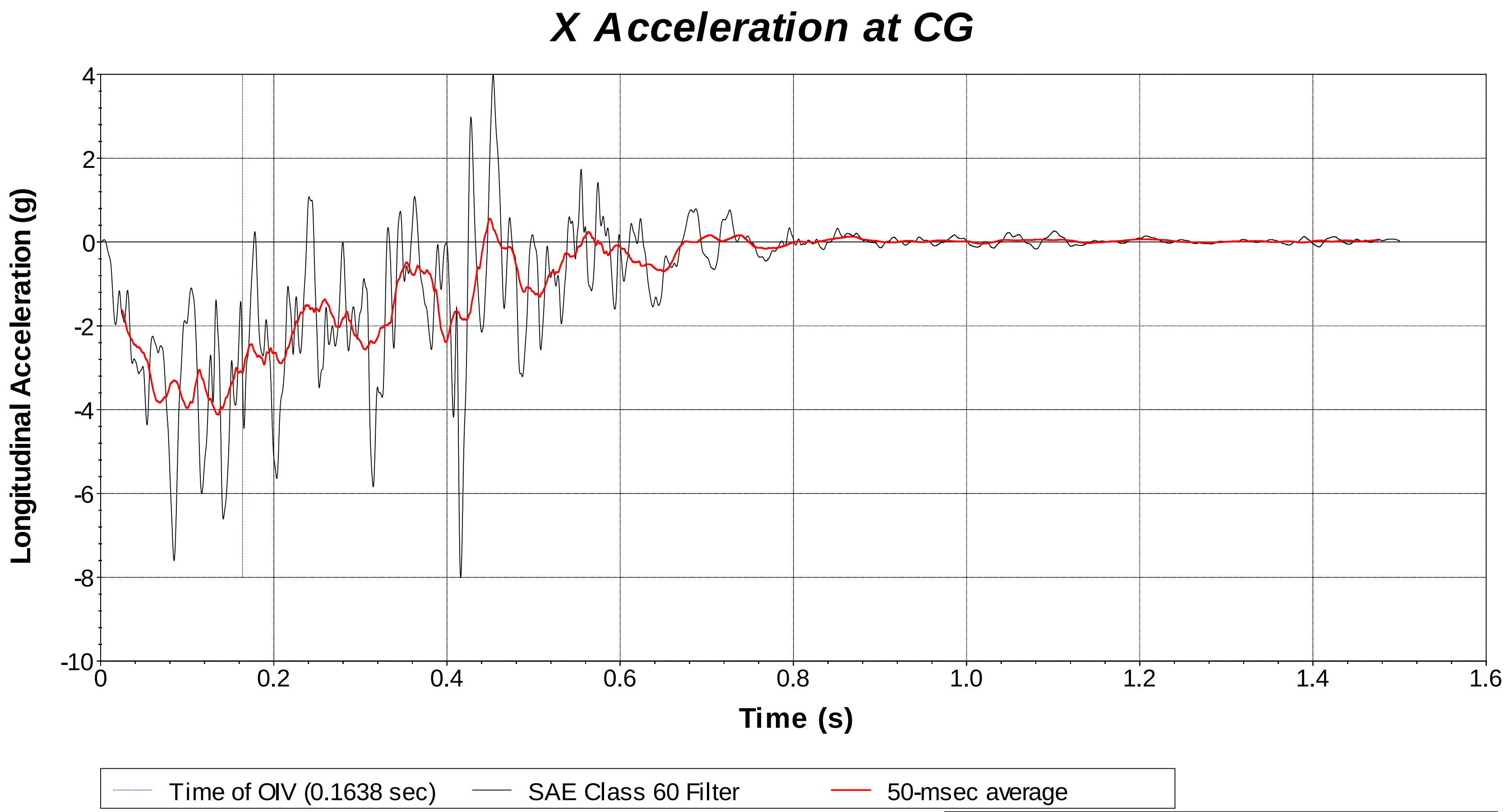
Axes are vehicle-fixed.
Sequence for determining orientation:

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



Test Number: 612051-02-1
Test Standard Test Number: MASH Test 3-21
Test Article: Guardrail transition from MGS Weak Post system to MGS Strong Post system
Test Vehicle: 2014 RAM 1500 pickup truck
Inertial Mass: 5005 lb
Gross Mass: 5005 lb
Impact Speed: 63.2 mi/h
Impact Angle: 25.3°

Figure D.3. Vehicle Angular Displacements for Test No. 612051-02-1.



Test Number: 612051-02-1
Test Standard Test Number: MASH Test 3-21
Test Article: Guardrail transition from MGS Weak Post system to MGS Strong Post system
Test Vehicle: 2014 RAM 1500 pickup truck
Inertial Mass: 5005 lb
Gross Mass: 5005 lb
Impact Speed: 63.2 mi/h
Impact Angle: 25.3°

Figure D.4. Vehicle Longitudinal Accelerometer Trace for Test No. 612051-02-1 (Accelerometer Located at Center of Gravity).

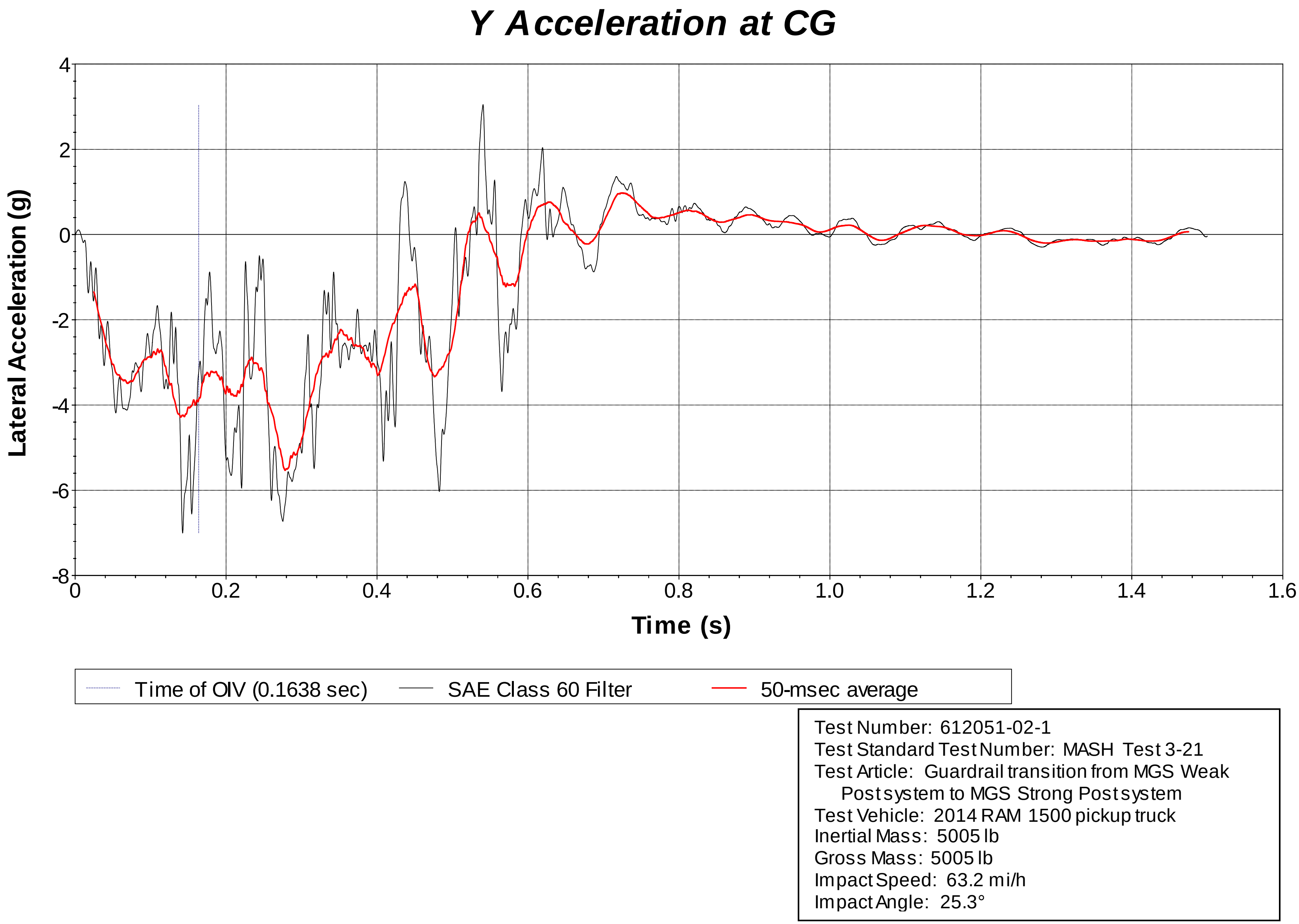


Figure D.5. Vehicle Lateral Accelerometer Trace for Test No. 612051-02-1 (Accelerometer Located at Center of Gravity).

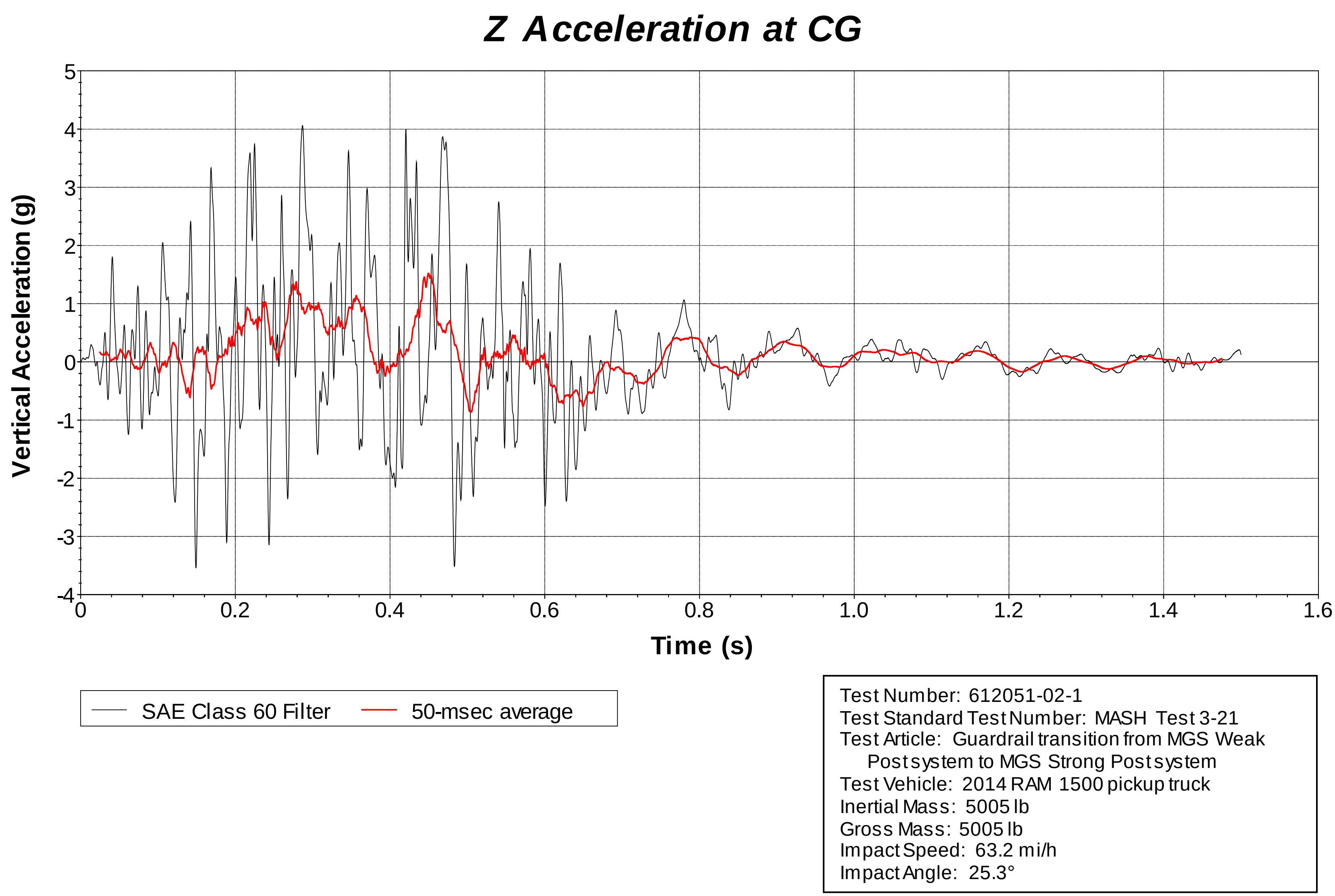


Figure D.6. Vehicle Vertical Accelerometer Trace for Test No. 612051-02-1 (Accelerometer Located at Center of Gravity).

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APPENIDX E. *MASH* TEST 3-20 (CRASH TEST NO. 612051-03-1)

E1 VEHICLE PROPERTIES AND INFORMATION

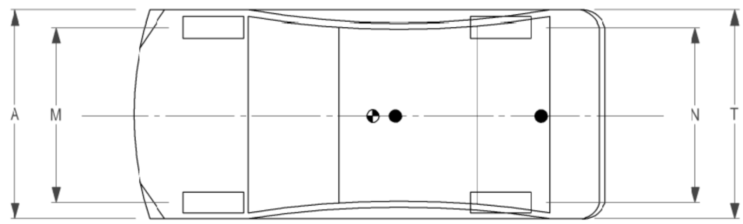
Table E.1. Vehicle Properties for Test No. 612051-03-1.

Date:	2019-10-07	Test No.:	612051-03-1	VIN No.:	KNADE223496453681
Year:	2009	Make:	Kia	Model:	Rio
Tire Inflation Pressure:	32 PSI	Odometer:	112872	Tire Size:	185/65R14

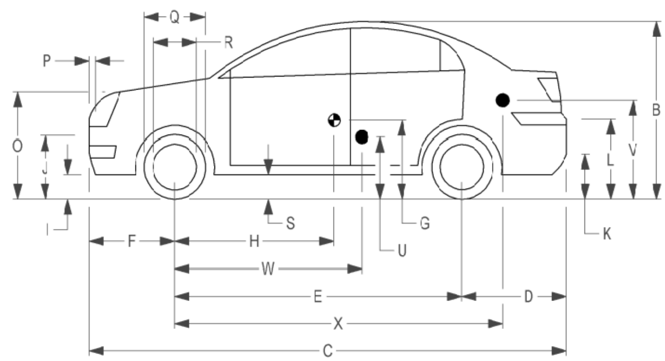
Describe any damage to the vehicle prior to test: None

● 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	35.10	M	57.75	R	15.50	W	35.15
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}	1600	1562	1647
Back	1874	M_{rear}	860	864	944
Total	3638	M_{Total}	2460	2426	2591

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

Mass Distribution:

lb	LF: 785	RF: 777	LR: 428	RR: 436

Table E.2. Exterior Crush Measurements for Test No. 612051-03-1.

Date:	2019-10-07	Test No.:	612051-03-1	VIN No.:	KNADE223496453681
Year:	2009	Make:	Kia	Model:	Rio

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage: Width** (CDC)	Direct Damage: Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	Front plane at bumper ht	14	10	30	.5	1	3	5	8	10	-12
2	Side plane at bumper ht	14	9	36	1	2.5	4	6	7.5	9	+56
	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.

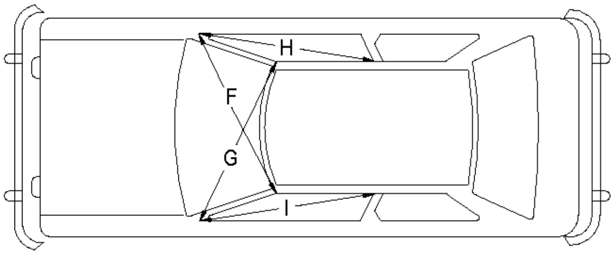
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

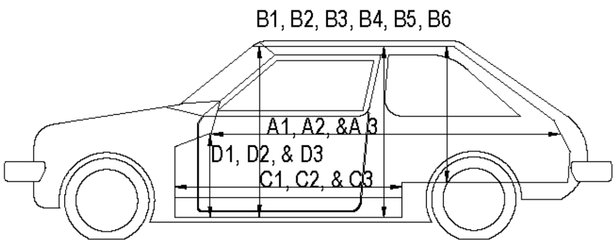
***Measure and document on the vehicle diagram the location of the maximum crush.

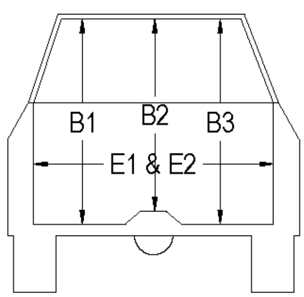
Note: Use as many lines/columns as necessary to describe each damage profile.

Table E.3. Occupant Compartment Measurements for Test No. 612051-03-1.

Date:	2019-10-07	Test No.:	612051-03-1	VIN No.:	KNADE223496453681
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	40.00	-0.50
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	8.50	-1.00
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

E2 SEQUENTIAL PHOTOGRAPHS

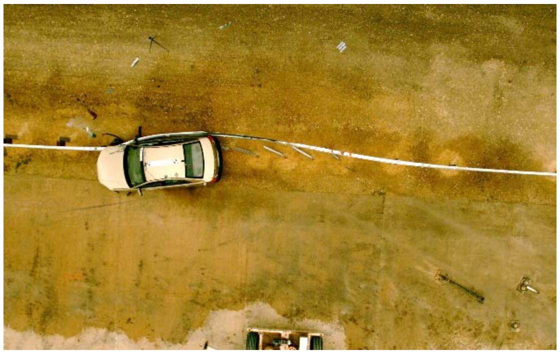
0.000 s

0.100 s

0.200 s

0.300 s

Figure E.1. Sequential Photographs for Test No. 612051-03-1 (Overhead and Frontal Views).



0.400 s

0.500 s

0.600 s

0.700 s

Figure E.1. Sequential Photographs for Test No. 612051-03-1 (Overhead and Frontal Views) (Continued).


0.000 s


0.400 s


0.100 s


0.500 s


0.200 s


0.600x s


0.300 s

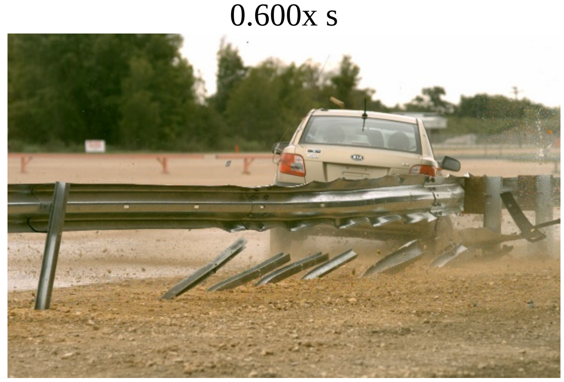

0.700 s

Figure E.2. Sequential Photographs for Test No. 612051-03-1 (Rear View).

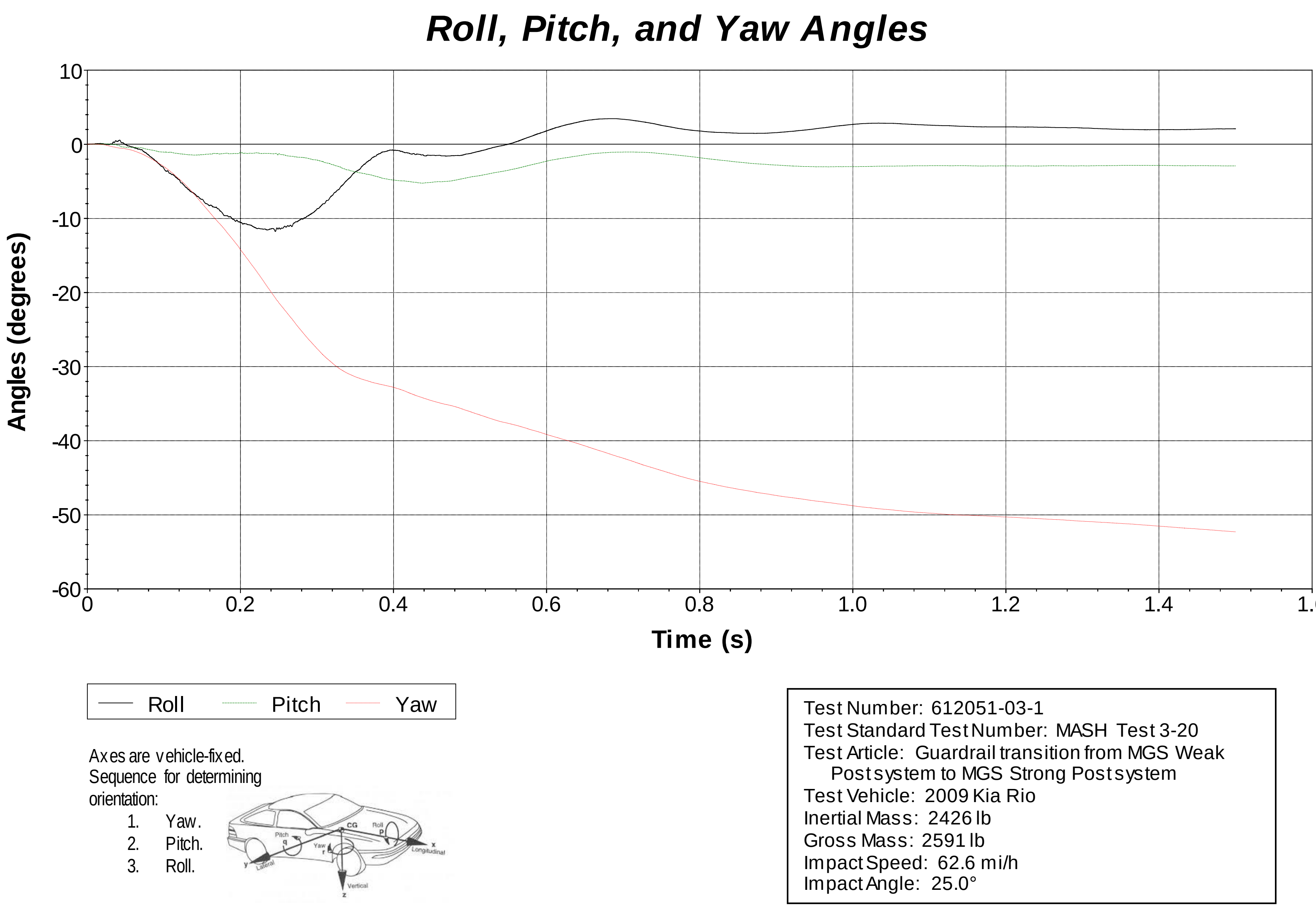
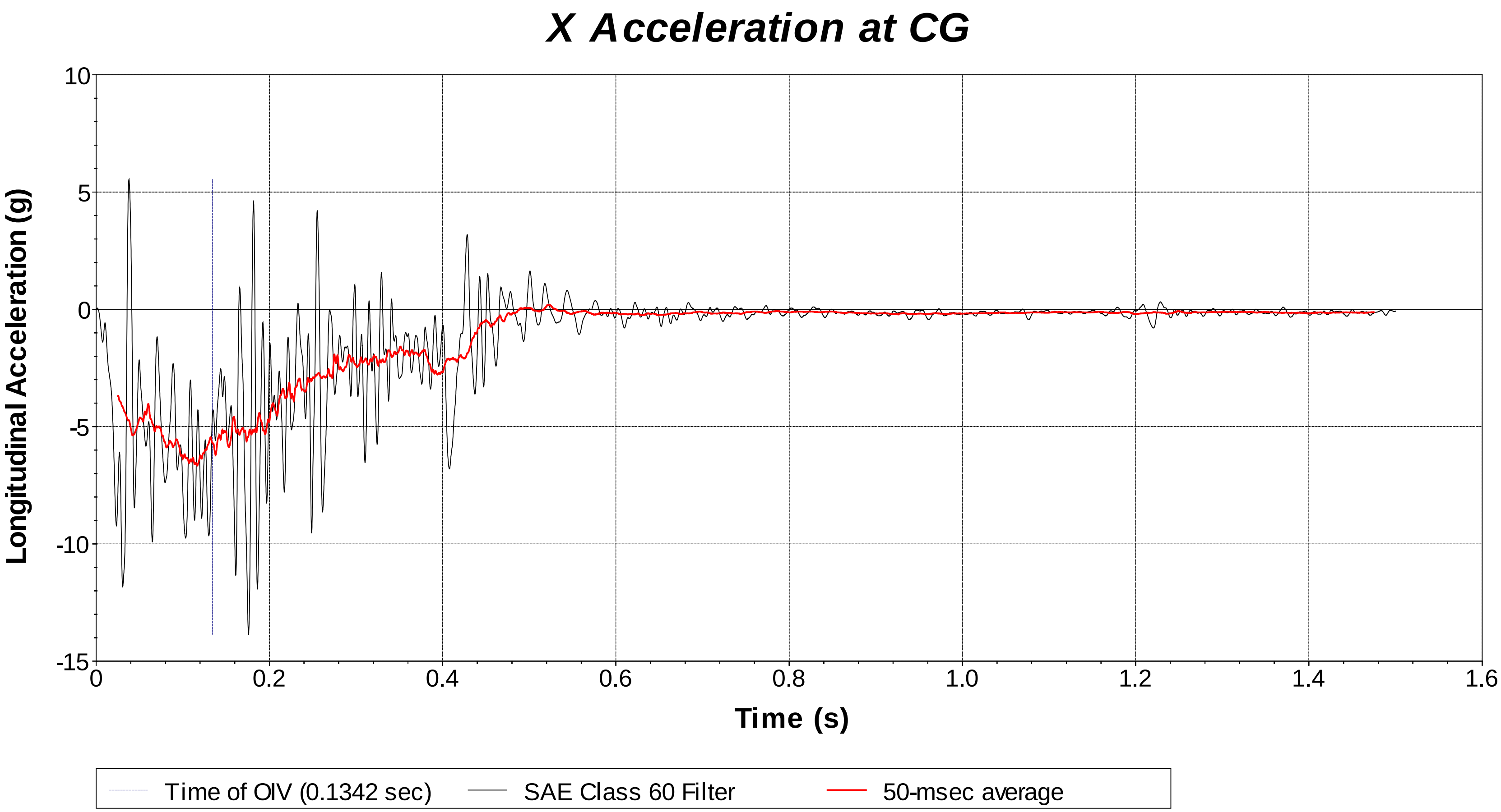


Figure E.3. Vehicle Angular Displacements for Test No. 612051-03-1.



Test Number: 612051-03-1
Test Standard Test Number: MASH Test 3-20
Test Article: Guardrail transition from MGS Weak Post system to MGS Strong Post system
Test Vehicle: 2009 Kia Rio
Inertial Mass: 2426 lb
Gross Mass: 2591 lb
Impact Speed: 62.6 mi/h
Impact Angle: 25.0°

Figure E.4. Vehicle Longitudinal Accelerometer Trace for Test No. 612051-03-1 (Accelerometer Located at Center of Gravity).

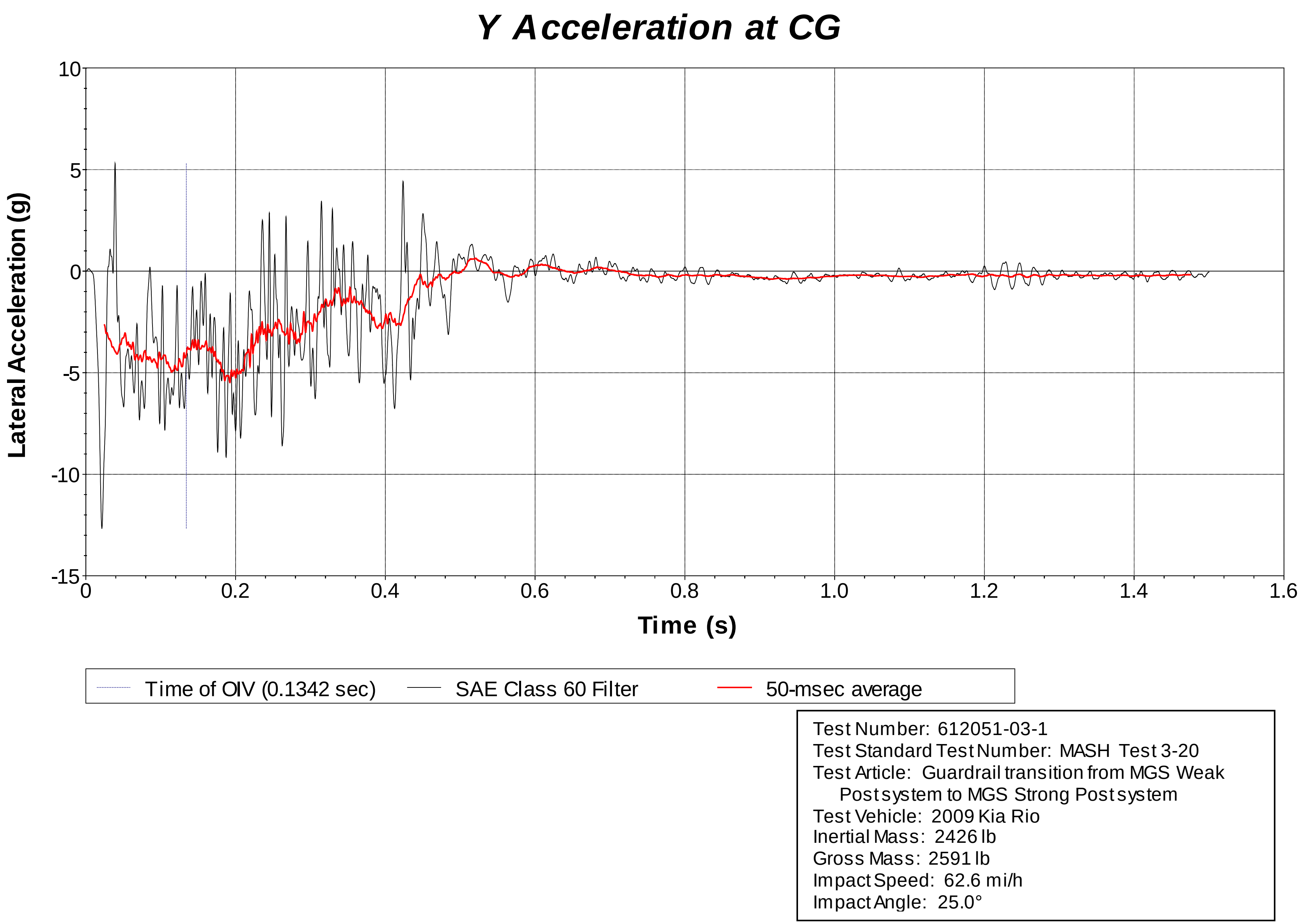


Figure E.5. Vehicle Lateral Accelerometer Trace for Test No. 612051-03-1 (Accelerometer Located at Center of Gravity).

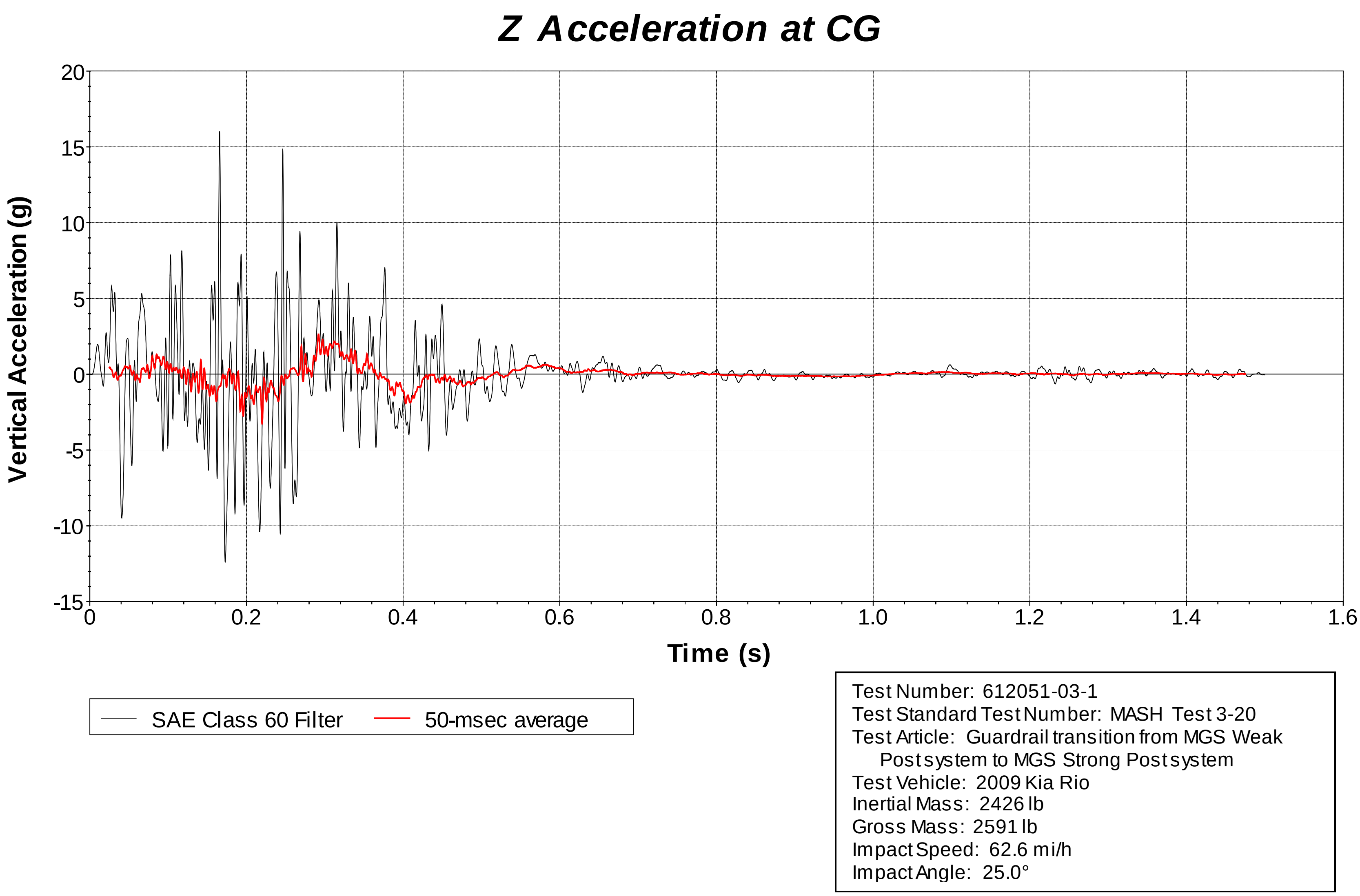


Figure E.6. Vehicle Vertical Accelerometer Trace for Test No. 612051-03-1 (Accelerometer Located at Center of Gravity).