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MASH TESTS 3-34 AND 3-35 ON THE 31-INCH BURIED-IN-BACKSLOPE TERMINAL COMPATIBLE WITH MGS GUARDRAIL

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16. Abstract

Buried (in backslope) terminal designs for beam guardrail were developed under National Cooperative Highway Research Program (NCHRP) *Report 350* criteria 27¾-inch high guardrail systems. Some states have modified this design so that it could be used with 31-inch high guardrail systems. Other agencies are hesitant to use this design for 31-inch high guardrail until it is crash tested or deemed acceptable for use by Federal Highway Administration.

The purpose of this research was to evaluate the safety performance of a 31-inch Buried-in-Backslope (BIB) terminal attached to a Midwest Guardrail System (MGS) in accordance with American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*) evaluation criteria. The proposed BIB terminal design successfully met the *MASH* evaluation criteria for *MASH* Tests 3-34 and 3-35.

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Chapter 1. INTRODUCTION

1.1 PROBLEM STATEMENT

Buried (in backslope) terminal designs for beam guardrail were developed under National Cooperative Highway Research Program (NCHRP) *Report 350* criteria for 27¾-inch high guardrail systems (*1*). When properly designed and located, this type of anchor eliminates the possibility of an end-on impact with the barrier terminal and minimizes the likelihood of vehicular intrusion behind the barrier. Some states desire to have a modified BIB design that is compatible with 31-inch high guardrail systems.

The purpose of this research was to perform full-scale crash tests and evaluate the performance of a 31-inch BIB terminal design attached to an MGS guardrail system.

1.2 BACKGROUND

A W-beam guardrail can be terminated by burying the end of the rail element into a soil berm. This type of guardrail termination installation is referred to as a "Buried-In-Backslope end terminal" (hereinafter "BIB"). BIB terminal designs for W-beam guardrail were developed under *NCHRP Report 350* criteria for 27-inch high guardrail systems.

With the satisfactory performance of the modified G4(1S) W-beam guardrail system with timber blockouts, the Federal Highway Administration (FHWA) decided to evaluate two terminal designs for the steel-post W-beam guardrail with similar modification (i.e., timber blockouts). Texas A&M Transportation Institute (TTI) evaluated two BIB end terminals for use with modified G4(1S) W-beam guardrails (*3*). Tests were conducted in accordance with *NCHRP Report 350*, and involved a 2000P vehicle impacting the terminal at a nominal impact speed and angle of 62 mi/h and 20°, respectively. The BIB end terminal for the W-beam guardrail was tested in two configurations: one with a ditch and the other with a drop inlet. The top of the rail was 27 inches high, as measured from the shoulder grade, and the guardrail end was anchored to a concrete block buried in the backslope.

In previous tests, for the ditch configuration, the earth was graded away from the shoulder at a 1V:10H slope for 6 ft, followed by a 3-ft wide ditch, then by a 1V:2H backslope. For the drop inlet configuration, the earth was graded away from the shoulder at a 1V:10H slope for 9 ft, followed by a 1V:2H backslope. Both installations met evaluation criteria set forth for *NCHRP Report 350* test designation 3-35. There was minimal deformation and no intrusion into the occupant compartment. The occupant risk factors were all well within the recommended limits.

Subsequently, the buried terminal design was also successfully tested on installations with a 1V:6H foreslope forming a V-ditch with a 1V:4H backslope and over a 1V:4H foreslope forming a V-ditch with a 1V:2H backslope (*4*). These tests were intended primarily to evaluate the ability of the device to contain and redirect a 2000P pickup truck (structural adequacy criteria). The tests performed were *NCHRP Report 350* test designation 3-35, with a 2000P vehicle impacting the beginning of the length of need of the terminal at a nominal speed and impact angle of 62 mi/h and 20°, respectively.

The BIB terminal with a 1V:6H ditch contained and redirected the vehicle. Maximum deformation of the occupant compartment was 1.77 inches. The terminal performed acceptably for *NCHRP Report 350* test designation 3-35. The BIB terminal with a 1V:4H slope contained and redirected the vehicle. Maximum deformation of the occupant compartment was 4.9 inches. The terminal performed acceptably for *NCHRP Report 350* test designation 3-35.

The satisfactory performance of the BIB tests in different ditch configurations culminated with FHWA acceptance letter #CC 53A (Acceptance Letter, 1998).

In recent years, guardrail heights have increased to 31 inches in many states. Considering the increase in guardrail height to 31 inches, it was advisable that the BIB terminal design for a 27¾-inch high guardrail be modified to satisfy *NCHRP Report 350* criteria for a 31-inch high guardrail. The BIB design offers the advantage of shielding guardrail ends from direct vehicle impact, thus reducing the potential for penetration behind the end terminal and/or for the guardrail to penetrate the vehicle.

A previous study funded by the Roadside Safety Pooled Fund Group was conducted with the objective to identify design modifications necessary to adapt a buried terminal design for 27¾-inch guardrail for use with a 31-inch guardrail system, and to assess impact performance criteria in accordance with *NCHRP Report 350* criteria (*5*). Results from the computer simulation of Test 3-35 on the 31-inch high buried-in-backslope terminal indicate that all applicable *NCHRP Report 350* evaluation criteria were met. Finite element (FE) computer simulations indicated the 31-inch high buried-in-backslope terminal would have very similar behavior to that of the 27¾-inch high system. In fact, the 31-inch rail height improved vehicle stability throughout the entire impact event, and occupant risk indices were well below the limiting values recommended in *NCHRP Report 350*.

1.3 OBJECTIVE

The purpose of this research was to evaluate the safety performance of a 31-inch BIB terminal attached to a Midwest Guardrail System (MGS) in accordance with American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*) evaluation criteria. Two full-scale crash tests were performed according to *MASH* Test Level 3 (TL-3). The first full-scale crash test, *MASH* Test 3-35, involved a 5000-lb pickup truck impacting the BIB at 62 mi/h nominal speed and at a nominal angle of 25° with respect to the roadway orientation. This test is intended to evaluate the strength and capacity of the terminal system. The second full-scale test, *MASH* Test 3-34, involved a 2420-lb passenger vehicle impacting the terminal at 62 mi/h nominal speed at a nominal angle of 15° with respect to the roadway orientation. This test assesses occupant risk as well as the likelihood for the small passenger car to underride the terminal system. Both tests were assessed according to the evaluation criteria set forth in *MASH* for TL-3 terminals.

Chapter 2. SYSTEM DETAILS

2.1. TEST ARTICLE AND INSTALLATION DETAILS

The test installation consisted of a guardrail with a BIB Terminal on the upstream end and a Texas Department of Transportation (TxDOT) Downstream Anchor Terminal (DAT) Terminal on the downstream end, for a total installation length of 242 ft 7 inches. The guardrail was flared across a V-ditch and its end was anchored to three 72-inch long steel posts using a special connection bracket that was buried in the backslope (see Sheet 5 of 6 in Appendix A). The installation used standard 12 gauge W-beam guardrail with the splices mid-span between the posts. All posts in the installation were spaced at 75 inches, except the two 37½-inch spaces at posts 1 to 2 and 2 to 3 in the BIB Terminal anchorage section. The W-beam guardrail was attached to 72-inch long W6×8.5 wide flange guardrail posts embedded in soil and nominal 6×8-inch timber blockouts using 10-inch long button head guardrail bolts such that the top of the guardrail was at 31 inches above grade.

The DAT Terminal and guardrail were placed parallel to an existing concrete apron, with the front of the rail aligned with the break point of “V” profile ditch. The ditch had a 72-inch wide, 4-to-1 foreslope that initiated from the pavement edge, and a 2-to-1 backslope. The bottom of the V-ditch crossed the rail terminal between posts 9 and 10.

The guardrail between posts 1, 2, 3, and 4 (numbered sequentially from the end anchor) is flared back in a 4-to-1 ratio. The guardrail between posts 4 and 6 is flared back in a 6-to-1 ratio; between posts 6 and 10 in an 8-to-1 ratio; and between posts 10 and 22 in a 13 to 1 ratio. In addition, the guardrail between post 10 and post 1 is tapered from a height of 31 inches to 15 inches, as measured from the top of the rail to the pavement grade. This places the top of the rail at post 1 12 inches below the surface of the soil. The guardrail, beginning at post 10, was parallel to the travel way with the top of the rail at a height of 31 inches.

Posts 1 through 3 and 22 through 39 were 72 inches long. Posts 4 through 21 were 96 inches long. A W-beam rub rail extended from post 4 to post 21. The rub rail was mounted to the steel guardrail posts with a 2-inch guardrail bolt. A 3-inch vertical gap was maintained between the W-beam guardrail and the rub rail. The upstream end of the rub rail was connected to post 4 with a special connection bracket and the downstream end of the rub rail was connected to the back of post 21 with a ⅝ inch diameter by 5-inch long bolt.

Figure 2.1 presents overall information on the BIB Terminal, and Figure 2.2 provides photographs of the installation. Appendix A provides further details of the BIB Terminal.

2.2. MATERIAL SPECIFICATIONS

Material certification documents for the materials used to install/construct the BIB Terminal are on file at TTI Proving Ground.

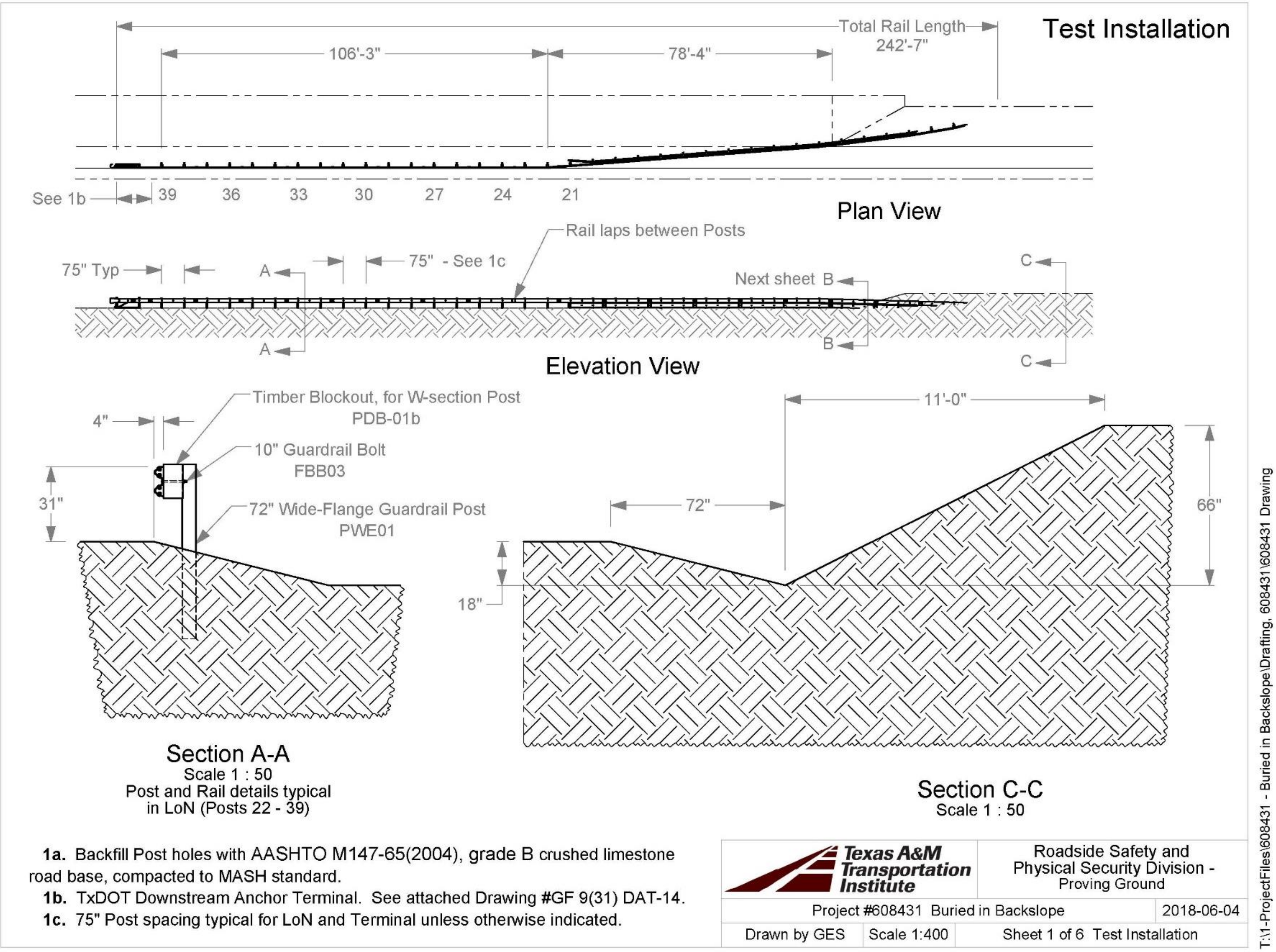


Figure 2.1. Details of the 31-inch BIB Terminal.

Figure 2.2. BIB Terminal prior to Testing.

2.3. SOIL CONDITIONS

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

In accordance with Appendix B of *MASH*, soil strength was measured the day of the crash test. During installation of the BIB terminal for full-scale crash testing, two W6×16 posts were installed in the immediate vicinity of the BIB terminal utilizing the same fill materials and installation procedures used in the test installation and the standard dynamic test. Table B.1 in

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

On the day of Test No. 608431-1-1, April 30, 2018, loads on the post at deflections of 5 inches, 10 inches, and 15 inches were 6717 lbf, 7121 lbf, and 7121 lbf, respectively. Table B.2 in Appendix B shows the strength of the backfill material in which the BIB Terminal was installed met minimum *MASH* requirements.

On the day of Test No. 608431-1-2, June 1, 2018, loads on the post at deflections of 5 inches, 10 inches, and 15 inches were 4494 lbf, 5202 lbf, and 5555 lbf, respectively. Table B.3 in Appendix B shows the strength of the backfill material in which the BIB Terminal was installed met the minimum *MASH* requirement at 5 inches, but did not meet minimum *MASH* requirements at 10 inches and 15 inches. The location where the two W6×16 pull posts were installed for soil strength measurements was roughly 100 ft upstream of the BIB impact location. The soil at this location had a significantly higher moisture content than the soil in the ditch in which the guardrail system was installed. The researchers decided to excavate in the ditch adjacent to a post in the vicinity of the impact location to verify and compare the soil moisture. The soil in the ditch appeared drier than the location where the two W6×16 pull posts were installed, and close to optimum moisture content. The difference was attributed to the fact that the area upstream of the ditch where the two W6×16 pull posts were installed retained rain water, while the ditch in which the guardrail and BIB terminal were installed allowed for the same water to drain faster. After discussions with the sponsor, the researchers decided to perform the crash test.

Chapter 3. TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1. CRASH TEST PERFORMED / MATRIX

Table 3.1 shows the recommended tests and evaluation criteria for evaluating the impact performance of terminals in *MASH*. *MASH* Tests 3-34 and 3-35 were performed on the BIB terminal. The crash tests and data analysis procedures were in accordance with guidelines presented in *MASH*.

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

	Test Designation	Test Vehicle	Impact Conditions		Evaluation Criteria
			Speed (mi/h)	Angle (deg.)	
Non-Gating Terminals	3-30	1100C	62	0	A, D, F, H, I
	3-31	2270P	62	0	A, D, F, H, I
	3-32	1100C	62	5-15	A, D, F, H, I
	3-33	2270P	62	5-15	A, D, F, H, I
	3-34	1100C	62	15	A, D, F, H, I
	3-35	2270P	62	25	A, D, F, H, I
	3-36	2270P	62	25	A, D, F, H, I
	3-37b	1100C	62	25	A, D, F, H, I
	3-38	1500A	62	0	A, D, F, H, I

Tests 3-30, 3-31, 3-32, and 3-33 are intended to evaluate occupant risk, vehicle stability and vehicle trajectory for head-on or oblique impacts on the end of the terminal system. In the case of the BIB system, there is no exposed end that can be impacted, therefore these tests are considered not relevant.

Test 3-36 is designed to examine the behavior of terminals when attached to rigid barriers or other very stiff features. In the case of the BIB, there is no rigid back-up structure attached to the terminal, therefore this test is considered not relevant.

Test 3-37 (a or b) examines the behavior of terminals during reverse-direction impacts. For post-and-beam terminals utilizing a breakaway cable system, the 1100C is generally the critical vehicle for this test (Test 3-37b). The BIB system doesn’t include a breakaway cable system that needs to be released. Also, the rubrail of the BIB system helps prevent interaction with posts during a reverse direction impact. In addition, the BIB system flaring away from the roadway reduces the effective impact angle and impact severity for a reverse direction hit. For these reasons, test 3-37b is considered not relevant.

Test 3-38 is intended to evaluate the performance of crash cushions and end terminals during impacts by mid-size vehicles. Since the BIB is not a staged device, this test is considered not relevant.

The crash tests reported herein were performed in accordance with *MASH* Tests 3-34 and 3-35 for non-gating terminals.

MASH defines the CIP for Test 34 as the point "where the behavior of these devices (i.e. the BIB terminal) changes from gating or capturing to redirection." With that in mind, the researchers selected the location that maximizes under-riding potential for the 1100C vehicle, as well as maximizes interaction between the passenger car and test installation. The target impact point for *MASH* Test 3-34 was selected to be 19 inches downstream of post 9, which was the point where the installation crosses the ditch bottom.

MASH indicates that for Test 35, "a 2270P vehicle is directed into the system at the beginning of the LON at an impact angle of 25 degrees". The AASHTO Roadside Design Guide defines the beginning of the LON for all buried-in-backslope designs as "the point where the installation crosses the ditch bottom". Therefore, the target impact point for *MASH* Test 3-35 was 19 inches downstream of post 9, which is the point where the installation crosses the ditch bottom.

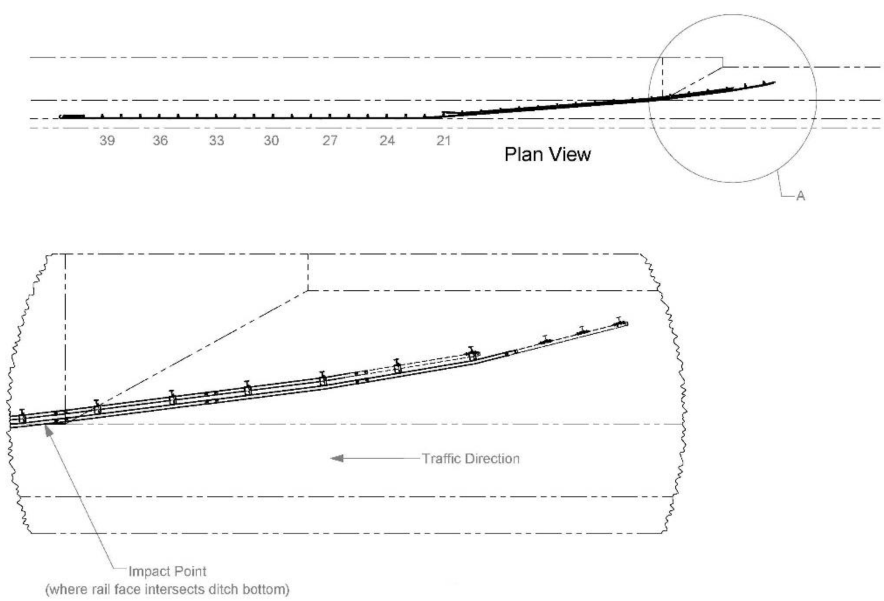


Figure 3.1. Target CIP for *MASH* Tests 3-34 and 3-35 on BIB Terminal.

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 2-3 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 non-gating terminals are listed in Table 3.1, and the substance of the evaluation criteria described in Table 3.2. An evaluation of each of the crash test results is presented in detail under the section Assessment of Test Results.

Table 3.2. Evaluation Criteria Required for *MASH* TL-3 Non-Gating Terminals.

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

Chapter 4. TEST CONDITIONS

4.1. TEST FACILITY

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

The test facilities of the TTI Proving Ground are located on the Texas A&M University 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 Buried-in-Backslope 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. Each 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 values per second with a resolution of one part in 65,536. Once data are recorded, internal batteries back these up inside the unit should the primary battery cable be severed. Initial contact of the pressure switch on the vehicle bumper provides a time zero mark as well as initiates the recording process. After each test, the data are downloaded from the TDAS Pro unit into a laptop computer at the test site. The Test Risk Assessment Program (TRAP) software then processes the raw data to produce detailed reports of the test results.

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

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

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

4.3.2 Anthropomorphic Dummy Instrumentation

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. Use of the dummy in the 2270P vehicle is recommended for tall rails to evaluate the “potential for an occupant to extend out of the vehicle and come into direct contact with the test article.” Although this information is reported, it is not part of the impact performance evaluation. A dummy was placed in the front seat of the 2270P vehicle on the impact side and restrained with lap and shoulder belts.

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 each of the impacting vehicles was activated by a pressure-sensitive tape switch to indicate the instant of contact with the BIB terminal. The flashbulb was visible from each camera. The video files from these digital high-speed cameras were analyzed to observe phenomena occurring during the collision and to obtain time-event, displacement, and angular data. A digital camera recorded and documented conditions of each test vehicle and the installation before and after the test.

Chapter 5. *MASH* TEST 3-34 (CRASH TEST NO. 608431-01-2)

5.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

MASH Test 3-34 involves an 1100C vehicle weighing 2420 lb ±55 lb impacting the beginning of length of need of the terminal at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 15° ±1.5°. The target impact point for *MASH* Test 3-34 on the BIB Terminal was at the rail location where the system crosses the ditch (approximately 19.0 inches downstream of post 9).

The 2009 Kia Rio* used in the test weighed 2427 lb, and the actual impact speed was 64.1 mi/h. The vehicle left the roadway at 14.5°, however, due to the vehicle's interaction with the slope as it traversed into the ditch, actual impact angle as it contacted the terminal was 17.8° to the roadway (24.9° effective angle with the tangent of the rail at impact point). The actual impact point was 18.5 inches downstream of post 9. Minimum target impact severity (IS) was ≥19 kip-ft, and actual IS was 31 kip-ft (59 kip-ft using 24.9° effective angle).

5.2 WEATHER CONDITIONS

MASH Test 3-34 on the BIB Terminal was performed on the afternoon of June 1, 2018. Weather conditions at the time of testing were as follows: wind speed: 9 mi/h; wind direction: 229° (vehicle was traveling in a southwesterly direction); temperature: 89°F; relative humidity: 66 percent.

5.3 TEST VEHICLE

Figures 5.1 and 5.2 show the 2009 Kia Rio used for the crash test. The vehicle's test inertia weight was 2427 lb, and its gross static weight was 2592 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 C.1 in Appendix C1 gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

Figure 5.1. BIB Terminal/Test Vehicle Geometrics for Test No. 608431-01-2.

* A test vehicle model older than 2012 was used, based upon availability. An older model vehicle is permitted by AASHTO as long as it is otherwise *MASH* compliant. Other than the year model, this vehicle met the *MASH* requirements.

Figure 5.2. Test Vehicle before Test No. 608431-01-2.

5.4 TEST DESCRIPTION

The test vehicle was traveling at an impact speed of 64.1 mi/h when it contacted the BIB Terminal 18.5 inches downstream of post 9, at an impact angle of 17.8° with respect to the roadway (24.9° effective angle with the tangent of the rail at impact point). Table 5.1 lists events that occurred during Test No. 608431-01-2. Figure C.1 in Appendix C2 present sequential photographs during the test.

Table 5.1. Events during Test No. 608431-01-2.

TIME (s)	EVENTS
0.013	Post 9 begins to deflect toward the field side
0.027	Post 10 begins to deflect toward the field side
0.037	Vehicle begins to redirect
0.046	Right front corner of bumper contacts post 10
0.048	Post 11 begins to deflect toward the field side
0.073	Right front corner of bumper contacts post 10
0.074	Post 12 begins to deflect toward the field side
0.097	Post 13 begins to deflect toward the field side
0.119	Right front corner of bumper contacts post 11
0.168	Rear of vehicle contacts rail element
0.175	Vehicle becomes parallel with the guardrail
0.199	Right front corner of bumper contacts blockout at post 12
0.363	Vehicle loses contact with the guardrail while traveling at exit speed and angle of 49.9 mi/h and 6.7° relative to tangent section of guardrail.

For longitudinal barriers, it is desirable that the vehicle redirects and exits the barrier within the exit box criteria (not less than 32.8 ft downstream from loss of contact for cars and pickups). The test vehicle exited within the exit box criteria defined in *MASH*. After loss of contact with the barrier, the vehicle came to rest 303 ft downstream of the impact and 54 ft toward traffic lanes.

5.5 DAMAGE TO TEST INSTALLATION

Figures 5.3 through 5.5 show the damage to the BIB Terminal, and Table 5.2 lists damage. Working width was 25.3 inches at a height of 32.0 inches. Maximum dynamic deflection during the test was 19.9 inches, and maximum permanent deformation was 5.5 inches.

Figure 5.3. BIB Terminal after Test No. 608431-01-2.

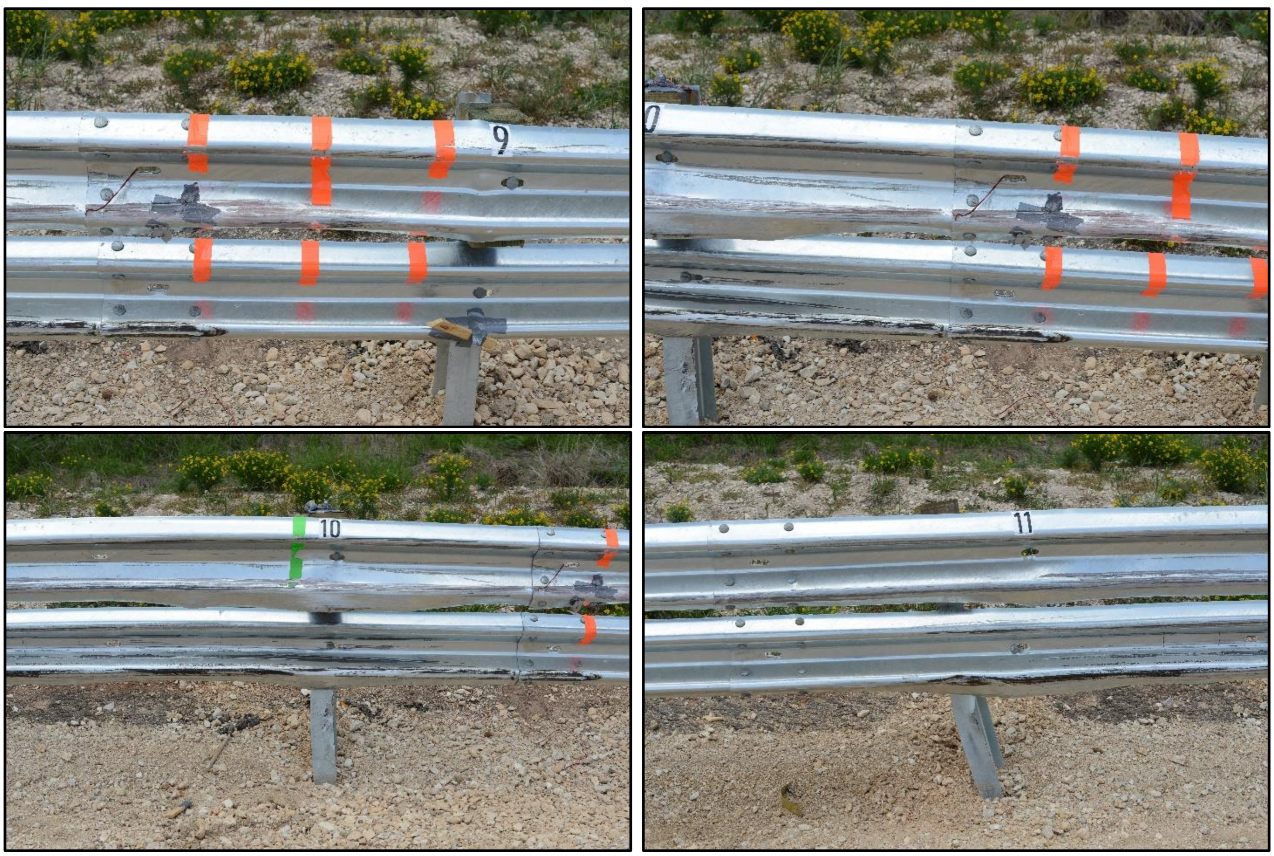


Figure 5.4. Posts 9 through 11 after Test No. 608431-01-2.

Figure 5.5. Field Side of Posts 9 through 12 after Test No. 608431-01-2.

Table 5.2. Damage to BIB Terminal after Test No. 608431-01-2.

POST NO.	DAMAGE
1-7	No noticeable damage
8	Soil around post disturbed
9	1.5 inch gap on traffic side; 0.4 inch gap on field side; leaning 86° toward field side
10	3.0 inch gap traffic side; 1.25 inch gap field side; post leaning 79° toward field side
11	4.5 inch gap traffic side; leaning 75° toward field side & 80° downstream; rail released from blockout; rubrail bolt tore through flange
12	0.75 inch gap on traffic side; 0.5 inch gap on field side; leaning 86° toward field side
13	0.25 inch gap on traffic side; 0.5 inch gap on field side; leaning 89° toward field side
14-40	No damage

5.6 VEHICLE DAMAGE

Figure 5.6 shows the damage sustained by the vehicle. The front bumper, hood, right front fender, right front tire and rim, right front strut, right front and rear doors, right rear tire, right rear quarter panel, and rear bumper were damaged. The windshield sustained stress cracking at the right lower corner. Maximum exterior crush to the vehicle was 8.0 inches in the side plane at the right front corner at bumper height. No occupant compartment deformation or intrusion was noted. Figure 5.7 shows the interior of the vehicle. Tables C.2 and C.3 in Appendix C1 provide exterior crush and occupant compartment measurements.

Figure 5.6. Test Vehicle after Test No. 608431-01-2.

Figure 5.7. Interior of Test Vehicle after Test No. 608431-01-2.

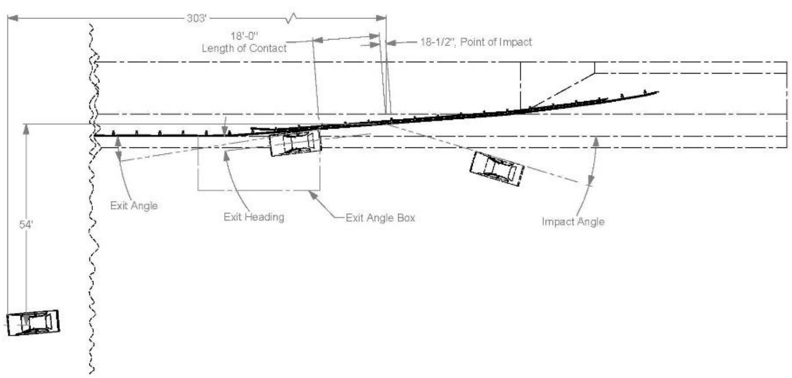
5.7 OCCUPANT RISK FACTORS

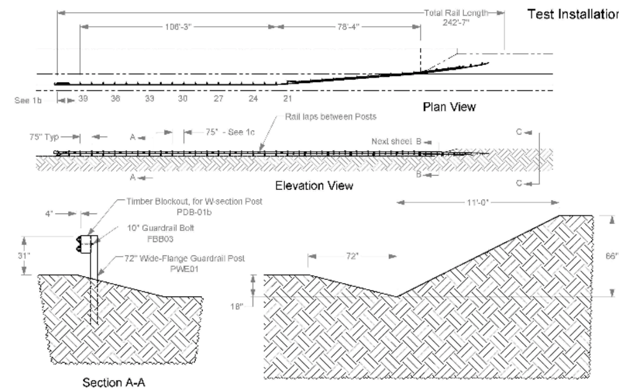
Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk and are shown in Table 5.3. Figure 6.8 summarizes these data and other pertinent information from the test. Figure C.2 in Appendix C3 shows the vehicle angular displacements, and Figures C.3 through C.8 in Appendix C4 show accelerations versus time traces.

Table 5.3. Occupant Risk Factors for Test No. 608431-01-2.

Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV) Longitudinal Lateral	 **14.1 ft/s** **20.3 ft/s**	at 0.1169 s on right side of interior
Occupant Ridedown Accelerations Longitudinal Lateral	 **7.5 g** **8.5 g**	 0.1546 - 0.1646 s 0.1180 - 0.1280 s
Theoretical Head Impact Velocity (THIV)	**26.0 km/h** **7.2 m/s**	at 0.1134 s on right side of interior
Post Head Deceleration (PHD)	**10.3 g**	0.1409 - 0.1509 s
Acceleration Severity Index (ASI)	**0.96**	0.0684 - 0.1184 s
Maximum 50-ms Moving Average Longitudinal Lateral Vertical	 **−5.7 g** **−7.4 g** **−2.8 g**	 0.0374 - 0.0874 s 0.0316 - 0.0816 s 0.1933 - 0.2433 s
Maximum Roll, Pitch, and Yaw Angles Roll Pitch Yaw	 **17°** **6°** **44°**	 0.4214 s 2.7930 s 2.7908 s

0.000 s | 0.150 s | 0.300 s | 0.450 s





General Information
Test Agency .... Texas A&M Transportation Institute (TTI)
Test Standard Test No. ...... MASH Test 3-34
TTI Test No. 608431-01-2
Test Date 2018-06-01

Test Article
Type .... Terminal
Name .... Buried-in-Backslope Terminal
Installation Length .... 242 ft 7 inches
Material or Key Elements ... W-Beam Terminal flared back at 4 different angles, for total setback of 14 ft, 31-inch rail height to the paved road; splices between posts; 4:1 foreslope; 2:1 backslope; W-beam rubrail

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

Test Vehicle
Type/Designation 1100C
Make and Model .... 2009 Kia Rio
Curb .... 2475 lb
Test Inertial .... 2427 lb
Dummy .... 165 lb
Gross Static .... 2592 lb

Impact Conditions
Speed .... 64.1 mi/h
Angle* .... 14.5° / 17.8° / 24.9°
Location/Orientation .... 18.5 inches dwnstrm of post 9

Impact Severity** .... 31 kip-ft / 59 kip-ft

Exit Conditions
Speed .... 49.9 mi/h
Exit Trajectory Angle .... 9.1°
Exit Heading Angle .... 6.7°

Occupant Risk Values
Longitudinal OIV .... 14.1 ft/s
Lateral OIV .... 20.3 ft/s
Longitudinal Ridedown .... 7.5 g
Lateral Ridedown .... 8.5 g
THIV .... 26.0 km/h
PHD .... 10.3 g
ASI 0.96
Max. 0.050-s Average
Longitudinal .... -5.7 g
Lateral .... -7.4 g
Vertical .... -2.8 g

Post-Impact Trajectory
Stopping Distance .... 303 ft downstream 54 ft toward traffic

Vehicle Stability
Maximum Yaw Angle .... 44°
Maximum Pitch Angle .... 6°
Maximum Roll Angle .... 17°
Vehicle Snagging .... No
Vehicle Pocketing .... No

Test Article Deflections
Dynamic .... 19.9 inches
Permanent .... 5.5 inches
Working Width .... 25.3 inches
Height of Working Width .... 32.0 inches

Vehicle Damage
VDS 01RFQ4
CDC 01FREW4
Max. Exterior Deformation .... 8.0 inches
OCDI RS0000000
Max. Occupant Compartment Deformation .... None

Figure 5.8. Summary of Results for *MASH* Test 3-34 on BIB Terminal.

* Angle at roadway departure; Impact angle at contact with terminal with respect to roadway; Effective impact angle with respect to tangent of flare at contact.
** IS at impact angle at contact with terminal with respect to roadway; IS at effective impact angle with respect to tangent of flare at impact.

Chapter 6. *MASH* TEST 3-35 (CRASH TEST NO. 608431-01-1)

6.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

MASH Test 3-35 involves a 2270P vehicle weighing 5000 lb ±110 lb impacting the beginning of the length of need of the terminal at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 25° ±1.5°. The target impact point for *MASH* Test 3-35 on the BIB terminal was at rail location where the system crosses the ditch (19 inches ±1 ft downstream of post 9).

The 2012 Dodge RAM 1500 pickup truck used in the test weighed 5035 lb, and the actual impact speed was 63.3 mi/h. The vehicle left the roadway at 25.4°, however, due to the vehicle's interaction with the slope as it traversed into the ditch, actual impact angle as it contacted the terminal was 27.2° to the roadway (34.3° effective angle with the tangent of the rail at impact point). The actual impact point was 19.6 inches downstream of post 9. Minimum target IS was ≥106 kip-ft, and actual IS was 141 kip-ft (214 kip-ft using 34.3° effective angle).

6.2 WEATHER CONDITIONS

The test was performed on the morning of April 30, 2018. Weather conditions at the time of testing were as follows: wind speed: 7 mi/h; wind direction: 180° (vehicle was traveling in a southwesterly direction); temperature: 73°F; relative humidity: 76 percent.

6.3 TEST VEHICLE

Figures 6.1 and 6.2 show the 2012 Dodge RAM 1500 pickup truck used for the crash test. The vehicle's test inertia weight was 5035 lb, and its gross static weight was 5200 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 28.38 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.

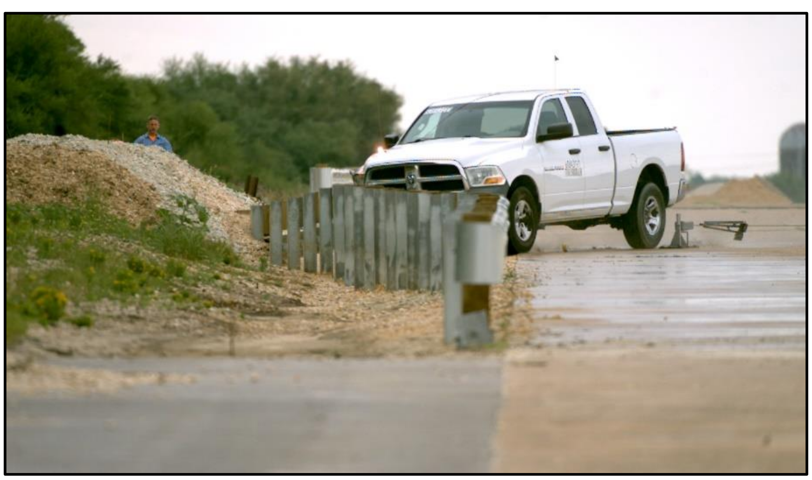


Figure 6.1. BIB Terminal/Test Vehicle Geometrics for Test No. 608431-01-1.

Figure 6.2. Test Vehicle before Test No. 608431-01-1.

6.4 TEST DESCRIPTION

The test vehicle was traveling at an impact speed of 63.3 mi/h when it contacted the BIB Terminal 19.6 inches downstream of post 9 at an impact angle of 27.2° with respect to the roadway (34.3° effective angle with the tangent of the rail at impact point). Table 6.1 lists events that occurred during Test No. 608431-01-1. Figures D.1 and D.2 in Appendix D2 present sequential photographs during the test.

Table 6.1. Events during Test No. 608431-01-1.

TIME (s)	EVENTS
0.000	Vehicle makes contact with terminal downstream of Post 9
0.048	Vehicle begins to redirect
0.078	Front right tire blows out hitting base of post 10
0.141	Rear left tire is airborne and off of pavement
0.192	Right rear of vehicle makes contact with rail between posts 9 and 10
0.223	Vehicle becomes parallel with terminal
0.655	Vehicle loses contact with terminal while traveling at 36.0 mi/h and 11.8°
1.118	Vehicle front left tire makes contact with pavement
1.700	Vehicle touches ground

For longitudinal barriers, it is desirable that the vehicle redirects and exits the barrier within the exit box criteria (not less than 32.8 ft downstream from loss of contact for cars and pickups). The test vehicle exited within the exit box criteria defined in *MASH*. After loss of contact with the barrier, the vehicle came to rest 167 ft downstream of the impact and 3 ft toward traffic lanes.

6.5 DAMAGE TO TEST INSTALLATION

Figures 6.3 through 6.5 show damage to the BIB Terminal, and Table 6.2 lists damage. Working width was 62.7 inches at a height of 54.7 inches. Maximum dynamic deflection during the test was 51.4 inches.

Figure 6.3. BIB Terminal after Test No. 608431-01-1.

Figure 6.4. Damage at Posts 9 through 15 after Test No. 608431-01-1.

Figure 6.5. Rail Tears after Test No. 608431-01-1.

Table 6.2. Damage to BIB Terminal after Test No. 608431-01-1.

POST NO.	DAMAGE
1-4	No noticeable damage
5	Soil disturbed; 0.25 inch gap on downstream side; blockout rotated 5°
6	Soil disturbed
7	Soil disturbed; 0.25 inch gap on traffic side; post leaning 89° toward field side
8	1.5 inch gap traffic side; 0.5 inch gap field side; 85° toward field side
9	5.0 inch gap traffic side; 2.0 inch gap field side; post leaning 75° toward field side
10	Post released from both rail elements; post leaning 50° toward field side
11	Post released from top rail element; post leaning 48° toward field side
--	4.5-inch tear in rub rail at joint between posts 11 and 12
12	Post released from both rail elements; post leaning 85° toward field side / 45° downstream
13	Post released from both rail elements; post leaning 85° toward field side / 45° downstream
14	Post released from both rail elements; post leaning 75° toward field side / 74° downstream
15	Post released from rub rail; 1.0 inch gap on traffic side; post leaning 88° twd field side
16	0.25 inch gap on traffic side; post leaning 89° toward field side
41	0.12 inch gap on downstream side

6.6 VEHICLE DAMAGE

Figure 6.6 shows the damage sustained by the vehicle. The front bumper grill, right front tire and rim, right front and rear doors, rear exterior bed, right rear tire and rim, and rear bumper were damaged Maximum exterior crush to the vehicle was 10.0 inches in the front plane at the right front corner at bumper height. No occupant compartment deformation or intrusion was noted. Figure 6.7 shows the interior of the vehicle. Tables D.3 and D.4D.4 in Appendix D1 provide exterior crush and occupant compartment measurements.

Figure 6.6. Test Vehicle after Test No. 608431-01-1.

Before Test After Test

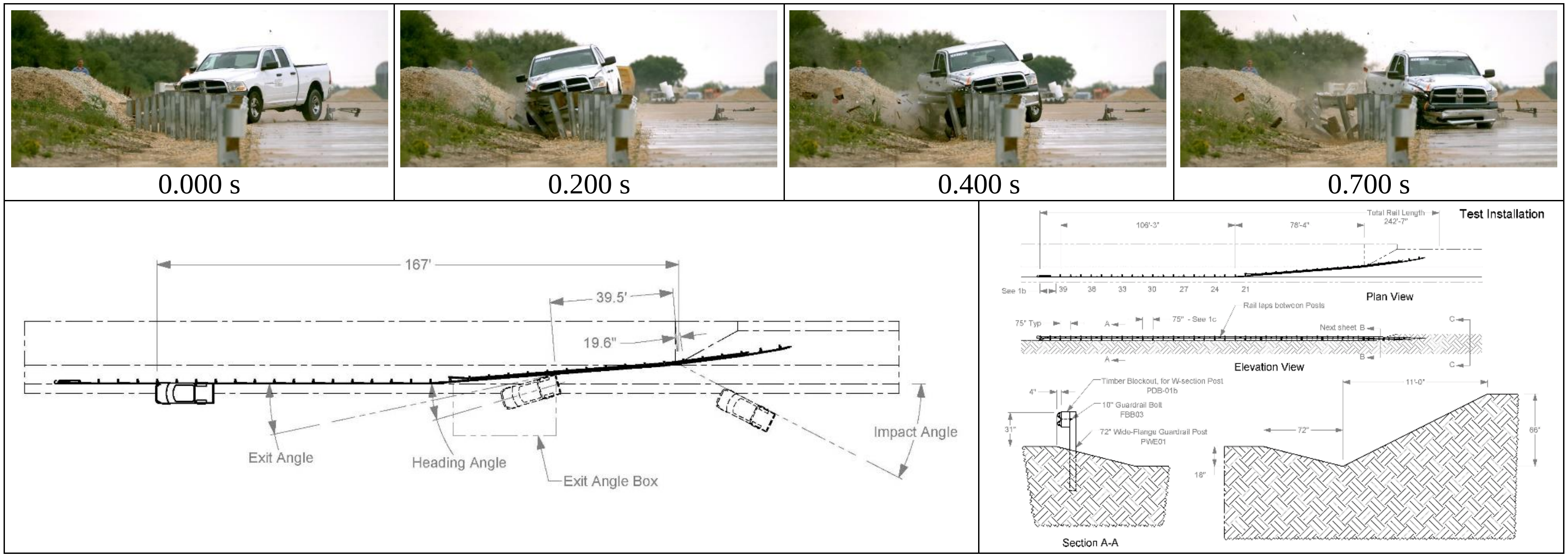
Figure 6.7. Interior of Test Vehicle for Test No. 608431-01-1.

6.7 OCCUPANT RISK FACTORS

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk and are shown in Table 6.3. Figure 6.8 summarizes these data and other pertinent information from the test. Figure D.3 in Appendix D3 shows the vehicle angular displacements, and Figures D.4 through D.9 in Appendix D4 show accelerations versus time traces.

Table 6.3. Occupant Risk Factors for Test No. 608431-01-1.

Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV) Longitudinal Lateral	 **17.4 ft/s** **16.4 ft/s**	at 0.1424 s on right side of interior
Occupant Ridedown Accelerations Longitudinal Lateral	 **5.4 g** **8.8 g**	 0.1424 - 0.1524 s 0.2327 - 0.2427 s
Theoretical Head Impact Velocity (THIV)	**24.8 km/h** **6.9 m/s**	at 0.1360 s on right side of interior
Post Head Deceleration (PHD)	**9.2 g**	0.2260 - 0.2360 s
Acceleration Severity Index (ASI)	**0.83**	0.2454 - 0.2954 s
Maximum 50-ms Moving Average Longitudinal Lateral Vertical	 **−5.3 g** **−7.0 g** **2.4 g**	 0.0726 - 0.1226 s 0.2258 - 0.2758 s 0.2424 - 0.2924 s
Maximum Roll, Pitch, and Yaw Angles Roll Pitch Yaw	 **6°** **3°** **36°**	 0.1959 s 0.8693 s 0.7859 s



General Information

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	MASH Test 3-35
TTI Test No.	608431-01-1
Test Date	2018-04-30

Test Article

Type	Terminal
Name	Buried-in-Backslope Terminal
Installation Length	242 ft 7 inches
Material or Key Elements	W-Beam Terminal flared back at 4 different angles, for total setback of 14 ft, 31-inch rail height to the paved road; splice between posts; 4:1 foreslope; 2:1 backslope; W-beam rubrail
Soil Type and Condition	AASHTO M147-65(2004), grading B Soil (crushed limestone), Damp

Test Vehicle

Type/Designation	2270P
Make and Model	2012 Dodge RAM 1500 Pickup
Curb	4968 lb
Test Inertial	5035 lb
Dummy	165 lb
Gross Static	5200 lb

Impact Conditions

Speed	63.3 mi/h
Angle*	25.4° / 27.2° / 34.3°
Location/Orientation	19.6 inches dwnstrm of post 9
Impact Severity**	141 kip-ft / 214 kip-ft

Exit Conditions

Speed	36.0 mi/h
Angle	11.8°

Occupant Risk Values

Longitudinal OIV	17.4 ft/s
Lateral OIV	16.4 ft/s
Longitudinal Ridedown	5.4 g
Lateral Ridedown	8.8 g
THIV	24.8 km/h
PHD	9.2 g
ASI	0.83
Max. 0.050-s Average	
Longitudinal	−5.3 g
Lateral	−7.0 g
Vertical	2.4 g

Post-Impact Trajectory

Stopping Distance	167 ft dwnstrm 3 ft twd traffic

Vehicle Stability

Maximum Yaw Angle	36°
Maximum Pitch Angle	3°
Maximum Roll Angle	6°
Vehicle Snagging	No
Vehicle Pocketing	No

Test Article Deflections

Dynamic	51.4 inches
Permanent	51.4 inches
Working Width	62.7 inches
Height of Working Width	54.7 inches

Vehicle Damage

VDS	01RFQ5
CDC	01FREW4
Max. Exterior Deformation	10.0 inches
OCDI	RF000000
Max. Occupant Compartment Deformation	None

Figure 6.8. Summary of Results for *MASH* Test 3-35 on BIB Terminal.

* Angle at roadway departure; Impact angle at contact with terminal with respect to roadway; Effective impact angle with respect to tangent of flare at contact.
** IS at impact angle at contact with terminal with respect to roadway; IS at effective impact angle with respect to tangent of flare at impact.

Chapter 7. CONCLUSIONS AND IMPLEMENTATION

7.1 ASSESSMENT OF TEST RESULTS

The crash tests reported herein were performed in accordance with *MASH* Tests 3-34 and 3-35 for non-gating terminals. An assessment of the tests based on the applicable safety evaluation criteria for *MASH* Tests 3-34 and 3-35 is provided in Tables 7.1 and 7.2, respectively.

7.2 CONCLUSIONS

The BIB Terminal performed acceptably for *MASH* Tests 3-34 and 3-35 for non-gating terminals.

7.3 IMPLEMENTATION*

Two tests were performed to evaluate the proposed design for a TL-3 BIB Terminal compatible with an MGS guardrail system. They represent the tests considered necessary to demonstrate *MASH* compliance of the device. The TL-3 BIB Terminal system met *MASH* requirements and is considered *MASH* compliant. It is considered suitable for implementation at V-ditch locations with a 4:1 or flatter foreslope where a *MASH* TL-3 BIB Terminal system is needed and/or desired.

---

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

Table 7.1. Performance Evaluation Summary for *MASH* Test 3-34 on BIB Terminal.

Test Agency: Texas A&M Transportation Institute | Test No.: 608431-01-2 | Test Date: 2018-06-01

MASH Test 3-34 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 BIB Terminal contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 19.9 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.	No occupant compartment deformation or intrusion occurred.	
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 17° and 6°, respectively.	Pass
H. Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 30 ft/s, or maximum allowable value of 40 ft/s.	Longitudinal OIV was 14.1 ft/s, and lateral OIV was 20.3 ft/s.	Pass
I. The occupant ridedown accelerations should satisfy the following limits: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	Maximum longitudinal occupant ridedown acceleration was 7.5 g, and maximum lateral occupant ridedown acceleration was 8.5 g.	Pass

Table 7.2. Performance Evaluation Summary for *MASH* Test 3-35 on BIB Terminal.

Test Agency: Texas A&M Transportation Institute   Test No.: 608431-01-1   Test Date: 2018-04-30

***MASH* Test 3-35 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 BIB Terminal contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 51.4 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 occurred.	
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 6° and 3°, respectively.	Pass
H. Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 30 ft/s, or maximum allowable value of 40 ft/s.	Longitudinal OIV was 17.4 ft/s, and lateral OIV was 16.4 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.	Maximum longitudinal occupant ridedown acceleration was 5.4 g, and maximum lateral occupant ridedown acceleration was 8.8 g.	Pass

REFERENCES

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

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

3. Arnold, A.G., Buth, C.E., and Menges, W.L., *Testing and Evaluation of W-Beam Guardrails Buried-in-Backslope*, Texas A&M Transportation Institute, College Station, TX, January 1999.

4. Buth, C.E., Menges, W.L., and Schoeneman, S.K., *NCHRP Report 350 Assessment of Existing Roadside Safety Hardware*, Texas A&M Transportation Institute, College Station, TX, November 2000.

5. Chiara Silvestri Dobrovolny, Dusty R. Arrington, and Abhinav P. Mohanakrishnan, *Buried Terminal Design Evaluation for Use with 31 Inches Guardrail Height through Finite Element Simulations*. Report No. 405160-39, College Station, TX, 2015.

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSTIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or metric ton”)	Mg (or “t”)
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5(F-32)/9 or (F-32)/1.8	Celsius	°C
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

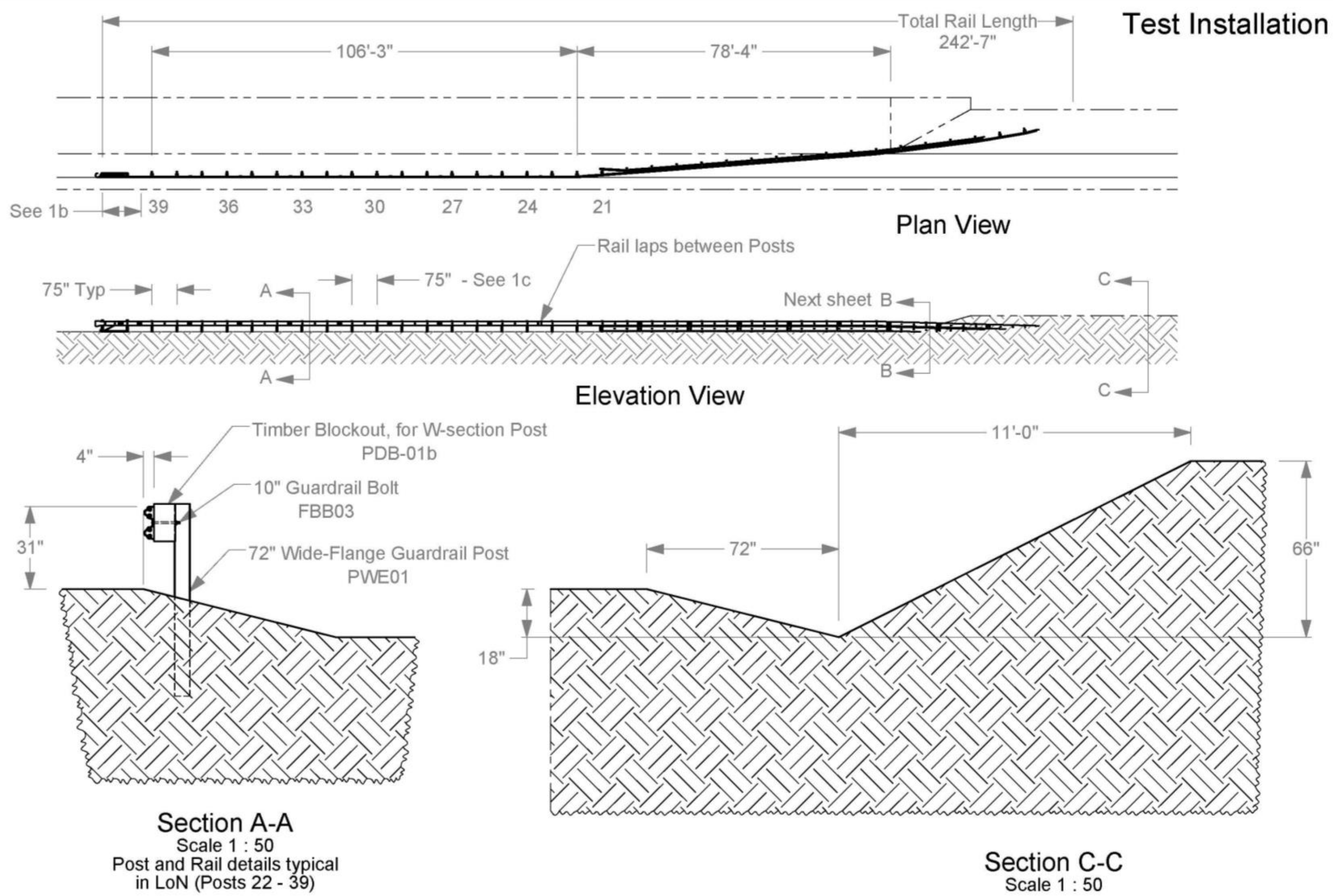
APPROXIMATE CONVERSTIONS FROM SI UNITS

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

*SI is the symbol for the International System of Units.

APPENDIX A. DETAILS OF THE BIB TERMINAL

Test Installation



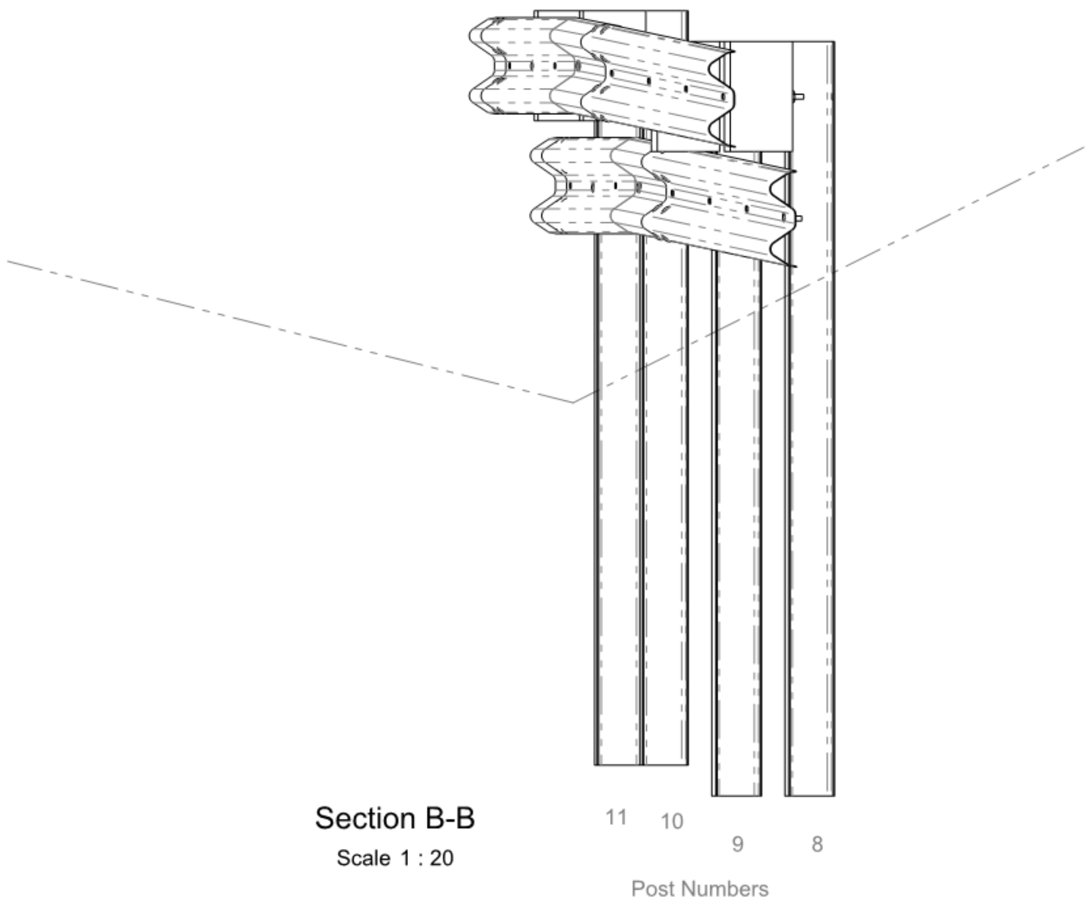
1a. Backfill Post holes with AASHTO M147-65(2004), grade B crushed limestone road base, compacted to MASH standard.

1b. TxDOT Downstream Anchor Terminal. See attached Drawing #GF 9(31) DAT-14.

1c. 75" Post spacing typical for LoN and Terminal unless otherwise indicated.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #608431 Buried in Backslope		2018-06-04
Drawn by GES	Scale 1:400	Sheet 1 of 6 Test Installation

T:\1-ProjectFiles\608431 - Buried in Backslope\Drafting, 608431\608431 Drawing



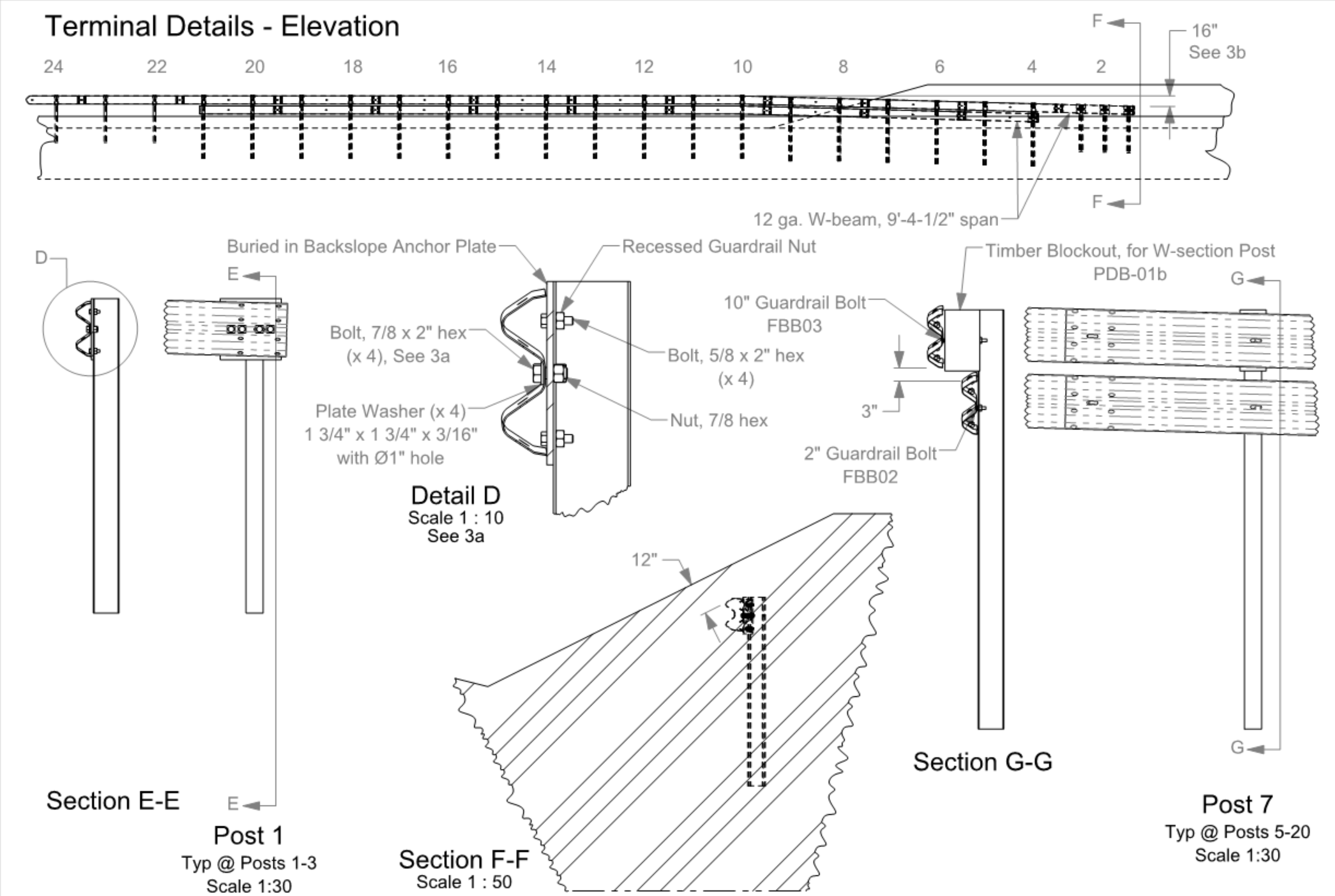
Section B-B

Scale 1 : 20

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #608431 Buried in Backslope		2018-02-02
Drawn by GES	Scale 1:400	Sheet 2 of 6 Section B-B

T:\1-ProjectFiles\608431 - Buried in Backslope\Drafting, 608431\608431 Drawing

Terminal Details - Elevation

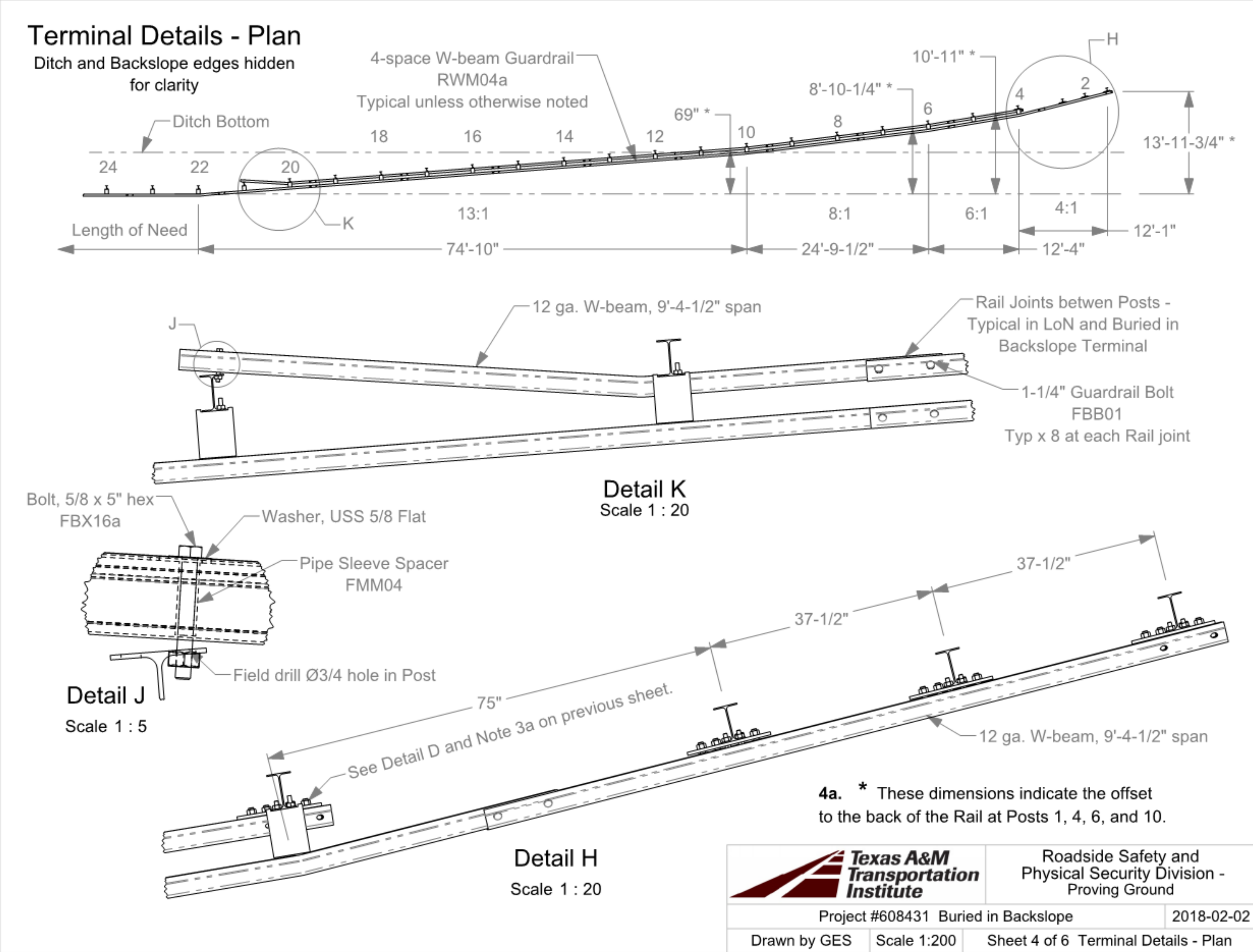


3a. Recessed Guardrail Nuts typical on all 5/8" Bolts. Anchor Plate and hardware are typical on top rail at Posts 1 - 3, and rub rail at Post 4. Field drill Ø1" holes in Guardrail as needed for 7/8 Bolts at Posts 1 - 4. Hex Head bolts are ASTM A307.

3b. Rail height changes 16" from Post 10 to 1 to achieve 12" of soil coverage at Post 1.

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Project #608431 Buried in Backslope			2018-02-02
Drawn by GES	Scale 1:200	Sheet 3 of 6 Terminal Details - Elevation	

T:\1-ProjectFiles\608431 - Buried in Backslope\Drafting, 608431\608431 Drawing



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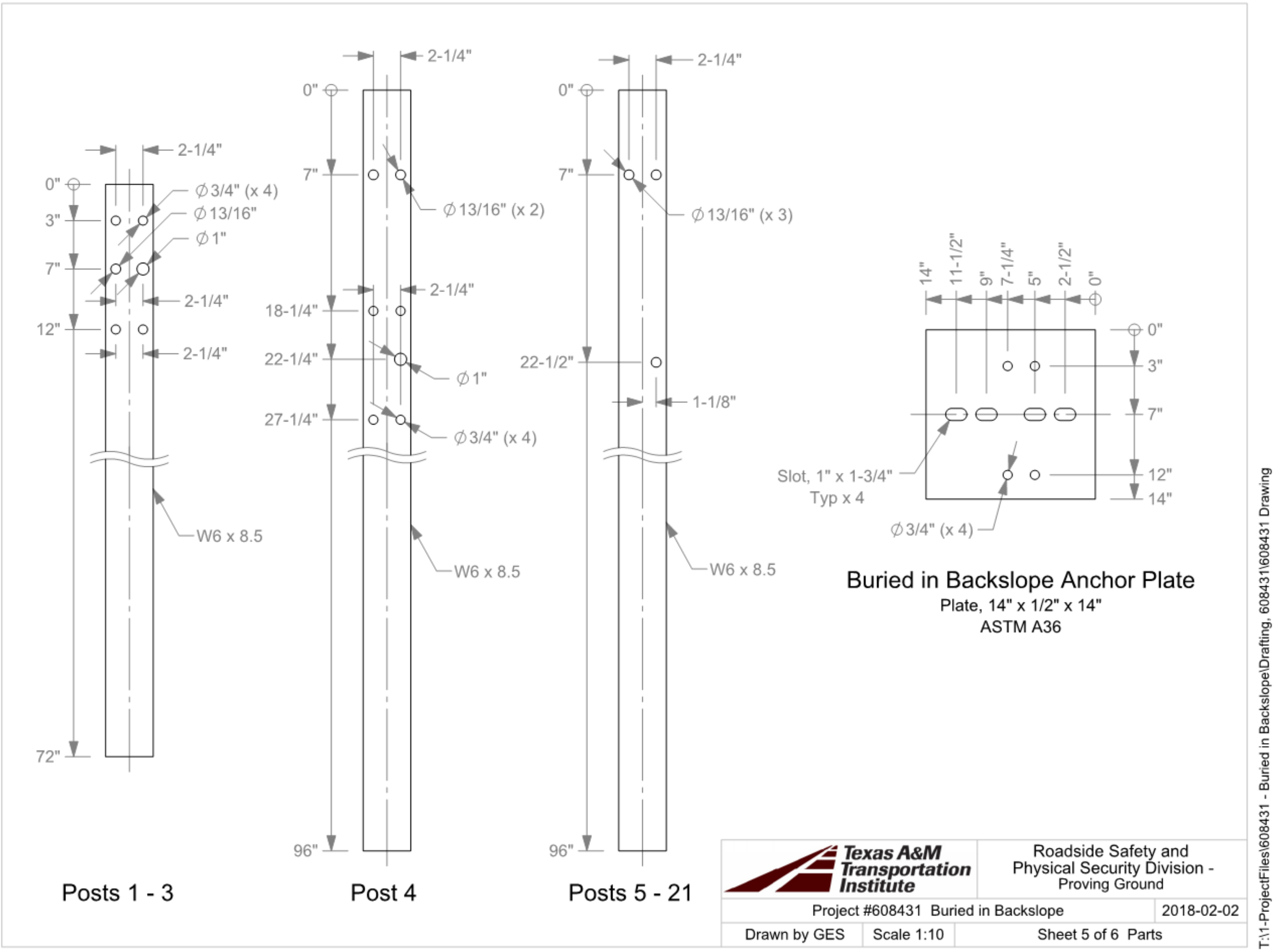
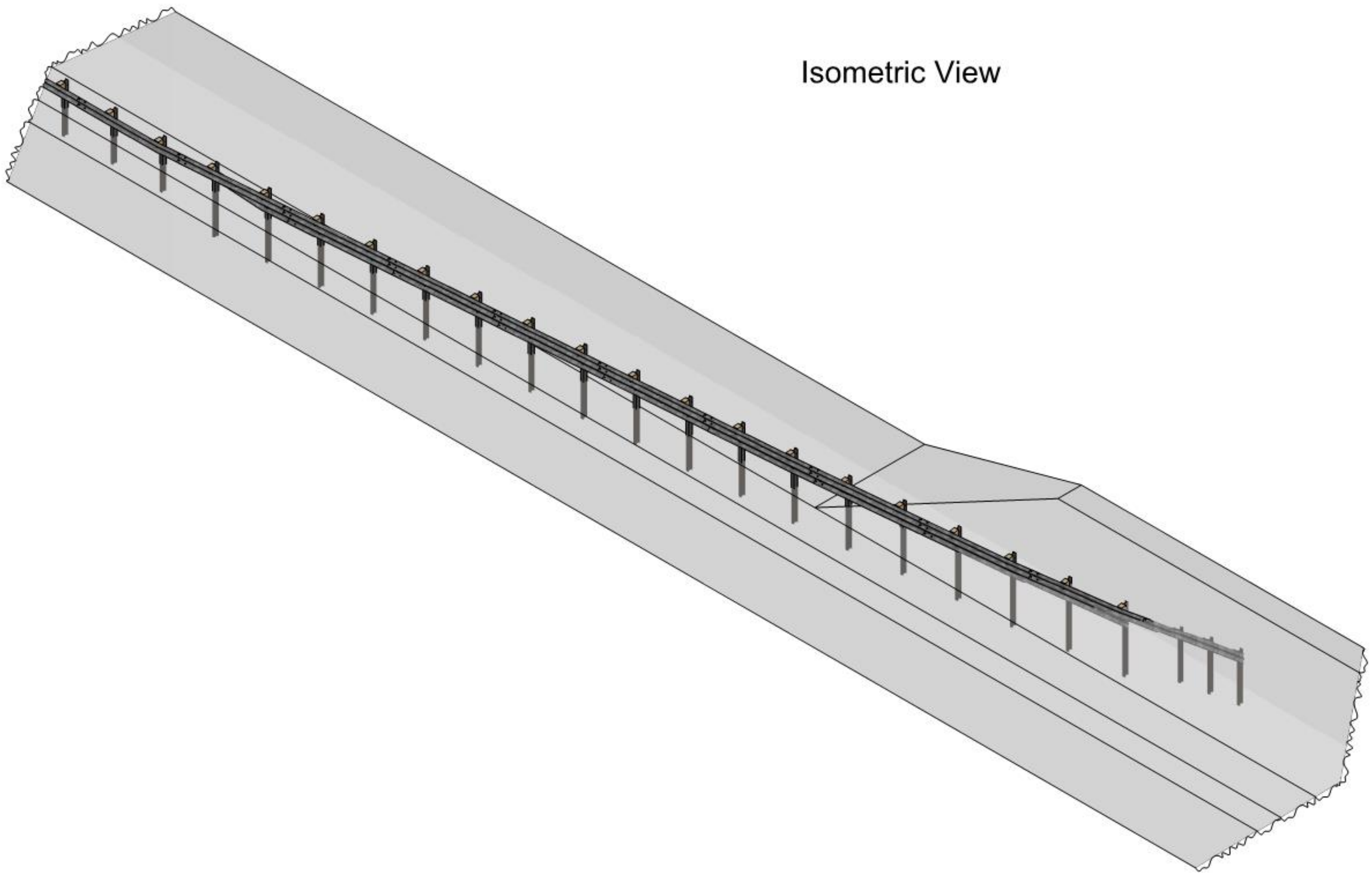


Posts 1 - 3
0"
3"
7"
12"
72"
2-1/4"
∅3/4" (x 4)
∅13/16"
∅1"
W6 x 8.5
Post 4
0"
7"
18-1/4"
22-1/4"
27-1/4"
96"
∅13/16" (x 2)
∅1"
∅3/4" (x 4)
Posts 5 - 21
22-1/2"
1-1/8"
∅13/16" (x 3)
Buried in Backslope Anchor Plate
Plate, 14" x 1/2" x 14"
ASTM A36
14"
11-1/2"
9"
7-1/4"
5"
2-1/2"
Slot, 1" x 1-3/4"
Typ x 4
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #608431 Buried in Backslope
2018-02-02
Drawn by GES
Scale 1:10
Sheet 5 of 6 Parts
T:\1-ProjectFiles\608431 - Buried in Backslope\Drafting, 608431\608431 Drawing

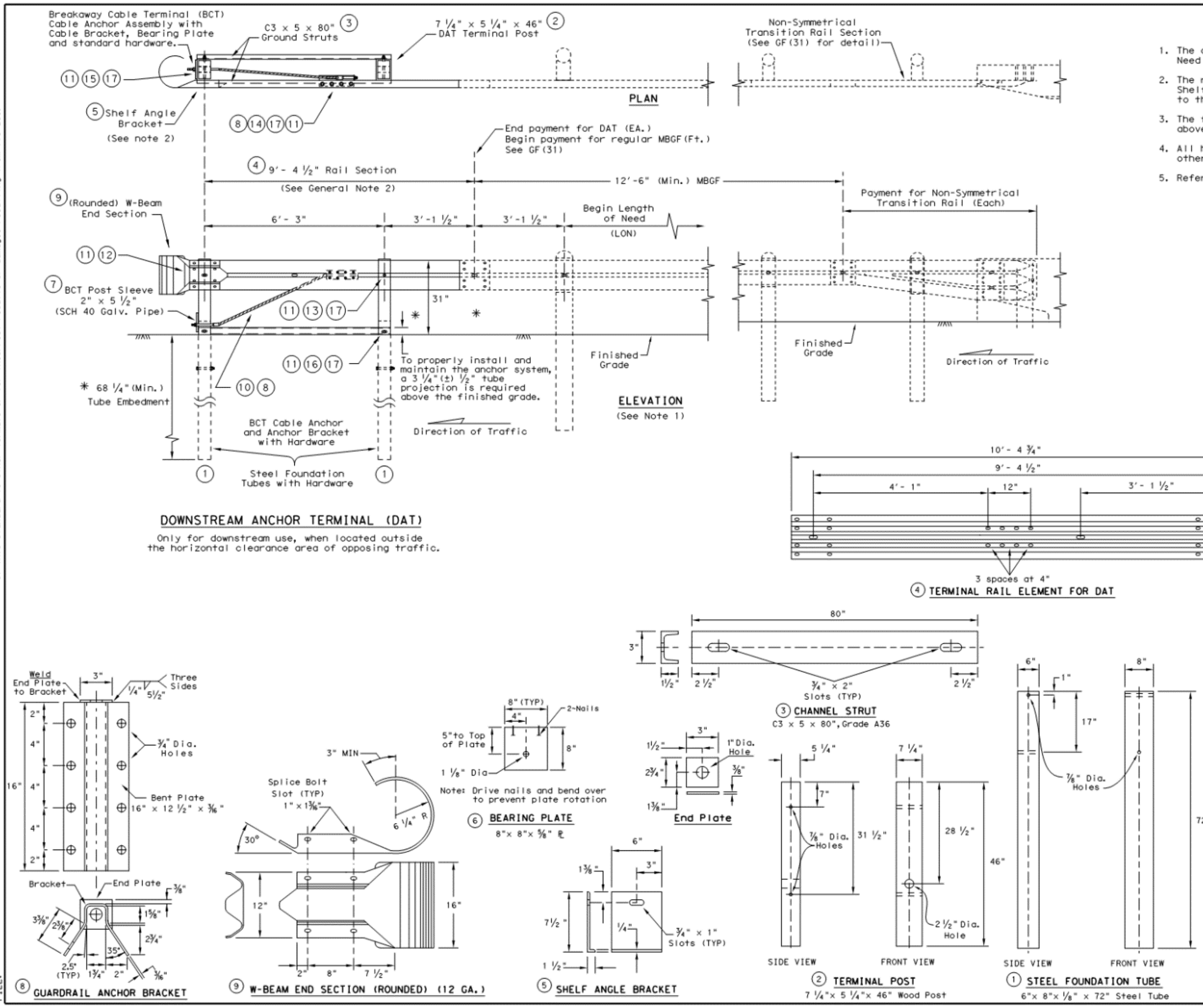


Texas A&M Transportation Institute

Roadside Safety and Physical Security Division - Proving Ground

Project #608431 Buried in Backslope		2018-02-02
Drawn by GES	Scale 1:150	Sheet 6 of 6 Isometric View

T:\1-ProjectFiles\608431 - Buried in Backslope\Drafting, 608431 Drawing



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

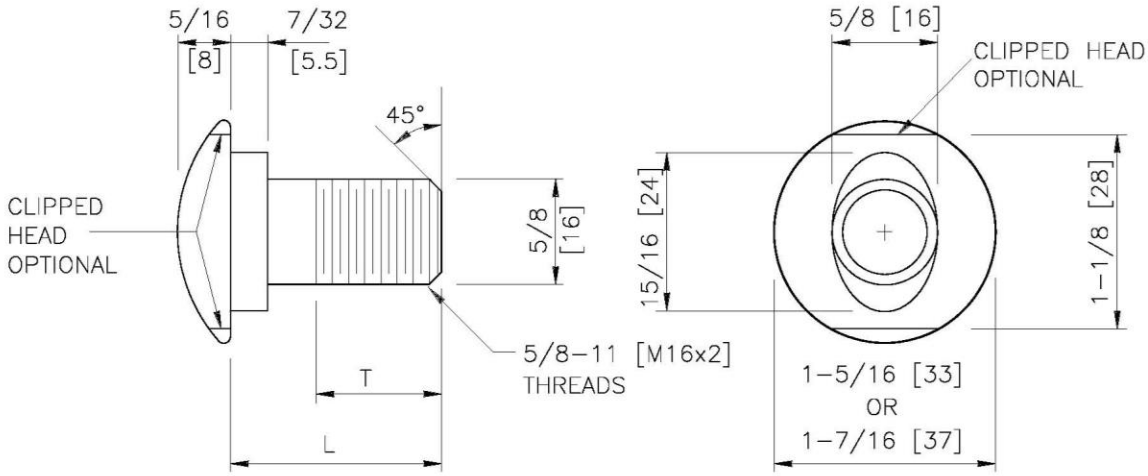
Texas Department of Transportation — Design Division Standard

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

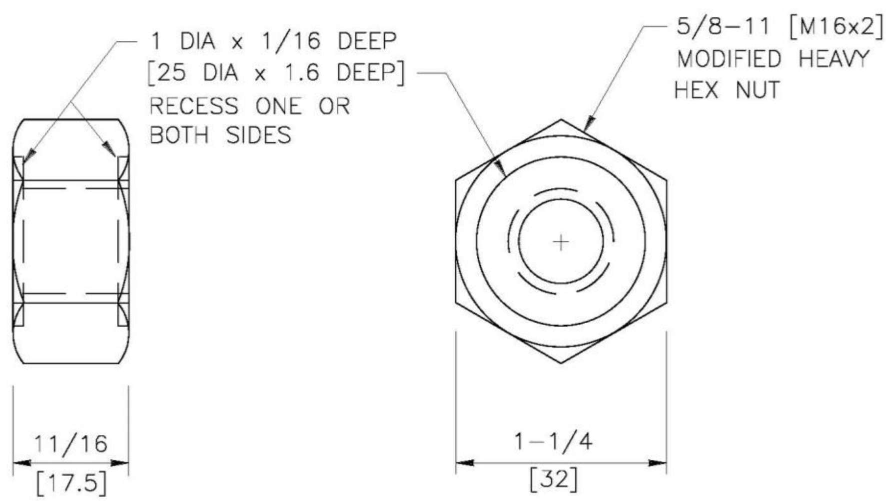
FILE: gf31dt14.dgn	DN: TxDOT	CK: AM	DW: VP	CK: CGL
© TxDOT: December 2011	CONT	SECT	JOB	HIGHWAY
REVISIONS	DIST	COUNTY		SHEET NO.

DATE:
FILE:

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



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



GUARDRAIL BOLT AND RECESSED NUT

FBB01–05

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

SPECIFICATIONS

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

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

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

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

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

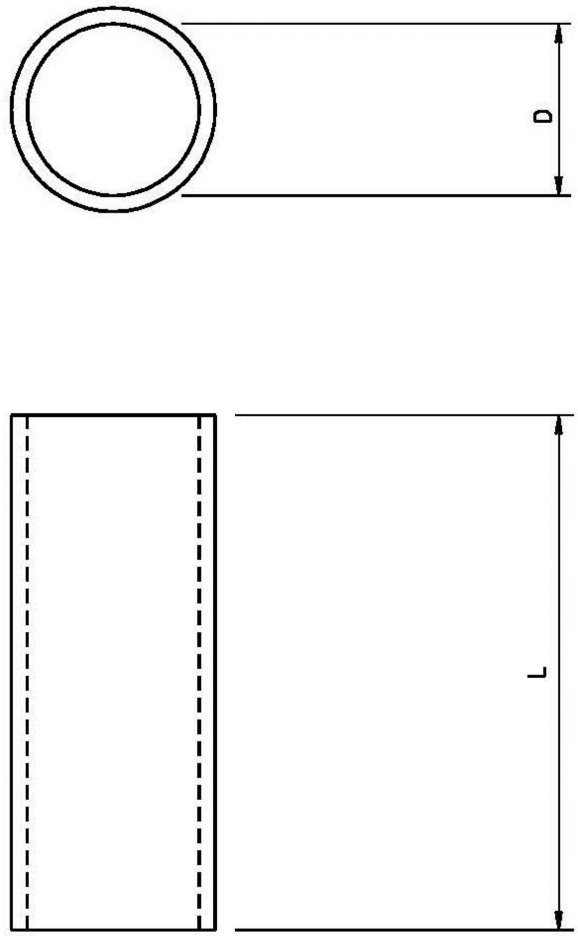
INTENDED USE

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

GUARDRAIL BOLT AND RECESSED NUT

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

TF 13



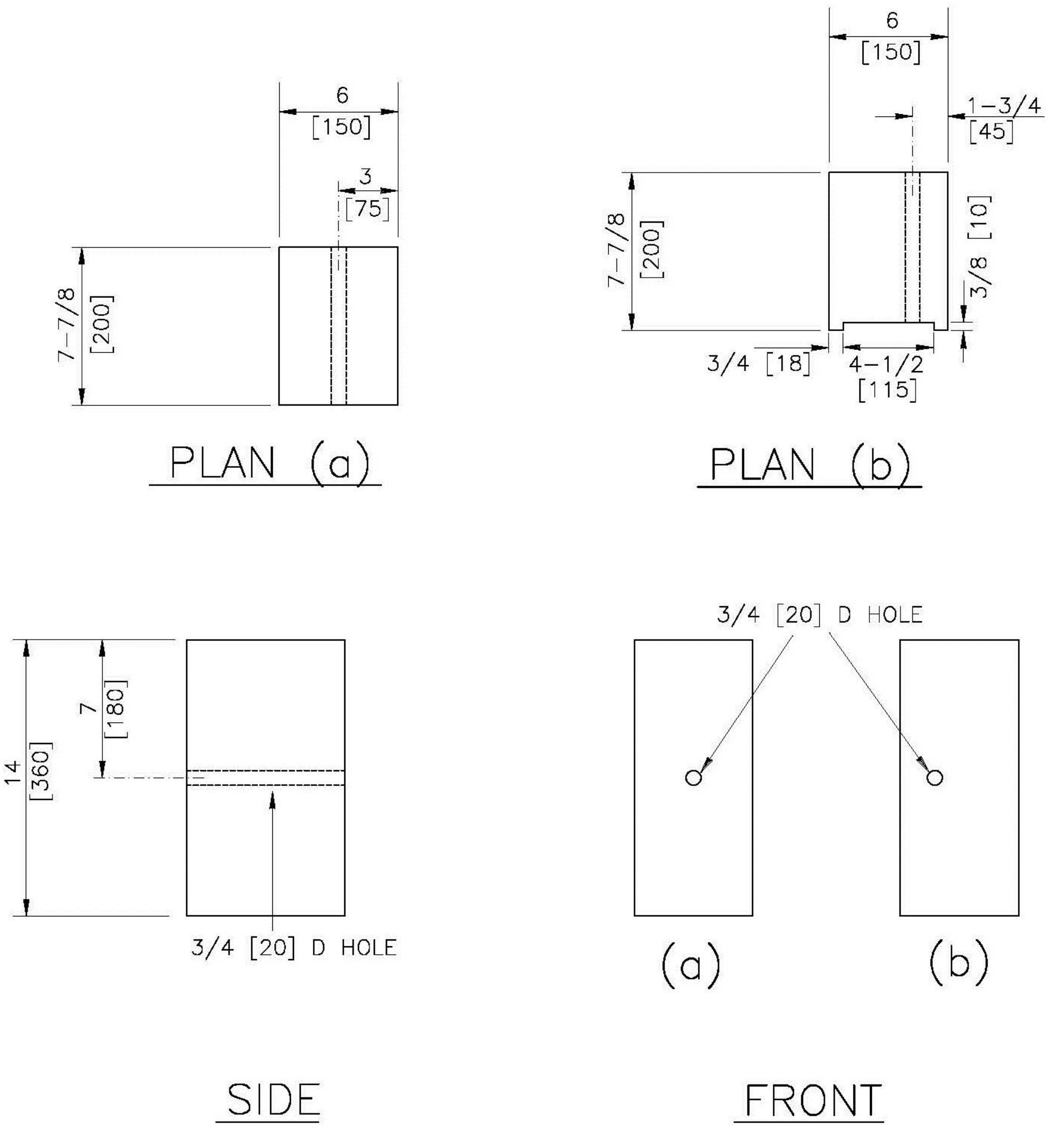
DESIGNATOR	NOMINAL DIAMETER	D	L
FMM03	32	35	54
FMM04	19	21	75

1994

PIPE SLEEVE SPACER

FMM03-04

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



1994

W-BEAM TIMBER BLOCKOUT

PDB01a-b	
SHEET NO.	DATE:
1 of 2	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.

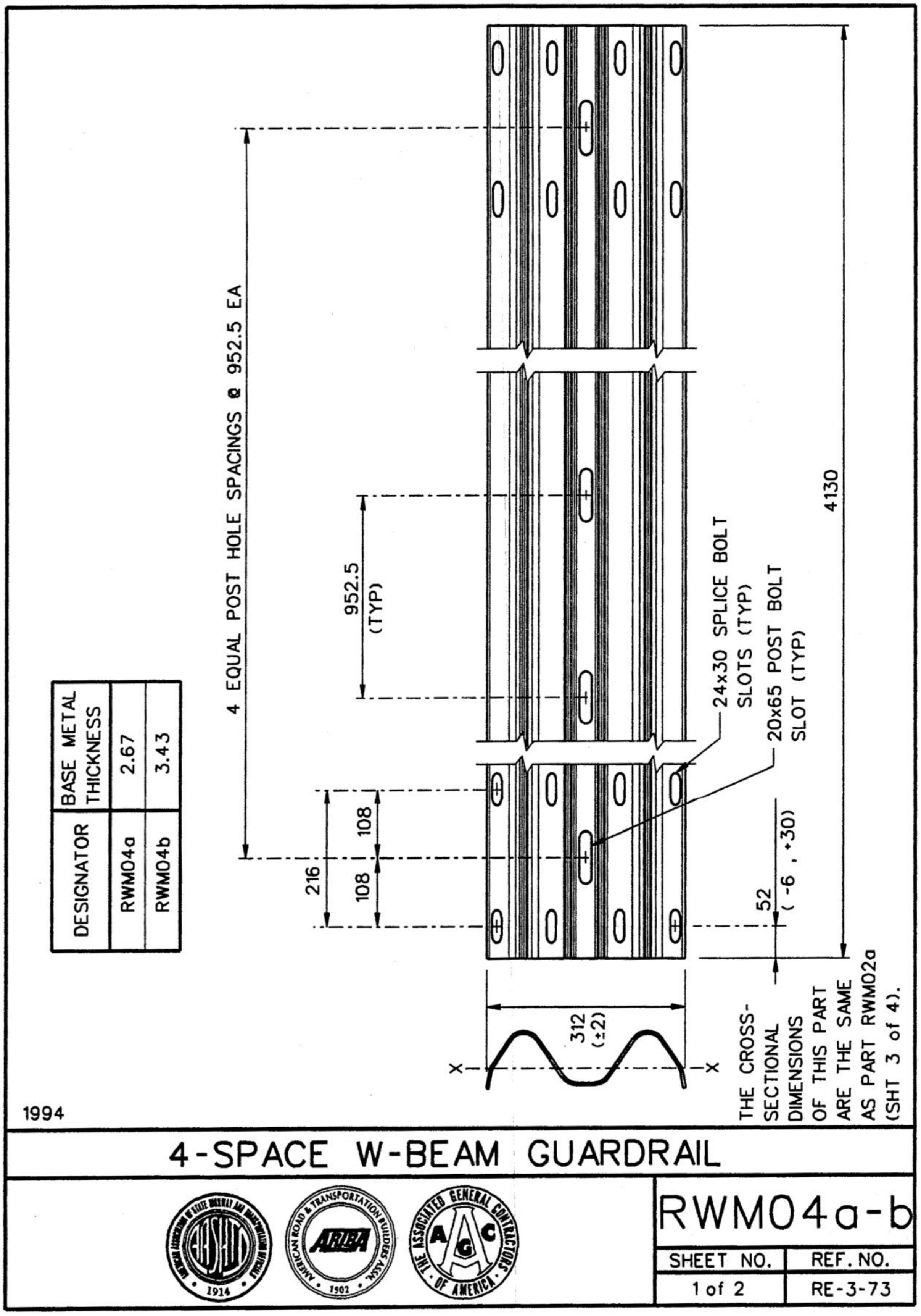
Dimensional tolerances not shown or implied are intended to be those consistent with the proper functioning of the part, including its appearance and accepted manufacturing practices.

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


4 EQUAL POST HOLE SPACINGS @ 952.5 EA
952.5
(TYP)
4130
24x30 SPLICE BOLT
SLOTS (TYP)
20x65 POST BOLT
SLOT (TYP)
DESIGNATOR
BASE METAL
THICKNESS
RWM04a
2.67
RWM04b
3.43
216
108
108
52
(-6 , +30)
312
(±2)
X
X
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.

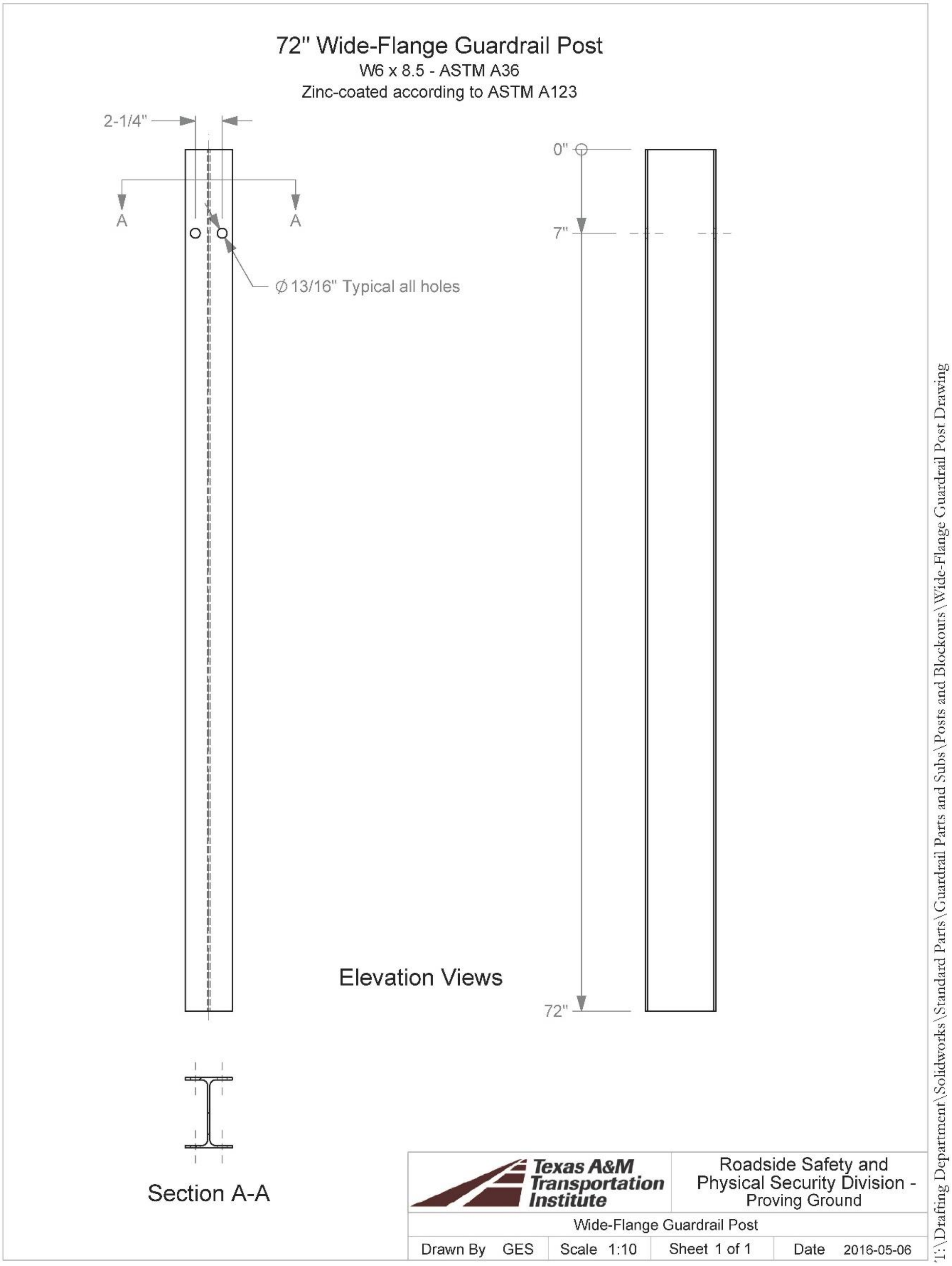
INTENDED USE

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

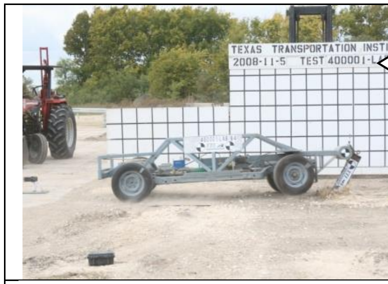
RWM04a-b

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



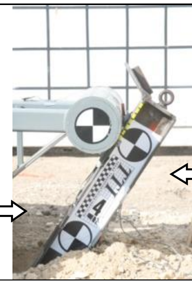
72" Wide-Flange Guardrail Post
W6 x 8.5 - ASTM A36
Zinc-coated according to ASTM A123
2-1/4"
A
A
Ø 13/16" Typical all holes
0"
7"
72"
Elevation Views
Section A-A
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Wide-Flange Guardrail Post
Drawn By GES
Scale 1:10
Sheet 1 of 1
Date 2016-05-06
T:\Drafting Department\Solidworks\Standard Parts\Guardrail Parts and Subs\Posts and Blockouts\Wide-Flange Guardrail Post Drawing

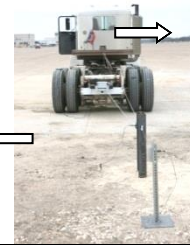
Table B.1. Summary of Strong Soil Test Results for Establishing Installation Procedure.



Dynamic Setup

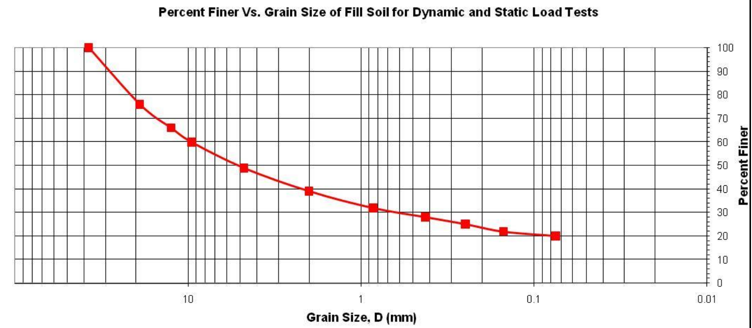
Post-Test Photo of post



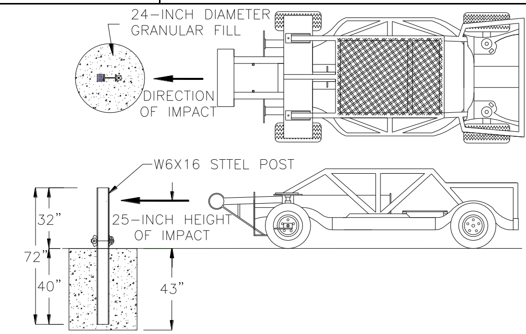


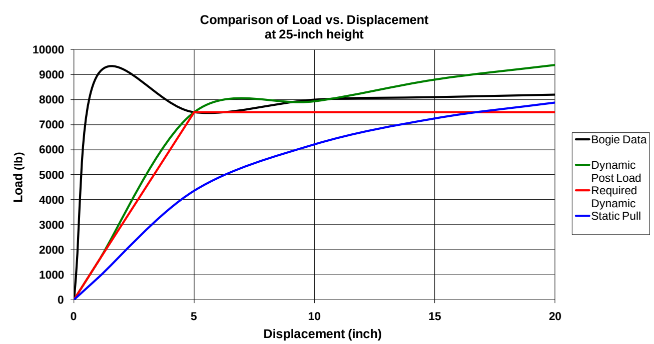
Post-Test Photo

Static Load Test

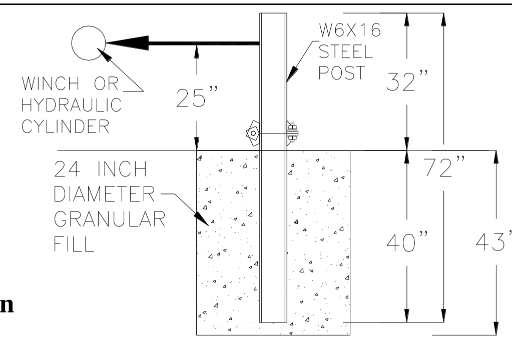


Dynamic Test Installation Details



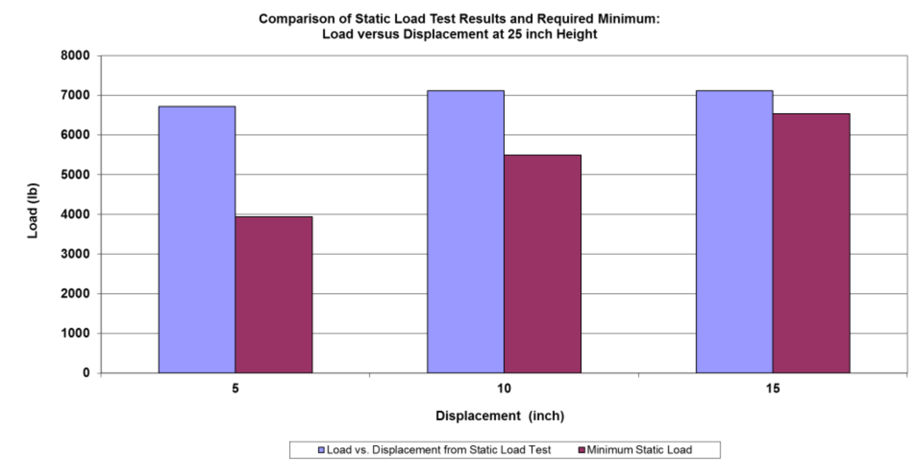


Static Load Test Installation Details

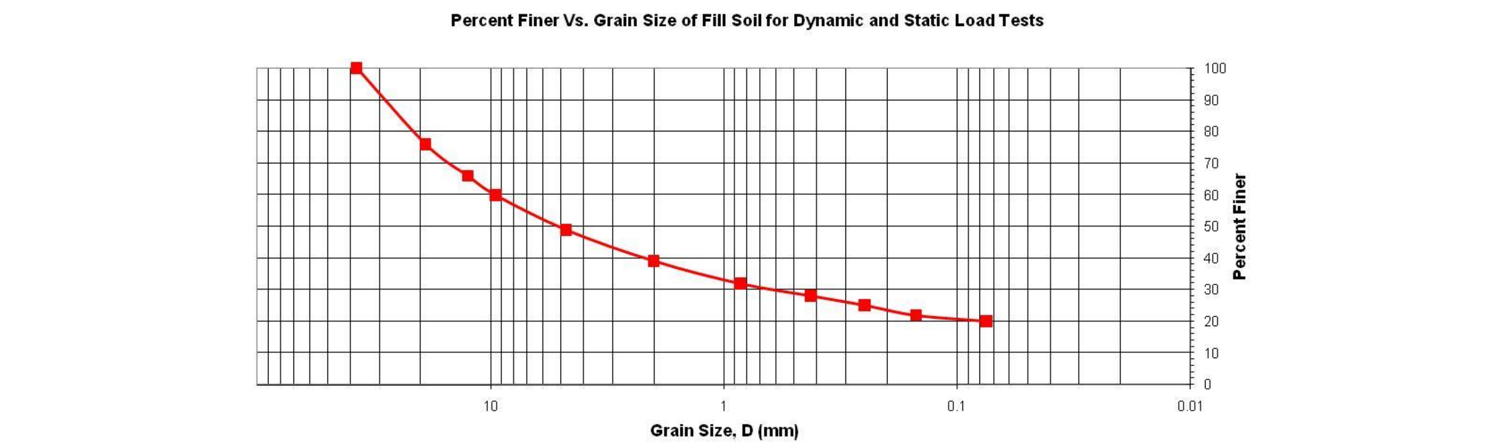


Date	2016-11-05
Test Facility and Site Location	TTI Proving Ground, 3100 SH 47, Bryan, TX 77807
In Situ Soil Description (ASTM D2487	Sandy gravel with silty fines
Fill Material Description (ASTM D2487) and sieve analysis	AASHTO Grade B Soil-Aggregate (see sieve analysis above)
Description of Fill Placement Procedure	6-inch lifts tamped with a pneumatic compactor
Bogie Weight	5009 lb
Impact Velocity	20.5 mph

Table B.2. Test Day Static Soil Strength Documentation for Test No. 608431-01-1.

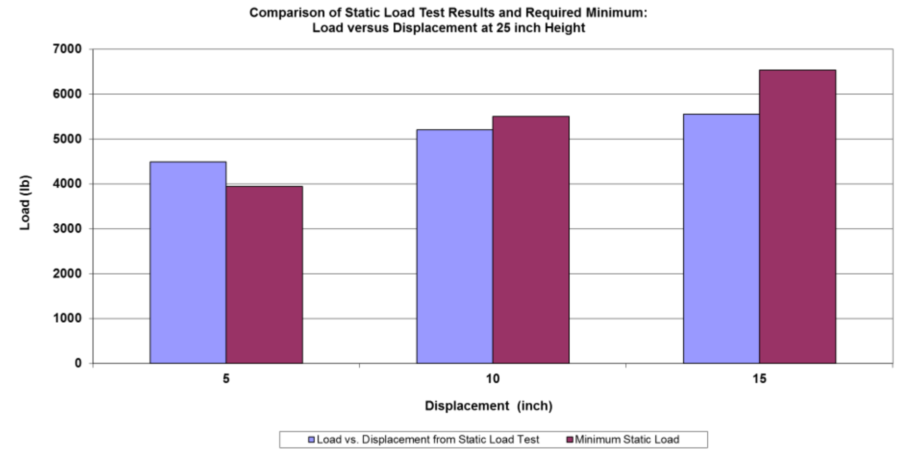


Static Load Setup

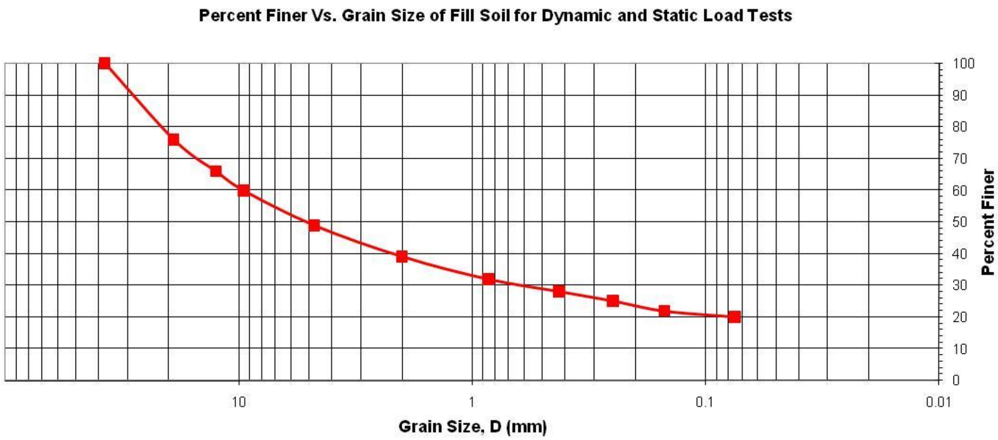


Date	2018-04-30 for Test No. 608431-01-1
Test Facility and Site Location	TTI Proving Ground – 3100 SH 47, Bryan, Tx
In Situ Soil Description (ASTM D2487)	Sandy gravel with silty fines
Fill Material Description (ASTM D2487) and sieve analysis	AASHTO Grade B Soil-Aggregate (see sieve analysis)
Description of Fill Placement Procedure	6-inch lifts tamped with a pneumatic compactor

Table B.3. Test Day Static Soil Strength Documentation for Test No. 608431-01-2.



Static Load Setup



Date	2018-06-01 for Test No. 608431-01-2
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

APPENIDX C. *MASH* TEST 3-34 (CRASH TEST NO. 608431-01-2)

C1 VEHICLE PROPERTIES AND INFORMATION

Table C.1. Vehicle Properties for Test No. 608431-01-2.

Date: 2018-06-01 Test No.: 608431-1-2 VIN No.: KNADE223896502932

Year: 2009 Make: KIA Model: RIO

Tire Inflation Pressure: 32 PSI Odometer: 157778 Tire Size: 185/65R14

Describe any damage to the vehicle prior to test: None

● Denotes accelerometer location.

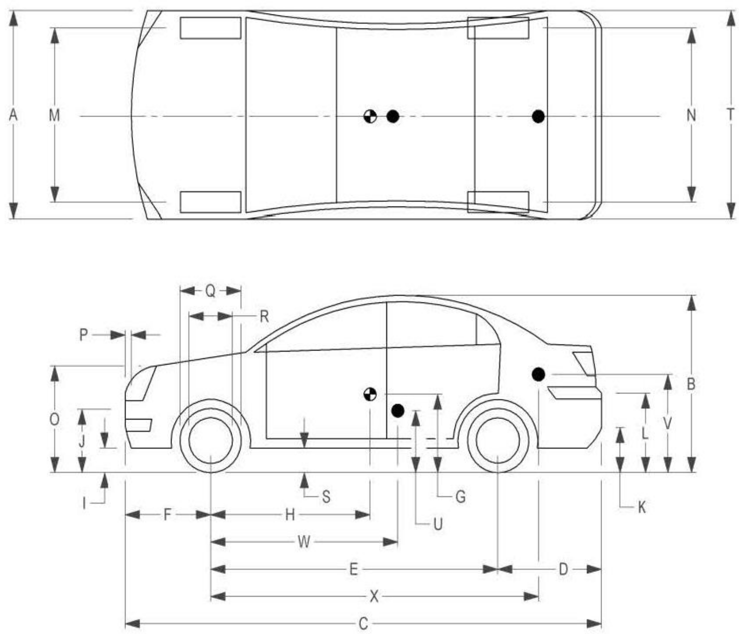
NOTES: None

Engine Type: 4 cylinder
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: Passenger Seat



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	19.50
C	165.75	H	36.49	M	57.75	R	15.50	W	36.50
D	34.00	I	7.75	N	57.70	S	8.25	X	107.00
E	98.75	J	21.50	O	28.25	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 = 168 ±8 inches; E = 98 ±5 inches; F = 35 ±4 inches; G = 39 ±4 inches; O = TOP OF RADIATOR SUPPORT ~~(24 ±4 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}	1572	1530	1615
Back	1874	M_{rear}	903	897	977
Total	3638	M_{Total}	2475	2427	2592

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

Mass Distribution:
lb LF: 766 RF: 764 LR: 433 RR: 464

Table C.2. Exterior Crush Measurements for Test No. 608431-01-2.

Date: 2018-06-01 Test No.: 608431-1-2 VIN No.: KNADE223896502932

Year: 2009 Make: KIA Model: RIO

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	AT FT BUMPER	16	3	9	3	2	1				+24
2	ABOVE FT BUMPER	16	8	27	1	2.5	3.5	4	6	8	+56
	Units in inches										

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

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

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

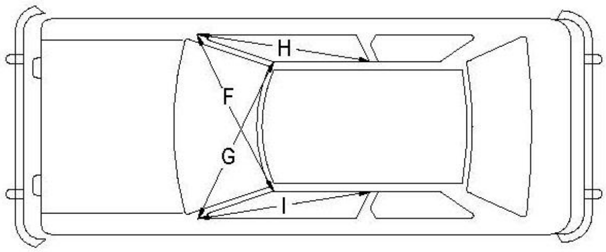
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

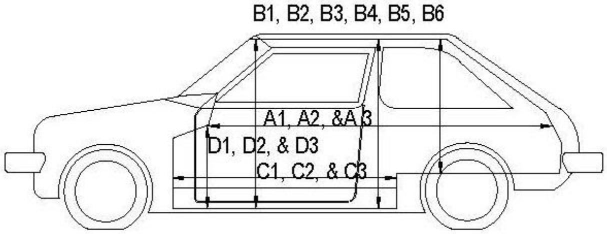
***Measure and document on the vehicle diagram the location of the maximum crush.

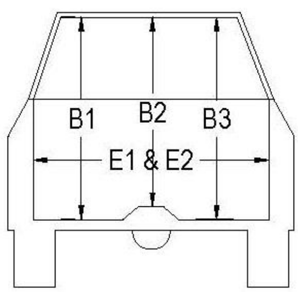
Note: Use as many lines/columns as necessary to describe each damage profile.

Table C.3. Occupant Compartment Measurements for Test No. 608431-01-2.

Date:	2018-06-01	Test No.:	608431-1-2	VIN No.:	KNADE223896502932
Year:	2009	Make:	KIA	Model:	RIO







OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

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

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

C2 SEQUENTIAL PHOTOGRAPHS

0.000 s

0.075 s

0.150 s

0.225 s

Figure C.1. Sequential Photographs for Test No. 608431-01-2 (Overhead and Frontal Views).

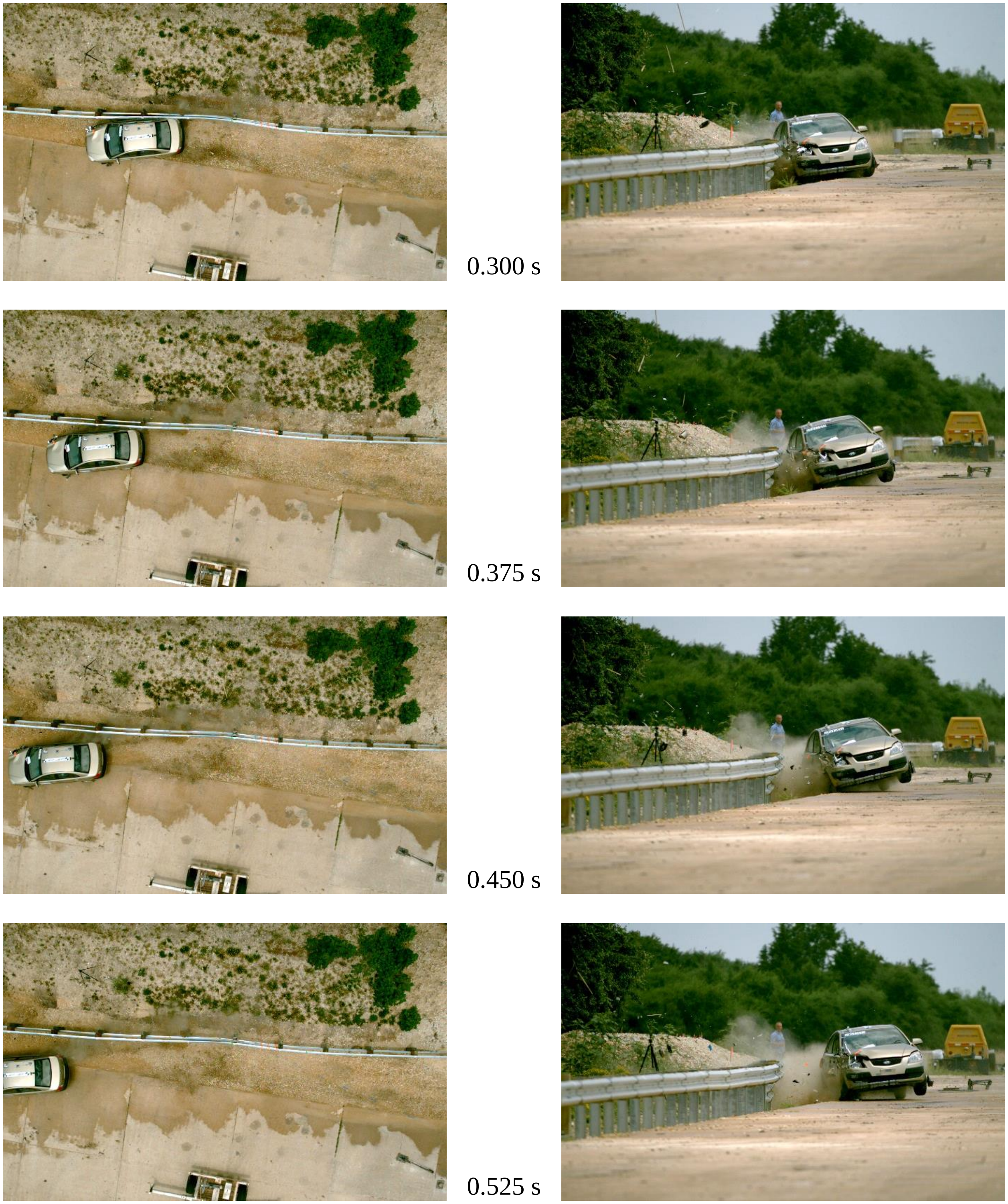
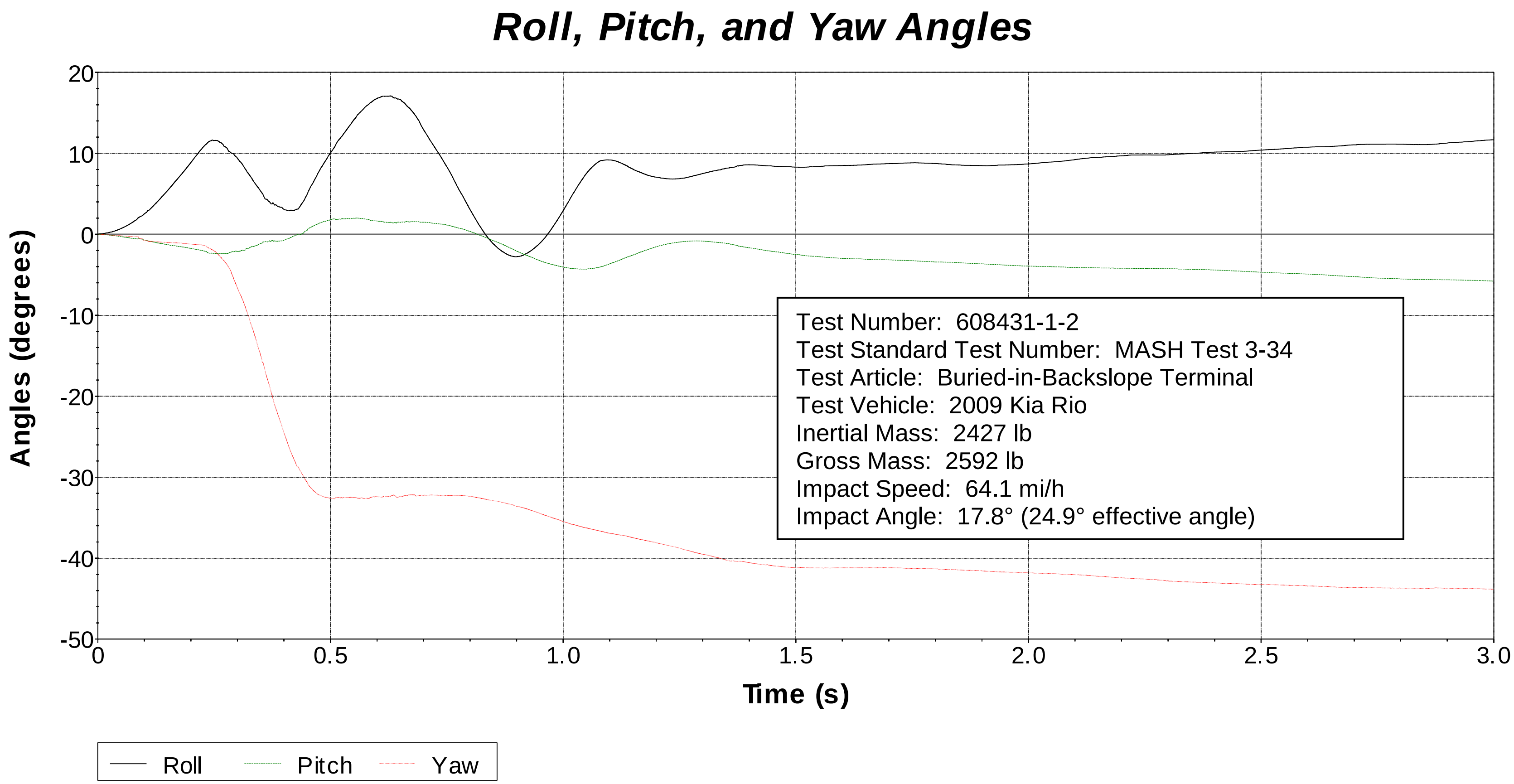


Figure C.1. Sequential Photographs for Test No. 608431-01-2 (Overhead and Frontal Views) (Continued).



NOTE: Data started 0.207 s prior to impact with terminal.

Axes are vehicle-fixed.
Sequence for determining orientation:
1. Yaw.
2. Pitch.
3. Roll.

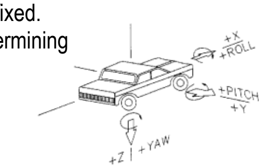
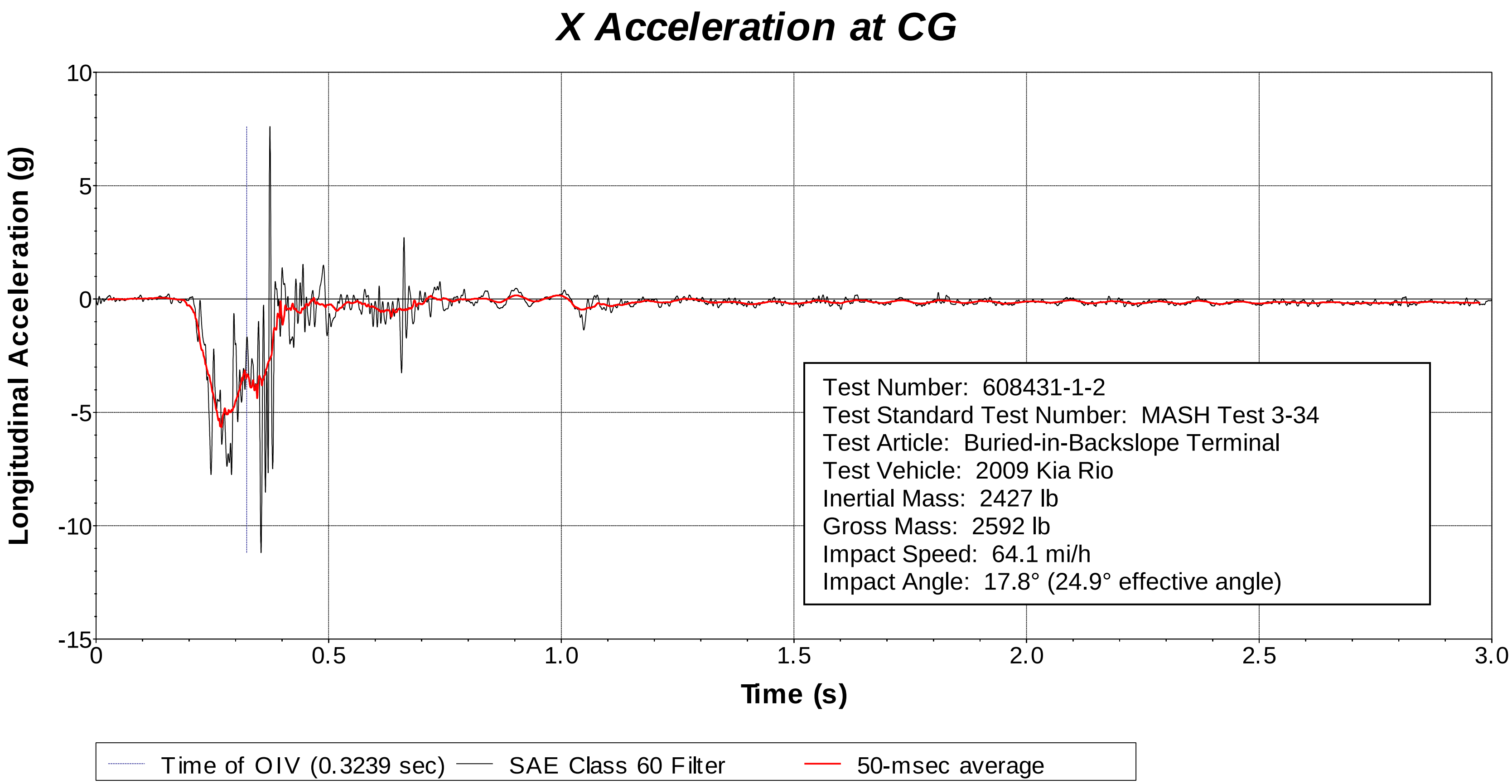
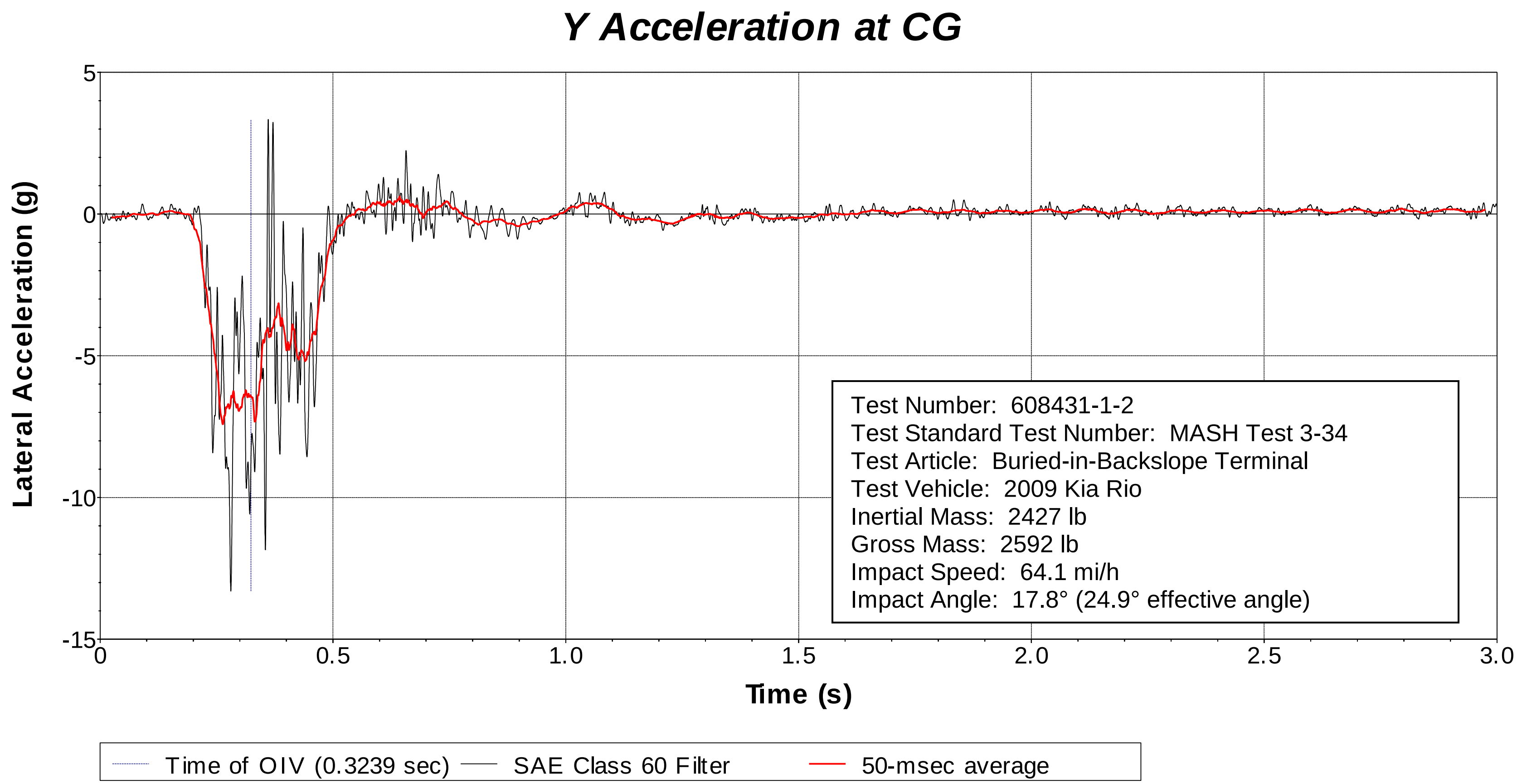


Figure C.2. Vehicle Angular Displacements for Test No. 608431-01-2.



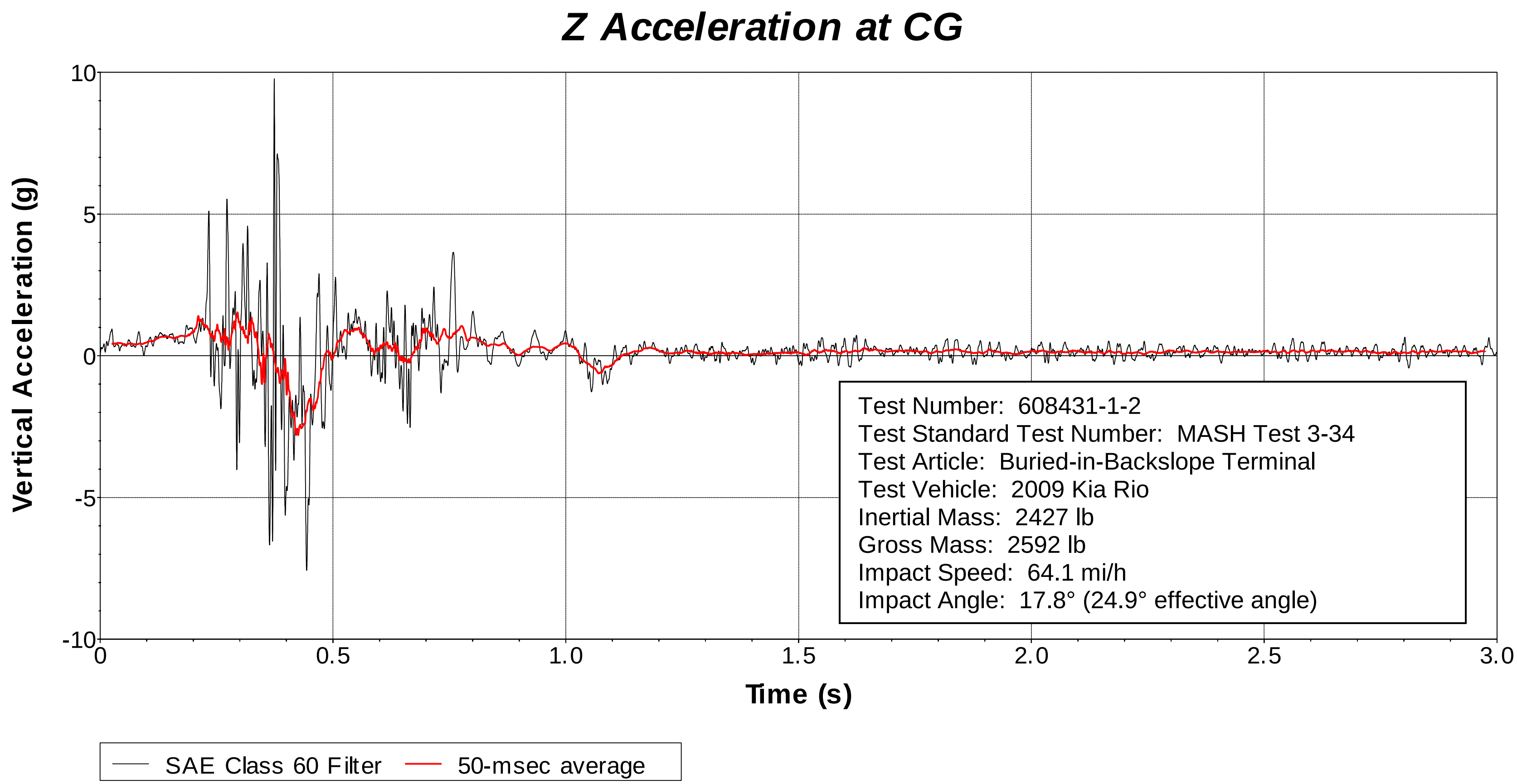
NOTE: Data started 0.207 s prior to impact with terminal.

Figure C.3. Vehicle Longitudinal Accelerometer Trace for Test No. 608431-01-2 (Accelerometer Located at Center of Gravity).



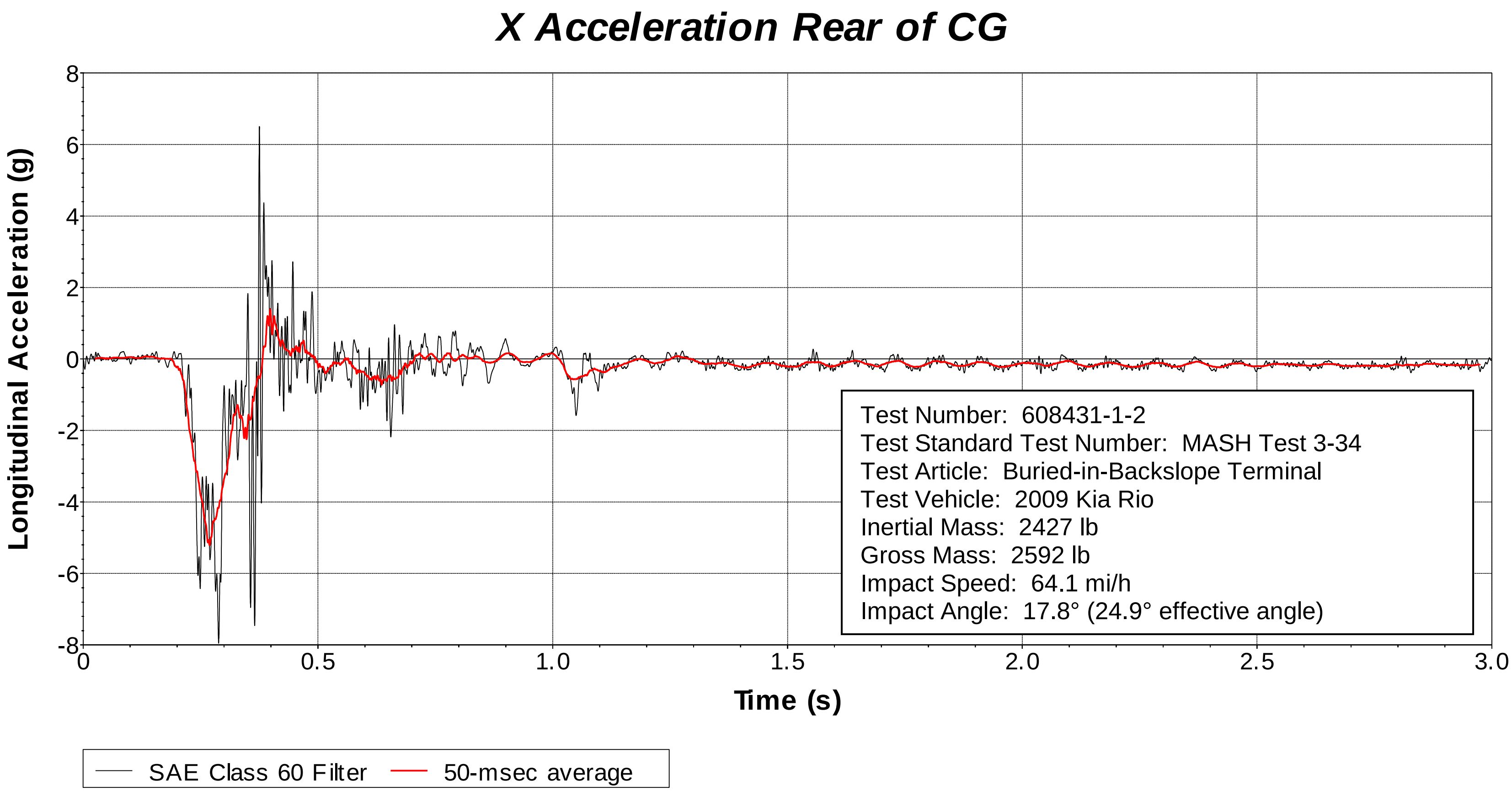
NOTE: Data started 0.207 s prior to impact with terminal.

Figure C.4. Vehicle Lateral Accelerometer Trace for Test No. 608431-01-2 (Accelerometer Located at Center of Gravity).



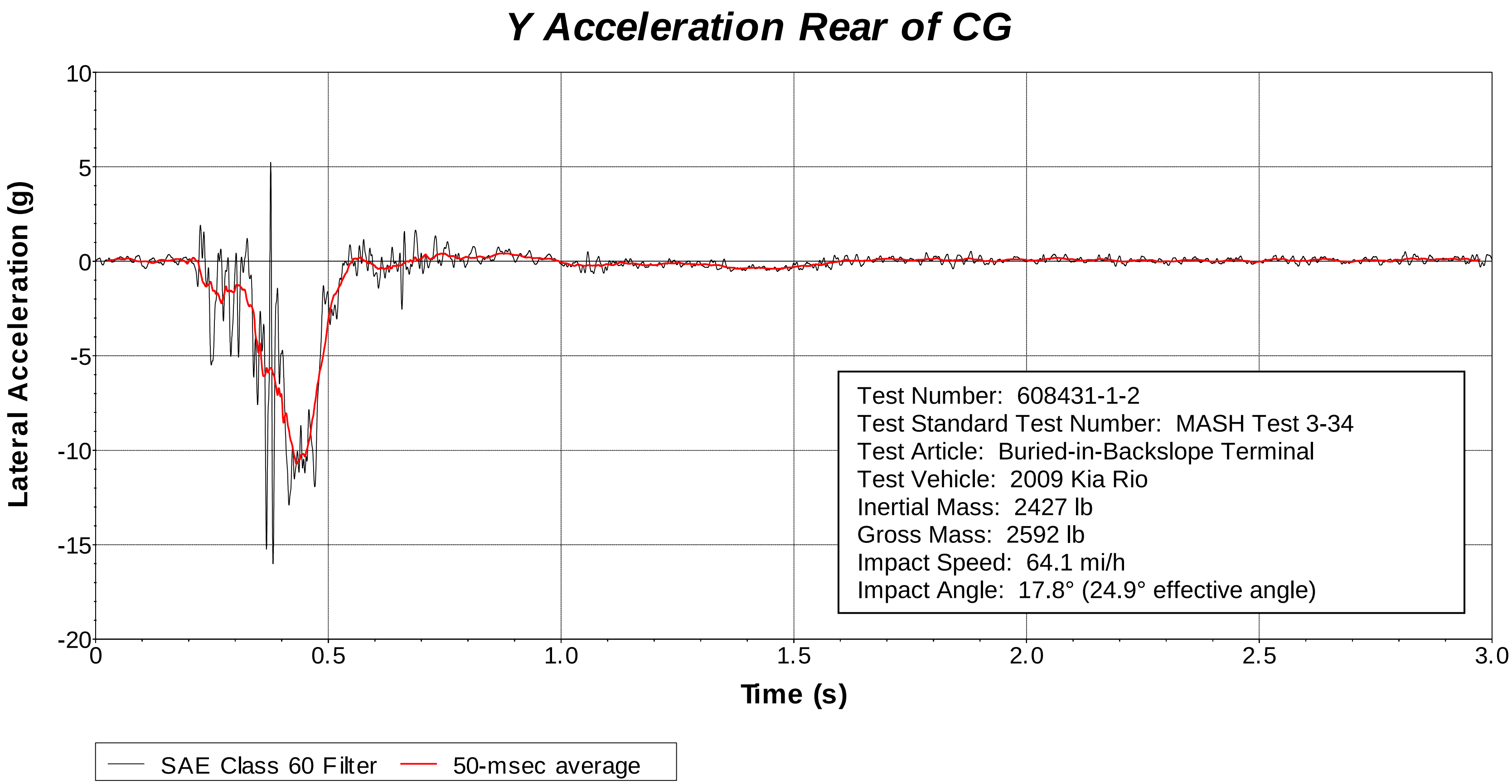
NOTE: Data started 0.207 s prior to impact with terminal.

Figure C.5. Vehicle Vertical Accelerometer Trace for Test No. 608431-01-2 (Accelerometer Located at Center of Gravity).



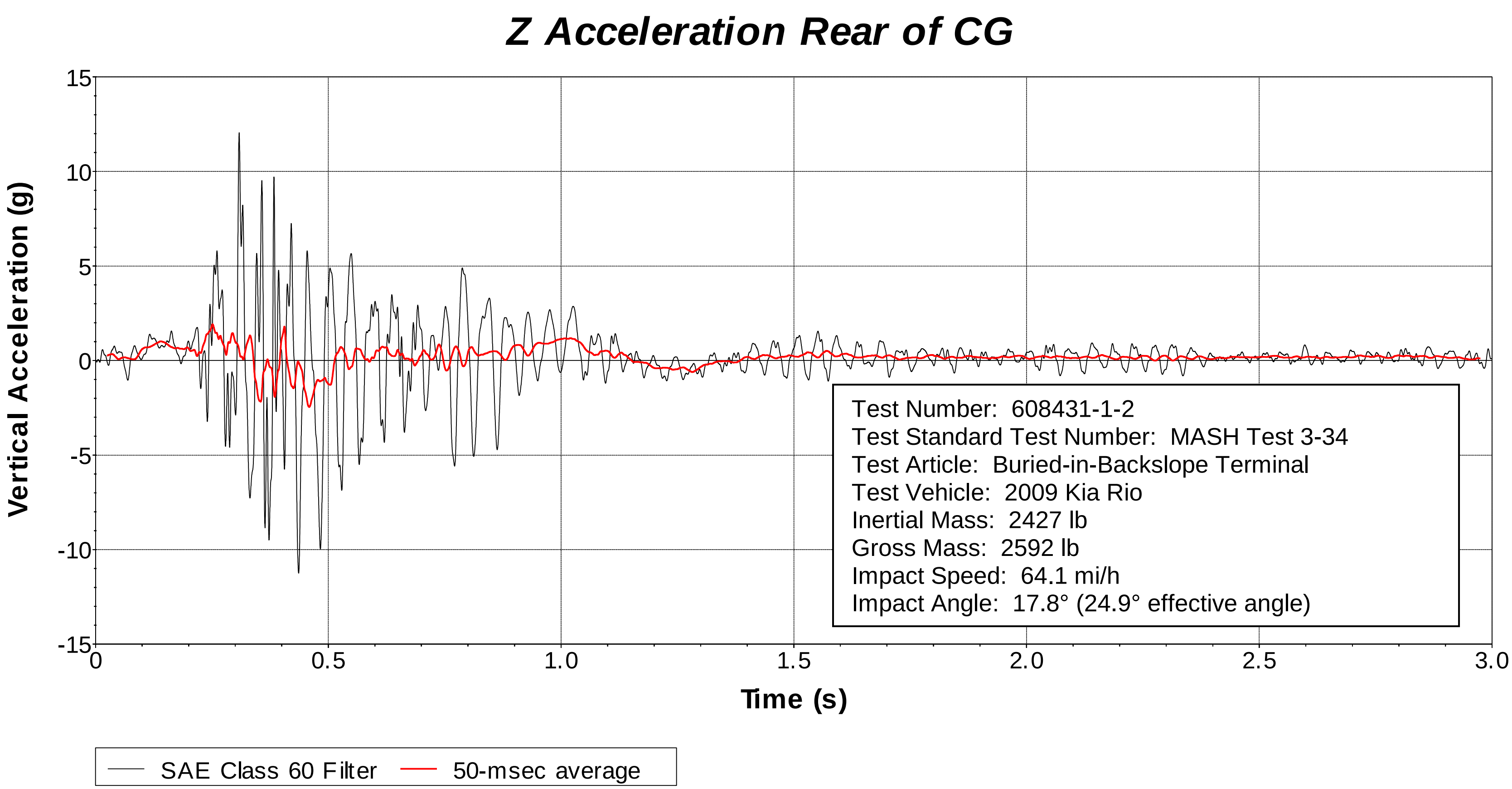
NOTE: Data started 0.207 s prior to impact with terminal.

Figure C.6. Vehicle Longitudinal Accelerometer Trace for Test No. 608431-01-2 (Accelerometer Located Rear of Center of Gravity).



NOTE: Data started 0.207 s prior to impact with terminal.

Figure C.7. Vehicle Lateral Accelerometer Trace for Test No. 608431-01-2 (Accelerometer Located Rear of Center of Gravity).



NOTE: Data started 0.207 s prior to impact with terminal.

Figure C.8. Vehicle Vertical Accelerometer Trace for Test No. 608431-01-2 (Accelerometer Located Rear of Center of Gravity).

APPENIDX D. *MASH* TEST 3-35 (CRASH TEST NO. 608431-01-1)

D1 VEHICLE PROPERTIES AND INFORMATION

Table D.1. Vehicle Properties for Test No. 608431-01-1.

Date: 2018-04-30 Test No.: 608431-1-1 VIN No.: 1C6RD6FP46S168775

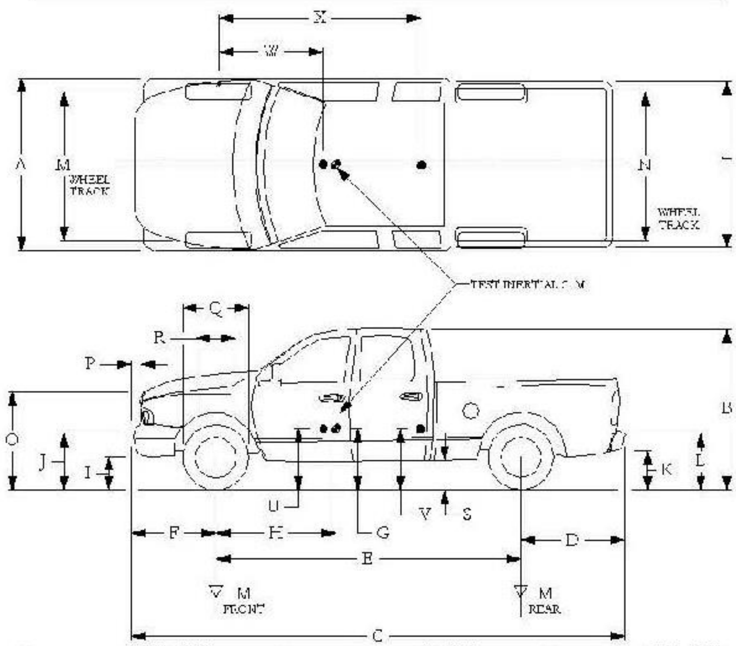
Year: 2012 Make: DODGE Model: RAM 1500

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

Tread Type: HIGHWAY Odometer: 217692

Note any damage to the vehicle prior to test: NONE

● Denotes accelerometer location.



NOTES:

Engine Type: V-8
Engine CID: 4.7 L

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

Optional Equipment:
NONE

Dummy Data:
Type: 50 percentile male
Mass: 165 lb
Seat Position: Passenger Side

Geometry: inches

A	78.50	F	40.00	K	20.00	P	3.00	U	27.00
B	74.00	G	28.38	L	30.00	Q	30.50	V	29.75
C	227.50	H	61.80	M	68.50	R	18.00	W	61.80
D	44.00	I	11.75	N	68.00	S	13.00	X	77.00
E	140.50	J	27.00	O	46.00	T	77.00		

Wheel Center Height Front	14.75	Wheel Well Clearance (Front)	6.00	Bottom Frame Height - Front	12.00
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	9.25	Bottom Frame Height - Rear	25.50

RANGE LIMIT: A=78 ±2 inches; C=237 ±13 inches; E=148 ±12 inches; F=39 ±3 inches; G = > 28 inches; H = 63 ±4 inches; O=43 ±4 inches; M+N/2=67 ±1.5 inches

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2825	2807	2892
Back	3900	M_{rear}	2143	2228	2308
Total	6700	M_{Total}	4968	5035	5200

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

Mass Distribution:
lb LF: 1373 RF: 1434 LR: 1153 RR: 1075

Table D.2. Measurements of Vehicle Vertical CG for Test No. 608431-01-1.

Date: 2018-04-30 Test No.: 608431-1-1 VIN: 1C6RD6FP46S168775

Year: 2012 Make: DODGE Model: RAM 1500

Body Style: QUAD CAB Mileage: 217692

Engine: 4.7L V-8 Transmission: AUTOMATIC

Fuel Level: EMPTY Ballast: 133 lb (440 lb max)

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

Measured Vehicle Weights: (lb)

LF:	1373	RF:	1434	Front Axle:	2807
LR:	1153	RR:	1075	Rear Axle:	2228
Left:	2526	Right:	2509	Total:	5035
					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:	62.17	inches	Rear of Front Axle	(63 ±4 inches allowed)
Y:	-0.12	inches	Left - Right +	of Vehicle Centerline
Z:	28.38	inches	Above Ground	(minumum 28.0 inches allowed)

Hood Height: 46.00 inches Front Bumper Height: 27.00 inches

43 ±4 inches allowed

Front Overhang: 40.00 inches Rear Bumper Height: 30.00 inches

39 ±3 inches allowed

Overall Length: 227.50 inches

237 ±13 inches allowed

Table D.3. Exterior Crush Measurements for Test No. 608431-01-1.

Date: 2018-04-30 Test No.: 608431-1-1 VIN No.: 1C6RD6FP46S168775

Year: 2012 Make: DODGE Model: RAM 1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	Front Plane at bumper height	18	10	25	10	1.	1.5	4	6	10	-20
2	Side Plane above bumper ht	18	8	48	1	2	3.5	4	6	8	+72
	inches										

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

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

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

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

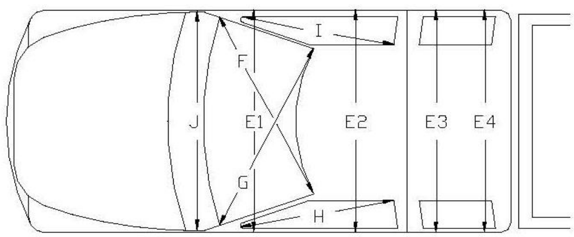
***Measure and document on the vehicle diagram the location of the maximum crush.

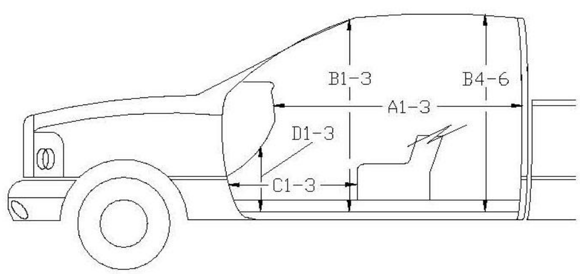
Note: Use as many lines/columns as necessary to describe each damage profile.

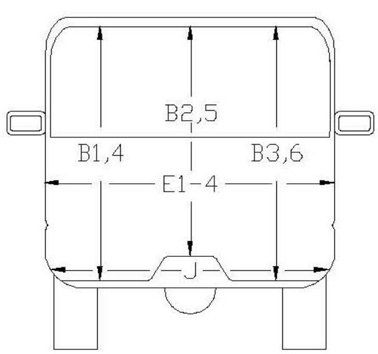
Table D.4. Occupant Compartment Measurements for Test No. 608431-01-1.

Date: 2018-04-30 Test No.: 608431-1-1 VIN No.: 1C6RD6FP46S168775

Year: 2012 Make: DODGE Model: RAM 1500





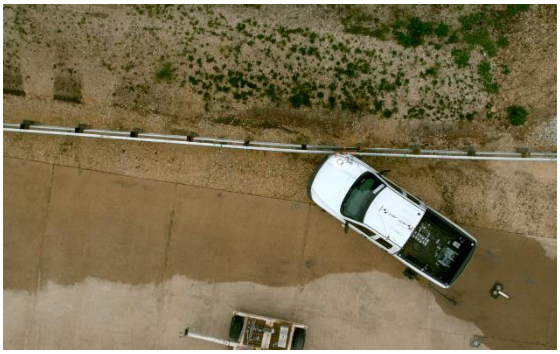


*Lateral area across the cab from driver's side kickpanel to passenger's side kickpanel.

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

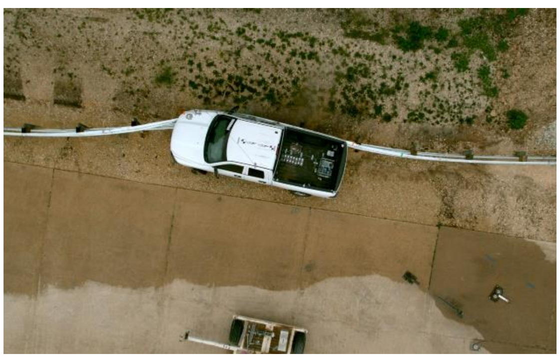
	Before	After	Differ.
		inches	
A1	65.00	65.00	0.00
A2	63.00	63.00	0.00
A3	65.50	65.50	0.00
B1	45.00	45.00	0.00
B2	38.00	38.00	0.00
B3	45.00	45.00	0.00
B4	39.50	39.50	0.00
B5	43.00	43.00	0.00
B6	39.50	39.50	0.00
C1	6.00	6.00	0.00
C2	0.00	0.00	0.00
C3	26.00	26.00	0.00
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
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


0.000 s



0.100 s



0.200 s

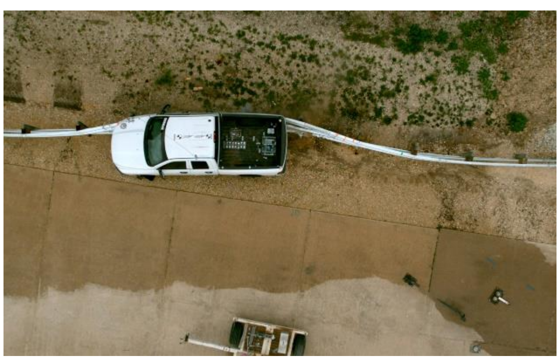


0.300 s


Figure D.1. Sequential Photographs for Test No. 608431-01-1 (Overhead and Frontal Views).

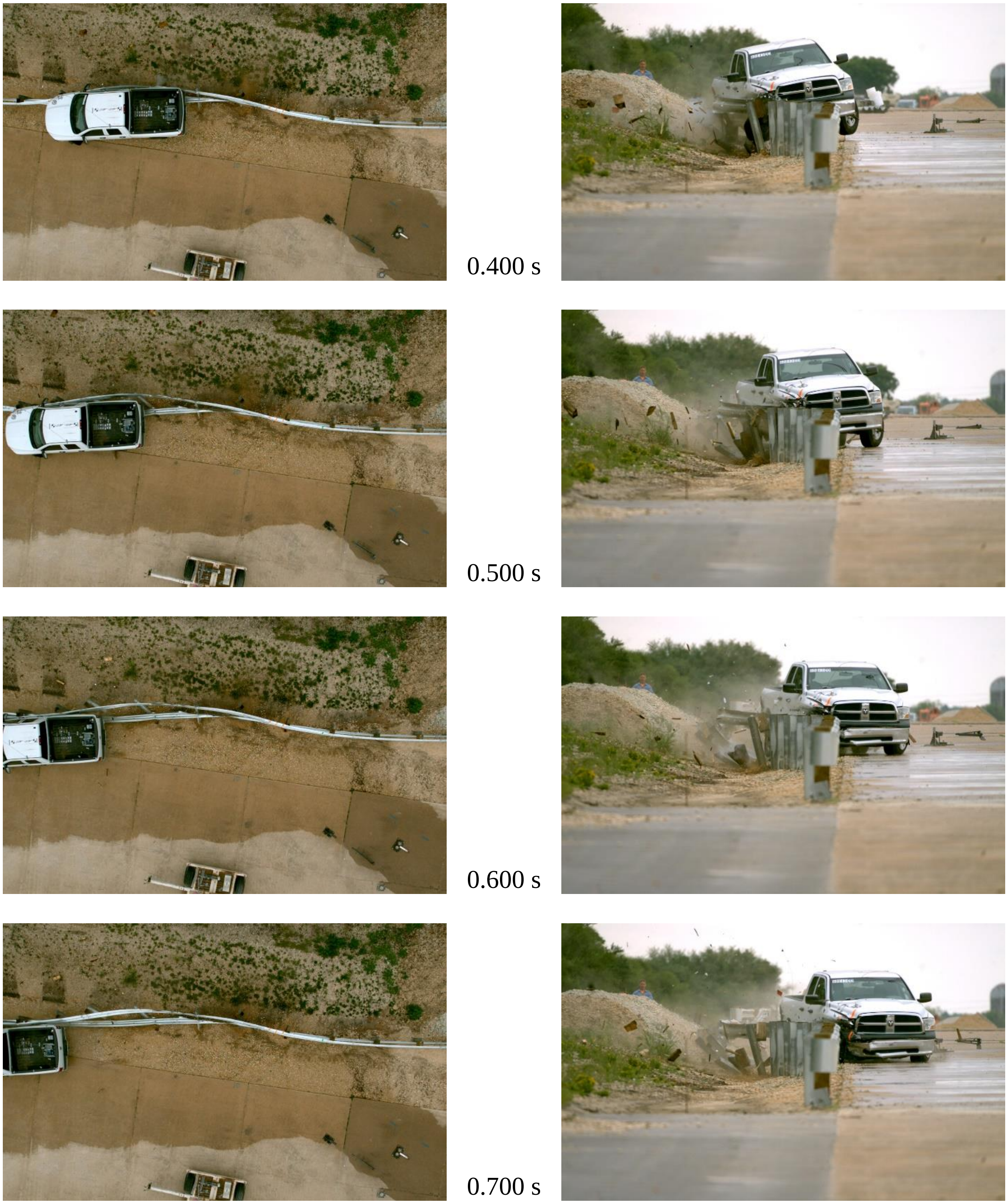


Figure D.1D.1**. Sequential Photographs for Test No. 608431-01-1 (Overhead and Frontal Views) (Continued).**

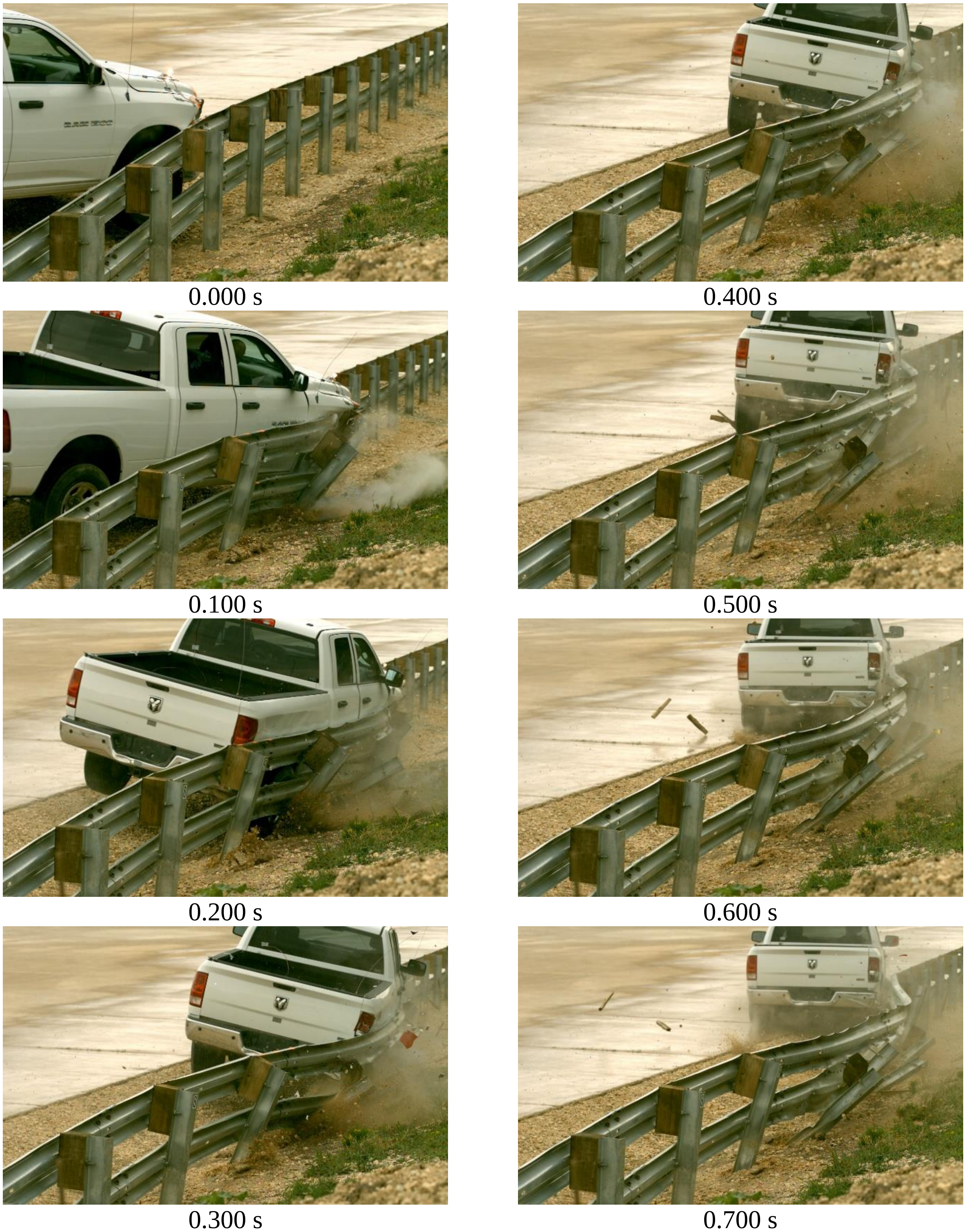


Figure D.2. Sequential Photographs for Test No. 608431-01-1 (Rear View).

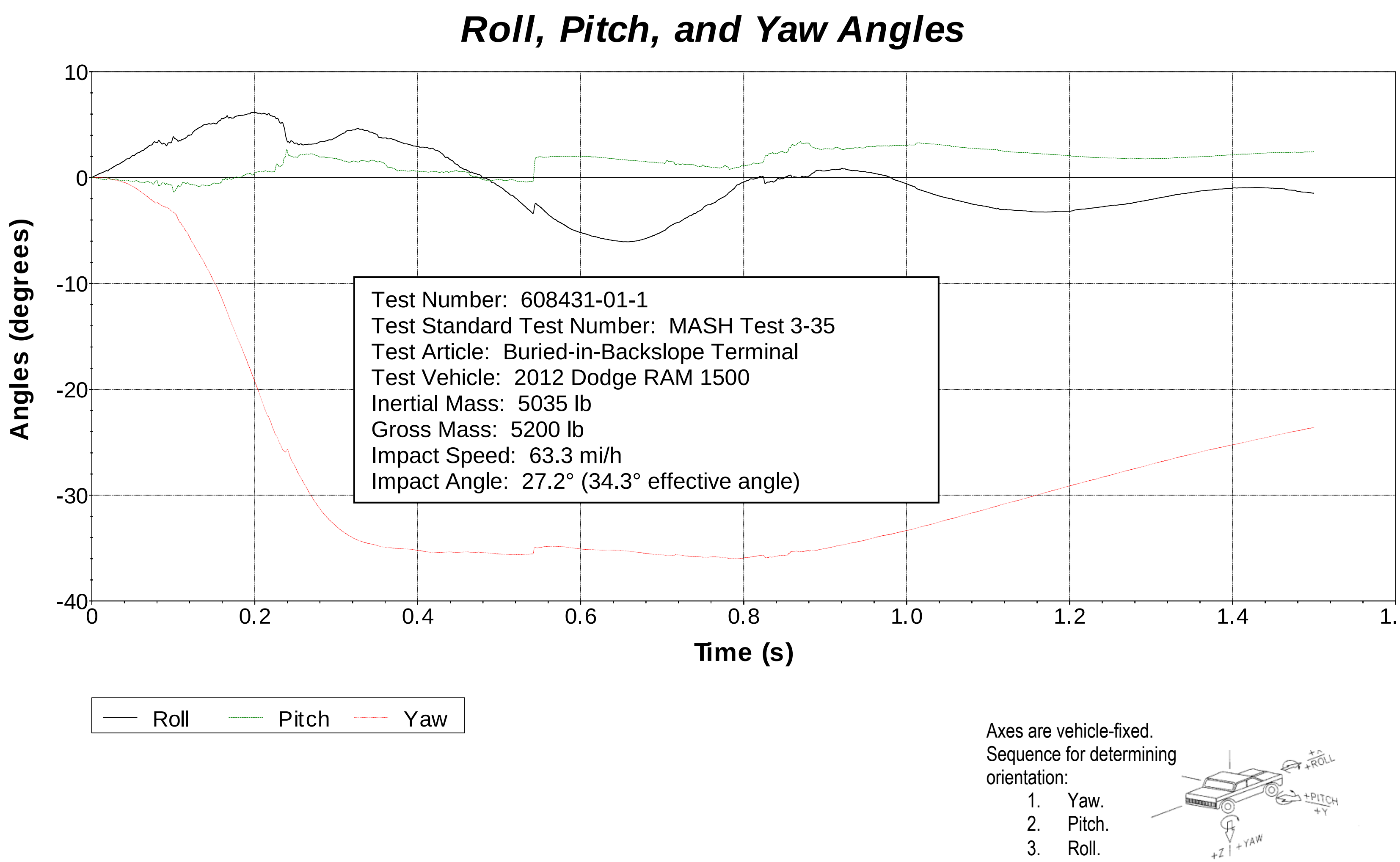


Figure D.3. Vehicle Angular Displacements for Test No. 608431-01-1.

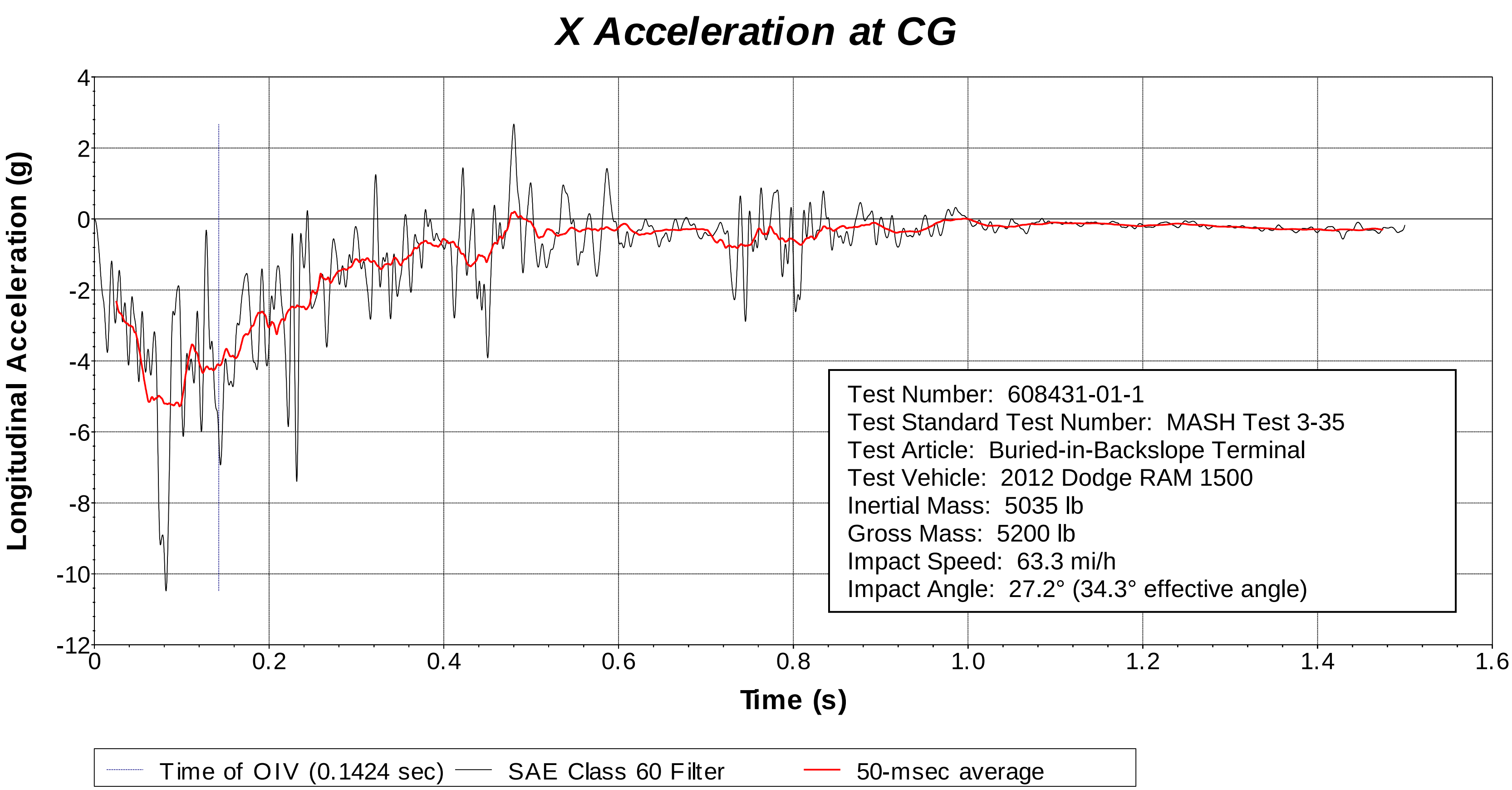


Figure D.4. Vehicle Longitudinal Accelerometer Trace for Test No. 608431-01-1 (Accelerometer Located at Center of Gravity).

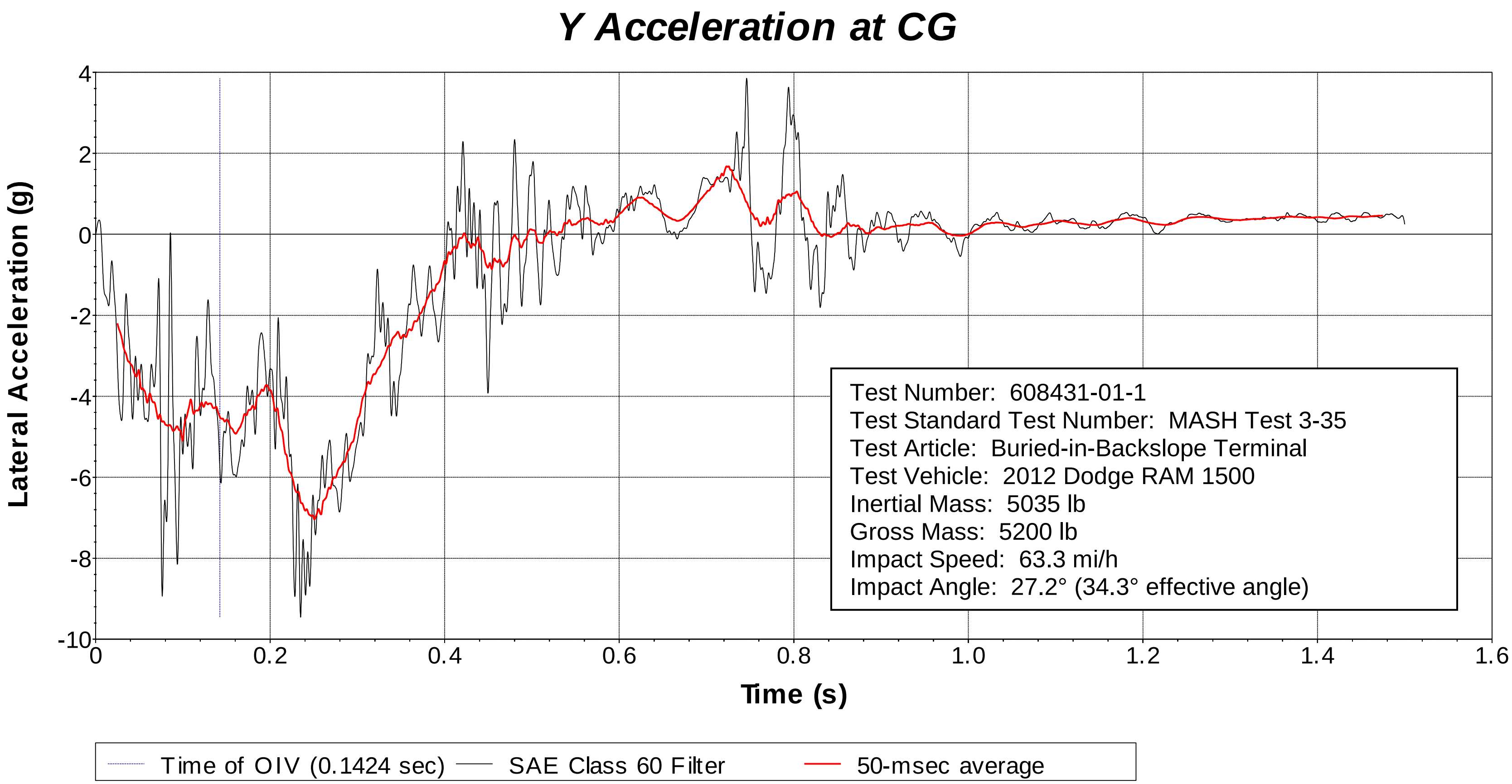


Figure D.5. Vehicle Lateral Accelerometer Trace for Test No. 608431-01-1 (Accelerometer Located at Center of Gravity).

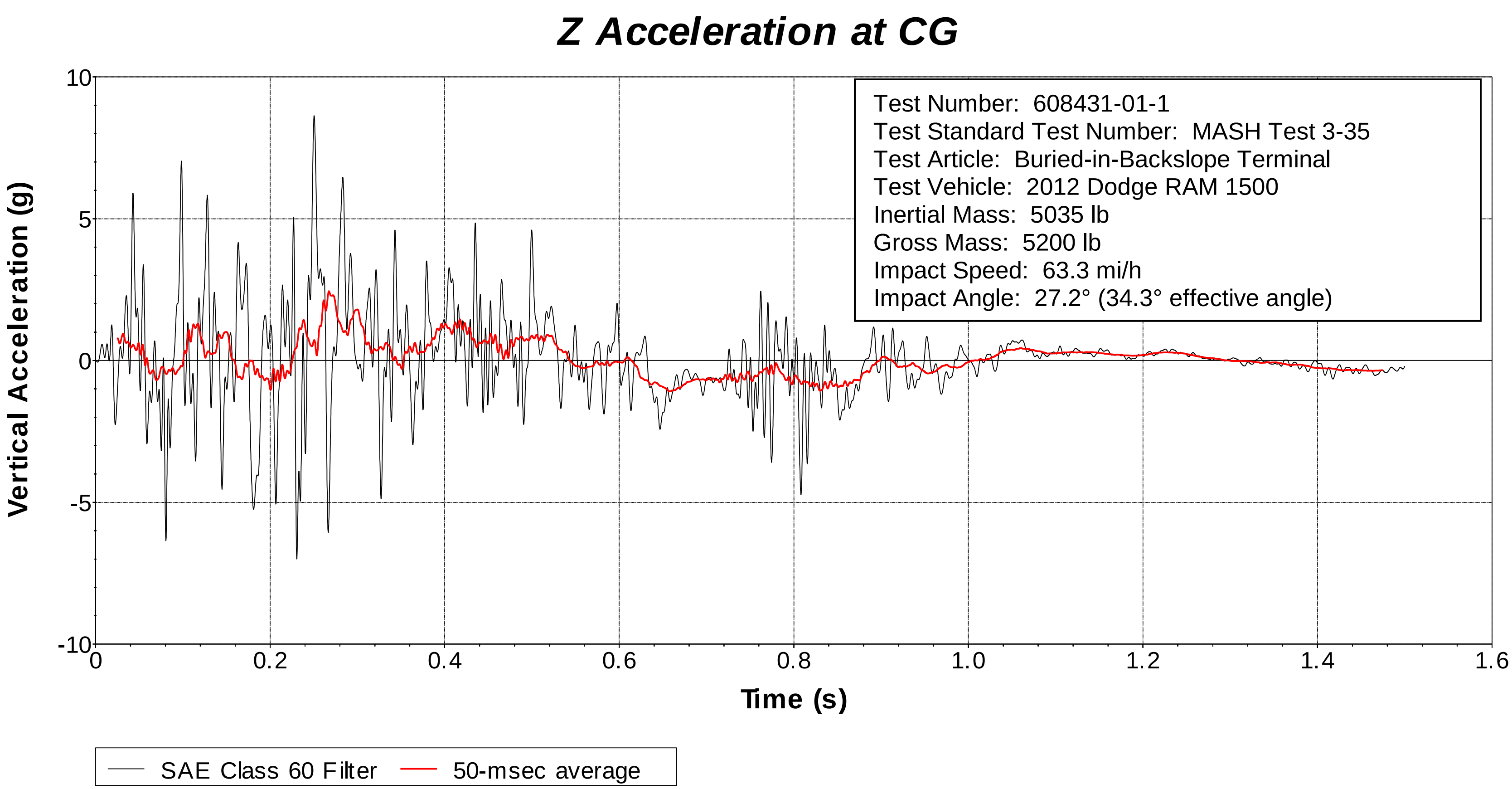


Figure D.6. Vehicle Vertical Accelerometer Trace for Test No. 608431-01-1 (Accelerometer Located at Center of Gravity).

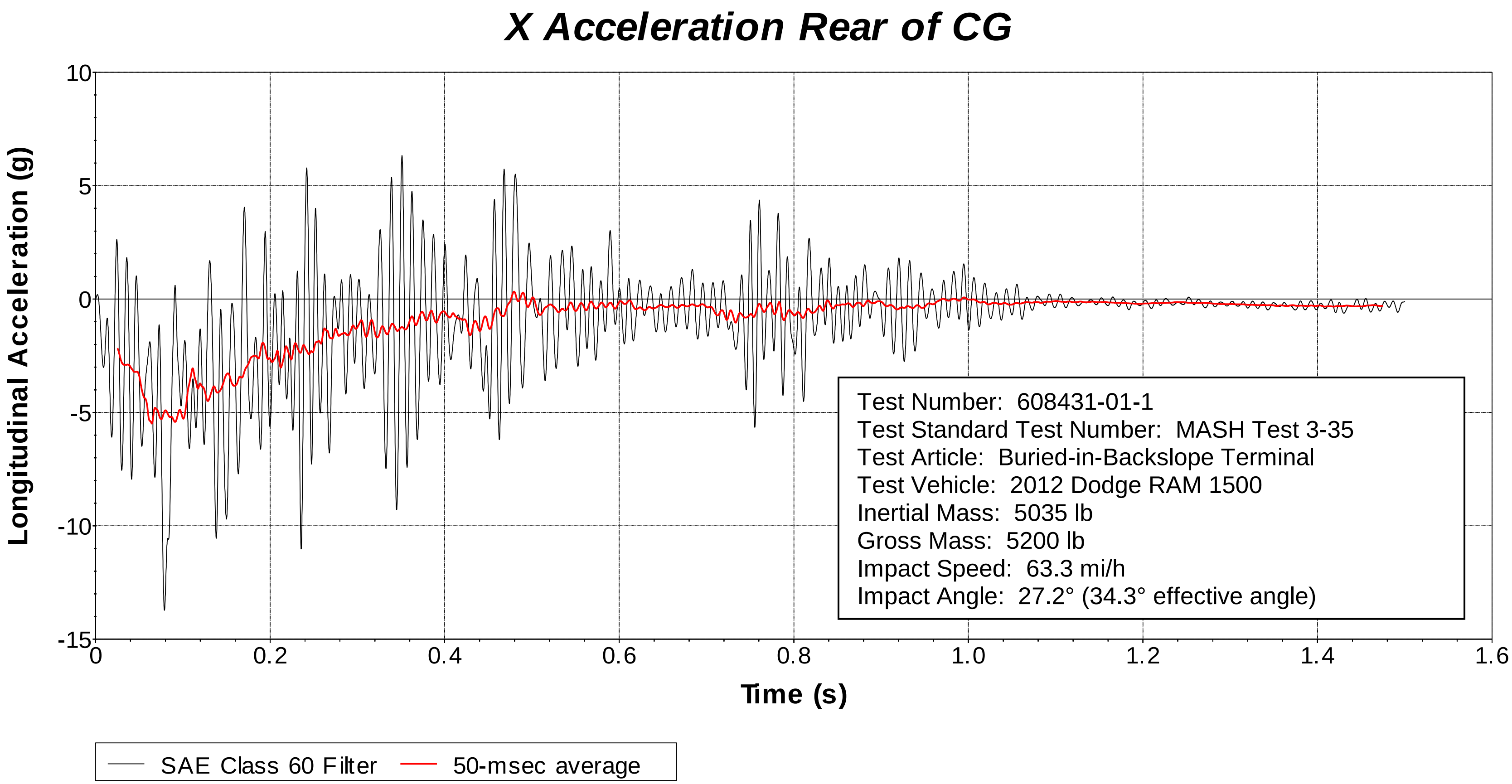


Figure D.7. Vehicle Longitudinal Accelerometer Trace for Test No. 608431-01-1 (Accelerometer Located Rear of Center of Gravity).

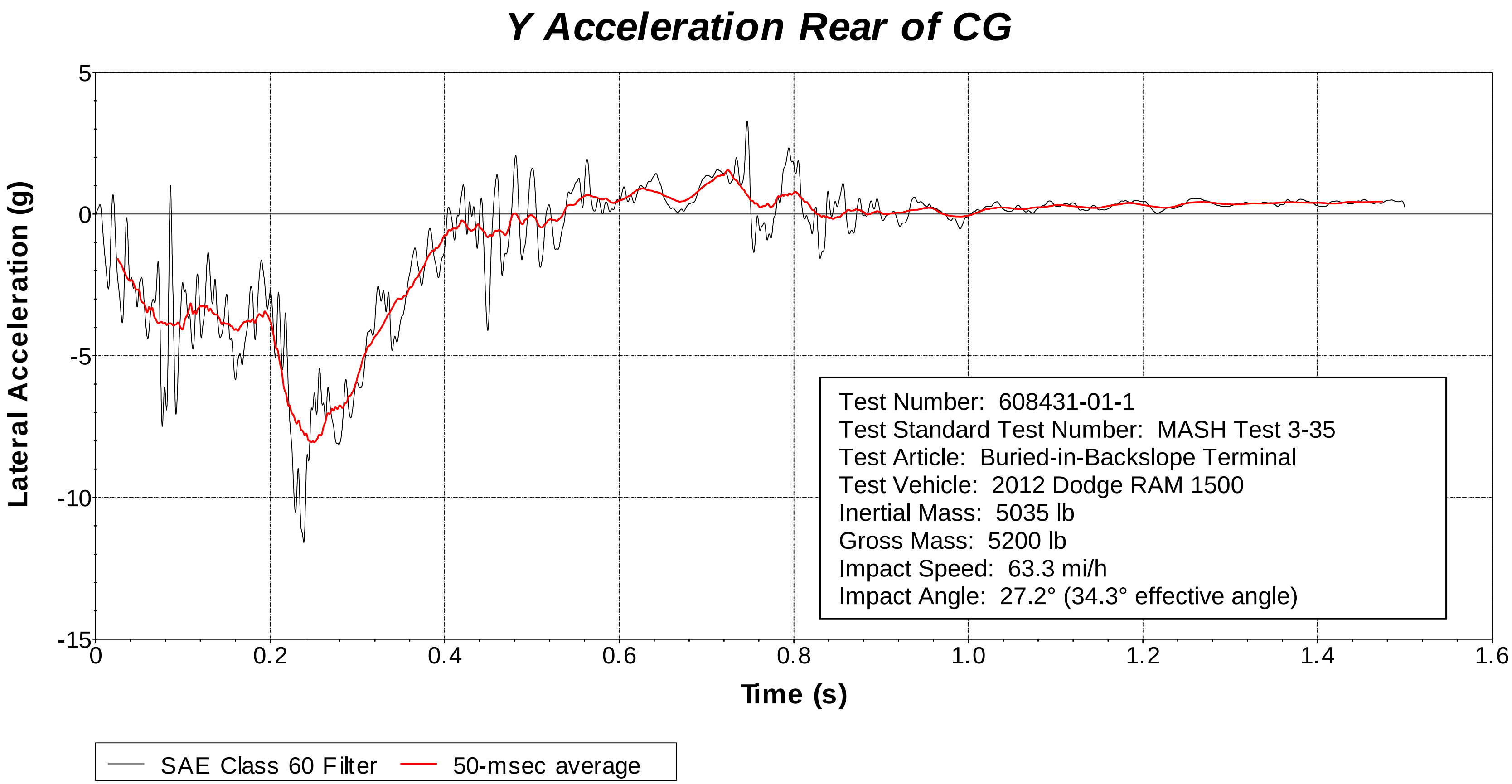


Figure D.8. Vehicle Lateral Accelerometer Trace for Test No. 608431-01-1 (Accelerometer Located Rear of Center of Gravity).

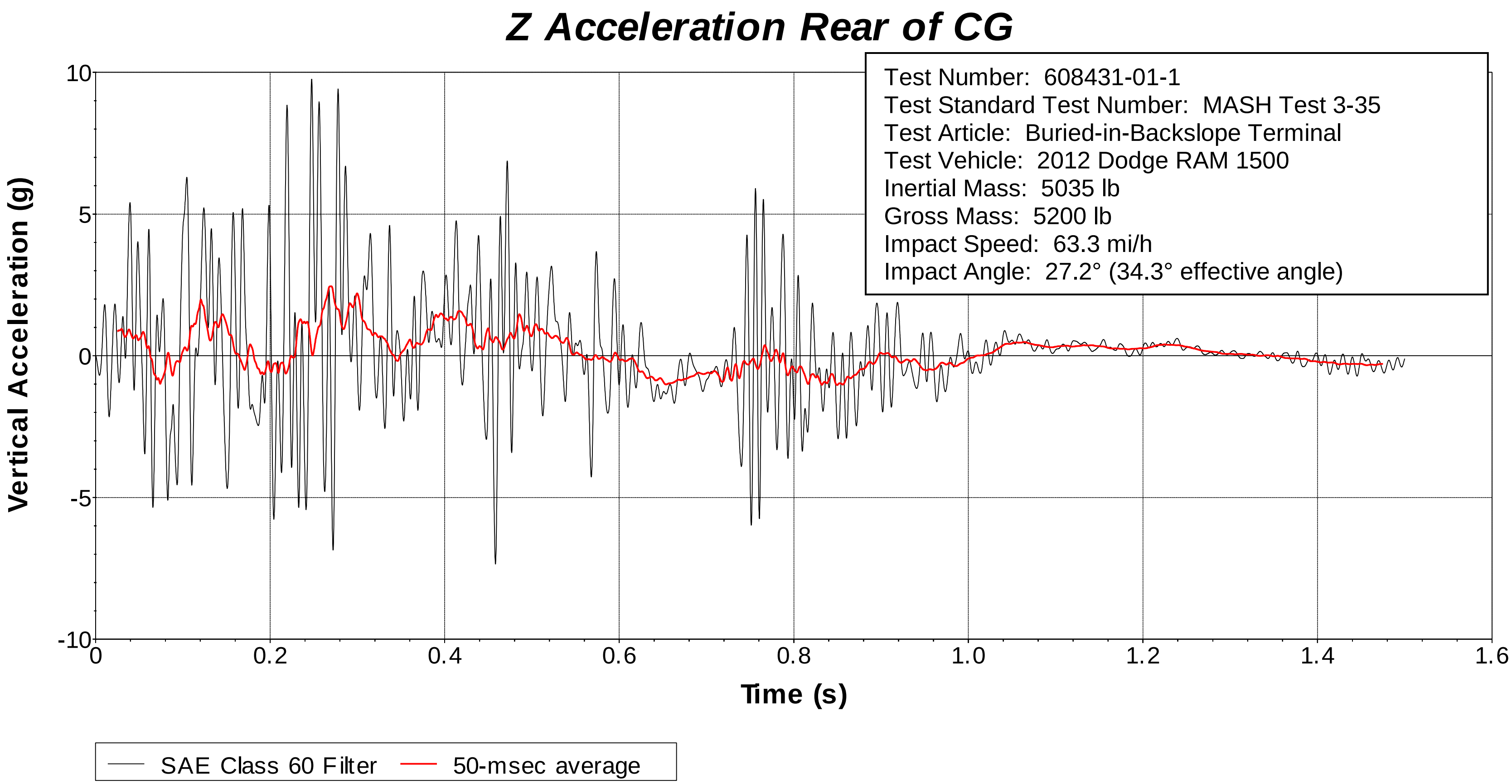


Figure D.9. Vehicle Vertical Accelerometer Trace for Test No. 608431-01-1 (Accelerometer Located Rear of Center of Gravity).