Texas A&M Transportation Institute Proving Ground

MASH TEST 3-10 ON WYOMING BOX BEAM SHOULDER BARRIER

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Report Date: May 2019

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16. Abstract

The objective of this project was to complete the *Manual for Assessing Safety Hardware (MASH)* evaluation of the Wyoming box beam shoulder barrier by performing *MASH* Test 3-10. *MASH* Test 3-10 involves an 1100C vehicle impacting the barrier at a target impact speed and impact angle of 62 mi/h and 25°, respectively.

This report provides details of the Wyoming box beam shoulder barrier, detailed documentation of the crash test results, and an assessment of the performance of the Wyoming box beam shoulder barrier for *MASH* Test 3-10 evaluation criteria. Additionally, the MASH compliance of the Wyoming box beam shoulder barrier is discussed.

The Wyoming box beam shoulder barrier performed acceptably for *MASH* Test 3-10. The Wyoming box beam shoulder barrier performed acceptably for *MASH* Test 3-11 under National Cooperative Highway Research Program Project 22-14(03). Based on the successful outcome of both tests, it is concluded that the Wyoming box beam shoulder barrier is *MASH* compliant as a Test Level 3 longitudinal barrier.

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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

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CHAPTER 1. INTRODUCTION

1.1 INTRODUCTION

The second edition of the *Manual for Assessing Safety Hardware* (*MASH*) was published by the American Association of State Highway and Transportation Officials (AASHTO) in December 2016 (*1*). Concurrent with this publication, an agreement for the implementation of *MASH* was jointly adopted by AASHTO and the Federal Highway Administration. The implementation agreement established phased adoption of *MASH*-compliant roadside safety devices.

As the Wyoming Department of Transportation began to formulate a strategy for *MASH* implementation, a *MASH*-compliant box beam guardrail system was identified as a priority. The *MASH* test matrix for Test Level 3 (TL-3) longitudinal barriers consists of two tests: *MASH* Test 3-10 with a passenger car and *MASH* Test 3-11 with a pickup truck.

Under National Cooperative Highway Research Program (NCHRP) Project 22-14(03), Evaluation of Existing Roadside Safety Hardware Using Update Criteria, the impact performance of several commonly used nonproprietary roadside safety features was evaluated using *MASH* criteria (*2*). One of the longitudinal barriers evaluated was the Wyoming box beam shoulder barrier (also referred to as the G3 weak-post box-beam guardrail system). The Wyoming box beam shoulder barrier performed acceptably for *MASH* Test 3-11 (*2*).

1.2 OBJECTIVE

The objective of this project was to complete the *MASH* evaluation of the Wyoming box beam shoulder barrier by performing *MASH* Test 3-10. *MASH* Test 3-10 involves an 1100C vehicle impacting the barrier at a target impact speed and impact angle of 62 mi/h and 25°, respectively.

This report provides details of the Wyoming box beam shoulder barrier, detailed documentation of the crash test results, and an assessment of the performance of the Wyoming box beam shoulder barrier for *MASH* Test 3-10 evaluation criteria. Additionally, the *MASH* compliance of the Wyoming box beam shoulder barrier is discussed.

CHAPTER 2. SYSTEM DETAILS

2.1. TEST ARTICLE AND INSTALLATION DETAILS

The test installation consisted of HSS 6×6×$^{3}/_{16}$–inch rail sections, supported by S3×5.7 posts (with soil plates) spaced at 72 inches. The top of the rails were located 28 inches above grade for the 186-ft length-of-need between posts 2 and 33. The rails sloped down at each end and were anchored to concrete blocks embedded in the soil. The total rail length, measured from the center of each of the anchor blocks, was 226 ft-10 inches.

Figure 2.1 presents overall information on the Wyoming box beam shoulder barrier, and figure 2.2 provides photographs of the installation. Appendix A provides further details of the Wyoming box beam shoulder barrier.

2.2. MATERIAL SPECIFICATIONS

Appendix B provides material certification documents for the materials used to install/construct the Wyoming box beam shoulder barrier.

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 barrier for full-scale crash testing, two W6×16 posts were installed in the immediate vicinity of the barrier utilizing the same fill materials and installation procedures used in the test installation and a previous standard dynamic test. Figure C.1 in Appendix C 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 C, Figure C.1, the minimum post loads required for deflections at 5 inches, 10 inches, and 15 inches, measured at a height of 25 inches, are 3940 lb, 5500 lb, and 6540 lb, respectively (90 percent of static load for the initial standard installation). On the day of the test, January 11, 2019, loads on the post at deflections of 5 inches, 10 inches, and 15 inches were 7272 lbf, 7626 lbf, and 7424 lbf, respectively. Figure C.2 in Appendix C shows that the strength of the backfill material in which the barrier was installed met minimum *MASH* requirements.

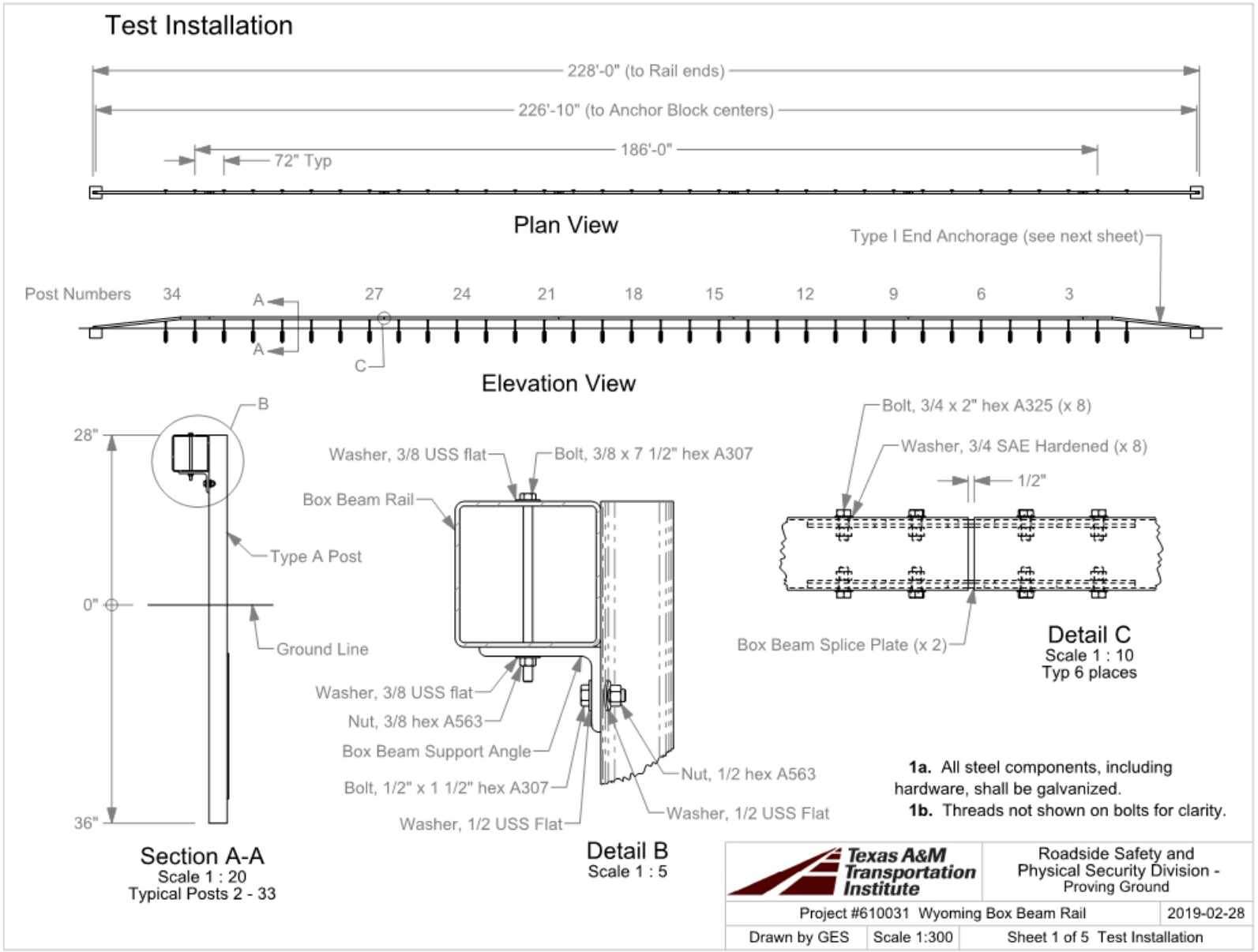


Figure 2.1. Details of the Wyoming Box Beam Shoulder Barrier.

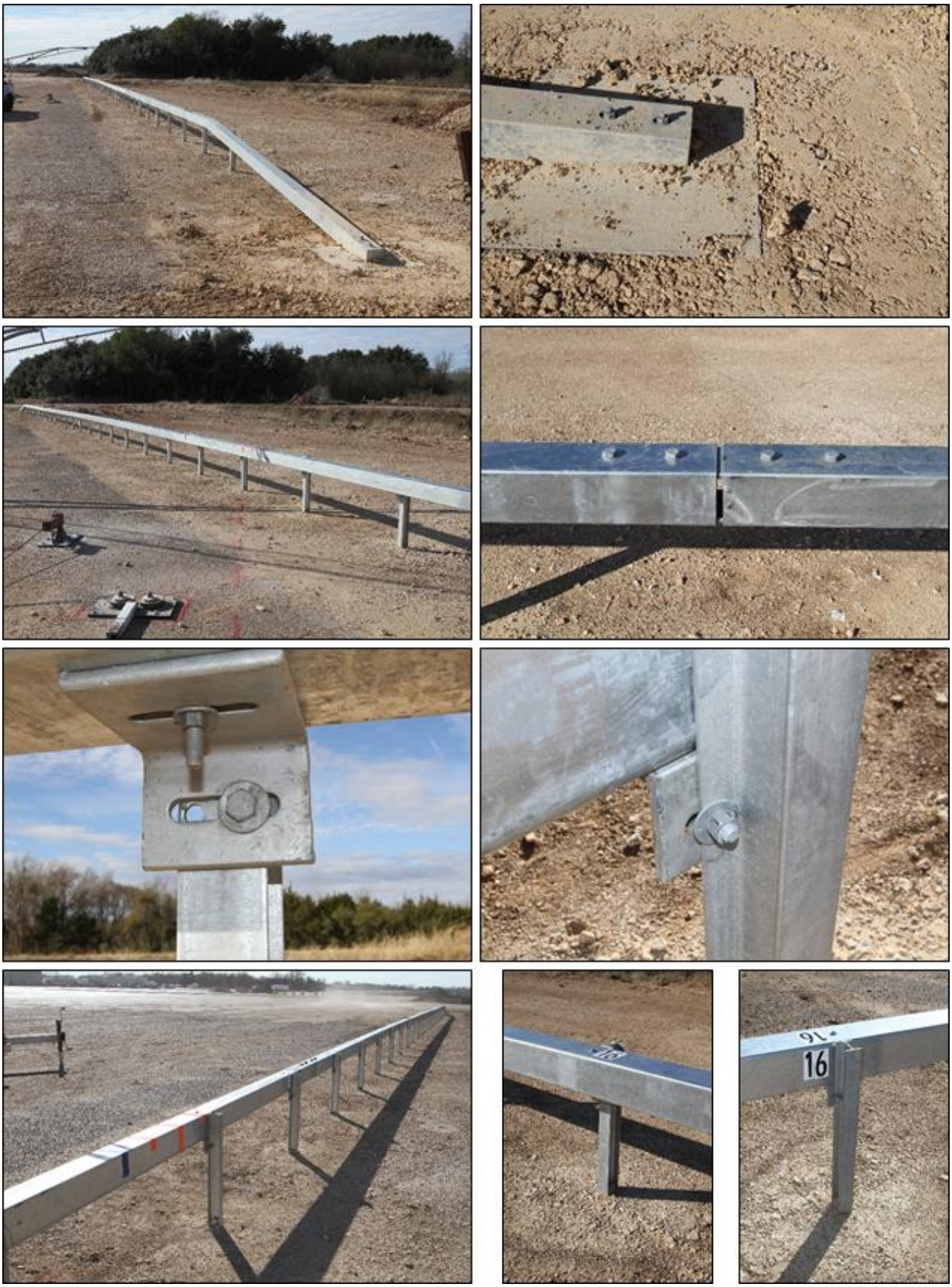


Figure 2.2. Wyoming Box Beam Shoulder Barrier prior to Testing.

CHAPTER 3. TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1. CRASH TEST PERFORMED/MATRIX

Table 3-1 shows the test conditions and evaluation criteria for *MASH* TL-3 for longitudinal barriers. *MASH* Test 3-11 on the Wyoming box beam shoulder barrier was performed under NCHRP Project 22-14(03) (*2*). *MASH* Test 3-10 involves an 1100C vehicle weighing 2420 lb ±55 lb impacting the critical impact point (CIP) of the barrier at a speed of 62 mi/h ±2.5 mi/h and an angle of 25° ±1.5°. Using the information provided in *MASH* Section 2.2.1, *MASH* Section 2.3.2, and *MASH* Figure 2-1, the target CIP was determined to be 10 ft-3 inches upstream of the centerline of the rail splice between posts 14 and 15.

Table 3-1. Test Conditions and Evaluation Criteria Specified for *MASH* TL-3 Longitudinal Barriers.

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

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

3.2. EVALUATION CRITERIA

The appropriate safety evaluation criteria from Tables 2-2 and 5-1 of *MASH* were used to evaluate the crash test reported herein. The test conditions and evaluation criteria required for *MASH* Test 3-10 are listed in Table 3-1, and the substance of the evaluation criteria are listed in Table 3-2. An evaluation of the crash test results is presented in detail under the Section 6.1, "Assessment of Test Results."

Table 3-2. Evaluation Criteria Required for *MASH* Test 3-10 for Longitudinal Barriers.

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

CHAPTER 4. TEST CONDITIONS

4.1. TEST FACILITY

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

The test facilities of the TTI Proving Ground are located on The Texas A&M University System RELLIS Campus, which consists of a 2000-acre complex of research and training facilities situated 10 miles northwest of the flagship campus of Texas A&M University. The site, formerly a United States Army Air Corps base, has large expanses of concrete runways and parking aprons well suited for experimental research and testing in the areas of vehicle performance and handling, vehicle-roadway interaction, durability and efficacy of highway pavements, and evaluation of roadside safety hardware and perimeter protective devices. The site selected for construction and testing of the Wyoming box beam shoulder barrier was along the edge of an out-of-service apron. The apron consists of an unreinforced jointed-concrete pavement in 12.5×15-ft blocks nominally 6 inches deep. The aprons were built in 1942, and the joints have some displacement but are otherwise flat and level.

4.2 VEHICLE TOW AND GUIDANCE SYSTEM

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

4.3 DATA ACQUISITION SYSTEMS

4.3.1 Vehicle Instrumentation and Data Processing

The test vehicle was instrumented with a self-contained, onboard 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 axes of vehicle acceleration, are strain gauge type with linear millivolt output proportional to acceleration. Angular rate sensors, measuring vehicle roll, pitch, and yaw rates, are ultra-small, solid state units designed for crash test service. The TDAS Pro hardware

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

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

TRAP uses the data from the TDAS Pro to compute occupant/compartment impact velocities, time of occupant/compartment impact after vehicle impact, and the highest 10-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 digital low-pass 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, and 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 are 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.

4.3.3 Photographic Instrumentation Data Processing

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

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

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

A flashbulb on the impacting vehicle was activated by a pressure-sensitive tape switch to indicate the instant of contact with the Wyoming box beam shoulder barrier. 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 the conditions of each test vehicle and the installation before and after the test.

CHAPTER 5. *MASH* TEST 3-10 (CRASH TEST NO. 610031-01-1)

5.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

MASH Test 3-10 involves an 1100C vehicle, weighing 2420 lb ±55 lb, impacting the CIP of the barrier at an impact speed of 62 mi/h ±2.5 mi/h and at an angle of 25° ±1.5°. The target CIP for *MASH* Test 3-10 on the Wyoming box beam shoulder barrier was 10 ft-3 inches ±1 ft upstream of the centerline of the rail splice between posts 14 and 15.

The 2009 Kia Rio[*] used in the test weighed 2441 lb, and the actual impact speed and angle were 63.9 mi/h and 24.6°, respectively. The actual impact point was 9 ft-9 inches upstream of the centerline of the rail splice between posts 14 and 15. Minimum target impact severity (IS) was 51 kip-ft, and actual IS was 58 kip-ft.

5.2 WEATHER CONDITIONS

The test was performed on the morning of January 11, 2019. Weather conditions at the time of testing were as follows:

- Wind speed: 8 mi/h;
- Wind direction: 139° (vehicle was traveling in a southwesterly direction);
- Temperature: 59°F; and
- Relative humidity: 68 percent.

5.3 TEST VEHICLE

Figure 5.1 and Figure 5.2 show the 2009 Kia Rio used for the crash test. The vehicle's test inertia weight was 2441 lb, and its gross static weight was 2606 lb. The height to the lower edge of the vehicle bumper was 7.75 inches, and the height to the upper edge of the bumper was 21.5 inches. Figure D.1 in Appendix D1 gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

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

Figure 5.1. Barrier/Test Vehicle Geometrics for Test No. 610031-01-1.

Figure 5.2. Test Vehicle before Test No. 610031-01-1.

5.4 TEST DESCRIPTION

The test vehicle was traveling at an impact speed of 63.9 mi/h when it contacted the Wyoming box beam shoulder barrier 9 ft-9 inches upstream of the centerline of the rail splice between posts 14 and 15, at an impact angle of 24.6°. Table 5-1 lists events that occurred during Test No. 610031-01-1. Figure D.4 and Figure D.5 in Appendix D2 present sequential photographs during the test.

Table 5-1. Events during Test No. 610031-01-1.

Time (s)*	Events
~0.0000	Vehicle contacts guardrail
~0.0140	Vehicle begins to redirect
~0.0160	Post 13 separates away from rail
~0.1170	Vehicle traveling parallel with rail
~0.2210	Vehicle loses contact with guardrail at a trajectory angle of 11.8° and heading angle of 2.7°

* Due to technical difficulties with the high-speed cameras, times are approximate.

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 173 ft downstream of the impact point and 13 ft toward the field side.

5.5 DAMAGE TO TEST INSTALLATION

Figure 5.3 and Figure 5.4 show the damage to the Wyoming box beam shoulder barrier. There was a 0.75-inch gap between the soil and the upstream side of the upstream anchor block, and a 0.5 inch gap between the soil and the downstream side of the downstream anchor block. No movement was observed at posts 1–8, 20–30, and 32–34. The rail was detached from posts 12–16. Posts 9–19 and 31 were leaning toward the field side (see Table 5-2). The damage near post 31 resulted from a secondary impact of the vehicle with the downstream end of the guardrail installation. The working width was 34.8 inches, and the height of the working width was 28.8 inches. Maximum dynamic deflection during the test was 28.8 inches, and maximum permanent deformation was 11.5 inches.

Figure 5.3. Barrier after Test No. 610031-01-1.

Figure 5.4. Damage at Impact Area after Test No. 610031-01-1.

Table 5-2. Post Lean for Test No. 610031-01-1.

Post No.	Lean*
9	89.9°
10	89.3°
11	84.7°
12	73.9°
13	25.0°
14	23.0°
15	15.0°
16	25.0°
17	82.9°
18	88.8°
19	89.3°
31	31.4°

* 90° is vertical.

5.6 VEHICLE DAMAGE

Figure 5.5 shows the damage sustained by the vehicle. The front bumper, hood, right front fender, right front strut and tower, right front tire and rim, right front and rear doors, right rear quarter panel, rear bumper, and left front fender were damaged. Maximum exterior crush to the vehicle was 7.0 inches in the front plane at the right front corner at bumper height. No occupant compartment deformation or intrusion was observed. Figure 5.6 shows the interior of the vehicle. Figure D.2 and Figure D.3 in Appendix D1 provide exterior crush and occupant compartment measurements, respectively.

Figure 5.5. Test Vehicle after Test No. 610031-01-1.

Figure 5.6. Interior of Test Vehicle after Test No. 610031-01-1.

5.7 OCCUPANT RISK FACTORS

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk. Table 5-3 shows the results. Table 5-4 and Figure 5.7 summarize these data and other pertinent information from the test. Figure D.6 in Appendix D3 shows the vehicle angular displacements, and Figure D.7 through Figure D.12 in Appendix D4 show acceleration versus time traces.

Table 5-3. Occupant Risk Factors for Test No. 610031-01-1.

Occupant Risk Factor	Value	Time
OIV, longitudinal	14.4 ft/s	at 0.1130 s on right side of interior
OIV, lateral	19.0 ft/s	at 0.1130 s on right side of interior
Occupant ridedown accelerations, longitudinal	5.7 g	0.1377–0.1477 s
Occupant ridedown accelerations, lateral	10.4 g	0.1476–0.1576 s
Theoretical head impact velocity (THIV)	25.5 km/h and 7.1 m/s	at 0.1087 s on right side of interior
Post head deceleration (PHD)	11.1 g	0.1477–0.1577 s
Acceleration severity index (ASI)	0.87	0.0560–0.1060 s
Maximum 50-ms moving average, longitudinal	−5.6 g	0.0271–0.0771 s
Maximum 50-ms moving average, lateral	−7.0 g	0.1168–0.1668 s
Maximum 50-ms moving average, vertical	−2.3 g	0.1415–0.1915 s
Maximum roll angle	11°	0.2060 s
Maximum pitch angle	6°	1.5000 s
Maximum yaw angle	43°	1.5000 s

Table 5-4. Summary of Results for *MASH* Test 3-10 on Wyoming Box Beam Shoulder Barrier.

Type of Information	Results
General information	Test agency ..... Texas A&M Transportation Institute Test standard test no. ..... MASH Test 3-10 TTI test no. ..... 610031-01-1 Test date 2019-01-11
Test article	Type ..... Longitudinal barrier—guardrail Name ..... Wyoming box beam shoulder barrier Installation length ..... 226 ft-10 inches Material or key elements ..... HSS 6×6×3/16–inch rail supported by S3×5.7 posts with soil plates spaced at 72 inches; height 28 inches above grade
Soil type and condition	Embedded in AASHTO M147-65(2004), grading B soil (crushed limestone)
Test vehicle	Type/designation ..... 1100C Make and model ..... 2009 Kia Rio Curb ..... 2500 lb Test inertial ..... 2441 lb Dummy ..... 165 lb Gross static ..... 2606 lb
Impact conditions	Speed ..... 63.9 mi/h Angle ..... 24.6° Location/orientation ..... 9 ft-9 inches upstream of splice between 14–15
Impact severity	58 kip-ft
Exit conditions	Speed ..... Not obtainable Trajectory/heading angle ..... 11.8°/2.7°
Occupant risk values	Longitudinal OIV ..... 14.4 ft/s Lateral OIV ..... 19.0 ft/s Longitudinal ridedown ..... 5.7 g Lateral ridedown ..... 10.4 g THIV ..... 25.5 km/h PHD ..... 11.1 g ASI ..... 0.87 Max. 0.050-s average: Longitudinal ..... −5.6 g Lateral ..... −7.0 g Vertical ..... −2.3 g
Post-impact trajectory	Stopping distance ..... 173 ft downstream, 13 ft toward field side
Vehicle stability	Maximum yaw angle ..... 43° Maximum pitch angle ..... 6° Maximum roll angle ..... 11° Vehicle snagging ..... No Vehicle pocketing ..... No
Test article deflections	Dynamic ..... 28.8 inches Permanent ..... 11.5 inches Working width ..... 34.8 inches Height of working width ..... 28.0 inches
Vehicle damage	VDS ..... 01RFQ5 CDC ..... 01FREW4 Max. exterior deformation ..... 7.0 inches OCDI ..... RF0000000 Max. occupant compartment deformation deformation…None

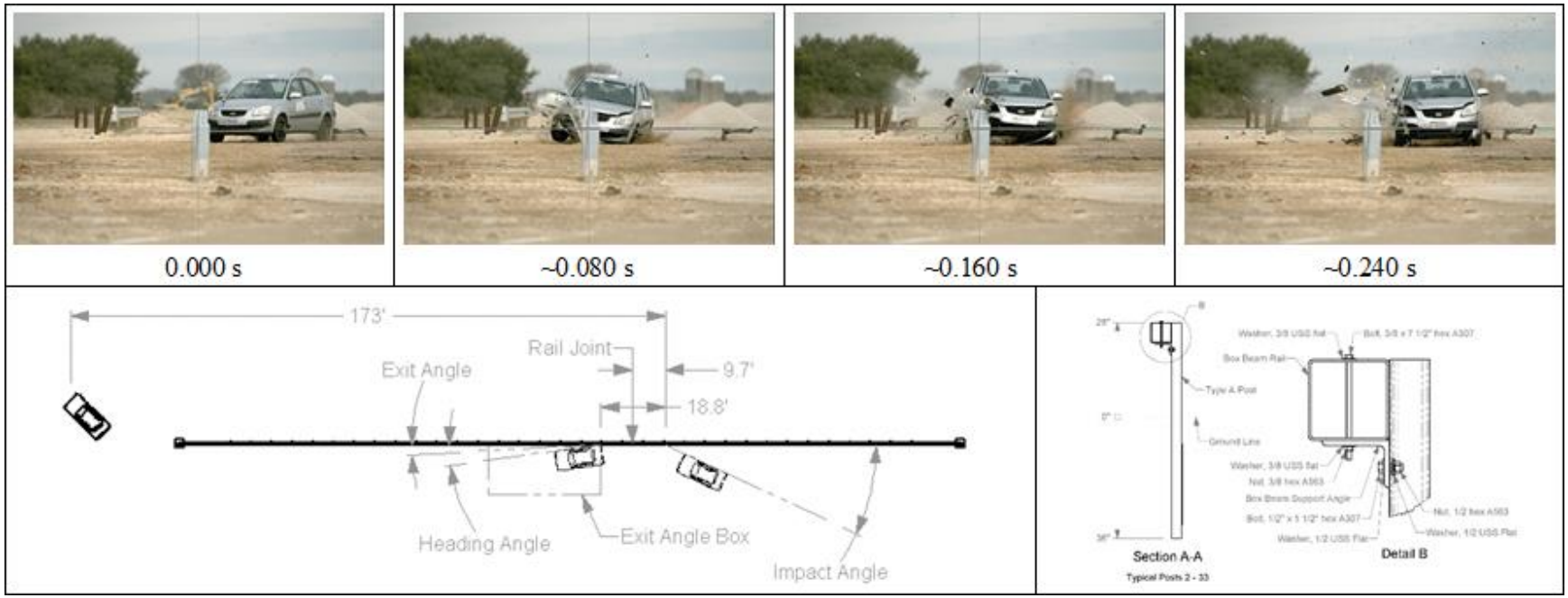


Figure 5.7. Summary of Results for *MASH* Test 3-10 on Wyoming Box Beam Shoulder Barrier.

CHAPTER 6. SUMMARY AND CONCLUSIONS

6.1. ASSESSMENT OF TEST RESULTS

The crash test reported herein was performed in accordance with *MASH* Test 3-10, which involves an 1100C vehicle impacting the Wyoming box beam shoulder barrier at a target impact speed and impact angle of 62 mi/h and 25°, respectively. Table 6-1 provides an assessment of the test based on the applicable safety evaluation criteria for *MASH* Test 3-10 for longitudinal barriers.

6.2 CONCLUSIONS

The Wyoming box beam shoulder barrier performed acceptably for *MASH* Test 3-10. The Wyoming box beam shoulder barrier performed acceptably for *MASH* Test 3-11 under NCHRP Project 22-14(03) (*2*). Based on the successful outcome of both tests, it is concluded that the Wyoming box beam shoulder barrier is *MASH* compliant as a TL-3 longitudinal barrier.

Table 6-1. Performance Evaluation Summary for *MASH* Test 3-10 on Wyoming Box Beam Shoulder Barrier.

Evaluation Factor	*MASH* Test 3-10 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 Wyoming box beam shoulder barrier contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic lateral deflection during the test was 28.8 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.*	The rail detached from several posts but did not penetrate or show potential for penetrating the occupant compartment, or show hazard to others in the area.	Pass
Occupant risk	*D. 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 deformation or intrusion of the occupant compartment was observed.	Pass
Occupant risk	*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 11° and 6°, respectively.	Pass
Occupant risk	*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 14.4 ft/s, and lateral OIV was 19.0 ft/s.	Pass
Occupant risk	*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 ridedown acceleration was 5.7 g, and lateral ridedown acceleration was 10.4 g.	Pass
Vehicle trajectory	For redirective devices, it is preferable that the vehicle be smoothly redirected and leave the barrier within the "exit box" criteria (not less than 32.8 ft for the 1100C and 2270P vehicles) and should be documented.	The 1100C vehicle exited within the exit box criteria.	Documenta-tion only

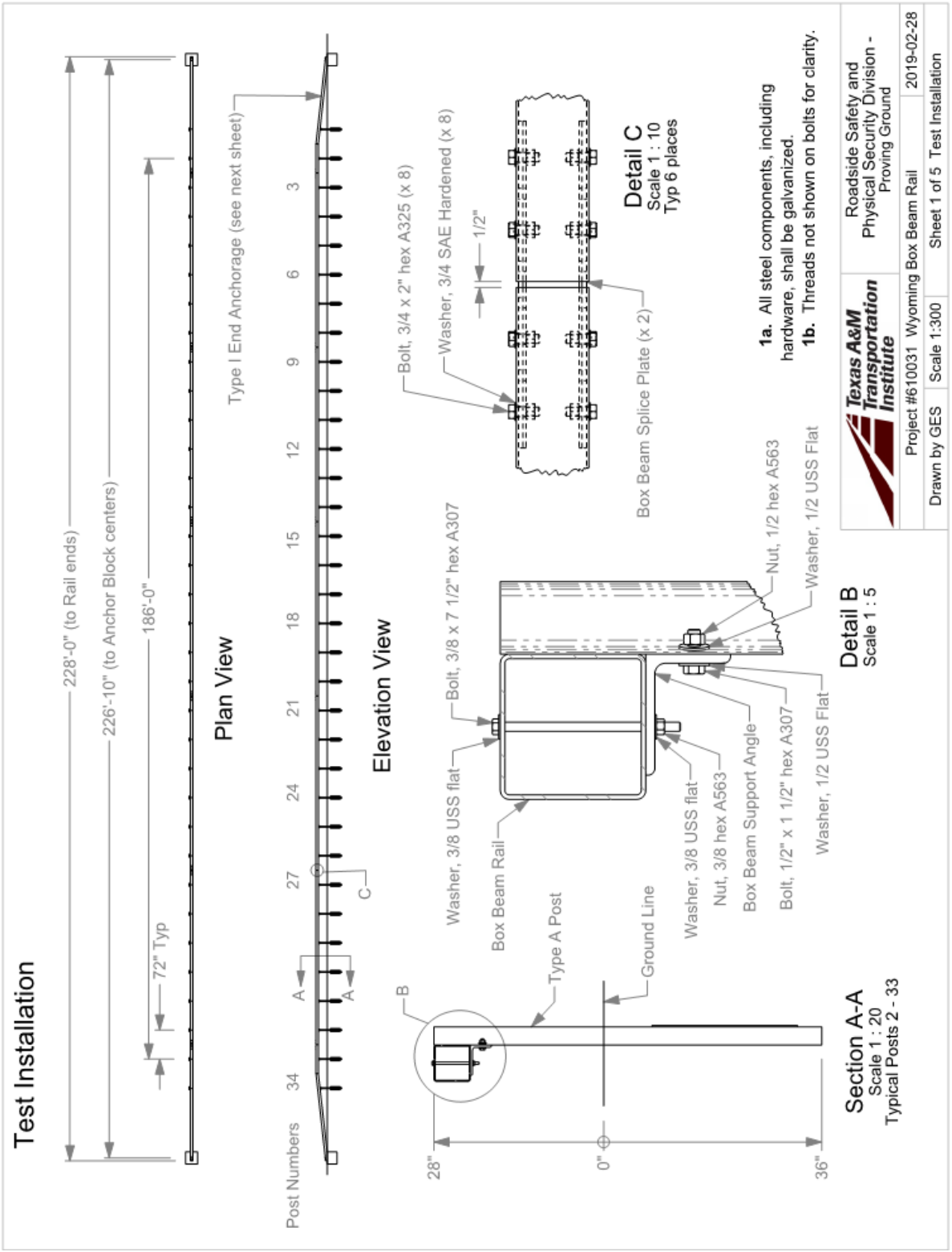
Note: Test agency: TTI, test no.: 610031-01-1, test date: 2019-01-11.

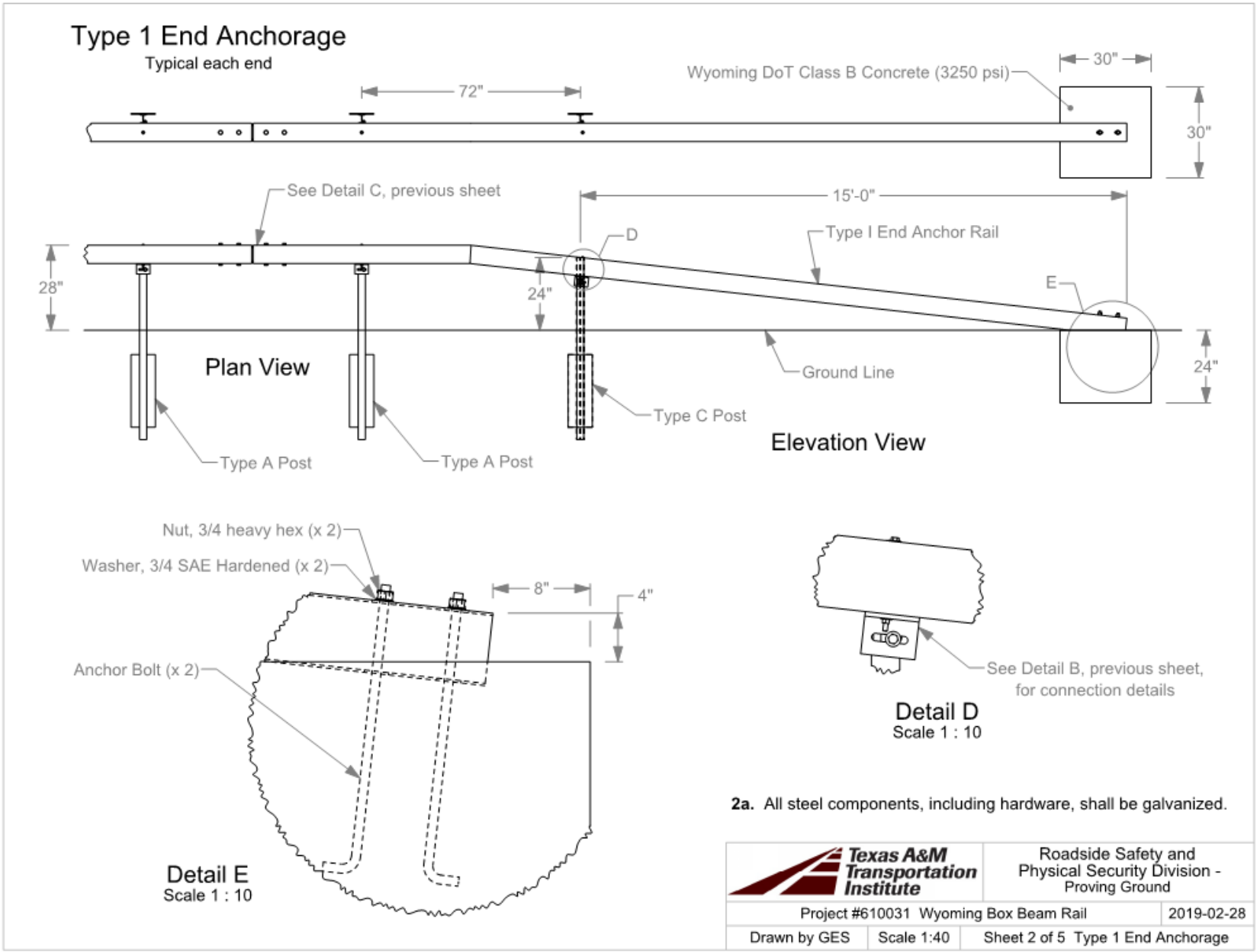
REFERENCES

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

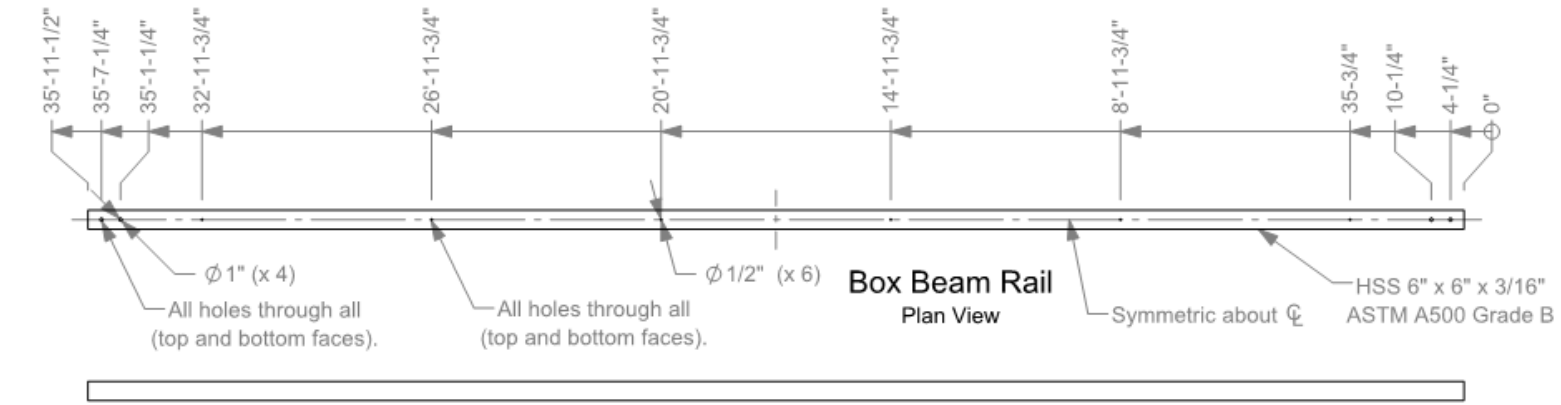
2. D. L. Bullard, Jr., R. P. Bligh, W. L. Menges, and R. R. Haug. *Evaluation of Existing Roadside Safety Hardware Using Updated Criteria—Technical Report*. NCHRP Web-Only Document 157. NCHRP Project 22-14(03), National Cooperative Highway Research Program, Washington, DC, March 2010. http://www.trb.org/Main/Blurbs/163969.aspx. Accessed on May 9, 2019.

APPENDIX A. DETAILS OF THE WYOMING BOX BEAM SHOULDER BARRIER

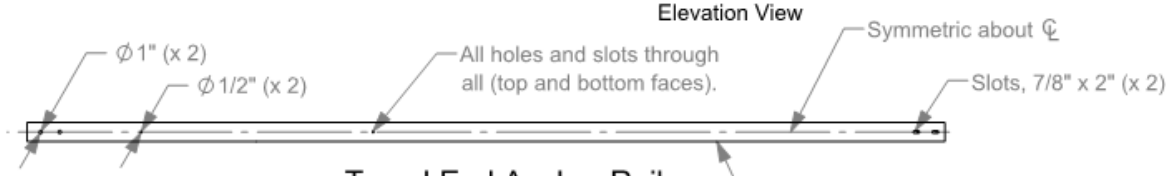



Type 1 End Anchorage
Typical each end
72"
30"
Wyoming DoT Class B Concrete (3250 psi)
30"
See Detail C, previous sheet
15'-0"
D
Type I End Anchor Rail
28"
24"
E
Plan View
Ground Line
24"
Type C Post
Type A Post
Type A Post
Elevation View
Nut, 3/4 heavy hex (x 2)
Washer, 3/4 SAE Hardened (x 2)
8"
4"
Anchor Bolt (x 2)
See Detail B, previous sheet, for connection details
Detail D
Scale 1 : 10
Detail E
Scale 1 : 10
2a. All steel components, including hardware, shall be galvanized.
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #610031 Wyoming Box Beam Rail
2019-02-28
Drawn by GES
Scale 1:40
Sheet 2 of 5 Type 1 End Anchorage

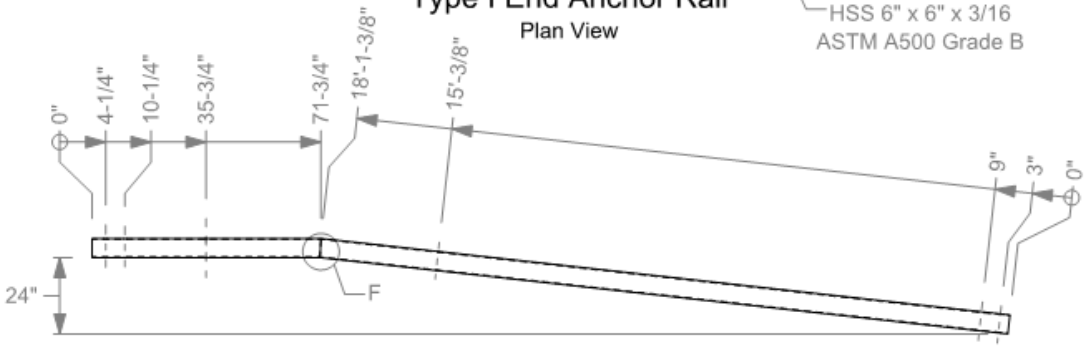
Rail Details

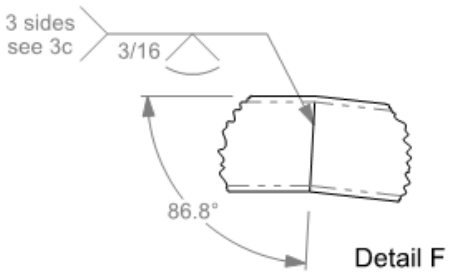


Box Beam Rail
Elevation View



Type I End Anchor Rail
Plan View



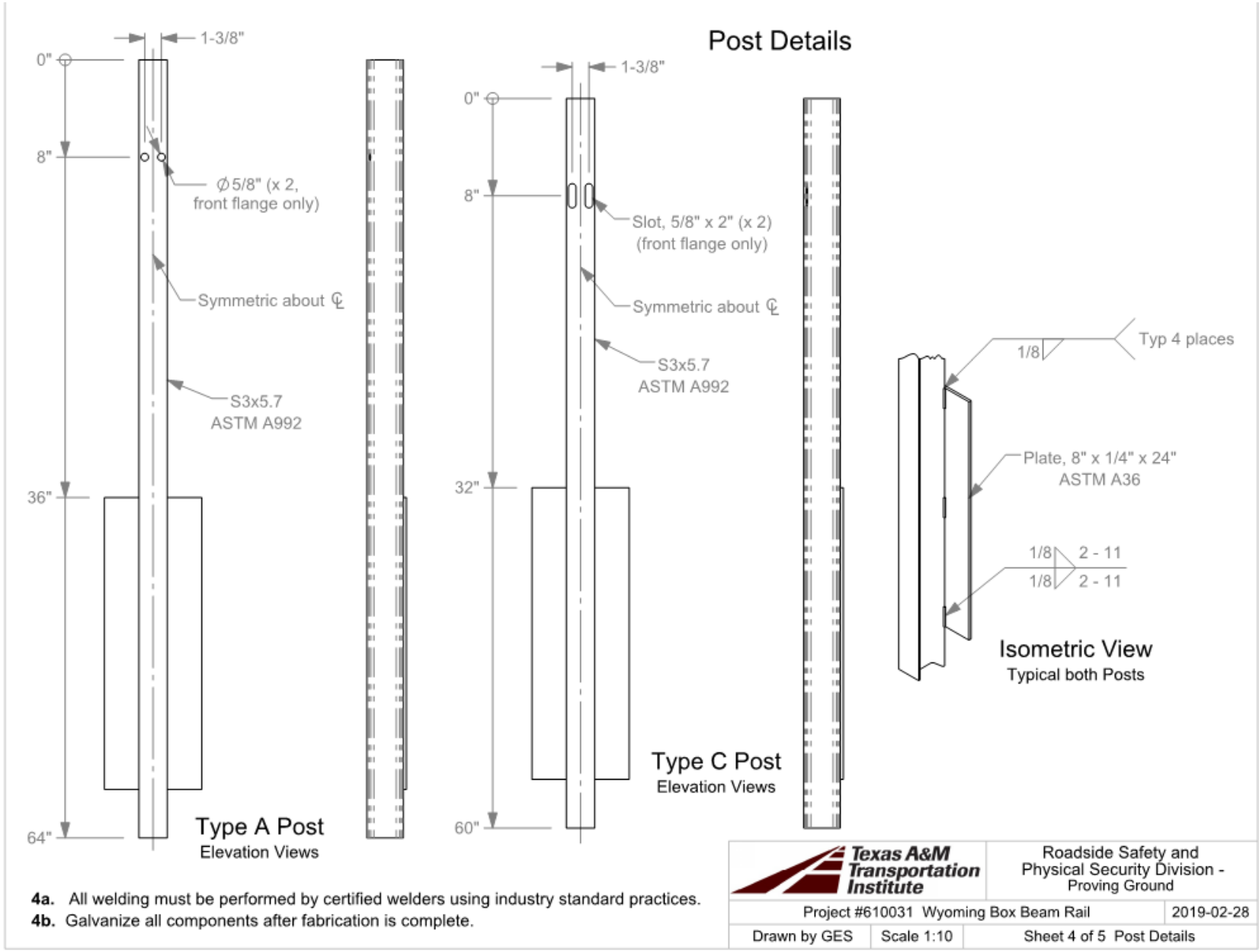


Detail F
Scale 1 : 10

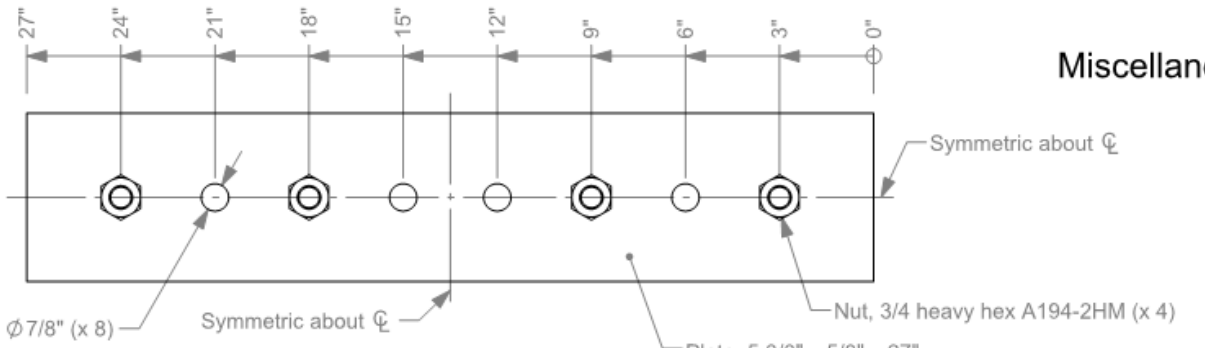
Type I End Anchor Rail
Elevation View

3a. All welding must be performed by certified welders using industry standard practices.
3b. Galvanize all components after fabrication is complete.
3c. Cut 3 sides (inverted V-shape, 5/8" wide at bottom), bend, and weld.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #610031 Wyoming Box Beam Rail		2019-02-28
Drawn by GES	Scale 1:50	Sheet 3 of 5 Rail Details

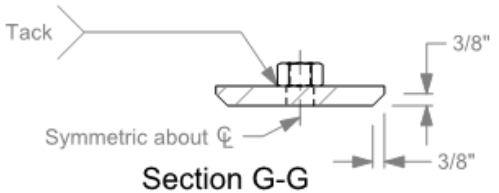

Post Details
1-3/8"
0"
8"
Ø5/8" (x 2,
front flange only)
Symmetric about ℄
S3x5.7
ASTM A992
36"
64"
Type A Post
Elevation Views
1-3/8"
0"
8"
Slot, 5/8" x 2" (x 2)
(front flange only)
Symmetric about ℄
S3x5.7
ASTM A992
32"
60"
Type C Post
Elevation Views
Typ 4 places
1/8
Plate, 8" x 1/4" x 24"
ASTM A36
1/8
2 - 11
1/8
2 - 11
Isometric View
Typical both Posts
4a. All welding must be performed by certified welders using industry standard practices.
4b. Galvanize all components after fabrication is complete.
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #610031 Wyoming Box Beam Rail
2019-02-28
Drawn by GES
Scale 1:10
Sheet 4 of 5 Post Details

Miscellaneous Parts

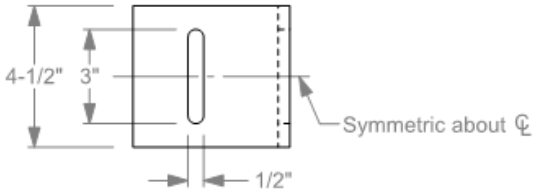


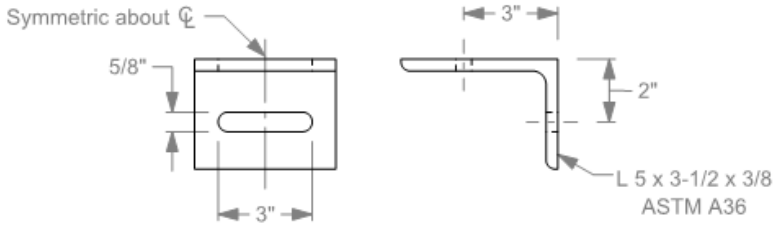
Box Beam Splice Plate
Plan View

Box Beam Splice Plate
Elevation View

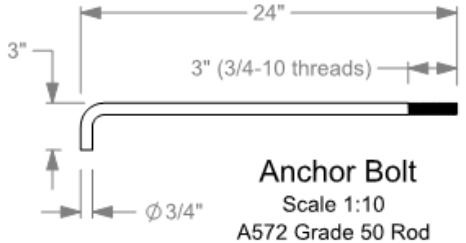


Section G-G





B1 Box Beam Support Angle



Anchor Bolt
Scale 1:10
A572 Grade 50 Rod

5a. All welding must be performed by certified welders using industry standard practices.

5b. Galvanize all components after fabrication is complete.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #610031 Wyoming Box Beam Rail		2019-02-28
Drawn by GES	Scale 1:5	Sheet 5 of 5 Miscellaneous Parts

APPENDIX B. SUPPORTING CERTIFICATION DOCUMENTS

Universal Industrial Sales

PO Box 699 - Pleasant Grove, UT 84062
Phone (801) 785-0505
www.uisutah.com

Material Certificate Of Compliance

Page 1/1

Order Number: **70723** Date: 08/15/18 Customer PO Number: **610031-00001**

Customer:	Ship To:
Texas A&M Transportation Institute	**Texas A&M Transportation Institute**
Business Office	Will Call
3135 TAMU	355 North 1200 West
College Station TX 77843-3135	Lindon UT 84042

Project ID: (BR) TTI Box Beam Crash Tests
Project Description:
(BR) Texas, Box Beam Crash Tests

Line #	QTY	Units	Description
1	2	EACH	(WY) Box Beam Anchor Type 1
2	180	LF	Box Beam Guardrail, Includes: Posts, Slice Plates, Tube Rails, Reflectors and Hardware. Galvanized.

This is to certify that the materials shipped meet the requirements of the above Contract Specifications and Special Provisions. Guardrail meets the requirements of AASHTO M-180, Type I, II, III, or IV as stamped. Steel Posts meet the requirements of AASHTO M-270 / M-183, ASTM A992-06a: A36 and are Galvanized per ASTM A-123 OR Steel Posts meet the requirements of ASTM A588 (if required per Contract Specifications). Cable meets the requirements of AASHTO M-30. Hardware meets the requirement of AASHTO M-180, ASTM A-307 and/or A-325 or A449 per contract requirements. Galvanized per ASTM A-153. All Structural Steel conforms to AASHTO M-270 / M-183 and the Buy America Act 23 CFR 635.410. All other Galvanized Materials conform to ASTM A-123 or ASTM A-153. The materials covered by this certification conform to the requirements specified in the contract documents. The individual signing has the legal authority to bind the manufacturer or supplier of material.

STATE OF UTAH, COUNTY OF UTAH
Sworn and Subscribed before me

Universal Industrial Sales, Inc.

SCOTT TURNER
this 14 day of SEPT., 2018.

ROBERT J. MCDONALD
NOTARY PUBLIC-STATE OF UTAH
COMMISSION# 690176
COMM. EXP. 08-06-2020

BY _____
Quality Control

Notary Public

Sign Structures, Bridge Rail, Steel Fabrication, Anchor Bolts, Highway Construction Products

POST PLATES

NUCOR STEEL ARKANSAS
A Division of Nucor Corp
PO Box 30
Armorel, AR 72310
Telephone: 870/762-2100

METALLURGICAL TEST

Date Printed: 9/30/16 Page 1 of 1

Sold To: UNIVERSAL INDUSTRIAL SALES INC
PO BOX 699
PLEASANT GROVE
HARDY, UT 84062

Ship To: UNIVERSAL INDUSTRIAL SALES INC
C/O PIONEER PIPE
UP AREA 068 YARD 01 TRACK 750 PIPE MILL
VINEYARD, UT 84058

Order/Line	H356787-2	Product	HOT BAND	B/L #: 938677	Ship Date 9/30/16
P/O Number	14657	Dimensions	.2400 MIN x 48.0000 MIN (INCHES)		Vehicle # BNSF529767
Description	For conversion A36/SA36		Si max 0.05%		Ticket # 993655
	P max 0.02%				Issue Date 9/26/16

With the following modifications: Customer Part Number COIL0.24

Heat 1265948 Coil ID 1182014.0000 1182016.0000 1182018.0000 1182020.0000

Heat	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Sn	Al	V	Nb	N	Ti	B	Ca	Sb
1265948	.21	.48	.007	.0012	.03	.10	.04	.04	.01	.005	.03	.002	.001	.006	.003	.000	.002	.000

Coil	Dir	Test	Val.	UOM	Test	Val.	UOM	Test	Val.	UOM
1182014.0000	T	Trans Yield	45.1	KSI	Trans Tensile	70.6	KSI	Tran Elong	32	%
1182016.0000	T	Trans Yield	46.5	KSI	Trans Tensile	73.9	KSI	Tran Elong	29	%
1182018.0000	T	Trans Yield	46.5	KSI	Trans Tensile	73.9	KSI	Tran Elong	29	%
1182020.0000	T	Trans Yield	46.5	KSI	Trans Tensile	73.9	KSI	Tran Elong	29	%

All goods are sold subject to the description, specifications and terms and conditions set forth on the face and reverse side, or otherwise provided with, Nucor Steel's order acknowledgement.
Tensile specimens are tested in accordance with ASTM A-370 specification: standard rectangular test configuration (Figure 3) with 2 inch gauge length and a 2% offset yield method. Steel is aluminum killed and produced to a fine grain practice.
This material has been produced in compliance with the chemistry and established rolling practices of the ordered specification. If material is ordered to a chemistry only, testing is not performed by producer.
Materials certified to most current revision of ASTM specifications.
We hereby certify the above is correct as contained in the records of the corporation.

100% MELTED AND MANUFACTURED IN THR USA

Ryan Brousseau

METC1100 Rev. 12/13/13 FRM-014-HM

P057

SWVA, INC.
A Subsidiary of
STEEL OF WEST VIRGINIA
Phone (304)696-8200

PACKING LIST/MTR

CUSTOMER ORDER NO.	DATED	OUR ORDER NO.	FREIGHT PMT	CUSTOMER NO.	CHANGE DATE	DATE SHIPPED	LOAD NUMBER
18709	8/17/17	73233-1	XXX & INCL	80900001		11 15 17	10-995

F.O.B HUNTINGTON

ROUTE REQUESTED	TERMS
RAIL CAR	NET 30 DAYS

ROUTING VIA TTPX804515 B.O.L.# 267373

SOLD TO:
UNIVERSAL IND SALES INC
P O BOX 699
PLEASANT GROVE UT 84062

SHIP TO:
C/O PIONEER STEEL & TUBE
UP AREA 068 YARD 01
TRACK 750
PIPE MILL UT 84058

This is to certify that the material specification is a true and correct report as contained in the records of this company.

Steve Fisher - Metallurgist

PROD. CODE	DESCRIPTION	LENGTH ORDERED	QUANTITY ORDERED	ESTIMATED WEIGHT	BUNDLES SHIPPED	QUANTITY THIS SHIPMENT PIECES	LIN FEET	POUNDS
2658	3" X 5.7# I BEAM							
	NO HOLES, BARE							
	NO CLIPS							
	SWV 67 ASTM = ASTM A36-08							
	CERTS REQUIRED W/SHIPMNT TO BE UNLOED							
	A36, NOTE # OF BDLS PER HEAT							
	SHIP VIA RAILCAR, FAX CERTS 8017859781							
	2658428	42' 8"	720 PCS	175,104#	20 of 36	720	42' 8"	175,104
						TARP MATERIAL		
						SHIPPED WITH: 73234-1		

All melting and manufacturing processes for these materials occurred in the U.S.A.

HEATNO	Strength (P.S.I) Yield	Tensile	Elongation %	Lth	Cu	Cr	Ni	MO	Nb
24584	50000	70000	22.2	8	.29	.18	.08	.03	.007
12155	49000	71000	21.9	8	.27	.27	.19	.03	.001
12063	49000	69000	23.9	8	.27	.17	.08	.02	.000

HEAT NO.	C	MN	P	S	SI	V	SN	CE
24584	.14	.73	.015	.028	.25	.006	.012	.33
12155	.13	.66	.017	.024	.24	.004	.011	.33
12063	.13	.64	.019	.028	.22	.003	.013	.30

POST CLIPS

NUCOR
NUCOR CORPORATION
NUCOR STEEL UTAH

Mill Certification
12/22/2016

MTR #: U1-364126
PO Box 100
7286 West 21200 North
PLYMOUTH, UT 84330
(435) 458-2300
Fax: (435) 458-2309

Sold To: UNIVERSAL INDUSTRIAL SALES INC
PO BOX 699
PLEASANT GROVE, UT 84062

Ship To: UNIVERSAL INDUSTRIAL SALES
435 NORTH 1200 WEST
LINDON, UT 84042
(801) 785-0505
Fax: (801) 785-9781

Customer P.O.	15091	Sales Order	269489.6
Product Group	Merchant Bar Quality	Part Number	2150353748010W0
Grade	NUCOR MULTIGRADE	Lot #	PL1610833001
Size	5x3-1/2x3/8 Angle	Heat #	PL16108330
Product	6x3-1/2x3/8 Angle 40' NUCOR MULTIGRADE	B.L. Number	U1-556171
Description	NUCOR MULTIGRADE	Load Number	U1-364126
Customer Spec		Customer Part #	

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.

Roll Date: 12/3/2016 Melt Date: 11/28/2016 Qty Shipped LBS: 16,640 Qty Shipped Pcs: 40

C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Cb	Sn
0.17%	0.62%	0.012%	0.047%	0.18%	0.35%	0.09%	0.13%	0.020%	0.0145%	0.000%	0.024%
CE4020	CEA529										
0.34%	0.37%										

CE4020: C. E. CSA G4020, AASHTO M270
CEA529: A529 CARBON EQUIVALENT

Yield 1: 50,020psi Tensile 1: 73,556psi Elongation: 32% In 8"(% In 203.3mm)

Yield 2: 50,382psi Tensile 2: 74,127psi Elongation 33% In 8"(% In 203.3mm)

Specification Comments: NUCOR MULTIGRADE MEETS THE REQUIREMENTS OF: ASTM A36/A36M-14, A529/A529M-14 GR50, A572/A572M-15 GR50, A709/A709M-16A GR36/50 NO CVN, CSA G40.21-13 GR44W(300W)/GR50W(350W), AASHTO M270/M270M-12 GR36/GR50, ASME SA36/SA36M-13

Comments: NUCOR - PLYMOUTH IS AN I.S.O. 9001 AND AN A.B.S. CERTIFIED MILL
CMTR COMPLIES WITH DIN EN 10204 - 3.1

1. ALL MANUFACTURING PROCESSES OF THE STEEL MATERIALS IN THIS PRODUCT, INCLUDING MELTING, CASTING, AND HOT ROLLING HAVE OCCURRED WITHIN THE UNITED STATES. ALL PRODUCTS PRODUCED ARE WELD FREE. MERCURY, IN ANY FORM, HAS NOT BEEN USED IN THE PRODUCTION OR TESTING OF THIS MATERIAL.
2. PROPOSITION 65 WARNING: THIS PRODUCT CONTAINS A CHEMICAL KNOWN TO THE STATE OF CALIFORNIA TO CAUSE CANCER AND/OR BIRTH DEFECTS OR OTHER REPRODUCTIVE HARM. FOR MORE INFORMATION, PLEASE CALL 1-435-458-2300.

Ryan Pennington
Division Metallurgist

SPLICE PLATES

NUCOR
NUCOR CORPORATION
NUCOR STEEL UTAH

Mill Certification
1/24/2018

MTR #: U1-400848
PO Box 100
7285 West 21200 North
PLYMOUTH, UT 84330
(435) 458-2300
Fax: (435) 458-2309

Sold To: UNIVERSAL INDUSTRIAL SALES INC
PO BOX 699
PLEASANT GROVE, UT 84062

Ship To: UNIVERSAL INDUSTRIAL SALES INC
435 N 1200 W
LINDON, UT 84042
(801) 785-0505
Fax: (801) 785-9781

Customer P.O.	19362	Sales Order	291278.7
Product Group	Merchant Bar Quality	Part Number	5462553748310W0
Grade	NUCOR MULTIGRADE	Lot #	PL1710952302
Size	5/8x5-3/8" REO Flat	Heat #	PL17109523
Product	5/8x5-3/8" REO Flat 40' 3" NUCOR MULTIGRADE	B.L. Number	U1-595320
Description	NUCOR MULTIGRADE	Load Number	U1-400848
Customer Spec		Customer Part #	7B209

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.

Roll Date: 12/13/2017 **Melt Date: 12/9/2017** **Qty Shipped LBS: 8,158** **Qty Shipped Pcs: 18**

C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Cb	Sn
0.17%	0.66%	0.007%	0.049%	0.18%	0.27%	0.09%	0.11%	0.027%	0.0205%	0.000%	0.011%

CE4020	CEA529
0.34%	0.37%

CE4020: C. E. CSA G4020, AASHTO M270
CEA529: A529 CARBON EQUIVALENT

Yield 1: 53,968psi	Tensile 1: 75,790psi	Elongation: 33% In 8"(% In 203.3mm)
Yield 2: 53,439psi	Tensile 2: 75,577psi	Elongation 32% In 8"(% In 203.3mm)

Specification Comments: NUCOR MULTIGRADE MEETS THE REQUIREMENTS OF: ASTM A36/A36M-14, A529/A529M-14 GR50, A572/A572M-15 GR50, A709/A709M-16A GR36/50 NO CVN, CSA G40.21-13 GR44W(300W)/GR50W(350W), AASHTO M270/M270M-12 GR36/GR50, ASME SA36/SA36M-13

Comments: NUCOR - PLYMOUTH IS AN I.S.O. 9001 AND AN A.B.S. CERTIFIED MILL
CMTR COMPLIES WITH DIN EN 10204 - 3.1

1. ALL MANUFACTURING PROCESSES OF THE STEEL MATERIALS IN THIS PRODUCT, INCLUDING MELTING, CASTING, AND HOT ROLLING HAVE OC WITHIN THE UNITED STATES. ALL PRODUCTS PRODUCED ARE WELD FREE, MERCURY, IN ANY FORM, HAS NOT BEEN USED IN THE PRODUCTION TESTING OF THIS MATERIAL.
2. PROPOSITION 65 WARNING: THIS PRODUCT CONTAINS A CHEMICAL KNOWN TO THE STATE OF CALIFORNIA TO CAUSE CANCER AND/OR BIRTH OR OTHER REPRODUCTIVE HARM. FOR MORE INFORMATION, PLEASE CALL 1-435-458-2300.

Bryden Morris
Division Metallurgist

TR No. 610031-01-1

TYPE 1 END

METALLURGICAL TEST REPORT

AMERICAN TUBULAR PRODUCTS USA

141 South Western Coil Road
Lindon, Utah 84042
(801) 785-8600 Fax (801) 785-4146

Date of Shipment: 5/21/2018

CUSTOMER: UNI IND

P.O. Box 699

Pleasant Gr UT 84062

SPEC: ASTM A 500-13 GRADE B

FAX: karlj@uismail.com

PO # 20465

ATTENTION: Karl J

ATP TAG	ATP COIL	HEAT NUMBER	SIZE		CHEMICAL PROPERTIES (WT%) C	Mn	P	S	Si	Cu	Cr	Al	MECHANICAL PROPERTIES YIELD (PSI)	TENSILE (PSI)	ELONGATION IN 2" (%)
54645	52777	161549	6" X 6" X .188"	48'	.18	0.54	0.006	0.001	0.019	0.122	.05	0.037	55,082	67,564	35
		Heat No. 161549 is 100% Domestic Melted and Manufactured.													
54646	52777	161549	6" X 6" X .188"	48'	.18	0.54	0.006	0.001	0.019	0.122	.05	0.037	55,082	67,564	35
		Heat No. 161549 is 100% Domestic Melted and Manufactured.													

WE CERTIFY THAT ALL TUBULAR PRODUCTS DESCRIBED HEREIN WERE MANUFACTURED, SAMPLED, TESTED, AND INSPECTED IN THE UNITED STATES OF AMERICA IN ACCORDANCE WITH THE LISTED SPECIFICATION AND WERE FOUND TO MEET ALL SUCH REQUIREMENTS. WE ALSO CERTIFY THAT THE CHEMICAL AND MECHANICAL PROPERTY INFORMATION IS CORRECT AND TRUE TO THE BEST OF OUR KNOWLEDGE.

SIGNED: Jeff Johnston

METALLURGY TECHNICIAN

May 2019

METALLURGICAL TESTING CERTIFICATION

D045868

NUCOR
SHEET MILL GROUP

Certificate Number: 647221
Date Issued: 01/24/2016

Page: 2 of 2

Nucor Steel-Crawfordsville
4537 South Nucor Road
Crawfordsville, IN 47933-0907

Order Number: 270390 - 0001
Order Dimensions: 0.1040 in X 47.5000 in
HOT ROLLED BAND,C1015,MILL

Customer Name: SCHAEFFER INDUSTRIES WESTERN
Customer Address: 141 S WESTERN COIL ROAD

LINDON UT 84042

Cust PO Number: 007127

Coil Number
2046813.000 15524

Part Number
12 GA HRHS 47.500 X C
Weight: 45,160 LBS

CHEMICAL ANALYSIS

Heat	Slab	C	Mn	P	S	Si	Cu	Sn	Ni	Cr	Mo	Al	N	V	Nb	Ti	B	Sb
161549	01	0.18	0.540	0.006	0.001	0.019	0.122	0.005	0.046	0.050	0.016	0.037	0.008	0.001	<0.001	0.003	<0.0005	0.002

Coil Number
2046814.000 15525

Part Number
12 GA HRHS 47.500 X C
Weight: 45,340 LBS

CHEMICAL ANALYSIS

Heat	Slab	C	Mn	P	S	Si	Cu	Sn	Ni	Cr	Mo	Al	N	V	Nb	Ti	B	Sb
161549	02	0.18	0.540	0.006	0.001	0.019	0.122	0.005	0.046	0.050	0.016	0.037	0.008	0.001	<0.001	0.003	<0.0005	0.002

WE HEREBY CERTIFY THE ABOVE IS CORRECT AS CONTAINED IN THE RECORDS OF THE CORPORATION
MELTED AND ROLLED IN THE USA

NUCOR QUALITY ASSURANCE

QF-0261 11/29/2012

1-800-777-0950 MTR_IND_INQUIRIES@NUCOR.COM

American Tubular Products
A Division of Schedler Industries

141 South Western Coil Road
Lindon, Utah 84042
(801) 785-8600 Fax (801) 785-4146

36'- TUBES

METALLURGICAL TEST REPORT

CUSTOMER: Universal Industrial
P.O. Box 699
Pleasant Gr UT 84062

ATTENTION: Karl J

Date of Shipment: 11/09/2017
SPEC: ASTM A 500-13 GRADE B
FAX: karlj@uismail.com
PO # 19259-1

ATP TAG	ATP COIL	HEAT NUMBER	SIZE	CHEMICAL PROPERTIES (WT%)								MECHANICAL PROPERTIES		
				C	Mn	P	S	Si	Cu	Cr	Al	YIELD (PSI)	TENSILE (PSI)	ELONGATION IN 2" (%)
47159	46833	151270	6" X 6" X .188"	36'	.18	0.54	0.007	0.003	0.015	0.158	.045	0.036	49,585	66,191	35
		Heat No. 151270 is 100% Domestic Melt and Manufactured.													
47160	46833	151270	6" X 6" X .188"	36'	.18	0.54	0.007	0.003	0.015	0.158	.045	0.036	49,585	66,191	35
		Heat No. 151270 is 100% Domestic Melt and Manufactured.													
47161	46833	151270	6" X 6" X .188"	36'	.18	0.54	0.007	0.003	0.015	0.158	.045	0.036	49,585	66,191	35
		Heat No. 151270 is 100% Domestic Melt and Manufactured.													
47162	46833	151270	6" X 6" X .188"	36'	.18	0.54	0.007	0.003	0.015	0.158	.045	0.036	49,585	66,191	35
		Heat No. 151270 is 100% Domestic Melt and Manufactured.													
47169	46209	76675D	6" X 6" X .188"	36'	.19	0.78	0.012	0.01	0.007	0.04	.04	0.025	57,042	72,212	34
		Heat No. 76675D is 100% Domestic Melted and Manufactured.													
47170	46209	76675D	6" X 6" X .188"	36'	.19	0.78	0.012	0.01	0.007	0.04	.04	0.025	57,042	72,212	34
		Heat No. 76675D is 100% Domestic Melted and Manufactured.													
47175	46210	76670D	6" X 6" X .188"	36'	.18	0.78	0.012	0.011	0.008	0.02	.03	0.036	56,526	73,694	35
		Heat No. 76670D is 100% Domestic Melted and Manufactured.													

WE CERTIFY THAT ALL TUBULAR PRODUCTS DESCRIBED HEREIN WERE MANUFACTURED, SAMPLED, TESTED, AND INSPECTED IN THE UNITED STATES OF AMERICA IN ACCORDANCE WITH THE LISTED SPECIFICATION AND WERE FOUND TO MEET ALL SUCH REQUIREMENTS. WE ALSO CERTIFY THAT THE CHEMICAL AND MECHANICAL PROPERTY INFORMATION IS CORRECT AND TRUE TO THE BEST OF OUR KNOWLEDGE.

SIGNED:

METALLURGY TECHNICIAN

METALLURGICAL TESTING CERTIFICATION

0045096

NUCOR
SHEET MILL GROUP

Certificate Number: 645352
Date Issued: 01/12/2016

Nucor Steel-Crawfordsville
4537 South Nucor Road
Crawfordsville, IN 47933-0907

Order Number: 270392 - 0001
Order Dimensions: 0.0820 in X 48.0000 in
HOT ROLLED BAND,C1015,MILL

Customer Name: SCHAEFFER INDUSTRIES WESTERN
Customer Address: 141 S WESTERN COIL ROAD

LYNDON UT 84042

Cust PO Number: 007128

Coil Number
2046839.000

Part Number
13 GA HRHS 48.000 X C
Weight: 44,310 LBS

15334

CHEMICAL ANALYSIS

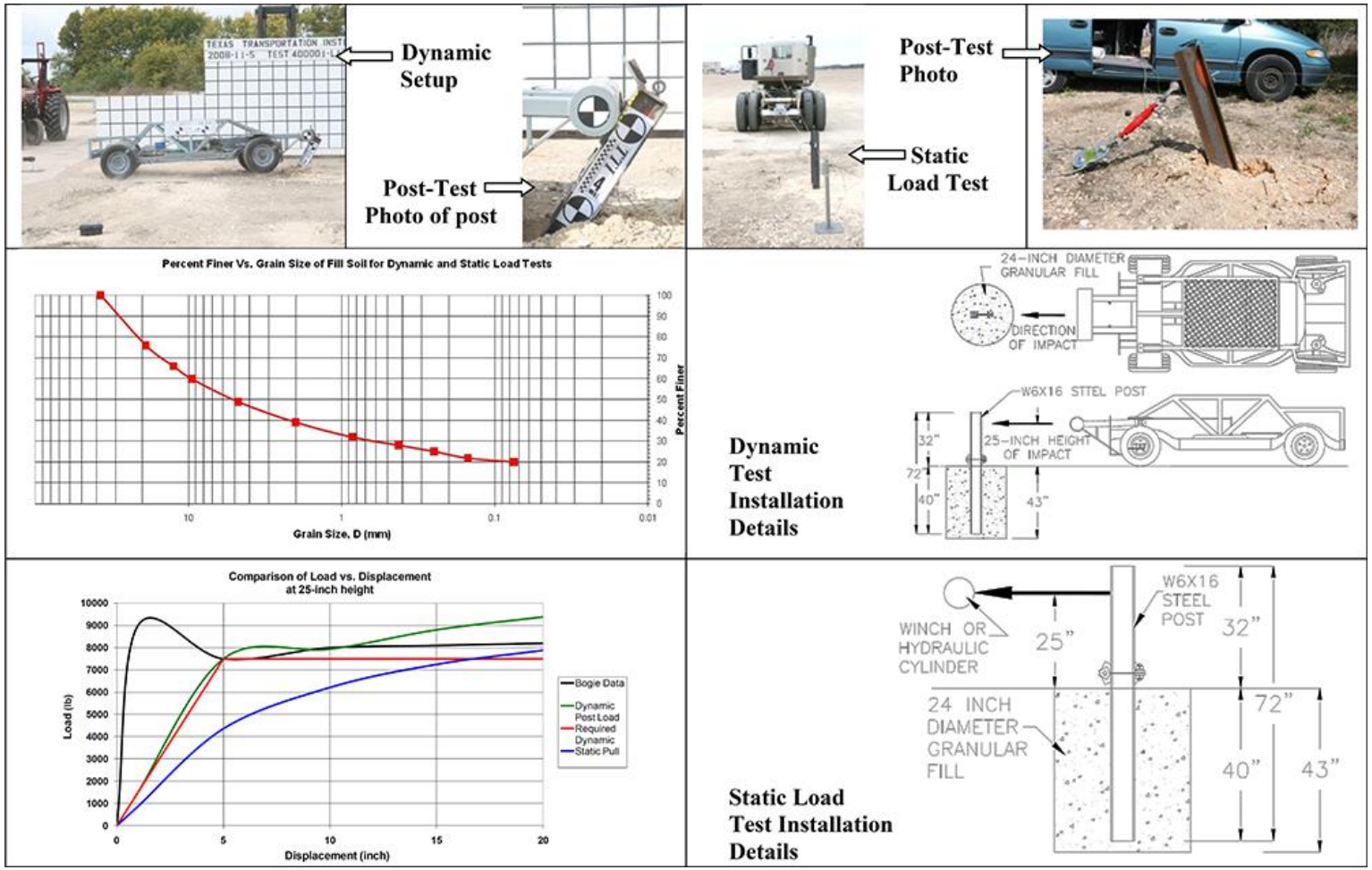
Heat	Slab	C	Mn	P	S	Si	Cu	Sn	Ni	Cr	Mo	Al	N	V	Nb	Ti	B	Sb
151270	01	0.18	0.540	0.007	0.003	0.015	0.158	0.006	0.045	0.045	0.012	0.036	0.00	0.001	<0.001	0.002	<0.0005	0.004

WE HEREBY CERTIFY THE ABOVE IS CORRECT AS CONTAINED IN THE RECORDS OF THE CORPORATION
MELTED AND ROLLED IN THE USA.

Eric E. Gallo
MGR QUALITY ASSURANCE

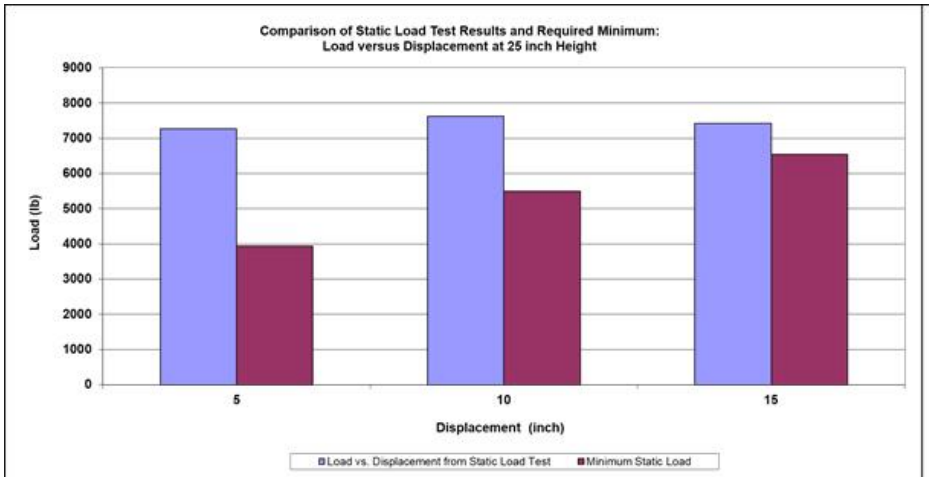
QF-0261 11/29/2012

1-800-777-0950 MTR_IND_INQUIRIES@NUCOR.COM

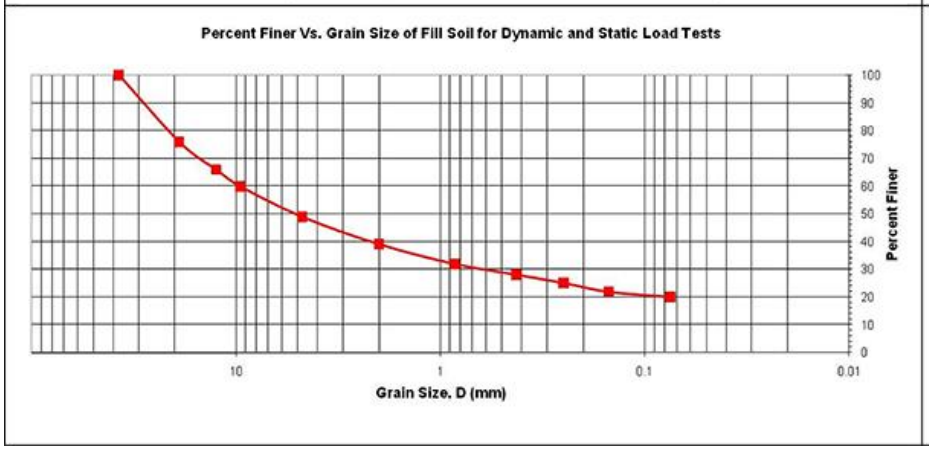


Date	2008-11-05
Test facility and site location	TTI Proving Ground, 3100 SH 47, Bryan, TX 77807
In-situ soil description (ASTM D2487)	Sandy gravel with silty fines
Fill material description (ASTM D2487) and sieve analysis	AASHTO Grade B soil-aggregate (see sieve analysis above)
Description of fill placement procedure	6-inch lifts tamped with a pneumatic compactor
Bogie weight	5009 lb
Impact velocity	20.5 mi/h

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



Typical Static Load Setup



Post-Test Photo of Post

Date	2019-01-11
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)
Description of fill placement procedure	6-inch lifts tamped with a pneumatic compactor

Figure C.2. Test Day Static Soil Strength Documentation for Test No. 610031-01-1.

APPENDIX D. *MASH* TEST 3-10 (CRASH TEST NO. 610031-01-1)

D1 VEHICLE PROPERTIES AND INFORMATION

Vehicle Inventory Number: 1370

Date: 2019-01-11 Test No.: 601031-01-1 VIN No.: KNADE223196477405

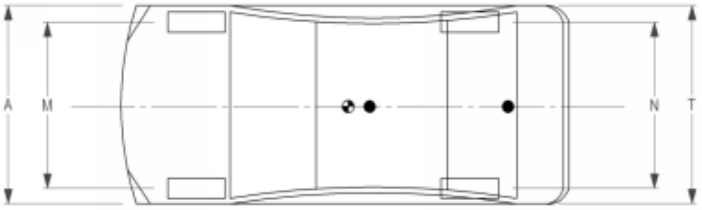
Year: 2009 Make: Kia Model: Rio

Tire Inflation Pressure: 32 PSI Odometer: 201776 Tire Size: 185/65R14

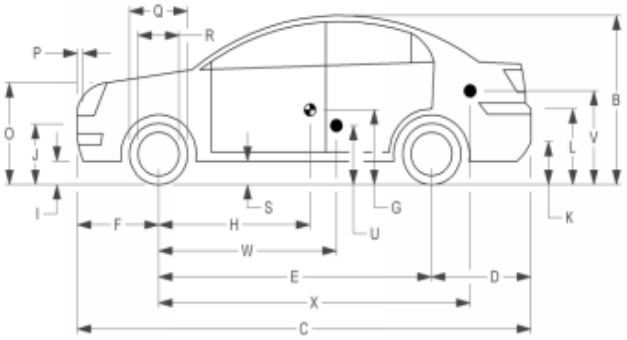
Describe any damage to the vehicle prior to test:

• Denotes accelerometer location.

NOTES:



Engine Type: 4 Cylinder
Engine CID: 1.6 L
Transmission Type:
☑ Auto or ☐ Manual
☑ FWD ☐ RWD ☐ 4WD
Optional Equipment:



Dummy Data:
Type: 50th percentile male
Mass: 165 lbs
Seat Position: Impact side

Geometry: inches

A	66.38	F	33.00	K	12.25	P	4.12	U	15.00
B	51.50	G		L	25.25	Q	22.50	V	20.50
C	165.75	H	35.50	M	57.75	R	15.50	W	35.50
D	34.00	I	7.75	N	57.70	S	8.25	X	102.00
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

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

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1718	M_{front}	1590	1563	1648
Back	1874	M_{rear}	910	878	958
Total	3638	M_{Total}	2500	2441	2606

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

Mass Distribution:
lb LF: 798 RF: 765 LR: 422 RR: 456

Performed by: SCD Date: 1/11/2019

Figure D.1. Vehicle Properties for Test No. 610031-01-1.

Date:	2019-01-11	Test No.:	601031-01-1	VIN No.:	KNADE223196477405
Year:	2009	Make:	Kia	Model:	Rio

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage		Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width** (CDC)	Max*** Crush								
1	AT FT BUMPER	18	5	20	5	2	1				+17
2	SAME	18	7	36	1	1.5	3	4	5.5	7	+60
	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.

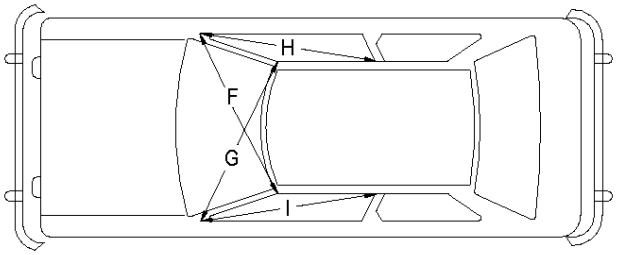
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

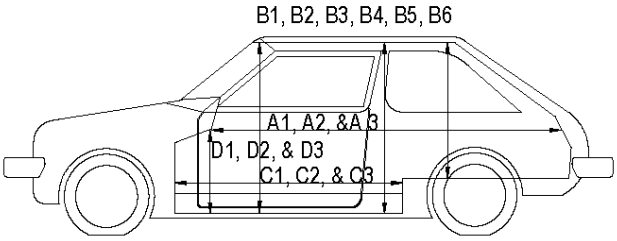
***Measure and document on the vehicle diagram the location of the maximum crush.

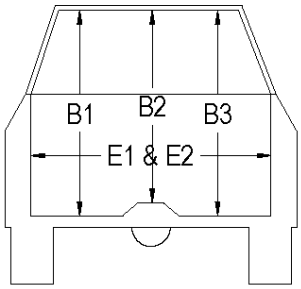
Note: Use as many lines/columns as necessary to describe each damage profile.

Figure D.2. Exterior Crush Measurements for Test No. 610031-01-1.

Date:	2019-01-11	Test No.:	601031-01-1	VIN No.:	KNADE223196477405
Year:	2009	Make:	Kia	Model:	Rio







OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

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

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

Figure D.3. Occupant Compartment Measurements for Test No. 610031-01-1.

D2 SEQUENTIAL PHOTOGRAPHS*

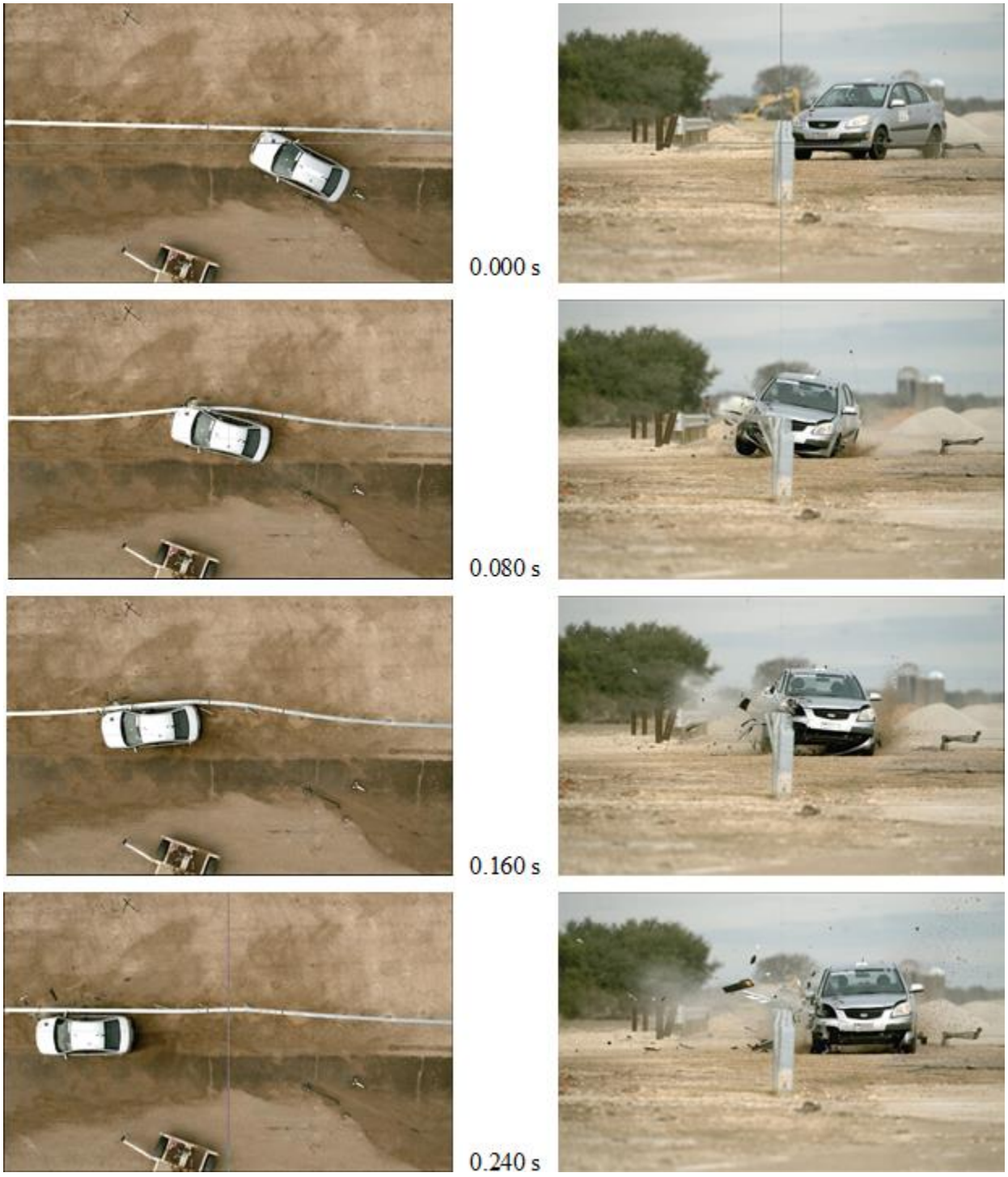


Figure D.4. Sequential Photographs for Test No. 610031-01-1 (Overhead and Frontal Views).

* Due to technical difficulties with the high-speed cameras, times are approximate.

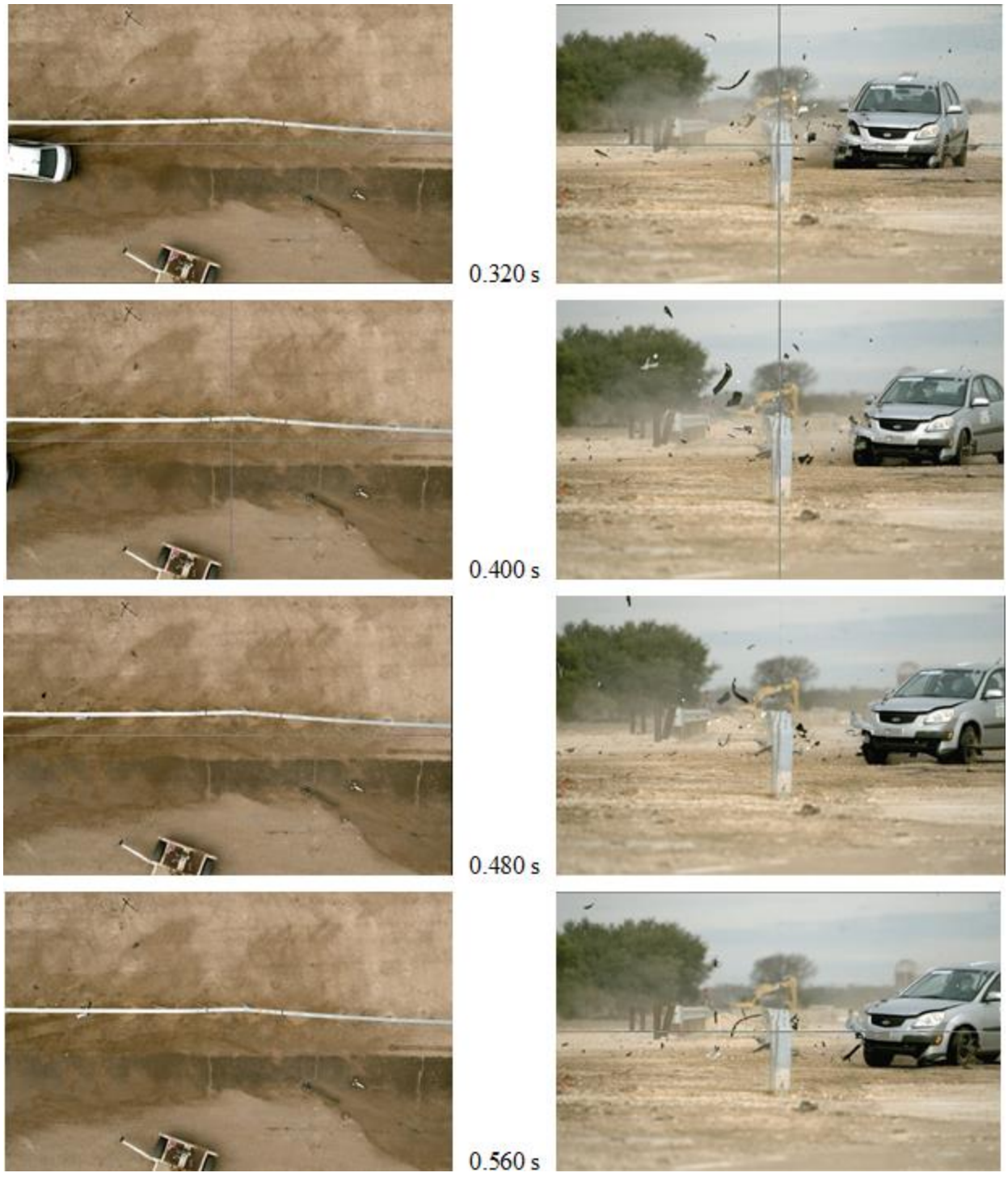


Figure D.4. Sequential Photographs for Test No. 610031-01-1 (Overhead and Frontal Views) (Continued).

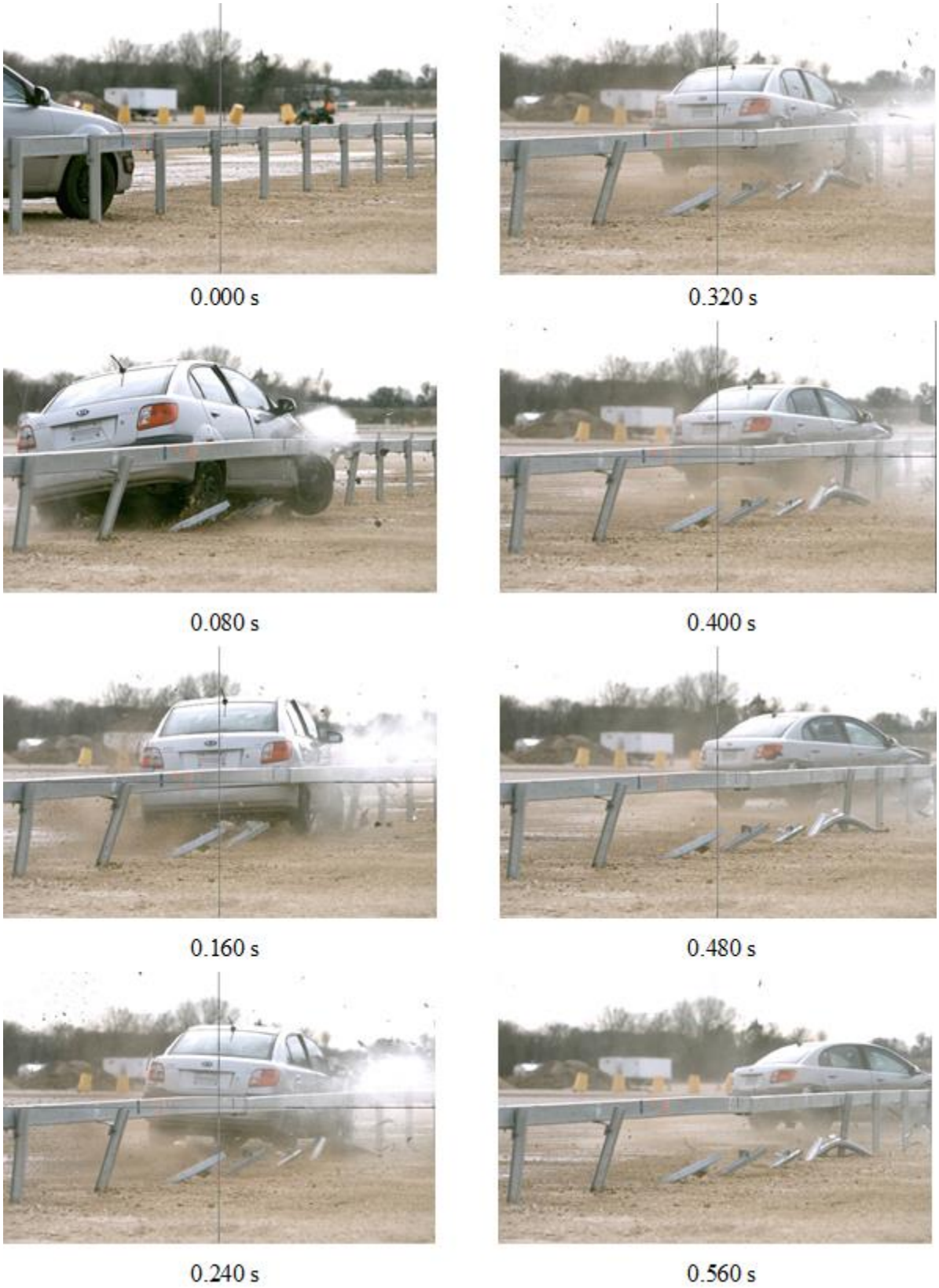


Figure D.5. Sequential Photographs for Test No. 610031-01-1 (Rear View).

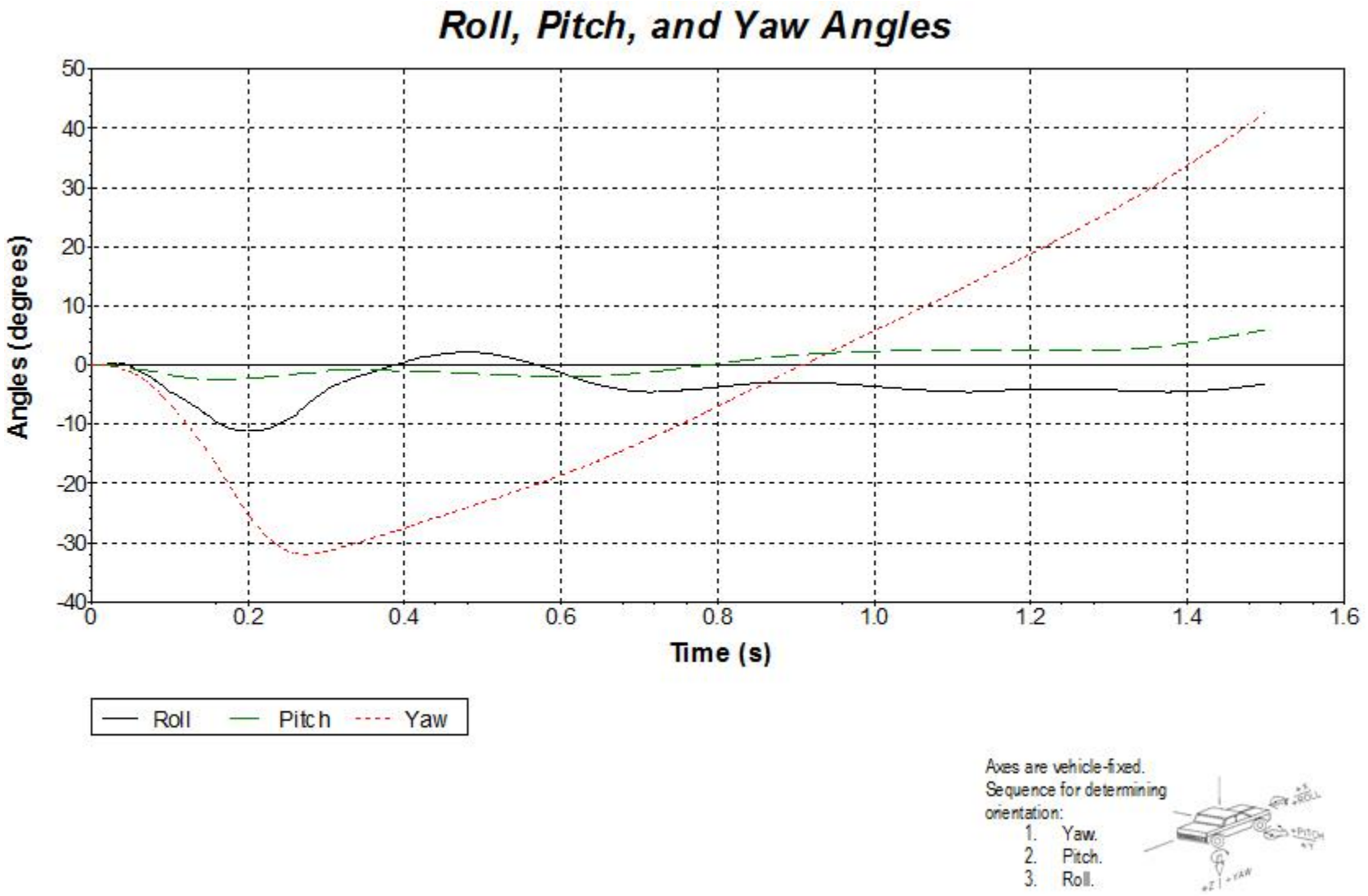


Figure D.6. Vehicle Angular Displacements for Test No. 610031-01-1.

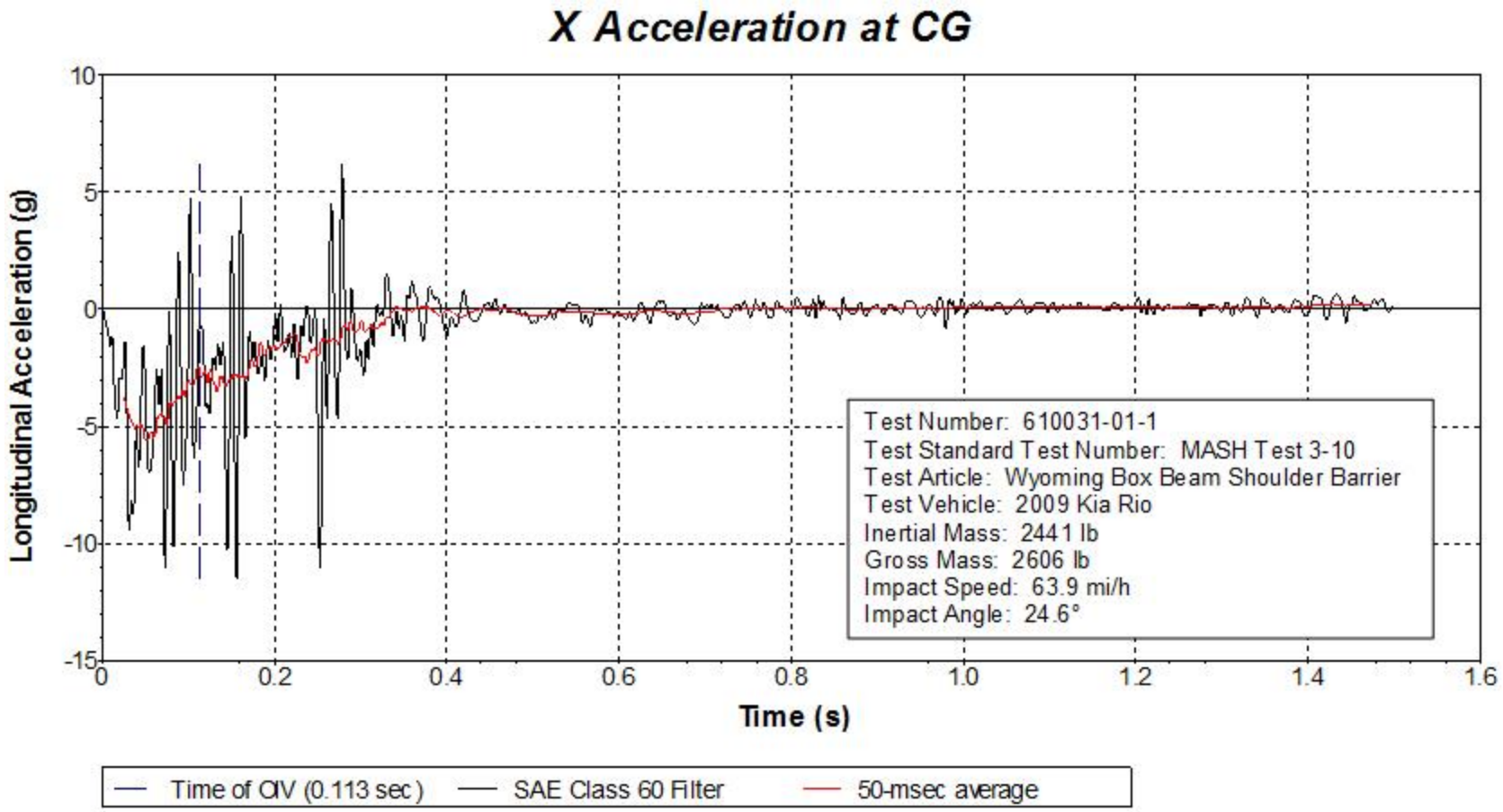


Figure D.7. Vehicle Longitudinal Accelerometer Trace for Test No. 610031-01-1 (Accelerometer Located at Center of Gravity).

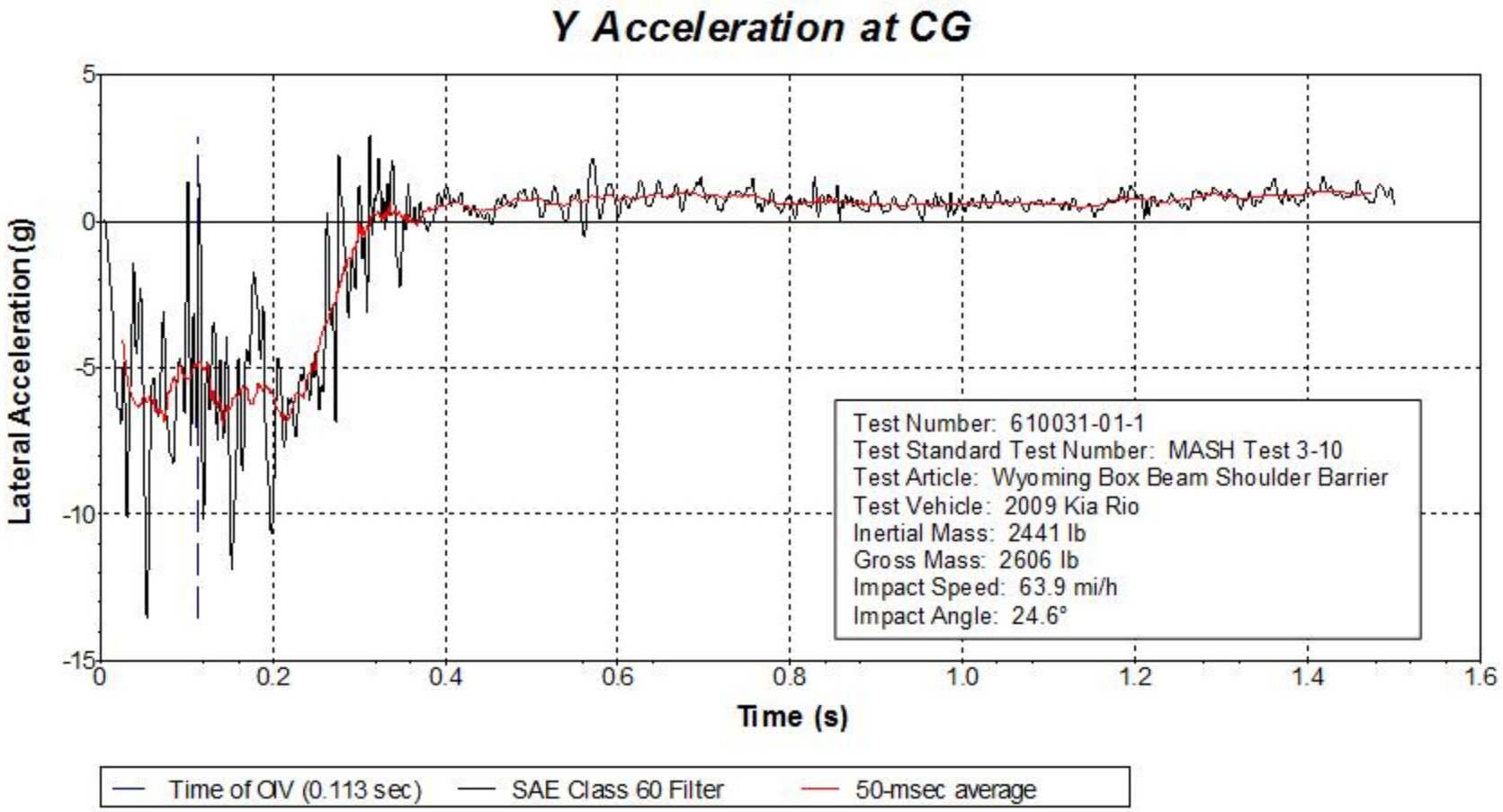


Figure D.8. Vehicle Lateral Accelerometer Trace for Test No. 610031-01-1 (Accelerometer Located at Center of Gravity).

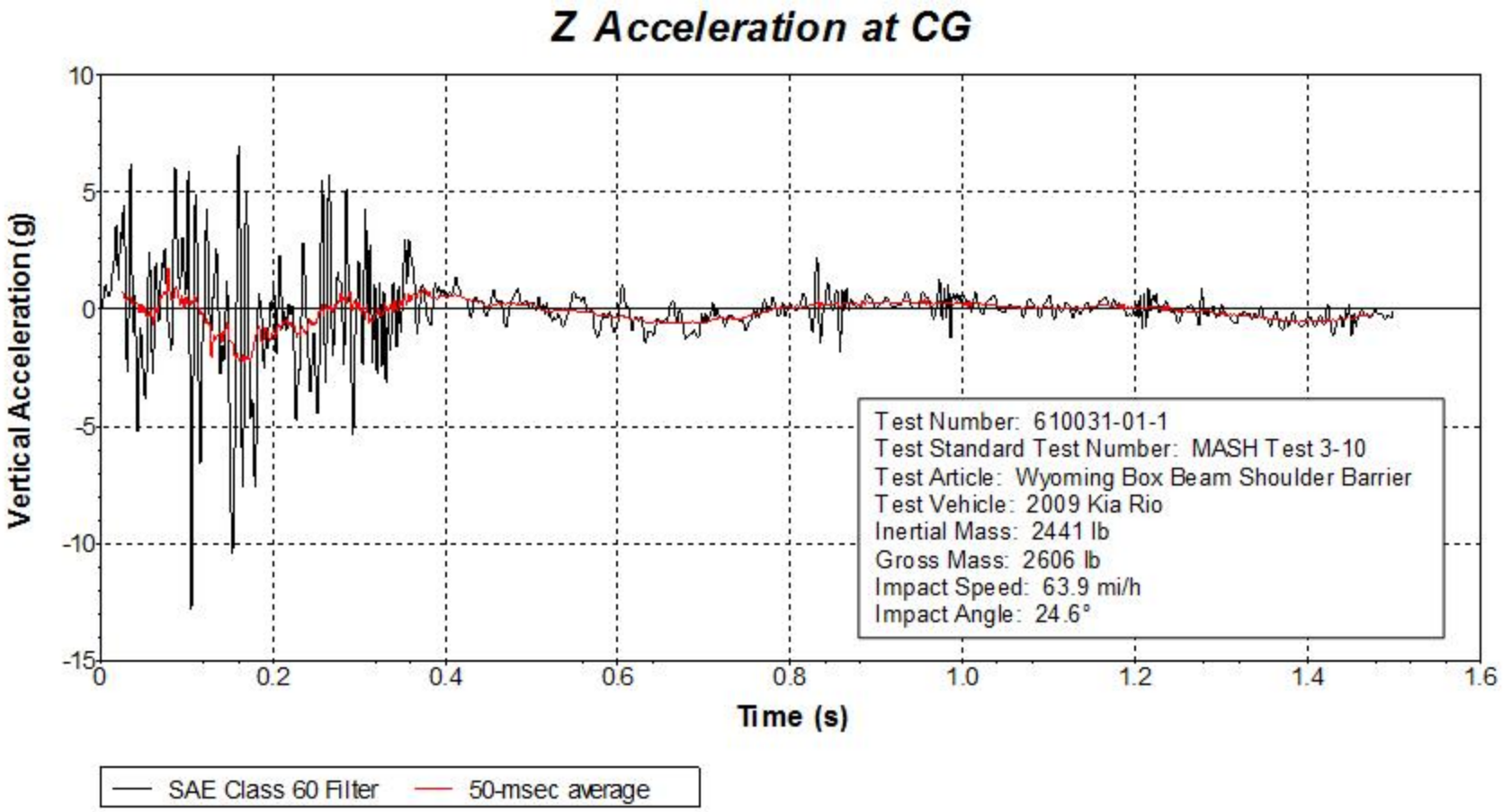


Figure D.9. Vehicle Vertical Accelerometer Trace for Test No. 610031-01-1 (Accelerometer Located at Center of Gravity).

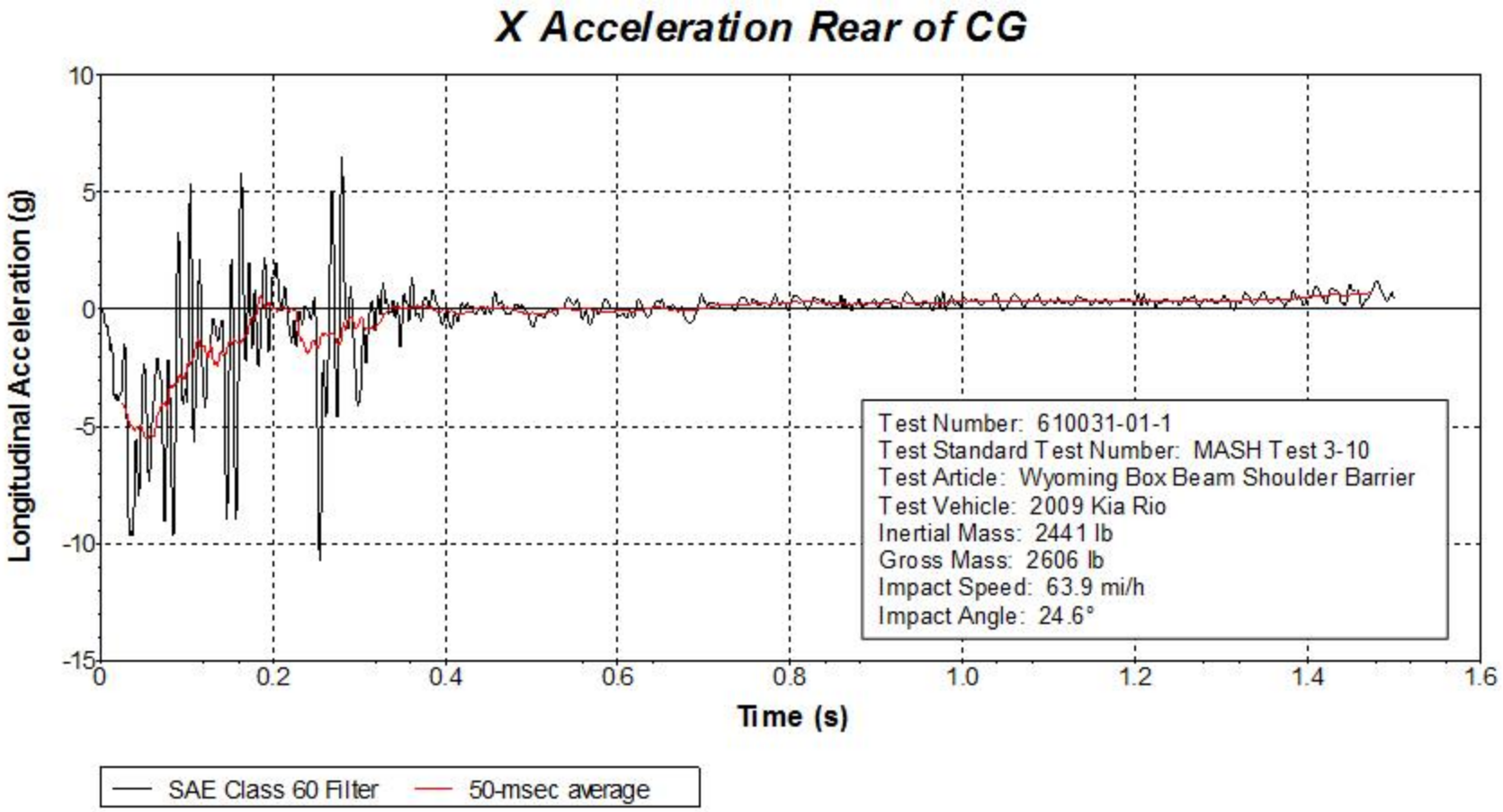


Figure D.10. Vehicle Longitudinal Accelerometer Trace for Test No. 610031-01-1 (Accelerometer Located Rear of Center of Gravity).

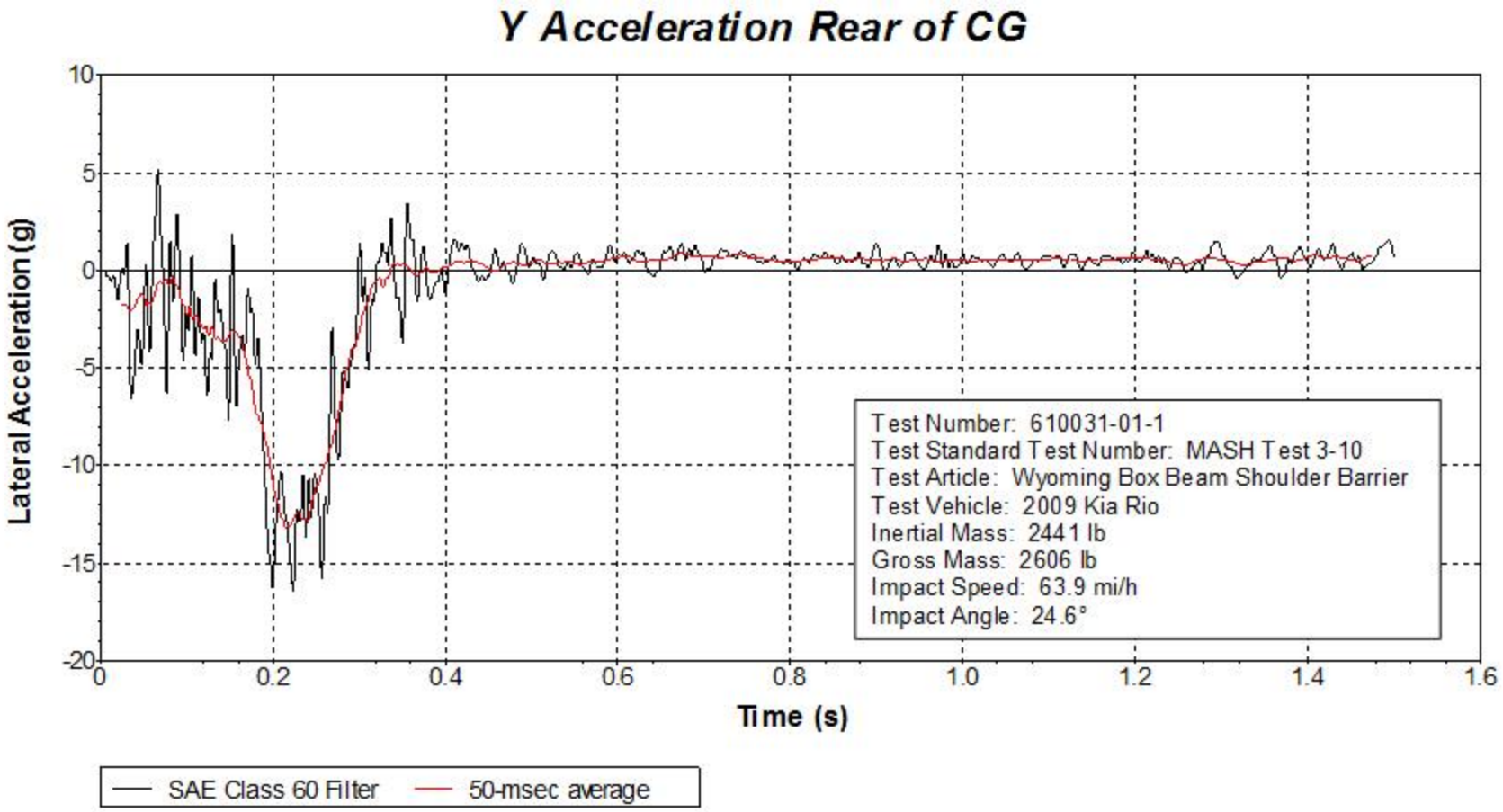


Figure D.11. Vehicle Lateral Accelerometer Trace for Test No. 610031-01-1 (Accelerometer Located Rear of Center of Gravity).

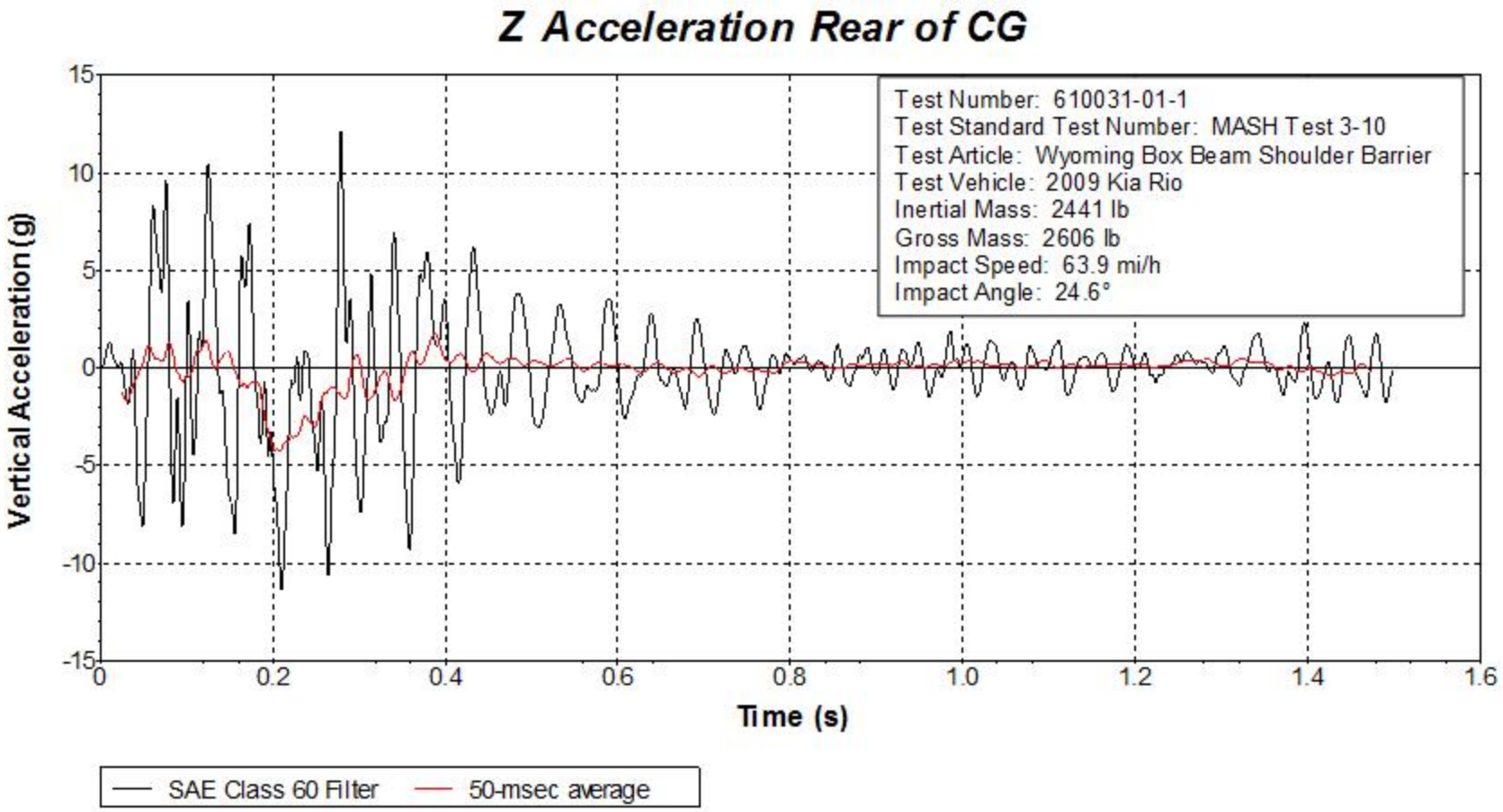


Figure D.12. Vehicle Vertical Accelerometer Trace for Test No. 610031-01-1 (Accelerometer Located Rear of Center of Gravity).