TTI: 9-1002-12

Texas A&M Transportation Institute

CRASH TEST AND EVALUATION OF THE TxDOT T631 BRIDGE RAIL

ACCREDITED
ISO 17025 Laboratory
Testing Certificate # 2821.01

Crash testing performed at:
TTI Proving Ground
3100 SH 47, Building 7091
Bryan, TX 77807

Test Report 9-1002-12-10

Cooperative Research Program

TEXAS A&M TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS

TEXAS DEPARTMENT OF TRANSPORTATION

in cooperation with the
Federal Highway Administration and the
Texas Department of Transportation
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16. Abstract

In August 2010, Midwest Roadside Safety Facility (MwRSF) developed and crash tested a low-cost, energy-absorbing bridge rail for the *Manual for Assessing Safety Hardware* (*MASH*) TL-3 applications. This low-cost bridge rail was designed to be compatible with the Midwest Guardrail System (MGS) such that an approach transition would not be required between the two barriers. It was desired that the system minimize bridge deck and rail costs. As part of this project, several concepts for an energy-absorbing bridge post were developed and tested. These concepts included strong-post systems designed with plastic hinges and weak-post systems designed to bend near the attachment to the bridge deck. The final post concept incorporated S3 × 5.7 steel sections designed to yield at their bases. These posts were located on 6 ft-3 inches on center. A W-beam section was used as the rail element and was attached to the posts with a bolt designed to break during and impact event. Two full-scale crash tests were performed according to the TL-2 impact conditions provided in *MASH*. The new bridge rail system successfully met all the safety performance criteria for *MASH* TL-2.

The Texas Type T631 Bridge Rail was developed as a low-cost, energy absorbing bridge rail system for TL-2 applications. Many of the features used for the system tested at Midwest Roadside Safety Facility for TL-3 were incorporated into the design developed for this project for *MASH* TL-2 application. The TxDOT Type T631 Bridge Rail designed and developed for this project was evaluated under *MASH* TL-2.

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DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation, and its contents are not intended for construction, bidding, or permit purposes. In addition, the above listed agencies assume no liability for its contents or use thereof. The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report. The engineer in charge of the project was Roger P. Bligh, P.E. (Texas, #78550).

TTI PROVING GROUND DISCLAIMER

The results of the crash testing reported herein apply only to the article being tested.

ACCREDITED
ISO 17025 Laboratory
Testing Certificate # 2821.01

Crash testing performed at:
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3100 SH 47, Building 7091
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CHAPTER 1. INTRODUCTION

1.1 INTRODUCTION

The project under which the current research was conducted was set up to provide the Texas Department of Transportation (TxDOT) with a mechanism to quickly and effectively evaluate high-priority issues related to roadside safety devices. Roadside safety devices shield motorists from roadside hazards such as non-traversable terrain and fixed objects. To maintain the desired level of safety for the motoring public, these safety devices must be designed to accommodate a variety of site conditions, placement locations, and a changing vehicle fleet. Periodically, there is a need to assess the compliance of existing safety devices with current vehicle testing criteria and develop new devices that address identified needs.

Under this project, roadside safety issues were identified and prioritized for investigation. Each roadside safety issue was addressed with a separate work plan, and the results are summarized in individual test reports.

1.2 BACKGROUND

In August 2010, Midwest Roadside Safety Facility (MwRSF) developed and crash-tested a low-cost, energy-absorbing bridge rail for American Association of State Highway and Transportation Officials *Manual for Assessing Safety Hardware* (*MASH*) Test Level 3 (TL-3) applications (*1*, *2*). This low-cost bridge rail was designed to be compatible with the Midwest Guardrail System (MGS) such that an approach transition would not be required between the two barriers. It was desired that the system minimize bridge deck and rail costs. As part of this project, several concepts for an energy-absorbing bridge post were developed and tested. These concepts included strong-post systems designed with plastic hinges and weak-post systems designed to bend near the attachment to the bridge deck. The final post concept incorporated S3 × 5.7 steel sections designed to yield at their bases. The posts were spaced on 6 ft-3 inch centers. A W-beam section was used as the rail element and was attached to the posts with a bolt designed to break during an impact event. Two full-scale crash tests were performed according to the TL-2 impact conditions provided in *MASH*. The new bridge rail system successfully met all the safety performance criteria for *MASH*.

The Texas Type T631 bridge rail was developed as a low-cost, energy-absorbing bridge rail system for TL-2 applications. Many of the features used for the system tested at MwRSF for TL-3 were incorporated into the design developed for this project for *MASH* TL-2 application. The TxDOT Type T631 bridge rail designed and developed for this project was evaluated under *MASH* TL-2.

1.3 OBJECTIVE/SCOPE OF RESEARCH

The objective of this research was to evaluate the impact performance of the new TxDOT Type T631 bridge rail. The TxDOT Type T631 bridge rail is intended to serve as a low-cost replacement for the TxDOT Type T6 bridge rail for *MASH* TL-2 applications. The TxDOT T631 bridge rail is intended for new construction. The crash testing was performed in accordance with the requirements of *MASH* TL-2.

This report describes the TxDOT Type T631 bridge rail, documents the performance of the rail system according to *MASH* TL-2 specificaitons, and presents recommendations regarding implementation and future work.

CHAPTER 2. SYSTEM DETAILS

2.1 TEST ARTICLE DESIGN AND CONSTRUCTION

The test installation consisted of a W-beam rail element and structural steel posts welded to steel baseplates that anchored to a concrete cantilever deck. The bridge rail was anchored on each end using a standard 25-ft ET-PLUS end terminal. The total installation length was 168 ft 9 inches. Twenty-eight posts were equally spaced at 6 ft 3 inches on center. The height of the W-beam rail element was approximately 31 inches to the top of the W-beam rail element.

Bridge rail Posts 7 through 23 were installed as S3×5.7 American Society for Testing and Materials (ASTM) A992 structural steel posts welded to base plates and subsequently bolted through the bridge deck cantilever (see Figure 2.1). The base plates were 8 inches × 8 inches × ⅝ inch thick ASTM A529 grade 55 steel and were welded to the bottom of each of Posts 7 through 23 with continuous ¼-inch fillet welds. The center lines of the posts and base plates coincided. The base plates contained four ¾-inch × 1-inch oblong bolting slots. Each base plate was attached to the bridge deck cantilever with four ⅝-inch diameter × 10-inch long FBX16a ASTM A325 bolts from below with an 8-inch × 6¾-inch × ¼-inch thick ASTM A36 steel washer plate on the bottom and corresponding ⅝-inch flat washers, lock washers, and hex nuts on top.

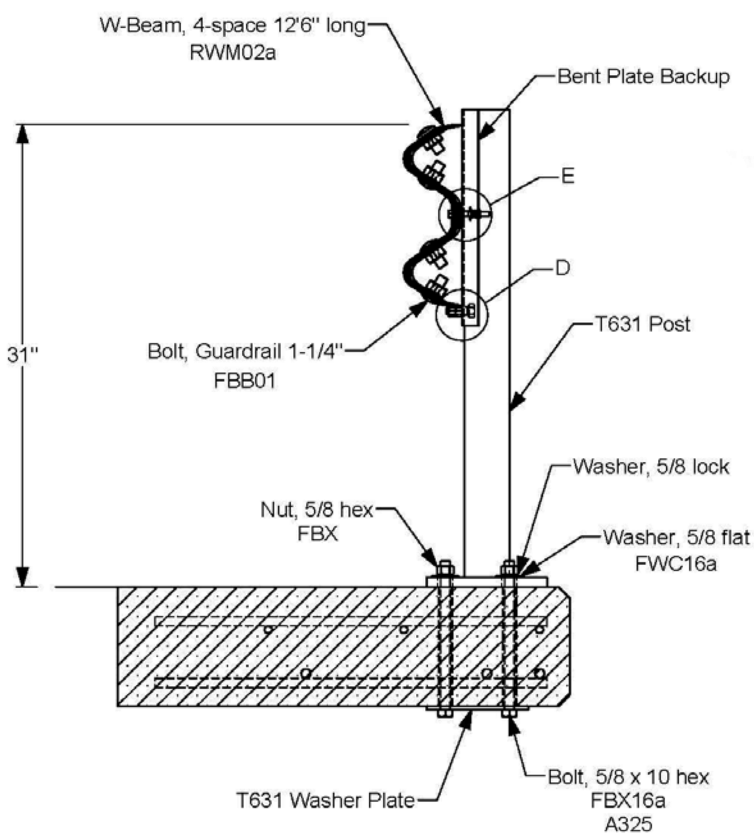


Figure 2.1. Cross Section of the T631 Bridge Rail.

For this test installation, a reinforced concrete bridge deck cantilever was constructed by adding on to the existing concrete runway mat. The cantilever was 30 inches wide × 101 ft 6 inches long × 8 inches thick reinforced concrete with a minimum specified unconfined compressive strength of 4000 psi. The centerlines of Posts 7 through 23 were located laterally approximately 5½ inches from the field side edge of the cantilevered deck slab.

Transverse reinforcement in the deck cantilever consisted of two layers of #5 reinforcing bars at approximately 2 inches and 6¾ inches below the upper surface of the deck. The transverse bars were welded to the existing rebar that protrudes from the edge of the runway. The upper transverse bars were spaced on 6-inch centers and longitudinally joined with #4 reinforcing bars placed at 2 inches, 11 inches, and 20 inches from the field side face of the cantilever and located on the bottom side of the upper transverse bars. The lower transverse bars were spaced on 18-inch centers longitudinally joined with three runs of #5 reinforcing bars placed at 2 inches, 5½ inches, and17½ inches from the field side face of the cantilever and located on the top side of the lower traverse bars.

Longitudinal reinforcement was overlapped a minimum of 15 inches for the #4 rebar in the top layer and overlapped a minimum of 19 inches for the #5 rebar in the bottom layer (see sheet 6 in Appendix A). All unions of longitudinal, traverse, and vertical rebar were wire-tied on site. The bolts were inserted through the deck via four ¾-inch nominal diameter EMT conduit sleeves cast into the deck at each of Posts 7 through 23.

Posts 1 and 28 were standard ET-PLUS cable release posts (CRPs) fabricated from W6×8.5 structural steel shape, and embedded in the soil per a typical ET-Plus Terminal installation A standard ET-PLUS anchor cable and cable anchor bracket were used to anchor the W-beam rail to Post 1 and Post 28. A 3 × 3 × ¼ inch steel angle ground strut on the field side of the terminals connected Posts 1 and 2, and Posts 27 and 28 (refer to sheet 3 in Appendix A). Posts 2, 3, and 4 and Posts 25, 26, and 27 were steel yielding terminal posts (SYTPs) fabricated from W6×8.5 structural steel shapes, and embedded in the soil per a typical ET-Plus Terminal installation. Posts 5, 6, and 24 were standard W6×8.5 structural steel line posts (SLPs) embedded in drilled and tamped soil as found in a typical ET-Plus Terminal installation.

The W-beam guardrail was attached to Posts 3, 4, 5, and 6, and Posts 24, 25, and 26 with standard routed wooden offset spacer blocks (type PDB01b).

On the cantilevered deck, posts 7 through 23 were 32 inches in overall height and had two ⅜-inch diameter holes drilled in the impact side flange of each post 25 inches above the base to attach the W-beam. The W-beam was attached using one $^{5}/_{16}$-inch diameter by 2½-inch long ASTM A307 bolt per post, each assembled with a corresponding standard square guardrail washer, a $^{5}/_{16}$-inch flat washer, lock washer, hex nut, and jam nut.

Bent backup plates were used between the posts and the W-beam rail at Posts 7 through 23 (see sheet 5 in Appendix A). These backup plates were 14½ inches tall, fabricated from 6-inch wide, ⅛-inch thick ASTM A36 strap with a 3-inch wide flat and equal legs (of approximately 1⅜ inches) bent longitudinally away from the guardrail at 45 degrees. Each backup plate contained two ⅝-inch diameter holes for attaching to the posts (one for attaching the guardrail, and one for a shelf bolt, below). Additionally, one $^{9}/_{16}$-inch diameter hole was drilled in one leg of the impact side flange of each post 18½ inches above the base to accommodate the installation of the shelf bolt (½-inch diameter by 1½-inch long ASTM A307 bolt with two hex nuts). W-beam guardrail sections were joined with standard 1¼-inch guardrail bolts and nuts.

Appendix A provides detailed drawings for the installation, and Figure 2.2 provides photographs of the completed installation.

2.2 MATERIAL SPECIFICATIONS

The TxDOT Class S specified minimum unconfined compressive strength of the concrete for the bridge deck cantilever was 4000 psi. The compressive strengths of the two batches of concrete used in the deck cantilever one and two days after the crash test measured an average of 6770 psi (at 28 days), and 4610 psi (at 28 days). Appendix B provides the concrete strength testing results for the bridge deck test installation.

Reinforcement of the bridge deck was comprised of ASTM A615 grade 60 material that Texas A&M Transportation Institute had fabricated onsite. Appendix B contains mill certifications sheets and other certification documents for the materials used in the bridge deck test installation.

2.3 SOIL CONDITIONS

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

In accordance with Appendix B of *MASH*, soil strength was measured on the day of the crash test. During installation of the T631 bridge rail for full-scale crash testing, two standard W6×16 posts were installed in the immediate vicinity of the T631 bridge rail, using the same fill materials and installation procedures in the standard dynamic test. As determined in the tests shown in Figure C1 in Appendix C, the minimum post load required for deflections at 5 inches, 10 inches, and 15 inches, measured at a height of 25 inches, is 3940 lb, 5500 lb, and 6540 lb, respectively (90 percent of static load for the initial standard installation).

On the day of Test No. 490023-1a, August 13, 2013, load on the post at deflections of 5 inches, 10 inches, and 15 inches was 8300 lbf, 5700 lbf, and 6300 lbf, respectively. The strength of the backfill material was slightly below minimum requirements at 15 inches (see Figure C2 in Appendix C); however, the soil was considered appropriate for testing. On the day of Test No. 490023-2, August 15, 2013, load on the post at deflections of 5 inches, 10 inches, and 15 inches was 7800 lbf, 8838 lbf, and 7926 lbf, respectively. The strength of the backfill material met minimum requirements (see Figure C3 in Appendix C).

Figure 2.2. T631 Bridge Rail Installation before Test No. 490023-6-1a.

CHAPTER 3. TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1 CRASH TEST MATRIX

According to *MASH*, two tests are recommended to evaluate longitudinal barriers to Test Level Two (TL-2).

- ***MASH* Test 2-10:** A 2420-lb vehicle impacting the critical impact point (CIP) of the length of need (LON) of the barrier at a nominal impact speed and angle of 44 mi/h and 25 degrees, respectively. This test investigates a barrier's ability to successfully contain and redirect a small passenger vehicle.

- ***MASH* Test 2-11:** A 5000-lb pickup truck impacting the CIP of the LON of the barrier at a nominal impact speed and angle of 44 mi/h and 25 degrees, respectively. This test investigates a barrier's ability to successfully contain and redirect light trucks and sport utility vehicles.

The tests reported herein correspond to *MASH* Test 2-10 and *MASH* Test 2-11. The target CIP for *MASH* Test 2-10 was 12.0 ft upstream of centerline Post 13, and the target CIP for *MASH* Test 2-11 was 6 ft 8⅜ inches upstream of centerline Post 11.

The crash tests and data analysis procedures performed for this research were in accordance with guidelines presented in *MASH,* and a brief description of these are provided in Chapter 4.

3.2 EVALUATION CRITERIA

The crash tests were evaluated in accordance with the criteria presented in *MASH*. The performance of the T631 bridge rail is judged on the basis of three factors: structural adequacy, occupant risk, and post-impact vehicle trajectory. Structural adequacy is judged on the ability of the T631 bridge rail to contain and redirect the vehicle, or bring the vehicle to a controlled stop in a predictable manner. Occupant risk criteria evaluate the potential risk of hazard to occupants in the impacting vehicle, and, to some extent, other traffic, pedestrians, or workers in construction zones, if applicable. Post-impact vehicle trajectory is assessed to determine potential for secondary impact with other vehicles or fixed objects, creating further risk of injury to occupants of the impacting vehicle and/or risk of injury to occupants in other vehicles. The appropriate safety evaluation criteria from Table 5-1 of *MASH* were used to evaluate each crash test reported here, and are listed in further detail under the assessment of each crash test.

CHAPTER 4. CRASH TEST PROCEDURES

4.1 TEST FACILITY

The full-scale crash tests reported here were performed at Texas A&M Transportation Institute (TTI) Proving Ground, an International Standards Organization (ISO) 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 the *MASH* guidelines and standards.

The TTI Proving Ground is a 2000-acre complex of research and training facilities located 10 miles northwest of the main campus of Texas A&M University. The site, formerly an Air Force 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 safety evaluation of roadside safety hardware. The site selected for construction and testing of the T631 bridge rail was along the edge of an out-of-service apron. The apron consists of an unreinforced jointed-concrete pavement in 12.5-ft × 15-ft blocks nominally 6 inches deep. The apron is over 60 years old, and the joints have some displacement, but are otherwise flat and level.

4.2 VEHICLE TOW AND GUIDANCE PROCEDURES

The test vehicles were 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 to be unrestrained. The vehicle remained freewheeling (i.e., no steering or braking inputs) until it cleared the immediate area of the test site, after which the brakes were activated to bring it to a safe and controlled stop, if needed.

4.3 DATA ACQUISITION SYSTEMS

4.3.1 Vehicle Instrumentation and Data Processing

The test vehicles were 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 that Diversified Technical Systems, Inc. produced. 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. Accelerometers and rate transducers are also calibrated annually with traceability to the National Institute for Standards and Technology. Acceleration data are measured with an expanded uncertainty of ±1.7 percent at a confidence factor of 95 percent (k = 2).

TRAP uses the data from the TDAS Pro to compute occupant/compartment impact velocities, time of occupant/compartment impact after vehicle impact, and the highest 10-millisecond (ms) average ridedown acceleration. TRAP calculates change in vehicle velocity at the end of a given impulse period. In addition, maximum average accelerations over 50-ms intervals in each of the three directions are computed. For reporting purposes, the data from the vehicle-mounted accelerometers are filtered with a 60-Hz 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 driver's position of the 1100C vehicle. The dummy was uninstrumented. Use of a dummy in the 2270P vehicle is optional according to *MASH*, and no dummy was used in the test with the 2270P vehicle.

4.3.3 Photographic Instrumentation and Data Processing

Photographic coverage of the test included three 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 activated by pressure-sensitive tape switches was positioned on the impacting vehicle to indicate the instant of contact with the installation and was visible from each camera. The films from these high-speed cameras were analyzed on a computer-linked motion analyzer to observe phenomena occurring during the collision and to obtain time-event, displacement, and angular data. A mini-DV camera and still cameras recorded and documented conditions of the test vehicle and installation before and after the test.

CHAPTER 5. *MASH* TEST 2-11 TEST RESULTS

5.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

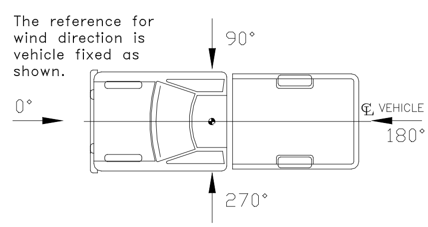
MASH Test 2-11 involves a 2270P vehicle weighing 5000 lb ±110 lb and impacting the bridge rail at an impact speed of 44 mi/h ±2.5 mi/h and an angle of 25 degrees ±1.5 degrees. The target impact point was 12.0 ft upstream of centerline post 13 (1 ft downstream of Post 11). The 2008 Dodge Ram 1500 pickup truck used in the test weighed 5050 lb; the actual impact speed and angle were 44.9 mi/h and 24.9 degrees, respectively. The actual impact point was 6 inches downstream of Post 11. Target impact severity (IS) was 57.8 kip-ft, and actual IS was 60.3 kip-ft.

5.2 TEST VEHICLE

Figures 5.1 and 5.2 show the 2008 Dodge Ram 1500 pickup truck used for the crash test. Test inertia weight of the vehicle was 5050 lb, and its gross static weight was 5050 lb. The height to the lower edge of the vehicle bumper was 15.50 inches, and it was 27.50 inches to the upper edge of the bumper. The height to the vehicle's center of gravity was 28.25 inches. Tables C1 and C2 in Appendix C give additional dimensions and information on the vehicle. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

5.3 WEATHER CONDITIONS

The test was performed on the morning of August 8, 2013. Weather conditions at the time of testing were as follows: wind speed: 9 mi/h; wind direction: 179 degrees with respect to the vehicle (vehicle was traveling in a northwesterly direction); temperature: 89°F; relative humidity: 62 percent.



5.4 TEST DESCRIPTION

The 2008 Dodge Ram 1500 pickup truck, traveling at an impact speed of 44.9 mi/h, impacted the T631 bridge rail 6 inches downstream of post 11 at an impact angle of 24.9 degrees. At approximately 0.093 s, the left front tire reached the edge of the bridge deck and began to drop off the edge of the bridge deck. Post 11 fractured at the base plate at 0.114 s, and the rear of the vehicle contacted the bridge rail at 0.285 s. At 0.354 s, the left front tire rode back up onto the bridge deck while the left rear tire slipped off the bridge deck. At 0.545 s, the vehicle lost contact with the bridge rail and was traveling at an exit speed and angle of 30.0 mi/h and 6.3 degrees, respectively. Brakes on the vehicle were not applied, and the vehicle came to rest 119 ft downstream of impact with the rear of the vehicle 2 ft from the traffic face of the bridge rail. Figures C1 and C2 in Appendix C show sequential photographs of the test period.

Figure 5.1. Vehicle/Installation Geometrics for Test No. 490023-6-1a.

Figure 5.2. Vehicle before Test No. 490023-6-1a.

5.5 DAMAGE TO TEST INSTALLATION

Post 1 was pulled downstream 0.25 inch, and Posts 10 and 11 were leaning toward the field side 2 degrees and 20 degrees, respectively. Posts 12 through 14 were leaning downstream 90 degrees; there was a partial tear at the base, and the rail separated from the posts. Post 15 was leaning towards the field side 5 degrees and downstream 14 degrees, and the rail separated from the post. The vehicle contacted the installation a second time at the downstream terminal post and anchor. Figures 5.3 and 5.4 show damage to the installation. The vehicle was in contact with the bridge rail 22.25 ft. Maximum dynamic deflection of the bridge rail was 25.7 inches, and permanent deformation was 21.5 inches. Working width was 30.0 inches, and vehicle intrusion was 28.8 inches.

5.6 VEHICLE DAMAGE

Figure 5.5 shows damage to the exterior of the vehicle. The left front wheel assembly broke from the upper and lower ball joints; the left upper and lower ball joints, A-arms, and left front tie rod end were deformed. Also damaged were the front bumper, left front fender, left front brake line, left front door, left front tire and wheel rim, left rear tire, left rear exterior bed, and the left rear bumper. Maximum exterior crush to the vehicle was 6 inches in the side plane at the left front corner at bumper height. No occupant compartment deformation or intrusion occurred. Figure 5.6 provides photographs of the interior of the vehicle. Tables C3 and C4 in Appendix C provide exterior crush and occupant compartment measurements.

5.7 OCCUPANT RISK FACTORS

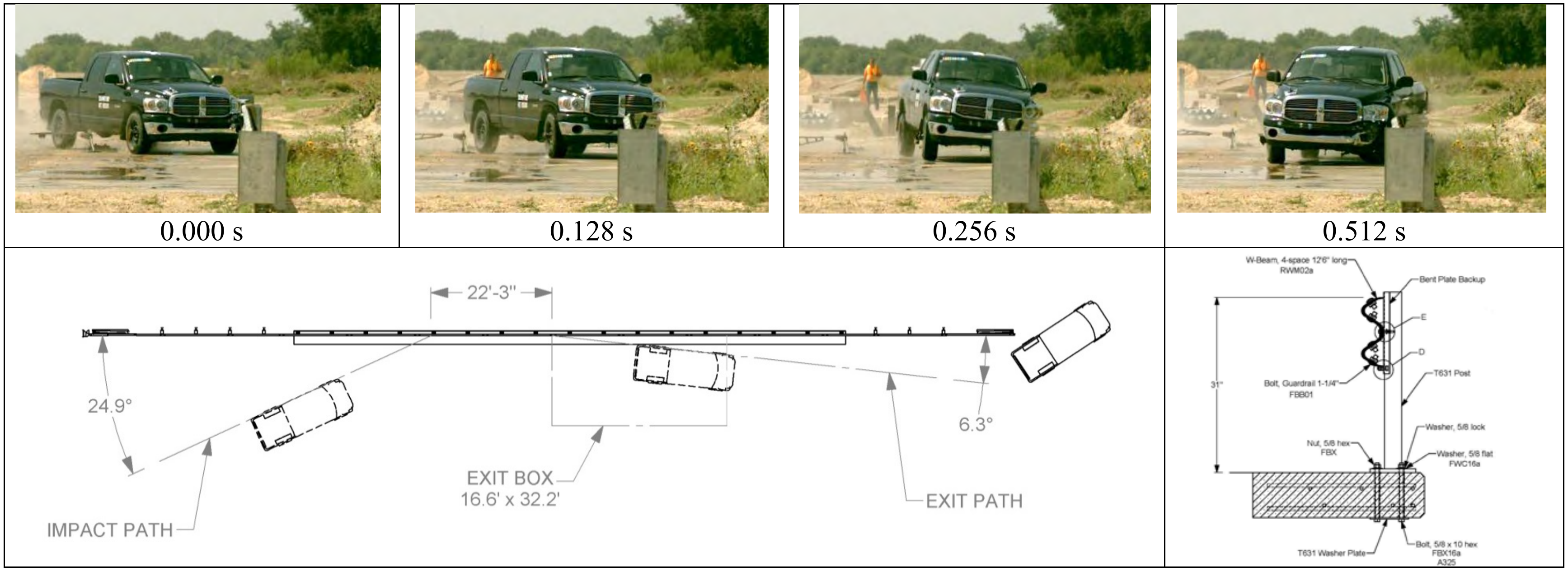
Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk. In the longitudinal direction, the occupant impact velocity was 10.5 ft/s at 0.178 s, the highest 0.010-s occupant ridedown acceleration was 10.0 Gs from 0.342 to 0.352 s, and the maximum 0.050-s average acceleration was −2.6 Gs between 0.303 and 0.353 s. In the lateral direction, the occupant impact velocity was 12.5ft/s at 0.178 s, the highest 0.010-s occupant ridedown acceleration was 5.3 Gs from 0.297 to 0.287 s, and the maximum 0.050-s average was 3.8 Gs between 0.265 and 0.315 s. Theoretical Head Impact Velocity (THIV) was 17.2 km/h or 4.8 m/s at 0.172 s; Post-Impact Head Decelerations (PHD) was 10.1 Gs between 0.342 and 0.352 s; and Acceleration Severity Index (ASI) was 0.49 between 0.380 and 0.430 s. Figure 5.7 summarized these data and other pertinent information from the test. Figures C3 through C9 in Appendix C show the vehicle angular displacements and accelerations versus time traces.

Figure 5.3. Test Article/Vehicle Positions after Test No. 490023-6-1a.

Figure 5.4. Installation after Test No. 490023-6-1a.

Figure 5.5. Vehicle after Test No. 490023-6-1a.

Figure 5.6. Interior of Vehicle for Test No. 490023-6-1a.



General Information	
Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	MASH Test 2-11
TTI Test No.	490023-6-1a
Test Date	2013-08-08
Test Article	
Type	Bridge Rail
Name	TxDOT T631 Bridge Rail
Installation Length	168.75 ft
Material or Key Elements	S3×5.7 A992 structural steel posts welded to base plates bolted through the bridge deck cantilever
Soil Type and Condition	Concrete Deck, Dry
Test Vehicle	
Type/Designation	2270P
Make and Model	2008 Dodge Ram 1500 Pickup
Curb	5094 lb
Test Inertial	5050 lb
Dummy	No Dummy
Gross Static	5050 lb

Impact Conditions	
Speed	44.9 mi/h
Angle	24.9 degrees
Location/Orientation	6 inches dwnstrm post 11
Impact Severity	60.3 kip-ft
Exit Conditions	
Speed	30.0 mi/h
Angle	6.3 degrees
Occupant Risk Values	
Impact Velocity	
Longitudinal	10.5 ft/s
Lateral	12.5 ft/s
Ridedown Accelerations	
Longitudinal	10.0 G
Lateral	5.3 G
THIV	17.2 km/h (4.8 m/s)
PHD	10.1 G
ASI	0.49
Max. 0.050-s Average	
Longitudinal	−2.6 G
Lateral	3.8 G
Vertical	3.1 G

Post-Impact Trajectory	
Stopping Distance	119 ft dwnstrm 2 ft twd traffic
Vehicle Stability	
Maximum Yaw Angle	35 degrees
Maximum Pitch Angle	3 degrees
Maximum Roll Angle	6 degrees
Vehicle Snagging	No
Vehicle Pocketing	No
Test Article Deflections	
Dynamic	25.7 inches
Permanent	21.5 inches
Working Width	30.0 inches
Vehicle Intrusion	28.8 inches
Vehicle Damage	
VDS	11LFQ5
CDC	11LDEW4
Max. Exterior Deformation	6 inches
OCDI	LF0000000
Max. Occupant Compartment Deformation	None

Figure 5.7. Summary of Results for *MASH* Test 2-11 on the T631 Bridge Rail.

5.8 ASSESSENT OF RESULTS

An assessment of the test based on the applicable *MASH* safety evaluation criteria is provided below.

5.8.1 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.

Results: The TxDOT T631 bridge rail contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the bridge rail. Maximum dynamic deflection was 25.7 inches. (PASS)

5.8.2 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.

Deformation of, or intrusions into the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH. (roof ≤4.0 inches; windshield = ≤3.0 inches; side windows = no shattering by test article structural member; wheel/foot well/toe pan ≤9.0 inches; forward of A-pillar ≤12.0 inches; front side door area above seat ≤9.0 inches; front side door below seat ≤12.0 inches; floor pan/transmission tunnel area ≤12.0 inches).

Results: The rail element separated from four posts but remained attached to the remaining installation; however, this detached element did not penetrate or show potential for penetrating the occupant compartment, or present a hazard to others in the area. (PASS)
No occupant compartment deformation or intrusion occurred. (PASS)

F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.

Results: The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 6 degrees and 3 degrees, respectively. (PASS)

H. Occupant impact velocities should satisfy the following:

Longitudinal and Lateral Occupant Impact Velocity

Preferred	*Maximum*
30 ft/s	*40 ft/s*

Results: Longitudinal occupant impact velocity was 10.5 ft/s, and lateral occupant impact velocity was 12.5 ft/s. (PASS)

I. Occupant ridedown accelerations should satisfy the following:

Longitudinal and Lateral Occupant Ridedown Accelerations

Preferred	*Maximum*
15.0 Gs	*20.49 Gs*

Results: Longitudinal ridedown acceleration was 10.0 G, and lateral ridedown acceleration was 5.3 G. (PASS)

5.8.3 Vehicle Trajectory

For redirective devices, the vehicle shall exit the barrier within the exit box (not less than 32.8 ft).

Result: The 2270P vehicle remained near the installation as it lost contact, and exited within the exit box criteria.

CHAPTER 6. *MASH* TEST 2-10 RESULTS

6.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

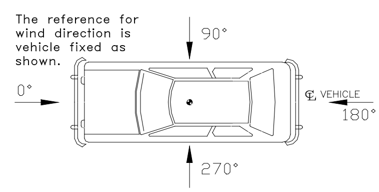
MASH Test 2-10 involves a 1100C vehicle weighing 2420 lb ±55 lb and impacting the test article at an impact speed of 44 mi/h ±2.5 mi/h and an angle of 25 degrees ±1.5 degrees. The target impact point was 6 ft 8 ⅜ inches upstream of centerline post. The 2008 Kia Rio used in the test weighed 2421 lb and the actual impact speed and angle were 43.8 mi/h and 25.2 degrees, respectively. The actual impact point was 6 ft-3 inches upstream of Post 11 (at Post 10). Target IS was 28.0 kip-ft, and actual IS was 28.1 kip-ft.

6.2 TEST VEHICLE

Figures 6.1 and 6.2 show the 2008 Kia Rio used for the crash test. Test inertia weight of the vehicle was 2421 lb, and its gross static weight was 2586 lb. The height to the lower edge of the vehicle bumper was 6.75 inches, and it was 21.50 inches to the upper edge of the bumper. Table D1 in Appendix D gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

6.3 WEATHER CONDITIONS

The test was performed on the morning of August 15, 2013. Weather conditions at the time of testing were as follows: wind speed: 2 mi/h; wind direction: 49 degrees with respect to the vehicle (vehicle was traveling in a northwesterly direction); temperature: 87°F; relative humidity: 68 percent.



6.4 TEST DESCRIPTION

The 2008 Kia Rio, traveling at an impact speed of 43.8 mi/h, impacted the T631 bridge rail 6 ft 3 inches upstream of Post 11 at an impact angle of 25.2 degrees. At approximately 0.038 s, the left front tire contacted Post 10, and at 0.061 s, the rail element detached from Post 10. The left front tire reached the edge of the bridge deck by 0.086 s and began to drop downward. At 0.105 s, the rail element pulled away from Post 11, and at 0.156 s, the bumper contacted the bridge deck. The rail element separated from Post 12 at 0.232 s and caught on the left front tire. By 0.242 s, the vehicle contacted Post 12, and at 0.339 s. the left rear tire rode over the base of Post 11. At 0.345 s, the vehicle was traveling parallel with the guardrail. The left front tire contacted Post 13, which detached from the rail element, and the left rear tire rode over the base of Post 13 at 0.550 s. At 0.638 s, the vehicle lost contact with the rail element and was traveling at an exit speed and angle of 20.1 mi/h and 9.3 degrees, respectively. Brakes on the vehicle were not applied, and the vehicle came to rest 49 ft downstream of impact and 3 ft in front of the traffic face of the guardrail. Figures D1 and D2 in Appendix D show sequential photographs of the test period.

Figure 6.1. Vehicle/Installation Geometrics for Test No. 490023-6-2.

Figure 6.2. Vehicle before Test No. 490023-6-2.

6.5 DAMAGE TO TEST INSTALLATION

Post 9 was leaning towards the field side 4 degrees. Post 10 was leaning towards the field side 95 degrees and the front flange and webbing were torn. Post 11 was leaning downstream 85 degrees and towards the field side 10 degrees; the front flange was partially torn, and the backup plate released. Post 12 was leaning downstream 85 degrees and the back flange was partially torn. Post 12 was leaning downstream 8 degrees. Figures 6.3 and 6.4 show damage to the installation. The 1100C vehicle was in contact with the bridge rail 17.8 ft. Maximum dynamic deflection of the bridge rail during the test was 22.6 inches, and maximum permanent deformation was 15.0 inches. Working width was 25.5 inches, and vehicle penetration was 30.3 inches.

6.6 VEHICLE DAMAGE

Figure 6.5 shows damage to the 1100C vehicle. The left strut, strut tower, and left tie rod end were deformed. Also damaged were the front bumper, hood, left front fender, left front tire and wheel rim, and the left front door. Maximum exterior crush to the vehicle was 9.5 inches in the side plane at the left front corner at bumper height. No occupant compartment deformation or intrusion occurred. Figure 6.6 provides photographs of the interior of the vehicle. Tables D3 and D4 in Appendix D provide exterior crush and occupant compartment measurements.

6.7 OCCUPANT RISK FACTORS

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk. In the longitudinal direction, the occupant impact velocity was 20.3 ft/s at 0.191 s, the highest 0.010-s occupant ridedown acceleration was 6.7 Gs from 0.460 to 0.470 s, and the maximum 0.050-s average acceleration was −4.9 Gs between 0.035 and 0.085 s. In the lateral direction, the occupant impact velocity was 5.6 ft/s at 0.191 s, the highest 0.010-s occupant ridedown acceleration was 5.3 Gs from 0.465 to 0.475 s, and the maximum 0.050-s average was 3.3 Gs between 0.017 and 0.067 s. Theoretical Head Impact Velocity (THIV) was 23.7 km/h or 6.6 m/s at 0.196 s; Post-Impact Head Decelerations (PHD) was 7.0 Gs between 0.460 and 0.470 s; and Acceleration Severity Index (ASI) was 0.62 between 0.048 and 0.098 s. Figure 6.7 summarized these data and other pertinent information from the test. Figures D3 through D9 in Appendix D show the vehicle angular displacements and accelerations versus time traces.

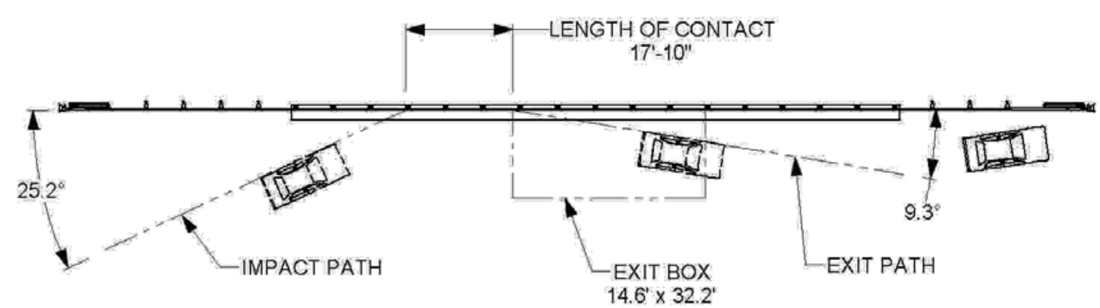
Figure 6.3. Test Article/Vehicle Positions after Test No. 490023-6-2.

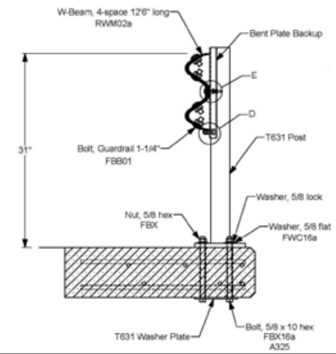
Figure 6.4. Installation after Test No. 490023-6-2.

Figure 6.5. Vehicle after Test No. 490023-6-2.

Figure 6.6. Interior of Vehicle for Test No. 490023-6-2.

0.000 s | 0.135 s | 0.405 s | 0.675 s





General Information
Test Agency........................Texas A&M Transportation Institute (TTI)
Test Standard Test No. ....MASH Test 2-10
TTI Test No. 490023-6-2
Test Date 2013-08-15
Test Article
Type....................................Bridge Rail
Name ....TxDOT T631 Bridge Rail
Installation Length ....168.75 ft
Material or Key Elements ....

Soil Type and Condition.........Concrete Deck, Dry
Test Vehicle
Type/Designation.................1100C
Make and Model ....2008 Kia Rio
Curb ....2418 lb
Test Inertial ....2421 lb
Dummy .... 165 lb
Gross Static ....2586 lb

Impact Conditions
Speed ....43.8 mi/h
Angle ....25.2 degrees
Location/Orientation ....Post 10
Impact Severity ....28.1 kip-ft
Exit Conditions
Speed ....20.1 mi/h
Angle ....9.3 degrees
Occupant Risk Values
Impact Velocity
Longitudinal ....20.3 ft/s
Lateral ....5.3 ft/s
Ridedown Accelerations
Longitudinal ....6.7 G
Lateral ....5.3 G
THIV ....23.7 km/h (6.6 m/s)
PHD ....7.0 G
ASI.....................................0.62
Max. 0.050-s Average
Longitudinal ....−4.9 G
Lateral ....3.3 G
Vertical ....1.8 G

Post-Impact Trajectory
Stopping Distance .... 49 ft dwnstrm
3 ft twd traffic
Vehicle Stability
Maximum Yaw Angle .... 35 degrees
Maximum Pitch Angle .... 3 degrees
Maximum Roll Angle .... 7 degrees
Vehicle Snagging .... No
Vehicle Pocketing...................... No
Test Article Deflections
Dynamic .... 22.6 inches
Permanent................................. 15.0 inches
Working Width........................... 25.5 inches
Vehicle Intrusion........................ 30.3 inches
Vehicle Damage
VDS... 11LFQ4
CDC 11FLEW4
Max. Exterior Deformation .... 9.5 inches
OCDI LF0000000
Max. Occupant Compartment
Deformation .... None

Figure 6.7. Summary of Results for *MASH* Test 2-11 on the T631 Bridge Rail.

6.8 ASSESSENT OF RESULTS

An assessment of the test based on the applicable *MASH* safety evaluation criteria is provided below.

6.8.1 Structural Adequacy

B. 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.

Results: The TxDOT T631 bridge rail contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the bridge rail. Maximum dynamic deflection was 22.6 inches. (PASS)

6.8.2 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.

Deformation of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH. (roof ≤4.0 inches; windshield = ≤3.0 inches; side windows = no shattering by test article structural member; wheel/foot well/toe pan ≤9.0 inches; forward of A-pillar ≤12.0 inches; front side door area above seat ≤9.0 inches; front side door below seat ≤12.0 inches; floor pan/transmission tunnel area ≤12.0 inches).

Results: The rail element separated from three posts but remained attached to the remaining installation; however, this detached element did not penetrate or show potential for penetrating the occupant compartment, or present a hazard to others in the area. (PASS)
No occupant compartment deformation or intrusion occurred. (PASS)

F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.

Results: The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 7 degrees and 3 degrees, respectively. (PASS)

H. Occupant impact velocities should satisfy the following:

Longitudinal and Lateral Occupant Impact Velocity

Preferred	*Maximum*
30 ft/s	*40 ft/s*

Results: Longitudinal occupant impact velocity was 20.3 ft/s, and lateral occupant impact velocity was 5.6 ft/s. (PASS)

I. Occupant ridedown accelerations should satisfy the following:

Longitudinal and Lateral Occupant Ridedown Accelerations

Preferred	*Maximum*
15.0 Gs	*20.49 Gs*

Results: Longitudinal ridedown acceleration was 6.7 G, and lateral ridedown acceleration was 5.3 G. (PASS)

6.8.3 Vehicle Trajectory

For redirective devices, the vehicle shall exit the barrier within the exit box (not less than 32.8 ft).

Result: The 1100C vehicle remained near the installation as it lost contact, and exited within the exit box criteria. (PASS)

CHAPTER 7. SUMMARY AND CONCLUSIONS

7.1 SUMMARY OF RESULTS

7.1.1 *MASH* Test 2-11 (Crash Test No. 490023-6-1a)

The TxDOT T631 bridge rail contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the bridge rail. Maximum dynamic deflection was 25.7 inches. The rail element separated from four posts but remained attached to the remaining installation; however, this detached element did not penetrate or show potential for penetrating the occupant compartment, or present a hazard to others in the area. No occupant compartment deformation or intrusion occurred. The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 6 degrees and 3 degrees, respectively. Occupant risk factors were within the limits specified in *MASH*. The 2270P vehicle remained near the installation as it lost contact, and exited within the exit box criteria.

7.1.2 *MASH* Test 2-10 (Crash Test No. 490023-6-2)

The TxDOT T631 bridge rail contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the bridge rail. Maximum dynamic deflection was 22.6 inches. The rail element separated from three posts but remained attached to the remaining installation; however, this detached element did not penetrate or show potential for penetrating the occupant compartment, or present a hazard to others in the area. No occupant compartment deformation or intrusion occurred. The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 7 degrees and 3 degrees, respectively. Occupant risk factors were within the limits specified in *MASH*. The 1100C vehicle remained near the installation as it lost contact, and exited within the exit box criteria.

7.2 CONCLUSIONS

Tables 7.1 and 7.2 show that the TxDOT T631 bridge rail performed acceptably for TL-2 of *MASH*.

Table 7.1. Performance Evaluation Summary for MASH Test 2-11 on the T631 Bridge Rail.

Test Agency: Texas Transportation Institute — Test No.: 490023-6-1a — Test Date: 2013-08-08

***MASH* Test 2-11 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 TxDOT T631 bridge rail contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the bridge rail. Maximum dynamic deflection was 25.7 inches.	Pass
Occupant Risk		
D. *Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	The rail element separated from four posts but remained attached to the remaining installation; however, this detached element did not penetrate or show potential for penetrating the occupant compartment, or present a hazard to others in the area.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	No occupant compartment deformation or intrusion occurred.	Pass
F. *The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.*	The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 6 degrees and 3 degrees, respectively.	Pass
H. *Longitudinal and lateral occupant impact velocities should fall below the preferred value of 30 ft/s, or at least below the maximum allowable value of 40 ft/s.*	Longitudinal occupant impact velocity was 10.5 ft/s, and lateral occupant impact velocity was 12.5 ft/s.	Pass
I. *Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15.0 Gs, or at least below the maximum allowable value of 20.49 Gs.*	Longitudinal ridedown acceleration was 10.0 G, and lateral ridedown acceleration was 5.3 G.	Pass
Vehicle Trajectory		
For redirective devices, the vehicle shall exit the barrier within the exit box (not less than 32.8 ft).	The 2270P vehicle remained near the installation as it lost contact, and exited within the exit box criteria.	Pass

Table 7.2. Performance Evaluation Summary for *MASH* Test 2-10 on the T631 Bridge Rail.

Test Agency: Texas Transportation Institute — Test No.: 490023-6-2 — Test Date: 2013-08-15

***MASH* Test 2-10 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 TxDOT T631 bridge rail contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the bridge rail. Maximum dynamic deflection was 22.6 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 element separated from three posts but remained attached to the remaining installation; however, this detached element did not penetrate or show potential for penetrating the occupant compartment, or present a hazard to others in the area.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	No occupant compartment deformation or intrusion occurred.	Pass
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 7 degrees and 3 degrees, respectively.	Pass
H. *Longitudinal and lateral occupant impact velocities should fall below the preferred value of 30 ft/s, or at least below the maximum allowable value of 40 ft/s.*	Longitudinal occupant impact velocity was 20.3 ft/s, and lateral occupant impact velocity was 5.6 ft/s.	Pass
I. *Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15.0 Gs, or at least below the maximum allowable value of 20.49 Gs.*	Longitudinal ridedown acceleration was 6.7 G, and lateral ridedown acceleration was 5.3 G.	Pass
Vehicle Trajectory *For redirective devices, the vehicle shall exit the barrier within the exit box (not less than 32.8 ft).*	The 1100C vehicle remained near the installation as it lost contact, and exited within the exit box criteria.	Pass

CHAPTER 8. IMPLEMENTATION STATEMENT

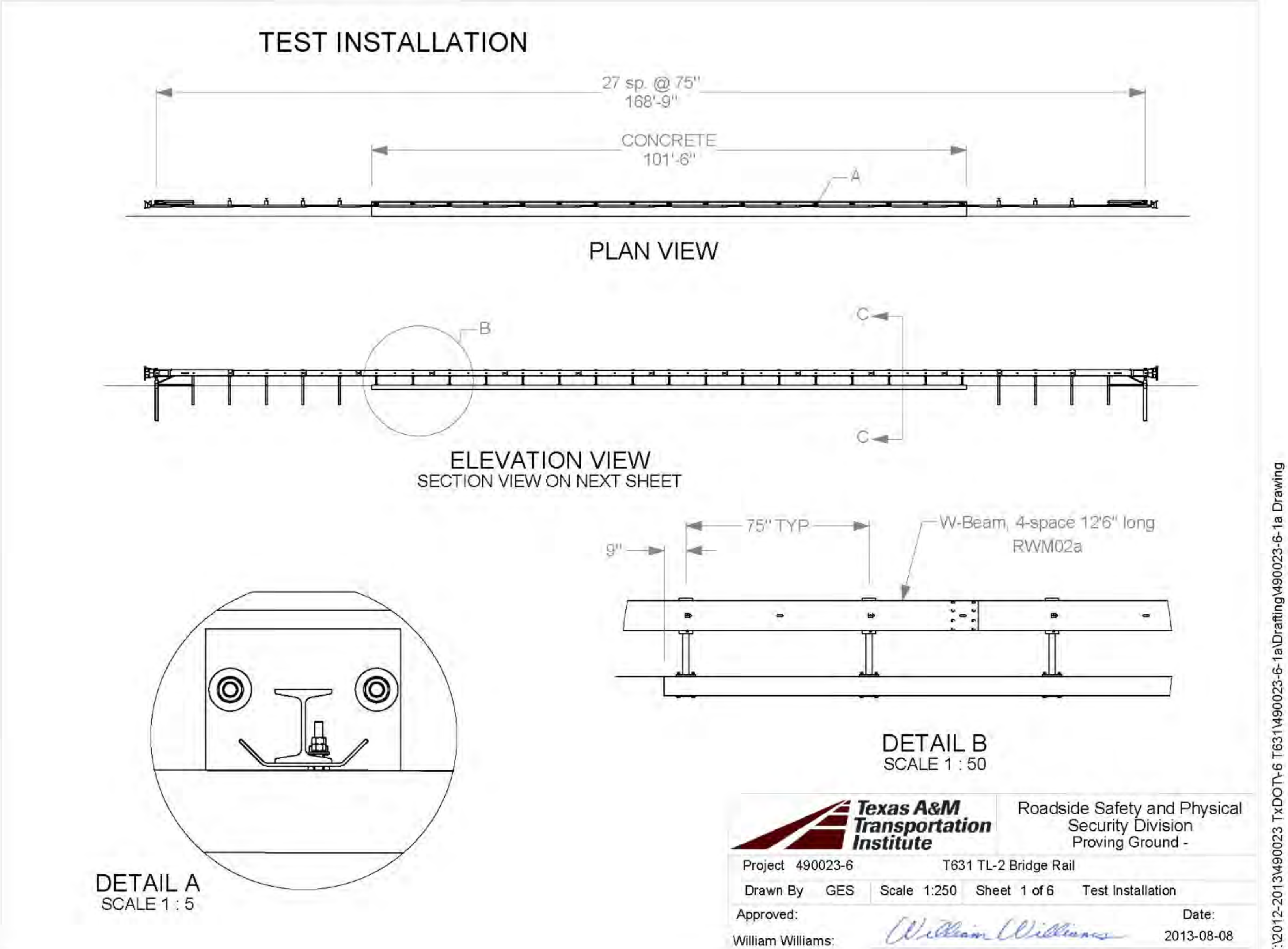
The Texas Type T631 bridge rail met all the performance criteria for *MASH* TL-2. The Texas Type T631 bridge rail, as tested herein, is recommended for *MASH* TL-2 application on new and existing bridge construction.

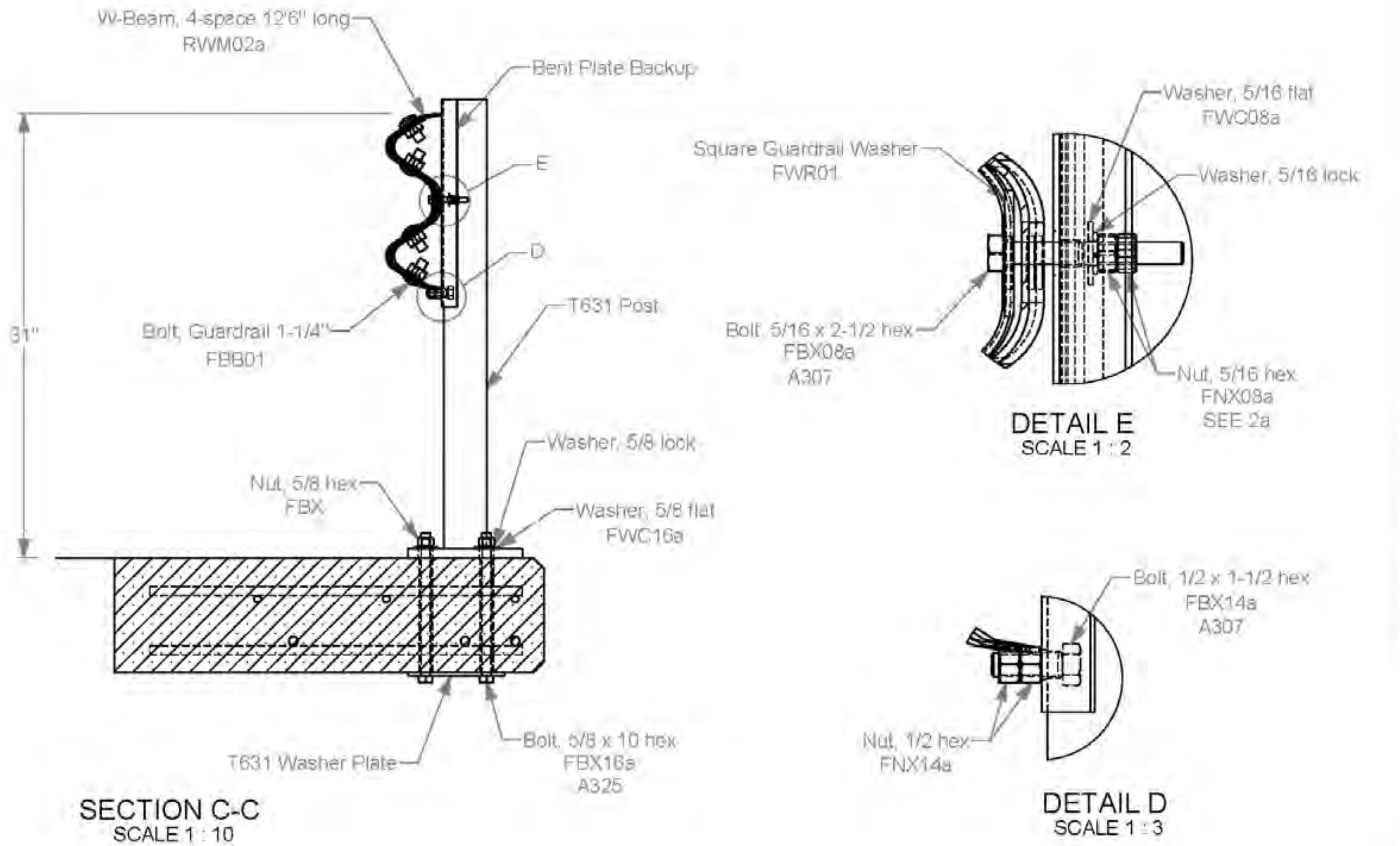
REFERENCES

1. AASHTO, *Manual for Assessing Safety Hardware*, American Association of State Highway and Transportation Officials, Washington, D.C., 2009.

2. Jeffrey Thiele, Dean Sicking, Ronald Faller, Robert Bielenberg, Karla (Polivka) Lechtenberg, John Reid, and Scott Rosenbaugh. *Development of a Low-Cost, Energy-Absorbing Bridge Rail*, MwRSF Research Report No. TRP-03-226-10, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, 2010.

APPENDIX A. DETAILS OF THE T631 BRIDGE RAIL





2a. Tighten the first nut by hand until the top and bottom edges of the rail engage the Bent Plate Backup (the Bent Plate Backup should be snug against the post). Then tighten one round with a wrench and secure with the second nut.

Texas A&M Transportation Institute

Roadside Safety and Physical Security Division - Proving Ground

Project 490023-6	T631 TL-2 Bridge Rail		2013-08-08
Drawn By GES	No Scale	Sheet 2 of 6	Cross Section

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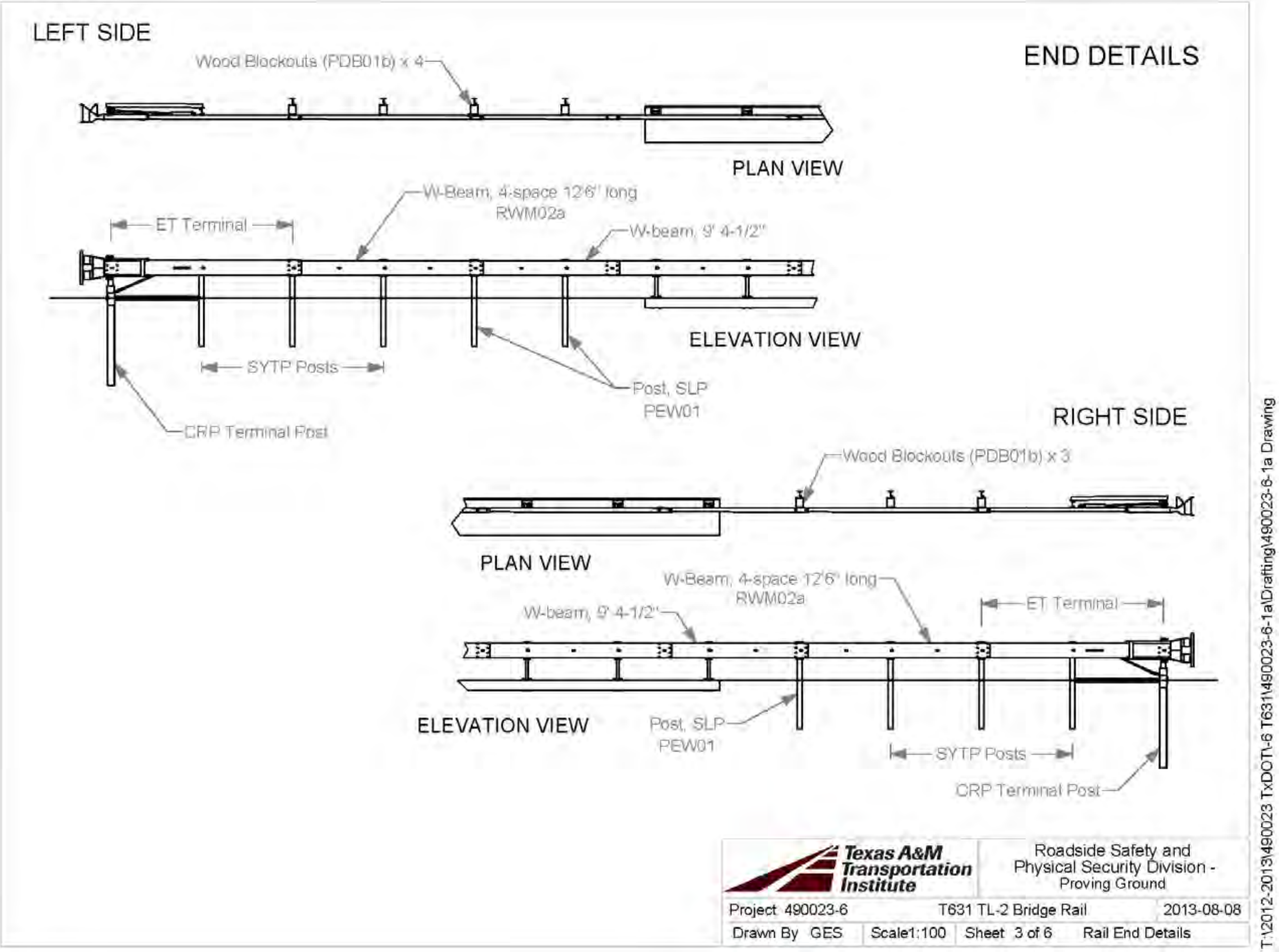
LEFT SIDE
END DETAILS
Wood Blockouts (PDB01b) x 4
PLAN VIEW
W-Beam, 4-space 12'6" long
RWM02a
ET Terminal
W-beam, 9' 4-1/2"
ELEVATION VIEW
SYTP Posts
Post, SLP
PEW01
CRP Terminal Post
RIGHT SIDE
Wood Blockouts (PDB01b) x 3
PLAN VIEW
W-Beam, 4-space 12'6" long
RWM02a
W-beam, 9' 4-1/2"
ET Terminal
ELEVATION VIEW
Post, SLP
PEW01
SYTP Posts
CRP Terminal Post
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project 490023-6
T631 TL-2 Bridge Rail
2013-08-08
Drawn By GES
Scale1:100
Sheet 3 of 6
Rail End Details
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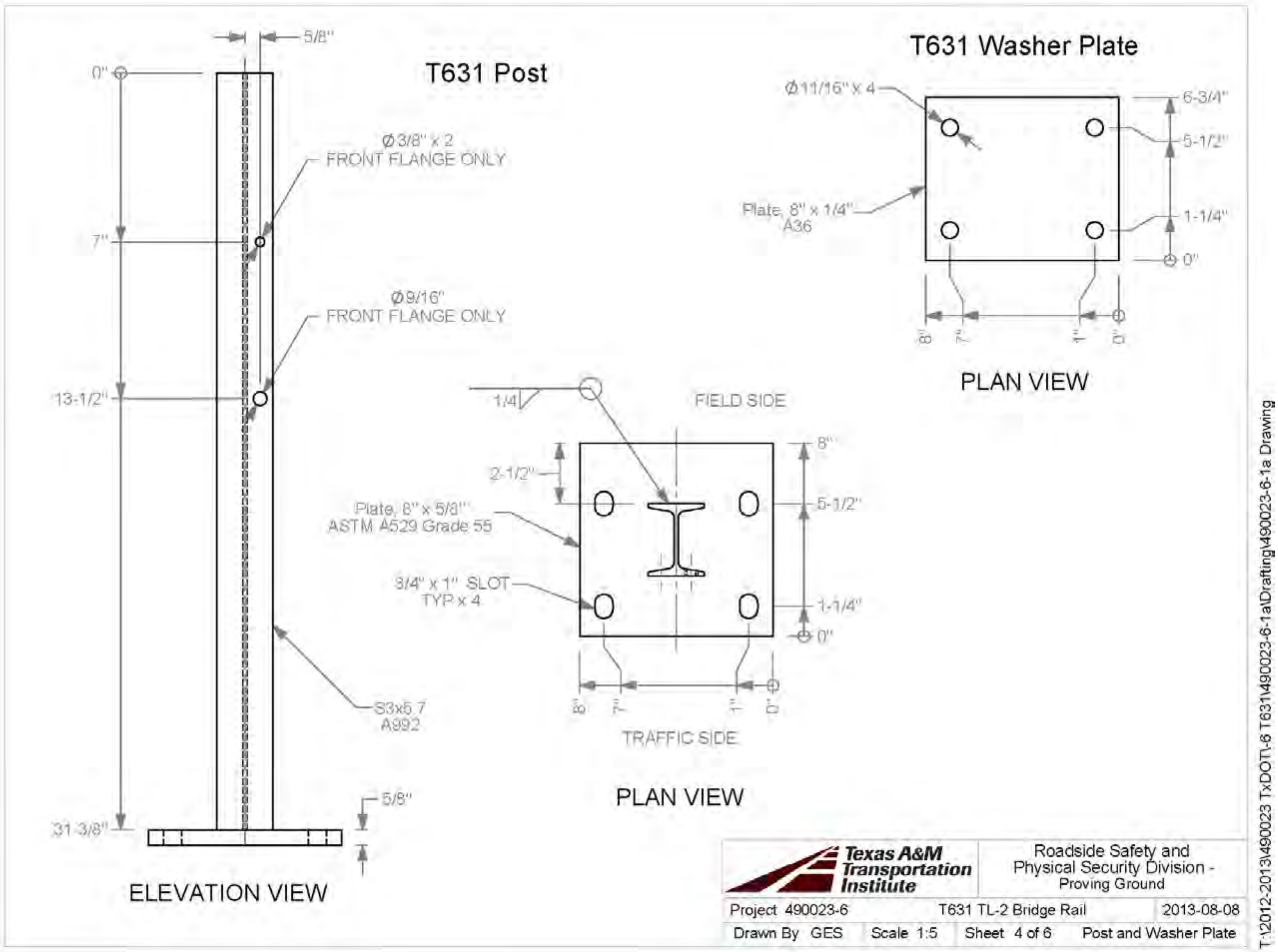
T631 Post
5/8"
0"
7"
13-1/2"
31-3/8"
Ø3/8" x 2
FRONT FLANGE ONLY
Ø9/16"
FRONT FLANGE ONLY
S3x5.7
A992
5/8"
ELEVATION VIEW
T631 Washer Plate
Ø11/16" x 4
Plate, 8" x 1/4"
A36
6-3/4"
5-1/2"
1-1/4"
0"
8"
7"
1"
0"
PLAN VIEW
1/4
FIELD SIDE
2-1/2"
Plate, 8" x 5/8"
ASTM A529 Grade 55
3/4" x 1" SLOT
TYP x 4
8"
5-1/2"
1-1/4"
0"
8"
7"
1"
0"
TRAFFIC SIDE
PLAN VIEW
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project 490023-6
T631 TL-2 Bridge Rail
2013-08-08
Drawn By GES
Scale 1:5
Sheet 4 of 6
Post and Washer Plate
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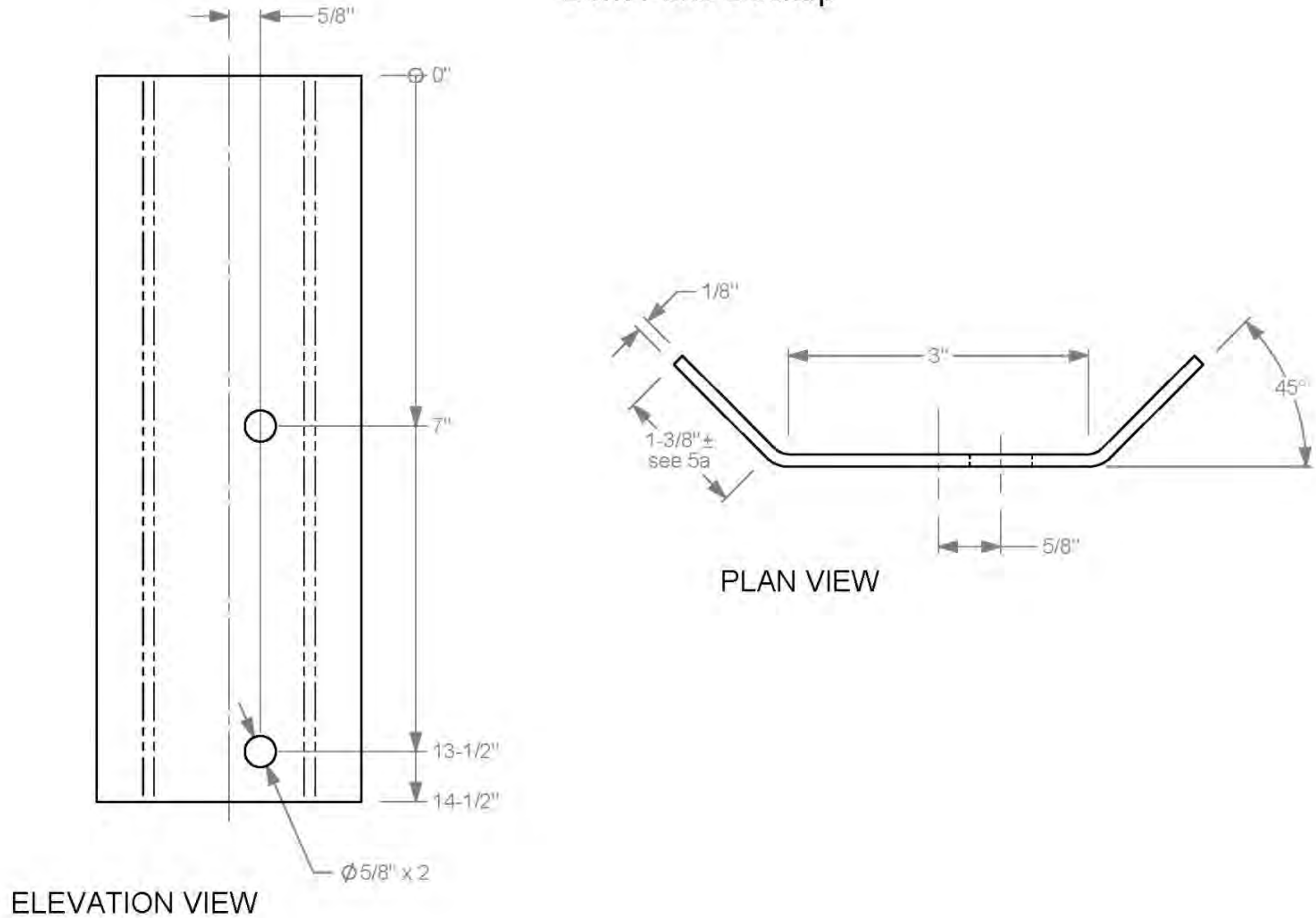
Bent Plate Backup

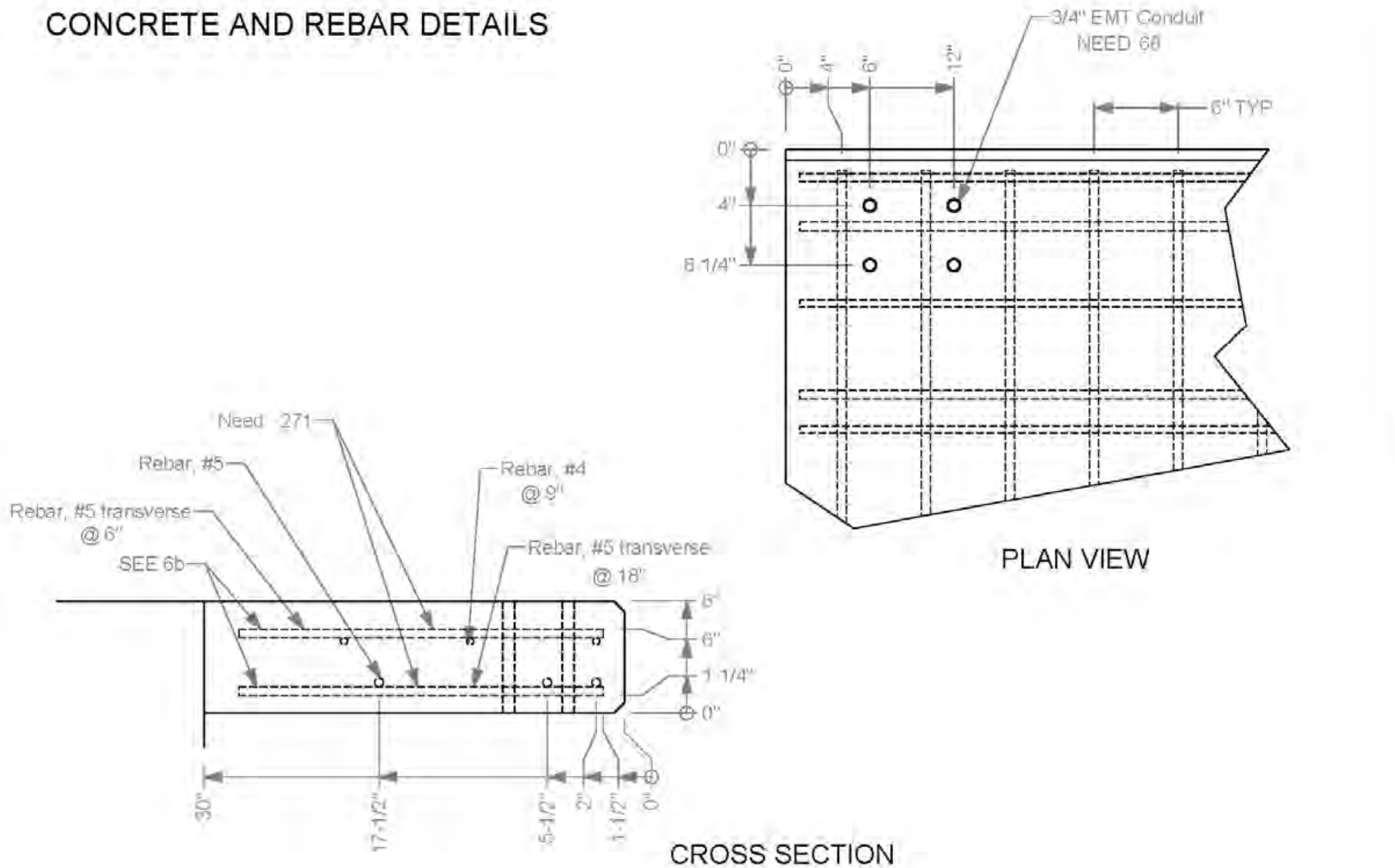


5a. This dimension is approximate. Part is made from 6" wide A36 plate. Use Industry Standard for bend radius.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project 490023-6	T631 TL-2 Bridge Rail	2013-08-08
Drawn By GES	No Scale	Sheet 5 of 6 Bent Plate

T:\2012-2013\490023 TxDOT-6 T631\490023-6-1a\Drafting\490023-6-1a Drawing

CONCRETE AND REBAR DETAILS



6a. Concrete is Class S (4000 psi). Rebar is grade 60. Minimum rebar laps are 15" for #4 bars (top mat) and 19" for #5 bars (bottom mat).
6b. Transverse Bars weld to existing rebar protruding from the runway (not shown).
6c. Chamfer exposed edges of the deck 3/4".

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Project 490023-6	T631 TL-2 Bridge Rail		2013-08-08
Drawn By GES	Scale 1:10	Sheet 6 of 6	Concrete and Rebar

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APPENDIX B. CERTIFICATION DOCUMENTATION

B1. CRASH TEST NO. 490023-6-1a

MATERIAL USED

TEST NUMBER 490023-1a

TEST NAME T631

DATE 2013-08-08

DATE RECEIVED	ITEM NUMBER	DESCRIPTION	SUPPLIER	HEAT #	
2013-06-28	Strap-12-05	5/8 x 8 x 240	Mack Bolt & Steel	JW1310233802	
2013-07-23	Hardware-12-01	bolts, nuts, etc.	Trinity	see attached	
2013-05-22	Parts-36	guardrail parts	Trinity	see attached	see note
2013-04-19	S-section-01	S3x5.7 x 240	Mack Bolt & Steel	26008630	
2013-05-23	S-section-02	S3x5.7 x 20' - A992	Mack Bolt & Steel	2302870	
2013-04-19	Strap, 0.2500-03	1/4" x 8" x 20' A36	Mack Bolt & Steel	JW10201238	
2013-04-19	Strap, 0.6250-1	5/8 x 8 x 240	Mack Bolt & Steel	JW12108919	
2013-05-22	W-beam-10	12 ga, 12.5'	Trinity	see attached	
2013-05-22	W-beam-11	12 ga, 9' 4-1/2"	Trinity	see attached	

All guardrail in the length of need is stamped L10613.

Page: 2

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800-527-6445

SHIP TO: KLOECKNER METALS
2560 SOUTH LOOP 4
BUDA, TX 78610-

Date: 7-May-2013
B.L. Number: 637177
Load Number: 243601

Material Safety Data Sheets are available at www.nucorbar.com or by contacting your inside sales representative.

NBMG-08 January 1, 2012

LOT # / HEAT #	DESCRIPTION	PHYSICAL TESTS					CHEMICAL TESTS						
		YIELD P.S.I.	TENSILE P.S.I.	ELONG % IN 8"	BEND	WT% / DEF	C / Ni	Mn / Cr	P / Mo	S / V	Si / Cb	Cu / Sn	C.E.
PO# =>	6658775												
JW1310204501	Nucor Steel - Texas	58,000	75,700	23.0%			.14	.86	.014	.025	.23	.38	
JW13102045	5x3x3/8 Angle	400MPa	522MPa				.15	.18	.039	.040	.002		
	40' A36/A529GR50	59,300	76,500	20.0%			CE4020	CEA529					
	ASTM A36-08, A529-05, A709-09a G	409MPa	527MPa				0.37	0.41					
	R36, ASME SA36-07 Ed 11 Ad												
	COMPLIES WITH DIN 50049 PARA 3.1B & EN 10204-3.1												
PO# =>	6660524												
JW1310204601	Nucor Steel - Texas	58,700	77,200	22.0%			.14	.89	.018	.031	.21	.34	
JW13102046	5x3x3/8 Angle	405MPa	532MPa				.13	.17	.037	.042	.002		
	40' A36/A529GR50	59,200	76,300	23.0%			CE4020	CEA529					
	ASTM A36-08, A529-05, A709-09a G	408MPa	526MPa				0.37	0.40					
	R36, ASME SA36-07 Ed 11 Ad												
	COMPLIES WITH DIN 50049 PARA 3.1B & EN 10204-3.1												
PO# =>	6661655												
JW1310233802	Nucor Steel - Texas	61,100	77,500	20.0%			.14	1.02	.011	.032	.21	.30	
JW13102338	5/8x8" Flat	421MPa	534MPa				.14	.16	.048	.079	.001		
	20' A529 Gr55	60,900	77,700	20.0%			CBV	CE4020	CEA529	MN/C			
	ASTM A529/A529M-05 GR 55	420MPa	536MPa				0.080	PB = *	0.43	07.29			
	COMPLIES WITH DIN 50049 PARA 3.1B & EN 10204-3.1												

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.
1.) Weld repair was not performed on this material.
2.) Melted and Manufactured in the United States.
3.) Mercury, Radium, or Alpha source materials in any form have not been used in the production of this material.

QUALITY ASSURANCE: Jim Critchard

Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801
Customer: SAMPLES,TESTING,TRAINING MTRLS
2525 STEMMONS FRWY

DALLAS, TX 75207

Project: PENNDOT WEAK POST

Order Number: 1197242 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO:
BOL Number: 76606 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 7/17/13

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
50	3240G	5/16" ROUND WASHER	HW			C6656													
76	3245G	5/16" HEX NUT A563	HW			1337002													
144	3300G	5/8" WASHER F844 A/W	HW			270674													
34	3319G	1/8"X1.75"X1.75" WSHR PL	HW			45290													
136	3361G	5/8" HVY HEX NUT A563	HW			1252029													
68	4303G	1/2" HEX NUT A563 GR A	HW			1211030													

TL -3 or TL-4 COMPLIANT when installed according to manufactures specifications

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy No. LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36

ALL COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT"
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM-123 (US DOMESTIC SHIPMENTS)
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A123 & ISO 1461 (INTERNATIONAL SHIPMENTS)

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

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

Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801

Customer: SAMPLES,TESTING,TRAINING MTRLS
2525 STEMMONS FRWY

DALLAS, TX 75207

Project: PENNDOT WEAK POST

Order Number: 1197242 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO:
BOL Number: 76606 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 7/17/13

State of Ohio, County of Allen. Sworn and subscribed before me this 17th day of July, 2013

Notary Public:
Commission Expires: 1/23/2016

STATE OF OHIO ★ ANGELA COUNTS NOTARY PUBLIC ID# 2011HT0014 Commission Expires January 23, 2016 AUGLAIZE COUNTY

Trinity Highway Products , LLC
Certified By:
Quality Assurance

Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801

Customer: SAMPLES,TESTING,TRAINING MTRLS
2525 STEMMONS FRWY

DALLAS, TX 75207

Order Number: 1197356 Prod Ln Grp: 9-End Terminals (Dom)
Customer PO:
BOL Number: 75527 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 5/17/13

Project: TTI TEST 400923-3 31" MEDIAN RAIL (NOT TRINITY)

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
48	11G	12/12'6/3'1.5/S			2	L10613													
			M-180	A	2	4144812	58,600	79,500	22.0	0.230	0.760	0.009	0.007	0.020	0.030	0.000	0.020	0.002	4
			M-180	A	2	4144813	57,100	79,000	27.0	0.210	0.770	0.009	0.006	0.020	0.020	0.000	0.030	0.001	4
			M-180	A	2	4144815	56,400	78,000	31.0	0.220	0.750	0.010	0.006	0.010	0.030	0.000	0.020	0.002	4
			M-180	A	2	4144816	55,600	75,200	22.0	0.220	0.750	0.011	0.006	0.010	0.020	0.000	0.020	0.002	4
			M-180	A	2	4144819	57,900	79,000	27.0	0.220	0.750	0.010	0.007	0.010	0.020	0.000	0.020	0.002	4
			M-180	A	2	9407528	54,700	75,500	30.0	0.200	0.720	0.010	0.006	0.010	0.020	0.002	0.030	0.003	4
			M-180	A	2	9407531	56,400	78,100	28.0	0.210	0.730	0.008	0.005	0.010	0.020	0.002	0.030	0.002	4
			M-180	A	2	9407555	56,400	76,700	29.0	0.220	0.740	0.009	0.008	0.010	0.030	0.002	0.030	0.002	4
			M-180	A	2	C63862	61,900	81,600	26.6	0.210	0.840	0.015	0.004	0.040	0.110	0.002	0.060	0.001	4
8	10545G	12/9'4.5/1'6.75/S			2	L12013													
			M-180	A	2	166224	58,340	74,860	32.3	0.190	0.730	0.011	0.004	0.010	0.130	0.000	0.090	0.001	4
			M-180	A	2	166282	58,270	74,990	26.7	0.190	0.720	0.011	0.002	0.020	0.120	0.000	0.070	0.001	4
			M-180	A	2	166768	59,620	75,820	26.8	0.200	0.740	0.009	0.004	0.020	0.080	0.001	0.050	0.000	4
			M-180	A	2	166769	55,220	71,140	28.5	0.180	0.710	0.010	0.002	0.020	0.070	0.000	0.050	0.001	4
			M-180	A	2	41315760	67,000	87,600	27.0	0.200	0.870	0.007	0.002	0.030	0.080	0.000	0.030	0.001	4

TL -3 or TL-4 COMPLIANT when installed according to manufactures specifications

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy No. LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36
ALL COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT"
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM-123 (US DOMESTIC SHIPMENTS)
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A123 & ISO 1461 (INTERNATIONAL SHIPMENTS)

Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801
Customer: SAMPLES,TESTING,TRAINING MTRLS
2525 STEMMONS FRWY

DALLAS, TX 75207

Order Number: 1197356 Prod Ln Grp: 9-End Terminals (Dom)
Customer PO:
BOL Number: 75527 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 5/17/13

Project: TTI TEST 400923-3 31" MEDIAN RAIL (NOT TRINITY)

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

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

State of Ohio, County of Allen, Sworn and subscribed before me this 17th day of May, 2013
Notary Public:
Commission Expires

STATE OF OHIO ANGELA COUNTS NOTARY PUBLIC Commission Expires January 22, 2016 AUGLAIZE COUNTY

Certified By: Trinity Highway Products , LLC
Quality Assurance

Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801

Order Number: 1197242 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO:
BOL Number: 75489 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 5/16/13

Customer: SAMPLES,TESTING,TRAINING MTRLS
2525 STEMMONS FRWY

DALLAS, TX 75207

Project: PENNDOT WEAK POST

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
34	3G	12/12"/BACKUP	M-180	A	2	166282	58,270	74,990	26.7	0.190	0.720	0.011	0.002	0.020	0.120	0.000	0.070	0.001	4
20	11G	12/12'6/3'1.5/S			2	L10613													
			M-180	A	2	4144812	58,600	79,500	22.0	0.230	0.760	0.009	0.007	0.020	0.030	0.000	0.020	0.002	4
			M-180	A	2	4144813	57,100	79,000	27.0	0.210	0.770	0.009	0.006	0.020	0.020	0.000	0.030	0.001	4
			M-180	A	2	4144815	56,400	78,000	31.0	0.220	0.750	0.010	0.006	0.010	0.030	0.000	0.020	0.002	4
			M-180	A	2	4144816	55,600	75,200	22.0	0.220	0.750	0.011	0.006	0.010	0.020	0.000	0.020	0.002	4
			M-180	A	2	4144819	57,900	79,000	27.0	0.220	0.750	0.010	0.007	0.010	0.020	0.000	0.020	0.002	4
			M-180	A	2	9407528	54,700	75,500	30.0	0.200	0.720	0.010	0.006	0.010	0.020	0.002	0.030	0.003	4
			M-180	A	2	9407531	56,400	78,100	28.0	0.210	0.730	0.008	0.005	0.010	0.020	0.002	0.030	0.002	4
			M-180	A	2	9407555	56,400	76,700	29.0	0.220	0.740	0.009	0.008	0.010	0.030	0.002	0.030	0.002	4
			M-180	A	2	C63862	61,900	81,600	26.6	0.210	0.840	0.015	0.004	0.040	0.110	0.002	0.060	0.001	4
4	62G	12/25/6'3/S ET-2000 ANC			2	L11713													
			M-180	A	2	165617	57,070	75,470	30.4	0.190	0.720	0.010	0.004	0.010	0.120	0.000	0.060	0.001	4
			M-180	A	2	165620	59,230	75,960	26.1	0.190	0.730	0.012	0.004	0.020	0.120	0.001	0.060	0.000	4
			M-180	A	2	165860	57,710	75,180	28.0	0.190	0.720	0.011	0.004	0.020	0.120	0.000	0.060	0.001	4
			M-180	A	2	166223	58,970	76,290	28.1	0.190	0.720	0.010	0.005	0.010	0.120	0.000	0.070	0.001	4
			M-180	A	2	166224	58,340	74,860	32.3	0.190	0.730	0.011	0.004	0.010	0.130	0.000	0.090	0.001	4
			M-180	A	2	166225	61,810	77,130	28.6	0.190	0.730	0.011	0.002	0.020	0.120	0.000	0.080	0.001	4
			M-180	A	2	166226	54,560	73,550	30.6	0.190	0.720	0.011	0.005	0.020	0.130	0.000	0.080	0.001	4
			M-180	A	2	166404	61,640	77,570	24.9	0.180	0.720	0.014	0.003	0.030	0.100	0.000	0.060	0.001	4
			M-180	A	2	166405	56,380	72,870	29.4	0.190	0.730	0.010	0.003	0.010	0.100	0.000	0.060	0.001	4
6	533G	6'0 POST/8.5/DDR	A-36			25161	47,000	69,000	24.1	0.130	0.670	0.019	0.030	0.230	0.260	0.000	0.160	0.003	4
4	704A	CABLE ANCHOR BRKT	A-36			JJ1621	50,000	72,500	28.1	0.150	0.970	0.027	0.009	0.220	0.090	0.000	0.260	0.021	4

Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801

Customer: SAMPLES,TESTING,TRAINING MTRLS
2525 STEMMONS FRWY

DALLAS, TX 75207

Project: PENNDOT WEAK POST

Order Number: 1197242 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO:
BOL Number: 75489 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 5/16/13

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
	704A		A-500			D43983	66,767	75,769	23.0	0.190	0.820	0.015	0.007	0.014	0.030	0.007	0.040	0.001	4
4	10545G	12/9'4.5/1'6.75/S			2	L12013													
			M-180	A	2	166224	58,340	74,860	32.3	0.190	0.730	0.011	0.004	0.010	0.130	0.000	0.090	0.001	4
			M-180	A	2	166282	58,270	74,990	26.7	0.190	0.720	0.011	0.002	0.020	0.120	0.000	0.070	0.001	4
			M-180	A	2	166768	59,620	75,820	26.8	0.200	0.740	0.009	0.004	0.020	0.080	0.001	0.050	0.000	4
			M-180	A	2	41315760	67,000	87,600	27.0	0.200	0.870	0.007	0.002	0.030	0.080	0.000	0.030	0.001	4
12	15000G	6'0 SYT PST/8.5/31" GR HT	A-36			11333	47,000	68,000	19.5	0.110	0.630	0.021	0.026	0.240	0.250	0.002	0.280	0.004	4
4	33795G	SYT-3"AN STRT 3-HL 6'6	A-36			DL13101192	55,000	74,000	25.0	0.140	0.690	0.020	0.025	0.200	0.440	0.003	0.140	0.028	4

TL -3 or TL-4 COMPLIANT when installed according to manufactures specifications

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy No. LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36

ALL COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT"
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ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A123 & ISO 1461 (INTERNATIONAL SHIPMENTS)

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

Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801

Customer: SAMPLES,TESTING,TRAINING MTRLS
2525 STEMMONS FRWY

DALLAS, TX 75207

Project: PENNDOT WEAK POST

Order Number: 1197242 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO:
BOL Number: 75489 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 5/16/13

State of Ohio, County of Allen. Sworn and subscribed before me this 16th day of May, 2013

Notary Public:
Commission Expires: 1/23/2016

STATE OF OHIO
ANGELA COUNTS
NOTARY PUBLIC
ID# 2011NT0014
Commission Expires
January 23, 2016
AUGLAIZE COUNTY

Trinity Highway Products , LLC
Certified By:
Quality Assurance

3 of 3

**LAND 15

NUCOR STEEL - BERKELEY
P.O. Box 2259
Mt. Pleasant, S.C. 29464
Phone: (843) 336-6000

CERTIFIED MILL TEST REPORT

3/19/13 16:05:39

100% MELTED AND MANUFACTURED IN THE USA
All beams produced by Nucor-Berkeley are cast and rolled to a fully killed and fine grain practice.
Mercury has not been used in the direct manufacturing of this material.

Customer #.: 997 - 12
Customer PO: HOU-152130
B.o.L. #...: 1002410
MOS: T

SPECIFICATIONS: Tested in accordance with ASTM specification A6-12/A6M-12 and A370, Quality Manual Rev #26.
AASHTO : M270-50-05
ASME : SA-36 07a
ASTM : A992-11:A36-08/A529-05-50/A572-12-50/A70911 50s
CSA : G40.21-50w

Description	Heat# Grade(s) Test/Heat JW	Yield/ Tensile Ratio	Yield (PSI) (MPa)	Tensile (PSI) (MPa)	Elong %	C Cr ******	Mn Mo Ti	P Sn ******	S B ******	Si V N	Cu Nb ******	Ni ****** CI	CE1 CE2 Pcm
S3X5.7	2302870	.82	59100	72500	26.68	.07	.81	.011	.036	.20	.26	.14	.25
040' 00.00"	A992-11		407	500		.07	.02	.0112	.0003	.004	.014		.2836
S75X8.5		.81	59600	73200	26.23		.001			.0078		5.34	.1357
012.1920m			411	505	105 Pc(s)	23,940 lbs						Inv#:	0
S4X7.7	2302796	.81	56100	69000	27.46	.06	.84	.010	.030	.19	.27	.08	.25
040' 00.00"	A992-11		387	476		.07	.01	.0115	.0001	.004	.014		.2805
S100X11.5		.81	55900	68600	26.50		.001			.0065		5.27	.1333
012.1920m			385	473	60 Pc(s)	18,480 lbs						Inv#:	0

2 Heat(s) for this MTR.

Elongation based on 8" (20.32cm) gauge length. 'No Weld Repair' was peformed.

CI = 26.01Cu+3.88Ni+1.20Cr+1.49Si+17.28P-(7.29Cu*Ni)-(9.10Ni*P)-33.39(Cu*Cu)

Pcm = C+(Si/30)+(Mn/20)+(Cu/20)+(Ni/60)+(Cr/20)+(Mo/15)+(V/10)+5B

CE1 = C+(Mn/6)+((Cr+Mo+V)/5)+((Ni+Cu)/15)

CE2 = C+((Mn+Si)/6)+((Cr+Mo+V+Cb)/5)+((Ni+Cu)/15)

I hereby certify that the contents of this report are accurate and correct. All test results and operations performed by the material manufacturer are in compliance with material specifications, and when designated by the Purchaser, meet applicable specifications.

Bruce A. Work
Metallurgist

**END

SOLD TO: NAMASCO CORP
500 COLONIAL CENTER PKWY
STE 500
ROSWELL, GA 30076-

SHIP TO: NAMASCO
SOUTH LOOP 4
BUDA, TX 78610-

NUCOR
NUCOR CORPORATION
NUCOR STEEL TEXAS

CERTIFIED MILL TEST REPORT

Page: 1

Ship from:

Nucor Steel - Texas
8812 Hwy 79 W
JEWETT, TX 75846
800-527-6445

Date: 4-Jun-2012
B.L. Number: 606769
Load Number: 215610

Material Safety Data Sheets are available at www.nucorbar.com or by contacting your inside sales representative.

NSMG-09 January 1, 2012

LOT # / HEAT #	DESCRIPTION	PHYSICAL TESTS					CHEMICAL TESTS						
		YIELD P.S.I.	TENSILE P.S.I.	ELONG % IN 8"	BEND	WT% / DEF	C / Ni	Mn / Cr	P / Mo	S / V	Si / Cb	Cu / Sn	C.E.
PO# =>	6477584												
JW1210123503	Nucor Steel - Texas	45,600	65,200	29.0%			.10	.76	.006	.030	.24	.32	.30
JW12101235	1/2x8" Flat	314MPa	450MPa				.21	.12	.063	.002	.002		
	20' A36	45,700	66,100	26.0%									
	ASTM A36/A36M-08, A709/709M-11 G	315MPa	456MPa										
	R36, ASME SA36-10 Ed '11 Ad.												
PO# =>	6477584												
JW1210123801	Nucor Steel - Texas	49,500	70,500	26.0%			.12	.77	.014	.030	.20	.30	.33
JW12101238	1/4x8" Flat	341MPa	486MPa				.20	.20	.059	.003	.002		
	20' A36	49,000	71,400	29.0%			REDRAT						
	ASTM A36/A36M-08, A709/709M-11 G	338MPa	492MPa				PB = *	**					
	R36, ASME SA36-10 Ed '11 Ad.												
PO# =>	6478956												
JW1210291801	Nucor Steel - Texas	49,900	71,000	27.0%			.12	.64	.019	.030	.18	.35	.32
JW12102918	3x2x1/4 Angle	344MPa	490MPa				.19	.20	.062	.003	.001		
	20' A36	49,000	70,400	23.0%									
	ASTM A36/A36M-08, A709/709M-11 G	338MPa	485MPa										
	R36, ASME SA36-10 Ed '11 Ad.												
	PCS: 189 / TONS: 7.75												
	COMPLIES WITH DIN 50049 PARA 3.1B & EN 10204-3.1												
PO# =>	6471915												
JW1210341702	Nucor Steel - Texas	53,000	72,800	27.0%			.12	.74	.013	.030	.23	.35	.32
JW12103417	1/4x12" Flat	365MPa	502MPa				.16	.18	.054	.003	.003		
	20' A36	52,300	71,100	26.0%									
	ASTM A36/A36M-08, A709/709M-11 G	361MPa	490MPa										
	R36, ASME SA36-10 Ed '11 Ad.												
	ASTM A709/A709M-11 GR 36												
	ASME SA36-2007 EDITION-2011 ADDE												
	NDA												

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.
1.) Weld repair was not performed on this material.
2.) Melted and Manufactured in the United States.
3.) Mercury, Radium, or Alpha source materials in any form have not been used in the production of this material.

QUALITY ASSURANCE: *Nathan Stewart*

TRIPLE-S STEEL

010709
STANDARD "I" BEAM A-36/A 572 GR 50
3 X 5.7 X 20'
PART NO.

P.O/Rel 129*97
TRIPLE S STEEL SUPPLY CO.

Certificate of Mill Test Results

BL HOU-107922-002

NUCOR STEEL - BERKELEY
P.O. Box 2259
Mt. Pleasant, S.C. 29464
Phone: (843) 336-6000

MILL TEST REPORT

6/08/06 0:23:35
100% MELTED AND MANUFACTURED IN THE USA
All beams produced by Nucor-Berkeley are cast and rolled to a fully killed and fine grain practice.

Sold To: TRIPLE S STEEL COMPANY
6000 JENSEN DRIVE
PO BOX 21119
HOUSTON, TX 77226

Ship To: TRIPLE S STEEL COMPANY
TRIPLE S STEEL COMPANY
6000 JENSEN DRIVE
HOUSTON, TX 77026

Customer #.: 997 - 1
Customer PO: HOU-108530
B.O.L. #...: 540529

SPECIFICATIONS: Tested in accordance with ASTM specification A6/A6M and A370.
AASHTO : M270-36-00/M270-50-00
ASME : SA-36
ASTM : A992-04a:/A36-04/A572-04-50/A709-04a36/A709-04a50/A709-345M
CSA : CSA-44W/G40.21-50W

Description	Heat# Grade(s) Test	Yield/ Tensile Ratio	Yield (PSI) (MPa)	Tensile (PSI) (MPa)	Elong %	C Cr Pb	Mn Mo Ti	P Sn Ca	S Al B	Si V N	Cu Nb Zr	Ni ****** CI	CE1 CE2 Pcm
S3X5.7 040' 00.00" S75X8.5 012.1920m	2608630 A992-04a	.80 .78	53400 368 51800 357	67100 463 66200 456	26.79 26.19	.0660 .0350 .0088	.9110 .0220 .0018	.0083 .0057 .0042	.0186 .0022 .0013	.1810 .0051 .0063	.0930 .0105 .0000	.0360 2.6978	.2389 .2711 .1329
						140 Piece(s)						Inv#:	0
S3X7.5 040' 00.00" S75X11.2 012.1920m	1608754 A992-04a	.82 .81	59000 407 57200 394	71600 494 70800 488	24.75 26.03	.0690 .0356 .0059	.8760 .0200 .0014	.0089 .0061 .0003	.0283 .0012 .0013	.2370 .0038 .0060	.1000 .0273 .0000	.0450 2.9542	.2364 .2814 .1363
						28 Piece(s)						Inv#:	0
S3X7.5 040' 00.00" S75X11.2 012.1920m	2608760 A992-04a	.81 .81	58100 401 58400 403	72100 497 72400 499	26.48 25.36	.0660 .0320 .0083	.8350 .0200 .0021	.0098 .0065 .0038	.0340 .0030 .0017	.2220 .0041 .0052	.0990 .0278 .0000	.0410 2.9121	.2257 .2683 .1325
						7 Piece(s)						Inv#:	0

3 Heat(s) for this MTR.

Elongation based on 8" (20.32cm) gauge length. 'No Weld Repair' was peformed.
CI = 26.01Cu+3.88Ni+1.20Cr+1.49Si+17.28P-(7.29Cu*Ni)-(9.10Ni*P)-33.39(Cu*Cu)
Pcm = C+(Si/30)+(Mn/20)+(Cu/20)+(Ni/60)+(Cr/20)+(Mo/15)+(V/10)+5B
CE1 = C+(Mn/6)+((Cr+Mo+V)/5)+((Ni+Cu)/15)
CE2 = C+((Mn+Si)/6)+((Cr+Mo+V+Cb)/5)+((Ni+Cu)/15)

I hereby certify that the contents of this report are accurate and correct. All test results and operations performed by the material manufacturer are in compliance with material specifications, and when designated by the Purchaser, meet applicable specifications.
**END

Bruce A. Work
Metallurgist

B2. CRASH TEST NO. 490023-6-2

MATERIAL USED

TEST NUMBER	490023-6-2
TEST NAME	F631
DATE	2013-08-15

DATE RECEIVED	ITEM NUMBER	DESCRIPTION	SUPPLIER	HEAT #
2013-08-12	S-section-03	S3x5.7 x 20' - A992	Mack Bolt & Steel	see attached

This material was used to fabricate posts 11 - 15, which were damaged in the previous test.
All other material and parts are the same as the previous test.

NUCOR STEEL - BERKELEY
P.O. Box 2259
Mt. Pleasant, S.C. 29464
Phone: (843) 336-6000

MILL TEST REPORT

6/08/06 0:23:35
100% MELTED AND MANUFACTURED IN THE USA
All beams produced by Nucor-Berkeley are cast and rolled to a fully killed and fine grain practice.

Customer #.: 597 - 1
Customer PO: HOU-108530
B.o.L. #...: 540529

SPECIFICATIONS: Tested in accordance with ASTM specification A6/A6M and A370.
AASHTO : M270-36-00/M270-50-00
ASME : SA-36
ASTM : A992-04a:/A36-04/A572-04-50/A709-04a36/A709-04a50/A709-345M
CSA : CSA-44W/G40.21-50W

Description	Heat# Grade(s) Test	Yield/ Tensile Ratio	Yield (PSI) (MPa)	Tensile (PSI) (MPa)	Elong %	C Cr Pb	Mn Mo Ti	P Sn Ca	S Al B	Si V N	Cu Nb Zr	Ni ****** CI	CE1 CE2 Pcm
S3X5.7	2608630	.80	53400	67100	26.79	.0660	.9110	.0083	.0186	.1810	.0930	.0360	.2389
040' 00.00"	A992-04a		368	463		.0250	.0220	.0057	.0022	.0051	.0105		.2711
S75X8.5		.78	51800	66200	26.19	.0088	.0018	.0042	.0013	.0063	.0000	2.6974	.1329
012.1920m			357	456		240 Piece(s)						Inv#:	0
S3X7.5	1608754	.82	59000	71600	24.76	.0690	.8760	.0089	.0283	.2370	.1000	.0450	.2364
040' 00.00"	A992-04a		407	494		.0350	.0200	.0061	.0012	.0038	.0273		.2814
S75X11.2		.81	57200	70800	26.03	.0059	.0014	.0003	.0013	.0060	.0000	2.9542	.1363
012.1920m			394	488		28 Piece(s)						Inv#:	0
S3X7.5	2608760	.81	58100	72100	26.48	.0660	.8350	.0098	.0340	.2220	.0950	.0410	.2257
040' 00.00"	A992-04a		401	497		.0320	.0200	.0065	.0030	.0041	.0278		.2683
S75X11.2		.81	58400	72400	25.36	.0083	.0021	.0038	.0017	.0052	.0000	2.9121	.1325
012.1920m			403	499		7 Piece(s)						Inv#:	0

3 Heat(s) for this MTR.

Elongation based on 8" (20.32cm) gauge length. 'No Weld Repair' was peformed.

$CI = 26.01Cu+3.88Ni+1.20Cr+1.49Si+17.28P-(7.29Cu*Ni)-(9.10Ni*P)-33.39(Cu*Cu)$

$Pcm = C+(Si/30)+(Mn/20)+(Cu/20)+(Ni/60)+(Cr/20)+(Mo/15)+(V/10)+5B$

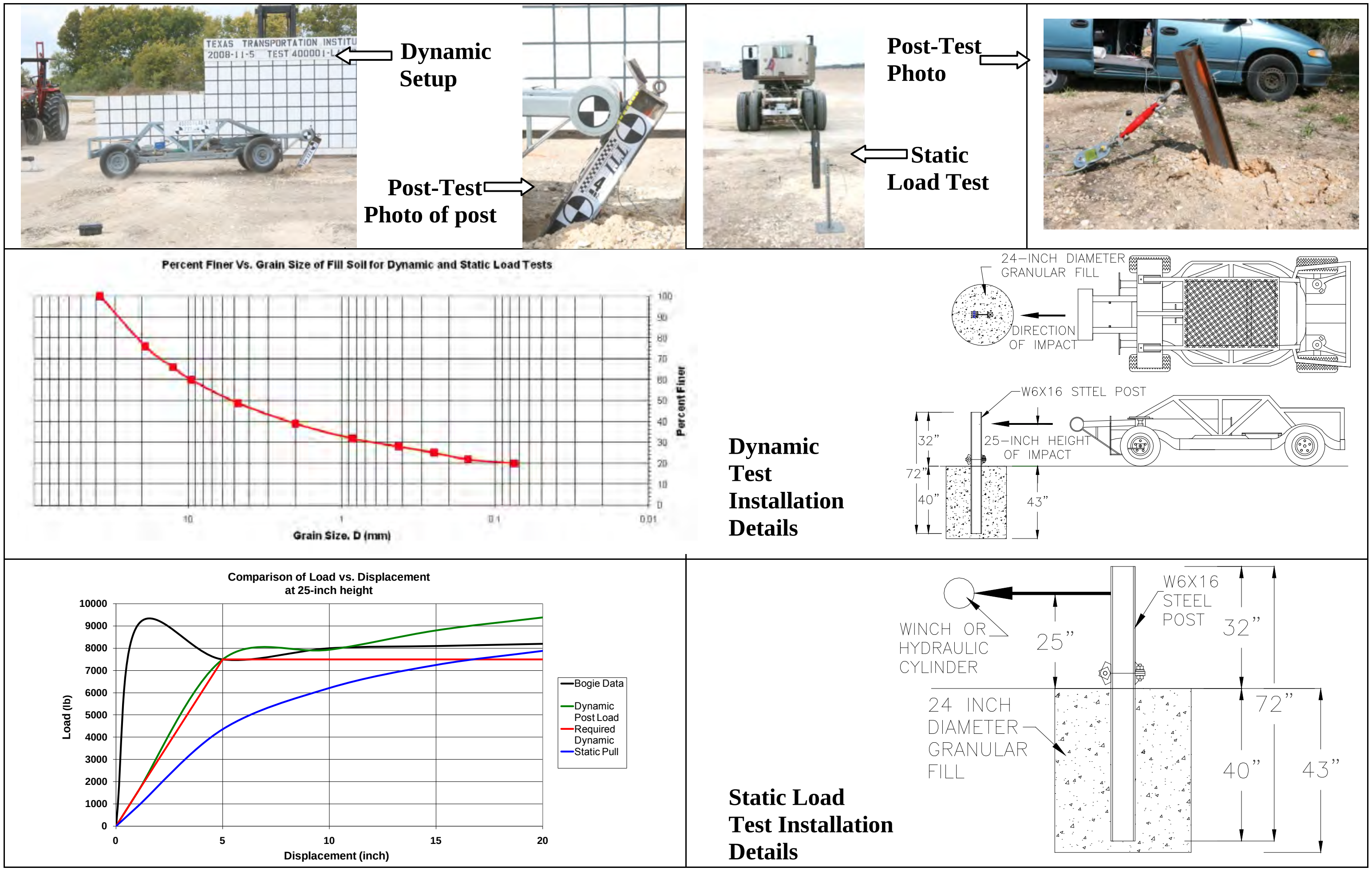
$CE1 = C+(Mn/6)+((Cr+Mo+V)/5)+((Ni+Cu)/15)$

$CE2 = C+((Mn+Si)/6)+((Cr+Mo+V+Cb)/5)+((Ni+Cu)/15)$

I hereby certify that the contents of this report are accurate and correct. All test results and operations performed by the material manufacturer are in compliance with material specifications, and when designated by the Purchaser, meet applicable specifications.

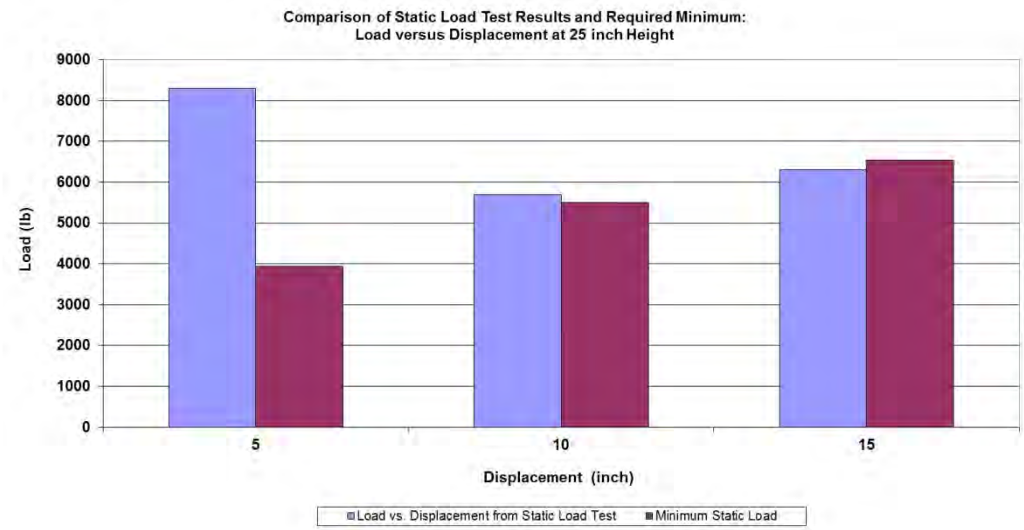
Bruce A. Work
Metallurgist

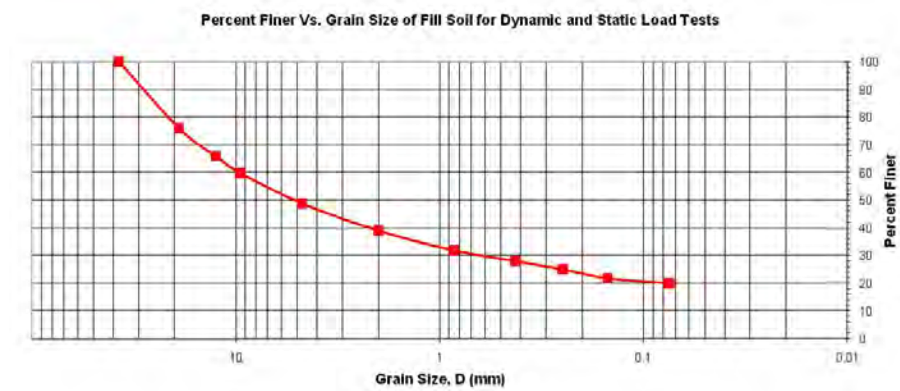
**END



Date	2008-11-05
Test Facility and Site Location	TTI Proving Ground, 3100 SH 47, Bryan, TX 77807
In Situ Soil Description (ASTM D2487	Sandy gravel with silty fines
Fill Material Description (ASTM D2487) and sieve analysis	AASHTO Grade B Soil-Aggregate (see sieve analysis above)
Description of Fill Placement Procedure	6-inch lifts tamped with a pneumatic compactor
Bogie Weight	5009 lb
Impact Velocity	20.5 mph

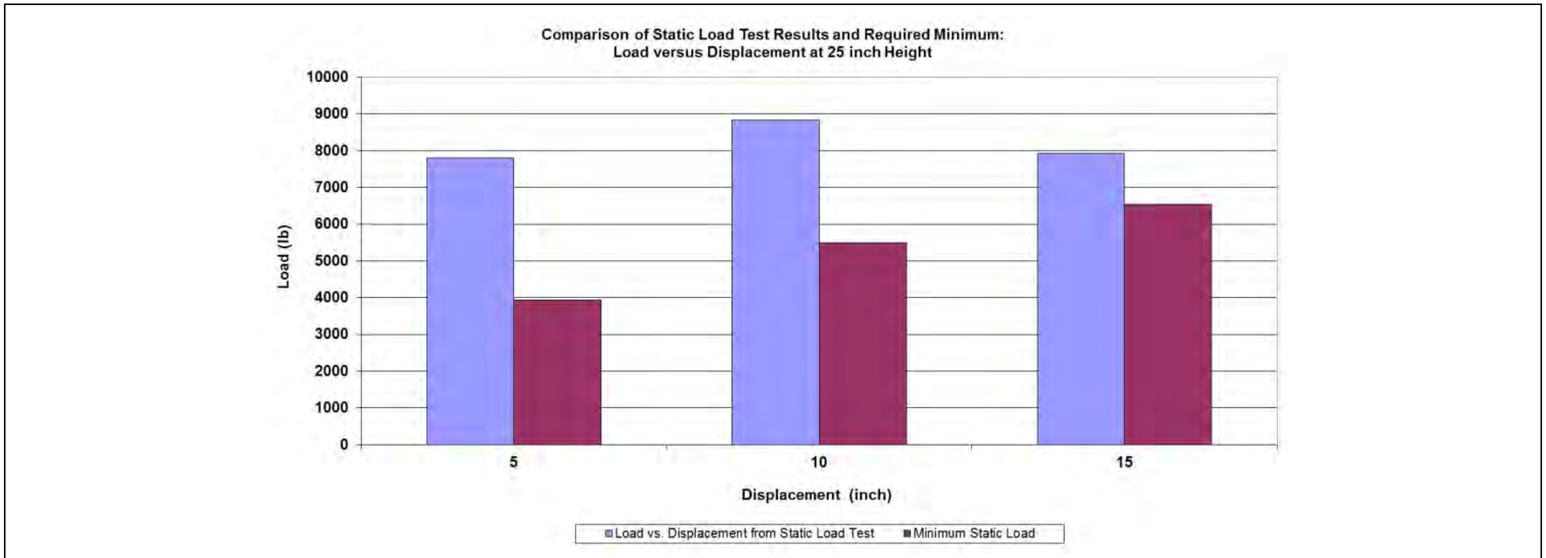
Figure C1. Summary of Strong Soil Test Results for Establishing Installation Procedure.

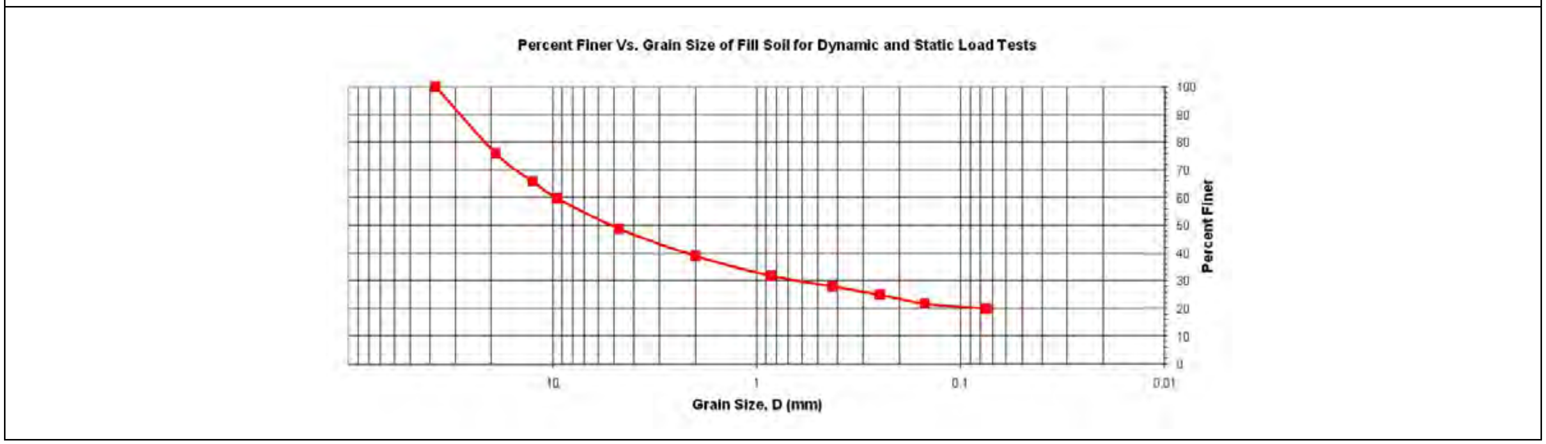




Date	2013-08-13
Test Facility and Site Location	TTI Proving Ground–3100 SH 47, Bryan, TX
In Situ Soil Description (ASTM D2487)	Sandy gravel with silty fines
Fill Material Description (ASTM D2487) and sieve analysis	AASHTO Grade B Soil-Aggregate (see sieve analysis)
Description of Fill Placement Procedure	6-inch lifts tamped with a pneumatic compactor

Figure C2. Test Day Static Soil Strength Documentation for Test No. 490023-6-1a.





Date	2013-08-15
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

Figure C3. Test Day Static Soil Strength Documentation for Test No. 490023-6-2.

APPENDIX D. CRASH TEST NO. 490023-6-1A.

D1. VEHICLE PROPERTIES AND INFORMATION

Table D1. Vehicle Properties for Test No. 490023-6-1a.

Date: 2013-08-08 Test No.: 490023-6-1a VIN No.: 1D7HA182Y8J109407

Year: 2008 Make: Dodge Model: Ram 1500

Tire Size: 265/70R17 Tire Inflation Pressure: 35 psi

Tread Type: ______ Odometer: 253131

Note any damage to the vehicle prior to test: ______

● Denotes accelerometer location.

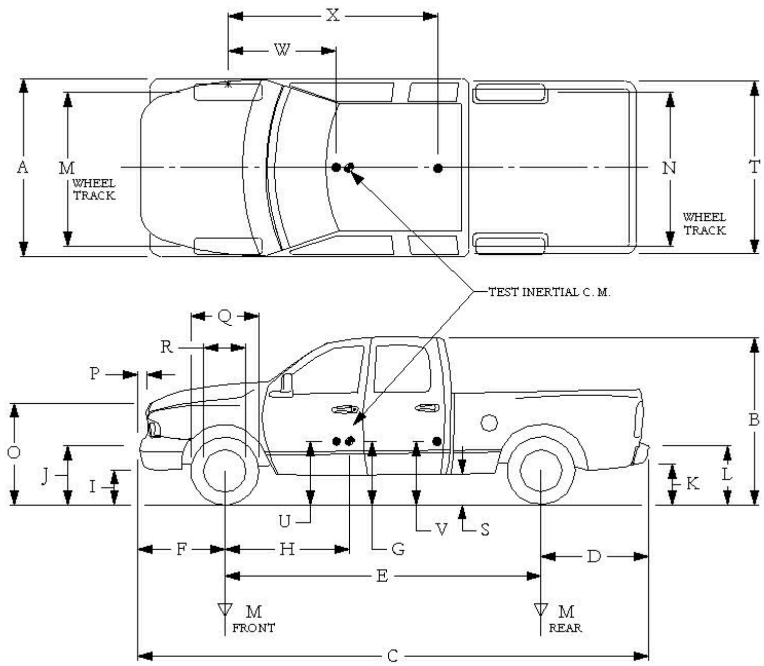
NOTES: ______

Engine Type: V-8
Engine CID: 5.7 liter

Transmission Type:
x Auto or ____ Manual
____ FWD x RWD ____ 4WD

Optional Equipment: ______

Dummy Data:
Type: No dummy used
Mass: ______
Seat Position: ______



Geometry: inches

A	78.25	F	36.00	K	19.50	P	3.88	U	28.75
B	76.00	G	28.25	L	29.00	Q	30.50	V	31.50
C	225.75	H	61.68	M	68.50	R	18.38	W	61.60
D	47.25	I	15.50	N	68.00	S	16.00	X	75.00
E	140.50	J	27.50	O	46.00	T	77.50		

Wheel Center Height Front	14.75	Wheel Well Clearance (Front)	6.00	Bottom Frame Height - Front	18.75
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	11.25	Bottom Frame Height - Rear	26.00

GVWR Ratings:		Mass: lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2903	2833	----
Back	3900	M_{rear}	2191	2217	----
Total	6700	M_{Total}	5094	5050	----

Mass Distribution:
lb LF: 1426 RF: 1407 LR: 1085 RR: 1132

Table D2. Vehicle Parametric Measurements for Vertical CG for Test No. 490023-6-1a.

Date: 2013-08-08 Test No.: 490023-6-1a VIN: 1D7HA182Y8J109407

Year: 2008 Make: Dodge Model: 1500 Ram

Body Style: Quad Cab Mileage: 253131

Engine: 5.7 liter V-8 Transmission: Automatic

Fuel Level: Empty Ballast: 176 lb (440 lb max)

Tire Pressure: Front: 35 psi Rear: 35 psi Size: 265/70R17

Measured Vehicle Weights: (lb)

LF:	1426	RF:	1407	Front Axle:	2833
LR:	1085	RR:	1132	Rear Axle:	2217
Left:	2511	Right:	2539	Total:	5050
					5000 ±110 lb allowed

Wheel Base: 140.5 inches Track: F: 68.5 inches R: 68 inches

148 ±12 inches allowed Track = (F+R)/2 = 67 ±1.5 inches allowed

Center of Gravity, SAE J874 Suspension Method

X: 61.68 in Rear of Front Axle (63 ±4 inches allowed)

Y: 0.19 in Left - Right + of Vehicle Centerline

Z: 28.25 in Above Ground (minumum 28.0 inches allowed)

Hood Height: 46.00 inches Front Bumper Height: 27.50 inches

43 ±4 inches allowed

Front Overhang: 36.00 inches Rear Bumper Height: 29.00 inches

39 ±3 inches allowed

Overall Length: 223.75 inches

237 ±13 inches allowed

Table D3. Exterior Crush Measurements for Test No. 490023-6-1a.

Date: 2013-08-08 Test No.: 490023-6-1a VIN No.: 1D7HA182Y8J109407

Year: 2008 Make: Dodge Model: Ram 1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage		Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width** (CDC)	Max*** Crush								
1	Front plane at bumper ht	14	5	20	5	4.5	3	1.5	0.75	0	-24
2	Side plane at bumper ht	14	6	57	1	1	---	---	5.5	6	180
	Measurements recorded										
	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).

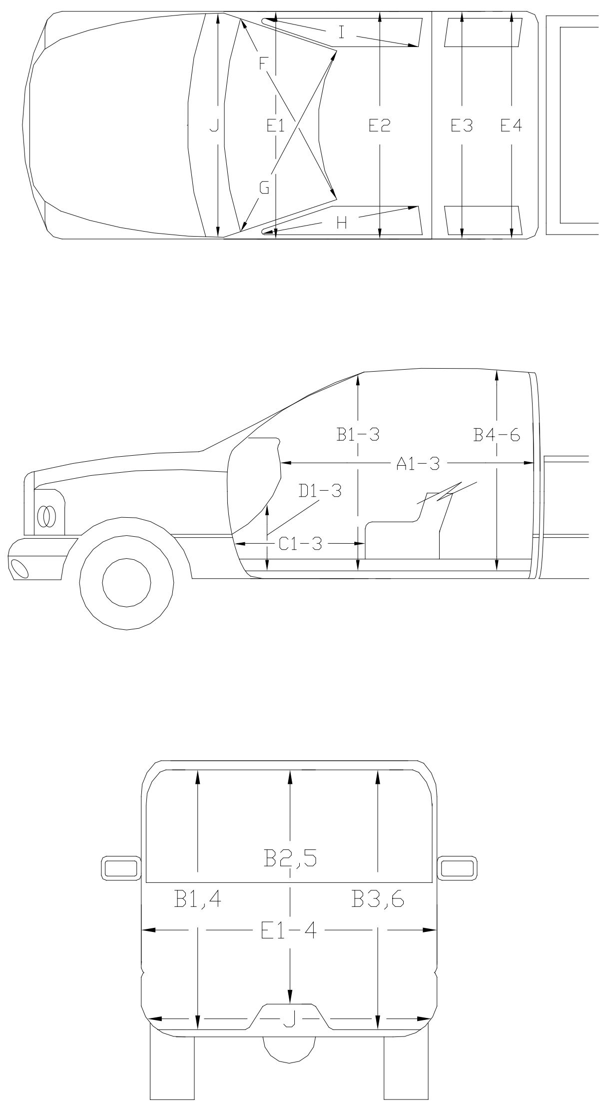
***Measure and document on the vehicle diagram the location of the maximum crush.

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

Table D4. Occupant Compartment Measurements for Test No. 490023-6-1a.

Date: 2013-08-08 Test No.: 490023-6-1a VIN No.: 1D7HA182Y8J109407

Year: 2008 Make: Dodge Model: Ram 1500



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

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before (inches)	**After** (inches)
A1	64.50	64.50
A2	64.50	64.50
A3	64.50	64.50
B1	45.12	45.12
B2	42.50	42.50
B3	45.12	45.12
B4	42.00	42.00
B5	44.75	44.75
B6	42.00	42.00
C1	29.00	29.00
C2	----	----
C3	26.75	26.75
D1	13.00	13.00
D2	----	----
D3	11.75	11.75
E1	62.75	62.75
E2	64.75	64.75
E3	64.12	64.12
E4	64.50	64.50
F	60.00	60.00
G	60.00	60.00
H	39.00	39.00
I	39.00	39.00
J*	62.17	62.17

D2. SEQUENTIAL PHOTOGRAPHS

0.000 s

0.128 s

0.256 s

0.384 s

Figure D1. Sequential Photographs for Test No. 490023-6-1a (Overhead and Frontal Views).

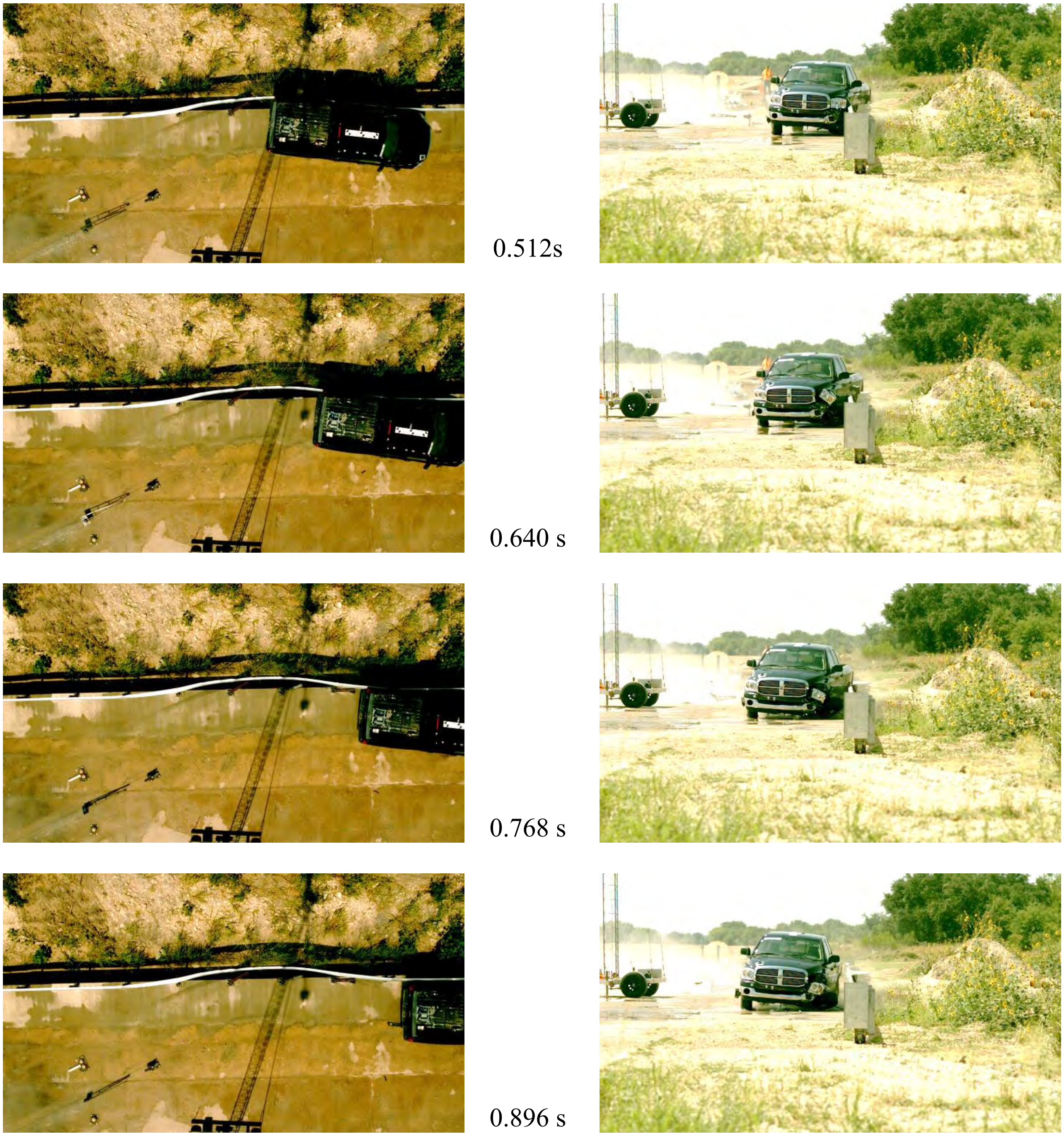


Figure D1. Sequential Photographs for Test No. 490023-6-1a (Overhead and Frontal Views) (continued).

0.000 s

0.128 s

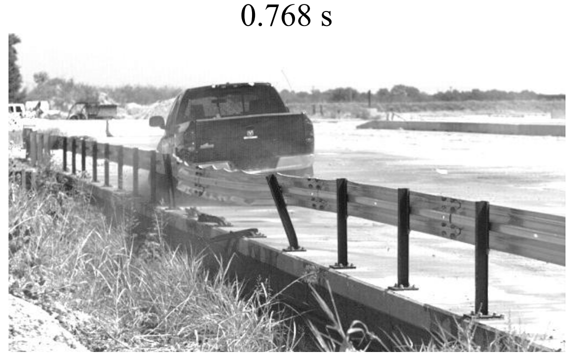
0.256 s

0.384 s

0.512 s

0.640 s

0.768 s



0.896 s

Figure D2. Sequential Photographs for Test No. 490023-6-1a (Rear View).

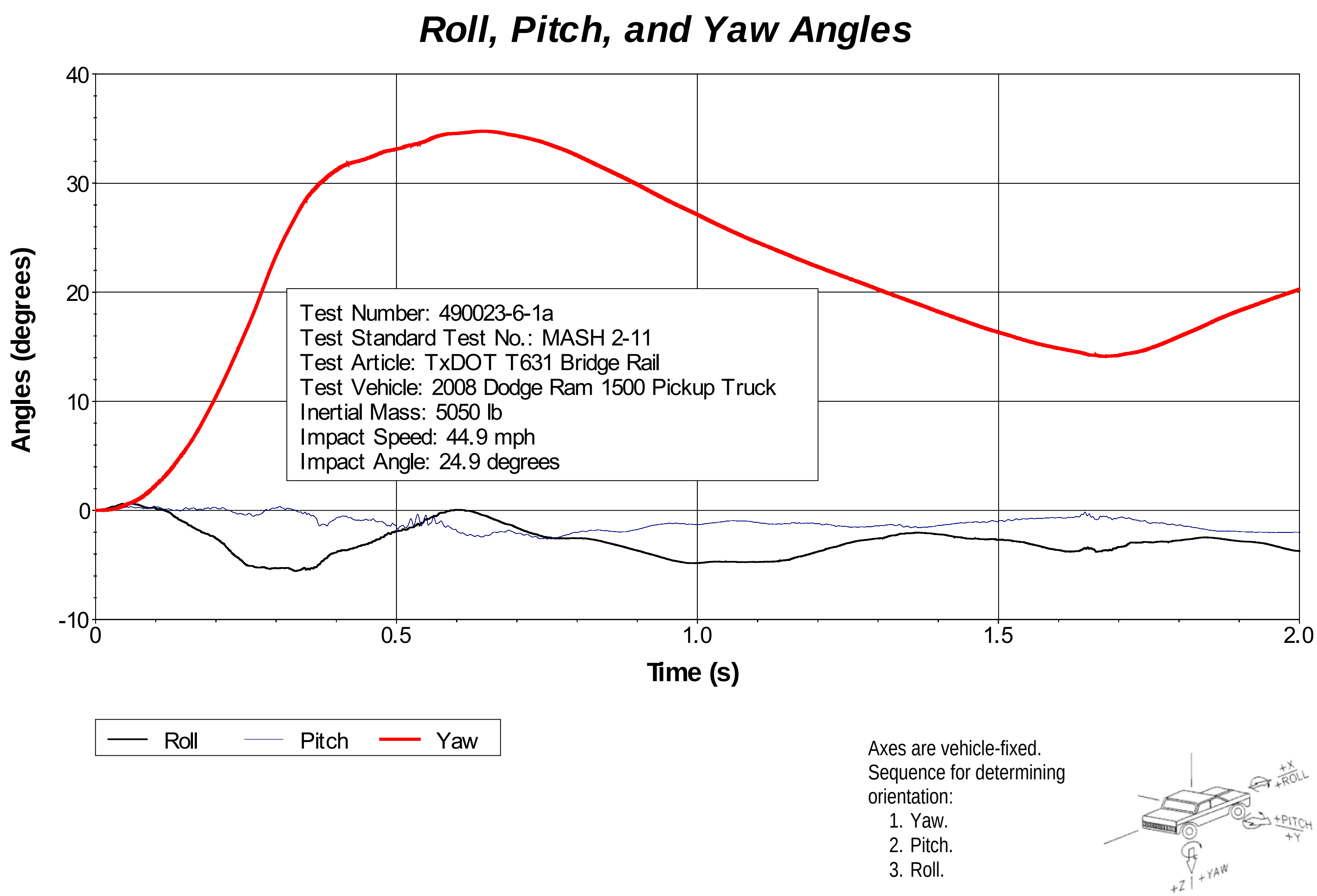


Figure D3. Vehicle Angular Displacements for Test No. 490023-6-1a.

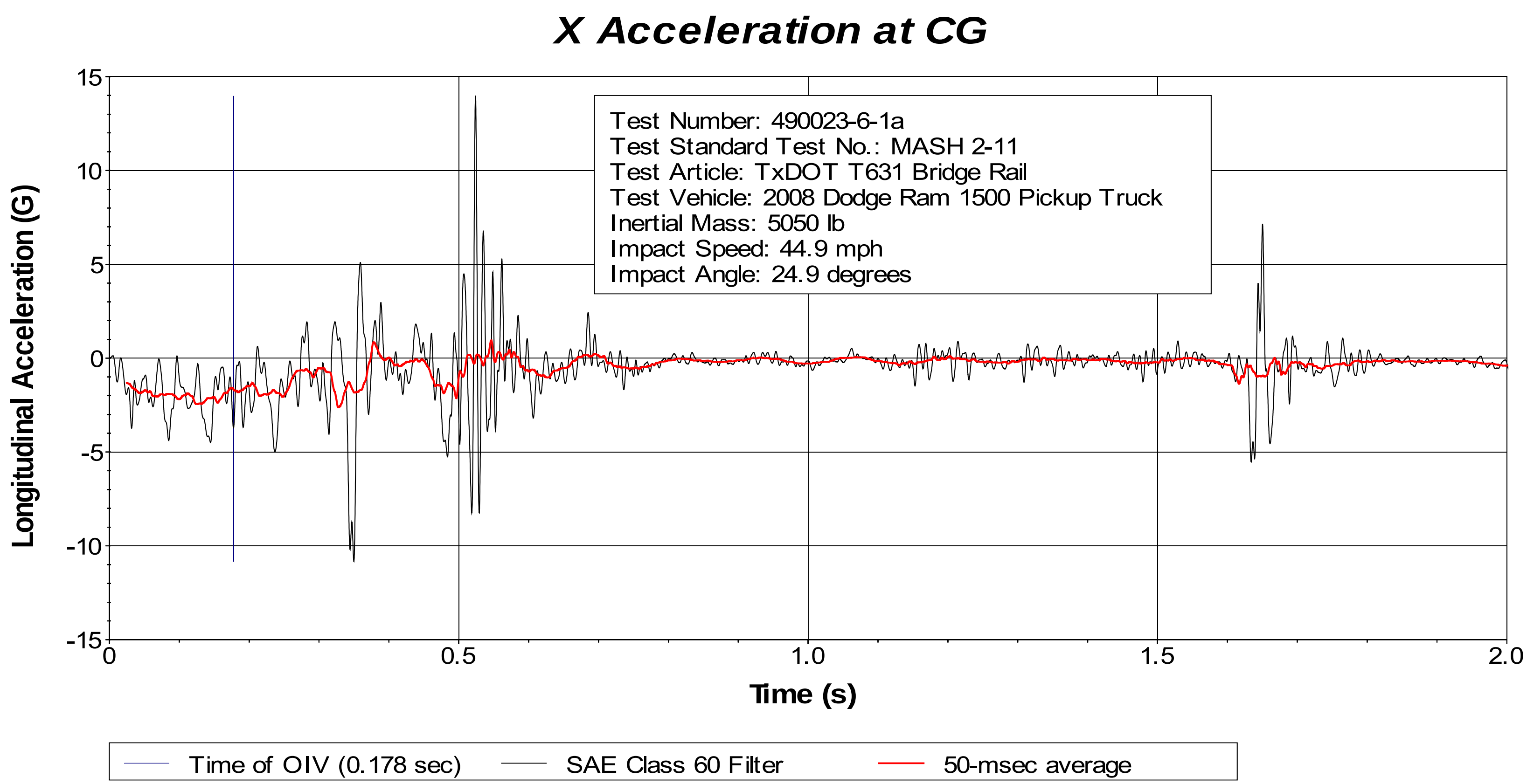


Figure D4. Vehicle Longitudinal Accelerometer Trace for Test No. 490023-6-1a (Accelerometer Located at Center of Gravity).

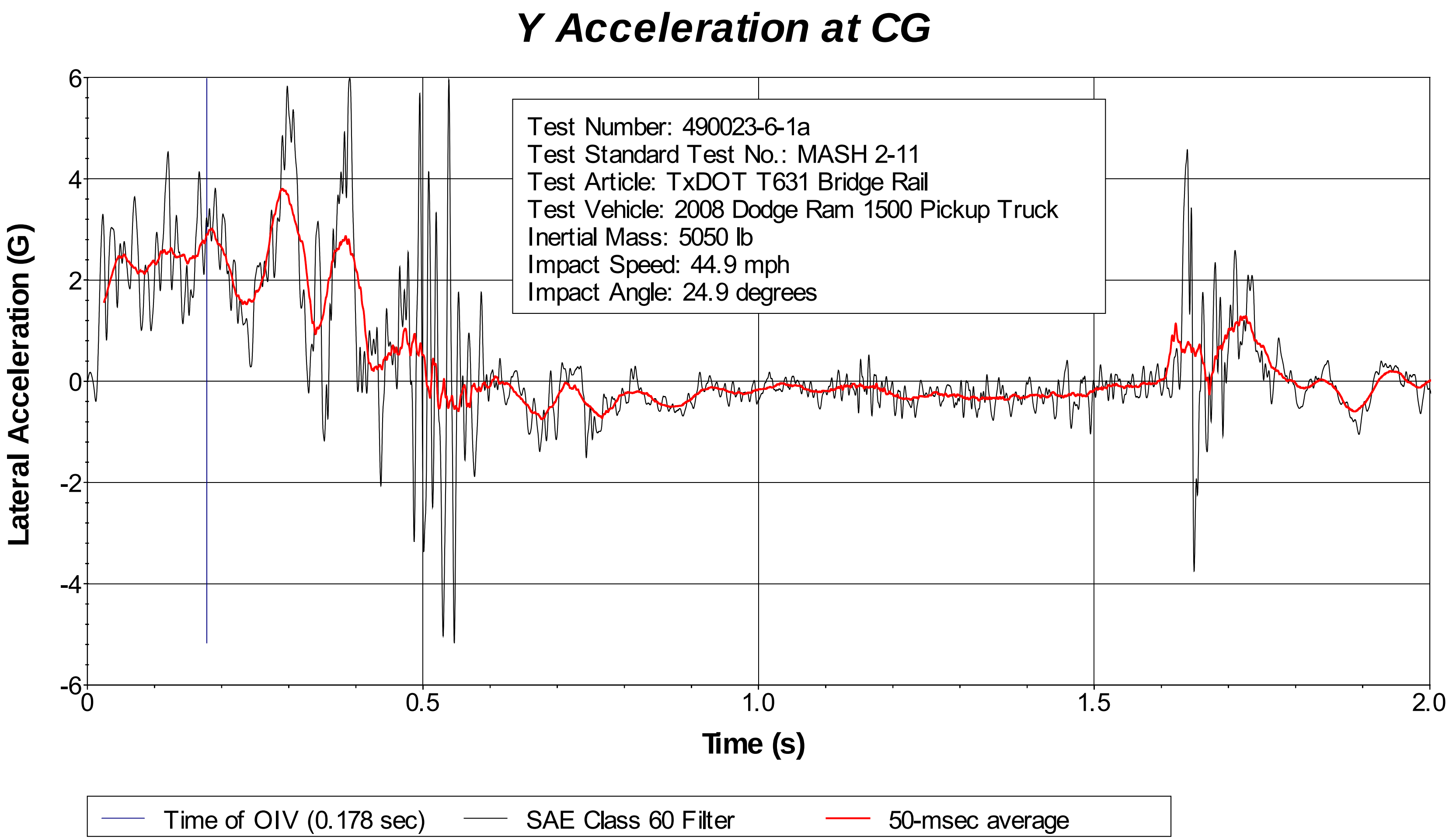


Figure D5. Vehicle Lateral Accelerometer Trace for Test No. 490023-6-1a (Accelerometer Located at Center of Gravity).

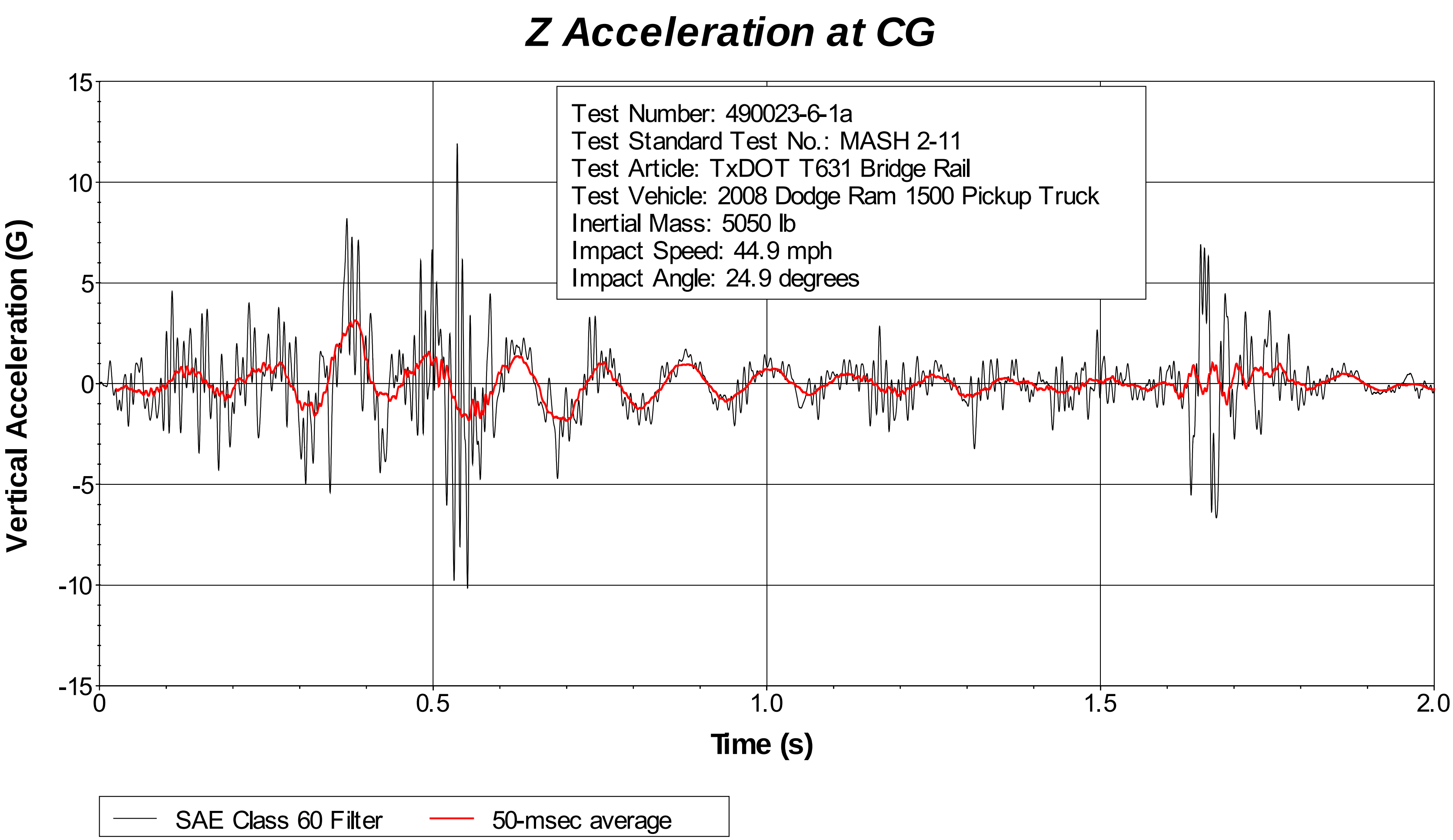


Figure D6. Vehicle Vertical Accelerometer Trace for Test No. 490023-6-1a (Accelerometer Located at Center of Gravity).

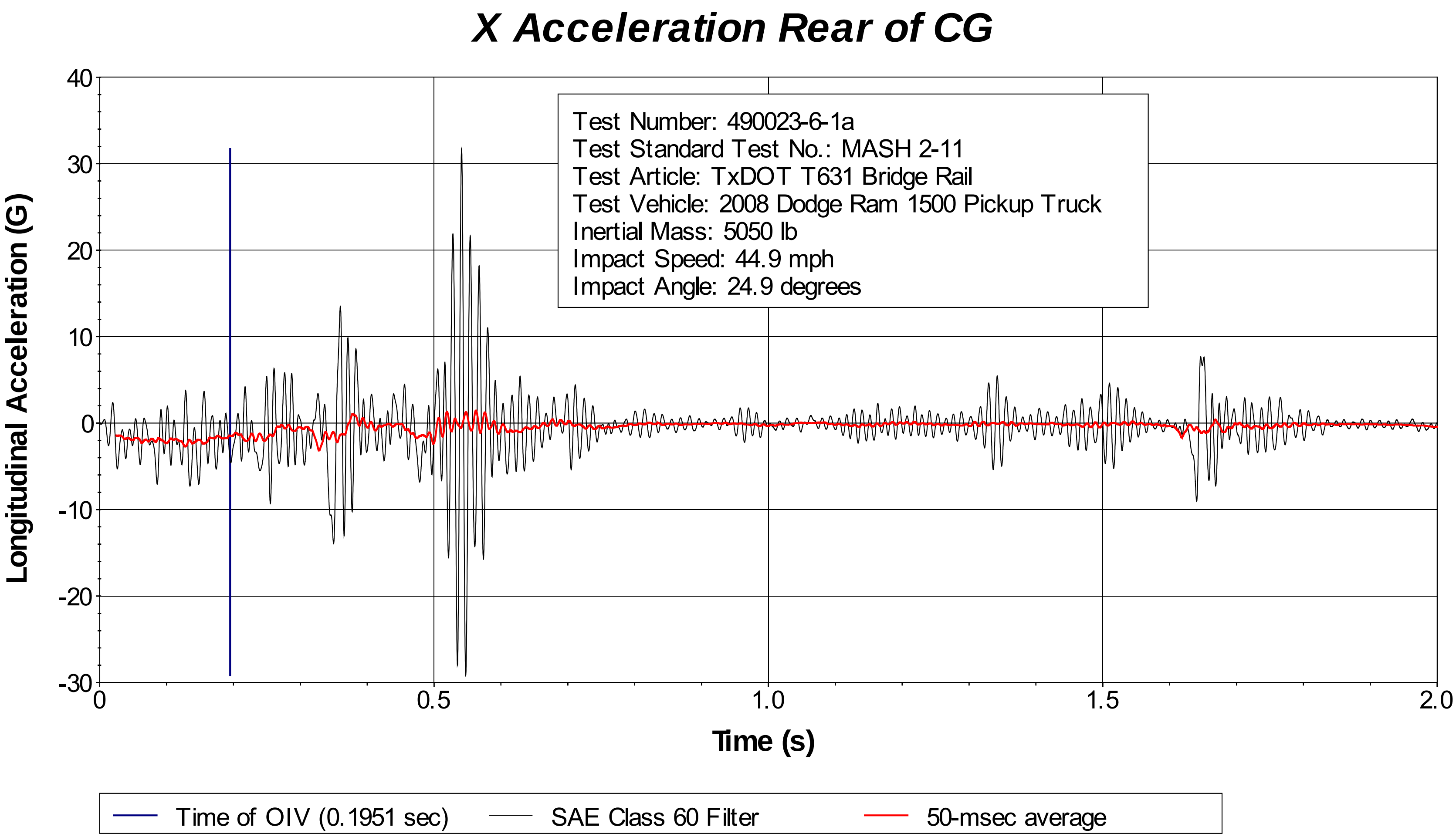


Figure D7. Vehicle Longitudinal Accelerometer Trace for Test No. 490023-6-1a (Accelerometer Located Rear of Center of Gravity).

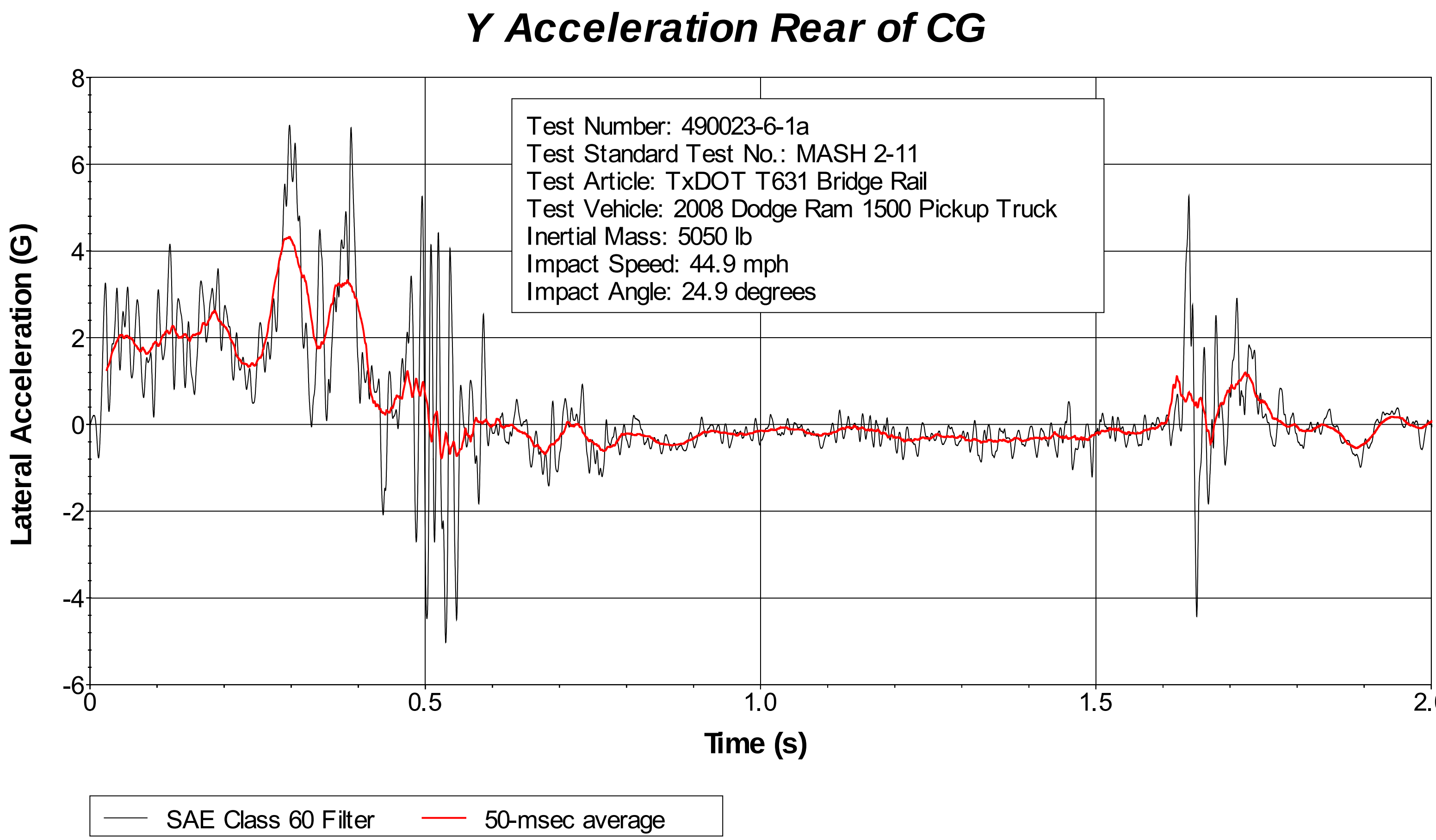


Figure D8. Vehicle Lateral Accelerometer Trace for Test No. 490023-6-1a (Accelerometer Located Rear of Center of Gravity).

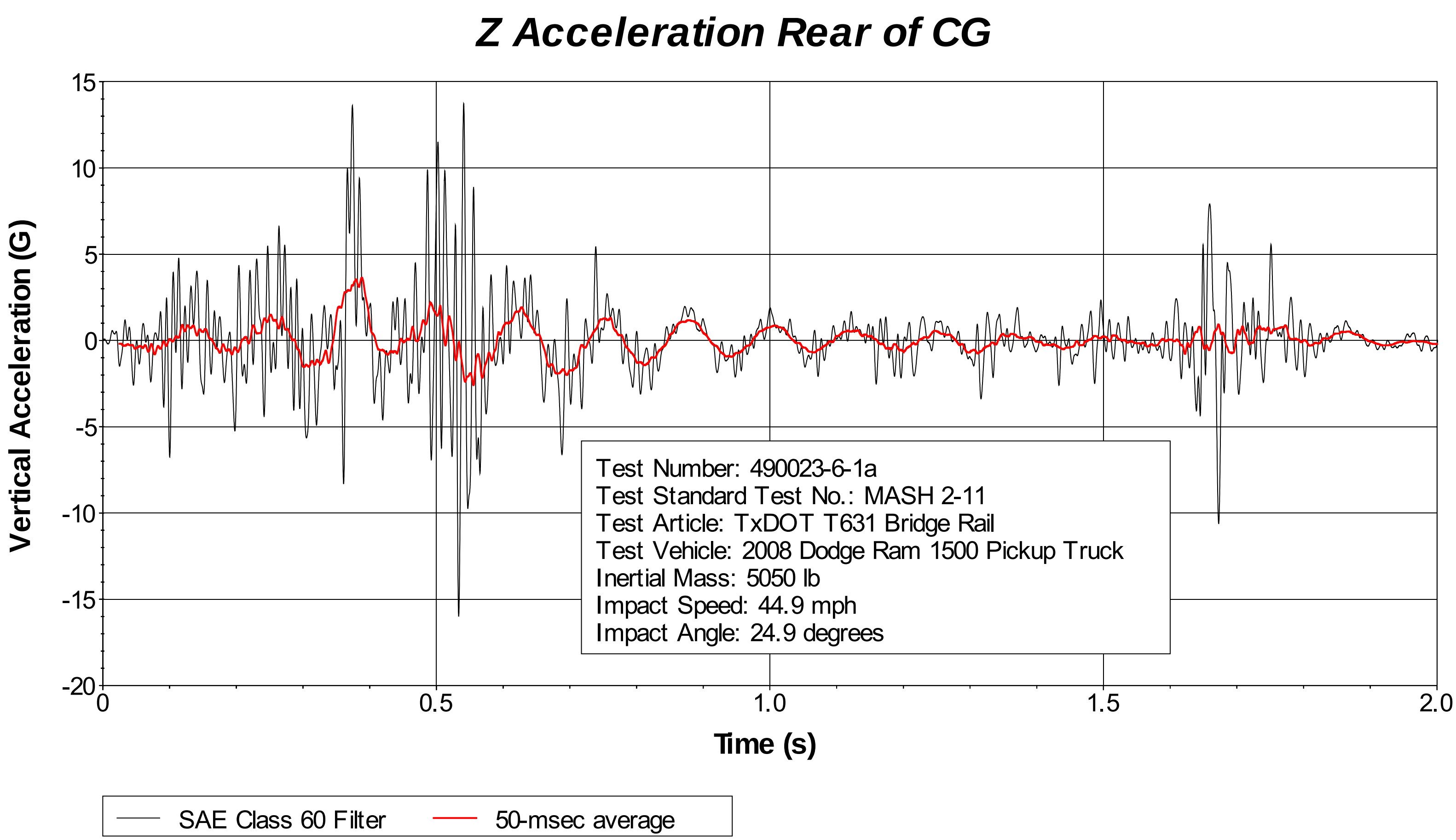


Figure D9. Vehicle Vertical Accelerometer Trace for Test No. 490023-6-1a (Accelerometer Located Rear of Center of Gravity).

APPENDIX E. CRASH TEST NO. 490023-6-2.

E1. VEHICLE PROPERTIES AND INFORMATION

Table E1. Vehicle Properties for Test No. 490023-6-2.

Date: 2013-08-15 Test No.: 490023-6-2 VIN No.: KNADE123286365964

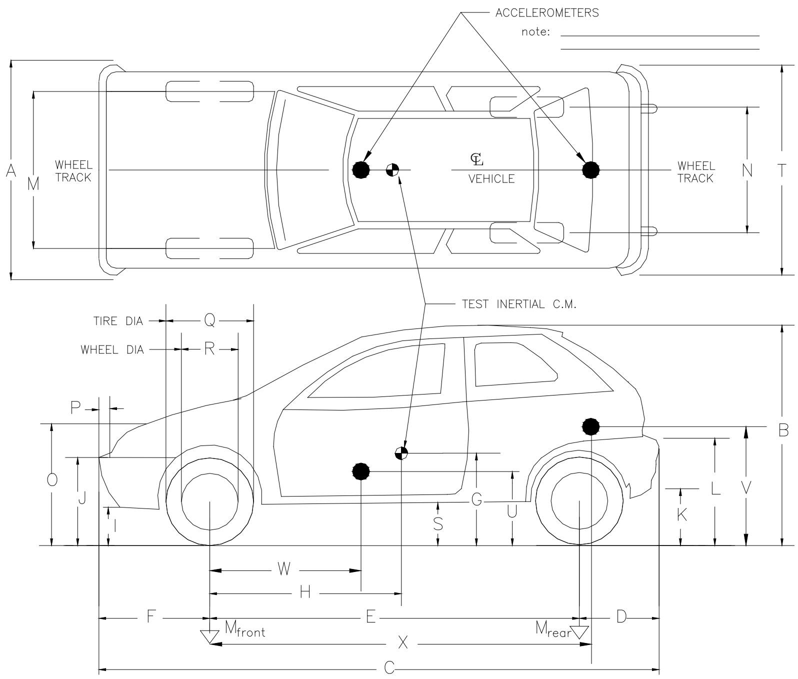
Year: 2008 Make: Kia Model: Rio

Tire Inflation Pressure: 32 psi Odometer: 114653 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 liter
Transmission Type:
____ Auto or x Manual
x FWD ____ RWD ____ 4WD
Optional Equipment:

Dummy Data:
Type: 50th percentile male
Mass: 165 lb
Seat Position: Driver seat

Geometry: inches

A	66.38	F	33.00	K	11.25	P	4.12	U	14.00
B	58.00	G	----	L	24.75	Q	22.18	V	20.50
C	165.75	H	36.42	M	57.75	R	15.38	W	46.50
D	34.00	I	6.75	N	51.12	S	8.00	X	108.00
E	98.75	J	21.50	O	28.00	T	66.13		

Wheel Center Ht Front 11.00 Wheel Center Ht Rear 11.00

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1918	M_{front}	1523	1528	1616
Back	1874	M_{rear}	895	893	970
Total	3638	M_{Total}	2418	2421	2586

Mass Distribution:
lb LF: 758 RF: 770 LR: 442 RR: 451

Table E2. Exterior Crush Measurements for Test No. 490023-6-2.

Date: 2013-08-15 Test No.: 490023-6-2 VIN No.: KNADE123286365964

Year: 2008 Make: Kia Model: Rio

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	Front plane at bumper ht	16	3	24	---	---	3	2	2	0	-12
2	Side plane at bumper ht	16	9.5	44	1	2.75	5	7.5	8	9.5	+49
	Measurements recorded										
	in inches mm										

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

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

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

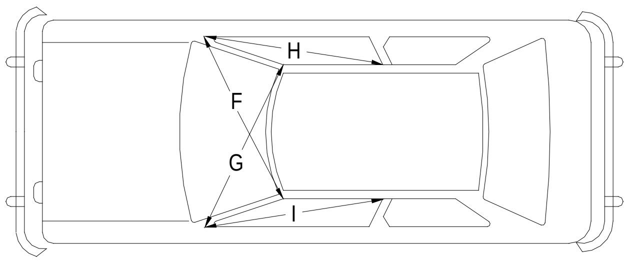
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

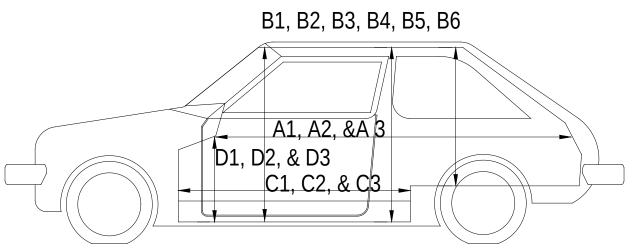
***Measure and document on the vehicle diagram the location of the maximum crush.

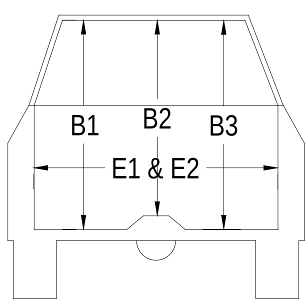
Note: Use as many lines/columns as necessary to describe each damage profile.

Table E3. Occupant Compartment Measurements for Test No. 490023-6-2.

Date:	2013-08-15	Test No.:	490023-6-2	VIN No.:	KNADE123286365964
Year:	2008	Make:	Kia	Model:	Rio







OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before (inches)	After (inches)
A1	71.50	71.50
A2	70.50	70.50
A3	71.50	71.50
B1	42.50	42.50
B2	34.75	34.75
B3	43.00	43.00
B4	34.75	34.75
B5	35.25	35.25
B6	34.75	34.75
C1	55.00	55.00
C2	43.50	43.50
C3	55.00	55.00
D1	12.00	12.00
D2	6.75	6.75
D3	12.00	12.00
E1	53.75	53.75
E2	53.75	53.75
F	53.50	53.50
G	53.50	53.50
H	35.75	35.75
I	35.75	35.75
J*	52.75	52.75

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

E2. SEQUENTIAL PHOTOGRAPHS

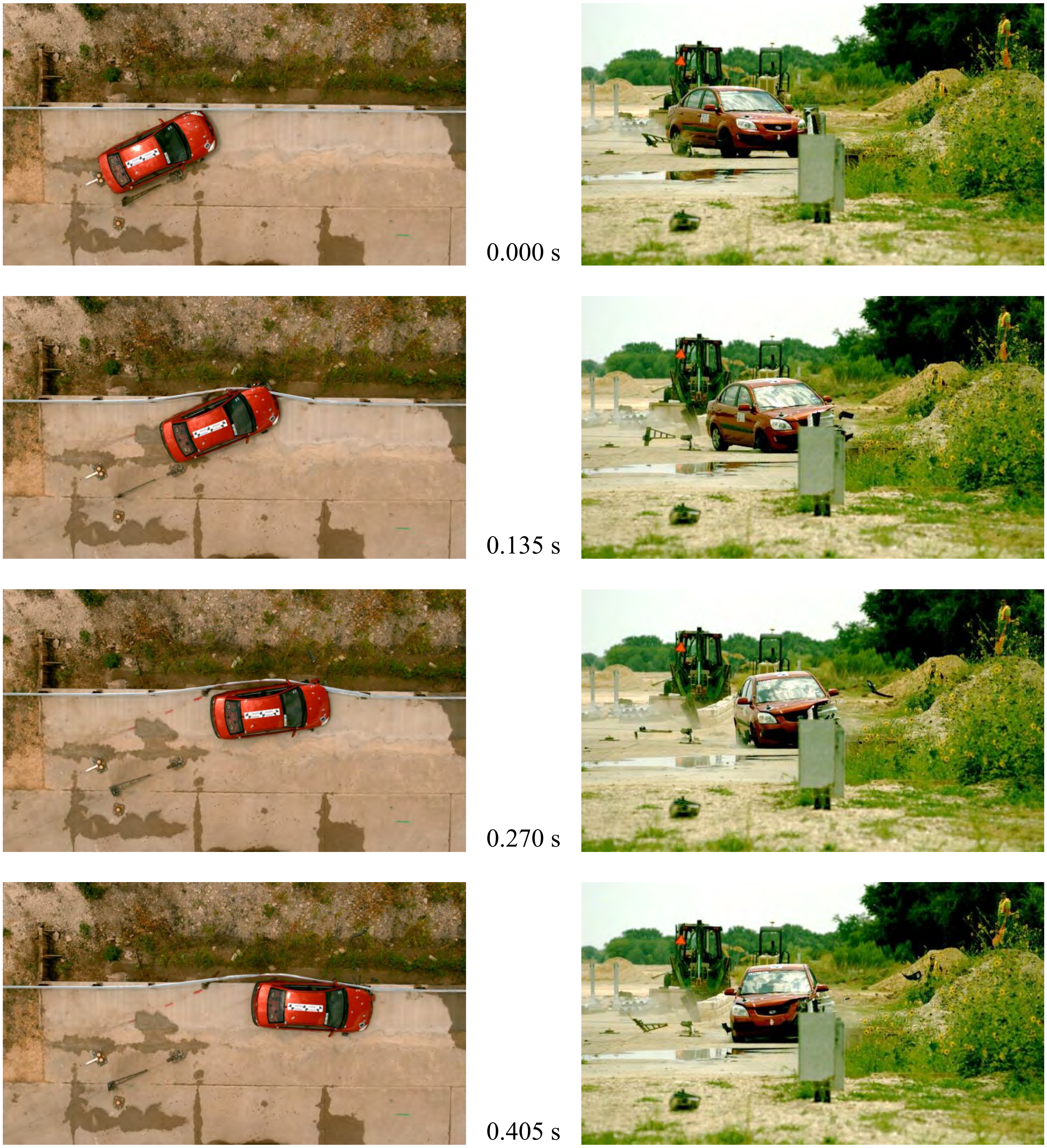


Figure E1. Sequential Photographs for Test No. 490023-6-2 (Overhead and Frontal Views).

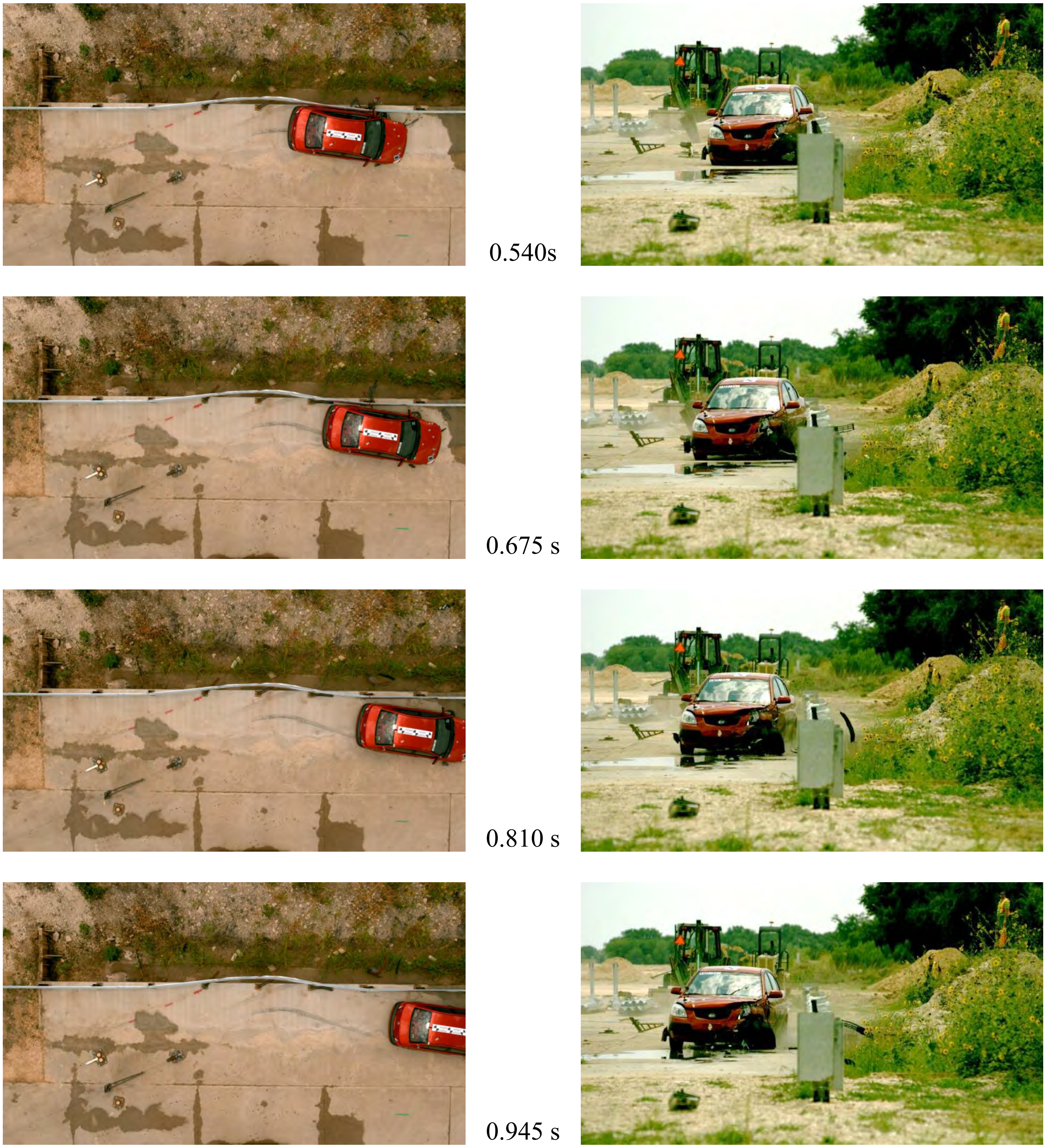
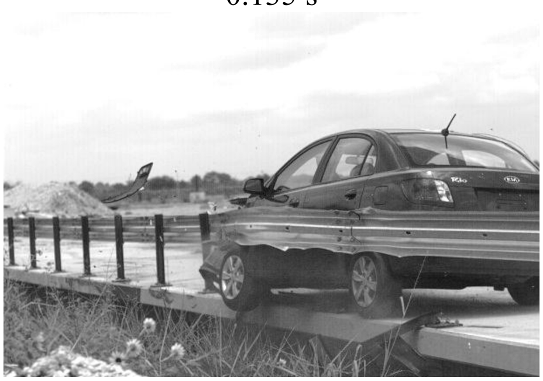


Figure E1. Sequential Photographs for Test No. 490023-6-2 (Overhead and Frontal Views) (continued).


0.000 s


0.135 s


0.270 s


0.405 s


0.540 s


0.675 s


0.810 s


0.945 s

Figure E2. Sequential Photographs for Test No. 490023-6-2 (Rear View).

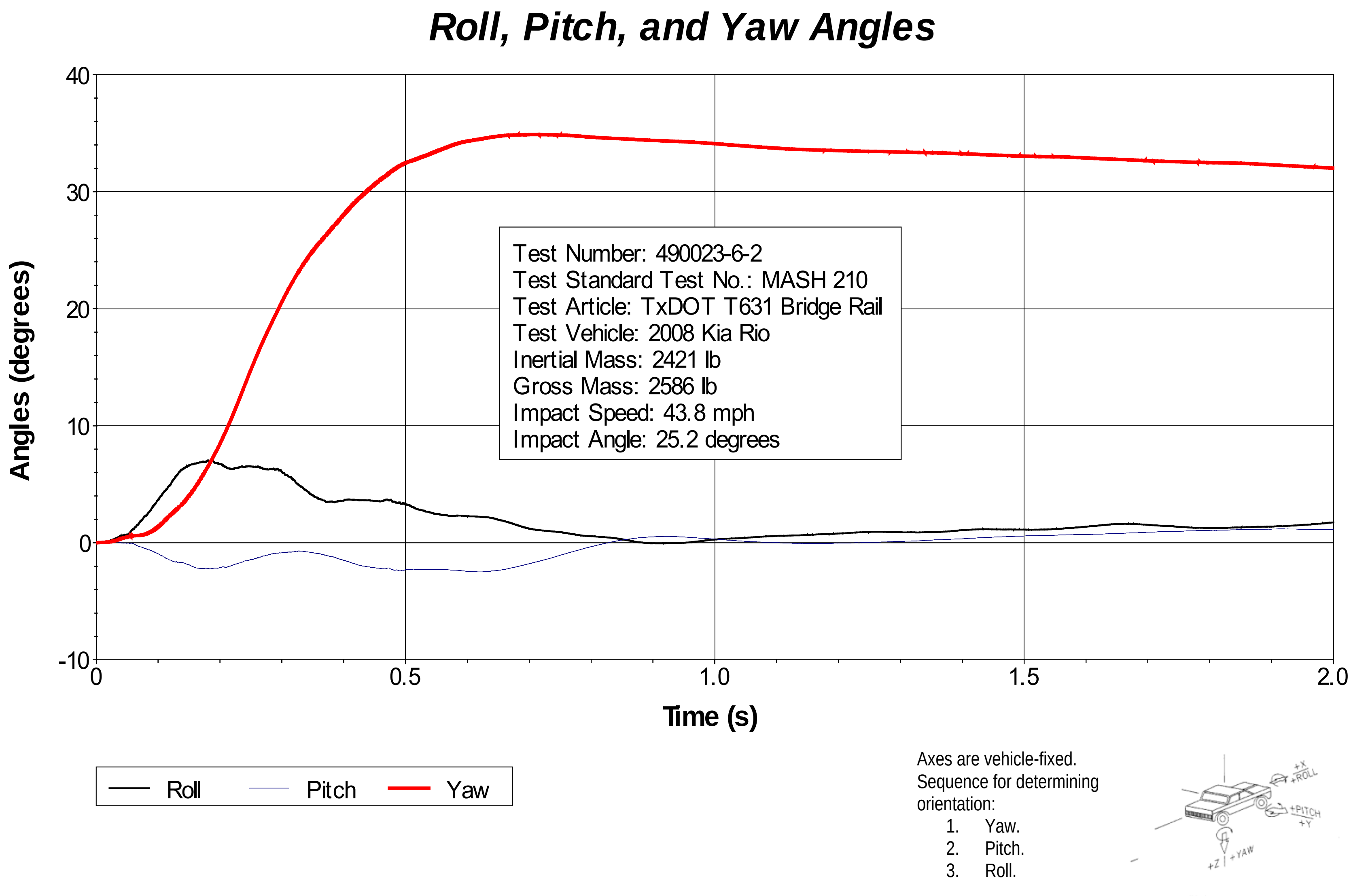


Figure E3. Vehicle Angular Displacements for Test No. 490023-6-2.

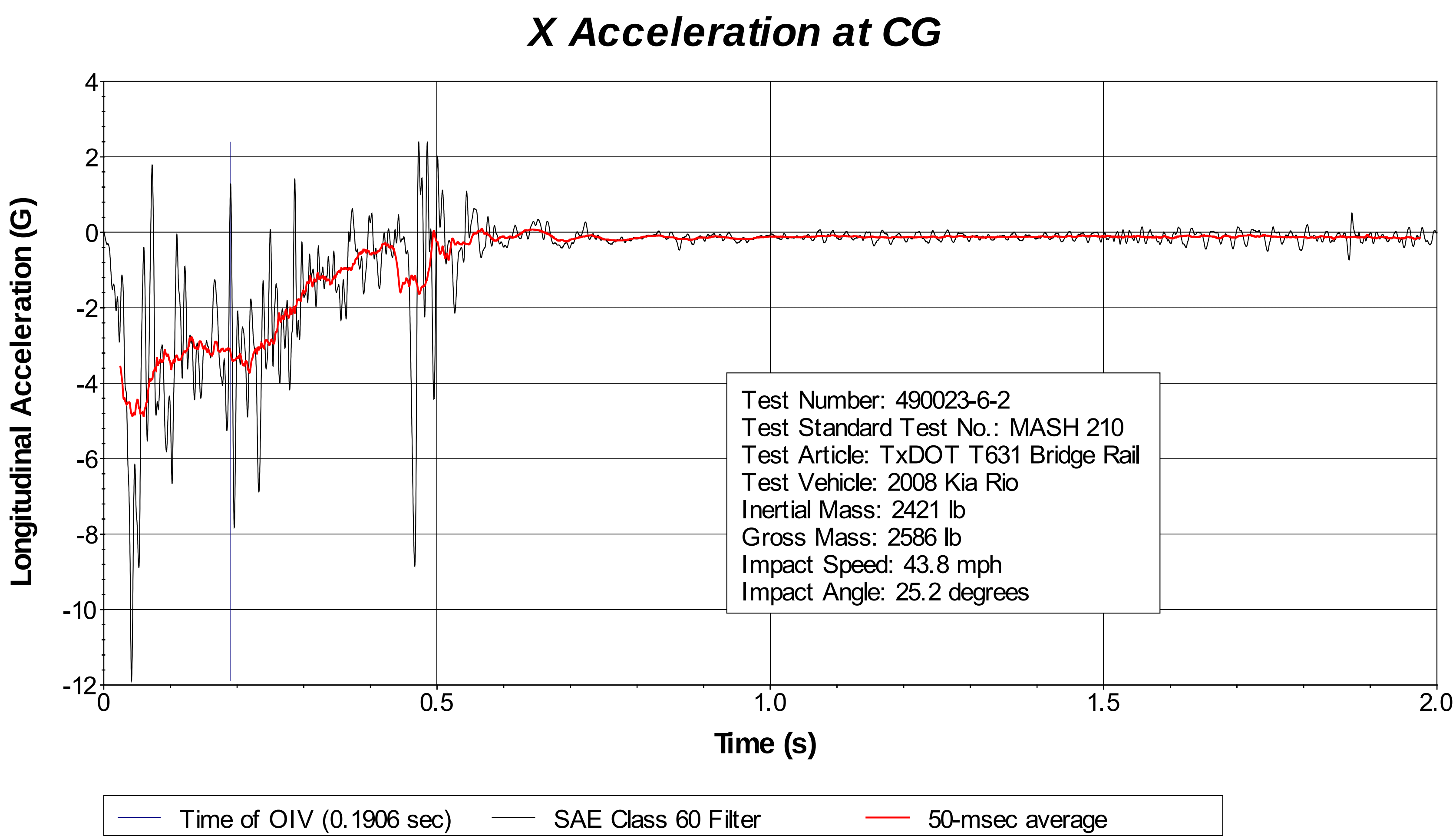


Figure E4. Vehicle Longitudinal Accelerometer Trace for Test No. 490023-6-2 (Accelerometer Located at Center of Gravity).

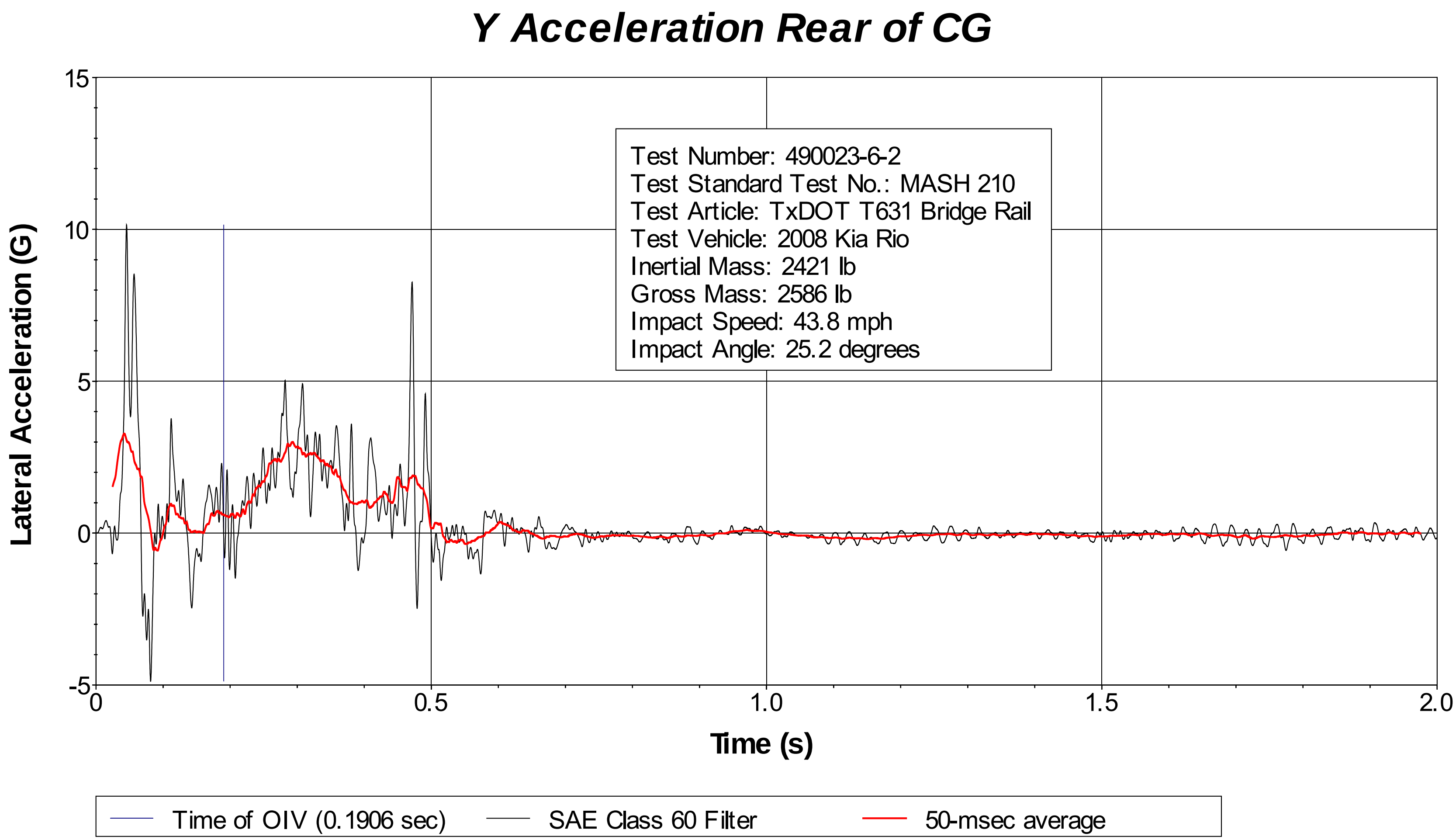


Figure E5. Vehicle Lateral Accelerometer Trace for Test No. 490023-6-2 (Accelerometer Located Rear of Center of Gravity).

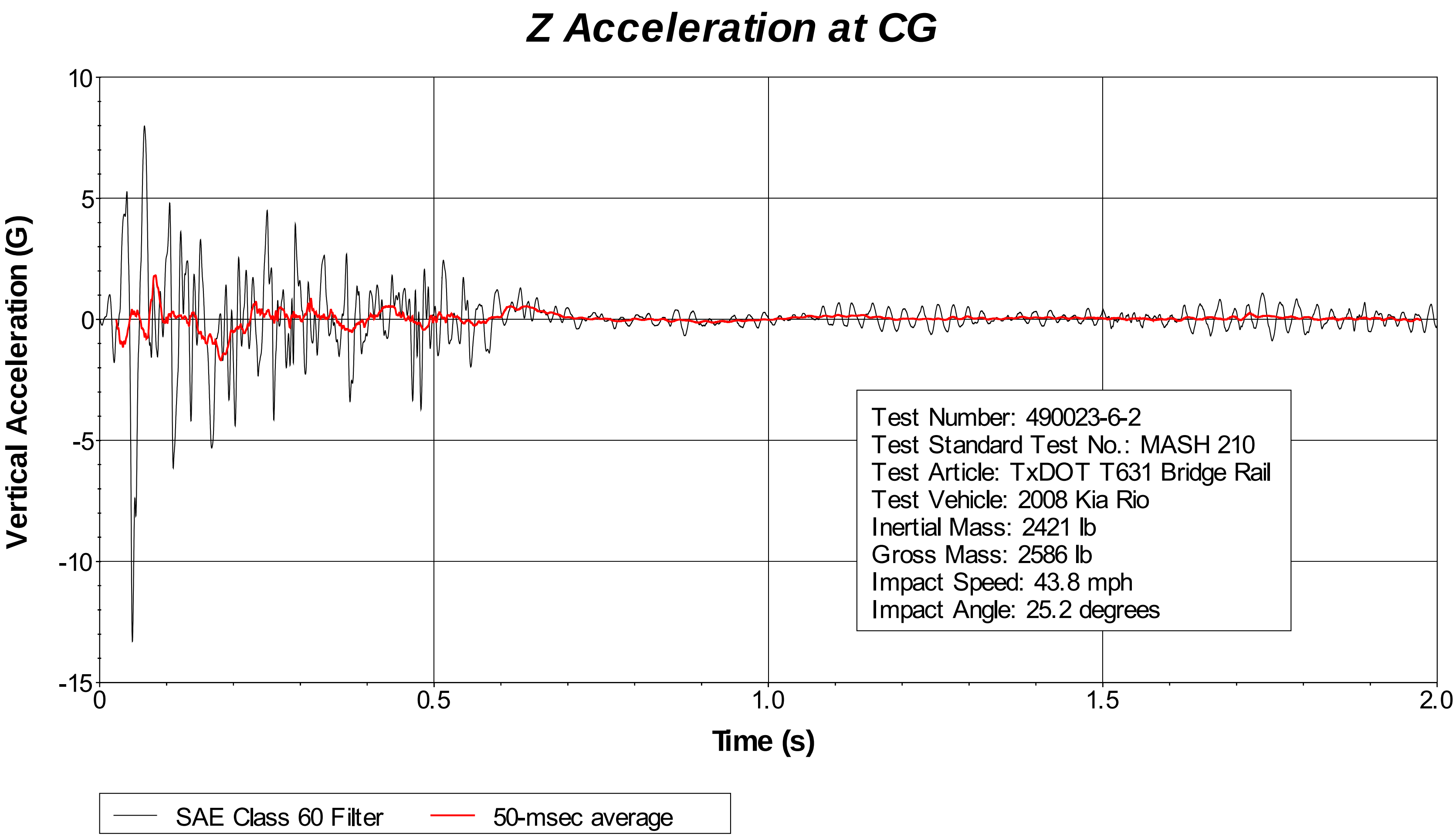


Figure E6. Vehicle Vertical Accelerometer Trace for Test No. 490023-6-2 (Accelerometer Located at Center of Gravity).