Texas A&M Transportation Institute

MASH TEST 3-11 OF THE TxDOT T222 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 9-1002-12-13

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

The objective of this research was to evaluate the impact performance of the TxDOT Type T222 Bridge Rail according to the *Manual for Assessing Safety Hardware* (*MASH)* TL-3. The crash testing was performed in accordance with the requirements of *MASH* TL-3. This report describes the TxDOT T222 Bridge Rail, documents the performance of the rail system according to *MASH* TL-3 specifications, and presents recommendations regarding implementation and future work.

The TxDOT T222 Bridge Rail contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 2.1 inches. No detached elements, fragments, or other debris was present to penetrate or to show potential for penetrating the occupant compartment, or to present hazard to others. Maximum occupant compartment deformation was 4.0 inches in the kick panel area near the right front passenger's feet. The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 7 degrees and 12 degrees, respectively. Occupant risk factors were within the limits specified in *MASH*. The vehicle exited within the exit box criteria. The TxDOT T222 Bridge Rail performed acceptably for *MASH* test 3-11. This barrier is recommended for implementation on new construction, retrofit applications, and in temporary applications in construction work zones.

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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.

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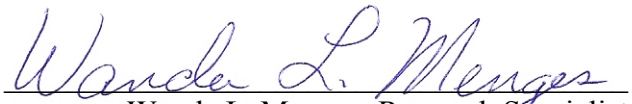

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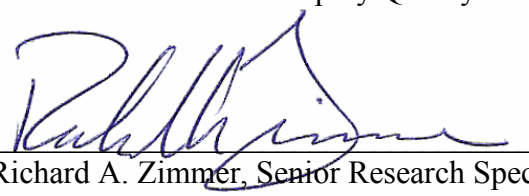

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CHAPTER 1. INTRODUCTION

1.1 INTRODUCTION

The current research was conducted under a project that sought to provide the Texas Department of Transportation (TxDOT) with a mechanism to quickly and effectively evaluate high-priority issues related to roadside safety devices. Such 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, the researchers identified roadside safety issues and prioritized these for investigation. They addressed each roadside safety issue with a separate work plan, and summarized the results in individual test reports.

1.2 OBJECTIVES/SCOPE OF RESEARCH

The objective of this research was to evaluate the impact performance of the TxDOT Type T222 Bridge Rail to the Manual for Assessing Safety Hardware (*MASH*) TL-3. Researchers performed the crash testing in accordance with the requirements of *MASH* TL-3.

This report describes the TxDOT T222 Bridge Rail, documents the performance of the rail system according to *MASH* TL-3 specifications, and presents recommendations regarding implementation and future work.

CHAPTER 2. SYSTEM DETAILS

2.1 TEST ARTICLE DESIGN AND CONSTRUCTION

The test installation was a 90-ft-1-inch-long TxDOT T222 Precast Traffic Rail (Type T222) made from three 30-ft long precast segments with a ½-inch gap expansion joint between each segment. The rail was anchored to the top of a 6-inch-thick reinforced concrete deck cantilever. Additionally, the deck had a ½-inch-wide expansion joint every 30 ft along the length of the installation, which coincided with the gap between adjacent rail segments. The Type T222 bridge rail was 32¾ inches high, and had a single, smooth vertical face on the traffic side. There was a ¾-inch gap between the top of the deck cantilever and the bottom of the bridge rail for the length of the installation except for the anchor plates (see below). The bridge rail was 10½ inches thick at the base and 12 inches thick at the top with a 1½-inch, 45-degree outward taper on the field side of the rail beginning 19¼ inches above the bottom of the anchor plate. The top field side and traffic side edges were chamfered ¾ inch.

Reinforcement of the TxDOT Type T222 bridge rail consisted of U-shaped stirrups of #4 rebar. These stirrups were 29½ inches tall, 7½ inches wide, and were spaced nominally 6 inches apart inside each precast rail segment. The stirrups were connected with eight (four on each side) longitudinal #4 rebars spaced at 8½ inches vertically along the height of the rail beginning at 3¼ inches above the bottom of the anchor plate. All unions of longitudinal and vertical rebars were field wire-tied before pouring concrete. Concrete cover was a minimum of 1½ inches on the top, and on the traffic and field side faces.

Each of the three 30-ft-long bridge rail sections were cast on top of eight 15¼-inch × 12-inch × ¾-inch-thick ASTM A36 steel anchor plates spaced at 4 ft along the length of each section (see Attachment A, Sheets 5 and 7 of 8). Five ⅝-inch-diameter deformed bar anchors (Nelson Stud D2L) were vertically attached to each anchor plate with ⅜-inch fillet welds. Three of these deformed bar anchors were 29 inches long, and were located closer to the traffic side of the rail. The remaining two deformed bar anchors were 12 inches long, and were located closer to the field side of the rail. Each 29-inch and 12-inch bar was wire-tied to the barrier reinforcement at four and two locations, respectively. The anchor plate had a 1⅛-inch-diameter hole centered 2 inches laterally from the traffic-side edge of the plate.

The TxDOT Type T222 bridge rail was anchored to the 6-inch-thick deck via the aforementioned steel anchor plates using 1-inch-diameter 10-inch-long ASTM A325 galvanized hex anchor bolts, with two 3-inch × 3-inch × ⅜-inch thick ASTM A36 plate washers (one above and one below), and a 1-inch heavy hex nut and a jam nut below the deck. Each bolt passed through the hole in the anchor plate and through the deck via a 1¼-inch-diameter core-drilled hole. The bolts were located on the traffic side face of the bridge rail approximately 14 inches from the field edge of the deck.

For this test, a 6-inch thick × approximately 33-inch-wide cantilever deck was constructed on the existing concrete runway apron. One layer of steel reinforced the deck cantilever. Transverse reinforcement consisted of 24½-inch × 17½-inch legs made from #4 rebar transverse reinforcing steel spaced on 6-inch longitudinal centers and at approximately 2 inches below the top of the deck. The traverse bars' vertical legs were anchored within a 12-inch-wide × 45-inch-tall vertical wall constructed immediately adjacent to the runway apron. One

longitudinal #4 rebar was placed within the deck approximately 2 inches from the field-side edge of the deck.

For additional transverse shear resistance between the barrier sections, a 42-inch-long × 6-inch-wide × ¾-inch-thick ASTM A572 Grade 50 shear plate to the top of the barriers at each joint. The shear plate was centered over the open joints between the barrier sections and contained two ⅞-inch-diameter holes on one end and two ⅞ × 2⅛-inch elongated slots in the opposite end. The shear plate was anchored to the top of the barrier sections with four ¾-inch-diameter × 8-inch-long ASTM A-193 B7 all-thread rods (two rods at each barrier end). The rods were embedded at a minimum of 6 inches into a core drilled hole in the barrier, and then anchored the rods using Hilti's RE500 epoxy anchoring system. The shear plate was secured to the barrier at each slot with a 2-inch-square × ¼-inch-thick ASTM A36 plate washer, a ¾-inch lock washer, and hex nut, and at each hole with a ¾-inch flat washer, lock washer, and hex nut.

Lifting lugs (Halfen TPA-FS 0070.010-00018; 15¾ inches long; each rated for a 5-ton load) were embedded in 2-inch × 4-inch × 2-inch-deep rounded recessed pockets in the bridge rails at two locations approximately 9 ft from each end of the 30-ft rail sections. The top of each lug was recessed approximately ⅜-inch below the top surface of the bridge rail.

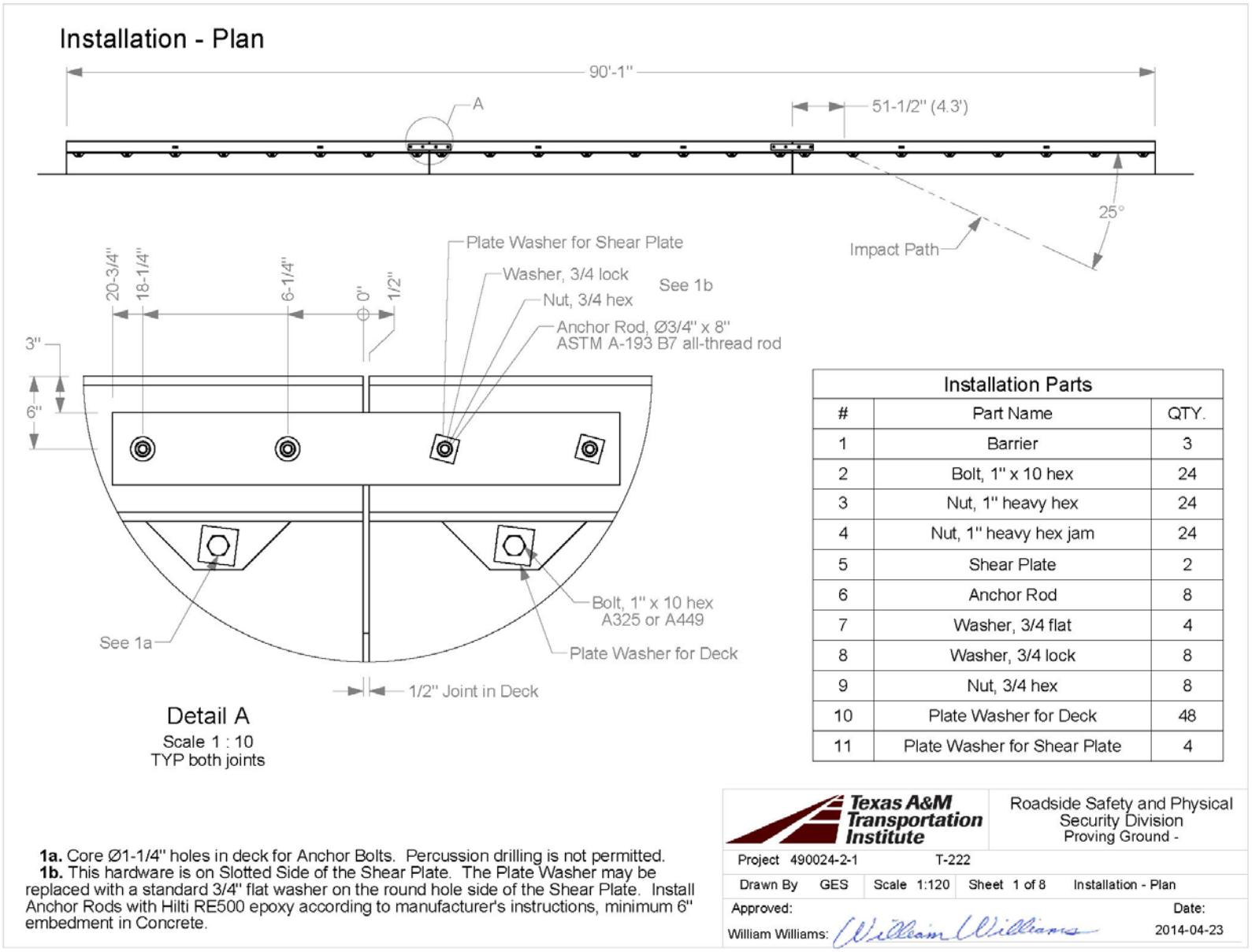
Figure 2.1 provides an overall layout of the TxDOT T222 Precast Traffic Rail, and Attachment A provides detailed drawings. Figure 2.2 shows photographs of the installation before testing.

2.2 MATERIAL SPECIFICATIONS

The TxDOT Class C specified the minimum unconfined compressive strength of the concrete for the T222 bridge rail at 3600 psi. The compressive strengths of the three batches of concrete used in the precast bridge rail barrier segments on the date of the crash test measured an average of 6170 psi (at 75 days from June 25, 2014), 5220 psi (at 69 days from June 25, 2013), and 4340 psi (at 60 days from June 25, 2014).

The compressive strength of the concrete used in the deck cantilever on the date of the crash test (at 37 days from May 20, 2014) averaged 6537 psi.

Reinforcement of the TxDOT Type T222 bridge rail was comprised of ASTM A615 Grade 60 rebar with specified minimum yield strength of 60 ksi.



Installation Parts		
#	Part Name	QTY.
1	Barrier	3
2	Bolt, 1" x 10 hex	24
3	Nut, 1" heavy hex	24
4	Nut, 1" heavy hex jam	24
5	Shear Plate	2
6	Anchor Rod	8
7	Washer, 3/4 flat	4
8	Washer, 3/4 lock	8
9	Nut, 3/4 hex	8
10	Plate Washer for Deck	48
11	Plate Washer for Shear Plate	4

1a. Core Ø1-1/4" holes in deck for Anchor Bolts. Percussion drilling is not permitted.
1b. This hardware is on Slotted Side of the Shear Plate. The Plate Washer may be replaced with a standard 3/4" flat washer on the round hole side of the Shear Plate. Install Anchor Rods with Hilti RE500 epoxy according to manufacturer's instructions, minimum 6" embedment in Concrete.

Figure 2.1. Details of the TxDOT T222 Bridge Rail.

Figure 2.2. Test Article/Installation before Test No. 490024-2-1.

CHAPTER 3. TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1 CRASH TEST MATRIX

MASH recommends the following two tests to evaluate longitudinal barriers to Test Level Three (TL-3):

- ***MASH* Test 3-10**: 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 62 mi/h and 25 degrees, respectively. This test investigates a barrier's ability to successfully contain and redirect a small passenger vehicle.
- ***MASH* Test 3-11**: A 5000-lb pickup truck impacting the CIP of the LON of the barrier at a nominal impact speed and angle of 62 mi/h and 25 degrees, respectively. This test investigates a barrier's ability to successfully contain and redirect light trucks and sport utility vehicles.

MASH Test 3-11 was performed on the TxDOT T222 Bridge Rail. The target impact point was 4.3 ft upstream of the centerline of the joint between barrier segments 1 and 2, calculated in accordance with the *MASH* specifications.

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

3.2 EVALUATION CRITERIA

The crash test was evaluated in accordance with the criteria presented in *MASH*. The performance of the TxDOT T222 Bridge Rail is judged based on three factors:

- Structural adequacy, which is judged on the ability of the TxDOT T222 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 the crash test reported here, and are listed in further detail under the assessment of the crash test.

CHAPTER 4. CRASH TEST PROCEDURES

4.1 TEST FACILITY

The full-scale crash test reported here was 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 test according to TTI Proving Ground quality procedures, and according to 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 a United States Army Air Corps base, has large expanses of concrete runways and parking aprons that are 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 TxDOT T222 Bridge Rail evaluated under this project was along the edge of an out-of-service apron. The apron consists of an unreinforced jointed-concrete pavement in 12.5-ft × 15-ft blocks nominally 6 inches deep. The aprons were built in 1942, and the joints have some displacement, but are otherwise flat and level.

4.2 VEHICLE TOW AND GUIDANCE PROCEDURES

The test vehicle was towed into the test installation using a steel cable guidance and reverse tow system. A steel cable for guiding the test vehicle was tensioned along the path, anchored at each end, and threaded through an attachment to the front wheel of the test vehicle. An additional steel cable was connected to the test vehicle, passed around a pulley near the impact point, through a pulley on the tow vehicle, and then anchored to the ground such that the tow vehicle moved away from the test site. A 2:1 speed ratio between the test and tow vehicle existed with this system. Just prior to impact with the installation, the test vehicle was released 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 the vehicle to a safe and controlled stop.

4.3 DATA ACQUISITION SYSTEMS

4.3.1 Vehicle Instrumentation and Data Processing

The test vehicle was instrumented with a self-contained, on-board data acquisition system. The signal conditioning and acquisition system is a 16-channel, Tiny Data Acquisition System (TDAS) Pro manufactured by Diversified Technical Systems, Inc. The accelerometers, which measure the x, y, and z axis of vehicle acceleration, are a strain gauge type with linear millivolt output proportional to acceleration. To measure vehicle roll, pitch, and yaw rates, angular rate sensors measure vehicle roll, pitch, and yaw rates; these sensors 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 available 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

Use of a dummy in the 2270P vehicle is optional according to MASH, and no dummy was used in the tests 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-digital video camera and still cameras recorded and documented conditions of the test vehicle and installation before and after the test.

CHAPTER 5. CRASH TEST RESULTS

5.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

MASH Test 3-11 involves a 2270P vehicle weighing 5000 lb ±110 lb and impacting the TxDOT T222 Bridge Rail at an impact speed of 62.2 mi/h ±2.5 mi/h and an angle of 25 degrees ±1.5 degrees. The target impact point was 4.3 ft upstream of the centerline of the joint between barrier segments 1 and 2. The 2008 Dodge Ram 1500 pickup truck used in the test weighed 5053 lb and the actual impact speed and angle were 64.4 mi/h and 25.5 degrees, respectively. The actual impact point was 51 inches (4 ft 3 inches) upstream of the centerline of the joint between barrier segments 1 and 2. Target impact severity (IS) was 115.1 kip-ft, and actual IS was 129.8 kip-ft (+12.8 percent).

5.2 TEST VEHICLE

The 2008 Dodge Ram 1500 pickup truck, shown in Figures 5.1 and 5.2, was used for the crash test. The truck's test inertia weight was 5053 lb, and its gross static weight was 5053 lb. The height to the lower edge of the vehicle bumper was 15.0 inches; to the upper edge, it was 26.5 inches. The height to the vehicle's center of gravity was 28.5 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 June 26, 2014. Weather conditions at the time of testing were as follows: wind speed: 6 mi/h; wind direction: 164 degrees with respect to the vehicle (vehicle was traveling in a southeasterly direction); temperature: 82°F; relative humidity: 75 percent.

5.4 TEST DESCRIPTION

The 2008 Dodge Ram 1500 pickup truck, traveling at an impact speed of 64.4 mi/h, contacted the TxDOT T222 Bridge Rail 51 inches (4 ft 3 inches) upstream of the centerline of the joint between barrier segments #1 and #2 at an impact angle of 25.5 degrees. At approximately 0.126 s, the vehicle began to redirect, and at 0.186 s, the rear of the vehicle contacted the bridge rail. The vehicle began traveling parallel with the bridge rail at 0.271 s. At 0.473 s, the vehicle lost contact with the bridge rail and was traveling at an exit speed and angle of 48.6 mi/h and 8.1 degrees, respectively. Brakes on the vehicle were applied at 2.5 s after impact. The 2270P vehicle subsequently came to rest 249 ft downstream of impact and 35 ft toward traffic lanes. Figure D1 in Appendix D shows sequential photographs of the test period.

Figure 5.1. Vehicle/Installation Geometrics for Test No. 490024-2-1.

Figure 5.2. Vehicle before Test No. 490024-2-1.

5.5 DAMAGE TO TEST INSTALLATION

Figure 5.3 and 5.4 show the damage to the bridge rail. Barrier segment 1 (leading) was pushed toward the field side 0.5 inch at the downstream end, and barrier segment 2 (mid) was pushed toward the field side 0.25 inch on the upstream end. Cracks in the deck were noted upstream of the joint between barrier segments 1 and 2, and there was a 0.75-inch offset between barrier segments 1 and 2 at the joint.

5.6 VEHICLE DAMAGE

Figure 5.5 shows the damage that the vehicle had sustained. The front bumper, grill, radiator, radiator support, right front fender, right front wheel rim (no loss of air), right front and rear doors, right rear cab corner, right exterior bed, right rear tire and wheel rim, rear bumper, and right front floor pan were deformed, and the windshield sustained stress fractures. Maximum exterior crush to the vehicle was 19.25 inches in the side plane at the right front corner at bumper height. Maximum occupant compartment deformation was 4.0 inches in the right front kick panel area near the right front passenger's feet. Tables C3 and C4 in Appendix C provide exterior crush measurements and occupant compartment measurements, respectively.

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 21.6 ft/s at 0.097 s, the highest 0.010-s occupant ridedown acceleration was 3.6 Gs from 0.196 to 0.206 s, and the maximum 0.050-s average acceleration was −9.8 Gs between 0.025 and 0.075 s. In the lateral direction, the occupant impact velocity was 26.9 ft/s at 0.097 s, the highest 0.010-s occupant ridedown acceleration was 11.1 Gs from 0.207 to 0.217 s, and the maximum 0.050-s average was −14.1 Gs between 0.041 and 0.091 s. Theoretical Head Impact Velocity (THIV) was 38.0 km/h or 10.5 m/s at 0.094 s; Post-Impact Head Decelerations (PHD) was 11.1 Gs between 0.207 and 0.217 s; and Acceleration Severity Index (ASI) was 1.95 between 0.063 and 0.113 s. Figure 5.7 summarizes these data and other pertinent information from the test. In Appendix E, Figures E1 through E7 show the vehicle angular displacements and accelerations versus time traces.

Figure 5.3. Vehicle/Bridge Rail after Test No. 490024-2-1.

Figure 5.4. Installation after Test No. 490024-2-1.

Figure 5.5. Vehicle after Test No. 490024-2-1.

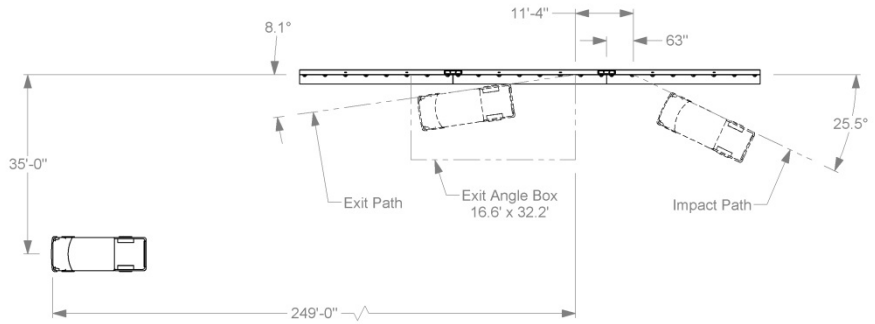
Figure 5.6. Interior of Vehicle for Test No. 490024-2-1.

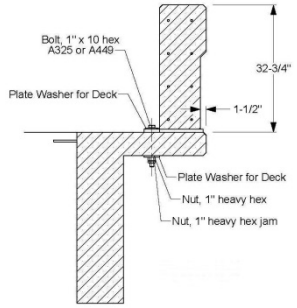
0.000 s

0.098 s

0.192 s

0.288 s





General Information
- Test Agency ..... Texas Transportation Institute (TTI)
- Test Standard Test No. ..... MASH Test 3-11
- TTI Test No. 490024-2-1
- Test Date 2014-06-26

Test Article
- Type ..... Bridge Rail
- Name ..... TxDOT T222 Bridge Rail
- Installation Length ..... 90 ft 1 inch
- Material or Key Elements ..... 30-ft long precast segments anchored to 6-inch thick reinforced concrete deck via steel anchor plates using 1-inch grade A325 galvanized anchor bolts

Soil Type and Condition ..... Concrete Bridge Deck, Dry

Test Vehicle
- Type/Designation 2270P
- Make and Model ..... 2008 Dodge Ram 1500 Pickup
- Curb ..... 4789 lb
- Test Inertial ..... 5053 lb
- Dummy ..... No dummy
- Gross Static ..... 5053 lb

Impact Conditions
- Speed ..... 64.4 mi/h
- Angle ..... 25.5 degrees
- Location/Orientation ..... 51 inches up from splice btw segs 1&2

Impact Severity ..... 129.8 kip-ft (+12.8%)

Exit Conditions
- Speed ..... 48.6 mi/h
- Angle ..... 8.1 degrees

Occupant Risk Values
- Longitudinal OIV ..... 21.6 ft/s
- Lateral OIV ..... 26.9 ft/s
- Longitudinal Ridedown ..... 3.6 G
- Lateral Ridedown ..... 11.1 G
- THIV ..... 38.0 km/h
- PHD ..... 11.1 G
- ASI 1.95

Max. 0.050-s Average
- Longitudinal ..... −9.8 G
- Lateral ..... −14.1 G
- Vertical ..... −3.3 G

Post-Impact Trajectory
- Stopping Distance ..... 249 ft dwnstrm
  35 ft twd traffic

Vehicle Stability
- Maximum Yaw Angle ..... 37 degrees
- Maximum Pitch Angle ..... 12 degrees
- Maximum Roll Angle ..... 7 degrees
- Vehicle Snagging ..... No
- Vehicle Pocketing ..... No

Test Article Deflections
- Dynamic ..... 2.13 inches
- Permanent ..... None
- Working Width ..... 13.18 inches
- Vehicle Intrusion ..... None

Vehicle Damage
- VDS 01RFQ5
- CDC 01FREW4
- Max. Exterior Deformation ..... 19.25 inches
- OCDI RF0000000
- Max. Occupant Compartment Deformation ..... 4.00 inches

Figure 5.7. Summary of Results for *MASH* Test 3-11 on the TxDOT T222 Bridge Rail.

CHAPTER 6. SUMMARY AND CONCLUSIONS

6.1 ASSESSMENT OF TEST RESULTS

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

6.1.1 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 T222 Bridge Rail contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 2.13 inches. (PASS)

6.1.2 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: No detached elements, fragments, or other debris was present to penetrate or to show potential for penetrating the occupant compartment, or to present hazard to others. (PASS)

Maximum occupant compartment deformation was 4.0 inches in the kick panel area near the right front passenger's feet. (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 7 degrees and 12 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 21.6 ft/s, and lateral occupant impact velocity was 26.9 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: Maximum longitudinal occupant ridedown acceleration was 3.6 g, and maximum lateral occupant ridedown acceleration was 11.1 G. (PASS)

6.1.3 Vehicle Trajectory

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

Result: The vehicle exited within the exit box criteria. (PASS)

6.2 CONCLUSIONS

Table 6.1 shows that the TxDOT T222 Bridge Rail performed acceptably for *MASH* test 3-11.

Table 6.1. Performance Evaluation Summary for *MASH* Test 3-11 on the TxDOT T222 Bridge Rail.

Test Agency: Texas A&M Transportation Institute Test No.: 490024-2-1 Test Date: 2014-06-26

***MASH* Test 3-11 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 T222 Bridge Rail contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 2.13 inches.	Pass
Occupant Risk		
D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.	No detached elements, fragments, or other debris was present to penetrate or to show potential for penetrating the occupant compartment, or to present hazard to others.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	Maximum occupant compartment deformation was 4.0 inches in the kick panel area near the right front passenger's feet.	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 was 7 degrees, and maximum pitch was 12 degrees.	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 21.6 ft/s, and lateral occupant impact velocity was 26.9 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.	Maximum longitudinal occupant ridedown acceleration was 3.6 G, and maximum lateral occupant ridedown acceleration was 11.1 G.	Pass
Vehicle Trajectory		
For redirective devices, the vehicle shall exit the barrier within the exit box (not less than 32.8 ft).	The vehicle exited within the exit box criteria.	Pass

CHAPTER 7. IMPLEMENTATION STATEMENT

The objective of this research was to evaluate the impact performance of the TxDOT Type T222 Bridge Rail to *MASH* TL-3. The crash testing was performed in accordance with the requirements of *MASH* TL-3. This barrier may be used on new construction, retrofit applications, and in temporary applications in construction work zones.

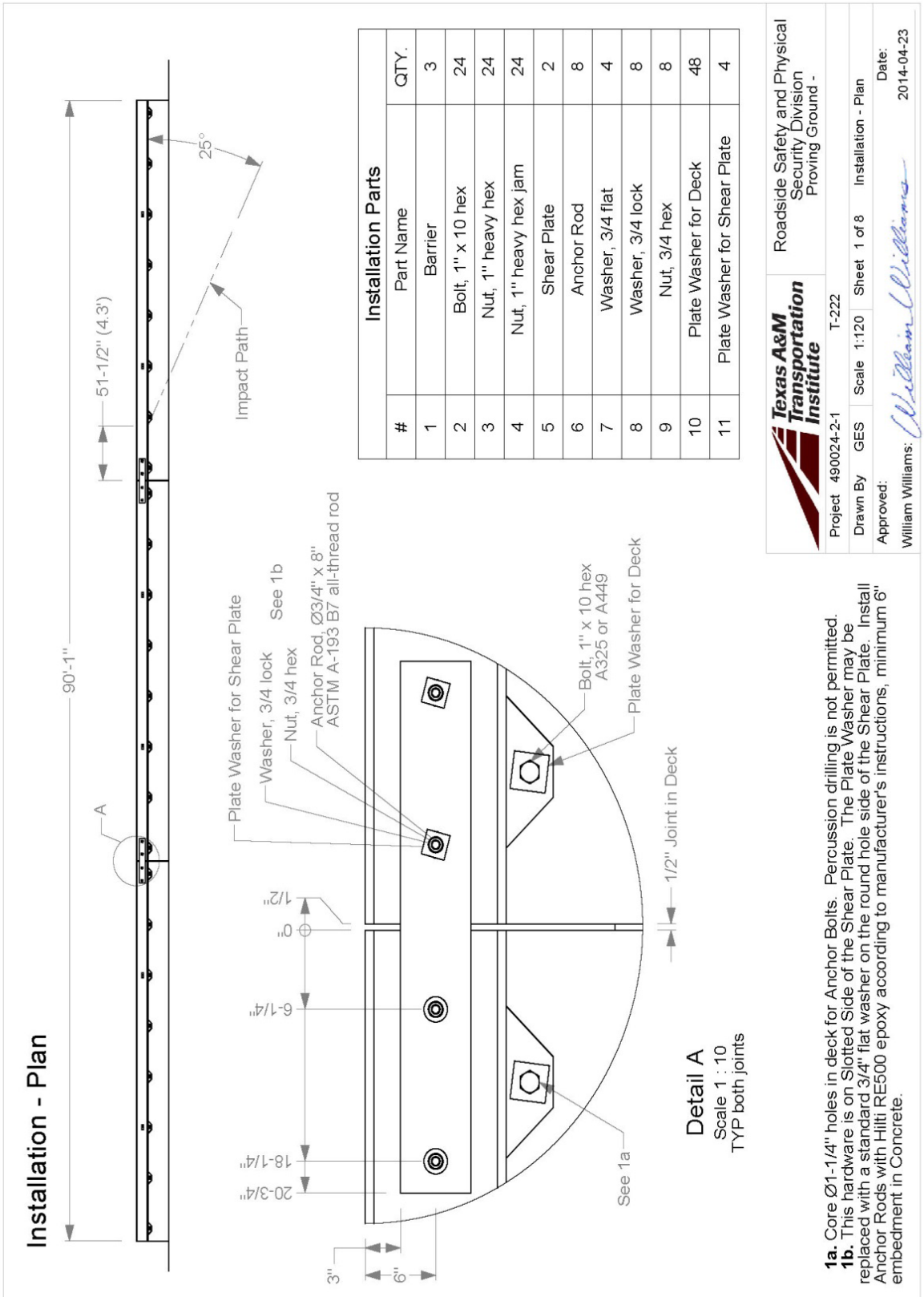
The TxDOT T222 Bridge Rail met all the strength and safety performance criteria of *MASH* TL-3. This barrier is recommended for implementation on new construction, retrofit applications, and in temporary applications in construction work zones.

REFERENCES

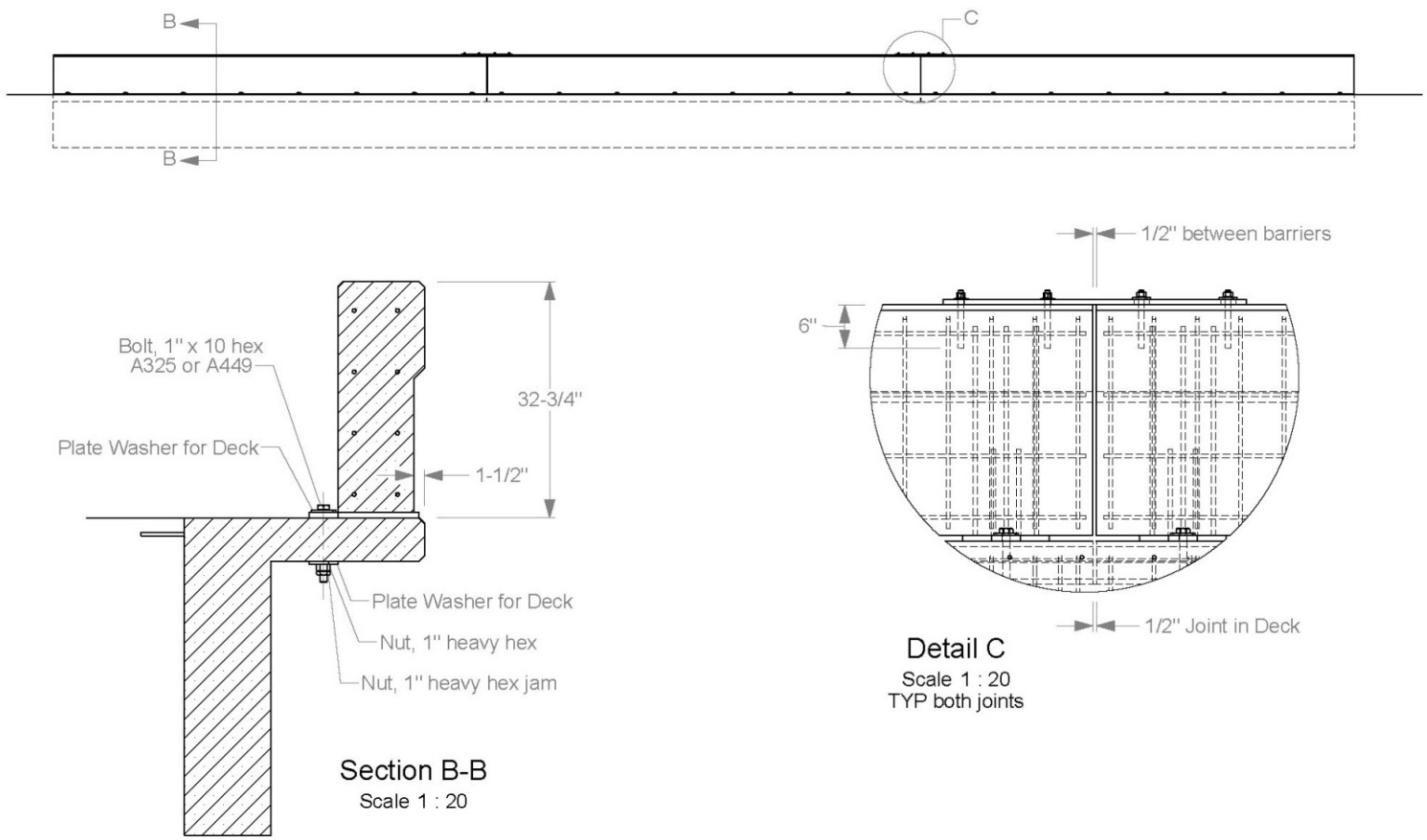
1. H. E. Ross, Jr., D. L. Sicking, R. A. Zimmer, and J. D. Michie. *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, National Cooperative Highway Research Program Report 350, Transportation Research Board, National Research Council, Washington, D.C., 1993.

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

APPENDIX A. DETAILS OF THE TEST ARTICLE



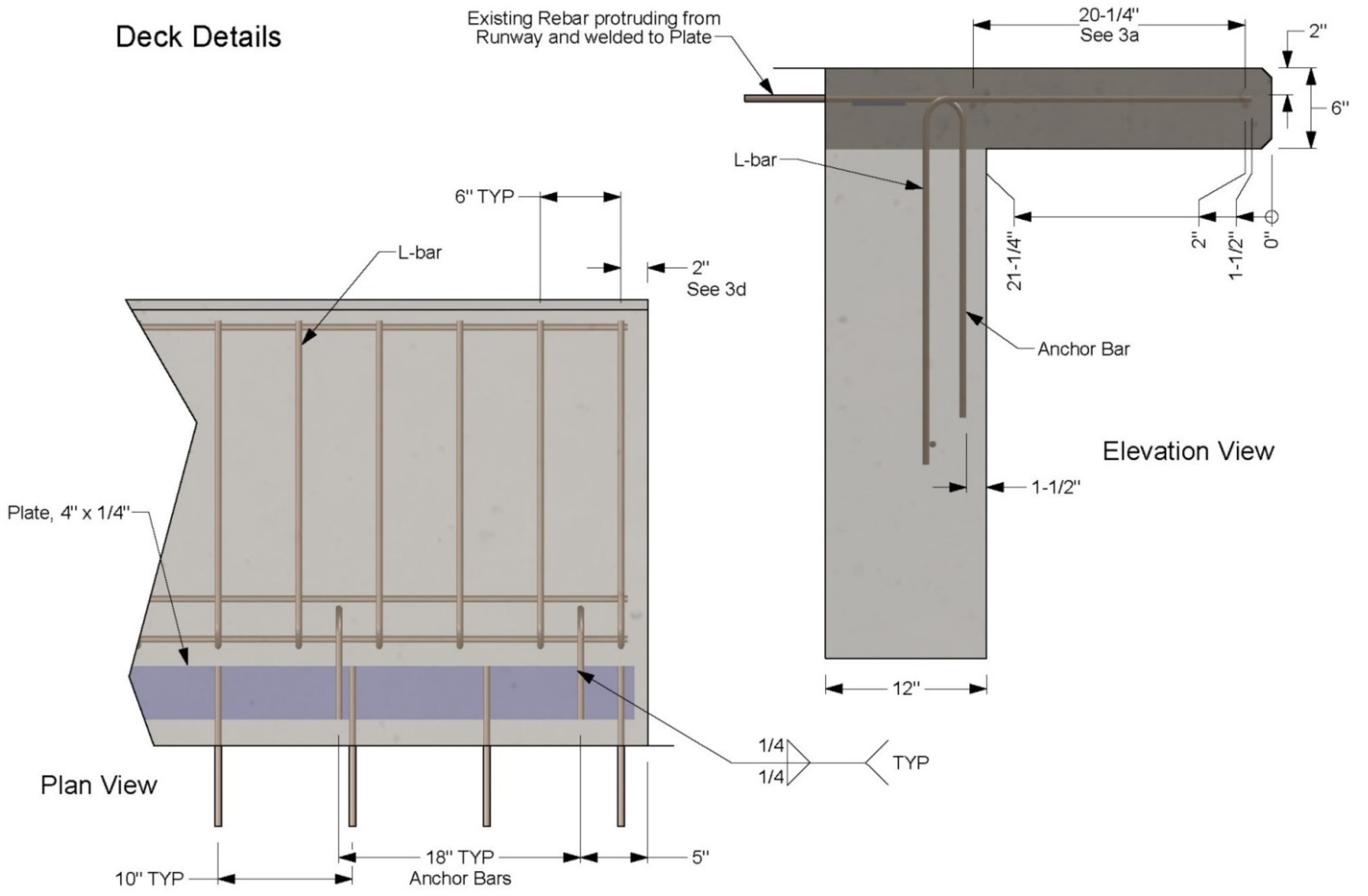
Installation - Elevation



Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground
Project 490024-2-1 T-222	2014-04-23
Drawn By GES / Scale1:120 / Sheet 2 of 8	Installation - Elevation

T:\2013-2014\490024 - TxDOT\490024-2 T-222\Drafting\490024-2-1 Drawing

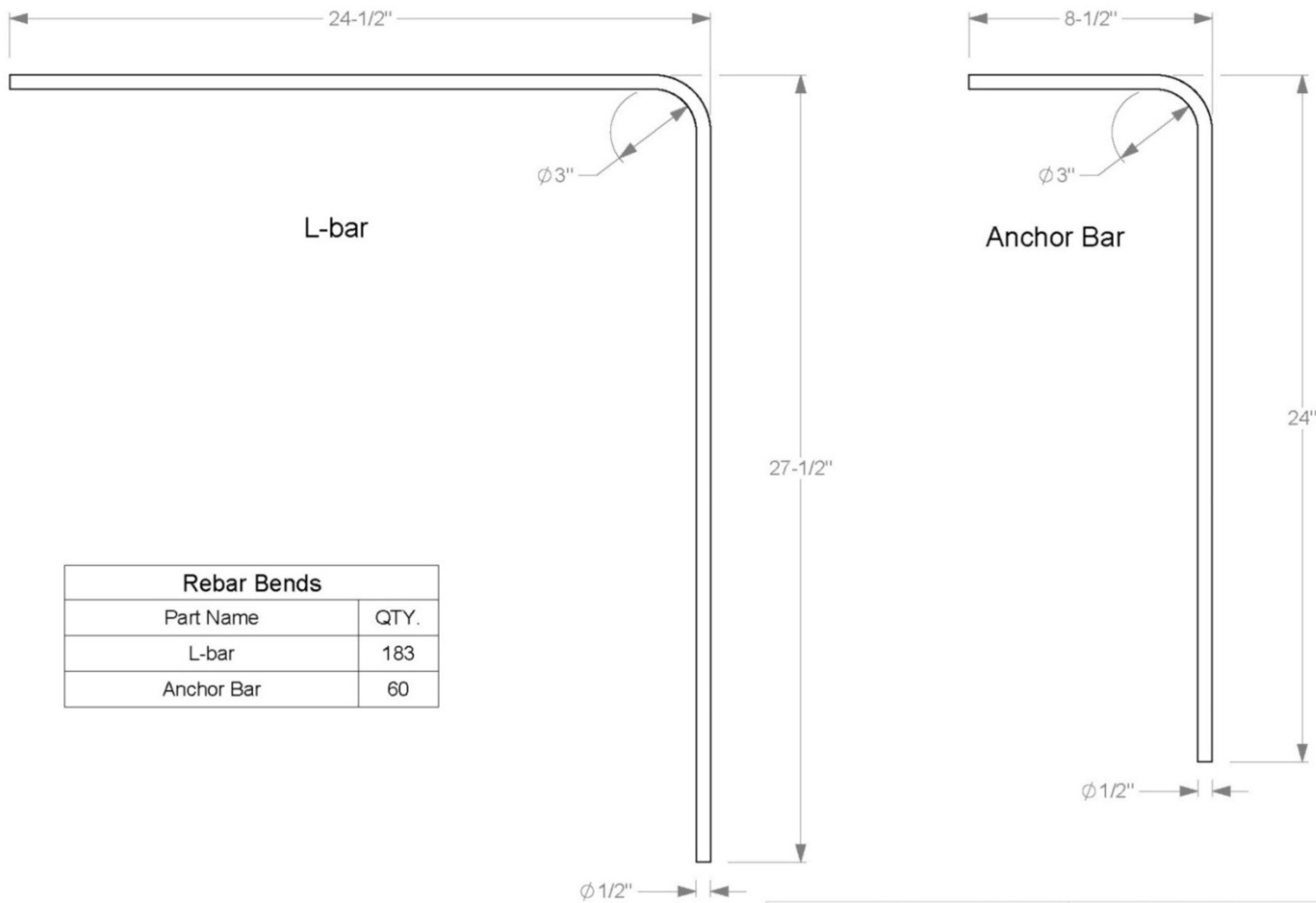
Deck Details



3a. Longitudinal Bars are ∅1/2" (#4). Laps are minimum 15". All rebar is grade 60.
3b. Concrete is TxDOT Class C (3600psi).
3c. Chamfer exposed Deck edges 3/4".
3d. Typical at each end and each side of construction joints.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground		
Project 490024-2-1	T-222		2014-04-23
Drawn By GES	Scale 1:10	Sheet 3 of 8	Deck Details

T:\2013-2014\490024 - TxDOT\490024-2 T-222\Drafting\490024-2-1 Drawing



Rebar Bends	
Part Name	QTY.
L-bar	183
Anchor Bar	60

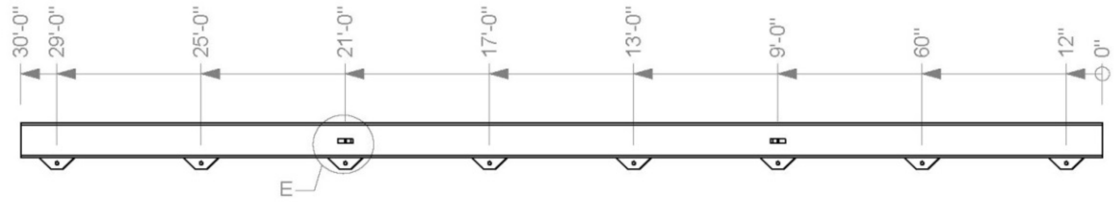
Texas A&M Transportation Institute

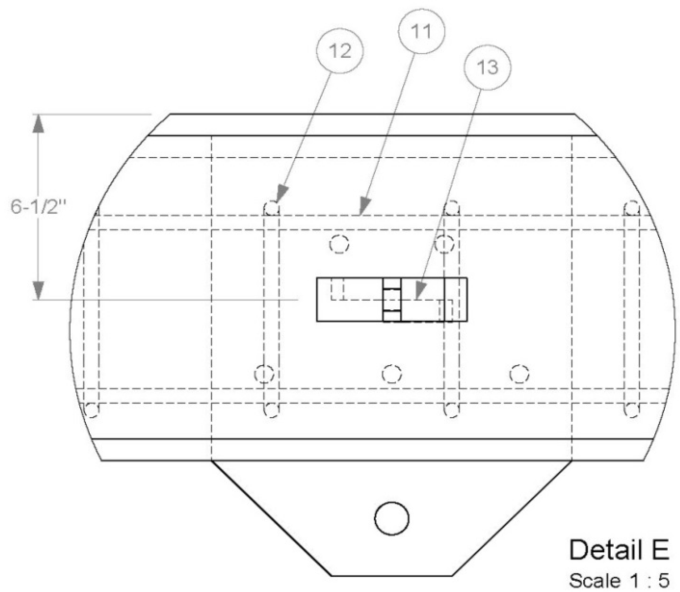
Roadside Safety and Physical Security Division - Proving Ground

Project 490024-2-1	T-222		2014-04-23
Drawn By GES	Scale 1:5	Sheet 4 of 8	Deck Bars

T:\2013-2014\490024 - TxDOT\490024-2 T-222\Drafting\490024-2-1 Drawing

Barrier Details - Plan





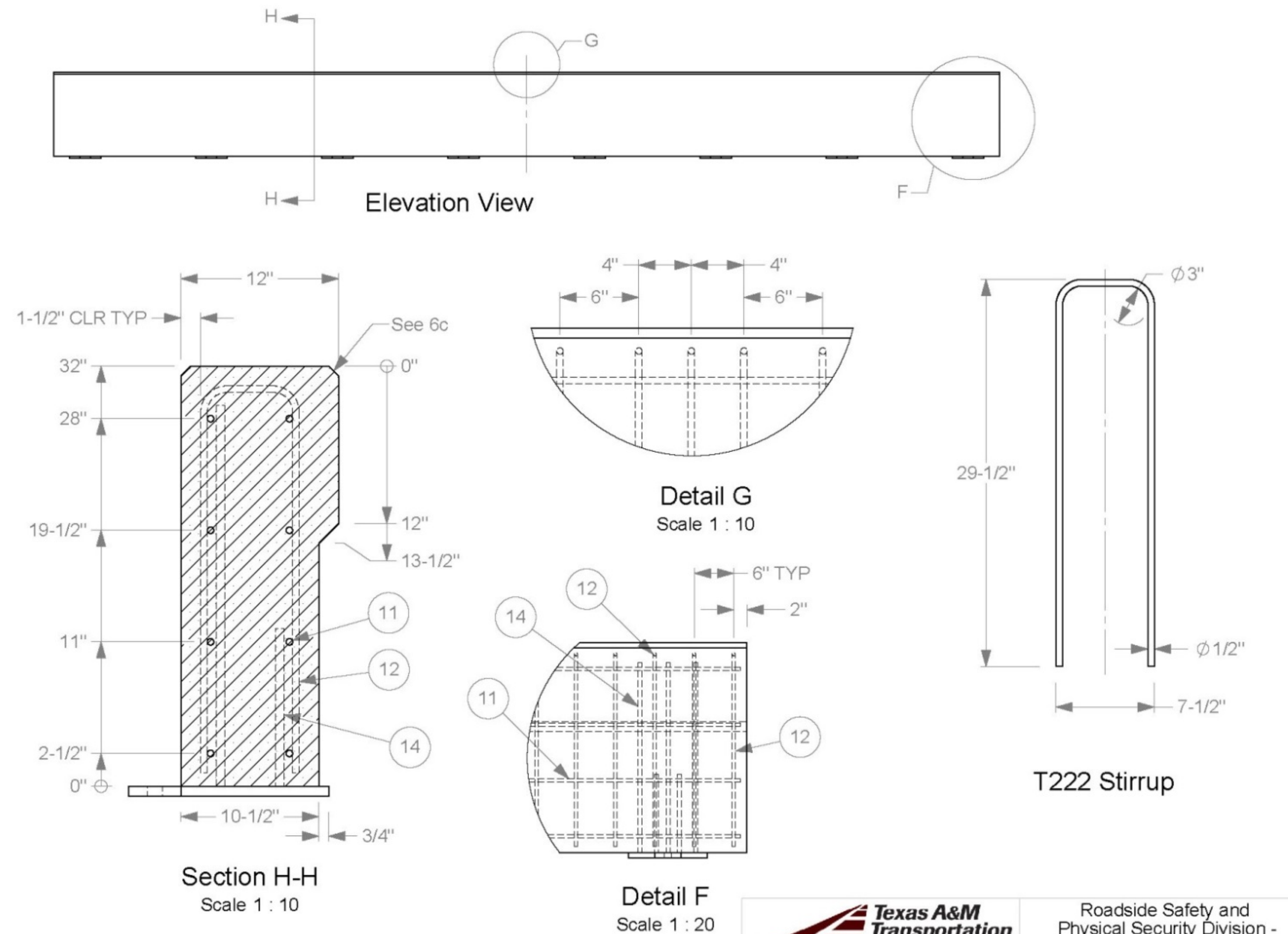
Detail E
Scale 1 : 5

Barrier Parts		
#	Part Name	QTY.
11	Longitudinal Bar, Ø1/2" (#4)	8
12	T222 Stirrup	61
13	Lifting Lug	2
14	T222 Anchor Plate	8

5a. Rebar shall be grade 60. Laps for #4 rebar shall be minimum 15".
5b. Concrete shall be TxDOT Class C (3600 psi).
5c. Chamfer edges 3/4" as shown.

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Project 490024-2-1	T-222		2014-04-23
Drawn By GES	Scale 1:50	Sheet 5 of 8	Barrier Details - Plan

T:\2013-2014\490024 - TxDOT\490024-2 T-222\Drafting\490024-2-1 Drawing

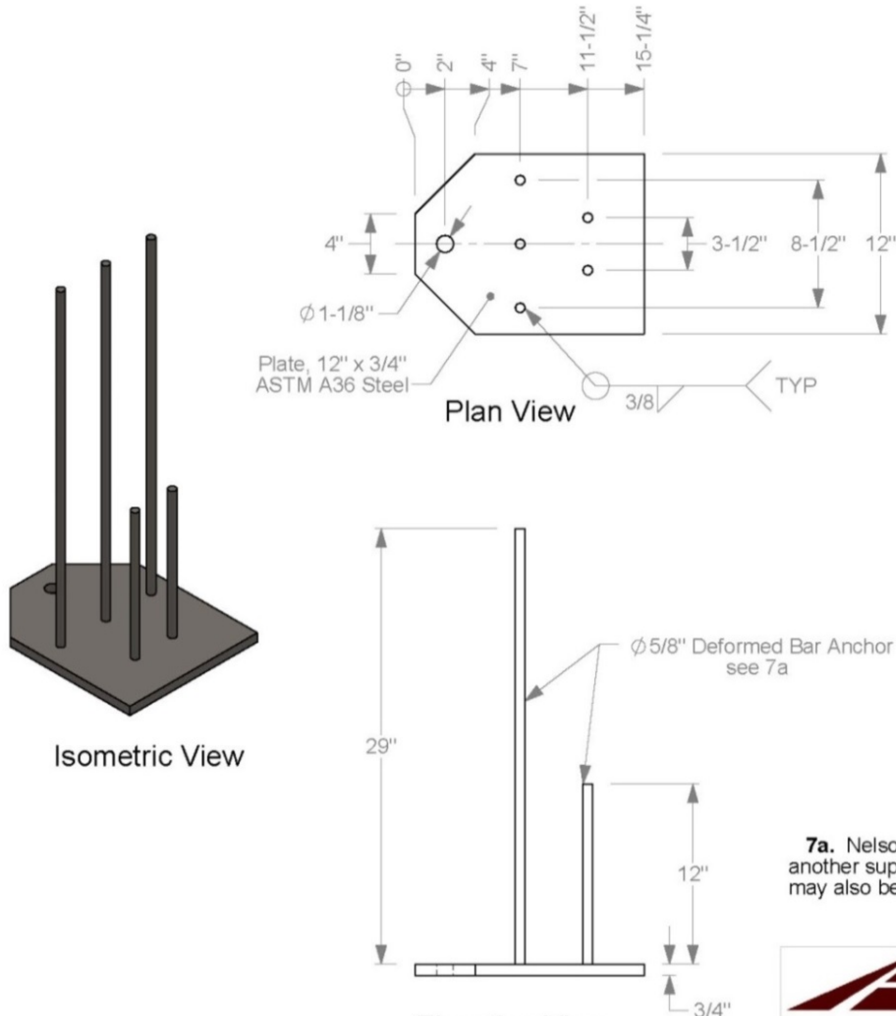


6a. Rebar shall be grade 60. Laps for #4 rebar shall be minimum 15".
6b. Concrete shall be TxDOT Class C (3600 psi).
6c. Chamfer edges 3/4" as shown.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground		
Project 490024-2-1	T-222		2014-04-23
Drawn By GES	Scale 1:50	Sheet 6 of 8	Barrier Details - Elevation

T:\2013-2014\490024 - TxDOT\490024-2 T-222\Drafting\490024-2-1 Drawing

(14) T222 Anchor Plate

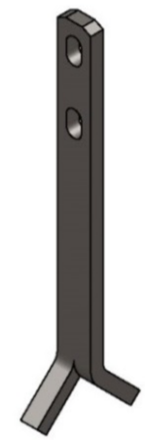


(13)

Lifting Lug

Halfen TPA-FS 0070.010-00018
(400mm long for 5 ton load)

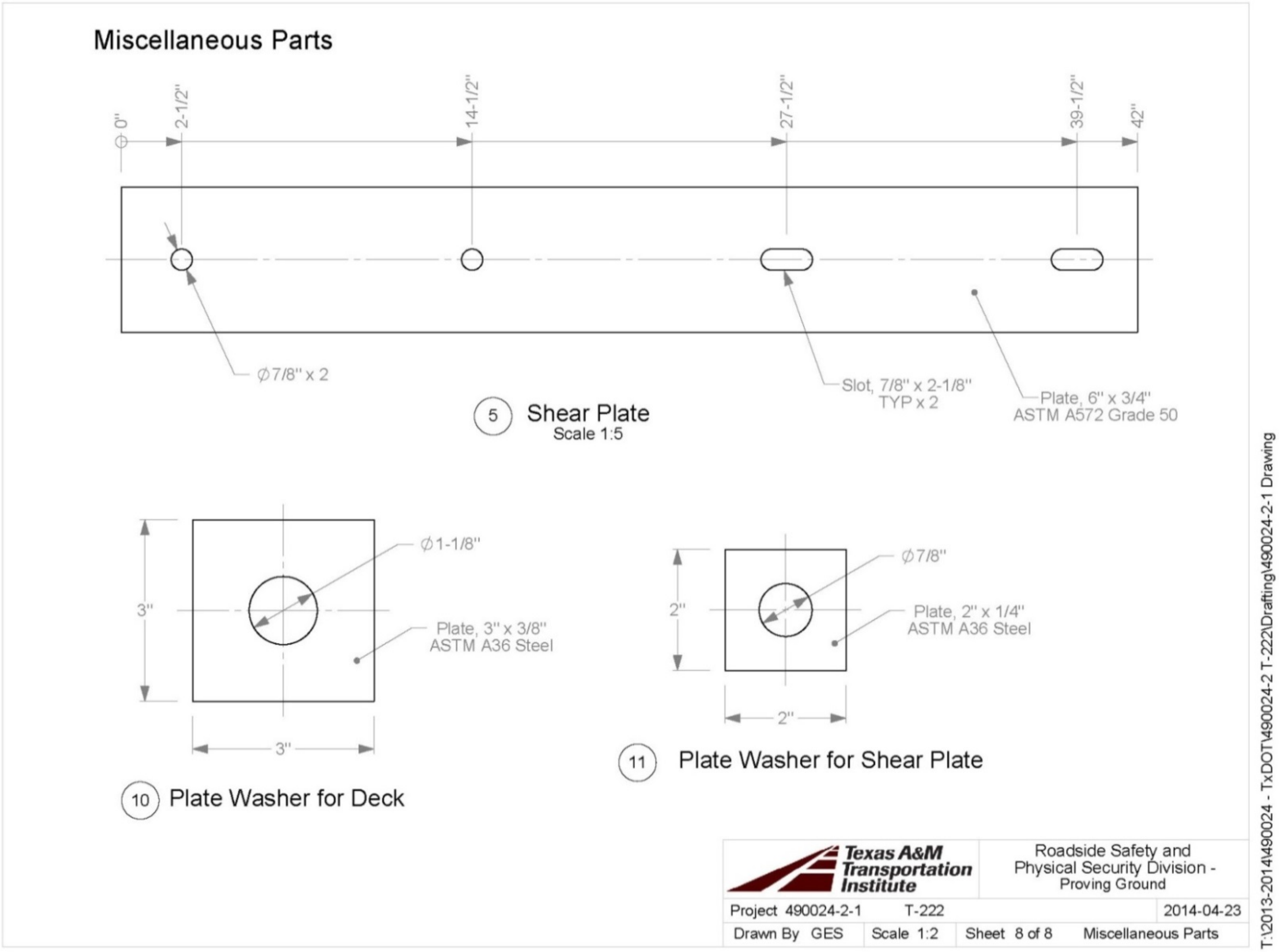
Scale 1:5



7a. Nelson Stud Welding D2L or a comparable product from another supplier. A comparable product from another supplier may also be substituted for the Lifting Lugs.

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Project 490024-2-1	T-222		2014-04-23
Drawn By GES	Scale 1:10	Sheet 7 of 8	Barrier Parts

T:\2013-2014\490024 - TxDOT\490024-2 T-222\Drafting\490024-2-1 Drawing


Miscellaneous Parts
0"
2-1/2"
14-1/2"
27-1/2"
39-1/2"
42"
∅7/8" x 2
Slot, 7/8" x 2-1/8"
TYP x 2
Plate, 6" x 3/4"
ASTM A572 Grade 50
5 Shear Plate
Scale 1:5
3"
3"
∅1-1/8"
Plate, 3" x 3/8"
ASTM A36 Steel
10 Plate Washer for Deck
2"
2"
∅7/8"
Plate, 2" x 1/4"
ASTM A36 Steel
11 Plate Washer for Shear Plate
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project 490024-2-1
T-222
2014-04-23
Drawn By GES
Scale 1:2
Sheet 8 of 8
Miscellaneous Parts
T:\2013-2014\490024 - TxDOT\490024-2 T-222\Drafting\490024-2-1 Drawing

MATERIAL USED

TEST NUMBER	490024-2-4
TEST NAME	T-222
DATE	2014-06-26

#	DATE RECEIVED	DESCRIPTION	GRADE	YIELD	TENSILE	SUPPLIER
	2013-04-04	Anchor Plates-01	see attached			Brazos Industries
	2013-04-19	Bolt, 1.0000-01	Ø1 x 10 A325			Mack Bolt & Steel
	2013-04-19	Nut, 1.0000-02	1" heavy hex			Mack Bolt & Steel
	2013-05-15	Nut, 1.0000-03	1" hex jam			Mack Bolt & Steel
	2013-02-05	Rebar 04-30	1/2" x 20' gr 60			CMC-Sheplers
	2013-04-02	Rebar 04-33	1/2" x 20' gr 60			CMC-Sheplers
	2013-04-19	Washer, 1.0000-02	Ø1 flat washer			Mack Bolt & Steel
	2013-04-19	Washer, 1.0000-03	Ø1 hardened washer			Mack Bolt & Steel
	2013-04-19	Washer, 1.0000-04	Ø1 lock washer			Mack Bolt & Steel
13-124	2014-04-16	Plate, 6 x 3/4	A36/A529 gr.50	54.9	76.3	Mack Bolt & Steel
13-125	2014-04-16	Threaded Rod, 3/4"	B7	121911-123072	138311-138602	Mack Bolt & Steel
13-126	2014-04-16	Nut, 3/4 heavy hex	A194-2H	-	-	Mack Bolt & Steel
13-127	2014-04-16	Washer, 3/4 lock	-	see paperwork	-	Mack Bolt & Steel

BLR466

BL - 3713912
Heat - SU13324
Order-Line - 9111503 / 7

Load - 1628918

03-21-2013 08:00
Brazos Industries Inc
Cust. PO -

)OSCO Mill Test Certificate/검사증명서

HOU - 6408107

Certificate No./증명서번호:120105-KPHE-008-001
Date of Issue/발행일자:Jan., 09, 2012

Order No./계약번호:0005039633
PO No./주문번호:5039633

Supplier/주문자:SK NETWORKS.CO.,LTD
Commodity/품명:HR PLATE(6408107)

Customer/고객사:TEMTCO HOU
Spec & Type/규격:AB/A A36 SA36

ORIGINAL

Size/치수	Product No. 제품번호	Quantity 수량	Weight 중량 (kg) (LBS)	Heat No. 제강번호	POSITION	Tensile/인장시험 YP (N/mm²)	TS (N/mm²)	EL (%)	Additional Tensile/인장시험 YP (N/mm²)	TS (N/mm²)	EL (%)	DIVISION	Chemical Composition/화학성분(%) C -4	Si -3	Mn -3	P -4	S -4	Cr -2	Ni -2	Cu -3	Mo -2	Nb -3	V -3	CEQ -3
0.75"x120"x480"	PP18066001-6004	4	22,220	SU13323	T	281	447	29	278	445	32	L	1529	251	694	165	30	2	1	9	Tr	Tr	1	269
			48,984									P	1484	245	692	177	33	1	1	9	Tr	Tr	Tr	
** Specimen No :	Tension => KP01402208																							
0.75"x120"x480"	PP18067201-7204	4	22,220	SU13324	T	286	439	30	279	448	31	L	1586	246	696	125	32	1	1	10	Tr	Tr	Tr	275
			48,984									P	1554	245	695	144	35	1	1	10	Tr	Tr	Tr	
** Specimen No :	Tension => KP01401802																							
0.75"x120"x480"	PP18067501-7503	3	16,665	SU13324	T	284	447	31	279	442	34	L	1586	246	696	125	32	1	1	10	Tr	Tr	Tr	275
			36,738									P	1554	245	695	144	35	1	1	10	Tr	Tr	Tr	
** Specimen No :	Tension => KP01401804																							
0.75"x120"x480"	PP18066801-6804	4	22,220	SU13324	T	270	444	32	279	442	34	L	1586	246	696	126	32	1	1	10	Tr	Tr	Tr	275
			48,984									P	1554	245	695	144	35	1	1	10	Tr	Tr	Tr	
0.75"x120"x480"	PP18067101-7104	4	22,220	SU13324	T	270	444	32	279	442	34	L	1586	246	696	125	32	1	1	10	Tr	Tr	Tr	275
			48,984									P	1554	245	695	144	35	1	1	10	Tr	Tr	Tr	
** Speciman No :	Tension => KP01401805																							
*** Sub Total	(060) ***	19	105,545 (kg)			232,683 (LBS)																		

* Position - T : Top, M : Middle, B : Bottom
* Tensile Test. Direction : Transversal, Gauge Length : 200mm(Rectangular).
* Additional Tensile Test. Direction : Transversal, Gauge Length : 200mm(Rectangular). YP Method :
0.2% off-set
Division - L:Ladle Analysis, P:Products Analysis
Chemical Composition Unit: -2:x1/100, -3:x1/1000, -4:x1/10000, -5:x1/100000
: It is within the standard range and include trace element.
Supply Condition : As-Rolled unless otherwise Heat Treated.

We hereby certify that the material has been made by an approved process in accordance with the rules of AMERICAN BUREAU OF SHIPPING and has been satisfactorily tested in the presence of the Society's representative.

No repair welding was performed to the products.
This material is fine grained steel.
Test Certificate is issued according to EN10204 3.2.
* This Mill Test Certificate cannot be copied for any purpose.

Surveyor To: ABS

ABS GEOJE

Kang. Y.S

OSCO Gwangyang Works, 700 Geumho-dong, Gwangyang-si, Jeollanam-do, 545-711, Korea

< PAGE:6 >

Chief of material testing section Kang. Y. S

Stud Welding Associates, Inc.,
an ISO 9001:2000
registered company

STUD WELDING ASSOCIATES

12200 ALAMEDA DR.
STRONGSVILLE, OH 44149
(440) 783-3160

620468
0

WELD STUD CERTIFICATION
DEFORMED BAR ANCHORS

SWA HEAT #: D-914 SUPPLIER HEAT #: 5077564

QTY: 500 PART#: DA0623018

SIZE: 5/8 X 30-3/16 DA

METRIC:

CUSTOMER: PO#: STOCK 9/20/11

Product Analysis - ASTM A-108 (Latest revision)

CERTIFIED MATERIAL TEST REPORT - CHEMICAL PROPERTIES

C: 0.160 Mn:0.716 Si:0.250 P: 0.008 S: 0.015 Cr:0.090 Ni:0.070 Mo:0.030

CERTIFIED MATERIAL TEST REPORT - MECHANICAL PROPERTIES

AISI GRADE: 1018 TENSILE: 101,060 YIELD: 98,100

REDUCTION (%): ELONG %:

CERTIFICATE OF CONFORMANCE

It is certified these products were fabricated from material conforming to original and current revisions of one or more of the following standards:

ASTM A496

All testing is in compliance with AWS D 1.1, D1.5 (original document and all current revisions)

Stud Welding Associates, Inc., as a Material Manufacturer, hereby certifies the stud welding product furnished herewith was manufactured from a single heat (code) or material. The certified chemical and mechanical properties recorded hereon constitute a Certified Material Test Report (CMTR) as required by AWS D 1.1.

* This material contains NO metallic mercury, mercury compounds nor is it contaminated with either substance.

William S. Houston
Stud Welding Associates, Inc.

Manufactured in U.S.A.
Melted in U.S.A.

Being duly sworn according to law says the information given in the foregoing certificate is true and correct to the best of his knowledge and belief.

Sworn to and subscribed before me this: 27th Day of October, 2011 AD

Judith E. Levendosky Notary Public, State of Ohio, U.S.A.

JUDITH E. LEVENDOSKY
Notary Public, State of Ohio
My Commission Expires Sept. 24, 2013

Form No. PRF
DCN No. 0174

Date: 10/30/08

619273

619273

STUD WELDING ASSOCIATES

Stud Welding Associates, Inc, an ISO 9001-2000 registered company

12200 ALAMEDA DR.
STRONGSVILLE, OH 44149
(440) 783-3160

WELD STUD CERTIFICATION
DEFORMED BAR ANCHORS

SWA HEAT #: B-914 SUPPLIER HEAT #: 5077564

QTY: 1,000 PART#: DA0621218

SIZE: 5/8 X 12-3/16 DA

METRIC:

CUSTOMER: PO#: STOCK - TROY

Product Analysis - ASTM A-108 (Latest revision)

CERTIFIED MATERIAL TEST REPORT - CHEMICAL PROPERTIES

C: 0.160 Mn:0.710 Si:0.250 P: 0.008 S: 0.015 Cr:0.090 Ni:0.070 Mo:0.030

CERTIFIED MATERIAL TEST REPORT - MECHANICAL PROPERTIES

AISI GRADE: 1018 TENSILE: 101,060 YIELD: 98,100

REDUCTION (%): ELONG %:

CERTIFICATE OF CONFORMANCE

It is certified these products were fabricated from material conforming to original and current revisions of one or more of the following standards:

ASTM A496

All testing is in compliance with AWS D 1.1, D1.5 (original document and all current revisions)

Stud Welding Associates, Inc., as a Material Manufacturer, hereby certifies the stud welding product furnished herewith was manufactured from a single heat (code) or material. The certified chemical and mechanical properties recorded hereon constitute a Certified Material Test Report (CMTR) as required by AWS D 1.1.

* This material contains NO metallic mercury, mercury compounds nor is it contaminated with either substance.

Manufactured in U.S.A.
Melted in U.S.A.

William S. Houston
Stud Welding Associates, Inc.

Being duly sworn according to law says the information given in the foregoing certificate is true and correct to the best of his knowledge and belief.

Sworn to and subscribed before me this: 20th Day of September, 2011 AD

Judith E. Levendosky Notary Public, State of Ohio, U.S.A.

JUDITH E. LEVENDOSKY
Notary Public, State of Ohio
My Commission Expires Sept. 24, 2013

Form No. PRF
DCN No. 0174

11

Date: 10/30/09

#1110 P.002/003 STUDWELDING ASSOCIATES (386) 839 013 12:13 09/09/2013

03-06-2013 05:00 Load - 1614117 BL - 3712580 BLR466
Brazos Industries Inc Heat - 52628
Cust. PO - Order-Line - 9027423 / 4,9007265 / 7

DEACERO

CERTIFICADO DE CALIDAD DE PRODUCTO TERMINADO / CERTIFICATE MATERIAL TEST

Ace Ramos — CARRETERA MONCLOVA KM 4 NUMERO 2125, TRA — RAMOS ARIZPE, COAHUILA

DATOS DEL CLIENTE / CUSTOMER DATA

Cliente/ Customer:	DEACERO USA INC
Dirección/ Address:	8411 IRVINGTON BLVD
Ciudad/ City:	HOUSTON — Estado/ State: TX
Teléfono/ Phone:	332 2376 — País/ Country — C.P./ ZIP: 77022-3449
Correo Electrónico/ eMail:	

No. Certificado/ Certificate No:	4188 - 10214312
Fecha/ Date:	28-Ene-2013

PRODUCTO TERMINADO/ FINISHING PRODUCT

DATOS DEL EMBARQUE

Num. Viaje/ Travel No:	4188
Remision/ Invoice No:	43003921
Pedido/ Customer Order No:	10214312
Num. Plan/ Shipping	4805
Fecha Embarque/ Shipping Date:	28-Ene-2013

COMPOSICION QUIMICA (% en Peso) / CHEMICAL COMPOSITION (% weight)

Colada/ Heat	Secuencia/ Sequence	Molino/ Mill	Clave	Producto / Description of Goods	%C	%Mn	%Si	%P	%S	%Ti	%V	%Nb
52628	4943	MOLRAM 01	60596	FLAT BAR 3" x 3/8" A-36 20' 2.0T	0.22	0.83	0.18	0.010	0.015	0.001	0.005	0.000

PROP. FISICAS/PHYSICAL TEST

Colada/ Heat	Secuencia/ Sequence	Molino/ Mill	Clave	Producto / Description of Goods	Cantidad / Quantity	RT / TS Kg / mm2	RT / TS Psi	Lf / Ys Kg/mm2	Lf / Ys Psi	Elongación en % de 8 pulgadas / Elongation in % of 8 inches	Prueba de Doblez / Bend Test
52628	4943	MOLRAM01	60596	FLAT BAR 3" x 3/8" A-36 20' 2.0T	2	54.5	77,447.6	41.9	59,542.4	34	Cumple

658259 2

We certify that this material has been produced, inspected and tested according to standards applicable in steelmaking, and to the dimensional standards NMX B 252, ASTM A6/A6M, provided the results satisfactorily.

Aseguramiento de Calidad / Certification
Ing. Octavio Sarabia Caballero
Gerente de Aseguramiento de Calidad / Quality Assurance Manager

邢台钢铁有限责任公司
XINGTAI IRON AND STEEL CORP.,LTD

产品质量证书
INSPECTION CERTIFICATE

地址：河北省邢台市钢铁南路262号
ADD:262 Gangtie Road, Xingtai,Hebei, Cina
电话：（86）0319-2044313
(TEL):(86)0319-2042815

邢钢质字（J）-070

订货单位 CUSTOMER	上海富仓钢铁有限公司	证书号 CERTIFICATE NO.	12099652	车号 TRAIN NO.	9865874
收货单位 PURCHASER	上海富仓钢铁有限公司	开证日期 DATE OF ISSUE	2012-9-12	重量合计（t） TOTAL WEIGHT	28.166
合同号 CONTRACT NO.	XG-IS-1209525984-XY-05	交货标准 SPECIPICATION	Q/XG114.1-2007	盘数合计（件） TOTAL QTY	14

批号 HEAT NO.	产品名称 PRODUCT	盘数 QTY	重量 WEIGHT (t)	化学成分 CHEMICAL COMPOSITION(%)								显微检验 M.E.T		
				C	Mn	Si	S	P	Mo	Cr	Ni	脱碳层 DEC(mm)	夹杂 INGLUSION	晶粒度 G.S
331206084	SWRCH45KΦ26mm	14	28.166	0.45	0.70	0.19	0.004	0.012	-	-	-	0	-	-

批号 HEAT NO.	拉伸试验 TENSILE TEST				冷弯试验 C.B.T	顶锻试验 C.H.T	硬度 HARDNESS TEST			冲击试验 IMPACT TEST (J)	低倍检验 MACROECTOHING TEST	
	屈服强度 ReL W.S(MPa)	抗拉强度 Rm T.S(MPa)	伸长率 A E.L(%)	面缩率 Z R.A(%)							疏松 POROSITY	偏析 SEGREGATION
331206084	-	-	-	-	-	1/2合格	-	-	-	-	-	0

备注 REMARK

1、质量证明书复印件不具有同等法律效应 THE COPY OF THE INSPECTION CERTIFICATE IS INEFFECTIVE LEGALLW.
2、热轧交货 DELIVERY AFTEN HOT HOLLING
3、DEC=DECARBURIZATION C.H.T.=COLD HEADING TEST G.S=GRAIN SI

质检印章 SEAL

签证人：

Stelfast Inc.

22979 Stelfast Parkway
Strongsville, Ohio

44149

Report of Chemical and Physical Properties

Issued To: Mack Bolt, Steel & Machine
5875 Hwy 21 East
BRYAN, TX
77808

Purchase Order: 24901
Stelfast Order: SO 83626
Certificate #: 447,607

Quantity: 600
Part #: DHWGA10000
Description: 1" Astm F436 Hard. Washers Hdg

Lot Number: GBR12538390-016
Heat Number: D112B05302
Country of Origin: CN

Chemical Analysis

C	Mn	P	S	Si	Cr	Mo	V	B	Ni	Cu
0.47	0.67	0.016	0.006	0.24	0.19					

Mechanical Properties

Hardness (Core) 29 - 34 HRC

We hereby certify that the above data is a true copy of the data furnished to us by the producing mill or the data resulting from tests performed in approved laboratories.

This certificate applies to the product shown on this document, as supplied by Stelfast Inc. Alterations to the product by our customer or a third party will render this certificate void.

ROBERT D. MEAGHER
QUALITY MANAGER

April 18, 2013

Page 1 of 1

Stelfast Inc.

22979 Stelfast Parkway
Strongsville, Ohio

44149

Report of Chemical and Physical Properties

Issued To: Mack Bolt, Steel & Machine
5875 Hwy 21 East
BRYAN, TX
77808

Purchase Order: 24901
Stelfast Order: SO 83626
Certificate #: 425,910

Quantity: 500
Part #: DMLGA10000
Description: 1" Med.L/Wshr Hdg .020 O/S

Lot Number: 1202528
Heat Number: F140009475
Country of Origin: CN

Chemical Analysis

C	Mn	P	S	Si	Cr	Mo	V	B	Ni	Cu
0.65	0.58	0.018	0.009	0.21						

Mechanical Properties

Hardness (Core) 41 - 45 HRC

We hereby certify that the above data is a true copy of the data furnished to us by the producing mill or the data resulting from tests performed in approved laboratories.

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ROBERT D. MEAGHER
QUALITY MANAGER

April 18, 2013

Page 1 of 1

Stelfast Inc.

22979 Stelfast Parkway
Strongsville, Ohio

44149

Report of Chemical and Physical Properties

Issued To: Mack Bolt, Steel & Machine
5875 Hwy 21 East
BRYAN, TX
77808

Purchase Order: 24833
Stelfast Order: SO 83088
Certificate #: 441,482

Quantity: 140
Part #: A2HHG1000C
Description: 1-8 2h Hvy.Hx.Nuts HDG/TOS 0.024

Lot Number: 5047860001
Heat Number: J11202392
Country of Origin: CN

Chemical Analysis

C	Mn	P	S	Si	Cr	Mo	V	B	Ni	Cu
0.44	0.69	0.015	0.003	0.19						

Mechanical Properties

Minimum Tempering Temp.	520 C
Result of 24 Hr. Temper Test	92 - 95 HRB
Hardness (Core)	28 - 31 HRC
Proof Load	106050 LBF PASSED
Macro Etch Test	S2,R2,C2
Grade Markings	ASTM A194(12a)-2H

We hereby certify that the above data is a true copy of the data furnished to us by the producing mill or the data resulting from tests performed in approved laboratories.

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ROBERT D. MEAGHER
QUALITY MANAGER

April 18, 2013

Page 1 of 1

CERTIFIED MATERIAL TEST REPORT
FOR ASTM A325 TYPE-1 HEAVY HEX STRUCTURAL BOLTS

FACTORY:ZHEJIANG NEW ORIENTAL FASTENER CO.,LTD
ADDRESS:XITANGQIAO HAIYAN ZHEJIANG,CHINA

DATE:2012-10-10

MFG LOT NUMBER:M-DF2145-1

CUSTOMEI PORTEOUS FASTENER COMPANY

PO NUMBER:12042442

SAMPLE SIZE:ACC.TO ASME B18.18.2M-93
SIZE:1-8X10" HDG QNTY: 450 PCS
HEADMARKS: A325+NDF

PART NO: 00152-4068-024

STEEL PROPERTIES:
STEEL GRADE:1045

HEAT NUMBER:331206084

CHEMISTRY SPEC:	C % 0.30-0.52	Mn% 0.60min	P % 0.040max	S % 0.050max	Si% 0.15-0.30
TEST:	0.45	0.70	0.012	0.004	0.19

DIMENSIONAL INSPECTIONS — SPECIFICATION: ASME B18.2.6-03

CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
APPEARANCE	ASTM F788-02	PASSED	100	0
THREAD	ASME B1.1-02 2A	PASSED	32	0
WIDTH FLATS.	1.625"-1.575"	1.585"-1.610"	8	0
WIDTH A/C	1.876"-1.796"	1.810"-1.832"	8	0
HEAD HEIGHT	0.627"-0.591"	0.594"-0.599"	8	0
BODY DIA.	1.022"-0.976"	0.981"-0.988"	8	0
THREAD LENGTH	ref1.75"	1.70"-1.73"	8	0
LENGTH	10.00"-9.75"	9.82"-9.86"	8	0

MECHANICAL PROPERTIES: 1/2"thru1" — SPECIFICATION: ASTM A325-10 TYPE 1

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS:	ASTM F606-10a	max 34 HRC	28-31 HRC	8	0
WEDGE TENSILE:	ASTM F606-10a	MIN 120000 PSI	132000-135000PSI	4	0
PROOF LOAD	ASTM F606-10a	MIN 85000 PSI	PASS	4	0
YIELD STRENGTH:	ASTM F606-10a	MIN 92000 PSI	104800PSI	1	0
DECARBURIZATION	SAE J121-97		PASS	1	0

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
HOT DIP GALVANIZEI	ASTM F2329	MIN 0.0017" IN	0.0024"-0.0028"	4	0

ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE ASTM SPECIFICATION. WE CERTIFY THAT THIS DAIA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.

All parts meet the requirements of FQA and records of compliance are on file.
Maker's ISO#CN06/01495

(SIGNATURE OF Q.A. LAB MGR.)
(ZHEJIANG NEW ORIENTAL FASTENER CO.,LTD)

SOLD TO: ADELPHIA METALS I LLC
411 MAIN ST E
NEW PRAGUE, MN 56071-

SHIP TO: ADELPHIA METALS-CUST PU
N/A
JEWETT, TX 75846-

NUCOR
NUCOR CORPORATION
NUCOR STEEL TEXAS

CERTIFIED MILL TEST REPORT

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

Date: 18-Sep-2012
B.L. Number: 617154
Load Number: 224234

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# =>	804753												
JW1210787001	Nucor Steel - Texas	72,200	104,800	11.0%			.36	.98	.011	.035	.16	.27	
JW12107870	13/#4 Rebar	498MPa	723MPa				.17	.15	.055	.017	.002		
	20' A615M GR 420 (Gr60)												
	ASTM A615/A615M-12 GR 60[420]												
	AASHTO M31-07												
PO# =>	804753												
JW1210787101	Nucor Steel - Texas	71,600	103,800	14.0%			.36	.94	.012	.024	.17	.34	
JW12107871	13/#4 Rebar	494MPa	716MPa				.18	.17	.058	.017	.003		
	20' A615M GR 420 (Gr60)												
	ASTM A615/A615M-12 GR 60[420]												
	AASHTO M31-07												

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

TR No. 9-1002-12-13

48

2014-08-29

CMC STEEL TEXAS
1 STEEL MILL DRIVE
SEGUIN TX 78155-7510

CERTIFIED MILL TEST REPORT
For additional copies call
830-372-8771

We hereby certify that the test results presented here, are accurate and conform to the reported grade specification

Daniel J. Schacht
Daniel J. Schacht
Quality Assurance Manager

HEAT NO.:3037827 SECTION: REBAR 13MM (#4) 20'0" 420/60 GRADE: ASTM A615-12 Gr 420/60 ROLL DATE: 02/10/2013 MELT DATE: 02/01/2013	SOLD TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	SHIP TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	Delivery#: 80937856 BOL#: 70336203 CUST PO#: 590387 CUST P/N: DLVRY LBS / HEAT: 2191.000 LB DLVRY PCS / HEAT: 164 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.42%				
Mn	0.85%				
P	0.016%				
S	0.035%				
Si	0.20%				
Cu	0.23%				
Cr	0.18%				
Ni	0.21%				
Mo	0.069%				
V	0.002%				
Cb	0.000%				
Sn	0.010%				
Al	0.002%				
Yield Strength test 1	66.9ksi				
Tensile Strength test 1	103.9ksi				
Elongation test 1	13%				
Elongation Gage Lgth test 1	8IN				
Bend Test Diameter	1.750IN				
Bend Test 1	Passed				

115 - #4

PO# 590027-2

THIS MATERIAL IS FULLY KILLED, 100% MELTED AND MANUFACTURED IN THE USA, WITH NO WELD REPAIR OR MERCURY CONTAMINATION IN THE PROCESS.

REMARKS :

02/20/2013 16:10:26

海盐三马标准件有限公司

Haiyan Sanma Standrd Hardware Co.,Ltd

检 测 报 告

地址：浙江海盐于城镇八字村五金工业园区振兴路 5 号
No.5Zhenxing Road,Yucheng Lndustry Pack Zone,
HaiyanZhejiang, China
电话(Tel)：0573-86466128
传真(Fax)：0573-86466118

合同号 Po No: U08716
日期 Report Date:2012.07.15
Country of Origin: China　　Part No.:314200
生产日期 Manufacture Date:2012.06.02

客户名称 Customer: BRIGHTON-BEST INTERNATIONAL (TAIWAN) INC.

品 名 Product: ASTMA194-2H Heavy Hex Nuts　　数　量 Quantity:18mpcs
规 格 Size: 3/4"-10　　标　记 Marker: SHS　2H
表面处理 Finish: PLAIN　　检验标准 Inspection Standard：ASTM/ASME A194/SA194
批 号 Lot　No: U08716-314200　　尺寸标准 Dimensional Specification: ASME B18.2.2

一、钢材性质 STEEL PROPERTIES:
材质 Material:SWRCH45K　　热处理批号 Heat No: B4108073　　规格 Steel Size:ø28mm

ELEMENT (成份)	C%	Mn%	P%	S%	Si%	Cr%	Ni%
B4108073	0.46	0.68	0.011	0.006	0.14	0.158	0.035

二、项目检测 Inspections Item:

检测项目 Item	标 准 值 Specified(in)	实 测 值 Actual Result	判定 Judgement
外 观 Appearance	Passed	Passed	OK
对 边(in) Across Flat(in)	1.212-1.250	1.220-1.225	OK
对 角(in) Across Corner(in)	1.382-1.443	1.396-1.402	OK
厚 度(in) Thickness(in)	0.710-0.758	0.725-0.738	OK
螺纹精度 Threcd	2B GO	OK	OK
	2B NOGO	OK	OK
硬 度(HRC) Hardness	24-35	29-33	OK
保证载荷(KSI) Proof Load	175KSI	175KSI	
540℃ 回火 24H 后硬度(HRB) Hardness After 24H AT 540℃	MIN 89	93-97	
回火温度(℃) Tempering Temperature	Min 455	530-545	
宏观腐蚀实验 Macro Etch Test	S1/R1/C1-S4/R4/C4	S2/R2/C2	OK

Stelfast Inc.
22979 Stelfast Parkway
Strongsville, Ohio
44149

Report of Chemical and Physical Properties

Issued To: Mack Bolt Steel & Machine
5875 Hwy 21 East
BRYAN TX 77808

Purchase Order: 25631
Stelfast Order: SO 89565
Certificate #: 469,131

Quantity: 0
Part #: ST7007508000CEND
Description: 3/4-10x8 Stud B7
MeasureEnd/End

Lot Number: 3237010008
Heat Number: 331301684
Country of Origin: CN

Chemical Analysis

C	Mn	P	S	Si	Cr	Mo	V	B	Ni	Cu
0.41	0.82	0.016	0.005	0.22	0.92	0.18				

Mechanical Properties

Minimum Tempering Temp	640 C
Macrotech	S2,R2,C2
Tensile	138311 - 138602 PSI
Yield	121911 - 123072 PSI
Elongation %	22.24
Red of Area%	63.87
Hardness (HRC)	28 - 30 HRC
Grade Markings	ASTM A193(2011) GR.B7

We hereby certify that the above data is a true copy of the data furnished to us by the producing mill or the data resulting from tests performed in approved laboratories.

This certificate applies to the product shown on this document, as supplied by Stelfast Inc. Alterations to the product by our customer or a third party will render this certificate void.

ROBERT D. MEAGHER
QUALITY MANAGER

April 14, 2014

CMC STEEL TEXAS
1 STEEL MILL DRIVE
SEGUIN TX 78155-7510

CERTIFIED MILL TEST REPORT

For additional copies call
830-372-8771

We hereby certify that the test results presented here are accurate and conform to the reported grade specification

Daniel J. Schacht
Daniel J. Schacht
Quality Assurance Manager

HEAT NO.:3036306 SECTION: FLAT 3/4x6 20'0" A36/52950 GRADE: ASTM A36-08/A529-05 Gr 50 ROLL DATE: 11/20/2012 MELT DATE: 11/19/2012	SOLD TO		SHIP TO		Delivery#: 80942827 BOL#: 70337937 CUST PO#: HOU-151420 CUST P/N: DLVRY LBS / HEAT: 9792.000 LB DLVRY PCS / HEAT: 32 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.17%				
Mn	0.83%				
P	0.012%				
S	0.032%				
Si	0.19%				
Cu	0.29%				
Cr	0.16%				
Ni	0.15%				
Mo	0.054%				
V	0.020%				
Cb	0.001%				
Sn	0.015%				
Al	0.002%				
Carbon Eq A529	0.42%				
Yield Strength test 1	54.9ksi				
Tensile Strength test 1	76.3ksi				
Elongation test 1	35%				
Elongation Gage Lgth test 1	8IN				

THIS MATERIAL IS FULLY KILLED, 100% MELTED AND MANUFACTURED IN THE USA, WITH NO WELD REPAIR OR MERCURY CONTAMINATION IN THE PROCESS.

REMARKS :

02/27/2013 13:14:21
Page 1 OF 1

APPENDIX C. TEST VEHICLE PROPERTIES AND INFORMATION

Table C1. Vehicle Properties for Test No. 490024-2-1.

Date: 2014-06-19 Test No.: 490024-2-1 VIN No.: 1D7HA18N585509318

Year: 2008 Make: Dodge Model: Ram 1500 Quad-Cab

Tire Size: P265/70R17 Tire Inflation Pressure: 35 psi

Tread Type: Highway Odometer: 168595

Note any damage to the vehicle prior to test:

• Denotes accelerometer location.

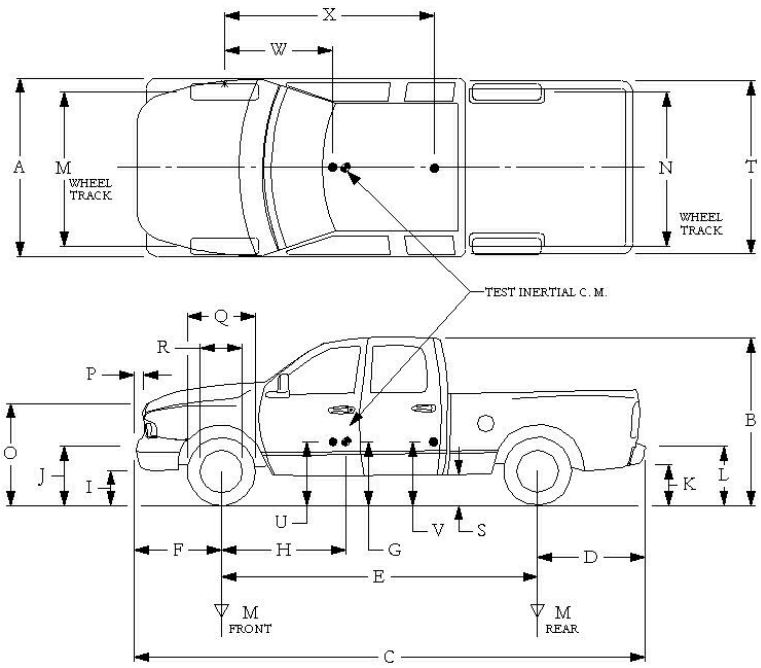
NOTES: -----

Engine Type: V-8
Engine CID: 4.7 liter

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

Optional Equipment:
None

Dummy Data:
Type: No dummy
Mass: NA
Seat Position: NA



Geometry: inches

A	78.25	F	36.00	K	20.50	P	2.88	U	28.50
B	75.00	G	28.50	L	29.00	Q	30.50	V	30.50
C	223.75	H	63.26	M	68.50	R	16.00	W	63.20
D	47.25	I	15.00	N	68.00	S	14.00	X	75.50
E	140.50	J	26.50	O	46.00	T	77.50		

Wheel Center Height Front	14.75	Wheel Well Clearance (Front)	6.00	Bottom Frame Height - Front	18.00
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	11.00	Bottom Frame Height - Rear	24.75

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

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2831	2778	2778
Back	3900	M_{rear}	1958	2275	2275
Total	6700	M_{Total}	4789	5053	5053

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

Mass Distribution:
lb LF: 1396 RF: 1382 LR: 1145 RR: 1130

Table C2. Vehicle Parameter Worksheet for Test No. 490024-2-1.

Date: 2014-06-19 Test No.: 490024-2-1 VIN: 1D7HA18N585509318

Year: 2008 Make: Dodge Model: Ram 1500

Body Style: Quad-Cab Mileage: 168595

Engine: 4.7 liter V-8 Transmission: Automatic

Fuel Level: Empty Ballast: 266 lb (440 lb max)

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

Measured Vehicle Weights: (lb)								
LF:	1396	RF:	1382	Front Axle:	2778			
LR:	1145	RR:	1130	Rear Axle:	2275			
Left:	2541	Right:	2512	Total:	5053			
				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:	63.26 in	Rear of Front Axle		(63 ±4 inches allowed)				
Y:	-0.20 in	Left -	Right +	of Vehicle Centerline				
Z:	28.5 in	Above Ground		(minumum 28.0 inches allowed)				

Hood Height: 46.00 inches
43 ±4 inches allowed

Front Bumper Height: 26.50 inches

Front Overhang: 36.00 inches
39 ±3 inches allowed

Rear Bumper Height: 29.00 inches

Overall Length: 223.75 inches
237 ±13 inches allowed

Table C3. Exterior Crush Measurements for Test No. 490024-2-1.

Date: 2014-06-19 Test No.: 490024-2-1 VIN No.: 1D7HA18N585509318

Year: 2008 Make: Dodge Model: Ram 1500 Quad-Cab

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage		Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width** (CDC)	Max*** Crush								
1	Front plane at bumper ht	20.0	11.50	30	0	0.5	2.5	7.0	9.5	11.5	+15
2	Side plane at bumper ht	20.0	19.25	50	5.0	8.0	----	----	18.0	19.5	+60
	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).

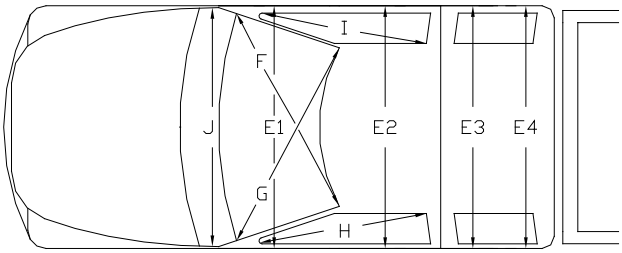
***Measure and document on the vehicle diagram the location of the maximum crush.

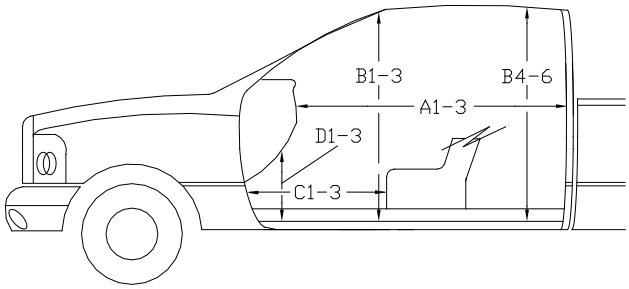
Note: Use as many lines/columns as necessary to describe each damage profile.

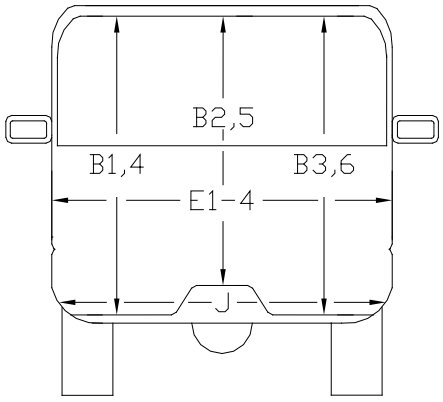
Table C4. Occupant Compartment Measurements for Test No. 490024-2-1.

Date: 2014-06-19 Test No.: 490024-2-1 VIN No.: 1D7HA18N585509318

Year: 2008 Make: Dodge Model: Ram 1500 Quad-Cab







*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	65.00	65.00
A2	64.50	64.50
A3	65.00	64.25
B1	45.25	45.25
B2	39.50	38.50
B3	45.25	45.75
B4	42.00	42.00
B5	44.75	44.75
B6	42.00	42.00
C1	29.00	29.00
C2	----	----
C3	26.75	25.00
D1	12.75	12.75
D2	----	----
D3	11.50	13.00
E1	63.00	62.00
E2	64.25	65.25
E3	64.00	63.25
E4	64.25	63.25
F	60.00	60.00
G	60.00	60.00
H	39.00	39.00
I	39.00	39.00
J*	62.25	58.25

APPENDIX D. SEQUENTIAL PHOTOGRAPHS

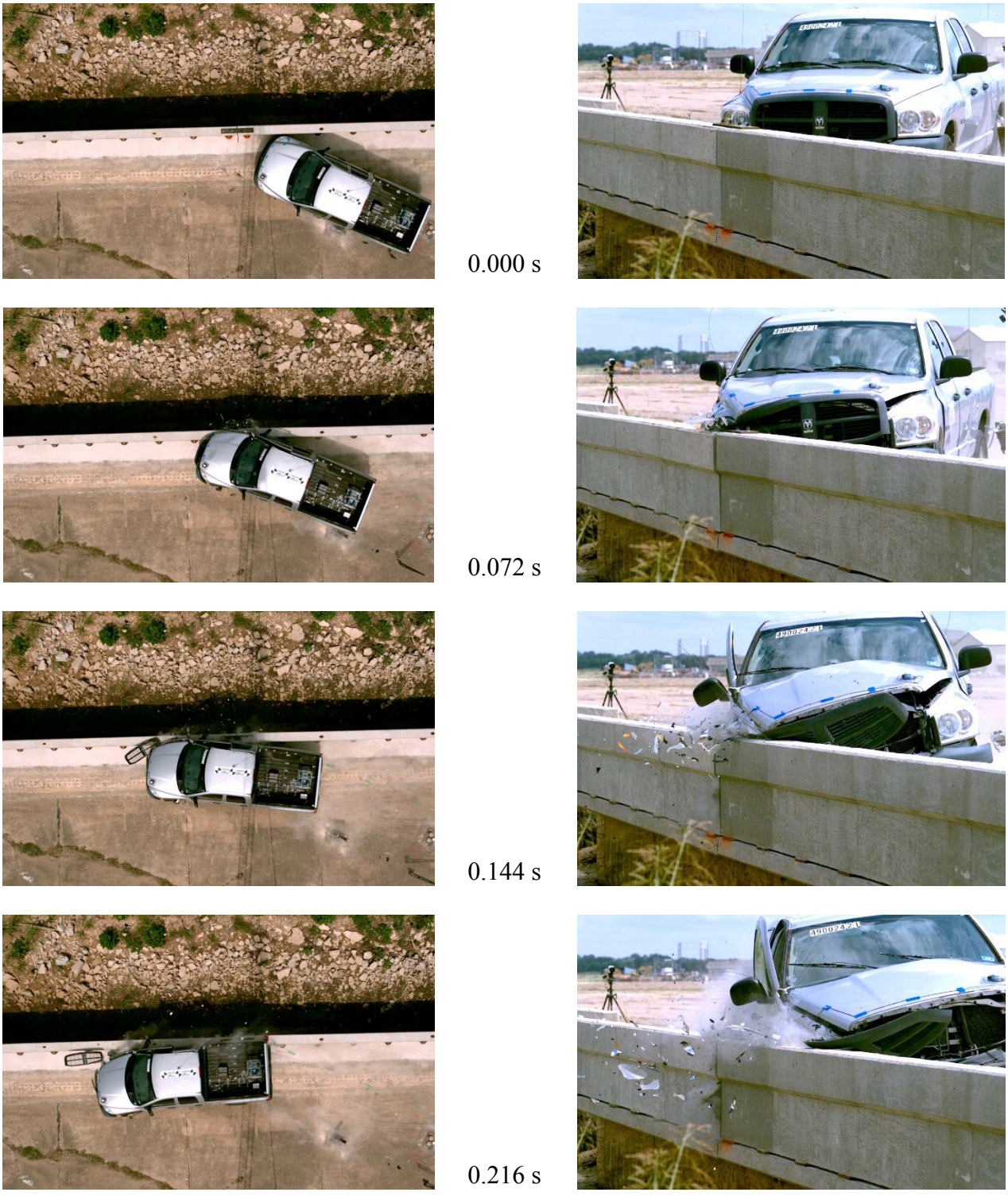


Figure D1. Sequential Photographs for Test No. 490024-2-1 (Overhead and Frontal Views).


0.288s


0.360 s


0.432 s


0.504 s

Figure D1. Sequential Photographs for Test No. 490024-2-1(Overhead and Frontal Views) (Continued).

APPENDIX E. VEHICLE ANGULAR DISPLACEMENTS AND ACCELERATIONS

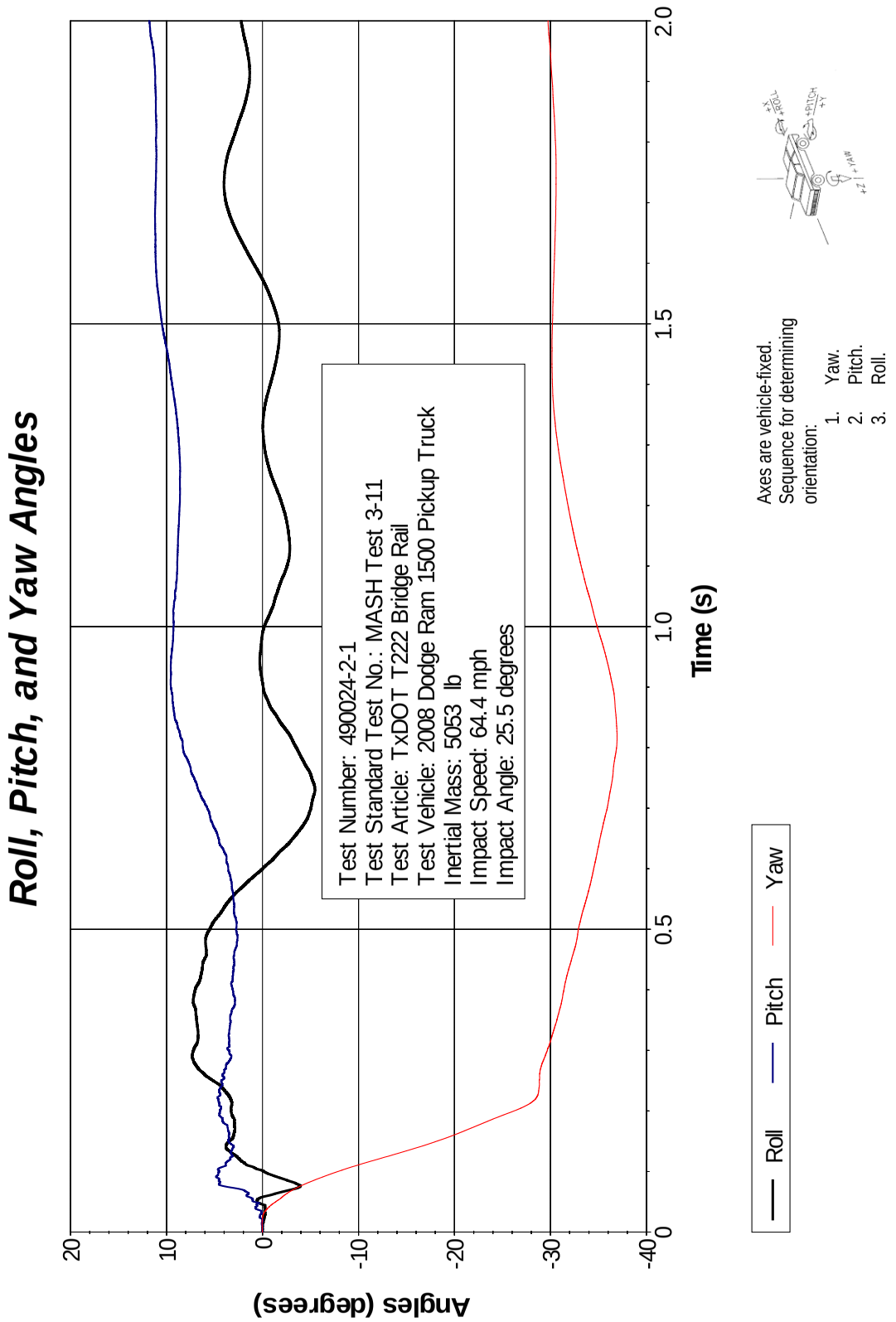


Figure E1. Vehicle Angular Displacement for Test No. 490024-2-1.

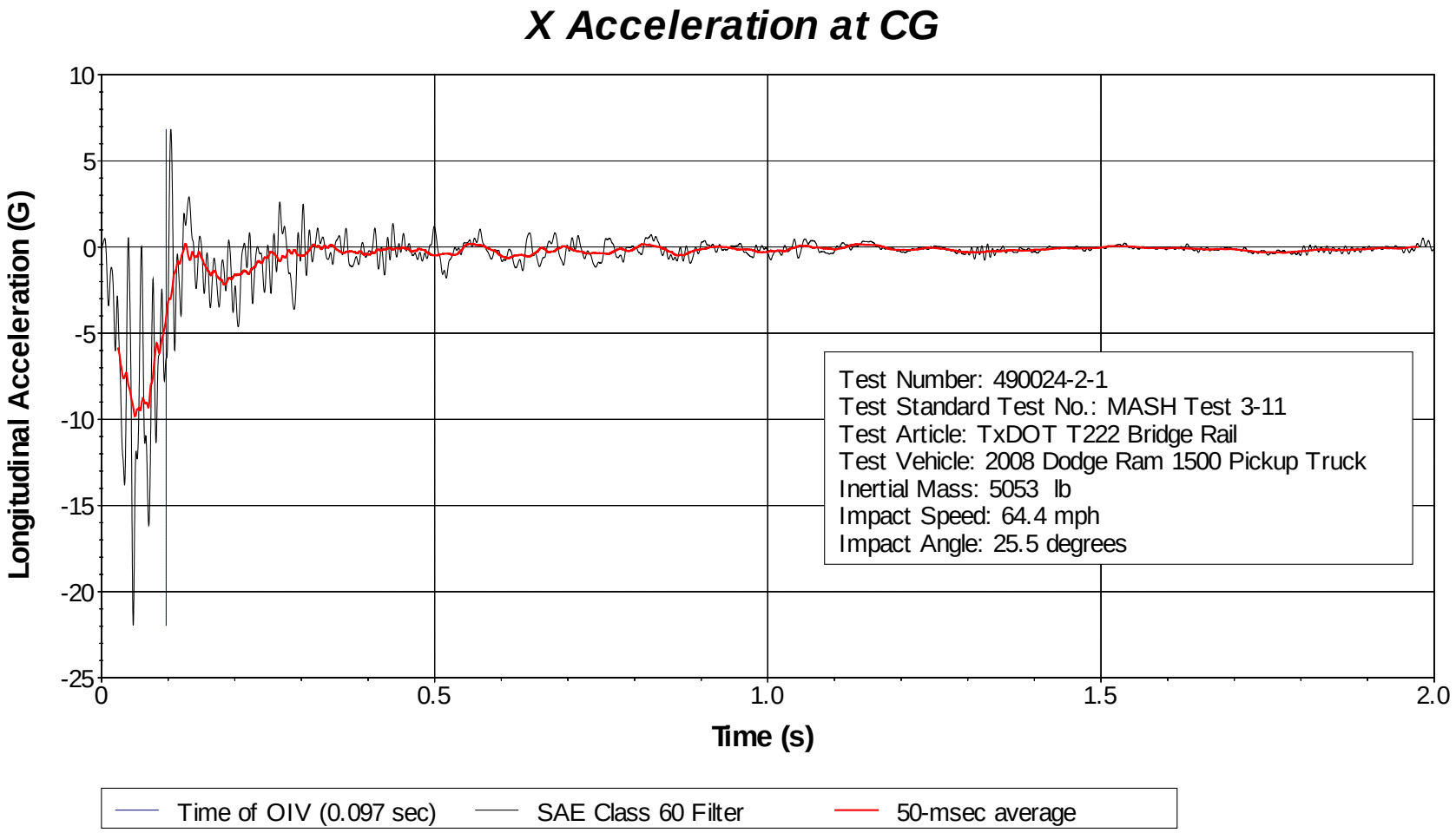


Figure E2. Vehicle Longitudinal Accelerometer Trace for Test No. 490024-2-1 (Accelerometer Located at Center of Gravity).

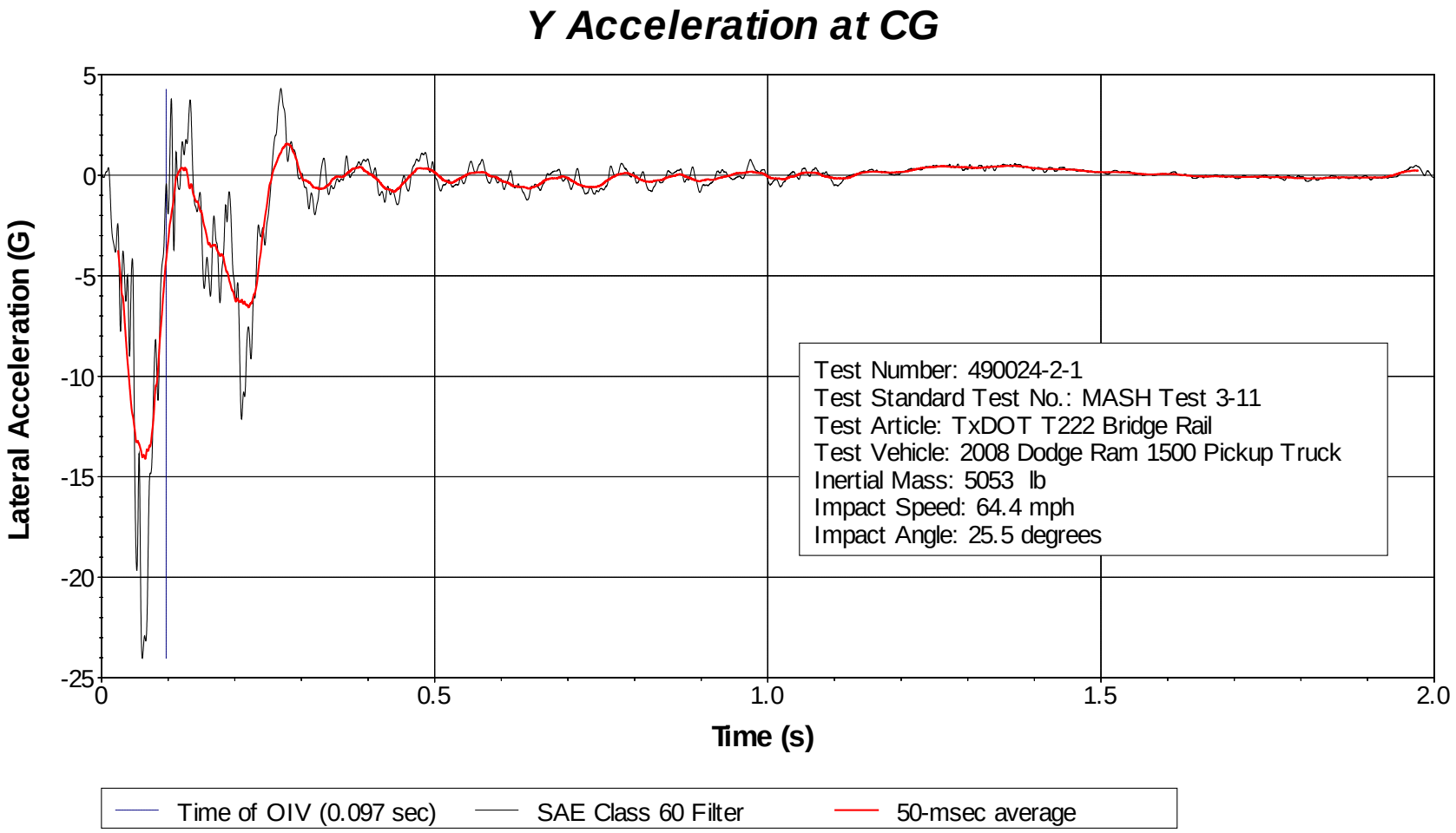


Figure E3. Vehicle Lateral Accelerometer Trace for Test No. 490024-2-1 (Accelerometer Located at Center of Gravity).

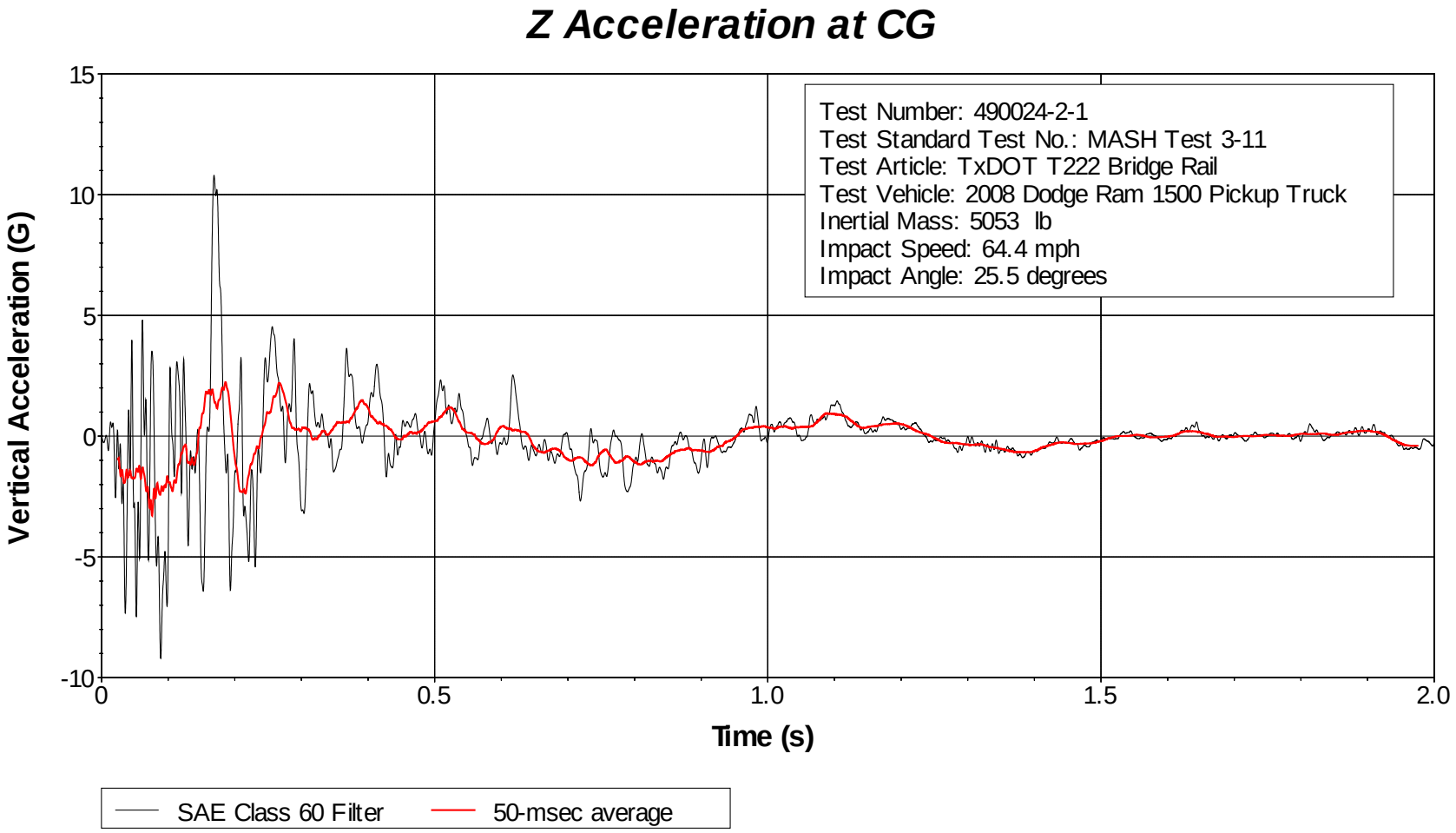


Figure E4. Vehicle Vertical Accelerometer Trace for Test No. 490024-2-1 (Accelerometer Located at Center of Gravity).

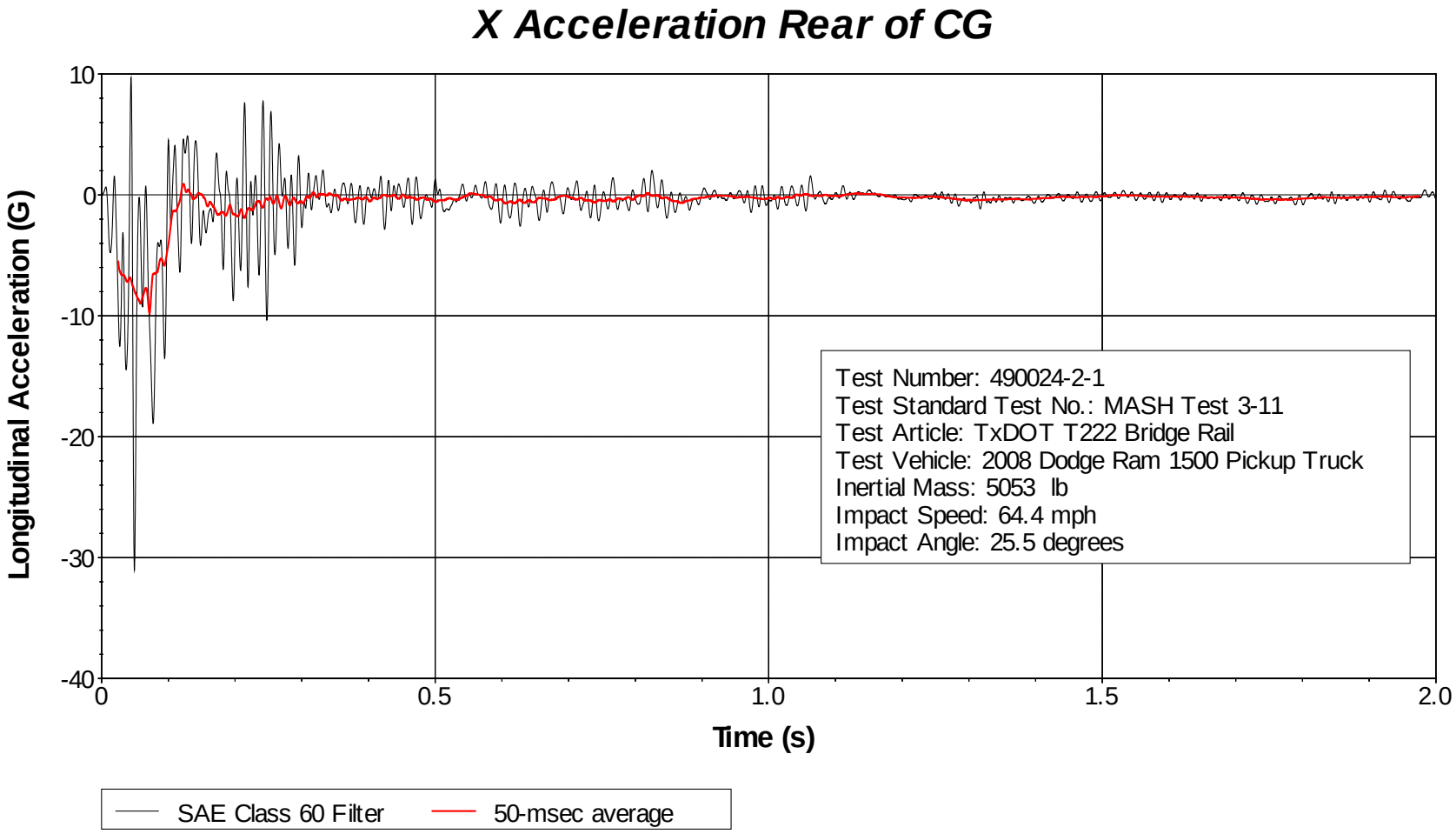


Figure E5. Vehicle Longitudinal Accelerometer Trace for Test No. 490024-2-1 (Accelerometer Located Rear of Center of Gravity).

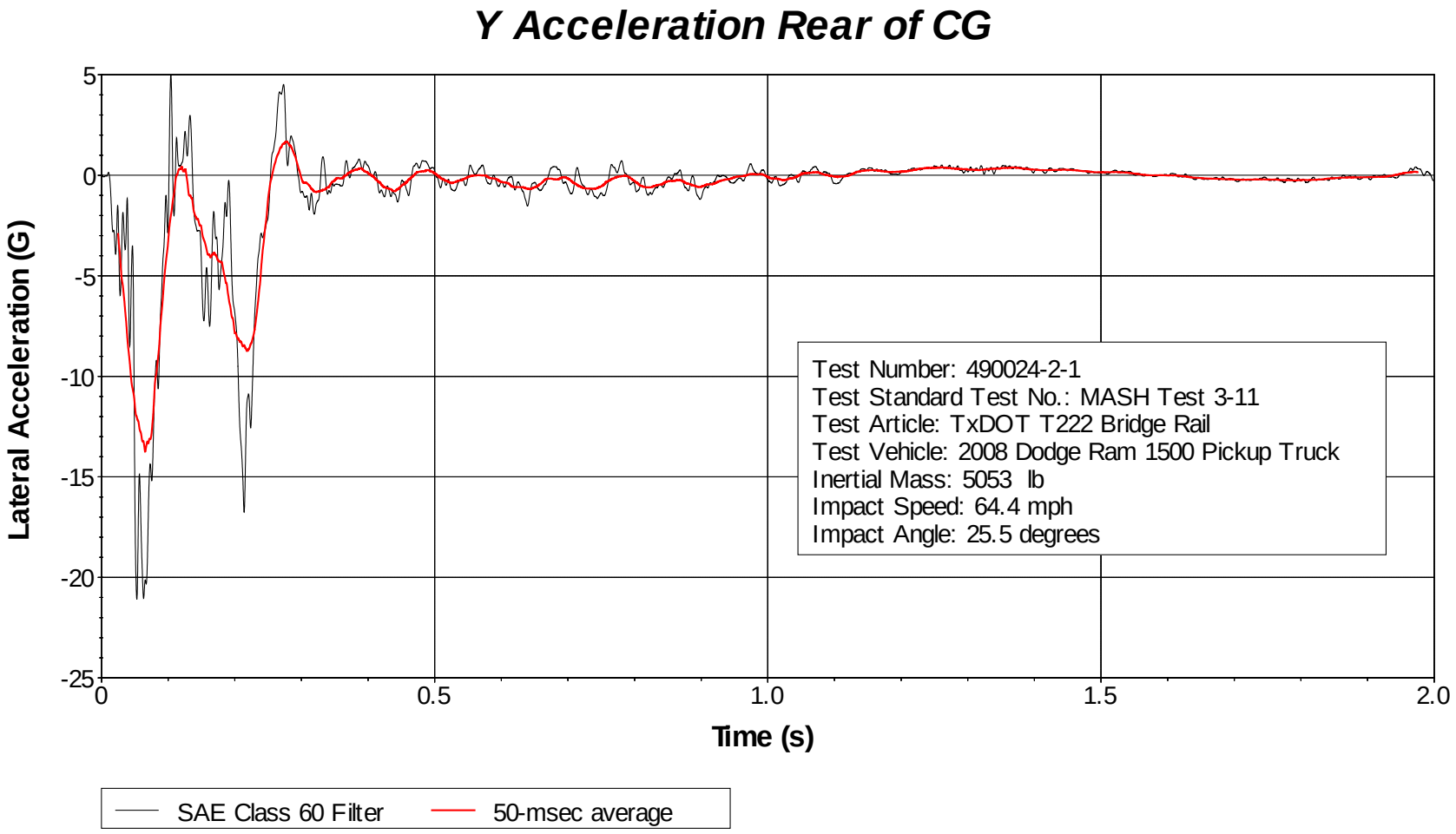


Figure E6. Vehicle Lateral Accelerometer Trace for Test No. 490024-2-1 (Accelerometer Located Rear of Center of Gravity).

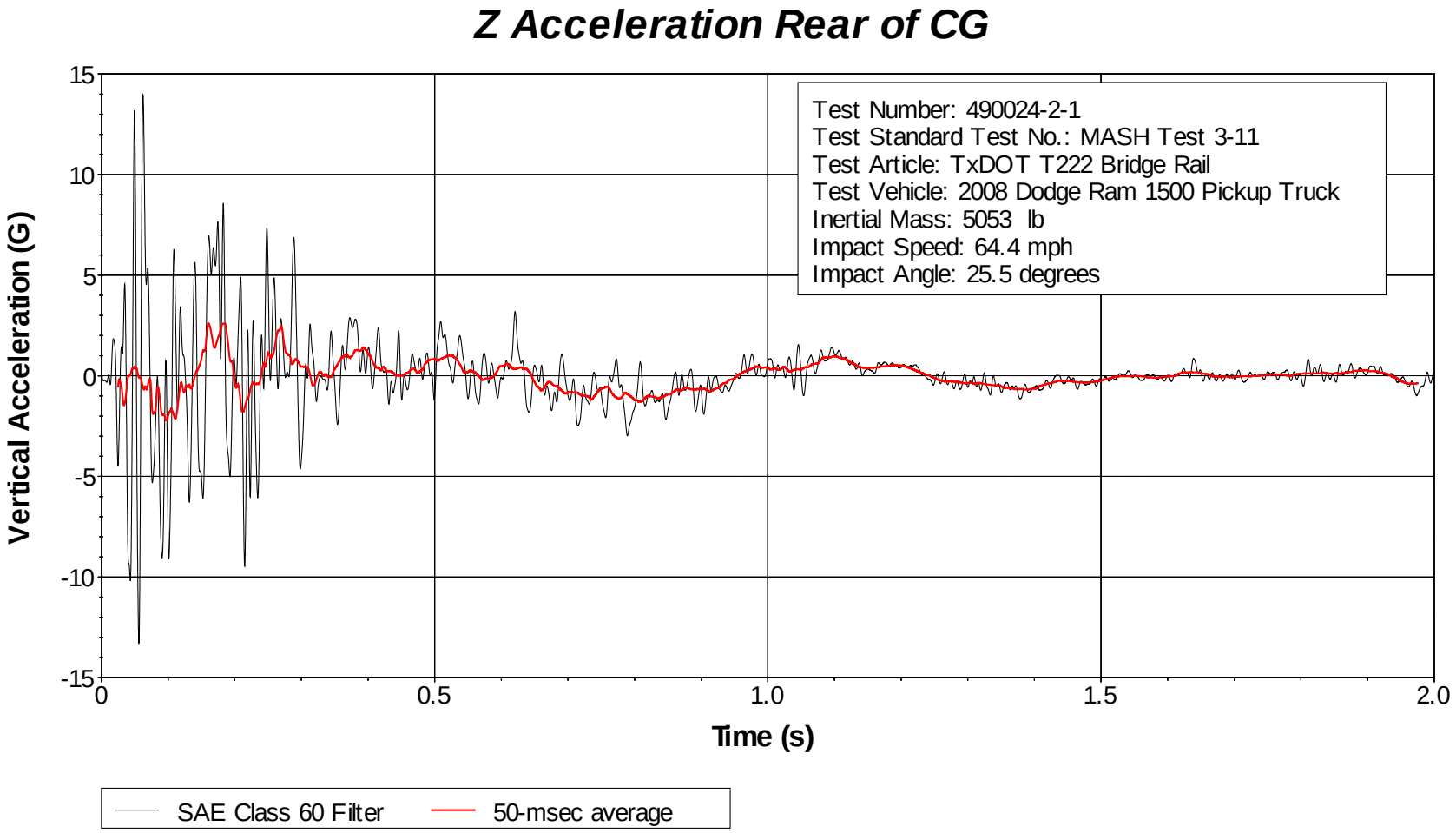


Figure E7. Vehicle Vertical Accelerometer Trace for Test No. 490024-2-1 (Accelerometer Located Rear of Center of Gravity).