TTI: 9-1002-12

MASH Test 3-11 on the T131RC 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 No. 9-1002-12-1

Cooperative Research Program

TEXAS A&M TRANSPORTATION INSTITUTE
THE TEXAS A&M UNIVERSITY SYSTEM
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

Texas Department of Transportation (TxDOT) currently uses the TxDOT Type T101RC Bridge Rail, a steel post and beam bridge rail anchored to the top of concrete curbs. The T101RC Bridge Rail is 27 inches in height and can be anchored to the top of concrete curbs of varying heights. The heights of the posts and the number of bridge rail elements vary depending on the height of the concrete curb. The posts are anchored to the curb using four adhesive anchors.

Based on crash testing of similar rail designs of the same height, the researchers believed that the TxDOT Type T101RC Bridge Rail would not meet the American Association of State Highway and Transportation Officials (AASHTO) Manual for Assessing Safety Hardware (*MASH*) Test Level 3 (TL-3) criteria. The purpose of this portion of the project was to design and crash test a modified design of the TxDOT T101RC Bridge Rail that would meet the strength and safety performance criteria for TL-3 of *MASH*. A new bridge rail was developed and tested for this project.

The TxDOT T131RC Bridge Rail met all the strength and safety performance criteria of *MASH*. This bridge rail is recommended for implementation on new or retrofit railing applications.

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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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CHAPTER 1. INTRODUCTION

1.1 INTRODUCTION

This project 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 are identified and prioritized for investigation. Each roadside safety issue is addressed with a separate work plan, and the results are summarized in individual test reports.

TxDOT currently uses a steel post and beam bridge rail that is anchored to the top of concrete curbs. This bridge rail is called the TxDOT Type T101RC Bridge Rail. The T101RC is 27 inches in height and can be anchored to the top of concrete curbs of varying heights. The heights of the posts and the number of bridge rail elements vary depending on the height of the concrete curb. The posts are anchored to the curb using four adhesive anchors. Based on crash testing of similar rail designs of the same height, the TxDOT Type T101RC Bridge Rail does not meet the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*) (*1*). The purpose of this portion of the project was to design and crash test a modified design of the TxDOT T101RC Bridge Rail that would meet the strength and safety performance criteria for Test Level 3 (TL-3) of *MASH*.

1.2 BACKGROUND

AASHTO published *MASH* in October 2009. *MASH* supersedes *National Cooperative Highway Research Program (NCHRP) Report 350* (*2*) as the recommended guidance for the safety performance evaluation of roadside safety features.

1.3 OBJECTIVES/SCOPE OF RESEARCH

The purpose of this project was to design and crash test a modified design of the TxDOT T101RC Bridge Rail that would meet the strength and safety performance criteria for TL-3 of *MASH*.

CHAPTER 2. SYSTEM DETAILS

2.1 TEST ARTICLE DESIGN AND CONSTRUCTION

The TxDOT T131RC Bridge Rail consists of two tubular steel rail elements supported by W6×20 steel posts. The overall length of the test installation was 80 ft and consisted of 16 posts spaced on 5 ft centers. The total height of the bridge rail is 36 inches above the pavement surface. The steel bridge rail was anchored to an 8-inch wide × 11-inch high cast in place concrete curb. The concrete curb was anchored to a cast-in-place 8-inch thick concrete deck cantilever. The width of the cantilever was 20.75 inches. Mr. John Holt with TxDOT provided the detailed design information on the bridge rail design.

The TxDOT Type T131RC Bridge Rail tested for this project consisted of two rail elements. Both rail elements were HSS6×6×1/4 A500 Grade C structural tubes. The centerline heights of the rail elements were 21 inches and 33 inches for the lower and top rail elements, respectively. Each rail element was attached to each post using a ⅝-inch diameter A307 button head bolt. The W6×15 posts were welded to 14-inch × 16-inch × ⅝-inch thick baseplates. These baseplates were bent using a 3-inch diameter radius to fit the front and top sides of the concrete curb. The baseplates were fabricated using A572 Grade 50 material, and the posts, from ASTM A992 material. The posts were anchored to the concrete curb using four ¾-inch diameter A193 B7 threaded rods 8½ inches long and anchored 6¾ inches in the concrete curb using the Hilti HAS-E anchor bolt.

A simulated concrete bridge deck cantilever and curb was constructed immediately adjacent to an existing concrete runway located at the Texas A&M Transportation Institute (TTI) Proving Ground test facility. The total length of the deck was 76 ft 6 inches long. The bridge deck cantilever was 20¾ inches wide and 6 inches thick. Reinforcement in the deck consisted of a single layer of reinforcing steel placed in the transverse and longitudinal directions. The transverse reinforcement consisted of #4 bars located 10 inches on centers. Longitudinal reinforcement consisted of three #4 bars. Two bars were located immediately beneath the concrete curb, with the third bar located approximately 22 inches from the edge of the deck cantilever. Vertical reinforcement in the curb consisted of #3 stirrups located on 10-inch centers. Two longitudinal #3 bars were located within the curb stirrup and at the top corners of the stirrups. For additional information on the bridge railing test installation, please refer to Figures 2.1 through 2.3 and Appendix A in this report.

2.2 MATERIAL SPECIFICATIONS

These baseplates were fabricated using A572 Grade 50 material, and the posts, from ASTM A992 material. All reinforcement used in the concrete deck had a minimum specified yield strength of 60 ksi. The concrete deck and curb has a specified concrete strength of 3600 psi. Concrete compressive strength tests were performed on the day the test was performed. The tests performed at 25 days age on the concrete deck resulted in an average compressive strength of 3870 psi. The tests performed at 21 days age on the concrete curb resulted in an average compressive strength of 4610 psi.

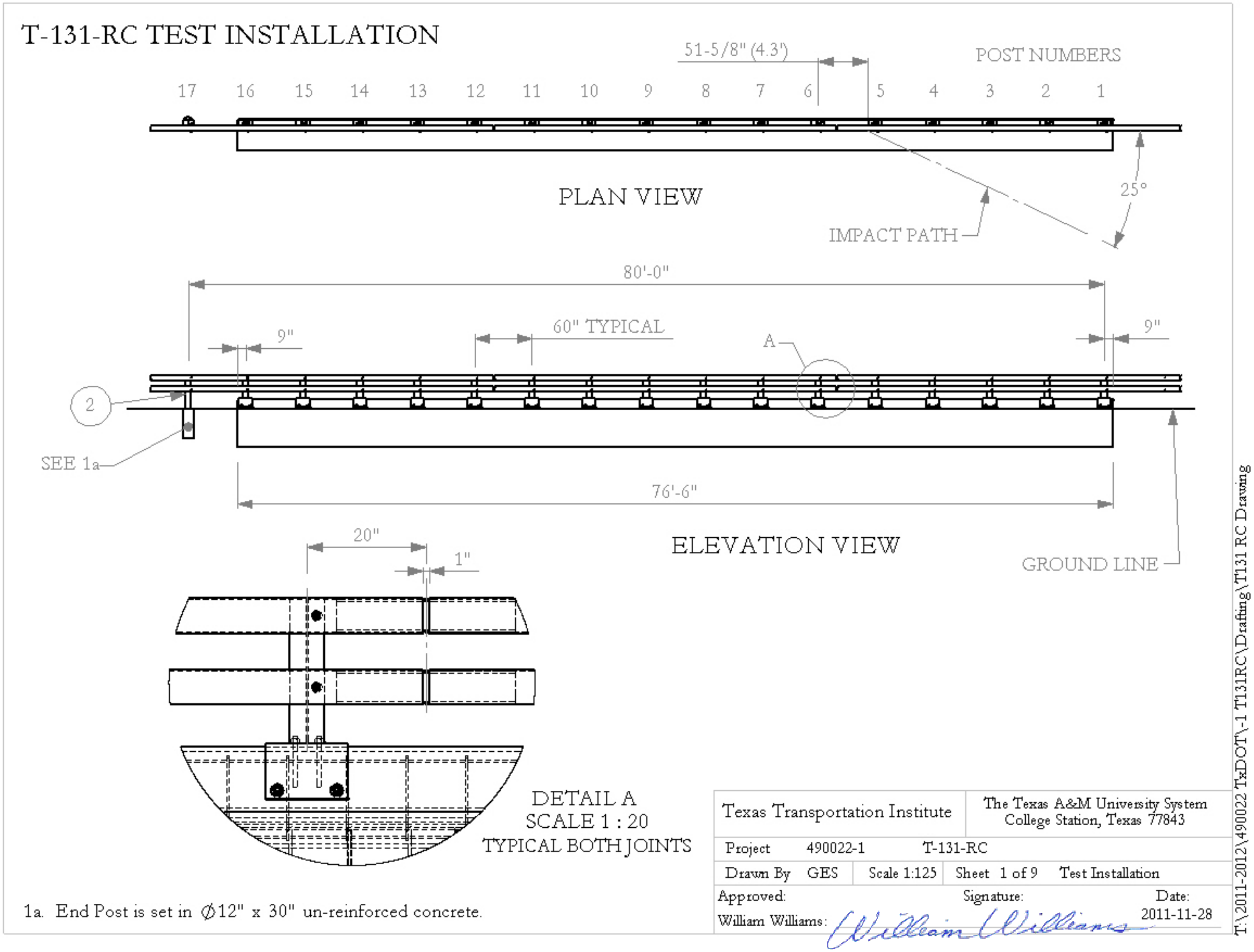
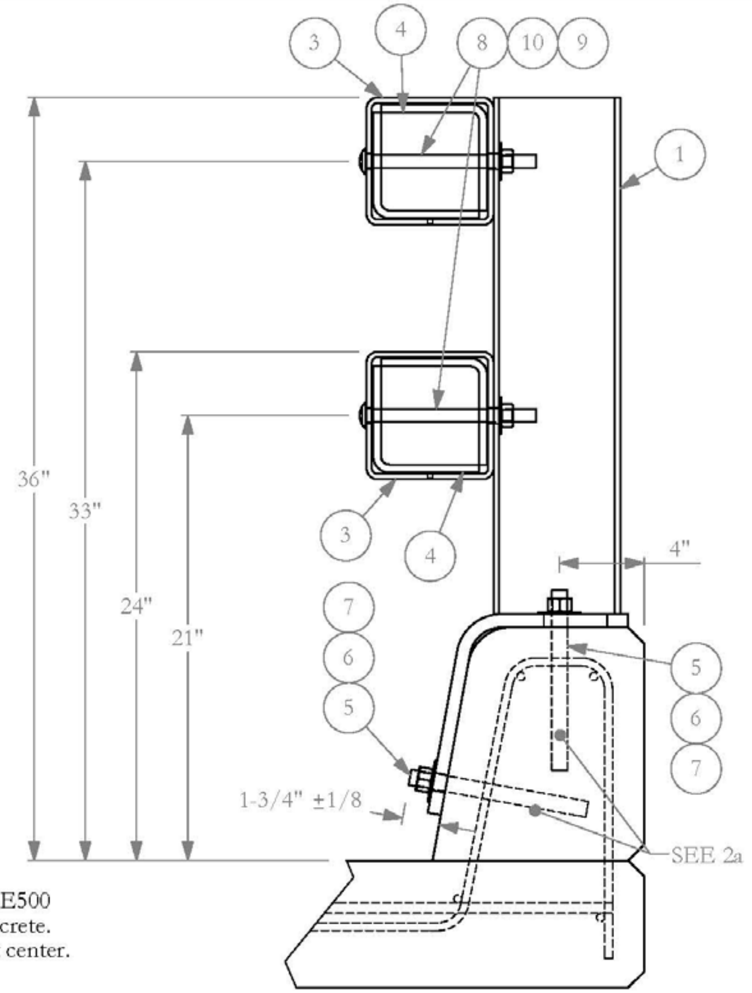


Figure 2.1. Layout of the T131RC Bridge Rail Installation.

#	PART NAME	QTY.	SHEET
1	Post, T131RC	16	3
2	Post, end T131RC	1	4
3	Rail, TS6x6x1/4	6	5
4	Splice Sleeve for 6x6 Rail	4	5
5	Hilti Anchor (see 1a)	64	
6	Nut, 3/4 hex	see 2e	
7	Washer, 3/4 flat	see 2e	
8	Bolt, 5/8 x 8 round-head slotted	34	6
9	Nut, 5/8 hex	34	
10	Washer, 5/8 flat	34	



2a. Hilti Super HAS-E Ø3/4 (cut off to 8-1/2" long), installed with Hilti RE500 epoxy according to label directions, with 1-3/4" ±1/8" protruding above concrete. Place anchors in curb top at 4" from back of curb. Do not place them in slot center. This is to allow removal of the posts.

2b. All bolts, nuts, and washers (except Hilti products) are grade A307.

2c. Threads not shown on bolts for clarity, and End Post and its foundation are also not shown here.

2d. Connection details typical for Bridge Posts and End Post.

2e. Ø3/4" nuts and washers are provided with Hilti Anchors and do not need to be supplied separately.

Texas Transportation Institute	The Texas A&M University System College Station, Texas 77843		
Project 490022-1	T-131-RC		2011-11-28
Drawn By GES	Scale 1:7	Sheet 2 of 9	Posts and Rail

T:\2011-2012\490022 TxDOT\-1 T131RC\Drafting\T131 RC Drawing

Figure 2.2. Details of the T131RC Bridge Rail Installation.

Figure 2.3. T131RC Bridge Rail Installation before Test No. 490022-1.

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 three (TL-3).

> ***MASH* Test Designation 3-10:** A 2425-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 Designation 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.

Based on the geometry and strength of the new rail design, the project team concluded that Test 3-10 was not warranted. The test reported here corresponds to Test 3-11 of *MASH* (5000-lb pickup, 62 mi/h, 25 degrees).

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 T131RC Bridge Rail is judged on the basis of three factors: structural adequacy, occupant risk, and post impact vehicle trajectory. Structural adequacy is judged upon the ability of the T131RC 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 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 was performed according to TTI Proving Ground quality procedures and according to the *MASH* guidelines and standards.

The Texas A&M Transportation Institute 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 T131RC 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 6–8 inches deep. The apron is over 50 years old, 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 two-to-one 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 free-wheeling (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.

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 produced by Diversified Technical Systems, Inc. The accelerometers that 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 size, 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 the data are recorded, internal batteries back these up inside the unit should the primary battery cable be severed. Initial contact of the pressure switch on the vehicle bumper provides a time zero mark and initiates the recording process. After each test, the data are downloaded from the TDAS Pro unit into a laptop computer at the test site. The Test Risk Assessment Program (TRAP) software then processes the raw data to produce detailed reports of the test results. Each of the TDAS Pro units are 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.

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, the program computes the maximum average accelerations over 50-ms intervals in each of the three directions. 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 and then plots yaw, pitch, and roll versus time. These displacements are in reference to the vehicle-fixed coordinate system with the initial position and orientation of the vehicle-fixed coordinate systems being initial impact.

4.3.2 Anthropomorphic Dummy Instrumentation

According to *MASH*, the use of a dummy in the 2270P vehicle is optional. Researchers did not use any dummy 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-DV 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

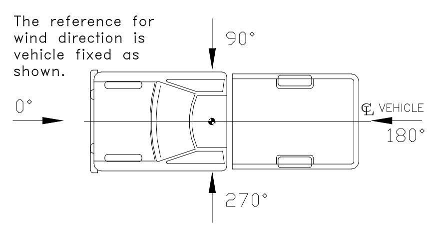
MASH Test 3-11 involves a 2270P vehicle weighing 5000 lb ±100 lb and impacting the bridge rail at an impact speed of 62.2 mi/h ±2.5 mi/h and an angle of 25 degrees ±1.5 degrees. The target impact point was 4.3 ft upstream of the centerline of post 6. The 2007 Dodge Ram 1500 pickup truck used in the test weighed 4985 lb and the actual impact speed and angle were 63.0 mi/h and 24.7 degrees, respectively. The actual impact point was 5 ft upstream of post 6. Impact severity (IS) was 115.5 kip-ft, which was equal to the target IS.

5.2 TEST VEHICLE

A 2007 Dodge Ram 1500 pickup truck, shown in Figures 4 and 5, was used for the crash test. Both the test inertia weight and the gross static weight of the vehicle was 4985 lb. The height to the lower edge of the vehicle bumper was 13.75 inches, and it was 25.38 inches to the upper edge of the bumper. The height to the vehicle's center of gravity was 28.48 inches. Tables C1 and C2 in Appendix C give additional dimensions and information on the vehicle. The pickup 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.

5.3 WEATHER CONDITIONS

The test was performed on the morning of February 14, 2012. Weather conditions at the time of testing were: Wind speed: 8 mi/h; Wind direction: 133 degrees with respect to the vehicle (vehicle was traveling in a southwesterly direction); Temperature: 67°F, Relative humidity: 70 percent.



5.4 TEST DESCRIPTION

The 2007 Dodge Ram 1500 pickup, traveling at an impact speed of 63.0 mi/h, impacted the T131RC bridge rail 5 ft upstream of post 6 at an impact angle of 24.7 degrees. At 0.014 s after impact, post 5 began to deflect toward the field side, and posts 6 and 7 began to deflect towards field side at 0.017 s and 0.026 s, respectively. The concrete deck around post 5 began to crack at 0.031 s, and at 0.046 s on the downstream side. Post 7 began to deflect toward the field side at 0.048 s, and the concrete deck around posts 6 and 7 began to crack at 0.069 and 0.073 s, respectively. At 0.082 s, the right front tire blew out, and at 0.082 s, the concrete deck at post 8 began to crack. The rear of the vehicle contacted the bridge rail at 0.174 s. At 0.343 s, the vehicle lost contact with the bridge rail. The overhead camera failed, and therefore exit speed and angle were not obtainable. Brakes on the vehicle were not applied, and the vehicle subsequently came to rest 310 ft downstream of impact. Figures D1 and D2 in Appendix D show sequential photographs of the test period.

Figure 5.1. Vehicle/Installation Geometrics for Test No. 490022-1.

Figure 5.2. Vehicle before Test No. 490022-1.

5.5 DAMAGE TO TEST INSTALLATION

Figures 5.3 and 5.4 show damage to the T131RC Bridge Rail after the test. The concrete curb sustained minor damage at posts 2 and 3, and more significant damage at posts 4 through 9. The curb separated 1 inch from the deck at posts 5 and 6. Posts 3 through 8 were leaning toward the field side between 3 degrees to a maximum of 8 degrees at post 6. Length of contact of the vehicle with the bridge rail was 13.2 ft. Maximum permanent deformation was 6.5 inches. The overhead camera failed to trigger, therefore, maximum dynamic deflection and working width were not obtainable.

5.6 VEHICLE DAMAGE

Figure 5.5 shows damage that the 2270P vehicle sustained. The right front upper and lower ball joints pulled out of the sockets, and the tie rod, the right upper and lower A-arms, and the right frame rail were deformed. Also damaged were the front bumper, grill, hood, right front tire and wheel rim, right front fender, right front and rear doors, right cab corner, right rear exterior bed, right rear tire and wheel rim, and rear bumper. Maximum exterior crush to the vehicle was 15.0 inches in the side plane at the right front corner at bumper height. Maximum occupant compartment deformation was 0.5 inch in the lateral area across the cab at the left front passenger's kickpanel. Figure 5.6 has photographs of the interior of the vehicle. In Appendix C, Tables C3 and C4 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 15.1 ft/s at 0.096 s, the highest 0.010-s occupant ridedown acceleration was 3.4 Gs from 0.187 to 0.197 s, and the maximum 0.050-s average acceleration was −7.0 Gs between 0.025 and 0.075 s. In the lateral direction, the occupant impact velocity was 25.9 ft/s at 0.096 s, the highest 0.010-s occupant ridedown acceleration was 10.6 Gs from 0.218 to 0.228 s, and the maximum 0.050-s average was −12.8 Gs between 0.038 and 0.088 s. Theoretical Head Impact Velocity (THIV) was 32.4 km/h or 9.0 m/s at 0.094 s; Post-Impact Head Decelerations (PHD) was 10.7 Gs between 0.218 and 0.228 s; and Acceleration Severity Index (ASI) was 1.52 between 0.025 and 0.075 s. Figure 5.7 summarizes these data and other pertinent information from the test. Figures E1 through E7 in Appendix E present the vehicle angular displacements and accelerations versus time traces.

Figure 5.3. Vehicle/Installation after Test No. 490022-1.

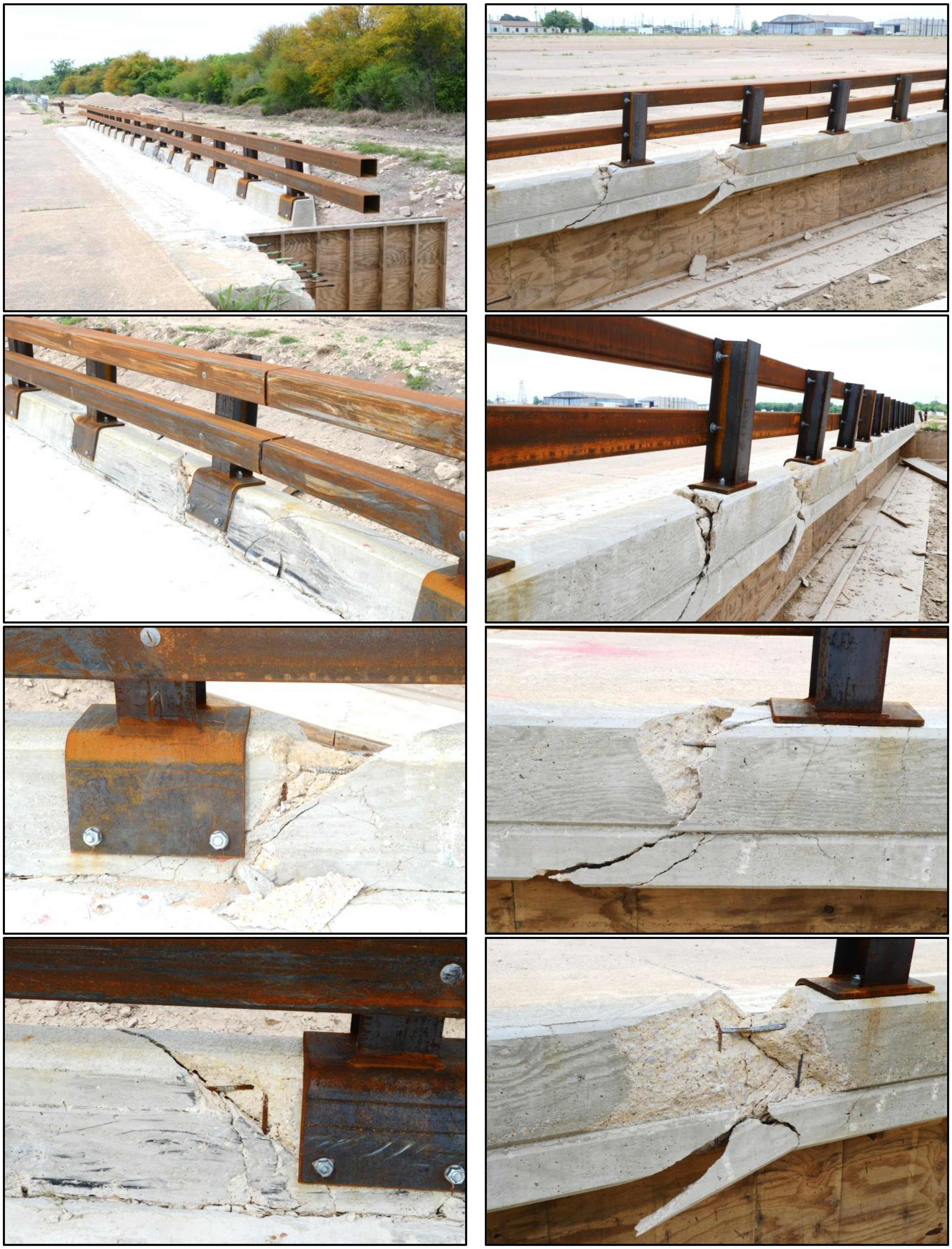
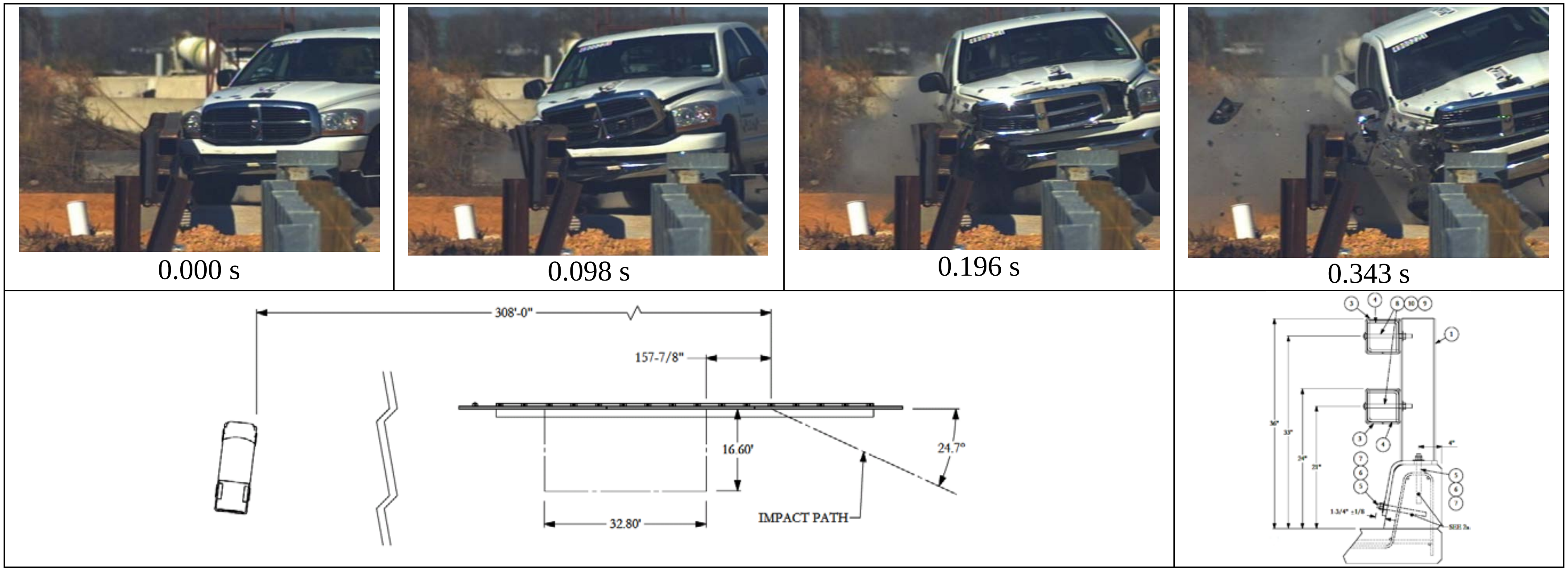


Figure 5.4. Installation after Test No. 490022-1.

Figure 5.5. Vehicle after Test No. 490022-1.

Figure 5.6. Interior of Vehicle after Test No. 490022-1.



General Information
- Test Agency .... Texas A&M Transportation Institute (TTI)
- Test Standard Test No. .... MASH Test 3-11
- TTI Test No. 490022-1
- Test Date 2012-02-14

Test Article
- Type .... Bridge Rail
- Name .... TxDOT T131RC Bridge Rail
- Installation Length .... 80 ft
- Material or Key Elements ......

Soil Type and Condition .... Concrete Bridge Deck

Test Vehicle
- Type/Designation 2270P
- Make and Model .... 2007 Dodge Ram 1500
- Curb .... 4922 lb
- Test Inertial .... 4985 lb
- Dummy .... No dummy
- Gross Static .... 4985 lb

Impact Conditions
- Speed .... 63.00 mi/h
- Angle .... 24.7 degrees
- Location/Orientation .... 5 ft upstream of post 6

Impact Severity .... 115.5 kip-ft

Exit Conditions
- Speed .... Not obtainable
- Angle .... Not obtainable

Occupant Risk Values
- Impact Velocity
  - Longitudinal .... 15.1 ft/s
  - Lateral .... 25.9 ft/s
- Ridedown Accelerations
  - Longitudinal .... 3.4 G
  - Lateral .... 10.6 G
- THIV .... 32.4 km/h
- PHD .... 10.7 G
- ASI 1.52
- Max. 0.050-s Average
  - Longitudinal .... −7.0 G
  - Lateral .... −12.8 G
  - Vertical .... −2.5 G

Post-Impact Trajectory
- Stopping Distance .... 308 ft dwnstrm

Vehicle Stability
- Maximum Yaw Angle .... 31 degrees
- Maximum Pitch Angle .... 11 degrees
- Maximum Roll Angle .... 23 degrees
- Vehicle Snagging .... No
- Vehicle Pocketing .... No

Test Article Deflections
- Dynamic .... Not obtainable
- Permanent .... 6.5 inches
- Working Width .... Not obtainable

Vehicle Damage
- VDS 01RFQ4
- CDC 01FREW4
- Max. Exterior Deformation .... 15.0 inches
- OCDI RF0000000
- Max. Occupant Compartment Deformation .... 0.5 inch

Figure 5.7. Summary of Results for *MASH* Test 3-11 on the T131RC 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 T131RC bridge rail contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum permanent deformation was 6.5 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 were present to penetrate or show potential for penetrating the occupant compartment, nor present hazard to others in the area. (PASS)
Maximum occupant compartment deformation was 0.5 inch in the lateral area across the cab at front passenger hip height and the lateral area across the cab at the front passenger side kickpanel. (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. The maximum roll and pitch angles were 23 degrees and 11 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 15.1 ft/s, and lateral occupant impact velocity was 25.9 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: Longitudinal ridedown acceleration was 3.4 G, and lateral ridedown acceleration was 10.6 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 2270P vehicle exited within the exit box. (PASS)

CONCLUSIONS

The T131RC bridge rail performed acceptably for *MASH* Test 3-11 (see Table 6.1).

Table 6.1. Performance Evaluation Summary for *MASH* Test 3-11 on the T131RC Bridge Rail.

Test Agency: Texas A&M Transportation Institute | Test No.: 490022-1 | Test Date: 2012-02-14

***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 T131RC Bridge Rail contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum permanent deformation was 6.5 inches.	Pass
Occupant Risk *D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, nor pose 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.	Maximum occupant compartment deformation was 0.5 inch in the lateral area across the cab at front passenger hip height and the lateral area across the cab at the front passenger side kickpanel.	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. The maximum roll and pitch angles were 23 degrees and 11 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 15.1 ft/s, and lateral occupant impact velocity was 25.9 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.	Longitudinal ridedown acceleration was 3.4 G, and lateral ridedown acceleration was 10.6 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 exited within the exit box.	Pass

CHAPTER 7. IMPLEMENTATION STATEMENT

TxDOT currently uses the TxDOT Type T101RC Bridge Rail, a steel post and beam bridge anchored to the top of concrete curbs. The T101RC Bridge Rail is 27 inches in height and can be anchored to the top of concrete curbs of varying heights. The heights of the posts and the number of bridge rail elements vary depending on the height of the concrete curb. The posts are anchored to the curb using four adhesive anchors.

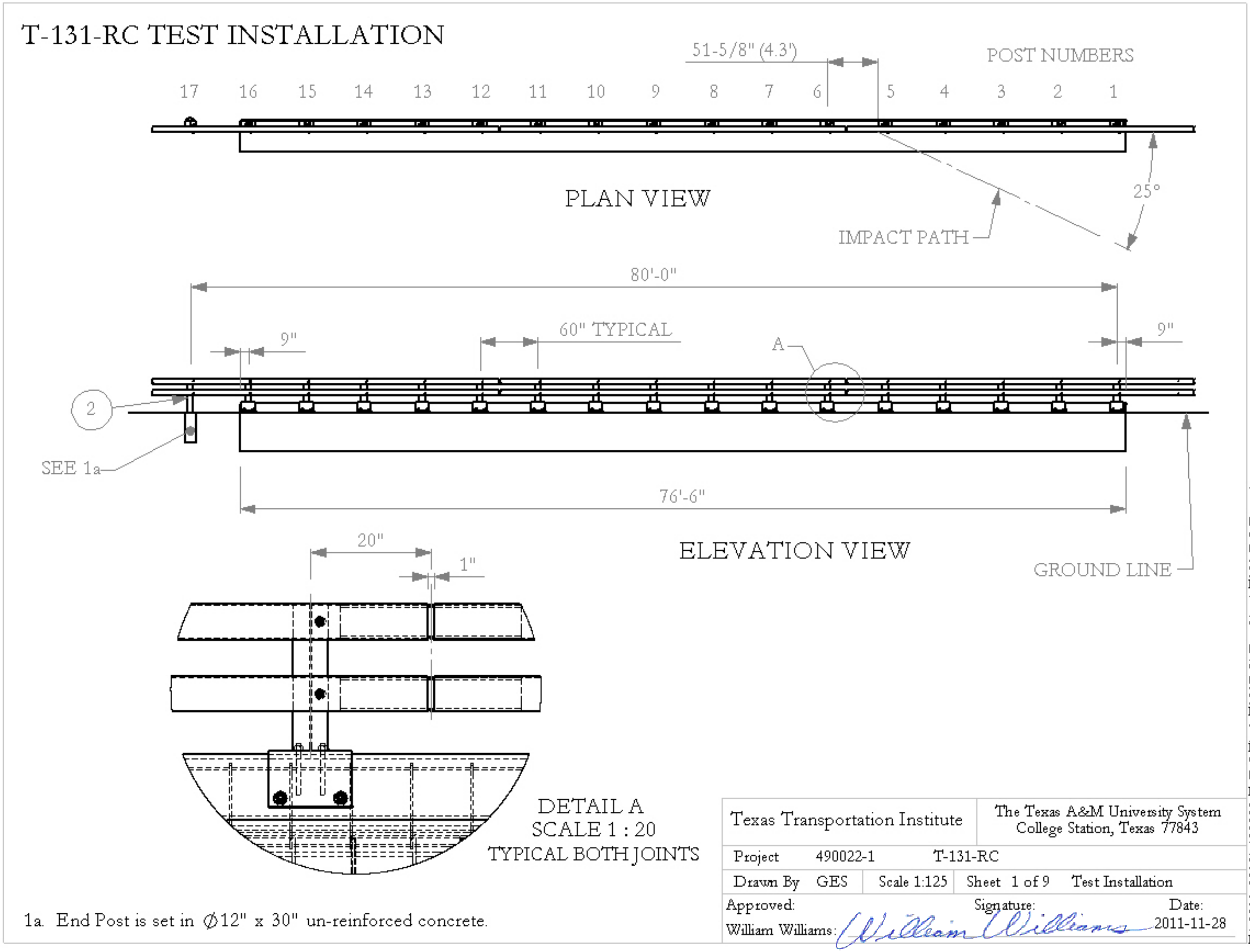
Based on crash testing of similar rail designs of the same height, the researchers believed that the TxDOT Type T101RC Bridge Rail would not meet the *MASH* TL-3 criteria. The purpose of this portion of the project was to design and crash test a modified design of the TxDOT T101RC Bridge Rail that would meet the strength and safety performance criteria for TL-3 of *MASH*. A new bridge rail was developed and tested for this project.

The TxDOT T131RC Bridge Rail met all the strength and safety performance criteria of *MASH*. This bridge rail is recommended for implementation on new or retrofit railing applications.

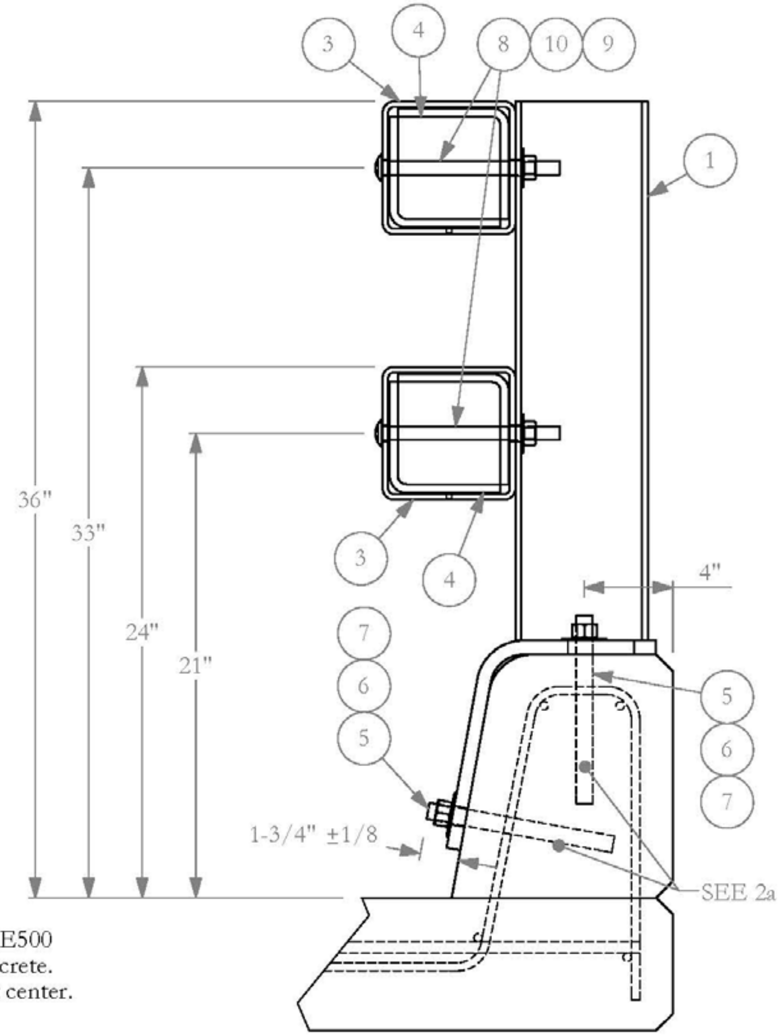
REFERENCES

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

APPENDIX A. DETAILS OF THE T131RC BRIDGE RAIL



#	PART NAME	QTY.	SHEET
1	Post, T131RC	16	3
2	Post, end T131RC	1	4
3	Rail, TS6x6x1/4	6	5
4	Splice Sleeve for 6x6 Rail	4	5
5	Hilti Anchor (see 1a)	64	
6	Nut, 3/4 hex	see 2e	
7	Washer, 3/4 flat	see 2e	
8	Bolt, 5/8 x 8 round-head slotted	34	6
9	Nut, 5/8 hex	34	
10	Washer, 5/8 flat	34	



2a. Hilti Super HAS-E Ø3/4 (cut off to 8-1/2" long), installed with Hilti RE500 epoxy according to label directions, with 1-3/4" ±1/8" protruding above concrete. Place anchors in curb top at 4" from back of curb. Do not place them in slot center. This is to allow removal of the posts.

2b. All bolts, nuts, and washers (except Hilti products) are grade A307.

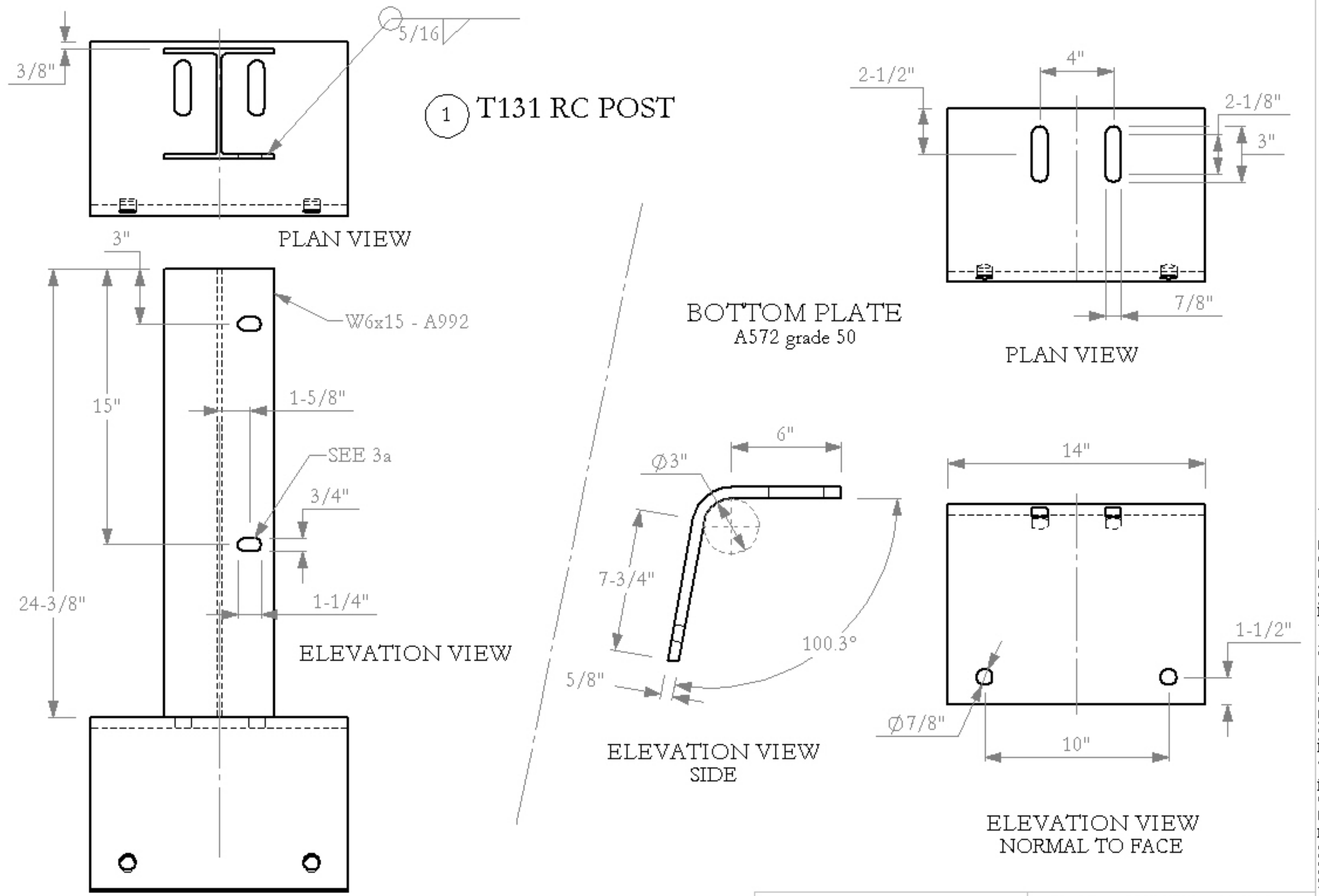
2c. Threads not shown on bolts for clarity, and End Post and its foundation are also not shown here.

2d. Connection details typical for Bridge Posts and End Post.

2e. Ø3/4" nuts and washers are provided with Hilti Anchors and do not need to be supplied separately.

Texas Transportation Institute		The Texas A&M University System College Station, Texas 77843	
Project 490022-1	T-131-RC		2011-11-28
Drawn By GES	Scale 1:7	Sheet 2 of 9	Posts and Rail

T:\2011-2012\490022 TxDOT\-1 T131RC\Drafting\T131 RC Drawing



3a. Slots on front face only, dimensions typical x 2.
3b. Bottom Plate is symmetrical about ℄.

Texas Transportation Institute		The Texas A&M University System College Station, Texas 77843	
Project 490022-1	T-131-RC		2011-11-28
Drawn By GES	Scale 1:7	Sheet 3 of 9	Bridge Post Details

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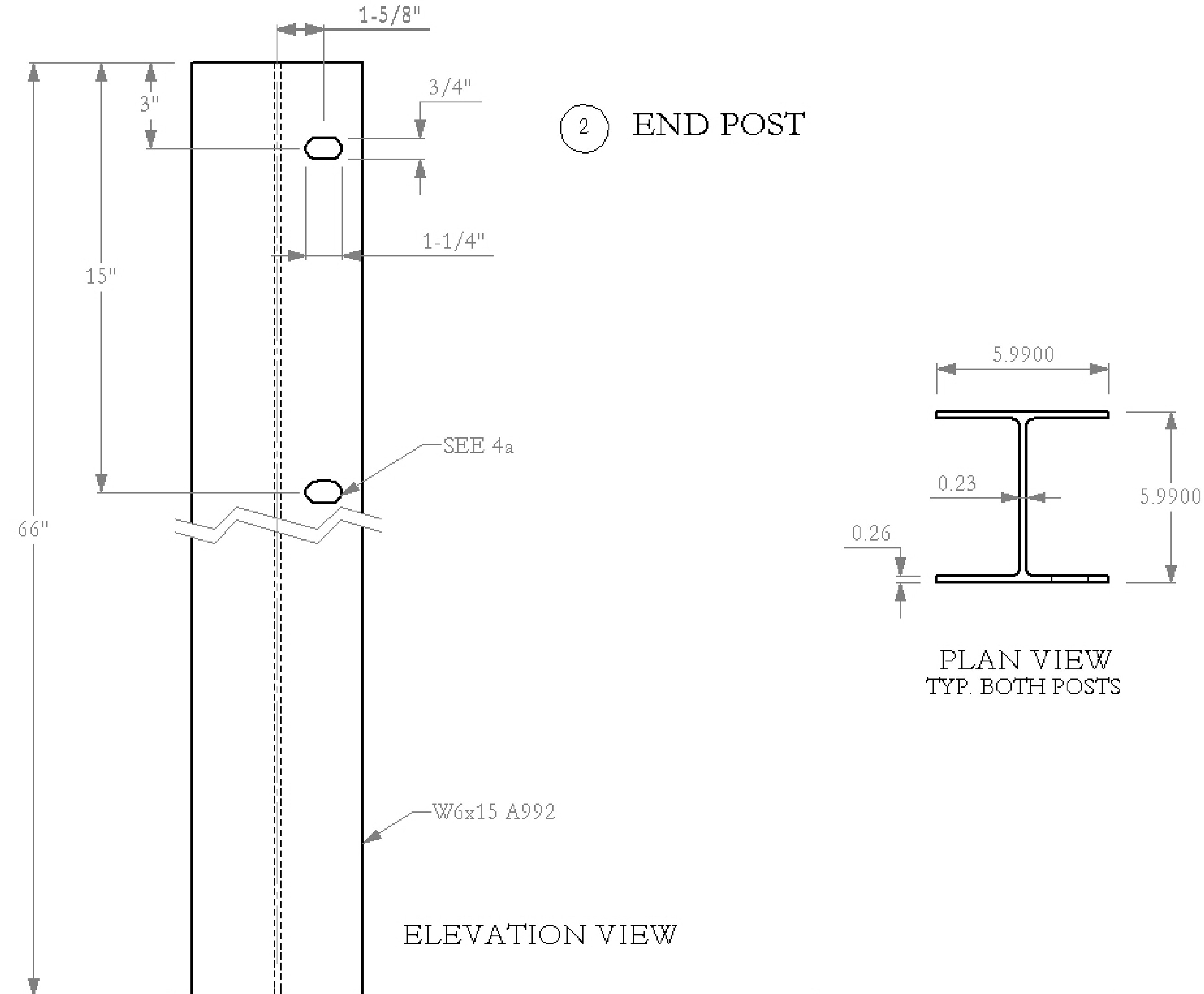

4a. Slots on front face only, dimensions typical x 2.

Texas Transportation Institute		The Texas A&M University System College Station, Texas 77843	
Project 490022-1	T-131-RC		2011-11-28
Drawn By GES	Scale 1:5	Sheet 4 of 9	End Post

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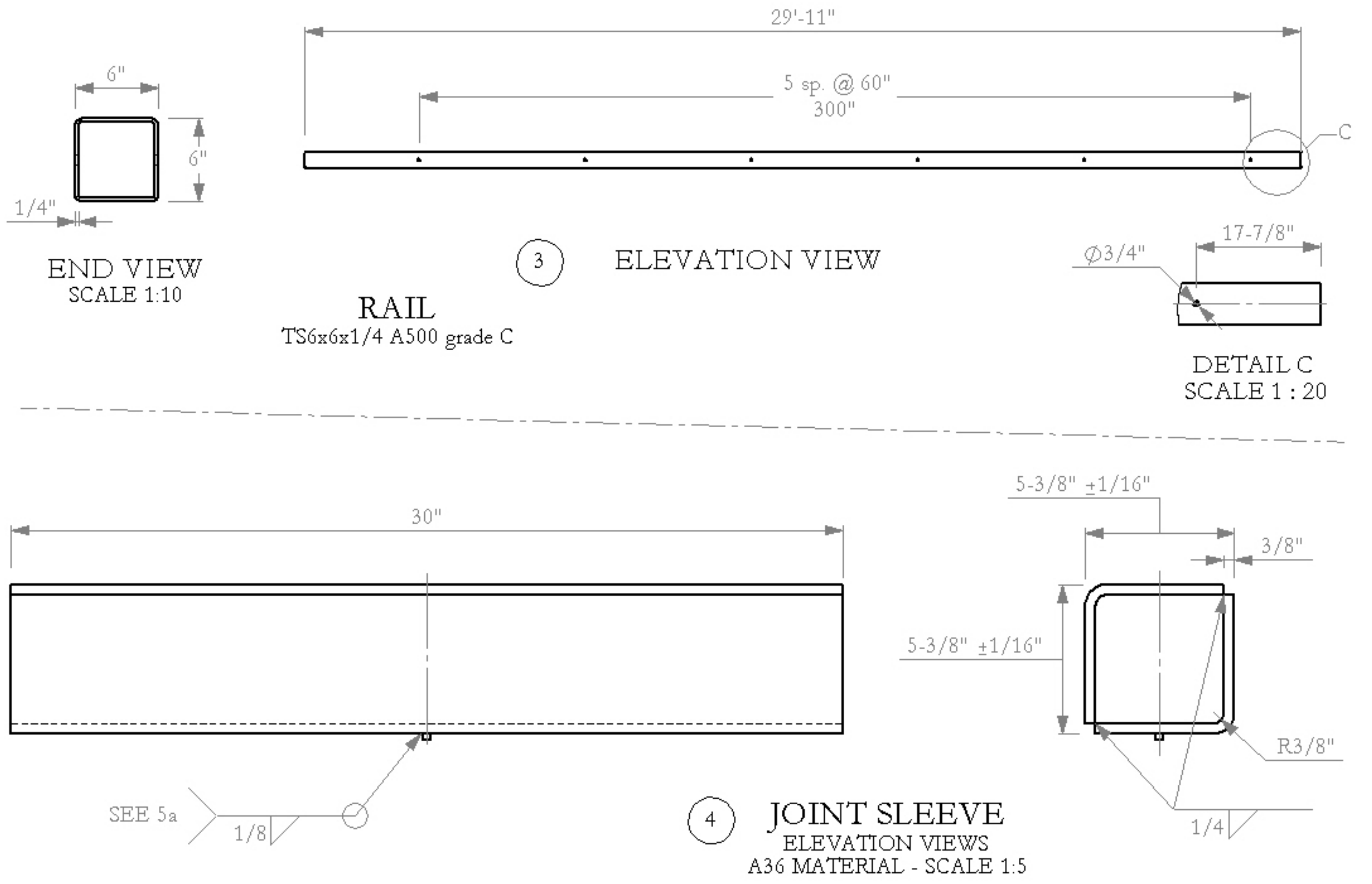

5a. Ø1/4" x 1/4" long welded stud (A36 rod) shown. Driving fit pin is acceptable alternative.

Texas Transportation Institute	The Texas A&M University System College Station, Texas 77843		
Project 490022-1	T-131-RC		2011-11-28
Drawn By GES	Scale 1:50	Sheet 5 of 9	Rail Details

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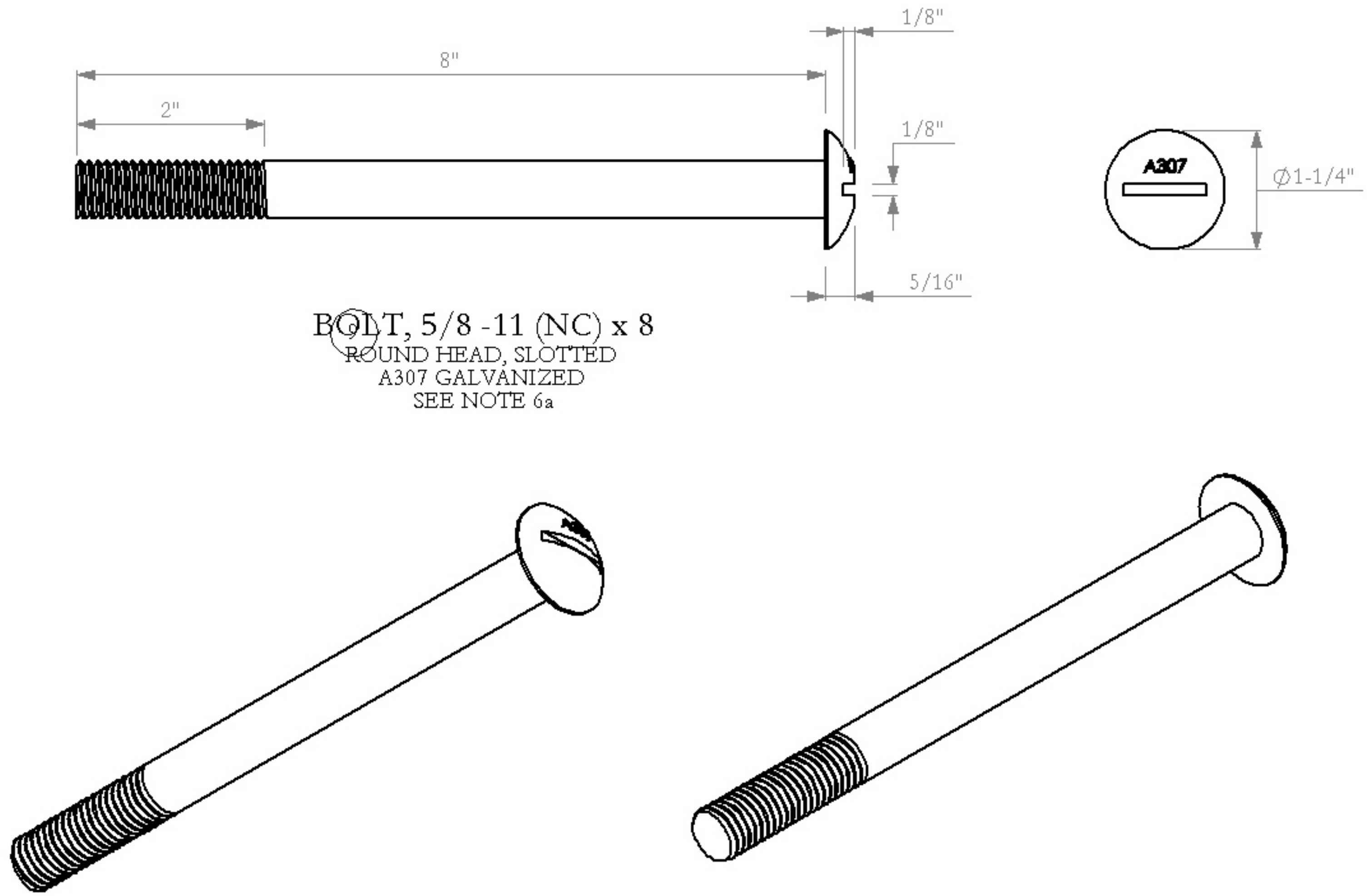

6a. This bolt may be difficult to obtain in small quantities. Carriage bolts may be substituted, but they must be of the same size and grade and with the square shoulders removed to allow them to fit in Ø3/4" holes.

Texas Transportation Institute	The Texas A&M University System College Station, Texas 77843		
Project 490022-1	T-131-RC		2011-11-28
Drawn By GES	Scale 1:1.5	Sheet 6 of 9	Round-Head Bolt

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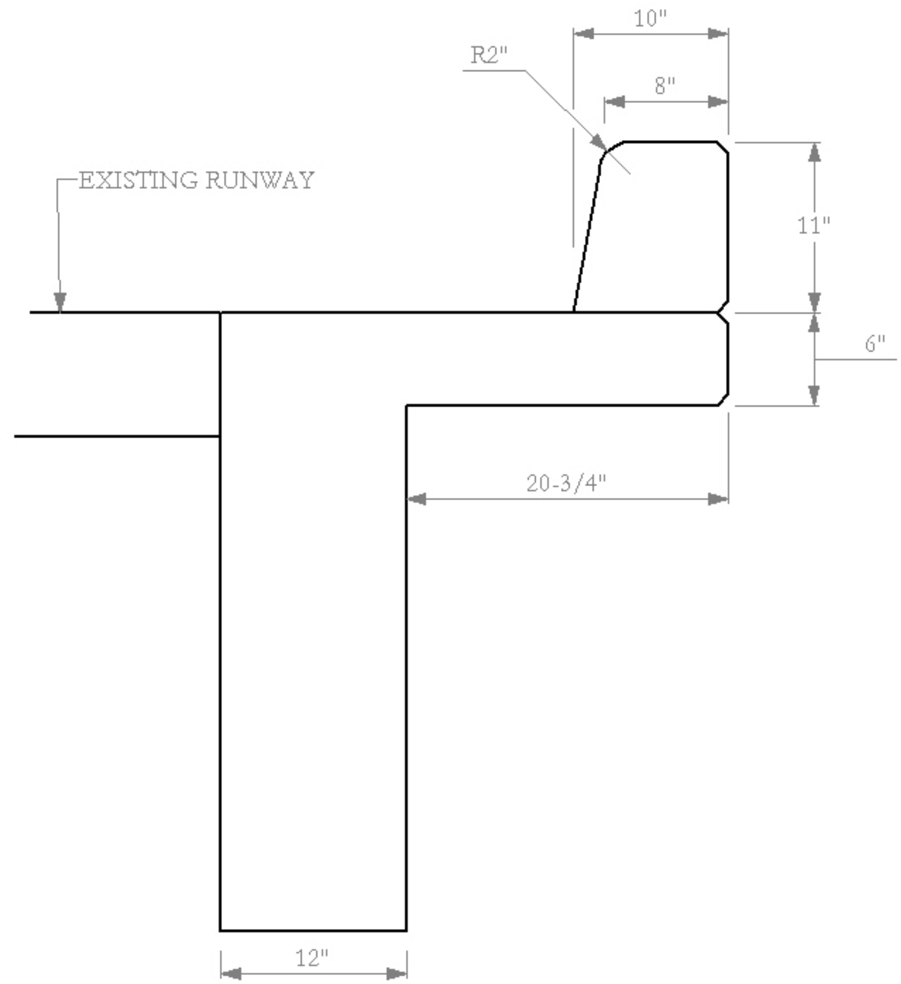

7a. Concrete is Class C (3600 psi).
7d. Chamfer exposed edges of concrete 3/4" unless otherwise indicated.

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Project 490022-1	T-131-RC		2011-11-28
Drawn By GES	Scale 1:10	Sheet 7 of 9	Concrete Details

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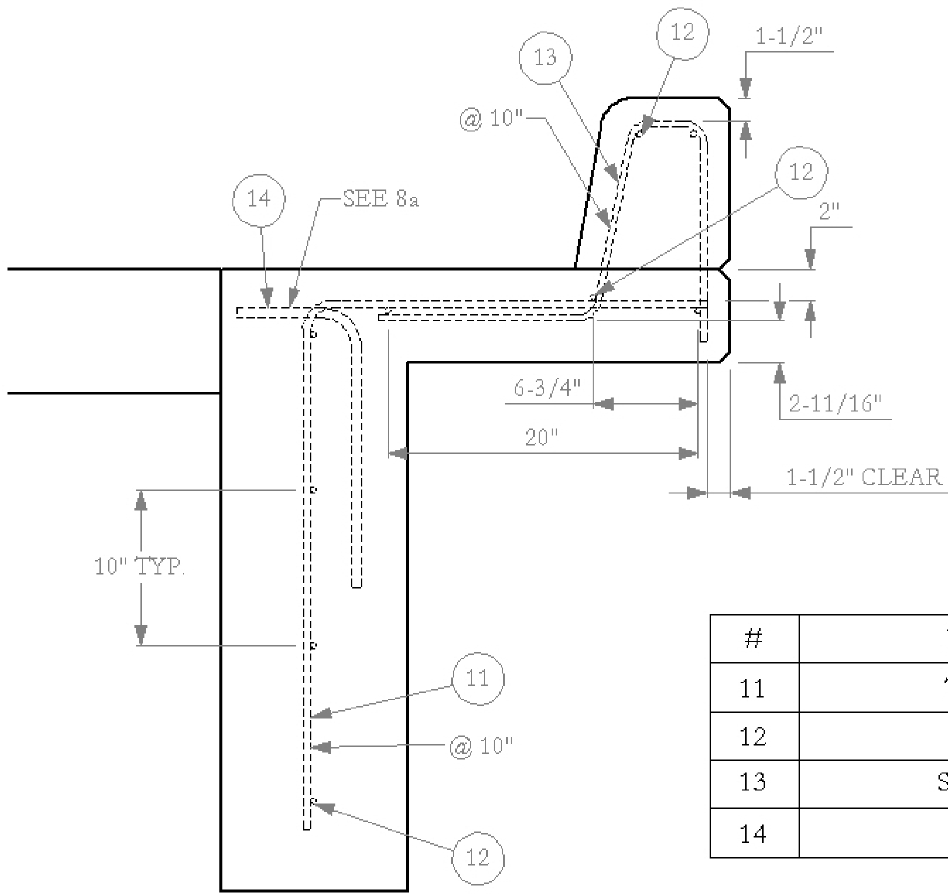

#	PART NAME	QTY.
11	Transverse Bar	92
12	Rebar, #3	*
13	Stirrup for Curb	92
14	L Bar	51

8a. L-bars spaced @ 18" and welded to existing rebar (not shown) protruding from runway.
8b. All rebar is grade 60.
8c. Longitudinal rebar lap distance is 16" for #3 bars.
8f. All rebar clearance is 1-1/2" unless otherwise noted.

Texas Transportation Institute		The Texas A&M University System College Station, Texas 77843	
Project 490022-1	T-131-RC		2011-11-28
Drawn By GES	Scale 1:10	Sheet 8 of 9	Rebar Layout

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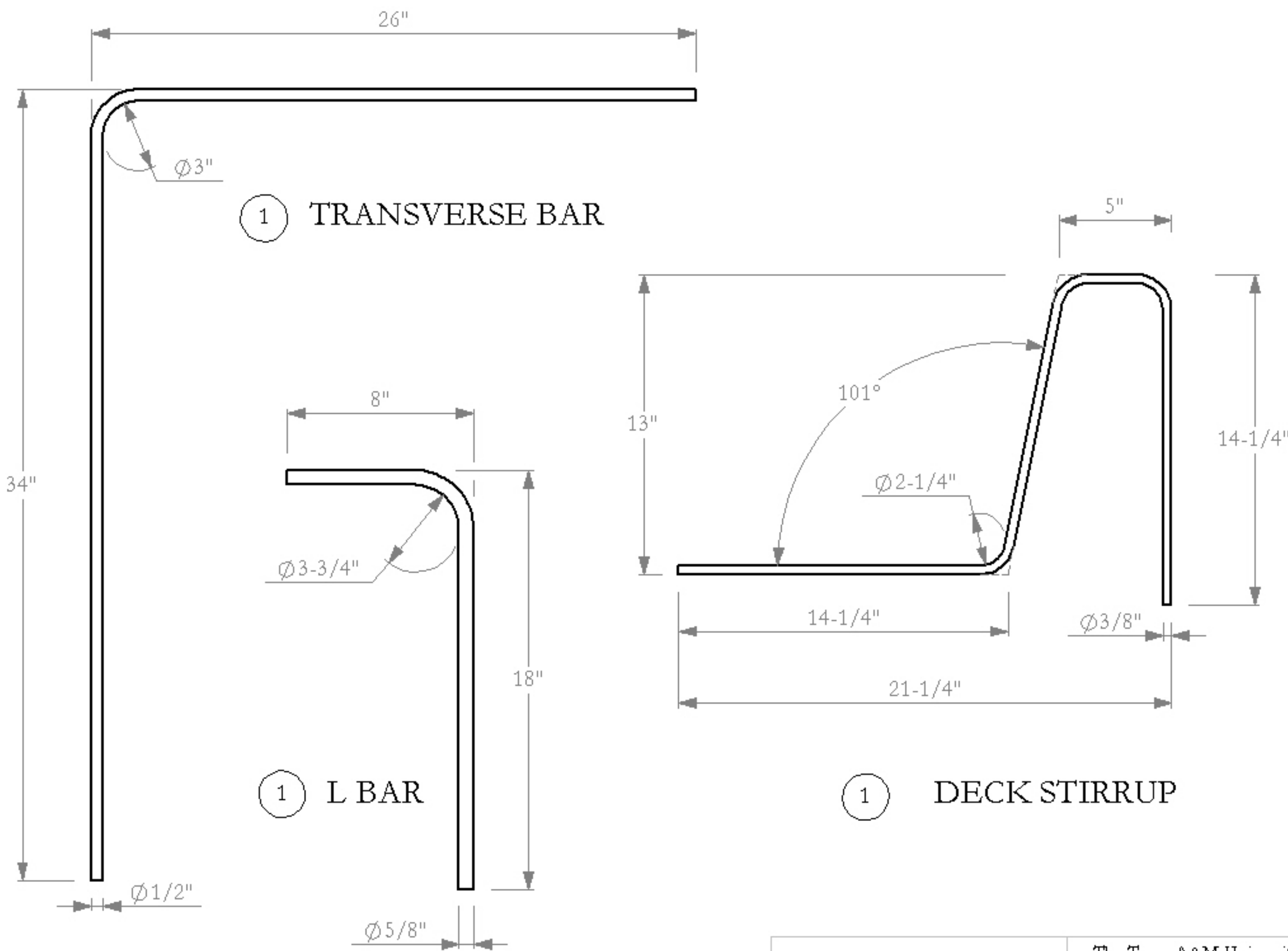


Texas Transportation Institute		The Texas A&M University System College Station, Texas 77843	
Project 490022-1	T-131-RC		2011-11-28
Drawn By GES	Scale 1:6	Sheet 9 of 9	Rebar Details

T:\2011-2012\490022 TxDOT\-1 T131RC\Drafting\T131 RC Drawing

APPENDIX B. CERTIFICATION DOCUMENTATION

MATERIAL USED

TEST NUMBER	490022-1
TEST NAME	T131RC
DATE	2012-02-14

DATE RECEIVED	ITEM NUMBER	DESCRIPTION	SUPPLIER	HEAT #
2012-01-26*	Parts-15	Guardrail Parts	Brazos Industries	see file
2012-01-12	Rebar 03-06	3/8" x 20' grd 60	CMC-Sheplers	3028608
2012-01-12	Rebar 04-25	1/2" x 20' gr 60	CMC-Sheplers	see file

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

CERTIFIED MILL TEST REPORT

12/29/11 23:27:11
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.

Sold To: NAMASCO CORPORATION
500 COLONIAL CENTER PKWY.
SUITE 500
ROSWELL, GA 30076

Ship To: NAMASCO
SOUTH LOOP 4 (6000 TH)
P.O. BOX 150367
AUSTIN, TX 78715

Customer #.: 485 - 49
B.O.L. #...: 517461

SPECIFICATIONS: Tested in accordance with ASTM specification A6-11/A6M-11 and A370. Quality Manual Rev #34.
AASHTO : M270-50-05
ASTM : A992-11;A36-08/A529-05-50/A572-07-50/A709-345M/A709-11 50S
CSA : G40.21-50W

Description	Heat# Grade(s) Test	Yield/ Tensile Ratio	Yield (PSI) (MPa)	Tensile (PSI) (MPa)	Elong %	C Cr xxxxxx	Mn Mo Ti	P Sn xxxxxx	S B xxxxxx	Si V N	Cu Nb xxxxxx	Ni xxxxxx CI	CE1 CE2 Pcm
W12x19	2113512	.84	60600	72400	25.80	.17	.85	.008	.030	.21	.23	.06	.35
040' 10.03'	A992-11		418	499		.03	.02	.0132	.0002	.004	.030		.2392
W310X28.3		.84	60130	71900	26.49		.002			.0051		4.84	.1397
012.1920m			414	496		8 Piece(s)		Customer PO: 5399303				Inv#:	0
W6x15	1113375	.84	57500	68830	27.79	.17	.83	.010	.024	.19	.15	.04	.23
040' 00.03'	A992-11		397	474		.03	.02	.0073	.0002	.004	.028		.2731
W150X22.5		.83	57590	69330	25.15		.002			.0056		1.78	.1321
012.1920m			396	478		27 Piece(s)		Customer PO: 6606051				Inv#:	0
W8x28	2115013	.80	58600	73330	23.50	.07	1.10	.009	.030	.24	.25	.06	.23
040' 10.03'	A992-11		404	505		.05	.02	.0094	.0002	.004	.029		.3339
W200X41.7		.80	59000	73330	23.39		.002			.0071		1.10	.1509
012.1920m			407	505		6 Piece(s)		Customer PO: 6607532				Inv#:	0
W8x31	2114961	.81	56600	70330	25.10	.07	1.06	.006	.029	.26	.16	.05	.27
040' 10.03'	A992-11		390	485		.03	.02	.0079	.0002	.004	.030		.3170
W200X46.1		.82	57530	70330	25.00		.002			.0033		1.00	.1425
012.1920m			396	485		12 Piece(s)		Customer PO: 6607532				Inv#:	0

Elongation based on 8' (20.32cm) gauge length. 'No Weld Repair' was performed. Hg free and no contact with Hg during manufacture.
CI = 26.01(Cu)+3.88(Ni)+1.20(Cr)+1.49(Si)+17.28(P)-(7.29(Cu)(Ni))-(9.10(Ni)(P))-33.39(Cu)(Cu)
CE1 = C+(Mn/6)+((Cr+Mo+V)/5)+((Ni+Cu)/15)
Pcm = C+(Si/30)+(Mn/20)+(Cu/20)+(Ni/60)+(Cr/20)+(Mo/15)+(V/10)+5B
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

ЭКСПОРТ EXPORT

лист 1 всего 1

Продавец(Экспортер) Seller(Exporter) ОАО ММК 455002 МАГНИТОГОРСК КИРОВА 93 MAGNITOGORSK IRON AND STEEL WORKS 93,ST.KIROV,MAGNITOGORSK 455002 RUSSIAN FEDERATION	Товаросопроводительный документ № Shipping document № 120-30318 (Сертификат качества Quality certificate) Контракт № Е163235 от297 Contract № Е163235 ap297
Грузополучатель, адрес, страна Consignee, address, country США United States ОАО НОВОРОССИЙСКИЙ СУДОРЕМОНТНЫЙ ЗАВОД КОД 3812 ГИН 353902,КРАСНОДАРСКИЙ КРАЙ,НОВОРОССИЙСК,СУХУМСКОЕ ШОССЕ ДЛЯ СТАРГЛОУБ ЛИМИТЕД (STARGLOBE LIMITED)	

Вагон № Freight car № 54997168

Наименование товара Description of goods	НД Standards	Форма расч. Geometry	Вид и вид груза Type of pack,coils	№ мест Package №
РУЛОНЫ ГК НЕДРЕССИРОВАННЫЕ HOT ROLLED COILS NON-SKIN PASSED	СТО ММК 380-2009		РУЛОНЫ 425 COILS	1-3

№ п/п	№ Pos. No	Код товара Code of goods	Номер плавки-партии Nos of heats-lots	Номера рул. Nos of coil	Марка стали и категория Steel grade and category	Группа прочн. Strength group	Кл точн. толщ. Accu. rcy	Вид повер. Surface appear.	Груп. по Appl. group	Груп. повер. Surface group	Хар. кромки Edge char.	Сорт.	[illegible]	[illegible]	Размеры мм Dimensions mm толщ*шир*длина thick*width*length	Масса т Mass t нетто netto	брутто gross
1	5	99131	1093843	0112	55 Grade 55-2 Type 2						К	1			12.500x1219	19.680	19.690
2	-"-	-"-	-"-	0212	-"-						К	1			-"-	20.570	20.580
3	-"-	-"-	-"-	0312	-"-						К	1			-"-	20.900	20.910
																61.150	61.180

Показатели качества товара Quality characteristics of goods

Номер плавки-партии Nos of heats-lots	C x100	Si x100	Mn x100	S x1000	P x1000	Cr x100	Ni x100	Cu x100	N x1000	Al x1000	Mo x1000	Nb x1000	V x1000	Ti x1000		Предел прочн. (N/mm2) Ultimate strength	Предел текуч. (N/mm2) Yield point	Относ. удлин. (%) Elongation	Изгиб Bend test	
1093843	16	10	97	14	16	4	4	8	7	54	3	1	4	1		450	380	38.0	yes sat_u	
1093843	16	10	97	14	16	4	4	8	7	34	3	1	4	1		450	400	39.0	yes sat_u	
1093843	16	10	97	14	16	4	4	8	7	34	3	1	4	1		450	386	38.0	yes sat_u	

HR 1/2 x 48
40# 17105
Heat# 1093843
PO# 6390465

Приме-чание
Note

Дата Date: 05.06.11 05:33 Подпись представителя ОКП Signature of the QCD representative: Полякова Е.Н. Лосягунова С.М.

Указанный в настоящем документе товар соответствует по качеству действующим в РФ стандартам техническим условиям и может быть отгружен на экспорт.
It is hereby certified that the quality of goods mentioned in this Document is in conformity with the RUS Standards and Specifications, and the goods may be exported. 97

Namasco

TTI

01-02-2012 04:10 Load - 1132336 BL - 3677708 BLR466
Brazos Industries Inc Heat - 762367
Cust. PO - Order-Line - 7073336 / 5

12/22/2011 THU 18:59 FAX 519 738 5081 atlastube shipping 004/005

Atlas Tube Canada ULC
200 Clark St.
Harrow, Ontario, Canada
N0R 1G0
Tel: 519-738-3541
Fax: 519-738-3637

Atlas Tube JMC STEEL GROUP

Ref.B/L: 80460468
Date: 12.22.2011
Customer: 990

MATERIAL TEST REPORT

Sold to

NAMASCO CORPORATION
Steel Warehousing Corporati
500 COLONIAL CENTER PR
ROSWELL GA 30076
USA

Shipped to

NAMASCO SOUTH WEST
SOUTH LOOP 4, P.O. BOX
BUDA TX 78715-0367
USA

Material: 5.0x5.0x250x48'0"0(4x2). Material No: 500502504800 Made in: Canada
Melted in: Canada
Sales order: 688743 Purchase Order: 6408907 Cust Material #: T514SQA5000576

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
762525	0.190	0.830	0.008	0.007	0.013	0.040	0.045	0.006	0.005	0.014	0.048	0.002	0.000	0.000	0.000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE: 0.35
M101100675	8	063850 Psi	078200 Psi	32.8 %	ASTM A500-10A GRADE B&C	

Material Note:
Sales Or.Note:

Material: 6.0x6.0x250x40'0"0(3x3). Material No: 600602504000 Made in: Canada
Melted in: Canada
Sales order: 689536 Purchase Order: 6409841 Cust Material #: T614SQA5000490

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
762367	0.190	0.790	0.007	0.008	0.014	0.061	0.042	0.005	0.006	0.018	0.028	0.002	0.000	0.000	0.000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE: 0.34
M101056080	9	054900 Psi	067270 Psi	34.0 %	ASTM A500-10A GRADE B&C	

Material Note:
Sales Or.Note:

Material: 8.0x4.0x250x40'0"0(2x4). Material No: 800402504000 Made in: Canada
Melted in: Canada
Sales order: 689538 Purchase Order: 6409841 Cust Material #: T8414RECTA5000480

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
762777	0.180	0.790	0.008	0.009	0.013	0.066	0.049	0.008	0.005	0.015	0.025	0.002	0.000	0.000	0.000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE: 0.33
M101056343	8	060430 Psi	075020 Psi	35.5 %	ASTM A500-10A GRADE B&C	

Material Note:
Sales Or.Note:

Authorized by Quality Assurance:
The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements.
CE calculated using AWS D1.1 method.

Steel Tube Institute OF NORTH AMERICA

Page : 2 Of 3

Metals Service Center Institute

BLR466

BL - 3678018 Heat - B1U7759 Order-Line - 7109178 / 2

Load - 1135417

01-05-2012 08:06 Brazos Industries Inc Cust. PO -

NUDOR STEEL TUSCALOOSA, INC.

MILL TEST CERTIFICATE

1700 HOLT RD N.E.
Tuscaloosa, AL 35404-1000
800-827-8872

Page #:1 of 1

Load Number	Tally	Mill Order Number	P.O. Number	Part Number	Certificate Number	Date
390866	00000000419759	N-107372-004	6361481		L335906-1	08/09/2011 13:46

Grade

Order Description:
A36, 0.6250 IN x 96.000 IN x 240.000 IN

Quality Plan Description:
A36MODMN-TRIPLE: ASTM A36-08 MOD MN/ASME SA36-03/A709-36-10

Customer:

Sold TO:
NAMASCO Buda TX

Ship TO:
NAMASCO Buda TX

Shipped Item	Heat/Slab Number	Certified By	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Cb	V	Al	Ti	N2	B	Ca	Sn	CEV
1H00930	B1U7759-03 ***	B1U7759	0.18	0.89	0.012	0.008	0.06	0.16	0.06	0.09	0.021	0.000	0.001	0.037	0.001	0.008	0.0001	0.0027	0.008	0.37
1H0093E	B1U7759-03 ***	B1U7759	0.18	0.89	0.012	0.008	0.06	0.16	0.06	0.09	0.021	0.000	0.001	0.037	0.001	0.008	0.0001	0.0027	0.008	0.37
1H00958	B1U7759-02 ***	B1U7759	0.18	0.89	0.012	0.008	0.06	0.16	0.06	0.09	0.021	0.000	0.001	0.037	0.001	0.008	0.0001	0.0027	0.008	0.37

Shipped Item	Certified By.	Heat Number	Yield ksi	Tensile ksi	Y/T %	ELONGATION % 2"	ELONGATION % 8"	Bend OK?	Hard HR	Charpy Impacts (ft-lbf) Size mm	1	2	3	Avg	Shear % 1	2	3	Avg	Test Temp
1H00930	S1H0093FTT	B1U7759 ***	46.7	67.9	68.8	38.6													
1H00930	S1H0093MTT	B1U7759 ***	44.9	63.8	70.4	40.1													
1H0093E	S1H0093FTT	B1U7759 ***	46.7	67.9	68.8	38.6													
1H0093E	S1H0093MTT	B1U7759 ***	44.9	63.8	70.4	40.1													
1H00958	S1H0092FTT	B1U7759 ***	49.0	66.7	71.3	41.0													
1H00958	S1H0094FTT	B1U7759 ***	49.0	68.3	71.7	36.6													
1H00958	S1H0092MTT	B1U7759 ***	46.8	63.3	73.9	40.9													
1H00958	S1H0094MTT	B1U7759 ***	45.8	64.0	71.6	39.9													

Items: 3 PCS: 10 Weight: 40839 LBS

Mercury has not come in contact with this product during the manufacturing process nor has any mercury been used by the manufacturing process. Certified in accordance with EN 10204 3.1. No weld repair has been performed on this material. Manufactured to a fully killed fine grain practice. ** Produced from Coil **
ISO 9001:2008 Registered. PED Certified

*** indicates Heats melted and Manufactured in the U.S.A.

We hereby certify that the product described above passed all of the tests required by the specifications.

April Pitts - QA Engineer

Porteous Fastener Company

Product Information Sheet

Carriage Bolt, Inch Series, Grade A

- PFC Product Category: 00100
- Typical Material: Low Carbon Steel
- Material and Mechanical Properties: Purchased to meet ASTM A307 Grade A.
- Dimensions: ASME B18.5, Round Head Square Neck Bolt, Rolled Threads
  - Full thread to 6 inches in length.
  - Undersize body and 6 inches of threads on lengths over 6 to 12 inches.
  - 6 inches threads and full size body on lengths over 12 inches.
- Zinc Plating: Purchased to meet ASTM F1941 FeZn3A
- Hot-Dip Galvanized: Purchased to meet ASTM A153.
- Typical Hardness: HRB 69-100
- Tensile Strength: 60,000 PSI Minimum

Tensile Strength - NC Threads ASTM A307 Grade A		
Size	PSI	Pounds
1/4-20	60,000	1900
5/16-18	60,000	3100
3/8-16	60,000	4650
7/16-14	60,000	6,350
1/2-13	60,000	8,500
9/16-12	60,000	11,000
5/8-11	60,000	13,550
3/4-10	60,000	20,050
7/8-9	60,000	27,700
1-8	60,000	36,350

Length Tolerances - Carriage Bolts				
	Nominal Size			
Nominal Length	#10 to 3/8	7/16 & 1/2	9/16 to 3/4	7/8 to 1
	Tolerance on Length			
Up to & incl 1"	+0.02/-0.03	+0.02/-0.03	+0.02/-0.03	
Over 1" to 2 1/2", incl.	+0.02/-0.04	+0.04/-0.05	+0.06/-0.08	+0.08/-0.10
Over 2 1/2" to 4", incl.	+0.04/-0.06	+0.06/-0.08	+0.08/-0.10	+0.10/-0.14
Over 4" to 6", incl.	+0.06/-0.10	+0.08/-0.10	+0.10/-0.10	+0.12/-0.16
Over 6"	+0.10/-0.18	+0.12/-0.18	+0.14/-0.18	+0.16/-0.20

Porteous Fastener Company

Page 1 of 1

Page: 1

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

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

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

Date: 26-Oct-2011
B.L. Number: 586989
Load Number: 195932

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

NBMG-08 March 9, 2011

HEAT NUM. *	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# =>	801746												
JW1110880201	Nucor Steel - Texas	70,000	110,500	13.0%			.42	1.02	.016	.024	.12	.33	.62
	13/#4 Rebar 20'	483MPa	762MPa				.13	.15	.039	.003	.001		
	A615M Gr 420 (Gr60)												
	ASTM A615/A615M-09b GR 60[420]												
	AASHTO M31-07												
PO# =>	801746												
JW1110880301	Nucor Steel - Texas	70,700	108,900	12.0%			.42	.98	.019	.044	.14	.32	.61
	13/#4 Rebar 20'	487MPa	751MPa				.14	.17	.042	.003	.001		
	A615M Gr 420 (Gr60)												
	ASTM A615/A615M-09b 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

QUALITY ASSURANCE: Nathan Stewart

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
Quality Assurance Manager

HEAT NO.:3028608 SECTION: REBAR 10MM (#3) 20'0" 420/60 GRADE: ASTM A615-09b Gr 420/60 ROLL DATE: 11/20/2011 MELT DATE: 11/19/2011	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#: 80634703 BOL#: 70224264 CUST PO#: 5390AB CUST P/N: DLVRY LBS / HEAT: 16848.000 LB DLVRY PCS / HEAT: 2240 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.45%				
Mn	0.81%				
P	0.012%				
S	0.037%				
Si	0.17%				
Cu	0.34%				
Cr	0.17%				
Ni	0.16%				
Mo	0.059%				
V	0.002%				
Cb	0.001%				
Sn	0.013%				
Al	0.002%				
Yield Strength test 1	70.6ksi				
Tensile Strength test 1	108.3ksi				
Elongation test 1	13%				
Elongation Gage Lgth test 1	8IN				
Bend Test Diameter	1.313IN				
Bend Test 1	Passed				

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

REMARKS :

11/22/2011 18:03:39

APPENDIX C. TEST VEHICLE PROPERTIES AND INFORMATION

Table C1. Vehicle Properties for Test No. 490022-1.

Date: 2012-02-14 Test No.: 490022-1 VIN No.: 1D7HA18P975187573

Year: 2007 Make: Dodge Model: Ram 1500

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

Tread Type: All Terrain Odometer: 153756

Note any damage to the vehicle prior to test: ____

● Denotes accelerometer location.

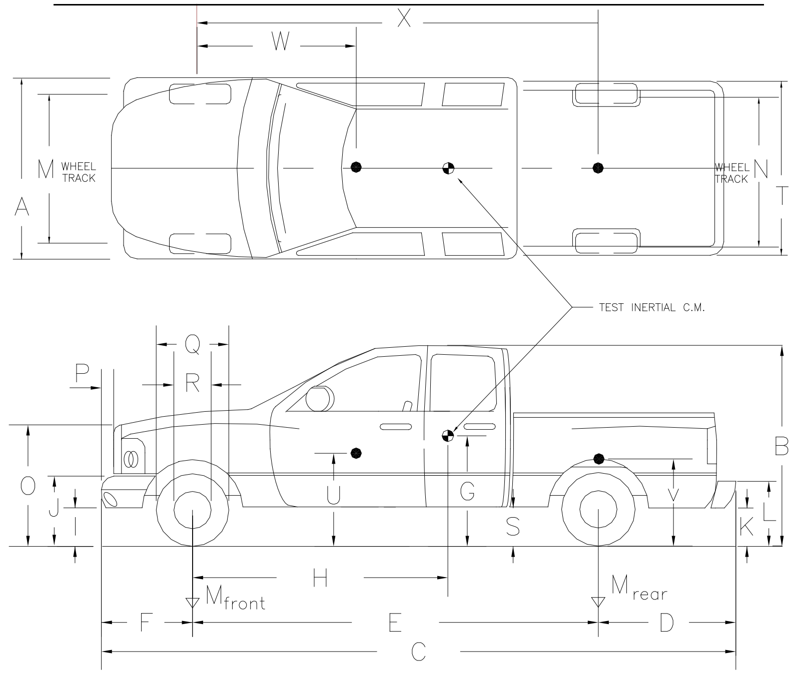
NOTES: ____

Engine Type: V-8
Engine CID: 4.7 liter

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

Optional Equipment: ____

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



Geometry: inches

A	78.25	F	36.00	K	20.50	P	2.88	U	29.00
B	75.00	G	28.44	L	29.12	Q	31.25	V	30.50
C	223.75	H	61.53	M	68.50	R	18.38	W	62.00
D	47.25	I	13.75	N	68.00	S	12.00	X	98.00
E	140.50	J	25.38	O	44.50	T	77.50		

Wheel Center Height Front	14.75	Wheel Well Clearance (Front)	5.00	Bottom Frame Height - Front	17.125
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	10.25	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}	2819	2802	
Back	3900	M_{rear}	2103	2183	
Total	6700	M_{Total}	4922	4985	

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

Mass Distribution:
lb LF: 1457 RF: 1345 LR: 1083 RR: 1100

Table C2. Vertical CG Measurements for Test No. 490022-1.

Date: 2012-02-14 Test No.: 490022-1 VIN No.: 1D7HA18P975187573

Year: 2007 Make: Dodge Model: Ram 1500

Body Style: Quad Cab Mileage: 153756

Engine: 4.7 liter V-8 Transmission: Automatic

Fuel Level: Empty Ballast: 76 lb at front of bed (440 lb max)

Tire Pressure: Front: 35 psi Rear: 35 psi Size: P265/70R17

Measured Vehicle Weights: (lb)

LF:	1433	RF:	1367	Front Axle:	2800
LR:	1075	RR:	1114	Rear Axle:	2189
Left:	2508	Right:	2481	Total:	4989
					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: 61.65 in Rear of Front Axle (63 ±4 inches allowed)

Y: -0.19 in Left - Right + of Vehicle Centerline

Z: 28.4375 in Above Ground (minumum 28.0 inches allowed)

Hood Height: 44.5 inches Front Bumper Height: 25.375 inches

43 ±4 inches allowed

Front Overhang: 36.0 inches Rear Bumper Height: 29.125 inches

39 ±3 inches allowed

Overall Length: 223.75 inches

237 ±13 inches allowed

Table C3. Exterior Crush Measurements for Test No. 490022-1.

Date: 2012-02-14 Test No.: 490022-1 VIN No.: 1D7HA18P975187573

Year: 2007 Make: Dodge Model: Ram 1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage		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	17.0	10.0	24.0	0	1	1.75	3.5	5.0	10.0	+14
2	Side plane at bumper ht	17.0	15.0	44.0	3	7.5	11	12.5	13.5	15.0	+67
	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).

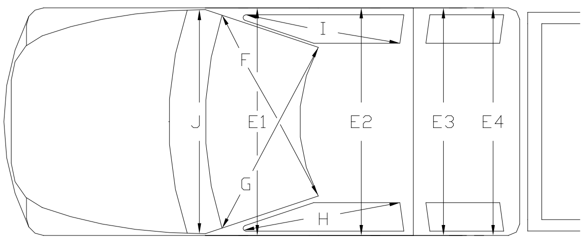
***Measure and document on the vehicle diagram the location of the maximum crush.

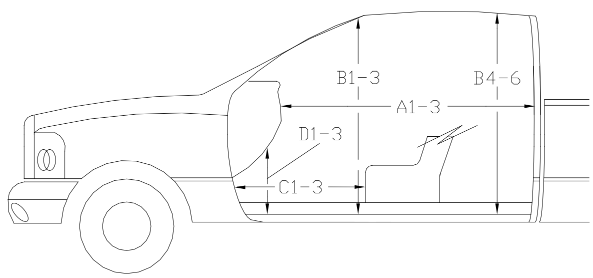
Note: Use as many lines/columns as necessary to describe each damage profile.

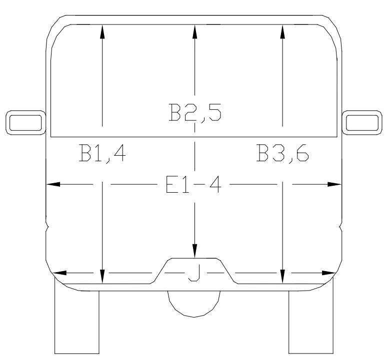
Table C4. Occupant Compartment Measurements for Test No. 490022-1.

Date: 2012-02-14 Test No.: 490022-1 VIN No.: 1D7HA18P975187573

Year: 2007 Make: Dodge Model: Ram 1500







OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before (inches)	**After** (inches)
A1	64.50	64.50
A2	64.50	64.50
A3	65.00	65.00
B1	45.12	45.12
B2	39.25	39.25
B3	45.12	45.12
B4	42.11	42.11
B5	42.00	42.00
B6	42.12	42.12
C1	29.00	29.00
C2	----	----
C3	27.00	27.00
D1	12.75	12.75
D2	----	----
D3	11.75	11.75
E1	62.75	62.25
E2	64.50	64.75
E3	64.00	63.75
E4	64.25	64.25
F	60.00	60.00
G	60.00	60.00
H	39.50	39.50
I	39.50	39.50
J*	61.75	61.25

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

APPENDIX D. SEQUENTIAL PHOTOGRAPHS

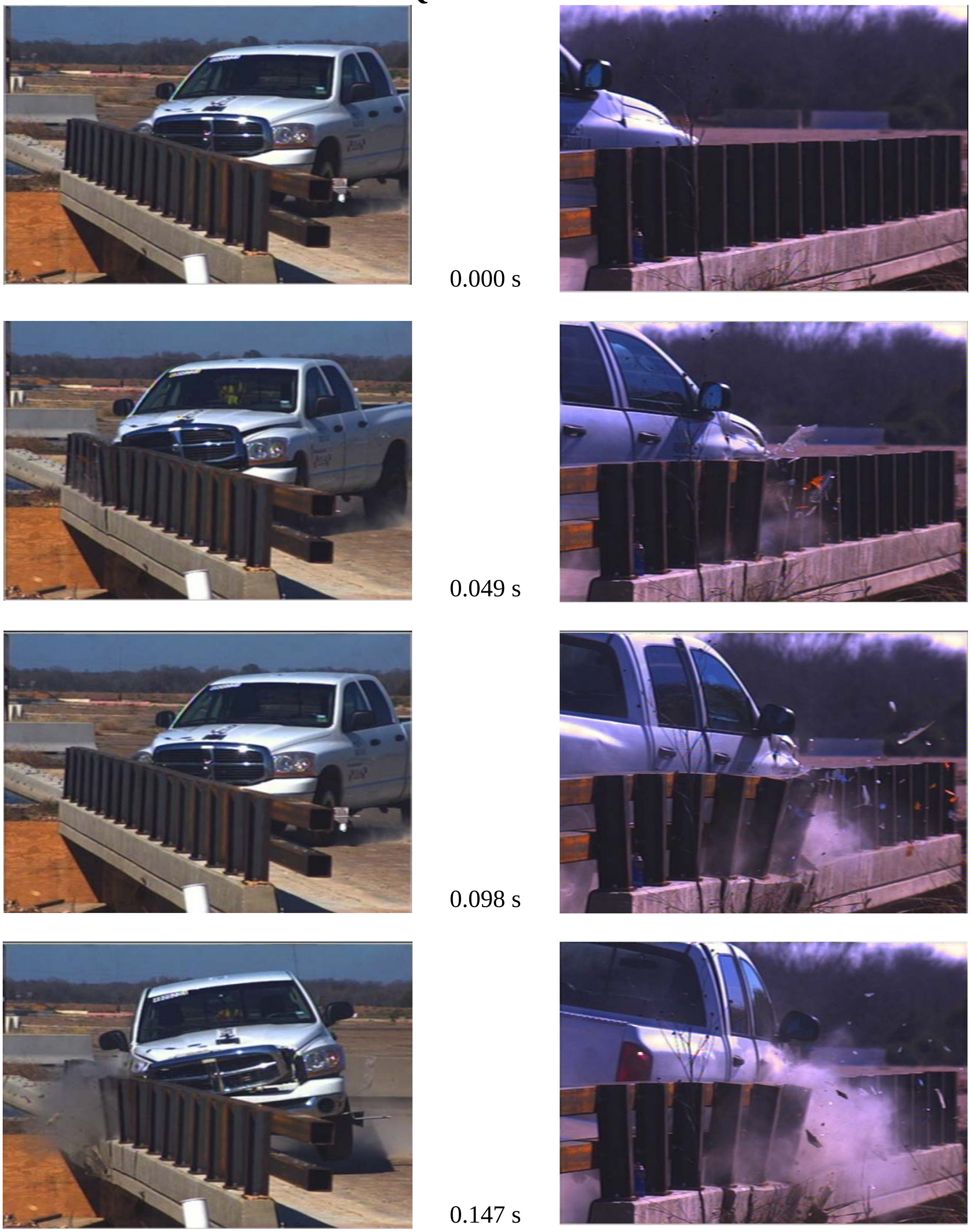
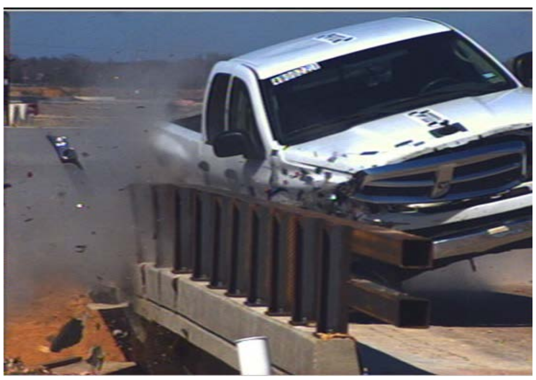


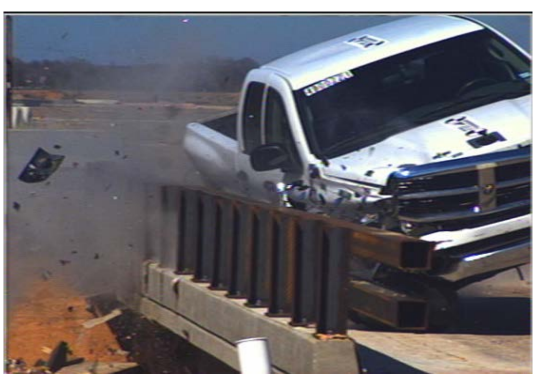
Figure D1. Sequential Photographs for Test No. 490022-1 (Field Side of Bridge Rail).

0.196s

0.245 s



0.294 s



0.343 s

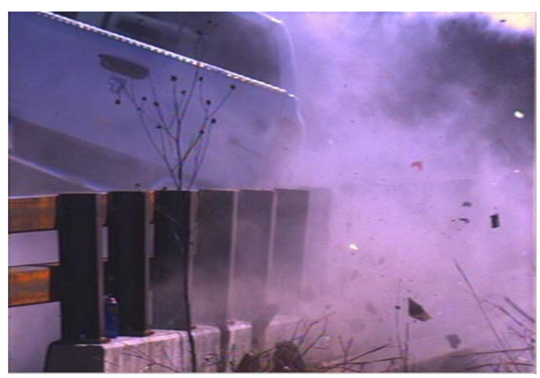


Figure D1. Sequential Photographs for Test No. 490022-1 (Field Side of Bridge Rail) (continued).

0.000 s | 0.196 s
0.049 s | 0.245 s
0.098 s | 0.294 s
0.147 s | 0.343 s

Figure D2. Sequential Photographs for Test No. 490022-1 (Frontal View).

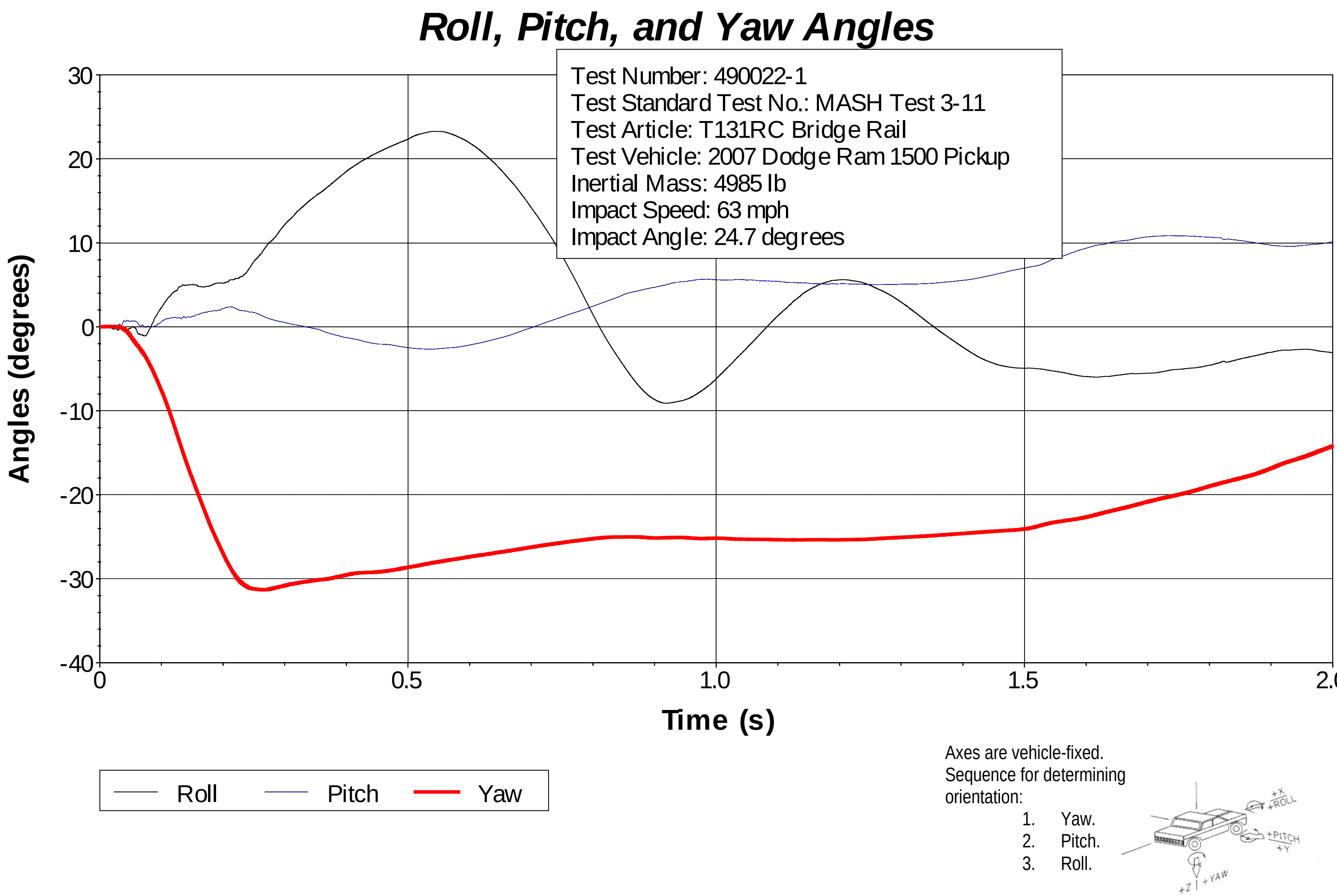


Figure E1. Vehicle Angular Displacements for Test No. 490022-1.

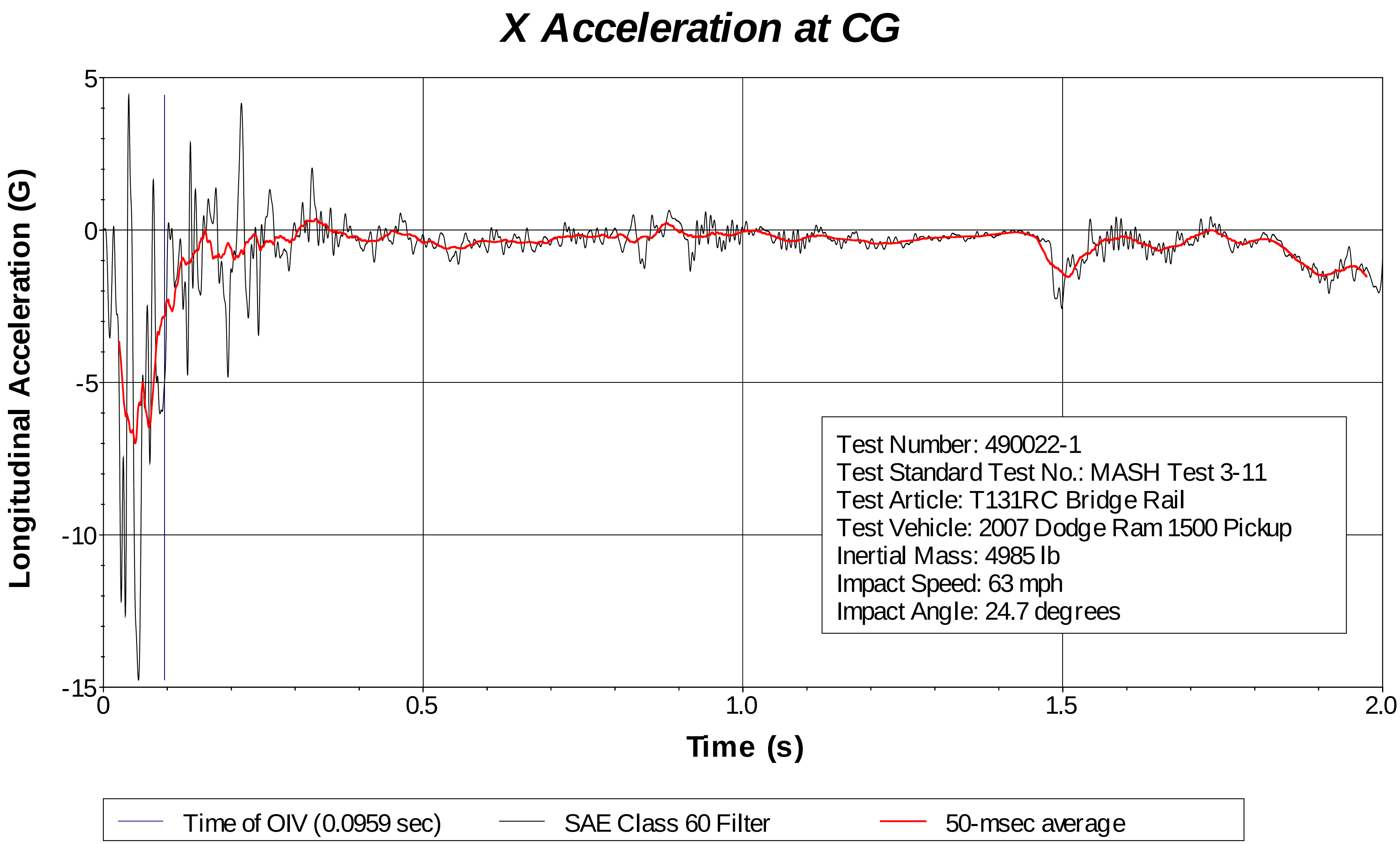


Figure E2. Vehicle Longitudinal Accelerometer Trace for Test No. 490022-1 (Accelerometer Located at Center of Gravity).

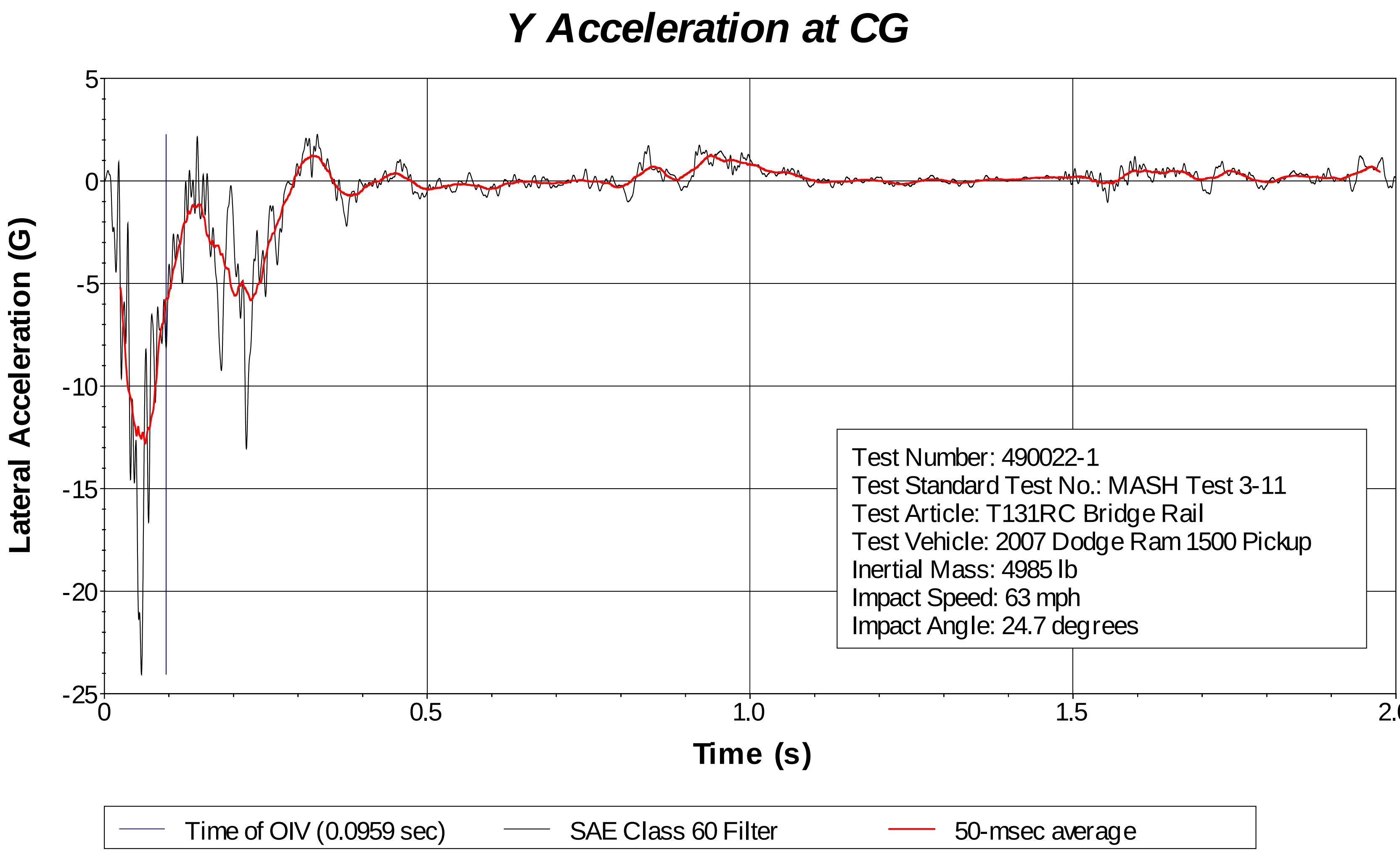


Figure E3. Vehicle Lateral Accelerometer Trace for Test No. 490022-1 (Accelerometer Located at Center of Gravity).

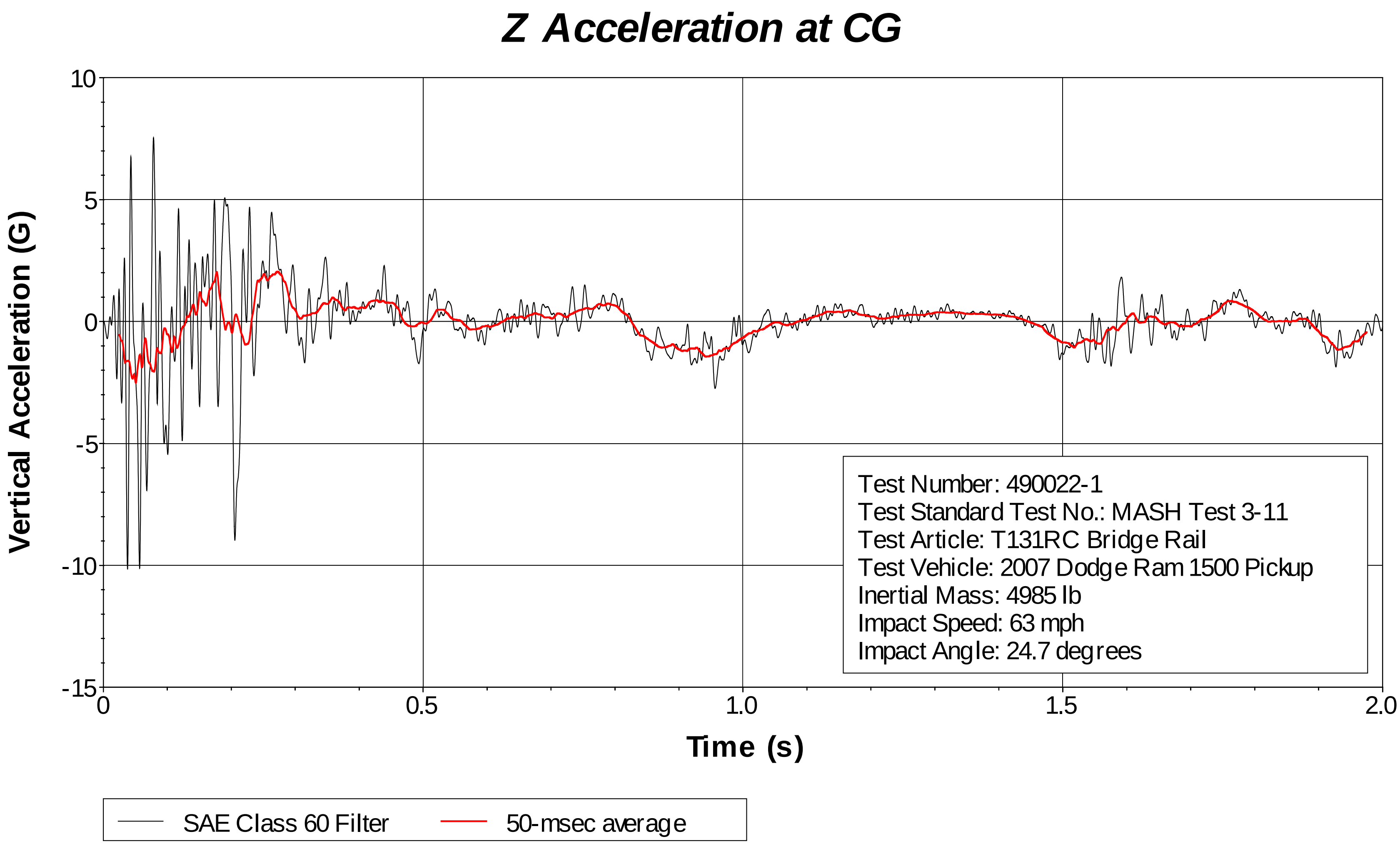


Figure E4. Vehicle Vertical Accelerometer Trace for Test No. 490022-1 (Accelerometer Located at Center of Gravity).

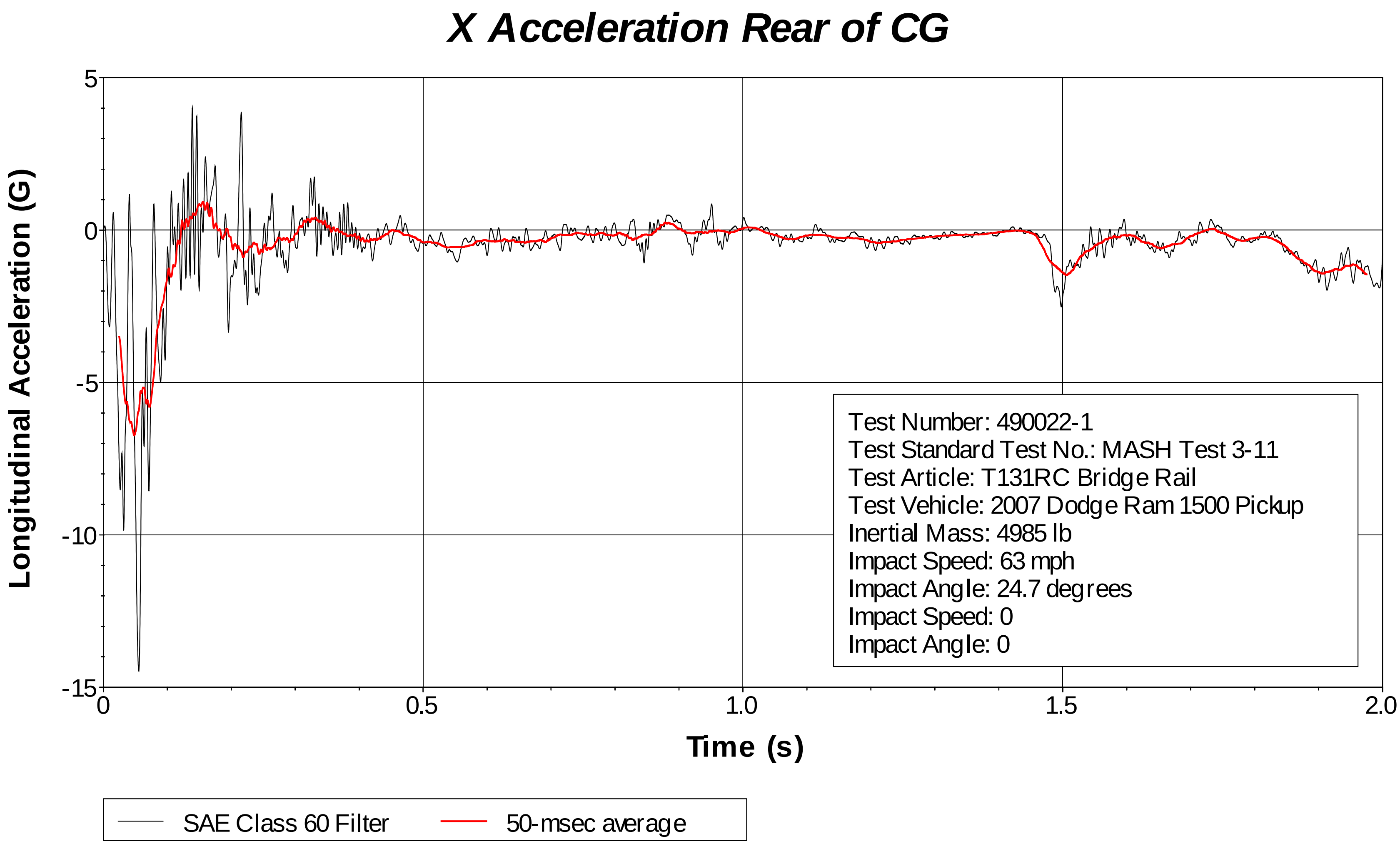


Figure E5. Vehicle Longitudinal Accelerometer Trace for Test No. 490022-1 (Accelerometer Located Rear of Center of Gravity).

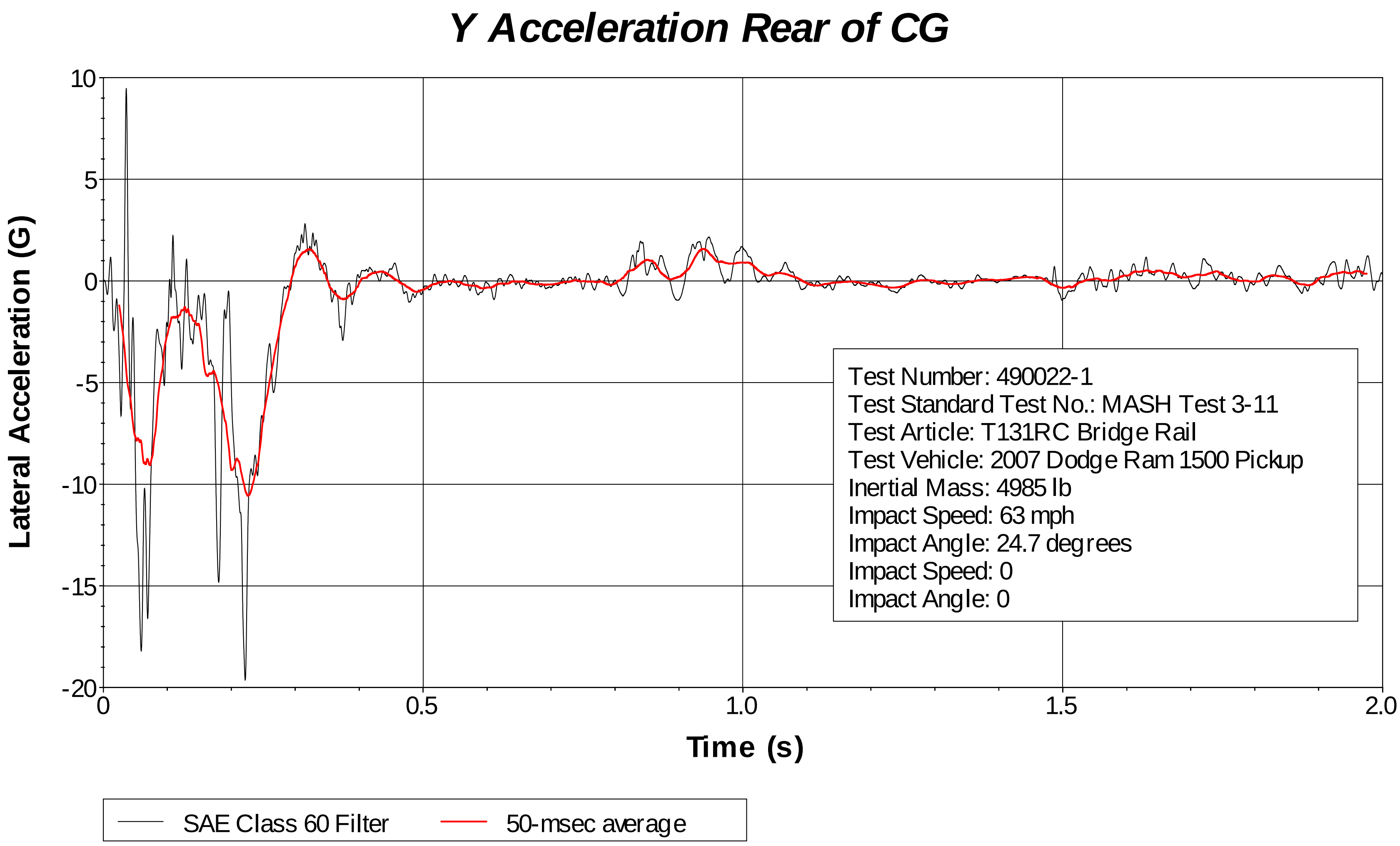


Figure E6. Vehicle Lateral Accelerometer Trace for Test No. 490022-1 (Accelerometer Located Rear of Center of Gravity).

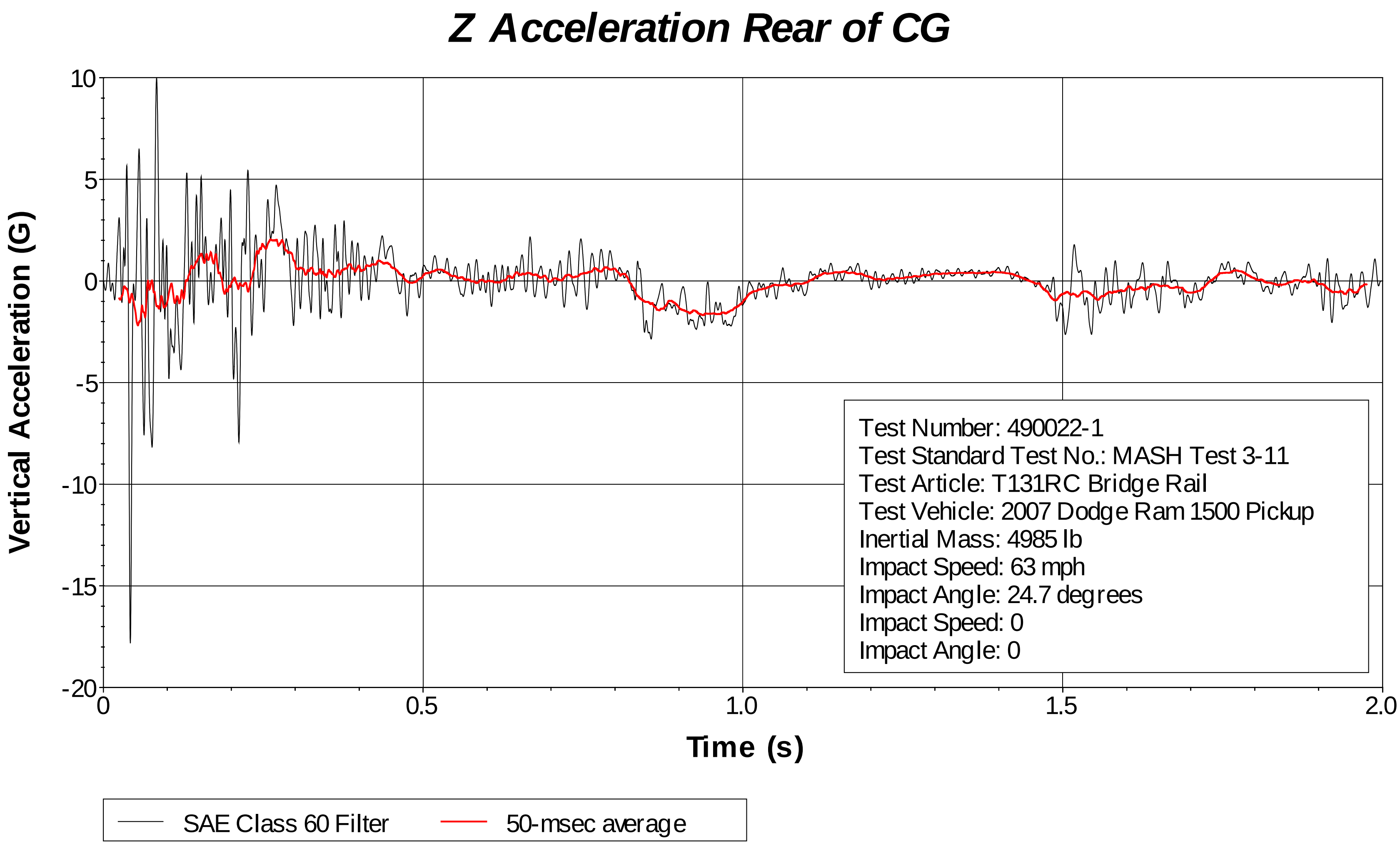


Figure E7. Vehicle Vertical Accelerometer Trace for Test No. 490022-1 (Accelerometer Located Rear of Center of Gravity).