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Texas A&M Transportation Institute

MASH TL-4 EVALUATION OF THE TXDOT TYPE C2P 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 9-1002-15-2 Rev.1

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 Texas Department of Transportation (TxDOT) Type C2P Bridge Rail according to the safety-performance evaluation guidelines included in the American Association of State Highway and Transportation Officials *Manual for Assessing Safety Hardware* (*MASH*) for Test Level Four (TL-4). This report describes the TxDOT Type C2P Bridge Rail, documents the impact performance of the bridge rail system according to *MASH* TL-4 evaluation criteria for longitudinal barriers, and presents recommendations regarding implementation.

MASH Tests 4-10 and 4-11 evaluate a barrier's ability to successfully contain and redirect passenger vehicles and evaluate occupant risk. *MASH* Test 4-12 evaluates the structural adequacy of the bridge rail. All three tests were performed on the TxDOT Type C2P Bridge Rail.

For Test 4-12, the post welds were not properly fabricated according to the project design drawings. As a result, some post welds in the immediate impact area did rupture from the *MASH* Test 4-12 truck impact. These ruptured post welds did aggravate the stability of the single unit truck during the test. For subsequent tests, the posts were welded correctly as per the project drawings. The bridge rail posts, with the correct post welds, should only improve the performance of the single unit truck. The TxDOT Type C2P Bridge Rail performed acceptably for *MASH* TL-4.

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and the
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October 2016

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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. 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. This report is not intended for construction, bidding, or permit purposes. The engineer in charge of the project was Roger P. Bligh, P.E. #78550.

TTI PROVING GROUND DISCLAIMER

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

ACCREDITED
ISO 17025 Laboratory
Testing Certificate # 2821.01

Crash testing performed at:
TTI Proving Ground
3100 SH 47, Building 7091
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Revision 1: June 24, 2022
Page 20, 27, and 36 added in windshield deformation information under the vehicle damage section.

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Chapter 1. INTRODUCTION

1.1. PROBLEM

The current research was conducted under a project that 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. Such safety devices help 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 various site conditions, placement locations, and a changing vehicle fleet. Periodically, there is a need to assess the compliance of existing safety devices with current evaluation and testing criteria and develop new devices that address identified needs.

Under this project, TxDOT identified roadside safety issues and prioritized these for investigation. Each roadside safety issue is addressed with a separate work plan and test report.

1.2. OBJECTIVES/SCOPE OF RESEARCH

The objective of this research was to evaluate the impact performance of the TxDOT Type C2P Bridge Rail according to the safety-performance evaluation guidelines included in the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*) for Test Level Four (TL-4) (*1*). This report describes the TxDOT Type C2P Bridge Rail, documents the impact performance of the bridge rail system according to *MASH* TL-4 evaluation criteria for longitudinal barriers, and presents recommendations on implementation.

Chapter 2. SYSTEM DETAILS

2.1. TEST ARTICLE AND INSTALLATION DETAILS

The test installation consisted of three 144-ft long (post-to-post) horizontal steel rails mounted on a 148-ft long concrete curb. Each rail was comprised of four 39-ft 10-inch long (40-ft long nominal) segments. The overall height of the bridge rail system was 42 inches above the bridge deck. The upper rail was comprised of a 4½-inch outside diameter (OD) × $^{3}/_{16}$–inch wall thickness round hollow structural section (HSS4.500×0.1875), and the middle and lower rails were each 6-inch × 2-inch × ¼–inch wall thickness rectangular hollow structural sections (HSS6.00×2.00×0.250). Nineteen 32-inch tall posts were equally spaced at 8 ft along the length of the installation. The posts were anchored to the top of a 9-inch tall steel reinforced concrete curb.

2.1.1 Horizontal Rail Members

The upper rail element was comprised of an HSS4.500×0.1875 fabricated from ASTM A500 grade B material. The horizontal centerline of the round upper rail was 39¾ inches above the bridge deck. The middle and lower rail elements were each comprised of HSS6.00×2.00×0.250 fabricated from ASTM A500 grade B material. The horizontal centerlines of the middle and lower rails were 27 inches and 17 inches above the bridge deck, respectively.

To facilitate attaching the rails to the posts, each rail contained five pairs of $1^{1}/_{16}$-inch diameter holes on 4½-inch centers on the field side located every 96 inches along the length of the rail. The rails were attached to the posts with ½-inch diameter ASTM A36 steel U-bolts with 2 inches of 13 UNC threads on 3½-inch long legs bent at 4½-inch centers. The bolts were inserted through the $1^{1}/_{16}$-inch diameter holes in the rail and through the post, then secured with 2-inch square × $^{5}/_{16}$-inch thick ASTM A36 plate washers containing a centered $^{9}/_{16}$-inch diameter hole, a lock washer, and a ½-inch, 13 UNC heavy hex nut (see Appendix A and/or B, drawing sheet 8 of 14 for details)

For test 1 with the small car and test 2 with the pickup truck, the most upstream four post locations of the installation were not used, so the fifth post location was numbered as post 1. The 2-inch wide rail expansion joints were centered 32 inches upstream of the centerlines of posts 6 and 11 of 15 posts. Each of the three rail sections were attached to five posts. The most upstream rail section had a 31-inch overhang preceding post 1, and the most downstream rail section had a 5-ft 3-inch overhang beyond post 15 (see Figure 2-1 and Appendix A)

For test 3 with the single unit truck, the three rail expansion joints for the four rail sections were each centered 32 inches upstream of the centerlines of posts 6, 11, and 16 of 19 posts. The most upstream three rail sections at posts 1 through 15 were each attached to five posts, with a 31-inch overhang preceding post 1, and the remaining downstream rail section at posts 16 through 19 was attached to four posts (16, 17, 18, and 19) with a 13 ft-3 inch overhang beyond post 19 (see Figure 2-2 and Appendix B)

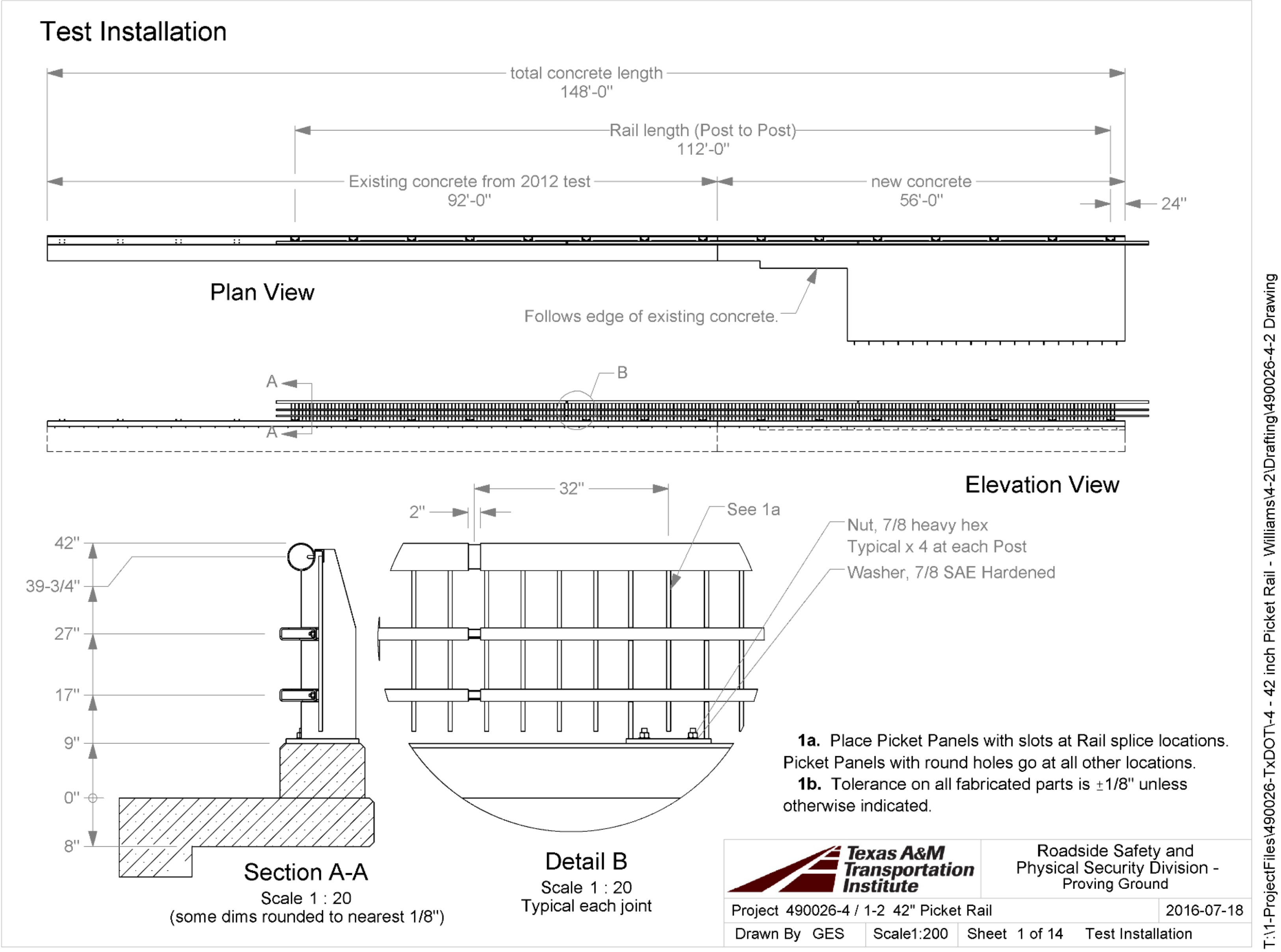


Figure 2-1. General Layout of the TxDOT Type C2P Bridge Rail for Test No. 490026-4-1 and 4-2.

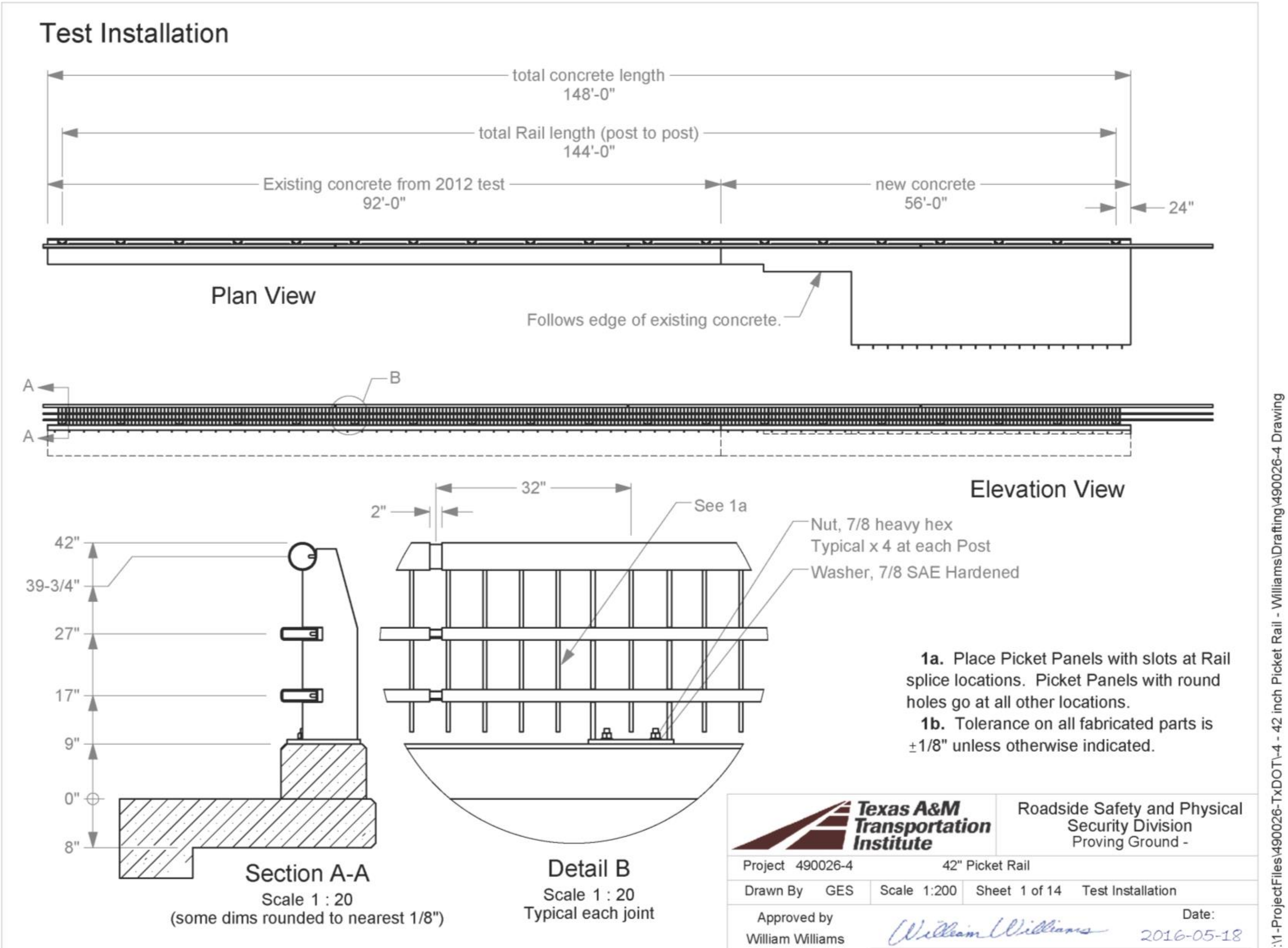


Figure 2-2. General Layout of the TxDOT Type C2P Bridge Rail for Test No. 490026-4-3.

The rail sections were connected with internal splice sections that matched the internal profile of the rails. The splice sections for the top rail were 28-inch long × 4-inch OD × ¼-inch thick round HSS fabricated from ASTM A500 grade B material with a ⅜-inch diameter locating pin located mid-span. The splice sections for the middle and bottom rails were 28-inch long welded rectangular tubes measuring 5⅜-inches wide × 1⅜-inches tall × $^{3}/_{16}$-inch thick fabricated from ASTM A36 steel plate. These splice tubes also contained a ⅜-inch diameter locating pin at mid-span (see Appendix A and/or B, drawing sheet 6 of 14 for details).

2.1.2 Picket Panels

Eighteen picket panels were attached to the field side of the bridge rail system, one between each of the 19 posts. Each panel measured 73⅛ inches long × 29⅞-inches high, and had thirteen ⅝-inch square vertical steel bars evenly spaced at 6 inches along the length. Three horizontal members connected the pickets. The top longitudinal member was a 2-inch × 1½-inch × $^{3}/_{16}$-inch thick angle oriented with the 2-inch leg vertical and on the field side of the pickets. The middle and bottom horizontal members were 1½-inch × ⅜-inch thick steel plate positioned 13¾ inches and 23⅞ inches below the top of the top angle. The middle and bottom horizontal members were positioned on the traffic side of the pickets. Fifteen picket sections had three $^{9}/_{16}$-inch diameter bolt holes located $3^{9}/_{16}$ inches, $33^{9}/_{16}$ inches, and $69^{9}/_{16}$ inches from the end of each middle and bottom horizontal plate (providing 30-inch and 36-inch spacings). The three picket sections located at the sleeved expansion joints had $^{9}/_{16}$-inch wide × 3½-inch long slots (instead of $^{9}/_{16}$-inch diameter holes) centered at the same locations. All picket materials were ASTM A36 steel. Each picket panel was secured to the middle and lower rails with six ½ × 1½ -13 UNC ASTM A325 bolts, two ½-inch SAE hardened washers, and ½-inch heavy hex nuts. The rails were constructed with 2-inch diameter hardware access holes on the bottom near the field side at each picket panel bolt location. Similar holes were field cut in the internal splice sections as needed, and 2-inch long bolts were used at these locations. The top horizontal angle was not connected to the round top rail (see Appendix A and/or B, drawing sheet 5 and 7 of 14 for details).

2.1.3 Bridge Rail Posts

Fabricated steel posts, each 32 inches in overall height, supported the three rails atop the curb at 19 locations equally spaced at 8 ft along the test installation. Each post was a built-up welded structure comprised of two 9-inch wide × 31¼-inch tall × ¾-inch thick side plates on 12½-inch centers welded to a base plate. The base plate was 14-inches wide × 12-inches deep × ¾-inch thick. Three rail bolting plates, each 2 inches wide × ¾ inch thick, were welded between the side plates. A ⅝-inch square vertical bar picket was welded to the field side of the middle and bottom rail plates. The front of each side plate was located 2½ inches back from the edge of the baseplate. Each side plate contained two rectangular notches, each 3¼ inches deep × 2⅛ inches high, that received the rail bolting plates and the middle/lower rail elements. The traffic side face of the middle and lower rails projected 3½ inches beyond the side plates, and was flush with the face of the curb.

The base plate contained two pairs of 1⅛-inch diameter anchor bolt holes located 2⅝ inches and 7⅜ inches from the front edge (traffic side) of the base plate and spaced on 4-inch centers about the centerline of the post. The base plates and post side plates were fabricated from ASTM A572 grade 50 material, and the pickets and rail bolting plates were fabricated from ASTM A36 material (see Appendix A and/or B, drawing sheet 3 and 4 of 14 for details).

In addition to the 12 existing anchor bolt sets, 7 new anchor bolt assemblies (for posts 13 through 19) were cast into the extended concrete curb. Four ⅞-inch diameter × 11½-inch long ASTM A193 grade B7 threaded rods were located in $^{15}/_{16}$-inch diameter holes in an 11-inch long × 6½-inch wide × ¼-inch thick ASTM A36 steel anchor plate and supported by heavy hex nuts welded to the underside. Anchor bolt threads projected 2½ inches above the top of the concrete curb. Each post was secured to the curb with a ⅞-inch diameter heavy hex nut and ⅞-inch SAE hardened washer on each anchor bolt (see Appendix A and/or B, drawing sheet 9 of 14 for details).

2.1.3.1 Bridge Rail Post Interim Repairs

The first test was test 3 with the single unit truck (*MASH* 4-12), followed by test 2 with the pickup truck (*MASH* 4-11), and finally test 1 with the small car (*MASH* 4-10). During test 3, the base plate welds failed at posts 5, 6, and 7 (refer to Section 7.5). Prior to test 2, the base plates for all 15 posts used for the remaining two tests were removed and new base plates of the same design were welded to the posts.

2.1.4 Concrete Curb and Bridge Deck

An existing steel reinforced concrete curb, bridge deck, and support wall from a previous bridge rail installation was used for the upstream 92-ft of the 148-ft installation length used for testing and evaluation of the TxDOT Type C2P Bridge Rail. On the downstream end of the installation, an additional 56 ft of curb, bridge deck, and sub-grade footer wall was constructed off of the existing concrete apron at the TTI Proving Ground facility. The curb was installed in three regions: A) an extension of the existing curb approximately 6-ft long; B) a new curb, deck, and sub-grade footer wall approximately 12 ft long; and C) a new curb, deck, sub-grade footer wall, and moment slab approximately 38 ft long.

The top of the curb was 9 inches above the finished grade of the bridge deck, and was 14 inches wide.

The cantilevered deck was constructed on top of a 12-inch thick × 3-ft deep vertical footer wall. The deck emulated the overhang of a bridge deck and was 8-inch thick × 30-inch wide. A 14-inch wide × 9-inch tall curb with ¾-inch chamfered corners was cast on top of the deck. The field side of the bridge deck extended 1½ inches beyond the field side of the curb (see Appendix A and/or B, drawing sheet 10 of 14 for details).

In the new deck region A, the bridge deck was extended laterally approximately 4 ft to the existing concrete apron.

In the new deck region B, the vertical footer wall was extended longitudinally and the bridge deck was extended laterally approximately 5½ ft over the new footer wall to the existing concrete apron (see Appendix A, drawing sheet 10 of 14 for details)

In the new deck region C, the vertical footer wall was extended farther longitudinally and the bridge deck was extended laterally approximately 14½ ft over the new footer wall to create a new moment slab that was joined to the existing concrete apron (see Appendix A, drawing sheet 12 of 14 for details)

The bridge deck and moment slab extension were secured to the existing concrete apron via 24-inch long × ⅝-inch diameter joint bars that were set a minimum of 6 inches deep in holes drilled horizontally into the edge of the apron 3½ inches below grade and 24 inches on center. The joint bars were secured into the apron using Hilti RE500 epoxy according to the manufacturer's instructions. The curb extension was similarly connected with four joint bars (see Appendix A and/or B, drawing sheet 10 and 11 of 14 for details).

The ⅝-inch diameter (#5) deck stirrups and transverse reinforcing steel bars were spaced on 6-inch longitudinal centers (except as noted) for the length of the curb. Also, a pair of #5 Z bars secured each anchor bolt assembly in the curb. Additional concrete reinforcement details can be found in Appendix A and/or B, drawing sheets 10 through 14.

Concrete cover over the reinforcing steel was 2 inches on the top of the deck, 1¼ inches at the bottom of the deck, and 1½ inches on the top and sides of the curb. Junctions of the steel reinforcing bars were field wire-tied as necessary.

Figure 2-1 and Figure 2-2 present overall information on the TxDOT Type C2P Bridge Rail, and Figure 2-3 provides photographs of the installation. Appendices A and B provide further details of the TxDOT Type C2P Bridge Rail.

2.2. MATERIAL SPECIFICATIONS

The specified minimum unconfined compressive strength for the bridge deck and curb concrete were 4000 psi. The average unconfined compressive strength of the concrete in the bridge wall was 4586 psi at 46 days of age. The average unconfined compressive strength of the concrete in the bridge deck was 4539 psi at 34 days of age. The average unconfined compressive strength of the concrete in the curb was 3850 psi at 15 days of age.

Reinforcement of the bridge deck and curb was comprised of ASTM A615 grade 60 rebar with specified minimum yield strength of 60 ksi.

Epoxied connections were installed with Hilti RE500 epoxy anchoring system according to the manufacturer's instructions.

Appendix C provides material certification documents for the materials used to install/construct the TxDOT Type C2P Bridge Rail.

Figure 2-3. TxDOT Type C2P Bridge Rail prior to First Test 4-12.

Chapter 3. TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1. CRASH TEST MATRIX

According to *MASH*, three tests are recommended to evaluate bridge rails for *MASH* Test Level 4 (TL-4). Details of these tests are described below:

> ***MASH* Test 4-10** involves a 2420-lb passenger car (1100C) impacting the critical impact point (CIP) of the length-of-need (LON) of the bridge rail while traveling at an impact speed and angle of 62 mi/h and 25 degrees, respectively.
>
> ***MASH* Test 4-11** involves a 5000-lb pickup truck (2270P) impacting the CIP of the LON of the bridge rail while traveling at an impact speed and angle of 62 mi/h and 25 degrees, respectively.
>
> ***MASH* Test 4-12** involves a 22046-lb single unit truck (10000S) impacting the CIP of the LON of the bridge rail while traveling at an impact speed and angle of 56 mi/h and 15 degrees, respectively.

MASH Tests 4-10 and 4-11 evaluate a barrier's ability to successfully contain and redirect passenger vehicles and evaluate occupant risk. *MASH* Test 4-12 evaluates the structural adequacy of the bridge rail. All three tests were performed on the TxDOT Type C2P Bridge Rail. The target CIP for each test was determined according to the information provided in *MASH* and is summarized in Figure 3-1 through Figure 3-3.

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

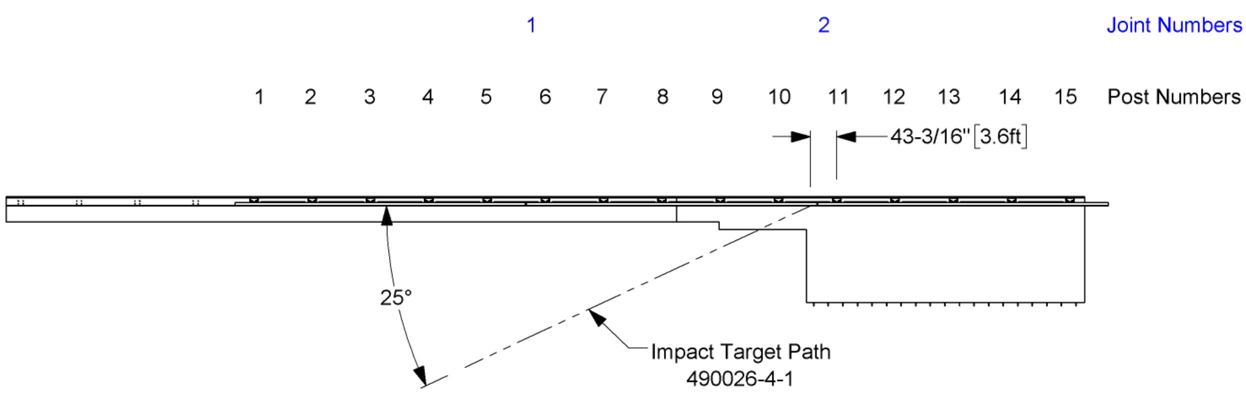


Figure 3-1. Target CIP for *MASH* Test 4-10 on TxDOT Type C2P Bridge Rail.

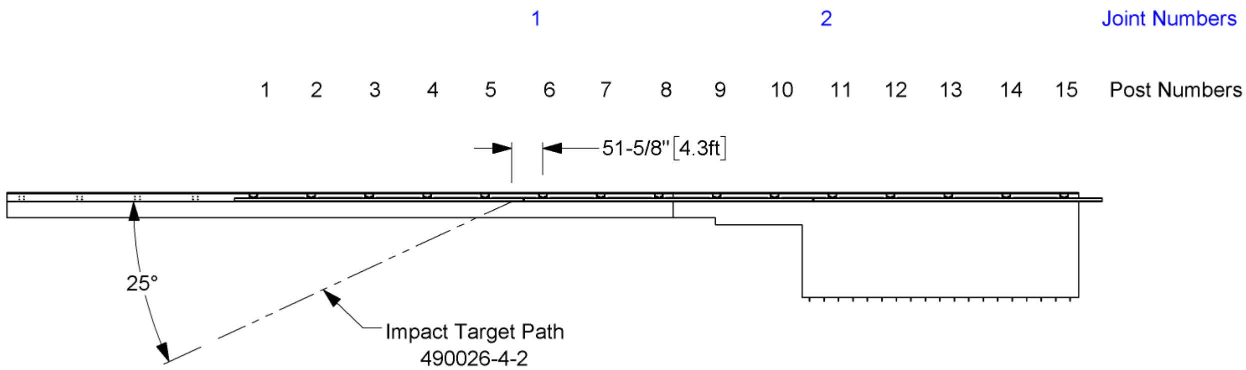


Figure 3-2. Target CIP for *MASH* Test 4-11 on TxDOT Type C2P Bridge Rail.

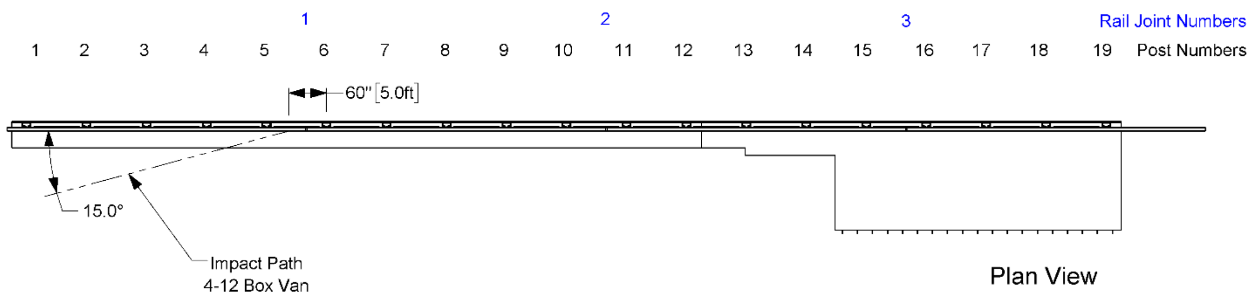


Figure 3-3. Target CIP for *MASH* Test 4-12 on TxDOT Type C2P Bridge Rail.

3.2. EVALUATION CRITERIA

The crash test results for each test were evaluated in accordance with the criteria presented in *MASH*. The impact performance of the TxDOT Type C2P Bridge Rail was judged based on the following factors:

- Structural adequacy, which is judged on the ability of the TxDOT Type C2P Bridge Rail to contain and redirect the vehicle.
- Risk of occupant compartment deformation or intrusion by detached elements, fragments, or other debris from the test article, which evaluates the potential risk of hazard to occupants, and, to some extent, other traffic, pedestrians, or workers in construction zones, if applicable.
- Occupant risk values, for which longitudinal and lateral occupant impact velocity and ridedown accelerations for the 1100C and 2270P vehicles must be within the limits specified in *MASH*, and determines the risk of injury to the occupants.
- Post-impact vehicle trajectory, which considers 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 tests reported herein. These criteria are listed in further detail under the assessment of each crash test.

Chapter 4. TEST CONDITIONS

4.1. TEST FACILITY

The full-scale crash tests reported herein were performed at the TTI Proving Ground, an International Standards Organization (ISO) 17025-accredited laboratory with American Association for Laboratory Accreditation (A2LA) Mechanical Testing certificate 2821.01. The full-scale crash tests were performed according to TTI Proving Ground quality procedures, and according to the *MASH* guidelines and standards.

The TTI Proving Ground is a 2000-acre complex of research and training facilities located 8 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 Type C2P Bridge Rail was along the edge of an out-of-service apron. The apron consists of an unreinforced jointed-concrete pavement in 12.5-ft × 15-ft blocks nominally 6 inches deep. The aprons were built in 1942, and the joints have some displacement, but are otherwise flat and level.

4.2 VEHICLE TOW AND GUIDANCE SYSTEM

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

4.3 DATA ACQUISITION SYSTEMS

4.3.1 Vehicle Instrumentation and Data Processing

Each test vehicle was instrumented with a self-contained, on-board data acquisition system. The signal conditioning and acquisition system is a 16-channel, Tiny Data Acquisition System (TDAS) Pro produced by Diversified Technical Systems, Inc. The accelerometers, which measure the x, y, and z axis of vehicle acceleration, are strain gauge type with linear millivolt output proportional to acceleration. Angular rate sensors, measuring vehicle roll, pitch, and yaw rates, are ultra-small, solid state units designed for crash test service. The TDAS Pro hardware and software conform to the latest SAE J211, Instrumentation for Impact Test. Each of the 16 channels is capable of providing precision amplification, scaling, and filtering based on transducer specifications and calibrations. During the test, data are recorded from each channel at a rate of 10,000 values per second with a resolution of one part in 65,536. Once data are recorded, internal batteries back these up inside the unit should the primary battery cable be severed. Initial contact of the pressure switch on the vehicle bumper provides a time zero mark and initiates the recording process. After each test, the data are downloaded from the TDAS Pro unit into a laptop computer at the test site. The Test Risk Assessment Program (TRAP) software then processes the raw data to produce detailed reports of the test results.

Each of the TDAS Pro units is returned to the factory annually for complete recalibration. Accelerometers and rate transducers are also calibrated annually with traceability to the National Institute for Standards and Technology. All accelerometers are calibrated annually according to SAE J211 *4.6.1* by means of an ENDEVCO® 2901, precision primary vibration standard. This device and its support instruments are returned to the factory annually for a National Institute of Standards Technology (NIST) traceable calibration. The subsystems of each data channel are also evaluated annually, using instruments with current NIST traceability, and the results are factored into the accuracy of the total data channel, per SAE J211. Calibrations and evaluations are also made any time data are suspect. Acceleration data are measured with an expanded uncertainty of ±1.7 percent at a confidence factor of 95 percent (k=2).

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

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

4.3.2 Anthropomorphic Dummy Instrumentation

An Alderson Research Laboratories Hybrid II, 50th percentile male anthropomorphic dummy, restrained with lap and shoulder belts, was placed in the front seat on the impact side of the 1100C vehicle. The dummy was not instrumented.

According to *MASH*, use of a dummy in the 2270P vehicle is optional. However, it is recommended a dummy be used when testing “any longitudinal barrier with a height greater than or equal to 33 inches.” Use of the dummy in the 2270P vehicle is recommended for tall rails to evaluate the “potential for an occupant to extend out of the vehicle and come into direct contact with the test article.” Although this information is reported, it is not part of the impact performance evaluation. Since the rail height of the TxDOT Type C2P Bridge Rail was

42 inches, a dummy was placed in the front seat of the 2270P vehicle on the impact side and restrained with lap and shoulder belts.

MASH does not recommend or require use of a dummy in the 10000S vehicle. However, for informational purposes, an H3 instrumented dummy provided by the National Highway Traffic Safety Association (NHTSA) was positioned in the driver's seat and restrained with lap and shoulder belts. Measurements and photographs were taken per NHTSA protocol for use in studying dummy interactions within large vehicles.

4.3.3 Photographic Instrumentation Data Processing

Photographic coverage of each 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.
- A third placed to have a field of view parallel to and aligned with the installation at the downstream end.

A flashbulb on each of the impacting vehicles was activated by a pressure-sensitive tape switch to indicate the instant of contact with the TxDOT Type C2P Bridge Rail. The flashbulb was visible from each camera to synchronize timing from the impact event. The videos from these high-speed cameras were analyzed 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 each test vehicle and the installation before and after each test.

Chapter 5. *MASH* TEST 4-10 (CRASH TEST NO. 490026-4-1)

5.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

MASH Test 4-10 involves an 1100C vehicle weighing 2425 lb ±55 lb impacting the CIP of the TxDOT Type C2P Bridge Rail at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 25 degrees ±1.5 degrees. The target CIP for *MASH* Test 4-10 on the TxDOT Type C2P Bridge Rail was $43^{3}/_{16}$ inches upstream of the centerline of post 11. The 2010 Kia Rio used in the test weighed 2433 lb, and the actual impact speed and angle were 63.0 mi/h and 25.7 degrees, respectively. The actual impact point was 45 inches upstream of the centerline of post 11. Minimum target impact severity (IS) was 51 kip-ft, and actual IS was 61 kip-ft.

5.2 WEATHER CONDITIONS

The test was performed on the morning of July 20, 2016. Weather conditions at the time of testing were as follows: wind speed: 3 mi/h; wind direction: 183 degrees (vehicle was traveling in a northwesterly direction); temperature: 90°F; relative humidity: 63 percent.

5.3 TEST VEHICLE

A 2010 Kia Rio, shown in Figure 5-1 and Figure 5-2, was used for the crash test. The vehicle's test inertia weight was 2433 lb, and its gross static weight was 2598 lb. The height to the lower edge of the vehicle bumper was 7.75 inches and the height to the upper edge of the vehicle bumper was 21.0 inches. Table D-1 in Appendix D1 gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

Figure 5-1. TxDOT Type C2P Bridge Rail/Test Vehicle Geometrics for Test No. 490026-4-1.

Figure 5-2. Test Vehicle before Test No. 490026-4-1.

5.4 TEST DESCRIPTION

As the 2010 Kia Rio was traveling at an impact speed of 63.0 mi/h, the left front corner of the bumper contacted the TxDOT Type C2P Bridge Rail 45 inches upstream of post 11 at an impact angle of 25.7 degrees. At 0.005 s after impact, the left front tire contacted the curb, and at 0.019 s, the hood contacted the middle horizontal rail element. The left front tire deformed at 0.022 s as the rim began traveling on the top surface of the curb, and the vehicle began to redirect at 0.032 s. At 0.040 s, the driver door opened slightly at the top near the roof, and at 0.050 s, cracks in the windshield began to radiate up and out from the left lower corner. The glass of the driver door began to dislodge from the frame of the window at 0.055 s, and the left front tire deflated at 0.064 s. At 0.089 s, the head of the dummy contacted the dislodged window glass, and at 0.101 s, the glass shattered as the dummy's head remained in contact with the door glass. The head of the dummy began to return to the vehicle interior at 0.132 s (the dummy's head did not contact the bridge rail), and the vehicle was traveling parallel with the installation at 0.178 s. At 0.350 s, the vehicle lost contact with the installation while traveling at an exit speed and exit angle of 49.5 mi/h and 9.7 degrees, respectively. Figures D-1 and D-2 in Appendix C2 present sequential photographs during the test.

For a bridge rail, it is desirable that the vehicle be redirected and exit the barrier within the exit box criteria (not less than 32.8 ft for cars and pickups). Brakes on the vehicle were applied 1.8 s after impact. The vehicle yawed counterclockwise and came to rest 174 ft downstream of impact and 2 ft toward the field side of the bridge rail. The 1100C vehicle exited within the exit box criteria defined in *MASH*.

5.5 DAMAGE TO TEST INSTALLATION

Figure 5-3 shows the damage to the TxDOT Type C2P Bridge Rail. The traffic face of the bridge rail was marred and scuffed, as was the traffic face and top of the curb. Working width was 14.0 inches. Maximum dynamic deflection during the test was 0.8 inch, and there was no notable maximum permanent deformation after the test.

Figure 5-3. TxDOT Type C2P Bridge Rail after Test No. 490026-4-1.

5.6 VEHICLE DAMAGE

Figure 5-4 shows the damage sustained by the vehicle. The front bumper, hood, left front tire and rim, left front strut and tower, left front fender, left front door and window glass, left rear door, left rear quarter panel, and rear bumper were damaged. The windshield was cracked in the left lower corner, and cracks radiated upward and toward the center, and deformation of the windshield was significantly less than 3 inches. Maximum exterior crush to the vehicle was 13.0 inches in the side plane at the left front corner at bumper height. Maximum occupant compartment deformation was 4.0 inches in the left front firewall area near the toe pan. Figure 5-5 shows the interior of the vehicle. Tables C-2 and C-3 in Appendix D1 provide exterior crush and occupant compartment measurements.

Figure 5-4. Test Vehicle after Test No. 490026-4-1.

Before Test After Test

Figure 5-5. Interior of Test Vehicle for Test No. 490026-4-1.

5.7 OCCUPANT RISK FACTORS

Data from the accelerometers located at the vehicle center of gravity were digitized for evaluation of occupant risk. In the longitudinal direction, the occupant impact velocity (OIV) was 26.2 ft/s at 0.071 s, the highest 0.010-s occupant ridedown acceleration was 2.8 g from

0.949 to 0.959 s, and the maximum 0.050-s average acceleration was –14.9 g between 0.014 and 0.064 s. In the lateral direction, the occupant impact velocity was 33.1 ft/s at 0.071 s, the highest 0.010-s occupant ridedown acceleration was 8.2 g from 0.199 to 0.209 s, and the maximum 0.050-s average was 19.7 g between 0.010 and 0.060 s. Theoretical Head Impact Velocity (THIV) was 46.0 km/h or 12.8 m/s at 0.069 s; Post-Impact Head Decelerations (PHD) was 8.5 g between 0.199 and 0.209 s; and Acceleration Severity Index (ASI) was 2.81 between 0.044 and 0.094 s. Figure 5-6 summarizes these data and other pertinent information from the test. Figures D-3 in Appendix D3 shows the vehicle angular displacements, and Figures D-4 through D-9 in Appendix D4 show accelerations versus time traces.

5.8 ASSESSMENT OF TEST RESULTS

An assessment of the test based on the applicable *MASH* safety evaluation criteria for *MASH* test 4-10 is provided below.

5.8.1 Structural Adequacy

A. *Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.*

Results: The TxDOT Type C2P Bridge Rail contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 0.8 inch. (PASS)

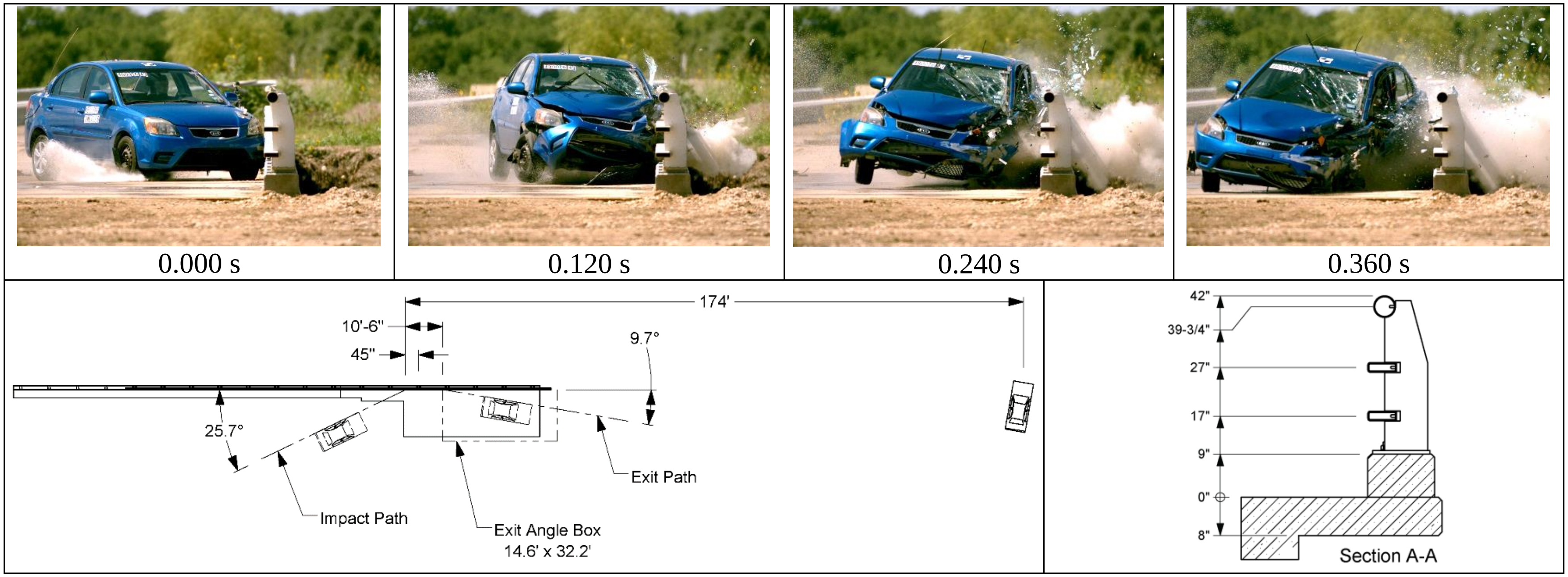
5.8.2 Occupant Risk

D. *Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*

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

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

Maximum occupant compartment deformation was 4.0 inches in the left front firewall area. (PASS)



General Information
- Test Agency: Texas A&M Transportation Institute (TTI)
- Test Standard Test No.: MASH Test 4-10
- TTI Test No.: 490026-4-1
- Test Date: 2016-07-20

Test Article
- Type: Bridge Rail
- Name: TxDOT Type C2P Bridge Rail
- Installation Length: 112 ft Rail Post-to-Post
- Material or Key Elements: Three steel rails supported on fabricated steel posts mounted on concrete curb and deck

Soil Type and Condition: Concrete Bridge Deck, Dry

Test Vehicle
- Type/Designation: 1100C
- Make and Model: 2010 Kia Rio
- Curb: 2493 lb
- Test Inertial: 2433 lb
- Dummy: 165 lb
- Gross Static: 2598 lb

Impact Conditions
- Speed: 63.0 mi/h
- Angle: 25.7 degrees
- Location/Orientation: 45 inches upstream of post 11

Impact Severity: 60 kip-ft

Exit Conditions
- Speed: 49.5 mi/h
- Angle: 9.7 degrees

Occupant Risk Values
- Longitudinal OIV: 26.2 ft/s
- Lateral OIV: 33.1 ft/s
- Longitudinal Ridedown: 2.8 g
- Lateral Ridedown: 8.2 g
- THIV: 46.0 km/h
- PHD: 8.5 g
- ASI: 2.81

Max. 0.050-s Average
- Longitudinal: −14.9 g
- Lateral: 19.7 g
- Vertical: −3.8 g

Post-Impact Trajectory
- Stopping Distance: 174 ft downstream 2 ft twd field side

Vehicle Stability
- Maximum Yaw Angle: 52 degrees
- Maximum Pitch Angle: 5 degrees
- Maximum Roll Angle: 6 degrees
- Vehicle Snagging: No
- Vehicle Pocketing: No

Test Article Deflections
- Dynamic: 0.8 inch
- Permanent: None noted
- Working Width: 14.0 inches

Vehicle Damage
- VDS: 11LFQ5
- CDC: 11FLEW4
- Max. Exterior Deformation: 13.0 inches
- OCDI: LF0033000
- Max. Occupant Compartment Deformation: 4.0 inches

Figure 5-6. Summary of Results for *MASH* Test 4-10 on TxDOT Type C2P Bridge Rail.

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

Results: The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 6 degrees and 5 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 OIV was 26.2 ft/s, and lateral OIV was 33.1 ft/s. (PASS)

I. *Occupant ridedown accelerations should satisfy the following:*

Longitudinal and Lateral Occupant Ridedown Accelerations

Preferred	*Maximum*
15 g	*20.49 g*

Results: Maximum longitudinal ridedown acceleration was 2.8 g, and maximum lateral ridedown acceleration was 8.2 g. (PASS)

Chapter 6. *MASH* TEST 4-11 (CRASH TEST NO. 490026-4-2)

6.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

MASH Test 4-11 involves a 2270P vehicle weighing 5000 lb ±110 lb impacting the CIP of the TxDOT Type C2P 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 CIP for *MASH* Test 4-11 on the TxDOT Type C2P Bridge Rail was 51⅝ inches upstream of the centerline of post 6. The 2011 Dodge RAM 1500 pickup truck used in the test weighed 5048 lb, and the actual impact speed and angle were 62.9 mi/h and 24.5 degrees, respectively. The actual impact point was 47½ inches upstream of the centerline of post 6. Minimum target impact severity was 106 kip-ft, and actual IS was 115 kip-ft.

6.2 WEATHER CONDITIONS

The test was performed on the morning of July 13, 2016. Weather conditions at the time of testing were as follows: wind speed: 14 mi/h; wind direction: 199 degrees (vehicle was traveling in a northwesterly direction); temperature: 92°F; relative humidity: 64 percent.

6.3 TEST VEHICLE

A 2011 Dodge RAM 1500 pickup truck, shown in Figure 6-1 and Figure 6-2, was used for the crash test. The vehicle's test inertia weight was 5048 lb, and its gross static weight was 5213 lb. The height to the lower edge of the vehicle bumper was 11.75 inches and the height to the upper edge of the vehicle bumper was 26.0 inches. The height to the center of gravity of the vehicle was 28.3 inches. Tables E-1 and E-2 in Appendix E1 give additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

Figure 6-1. TxDOT Type C2P Bridge Rail/Test Vehicle Geometrics for Test No. 490026-4-2.

Figure 6-2. Test Vehicle before Test No. 490026-4-2.

6.4 TEST DESCRIPTION

As the 2011 Dodge RAM 1500 pickup truck was traveling at an impact speed of 62.9 mi/h, the left front corner of the bumper contacted the TxDOT Type C2P Bridge Rail 47½ inches upstream of the centerline of post 6 at an impact angle of 24.5 degrees. At 0.014 s after impact, the left front tire contacted the curb, and at 0.018 s, the hood and grill contacted the middle horizontal rail element. The left front tire began to climb the curb at 0.024 s, and the tire deflated at 0.028 s. At 0.038 s, the vehicle began to redirect, and at 0.042 s, a crack formed on the field side of the curb at post 6. The door opened near the roof at 0.058 s, and the head of the dummy contacted the door glass at 0.096 s. At 0.103 s, cracks began to radiate up and out from the left lower corner of the windshield, and at 0.106 s, the door glass in the driver door shattered. The head of the dummy was at maximum extent outside the vehicle at 0.134 s but did not contact the bridge rail. The vehicle began was traveling parallel with the installation at 0.169 s. The dummy began retracting into the interior of the vehicle at 0.172 s, and the rear of the vehicle contacted the bridge rail at 0.180 s. At 0.340 s, the vehicle lost contact with the installation traveling at an exit speed and exit angle of 50.5 mi/h and 8.1 degrees, respectively. Figures E-1 and E-2 in Appendix E2 present sequential photographs during the test.

For a bridge rail, it is desirable that the vehicle be redirected and exit the barrier within the exit box criteria (not less than 32.8 ft for cars and pickups). Brakes on the vehicle were applied at 1.8 s after impact. The vehicle yawed counterclockwise and came to rest against a secondary barrier 220 ft downstream of impact and 1 ft toward the traffic side of the bridge rail. The 2270P vehicle exited within the exit box criteria defined in *MASH*.

6.5 DAMAGE TO TEST INSTALLATION

Figure 6-3 shows the damage to the TxDOT Type C2P Bridge Rail. No damage to the posts was noted. Small cracks in the curb radiated from the anchor bolts at post 5, and larger cracks radiated from the anchor bolts at post 6. Working width was 14.0 inches. Maximum dynamic deflection during the test was 2.5 inches, and maximum permanent deformation was 1.4 inches.

Figure 6-3. TxDOT Type C2P Bridge Rail after Test No. 490026-4-2.

6.6 VEHICLE DAMAGE

Figure 6-4 shows the damage sustained by the vehicle. The front bumper, grill, hood, left front tire and rim, left upper and lower A-arms, left front fender, left front door and window glass, left rear door, left rear cab corner, left rear exterior bed, left rear tire and rim, left rear bumper, and left rear tailgate were damaged. The windshield sustained stress cracks radiating form the lower left corner of the A-pillar, and there was no deformation to the windshield. Maximum exterior crush to the vehicle was 13.0 inches in the side plane at the left front corner at bumper height. Maximum occupant compartment deformation was 2.25 inches in the instrument panel area. Figure 6-5 shows the interior of the vehicle. Tables E-3 and E-4 in Appendix E1 provide exterior crush and occupant compartment measurements.

Figure 6-4. Test Vehicle after Test No. 490026-4-2.

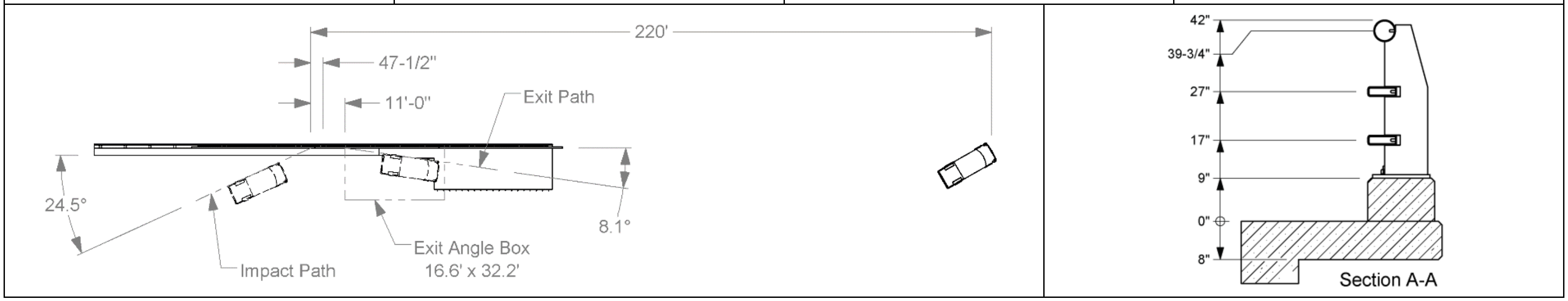
Before Test After Test

Figure 6-5. Interior of Test Vehicle for Test No. 490026-4-2.

6.7 OCCUPANT RISK FACTORS

Data from the accelerometers located at the vehicle center of gravity were digitized for evaluation of occupant risk. In the longitudinal direction, the OIV was 18.4 ft/s at 0.094 s, the highest 0.010-s occupant ridedown acceleration was 3.0 g from 0.200 to 0.210 s, and the maximum 0.050-s average acceleration was –9.9 g between 0.032 and 0.082 s. In the lateral direction, the occupant impact velocity was 29.5 ft/s at 0.094 s, the highest 0.010-s occupant ridedown acceleration was 9.5 g from 0.222 to 0.232 s, and the maximum 0.050-s average was 15.3 g between 0.042 and 0.092 s. THIV was 38.7 km/h or 10.7 m/s at 0.091 s; PHD was 9.9 g between 0.222 and 0.232 s; and ASI was 2.03 between 0.062 and 0.112 s. Figure 6-6 summarizes these data and other pertinent information from the test. Figure E-3 in Appendix E3 shows the vehicle angular displacements, and Figures E-4 through E-9 in Appendix E4 show accelerations versus time traces.

0.000 s | 0.120 s | 0.240 s | 0.360 s



General Information

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	MASH Test 4-11
TTI Test No.	490026-4-2
Test Date	2016-07-13

Test Article

Type	Bridge Rail
Name	TxDOT Type C2P Bridge Rail
Installation Length	112 ft Rail Post-to-Post
Material or Key Elements	Three steel rails supported on fabricated steel posts mounted on concrete curb and deck

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

Test Vehicle

Type/Designation	2270P
Make and Model	2011 Dodge RAM 1500
Curb	4911 lb
Test Inertial	5048 lb
Dummy	165 lb
Gross Static	5213 lb

Impact Conditions

Speed	62.9 mi/h
Angle	24.5 degrees
Location/Orientation	47½ inches upstream of post 6

Impact Severity ...... 115 kip-ft

Exit Conditions

Speed	50.5 mi/h
Angle	8.1 degrees

Occupant Risk Values

Longitudinal OIV	18.4 ft/s
Lateral OIV	29.5 ft/s
Longitudinal Ridedown	3.0 g
Lateral Ridedown	9.5 g
THIV	38.7 km/h
PHD	9.9 g
ASI	2.03
Max. 0.050-s Average	
Longitudinal	−9.9 g
Lateral	15.3 g
Vertical	−2.5 g

Post-Impact Trajectory

Stopping Distance	220 ft downstream 1 ft twd traffic lanes

Vehicle Stability

Maximum Yaw Angle	37 degrees
Maximum Pitch Angle	4 degrees
Maximum Roll Angle	5 degrees
Vehicle Snagging	No
Vehicle Pocketing	No

Test Article Deflections

Dynamic	2.5 inches
Permanent	1.4 inches
Working Width	14.0 inches

Vehicle Damage

VDS	11LFQ4
CDC	11FLEW3
Max. Exterior Deformation	13.0 inches
OCDI	LF0000000
Max. Occupant Compartment Deformation	2.25 inches

Figure 6-6. Summary of Results for *MASH* Test 4-11 on TxDOT Type C2P Bridge Rail.

6.8 ASSESSMENT OF TEST RESULTS

An assessment of the test based on the applicable *MASH* safety evaluation criteria for *MASH* test 4-11 is provided below.

6.8.1 Structural Adequacy

A. *Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.*

Results: The TxDOT Type C2P 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 2.5 inches. (PASS)

6.8.2 Occupant Risk

D. *Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*

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

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

Maximum occupant compartment deformation was 2.25 inches in the instrument panel area. (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 collision event. Maximum roll and pitch angles were 5 degrees and 4 degrees, respectively. (PASS)

H. *Occupant impact velocities should satisfy the following:*

<u>Longitudinal and Lateral Occupant Impact Velocity</u>

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

Results: Longitudinal OIV was 18.4 ft/s, and lateral OIV was 29.5 ft/s. (PASS)

I. *Occupant ridedown accelerations should satisfy the following:*

<u>Longitudinal and Lateral Occupant Ridedown Accelerations</u>

Preferred	*Maximum*
15 g	*20.49 g*

Results: Maximum longitudinal ridedown acceleration was 3.0 g, and maximum lateral ridedown acceleration was 9.5 g. (PASS)

Chapter 7. *MASH* TEST 4-12 (CRASH TEST NO. 490026-4-3)

7.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

MASH Test 4-12 involves a 10000S vehicle weighing 22,000 lb ±660 lb impacting the CIP of the TxDOT Type C2P Bridge Rail at an impact speed of 56 mi/h ±2.5 mi/h and an angle of 15 degrees ±1.5 degrees. The CIP for *MASH* Test 4-12 on the TxDOT Type C2P Bridge Rail was 5 ft (60 inches) upstream of centerline of post 6. The 2004 International 4200 single-unit box van truck used in the test weighed 22,220 lb, and the actual impact speed and angle were 58.4 mi/h and 15.3 degrees, respectively. The actual impact point was 63 inches upstream of centerline of post 6. Minimum target impact severity was 142 kip-ft, and actual IS was 176 kip-ft.

7.2 WEATHER CONDITIONS

The test was performed on the morning of June 27, 2016. Weather conditions at the time of testing were as follows: wind speed: 2 mi/h; wind direction: 198 degrees (vehicle was traveling in a northwesterly direction); temperature: 91°F; relative humidity: 54 percent.

7.3 TEST VEHICLE

A 2004 International 4200 single-unit box van truck, shown in Figure 7-1 and Figure 7-2, was used for the crash test. Test inertia weight of the test vehicle was 22,220 lb, and its gross static weight was 22,385 lb. The height to the lower edge of the vehicle front bumper was 19.25 inches and height to the upper edge of the vehicle front bumper was 34.0 inches. Table F-1 in Appendix F1 gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

Figure 7-1. TxDOT Type C2P Bridge Rail/Test Vehicle Geometrics for Test No. 490026-4-3.

Figure 7-2. Test Vehicle before Test No. 490026-4-3.

7.4 TEST DESCRIPTION

As the 2004 International 4200 single-unit box van truck was traveling at an impact speed of 58.4 mi/h, the left front corner of the bumper contacted the middle horizontal rail element of the TxDOT Type C2P Bridge Rail 63 inches upstream of centerline of post 6 at an impact angle of 15.3 degrees. At 0.008 s after impact, the left front fender of the vehicle contacted the top horizontal rail element, and at 0.009 s, the left front tire contacted the lower rail element. The left front tire contacted the curb at 0.011 s, and the tire began to climb the curb at 0.025 s. At 0.063 s, the cab of the vehicle began to redirect, and at 0.098 s, the left lower corner of the box contacted the top horizontal rail element. The box of the vehicle began to redirect at 0.110 s, and the base plate at post 5 began to lift up off the curb at 0.234 s. At 0.235 s, the left lower rear corner of the box contacted the top horizontal rail element, and at 0.242 s, the box was traveling parallel with the installation. The weld at the connection between post 5 and the base plate began to rupture at 0.257 s, and the cab of the vehicle was traveling parallel with the installation at 0.270 s. At 0.294 s, post 5 was at maximum dynamic angle of 23 degrees toward the field side, and at 0.408 s, the left rear lower corner of the box lifted upward off the top horizontal rail element. Between 0.500 s and 0.600 s, the vehicle was traveling at 54.1 mi/h as it left the view of the overhead camera. The left front corner of the box contacted the top horizontal rail element at 0.580 s, and the left rear corner of the box contacted the top horizontal rail element a second time at 0.838 s. At 1.278 s, the left upper corner of the box contacted the top horizontal rail element, and at 1.739 s, the left rear upper corner of the box contacted the top horizontal rail element. Figures F-1 and F-2 in Appendix F2 present sequential photographs during the test.

For a bridge rail, it is desirable that the vehicle be redirected and exit the barrier within the exit box criteria (not less than 65.6 ft for vehicles other than cars and pickups). Brakes on the vehicle were not applied. The vehicle rode off the end of the bridge rail while traveling approximately parallel with the bridge rail. As the vehicle lost contact with the bridge rail, the vehicle rolled clockwise and came to rest on its left side 240 ft downstream of impact and 6 ft toward the traffic side of the bridge rail. The 10000S vehicle exited within the exit box criteria defined in *MASH*.

7.5 DAMAGE TO TEST INSTALLATION

Figure 7-3 shows the damage to the TxDOT Type C2P Bridge Rail. The welds failed at the base plates of post 5, 6, and 7. It was determined that the welds were not constructed correctly by the fabricator. After the welds failed at Posts 5, 6, and 7, the post plates rotated toward the field side 10 degrees, 13 degrees, and 7 degrees, respectively. The picket section between posts 5 and 6 released at the center and downstream locations but remained attached to the rail. Cracks radiated through the curb at posts 3 and 4, through the curb and deck at posts 5, 6, and 7, and through the curb at post 8. Working width was 62.3 inches. Maximum dynamic deflection during the test was 11.4 inches. Maximum permanent deformation as 7.25 inches at the joint between posts 5 and 6.

Figure 7-3. TxDOT Type C2P Bridge Rail after Test No. 490026-4-3.

7.6 VEHICLE DAMAGE

Figure 7-4 shows the damage sustained by the vehicle. The front bumper, hood, left front tire and rim, left battery box, left steps, left door and vent glass, left side of the cargo box, left rear outer tire and rim, and roof were damaged. The windshield sustained stress cracks during the test, and there was no deformation to the windshield. Maximum exterior crush to the vehicle was 14.0 inches in the side plane at the left front corner at bumper height. No occupant compartment deformation was noted. Figure 7-5 shows the interior of the vehicle.

Figure 7-4. Test Vehicle after Test No. 490026-4-3.

Figure 7-5. Interior of Test Vehicle for Test No. 490026-4-3.

7.7 OCCUPANT RISK FACTORS

Data from accelerometers located near the near the center of gravity were digitized only for information purposes. In the longitudinal direction, the OIV was 6.2 ft/s at 0.212 s, the highest 0.010-s occupant ridedown acceleration was 3.6 g from 0.260 to 0.270 s, and the maximum 0.050-s average acceleration was –1.8 g between 0.048 and 0.098 s. In the lateral direction, the occupant impact velocity was 15.1 ft/s at 0.212 s, the highest 0.010-s occupant ridedown acceleration was 8.0 g from 0.278 to 0.288 s, and the maximum 0.050-s average was 5.4 g between 0.111 and 0.161 s. THIV was 17.8 km/h or 4.9 m/s at 0.206 s; PHD was 8.0 g between 0.278 and 0.288 s; and ASI was 0.61 between 0.136 and 0.186 s. Figure 7-6 summarizes these data and other pertinent information from the test. Figure F-3 in Appendix F3 shows the vehicle angular displacements, and Figures F-4 through F-9 in Appendix F4 show accelerations versus time traces.

7.8 ASSESSMENT OF TEST RESULTS

An assessment of the test based on the applicable *MASH* safety evaluation criteria for *MASH* test 4-12 is provided below.

7.8.1 Structural Adequacy

A. Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.

Results: The TxDOT Type C2P Bridge Rail contained and redirected the 10000S vehicle. Although the welds partially failed on several posts in the impact region (due to incorrect weldment by the fabricator), the vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 11.4 inches. (PASS)

7.8.2 Occupant Risk

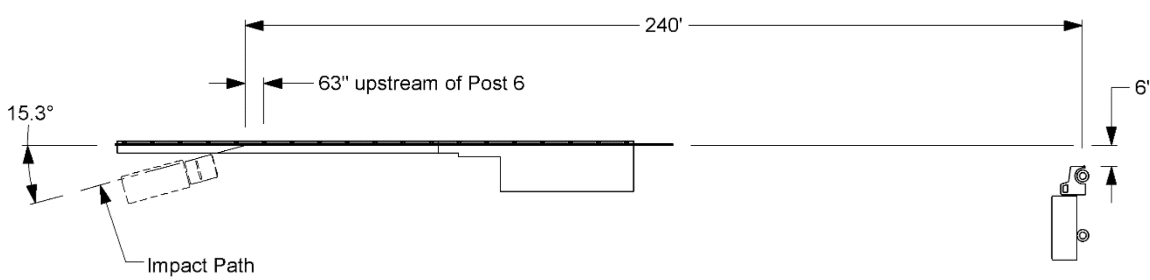
D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.

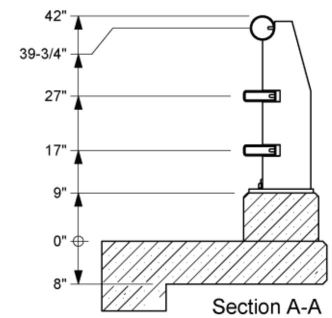
Deformation of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH. (roof ≤4.0 inches; windshield = ≤3.0 inches; side windows = no shattering by test article structural member; wheel/foot well/toe pan ≤9.0 inches; forward of A-pillar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

Results: No detached elements, fragments, or other debris from the bridge rail was present to penetrate or show potential for penetrating the occupant compartment, or to present hazard to others in the area. (PASS)

No deformation or intrusion into the occupant compartment occurred. (PASS)

0.000 s | 0.200 s | 0.400 s | 0.600 s





General Information

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	MASH Test 4-12
TTI Test No.	490026-4-3
Test Date	2016-06-27

Test Article

Type	Bridge Rail
Name	TxDOT Type C2P Bridge Rail
Installation Length	144 ft Rail Post-to-Post
Material or Key Elements	Three steel rails supported on fabricated steel posts mounted on concrete curb and deck

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

Test Vehicle

Type/Designation	10000S
Make and Model	2004 International 4200 single-unit box van truck
Curb	12,360 lb
Ballast	10,287
Test Inertial	22,220 lb
Gross Static	23,385 lb

Impact Conditions

Speed	58.4 mi/h
Angle	15.3 degrees
Location/Orientation	63 inches upstream of post 6

Impact Severity ...... 176 kip-ft

Exit Conditions

Speed	54.1 mi/h
Angle	Not obtainable

Occupant Risk Values

Longitudinal OIV	6.2 ft/s
Lateral OIV	15.1 ft/s
Longitudinal Ridedown	3.6 g
Lateral Ridedown	8.0 g
THIV	17.8 km/h
PHD	8.0 g
ASI	0.61
Max. 0.050-s Average	
Longitudinal	-1.8 g
Lateral	5.4 g
Vertical	-2.5 g

Post-Impact Trajectory

Stopping Distance	240 ft dwnstrm 6 ft twd traffic

Vehicle Stability

Maximum Yaw Angle	29 degrees
Maximum Pitch Angle	10 degrees
Maximum Roll Angle	89 degrees
Vehicle Snagging	No
Vehicle Pocketing	No

Test Article Deflections

Dynamic	11.4 inches
Permanent	7.25 inches
Working Width	62.3 inches

Vehicle Damage

VDS	NA
CDC	11FLEW5
Max. Exterior Deformation	14.0 inches
OCDI	LF0000000
Max. Occupant Compartment Deformation	None

Figure 7-6. Summary of Results for *MASH* Test 4-12 on TxDOT Type C2P Bridge Rail.

G. *It is preferable, although not essential, that the vehicle remain upright during and after the collision.*

Results: After losing contact with the bridge rail, the vehicle yawed counterclockwise and rolled onto its left side.

Chapter 8. SUMMARY AND CONCLUSIONS

8.1 ASSESSMENT OF TEST RESULTS

An assessment for each *MASH* test performed on the TxDOT Type C2P Bridge Rail is provided below.

8.1.1 *MASH* Test 4-10 (Crash Test No. 490026-4-1)

The TxDOT Type C2P Bridge Rail contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 0.8 inch. No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present hazard to others in the area. Maximum occupant compartment deformation was 4.0 inches in the left front firewall area. The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 6 degrees and 5 degrees, respectively. Occupant risk factors were within the limits specified in *MASH*.

8.1.2 *MASH* Test 4-11 (Crash Test No. 490026-4-2

The TxDOT Type C2P 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 2.5 inches. No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present hazard to others in the area. Maximum occupant compartment deformation was 2.25 inches in the instrument panel area. The 2270P vehicle remained upright during and after collision event. Maximum roll and pitch angles were 5 degrees and 4 degrees, respectively. Occupant risk factors were within the preferred limits specified in *MASH*.

8.1.3 *MASH* Test 4-12 (Crash Test No. 490026-4-3)

The TxDOT Type C2P Bridge Rail contained and redirected the 10000S vehicle. Although the welds partially failed on several posts in the impact region (due to poor weld penetration during fabrication), the vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 11.4 inches. No detached elements, fragments, or other debris from the bridge rail was present to penetrate or show potential for penetrating the occupant compartment, or to present hazard to others in the area. No deformation or intrusion into the occupant compartment occurred. After losing contact with the bridge rail, the vehicle yawed counterclockwise and rolled onto its left side.

8.2 CONCLUSIONS

For *MASH* Test 4-12, the post welds were not properly fabricated according to the project design drawings. As a result, some post welds in the immediate impact area did rupture from the *MASH* Test 4-12 truck impact. These ruptured post welds did aggravate the stability of the single unit truck during the test. For subsequent tests, the posts were welded correctly as per the project drawings. The bridge rail posts, with the correct post welds, should only improve the performance of the single unit truck.*

Table 8-1 through Table 8-3 show that the TxDOT Type C2P Bridge Rail performed acceptably for *MASH* TL-4.

* The opinions expressed in this paragraph are outside the scope of TTI Proving Ground's A2LA Accreditation.

Table 8-1. Performance Evaluation Summary for *MASH* Test 4-10 on TxDOT Type C2P Bridge Rail.

Test Agency: Texas A&M Transportation Institute | Test No.: 490026-4-1 | Test Date: 2016-07-26

***MASH* Test 4-10 Evaluation Criteria**	**Test Results**	**Assessment**
Structural Adequacy *A. Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.*	The TxDOT Type C2P Bridge Rail contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 0.8 inch.	Pass
Occupant Risk *D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present hazard to others in the area.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	Maximum occupant compartment deformation was 4.0 inches in the left front firewall area.	Pass
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 6 degrees and 5 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 OIV was 26.2 ft/s, and lateral OIV was 33.1 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 ridedown acceleration was 2.8 g, and maximum lateral ridedown acceleration was 8.2 g.	Pass

Table 8-2. Performance Evaluation Summary for *MASH* Test 4-11 on TxDOT Type C2P Bridge Rail.

Test Agency: Texas A&M Transportation Institute | Test No.: 490026-4-2 | Test Date: 2016-07-13

***MASH* Test 4-11 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 Type C2P 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 2.5 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, or to present hazard to others in the area.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	Maximum occupant compartment deformation was 2.25 inches in the instrument panel area.	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 collision event. Maximum roll and pitch angles were 5 degrees and 4 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 OIV was 18.4 ft/s, and lateral OIV was 29.5 ft/s.	Pass
I. Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15.0 Gs, or at least below the maximum allowable value of 20.49 Gs.	Maximum longitudinal ridedown acceleration was 3.0 g, and maximum lateral ridedown acceleration was 9.5 g.	Pass

Table 8-3. Performance Evaluation Summary for *MASH* Test 4-12 on TxDOT Type C2P Bridge Rail.

Test Agency: Texas A&M Transportation Institute | Test No.: 490026-4-3 | Test Date: 2016-06-27

***MASH* Test 4-12 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 Type C2P Bridge Rail contained and redirected the 10000S vehicle. Although the welds partially failed on several posts in the impact region (due to poor weld penetration during fabrication), the vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 11.4 inches.	Pass
Occupant Risk *D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	No detached elements, fragments, or other debris from the bridge rail was present to penetrate or show potential for penetrating the occupant compartment, or to present hazard to others in the area.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	No deformation or intrusion into the occupant compartment occurred.	Pass
G. It is preferable, although not essential, that the vehicle remain upright during and after collision.	After losing contact with the bridge rail, the vehicle yawed counterclockwise and rolled onto its left side.	Not Required

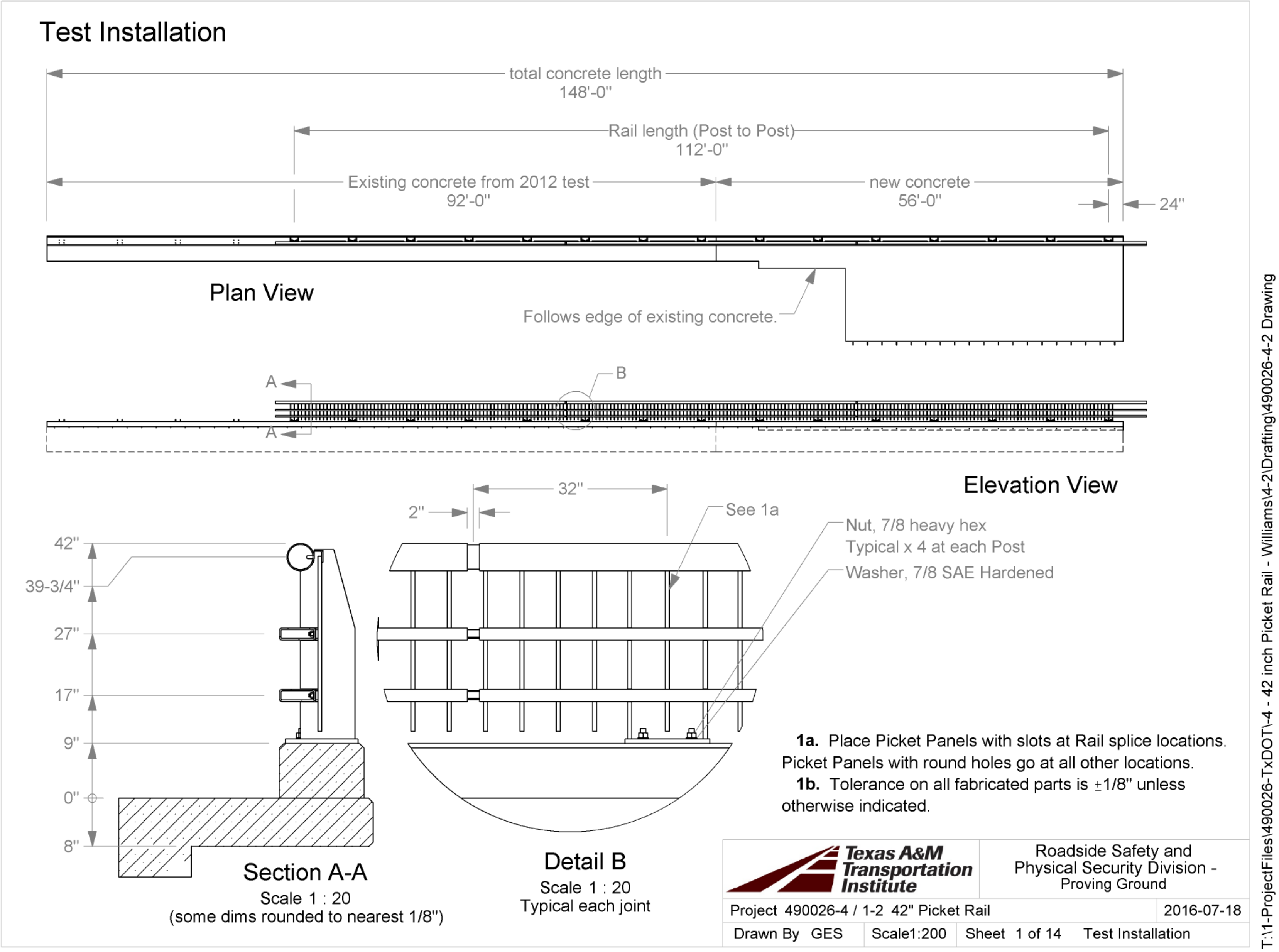
Chapter 9. IMPLEMENTATION PLAN

The TxDOT Type C2P Bridge Rail, as tested and reported herein, met all the strength and impact performance requirements of *MASH* TL-4. Based on these testing results, the researchers consider the TxDOT Type C2P Bridge Rail suitable for implementation on bridges on which a *MASH* TL-4 barrier is desired.

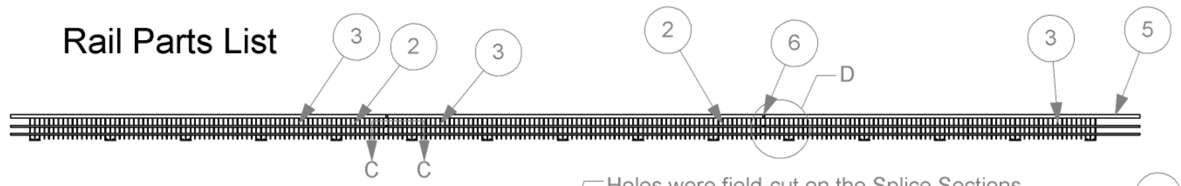
REFERENCES

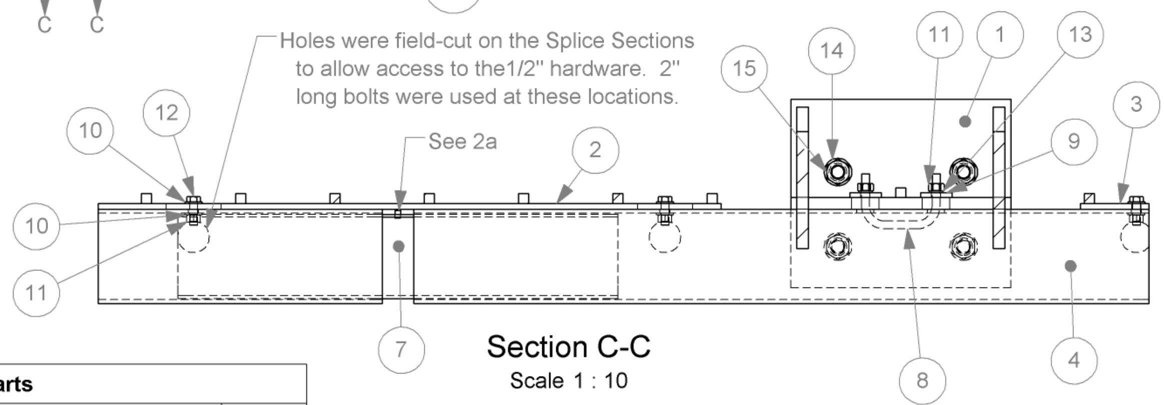
1. AASHTO. *Manual for Assessing Roadside Safety Hardware.* 2009, American Association of State Highway and Transportation Officials: Washington, D.C.

APPENDIX A. DETAILS OF THE TXDOT TYPE C2P BRIDGE RAIL USED IN TEST NOS. 490026-4-1 AND 4-2

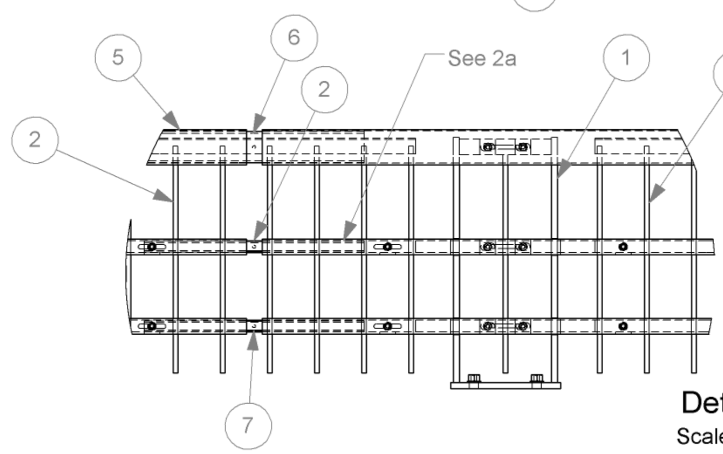


Rail Parts List





Section C-C
Scale 1 : 10



Detail D
Scale 1 : 20

Rail Parts		
#	Part Name	Qty.
1	Post for 42" Picket Rail	15
2	Picket Rail Panel, with slots	2
3	Picket Rail Panel, with holes	12
4	Rectangular Rail	6
5	Round Rail	3
6	Splice Section for Round Rail	2
7	Splice Section for Rectangular Rail	4
8	U-bolt for Picket Rail	45
9	Plate Washer for U-bolt	90
10	Washer, 1/2 SAE Hardened	168
11	Nut, 1/2 heavy hex	174
12	Bolt, 1/2" x 1 1/2" hex	84
13	Washer, 1/2 Lock	90
14	Washer, 7/8 SAE Hardened	60
15	Nut, 7/8 heavy hex	60

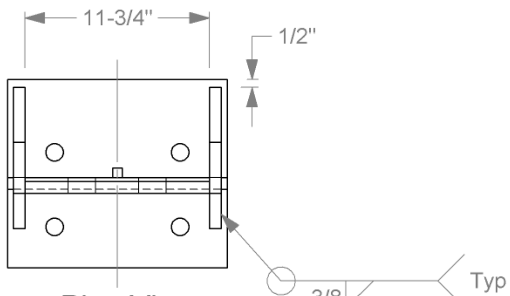
2a. Place Splice Sections with Pins on Field Side.
2b. Ø1/2" Bolts are ASTM A325. Ø7/8" Bolts are ASTM A449.

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Project 490026-4 / 1-2	42" Picket Rail		2016-07-18
Drawn By GES	Scale1:200	Sheet 2 of 14	Rail Parts List

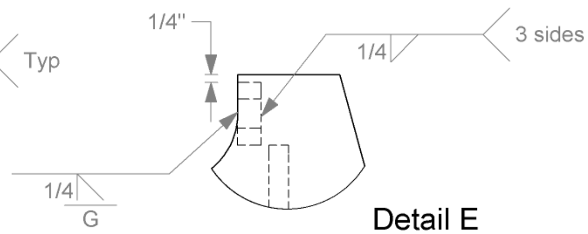
T:\1-ProjectFiles\490026-TxDOT\-4 - 42 inch Picket Rail - Williams\4-2\Drafting\490026-4-2 Drawing

Post

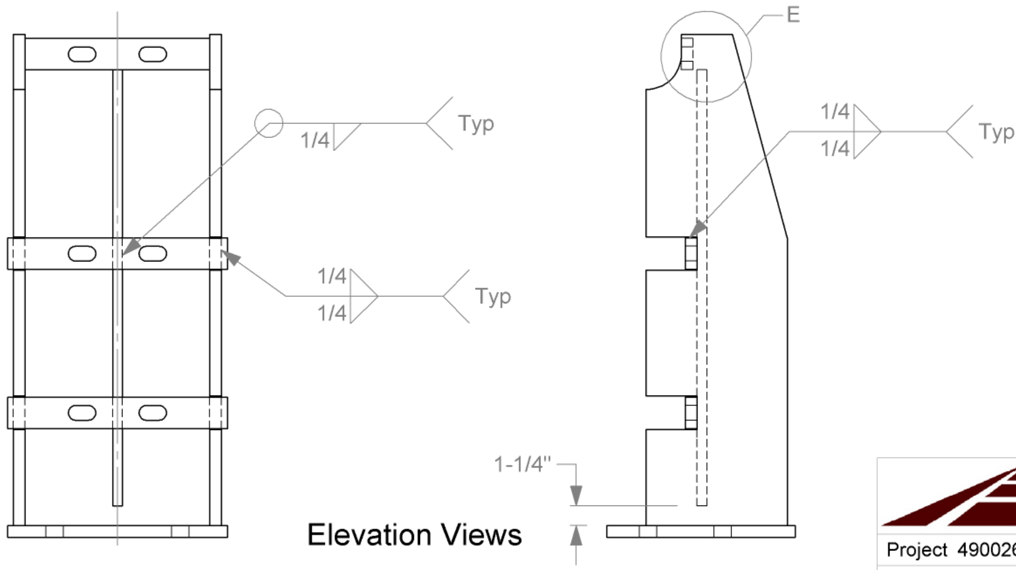
Post Parts					
#	Body Name	Description	Length	MATERIAL	Qty
16	Base Plate	Plate, 12" x 3/4"	14"	ASTM A572 Grade 50	1
17	Side Plate	Plate, 9" x 3/4"	31 1/4"	ASTM A572 Grade 50	2
18	Rail Plate, Top	Plate, 2" x 3/4"	11 3/4"	ASTM A36 Steel	1
19	Rail Plate, Bot and Mid	Plate, 2" x 3/4"	14"	ASTM A36 Steel	2
20	Picket	Plate, 5/8" x 5/8"	27 3/4"	ASTM A36 Steel	1



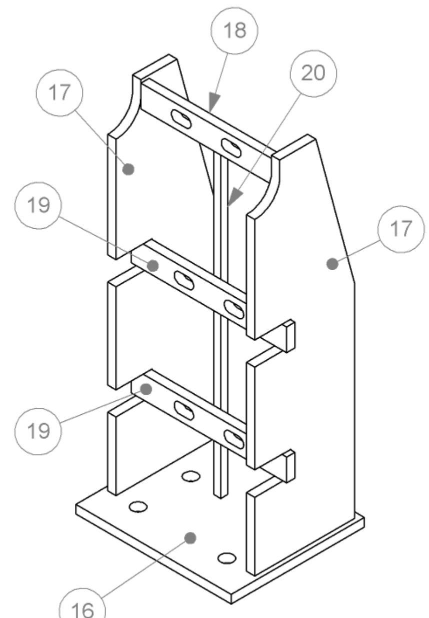
Plan View



Detail E
Scale 1 : 5



Elevation Views



Isometric View

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project 490026-4 / 1-2	42" Picket Rail	2016-07-18
Drawn By GES	Scale1:500	Sheet 3 of 14 Post

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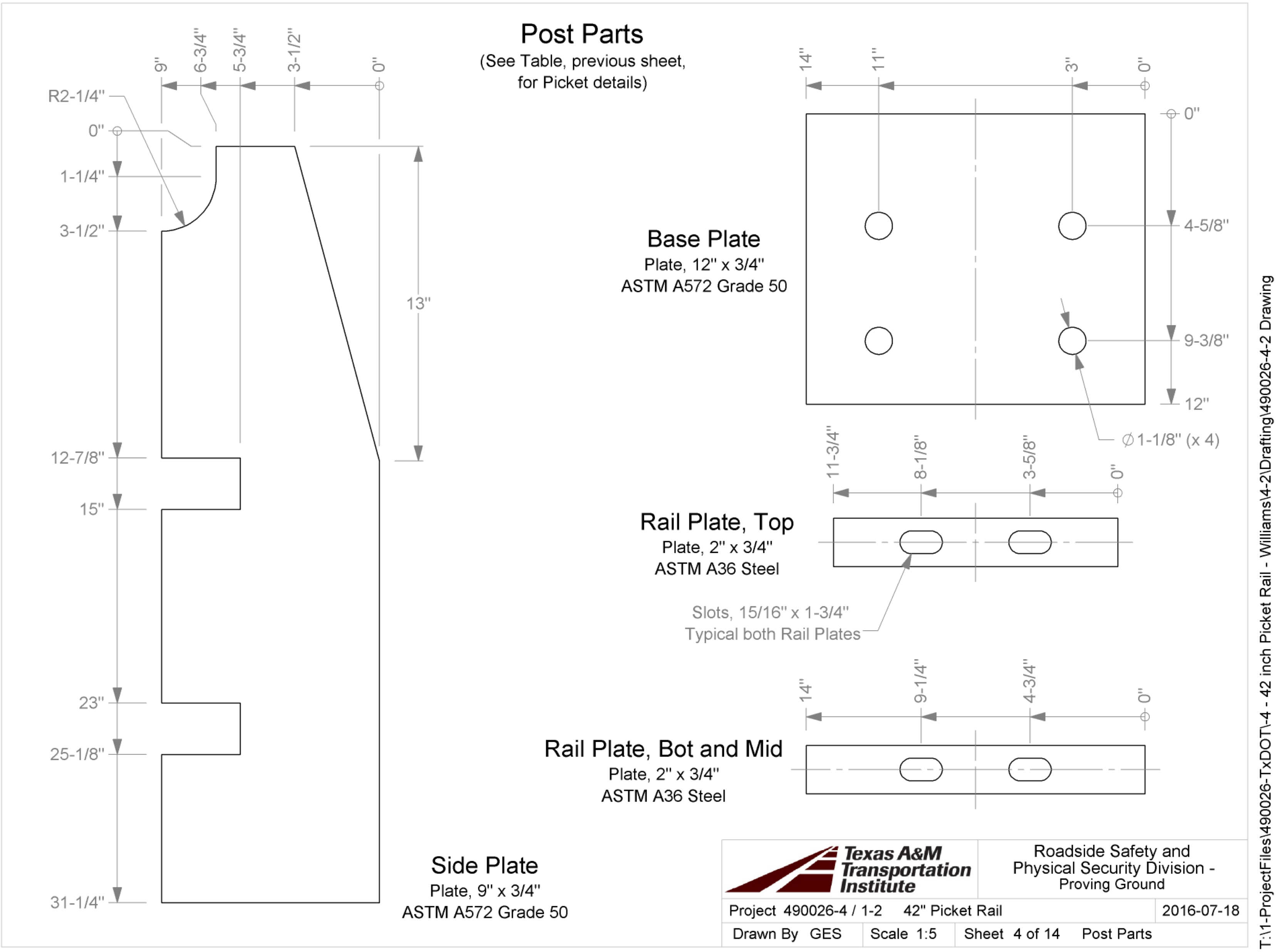
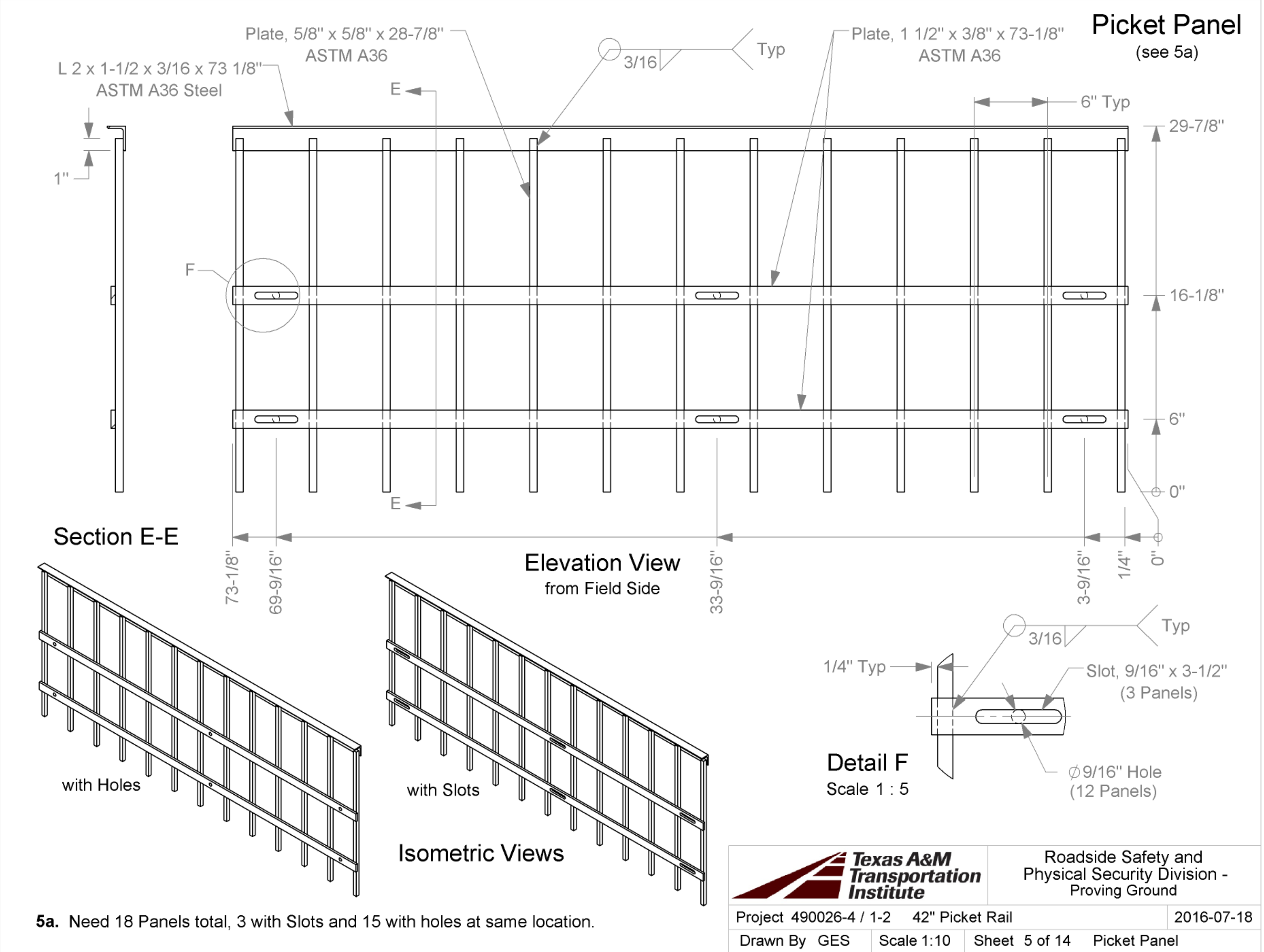
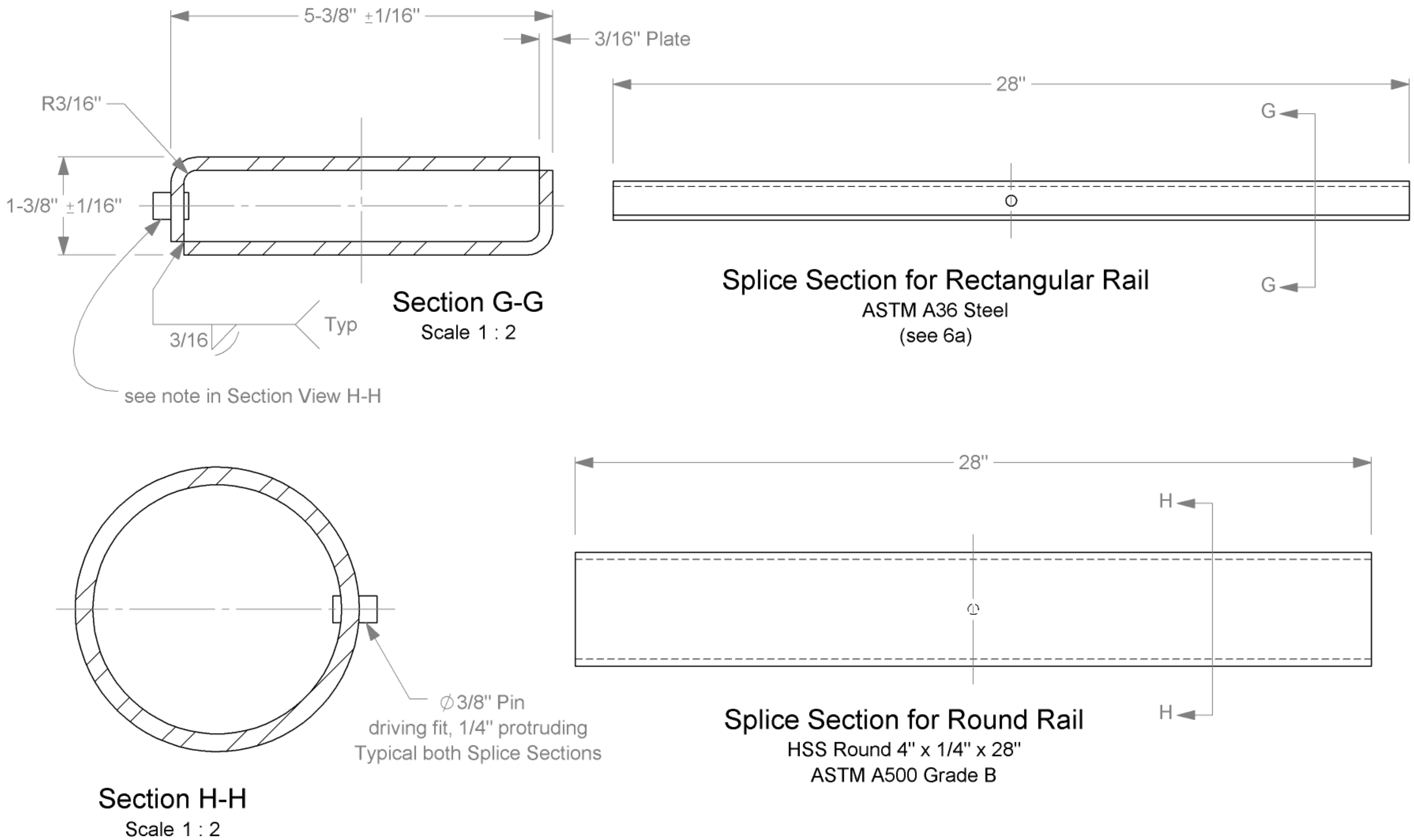

Post Parts
(See Table, previous sheet, for Picket details)
Side Plate
Plate, 9" x 3/4"
ASTM A572 Grade 50
R2-1/4"
9"
6-3/4"
5-3/4"
3-1/2"
0"
1-1/4"
3-1/2"
13"
12-7/8"
15"
23"
25-1/8"
31-1/4"
Base Plate
Plate, 12" x 3/4"
ASTM A572 Grade 50
14"
11"
3"
0"
4-5/8"
9-3/8"
12"
∅1-1/8" (x 4)
Rail Plate, Top
Plate, 2" x 3/4"
ASTM A36 Steel
11-3/4"
8-1/8"
3-5/8"
0"
Slots, 15/16" x 1-3/4"
Typical both Rail Plates
Rail Plate, Bot and Mid
Plate, 2" x 3/4"
ASTM A36 Steel
14"
9-1/4"
4-3/4"
0"
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project 490026-4 / 1-2
42" Picket Rail
2016-07-18
Drawn By GES
Scale 1:5
Sheet 4 of 14
Post Parts
T:\1-ProjectFiles\490026-TxDOT\-4 - 42 inch Picket Rail - Williams\4-2\Drafting\490026-4-2 Drawing



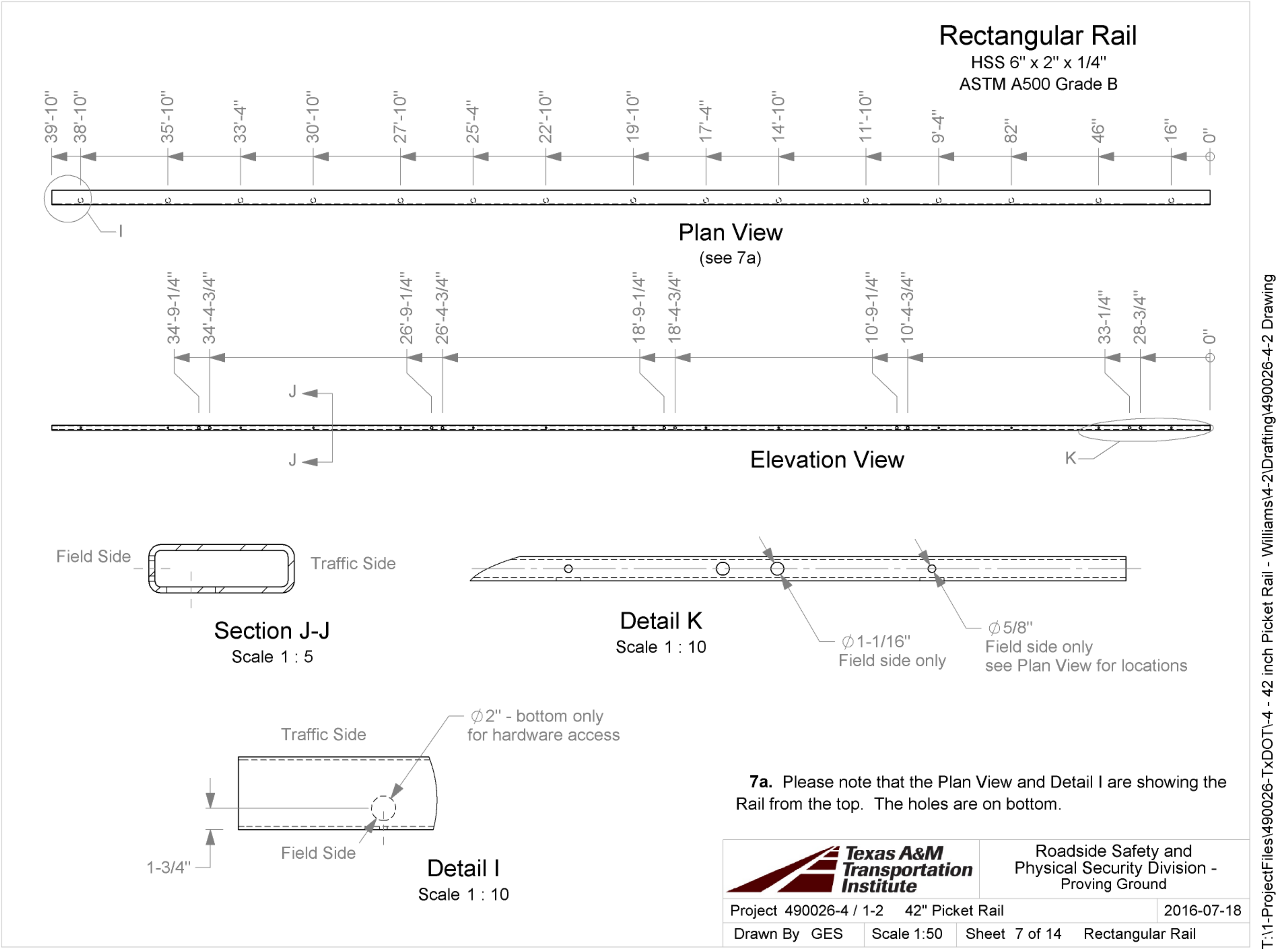
T:\1-ProjectFiles\490026-TxDOT\-4 - 42 inch Picket Rail - Williams\4-2\Drafting\490026-4-2 Drawing

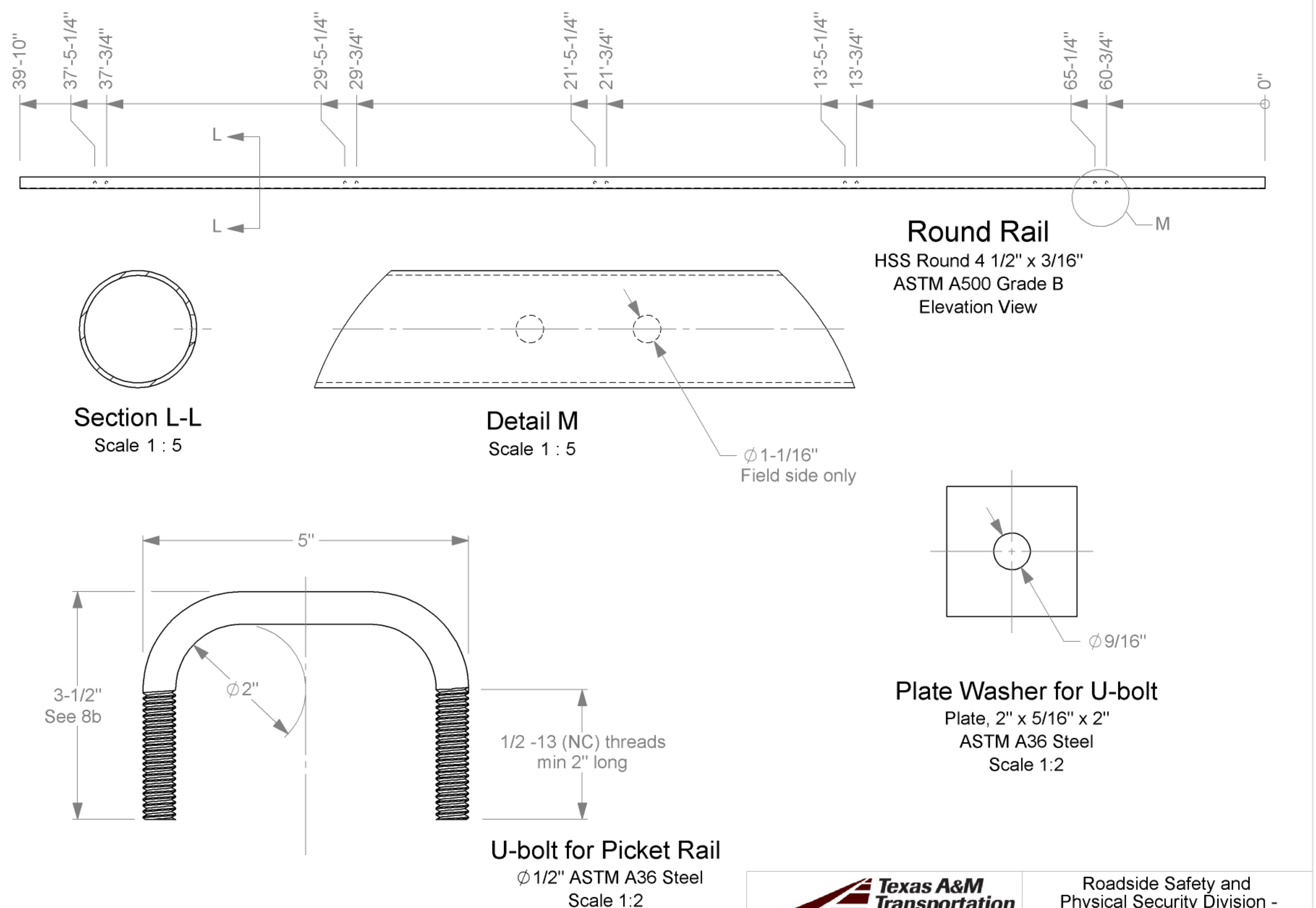
Splice Sections



6a. Check Splice Sleeve for Rectangular Rail for loose fit in Rectangular Rail after fabrication is completed.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground		
Project 490026-4 / 1-2	42" Picket Rail		2016-07-18
Drawn By GES	Scale 1:5	Sheet 6 of 14	Splice Sections


Rectangular Rail
HSS 6" x 2" x 1/4"
ASTM A500 Grade B
39'-10"
38'-10"
35'-10"
33'-4"
30'-10"
27'-10"
25'-4"
22'-10"
19'-10"
17'-4"
14'-10"
11'-10"
9'-4"
82"
46"
16"
0"
I
Plan View
(see 7a)
34'-9-1/4"
34'-4-3/4"
26'-9-1/4"
26'-4-3/4"
18'-9-1/4"
18'-4-3/4"
10'-9-1/4"
10'-4-3/4"
33-1/4"
28-3/4"
0"
J
J
Elevation View
K
Field Side
Traffic Side
Section J-J
Scale 1 : 5
Detail K
Scale 1 : 10
∅1-1/16"
Field side only
∅5/8"
Field side only
see Plan View for locations
∅2" - bottom only
for hardware access
Traffic Side
Field Side
1-3/4"
Detail I
Scale 1 : 10
7a. Please note that the Plan View and Detail I are showing the Rail from the top. The holes are on bottom.
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project 490026-4 / 1-2
42" Picket Rail
2016-07-18
Drawn By GES
Scale 1:50
Sheet 7 of 14
Rectangular Rail
T:\1-ProjectFiles\490026-TxDOT\-4 - 42 inch Picket Rail - Williams\4-2\Drafting\490026-4-2 Drawing

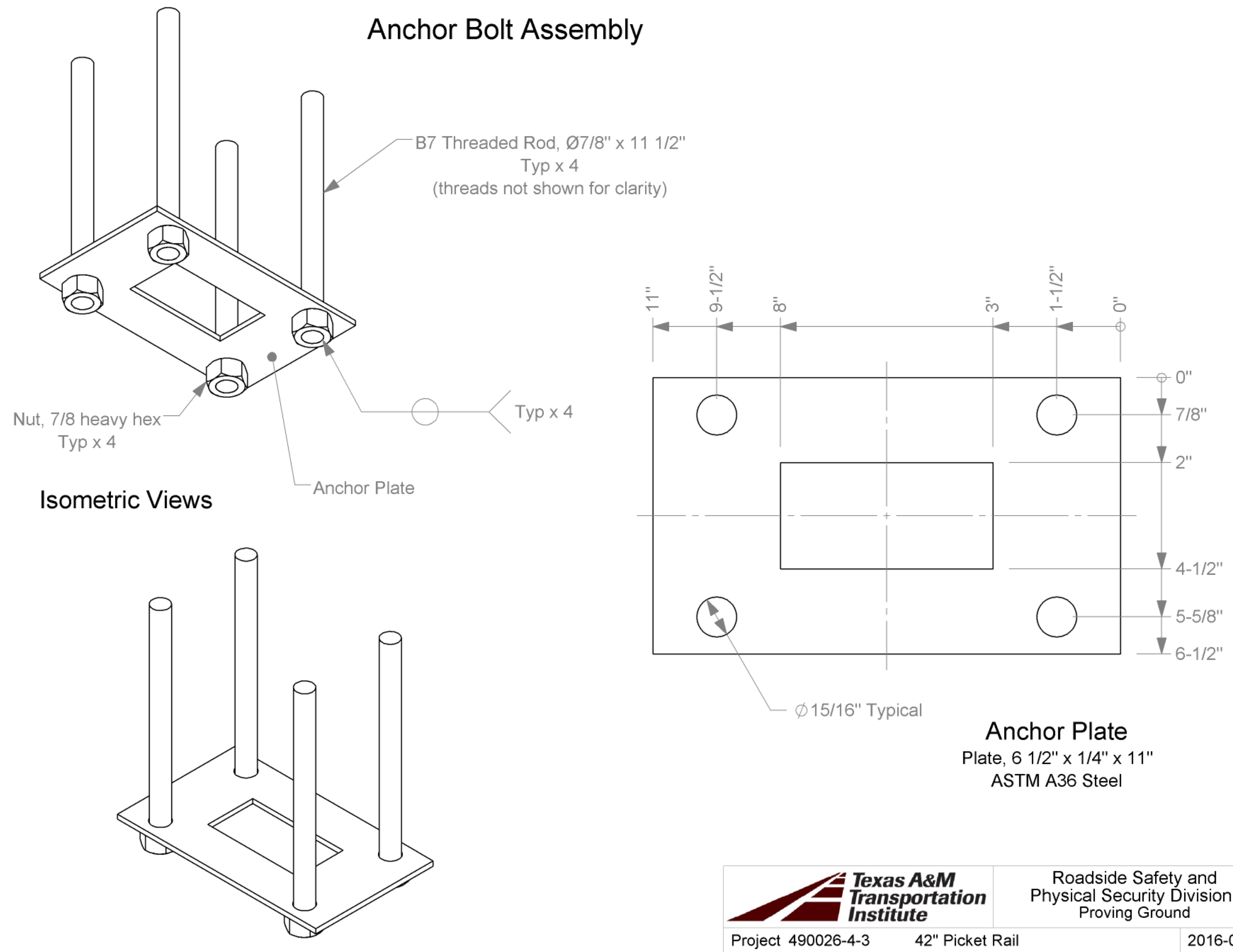


8a. Dimension is approximate. Rod is 10" long before bending.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground		
Project 490026-4-3	42" Picket Rail		2016-07-20
Drawn By GES	Scale 1:50	Sheet 8 of 14	Round Rail, etc.

T:\1-ProjectFiles\490026-TxDOT\-4 - 42 inch Picket Rail - Williams\4-3\Drafting\490026-4-3 Drawing

Anchor Bolt Assembly

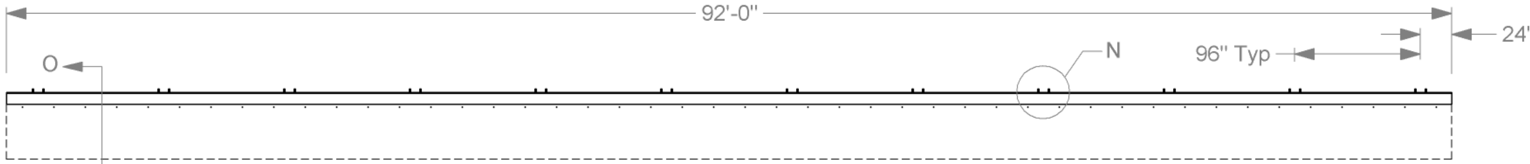


Texas A&M Transportation Institute

Roadside Safety and Physical Security Division - Proving Ground

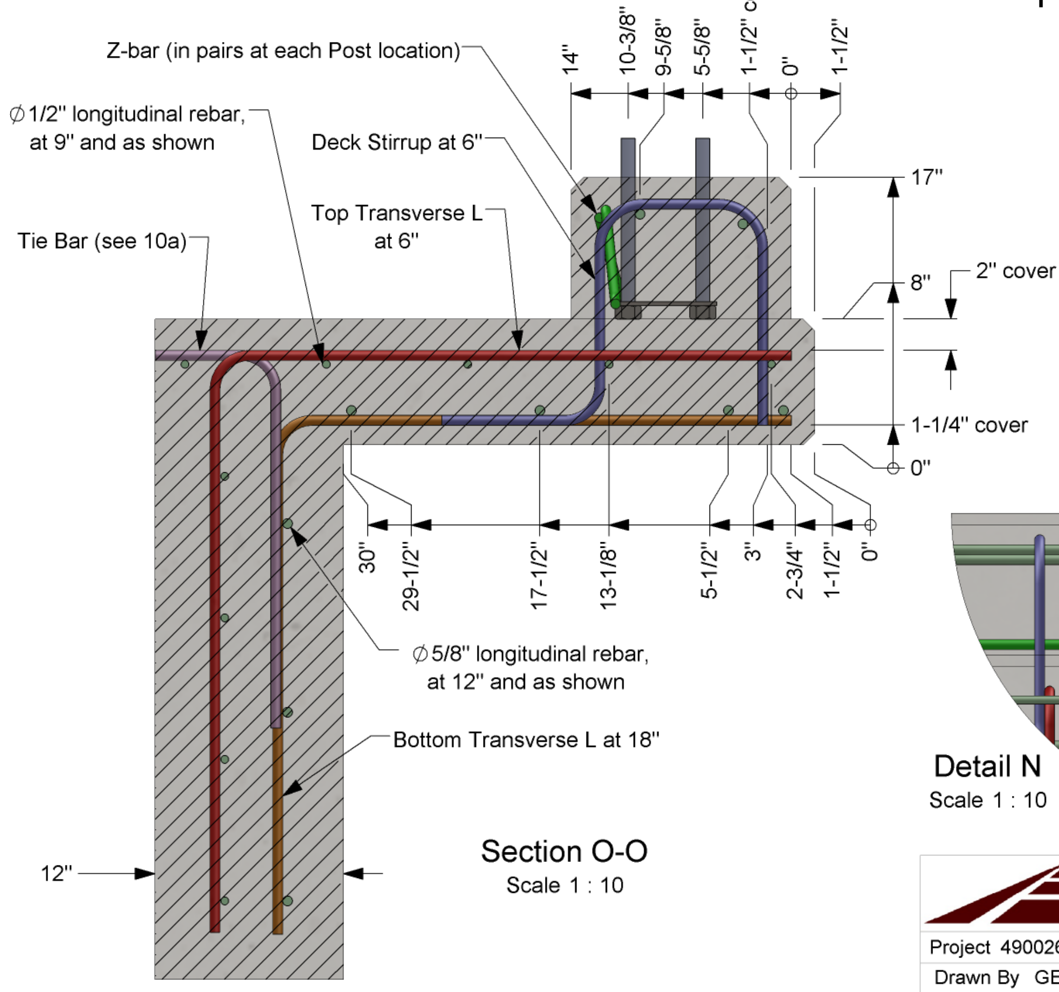
Project 490026-4-3	42" Picket Rail		2016-07-20
Drawn By GES	Scale 1:3	Sheet 9 of 14	Anchor Bolt Assembly

T:\1-ProjectFiles\490026-TxDOT\-4 - 42 inch Picket Rail - Williams\4-3\Drafting\490026-4-3 Drawing



Elevation View

Previous Concrete

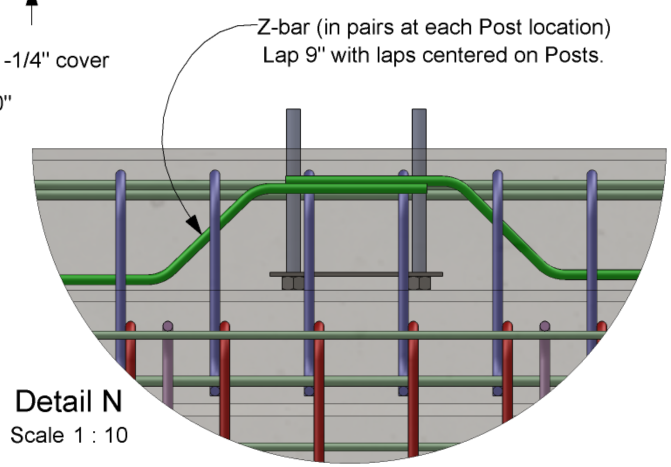


Section O-O
Scale 1 : 10

10a. Tie Bars spaced at 24", and welded to existing rebar protruding from the runway (not shown here).

10b. All Rebar is grade 60. Minimum lap distance is 17" for Ø1/2" bars and 21" for Ø5/8" bars.

10b. Concrete is TxDOT Class S (4000 psi). Chamfer edges of Deck and Curb 3/4" as shown.

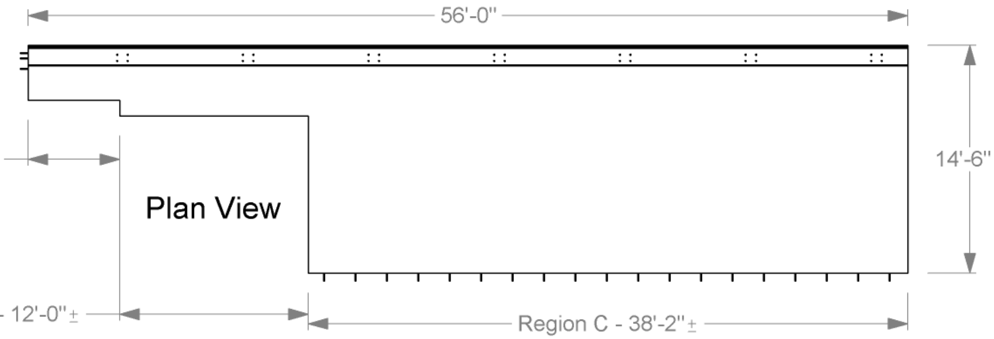


Detail N
Scale 1 : 10

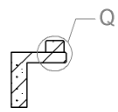
Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground		
Project 490026-4-3	42" Picket Rail		2016-07-20
Drawn By GES	Scale1:120	Sheet 10 of 14	Previous Concrete

T:\1-ProjectFiles\490026-TxDOT\-4 - 42 inch Picket Rail - Williams\4-3\Drafting\490026-4-3 Drawing

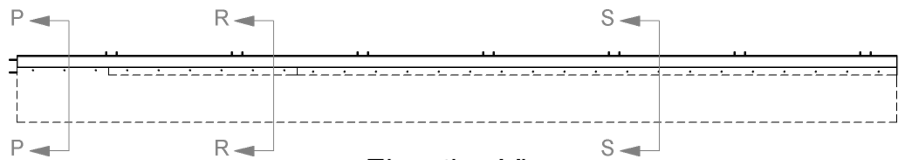
New Concrete



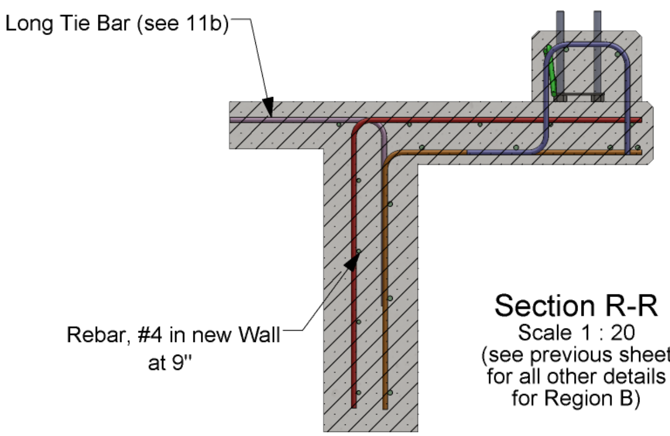
Plan View



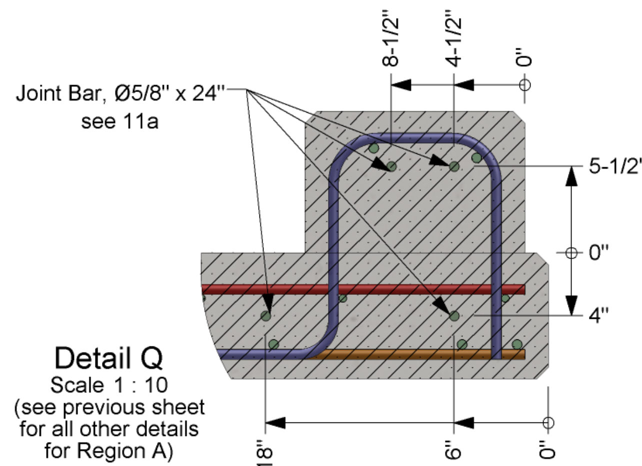
Section P-P



Elevation View



Section R-R
Scale 1 : 20
(see previous sheet for all other details for Region B)



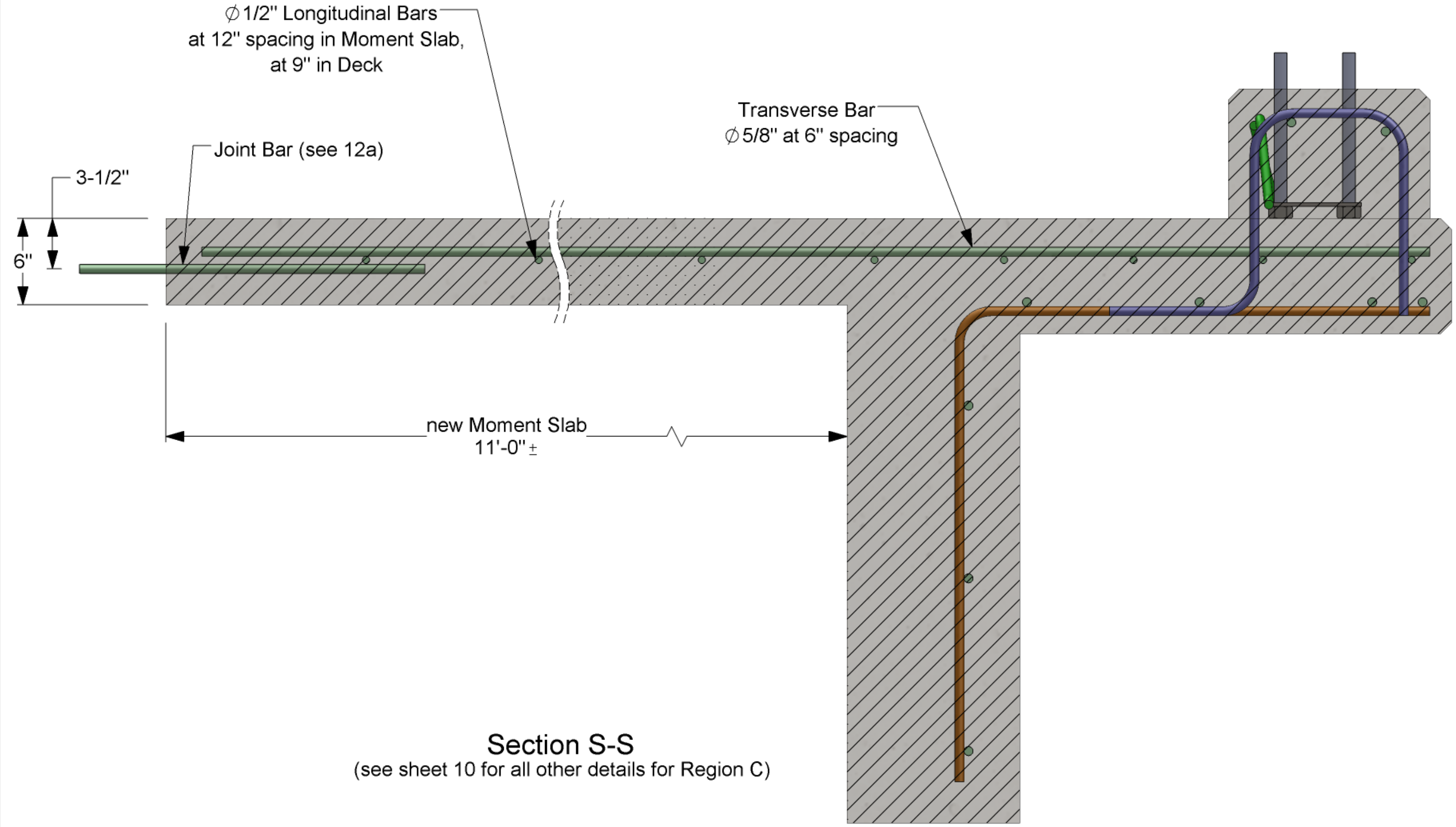
Detail Q
Scale 1 : 10
(see previous sheet for all other details for Region A)

11a. Drill minimum 6" into existing concrete and secure Joint Bars with Hilti RE-500 epoxy, according to manufacturer's instructions.

11b. Long Tie Bars spaced at 24" and welded to existing rebar protruding from the runway (not shown here).

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Project 490026-4-3	42" Picket Rail		2016-07-20
Drawn By GES	Scale1:120	Sheet 11 of 14	New Concrete

T:\1-ProjectFiles\490026-TxDOT\-4 - 42 inch Picket Rail - Williams\4-3\Drafting\490026-4-3 Drawing



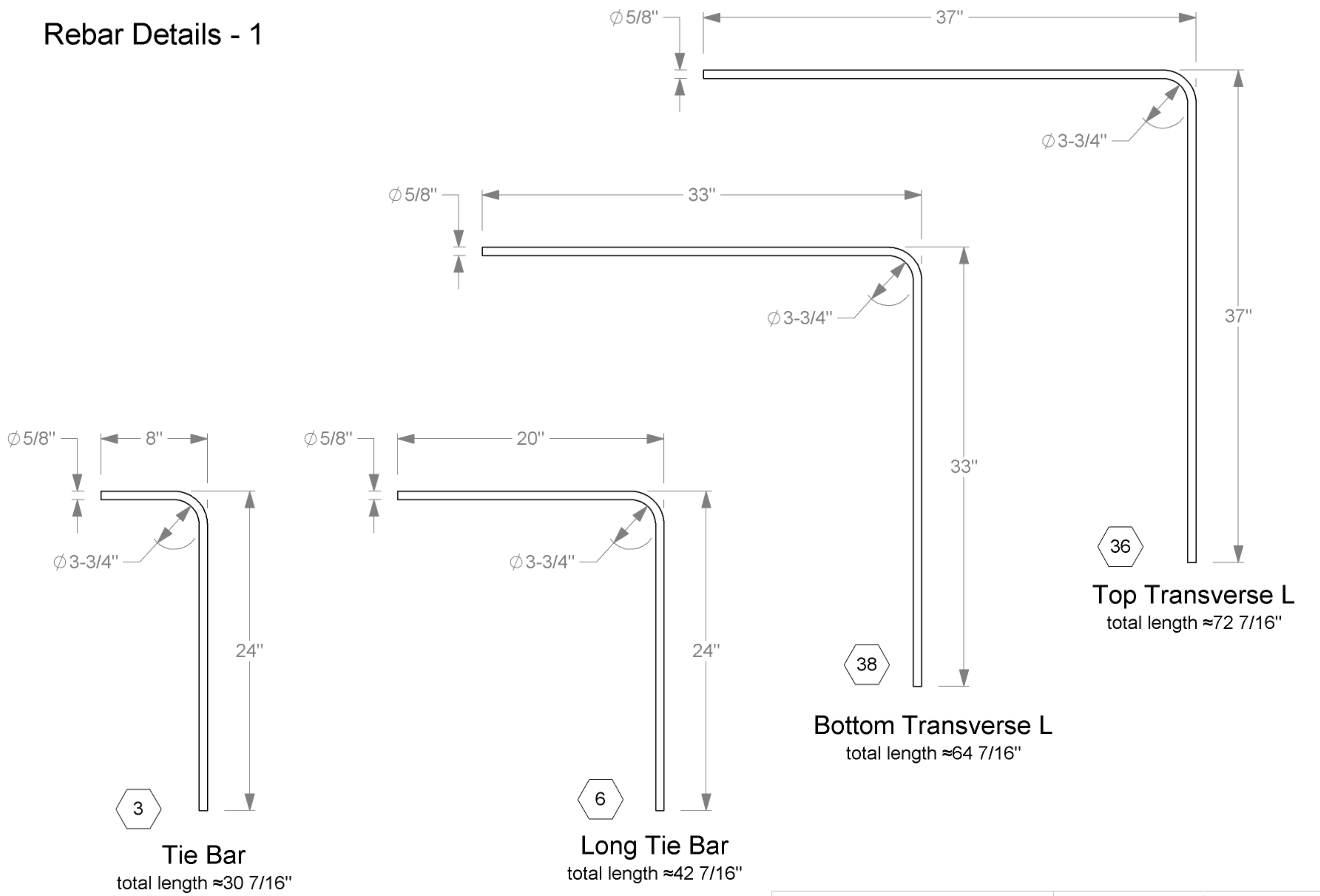
Section S-S
(see sheet 10 for all other details for Region C)

12a. Drill minimum 6" into existing concrete and secure Joint Bars with Hilti RE-500 epoxy, according to manufacturer's instructions. Space at 24".

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground		
Project 490026-4-3	42" Picket Rail		2016-07-20
Drawn By GES	Scale 1:10	Sheet 12 of 14	Section View

T:\1-ProjectFiles\490026-TxDOT\-4 - 42 inch Picket Rail - Williams\4-3\Drafting\490026-4-3 Drawing

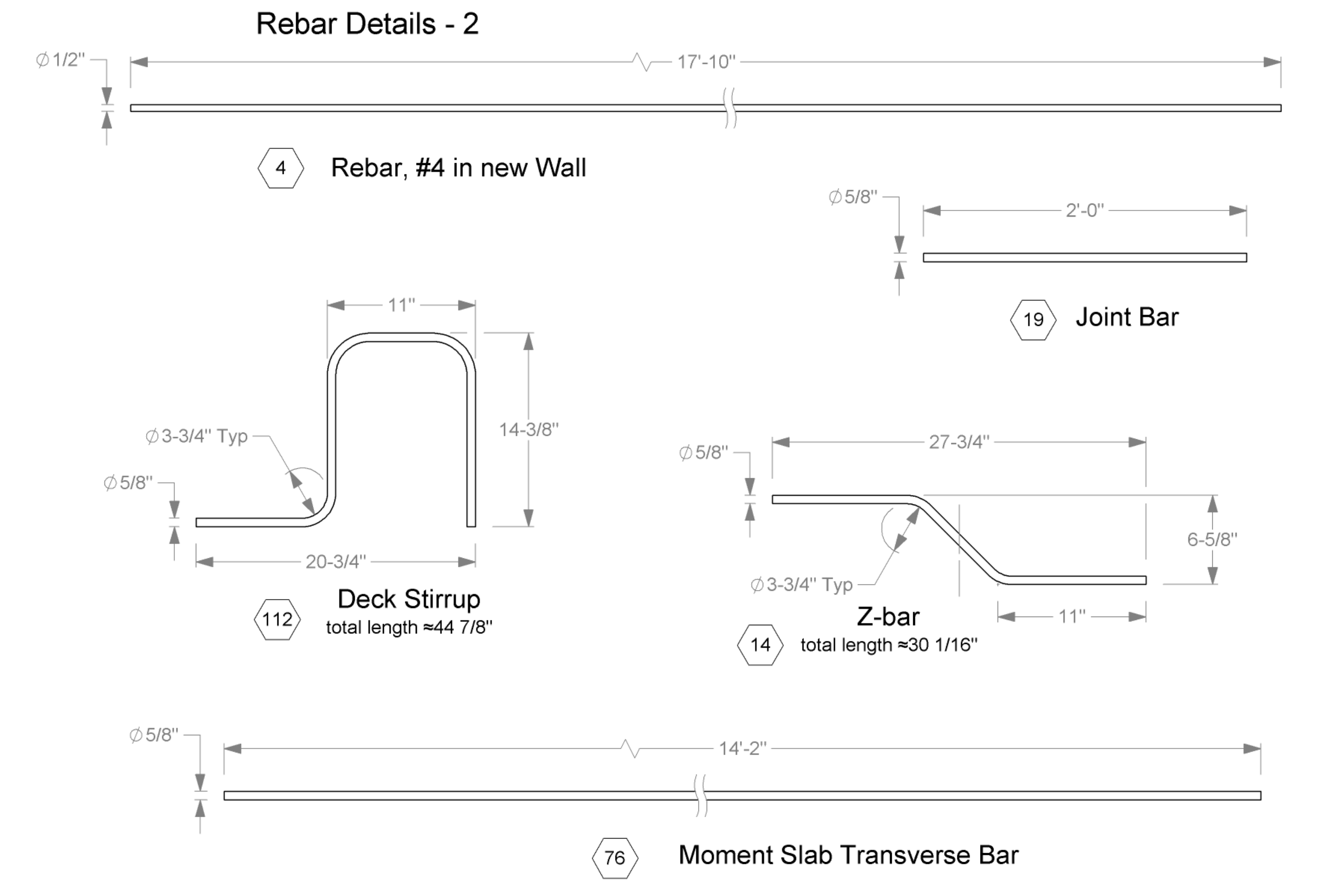
Rebar Details - 1



13a. The numeral in the hexagon denotes the quantity needed for each Bar.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project 490026-4-3	42" Picket Rail	2016-07-20
Drawn By GES	Scale 1:10	Sheet 13 of 14 Rebar Details - 1

T:\1-ProjectFiles\490026-TxDOT\-4 - 42 inch Picket Rail - Williams\4-3\Drafting\490026-4-3 Drawing

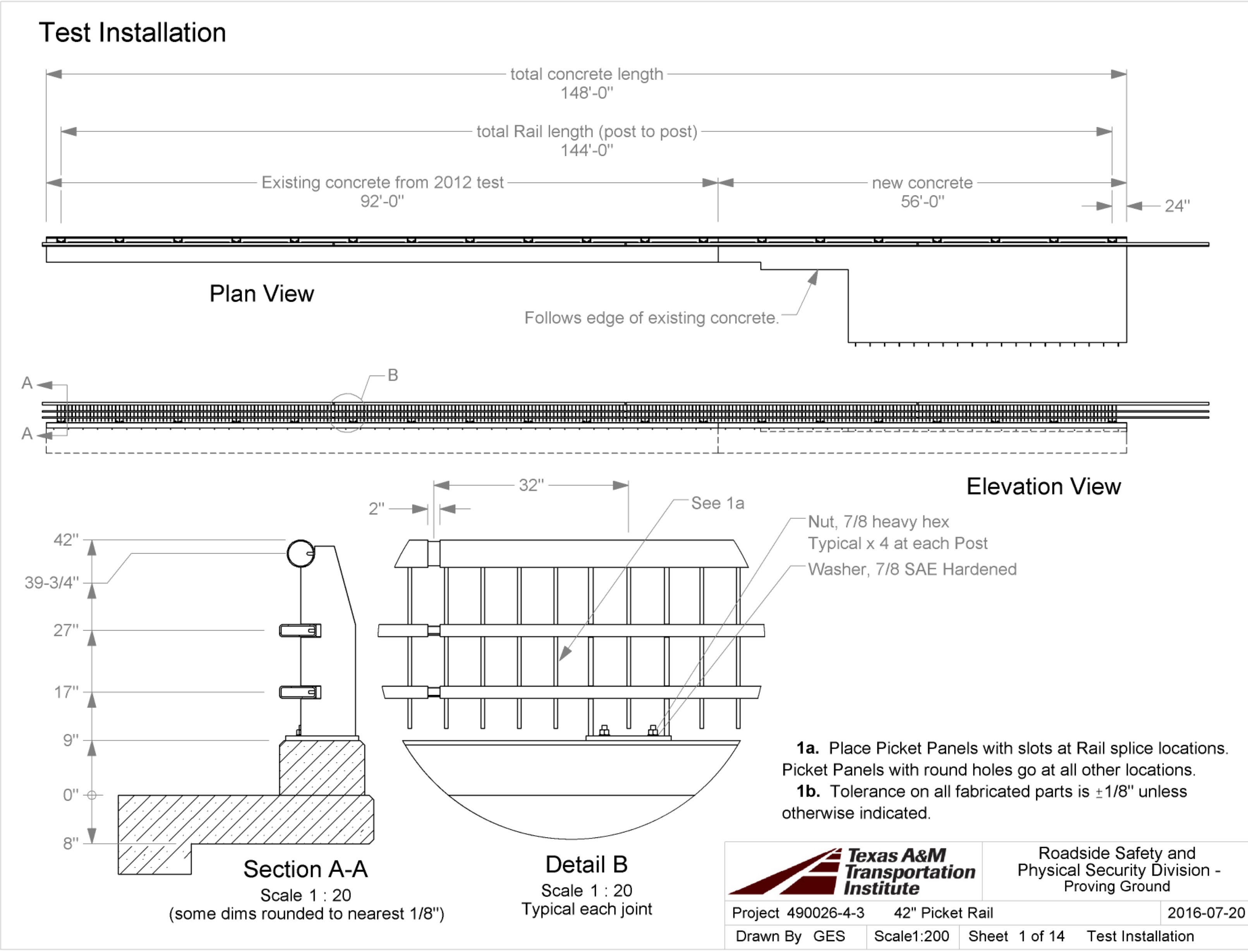


14a. The numeral in the hexagon denotes the quantity needed for each Bar.

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground
Project 490026-4-3	42" Picket Rail	2016-07-20
Drawn By GES	Scale 1:10	Sheet 14 of 14 Rebar Details - 2

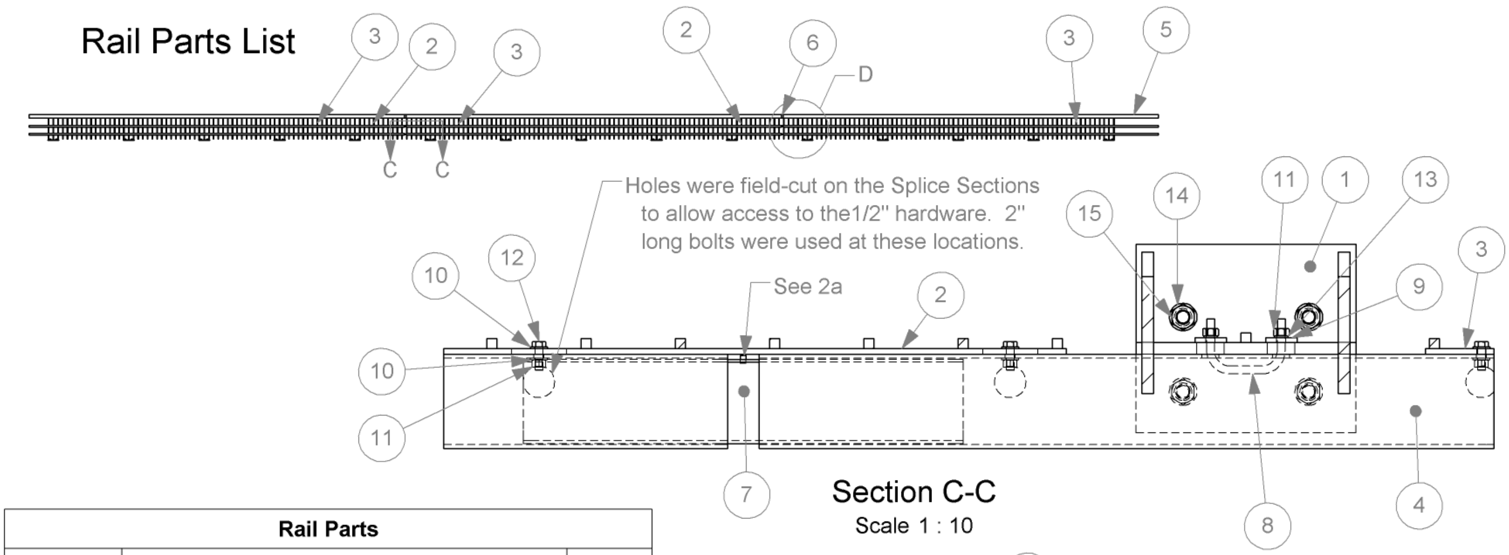
T:\1-ProjectFiles\490026-TxDOT\-4 - 42 inch Picket Rail - Williams\4-3\Drafting\490026-4-3 Drawing

APPENDIX B. DETAILS OF THE TXDOT TYPE C2P BRIDGE RAIL USED IN TEST NOS. 490026-4-3



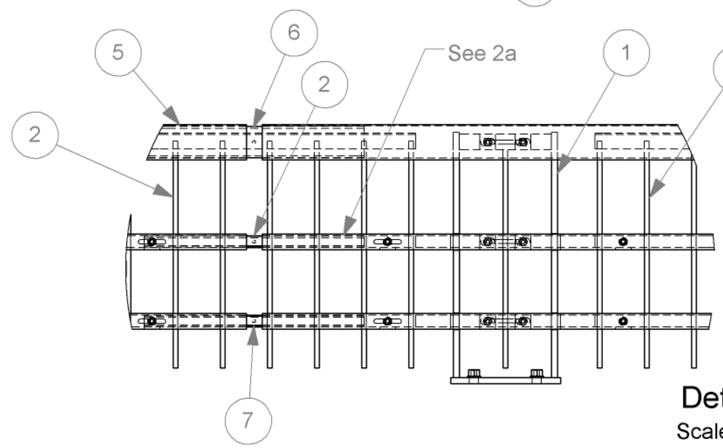
T:\1-ProjectFiles\490026-TxDOT\-4 - 42 inch Picket Rail - Williams\4-3\Drafting\490026-4-3 Drawing

Rail Parts List



Section C-C
Scale 1 : 10

Rail Parts		
#	Part Name	Qty.
1	Post for 42" Picket Rail	15
2	Picket Rail Panel, with slots	2
3	Picket Rail Panel, with holes	12
4	Rectangular Rail	6
5	Round Rail	3
6	Splice Section for Round Rail	2
7	Splice Section for Rectangular Rail	4
8	U-bolt for Picket Rail	45
9	Plate Washer for U-bolt	90
10	Washer, 1/2 SAE Hardened	168
11	Nut, 1/2 heavy hex	174
12	Bolt, 1/2" x 1 1/2" hex	84
13	Washer, 1/2 Lock	90
14	Washer, 7/8 SAE Hardened	60
15	Nut, 7/8 heavy hex	60



Detail D
Scale 1 : 20

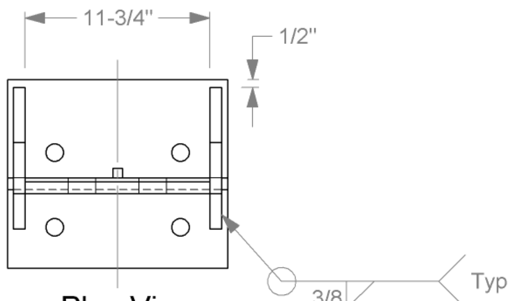
2a. Place Splice Sections with Pins on Field Side.
2b. Ø1/2" Bolts are ASTM A325. Ø7/8" Bolts are ASTM A449.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground		
Project 490026-4 / 1-2	42" Picket Rail		2016-07-18
Drawn By GES	Scale1:200	Sheet 2 of 14	Rail Parts List

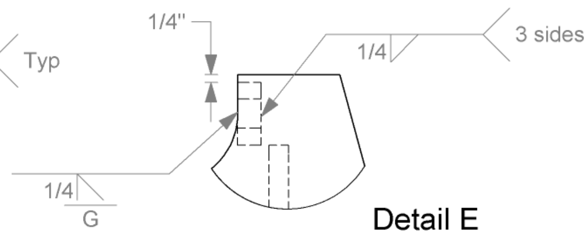
T:\1-ProjectFiles\490026-TxDOT\-4 - 42 inch Picket Rail - Williams\4-2\Drafting\490026-4-2 Drawing

Post

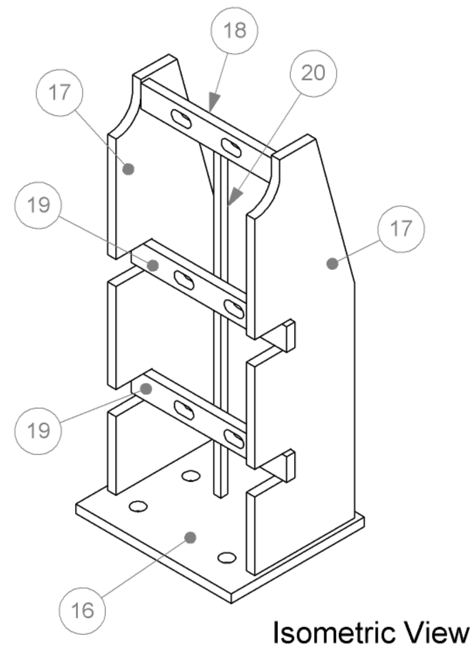
Post Parts					
#	Body Name	Description	Length	MATERIAL	Qty
16	Base Plate	Plate, 12" x 3/4"	14"	ASTM A572 Grade 50	1
17	Side Plate	Plate, 9" x 3/4"	31 1/4"	ASTM A572 Grade 50	2
18	Rail Plate, Top	Plate, 2" x 3/4"	11 3/4"	ASTM A36 Steel	1
19	Rail Plate, Bot and Mid	Plate, 2" x 3/4"	14"	ASTM A36 Steel	2
20	Picket	Plate, 5/8" x 5/8"	27 3/4"	ASTM A36 Steel	1



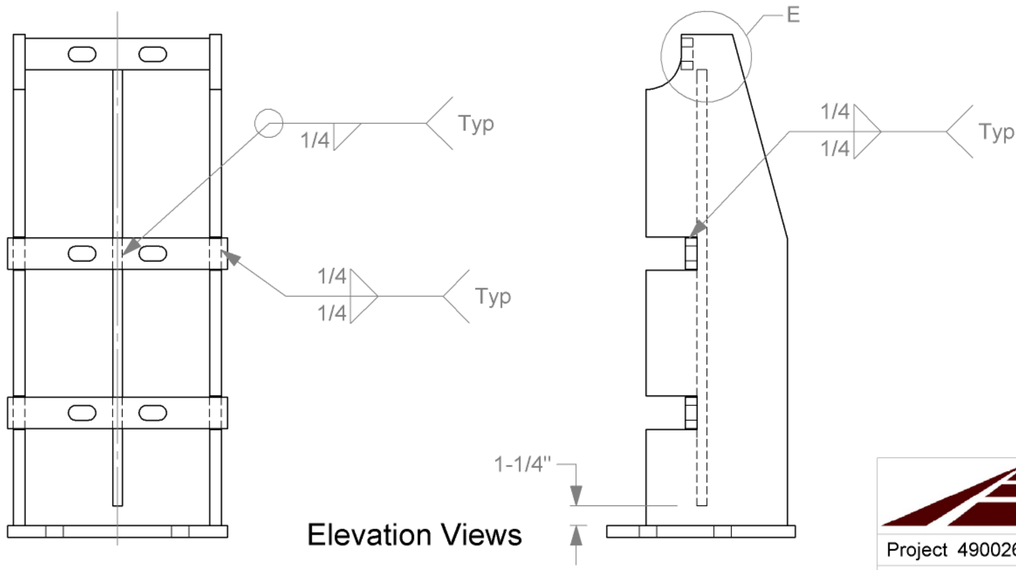
Plan View



Detail E
Scale 1 : 5



Isometric View



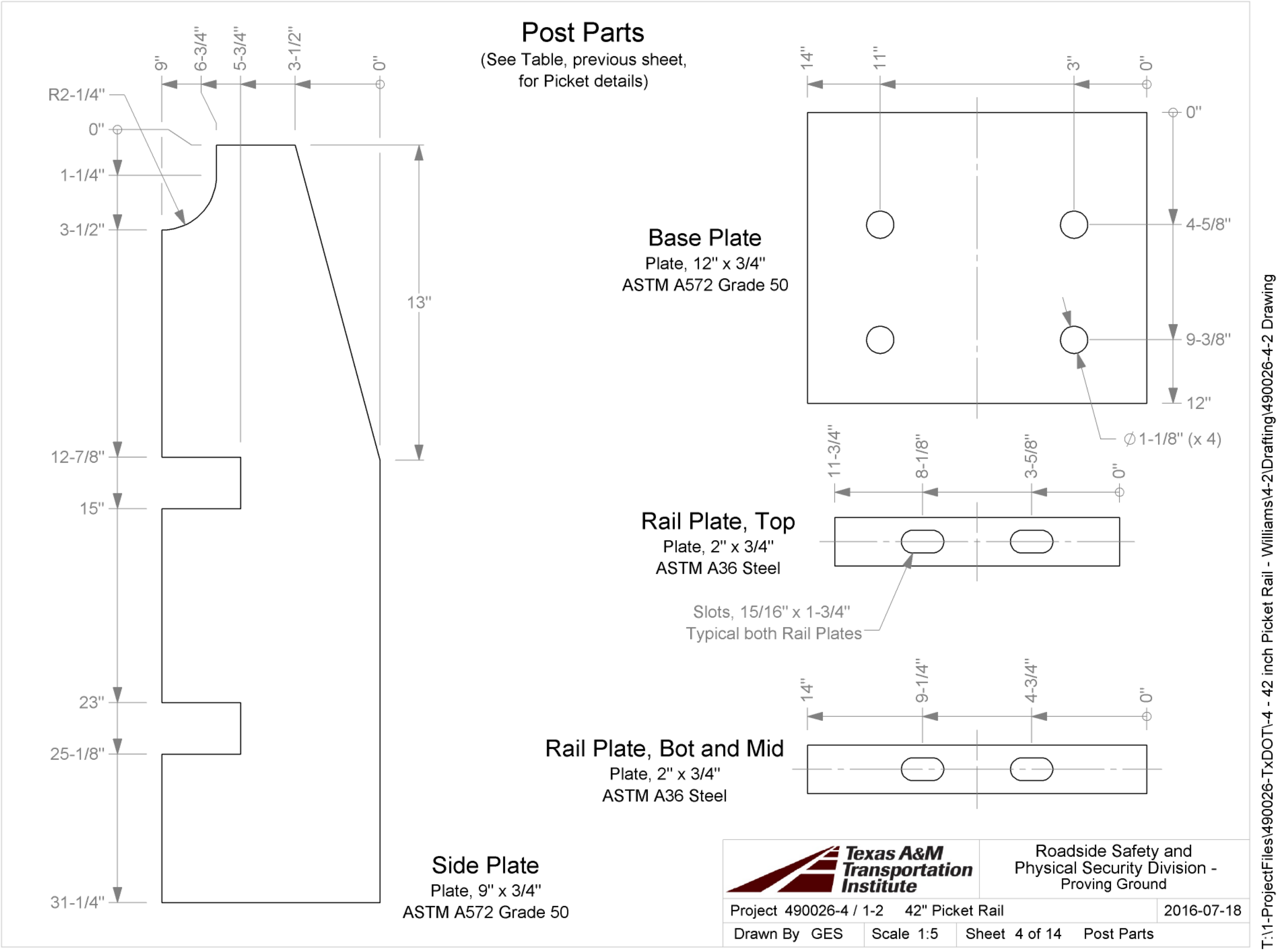
Elevation Views

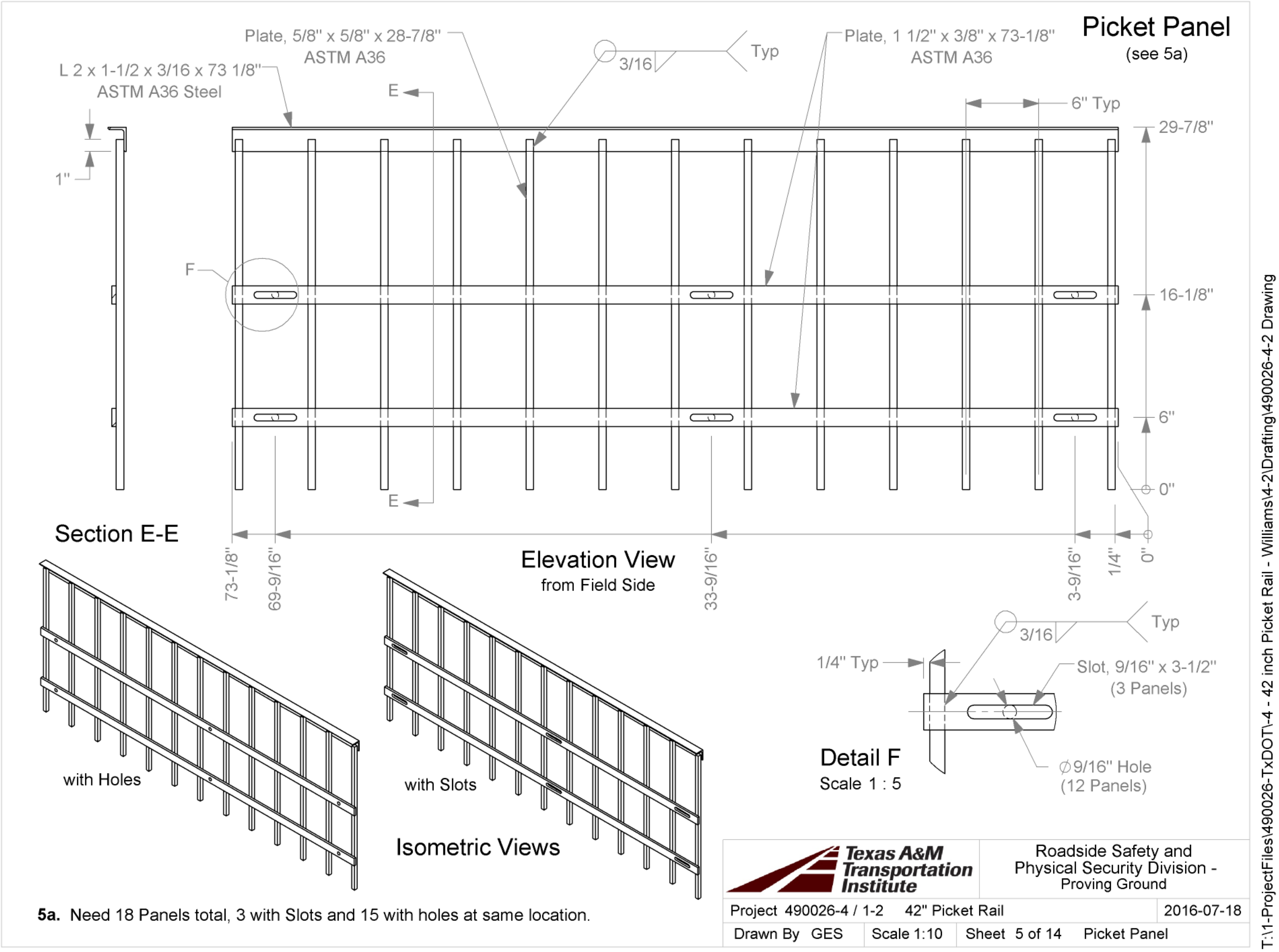
Texas A&M Transportation Institute

Roadside Safety and Physical Security Division - Proving Ground

Project 490026-4 / 1-2	42" Picket Rail		2016-07-18
Drawn By GES	Scale1:500	Sheet 3 of 14	Post

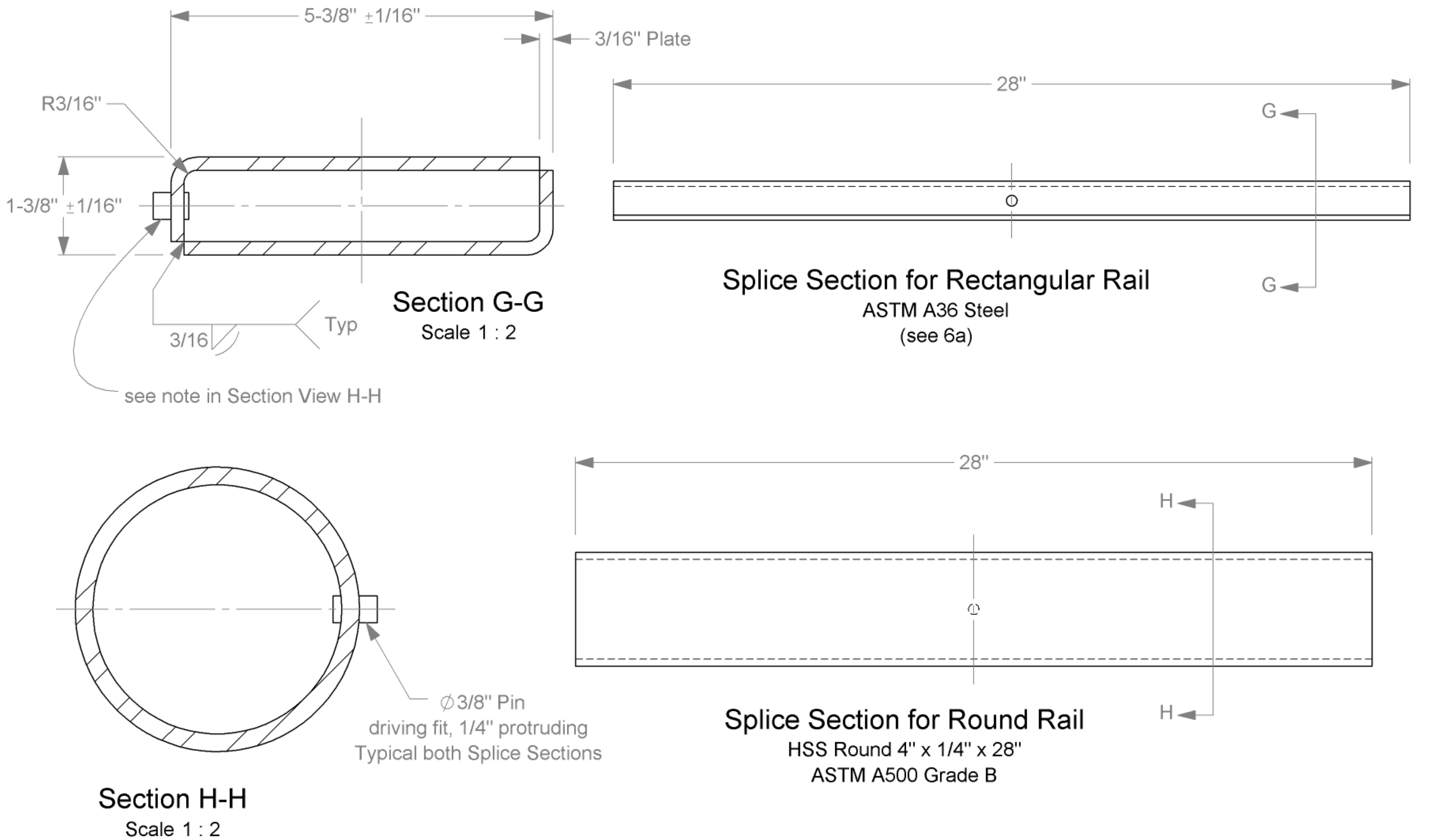
T:\1-ProjectFiles\490026-TxDOT\-4 - 42 inch Picket Rail - Williams\4-2\Drafting\490026-4-2 Drawing


Post Parts
(See Table, previous sheet, for Picket details)
R2-1/4"
9"
6-3/4"
5-3/4"
3-1/2"
0"
0"
1-1/4"
3-1/2"
13"
12-7/8"
15"
23"
25-1/8"
31-1/4"
Side Plate
Plate, 9" x 3/4"
ASTM A572 Grade 50
14"
11"
3"
0"
0"
4-5/8"
9-3/8"
12"
Base Plate
Plate, 12" x 3/4"
ASTM A572 Grade 50
∅1-1/8" (x 4)
11-3/4"
8-1/8"
3-5/8"
0"
Rail Plate, Top
Plate, 2" x 3/4"
ASTM A36 Steel
Slots, 15/16" x 1-3/4"
Typical both Rail Plates
14"
9-1/4"
4-3/4"
0"
Rail Plate, Bot and Mid
Plate, 2" x 3/4"
ASTM A36 Steel
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project 490026-4 / 1-2
42" Picket Rail
2016-07-18
Drawn By GES
Scale 1:5
Sheet 4 of 14
Post Parts
T:\1-ProjectFiles\490026-TxDOT\-4 - 42 inch Picket Rail - Williams\4-2\Drafting\490026-4-2 Drawing



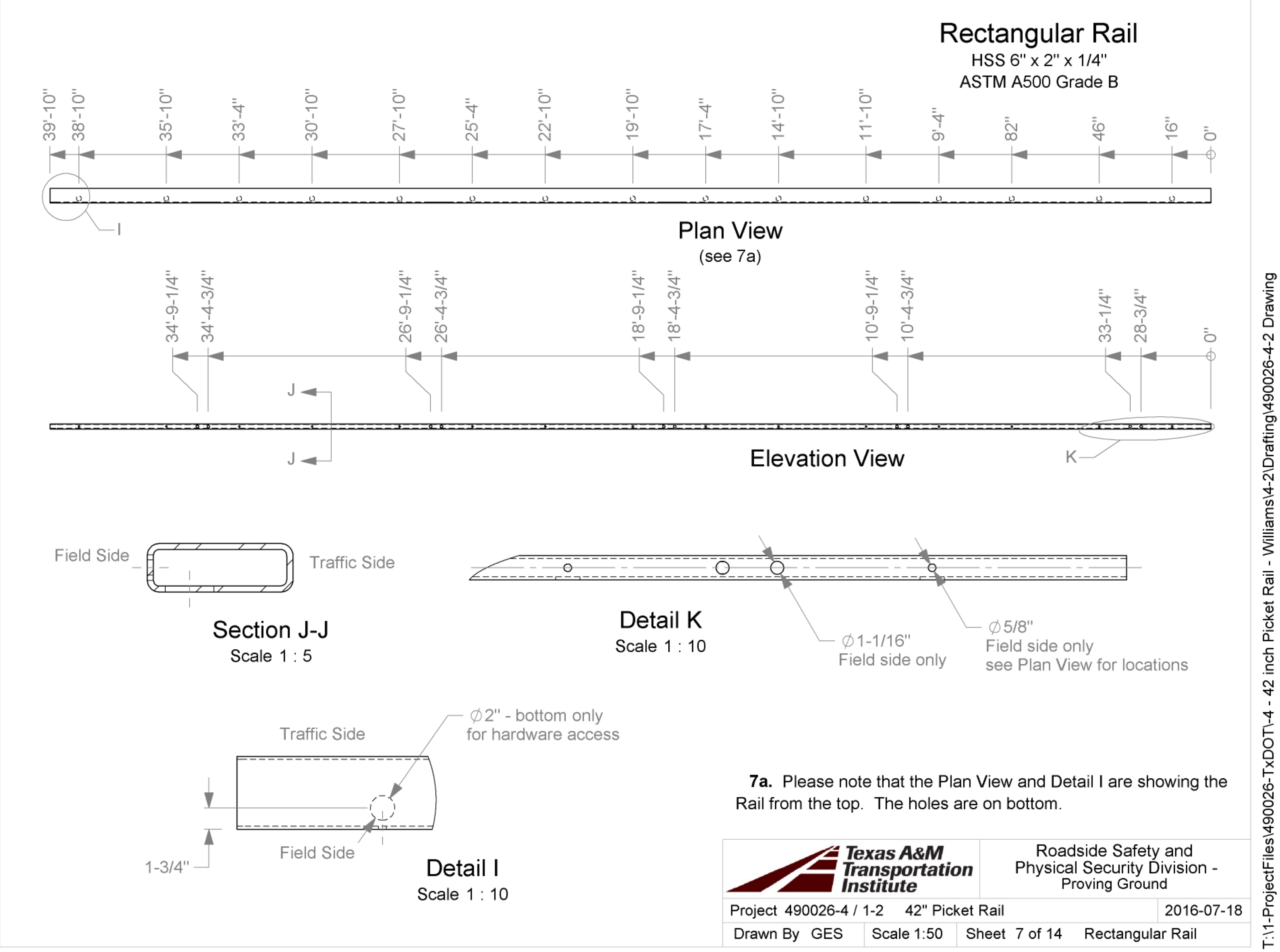
Picket Panel
(see 5a)
L 2 x 1-1/2 x 3/16 x 73 1/8"
ASTM A36 Steel
Plate, 5/8" x 5/8" x 28-7/8"
ASTM A36
3/16
Typ
Plate, 1 1/2" x 3/8" x 73-1/8"
ASTM A36
6" Typ
29-7/8"
16-1/8"
6"
0"
1"
E
F
Section E-E
Elevation View
from Field Side
73-1/8"
69-9/16"
33-9/16"
3-9/16"
1/4"
0"
1/4" Typ
Slot, 9/16" x 3-1/2"
(3 Panels)
∅9/16" Hole
(12 Panels)
Detail F
Scale 1 : 5
with Holes
with Slots
Isometric Views
5a. Need 18 Panels total, 3 with Slots and 15 with holes at same location.
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project 490026-4 / 1-2
42" Picket Rail
2016-07-18
Drawn By GES
Scale 1:10
Sheet 5 of 14
Picket Panel
T:\1-ProjectFiles\490026-TxDOT\-4 - 42 inch Picket Rail - Williams\4-2\Drafting\490026-4-2 Drawing

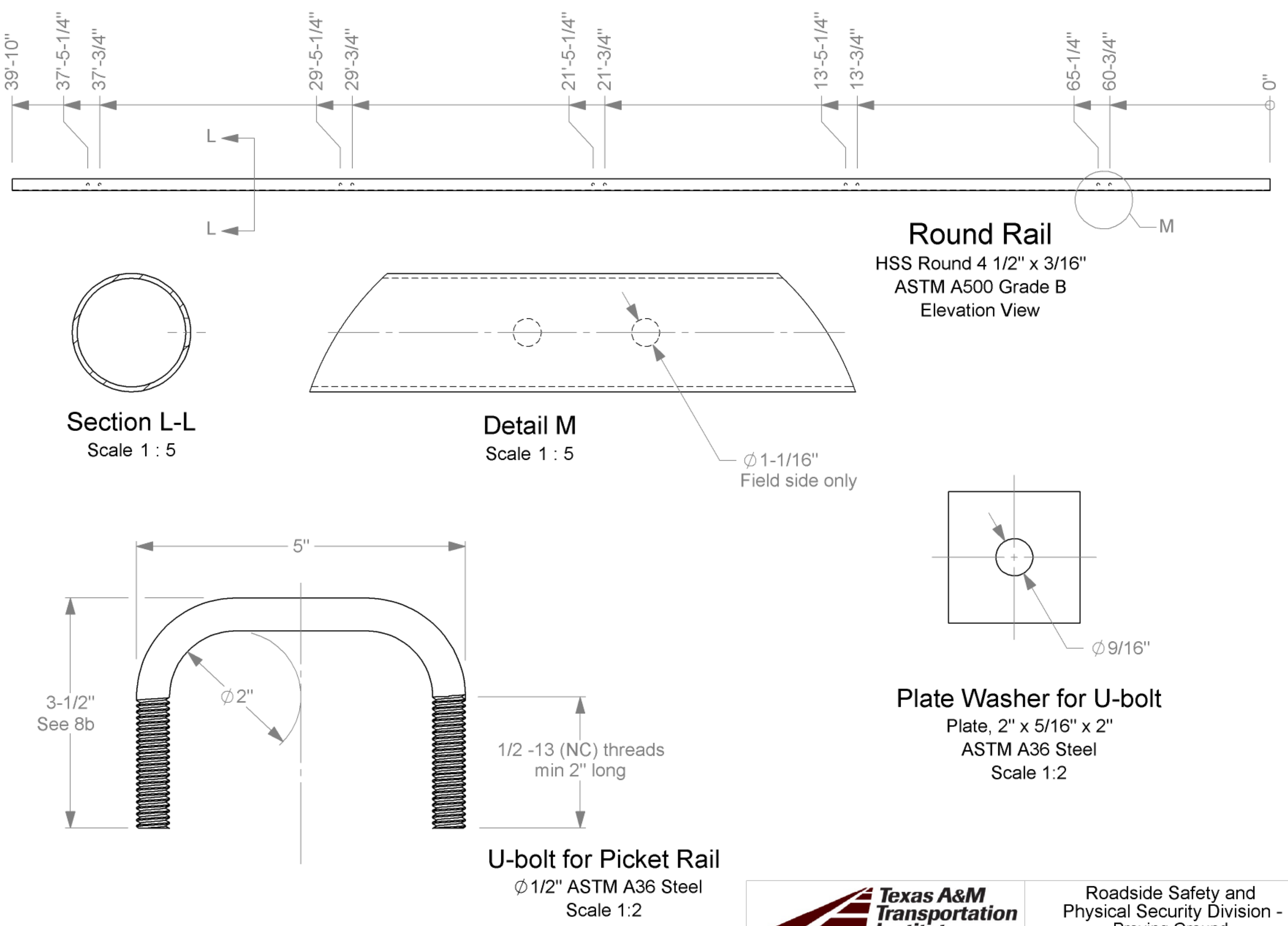
Splice Sections



6a. Check Splice Sleeve for Rectangular Rail for loose fit in Rectangular Rail after fabrication is completed.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground		
Project 490026-4 / 1-2	42" Picket Rail		2016-07-18
Drawn By GES	Scale 1:5	Sheet 6 of 14	Splice Sections


Rectangular Rail
HSS 6" x 2" x 1/4"
ASTM A500 Grade B
39'-10"
38'-10"
35'-10"
33'-4"
30'-10"
27'-10"
25'-4"
22'-10"
19'-10"
17'-4"
14'-10"
11'-10"
9'-4"
82"
46"
16"
0"
I
Plan View
(see 7a)
34'-9-1/4"
34'-4-3/4"
26'-9-1/4"
26'-4-3/4"
18'-9-1/4"
18'-4-3/4"
10'-9-1/4"
10'-4-3/4"
33-1/4"
28-3/4"
0"
J
J
Elevation View
K
Field Side
Traffic Side
Section J-J
Scale 1 : 5
Detail K
Scale 1 : 10
∅1-1/16"
Field side only
∅5/8"
Field side only
see Plan View for locations
Traffic Side
∅2" - bottom only
for hardware access
Field Side
1-3/4"
Detail I
Scale 1 : 10
7a. Please note that the Plan View and Detail I are showing the Rail from the top. The holes are on bottom.
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project 490026-4 / 1-2
42" Picket Rail
2016-07-18
Drawn By GES
Scale 1:50
Sheet 7 of 14
Rectangular Rail
T:\1-ProjectFiles\490026-TxDOT\-4 - 42 inch Picket Rail - Williams\4-2\Drafting\490026-4-2 Drawing

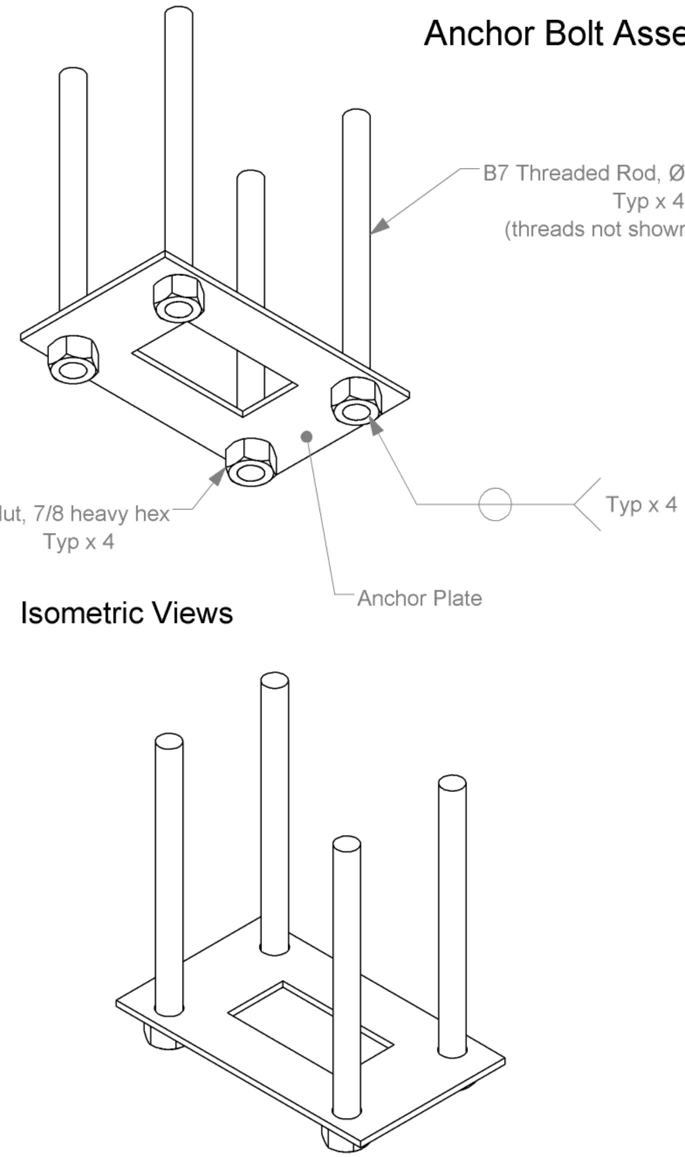


8a. Dimension is approximate. Rod is 10" long before bending.

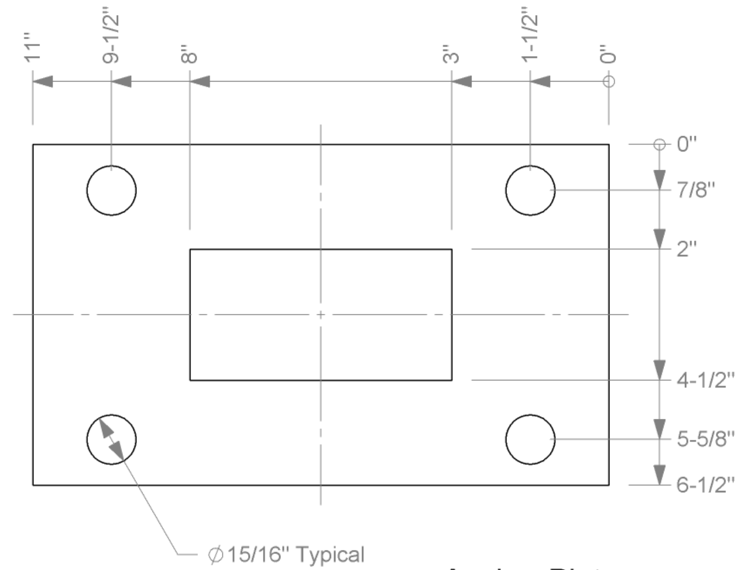
Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground		
Project 490026-4 / 1-2	42" Picket Rail		2016-07-18
Drawn By GES	Scale 1:50	Sheet 8 of 14	Round Rail, etc.

T:\1-ProjectFiles\490026-TxDOT\-4 - 42 inch Picket Rail - Williams\4-2\Drafting\490026-4-2 Drawing

Anchor Bolt Assembly



Isometric Views

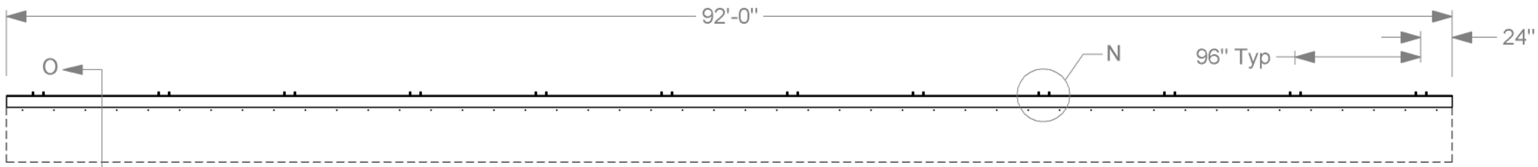


Anchor Plate

Plate, 6 1/2" x 1/4" x 11"
ASTM A36 Steel

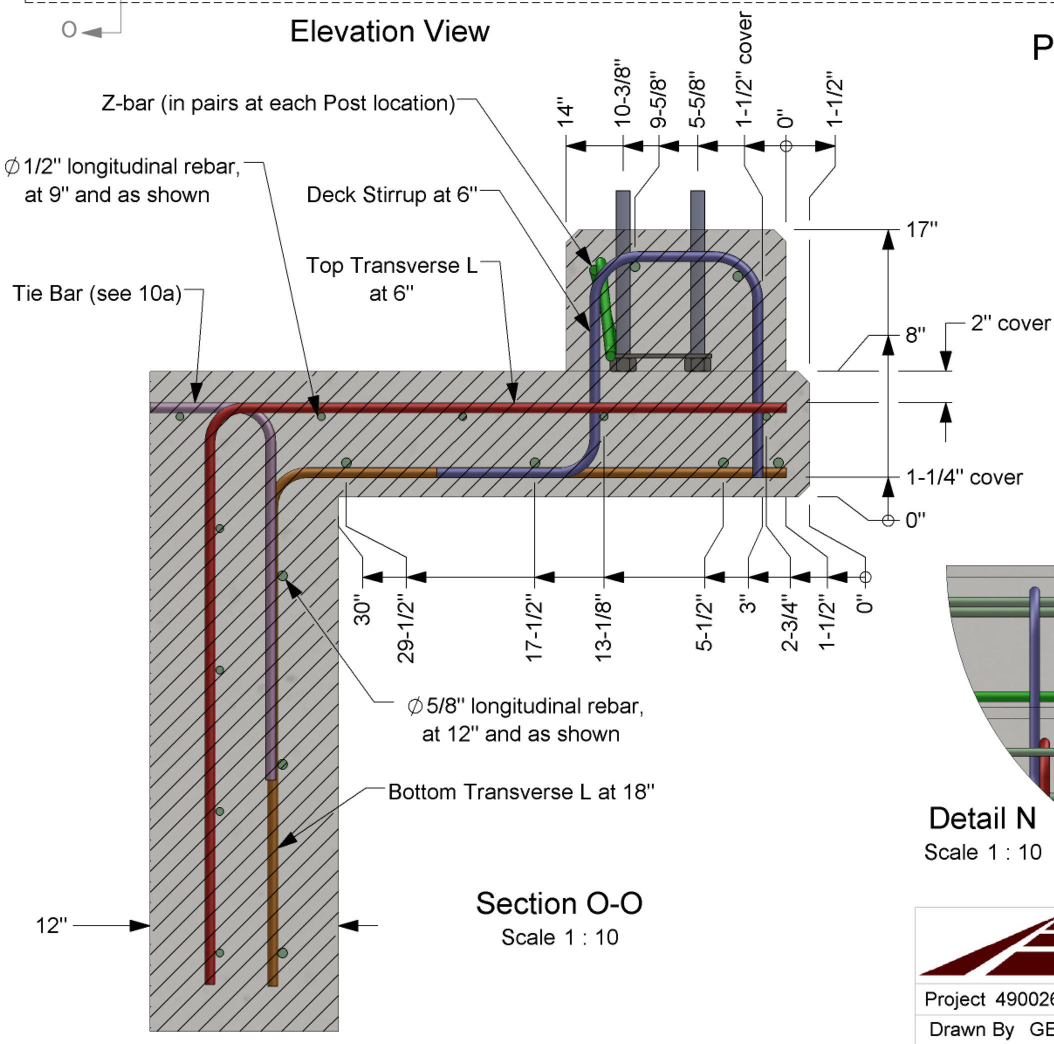
Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground		
Project 490026-4 / 1-2	42" Picket Rail		2016-07-18
Drawn By GES	Scale 1:3	Sheet 9 of 14	Anchor Bolt Assembly

T:\1-ProjectFiles\490026-TxDOT\-4 - 42 inch Picket Rail - Williams\4-2\Drafting\490026-4-2 Drawing



Elevation View

Previous Concrete

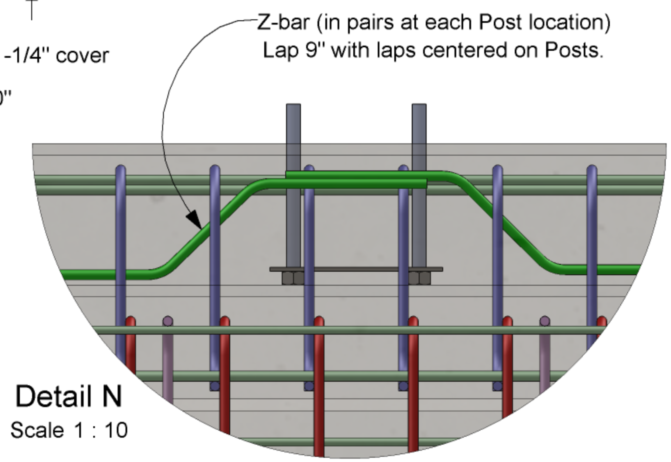


Section O-O
Scale 1 : 10

10a. Tie Bars spaced at 24", and welded to existing rebar protruding from the runway (not shown here).

10b. All Rebar is grade 60. Minimum lap distance is 17" for Ø1/2" bars and 21" for Ø5/8" bars.

10b. Concrete is TxDOT Class S (4000 psi). Chamfer edges of Deck and Curb 3/4" as shown.

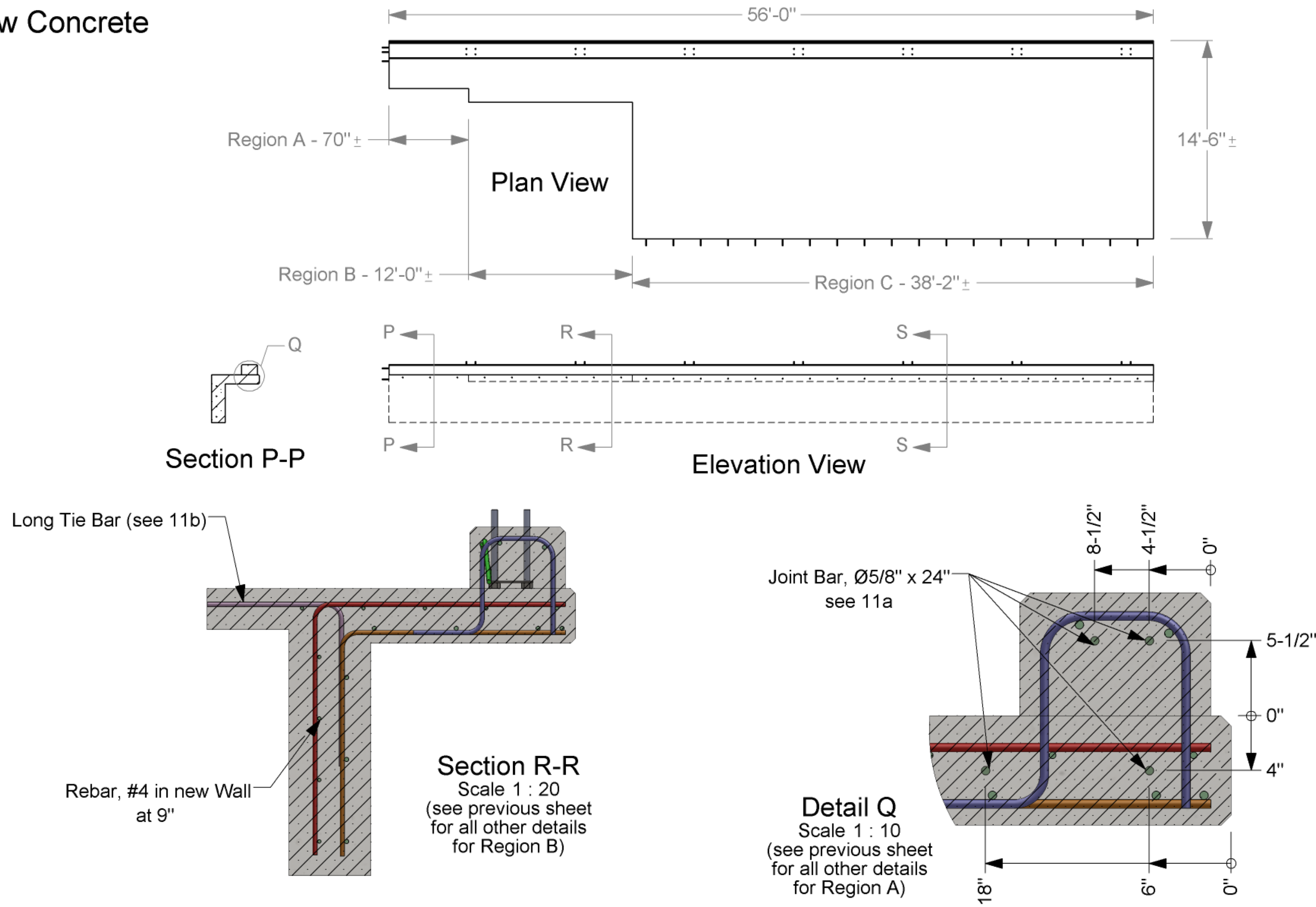


Detail N
Scale 1 : 10

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project 490026-4 / 1-2	42" Picket Rail	2016-07-18
Drawn By GES	Scale1:120	Sheet 10 of 14 Previous Concrete

T:\1-ProjectFiles\490026-TxDOT\-4 - 42 inch Picket Rail - Williams\4-2\Drafting\490026-4-2 Drawing

New Concrete

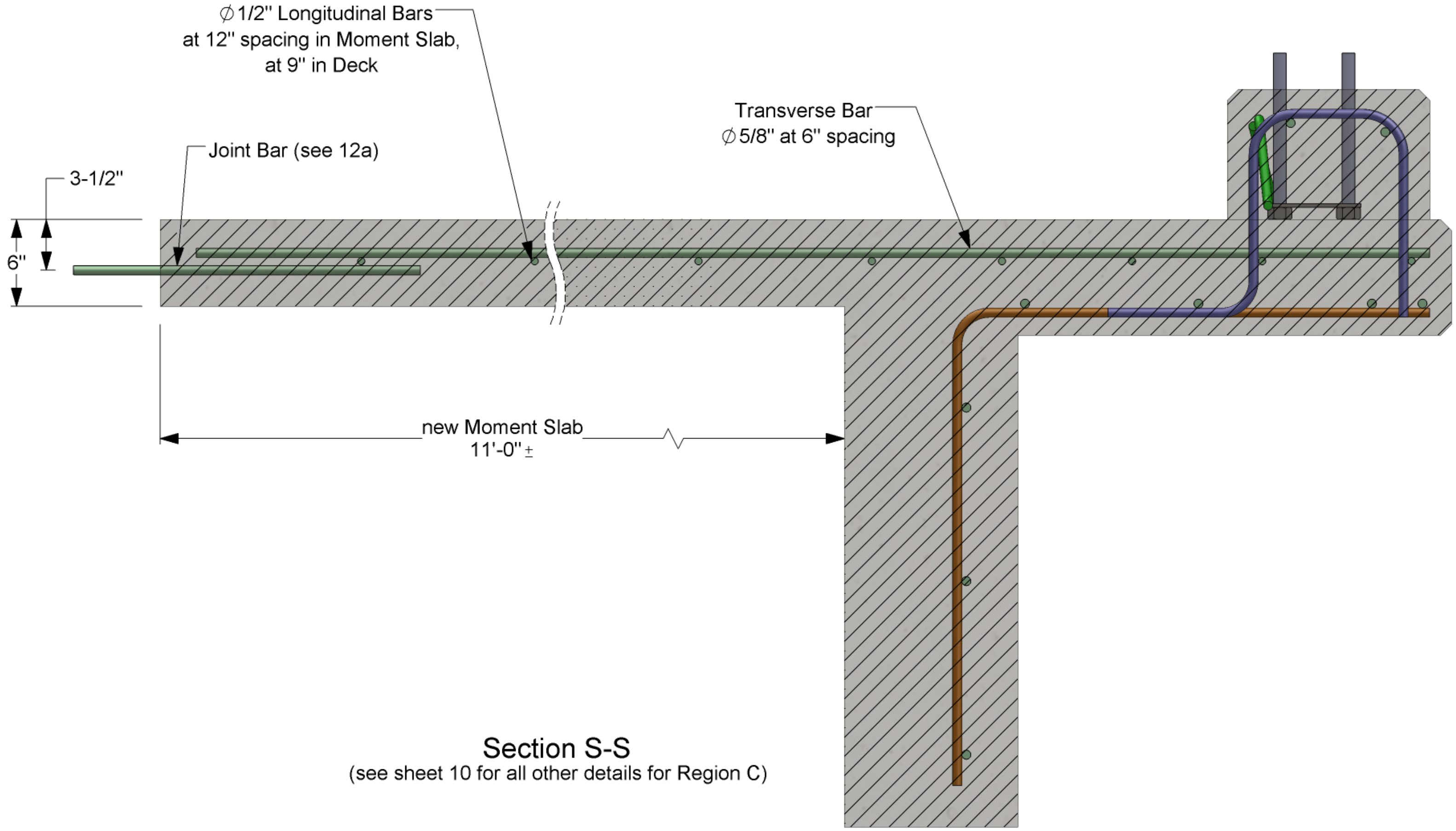


11a. Drill minimum 6" into existing concrete and secure Joint Bars with Hilti RE-500 epoxy, according to manufacturer's instructions.

11b. Long Tie Bars spaced at 24" and welded to existing rebar protruding from the runway (not shown here).

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Project 490026-4 / 1-2	42" Picket Rail		2016-07-18
Drawn By GES	Scale1:120	Sheet 11 of 14	New Concrete

T:\1-ProjectFiles\490026-TxDOT\-4 - 42 inch Picket Rail - Williams\4-2\Drafting\490026-4-2 Drawing



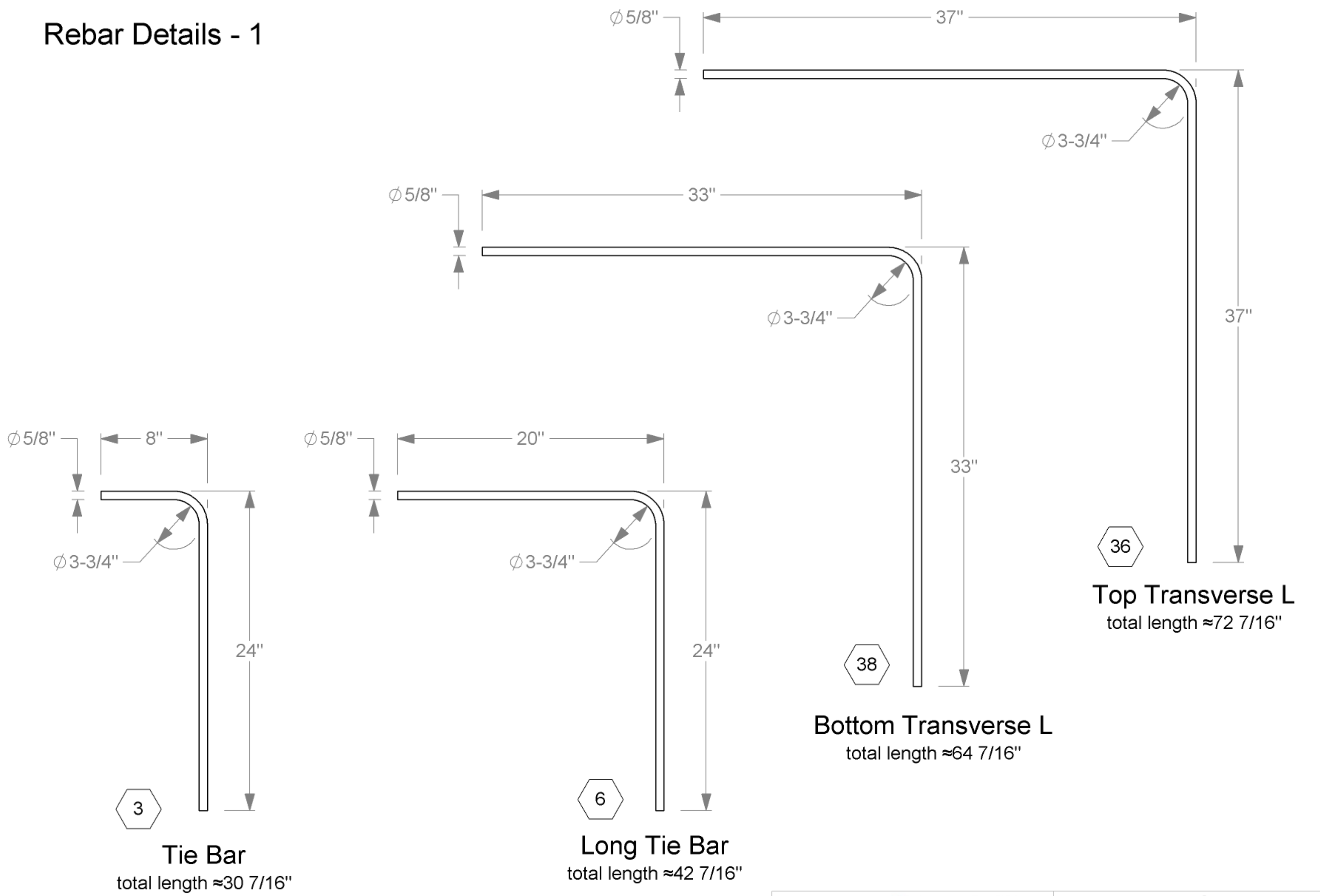
Section S-S
(see sheet 10 for all other details for Region C)

12a. Drill minimum 6" into existing concrete and secure Joint Bars with Hilti RE-500 epoxy, according to manufacturer's instructions. Space at 24".

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground		
Project 490026-4 / 1-2	42" Picket Rail		2016-07-18
Drawn By GES	Scale 1:10	Sheet 12 of 14	Section View

T:\1-ProjectFiles\490026-TxDOT\-4 - 42 inch Picket Rail - Williams\4-2\Drafting\490026-4-2 Drawing

Rebar Details - 1



13a. The numeral in the hexagon denotes the quantity needed for each Bar.

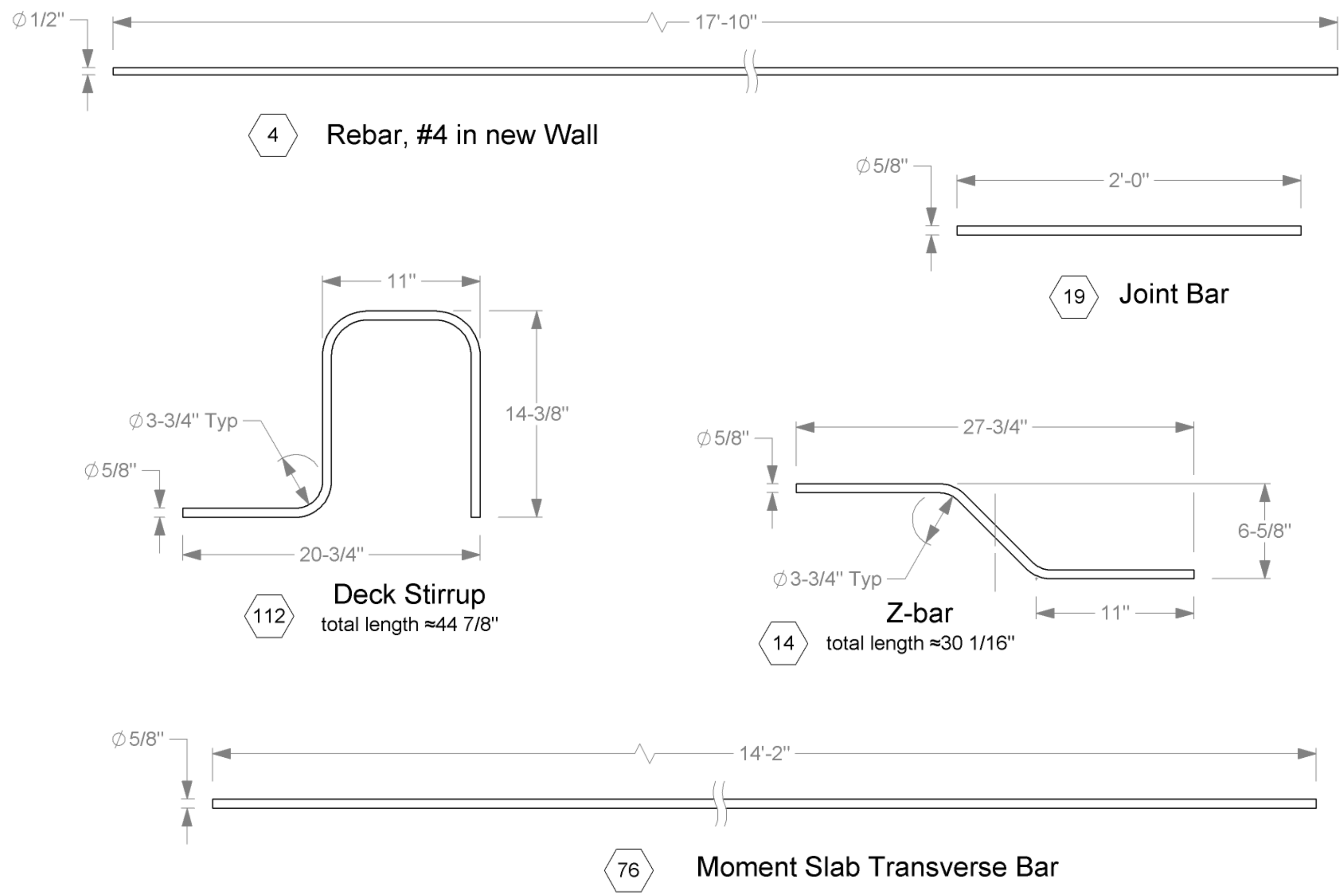
Texas A&M Transportation Institute

Roadside Safety and Physical Security Division - Proving Ground

Project 490026-4 / 1-2	42" Picket Rail		2016-07-18
Drawn By GES	Scale 1:10	Sheet 13 of 14	Rebar Details - 1

T:\1-ProjectFiles\490026-TxDOT\-4 - 42 inch Picket Rail - Williams\4-2\Drafting\490026-4-2 Drawing

Rebar Details - 2



14a. The numeral in the hexagon denotes the quantity needed for each Bar.

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Project 490026-4 / 1-2	42" Picket Rail		2016-07-18
Drawn By GES	Scale 1:10	Sheet 14 of 14	Rebar Details - 2

T:\1-ProjectFiles\490026-TxDOT\-4 - 42 inch Picket Rail - Williams\4-2\Drafting\490026-4-2 Drawing

APPENDIX C.SUPPORTING CERTIFICATION DOCUMENTS

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Terracon
6198 Imperial Loop
College Station, TX 77845-5765
979-846-3767 Reg No: F-3272

Report Number: A1161016.0010
Service Date: 06/09/16
Report Date: 06/28/16 Revision 1 - 15-day results
Task: PO #490026-4

Client

Texas Transportation Institute
Attn: Gary Gerke
TTI Business Office
3135 TAMU
College Station, TX 77843-3135

Project

Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1161016

Material Information

Specified Strength: 4,000 psi @ 28 days

Mix ID:
Supplier: Martin Marietta Materials
Batch Time: 1237 **Plant:**
Truck No.: 7130 **Ticket No.:** 3364590

Sample Information

Sample Date: 06/09/16 **Sample Time:** 1320
Sampled By: Randolph E. Rohrbach
Weather Conditions: Clear, light wind
Accumulative Yards: 5.5/5.5 **Batch Size (cy):** 5.5
Placement Method: Direct Discharge
Water Added Before (gal):
Water Added After (gal):
Sample Location: West end
Placement Location: Curb

Field Test Data

Test	Result	Specification
Slump (in):	4 3/4	Not Specified
Air Content (%):		Not Specified
Concrete Temp. (F):	92	40 - 95
Ambient Temp. (F):	91	40 - 95
Plastic Unit Wt. (pcf):		Not Specified
Yield (Cu. Yds.):		

Laboratory Test Data

Set No.	Specimen ID	Avg Diam. (in)	Area (sq in)	Date Received	Date Tested	Age at Test (days)	Maximum Load (lbs)	Compressive Strength (psi)	Fracture Type
1	A	4.00	12.57	06/13/16	06/24/16	15	48,940	3,890	5
1	B	4.00	12.57	06/13/16	06/24/16	15	45,420	3,610	2
1	C	4.00	12.57	06/13/16	06/24/16	15	50,860	4,050	3
						Average (15 days)		**3,850**	
1	D	4.00	12.57	06/13/16	07/07/16	28			
1	E	4.00	12.57	06/13/16	07/07/16	28			

Comments: Not tested for plastic unit weight.

Samples Made By: Terracon
Services: Obtain samples of fresh concrete at the placement locations (ASTM C 172), perform required field tests and cast, cure, and test compressive strength samples (ASTM C 31, C 39, C 1231).
Terracon Rep.: Randolph E. Rohrbach **Start/Stop:** 1230-1415
Reported To:
Contractor:
Report Distribution:
(1) Texas Transportation Institute, Gary Gerke (1) Terracon Consultants, Inc., Nicole Farabee

Reviewed By: Mark E.Dornak, P.E.
Project Manager

Test Methods: ASTM C 31, ASTM C143, ASTM C231, ASTM C1064

CR0001, 11-16-12, Rev.6 Page 1 of 1

Texas A&M Transportation Institute Proving Ground, 3100 SH 47, Bldg 7091, Bryan, TX 77807 Texas A&M University, College Station, TX 77843, Phone 979-845-6375	5.7.2 Concrete Break	Doc. No. QPF 5.7.2	Revision Date: 2012-09-17
Quality Policy Form	Revised by: G. E. Schroeder Approved by: C. E. But	Revision: 5	Page: 1 of 1

Project No.: 490026-4

Placement: WALL

Casting Date: 2016-05-13

Mix Design P.S.I.: 4000

Truck No.	Batch Ticket	Yards
|	|	|
|	|	|
|	|	|

Printed name of Technician taking sample: GLENN SCHROEDER

Signature of Technician taking sample:

Printed name of Technician breaking sample: EDWIN HANG

Signature of Technician breaking sample:

Break Date	Cylinder Age	Truck No.	Total Load (Pounds)	PSI Break	Average
2016-06-27	46 DAYS		131,000	4633	4586
|	|		128,000	4527	
|	|		130,000	4598	

Texas A&M Transportation Institute Proving Ground, 3100 SH 47, Bldg 7091, Bryan, TX 77807 Texas A&M University, College Station, TX 77843, Phone 979-845-6375	5.7.2 Concrete Break	Doc. No. QPF 5.7.2	Revision Date: 2012-09-17
Quality Policy Form	Revised by: G. E. Schroeder Approved by: C. E. But	Revision: 5	Page: 1 of 1

Project No.: 490026-4 **Casting Date:** 2016-05-25

Placement: DECK **Mix Design P.S.I.:** 4000

Truck No.	Batch Ticket	Yards

Printed name of Technician taking sample: GLENN SCHROEDER

Signature of Technician taking sample:

Printed name of Technician breaking sample: EDWIN HANEY

Signature of Technician breaking sample:

Break Date	Cylinder Age	Truck No.	Total Load (Pounds)	PSI Break	Average
2016-06-27	34 DAYS		131,000	4633	
			125,000	4421	4539
			129,000	4563	

MATERIAL USED

TEST NUMBER	490026-4
TEST NAME	42" Picket Rail
DATE	2016-06/07

#	DATE RECEIVED	DESCRIPTION	GRADE	YIELD	TENSILE	SUPPLIER
15-044	2016-04-12	Rebar, #5 x 20'	60	63.8 ksi	102.5 ksi	CMC Steel
15-045	2016-04-12	Rebar, #4 x 20'	60	none given		CMC Steel
15-049	2016-05-31	Ø7/8 x 11-1/2 Rod	B7	125000	138000	Mack Bolt & Steel
15-050	2016-05-31	Nut, 7/8 Heavy Hex	2H			Mack Bolt & Steel
15-051	2016-05-31	Washer, 7/8 flat	SAE			Mack Bolt & Steel
15-053	2016-06-20	Rail Parts		see attached		Rik-Mar

15-044

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

William VanderWaal
Quality Assurance/Reliability Manager

HEAT NO.:3060965 SECTION: REBAR 16MM (#5) 20'0" 420/60 B096 GRADE: ASTM A615-14 Gr 420/60 ROLL DATE: 01/20/2016 MELT DATE: 01/17/2016	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#: 81728421 BOL#: 71536214 CUST PO#: 707820 CUST P/N: 552520 DLVRY LBS / HEAT: 4006.000 LB DLVRY PCS / HEAT: 192 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.43%				
Mn	1.00%				
P	0.012%				
S	0.044%				
Si	0.21%				
Cu	0.24%				
Cr	0.12%				
Ni	0.13%				
Mo	0.035%				
V	0.000%				
Cb	0.003%				
Sn	0.009%				
Al	0.003%				
Yield Strength test 1	63.8ksi				
Tensile Strength test 1	102.5ksi				
Elongation test 1	16%				
Elongation Gage Lgth test 1	8IN				
Bend Test Diameter	2.188IN				
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 :

02/18/2016 17:55:00

15-045

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

William VanderWaal
Quality Assurance/Reliability Manager

HEAT NO.:3062573 SECTION: REBAR 13MM (#4) 20'0" 420/60 GRADE: ASTM A615-14 Gr 420/60 ROLL DATE: 04/06/2016 MELT DATE: 04/01/2016	S O L D T O	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	S H I P T O	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	Delivery#: 81766737 BOL#: 71582102 CUST PO#: 712289 CUST P/N: 552420D DLVRY LBS / HEAT: 35056.000 LB DLVRY PCS / HEAT: 2624 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.41%				
Mn	0.96%				
P	0.012%				
S	0.043%				
Si	0.20%				
Cu	0.33%				
Cr	0.10%				
Ni	0.09%				
Mo	0.038%				
V	0.000%				
Cb	0.002%				
Sn	0.015%				
Al	0.001%				

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

REMARKS :

04/06/2016 16:01:44

2022-06-29

15-049

B&G Manufacturing Co, Inc EEO/AA
3067 Unionville Pike, P.O. Box 904, Hatfield, PA 19440-0904
General Telephone: 215-822-1925

Manufacturing Company

Customer number: 1310
Mack Bolt, Steel & Machine
5875 Hwy 21 E
Bryan TX 77808

Shipping Address:
Mack Bolt, Steel & Machine
5875 Hwy 21 E
BRYAN TX 77808
USA

Quality certificate

Date
05/27/2016

Purchase order item
30986

B&G Delivery item
80610282 000010

B&G Sales Order item
418418 000010

Page 1 of 3

We certify that the material or fasteners supplied were manufactured, sampled, tested and inspected in accordance with the specification and other requirements designated in the purchase order and was found to meet those requirements. While in our possession, the material did not come in contact with mercury. The recording of false, fictitious or fraudulent statements or entries on this document may be punishable as a felony under Federal Statute.

Material Number : 60372
Batch 0000431559 / Quantity 2 EA
Heat Number: 6613040020

Specification / Description
TFL STUDS
ASTM A193 B7
.875-9 X 11.500 MEASURED OVERALL LENGTH

Characteristic	Unit	Value
Specifications	-	ASTM-A193-06A GR. B7
Heat Number	-	6613040020
Country Of Melt / Mill	-	China
Carbon Content	%	0.4000
Chromium Content	%	0.9100
Manganese Content	%	0.7700
Molybdenum Content	%	0.1800
Phosphorus Content	%	0.0130
Silicon Content	%	0.1900
Sulfur Content	%	0.0050
Tensile Strength	psi	138000
Yield Strength	psi	125000
Elongation	%	20.000
Reduction of Area	%	58.000
Hardness RC		30
Tempering Temperature	°F	1148

15-049

B&G Manufacturing Company, Inc. Quality Certificate Date:05/27/2016

3067 Unionville Pike, Hatfield, PA 19440 Phone: 215-822-1925

B&G Delivery Item 80610282 / 000010

B&G Sales Order 418418 Item 000010 B&G Part# 60372

Customer: Mack Bolt, Steel & Machine

Purchase order 30986

Page 2 of 3

Macro Etch Testing	-	Pass
MACRO CENTER SEGREGATION	-	ASTM E381-01 C2
MACRO RANDOM CONDITION	-	ASTM E381-01 R2
MACRO SUBSURFACE CONDITION	-	ASTM E381-01 S2
Condition	-	Quenched and Tempered
Condition	-	Stress Relieved

If you have any questions concerning this document, please contact our customer service dept at 215-996-3301.

Certification Service Specialist: Amanda Culp Amanda Culp

15-049

B&G Manufacturing Company, Inc. Quality Certificate Date:05/27/2016

3067 Unionville Pike, Hatfield, PA 19440 Phone: 215-822-1925

B&G Delivery Item 80610282 / 000010
B&G Sales Order 418418 Item 000010 B&G Part# 60372
Customer: Mack Bolt, Steel & Machine
Purchase order 30986

Material Number : 60372
Batch 0000431561 / Quantity 48 EA
Heat Number: 4104544

Specification / Description
TFL STUDS
ASTM A193 B7
.875-9 X 11.500 MEASURED OVERALL LENGTH

Characteristic	Unit	Value
Specifications	-	ASTM-A193-06A GR. B7
Heat Number	-	4104544
Country Of Melt / Mill	-	China
Carbon Content	%	0.4000
Chromium Content	%	0.9600
Manganese Content	%	0.8500
Molybdenum Content	%	0.1800
Phosphorus Content	%	0.0120
Silicon Content	%	0.2400
Sulfur Content	%	0.0050
Tensile Strength	psi	126000
Yield Strength	psi	113000
Elongation	%	19.000
Reduction of Area	%	61.000
Hardness RC		27
Tempering Temperature	°F	1166
Macro Etch Testing	-	Pass
MACRO CENTER SEGREGATION	-	ASTM E381-01 C2
MACRO RANDOM CONDITION	-	ASTM E381-01 R2
MACRO SUBSURFACE CONDITION	-	ASTM E381-01 S2
Decarburization	-	Pass
Condition	-	Quenched and Tempered
Condition	-	Stress Relieved

If you have any questions concerning this document, please contact our customer service dept at 215-996-3301.

Certification Service Specialist: Amanda Culp Amanda Culp

15-050

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: 30993
Stelfast Order: SO 154320
Certificate #: 557,946

Quantity: 150
Part #: A2HHO0875C
Description: 7/8-9 Hvy Hx Nut 2H

Lot Number: 1410200458B
Heat Number: J21401603
Country of Origin: CN

Chemical Analysis

C	Mn	P	S	Si	Cr	Mo	V	B	Ni	Cu
0.44	0.7	0.021	0.003	0.16						

Mechanical Properties

Grade of Steel	1045
Minimum Tempering Temp.	540 C
Result of 24 Hr. Temper Test	96 - 98 HRB
Hardness (Core)	29 - 32 HRC
Proof Load	175 KSI MIN
Macro Etch Test	SW, R2, C2
Grade Markings	ASTM A194(12)-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. Stelfast does not certify to customer's part number.

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.

David Biss

David Biss
Quality Manager

May 25, 2016

15-051

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: 31004
Stelfast Order: SO 154470
Certificate #: 523,030

Quantity: 750
Part #: DHW0008750
Description: 7/8 Hardened Washer F436

Lot Number: GBR14538173A-007
Heat Number: D113007143
Country of Origin: CN

Chemical Analysis

C	Mn	P	S	Si	Cr	Mo	V	B	Ni	Cu
0.45	0.59	0.014	0.007	0.22						

Mechanical Properties

Hardness (Core)	39 - 44 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. Stelfast does not certify to customer's part numbers.
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.

David Biss
Quality Manager

May 27, 2016

Page 1 of 1

TR No. 9-1002-15-2

90

2022-06-29

15-053

TRIPLES

AHMSA ALTOS HORNOS DE MEXICO

MILL TEST CERTIFICATE AHMSA:QUALITY WITH THE STRENGTH OF STEEL

PROLONGACION JUAREZ SIN NUMERO COLONIA LA LOMA MONCLOVA COAHUILA 25770

B856841B

CUSTOMER	DATE OF ISSUED	PAGE
AHMSA INT/ TRIPLE-S HOUSTON	21.04.2016	1

ADDRESS: 5150 N LOOP1604 W SAN ANTONIO, TX.

PRODUCT: WIDE PLATE..

WE HEREBY THAT CHEMICAL AND / OR TEST SHOW IN THIS REPORT ARE CORRECT AS CONTAINED THE RECORDS OF THE COMPANY.

ING. RAMIRO CISNEROS MENCHACA

MECHANICAL TESTS AND CERTIFICATION

CHEMICAL COMPOSITION

HEAT	SPECIFICATION	C	Mn	P	S	Si	Cu	Cr	Ni	Mo	Alt	V	Cb	Ti
261731	ASTM A 572 50 T1 REV12	0.160	1.420	0.023	0.005	0.170	0.010	0.016	0.017	0.002	0.039	0.005	0.017	0.011
261732	ASTM A 572 50 T1 REV12	0.170	1.420	0.023	0.004	0.190	0.012	0.017	0.020	0.003	0.034	0.004	0.019	0.011

TEST OF THE PRODUCT

HEAT	SLAB	PLATE NO.	THICKNESS(Inch)	Y.STRENGTH	T.STRENGTH	%ELON.	T.ELONG.
261731	3010	94305321	1.5000	54.670(KSI)	77.624(KSI)	52(%)	2
261731	3080	94302211	0.7500	54.058(KSI)	81.270(KSI)	42(%)	2
261731	3100	94302221	0.7500	54.558(KSI)	75.583(KSI)	42(%)	2
261731	3160	94341301	1.0000	64.851(KSI)	91.474(KSI)	46(%)	2
261732	3010	94303501	0.7500	53.784(KSI)	78.149(KSI)	42(%)	2
261732	3020	94305401	1.5000	55.061(KSI)	78.295(KSI)	50(%)	2
261732	3130	94343921	1.0000	56.013(KSI)	78.107(KSI)	48(%)	2
261732	4020	94303531	0.7500	53.339(KSI)	77.698(KSI)	45(%)	2
261732	4070	94304521	1.2500	58.348(KSI)	78.602(KSI)	47(%)	2

SHIPPED PRODUCT

HEAT	PLANCHON	PLATE NO.	THICKNESS(Inch)	WIDTH(Inch)	LARGE(Inch)	ORDER	ITEM	DELIVERY
261731	3130	94303782	0.7500	96.0000	240.0000	0000184118	000080	1002268931
261731	4140	94303721	0.7500	96.0000	240.0000	0000184118	000080	1002268931
261731	4140	94303722	0.7500	96.0000	240.0000	0000184118	000080	1002268931
261732	3030	94303752	0.7500	96.0000	240.0000	0000184118	000080	1002268931
261732	3050	94303741	0.7500	96.0000	240.0000	0000184118	000080	1002268931
261732	3050	94303742	0.7500	96.0000	240.0000	0000184118	000080	1002268931

HEAT	PLANCHON	PLATE NO.	CUSTOMER ORD.	STANDARD
261731	3130	94303782	AHI4196(WLY-18736)/M	A-6
261731	4140	94303721	AHI4196(WLY-18736)/M	A-6
261731	4140	94303722	AHI4196(WLY-18736)/M	A-6
261732	3030	94303752	AHI4196(WLY-18736)/M	A-6
261732	3050	94303741	AHI4196(WLY-18736)/M	A-6
261732	3050	94303742	AHI4196(WLY-18736)/M	A-6

All heats and sizes are fully aluminum killed with fine grain practice. DIN EN 10204 § 3.1 compliant.

COUNTRY OF ORIGIN: MÉXICO

END OF DATA

ISSUED : C01AI10

AHMSA'S COMPROMISE IS ONLY WITH THE CUSTOMER MENTIONED IN THISCERTIFICATE, AHMSA WILL ONLY ACCEPT THE ORIGINAL DOCUMENT.

CC-03-F-01-A

TR No. 9-1002-15-2

15-053

DELTA STEEL

Texas Tubular Products

P.O. Box 0388, F.M. 250 North, Lone Star, TX 75668 **Material Test Report**

Print Date: 4/27/2016

Page 5 of 8

Results relate only to items tested. Test report not to be reproduced except in it's entirety.

In accordance with EN 10204 - Type 3.1

Sold To:

DELTA STEEL INC
2000 N 170TH E AVE.
TULSA OK 74116

Mtr#: 4686

Customer Order Number: DHO-146395

Date: 4/27/2016

Product: 4.5 .188 8.67#

Specification: ASTM A500/A500M-13 Grade B, ERW

Melted and Manufactured in the U.S.A.

Chemical Analysis, % (Heat Analysis)

Heat Number	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V
A514783	0.2	0.46	0.014	0.005	0.03	0.08	0.03	0.06	0.01	0.005

Mechanical Properties

			Yield	Tensile	Elong %	Hydrotest 5 sec. hold	Flattening	UT N10 Notch
Test	Dir	Loc	KSI (0.2% offset)	KSI	in 2"	PSI		
1	L	B	64.1	74.8	27	N/A	PASSED	N/A
2	T	B						
3	T	W						

WE HEREBY VERIFY THAT THE ABOVE INFORMATION IS CORRECT AS CONTAINED IN THE RECORDS OF TEXAS TUBULAR PRODUCTS

By:

Vice-President Friedman Industries Inc.
Texas Tubular Products Division

TTFM-052/0 01/04/10

ROUND TUBING
E.R.W. A-500 GR B
6/ /16

DELTA STEEL, INC.
RIK-MAR FABRICATORS, INC.
Heat No. A514783
Doc No. 142042 Indexed 28-Apr-16 by cdaughen

PO/Rel: 16-18774 / THANKS VINCE
B/L: DHO-106985 W/O: DHO-124786-1

Certificate of Mill Test Results
01-Jun-16
Page 1 of 1

2022-06-29

TR No. 9-1002-15-2

92

2022-06-29

TRIPLE S

15-053

TUBING, PURLINS & SHAPES

PROLAMSA

www.prolamsausa.com

CERTIFICADO DE CALIDAD / MILL TEST REPORT

CLIENTE / SOLD TO	DESTINATARIO/SHIP TO	FACTURA/INVOICE
Triple S Steel Supply Co. PO Box 21119 Houston TX C.P.77226	Triple S - Irvington Whs 8411 Irvington Houston TX C.P. 77022	1200060678 FECHA/DATE 11/17/2015

O.C./ P.O.	PEDIDO/ ORDER	ROLLO/ COIL	LOTE/ PACKAGE	CODIGO/ CODE	DESCRIPCION DEL MATERIAL/ MATERIAL DESCRIPTION	LONGITUD/ LENGTH	ANALISIS %C	%Mn	%P	%S	%SI
HOU-167987	30039108-20	0011069329	0011130578	301666	RECT 6.00X2.00 0.2500 HGB STK 40.00	40.000 Feet	0.1644	0.9529	0.0128	0.0056	0.0214
HOU-167987	30039108-30	0010697386	0011022855	306201	SQR 2.000 0.2500 HGB STK 20.00	20.000 Feet	0.1560	0.9481	0.0241	0.0083	0.0147
HOU-167987	30039108-30	0010697386	0011022845	306201	SQR 2.000 0.2500 HGB STK 20.00	20.000 Feet	0.1560	0.9481	0.0241	0.0083	0.0147
HOU-167987	30039108-50	0011029598	0011068029	306204	SQR 2.000 0.2500 HGB STK 40.00	40.000 Feet	0.1693	0.9487	0.0152	0.0076	0.0138
HOU-167987	30039108-50	0011029616	0011067482	306204	SQR 2.000 0.2500 HGB STK 40.00	40.000 Feet	0.1693	0.9487	0.0152	0.0076	0.0138
HOU-167987	30039108-50	0011029598	0011067776	306204	SQR 2.000 0.2500 HGB STK 40.00	40.000 Feet	0.1693	0.9487	0.0152	0.0076	0.0138
HOU-167987	30039108-60	0011063615	0011119741	300552	SQR 3.000 0.2500 HGB STK 24.00	24.000 Feet	0.1483	0.9245	0.0194	0.0076	0.0145

O.C./ P.O.	PEDIDO/ ORDER	ROLLO/ COIL	LOTE/ PACKAGE	PROPIEDADES FISICAS/ MECHANICAL PROPERTIES DUREZA/ (HRB)	TENSION/ TENSILE (ksi)	CEDENCIA/ YIELD (ksi)	ELONGACION/ ELONGATION(%)	ESTANDAR/ STANDAR	COLADA/ HEAT	HECHO / MADE
HOU-167987	30039108-20	0011069329	0011130578	85	80	65	25	A500 HR-B HR Gr	257593	Made in Mexico
HOU-167987	30039108-30	0010697386	0011022855	86	81	67	25	A500 HR-B HR Gr	255130	Made in Mexico
HOU-167987	30039108-30	0010697386	0011022845	86	81	67	25	A500 HR-B HR Gr	255130	Made in Mexico
HOU-167987	30039108-50	0011029598	0011068029	82	77	63	25	A500 HR-B HR Gr	257232	Made in Mexico
HOU-167987	30039108-50	0011029616	0011067482	82	77	63	25	A500 HR-B HR Gr	257232	Made in Mexico
HOU-167987	30039108-50	0011029598	0011067776	82	77	63	25	A500 HR-B HR Gr	257232	Made in Mexico
HOU-167987	30039108-60	0011063615	0011119741	85	73	60	29	A500 HR-B HR Gr	257582	Made in Mexico

Imprimió/Printed by: Info. Prolamsa 11/17/2015 19:51:51 Pág:1/ 1

Emitted by: Luis de Alvarado
Coord. De Laboratorio

RECTANGULAR TUBING A500 GR B
6X2X 1/4 X 40

TR No. 9-1002-15-2

15-053

TRIPLES

DEACERO

EXCELENCIA EN CALIDAD

Acería Ramos Arizpe
CARRETERA MONCLOVA KM 4 NUMERO 2125, TRA
C.P./ZIP RAMOS ARIZPE, COAHUILA
Tel/Phone (+52) 01 818 368 1111
MX 01 800 021 3322, USA 1800 332 2376

/ CERTIFICATE OF TEST AN ANALYSIS

No. Certificado / Certificate No:	62598 - 20356715
Fecha / Date:	22/02/2016

Hecho en México / Made in Mexico

DATOS DEL CLIENTE / SOLD TO		CLIENTE CONSIGNADO / SHIP TO		DATOS DEL EMBARQUE / SHIPPING INFORMATION
Cliente / Customer: DEACERO USA, INC. (HOUSTON)		Cliente / Customer: DEACERO USA INC (HOUSTON DISTRIBUTION CENTER)		Núm. Viaje / Travel No: 62598
Dirección / Address: 8411 IRVINGTON BLVD		Dirección / Address: 1755 FEDERAL RD		Núm. Factura / Invoice No: FQ34981
Ciudad / City: HOUSTON	Estado / State: , TX	Ciudad / City: HOUSTON	Estado / State: , TX	Pedido / Customer Order No: 2035 715
Teléfono / Phone: 332 2376	País / Country: U.S.A. C.P./ZIP 77022-3			Núm. Plan / Shipping Plan: 67442
Correo Electrónico / eMail:				Fecha Embarque / Date: 11/02/2016
				Orden de Compra / Purchase Order:

COMPOSICIÓN QUÍMICA / CHEMICAL COMPOSITION (% PESO / WEIGHT)

Colada / Heat	Secuencia / Sequence	Clave / Code	Producto / Description of Goods	% C AVG	% Mn AVG	% Si AVG	% P AVG	% S AVG	% Cu AVG	% Cr AVG	% Ni AVG	% Mo AVG	% Sn AVG	% Ti AVG	% V AVG	% Nb AVG	% N AVG	CE AVG
79166	146001	60671	SQUARE BAR 5/8" A-36 20' 2.0T	0.23	0.55	0.14	0.005	0.012	0.19	0.0836	0.0842	0.0198	0.0279	0.0011	0.0030	0.0000	0.0000	0.3434
13661	22509	63335	FLAT BAR 2" x 1/2" A36/529-50 20' 2.0T	0.20	0.72	0.18	0.013	0.010	0.19	0.0945	0.0750	0.0230	0.0100	0.0008	0.0034	0.0014	0.0094	0.3428
13662	22508	63335	FLAT BAR 2" x 1/2" A36/529-50 20' 2.0T	0.21	0.71	0.18	0.011	0.009	0.19	0.0835	0.0755	0.0230	0.0115	0.0007	0.0040	0.0020	0.0082	0.3525
10675	19789	63181	FLAT BAR 3" x 5/8" A36/529-50 20' 2.0T	0.21	0.95	0.22	0.006	0.005	0.10	0.0570	0.0470	0.0095	0.0060	0.0100	0.0144	0.0120	0.0092	0.3844
13516	22431	79035	FLAT BAR 6" x 1/4" A36/529-50 20' 2.0T	0.21	0.90	0.18	0.010	0.009	0.10	0.0570	0.0535	0.0165	0.0070	0.0092	0.0150	0.0088	0.0096	0.3725
13500	22365	10702	FLAT BAR 8" x 3/8" A36/529-50 20' 2.0T	0.23	0.93	0.21	0.009	0.006	0.08	0.0520	0.0400	0.0130	0.0060	0.0120	0.0149	0.0098	0.0088	0.3929

PROPIEDADES MECÁNICAS / MECHANICAL PROPERTIES

Colada / Heat	Secuencia / Sequence	Clave / Code	Producto / Description of Goods	Calibre / Diameter	Cantidad / Bundle	RT kg/mm²	TS PSI	% Elong / Elong	LF kg/mm²	YS PSI	P. Doblez / Bend Test
[redacted]						AVG	AVG	AVG	AVG	AVG	
79166	146001	60671	SQUARE BAR 5/8" A-36 20' 2.0T	5/8"	10	49.86	70950.78	26.11	34.30	48808.90	Cumple / Successfully
13661	22509	63335	FLAT BAR 2" x 1/2" A36/529-50 20' 2.0T	2" x 1/2"	3	52.39	74550.97	29.63	35.34	50288.82	Cumple / Successfully
13662	22508	63335	FLAT BAR 2" x 1/2" A36/529-50 20' 2.0T	2" x 1/2"	7	51.82	73739.86	28.64	36.27	51612.21	Cumple / Successfully
10675	19789	63181	FLAT BAR 3" x 5/8" A36/529-50 20' 2.0T	3" x 5/8"	2	51.79	73697.17	32.95	37.98	54045.54	Cumple / Successfully
13516	22431	79035	FLAT BAR 6" x 1/4" A36/529-50 20' 2.0T	6" x 1/4"	8	55.30	78691.90	34.25	39.30	55923.90	Cumple / Successfully
13500	22365	10702	FLAT BAR 8" x 3/8" A36/529-50 20' 2.0T	8" x 3/8"	8	51.07	72672.61	34.31	36.60	52081.80	Cumple / Successfully

93

Certificamos que este material ha sido producido, inspeccionado y probado de acuerdo a las normas de fabricación del acero aplicables a la ASTM A36-2008, A529-2005 (re aprobada el 2009), A572-2012 y A992-2011 y a las normas dimensionales NMX B252, ASTM A6/A6M-2012. / We certify that this material has been produced hot-rolled carbon, inspected and tested according to standards applicable steelmaking to ASTM A36-2008, A529-2005 (Reapproved 2009), A572-2012 y A992-2011, and the dimensional standards NMX B252, ASTM A6/A6M-2012.

DEACERO +VERDE

SQUARE BAR A-36 5/8 X 20'
5/31/16

FRANCISCO JAVIER VARGAS SOTO
Gerente de Aseguramiento de Calidad / Quality Assurance Manager

2022-06-29

TRIPLE S 15-053

GERDAU

CA-ML-CAMBRIDGE
160 ORION PLACE
CAMBRIDGE, ON N1T 1R9
Canada

CERTIFIED MATERIAL TEST REPORT

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CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE
TRIPLE S STEEL SUPPLY 6000 JENSEN DR HOUSTON,TX 77026-1113 USA	TRIPLE S STEEL 6000 JENSEN DR HOUSTON,TX 77226-1119 USA	GGMULTI	Flat / 5/16 X 2

LENGTH	WEIGHT	HEAT / BATCH
20'00"	5,112 LB	52069747/05

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
2696421/000030		

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
HOU-166824	1301-0000018869	08/28/2015

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	V %	Nb %
0.08	1.16	0.014	0.040	0.21	0.26	0.08	0.11	0.026	0.023	0.001

MECHANICAL PROPERTIES

Elong. %	G/L Inch	UTS PSI	UTS MPa	YS PSI	YS MPa
22.00	8.000	71771	495	50150	346
20.00	8.000	73509	507	51521	355

COMMENTS / NOTES

This grade meets the requirements for the following grades:
ASTM Grades: A36; A529-50; A572-50; A709-36; A709-50
CSA Grades: 44W; 50W
AASHTO Grades: M270-36; M270-50
ASME Grades: SA36

A-36 FLAT BAR. 5/16 x 2 x 20'

5/31/16

The above figures are certified chemical and physical test records as contained in the permanent records of company. We certify that these data are correct and in compliance with specified requirements. This material, including the billets, was melted and manufactured in Canada. CMTR complies with EN 10204 3.1.

Bhaskar
BHASKAR YALAMANCHILI
QUALITY DIRECTOR

MANNY ROCILLO
QUALITY ASSURANCE MGR.

TRIPLE S

15-053

PERFILES COMERCIALES SIGOSA S.A. DE . C.V.

Calzada Vallejo No. 1361 Local H. Nueva Industrial Vallejo Mexico, D.F. C.P. 07700
Almacén Matamoros Tel. (868)150-1900 al 29 Fax. (868)150-19-53 y 54

Certificado de Calidad de Pruebas Físicas y Químicas
(Mill Test Report)

P.O 170129

Información del Cliente / Client Information : | **Orden / Order:41166** | **Certificado / Certificate: B41075**

TRIPLE S STEEL SUPPLY CO.

* 0 0 0 0 B 4 1 0 7 5 *

Fecha / Date:21/04/2016 18:08 PM
Fecha Impresión / Print Date:21/04/2016 18:11 PM

SERIE SERIAL	PRODUCTO PRODUCT	COLADA HEAT	GRADO GRADE	*LE *YS	*UT *TS	PE %EL	LE/UT (YS/TS)	C	Mn	Si	P	S	Cu	Cr	Ni	Mo	Sn	V	Nb	Al	CEQ
1201511252018	SOL 20ft 1-1/2x3/8	000000152482	A36/A529-50	51245	73521	30	0.7	.168	.859	.149	.011	.028	.22	.052	.086	.033	.015	.001	.008	.001	.376
1201511252009	SOL 20ft 1-1/2x3/8	000000152482	A36/A529-50	51245	73521	30	0.7	.168	.859	.149	.011	.028	.22	.052	.086	.033	.015	.001	.008	.001	.376
1201511252004	SOL 20ft 1-1/2x3/8	000000152482	A36/A529-50	51245	73521	30	0.7	.168	.859	.149	.011	.028	.22	.052	.086	.033	.015	.001	.008	.001	.376
1201511252005	SOL 20ft 1-1/2x3/8	000000152482	A36/A529-50	51245	73521	30	0.7	.168	.859	.149	.011	.028	.22	.052	.086	.033	.015	.001	.008	.001	.376
1201512163031	ANG 20ft 1x1x1/8	000000152560	A36/A529-50	51300	72500	29	0.71	.162	.82	.161	.016	.02	.287	.131	.095	.019	.012	.001	.001	.002	.381
1201512163035	ANG 20ft 1x1x1/8	000000152560	A36/A529-50	51300	72500	29	0.71	.162	.82	.161	.016	.02	.287	.131	.095	.019	.012	.001	.001	.002	.381
1201512163032	ANG 20ft 1x1x1/8	000000152560	A36/A529-50	51300	72500	29	0.71	.162	.82	.161	.016	.02	.287	.131	.095	.019	.012	.001	.001	.002	.381
1201512163038	ANG 20ft 1x1x1/8	000000152560	A36/A529-50	51300	72500	29	0.71	.162	.82	.161	.016	.02	.287	.131	.095	.019	.012	.001	.001	.002	.381
1201512153021	ANG 20ft 1x1x1/8	000000152455	A36/A529-50	51800	71600	36	0.72	.166	.82	.164	.011	.022	.29	.081	.092	.025	.017	.001	.005	.002	.377

5/31/16
FLAT BAR A-36/GR 50 - 3/8 X 1½ x 20

'Las unidades expresadas en L.E. y U.T son en PSI. La composición química esta expresada en % en peso.
'The units expressed in L.E and U.T are in PSI. The chemical composition is expressed in % in weight.

Certificamos que el producto aquí descrito, cumple y ha sido fabricado, muestreado, probado e inspeccionado de acuerdo con los requisitos aplicables de la especificación:
ASTM A6/ A6 M-13 a (2014); A529 / A529M; ASME SA-6/SA-6M.

We certify that the product above mentioned accomplishes and has been manufactured, sampled, tested and inspected in accordance with applicable requirements of specifications:
ASTM A6/ A6 M-13 a (2014); A529 / A529M; ASME SA-6/SA-6M.

Gerente de Aseguramiento de Calidad

En SIGOSA, SA DE CV nos comprometemos a satisfacer las expectativas y requerimientos de nuestros clientes, Mediante un sistema de Gestión de Calidad, la mejora continua de nuestro productos, el uso eficiente de los recursos, y la participación individual y de equipo de todo su personal.

~~TRIPLE S~~ 15-053

GERDAU

US-ML-CHARLOTTE
6601 LAKEVIEW ROAD
CHARLOTTE, NC 28269
USA

CERTIFIED MATERIAL TEST REPORT

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CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
TRIPLE S STEEL SUPPLY 6000 JENSEN DR HOUSTON,TX 77026-1113 USA	TRIPLE S STEEL 6000 JENSEN DR HOUSTON,TX 77226-1119 USA	GGMULTI	Angle / 2X1 1/2X3/16	0000002412
		LENGTH: 20'00"	WEIGHT: 2,968 LB	HEAT / BATCH: 54149200/03

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
3558760/000020		ASTM A529-14, A572-15 ASTM A6-14,A36-14, ASME SA-36 ASTM A709-13A, AASHTO M270-12 CSA G40.20-13/G40.21-13

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
HOU-169975	1321-0000038325	04/05/2016

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	V %	Nb %	Sn %
0.16	0.68	0.014	0.038	0.19	0.34	0.13	0.14	0.040	0.016	0.002	0.015

MECHANICAL PROPERTIES

Elong. %	G/L Inch	UTS PSI	UTS MPa	YS PSI	YS MPa
29.00	8.000	74755	515	55343	382

GEOMETRIC CHARACTERISTICS

R:R
40.00

COMMENTS / NOTES

This grade meets the requirements for the following grades:
ASTM Grades: A36; A529-50; A572-50; A709-36; A709-50
CSA Grades: 44W; 50W
AASHTO Grades: M270-36; M270-50
ASME Grades: SA36

5/31/16
ANGLE A36 GR 50 2x 1½ X 3/16 x20

The above figures are certified chemical and physical test records as contained in the permanent records of company. We certify that these data are correct and in compliance with specified requirements. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

Bhaskar — BHASKAR YALAMANCHILI, QUALITY DIRECTOR

Jordan Foster — JORDAN FOSTER, QUALITY ASSURANCE MGR.

15-053

MATERIAL CERTIFICATION

Date: 4/14/2016
Time: 6:24:06PM

AMERICAN TUBE MANUFACTURING, INC.

Shipper's No. 33944

Customer Information:
Triple S Steel
P.O. Box 21119

Houston, TX 77226

Ship To:
Dallas / Fort Worth Prime Stock
3201 N. Sylvania Avenue BLDG 105
817-222-1603 Shelley
Fort Worth, TX 76111

Shipped Date: 4/14/2016 12:00:00AM

Item Description / Customer Item # / Order Number	Qty Shipped	C	Mn	P	S	Si	Yield Strength	Tensile Strength	Elongation
3.000 x 3.000 x 1/4 x 240	75.00 **HEAT #:**NF1019	0.190	0.870	0.011	0.002	0.027	64866	80777	26
00050197	**Customer PO #:** TXN-3195						Grade: ASTM A500 B/C Rev 10a		
4.000 x 4.000 x 1/4 x 288	48.00 **HEAT #:**NF1619	0.190	0.840	0.009	0.006	0.024	61570	85495	25
00050197	**Customer PO #:** TXN-3195						Grade: ASTM A500 B/C Rev 10a		
4.000 x 4.000 x 1/4 x 288	12.00 **HEAT #:**SF1994	0.190	0.860	0.009	0.002	0.024	61403	81219	27
00050197	**Customer PO #:** TXN-3195						Grade: ASTM A500 B/C Rev 10a		
6.000 x 2.000 x 1/4 x 480	24.00 **HEAT #:**A602083	0.210	0.470	0.014	0.004	0.020	62274	83328	25
00050197	**Customer PO #:** TXN-3195						Grade: ASTM A500 B/C Rev 10a		
6.000 x 4.000 x 1/4 x 576	9.00 **HEAT #:**NF1017	0.200	0.850	0.014	0.003	0.018	58327	78134	30
00050197	**Customer PO #:** TXN-3195						Grade: ASTM A500 B/C Rev 10a		

Comments:
- All items above were Melted and Manufactured in the U.S.A.
- Mercury free.
- The material test results meeting ASTM A500 B and/or B/C Rev 10a also meet the requirements for ASTM A500 B Rev 10 and Rev 13.
- Material that meets A500 B and B/C Rev 10a also meet the requirements for A513.
- Pipe sizes above meet ASTM A53 Grade B Non-Hydro Type E / A500 Grade B tensile requirements only.

171 Cleage Dr. Birmingham, Alabama 35217
(205) 520-0238. 1-800-956-5440 . Fax (205) 520-9573

C:\Users\gwilliams\AppData\Roaming\Wisys\Agility\Docs\MATCERTV6_base.RPT

Independence Tube

6226 W. 74th St
Chicago, IL 60638
708-496-0380
Fax: 708-563-1950

independencetube.com
itctube.com
Certificate Number: MAR 409637

Sold By:
INDEPENDENCE TUBE CORPORATION
6226 W. 74th St.
Chicago, IL 60638
Tel: 708-496-0380
Fax: 708-563-1950

Purchase Order No: DHO-145785
Sales Order No: MAR 302824 - 2
Bill of Lading No: MAR 176204 - 3
Invoice No:

Shipped: 3/1/2016
Invoiced:

Sold To:
413 - DELTA STEEL INC-HOUSTON
P.O. BOX 2289
HOUSTON, TX 77252

Ship To:
1 - DELTA STEEL, INC.
7355 ROUNDHOUSE LANE
HOUSTON, TX 77078

CERTIFICATE of ANALYSIS and TESTS

Customer Part No:

Certificate No: MAR 409637
Test Date: 2/29/2016

ROUND A500 GRADE B(C)
4.000"OD (3.5"NPS)X SCH40 X 42'

Total Pieces	Total Weight
10	3,826

Bundle Tag	Mill	Heat	Specs	Y/T Ratio	Pieces	Weight
6922	6	D01629	YLD=60740/TEN=69760/ELG=34.1	0.8707	10	3,826

Mill #: 6 Heat #: D01629 Carbon Eq: 0.2746 Heat Src Origin: MELTED AND MANUFACTURED IN THE USA

C	Mn	P	S	Si	Al	Cu	Cr	Mo	V	Ni	Nb	Cb
0.1800	0.5200	0.0150	0.0080	0.0100	0.0470	0.0100	0.0300	0.0020	0.0010	0.0100	0.0010	0.0010

Sn	N	B	Ti
0.0030	0.0050	0.0001	0.0010

LEED Information (based on the most recent LEED information from the producing mill)

Method	Location	Recycled Content	Post Consumer	Post Industrial
BOF	Gary Works, IN	36.9%	19.8%	14.4%

Certification:

I certify that the above results are a true and correct copy of records prepared and maintained by Independence Tube Corporation. Sworn this day, 2/29/2016

WE PROUDLY MANUFACTURE ALL OUR PRODUCT IN THE USA.
INDEPENDENCE TUBE PRODUCT IS MANUFACTURED, TESTED, AND INSPECTED IN ACCORDANCE WITH ASTM STANDARDS.
MATERIAL IDENTIFIED AS A500 GRADE B(C) MEETS BOTH ASTM A500 GRADE B AND A500 GRADE C SPECIFICATIONS.

Mihai Popa

Mihai (Mike) Popa, Corporate Metallurgist

CURRENT STANDARDS:
A252-10
A500/A500M-13
A513-13
ASTM A53/A53M-12 | ASME SA-53/SA-53M-13
A847/A847M-14
A1085/A1085M-15

BLACK PLAIN END PIPE
ASTM A-500 GR B
6/2/16

Page - 1

APPENDIX D. *MASH* TEST 4-10 (CRASH TEST NO. 490026-4-1)

D1 VEHICLE PROPERTIES AND INFORMATION

Table D-1. Vehicle Properties for Test No. 490026-4-1.

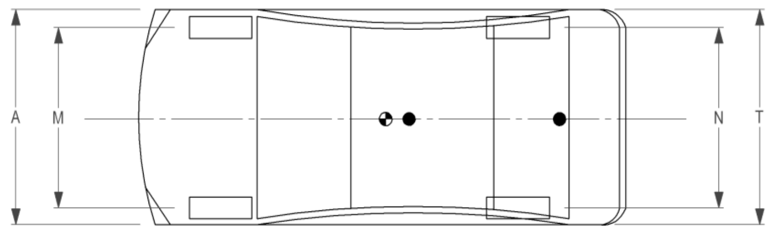
Date: 2016-07-20 Test No.: 490026-4-1 VIN No.: KNADH4A31A6679041

Year: 2010 Make: Kia Model: Rio

Tire Inflation Pressure: 32 psi Odometer: 101244 Tire Size: 185/65R14

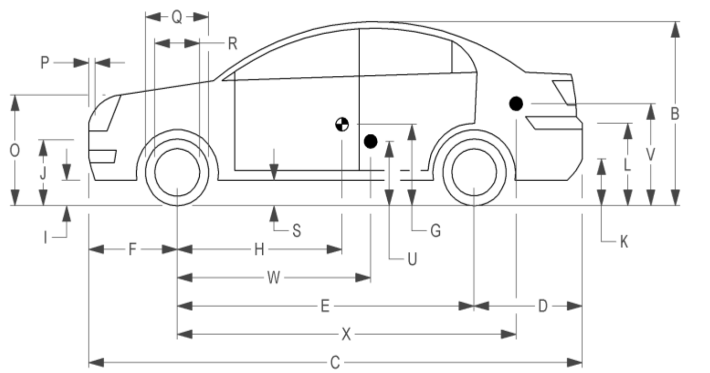
Describe any damage to the vehicle prior to test: None

● Denotes accelerometer location.



NOTES: None

Engine Type: 4 cylinder
Engine CID: 1.6 liter
Transmission Type:
x Auto or ____ Manual
x FWD ____ RWD ____ 4WD
Optional Equipment:
None



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

Geometry: inches

A	66.38	F	33.00	K	10.75	P	4.12	U	15.10
B	57.50	G	-----	L	25.00	Q	22.50	V	20.75
C	165.75	H	35.35	M	57.75	R	15.50	W	35.35
D	34.00	I	7.75	N	57.10	S	7.50	X	102.25
E	97.75	J	21.00	O	28.25	T	66.20		

Wheel Center Ht Front 11.00 Wheel Center Ht Rear 11.00 W-H 0

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1918	M_{front}	1598	1562	1552
Back	1874	M_{rear}	895	871	1046
Total	3638	M_{Total}	2493	2433	2598

Mass Distribution:
lb LF: 770 RF: 792 LR: 445 RR: 426

Table D-2. Exterior Crush Measurements for Test No. 490026-4-1.

Date:	2016-07-20	Test No.:	490026-4-1	VIN No.:	KNADH4A31A6679041
Year:	2010	Make:	Kia	Model:	Rio

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	Front plane at bumper ht	20	12	30	12	---	---	---	---	---	-15
2	Side plane at bumper ht	20	13	52	0	4	4.5	7.5	10.5	13	+50
	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).

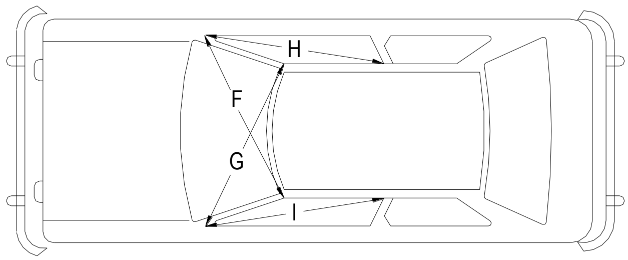
***Measure and document on the vehicle diagram the location of the maximum crush.

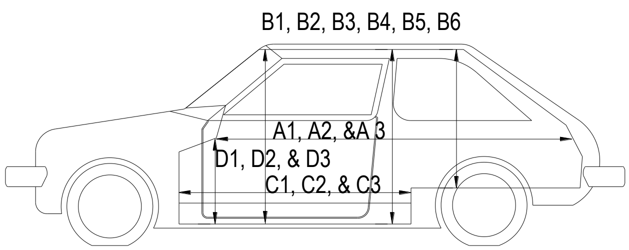
Note: Use as many lines/columns as necessary to describe each damage profile.

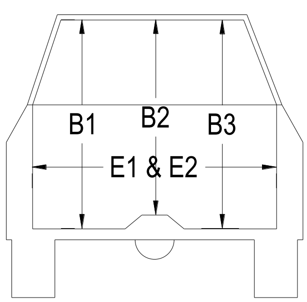
Table D-3. Occupant Compartment Measurements for Test No. 490026-4-1.

Date: 2016-07-20 Test No.: 490026-4-1 VIN No.: KNADH4A31A6679041

Year: 2010 Make: Kia Model: Rio







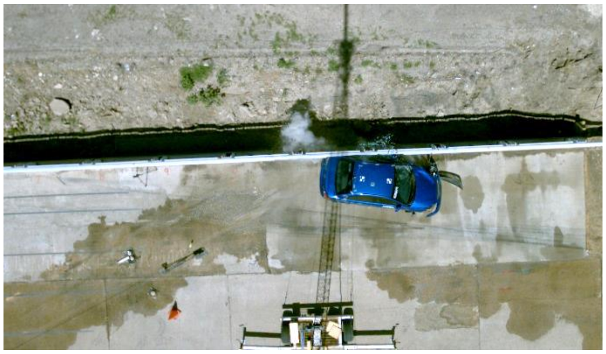
OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before (inches)	**After** (inches)
A1	67.25	67.00
A2	67.25	67.25
A3	67.50	67.50
B1	40.50	38.75
B2	36.75	36.25
B3	40.50	40.00
B4	36.00	36.00
B5	36.00	36.00
B6	36.00	36.00
C1	26.50	22.50
C2	-----	-----
C3	26.50	26.50
D1	9.50	8.00
D2	-----	-----
D3	9.50	9.50
E1	51.50	52.75
E2	51.12	51.75
F	51.00	51.00
G	51.00	51.00
H	36.75	36.75
I	36.75	36.75
J*	51.00	49.50

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

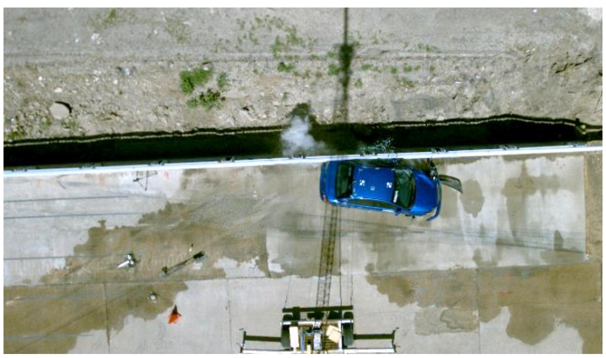
D2 SEQUENTIAL PHOTOGRAPHS

Figure D-1. Sequential Photographs for Test No. 490026-4-1 (Overhead and Frontal Views).

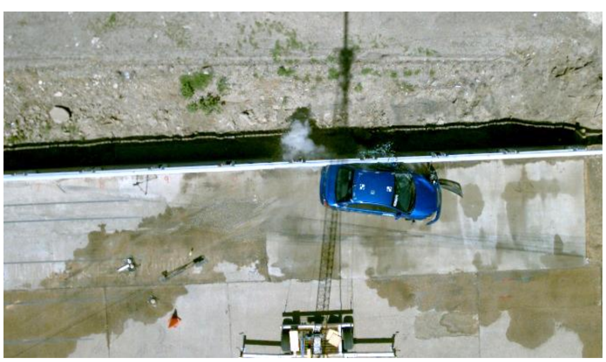


0.240 s

0.300 s



0.360 s



0.420 s

Figure D-1. Sequential Photographs for Test No. 490026-4-1 (Overhead and Frontal Views) (Continued).

0.000 s

0.060 s

0.120 s

0.180 s

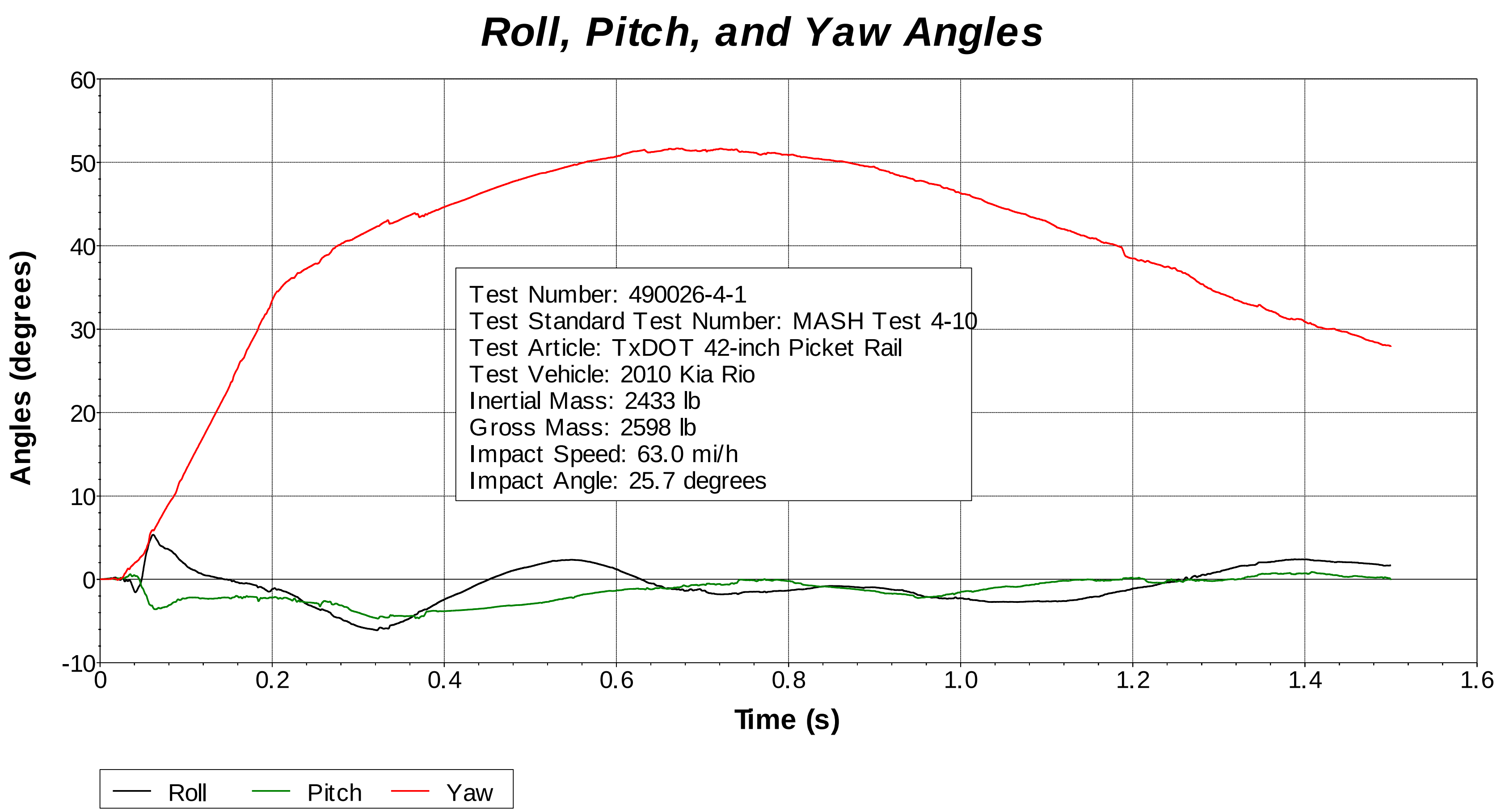
0.240 s

0.300 s

0.360 s

0.420 s

Figure D-2. Sequential Photographs for Test No. 490026-4-1 (Rear View).



Axes are vehicle-fixed.
Sequence for determining orientation:

1. Yaw.
2. Pitch.
3. Roll.

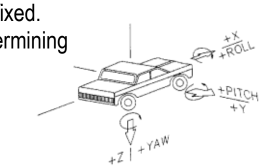


Figure D-3. Vehicle Angular Displacements for Test No. 490026-4-1.

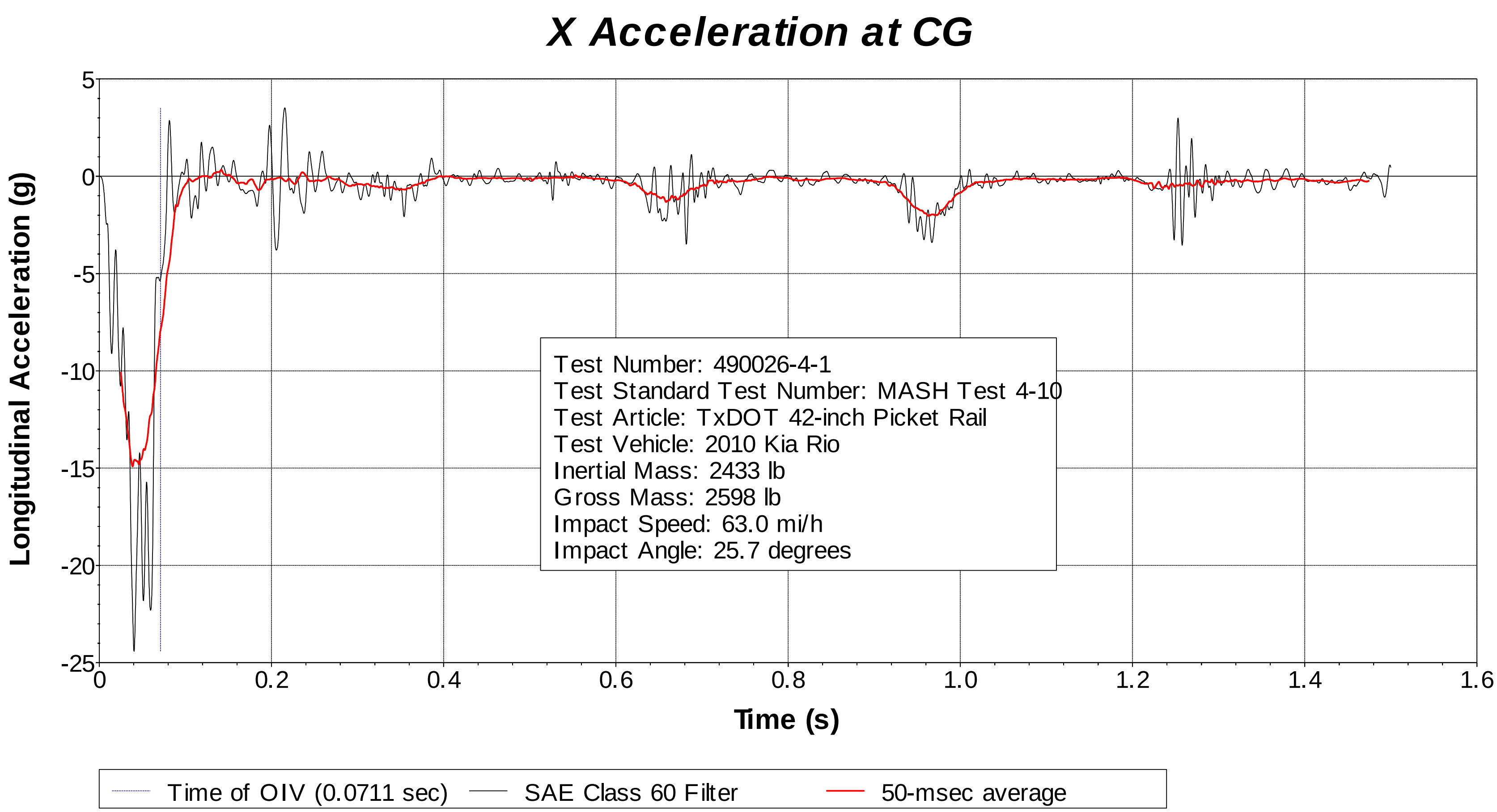


Figure D-4. Vehicle Longitudinal Accelerometer Trace for Test No. 490026-4-1 (Accelerometer Located at Center of Gravity).

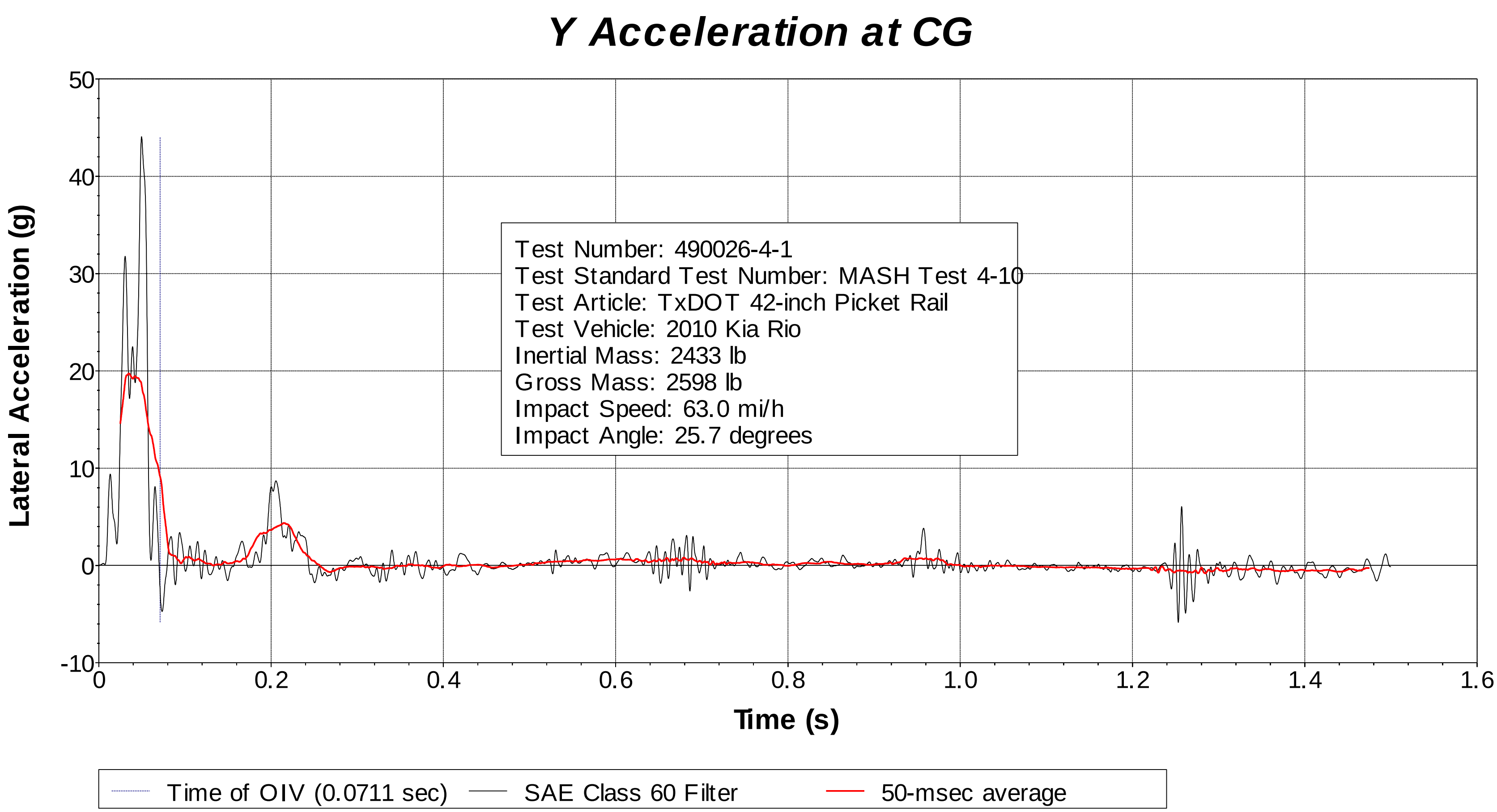


Figure D-5. Vehicle Lateral Accelerometer Trace for Test No. 490026-4-1 (Accelerometer Located at Center of Gravity).

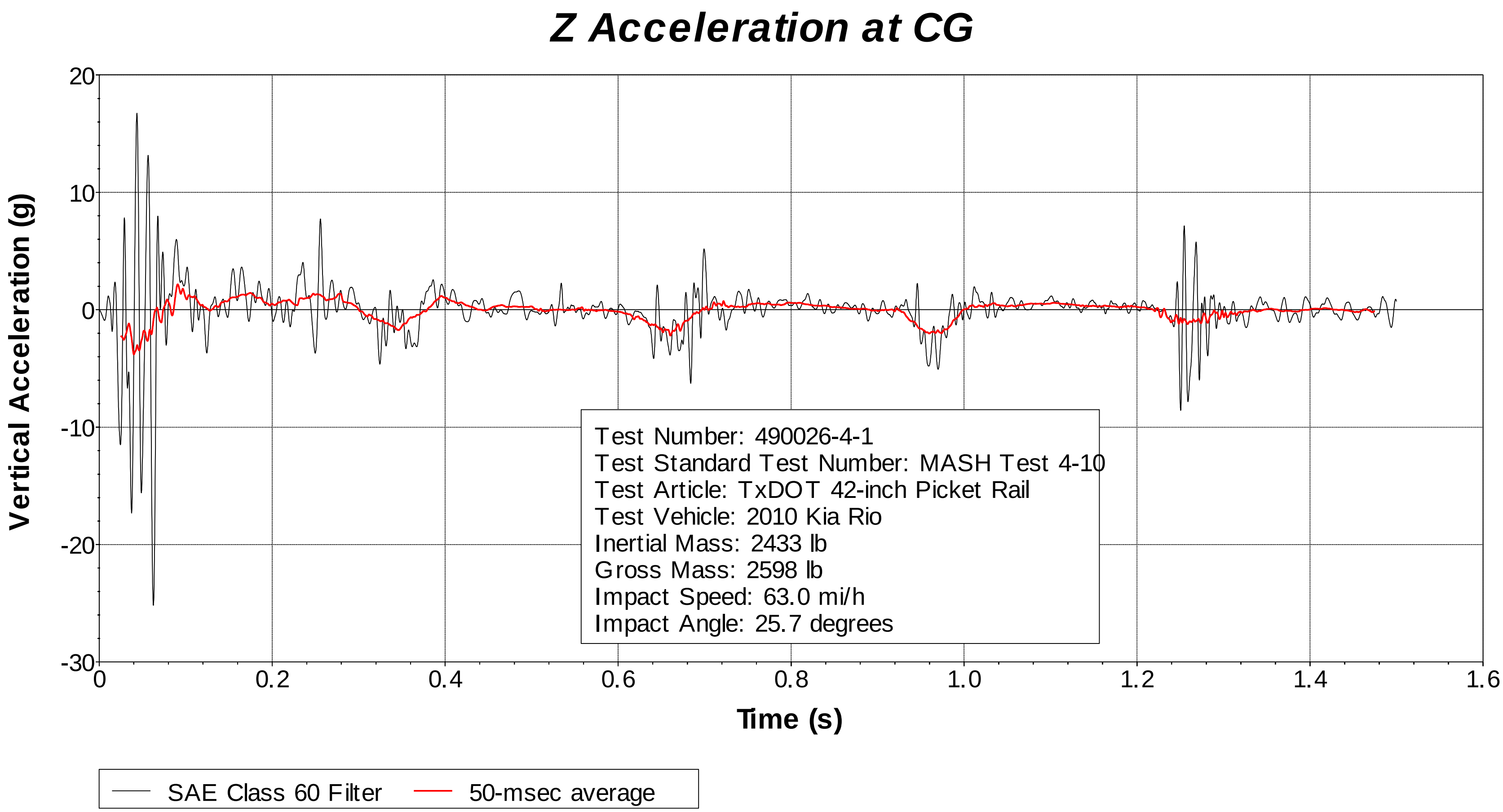


Figure D-6. Vehicle Vertical Accelerometer Trace for Test No. 490026-4-1 (Accelerometer Located at Center of Gravity).

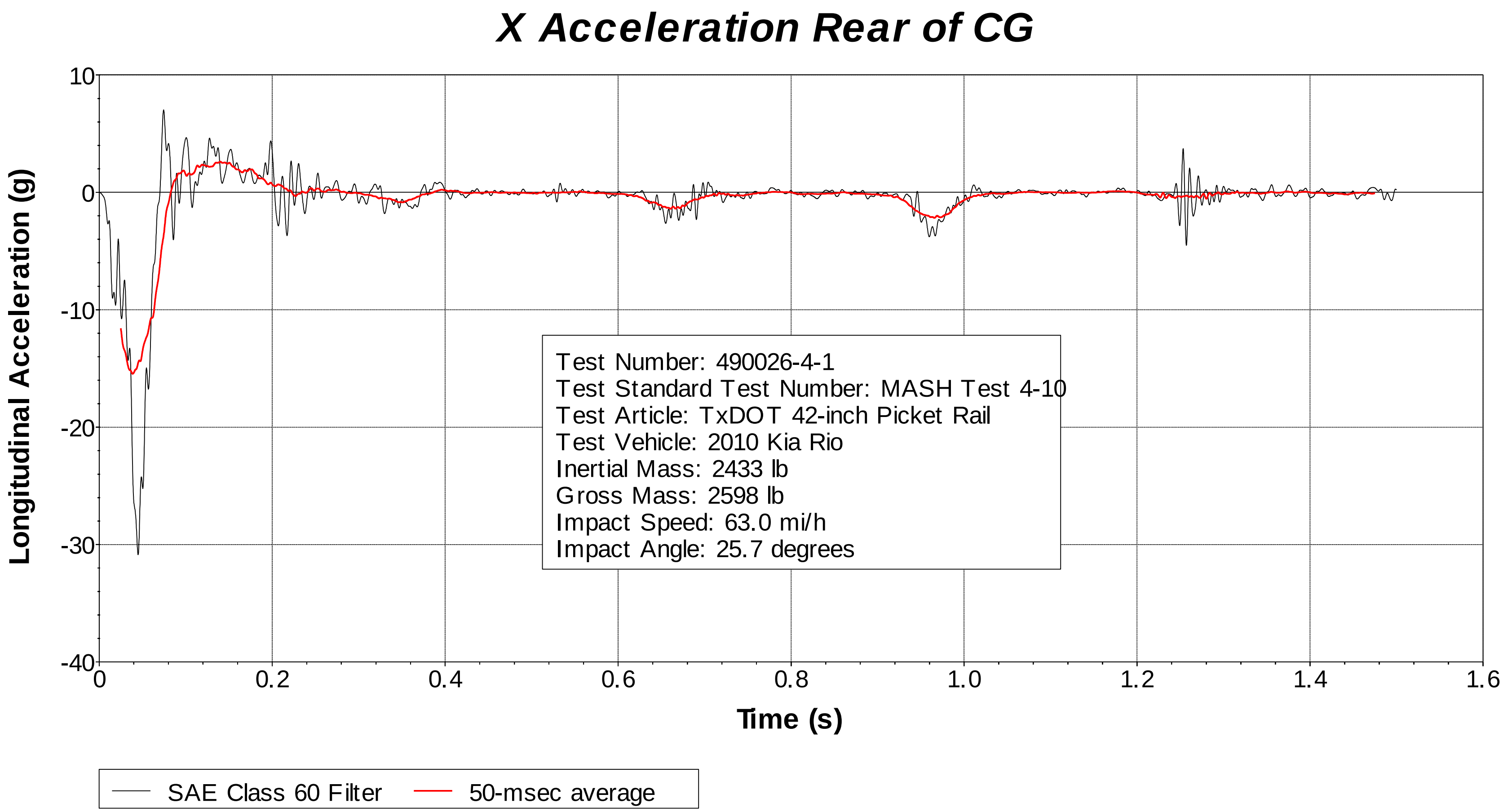


Figure D-7. Vehicle Longitudinal Accelerometer Trace for Test No. 490026-4-1 (Accelerometer Located Rear of Center of Gravity).

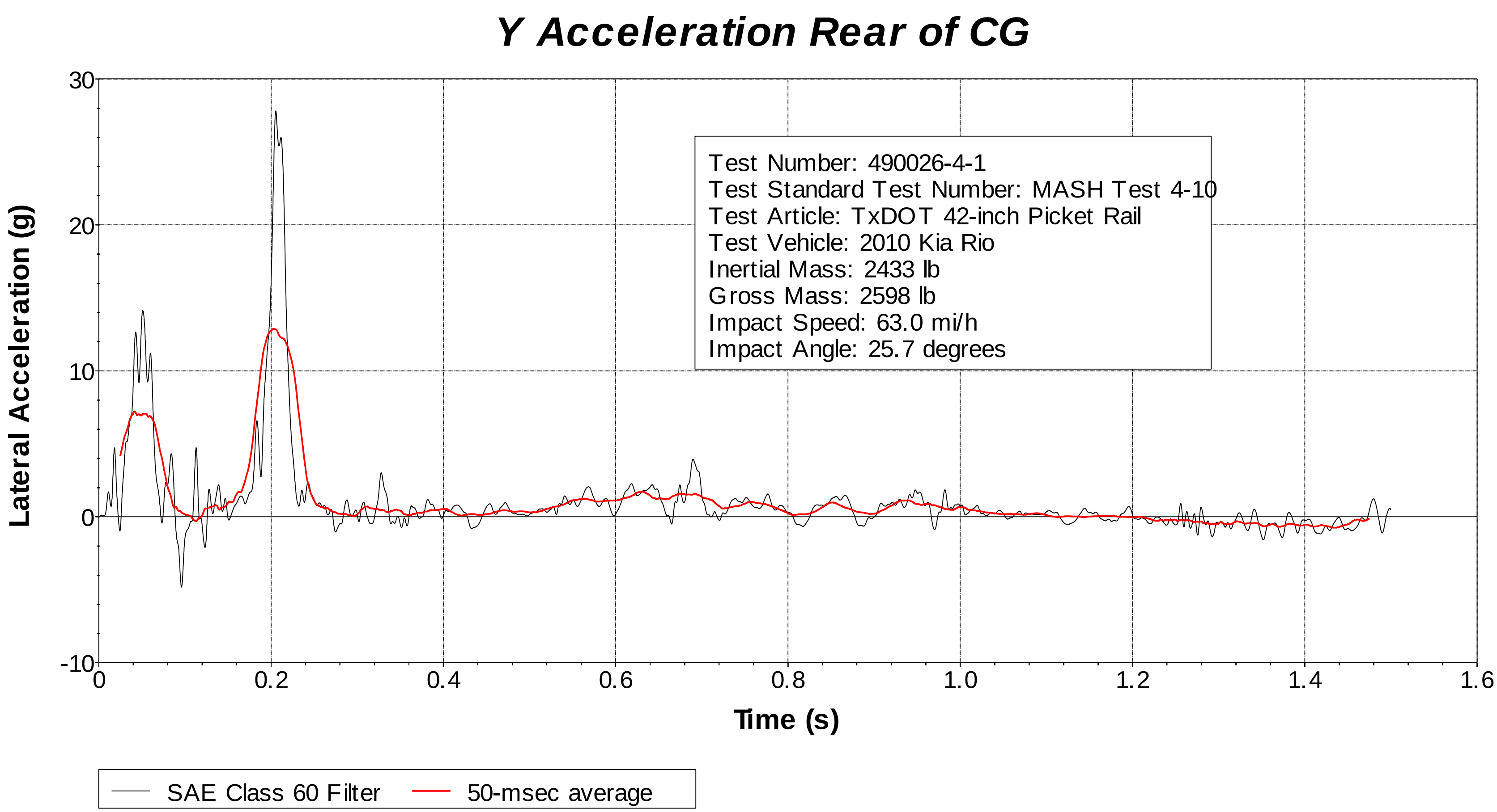


Figure D-8. Vehicle Lateral Accelerometer Trace for Test No. 490026-4-1 (Accelerometer Located Rear of Center of Gravity).

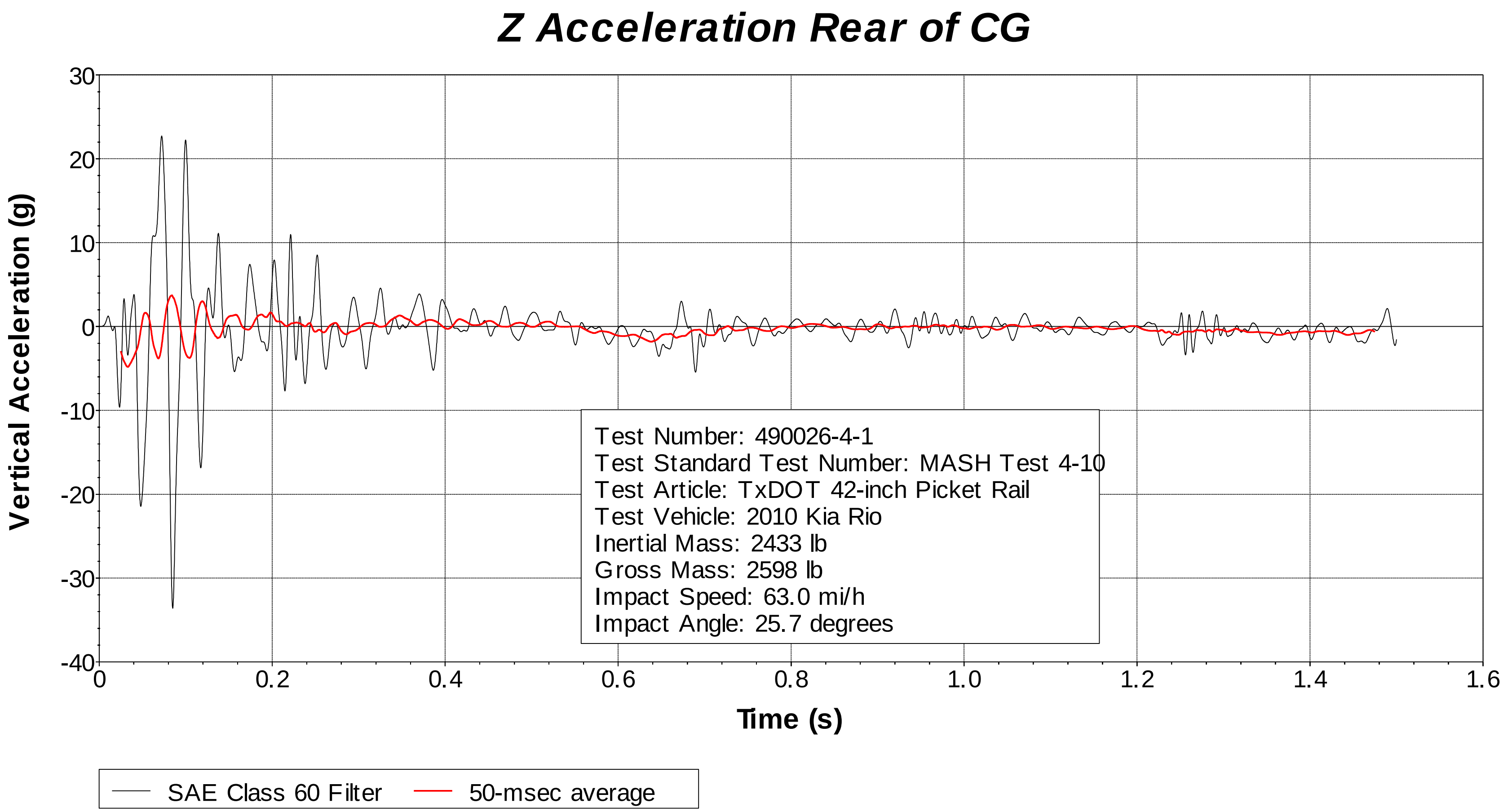


Figure D-9. Vehicle Vertical Accelerometer Trace for Test No. 490026-4-1 (Accelerometer Located Rear of Center of Gravity).

APPENDIX E. *MASH* TEST 4-11 (CRASH TEST NO. 490026-4-2)

E1 VEHICLE PROPERTIES AND INFORMATION

Table E-1. Vehicle Properties for Test No. 490026-4-2.

Date: 2016-07-13 Test No.: 490026-4-2 VIN No.: 1D7RB16P1B5550752

Year: 2011 Make: Dodge Model: RAM 1500

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

Tread Type: Highway Odometer: 120216

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

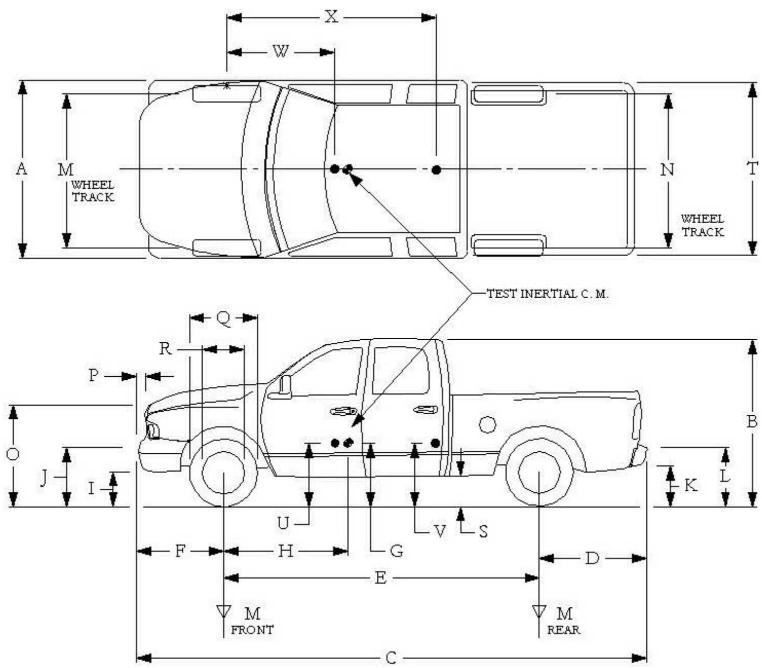
NOTES: None

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



Geometry: inches

A	78.50	F	41.50	K	20.00	P	3.00	U	26.75
B	75.00	G	28.30	L	29.25	Q	30.50	V	29.50
C	231.00	H	62.20	M	68.50	R	18.00	W	62.20
D	49.50	I	11.75	N	68.00	S	13.00	X	78.45
E	140.50	J	26.00	O	45.50	T	77.00		

Wheel Center Height Front	14.75	Wheel Well Clearance (Front)	6.00	Bottom Frame Height - Front	17.50
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	9.25	Bottom Frame Height - Rear	25.50

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2874	2813	2898
Back	3900	M_{rear}	2037	2235	2315
Total	6700	M_{Total}	4911	5048	5213

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

Mass Distribution:
lb LF: 1415 RF: 1398 LR: 1118 RR: 1117

Table E-2. Measurements of Vehicle Vertical CG for Test No. 490026-4-2.

Date: 2016-07-13 Test No.: 490026-4-2 VIN: 1D7RB16P1B5550752

Year: 2011 Make: Dodge Model: RAM 1500

Body Style: Quad Cab Mileage: 120216

Engine: 4.7 liter V-8 Transmission: Automatic

Fuel Level: Empty Ballast: 212 lb (440 lb max)

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

Measured Vehicle Weights: (lb)							
LF:	1415		RF:	1398		Front Axle:	2813
LR:	1118		RR:	1117		Rear Axle:	2235
Left:	2533		Right:	2515		Total:	5048
						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:	62.21	inches	Rear of Front Axle	(63 ±4 inches allowed)			
Y:	-0.12	inches	Left - Right +	of Vehicle Centerline			
Z:	28.3	inches	Above Ground	(minumum 28.0 inches allowed)			

Hood Height: 45.50 inches Front Bumper Height: 26.00 inches
43 ±4 inches allowed

Front Overhang: 41.50 inches Rear Bumper Height: 29.25 inches
39 ±3 inches allowed

Overall Length: 231.00 inches
237 ±13 inches allowed

Table E-3. Exterior Crush Measurements for Test No. 490026-4-2.

Date: 2016-07-13 Test No.: 490026-4-2 VIN No.: 1D7RB16P1B5550752

Year: 2011 Make: Dodge Model: RAM 1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	Front plane at bumper ht	20	11	25	11	7	3	2.5	2	0	-12.5
2	Side plane at bumper ht	20	13	70	1	2	6.25	8	10	13	+70
	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).

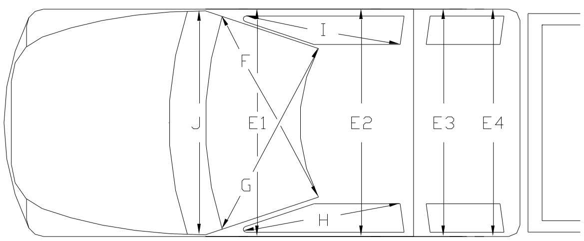
***Measure and document on the vehicle diagram the location of the maximum crush.

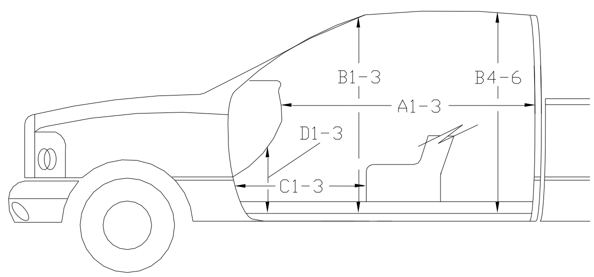
Note: Use as many lines/columns as necessary to describe each damage profile.

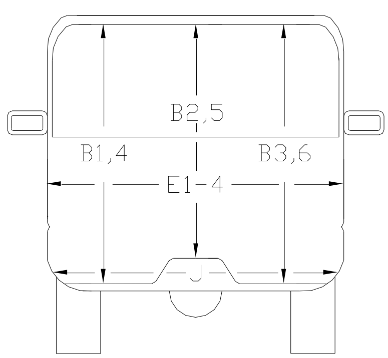
Table E-4. Occupant Compartment Measurements for Test No. 490026-4-2.

Date: 2016-07-13 Test No.: 490026-4-2 VIN No.: 1D7RB16P1B5550752

Year: 2011 Make: Dodge Model: RAM 1500







OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before (inches)	**After** (inches)
A1	65.25	63.00
A2	63.25	63.25
A3	65.25	65.25
B1	44.75	44.75
B2	38.00	38.00
B3	44.75	44.75
B4	39.50	39.50
B5	43.00	43.00
B6	39.50	39.50
C1	28.00	27.00
C2	-----	-----
C3	25.25	25.25
D1	11.25	11.25
D2	-----	-----
D3	11.25	11.25
E1	58.75	61.75
E2	63.50	65.50
E3	63.50	63.50
E4	63.25	63.25
F	59.00	59.00
G	59.00	59.00
H	37.00	37.00
I	37.00	37.00
J*	23.50	21.50

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

E2 SEQUENTIAL PHOTOGRAPHS

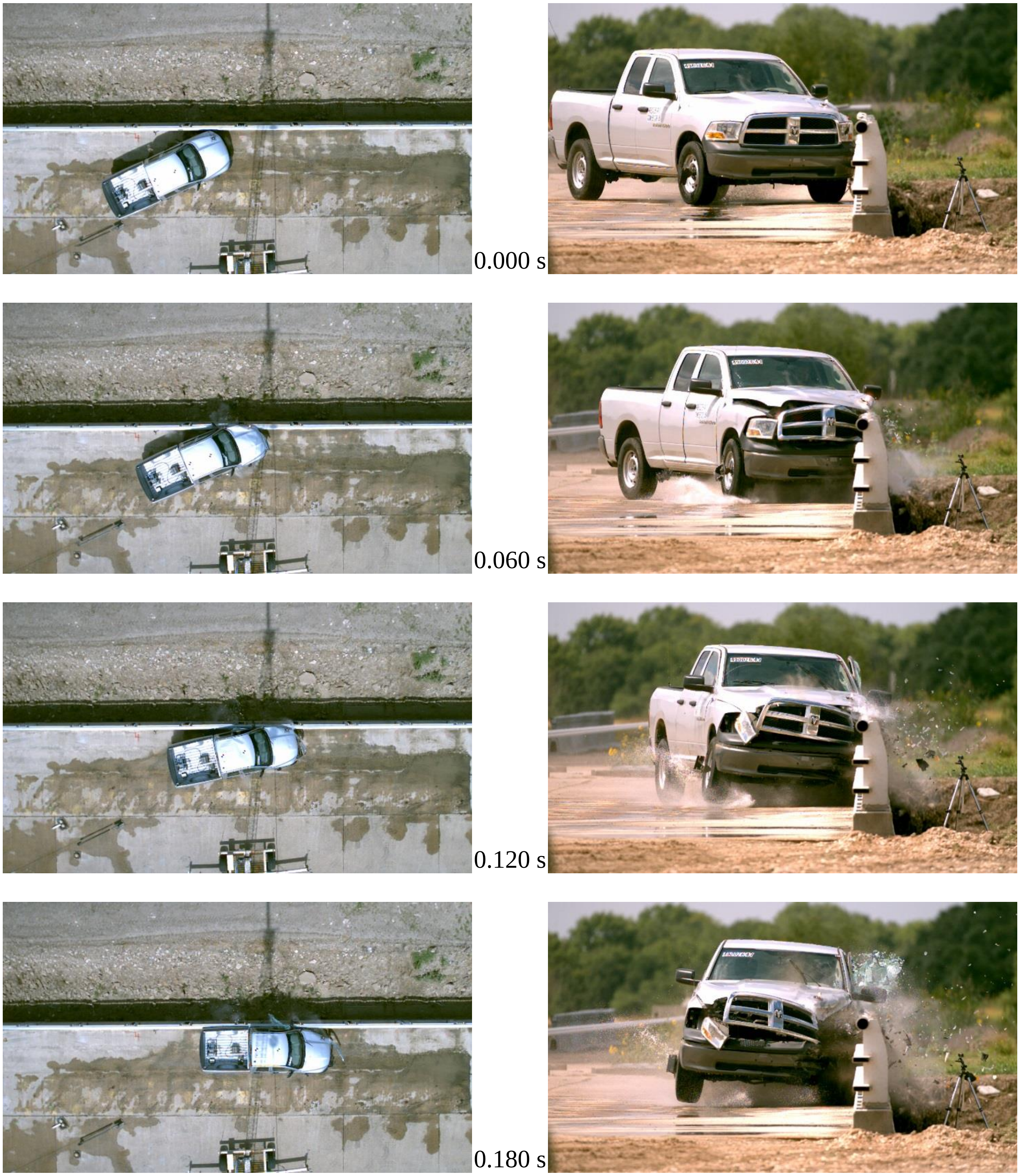


Figure E-1. Sequential Photographs for Test No. 490026-4-2 (Overhead and Frontal Views).


0.240 s



0.300 s



0.360 s

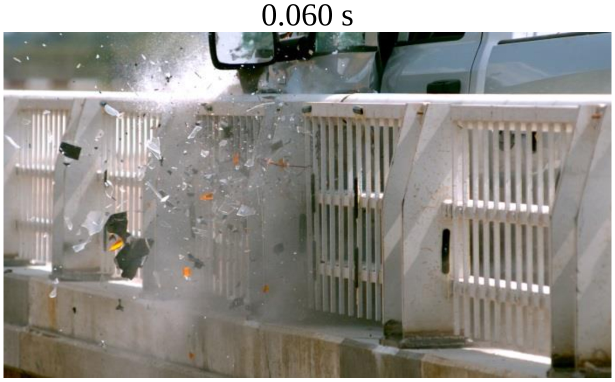


0.420 s


Figure E-1. Sequential Photographs for Test No. 490026-4-2 (Overhead and Frontal Views) (Continued).


0.000 s

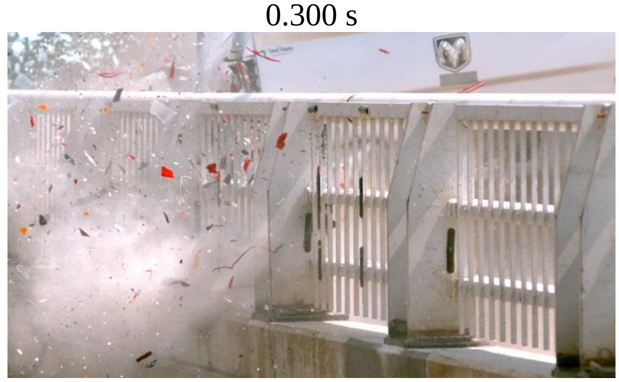

0.060 s


0.120 s


0.180 s


0.240 s


0.300 s


0.360 s

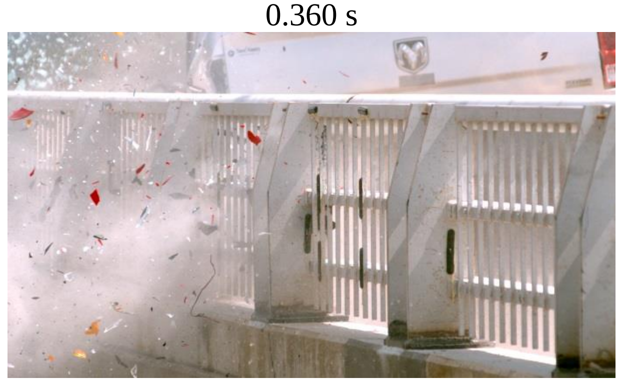
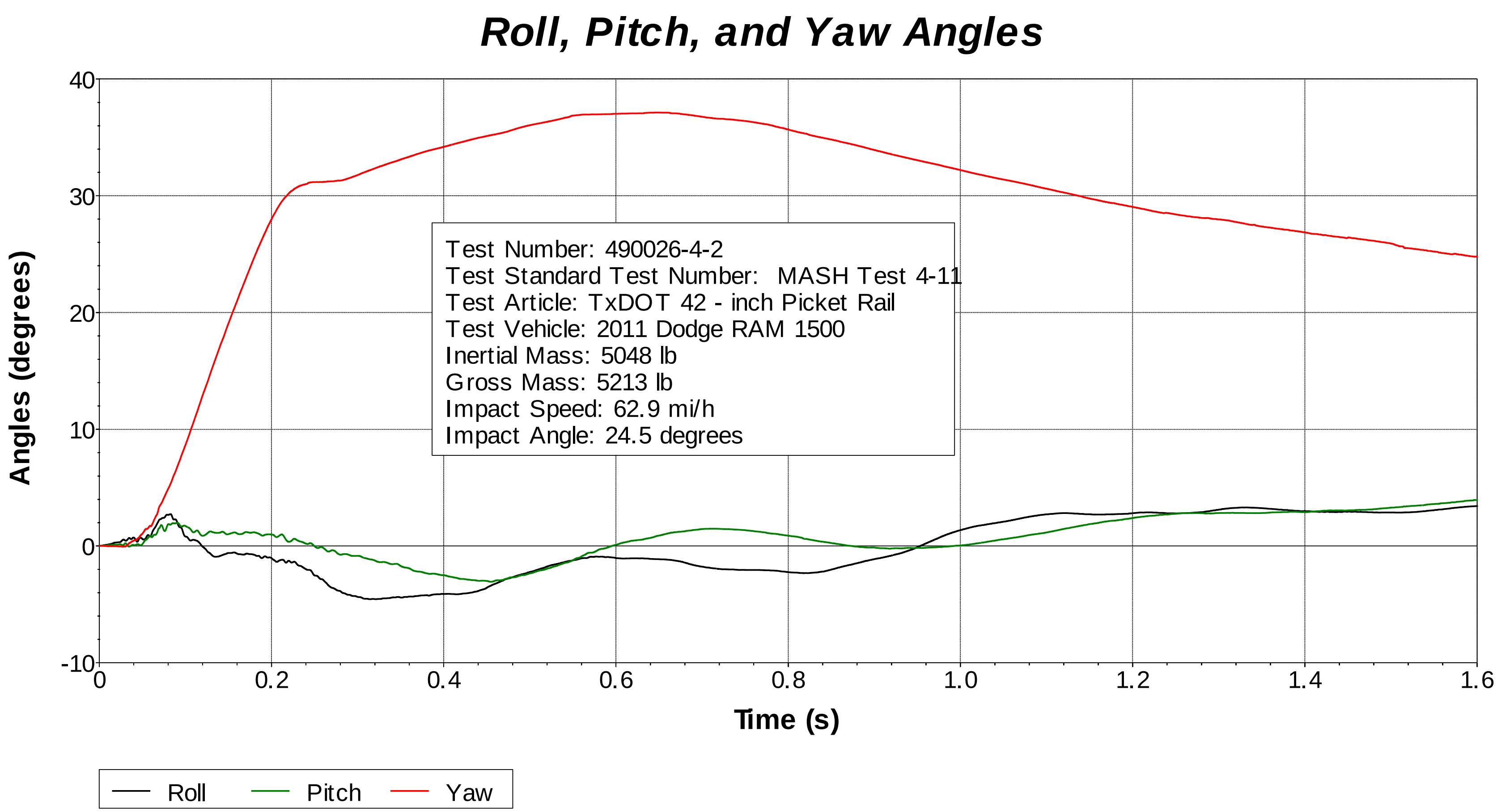

0.420 s

Figure E-2. Sequential Photographs for Test No. 490026-4-2 (Rear View).



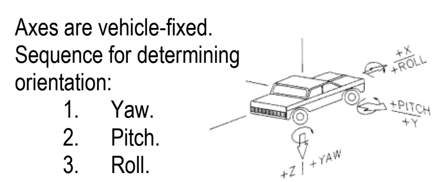


Figure E-3. Vehicle Angular Displacements for Test No. 490026-4-2.

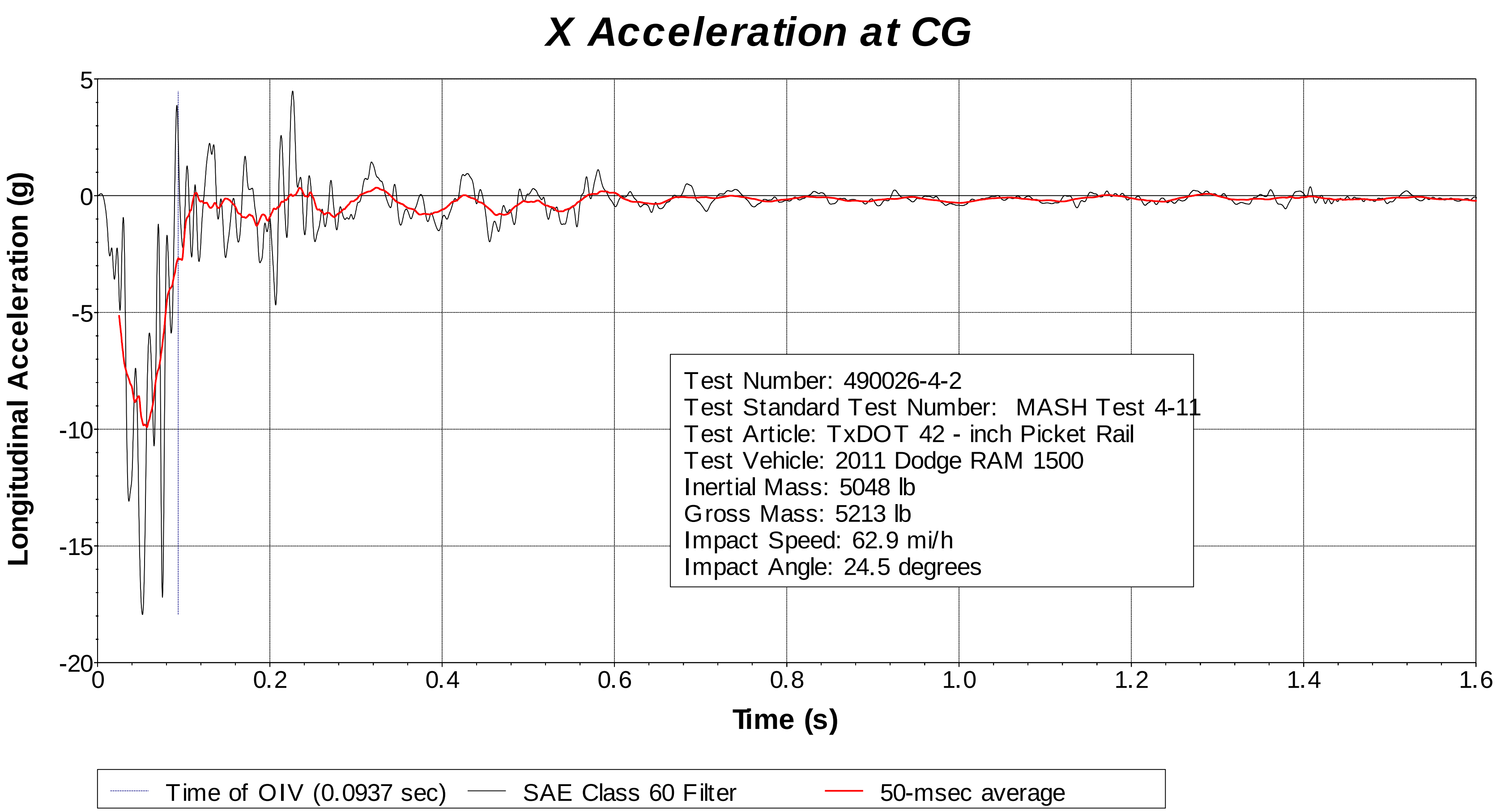


Figure E-4. Vehicle Longitudinal Accelerometer Trace for Test No. 490026-4-2 (Accelerometer Located at Center of Gravity).

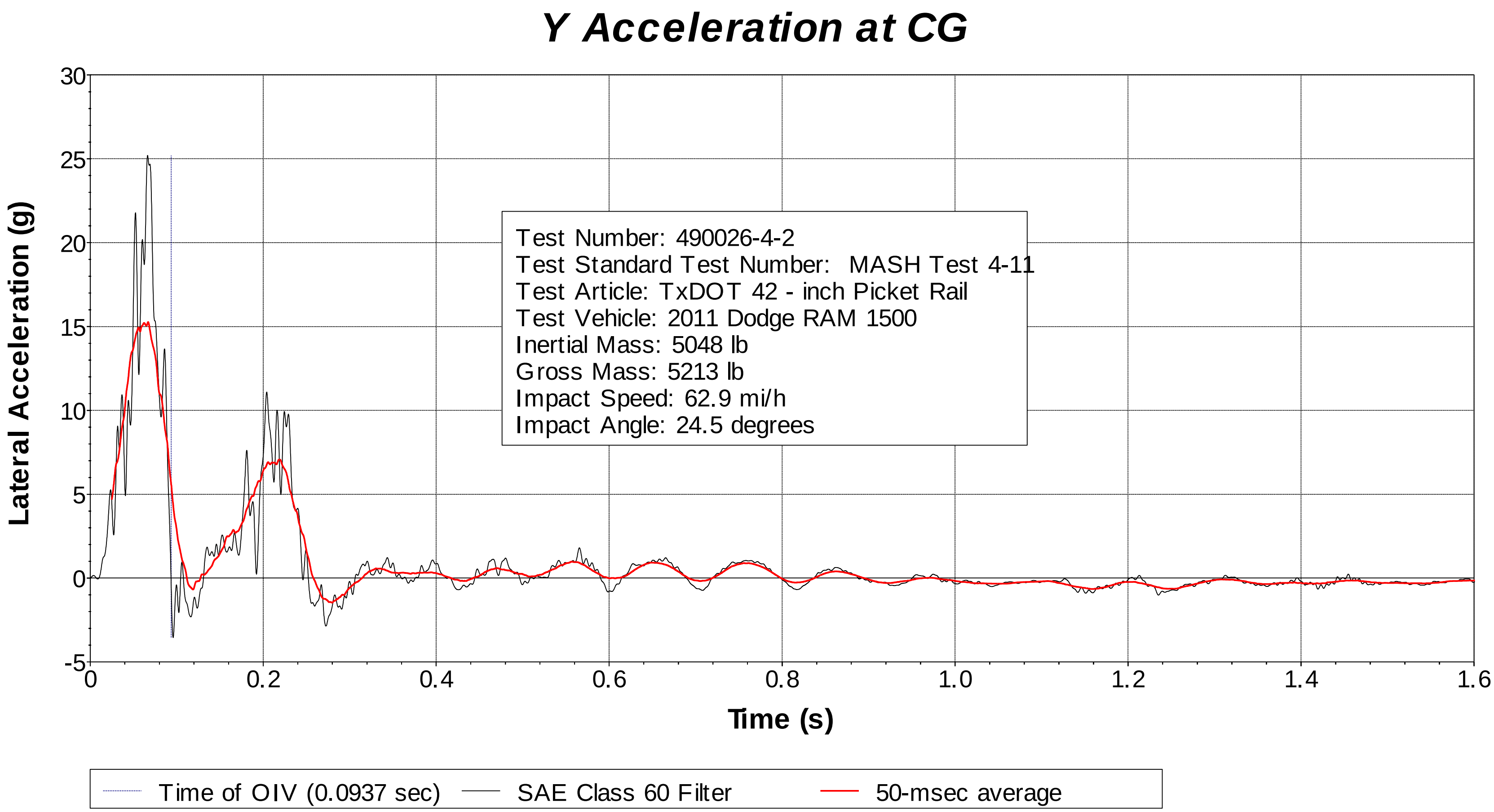


Figure E-5. Vehicle Lateral Accelerometer Trace for Test No. 490026-4-2 (Accelerometer Located at Center of Gravity).

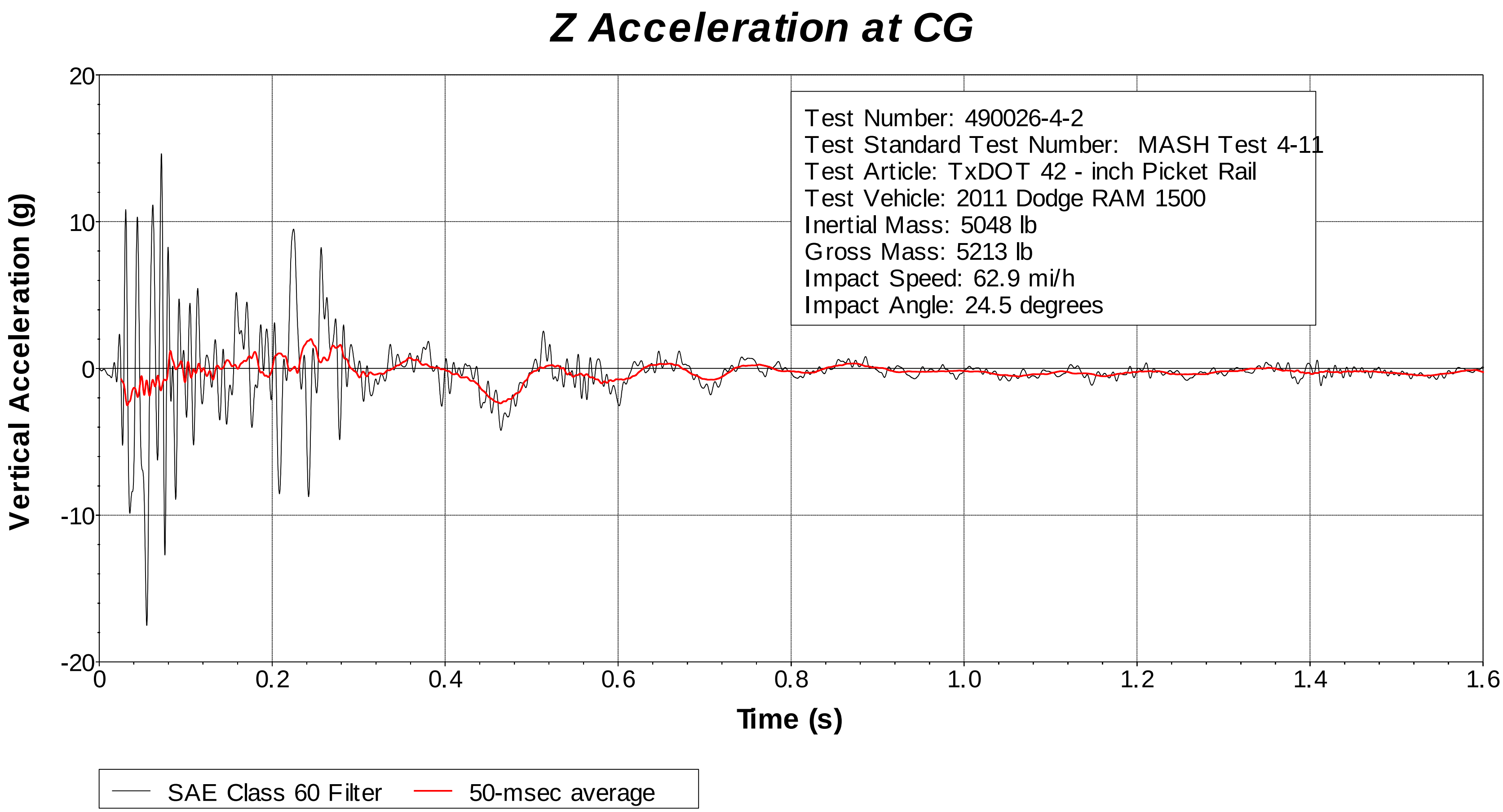


Figure E-6. Vehicle Vertical Accelerometer Trace for Test No. 490026-4-2 (Accelerometer Located at Center of Gravity).

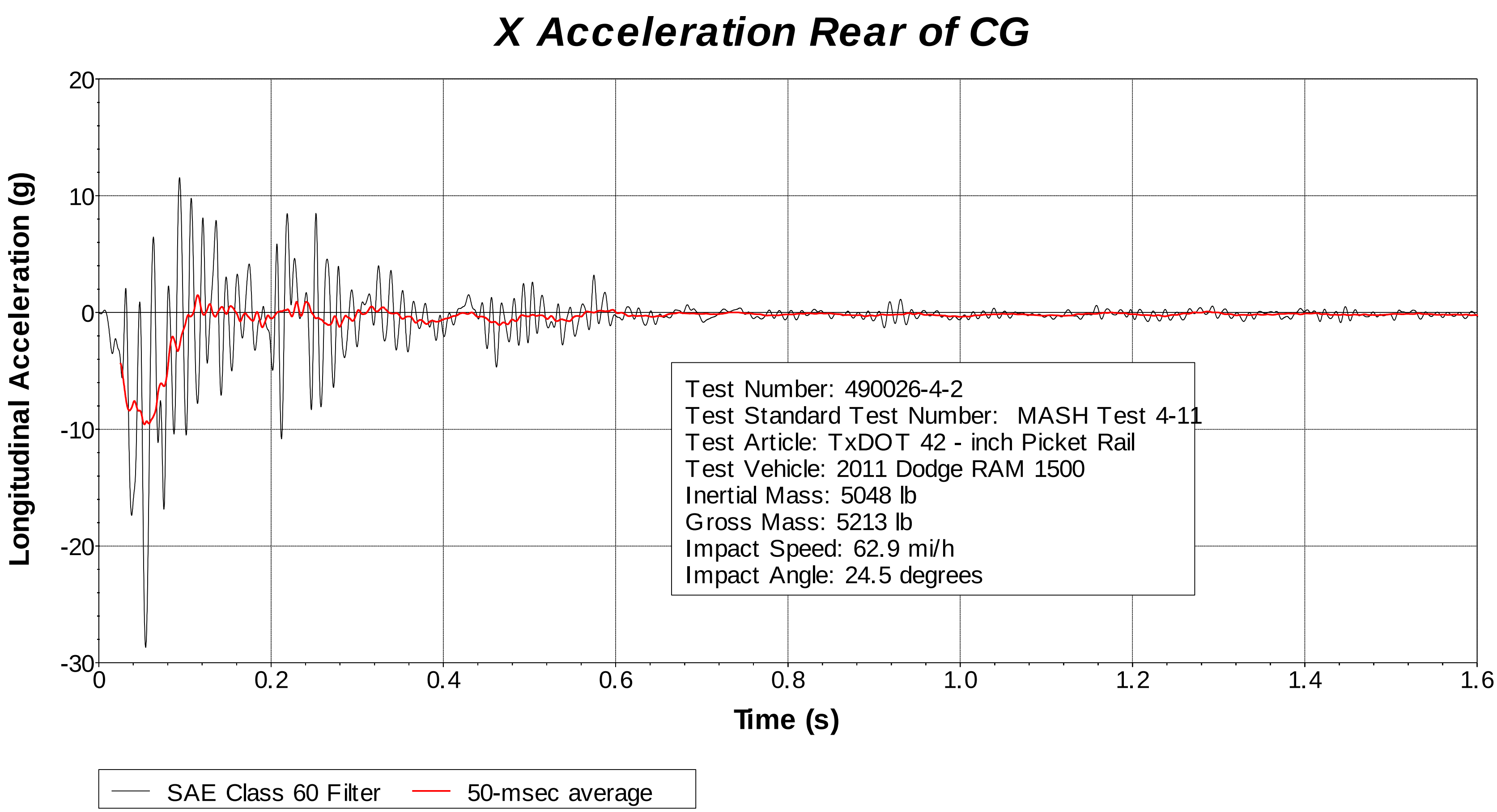


Figure E-7. Vehicle Longitudinal Accelerometer Trace for Test No. 490026-4-2 (Accelerometer Located Rear of Center of Gravity).

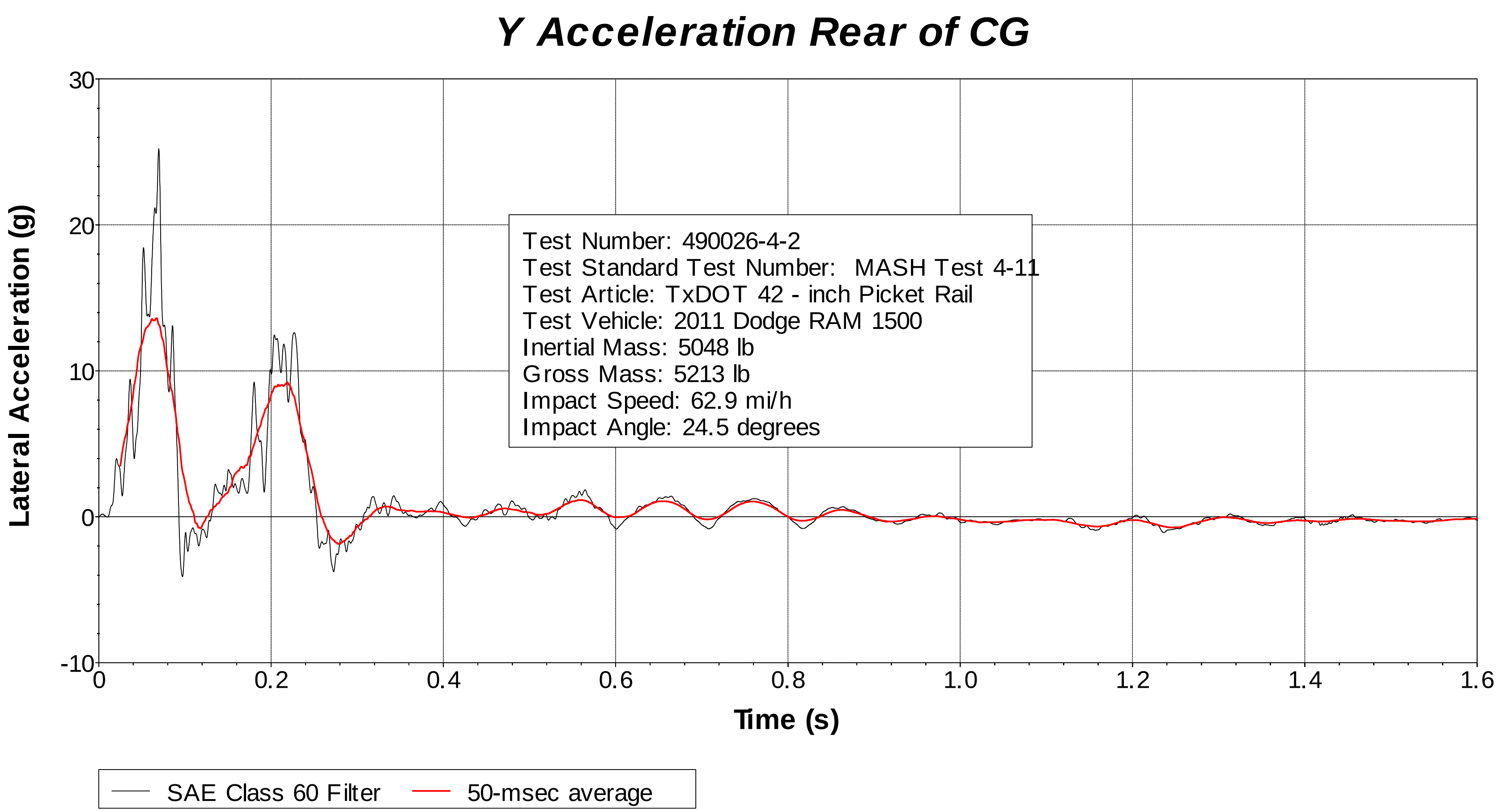


Figure E-8. Vehicle Lateral Accelerometer Trace for Test No. 490026-4-2 (Accelerometer Located Rear of Center of Gravity).

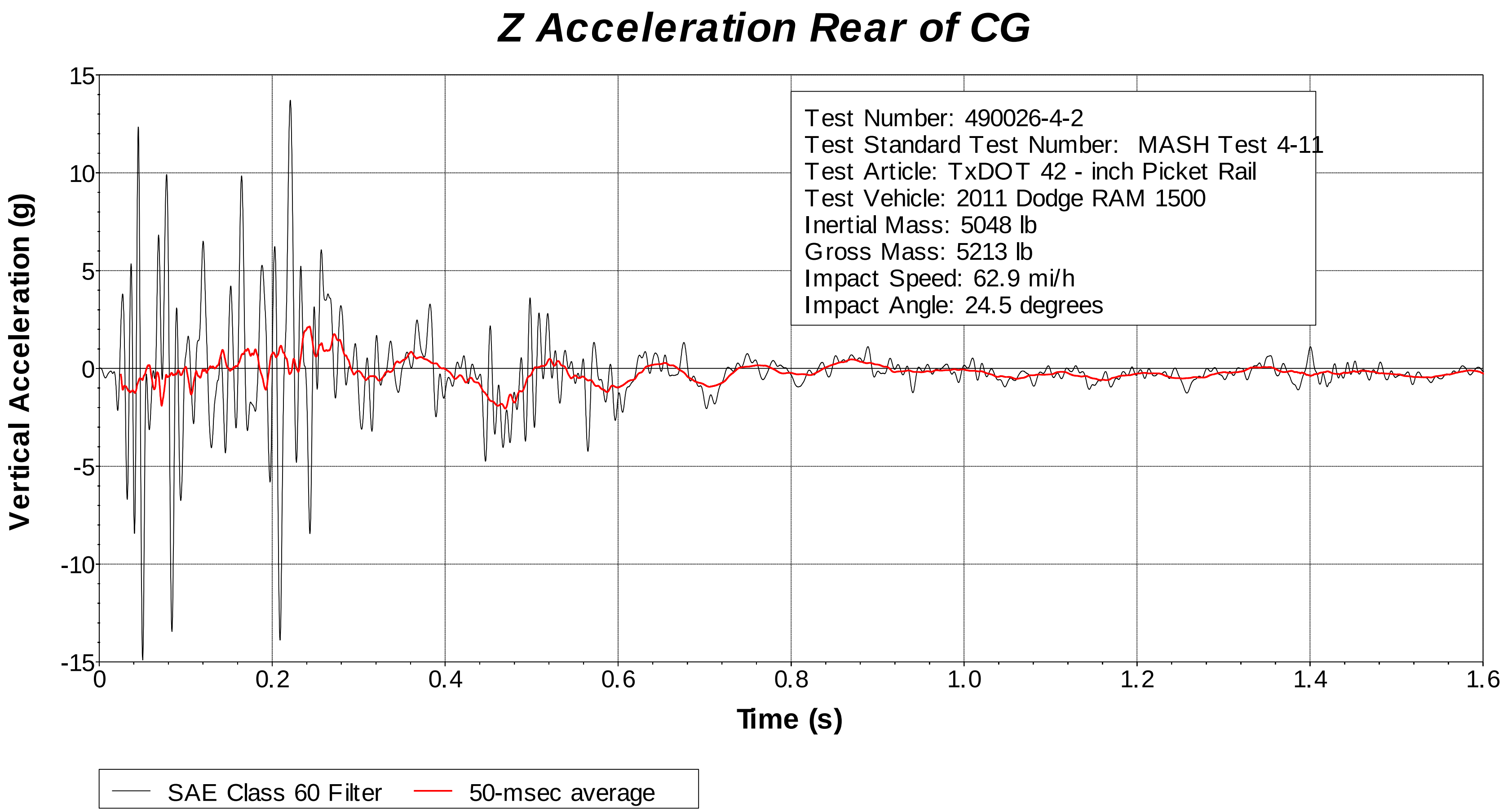


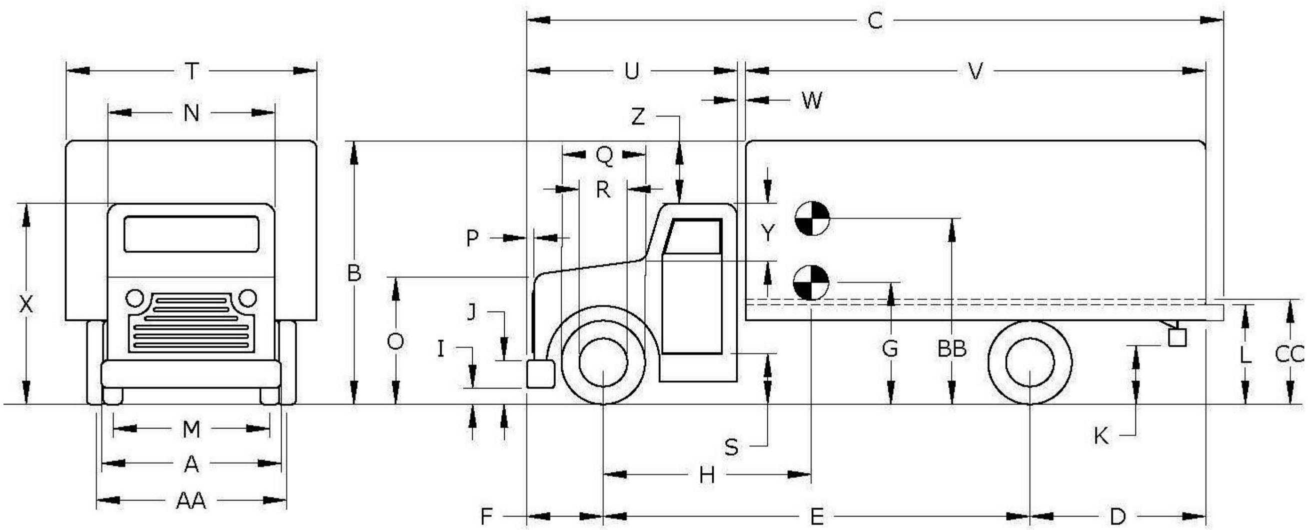
Figure E-9. Vehicle Vertical Accelerometer Trace for Test No. 490026-4-2 (Accelerometer Located Rear of Center of Gravity).

APPENDIX F. *MASH* TEST 4-12 (CRASH TEST NO. 490026-4-3)

F1 VEHICLE PROPERTIES AND INFORMATION

Table F-1. Vehicle Properties for Test No. 490026-4-3.

Date:	2016-06-27	Test No.:	490026-4-3	VIN No.:	1HTMPAFN24H662565
Year:	2004	Make:	International	Model:	4200
Odometer:	103161	Tire Size Front:	275/80R22.5	Tire Size Rear:	275/80R22.5



Vehicle Geometry: inches

A	Front Bumper Width:	92.00	K	Rear Bumper Bottom:	-----	U	Cab Length:	106.00
B	Overall Height:	133.50	L	Rear Frame Top:	37.50	V	Trailer/Box Length:	226.00
C	Overall Length:	330.25	M	Front Track Width:	80.00	W	Gap Width:	2.25
D	Rear Overhang:	89.50	N	Roof Width:	71.00	X	Overall Front Height:	98.50
E	Wheel Base:	204.75	O	Hood Height:	59.50	Y	Roof-Hood Distance:	30.00
F	Front Overhang:	36.00	P	Bumper Extension:	1.00	Z	Roof-Box Height Difference:	41.00
G	C.G. Height:		Q	Front Tire Width:	39.00	AA	Rear Track Width:	73.00
H	C.G. Horizontal Dist. w/Ballast:	132.87	R	Front Wheel Width:	23.00	BB	Ballast Center of Mass:	61.50
I	Front Bumper Bottom:	19.25	S	Bottom Door Height:	37.25	CC	Cargo Bed Height:	50.00
J	Front Bumper Top:	34.00	T	Overall Width:	96.00			

Wheel Center Height Front	18.75	Wheel Well Clearance (Front)	9.00	Bottom Frame Height (Front)	25.25
Wheel Center Height Rear	19.00	Wheel Well Clearance (Rear)	2.25	Bottom Frame Height (Rear)	27.00

More information needed on next page ➡

Table F-1. Vehicle Properties for Test No. 490026-4-3 (Continued).

Date: 2016-06-27 Test No.: 490026-4-3 VIN No.: 1HTMPAFN24H662565

Year: 2004 Make: International Model: 4200

WEIGHTS (lb or kg)	CURB	TEST INERTIAL
$W_{front\ axle}$	6110	7800
$W_{rear\ axle}$	6250	14420
W_{TOTAL}	12360	22220

Allowable Range for CURB = 13,200 ±2200 lb | Allowable Range for TIM = 22,046 ±660 lb

Ballast: 10287 (lb) **(as-needed)**
(See *MASH* Section 4.2.1.2 for recommended ballasting)

Mass Distribution
(lb or kg): **LF:** 4030 **RF:** 3770 **LR:** 7350 **RR:** 7070

Engine Type: VT

Engine Size: 365

Transmission Type:

x Auto or ____ Manual

____ FWD x RWD ____ 4WD

Accelerometer Locations (inches)

	x[2]	y	z[3]
Front:	132.80	0	49.00
Over 5th Wheel:	239.00	0	49.00

Describe any damage to the vehicle prior to test:

None

Other notes to include ballast type, dimensions, mass, location, center of mass, and method of attachment:

4612 lb block; H=30 inches, W=60 inches; L=30 inches

5270 lb block; H=60 inches; W=60 inches; L=30 inches

Centered in middle of bed

61.5 inches to center of block to ground

Four 5/16-inch cable per block

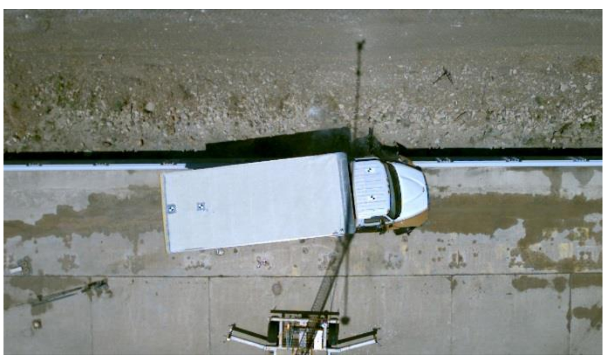
[2] Referenced to the front axle
[3] Above ground

F2 SEQUENTIAL PHOTOGRAPHS


0.000 s



0.100 s



0.200 s

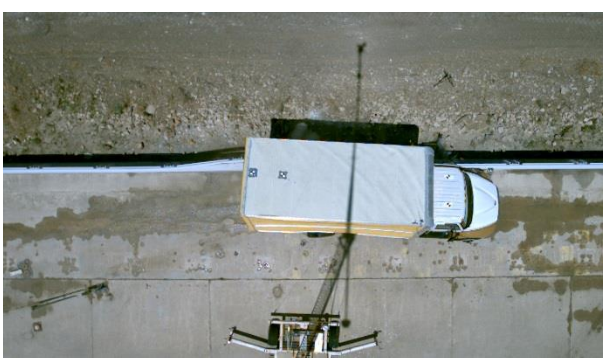
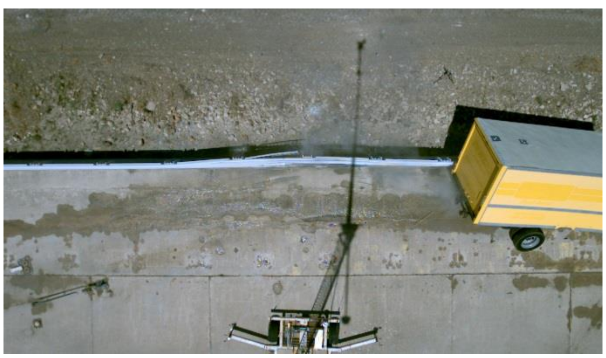


0.300 s


Figure F-1. Sequential Photographs for Test No. 490026-4-3 (Overhead and Frontal Views).


0.400 s



0.500 s



0.600 s



0.xxx s


Figure F-1. Sequential Photographs for Test No. 490026-4-3 (Overhead and Frontal Views) (Continued).

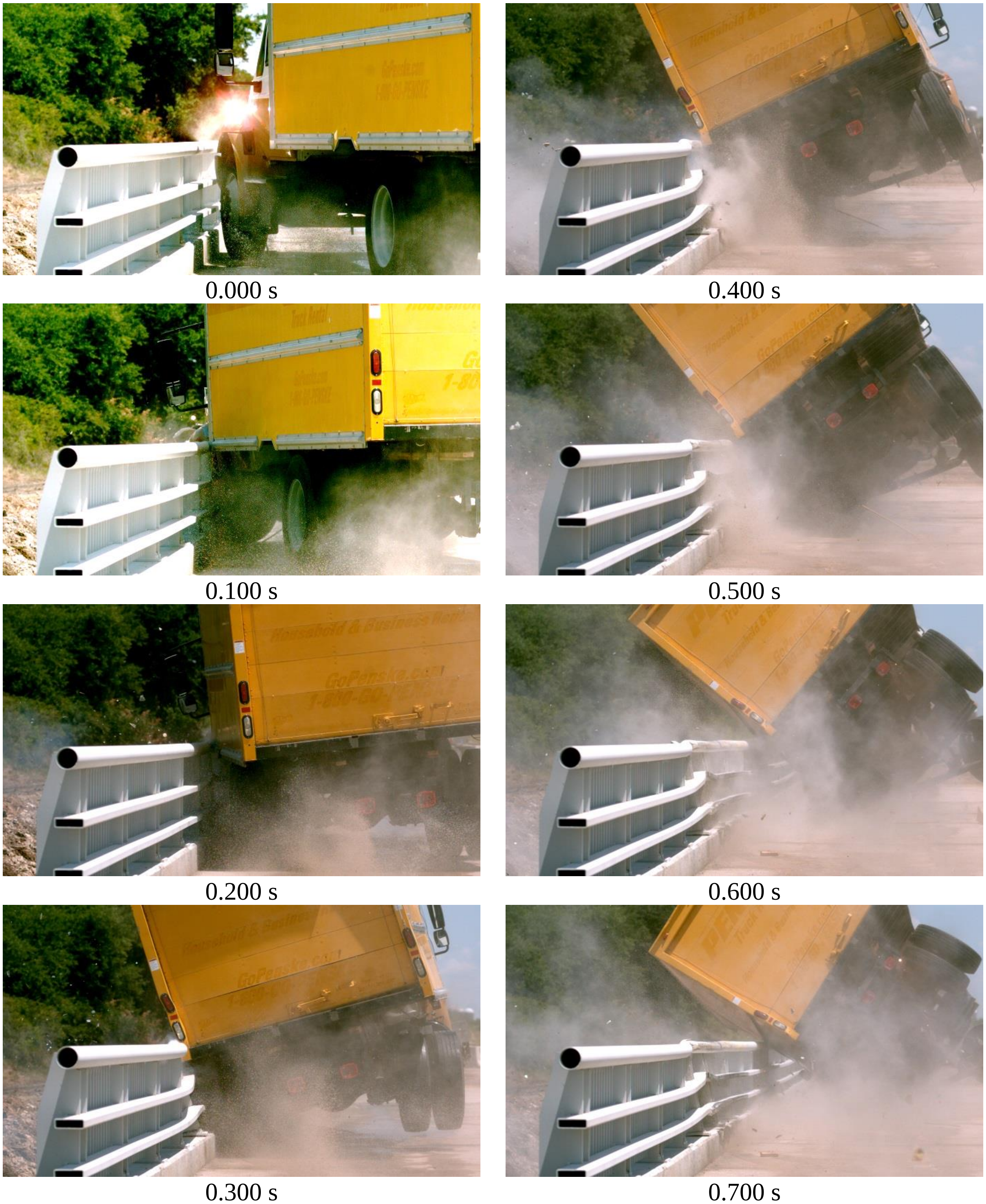


Figure F-2. Sequential Photographs for Test No. 490026-4-3 (Rear View).

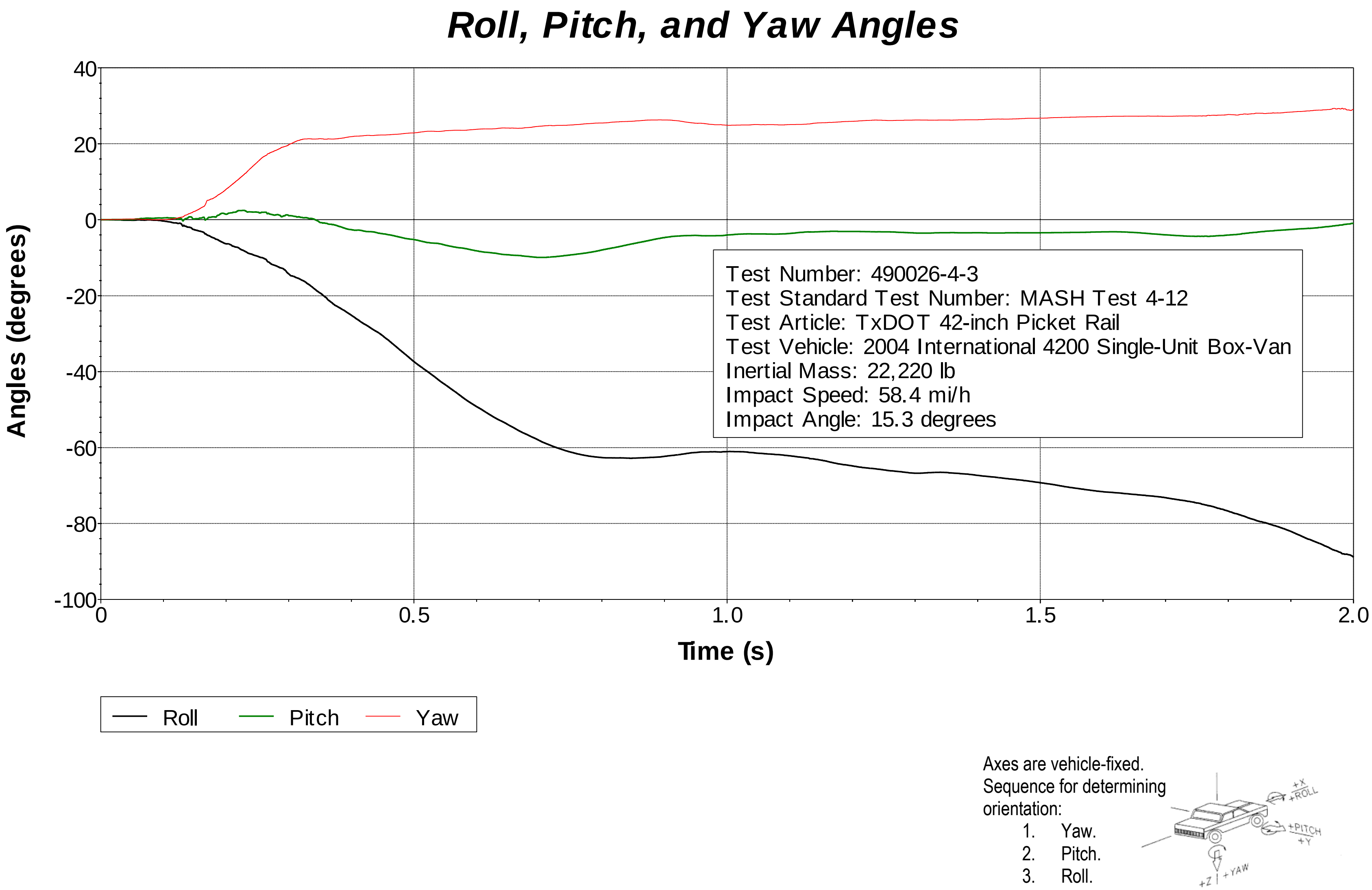


Figure F-3. Vehicle Angular Displacements for Test No. 490026-4-3.

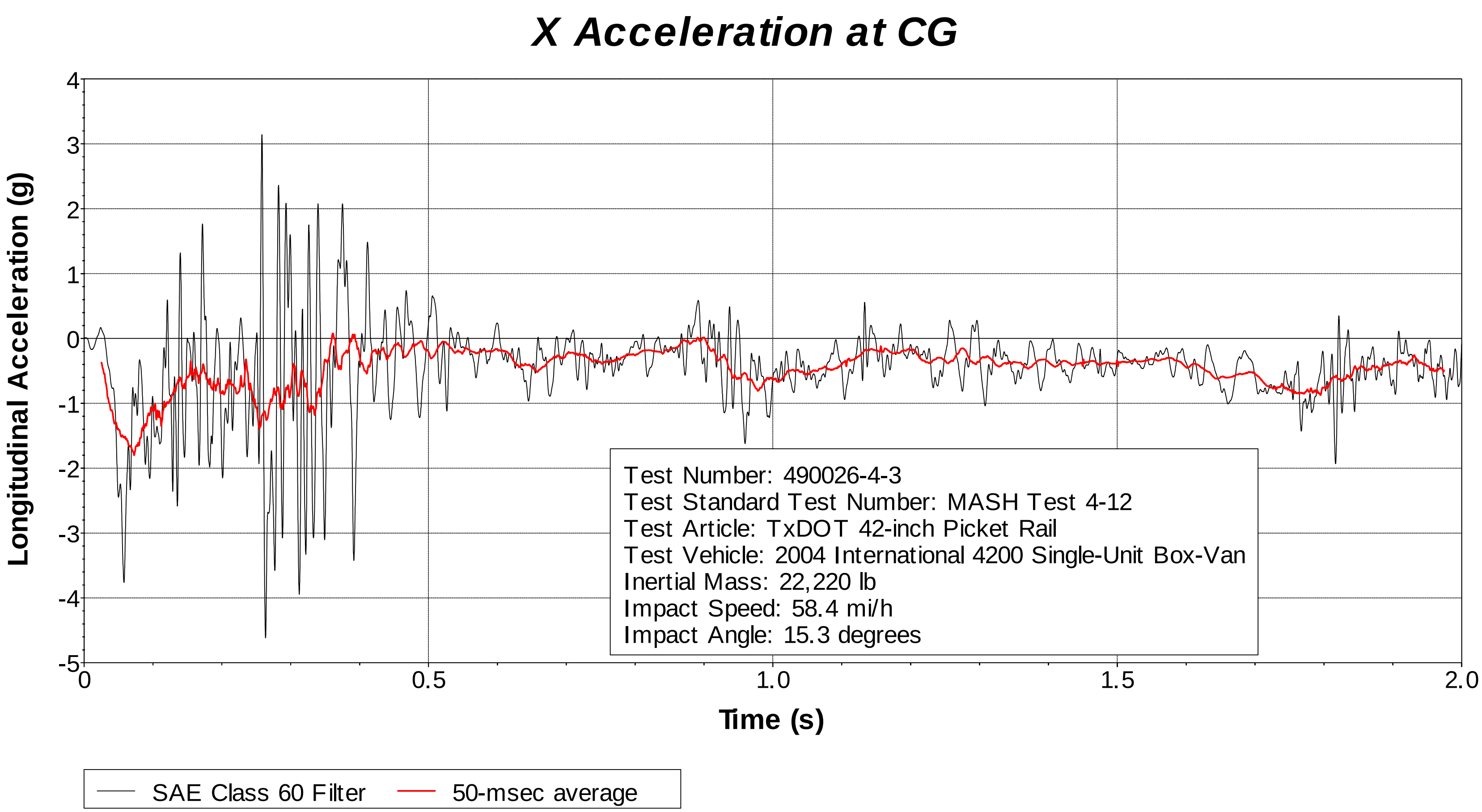


Figure F-4. Vehicle Longitudinal Accelerometer Trace for Test No. 490026-4-3 (Accelerometer Located at Horizontal Center of Gravity).

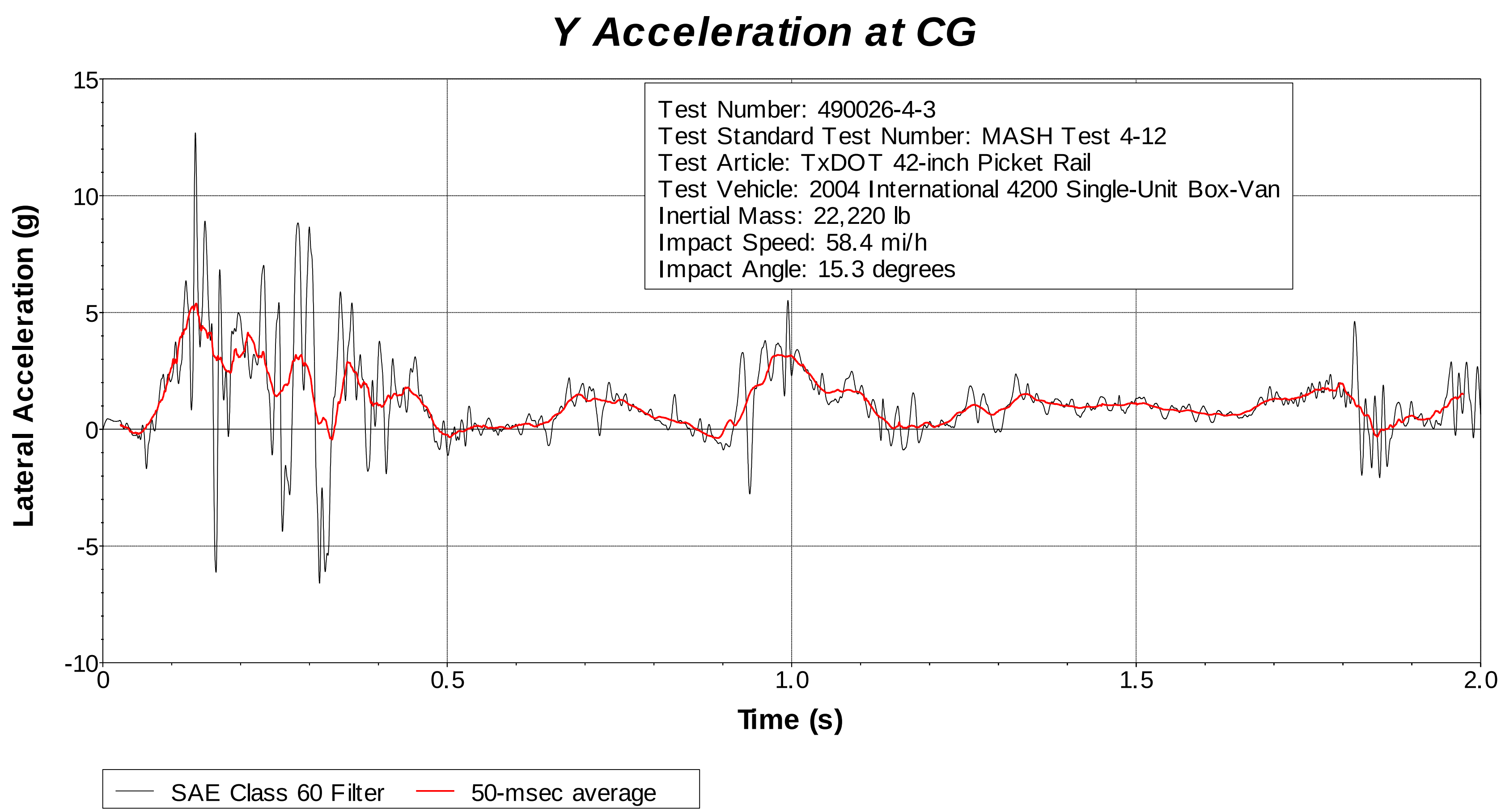


Figure F-5. Vehicle Lateral Accelerometer Trace for Test No. 490026-4-3 (Accelerometer Located at Horizontal Center of Gravity).

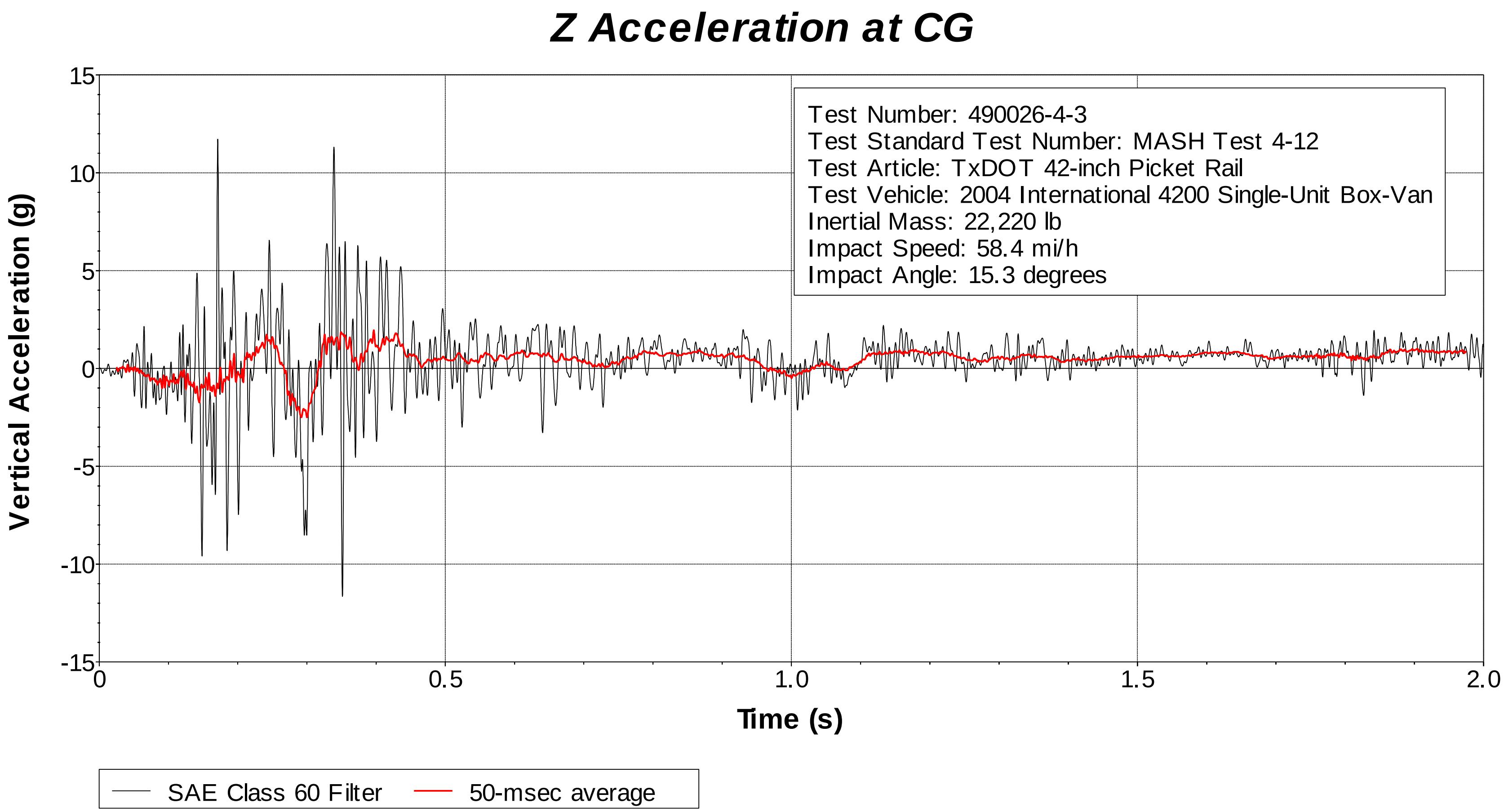


Figure F-6. Vehicle Vertical Accelerometer Trace for Test No. 490026-4-3 (Accelerometer Located at Horizontal Center of Gravity).

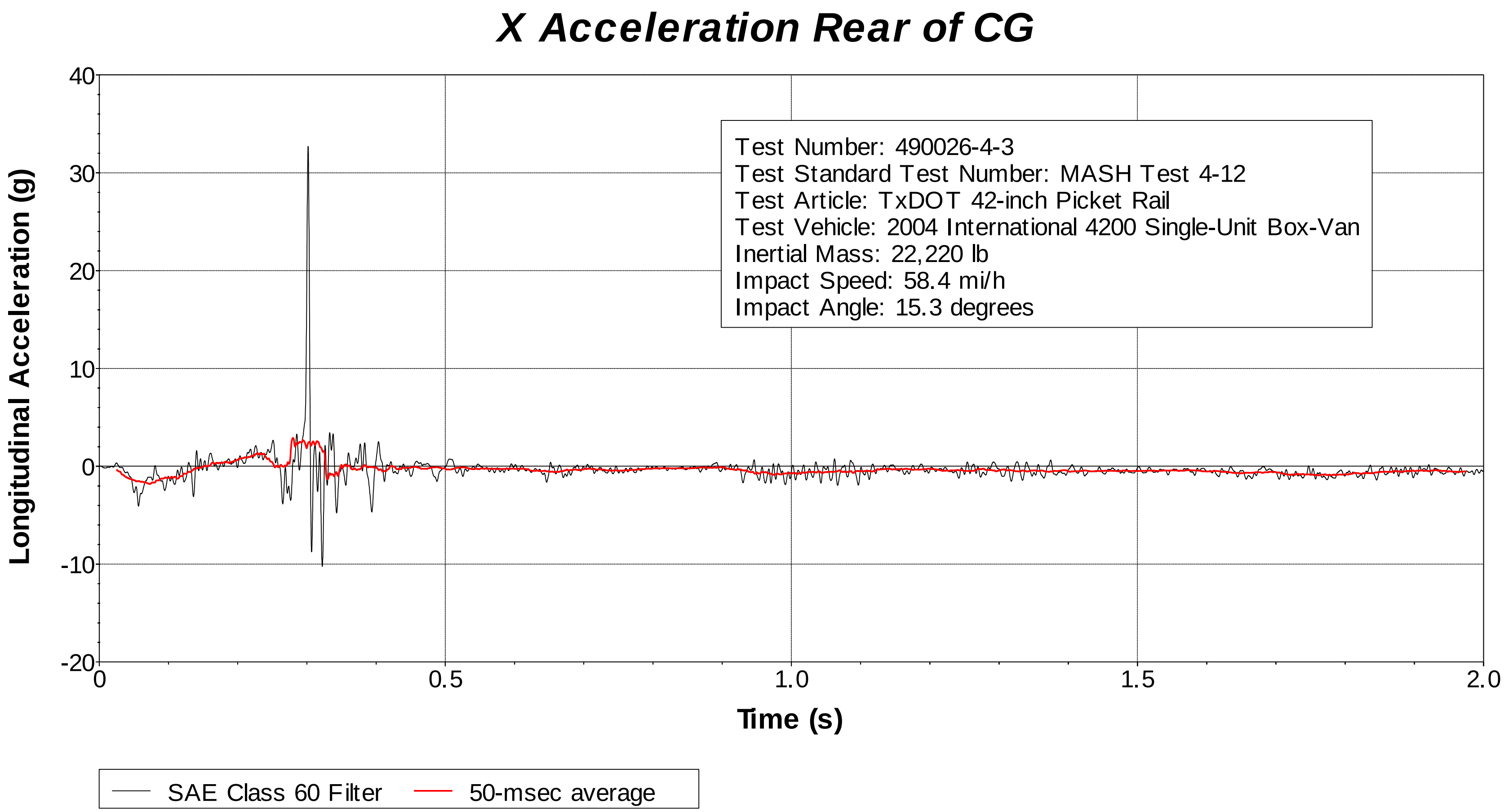


Figure F-7. Vehicle Longitudinal Accelerometer Trace for Test No. 490026-4-3 (Accelerometer Located Rear of Horizontal Center of Gravity).

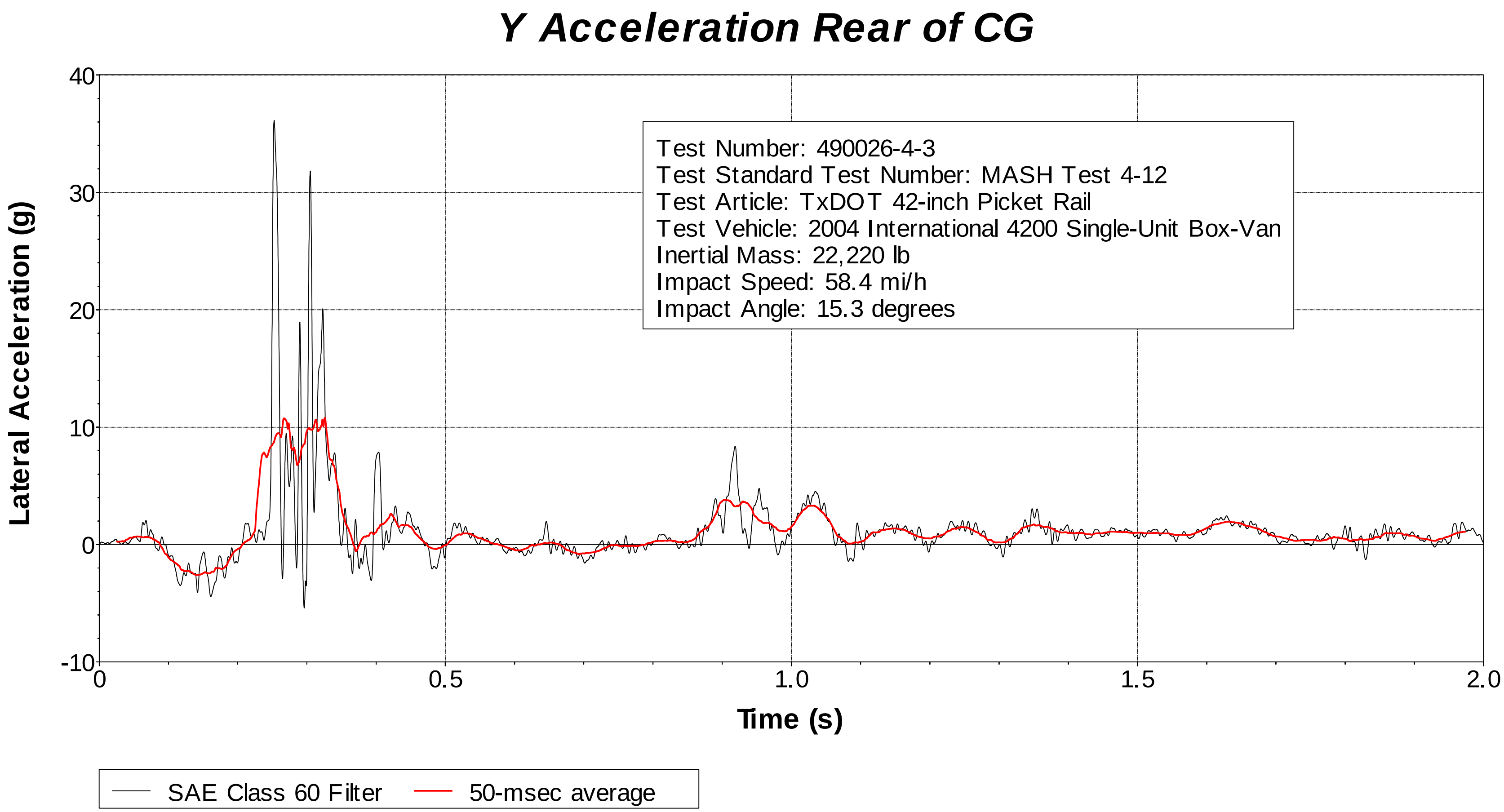


Figure F-8. Vehicle Lateral Accelerometer Trace for Test No. 490026-4-3 (Accelerometer Located Rear of Horizontal Center of Gravity).

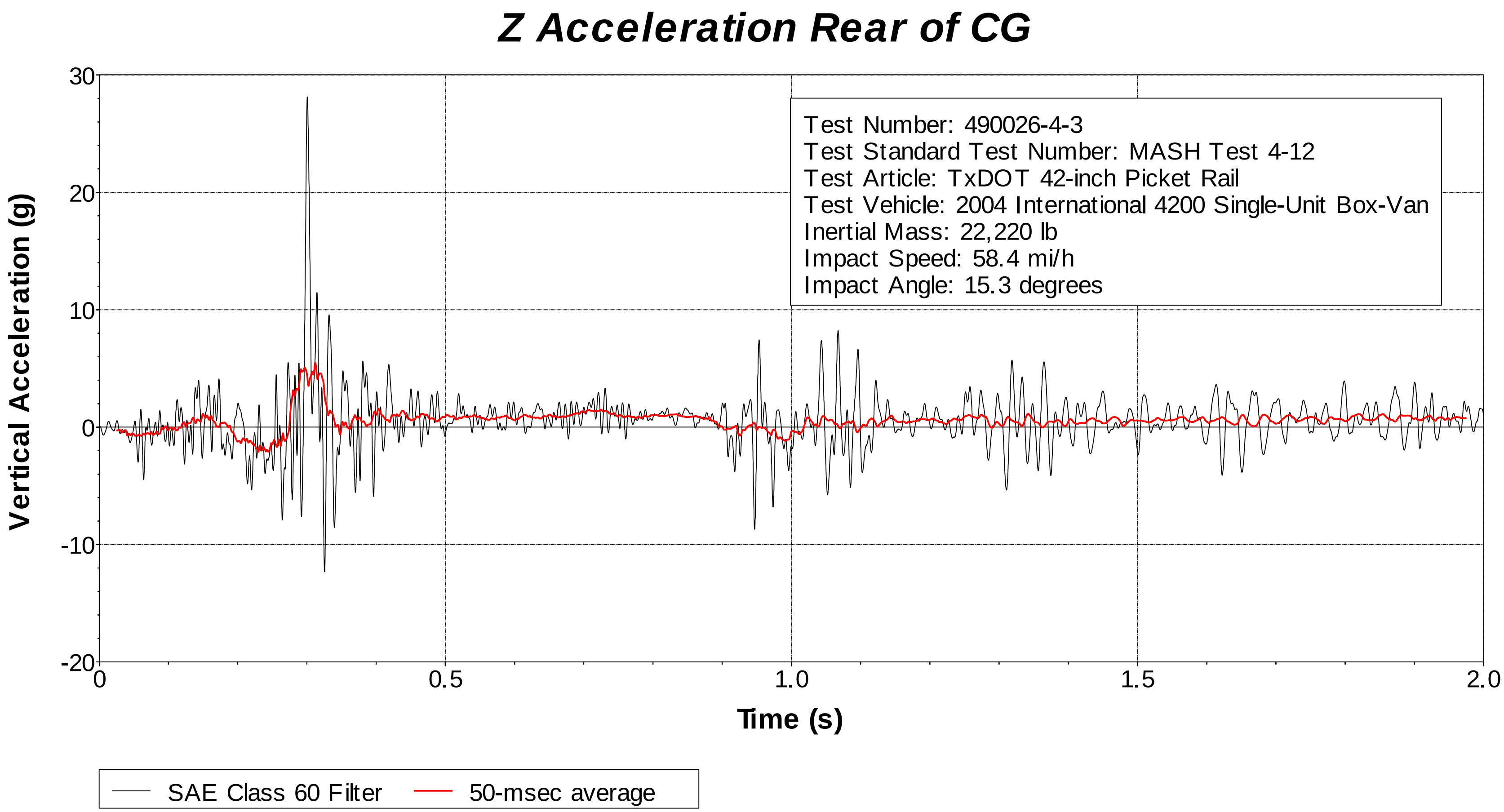


Figure F-9. Vehicle Vertical Accelerometer Trace for Test No. 490026-4-3 (Accelerometer Located Rear of Horizontal Center of Gravity).