MASH TEST 3-11 OF THE TxDOT T222 BRIDGE RAIL

Test Report 9-1002-12-13

Cooperative Research Program

TEXAS A&M TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS

TEXAS DEPARTMENT OF TRANSPORTATION

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

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

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

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Report 9-1002-12-13
Project 9-1002-12
Project Title: Roadside Safety Device Crash Testing Program

Performed in cooperation with the
Texas Department of Transportation
and the
Federal Highway Administration

Published: July 2016

TEXAS A&M TRANSPORTATION INSTITUTE
College Station, Texas 77843-3135
DISCLAIMER

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

TTI PROVING GROUND DISCLAIMER

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

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ACKNOWLEDGMENTS

This research project was conducted under a cooperative program between the Texas Transportation Institute, the Texas Department of Transportation, and the Federal Highway Administration. The TxDOT project manager for this research was Wade Odell, Research and Technology Implementation Office. Amy Smith, P.E., TxDOT Bridge Division, provided support. The authors acknowledge and appreciate their guidance and assistance.
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CHAPTER 1. INTRODUCTION

1.1 INTRODUCTION

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

Under this project, the researchers identified roadside safety issues and prioritized these for investigation. They addressed each roadside safety issue with a separate work plan, and summarized the results in individual test reports.

1.2 OBJECTIVES/SCOPE OF RESEARCH

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

This report describes the TxDOT T222 Bridge Rail, documents the performance of the rail system according to MASH TL-3 specifications, and presents recommendations regarding implementation and future work.
CHAPTER 2. SYSTEM DETAILS

2.1 TEST ARTICLE DESIGN AND CONSTRUCTION

The test installation was a 90-ft-1-inch-long TxDOT T222 Precast Traffic Rail (Type T222) made from three 30-ft long precast segments with a $\frac{1}{2}$-inch gap expansion joint between each segment. The rail was anchored to the top of a 6-inch-thick reinforced concrete deck cantilever. Additionally, the deck had a $\frac{1}{2}$-inch-wide expansion joint every 30 ft along the length of the installation, which coincided with the gap between adjacent rail segments. The Type T222 bridge rail was 32¼ inches high, and had a single, smooth vertical face on the traffic side. There was a $\frac{3}{4}$-inch gap between the top of the deck cantilever and the bottom of the bridge rail for the length of the installation except for the anchor plates (see below). The bridge rail was 10½ inches thick at the base and 12 inches thick at the top with a 1½-inch, 45-degree outward taper on the field side of the rail beginning 19¼ inches above the bottom of the anchor plate. The top field side and traffic side edges were chamfered $\frac{3}{4}$ inch.

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

Each of the three 30-ft-long bridge rail sections were cast on top of eight 15¼-inch × 12-inch × $\frac{3}{4}$-inch-thick ASTM A36 steel anchor plates spaced at 4 ft along the length of each section (see Attachment A, Sheets 5 and 7 of 8). Five $\frac{3}{8}$-inch-diameter deformed bar anchors (Nelson Stud D2L) were vertically attached to each anchor plate with $\frac{3}{8}$-inch fillet welds. Three of these deformed bar anchors were 29 inches long, and were located closer to the traffic side of the rail. The remaining two deformed bar anchors were 12 inches long, and were located closer to the field side of the rail. Each 29-inch and 12-inch bar was wire-tied to the barrier reinforcement at four and two locations, respectively. The anchor plate had a 1½-inch-diameter hole centered 2 inches laterally from the traffic-side edge of the plate.

The TxDOT Type T222 bridge rail was anchored to the 6-inch-thick deck via the aforementioned steel anchor plates using 1-inch-diameter 10-inch-long ASTM A325 galvanized hex anchor bolts, with two 3-inch × 3-inch × $\frac{3}{8}$-inch thick ASTM A36 plate washers (one above and one below), and a 1-inch heavy hex nut and a jam nut below the deck. Each bolt passed through the hole in the anchor plate and through the deck via a 1½-inch-diameter core-drilled hole. The bolts were located on the traffic side face of the bridge rail approximately 14 inches from the field edge of the deck.

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

For additional transverse shear resistance between the barrier sections, a 42-inch-long × 6-inch-wide × ¾-inch-thick ASTM A572 Grade 50 shear plate to the top of the barriers at each joint. The shear plate was centered over the open joints between the barrier sections and contained two ¾-inch-diameter holes on one end and two ¾ × 2¾-inch elongated slots in the opposite end. The shear plate was anchored to the top of the barrier sections with four ¾-inch-diameter × 8-inch-long ASTM A-193 B7 all-thread rods (two rods at each barrier end). The rods were embedded at a minimum of 6 inches into a core drilled hole in the barrier, and then anchored the rods using Hilti’s RE500 epoxy anchoring system. The shear plate was secured to the barrier at each slot with a 2-inch-square × ¼-inch-thick ASTM A36 plate washer, a ¾-inch lock washer, and hex nut, and at each hole with a ¾-inch flat washer, lock washer, and hex nut.

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

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

### 2.2 MATERIAL SPECIFICATIONS

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

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

Reinforcement of the TxDOT Type T222 bridge rail was comprised of ASTM A615 Grade 60 rebar with specified minimum yield strength of 60 ksi.
Figure 2.1. Details of the TxDOT T222 Bridge Rail.
Figure 2.2. Test Article/Installation before Test No. 490024-2-1.
CHAPTER 3. TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1 CRASH TEST MATRIX

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

- **MASH Test 3-10**: A 2420-lb vehicle impacting the critical impact point (CIP) of the length of need (LON) of the barrier at a nominal impact speed and angle of 62 mi/h and 25 degrees, respectively. This test investigates a barrier’s ability to successfully contain and redirect a small passenger vehicle.

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

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

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

3.2 EVALUATION CRITERIA

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

- Structural adequacy, which is judged on the ability of the TxDOT T222 Bridge Rail to contain and redirect the vehicle, or bring the vehicle to a controlled stop in a predictable manner.

- Occupant risk criteria evaluate the potential risk of hazard to occupants in the impacting vehicle, and, to some extent, other traffic, pedestrians, or workers in construction zones, if applicable.

- Post-impact vehicle trajectory is assessed to determine potential for secondary impact with other vehicles or fixed objects, creating further risk of injury to occupants of the impacting vehicle and/or risk of injury to occupants in other vehicles.

The appropriate safety evaluation criteria from Table 5-1 of *MASH* were used to evaluate the crash test reported here, and are listed in further detail under the assessment of the crash test.
CHAPTER 4. CRASH TEST PROCEDURES

4.1 TEST FACILITY

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

The TTI Proving Ground is a 2000-acre complex of research and training facilities located 10 miles northwest of the main campus of Texas A&M University. The site, formerly a United States Army Air Corps base, has large expanses of concrete runways and parking aprons that are well-suited for experimental research and testing in the areas of vehicle performance and handling, vehicle-roadway interaction, durability and efficacy of highway pavements, and safety evaluation of roadside safety hardware. The site selected for construction and testing of the TxDOT T222 Bridge Rail evaluated under this project was along the edge of an out-of-service apron. The apron consists of an unreinforced jointed-concrete pavement in 12.5-ft × 15-ft blocks nominally 6 inches deep. The aprons were built in 1942, and the joints have some displacement, but are otherwise flat and level.

4.2 VEHICLE TOW AND GUIDANCE PROCEDURES

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

4.3 DATA ACQUISITION SYSTEMS

4.3.1 Vehicle Instrumentation and Data Processing

The test vehicle was instrumented with a self-contained, on-board data acquisition system. The signal conditioning and acquisition system is a 16-channel, Tiny Data Acquisition System (TDAS) Pro manufactured by Diversified Technical Systems, Inc. The accelerometers, which measure the x, y, and z axis of vehicle acceleration, are a strain gauge type with linear millivolt output proportional to acceleration. To measure vehicle roll, pitch, and yaw rates, angular rate sensors measure vehicle roll, pitch, and yaw rates; these sensors are ultra-small, solid state units designed for crash test service. The TDAS Pro hardware and software conform to the latest SAE J211, Instrumentation for Impact Test. Each of the 16 available channels is capable of providing precision amplification, scaling, and filtering based on transducer specifications and calibrations. During the test, data are recorded from each channel at a rate of
10,000 values per second with a resolution of one part in 65,536. Once data are recorded, internal batteries back these up inside the unit should the primary battery cable be severed. Initial contact of the pressure switch on the vehicle bumper provides a time zero mark as well as initiates the recording process. After each test, the data are downloaded from the TDAS Pro unit into a laptop computer at the test site. The Test Risk Assessment Program (TRAP) software then processes the raw data to produce detailed reports of the test results. Each of the TDAS Pro units is returned to the factory annually for complete recalibration. Accelerometers and rate transducers are also calibrated annually with traceability to the National Institute for Standards and Technology. Acceleration data are measured with an expanded uncertainty of ±1.7 percent at a confidence factor of 95 percent (k = 2).

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

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

4.3.2 Anthropomorphic Dummy Instrumentation

Use of a dummy in the 2270P vehicle is optional according to MASH, and no dummy was used in the tests with the 2270P vehicle.

4.3.3 Photographic Instrumentation and Data Processing

Photographic coverage of the test included three high-speed cameras: one overhead with a field of view perpendicular to the ground and directly over the impact point; one placed behind the installation at an angle; and a third placed to have a field of view parallel to and aligned with the installation at the downstream end. A flashbulb activated by pressure-sensitive tape switches was positioned on the impacting vehicle to indicate the instant of contact with the installation and was visible from each camera. The films from these high-speed cameras were analyzed on a computer-linked motion analyzer to observe phenomena occurring during the collision and to obtain time-event, displacement, and angular data. A mini-digital video camera and still cameras recorded and documented conditions of the test vehicle and installation before and after the test.
CHAPTER 5. CRASH TEST RESULTS

5.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

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

5.2 TEST VEHICLE

The 2008 Dodge Ram 1500 pickup truck, shown in Figures 5.1 and 5.2, was used for the crash test. The truck’s test inertia weight was 5053 lb, and its gross static weight was 5053 lb. The height to the lower edge of the vehicle bumper was 15.0 inches; to the upper edge, it was 26.5 inches. The height to the vehicle’s center of gravity was 28.5 inches. Tables C1 and C2 in Appendix C give additional dimensions and information on the vehicle. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

5.3 WEATHER CONDITIONS

The test was performed on the morning of June 26, 2014. Weather conditions at the time of testing were as follows: wind speed: 6 mi/h; wind direction: 164 degrees with respect to the vehicle (vehicle was traveling in a southeasterly direction); temperature: 82°F; relative humidity: 75 percent.

5.4 TEST DESCRIPTION

The 2008 Dodge Ram 1500 pickup truck, traveling at an impact speed of 64.4 mi/h, contacted the TxDOT T222 Bridge Rail 51 inches (4 ft 3 inches) upstream of the centerline of the joint between barrier segments #1 and #2 at an impact angle of 25.5 degrees. At approximately 0.126 s, the vehicle began to redirect, and at 0.186 s, the rear of the vehicle contacted the bridge rail. The vehicle began traveling parallel with the bridge rail at 0.271 s. At 0.473 s, the vehicle lost contact with the bridge rail and was traveling at an exit speed and angle of 48.6 mi/h and 8.1 degrees, respectively. Brakes on the vehicle were applied at 2.5 s after impact. The 2270P vehicle subsequently came to rest 249 ft downstream of impact and 35 ft toward traffic lanes. Figure D1 in Appendix D shows sequential photographs of the test period.
Figure 5.1. Vehicle/Installation Geometrics for Test No. 490024-2-1.
Figure 5.2. Vehicle before Test No. 490024-2-1.
5.5 DAMAGE TO TEST INSTALLATION

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

5.6 VEHICLE DAMAGE

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

5.7 OCCUPANT RISK FACTORS

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk. In the longitudinal direction, the occupant impact velocity was 21.6 ft/s at 0.097 s, the highest 0.010-s occupant ridedown acceleration was 3.6 Gs from 0.196 to 0.206 s, and the maximum 0.050-s average acceleration was −9.8 Gs between 0.025 and 0.075 s. In the lateral direction, the occupant impact velocity was 26.9 ft/s at 0.097 s, the highest 0.010-s occupant ridedown acceleration was 11.1 Gs from 0.207 to 0.217 s, and the maximum 0.050-s average was −14.1 Gs between 0.041 and 0.091 s. Theoretical Head Impact Velocity (THIV) was 38.0 km/h or 10.5 m/s at 0.094 s; Post-Impact Head Decelerations (PHD) was 11.1 Gs between 0.207 and 0.217 s; and Acceleration Severity Index (ASI) was 1.95 between 0.063 and 0.113 s. Figure 5.7 summarizes these data and other pertinent information from the test. In Appendix E, Figures E1 through E7 show the vehicle angular displacements and accelerations versus time traces.
Figure 5.3. Vehicle/Bridge Rail after Test No. 490024-2-1.
Figure 5.4. Installation after Test No. 490024-2-1.
Figure 5.5. Vehicle after Test No. 490024-2-1.
Figure 5.6. Interior of Vehicle for Test No. 490024-2-1.
General Information

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

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

Soil Type and Condition: Concrete Bridge Deck, Dry

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

Impact Conditions
Speed: 64.4 mi/h
Angle: 25.5 degrees
Location/Orientation: 51 inches up from
splice btw segs 1&2
Impact Severity: 129.8 kip-ft (+12.8%)

Exit Conditions
Speed: 48.6 mi/h
Angle: 8.1 degrees

Occupant Risk Values
Longitudinal OIV: 129.8 kip-ft (+12.8%)
Lateral OIV: 21.6 ft/s
Longitudinal Ridedown: 3.6 G
Lateral Ridedown: 11.1 G
THIV: 38.0 km/h
PHD: 11.1 G
ASI: 1.95
Max. 0.050-s Average:
Longitudinal: −9.8 G
Lateral: −14.1 G
Vertical: −3.3 G

Post-Impact Trajectory
Stopping Distance: 249 ft dwstrm
Vehicle Stability
Maximum Yaw Angle: 37 degrees
Maximum Pitch Angle: 12 degrees
Maximum Roll Angle: 7 degrees
Vehicle Snagging: No
Vehicle Pocketing: No

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

Vehicle Damage
VDS: 01RFQ5
CDC: 01FREW4
Max. Exterior Deformation: 19.25 inches
OCDD: RF000000
Max. Occupant Compartment Deformation: 4.00 inches

Figure 5.7. Summary of Results for MASH Test 3-11 on the TxDOT T222 Bridge Rail.
CHAPTER 6. SUMMARY AND CONCLUSIONS

6.1 ASSESSMENT OF TEST RESULTS

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

6.1.1 Structural Adequacy

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

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

6.1.2 Occupant Risk

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

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

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

Maximum occupant compartment deformation was 4.0 inches in the kick panel area near the right front passenger’s feet. (PASS)

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

Results: The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 7 degrees and 12 degrees, respectively. (PASS)

H. Occupant impact velocities should satisfy the following:

<table>
<thead>
<tr>
<th>Longitudinal and Lateral Occupant Impact Velocity</th>
<th>Preferred</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 ft/s</td>
<td>40 ft/s</td>
<td></td>
</tr>
</tbody>
</table>
Results: Longitudinal occupant impact velocity was 21.6 ft/s, and lateral occupant impact velocity was 26.9 ft/s. (PASS)

I. Occupant ridedown accelerations should satisfy the following:

<table>
<thead>
<tr>
<th>Longitudinal and Lateral Occupant Ridedown Accelerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preferred</td>
</tr>
<tr>
<td>15.0 Gs</td>
</tr>
</tbody>
</table>

Results: Maximum longitudinal occupant ridedown acceleration was 3.6 g, and maximum lateral occupant ridedown acceleration was 11.1 G. (PASS)

6.1.3 Vehicle Trajectory

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

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

6.2 CONCLUSIONS

Table 6.1 shows that the TxDOT T222 Bridge Rail performed acceptably for MASH test 3-11.
## Table 6.1. Performance Evaluation Summary for MASH Test 3-11 on the TxDOT T222 Bridge Rail.

<table>
<thead>
<tr>
<th>MASH Test 3-11 Evaluation Criteria</th>
<th>Test Results</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structural Adequacy</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>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.</td>
<td>The TxDOT T222 Bridge Rail contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 2.13 inches.</td>
<td>Pass</td>
</tr>
<tr>
<td><strong>Occupant Risk</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>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.</td>
<td>No detached elements, fragments, or other debris was present to penetrate or to show potential for penetrating the occupant compartment, or to present hazard to others.</td>
<td>Pass</td>
</tr>
<tr>
<td>Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.</td>
<td>Maximum occupant compartment deformation was 4.0 inches in the kick panel area near the right front passenger’s feet.</td>
<td>Pass</td>
</tr>
<tr>
<td>F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</td>
<td>The 2270P vehicle remained upright during and after the collision event. Maximum roll was 7 degrees, and maximum pitch was 12 degrees.</td>
<td>Pass</td>
</tr>
<tr>
<td>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.</td>
<td>Longitudinal occupant impact velocity was 21.6 ft/s, and lateral occupant impact velocity was 26.9 ft/s.</td>
<td>Pass</td>
</tr>
<tr>
<td>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.</td>
<td>Maximum longitudinal occupant ridedown acceleration was 3.6 G, and maximum lateral occupant ridedown acceleration was 11.1 G.</td>
<td>Pass</td>
</tr>
<tr>
<td><strong>Vehicle Trajectory</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>For redirective devices, the vehicle shall exit the barrier within the exit box (not less than 32.8 ft).</td>
<td>The vehicle exited within the exit box criteria.</td>
<td>Pass</td>
</tr>
</tbody>
</table>
CHAPTER 7. IMPLEMENTATION STATEMENT

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

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


APPENDIX A. DETAILS OF THE TEST ARTICLE

Installation - Plan

<table>
<thead>
<tr>
<th>Installation Parts</th>
<th>QTY.</th>
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<tbody>
<tr>
<td>1 Barrier</td>
<td>3</td>
</tr>
<tr>
<td>2 Bolt, 1&quot; x 10 hex</td>
<td>24</td>
</tr>
<tr>
<td>3 Nut, 1&quot; heavy hex</td>
<td>24</td>
</tr>
<tr>
<td>4 Nut, 1&quot; heavy hex jam</td>
<td>24</td>
</tr>
<tr>
<td>5 Shear Plate</td>
<td>2</td>
</tr>
<tr>
<td>6 Anchor Rod</td>
<td>8</td>
</tr>
<tr>
<td>7 Washer, 3/4 flat</td>
<td>4</td>
</tr>
<tr>
<td>8 Washer, 3/4 lock</td>
<td>8</td>
</tr>
<tr>
<td>9 Nut, 3/4 hex</td>
<td>8</td>
</tr>
<tr>
<td>10 Plate Washer for Deck</td>
<td>48</td>
</tr>
<tr>
<td>11 Plate Washer for Shear Plate</td>
<td>4</td>
</tr>
</tbody>
</table>

1a. Core Ø1-1/4" holes in deck for Anchor Bolts. Percussion drilling is not permitted.

1b. This hardware is on Slotted Side of the Shear Plate. The Plate Washer may be replaced with a standard 3/4" flat washer on the round hole side of the Shear Plate. Install Anchor Rods with Hilti RE500 epoxy according to manufacturer's instructions, minimum 6" embedment in Concrete.
Deck Details

3a. Longitudinal Bars are \( \frac{2}{12}''\) (#4). Laps are minimum 15''. All rebar is grade 60.
3b. Concrete is TxDOT Class C (3600psi).
3c. Chamfer exposed Deck edges 3/4''.
3d. Typical at each end and each side of construction joints.

Plate, 4'' x 1/4''

10'' TYP

18'' TYP

Anchor Bars

5''

2''

L-bar

6'' TYP

Existing Rebar protruding from Runway and welded to Plate

20-1/4''

2-1/4''

1-1/2''

Anchor Bar

Elevation View

Plan View

2-1/4''

2-1/4''

1/4''

1/4''

TYP

6''

2''

see 3d

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

Barrier Details - Plan

Barrier Parts

<table>
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<tr>
<th>#</th>
<th>Part Name</th>
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<td>Longitudinal Bar, Ø1/2&quot; (#4)</td>
<td>8</td>
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<tr>
<td>12</td>
<td>T222 Stirrup</td>
<td>61</td>
</tr>
<tr>
<td>13</td>
<td>Lifting Lug</td>
<td>2</td>
</tr>
<tr>
<td>14</td>
<td>T222 Anchor Plate</td>
<td>8</td>
</tr>
</tbody>
</table>
14 T222 Anchor Plate

Plan View

Lifting Lug
Halten TPA-FS 0070.010-00018
(400mm long for 5 ton load)
Scale 1:5

13

Isometric View

Plate, 12" x 3/4"
ASTM A36 Steel

1/2" 8-1/2" 12"
11-1/2" 15-1/4"
4" 1-1/8"

Elevation View

ϕ5/8" Deformed Bar Anchor
see 7a

ϕ1/8"

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

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

5 Shear Plate
Scale 1:5

6 Plate Washer for Deck

Plate, 3" x 3/8"
ASTM A36 Steel

7 Slot, 7/8" x 2-1/8"
TYP x 2

8 Plate, 6" x 3/4"
ASTM A572 Grade 50

9 Plate Washer for Shear Plate

Plate, 2" x 1/4"
ASTM A36 Steel
# MATERIAL USED

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<th>#</th>
<th>DATE RECEIVED</th>
<th>DESCRIPTION</th>
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<th>YIELD</th>
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<td>76.3</td>
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<td>Washer, 3/4 lock</td>
<td>-</td>
<td>see paperwork</td>
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<td>Mack Bolt &amp; Steel</td>
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APPENDIX B. CERTIFICATION DOCUMENTATION
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<th>Test Report No.</th>
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<td>TR-9-1002-12-13</td>
<td>Visual Inspection</td>
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**Certificate No.:** TR-9-1002-12-13

Date of Testing: 08-29-2014

Certificate Issued: 08-29-2014

Certificate Essential for Domestic and Export Sales.
STUD WELDING ASSOCIATES

1200 ALAMEDA DR.
STRONGBUILD, OH 44149
(440) 783-3160
WELD STUD CERTIFICATION
DEFORMED BAR ANCHORS

SMA HEAT #: 0-914
SUPPLIER HEAT #: 5077564

QTY: 500
PART #: DA0623018
SIZE: 5/8 X 30-3/16 DA

METRIC:

CUTTER:

SUPPLY:

Product Analysis - ASTM A-108 (Latest revision)

CERTIFIED MATERIAL TEST REPORT - CHEMICAL PROPERTIES

C: 0.160
Mn: 0.716
Si: 0.250
P: 0.008
S: 0.018
Cr: 0.080
Ni: 0.070
Mo: 0.380

CERTIFIED MATERIAL TEST REPORT - MECHANICAL PROPERTIES

AISI GRADE: 1018
TENSILE: 101,060
YIELD: 98.100
REDUCTION (%):
ELONG (%):

CERTIFICATE OF CONFORMANCE

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

ASTM A496

All testing is in compliance with AWS D 1.1, D1.6 (original document and all current
revisions)

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

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

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

[Signature]
Stud Welding Associates, Inc.

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

[Signature]
Notary Public, State of Ohio, U.S.A.

Date: 10/20/11

TR No. 9-1002-12-13 39 2014-08-29
STUD WELDING ASSOCIATES
12200 ALAMEDA DR.
STRONGSVILLE, OH 44149
(440) 788-3160
WELD STUD CERTIFICATION
DEFORMED BAR ANCHORS

SPOOL 9: 8-914
SPOOL 9: 5077584

QTY: 1,000
BRAND: DA0621218
SIZE: 5/8 X 12-3/16 DA
METRIC:

CUSTOMER:
FOB: STOCK - TROY
Product Analysis - ASTM A-108 (Latest revision)

CERTIFIED MATERIAL TEST REPORT - CHEMICAL PROPERTIES
C: 0.160
Mn: 0.320
Si: 0.250
P: 0.008
S: 0.015
Cr: 0.090
Ni: 0.070
Mo: 0.050

CERTIFIED MATERIAL TEST REPORT - MECHANICAL PROPERTIES
AISI GRADE: 1018
TENSILE: 101,060
YIELD: 98.100
REDUCTION (%): 11
ELONG (%): 99

CERTIFICATE OF CONFORMANCE

It is certified these products were fabricated from material conforming to original and current revisions of one or more of the following standards:
ASTM A496

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

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

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

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

Stud Welding Associates, Inc.

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

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

JUDITH E. LEMONE
Notary Public, State of Ohio, U.S.A.

Form No: PRF
DCM No: 917
DCC: 01/25/13
DCM: 09/24/13

TR No. 9-1002-12-13

2014-08-29
CERTIFICADO DE CALIDAD DE PRODUCTO TERMINADO / CERTIFICATE MATERIAL TEST

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<th>Cliente / Customer:</th>
<th>DEACERO USA INC</th>
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<tr>
<td>Dirección / Address:</td>
<td>5411 URVINGTON BLVD</td>
</tr>
<tr>
<td>N° Certificado / Certificate No:</td>
<td>4181 - 10214312</td>
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<td>Fecha del Certificado / Certificate Date:</td>
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PRUEBA DE CALIDAD / QUALITY TEST

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Asignación de Calidad / Certificate:
Ing. Odacio Saldana Caballero
Gerente de Asesoramiento de Calidad / Quality Assurance Manager
<table>
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<th>批号</th>
<th>产品名称</th>
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<th>化学成分 (%)</th>
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<table>
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<td>POROSITY</td>
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</table>

1. 质量证书复印件不具有同等法律效应 THE COPY OF THE INSPECTION CERTIFICATE IS INEFFECTIVE LEGALLY.
2. 热轧交货 DELIVERY AFTER HOT HOLLING
3. DEC=DECARBURIZATION  C.H.T.=COLD HEADING TEST  G.S=GRAIN SI
Stelfast Inc.
22979 Stelfast Parkway
Strongsville, Ohio
44149

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

Quantity: 600
Part #: DHWGA10000
Description: 1" Asim P436 Hard. Washers Hdg

Purchase Order: 24901
Stelfast Order: SO 83626
Certificate #: 447,607
Lot Number: GBR12538390-016
Heat Number: D112B05302
Country of Origin: CN

Chemical Analysis

<table>
<thead>
<tr>
<th>Element</th>
<th>C</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Si</th>
<th>Cr</th>
<th>Mo</th>
<th>V</th>
<th>B</th>
<th>Ni</th>
<th>Cu</th>
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<tr>
<td></td>
<td>0.47</td>
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<td>0.016</td>
<td>0.006</td>
<td>0.24</td>
<td>0.19</td>
<td></td>
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</tr>
</tbody>
</table>

Mechanical Properties

Hardness (Core) 29 - 34 HRC

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

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

ROBERT D. MEAGHER
QUALITY MANAGER

April 18, 2013
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

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

Purchase Order: 24901
Stelfast Order: SO 83626
Certificate #: 425,910
Lot Number: 1202528
Heat Number: F140009475
Country of Origin: CN

Chemical Analysis

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<th>C</th>
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<th>P</th>
<th>S</th>
<th>Si</th>
<th>Cr</th>
<th>Mo</th>
<th>V</th>
<th>B</th>
<th>Ni</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.65</td>
<td>0.58</td>
<td>0.018</td>
<td>0.009</td>
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<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Mechanical Properties

Hardness (Core) 41 - 45 HRC

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

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

ROBERT D. MEAGHER
QUALITY MANAGER

April 18, 2013
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

Quantity: 140
Part #: A2HHG1000C
Description: 1-8-2b Hwy.Hx.Nuts HDG/TOS 0.004

Purchase Order: 24833
Stelfast Order: SO 83088
Certificate #: 441,482
Lot Number: 5047860001
Heat Number: J11202392
Country of Origin: CN

Chemical Analysis

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<tr>
<td>C</td>
<td>Mn</td>
<td>P</td>
<td>S</td>
<td>Si</td>
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<tr>
<td>0.44</td>
<td>0.69</td>
<td>0.015</td>
<td>0.003</td>
<td>0.19</td>
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</tbody>
</table>

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

Mechanical Properties

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

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

ROBERT D. MEAGHER
QUALITY MANAGER

April 18, 2013

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

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

CUSTOMER: PORTEOUS FASTENER COMPANY
MFG LOT NUMBER: M-DF2145-1

SAMPLE SIZE: ACC. TO ASME B18.18.2M-93
SIZE: 1.8X10” HDG
HEADMARKS: A325+NDF

QNTY: 450 PCS
PART NO: 00152-4068-024

STEEL PROPERTIES:
STEEL GRADE: 1045
HEAT NUMBER: 331206084

CHEMISTRY SPEC:

<table>
<thead>
<tr>
<th>C %</th>
<th>Mn %</th>
<th>P %</th>
<th>S %</th>
<th>Si %</th>
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</thead>
<tbody>
<tr>
<td>0.30-0.52</td>
<td>0.60</td>
<td>0.04</td>
<td>0.050</td>
<td>0.15-0.30</td>
</tr>
</tbody>
</table>

TEST:
0.45 | 0.70 | 0.012 | 0.004 | 0.19

DIMENSIONAL INSPECTIONS
CHARACTERISTICS | SPECIFIED | ACTUAL RESULT | ACC. | REJ.

APPEARANCE | ASTM F788-02 | Passed | 100 | 0
THREAD | ASME B1.1-02 2A | Passed | 32 | 0
WIDTH FLATS | 1.625"-1.575" | 1.585"-1.610" | 8 | 0
WIDTH A/C | 1.875"-1.706" | 1.810"-1.832" | 8 | 0
HEAD HEIGHT | 0.627"-0.591" | 0.594"-0.599" | 8 | 0
BODY DIA | 1.022"-0.976" | 0.981"-0.988" | 8 | 0
THREAD LENGTH | ref 1.75" | 1.70"-1.73" | 8 | 0
LENGTH | 10.00"-9.75" | 9.82"-9.86" | 8 | 0

MECHANICAL PROPERTIES: 1/2" thru 1"

CHARACTERISTICS | TEST METHOD | SPECIFIED | ACTUAL RESULT | ACC. | REJ.

CORE HARDNESS | ASTM F606-10a max 34 HRC | 28-31 HRC | 8 | 0
WEDGE TENSILE | ASTM F606-10a MIN 120000 PSI | 120000-135000 PSI | 4 | 0
PROOF LOAD | ASTM F606-10a MIN 85000 PSI | PASS | 4 | 0
YIELD STRENGTH | ASTM F606-10a MIN 92000 PSI | 104800 PSI | 1 | 0
DECARBURIZATION | SAE J312-97 | PASS | 1 | 0

CHARACTERISTICS | TEST METHOD | SPECIFIED | ACTUAL RESULT | ACC. | REJ.

HOT DIP GALVANIZE | ASTM F2329 MIN 0.0017" IN | 0.0024"-0.0028" | 4 | 0

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

All parts meet the requirements of FQA and records of compliance are on file.

Maker’s ISO# CN06/01495

(SIGNATURE OF Q.A. LABORATORY)
(ZHEJIANG NEW ORIENTAL FASTENER CO., LTD)
**CERTIFIED MILL TEST REPORT**

Ship from:  
Nucor Steel - Texas  
8812 Hwy 79 W  
JEWETT, TX 75846  
800-527-8445

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

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

<table>
<thead>
<tr>
<th>LOT #</th>
<th>DESCRIPTION</th>
<th>YIELD P.S.I.</th>
<th>TENSILE P.S.I.</th>
<th>ELONG % IN 2</th>
<th>BEND</th>
<th>C</th>
<th>Ni</th>
<th>Mn</th>
<th>Cr</th>
<th>P</th>
<th>S</th>
<th>Si</th>
<th>Sb</th>
<th>Cu</th>
<th>Sn</th>
</tr>
</thead>
<tbody>
<tr>
<td>JW1210787001</td>
<td>Nucor Steel - Texas</td>
<td>72,200</td>
<td>104,800</td>
<td>11.0%</td>
<td>.36</td>
<td>.98</td>
<td>.011</td>
<td>.035</td>
<td>.16</td>
<td>.27</td>
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<tr>
<td>JW12107870</td>
<td>13/84 Rebar</td>
<td>498MPa</td>
<td>723MPa</td>
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<td>.17</td>
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<td>.055</td>
<td>.017</td>
<td>.002</td>
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<td>JW12107871</td>
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<td>103,800</td>
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<td>.94</td>
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<td>.17</td>
<td>.34</td>
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<td>13/84 Rebar</td>
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</table>

1) Verify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.
2) Material is manufactured in the United States.
3) Material, Radium, or Alpha emission material in any form have not been used in the production of this material.

QUALITY ASSURANCE: Nathan Stewart
HEAT NO.: 3037827  
SECTION: REBAR 13 MM (#4) 20'0"  
GRADE: ASTM A615-12 Gr 420/60  
ROLL DATE: 02/10/2013  
MELT DATE: 02/01/2013

<table>
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<tr>
<th>Characteristic</th>
<th>Value</th>
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<tbody>
<tr>
<td>C</td>
<td>0.42%</td>
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<tr>
<td>Mn</td>
<td>0.85%</td>
</tr>
<tr>
<td>P</td>
<td>0.016%</td>
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<tr>
<td>S</td>
<td>0.039%</td>
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<tr>
<td>Si</td>
<td>0.20%</td>
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<tr>
<td>Cu</td>
<td>0.23%</td>
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<tr>
<td>Cr</td>
<td>0.18%</td>
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<tr>
<td>Ni</td>
<td>0.21%</td>
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<tr>
<td>Mo</td>
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<tr>
<td>V</td>
<td>0.002%</td>
</tr>
<tr>
<td>Cb</td>
<td>0.000%</td>
</tr>
<tr>
<td>Sn</td>
<td>0.016%</td>
</tr>
<tr>
<td>Al</td>
<td>0.002%</td>
</tr>
</tbody>
</table>

Yield Strength test 1 66.9ksi  
Torsile Strength test 1 103.9ksi  
Elongation test 1 13%  
Elongation Gage Lgth test 1 8IN  
Bend Test Diameter 1.750IN  
Bend Test 1 Passed

115 - #4  
RM 80009 - 2

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

REMARKS:

02/20/2013 16:10:26
Page 1 OF 1
# 检测报告

**客户名称**：BRIGHTON-BEST INTERNATIONAL (TAIWAN) INC.  
**地址**：浙江海盐三马标准件有限公司

<table>
<thead>
<tr>
<th>品名</th>
<th>P19A4-2H Heavy Hex Nuts</th>
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<tbody>
<tr>
<td>规格</td>
<td>M3-10</td>
</tr>
<tr>
<td>表面处理</td>
<td>Finish: PLAIN</td>
</tr>
<tr>
<td>批号</td>
<td>Lot No: US8716-314200</td>
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</table>

一、钢材性能 STEEL PROPERTIES:  
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<tr>
<th>ELEMENT (成分)</th>
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<th>P%</th>
<th>S%</th>
<th>Si%</th>
<th>Cr%</th>
<th>Ni%</th>
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二、项目检测 Inspections Items:

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<th>检测项目</th>
<th>标准值 Specified</th>
<th>实测值 Actual Result</th>
<th>判定 Judgement</th>
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</thead>
<tbody>
<tr>
<td>外观 Appearance</td>
<td>Passed</td>
<td>Passed</td>
<td>OK</td>
</tr>
<tr>
<td>对边 Across Flat</td>
<td>1.212-1.250</td>
<td>1.220-1.225</td>
<td>OK</td>
</tr>
<tr>
<td>对角 Across Corner</td>
<td>1.382-1.443</td>
<td>1.396-1.402</td>
<td>OK</td>
</tr>
<tr>
<td>厚度 Thickness</td>
<td>0.710-0.758</td>
<td>0.725-0.738</td>
<td>OK</td>
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<tr>
<td>螺纹精度 Thread</td>
<td>2B GO</td>
<td>OK</td>
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</tr>
<tr>
<td>硬度(HRC) Hardness</td>
<td>24-35</td>
<td>29-33</td>
<td>OK</td>
</tr>
<tr>
<td>保证荷载(KSI) Proof Load</td>
<td>175KSI</td>
<td>175KSI</td>
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<tr>
<td>540℃回火24H后硬度(HRB) Hardness After 24H AT 540℃</td>
<td>MIN 89</td>
<td>93-97</td>
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<tr>
<td>回火温度(℃) Tempering Temperature</td>
<td>Min 455</td>
<td>530-545</td>
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<tr>
<td>宏观腐蚀试验 Macro Etch Test</td>
<td>S1/R1+C1-S4/R4/C4</td>
<td>S2/R2/C2</td>
<td>OK</td>
</tr>
</tbody>
</table>
Stelfast Inc.

22479 Stelfast Parkway
Stow, Ohio

44139

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

Quantity: 0
Lot #: 5237010008

Part #: 37007308008CEND
Heat Number: 331301684

Description: 3/4-10x8 Stud B7
Country of Origin: CN

MeasureEnd

Report of Chemical and Physical Properties

Purchase Order: 25631
Stelfast Order: SO 89565
Certificate #: 469.131

Chemical Analysis

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

Mechanical Properties

Minimum Tempering Temp ———— 640 C
Macroetch ———— S2R2.C2
Tensile ———— 138311 - 138602 PSI
Yield ———— 121911 - 123072 PSI
Elongation % ———— 22.24
Red of Area % ———— 63.87
Hardness (HRC) ———— 28 - 30 HRC
Grade Markings ———— ASTM A193(2011) GR.B7

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

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

Robert D. Meagher
Quality Manager

April 14, 2014
# Certified Mill Test Report

## CMC Steel Texas

**1 Steel Mill Drive**

**Seguin, TX 78155-7510**

**Certified Mill Test Report**

For additional copies call

830-372-8771

---

**Heat No.: 3036306**

**Section:** Flat 3/4" x 6" 20'0"

**A36/52950**

**Grade:** ASTM A36-08/A529-05 Gr 50

**Roll Date:** 11/20/2012

**Melt Date:** 11/19/2012

---

<table>
<thead>
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<th>Value</th>
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<tr>
<td>Mn</td>
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</tr>
<tr>
<td>P</td>
<td>0.012%</td>
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<td>0.032%</td>
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<td>Si</td>
<td>0.19%</td>
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<tr>
<td>Ni</td>
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</tr>
<tr>
<td>Mo</td>
<td>0.054%</td>
</tr>
<tr>
<td>V</td>
<td>0.020%</td>
</tr>
<tr>
<td>Nb</td>
<td>0.001%</td>
</tr>
<tr>
<td>Sn</td>
<td>0.015%</td>
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<tr>
<td>Al</td>
<td>0.002%</td>
</tr>
<tr>
<td>Carbon Eq A529</td>
<td>0.42%</td>
</tr>
</tbody>
</table>

- **Yield Strength Test:** 54.9ksi
- **Tensile Strength Test:** 76.3ksi
- **Elongation Test:** 35%
- **Elongation Gage Lgth Test:** 8IN

---

**Delivery#: 80942827**

**BOL#: 70337937**

**CUST PO#: HOU-151420**

**CUST PIN**: 

**DLVRY LBS / HEAT: 9792.000 LB**

**DLVRY PCS / HEAT: 32 EA**

---

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

Daniel J. Schacht

Quality Assurance Manager

---

**Remarks**: This material is fully killed, 100% melted and manufactured in the USA, with no weld repair or mercury contamination in the process.

---

02/27/2013 13:14:21

Page 1 of 1
APPENDIX C. TEST VEHICLE PROPERTIES AND INFORMATION

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

<table>
<thead>
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<th>2014-06-19</th>
<th>Test No.:</th>
<th>490024-2-1</th>
<th>VIN No.:</th>
<th>1D7HA18N585509318</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year:</td>
<td>2008</td>
<td>Make:</td>
<td>Dodge</td>
<td>Model:</td>
<td>Ram 1500 Quad-Cab</td>
</tr>
<tr>
<td>Tire Size:</td>
<td>P265/70R17</td>
<td>Tire Inflation Pressure:</td>
<td>35 psi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tread Type:</td>
<td>Highway</td>
<td>Odometer:</td>
<td>168595</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note any damage to the vehicle prior to test:

- Denotes accelerometer location.

NOTES: -----

Engine Type: V-8
Engine CID: 4.7 liter

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

Optional Equipment: None

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

Geometry: inches

<p>| | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>78.25</td>
<td>F</td>
<td>36.00</td>
<td>K</td>
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<td>P</td>
<td>2.88</td>
<td>U</td>
</tr>
<tr>
<td>B</td>
<td>75.00</td>
<td>G</td>
<td>28.50</td>
<td>L</td>
<td>29.00</td>
<td>Q</td>
<td>30.50</td>
<td>V</td>
</tr>
<tr>
<td>C</td>
<td>223.75</td>
<td>H</td>
<td>63.26</td>
<td>M</td>
<td>68.50</td>
<td>R</td>
<td>16.00</td>
<td>W</td>
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<td>47.25</td>
<td>I</td>
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<td>N</td>
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<td>O</td>
<td>46.00</td>
<td>T</td>
<td>77.50</td>
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</tbody>
</table>

Wheel Center Height Front: 14.75
Wheel Well Clearance (Front): 6.00

Wheel Center Height Rear: 14.75
Wheel Well Clearance (Rear): 11.00

Bottom Frame Height - Front: 18.00
Bottom Frame Height - Rear: 24.75

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

GVWR Ratings:

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Front</td>
<td>3700</td>
<td>M_{front}</td>
<td>2831</td>
<td>2778</td>
<td>2778</td>
</tr>
<tr>
<td>Back</td>
<td>3900</td>
<td>M_{rear}</td>
<td>1958</td>
<td>2275</td>
<td>2275</td>
</tr>
<tr>
<td>Total</td>
<td>6700</td>
<td>M_{Total}</td>
<td>4789</td>
<td>5053</td>
<td>5053</td>
</tr>
</tbody>
</table>

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

Mass Distribution:

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>lb</td>
<td>LF: 1396</td>
<td>RF: 1382</td>
</tr>
</tbody>
</table>
Table C2. Vehicle Parameter Worksheet for Test No. 490024-2-1.

<table>
<thead>
<tr>
<th>Date: 2014-06-19</th>
<th>Test No.: 490024-2-1</th>
<th>VIN: 1D7HA18N585509318</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year: 2008</td>
<td>Make: Dodge</td>
<td>Model: Ram 1500</td>
</tr>
<tr>
<td>Body Style: Quad-Cab</td>
<td>Mileage: 168595</td>
<td></td>
</tr>
<tr>
<td>Engine: 4.7 liter V-8</td>
<td>Transmission: Automatic</td>
<td></td>
</tr>
<tr>
<td>Fuel Level: Empty</td>
<td>Ballast: 266 lb</td>
<td></td>
</tr>
<tr>
<td>Tire Pressure: Front 35 psi</td>
<td>Rear: 35 psi</td>
<td>Size: 265/70R17</td>
</tr>
</tbody>
</table>

**Measured Vehicle Weights:** (lb)

| LF: 1396 | RF: 1382 | Front Axle: 2778 |
| LR: 1145 | RR: 1130 | Rear Axle: 2275 |
| Left: 2541 | Right: 2512 | Total: 5053 |
|                      |          | 5000 ±110 lb allowed |
| Wheel Base: 140.5 inches | Track: F: 68.5 inches | R: 68 inches |
| 148 ±12 inches allowed | Track = (F+R)/2 = 67 ±1.5 inches allowed |

**Center of Gravity, SAE J874 Suspension Method**

| X: 63.26 in | Rear of Front Axle (63 ±4 inches allowed) |
| Y: -0.20 in | Left - Right + of Vehicle Centerline |
| Z: 28.5 in | Above Ground (minimum 28.0 inches allowed) |

| Hood Height: 46.00 inches | Front Bumper Height: 26.50 inches |
| 43 ±4 inches allowed |

| Front Overhang: 36.00 inches | Rear Bumper Height: 29.00 inches |
| 39 ±3 inches allowed |

| Overall Length: 223.75 inches |
| 237 ±13 inches allowed |
Table C3. Exterior Crush Measurements for Test No. 490024-2-1.

<table>
<thead>
<tr>
<th>Date: 2014-06-19</th>
<th>Test No.: 490024-2-1</th>
<th>VIN No.: 1D7HA18N585509318</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year: 2008</td>
<td>Make: Dodge</td>
<td>Model: Ram 1500 Quad-Cab</td>
</tr>
</tbody>
</table>

**VEHICLE CRUSH MEASUREMENT SHEET**

<table>
<thead>
<tr>
<th>Complete When Applicable</th>
<th>End Damage</th>
<th>Side Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undefomed end width</td>
<td>________</td>
<td>Bowing: B1  ________</td>
</tr>
<tr>
<td>Corner shift: A1</td>
<td>________</td>
<td>________</td>
</tr>
<tr>
<td>A2</td>
<td>________</td>
<td>B2 ________</td>
</tr>
<tr>
<td>End shift at frame (CDC)</td>
<td>(check one)</td>
<td>Bowing constant</td>
</tr>
</tbody>
</table>
| < 4 inches ________       | ________  | \[
| ≥ 4 inches ________       | ________  | \[

Note: Measure C1 to C6 from Driver to Passenger Side in Front or Rear impacts – Rear to Front in Side Impacts.

<table>
<thead>
<tr>
<th>Specific Impact Number</th>
<th>Plane* of C-Measurements</th>
<th>Direct Damage</th>
<th>Field L**</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
<th>±D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Front plane at bumper ht</td>
<td>20.0</td>
<td>11.50</td>
<td>30</td>
<td>0</td>
<td>0.5</td>
<td>2.5</td>
<td>7.0</td>
<td>9.5</td>
<td>11.5</td>
</tr>
<tr>
<td>2</td>
<td>Side plane at bumper ht</td>
<td>20.0</td>
<td>19.25</td>
<td>50</td>
<td>5.0</td>
<td>8.0</td>
<td>----</td>
<td>----</td>
<td>18.0</td>
<td>19.5</td>
</tr>
</tbody>
</table>

Measurements recorded in inches

Table taken from National Accident Sampling System (NASS).

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

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

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

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

Note: Use as many lines/columns as necessary to describe each damage profile.
Table C4. Occupant Compartment Measurements for Test No. 490024-2-1.

Date: 2014-06-19  Test No.: 490024-2-1  VIN No.: 1D7HA18N585509318
Year: 2008  Make: Dodge  Model: Ram 1500 Quad-Cab

### OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

<table>
<thead>
<tr>
<th></th>
<th>Before (inches)</th>
<th>After (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>65.00</td>
<td>65.00</td>
</tr>
<tr>
<td>A2</td>
<td>64.50</td>
<td>64.50</td>
</tr>
<tr>
<td>A3</td>
<td>65.00</td>
<td>64.25</td>
</tr>
<tr>
<td>B1</td>
<td>45.25</td>
<td>45.25</td>
</tr>
<tr>
<td>B2</td>
<td>39.50</td>
<td>38.50</td>
</tr>
<tr>
<td>B3</td>
<td>45.25</td>
<td>45.75</td>
</tr>
<tr>
<td>B4</td>
<td>42.00</td>
<td>42.00</td>
</tr>
<tr>
<td>B5</td>
<td>44.75</td>
<td>44.75</td>
</tr>
<tr>
<td>B6</td>
<td>42.00</td>
<td>42.00</td>
</tr>
<tr>
<td>C1</td>
<td>29.00</td>
<td>29.00</td>
</tr>
<tr>
<td>C2</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>C3</td>
<td>26.75</td>
<td>25.00</td>
</tr>
<tr>
<td>D1</td>
<td>12.75</td>
<td>12.75</td>
</tr>
<tr>
<td>D2</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>D3</td>
<td>11.50</td>
<td>13.00</td>
</tr>
<tr>
<td>E1</td>
<td>63.00</td>
<td>62.00</td>
</tr>
<tr>
<td>E2</td>
<td>64.25</td>
<td>65.25</td>
</tr>
<tr>
<td>E3</td>
<td>64.00</td>
<td>63.25</td>
</tr>
<tr>
<td>E4</td>
<td>64.25</td>
<td>63.25</td>
</tr>
<tr>
<td>F</td>
<td>60.00</td>
<td>60.00</td>
</tr>
<tr>
<td>G</td>
<td>60.00</td>
<td>60.00</td>
</tr>
<tr>
<td>H</td>
<td>39.00</td>
<td>39.00</td>
</tr>
<tr>
<td>I</td>
<td>39.00</td>
<td>39.00</td>
</tr>
<tr>
<td>J*</td>
<td>62.25</td>
<td>58.25</td>
</tr>
</tbody>
</table>

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

Figure D1. Sequential Photographs for Test No. 490024-2-1 (Overhead and Frontal Views).
Figure D1. Sequential Photographs for Test No. 490024-2-1 (Overhead and Frontal Views) (Continued).
Figure E1. Vehicle Angular Displacement for Test No. 490024-2-1.
Figure E2. Vehicle Longitudinal Accelerometer Trace for Test No. 490024-2-1
(Accelerometer Located at Center of Gravity).
Figure E3. Vehicle Lateral Accelerometer Trace for Test No. 490024-2-1 (Accelerometer Located at Center of Gravity).
Figure E4. Vehicle Vertical Accelerometer Trace for Test No. 490024-2-1 (Accelerometer Located at Center of Gravity).
Figure E5. Vehicle Longitudinal Accelerometer Trace for Test No. 490024-2-1
(Accelerometer Located Rear of Center of Gravity).
Figure E6. Vehicle Lateral Accelerometer Trace for Test No. 490024-2-1 (Accelerometer Located Rear of Center of Gravity).
Figure E7. Vehicle Vertical Accelerometer Trace for Test No. 490024-2-1 (Accelerometer Located Rear of Center of Gravity).