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# MASH TL-3 EVALUATION OF TRANSITION TO HAWAII MODIFIED DELAWARE RETROFIT THRIE-BEAM BRIDGE RAIL

Submitted by


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**16. Abstract**

This report documents four full-scale crash tests conducted to evaluate the safety performance of the Hawaii Department of Transportation's (HDOT's) Thrie-Beam Approach Guardrail Transition (AGT) according to the Manual for Assessing Safety Hardware, Second Edition (MASH 2016) Test Level 3 (TL-3) crash test criteria. This HDOT AGT consisted of 12.5 ft of nested thrie-beam rail and 6.25 ft of single ply thrie beam rail supported by W6x15 and W6x8.5 steel posts. The downstream end of the AGT was attached directly to the Hawaii Modified Delaware Retrofit Thrie-Beam Bridge Rail at the first bridge rail post. Below the AGT, a 6-in. tall concrete curb was placed flush with the front of the thrie beam rail. The curb's height transitioned up to meet the height of the elevated sidewalk on the bridge.

Test no. HMDT-1 was conducted in accordance with MASH test 3-21. In test no. HMDT-1, the transition contained and redirected the vehicle; however, the maximum allowable intrusion limits for the wheel well and toe pan area violated the MASH limits. Thus, test no. HMDT-1 was deemed unacceptable. Modifications were incorporated into the AGT design to mitigate the vehicle snag and excessive toe pan deformations. The vertical slope for the curb was flattened from 3H:1V to 6H:1V, and the AGT was stiffened by reducing the post spacing adjacent to the bridge rail end from 37½ in. to 18¾ in. Two full-scale crash tests, test nos. HMDT-2 and HMDT-3, were conducted on this modified AGT in accordance with MASH test designation nos. 3-21 and 3-20, respectively. Test no. HMDT-2 was deemed to have satisfied all safety performance criteria. In test no. HMDT-3, the transition redirected the vehicle; however, the maximum allowable intrusion limits for the side front panel area violated the MASH limits. Thus, test no. HMDT-3 was deemed unacceptable. Again, modifications were applied to the AGT, and the rail adjacent to the bridge rail was stiffened by adding a steel plate to the back side of the rail. In test no. HMDT-4, the AGT successfully contained and safely redirected the test vehicle. Test nos. HMDT-2 and HMDT-4 were deemed to have satisfied all safety performance criteria. Thus, the AGT to Hawaii Modified Delaware Thrie-Beam Bridge Rail installed behind and above a 6-in. tall curb was determined to be crashworthy according to MASH 2016 TL-3.

| | | | |
|---|---|---|---|
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## UNCERTAINTY OF MEASUREMENT STATEMENT

The Midwest Roadside Safety Facility (MwRSF) has determined the uncertainty of measurements for several parameters involved in standard full-scale crash testing and non-standard testing of roadside safety features. Information regarding the uncertainty of measurements for critical parameters is available upon request by the sponsor and the Federal Highway Administration.

## INDEPENDENT APPROVING AUTHORITY

The Independent Approving Authority for the data contained herein was Mr. Scott Rosenbaugh.

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| SI* (MODERN METRIC) CONVERSION FACTORS | | | | |
|---|---|---|---|---|
| **APPROXIMATE CONVERSIONS TO SI UNITS** | | | | |
| **Symbol** | **When You Know** | **Multiply By** | **To Find** | **Symbol** |
| | | **LENGTH** | | |
| in. | inches | 25.4 | millimeters | mm |
| ft | feet | 0.305 | meters | m |
| yd | yards | 0.914 | meters | m |
| mi | miles | 1.61 | kilometers | km |
| | | **AREA** | | |
| $in^2$ | square inches | 645.2 | square millimeters | $mm^2$ |
| $ft^2$ | square feet | 0.093 | square meters | $m^2$ |
| $yd^2$ | square yard | 0.836 | square meters | $m^2$ |
| ac | acres | 0.405 | hectares | ha |
| $mi^2$ | square miles | 2.59 | square kilometers | $km^2$ |
| | | **VOLUME** | | |
| fl oz | fluid ounces | 29.57 | milliliters | mL |
| gal | gallons | 3.785 | liters | L |
| $ft^3$ | cubic feet | 0.028 | cubic meters | $m^3$ |
| $yd^3$ | cubic yards | 0.765 | cubic meters | $m^3$ |
| | | NOTE: volumes greater than 1,000 L shall be shown in $m^3$ | | |
| | | **MASS** | | |
| oz | ounces | 28.35 | grams | g |
| lb | pounds | 0.454 | kilograms | kg |
| T | short ton (2,000 lb) | 0.907 | megagrams (or “metric ton”) | Mg (or "t") |
| | | **TEMPERATURE (exact degrees)** | | |
| °F | Fahrenheit | 5(F-32)/9<br>or (F-32)/1.8 | Celsius | °C |
| | | **ILLUMINATION** | | |
| fc | foot-candles | 10.76 | lux | lx |
| fl | foot-Lamberts | 3.426 | candela per square meter | $cd/m^2$ |
| | | **FORCE & PRESSURE or STRESS** | | |
| lbf | poundforce | 4.45 | newtons | N |
| $lbf/in^2$ | poundforce per square inch | 6.89 | kilopascals | kPa |
| **APPROXIMATE CONVERSIONS FROM SI UNITS** | | | | |
| **Symbol** | **When You Know** | **Multiply By** | **To Find** | **Symbol** |
| | | **LENGTH** | | |
| mm | millimeters | 0.039 | inches | in. |
| m | meters | 3.28 | feet | ft |
| m | meters | 1.09 | yards | yd |
| km | kilometers | 0.621 | miles | mi |
| | | **AREA** | | |
| $mm^2$ | square millimeters | 0.0016 | square inches | $in^2$ |
| $m^2$ | square meters | 10.764 | square feet | $ft^2$ |
| $m^2$ | square meters | 1.195 | square yard | $yd^2$ |
| ha | hectares | 2.47 | acres | ac |
| $km^2$ | square kilometers | 0.386 | square miles | $mi^2$ |
| | | **VOLUME** | | |
| mL | milliliter | 0.034 | fluid ounces | fl oz |
| L | liters | 0.264 | gallons | gal |
| $m^3$ | cubic meters | 35.314 | cubic feet | $ft^3$ |
| $m^3$ | cubic meters | 1.307 | cubic yards | $yd^3$ |
| | | **MASS** | | |
| g | grams | 0.035 | ounces | oz |
| kg | kilograms | 2.202 | pounds | lb |
| Mg (or "t") | megagrams (or “metric ton”) | 1.103 | short ton (2,000 lb) | T |
| | | **TEMPERATURE (exact degrees)** | | |
| °C | Celsius | 1.8C+32 | Fahrenheit | °F |
| | | **ILLUMINATION** | | |
| lx | lux | 0.0929 | foot-candles | fc |
| $cd/m^2$ | candela per square meter | 0.2919 | foot-Lamberts | fl |
| | | **FORCE & PRESSURE or STRESS** | | |
| N | newtons | 0.225 | poundforce | lbf |
| kPa | kilopascals | 0.145 | poundforce per square inch | $lbf/in^2$ |

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

# TABLE OF CONTENTS

## LIST OF FIGURES

# LIST OF TABLES

# 1 INTRODUCTION

## 1.1 Background

The Hawaii Department of Transportation (HDOT) utilizes a thrie-beam approach guardrail transition (AGT) to connect W-beam guardrail to the Hawaii Modified Delaware Retrofit Thrie-Beam Bridge Rail. However, the crashworthiness of this AGT has not been investigated under the current impact safety standards. This report documents four full-scale crash tests conducted in support of a study to evaluate the safety performance of the HDOT thrie-beam AGT to Hawaii Modified Delaware Retrofit Thrie-Beam Bridge Rail according to the Test Level 3 (TL-3) criteria of the *Manual for Assessing Safety Hardware, Second Edition* (MASH 2016) [1].

The original HDOT design of the thrie-beam AGT to Hawaii Modified Delaware Retrofit Thrie-Beam Bridge Rail is shown in Figure 1. The original HDOT AGT consisted of an 18-ft 9-in. long nested thrie-beam rail supported by four 6-ft 9-in. long W6x9 steel posts with 37½-in. spacing. A 6-in. tall, vertical curb was located below the thrie-beam rail. The upstream end of the AGT included another four 6-ft long, W6x9 posts with 18¾-in. spacing prior to an asymmetrical W-to-thrie transition rail segment and standard 6-ft long W6x8.5 or W6x9 MGS guardrail posts. The downstream end of the AGT was connected to the Hawaii Modified Delaware Retrofit Thrie-Beam Bridge Rail, which was evaluated to MASH TL-3 criteria in a parallel study by the researchers at the Midwest Roadside Safety Facility and documented in a separate report [2].

Note that a similar AGT system, connecting a W-beam guardrail to a concrete end post (i.e., the HDOT Type 2 End Post), was previously evaluated to MASH TL-3 criteria [3]. In that study, prior to full-scale crash testing, the HDOT AGT design was modified to improve its performance and connect to a 31-in. tall MGS guardrail. The modified AGT consisted of a nested thrie-beam rail supported by W6x15 posts with a 6-in. tall, vertical curb located below the thrie-beam guardrail, as shown in Figures 2 and 3. The upstream end of the modified HDOT AGT included the MASH-crashworthy, MGS upstream stiffness transition, and multiple W6x15 posts were removed from the downstream end of the AGT based on MASH testing of similar transitions. The height of this AGT to concrete bridge end post was reduced from 32 in. to 31 in. to match the adjacent MGS. The W6x12 blockouts were replaced with rectangular HSS sections to improve strength and prevent premature collapse. Finally, the flare at the upstream end of the curb was eliminated, and a vertical taper was used to terminate the curb for minimizing wheel snag. Two full-scale crash tests, test nos. HWTT-1 and HWTT-2, were conducted in accordance with MASH 2016 test designation nos. 3-20 and 3-21, respectively [3]. Both tests were deemed to have satisfied all safety performance criteria, and the modified HDOT thrie-beam AGT to concrete parapet was determined to be crashworthy to MASH TL-3.

The HDOT modified Delaware thrie-beam AGT system, that was crash tested in this research study, was similar to the HDOT thrie-beam AGT system evaluated in test nos. HWTT-1 and HWTT-2. One difference between the current AGT and the previously tested AGT was the substitution of the concrete parapet evaluated in tests HWTT-1 and HWTT-2 with the Hawaii Modified Delaware Retrofit Thrie-Beam Bridge Rail in the current study. Therefore, similar modifications were incorporated into the original Hawaii AGT (Figure 1), as used to modify the HWTT system [3]. First, the length of the nested thrie-beam section was reduced from 18 ft – 9 in. to 12 ft – 6 in. to match the common rail segment length. A single-ply, 6 ft – 3 in. thrie-beam rail was placed between the asymmetric rail and the nested rail. The location of rail splices were accordingly revised. Also, the four 6-ft 9-in. long W6x9 posts were replaced by three 6-ft 6-in. long W6x15 steel posts. The other W6x9 posts in the nested thrie-beam section retained the 18¾-in. spacing. The length of the curb was reduced from 176¼ in. to 170¾ in. to be compatible with the shortened nested thrie-beam section. The modified AGT connected to the HDOT AGT to Hawaii Modified Delaware Thrie-Beam Bridge Rail was evaluated to MASH TL-3 criteria.

## 1.2 Objective

The objective of this research was to evaluate the safety performance of the modified HDOT AGT to the Hawaii Modified Delaware Retrofit Thrie-beam Bridge Rail. The modified AGT system was to be evaluated according to the TL-3 criteria of MASH 2016 [1].

## 1.3 Scope

The research objective was achieved through the completion of several tasks. The first task included a review of the existing details of the HDOT AGT to Hawaii Modified Delaware Retrofit Thrie-Beam Bridge Rail, the identification of potential safety issues, and the recommendation of system modifications to improve the crashworthiness of the AGT. The modifications were made to the transition and the curb in the original HDOT AGT system. The modified system was constructed and subjected to full-scale crash tests in accordance with MASH 2016 test designation nos. 3-20 and 3-21. Design modifications were also required to resolve problems identified during the crash testing program. Following full-scale crash testing, the test results were analyzed, evaluated, and documented. Conclusions and recommendations were then made pertaining to the safety performance of the HDOT AGT to Hawaii Modified Delaware Retrofit Thrie-Beam Bridge Rail. Note that the evaluation and crash testing of the bridge rail was documented separately in another report [2].

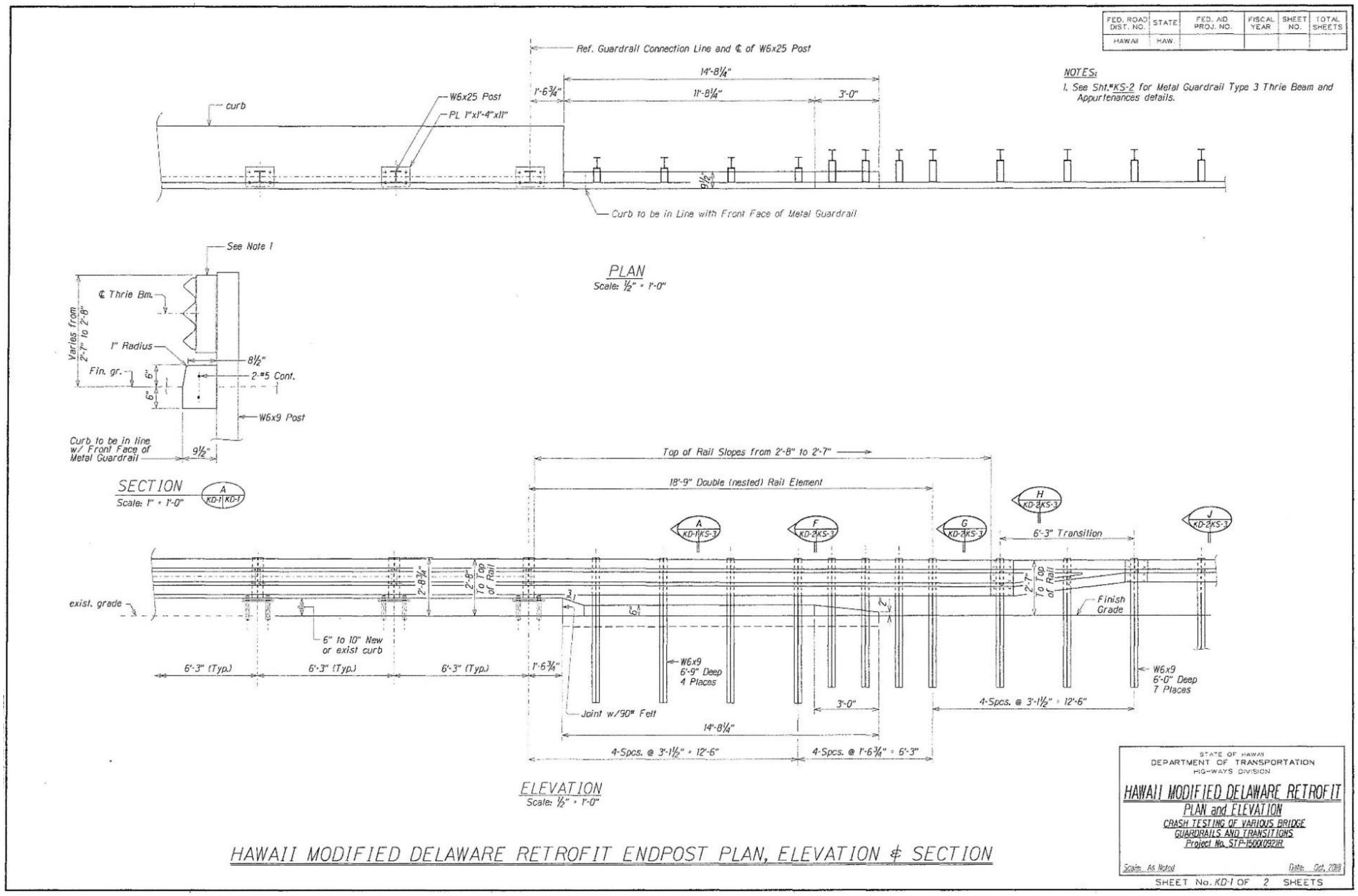



Figure 1. Original HDOT AGT Transition to Hawaii Modified Delaware Thrie-Beam Bridge Rail Details

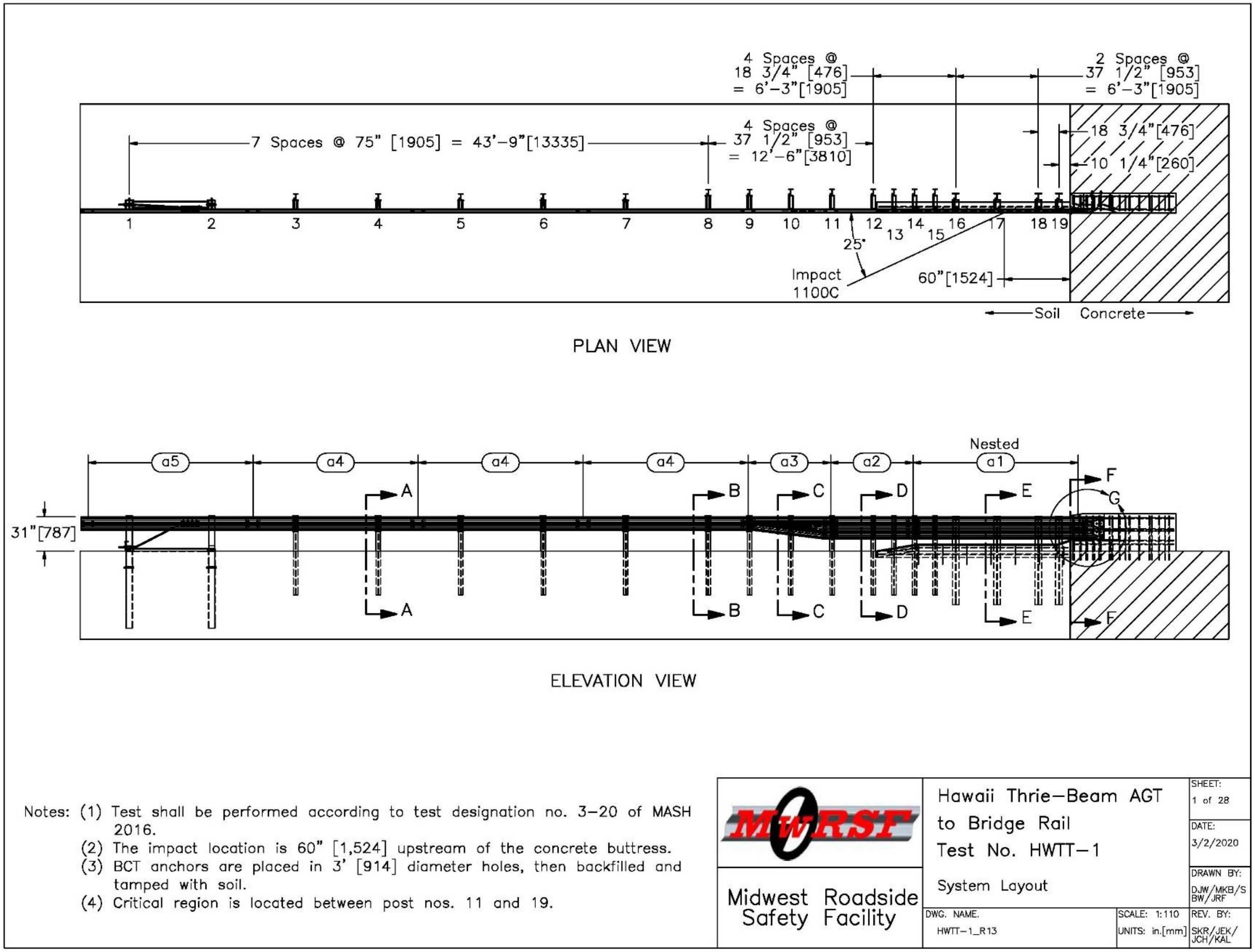



Figure 2. System Layout for Test No. HWTT-1 [3]

Figure 3. System Installation – Test Nos. HWTT-1 and HWTT-2 [3]

# 2 TEST REQUIREMENTS AND EVALUATION CRITERIA

## 2.1 Test Requirements

Longitudinal barriers, such as approach guardrail transitions, must satisfy impact safety standards in order to be declared eligible for federal reimbursement by the Federal Highway Administration (FHWA) for use on the National Highway System (NHS). For new hardware, these safety standards consist of the guidelines and procedures published in MASH 2016. Note that there is no difference between MASH 2009 [4] and MASH 2016 for longitudinal barriers, such as the system tested in this project, except that additional occupant compartment deformation measurements, photographs, and documentation are required by MASH 2016. According to TL-3 of MASH 2016, longitudinal barrier transition systems must be subjected to two full-scale vehicle crash tests, as summarized in Table 1.

Table 1. MASH 2016 TL-3 Crash Test Conditions for Longitudinal Barriers

| Test Article | Test Designation No. | Test Vehicle | Vehicle Weight lb | Impact Conditions | | Evaluation Criteria [1] |
|---|---|---|---|---|---|---|
| | | | | Speed mph | Angle degrees | |
| Longitudinal Barrier | 3-20 | 1100C | 2,420 | 62 | 25 | A,D,F,H,I |
| | 3-21 | 2270P | 5,000 | 62 | 25 | A,D,F,H,I |

[1] Evaluation criteria are explained in Table 2

Recent testing of AGTs has illustrated the importance of evaluating two different transition regions along the length of the AGT: (1) the downstream transition where the thrie-beam rail connects to the bridge rail and (2) the upstream stiffness transition where the W-beam guardrail transitions to a stiffer thrie-beam barrier. The upstream stiffness transition of this HDOT AGT was specifically designed to replicate the MASH-crashworthy MGS stiffness transition [5]. Therefore, crash testing of the upstream stiffness transition was deemed non-critical.

According to MASH 2016, the AGT should be crash tested at a location that evaluates the greatest propensity for vehicle snag. For non-rigid longitudinal barriers, the critical impact points (CIPs) are primarily controlled by the post dynamic yield force and the plastic moment of the rail elements. In MASH, CIP selection curves are provided as a function of plastic moment of rail ($M_p$) and post yield force per unit length of barrier ($F_p$). For this AGT, the CIPs were selected using the calculated $F_p$ and $M_p$ values in conjunction with the CIP plots found in Section 2.3.2.1 of MASH 2016. The centerline of the first post of the bridge rail (post no. 19) was selected as the reference point for the critical impact distance, $x$, in the MASH CIP plots. The CIP determination for both tests are provided in Appendix A.

Note that the test matrix detailed herein represents the researchers' best engineering judgement with respect to the MASH 2016 safety requirements and their internal evaluation of critical tests deemed necessary to evaluate the crashworthiness of the approach guardrail transition system. However, these opinions may change in the future due to the development of new knowledge (crash testing, real-world performance, etc.) or changes to the evaluation criteria. Thus, any tests within the evaluation matrix deemed non-critical may eventually need to be evaluated based on additional knowledge gained over time or revisions to the MASH 2016 criteria.

Table 2. MASH 2016 Evaluation Criteria for Longitudinal Barriers

<table>
<tr><td>Structural Adequacy</td><td>A.</td><td colspan="3">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></tr>
<tr><td rowspan="10">Occupant Risk</td><td>D.</td><td colspan="3">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. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH 2016.</td></tr>
<tr><td>F.</td><td colspan="3">The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</td></tr>
<tr><td rowspan="4">H.</td><td colspan="3">Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:</td></tr>
<tr><td colspan="3">Occupant Impact Velocity Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>30 ft/s</td><td>40 ft/s</td></tr>
<tr><td rowspan="4">I.</td><td colspan="3">The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:</td></tr>
<tr><td colspan="3">Occupant Ridedown Acceleration Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>15.0 g’s</td><td>20.49 g’s</td></tr>
</table>

## 2.2 Evaluation Criteria

Evaluation criteria for full-scale vehicle crash testing are based on three factors: (1) structural adequacy; (2) occupant risk; and (3) vehicle trajectory after collision. Criteria for structural adequacy are intended to evaluate the ability of the thrie-beam guardrail transition system to contain and redirect impacting vehicles. In addition, controlled lateral deflection of the test article is acceptable. Occupant risk evaluates the degree of hazard to occupants in the impacting vehicle. Post-impact vehicle trajectory is a measure of the potential of the vehicle to result in a secondary collision with other vehicles and/or fixed objects, thereby increasing the risk of injury to the occupants of the impacting vehicle and/or other vehicles. These evaluation criteria are summarized in Table 2 and defined in greater detail in MASH 2016. The full-scale vehicle crash tests were conducted and reported in accordance with the procedures provided in MASH 2016.

In addition to the standard occupant risk measures, the Post-Impact Head Deceleration (PHD), the Theoretical Head Impact Velocity (THIV), and the Acceleration Severity Index (ASI) were determined and reported. Additional discussion on PHD, THIV, and ASI is provided in MASH 2016.

### 2.3 Soil Strength Requirements

In accordance with Chapter 3 and Appendix B of MASH 2016, foundation soil strength must be verified before any full-scale crash testing can occur. During the installation of a soil dependent system, W6x16 posts are installed near the impact region utilizing the same installation procedures as the system itself. Prior to full-scale testing, a dynamic impact test must be conducted to verify a minimum dynamic soil resistance of 7.5 kips at post deflections between 5 and 20 in. measured at a height of 25 in. If dynamic testing near the system is not desired, MASH 2016 permits a static test to be conducted instead and compared against the results of a previously established baseline test. In this situation, the soil must provide a resistance of at least 90 percent of the static baseline test at deflections of 5, 10, and 15 in. Further details can be found in Appendix B of MASH 2016.

# 3 DESIGN DETAILS, TEST NO. HMDT-1

The test installation had a total length of 177 ft – 6 in. and consisted of a 100-ft long section of the Hawaii Modified Delaware Thrie-Beam Bridge Rail, the preliminary design of the HDOT thrie-beam AGT, MGS rail, and anchorage system at the upstream end, and a thrie-beam anchorage system at the downstream end of the bridge rail, as shown in Figures 4 through 38. Photographs of the test installation are shown in Figure 39 through Figure 41. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix B. Note that the drawing set includes details for the entire system, including the bridge rail, AGT, W-beam rail installation, and anchorage systems. However, only the AGT details are described below and in Appendix B.

The preliminary design of HDOT's thrie-beam AGT consisted of a 12-ft 6-in. long, 12-gauge nested thrie-beam rail and 6-ft 3-in. of single ply 12-ga. thrie beam rail supported by W6x15 and W6x9 steel posts at various spacings. Posts in the nested thrie-beam section of AGT consisted of three 6-ft 6-in. long W6x15 steel sections with 37½-in. spacing and four 6-ft long W6x9 steel sections with 18¾-in. spacing. The remaining posts were 6-ft long W6x9 steel sections. The upstream end of the AGT incorporated the previously MASH-tested MGS upstream stiffness transition to connect the AGT to the adjacent MGS [5]. Approximately 50 ft of the MGS extended from the upstream end of the AGT and was anchored using an MGS trailing end anchor system. The guardrail anchorage system consisted of timber posts, foundation tubes, anchor cables, bearing plates, rail brackets, and channel struts, which closely resembled the hardware used in the Modified Breakaway Cable Terminal (BCT) system. The guardrail anchorage system has been MASH TL-3 crash tested as a downstream trailing end terminal [6-9]. Blockouts within the AGT consisted of rectangular HSS steel tubes. Blockouts on the W6x15 posts were 6 in. wide, while 4-in. wide blockouts were used with W6x8.5/W6x9 posts. This MGS upstream stiffness transition was designed to transition from the 31-in. tall Midwest Guardrail System (MGS) to the stiffened thrie-beam regions of the AGT using an asymmetrical W-to-thrie transition rail segment and standard 6-ft long W6x8.5 or W6x9 guardrail posts. The MGS upstream stiffness transition was already successfully evaluated, and crash tested to MASH TL-3 [5].

A 6-in. tall concrete curb was located below the AGT with its front face tapered with a slope of 6V:1H and aligned with the face of the guardrail above. The curb began at the upstream end of the bridge rail and farther extended 14 ft – 2¾ in. upstream. The upstream end of the curb was terminated with a vertical taper measuring 4 in. vertically by 36 in. longitudinally. A 3-in. x 9-in. vertical taper was applied to the downstream end of the curb adjacent to the bridge rail sidewalk to mitigate wheel snag on the curb.

The downstream end of transition was connected to the Hawaii Modified Delaware Thrie-Beam Bridge Rail, which consisted of a 10-gauge thrie-beam rail with a mounting height of 32 in. supported by W6x25 steel posts, spaced at 6 ft – 3 in. and installed on a 9-in. tall concrete sidewalk. The top rail mounting height gradually changed from 31 in. at post no. 11 (i.e., upstream of the asymmetrical W-to-thrie transition rail segment) to 32 in. at post no. 19 (i.e., first post of the bridge rail) over a length of 18¾ ft. The bridge rail was designed for use with a 6- to 9-in. tall concrete sidewalk and was successfully crash tested to MASH TL-3 criteria in a parallel study by the researchers at the Midwest Roadside Safety Facility and documented in a separate report [2].

The downstream end of the bridge rail incorporated a thrie-beam end anchor assembly that developed the necessary tensile strength and consisted of a vertical HSS6x12x¼ steel tube, an HSS6x4x$\frac{5}{16}$ steel tube angled at 55 degrees to the ground, and a 10-gauge thrie-beam terminal connector, as shown in Figure 30. This thrie-beam downstream end anchorage was successfully crash tested and reported in another project [10]. Note that this anchorage is not an essential part of the system and was incorporated to anchor the bridge rail at the downstream end.

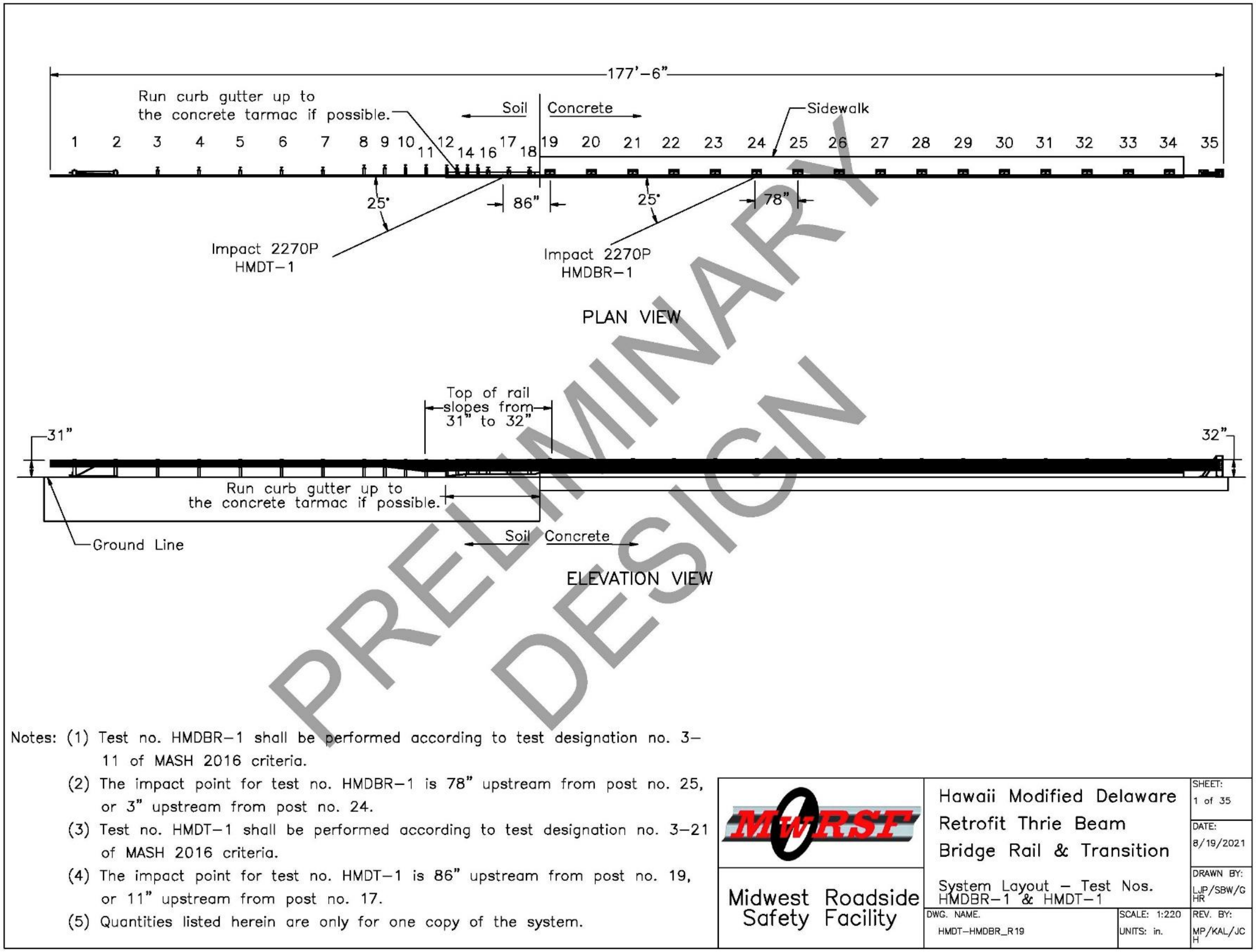



Figure 4. Test Installation Layout, Test No. HMDT-1

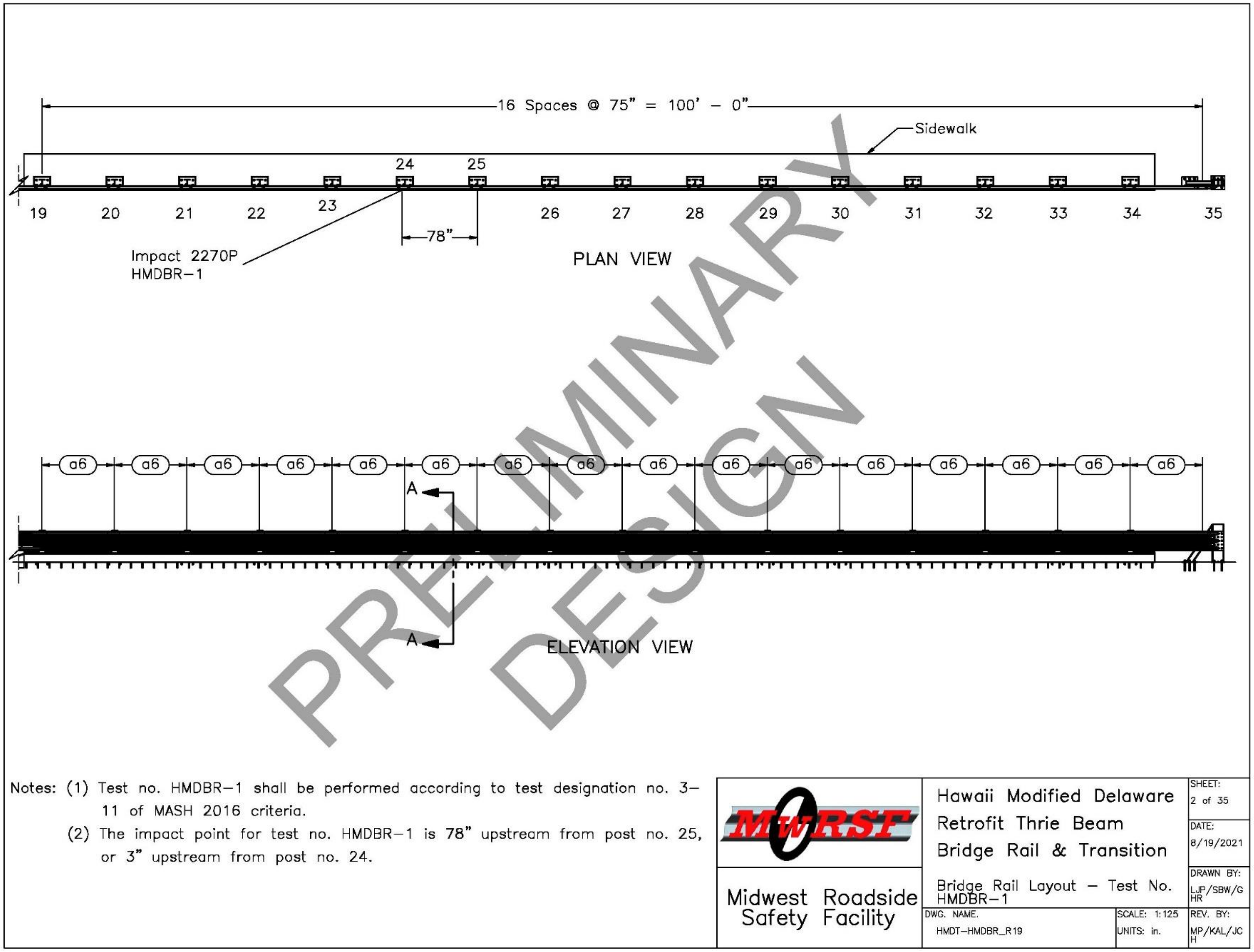



Figure 5. Bridge Rail Layout, Test No. HMDT-1

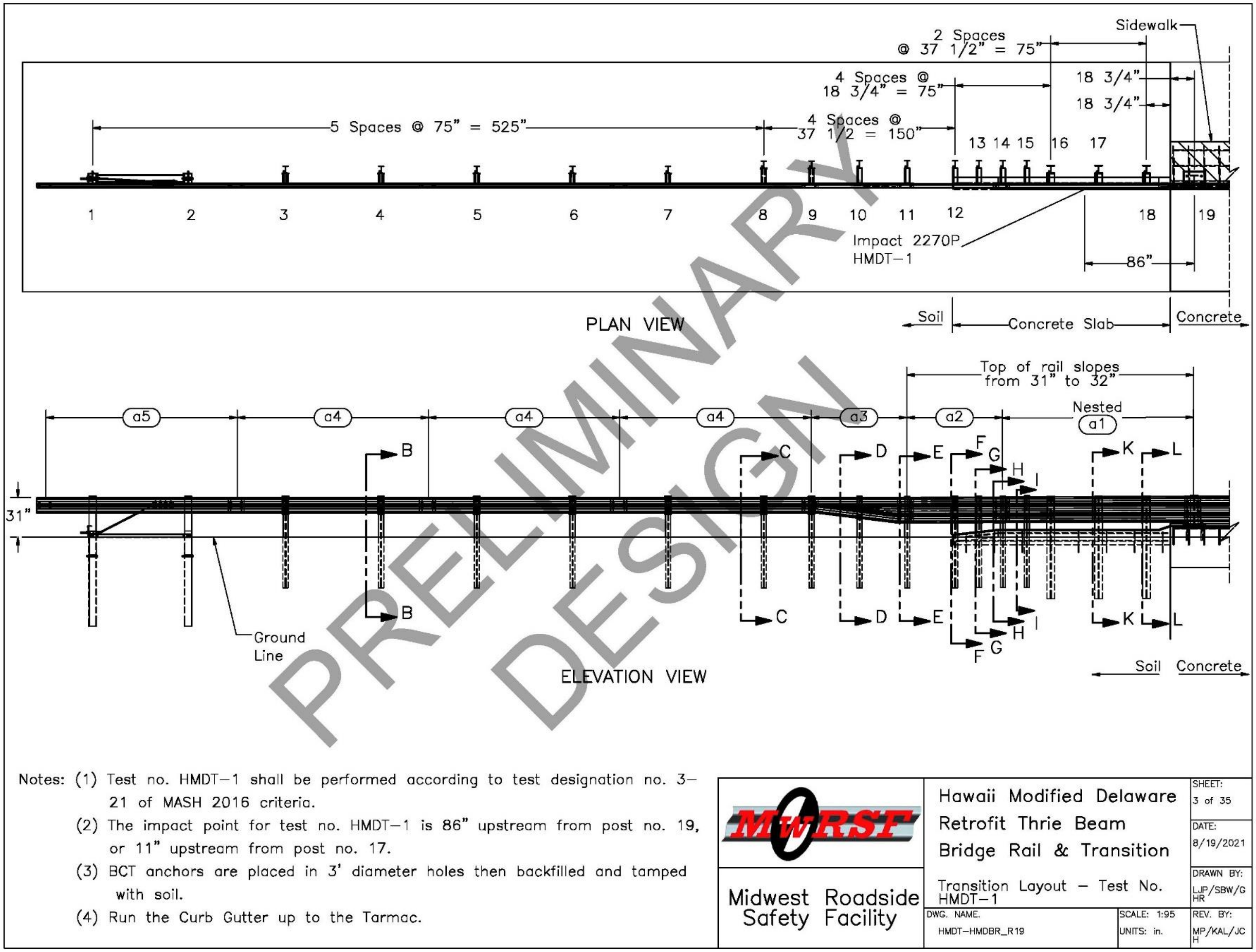



Figure 6. Transition Layout, Test No. HMDT-1

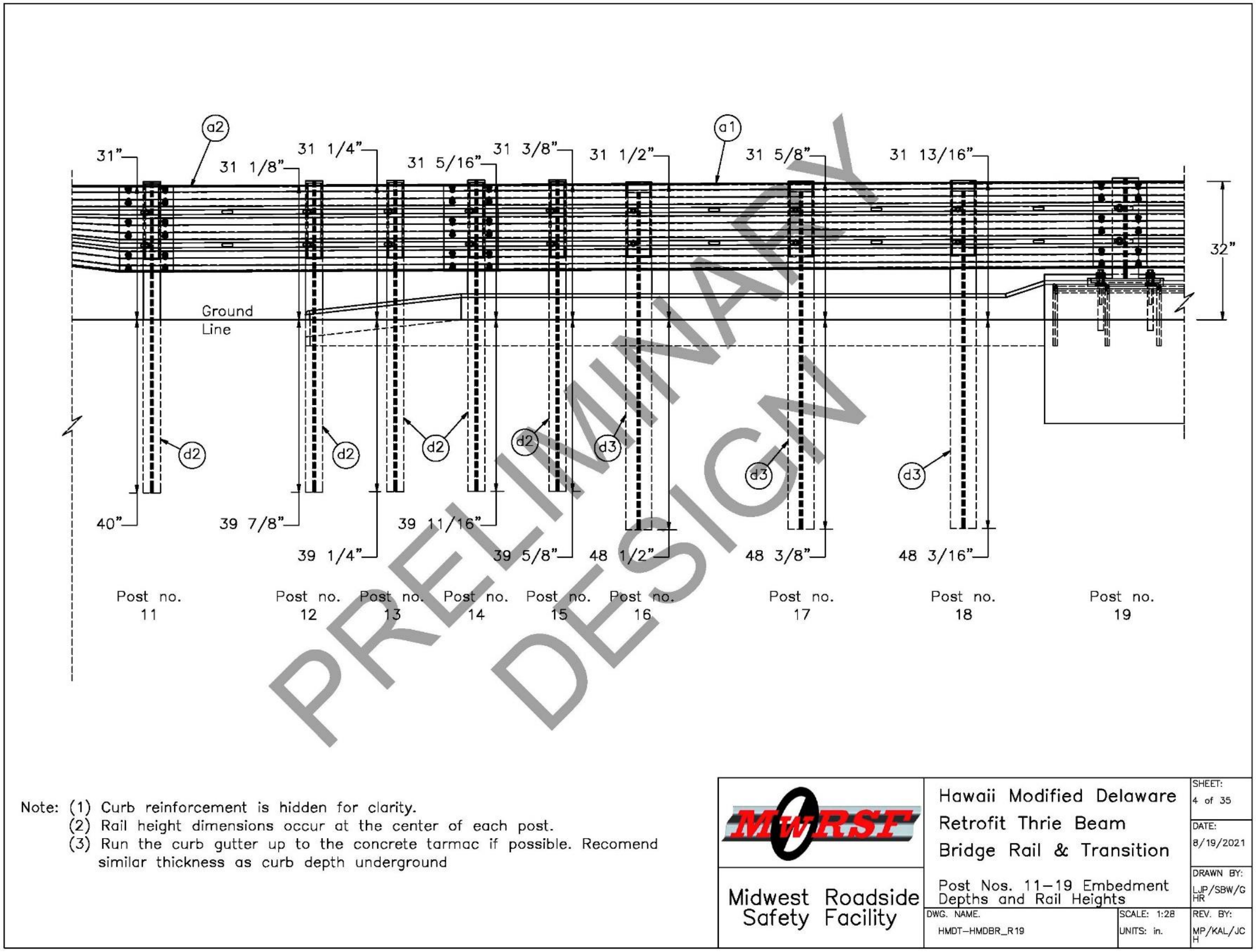



Figure 7. Post Nos. 11 through 19 Embedment Depths and Rail Heights, Test No. HMDT-1

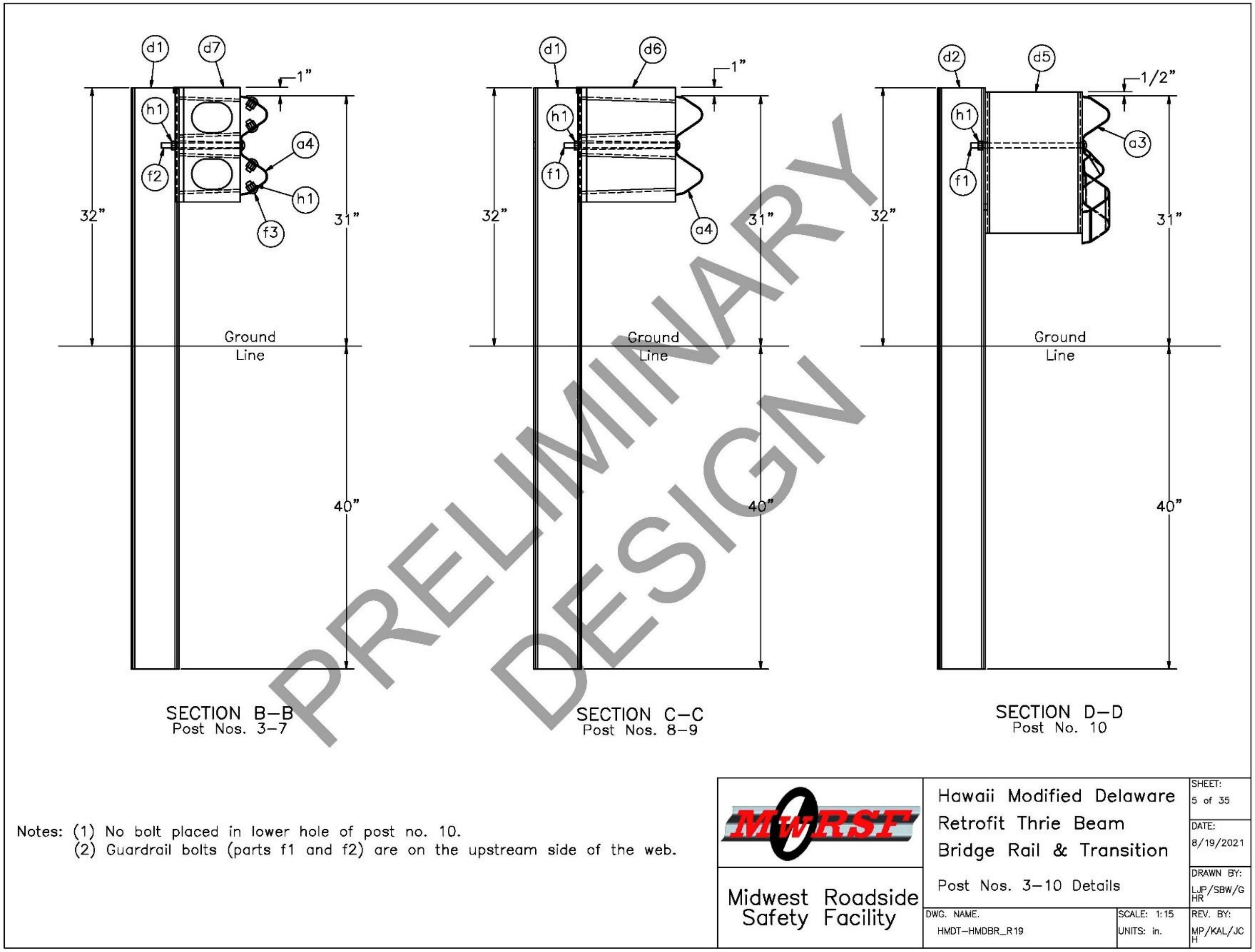



Figure 8. Post Nos. 3 through 10 Details, Test No. HMDT-1

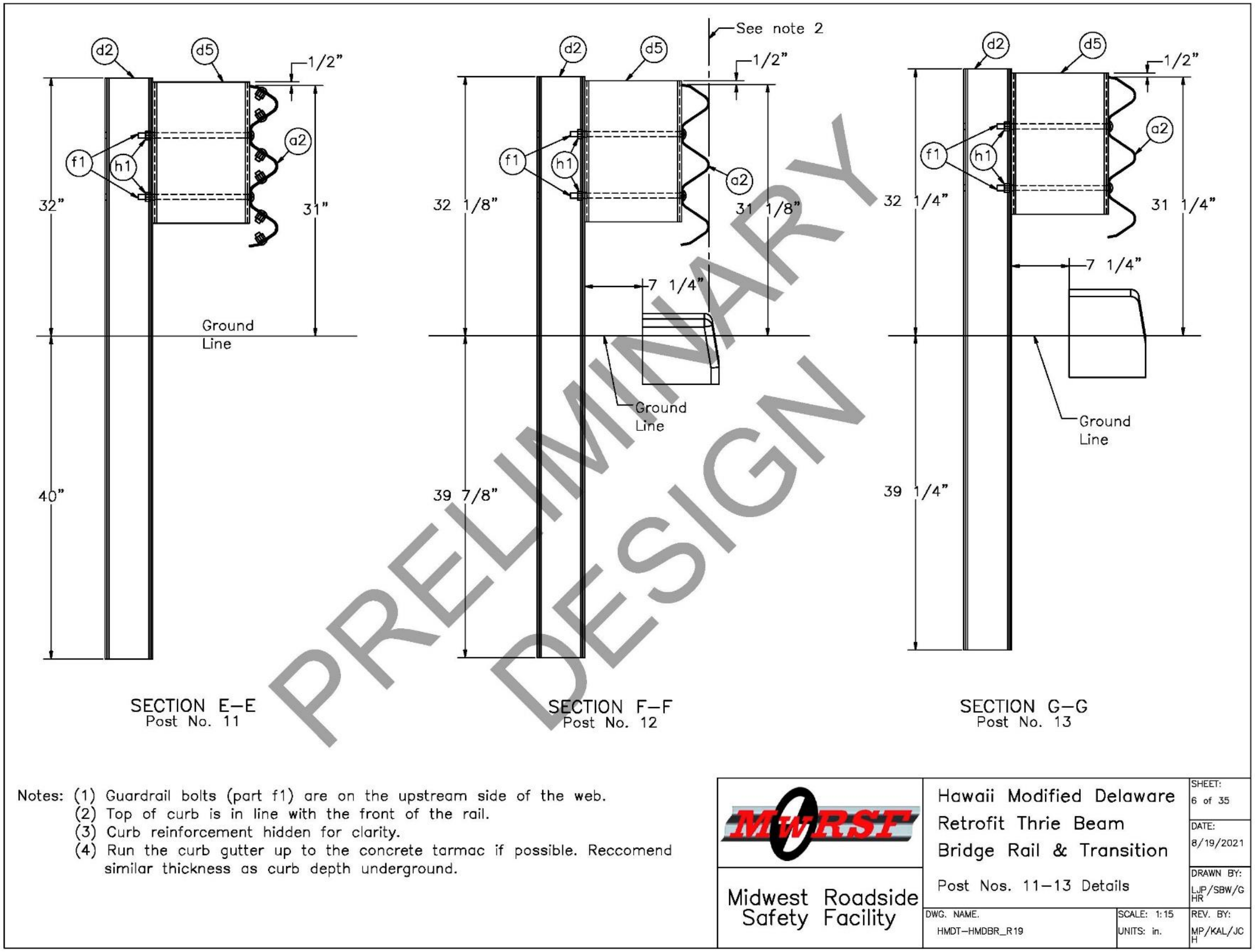



Figure 9. Post Nos. 11 through 13 Details, Test No. HMDT-1

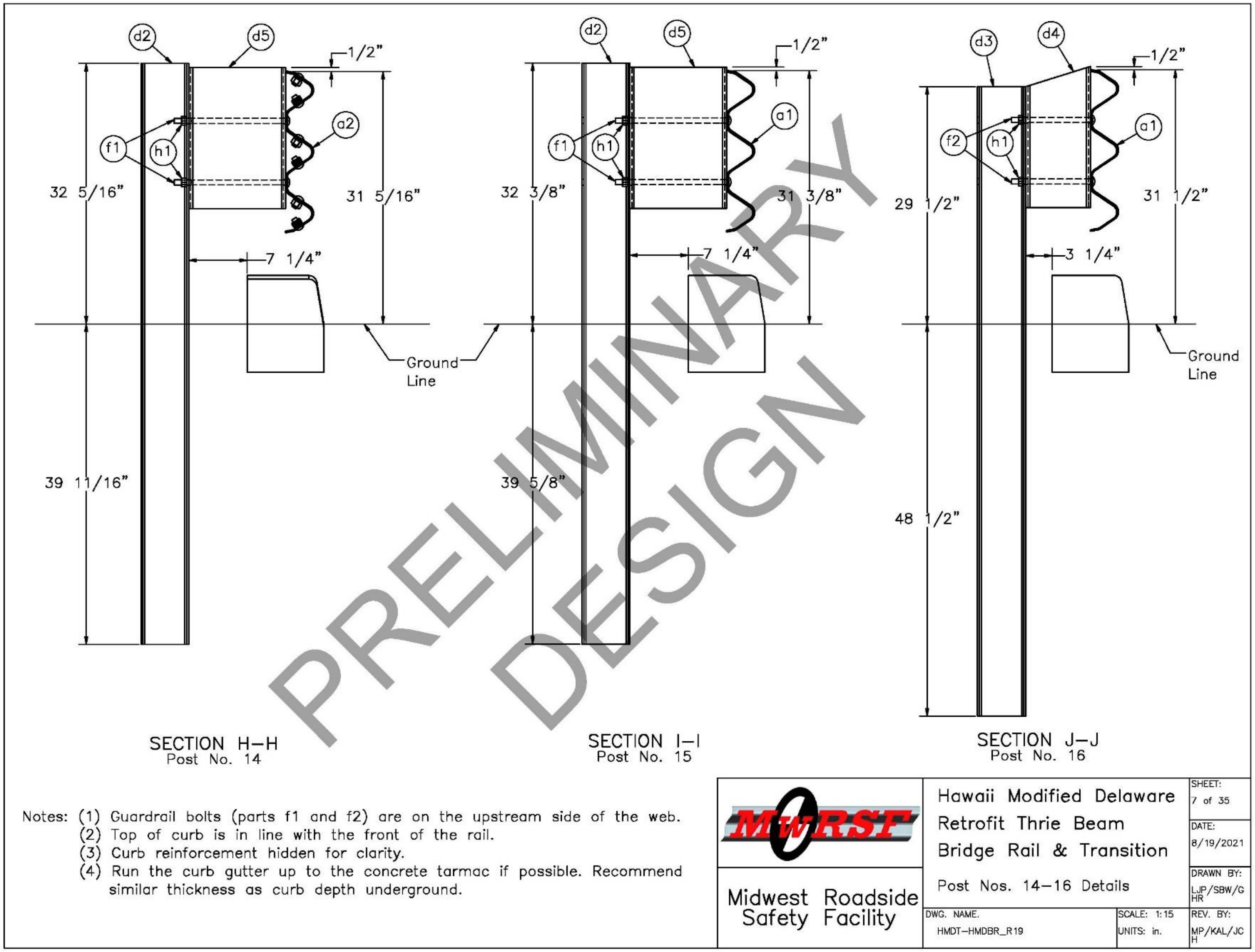
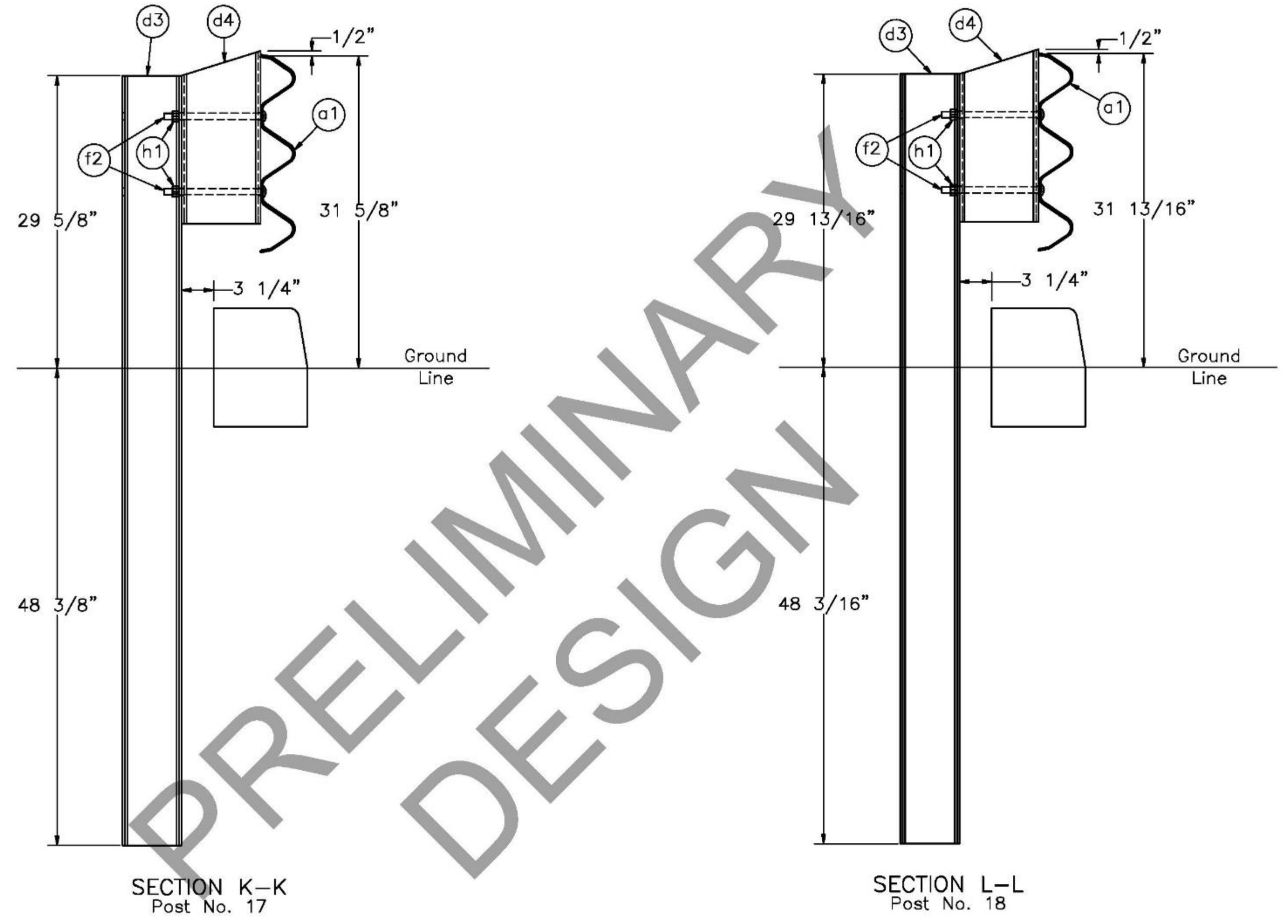



Figure 10. Post Nos. 14 through 16 Details, Test No. HMDT-1




Notes: (1) Guardrail bolts (part f2) are on the upstream side of the web.
(2) Top of curb is in line with the front of the rail.
(3) Curb reinforcement hidden for clarity.
(4) Run the curb gutter up to the concrete tarmac if possible. Recommend similar thickness as curb depth underground.

| | | | |
|---|---|---|---|
| MwRSF Midwest Roadside Safety Facility | Hawaii Modified Delaware Retrofit Thrie Beam Bridge Rail & Transition | | SHEET: 8 of 35 |
| | | | DATE: 8/19/2021 |
| | Post Nos. 17–18 Details | | DRAWN BY: LJP/SBW/GHR |
| | DWG. NAME. HMDT–HMDBR_R19 | SCALE: 1:15 UNITS: in. | REV. BY: MP/KAL/JCH |

Figure 11. Post Nos. 17 and 18 Details, Test No. HMDT-1

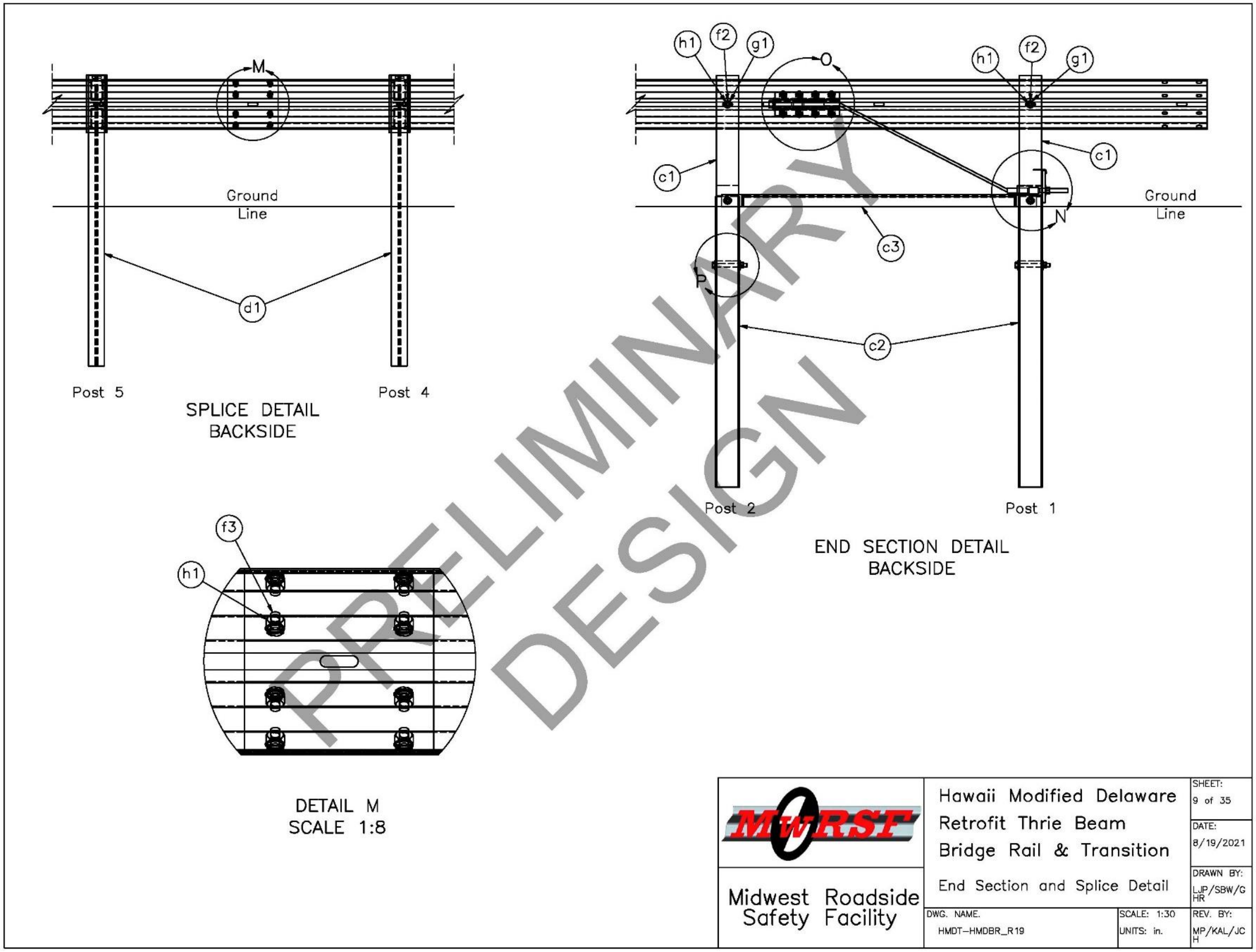



Figure 12. End Section and Splice Detail, Test No. HMDT-1

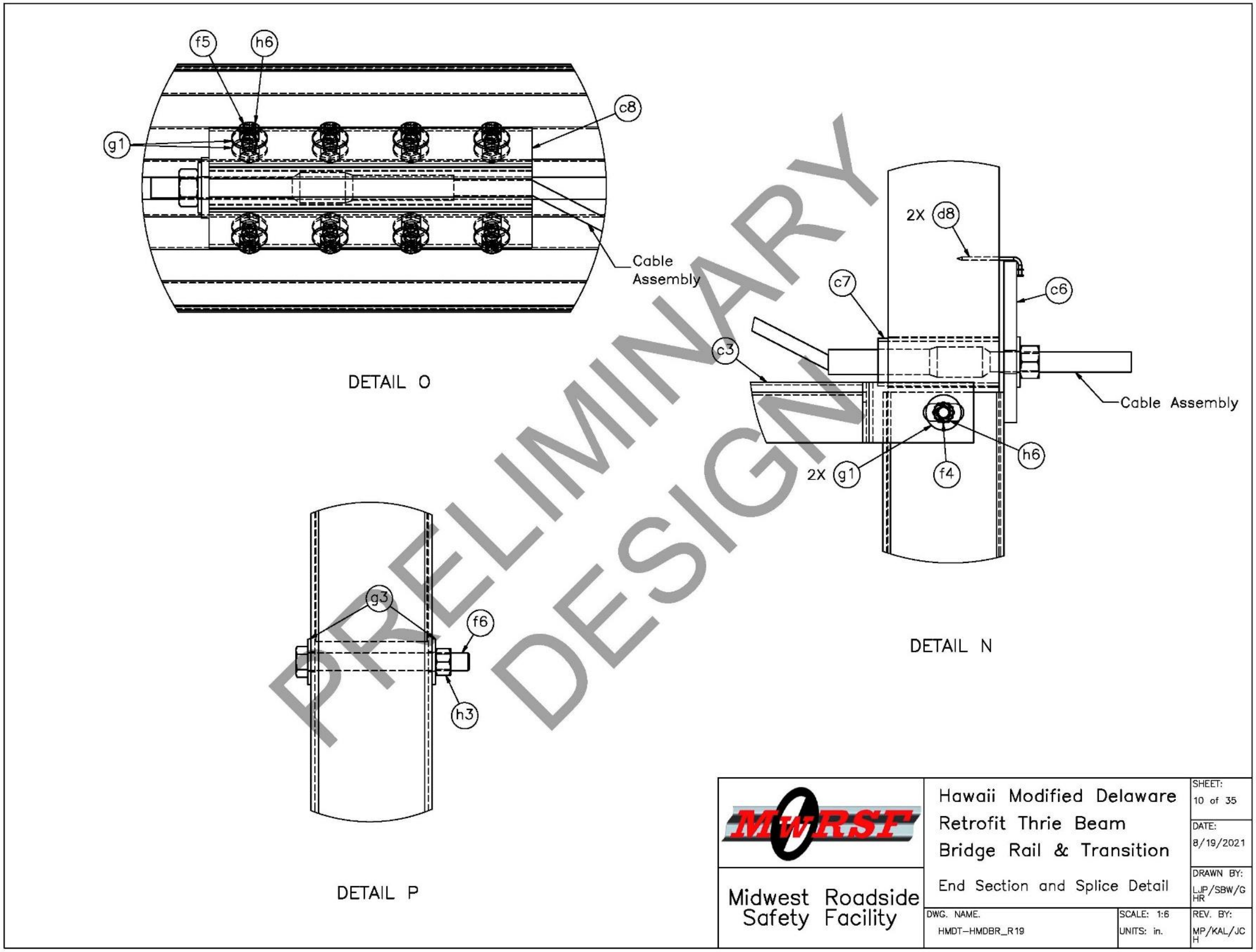



Figure 13. End Section and Splice Detail, Test No. HMDT-1

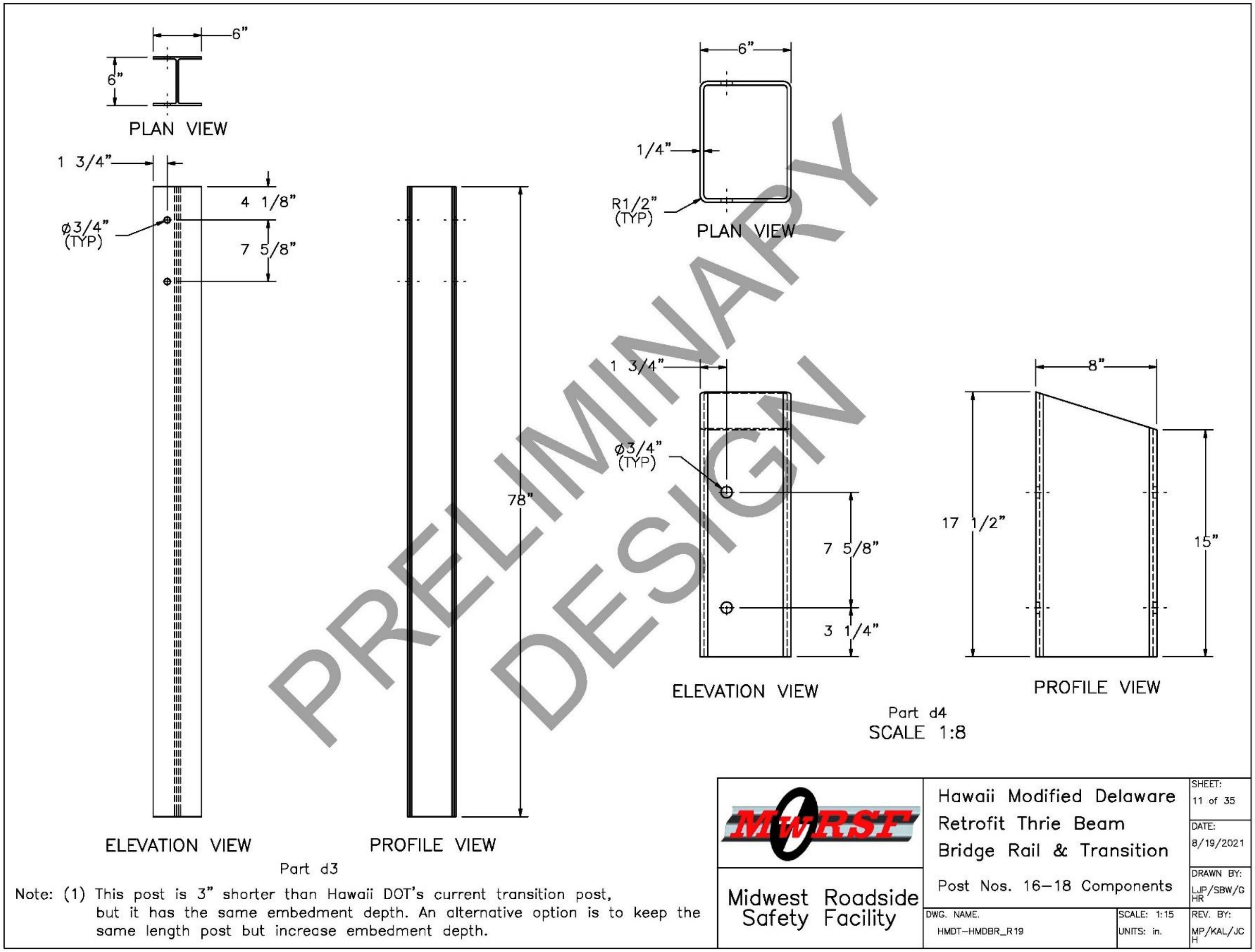



Figure 14. Post Nos. 16 through 18 Components, Test No. HMDT-1

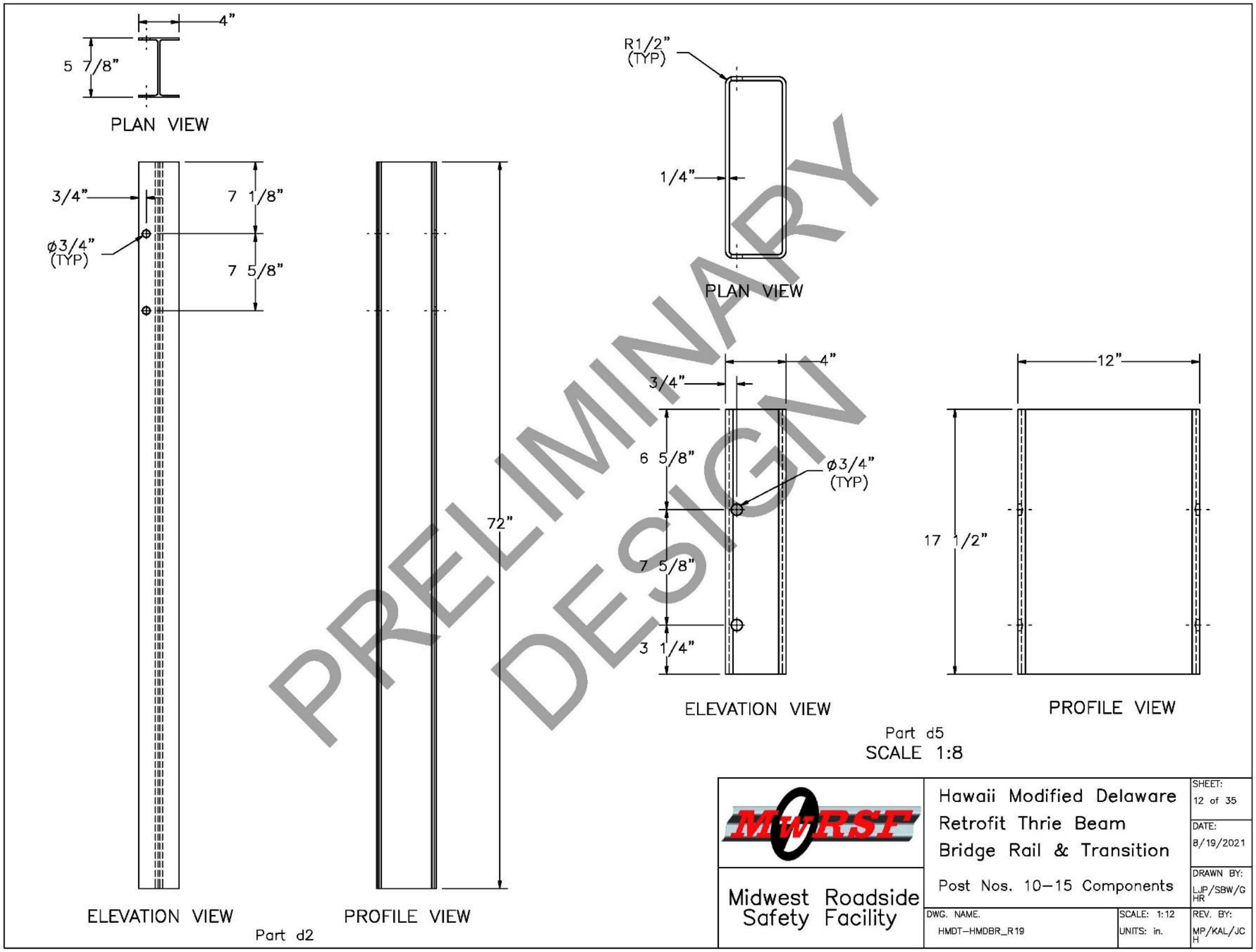



Figure 15. Post Nos. 10 through 15 Components, Test No. HMDT-1

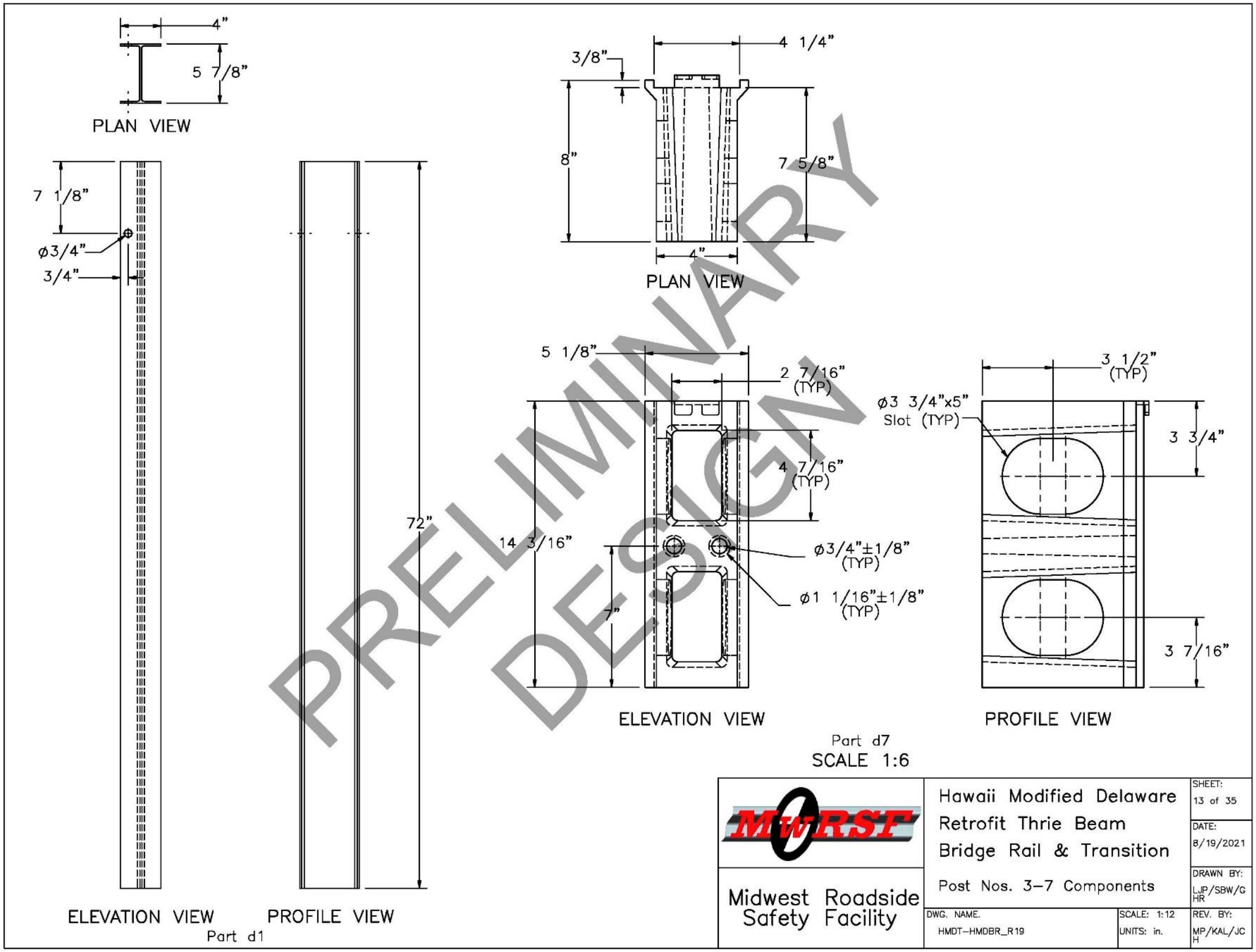



Figure 16. Post Nos. 3 through 7 Components, Test No. HMDT-1

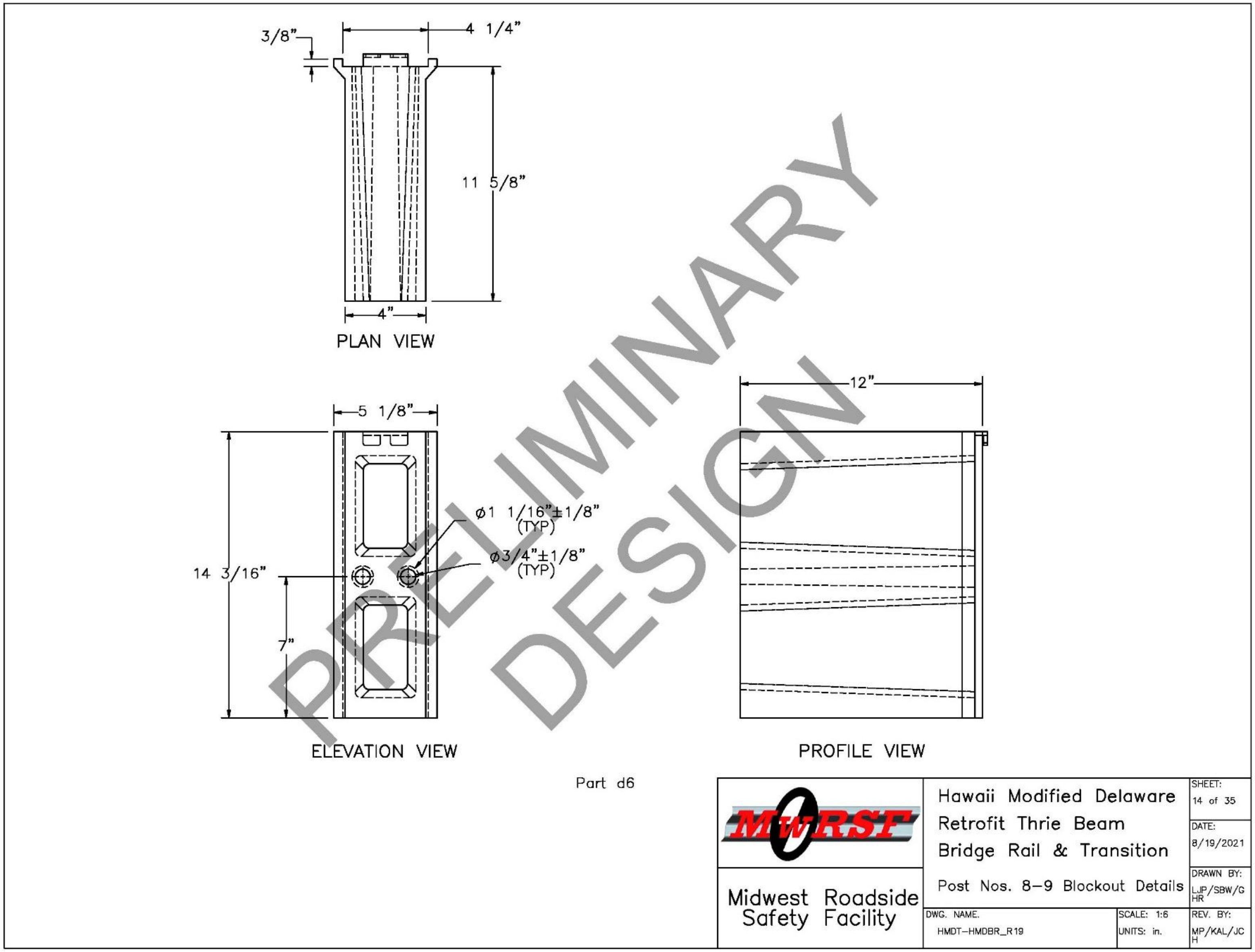



Figure 17. Post Nos. 8 and 9 Blockout Details, Test No. HMDT-1

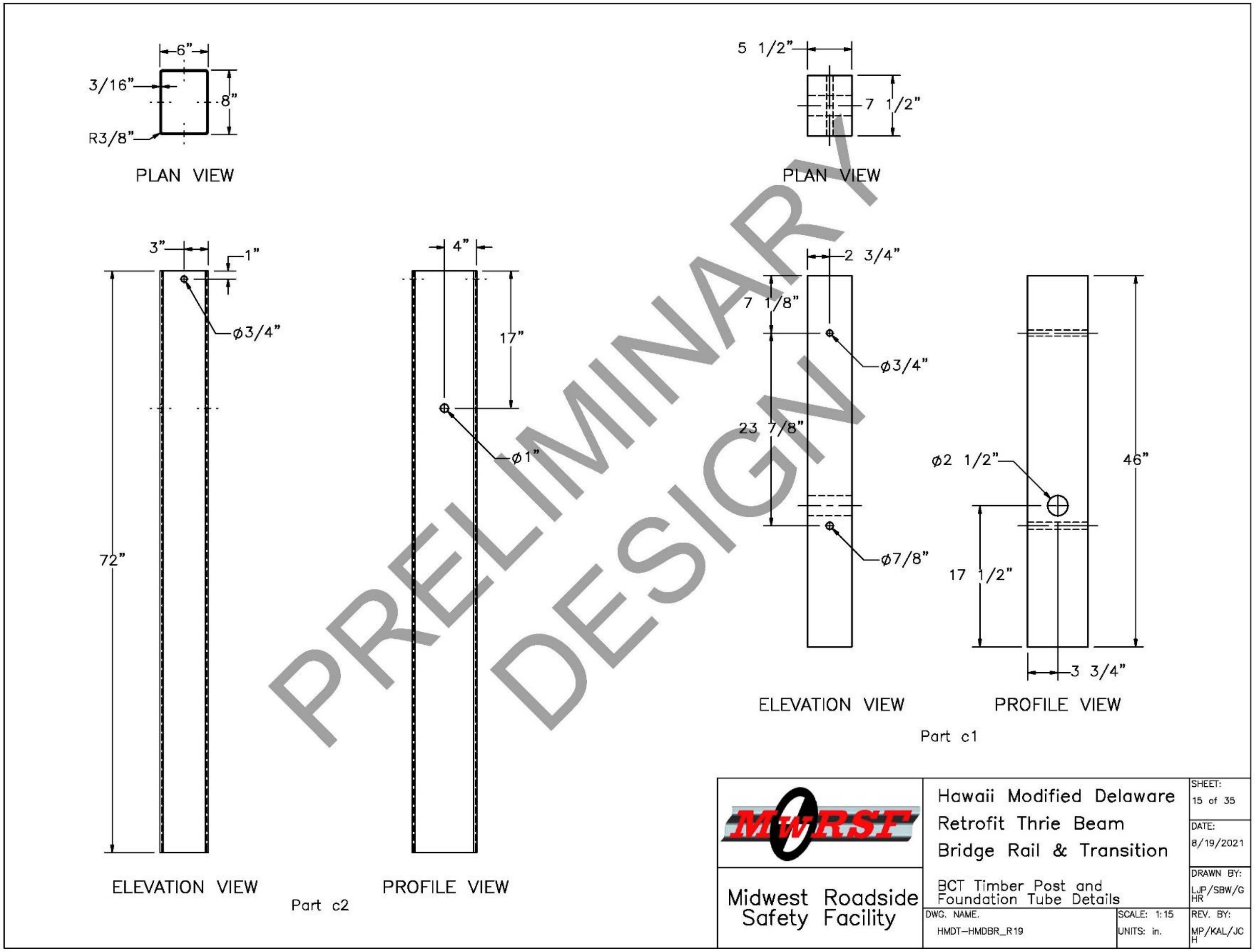



Figure 18. BCT Timber Post and Foundation Tube Details, Test No. HMDT-1

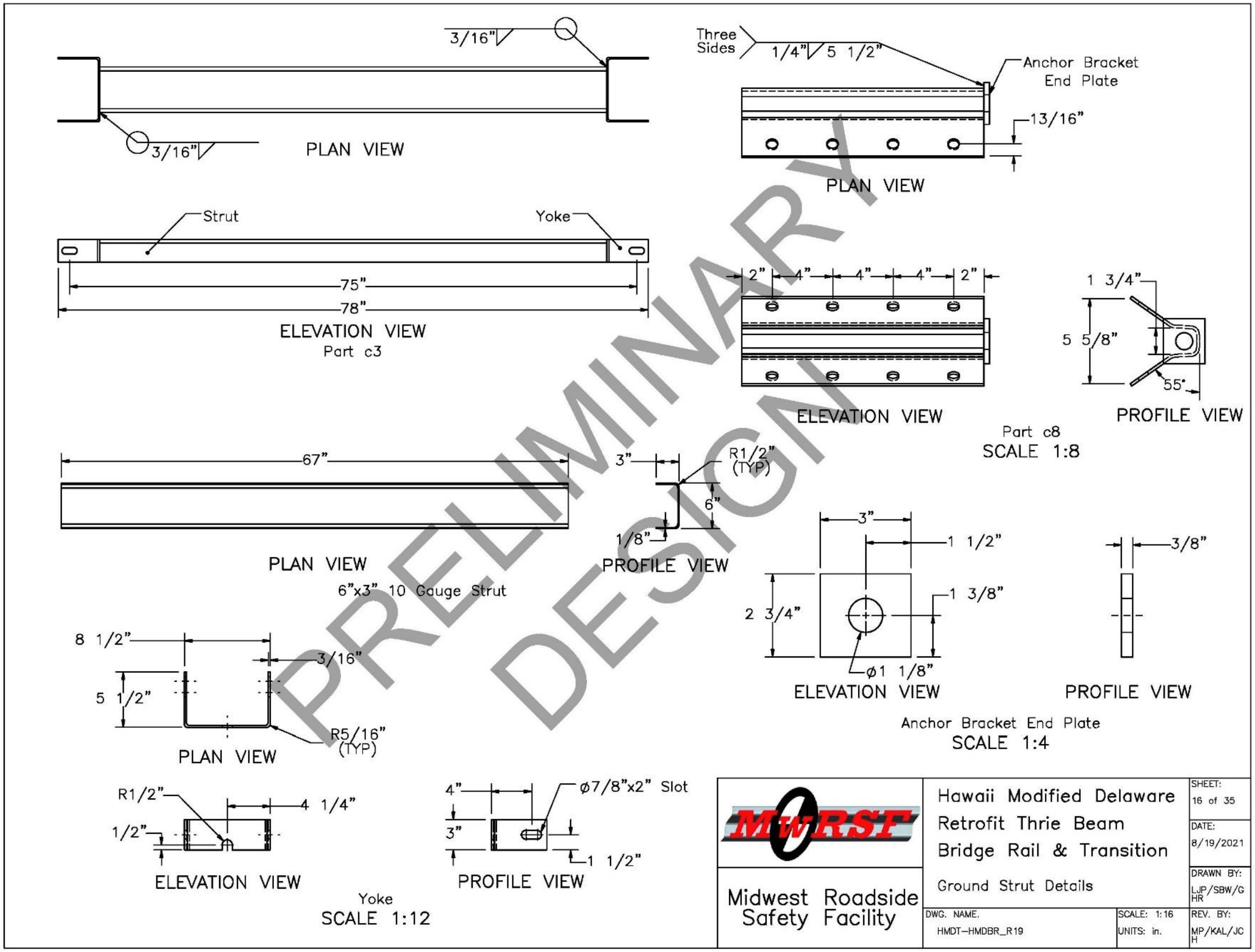
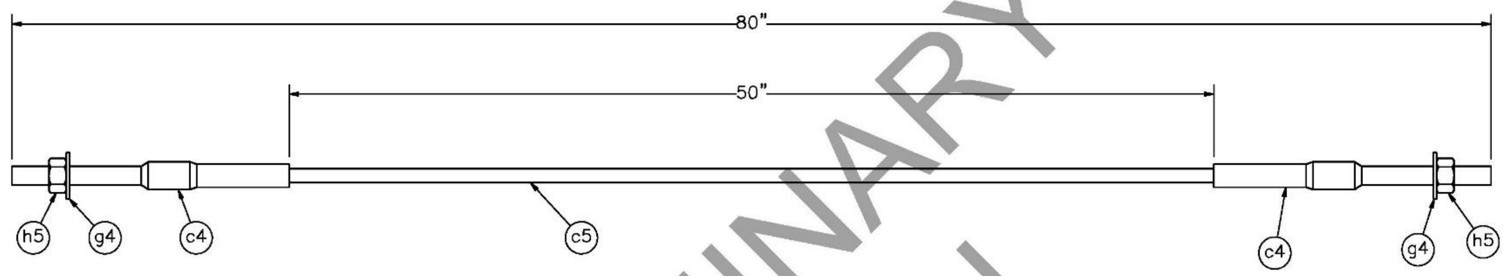



Figure 19. Ground Strut Details, Test No. HMDT-1






| Item No. | QTY. | Description | Material Specification | Treatment Specification | Hardware Guide |
|---|---|---|---|---|---|
| – | 1 | Cable Assembly | – | – | FCA01 |
| c4 | 2 | BCT Anchor Cable End Swaged Fitting | Fitting – ASTM A576 Gr. 1035<br>Stud – ASTM F568 Class C | Fitting – ASTM A153<br>Stud – ASTM A153 or B695 | – |
| c5 | 1 | 3/4" Dia. 6x19 IWRC IPS Wire Rope | ASTM A741 Type 2 | Class A Coating | – |
| h5 | 2 | 1"–8 UNC Heavy Hex Nut | ASTM A563DH or equivalent | ASTM A153 or B695 Class 55 or F2329 | FNX24b |
| g4 | 2 | 1" Dia. Plain USS Washer | ASTM F844 | ASTM A123 or A153 or F2329 | FWC24a |

MwRSF

Midwest Roadside Safety Facility

Hawaii Modified Delaware Retrofit Thrie Beam Bridge Rail & Transition

BCT Anchor Cable

SHEET: 17 of 35

DATE: 8/19/2021

DRAWN BY: LJP/SBW/GHR

REV. BY: MP/KAL/JCH

DWG. NAME. HMDT-HMDBR_R19

SCALE: 1:8

UNITS: in.

Figure 20. BCT Anchor Cable, Test No. HMDT-1

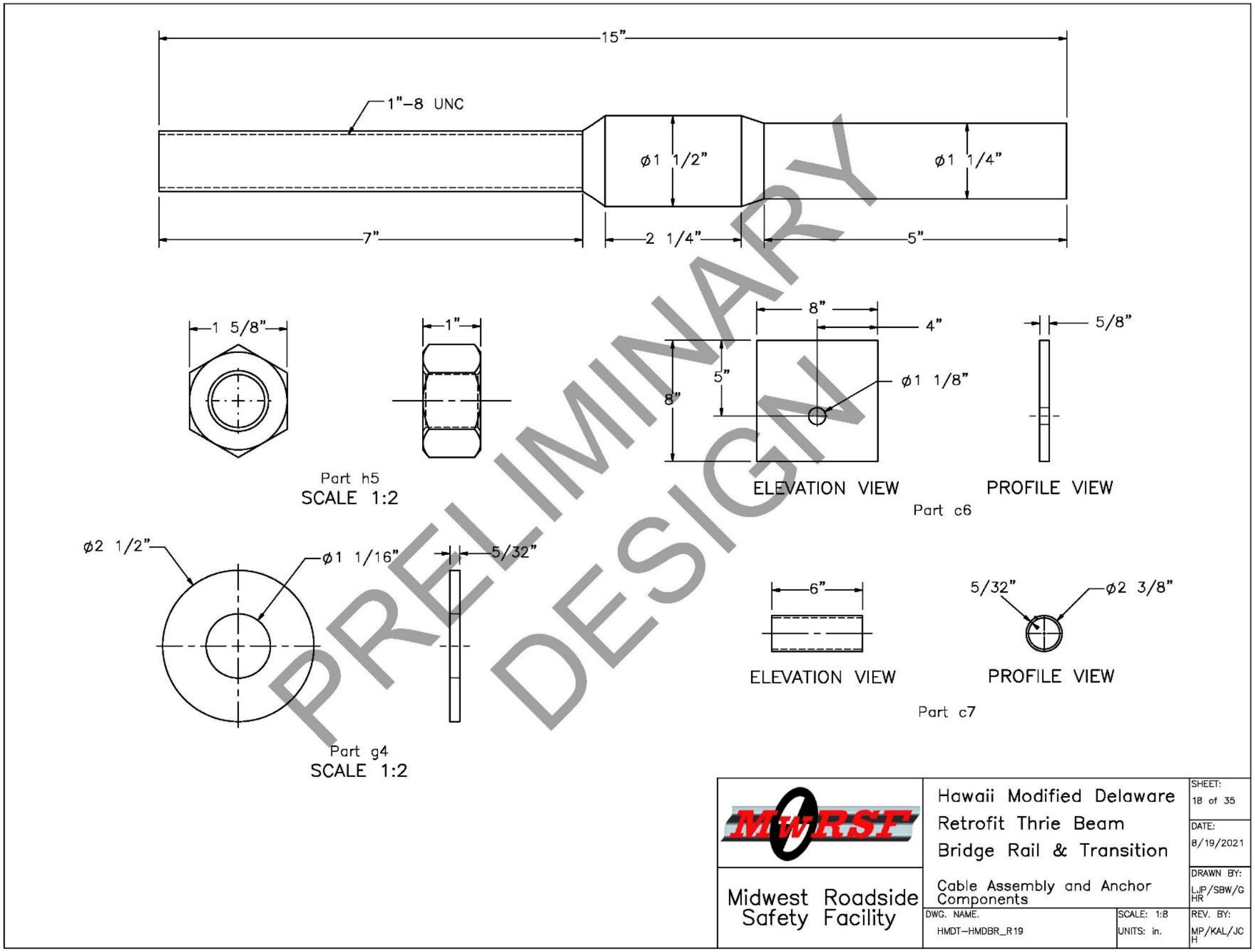



Figure 21. Cable Assembly and Anchor Components, Test No. HMDT-1

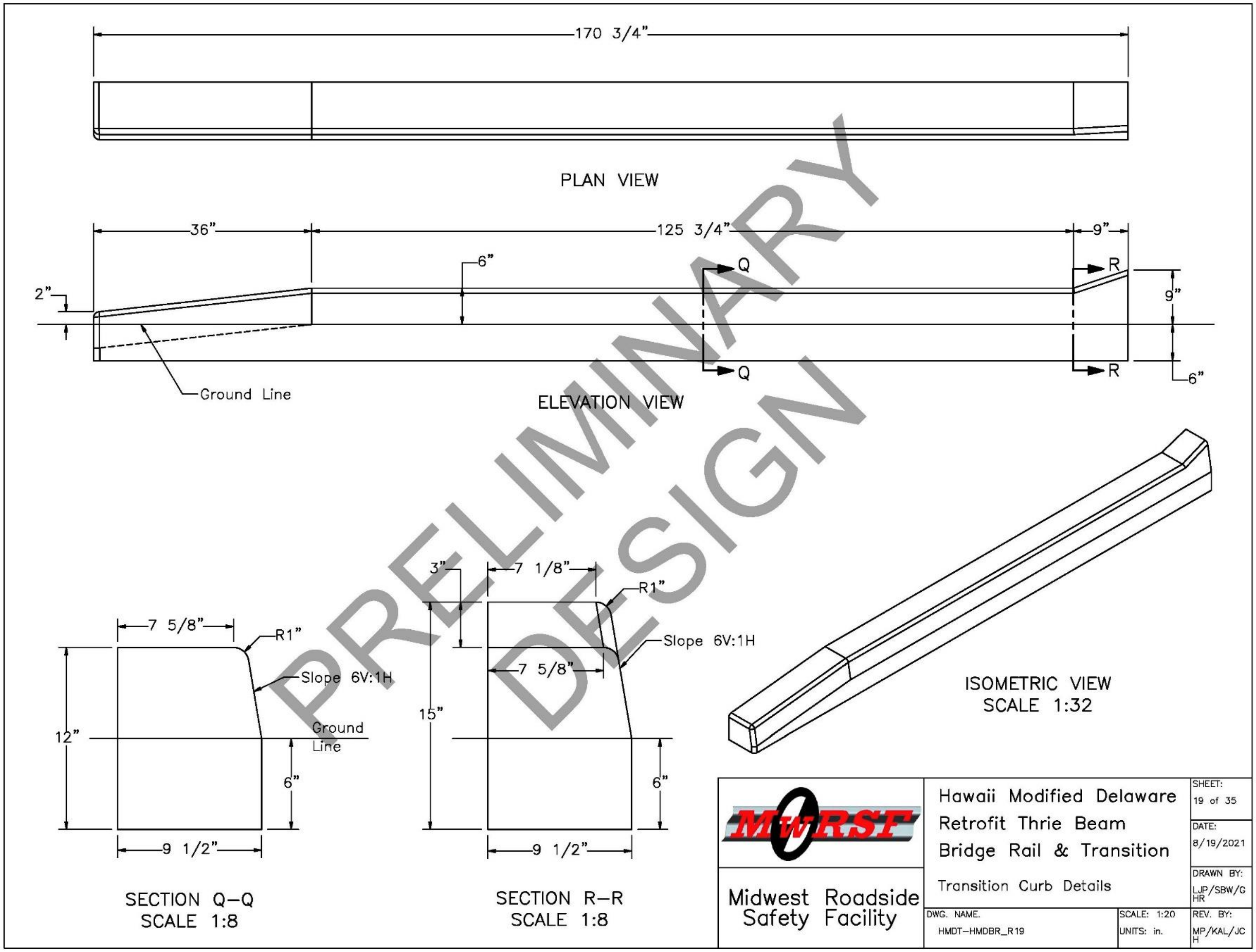



Figure 22. Transition Curb Details, Test No. HMDT-1

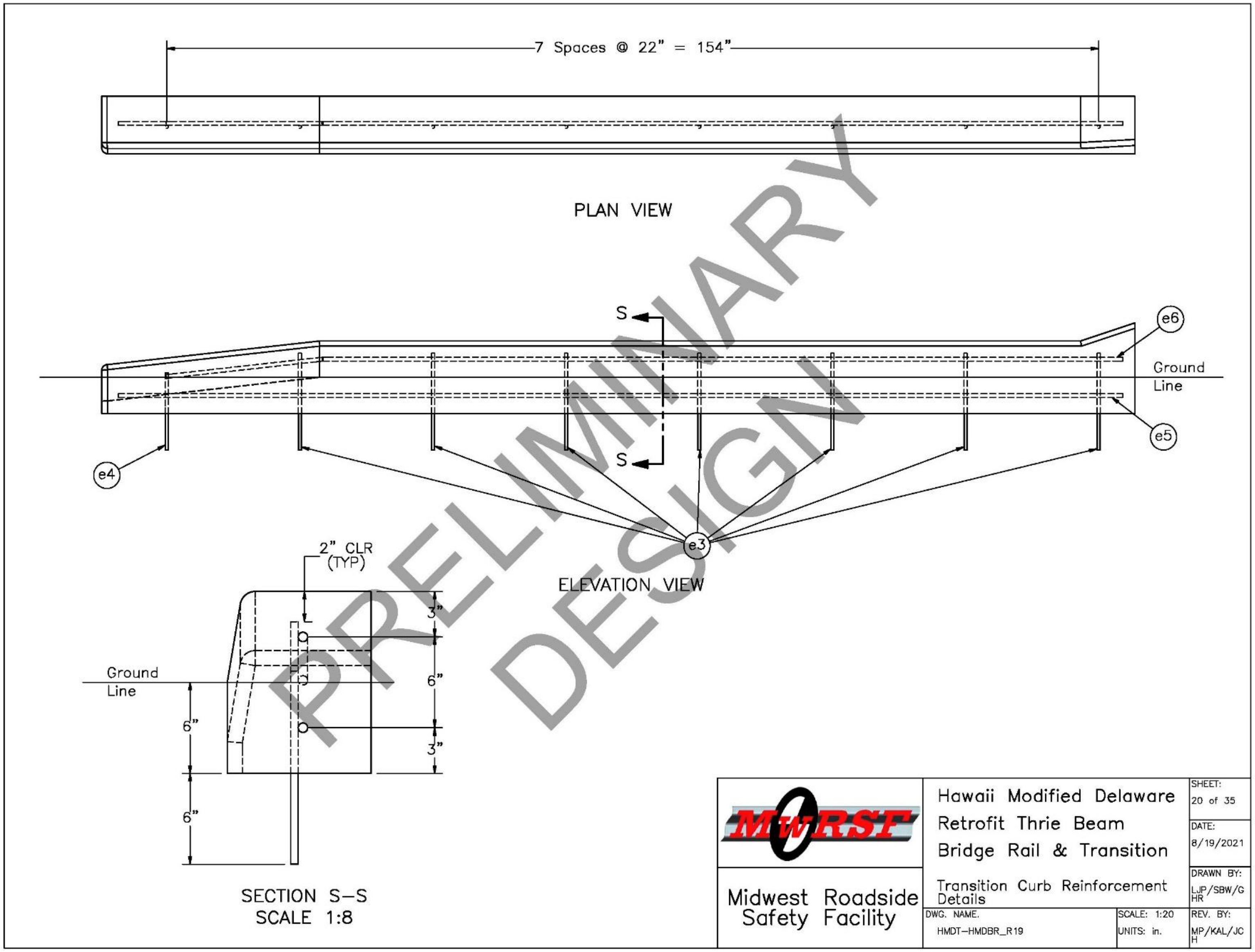
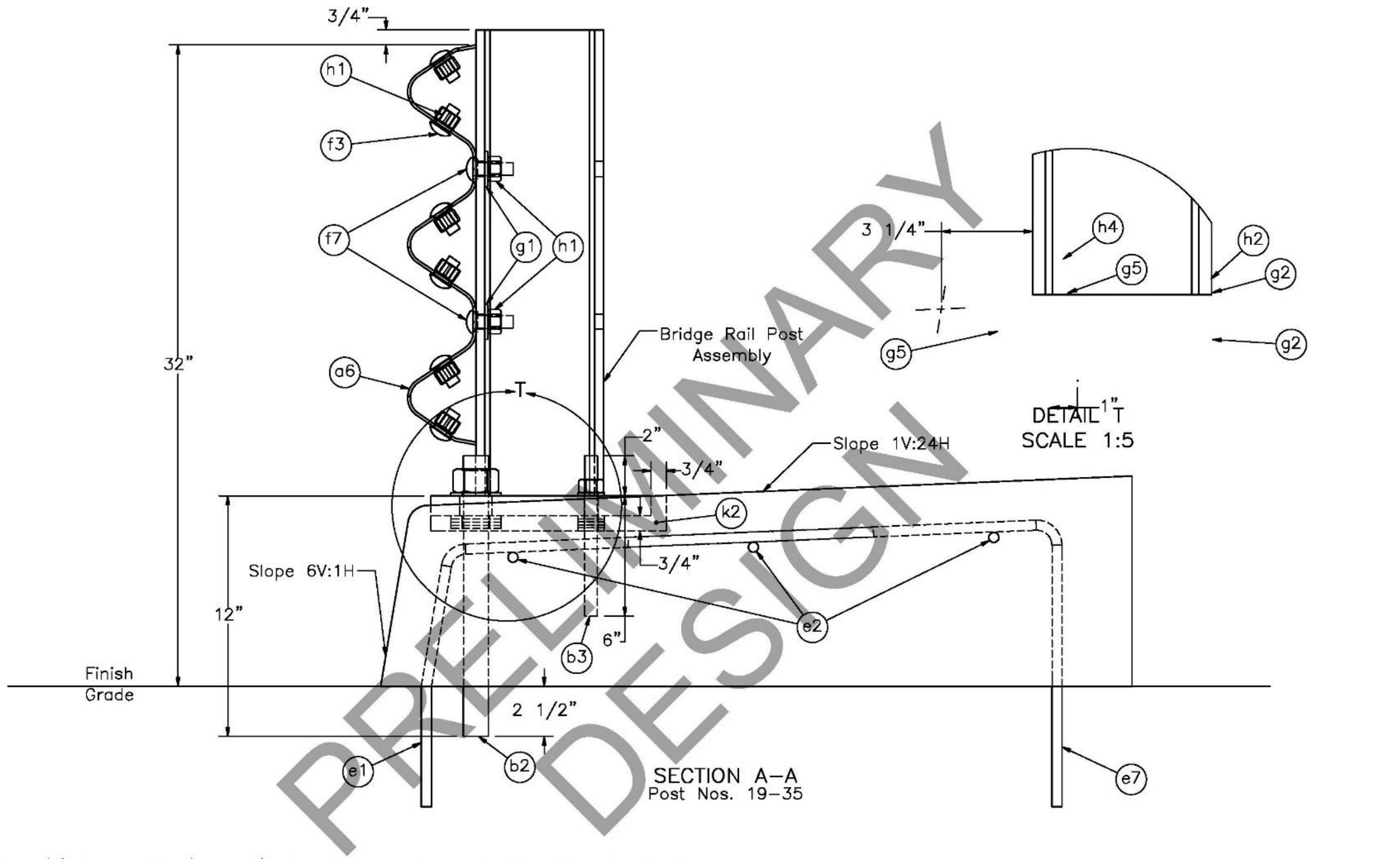



Figure 23. Transition Curb Reinforcement Details, Test No. HMDT-1




Notes: (1) Base plate (part b1) should be counter sunk into sidewalk, slightly over sized, then backfilled with epoxy grout (part k2).
(2) Epoxy grout used to backfill post cavities should be in compliance with ASTM C881 Type IV, Grade I, Class C.
(3) Add washers (parts g2 and g5) to level base plates.
(4) Anchor rods (parts b2 and b3) should be epoxied into the concrete sidewalk and concrete tarmac.
(5) Rebar (parts e1 and e7) should be epoxied into concrete tarmac for a minimum depth of 6".
(6) Anchors and rebar should be epoxied with Hilti HIT RE–500 V3 (part k1) or equivalent, in compliance with Class C, C881.

Midwest Roadside Safety Facility

Hawaii Modified Delaware Retrofit Thrie Beam Bridge Rail & Transition

Bridge Rail Post Details

SHEET: 21 of 35
DATE: 8/19/2021
DRAWN BY: LJP/SBW/GHR
DWG. NAME. HMDT–HMDBR_R19
SCALE: 1:7
UNITS: in.
REV. BY: MP/KAL/JCH

Figure 24. Bridge Rail Post Details, Test No. HMDT-1

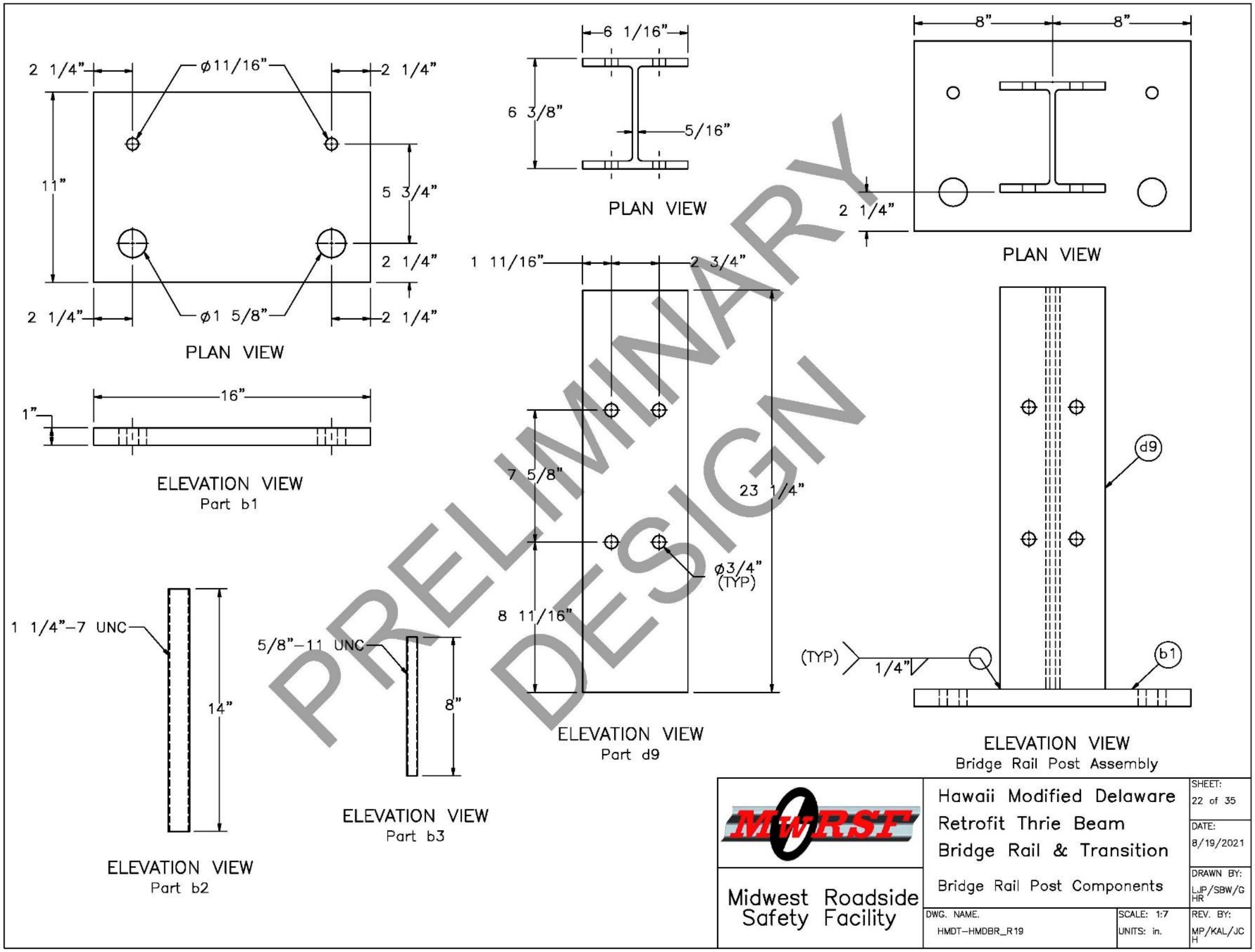



Figure 25. Bridge Rail Post Components, Test No. HMDT-1

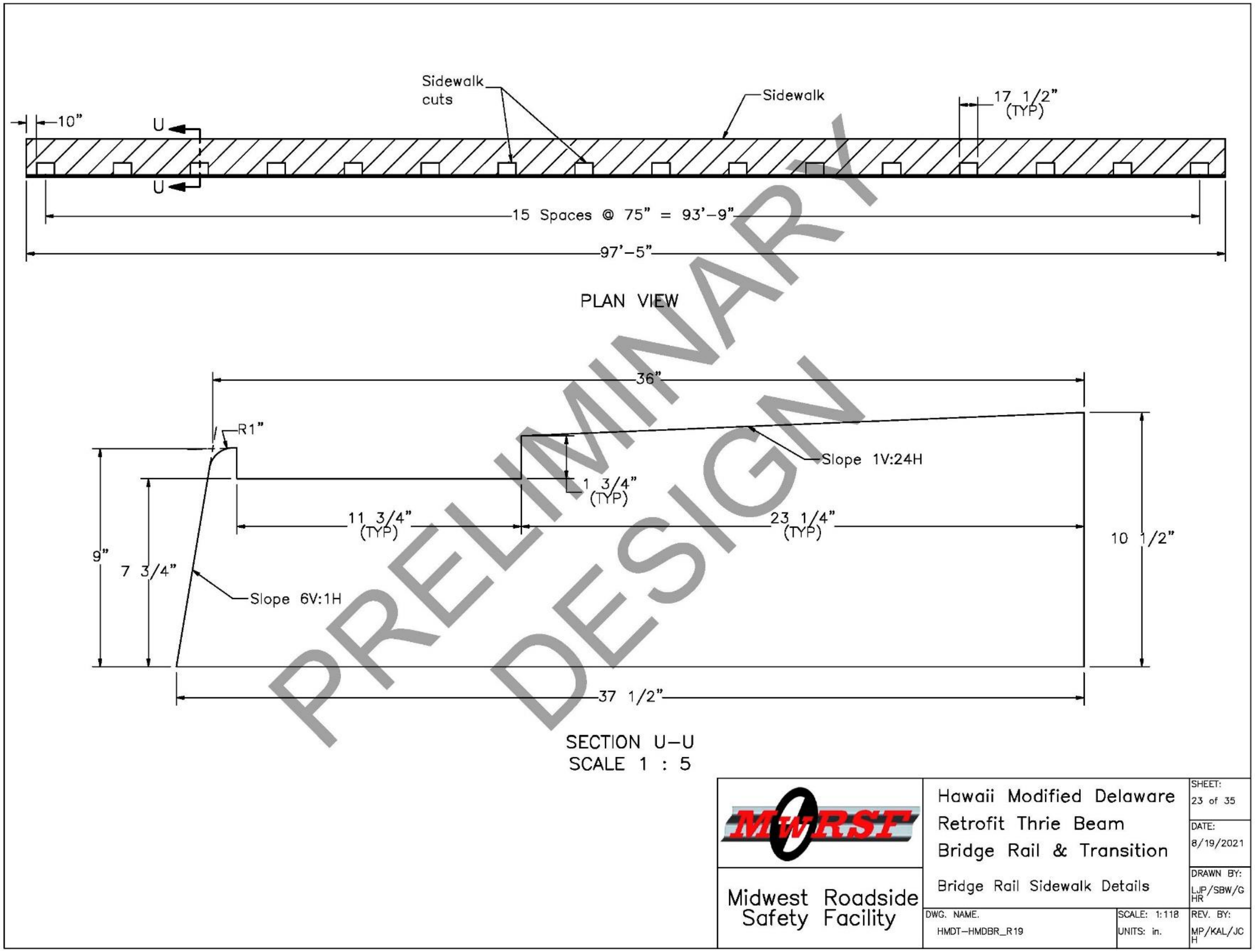



Figure 26. Bridge Rail Sidewalk Details, Test No. HMDT-1

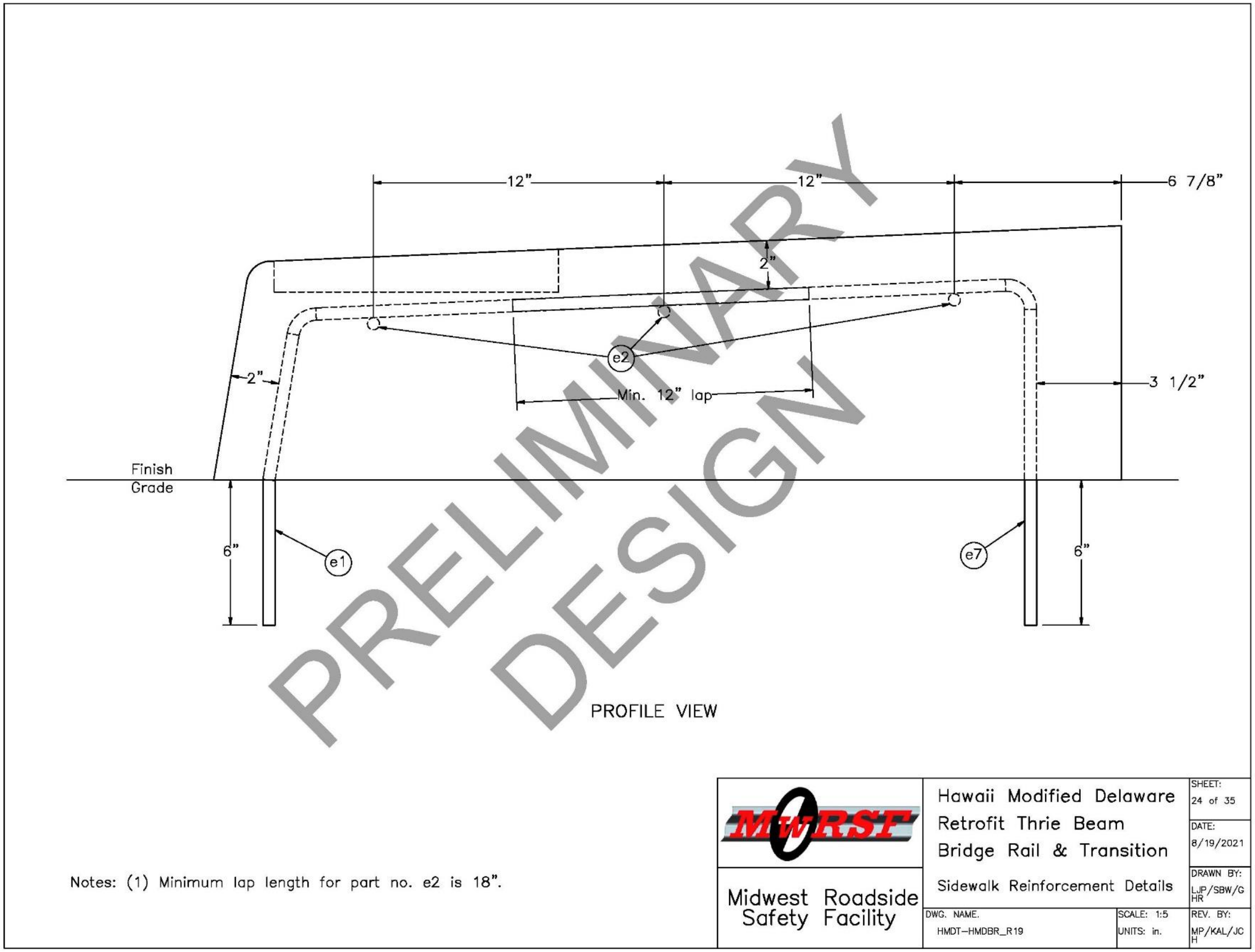



Figure 27. Sidewalk Reinforcement Details, Test No. HMDT-1

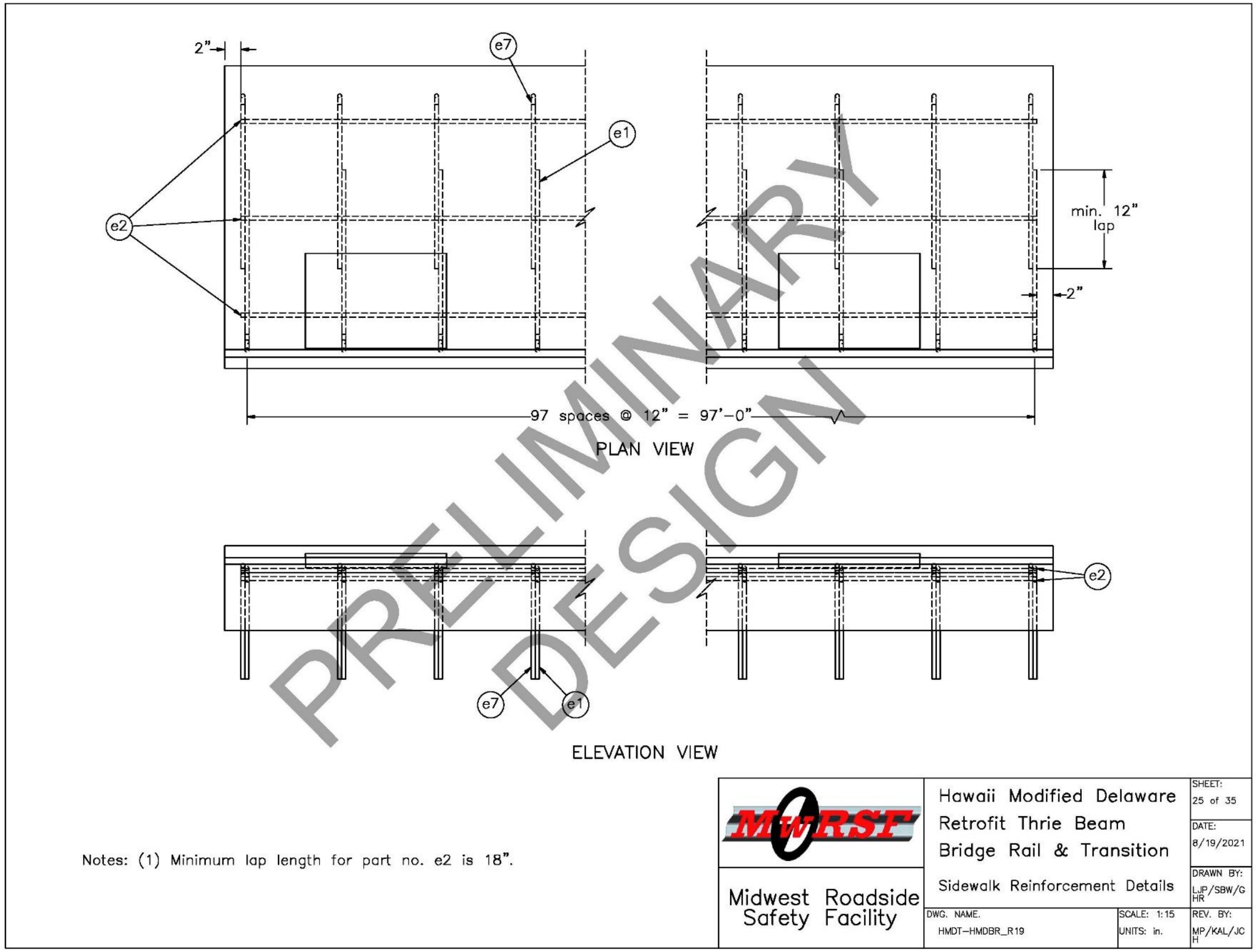
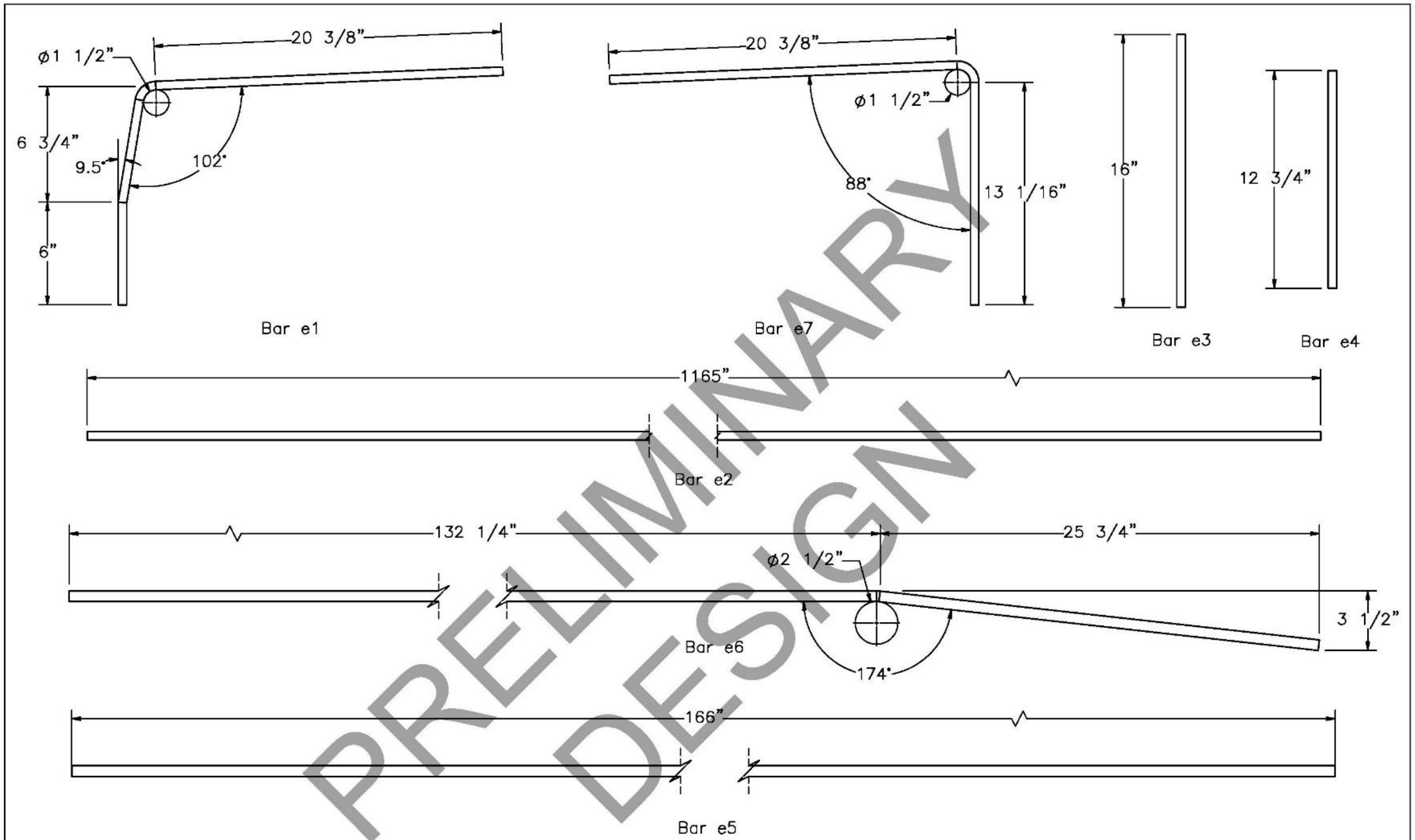



Figure 28. Sidewalk Reinforcement Details, Test No. HMDT-1




| Part No. | Bar No. | Qty. | Unbent Length | Material Specification |
|---|---|---|---|---|
| e1 | #4 | 98 | 33 7/8" | ASTM A615 Gr. 60 |
| e2 | #4 | 3 | 1165" | ASTM A615 Gr. 60 |
| e3 | #4 | 7 | 16" | ASTM A615 Gr. 60 |
| e4 | #4 | 1 | 12 3/4" | ASTM A615 Gr. 60 |
| e5 | #5 | 1 | 166" | ASTM A615 Gr. 60 |
| e6 | #5 | 1 | 158 1/4" | ASTM A615 Gr. 60 |
| e7 | #4 | 98 | 35" | ASTM A615 Gr. 60 |

Notes: (1) Minimum lap length for part no. e2 is 18".

Midwest Roadside Safety Facility

Hawaii Modified Delaware Retrofit Thrie Beam Bridge Rail & Transition

Curb Reinforcement Details

SHEET: 26 of 35

DATE: 8/19/2021

DRAWN BY: LJP/SBW/GHR

DWG. NAME. HMDT-HMDBR_R19

SCALE: 1:8

UNITS: in.

REV. BY: MP/KAL/JCH

Figure 29. Curb Reinforcement Details, Test No. HMDT-1

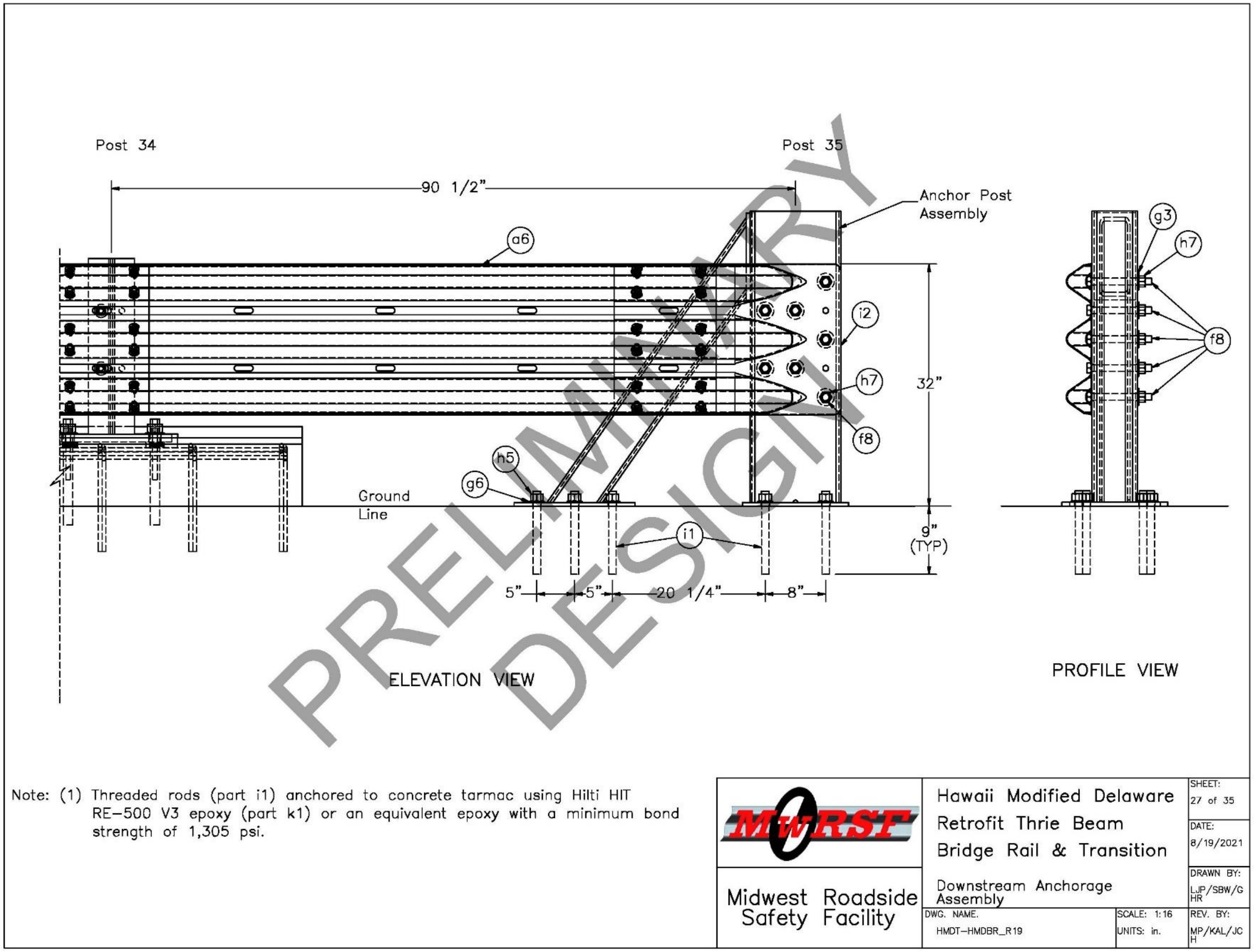



Figure 30. Downstream Anchorage Assembly, Test No. HMDT-1

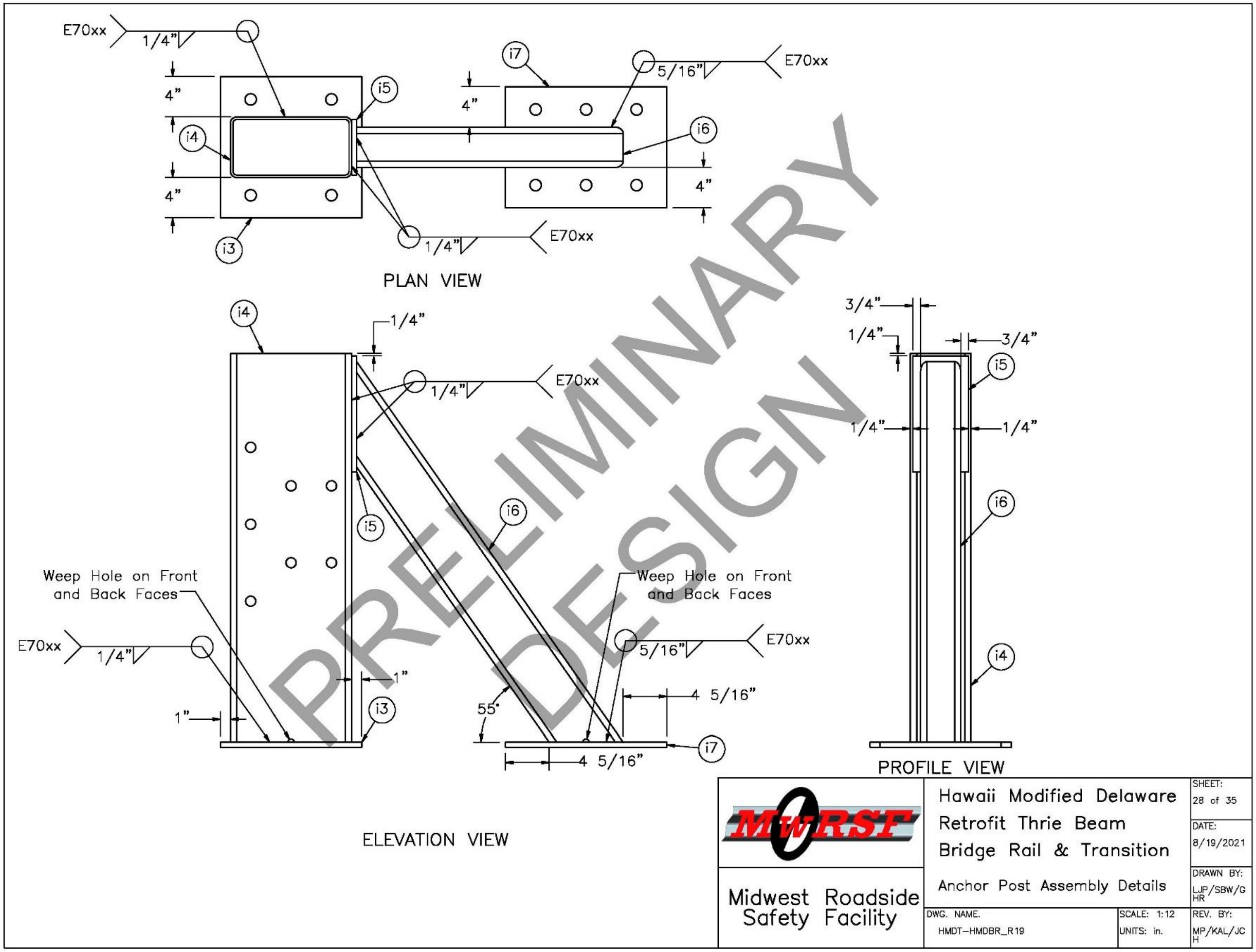



Figure 31. Anchor Post Assembly Details, Test No. HMDT-1

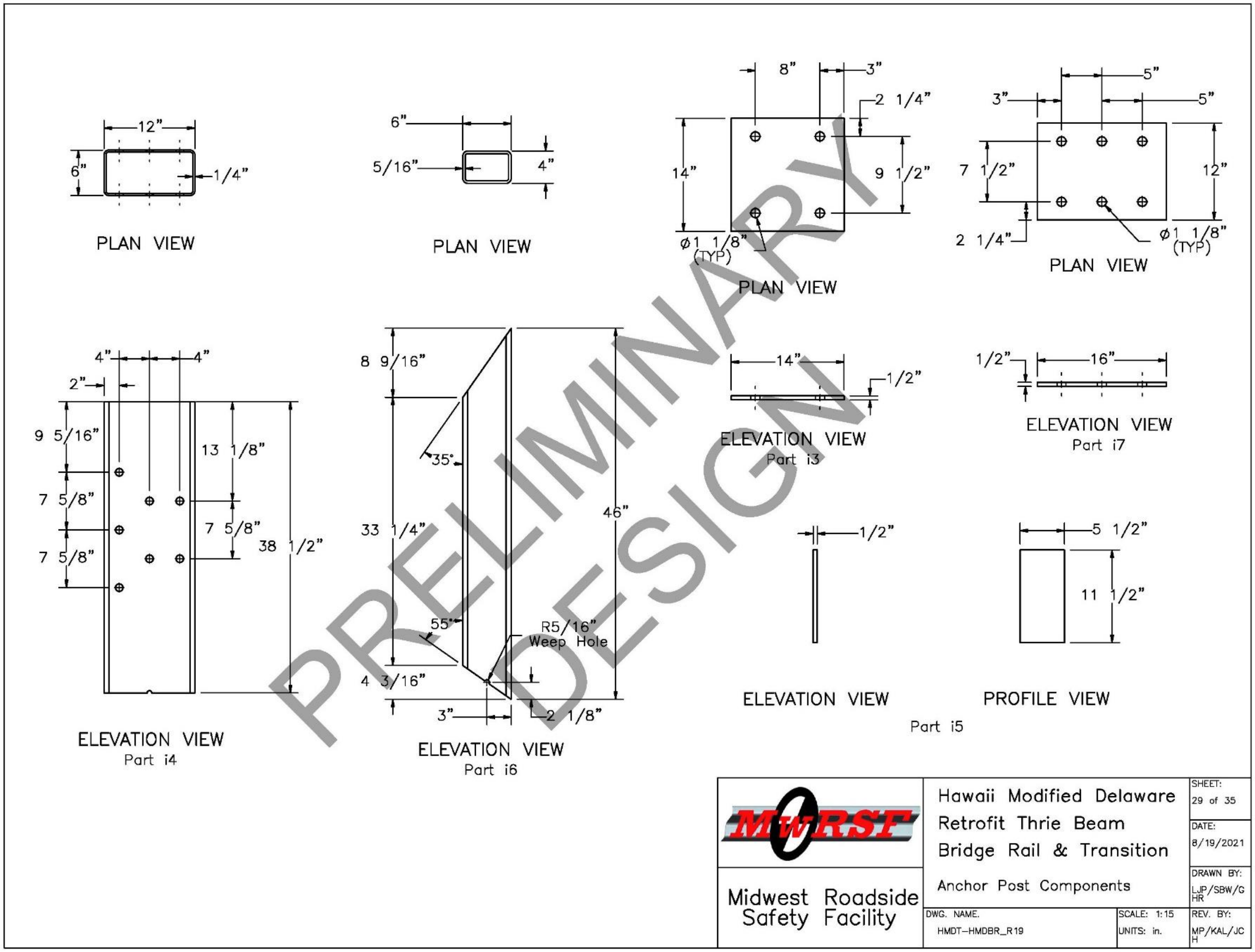



Figure 32. Anchor Post Components, Test No. HMDT-1

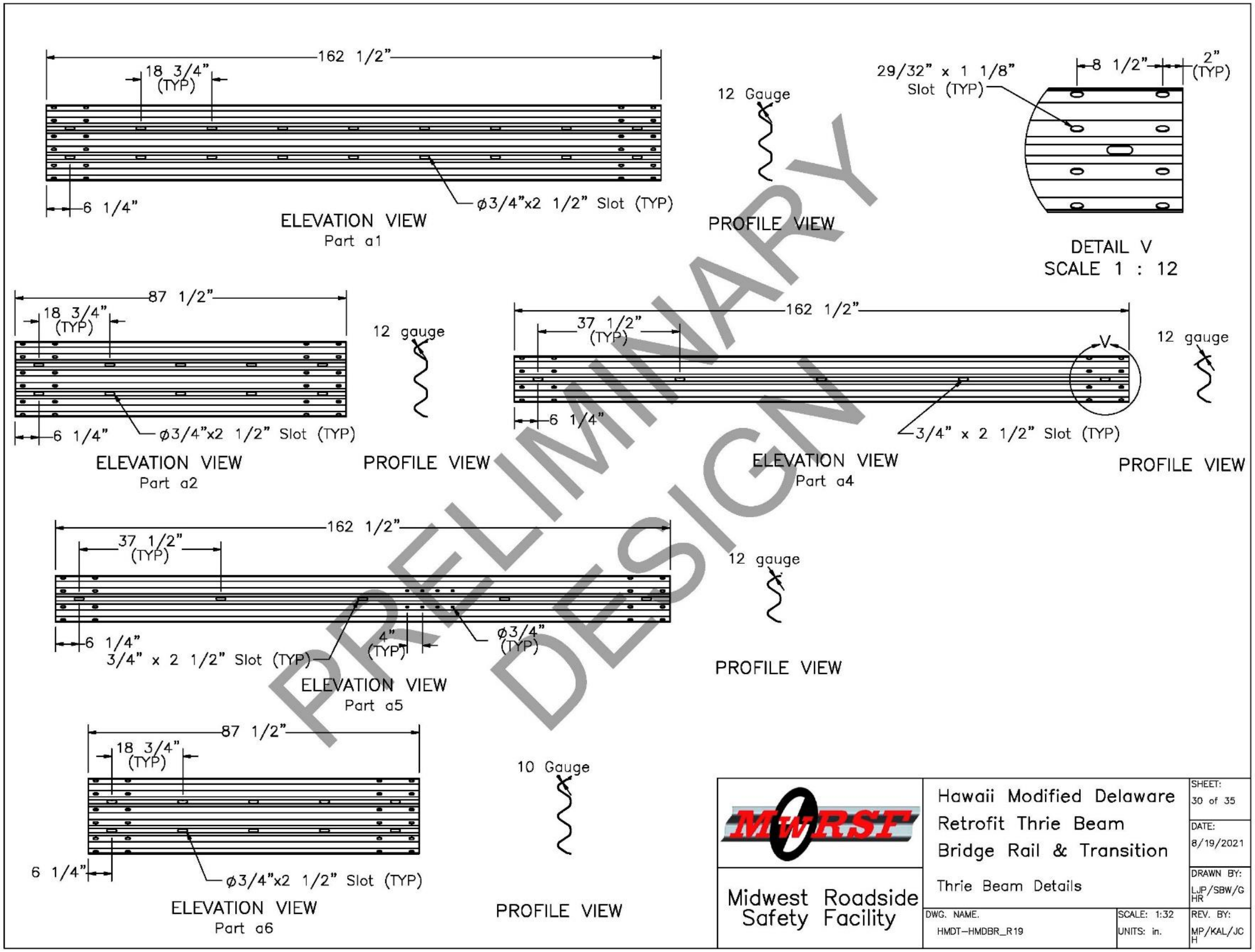



Figure 33. Thrie-Beam Rail Details, Test No. HMDT-1

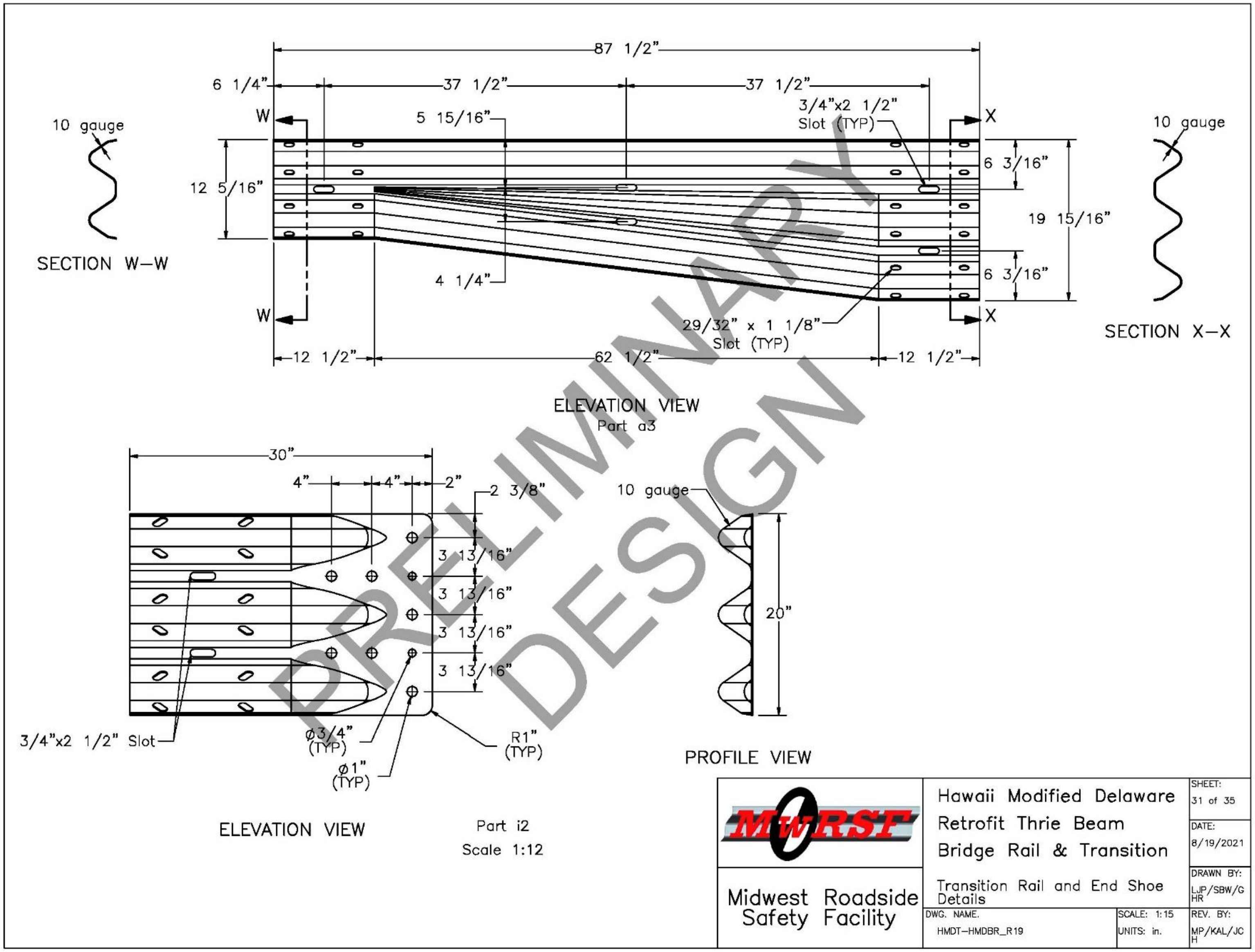



Figure 34. Transition Rail and End Shoe Details, Test No. HMDT-1

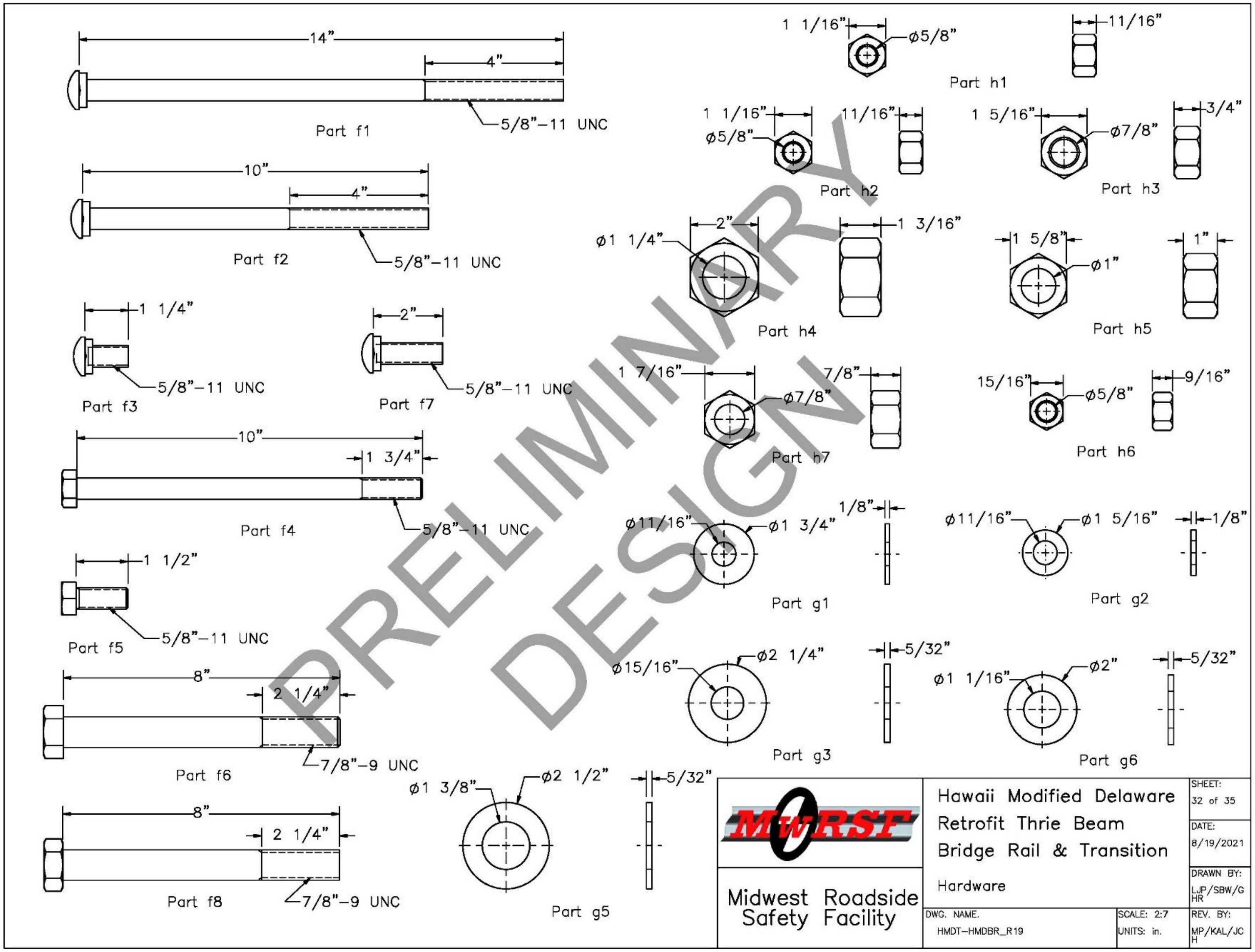



Figure 35. Hardware, Test No. HMDT-1

| Item No. | QTY. | Description | Material Specification | Treatment Specification | Hardware Guide |
|---|---|---|---|---|---|
| a1 | 2 | 12'–6" 12–gauge Thrie Beam Section | AASHTO M180 | ASTM A123 or A653 | RTM08a |
| a2 | 1 | 6'–3" 12–gauge Thrie Beam Section | AASHTO M180 | ASTM A123 or A653 | RTM19a |
| a3 | 1 | 6'–3" 10–gauge W–Beam to Thrie–Beam Asymmetric Transition Section | AASHTO M180 | ASTM A653 | RWT02 |
| a4 | 3 | 12'–6" 12–gauge W–Beam MGS Section | AASHTO M180 | ASTM A123 or A653 | RWM04a |
| a5 | 1 | 12'–6" 12–gauge W–Beam MGS End Section | AASHTO M180 | ASTM A123 or A653 | RWM14a |
| a6 | 16 | 6'–3" 10–gauge Thrie Beam Section | AASHTO M180 | ASTM A123 or A653 | RTM19a |
| b1 | 16 | 16"x11"x1" Base Plate | ASTM A36 | ASTM A123 | – |
| b2 | 32 | 1 1/4" Dia., 14" Long Anchor Rod | ASTM F1554–15 Grade 105, Class 2A | ASTM F2329 / F2329M–15 | – |
| b3 | 32 | 5/8" Dia., 8" Long Anchor Rod | ASTM F1554–15 Grade 105, Class 2A | ASTM F2329 / F2329M–15 | – |
| c1 | 2 | BCT Timber Post – MGS Height | SYP Grade No. 1 or better (No knots +/– 18" from ground on tension face) | – | PDF01 |
| c2 | 2 | 72" Long Foundation Tube | ASTM A500 Gr. B | ASTM A123 | PTE06 |
| c3 | 1 | Ground Strut Assembly | ASTM A36 | ASTM A123 | PFP02 |
| c4 | 2 | BCT Anchor Cable End Swaged Fitting | Fitting – ASTM A576 Gr. 1035<br>Stud – ASTM F568 Class C | Fitting – ASTM A153<br>Stud – ASTM A153 or B695 | – |
| c5 | 1 | BCT Cable Anchor Assembly | – | – | FCA01 |
| c6 | 1 | 8"x8"x5/8" Anchor Bearing Plate | ASTM A36 | ASTM A123 | FPB01 |
| c7 | 1 | 2 3/8" O.D. x 6" Long BCT Post Sleeve | ASTM A53 Gr. B Schedule 40 | ASTM A123 | FMM02 |
| c8 | 1 | Anchor Bracket Assembly | ASTM A36 | ASTM A123 | FPA01 |
| d1 | 7 | W6x9 or W6x8.5, 72" Long Steel Post | ASTM A992 | ASTM A123* | PWE06 |
| d2 | 6 | W6x9 or W6x8.5, 72" Long Steel Post | ASTM A992 | ASTM A123* | PWE06 |
| d3 | 3 | W6x15, 78" Long Steel Post | ASTM A992 | ASTM A123* | – |
| d4 | 3 | 17 1/2" Long, 8"x6"x1/4" Steel Blockout | ASTM A500 Gr. B | ASTM A123* | – |
| d5 | 6 | 17 1/2" Long, 12"x4"x1/4" Steel Blockout | ASTM A500 Gr. B | ASTM A123* | – |
| d6 | 2 | 14 3/16"x12"x5 1/8" Composite Recycled Blockout | Mondo Polymer MGS14SH or Equivalent | – | – |
| d7 | 5 | 14 3/16"x8"x5 1/8" Composite Recycled Blockout | Mondo Polymer GB14SH2 or Equivalent | – | – |
| d8 | 2 | 16D Double Head Nail | Galvanized | – | – |
| d9 | 16 | W6x25, 23 1/4" Long Steel Post | ASTM A992 | ASTM A123 | – |

* Component does not need to be galvanized for testing purposes

Notes: (1) Quantities listed herein are only for one copy of the system.
(2) Purchase additional materials to repair the barrier system following the first transition test, test no. HMDT–1.



| | | |
|---|---|---|
| Midwest Roadside Safety Facility | Hawaii Modified Delaware Retrofit Thrie Beam Bridge Rail & Transition<br>Bill of Materials | SHEET: 33 of 35<br>DATE: 8/19/2021<br>DRAWN BY: LJP/SBW/GHR |
| | DWG. NAME. HMDT–HMDBR_R19<br>SCALE: None<br>UNITS: in. | REV. BY: MP/KAL/JCH |

Figure 36. Bill of Materials, Test No. HMDT-1

| Item No. | QTY. | Description | Material Specification | Treatment Specification | Hardware Guide |
|---|---|---|---|---|---|
| e1 | 98 | #4 Rebar, 33 7/8" Total Unbent Length | ASTM A615 Gr. 60 | Epoxy-Coated (ASTM A775 or A934) | – |
| e2 | 3 | #4 Rebar, 97' 1" Total Length* | ASTM A615 Gr. 60 | Epoxy-Coated (ASTM A775 or A934) | – |
| e3 | 7 | #4 Rebar, 16" Total Length | ASTM A615 Gr. 60 | Epoxy-Coated (ASTM A775 or A934) | – |
| e4 | 1 | #4 Rebar, 12 3/4" Total Length | ASTM A615 Gr. 60 | Epoxy-Coated (ASTM A775 or A934) | – |
| e5 | 1 | #5 Rebar, 166" Total Length | ASTM A615 Gr. 60 | Epoxy-Coated (ASTM A775 or A934) | – |
| e6 | 1 | #5 Rebar, 158 1/4" Total Unbent Length | ASTM A615 Gr. 60 | Epoxy-Coated (ASTM A775 or A934) | – |
| e7 | 98 | #4 Rebar, 35" Total Unbent Length | ASTM A615 Gr. 60 | Epoxy-Coated (ASTM A775 or A934) | – |
| f1 | 13 | 5/8"-11 UNC, 14" Long Guardrail Bolt | ASTM A307 Gr. A | ASTM A153 or B695 Class 55 or F2329 | FBB06 |
| f2 | 13 | 5/8"-11 UNC, 10" Long Guardrail Bolt | ASTM A307 Gr. A | ASTM A153 or B695 Class 55 or F2329 | FBB03 |
| f3 | 260 | 5/8"-11 UNC, 1 1/4" Long Guardrail Bolt | ASTM A307 Gr. A | ASTM A153 or B695 Class 55 or F2329 | FBB01 |
| f4 | 2 | 5/8"-11 UNC, 10" Long Hex Head Bolt | ASTM A307 Gr. A or equivalent | ASTM A153 or B695 Class 55 or F2329 | FBX16a |
| f5 | 8 | 5/8"-11 UNC, 1 1/2" Long Hex Head Bolt | ASTM A307 Gr. A or equivalent | ASTM A153 or B695 Class 55 or F2329 | FBX16a |
| f6 | 2 | 7/8"-9 UNC, 8" Long Hex Head Bolt | ASTM A307 Gr. A or equivalent | ASTM A153 or B695 Class 55 or F2329 | – |
| f7 | 32 | 5/8"-11 UNC, 2" Long Guardrail Bolt | ASTM A307 Gr. A | ASTM F2329 | FBB01 |
| f8 | 7 | 7/8" Dia., 8" Long Heavy Hex Head Bolt | ASTM F3125 Gr. A325 Type 1 | ASTM A153 or B695 Class 55 or F1136 Gr. 3 or F2329 or F2833 Gr. 1 | FBX22b |
| g1 | 54 | 5/8" Dia. Plain USS Washer | ASTM F844 | ASTM F2329 | FWC16a |
| g2 | 192 | 5/8" Dia. Hardened Washer | ASTM F436 | ASTM F2329 | FWC16a |
| g3 | 11 | 7/8" Dia. Plain Round Washer | ASTM F844 | ASTM A123 or A153 or F2329 | – |
| g4 | 2 | 1" Dia. Plain USS Washer | ASTM F844 | ASTM A123 or A153 or F2329 | FWC24a |
| g5 | 160 | 1 1/4" Dia. Hardened Washer | ASTM F436 | ASTM F2329 | FWC30a |
| g6 | 10 | 1" Dia. Hardened Flat Washer | ASTM F436 | ASTM A153 or B695 Class 55 or F1136 Gr. 3 or F2329 | FWC24b |
| h1 | 318 | 5/8"-11 UNC Heavy Hex Nut | ASTM A563A or equivalent | ASTM A153 or B695 Class 55 or F2329 | FNX16b |
| h2 | 32 | 5/8"-11 UNC Heavy Hex Nut | ASTM A563-15 Grade DH | ASTM F2329 / F2329U-15 | FNX16b |
| h3 | 2 | 7/8"-9 UNC Hex Nut | ASTM A563A or equivalent | ASTM A153 or B695 Class 55 or F2329 | – |
| h4 | 32 | 1 1/4"-7 UNC Heavy Hex Nut | ASTM A563-15 Grade DH | ASTM F2329 / F2329U-15 | – |
| h5 | 12 | 1" Dia. Heavy Hex Nut | ASTM A563DH or A194 Gr. 2H | ASTM A153 or B633 or B695 Class 55 or F1941 or F2329 | FNX24b |
| h6 | 10 | 5/8"-11 UNC Hex Nut | ASTM A563A or equivalent | ASTM A153 or B695 Class 55 or F2329 | FNX16a |
| h7 | 7 | 7/8" Dia. UNC Heavy Hex Nut | ASTM A563DH or ASTM A194 Gr. 2H | ASTM A153 for Class C or ASTM B695 for Class 50 | – |

* Minimum lap length for part e2 is 18".



Midwest Roadside Safety Facility

Hawaii Modified Delaware Retrofit Thrie Beam Bridge Rail & Transition

Bill of Materials

SHEET: 34 of 35

DATE: 8/19/2021

DRAWN BY: LJP/SBW/GHR

REV. BY: MP/KAL/JCH

DWG. NAME. HMDT-HMDBR_R19

SCALE: None

UNITS: in.

Figure 37. Bill of Materials, Test No. HMDT-1

| Item No. | QTY. | Description | Material Specification | Treatment Specification | Hardware Guide |
|---|---|---|---|---|---|
| i1 | 10 | 1" Dia. UNC, 11" Long Threaded Rod | ASTM A449 or A354 Gr. BC or A193 Gr. B7 | ASTM A153 or B633 or B695 Class 55 or F1941 or F2329 | FRR24b |
| i2 | 1 | 10-gauge Thrie Beam Terminal Connector | AASHTO M180<br>Min. yield strength = 50 ksi<br>Min. tensile strength = 70 ksi | ASTM A123 or A653 | RTE01b |
| i3 | 1 | 14"x14"x1/2" Steel Plate | ASTM A36 or A572 Gr. 50 | ASTM A123* | – |
| i4 | 1 | HSS 6"x12"x1/4" Tube, 38 1/2" Long | ASTM A500 Gr. B | ASTM A123* | – |
| i5 | 1 | 11 1/2"x5 1/2"x1/2" Steel Plate | ASTM A36 or A572 Gr. 50 | ASTM A123* | – |
| i6 | 1 | HSS 6"x4"x5/16" Tube, 46" Long | ASTM A500 Gr. B | ASTM A123* | – |
| i7 | 1 | 16"x12"x1/2" Steel Plate | ASTM A36 or A572 Gr. 50 | ASTM A123* | – |
| j1 | 1 | Concrete | Min. f'c = 4,000 psi<br>NE Mix 47BD1S/1PF4000HW | – | – |
| k1 | – | Hilti HIT RE-500 V3 Epoxy Adhesive | Class C 881 | – | – |
| k2 | – | SpecChem 500 Epoxy Filler | ASTM C881 Type IV, Grade I, Class C | – | – |

* Component does not need to be galvanized for testing purposes

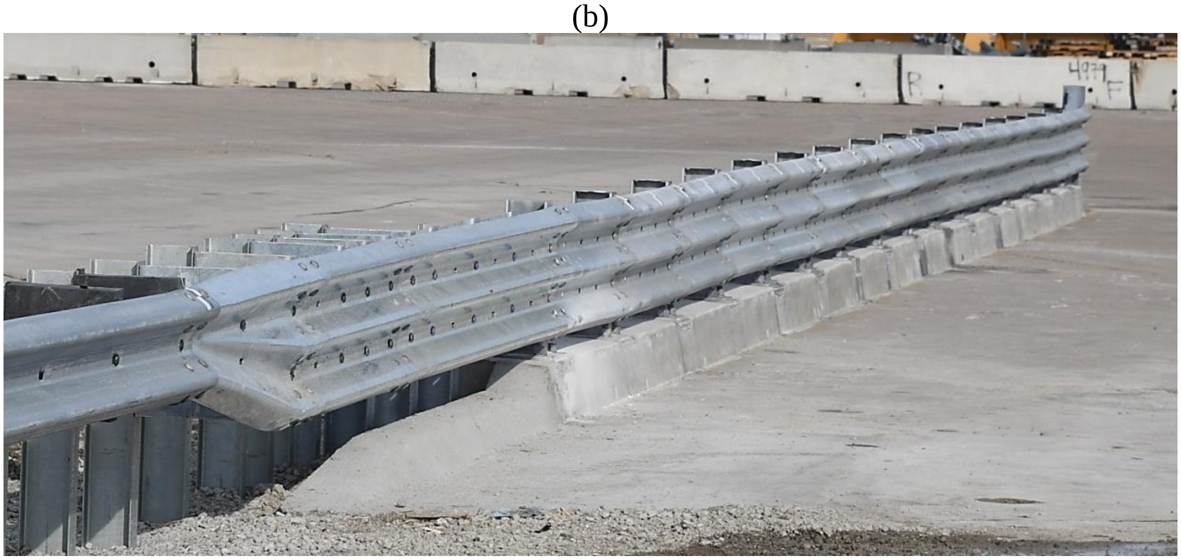


| | | | |
|---|---|---|---|
| MwRSF<br>Midwest Roadside Safety Facility | Hawaii Modified Delaware Retrofit Thrie Beam Bridge Rail & Transition<br><br>Bill of Materials | | SHEET: 35 of 35<br>DATE: 8/19/2021<br>DRAWN BY: LJP/SBW/GHR |
| | DWG. NAME. HMDT-HMDBR_R19 | SCALE: None<br>UNITS: in. | REV. BY: MP/KAL/JCH |

Figure 38. Bill of Materials, Test No. HMDT-1

(a)

(b)



(c)

Figure 39. Test Installation: (a) Upstream Anchorage and MGS Rail; (b) AGT with Transition Curb and MGS; and (c) Hawaii Modified Delaware Thrie-Beam Bridge Rail, Test No. HMDT-1


Figure 40. Test Installation: Post Nos. 1 through 19, Test No. HMDT-1

Figure 41. Test Installation: End Anchorage Assemblies, Test No. HMDT-1

# 4 TEST CONDITIONS

## 4.1 Test Facility

The Outdoor Test Site is located at the Lincoln Air Park on the northwest side of the Lincoln Municipal Airport and is approximately five miles northwest of the University of Nebraska-Lincoln.

## 4.2 Vehicle Tow and Guidance System

A reverse-cable tow system with a 1:2 mechanical advantage was used to propel each test vehicle. The distance traveled and the speed of the tow vehicle was one-half that of the test vehicle. The test vehicle was released from the ⅜-in. diameter tow cable before impact with the barrier system. A digital speedometer on the tow vehicle increased the accuracy of the test vehicle impact speed.

A vehicle guidance system developed by Hinch [11] was used to steer the test vehicles. A guide flag, attached to the non-impact side front wheel and the guide cable, was sheared off before impact with the barrier system. The ⅜-in. diameter guide cable was tensioned to approximately 3,500 lb and supported both laterally and vertically every 100 ft by hinged stanchions. The hinged stanchions stood upright while holding up the guide cable, but as the vehicle was towed down the line, the guide flag struck and knocked each stanchion to the ground.

## 4.3 Test Vehicles

For test no. HMDT-1, a 2015 Dodge RAM 1500 Quad cab pickup truck was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 4,918 lb, 5,029 lb, and 5,188 lb, respectively. The test vehicle is shown in Figures 42 and 43, and vehicle dimensions are shown in Figure 44.

For test no. HMDT-2, a 2015 Dodge RAM 1500 crew cab pickup truck was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 4,958 lb, 4,981 lb, and 5,140 lb, respectively. The test vehicle is shown in Figures 45 and 46, and vehicle dimensions are shown in Figure 47.

For test no. HMDT-3, a 2016 Kia Rio was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 2,542 lb, 2,430 lb, and 2,585 lb, respectively. The test vehicle is shown in Figures 48 and 49, and vehicle dimensions are shown in Figure 50.

For test no. HMDT-4, a 2016 Hyundai Accent was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 2,502 lb, 2,431 lb, and 2,596 lb, respectively. The test vehicle is shown in Figures 51 and 52, and vehicle dimensions are shown in Figure 53.

The longitudinal component of the center of gravity (c.g.) was determined using the measured axle weights. The Suspension Method [12] was used to determine the vertical component of the c.g. for the pickup trucks. This method is based on the principle that the c.g. of any freely suspended body is in the vertical plane through the point of suspension. The vehicles were suspended successively in three positions, and the respective planes containing the c.g. were established. The intersection of these planes pinpointed the final c.g. location for the test inertial condition. The vertical component of the c.g. for the 1100C vehicles was determined utilizing a procedure published by SAE [13]. The final c.g. locations are shown in Figures 44, 47, 50, and 53. Data used to calculate the location of the c.g. and ballast information are shown in Appendix C.

Square, black-and-white checkered targets were placed on the vehicles to serve as a reference in the high-speed digital video and aid in the video analysis, as shown in Figures 54 through 57. Round, checkered targets were placed at the c.g. on the left-side door, the right-side door, and the roof of the vehicles.

The front wheels of the test vehicles were aligned to vehicle standards except the toe-in value was adjusted to zero such that the vehicles would track properly along the guide cable. A 5B flash bulb was mounted under the vehicles' left-side windshield wiper and it was fired by a pressure tape switch mounted at the impact corner of the bumper. The flash bulb was fired upon initial impact with the test article to create a visual indicator of the precise time of impact on the high-speed digital videos. A radio-controlled brake system was installed in each test vehicle so the vehicles could be brought safely to a stop after the test.


Figure 42. Test Vehicle, Test No. HMDT-1

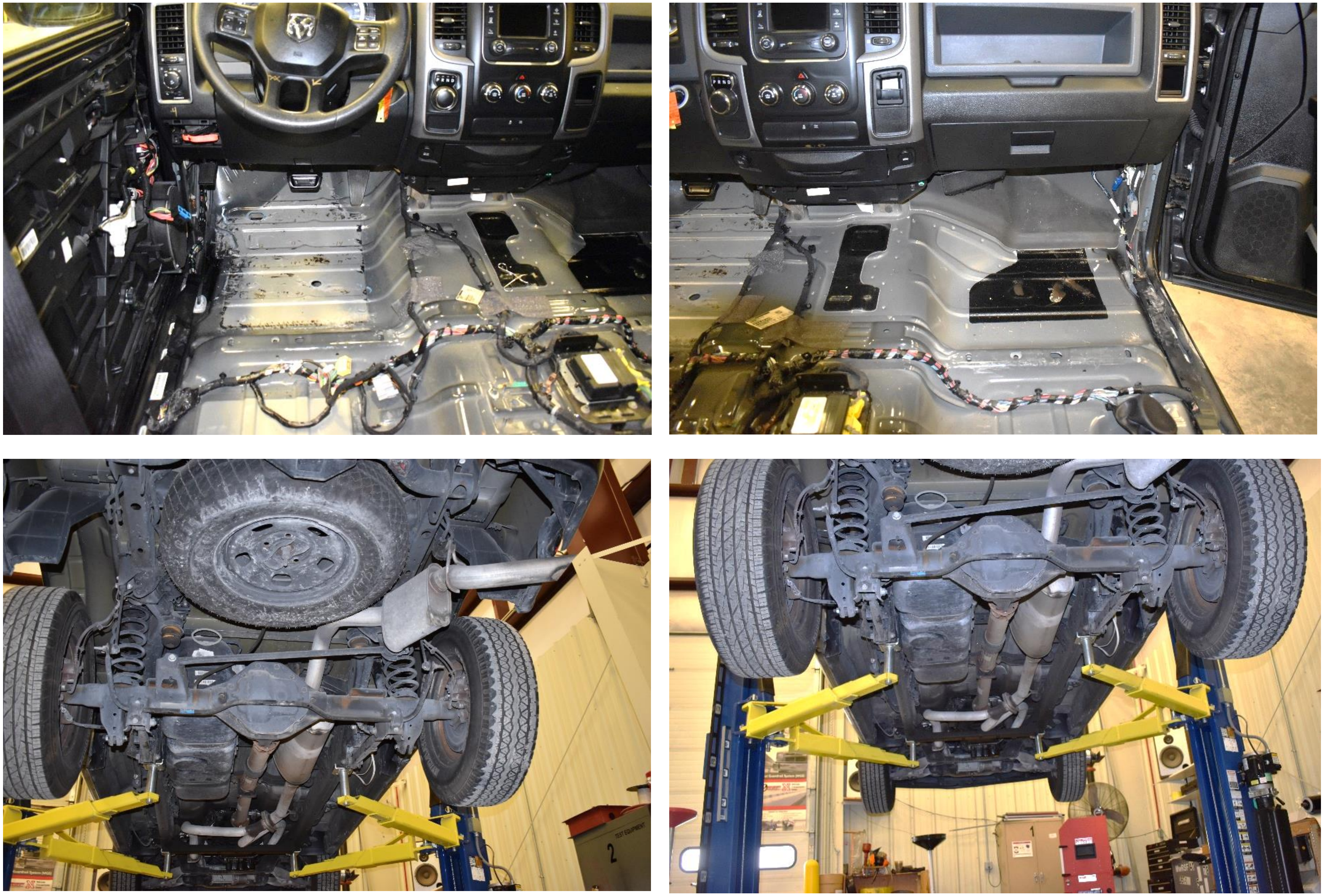
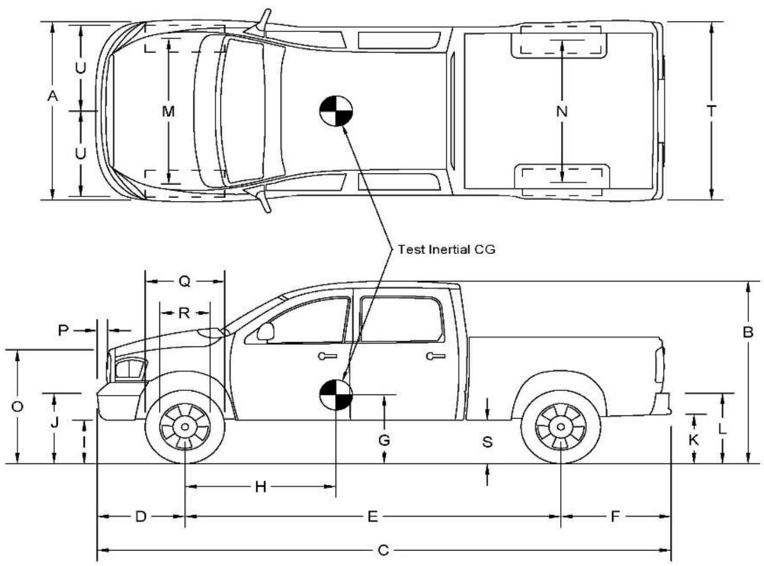


Figure 43. Test Vehicle's Interior Floorboards and Undercarriage, Test No. HMDT-1

| | | | | | |
|---|---|---|---|---|---|
| | | Test Name: | HMDT-1 | VIN No: | 1C6RR6FG3FS661207 |
| Model Year: | 2015 | Make: | Dodge RAM | Model: | 1500 Quad Cab |
| Tire Size: | p265/70R17 | Tire Inflation Pressure: | 35 psi | Odometer: | 174901 |




**Vehicle Geometry - in. (mm)**
Target Ranges listed below

| | | | | | |
|---|---|---|---|---|---|
| A: | 77 1/2 | (1969) | B: | 74 | (1880) |
| | 78±2 (1950±50) | | | | |
| C: | 229 3/8 | (5826) | D: | 41 7/8 | (1064) |
| | 237±13 (6020±325) | | | 39±3 (1000±75) | |
| E: | 140 1/4 | (3562) | F: | 47 1/4 | (1200) |
| | 148±12 (3760±300) | | | | |
| G: | 28 1/2 | (724) | H: | 66 13/16 | (1697) |
| | min: 28 (710) | | | 63±4 (1575±100) | |
| I: | 14 1/2 | (368) | J: | 27 | (686) |
| K: | 19 | (483) | L: | 28 | (711) |
| M: | 68 1/2 | (1740) | N: | 67 3/4 | (1721) |
| | 67±1.5 (1700±38) | | | 67±1.5 (1700±38) | |
| O: | 45 1/2 | (1156) | P: | 4 3/4 | (121) |
| | 43±4 (1100±75) | | | | |
| Q: | 31 | (787) | R: | 18 | (457) |
| S: | 13 3/4 | (349) | T: | 77 5/8 | (1972) |

| | | |
|---|---|---|
| U (impact width): | 37 | (940) |
| Wheel Center Height (Front): | 15 | (381) |
| Wheel Center Height (Rear): | 15 1/4 | (387) |
| Wheel Well Clearance (Front): | 36 | (914) |
| Wheel Well Clearance (Rear): | 37 | (940) |
| Bottom Frame Height (Front): | 19 1/4 | (489) |
| Bottom Frame Height (Rear): | 24 1/4 | (616) |
| Engine Type: | Gasoline | |
| Engine Size: | 3.6L V6 | |
| Transmission Type: | Automatic | |
| Drive Type: | RWD | |
| Cab Style: | Quad Cab | |
| Bed Length: | 76" | |

**Mass Distribution - lb (kg)**

| | | | | | | |
|---|---|---|---|---|---|---|
| Gross Static | LF | 1413 | (641) | RF | 1326 | (601) |
| | LR | 1238 | (562) | RR | 1211 | (549) |

| Weights lb (kg) | Curb | | Test Inertial | | Gross Static | |
|---|---|---|---|---|---|---|
| W-front | 2677 | (1214) | 2634 | (1195) | 2739 | (1242) |
| W-rear | 2241 | (1017) | 2395 | (1086) | 2449 | (1111) |
| W-total | 4918 | (2231) | 5029 | (2281) | 5188 | (2353) |
| | | | 5000±110 (2270±50) | | 5165±110 (2343±50) | |

| GVWR Ratings - lb | | Surrogate Occupant Data | |
|---|---|---|---|
| Front | 3700 | Type: | Hybrid II |
| Rear | 3900 | Mass: | 159 lb |
| Total | 6800 | Seat Position: | Left/Driver |

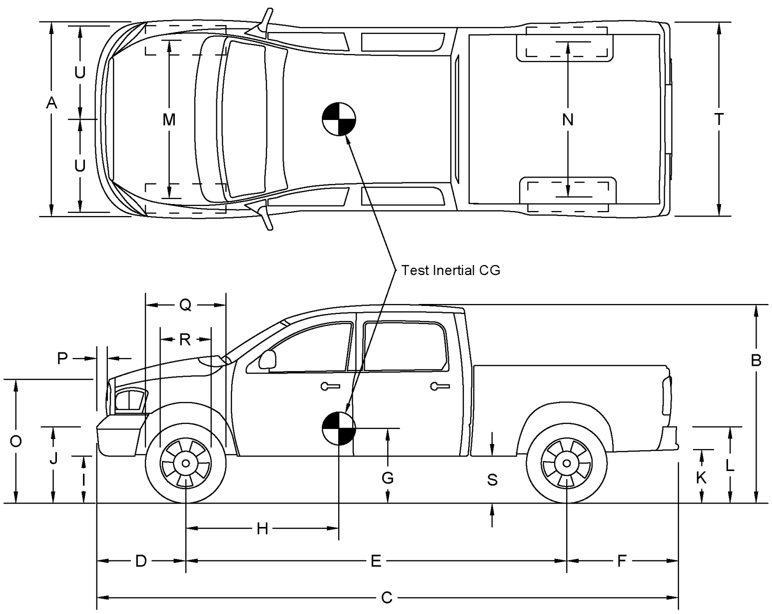
Note any damage prior to test: Slight scraping at left rear tail light area.

Figure 44. Vehicle Dimensions, Test No. HMDT-1


Figure 45. Test Vehicle, Test No. HMDT-2

Figure 46. Test Vehicle's Interior Floorboards and Undercarriage, Test No. HMDT-2

| | | | | | |
|---|---|---|---|---|---|
| | | **Test Name:** | HMDT-2 | **VIN No:** | 1C6RR6KG1FS542139 |
| **Model Year:** | 2015 | **Make:** | Dodge Ram | **Model:** | 1500 Crew Cab |
| **Tire Size:** | 265 70R17 | **Tire Inflation Pressure:** | 40 psi | **Odometer:** | 156652 |




**Vehicle Geometry - in. (mm)**
Target Ranges listed below

| | | | |
|---|---|---|---|
| A: | 76 7/8 (1953)<br>78±2 (1950±50) | B: | 74 1/2 (1892) |
| C: | 229 (5817)<br>237±13 (6020±325) | D: | 39 3/4 (1010)<br>39±3 (1000±75) |
| E: | 140 3/8 (3566)<br>148±12 (3760±300) | F: | 48 7/8 (1241) |
| G: | 28 1/16 (713)<br>min: 28 (710) | H: | 65 1/2 (1664)<br>63±4 (1575±100) |
| I: | 13 1/2 (343) | J: | 26 3/8 (670) |
| K: | 20 (508) | L: | 29 (737) |
| M: | 68 1/8 (1730)<br>67±1.5 (1700±38) | N: | 67 1/4 (1708)<br>67±1.5 (1700±38) |
| O: | 45 (1143)<br>43±4 (1100±75) | P: | 4 1/2 (114) |
| Q: | 31 1/2 (800) | R: | 18 1/2 (470) |
| S: | 14 1/2 (368) | T: | 77 1/8 (1959) |

| | |
|---|---|
| U (impact width): | 36 5/8 (930) |
| Wheel Center Height (Front): | 14 3/4 (375) |
| Wheel Center Height (Rear): | 15 (381) |
| Wheel Well Clearance (Front): | 35 (889) |
| Wheel Well Clearance (Rear): | 38 (965) |
| Bottom Frame Height (Front): | 11 3/4 (298) |
| Bottom Frame Height (Rear): | 13 1/4 (337) |
| Engine Type: | Gasoline |
| Engine Size: | 3.6L V6 |
| Transmission Type: | Automatic |
| Drive Type: | RWD |
| Cab Style: | Crew Cab |
| Bed Length: | 67" |

**Mass Distribution - lb (kg)**

| | | | | |
|---|---|---|---|---|
| Gross Static | LF | 1448 (657) | RF | 1303 (591) |
| | LR | 1224 (555) | RR | 1165 (528) |

| Weights lb (kg) | Curb | Test Inertial | Gross Static |
|---|---|---|---|
| W-front | 2698 (1224) | 2656 (1205) | 2751 (1248) |
| W-rear | 2260 (1025) | 2325 (1055) | 2389 (1084) |
| W-total | 4958 (2249) | 4981 (2259)<br>5000±110 (2270±50) | 5140 (2331)<br>5165±110 (2343±50) |

| GVWR Ratings - lb | |
|---|---|
| Front | 3700 |
| Rear | 3900 |
| Total | 6800 |

| Surrogate Occupant Data | |
|---|---|
| Type: | Hybrid II |
| Mass: | 159 lb |
| Seat Position: | Left/Driver |

**Note any damage prior to test:** None

Figure 47. Vehicle Dimensions, Test No. HMDT-2

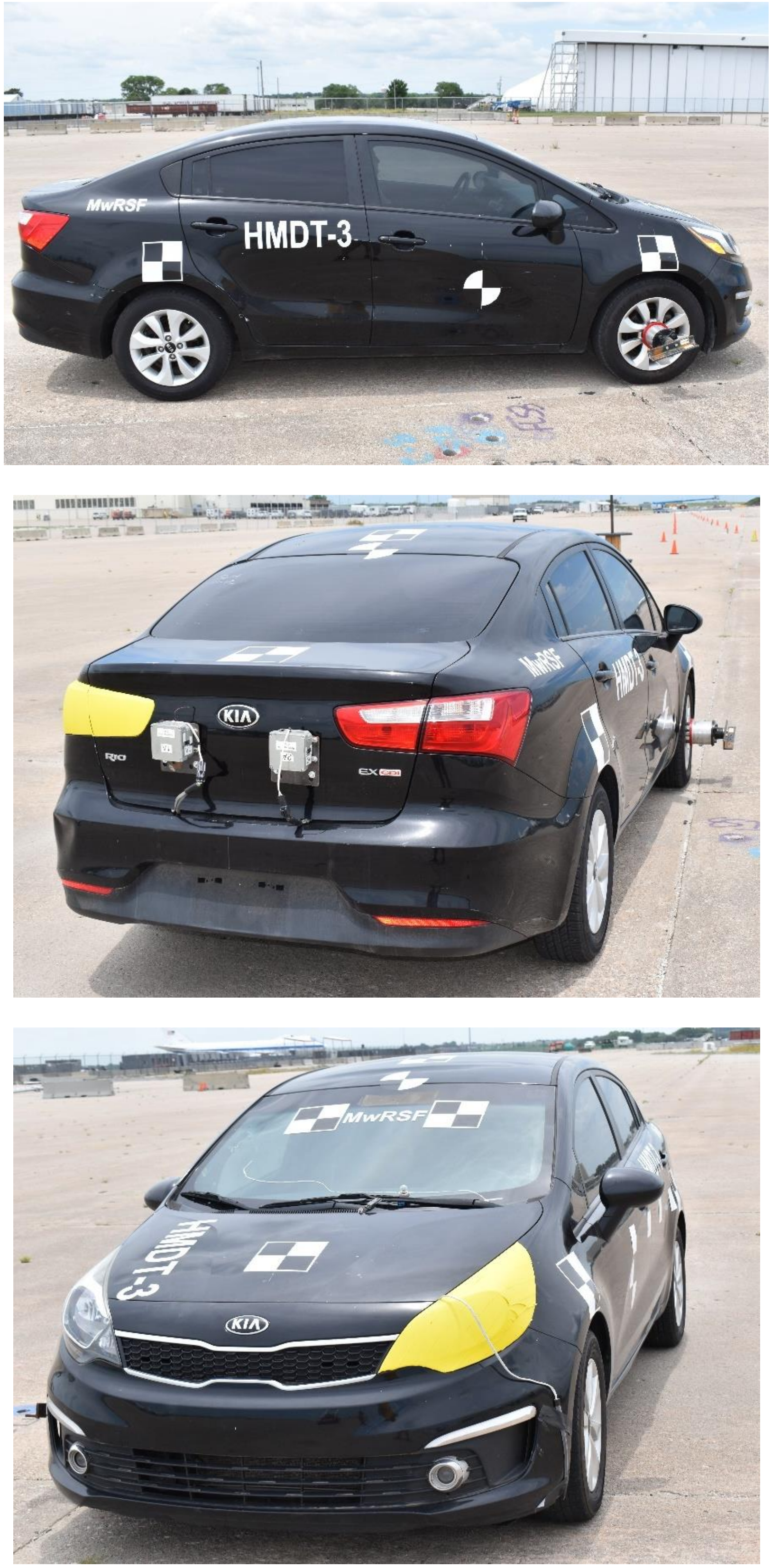



Figure 48. Test Vehicle, Test No. HMDT-3

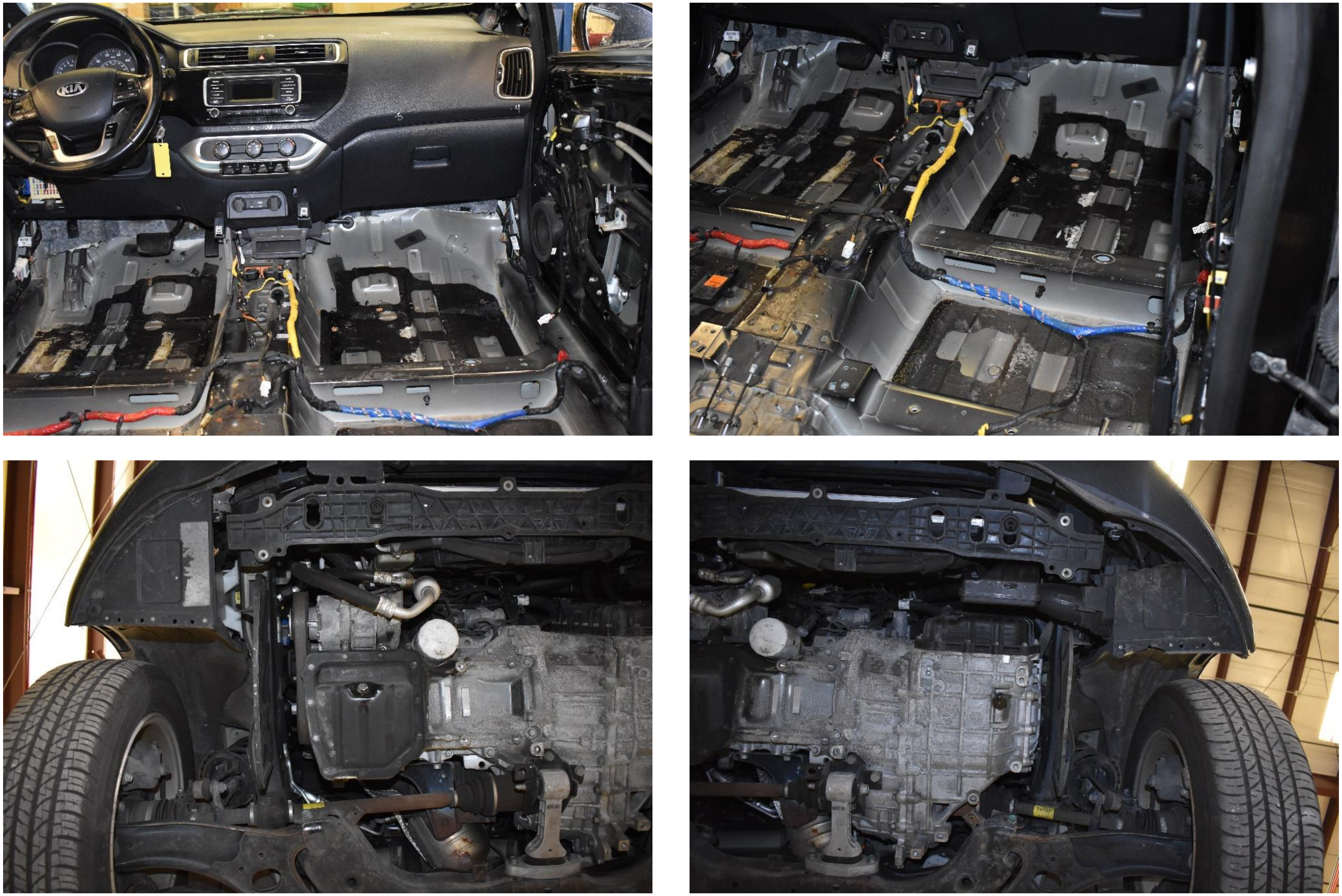
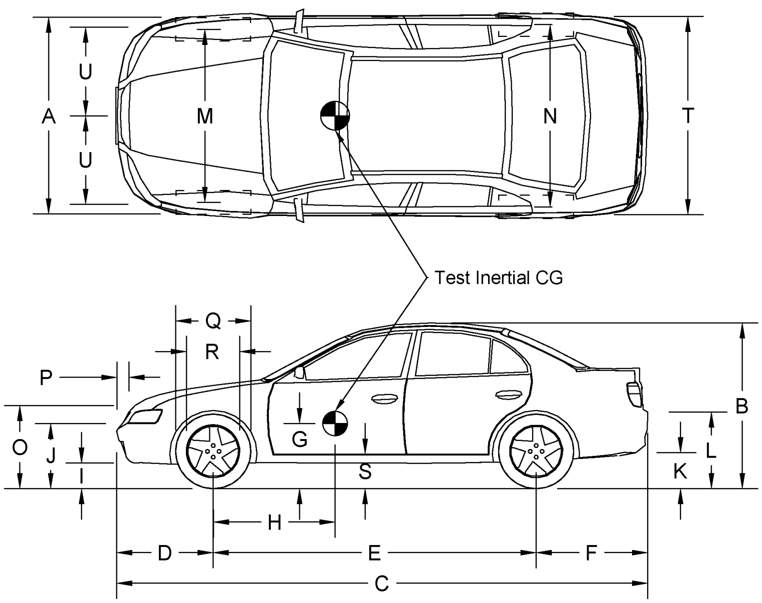


Figure 49. Test Vehicle’s Interior Floorboards and Undercarriage, Test No. HMDT-3

| | | | | | |
|---|---|---|---|---|---|
| | | Test Name: | HMDT-3 | VIN No: | KNADN4A38G6572229 |
| Model Year: | 2016 | Make: | Kia | Model: | Rio |
| Tire Size: | 185/65R15 | Tire Inflation Pressure: | 33 psi | Odometer: | 163813 |




**Vehicle Geometry - in. (mm)**
Target Ranges listed below

| | | | |
|---|---|---|---|
| A: | 66 1/4 (1683)<br>65±3 (1650±75) | B: | 57 3/8 (1457) |
| C: | 171 3/4 (4362)<br>169±8 (4300±200) | D: | 31 3/4 (806)<br>35±4 (900±100) |
| E: | 101 1/2 (2578)<br>98±5 (2500±125) | F: | 38 1/2 (978) |
| G: | 22 5/8 (575) | H: | 37 5/8 (956)<br>39±4 (990±100) |
| I: | 7 1/4 (184) | J: | 21 (533) |
| K: | 12 (305) | L: | 25 1/2 (648) |
| M: | 59 (1499)<br>59±2 (1498±50) | N: | 58 (1473)<br>56±2 (1425±50) |
| O: | 27 (686)<br>28±4 (711±100) | P: | 2 (51) |
| Q: | 24 (610) | R: | 16 1/4 (413) |
| S: | 8 1/2 (216) | T: | 66 5/8 (1692) |

| | |
|---|---|
| U (impact width): | 33 1/8 (841) |
| Top of radiator core support: | 27 (686) |
| Wheel Center Height (Front): | 11 1/4 (286) |
| Wheel Center Height (Rear): | 11 3/4 (298) |
| Wheel Well Clearance (Front): | 25 1/2 (648) |
| Wheel Well Clearance (Rear): | 26 (660) |
| Bottom Frame Height (Front): | 6 3/4 (171) |
| Bottom Frame Height (Rear): | 7 1/4 (184) |
| Engine Type: | Gasoline |
| Engine Size: | 1.4L 4 cyl |
| Transmission Type: | Automatic |
| Drive Type: | FWD |

**Mass Distribution - lb (kg)**

| | | | | |
|---|---|---|---|---|
| Gross Static | LF | 787 (357) | RF | 826 (375) |
| | LR | 468 (212) | RR | 504 (229) |

| Weights lb (kg) | Curb | Test Inertial | Gross Static |
|---|---|---|---|
| W-front | 1582 (718) | 1529 (694) | 1613 (732) |
| W-rear | 960 (435) | 901 (409) | 972 (441) |
| W-total | 2542 (1153) | 2430 (1102)<br>2420±55 (1100±25) | 2585 (1173)<br>2585±55 (1175±50) |

**GVWR Ratings lb**

| | |
|---|---|
| Front | 2028 |
| Rear | 1852 |
| Total | 3660 |

**Surrogate Occupant Data**

| | |
|---|---|
| Type: | Hybrid II |
| Mass: | 161 lb |
| Seat Position: | Right/Passenger |

Note any damage prior to test: None

Figure 50. Vehicle Dimensions, Test No. HMDT-3

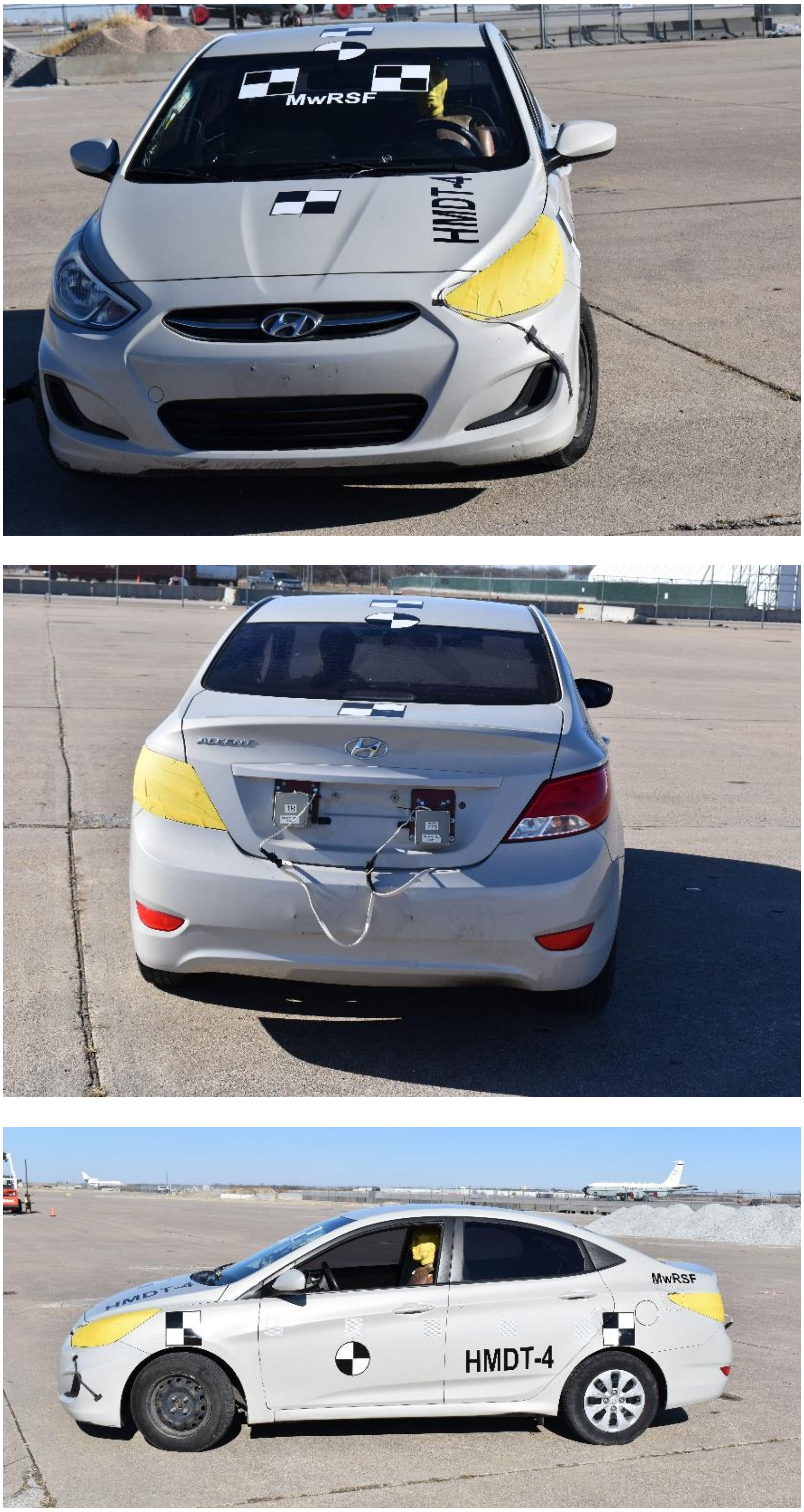


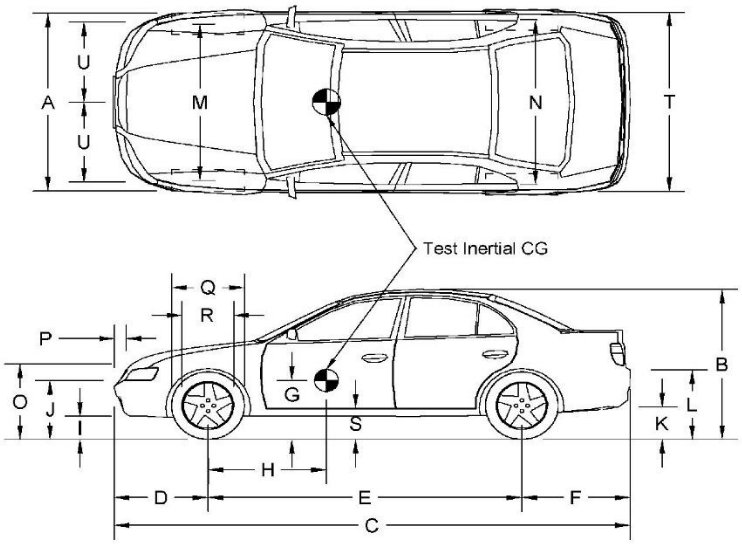

Figure 51. Test Vehicle, Test No.  HMDT-4

Figure 52. Test Vehicle’s Interior Floorboards and Undercarriage, Test No. HMDT-4

Test Name: HMDT-4 VIN No: KMHCT4AE9GU115037

Model Year: 2016 Make: Hyundai Model: Accent

Tire Size: P175/70R14 Tire Inflation Pressure: 33 psi Odometer: 216189




**Vehicle Geometry - in. (mm)**
Target Ranges listed below

| | | | | | |
|---|---|---|---|---|---|
| A: | 66 1/4 (1683)<br>65±3 (1650±75) | B: | 56 3/8 (1432) | | |
| C: | 171 7/8 (4366)<br>169±8 (4300±200) | D: | 31 7/8 (810)<br>35±4 (900±100) | | |
| E: | 100 1/2 (2553)<br>98±5 (2500±125) | F: | 39 1/2 (1003) | | |
| G: | 21 3/4 (552) | H: | 37 3/4 (959)<br>39±4 (990±100) | | |
| I: | 6 1/2 (165) | J: | 24 (610) | | |
| K: | 10 (254) | L: | 29 1/2 (749) | | |
| M: | 59 7/8 (1521)<br>59±2 (1498±50) | N: | 59 5/8 (1514)<br>59±2 (1425±50) | | |
| O: | 29 (737)<br>28±4 (711±100) | P: | 5 1/8 (130) | | |
| Q: | 23 (584) | R: | 15 1/4 (387) | | |
| S: | 7 1/2 (191) | T: | 66 7/8 (1699) | | |

| | |
|---|---|
| U (impact width): | 31 (787) |
| Top of radiator core support: | 28 (711) |
| Wheel Center Height (Front): | 10 3/4 (273) |
| Wheel Center Height (Rear): | 11 1/8 (283) |
| Wheel Well Clearance (Front): | 24 1/2 (622) |
| Wheel Well Clearance (Rear): | 24 3/4 (629) |
| Bottom Frame Height (Front): | 15 (381) |
| Bottom Frame Height (Rear): | 15 1/4 (387) |
| Engine Type: | Gasoline |
| Engine Size: | 1.6L 4 cyl |
| Transmission Type: | Automatic |
| Drive Type: | FWD |

**Mass Distribution - lb (kg)**

| | | | | |
|---|---|---|---|---|
| Gross Static | LF | 844 (383) | RF | 759 (344) |
| | LR | 494 (224) | RR | 499 (226) |

| Weights lb (kg) | Curb | Test Inertial | Gross Static |
|---|---|---|---|
| W-front | 1562 (709) | 1518 (689) | 1603 (727) |
| W-rear | 940 (426) | 913 (414) | 993 (450) |
| W-total | 2502 (1135) | 2431 (1103)<br>2420±55 (1100±25) | 2596 (1178)<br>2585±55 (1175±50) |

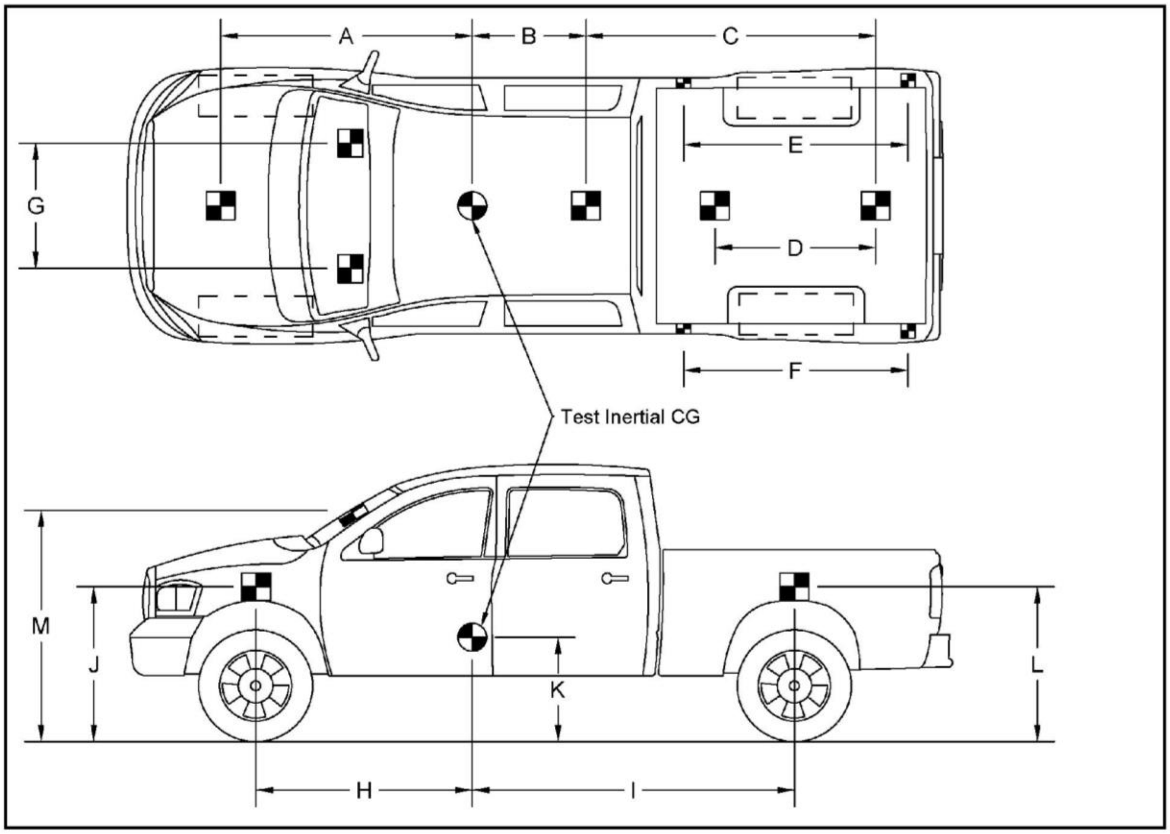
| GVWR Ratings lb | |
|---|---|
| Front | 1874 |
| Rear | 1852 |
| Total | 3527 |

| Surrogate Occupant Data | |
|---|---|
| Type: | Hybrid II |
| Mass: | 165 lb |
| Seat Position: | Left/Driver |

Note any damage prior to test: Large dent above the back left wheel well.

Figure 53. Vehicle Dimensions, Test No. HMDT-4

| | | | | | |
|---|---|---|---|---|---|
| | | Test Name: | HMDT-1 | VIN: | 1C6RR6FG3FS661207 |
| Model Year: | 2015 | Make: | Dodge RAM | Model: | 1500 Quad Cab |

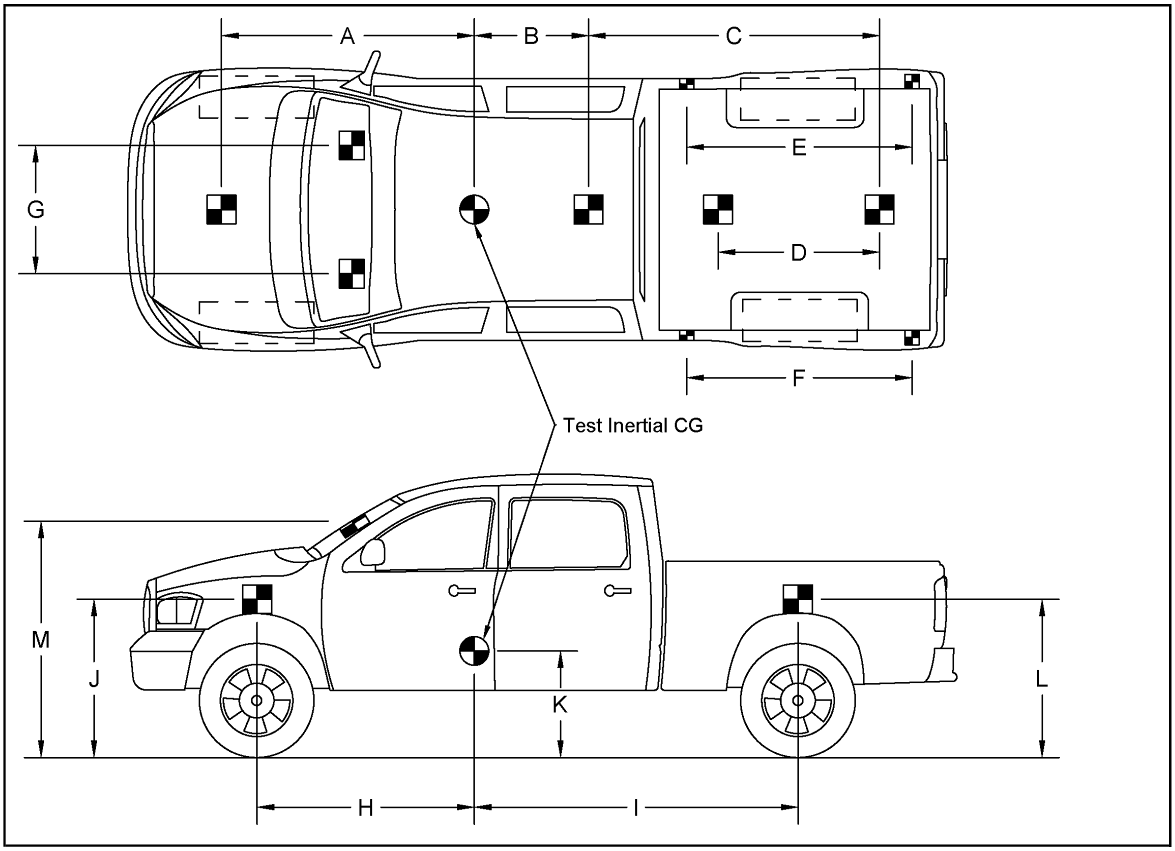



**TARGET GEOMETRY-- in. (mm)**

| | | | | | |
|---|---|---|---|---|---|
| A: | 80 3/16 (2037) | E: | 63 5/16 (1608) | J: | 40 (1016) |
| B: | 23 7/8 (606) | F: | 63 5/16 (1608) | K: | 28 7/16 (722) |
| C: | 77 (1956) | G: | 38 3/16 (970) | L: | 41 (1041) |
| D: | 37 13/16 (960) | H: | 66 3/4 (1695) | M: | 61 9/16 (1564) |
| | | I: | 73 7/8 (1876) | | |

Figure 54. Target Geometry, Test No. HMDT-1

| | | | | | |
|---|---|---|---|---|---|
| | | **Test Name:** | **HMDT-2** | **VIN:** | **1C6RR6KG1FS542139** |
| **Model Year:** | **2015** | **Make:** | **Dodge Ram** | **Model:** | **1500 Crew Cab** |

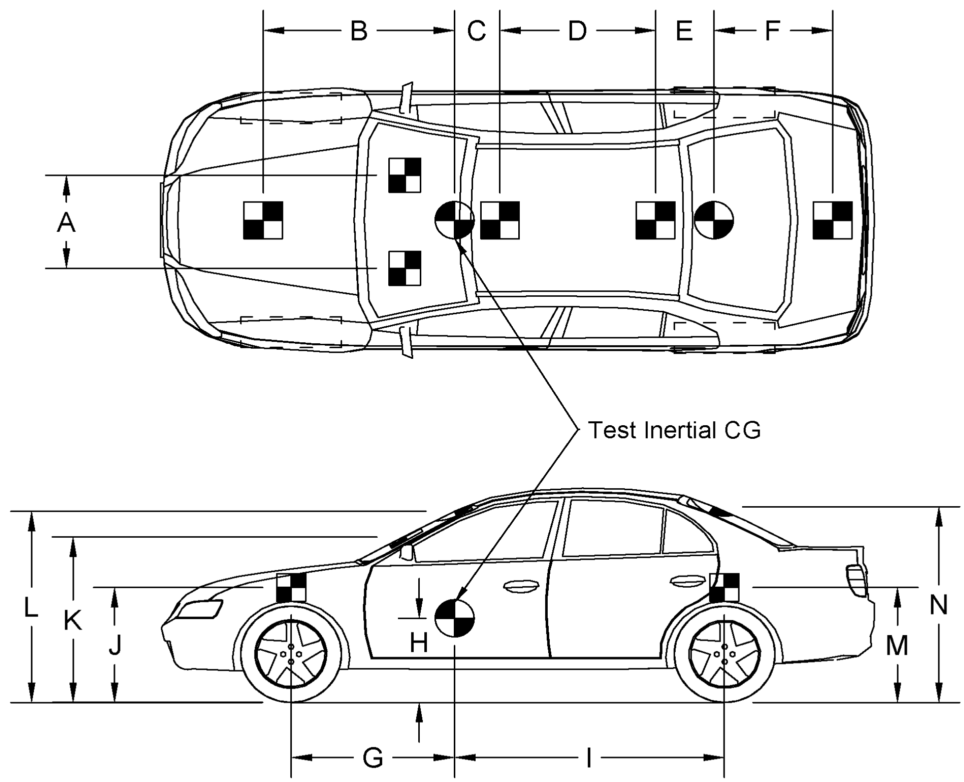



**TARGET GEOMETRY-- in. (mm)**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **A:** | **79 3/16** | **(2011)** | **E:** | **54 1/2** | **(1384)** | **J:** | **39 1/4** | **(997)** |
| **B:** | **30 3/8** | **(772)** | **F:** | **54 1/2** | **(1384)** | **K:** | **28 1/6** | **(715)** |
| **C:** | **67 5/8** | **(1718)** | **G:** | **36 3/4** | **(933)** | **L:** | **42 1/16** | **(1068)** |
| **D:** | **29 7/8** | **(759)** | **H:** | **65 1/2** | **(1664)** | **M:** | **63 5/8** | **(1616)** |
| | | | **I:** | **75** | **(1905)** | | | |

Figure 55. Target Geometry, Test No. HMDT-2

| | | | | | |
|---|---|---|---|---|---|
| | | **Test Name:** | **HMDT-3** | **VIN:** | **KNADN4A38G6572229** |
| **Model Year:** | **2016** | **Make:** | **Kia** | **Model:** | **Rio** |



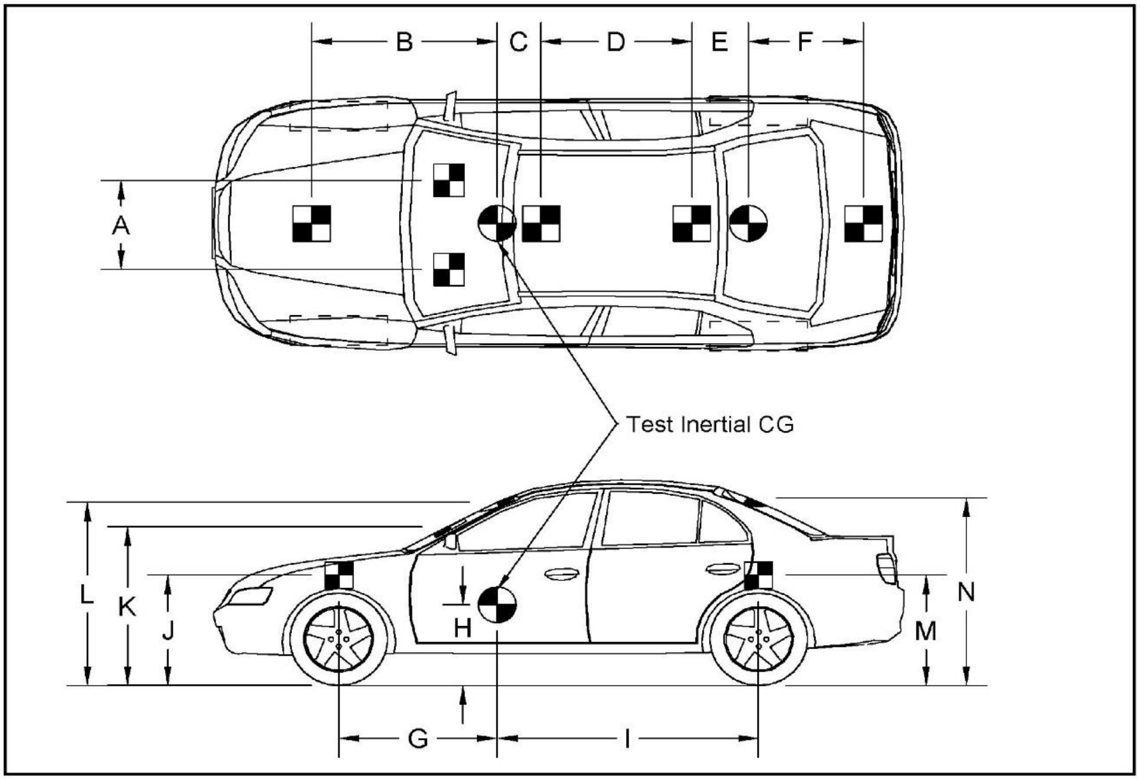

**TARGET GEOMETRY-- in. (mm)**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **A:** | **21** | **(533)** | **F:** | **34 1/2** | **(876)** | **K:** | **48 5/8** | **(1235)** |
| | | | | | | | Windshield Target | |
| **B:** | **51 3/8** | **(1305)** | **G:** | **37 5/8** | **(956)** | **L:** | **54 1/4** | **(1378)** |
| | | | | | | | Front round CG target | |
| **C:** | **13 9/16** | **(344)** | **H:** | **22 9/16** | **(573)** | **M:** | **30** | **(762)** |
| **D:** | **35 15/16** | **(913)** | **I:** | **63 1/2** | **(1613)** | **N:** | **54 1/4** | **(1378)** |
| | | | | | | | Rear Round target | |
| **E:** | **12 5/8** | **(321)** | **J:** | **29 1/4** | **(743)** | | | |

Figure 56. Target Geometry, Test No. HMDT-3

**Test Name:** HMDT-4 **VIN:** KMHCT4AE9GU115037

**Model Year:** 2016 **Make:** Hyundai **Model:** Accent




**TARGET GEOMETRY-- in. (mm)**

| | | | | | |
|---|---|---|---|---|---|
| A: | 18 7/8 (479) | F: | 32 3/8 (822) | K: | 49 (1245) Windshield Target |
| B: | 46 1/4 (1175) | G: | 37 3/4 (959) | L: | 53 1/4 (1353) Front round CG target |
| C: | 11 3/16 (284) | H: | 21 3/4 (552) | M: | 28 7/8 (733) |
| D: | 34 1/8 (867) | I: | 63 1/2 (1613) | N: | 53 1/4 (1353) Rear Round target |
| E: | 11 7/8 (302) | J: | 28 1/2 (724) | | |

Figure 57. Target Geometry, Test No. HMDT-4

## 4.4 Simulated Occupant

For test nos. HMDT-1, HMDT-2, HMDT-3, and HMDT-4, a Hybrid II 50$^{th}$-Percentile, Adult Male Dummy equipped with the footwear was placed in the front seat of the test vehicle with the seat belt fastened. In test nos. HMDT-1 and HMDT-2, the simulated occupant was placed in the left-front seat of the test vehicle and had a final weight of 159 lb. In test no. HMDT-3, the simulated occupant was placed in the right-front seat of the test vehicle and had a final weight of 161 lb. In test no. HMDT-4, the simulated occupant was placed in the left-front seat of the test vehicle and had a final weight of 165 lb. As recommended by MASH 2016, the simulated occupant weight was not included in calculating the c.g. location.

## 4.5 Data Acquisition Systems

### 4.5.1 Accelerometers

In each test, two environmental shock and vibration sensor/recorder systems mounted near the c.g. of the test vehicle were used to measure the accelerations in the longitudinal, lateral, and vertical directions. The electronic accelerometer data obtained in dynamic testing was filtered using the SAE Class 60 and the SAE Class 180 Butterworth filter conforming to the SAE J211/1 specifications [14].

The two systems, the SLICE-1 and SLICE-2 units, were modular data acquisition systems manufactured by Diversified Technical Systems, Inc. of Seal Beach, California. The SLICE-2 unit was designated as the primary system for test nos. HMDT-1 and HMDT-2, while the SLICE-1 unit was designated as the primary system for test nos. HMDT-3 and HMDT-4. The acceleration sensors were mounted inside the bodies of custom-built, SLICE 6DX event data recorders and recorded data at 10,000 Hz to the onboard microprocessor. Each SLICE 6DX was configured with 7 GB of non-volatile flash memory, a range of ±500 g's, a sample rate of 10,000 Hz, and a 1,650 Hz (CFC 1000) anti-aliasing filter. The "SLICEWare" computer software program and a customized Microsoft Excel worksheet were used to analyze and plot the accelerometer data.

### 4.5.2 Rate Transducers

Two identical angular rate sensor systems mounted inside the bodies of the SLICE-1 and SLICE-2 event data recorders were used to measure the rates of rotation of the test vehicle. Each SLICE MICRO Triax ARS had a range of 1,500 degrees/sec in each of the three directions (roll, pitch, and yaw) and recorded data at 10,000 Hz to the onboard microprocessors. The raw data measurements were then downloaded, converted to the proper Euler angles for analysis, and plotted. The "SLICEWare" computer software program and a customized Microsoft Excel worksheet were used to analyze and plot the angular rate sensor data.

### 4.5.3 Retroreflective Optic Speed Trap

A retroreflective optic speed trap was used to determine the speed of the test vehicle before impact. Five retroreflective targets, spaced at approximately 18-in. intervals, were applied to the side of the vehicles. When the emitted beam of light was reflected by the targets and returned to the Emitter/Receiver, a signal was sent to the data acquisition computer, recording at 10,000 Hz, as well as the external LED box activating the LED flashes. The speed was then calculated using the spacing between the retroreflective targets and the time between the signals. LED lights and high-speed digital video analysis are used as a backup in the event that speeds cannot be determined from the electronic data.

#### 4.5.4 Digital Photography

Five AOS high-speed digital video cameras, nine GoPro digital video cameras, and six Panasonic digital video cameras were utilized to film test no. HMDT-1. Six AOS high-speed digital video cameras, nine GoPro digital video cameras, and five Panasonic digital video cameras were utilized to film test no. HMDT-2. Six AOS high-speed digital video cameras, nine GoPro digital video cameras, and four Panasonic digital video cameras were utilized to film test no. HMDT-3. Six AOS high-speed digital video cameras, six GoPro digital video cameras, and four Panasonic digital video cameras were utilized to film test no. HMDT-4. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system for test nos. HMDT-1, HMDT-2, HMDT-3, and HMDT-4 are shown in Figures 58 through 61 and Tables 3 through 6.

The high-speed videos were analyzed using TEMA Motion and Redlake MotionScope software programs. Actual camera speed and camera divergence factors were considered in the analysis of the high-speed videos. A digital still camera was also used to document pre- and post-test conditions for the test.

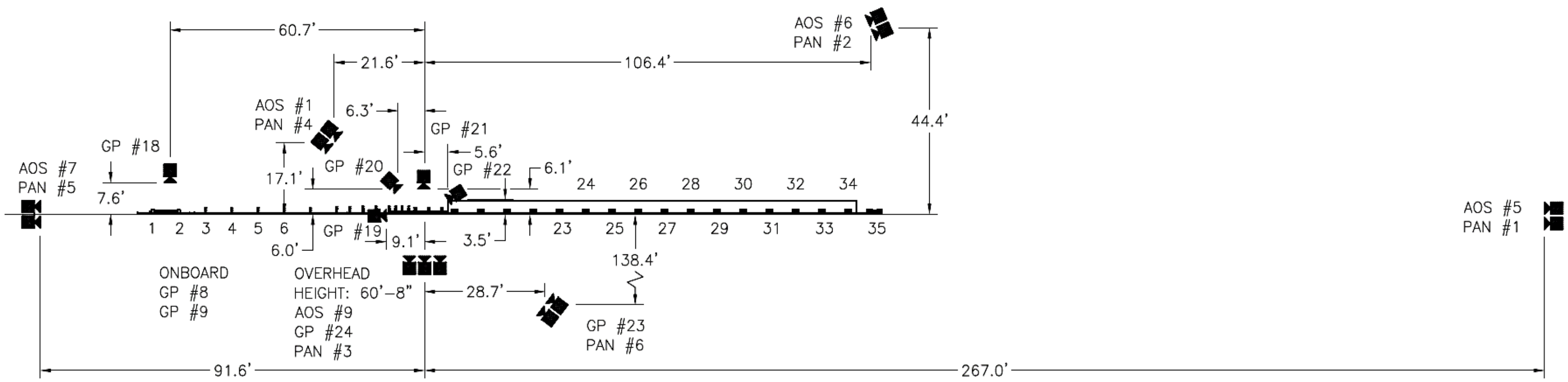


Figure 58. Camera Locations, Test No. HMDT-1

Table 3. Camera Speeds and Lens Settings, Test No. HMDT-1

| No. | Type | Operating Speed (frames/sec) | Lens | Lens Setting |
|---|---|---|---|---|
| AOS-1 | AOS Vitcam CTM | 500 | Fujinon 35mm | |
| AOS-5 | AOS X-PRI Gigabit | 500 | 100mm | |
| AOS-6 | AOS X-PRI Gigabit | 500 | Fujinon 75mm | |
| AOS-7 | AOS X-PRI Gigabit | 500 | Fujinon 75mm | |
| AOS-9 | AOS TRI-VIT 2236 | 1000 | Kowa 12mm | |
| GP-8 | GoPro Hero 4 | 120 | | |
| GP-9 | GoPro Hero 4 | 120 | | |
| GP-18 | GoPro Hero 6 | 240 | | |
| GP-19 | GoPro Hero 6 | 240 | | |
| GP-20 | GoPro Hero 6 | 240 | | |
| GP-21 | GoPro Hero 6 | 240 | | |
| GP-22 | GoPro Hero 7 | 240 | | |
| GP-23 | GoPro Hero 7 | 240 | | |
| GP-24 | GoPro Hero 7 | 240 | | |
| PAN-1 | Panasonic HC-V770 | 120 | | |
| PAN-2 | Panasonic HC-V770 | 120 | | |
| PAN-3 | Panasonic HC-V770 | 120 | | |
| PAN-4 | Panasonic HC-V770 | 120 | | |
| PAN-5 | Panasonic HC-VX981 | 120 | | |
| PAN-6 | Panasonic HC-VX981 | 120 | | |

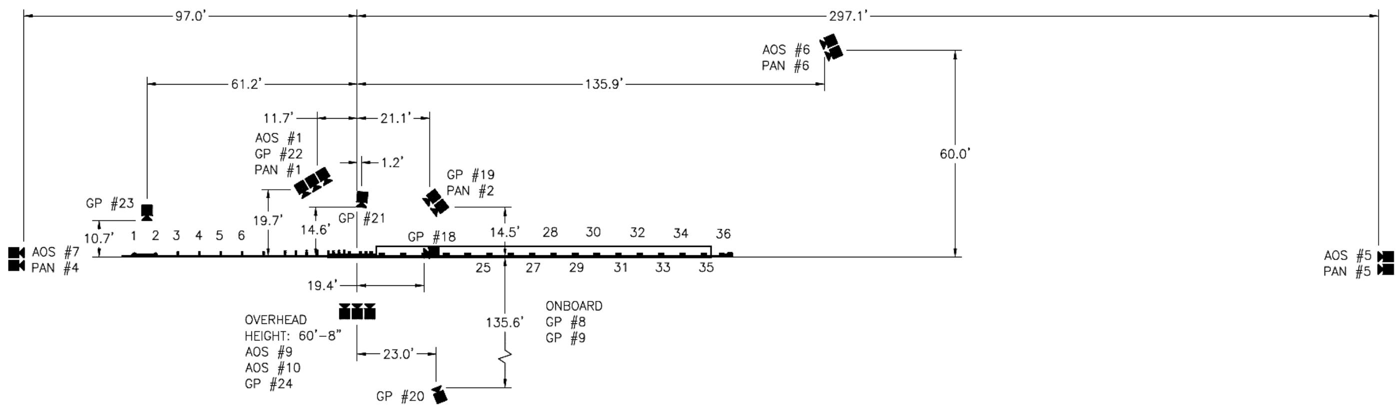



Figure 59. Camera Locations, Test No. HMDT-2

Table 4. Camera Speeds and Lens Settings, Test No. HMDT-2

| No. | Type | Operating Speed (frames/sec) | Lens | Lens Setting |
|---|---|---|---|---|
| AOS-1 | AOS Vitcam CTM | 500 | Kowa 25mm | |
| AOS-5 | AOS X-PRI Gigabit | 500 | 100 mm | |
| AOS-6 | AOS X-PRI Gigabit | 500 | Fujinon 50mm | |
| AOS-7 | AOS X-PRI Gigabit | 500 | Fujinon 50mm | |
| AOS-9 | AOS TRI-VIT 2236 | 1000 | Kowa 12mm | |
| AOS-10 | AOS TRI-VIT 2236 | 500 | Kowa 16mm | |
| GP-8 | GoPro Hero 4 | 120 | | |
| GP-9 | GoPro Hero 4 | 120 | | |
| GP-18 | GoPro Hero 6 | 240 | | |
| GP-19 | GoPro Hero 6 | 240 | | |
| GP-20 | GoPro Hero 6 | 240 | | |
| GP-21 | GoPro Hero 6 | 240 | | |
| GP-22 | GoPro Hero 7 | 240 | | |
| GP-23 | GoPro Hero 7 | 240 | | |
| GP-24 | GoPro Hero 7 | 240 | | |
| PAN-1 | Panasonic HC-V770 | 120 | | |
| PAN-2 | Panasonic HC-V770 | 120 | | |
| PAN-4 | Panasonic HC-V770 | 120 | | |
| PAN-5 | Panasonic HC-VX981 | 120 | | |
| PAN-6 | Panasonic HC-VX981 | 120 | | |

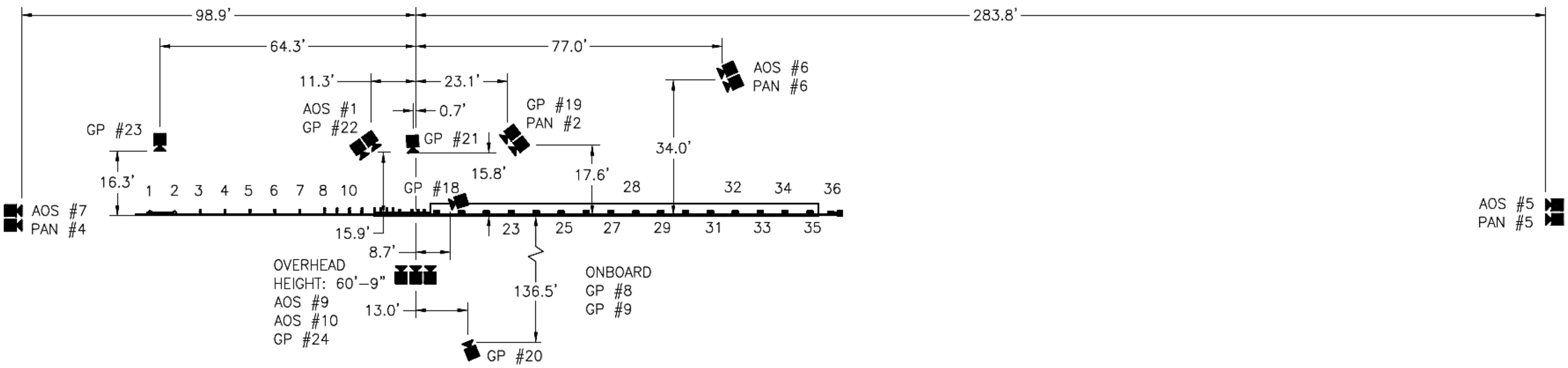



Figure 60. Camera Locations, Test No. HMDT-3

Table 5. Camera Speeds and Lens Settings, Test No. HMDT-3

| No. | Type | Operating Speed (frames/sec) | Lens | Lens Setting |
|---|---|---|---|---|
| AOS-1 | AOS Vitcam CTM | 500 | Kowa 25mm | |
| AOS-5 | AOS X-PRI Gigabit | 500 | 100mm | |
| AOS-6 | AOS X-PRI Gigabit | 500 | Fujinon 50mm | |
| AOS-7 | AOS X-PRI Gigabit | 500 | Fujinon 50mm | |
| AOS-9 | AOS TRI-VIT 2236 | 1000 | Kowa 12mm | |
| AOS-10 | AOS TRI-VIT 2236 | 500 | Kowa 16mm | |
| GP-8 | GoPro Hero 4 | 120 | | |
| GP-9 | GoPro Hero 4 | 120 | | |
| GP-18 | GoPro Hero 6 | 240 | | |
| GP-19 | GoPro Hero 6 | 240 | | |
| GP-20 | GoPro Hero 6 | 240 | | |
| GP-21 | GoPro Hero 6 | 240 | | |
| GP-22 | GoPro Hero 7 | 240 | | |
| GP-23 | GoPro Hero 7 | 240 | | |
| GP-24 | GoPro Hero 7 | 240 | | |
| PAN-2 | Panasonic HC-V770 | 120 | | |
| PAN-4 | Panasonic HC-V770 | 120 | | |
| PAN-5 | Panasonic HC-VX981 | 120 | | |
| PAN-6 | Panasonic HC-VX981 | 120 | | |

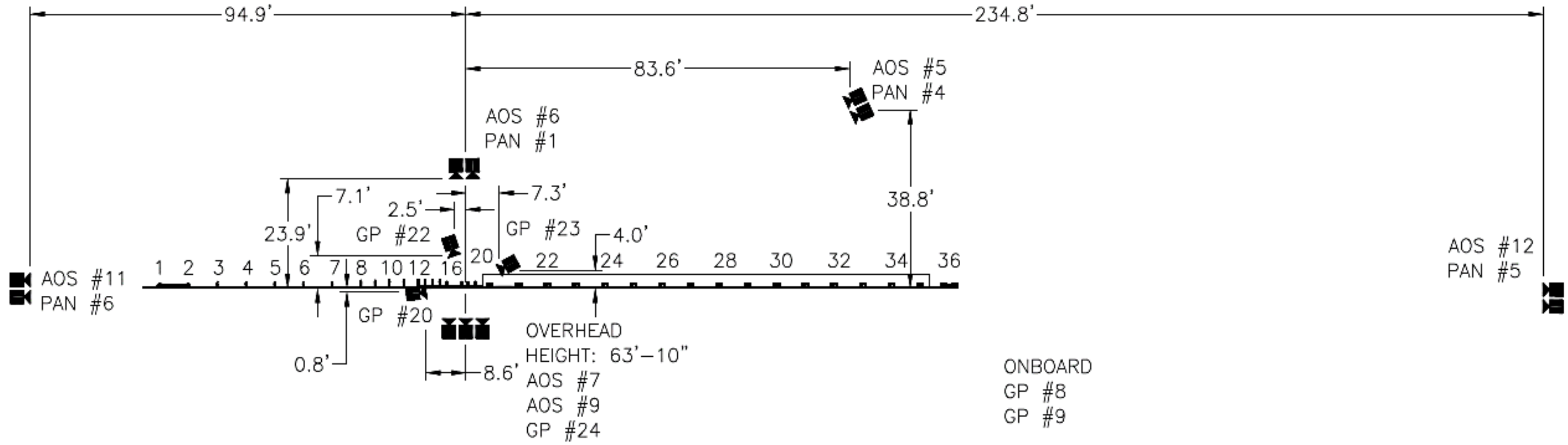



Figure 61. Camera Locations, Test No. HMDT-4



Table 6. Camera Speeds and Lens Settings, Test No. HMDT-4

| No. | Type | Operating Speed (frames/sec) | Lens | Lens Setting |
|---|---|---|---|---|
| AOS-5 | AOS X-PRI Gigabit | 500 | Fujinon 50 mm Fixed | - |
| AOS-6 | AOS X-PRI Gigabit | 500 | Kowa 25 mm Fixed | - |
| AOS-7 | AOS X-PRI Gigabit | 500 | Kowa 16 mm Fixed | - |
| AOS-9 | AOS TRI-VIT 2236 | 1000 | Kowa 12 mm Fixed | - |
| AOS-11 | AOS J-PRI | 500 | Sigma 28-70 #2 | 50 |
| AOS-12 | AOS J-PRI | 500 | Sigma 24-135 | 135 |
| GP-8 | GoPro Hero 4 | 120 | | |
| GP-9 | GoPro Hero 4 | 120 | | |
| GP-20 | GoPro Hero 6 | 120 | | |
| GP-22 | GoPro Hero 7 | 240 | | |
| GP-23 | GoPro Hero 7 | 240 | | |
| GP-24 | GoPro Hero 7 | 240 | | |
| PAN-1 | Panasonic HC-V770 | 120 | | |
| PAN-4 | Panasonic HC-V770 | 120 | | |
| PAN-5 | Panasonic HC-VX981 | 120 | | |
| PAN-6 | Panasonic HC-VX981 | 120 | | |

# 5 FULL-SCALE CRASH TEST NO. HMDT-1

## 5.1 Static Soil Test

Before full-scale crash test no. HMDT-1 was conducted, and the strength of the foundation soil was evaluated with a static test, as described in MASH 2016. The static test results, as shown in Appendix D, demonstrated a soil resistance above the baseline test limits. Thus, the soil provided adequate strength, and full-scale crash testing could be conducted on the barrier system.

## 5.2 Weather Conditions

Test no. HMDT-1 was conducted on January 13, 2021, at approximately 2:15 p.m. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/LNK) were reported and are shown in Table 7.

Table 7. Weather Conditions, Test No. HMDT-1

| | |
|---|---|
| Temperature | 53 °F |
| Humidity | 43% |
| Wind Speed | 9 mph |
| Wind Direction | 310° from True North |
| Sky Conditions | Sunny |
| Visibility | 1 Statute mile |
| Pavement Surface | Dry |
| Previous 3-Day Precipitation | 0.00 in. |
| Previous 7-Day Precipitation | 0.01 in. |

## 5.3 Test Description

Initial vehicle impact was to occur 86 in. upstream from post no. 19, as shown in Figure 62, which was selected using the CIP plots found in Figure 2-17 of MASH 2016 to maximize the probability of pocketing and vehicle snag on the first post of the bridge rail adjacent to the AGT. The 5,029-lb quad cab pickup truck impacted the preliminary HDOT AGT at a speed of 61.6 mph and an angle of 25.3 degrees. The actual point of impact was 1.4 in. downstream from the targeted impact location. The vehicle came to rest 122.1 ft downstream from impact and 4 ft laterally in front of the barrier after brakes were applied. Impact severity (I.S.) is an additional limiting condition required in MASH 2016. The measured I.S. of test no. HMDT-1 was 116.9 kip-ft, which exceeded the 105.6 kip-ft minimum limit as defined in MASH 2016 for test designation no. 3-21.

A detailed description of the sequential impact events is contained in Table 8. Sequential photographs are shown in Figures 63 and 64. Documentary photographs of the crash test are shown in Figures 65 and 66. The vehicle trajectory and final position are shown in Figure 67.


Figure 62. Impact Location, Test No. HMDT-1

Table 8. Sequential Description of Impact Events, Test No. HMDT-1

| Time sec | Event |
|---|---|
| 0.000 | Vehicle’s front bumper contacted rail between post nos. 16 and 17. |
| 0.008 | Vehicle’s left-front tire contacted rail. |
| 0.012 | Vehicle’s left fender contacted rail and deformed. |
| 0.016 | Vehicle’s left headlight contacted rail and deformed. |
| 0.020 | Post nos. 16, 17, and 18 deflected backward. |
| 0.040 | Post nos. 11 and 12 rotated downstream. |
| 0.046 | Post no. 10 rotated downstream. Vehicle’s hood, right headlight, and grille deformed. |
| 0.052 | Post nos. 13, 14, and 15 deflected backward. |
| 0.056 | Vehicle’s left-front door contacted rail and deformed, and vehicle’s left headlight became disengaged. |
| 0.062 | Post no. 19 deflected backward. |
| 0.078 | Vehicle’s right headlight became disengaged. |
| 0.084 | Vehicle’s left-front tire deflated. |
| 0.094 | Vehicle’s left-front window shattered. Top of vehicle’s left-front door deformed, and the top was ajar. Occupant’s head contacted left-front window. |
| 0.100 | Vehicle’s roof deformed. |
| 0.130 | Vehicle’s right-rear tire became airborne. |
| 0.142 | Vehicle’s right-front tire became airborne. |
| 0.160 | Vehicle’s left-rear door deformed. |
| 0.166 | Vehicle’s windshield cracked. |
| 0.192 | Vehicle rolled toward system. |
| 0.196 | Vehicle yawed away from system. |
| 0.198 | Vehicle was parallel to the system at a speed of 43.5 mph. |
| 0.205 | Vehicle’s left-rear door contacted rail. |
| 0.206 | Vehicle’s rear bumper contacted rail and deformed. |
| 0.216 | Vehicle’s left quarter panel contacted and deformed. |
| 0.218 | Vehicle’s tailgate contacted rail and deformed. |
| 0.350 | Vehicle’s left-front wheel deformed, and vehicle’s left A-pillar deformed. |
| 0.360 | Vehicle exited system at a speed of 42.6 mph and an angle of 8.6 degrees. |
| 0.412 | Vehicle pitched downward. |
| 0.820 | Vehicle’s right-front tire regained contact with ground. |
| 0.917 | Vehicle’s right-rear tire regained contact with ground. |
| 1.020 | Vehicle yawed toward system. Vehicle rolled away from system. |
| 1.570 | Vehicle rolled toward system. |
| 3.950 | Vehicle came to rest 122 ft – 1 in. downstream from impact. |

0.000 sec

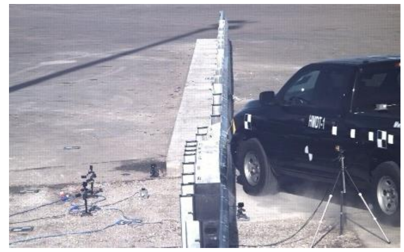
0.100 sec

0.200 sec

0.300 sec

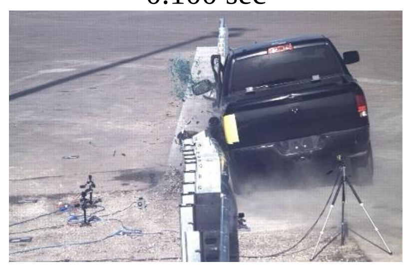
0.400 sec

0.500 sec



0.000 sec

0.100 sec



0.200 sec

0.300 sec

0.400 sec

0.500 sec

Figure 63. Sequential Photographs, Test No. HMDT-1

0.000 sec

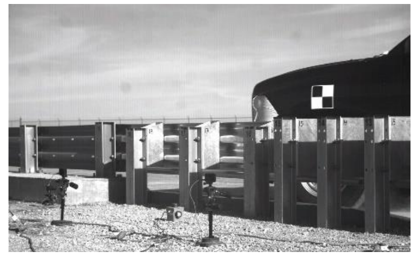
0.100 sec

0.200 sec

0.300 sec

0.400 sec

0.500 sec



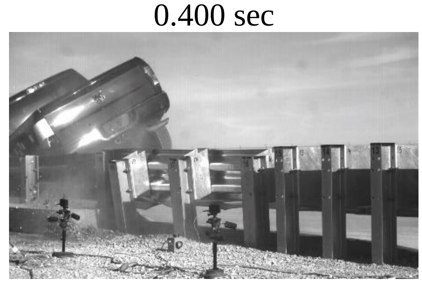
0.000 sec


0.100 sec

0.200 sec

0.300 sec

0.400 sec



0.500 sec

Figure 64. Sequential Photographs, Test No. HMDT-1

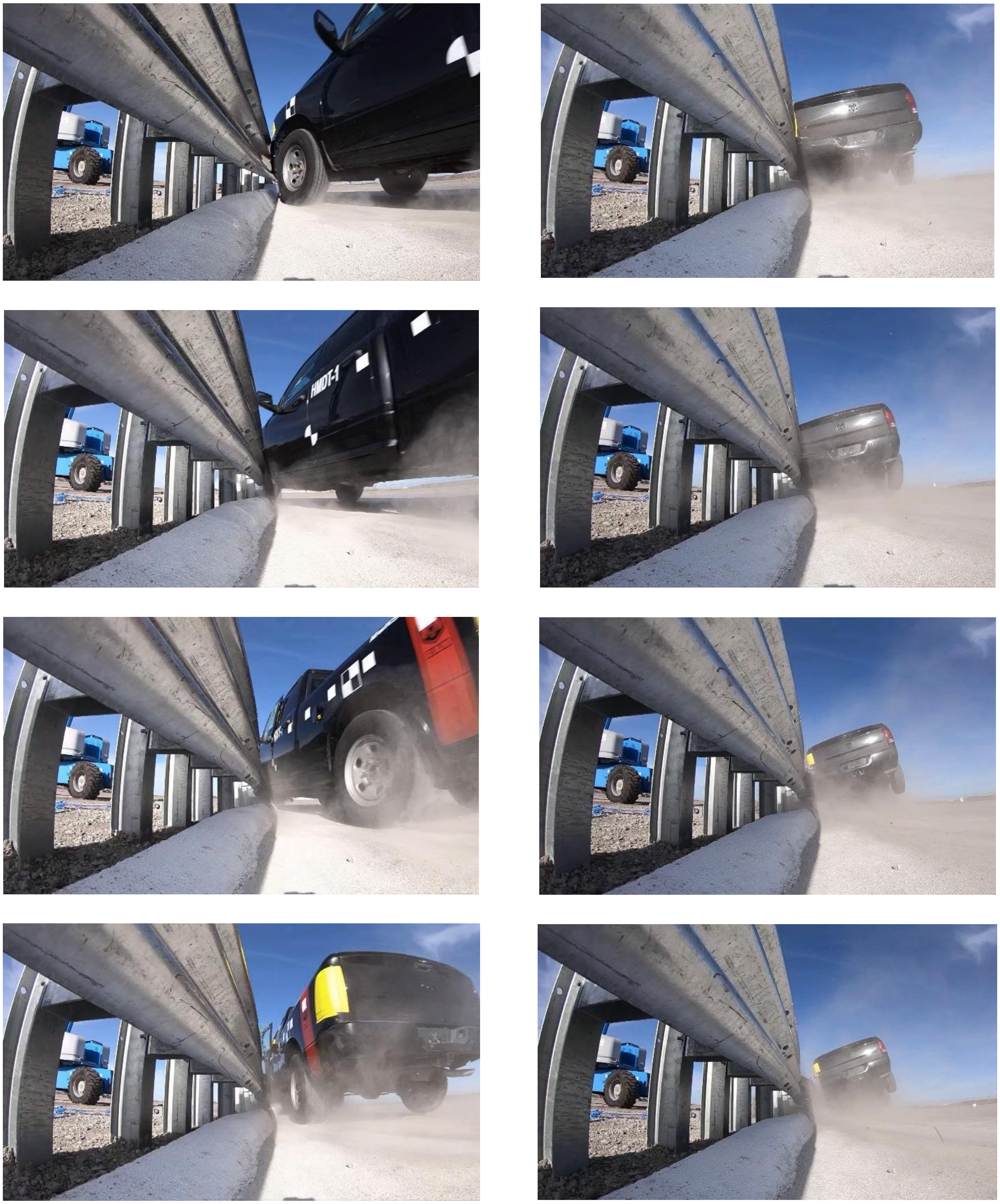



Figure 65. Documentary Photographs, Test No. HMDT-1

Figure 66. Documentary Photographs, Test No. HMDT-1


Figure 67. Vehicle Final Position and Trajectory Marks, Test No. HMDT-1

## 5.4 Barrier Damage

Damage to the barrier was moderate, as shown in Figures 68 through 70. Note that some pre-existing damage to the bridge rail was present from a previous test, test no. HMBDR-1, which has been previously reported [2]. The pre-existing damage included spalling of the concrete sidewalk between post nos. 24 and 26, missing post no. 25, and contact marks on the thrie-beam rail and sidewalk at post no. 24.

Barrier damage from test no. HMDT-1 consisted of deflected posts, flattening, contact marks and kinks on the thrie-beam rail, and minor concrete spalling and contact marks on the front face of the concrete curb and sidewalk. The length of vehicle contact along the barrier was approximately 19 ft – 3 in., which started 20 in. downstream from post no. 16 and extended to 63½ in. downstream from post no. 20. The bottom rail corrugation sustained various degrees of flattening starting from post no. 17 and continued 78¾ in. downstream. Multiple kinks were observed on the top and bottom corrugation of the thrie-beam rail from post no. 16 to post no. 20.

Post nos. 3 through 19 were slightly twisted counterclockwise except for posts nos. 15 and 18, and posts nos. 15 through 19 rotated backward. Post nos. 17, 18, and 19 experienced local buckling on the flange on the traffic side face. The upper rail connection bolt at post no. 19 sheared off during the impact event. Posts nos. 1 through 15 had minor soil gaps measuring less than 1 in. in front of the posts, while post nos. 16 through 18 had larger soil gaps between 1½ in. and 4½ in. in front of the posts. No movement was observed in the upstream anchorage system.

Tire contact marks were visible on the traffic side and top of the curb starting upstream from post no. 17, which extended for the length of 73½ in. downstream. The tire contact marks on the concrete sidewalk began from its upstream end and extended 55¾ in. downstream. Minor concrete spalling, measuring 5 in. x 7in. x 3½ in. deep and 9 in. x 7 in. x 2¼ in. deep, was found on the top and front edge of the transition curb and sidewalk, respectively, at the joint between the transition curb and concrete sidewalk.

Figure 68. System Damage, Test No. HMDT-1


Figure 69. Thrie-Beam Rail Damage, Test No. HMDT-1


Figure 70. Soil Gap and Post Nos. 14 through 19 Damage, Test No. HMDT-1

The maximum lateral permanent set of the barrier system was 9.4 in., which occurred in the thrie-beam rail between post nos. 17 and 18, as measured in the field. The maximum lateral dynamic barrier deflection was 11.4 in. at the rail at post no. 18, as determined from high-speed digital video analysis. The working width of the system was found to be 28.9 in., also determined from high-speed digital video analysis. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 71.

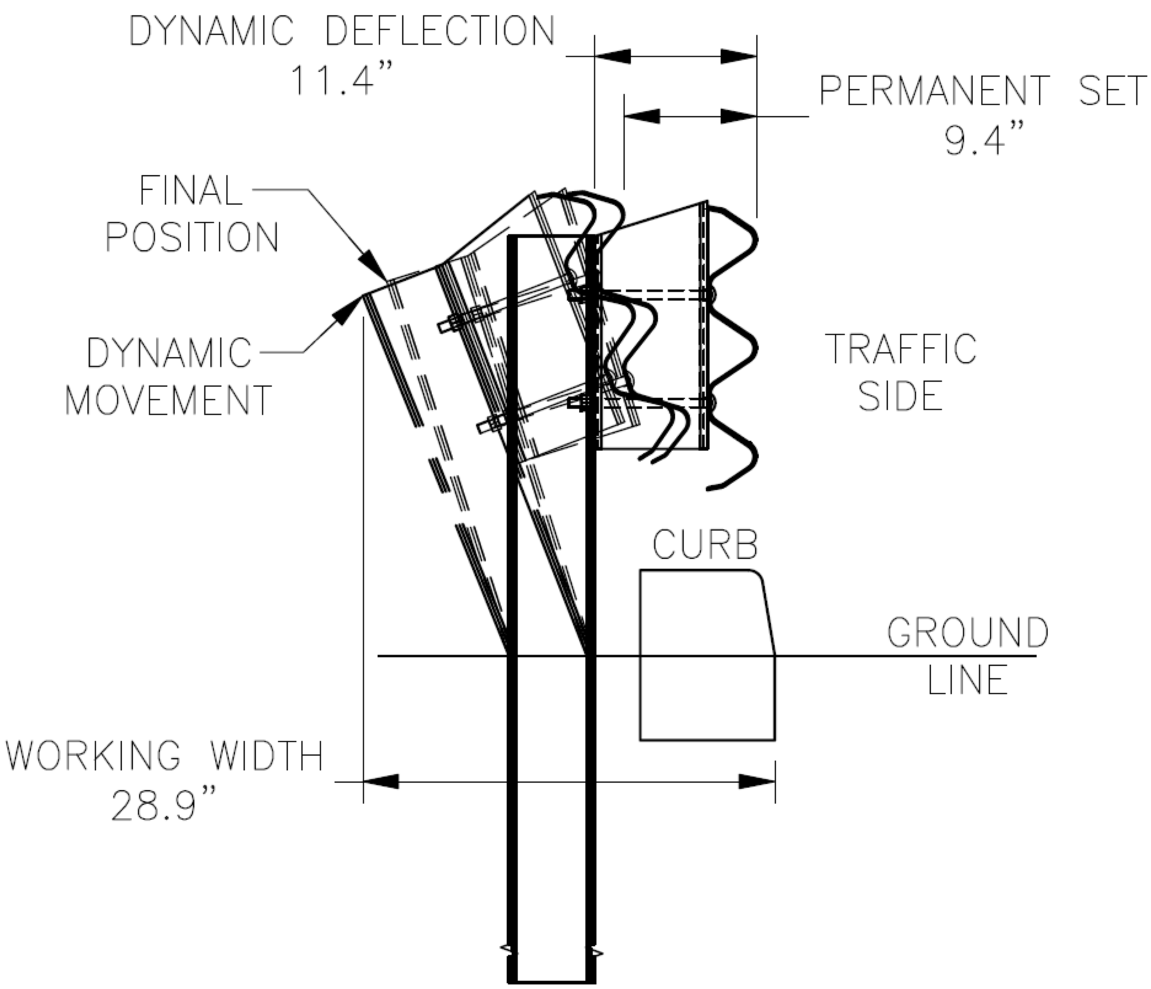



Figure 71. Permanent Set Deflection, Dynamic Deflection, and Working Width, Test No. HMDT-1

## 5.5 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 72 through 74. Concentrated damage occurred to the left-front corner and left side of the vehicle where the impact had occurred, with additional damage to the front of the vehicle and undercarriage.

The left-front wheel hub was crushed inward toward the engine compartment. The front bumper cover and grille were disengaged. The bumper structure remained intact but was shifted to the right. The left fender was pushed inward at the wheel opening and rearward at the A-pillar, while the right fender was slightly bowed outward. The full length of both left-side doors was dented and scraped at the approximate center height.

The vehicle's left-front shock and spring were bent and twisted toward the center of the vehicle. The left-side bump stop was disengaged. The front sway bar shifted ¾ in. to the right and was bent at the end link connections. The left-bottom control arm was disengaged, while the upper control arm was bent and kinked inward. The left tie rod was disengaged from the joint, and the right tie rod was bent. The rear sway bar was shifted ⅛ in. to the right.

The front of the longitudinal frame rails was bent into an S-shape. Kinks and buckles were observed on the left side of all cross members. The front engine and transmission cross members were scraped and bent backward on the right side at the control arm joint. The middle cross member was bent downward, twisted, and backward on the left side at the control arm joint. The front windshield was intact with cracks on the left side, and the left-front window was shattered.

The maximum occupant compartment intrusions are listed in Table 9, along with the intrusion limits established in MASH 2016 for various areas of the occupant compartment. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix E. MASH 2016 defines intrusion or deformation as the occupant compartment being deformed and reduced in size with no observed penetration. Outward deformations, which are denoted as negative numbers in Appendix E, are not considered crush toward the occupant and are not evaluated by MASH 2016 criteria. Note that the maximum wheel well and toe pan intrusion of 10.5 in. exceeded the MASH 2016 limit of 9 in. There were no penetrations into the occupant compartment, but the measurement of the occupant compartment intrusion limits exceeded MASH criteria for occupant compartment deformation limits and resulted in the failure of test no. HMDT-1 to meet MASH 2016 criteria.


Figure 72. Vehicle Damage, Test No. HMDT-1


Figure 73. Vehicle Damage, Test No. HMDT-1

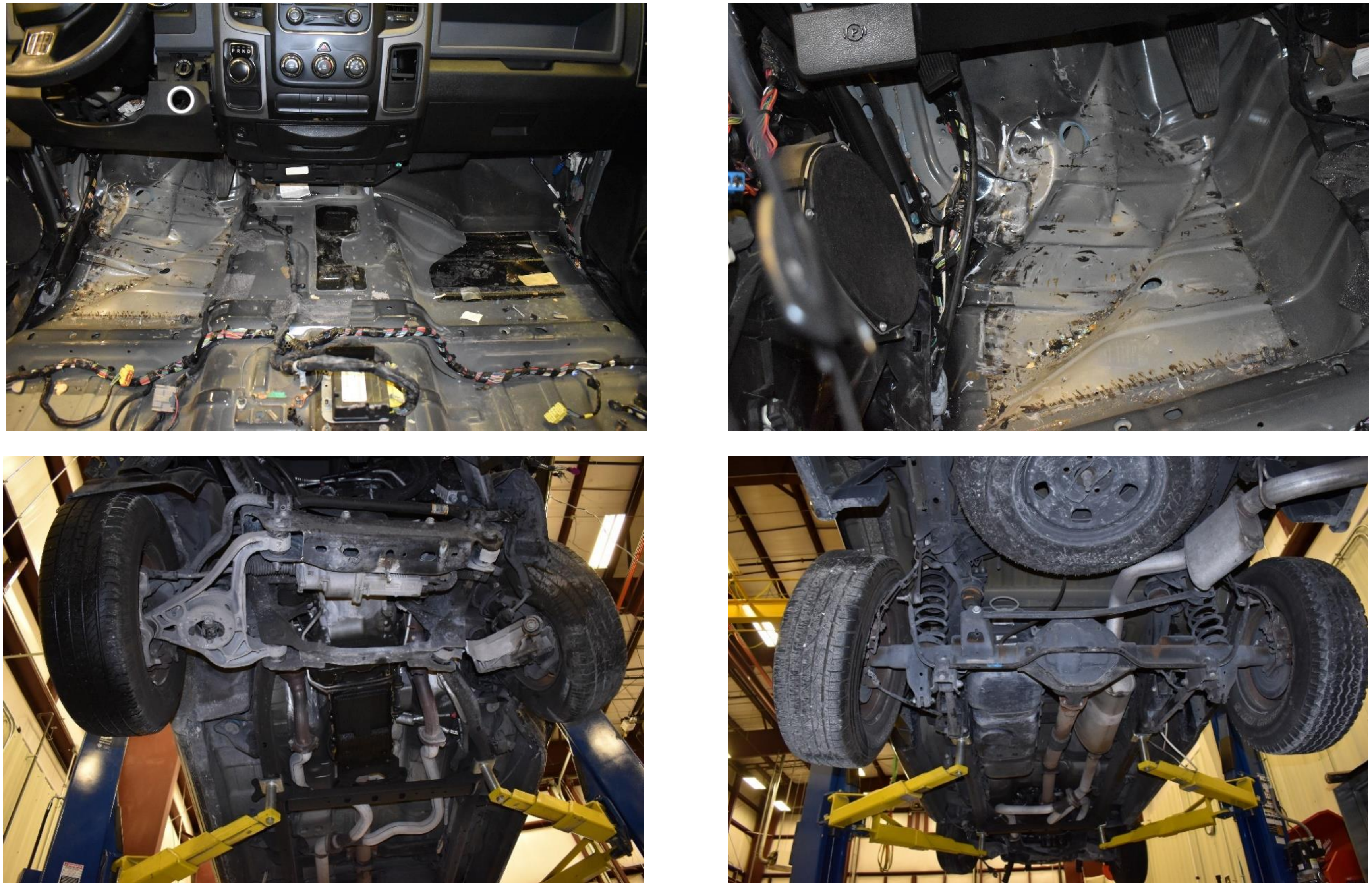


Figure 74. Interior and Undercarriage Damage, Test No. HMDT-1

Table 9. Maximum Occupant Compartment Intrusion by Location, Test No. HMDT-1

| Location | Maximum Intrusion in. | MASH 2016 Allowable Intrusion in. |
|---|---|---|
| Wheel Well & Toe Pan | 10.5 | ≤ 9 |
| Floor Pan & Transmission Tunnel | 5.8 | ≤ 12 |
| A-Pillar | 0.0 | ≤ 5 |
| A-Pillar (Lateral) | 0.0* | ≤ 3 |
| B-Pillar | 0.3 | ≤ 5 |
| B-Pillar (Lateral) | 0.0* | ≤ 3 |
| Side Front Panel (in Front of A-Pillar) | 3.9 | ≤ 12 |
| Side Door (Above Seat) | 0.0* | ≤ 9 |
| Side Door (Below Seat) | 0.0* | ≤ 12 |
| Roof | 0.0* | ≤ 4 |
| Windshield | 0.0 | ≤ 3 |
| Side Window | Shattered due to contact with simulated occupant's head | No shattering resulting from contact with structural member of test article |
| Dash | 3.4 | N/A |

N/A – No MASH 2016 criteria exist for this location
*Negative value reported as 0.0. See Appendix E for further information.

## 5.6 Occupant Risk

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined from the accelerometer data, are shown in Table 10. Note that the OIVs and ORAs were within suggested limits, as provided in MASH 2016. The calculated THIV, PHD, and ASI values are also shown in Table 10. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix F.

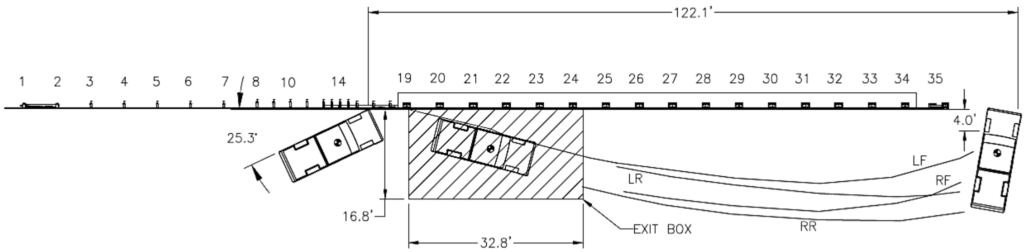
Table 10. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. HMDT-1

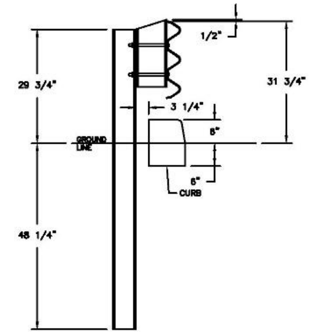
| Evaluation Criteria | | Transducer | | MASH 2016 Limits |
|---|---|---|---|---|
| | | SLICE-1 | SLICE-2 (primary) | |
| OIV ft/s | Longitudinal | -26.94 | -27.17 | ±40 |
| | Lateral | 23.94 | 24.18 | ±40 |
| ORA g's | Longitudinal | -9.42 | -12.20 | ±20.49 |
| | Lateral | 10.16 | 10.07 | ±20.49 |
| Max Angular Displacement. deg. | Roll | -26.1 | -28.1 | ±75 |
| | Pitch | -11.6 | -9.1 | ±75 |
| | Yaw | 37.0 | 36.6 | not required |
| THIV ft/s | | 36.86 | 36.70 | not required |
| PHD g's | | 13.03 | 13.58 | not required |
| ASI | | 1.58 | 1.62 | not required |

### 5.7 Discussion

The analysis of the results for test no. HMDT-1 showed that the system contained and redirected the 2270P vehicle with controlled lateral displacements of the barrier. However, deformations of, or intrusions into, the wheel well and toe pan area of 10.5 in. exceeded the deformation limits of 9 in., as defined in MASH 2016. A summary of the test results and sequential photographs are shown in Figure 75. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or work-zone personnel. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix F, were deemed acceptable, because they did not adversely influence occupant risk nor cause a rollover. After impact, the vehicle exited the barrier at an angle of 8.6 degrees, and its trajectory did not violate the bounds of the exit box. Therefore, test no. HMDT-1 was determined to be unacceptable according to the MASH 2016 safety performance criteria for test designation no. 3-21 due to the excessive wheel well and toe pan intrusion.

0.000 sec | 0.100 sec | 0.200 sec | 0.300 sec | 0.400 sec




- Test Agency .......... MwRSF
- Test Number .......... HMDT-1
- Date .......... 1/13/2021
- MASH 2016 Test Designation No. .......... 3-21
- Test Article .......... Hawaii Transition to Modified Delaware Retrofit Bridge Rail
- Total Length .......... 177 ft – 6 in.
- Key Component – Thrie-Beam Guardrail
  - Thickness .......... 12 ga.
  - Length .......... 12.5 ft (nested), and 6.25 ft (single ply)
- Key Component – W6x15 Steel Posts
  - Length .......... 78 in.
  - Embedment Depth .......... 48½ in., 48⅜ in, 48$^{3}/_{16}$ in. (post nos. 16-18)
  - Spacing .......... 37½ in.
- Soil Type .......... Coarse, Crushed, Limestone (Well-Graded Gravel)
- Vehicle Make /Model .......... 2015 Dodge RAM 1500 Quad cab pickup truck
  - Curb .......... 4,918 lb
  - Test Inertial .......... 5,029 lb
  - Gross Static .......... 5,188 lb
- Impact Conditions
  - Speed .......... 61.7 mph
  - Angle .......... 25.3 degrees
  - Impact Location .......... 84.6 in. upstream from post no. 19
- Impact Severity .......... 116.9 kip-ft > 105.6 kip-ft limit from MASH 2016
- Exit Conditions
  - Speed .......... 42.6 mph
  - Angle .......... 8.6 degrees
- Exit Box Criterion .......... Pass
- Vehicle Stability .......... Satisfactory
- Vehicle Stopping Distance .......... 122 ft – 1 in. downstream and 4 ft in front
- Vehicle Damage .......... Moderate
  - VDS [15] .......... 10-LFQ-5
  - CDC [16] .......... 11-LFEW-4
  - Maximum Interior Deformation .......... 10.5 in. at toe pan area ≥ 9 in. MASH 2016 limit
- Test Article Damage .......... Minimal
- Maximum Test Article Deflections
  - Permanent Set .......... 9.4 in.
  - Dynamic .......... 11.4 in.
  - Working Width .......... 28.9 in.
- Transducer Data

| Evaluation Criteria | | Transducer | | MASH 2016 Limits |
|---|---|---|---|---|
| | | SLICE-1 | SLICE-2 (primary) | |
| OIV ft/s | Longitudinal | -26.94 | -27.17 | ±40 |
| | Lateral | 23.94 | 24.18 | ±40 |
| ORA g's | Longitudinal | -9.42 | -12.20 | ±20.49 |
| | Lateral | 10.16 | 10.07 | ±20.49 |
| Maximum Angular Displacement deg. | Roll | -26.1 | -28.1 | ±75 |
| | Pitch | -11.6 | -9.1 | ±75 |
| | Yaw | 37.0 | 36.6 | not required |
| THIV – ft/s | | 36.86 | 36.70 | not required |
| PHD – g's | | 13.03 | 13.58 | not required |
| ASI | | 1.58 | 1.62 | not required |

Figure 75. Summary of Test Results and Sequential Photographs, Test No. HMDT-1

# 6 DESIGN MODIFICATIONS – ROUND 1

As previously described, test no. HMDT-1 did not pass the MASH 2016 safety performance criteria for test designation no. 3-21 due to the excessive deformation of the wheel well and toe pan. Potential causes of failure and modifications to mitigate the concerns were investigated and discussed with HDOT prior to moving forward with crash testing of a modified AGT design.

In test no. HMDT-1, the left-front wheel snagged on the first post of the bridge rail, resulting in deformation of the suspension and wheel displacement into the firewall. Snagging occurred after the left-front tire climbed the curb and loaded the rail as the posts in the transition region deflected, forming a pocket in front of the vehicle.

Several design modifications were proposed to mitigate the vehicle snag and excessive wheel well and toe pan deformations. First, a flatter vertical slope for the curb may reduce abrupt wheel climb by reducing the slope from 3H:1V to 6H:1V, as shown in Figure 76. Second, reducing the post spacing adjacent to the bridge rail from 37½ in. to 18¾ in. and adding a W6x15 post between posts nos. 17 and 18 could increase the stiffness of the transition and reduce the potential for pocketing, as shown in Figure 77.

After consulting with HDOT, the AGT test plan was revised. The modified AGT is shown in Figures 78 through 111. Photographs of the modified AGT test installation are shown in Figures 112 through 116. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix G.

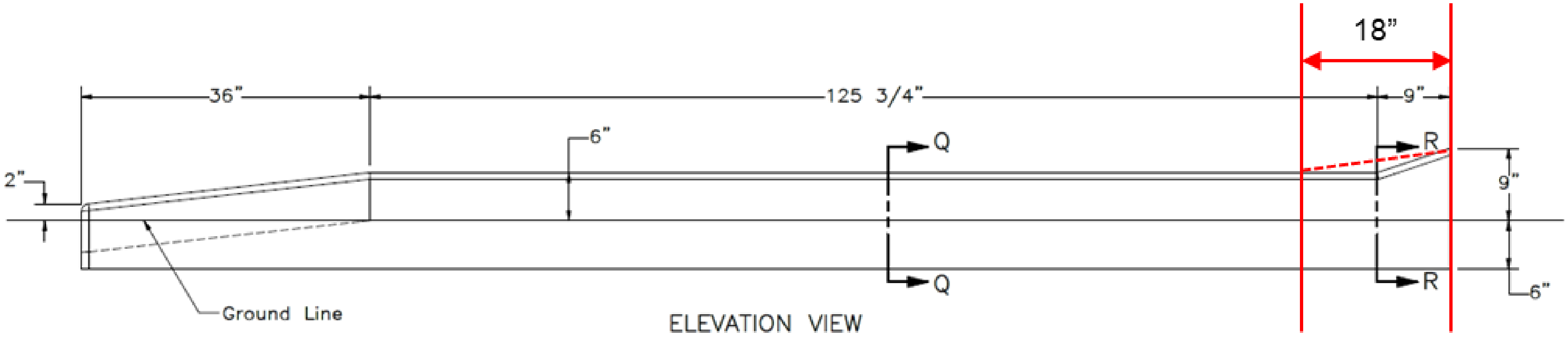



Figure 76. Curb Modification

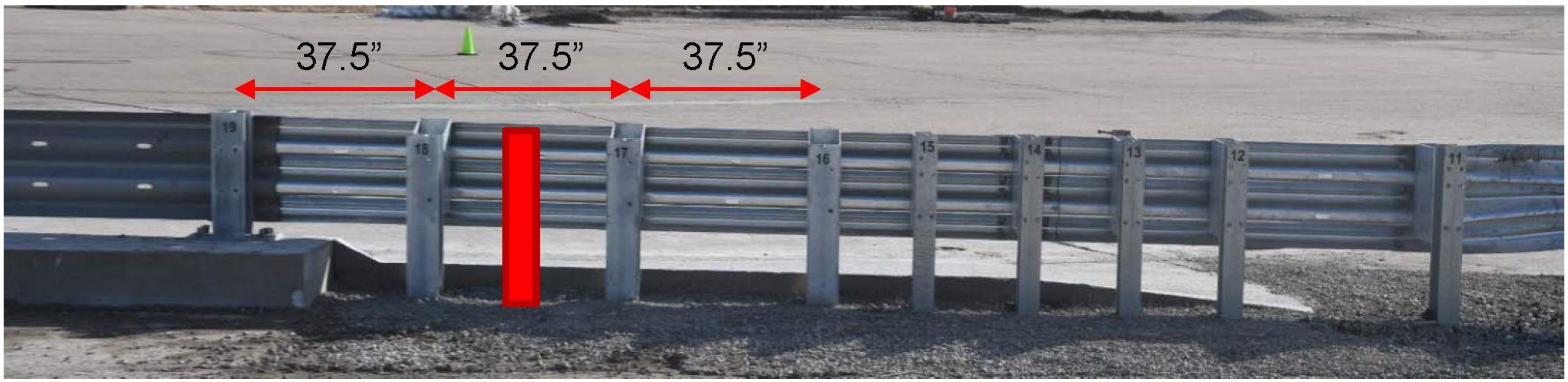



Figure 77. Post Spacing Modification

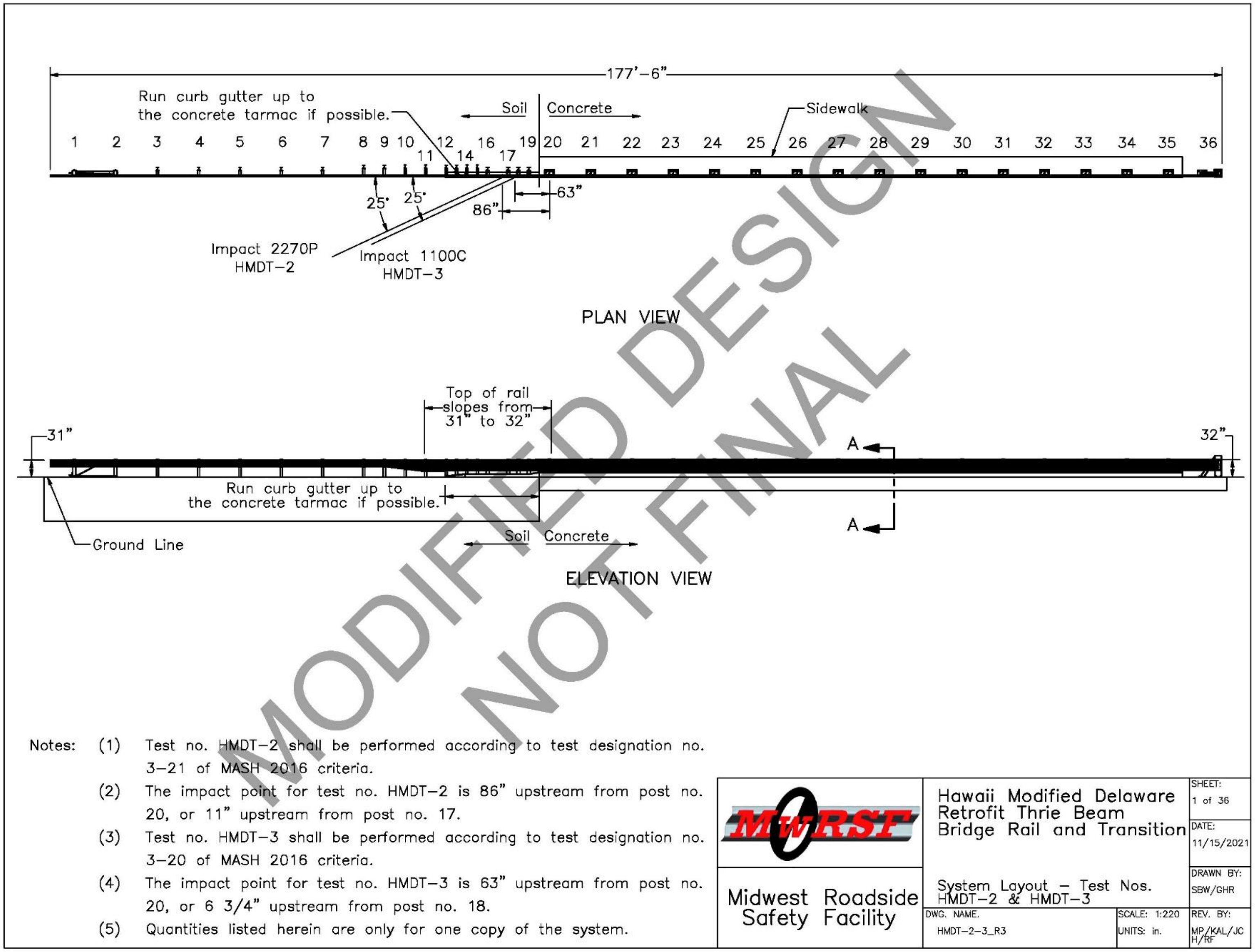



Figure 78. Test Installation Layout, Test Nos. HMDT-2 and HMDT-3

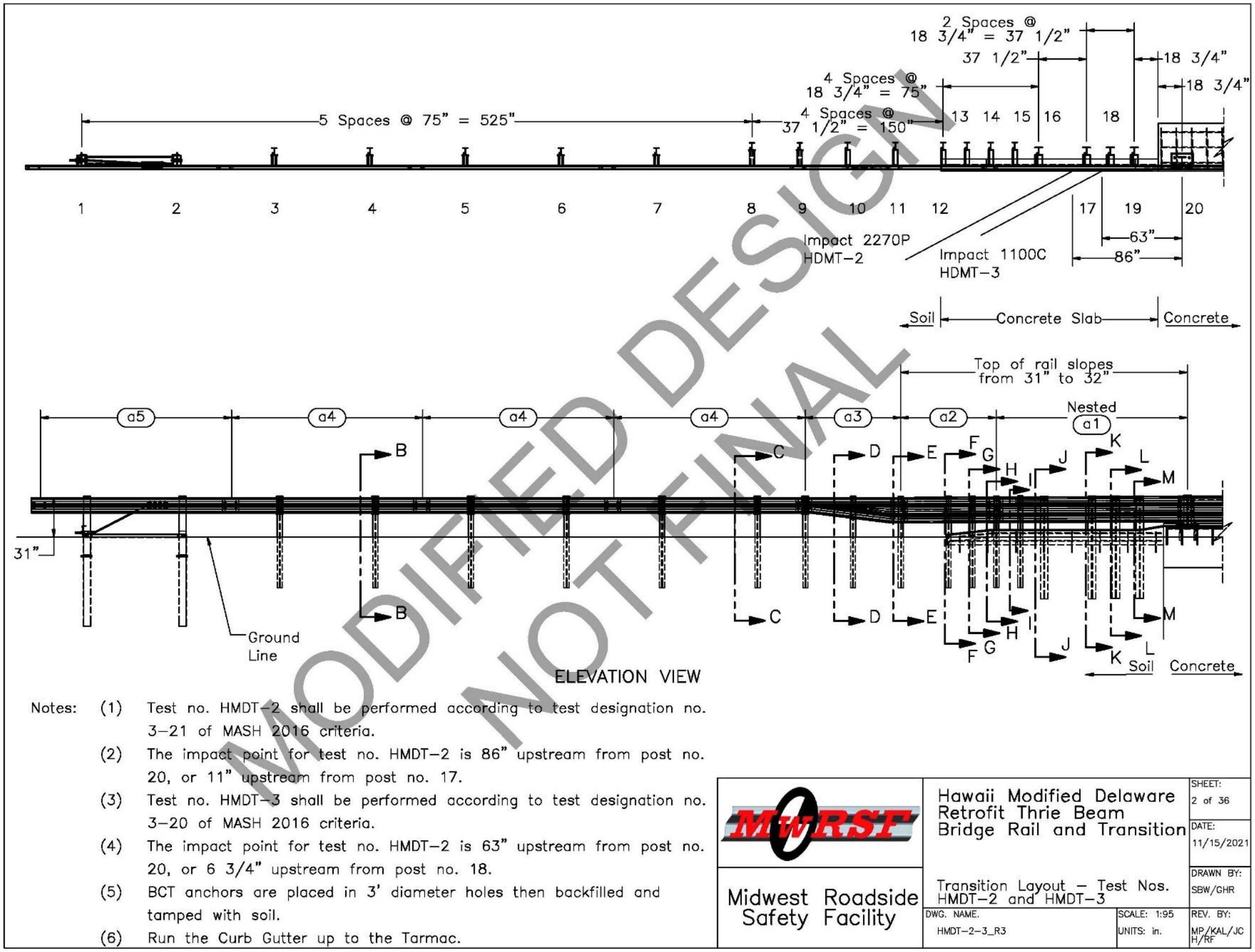



Figure 79. Transition Layout, Test Nos. HMDT-2 and HMDT-3

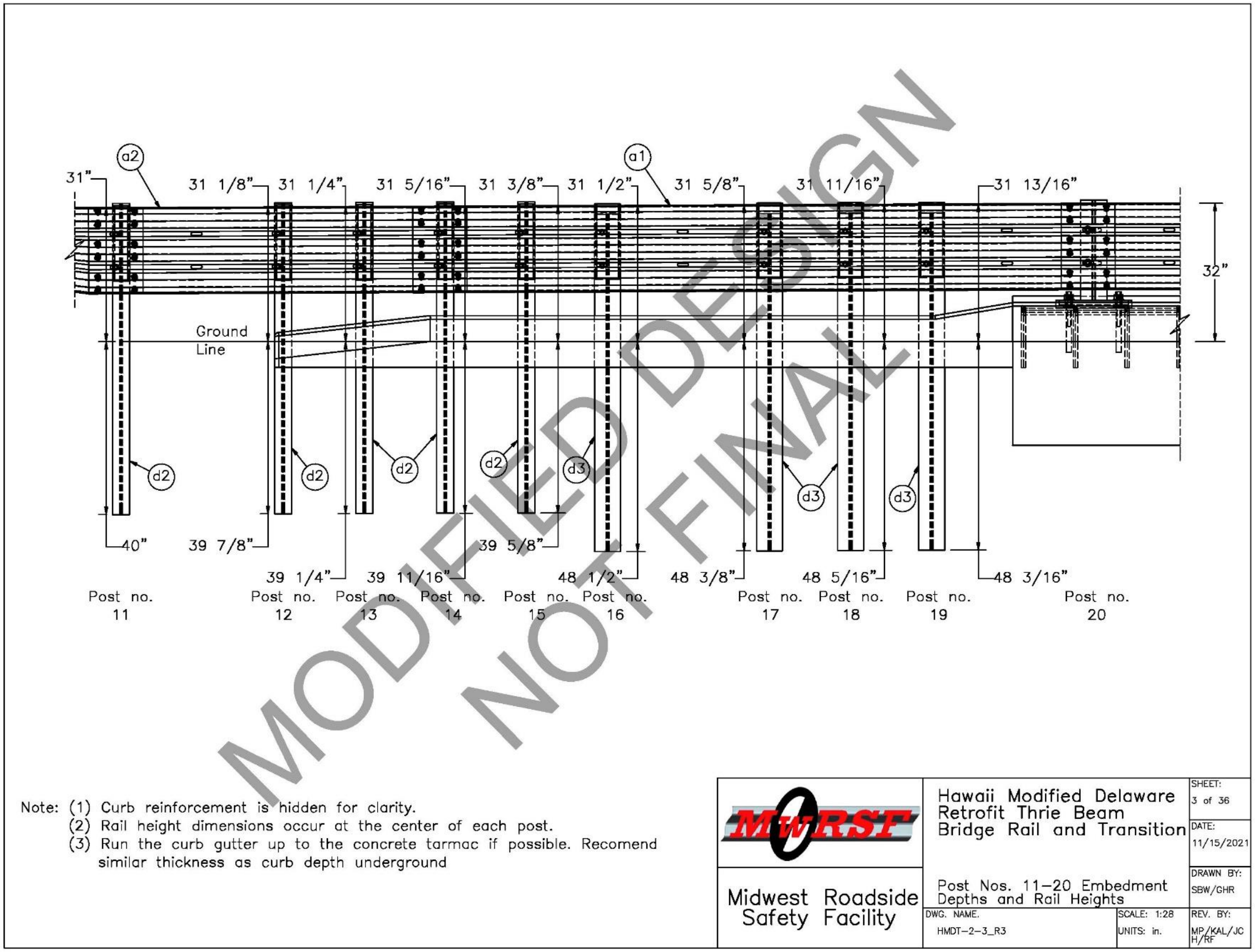



Figure 80. Post Nos. 11 through 20 Embedment Depths and Rail Heights, Test Nos. HMDT-2 and HMDT-3

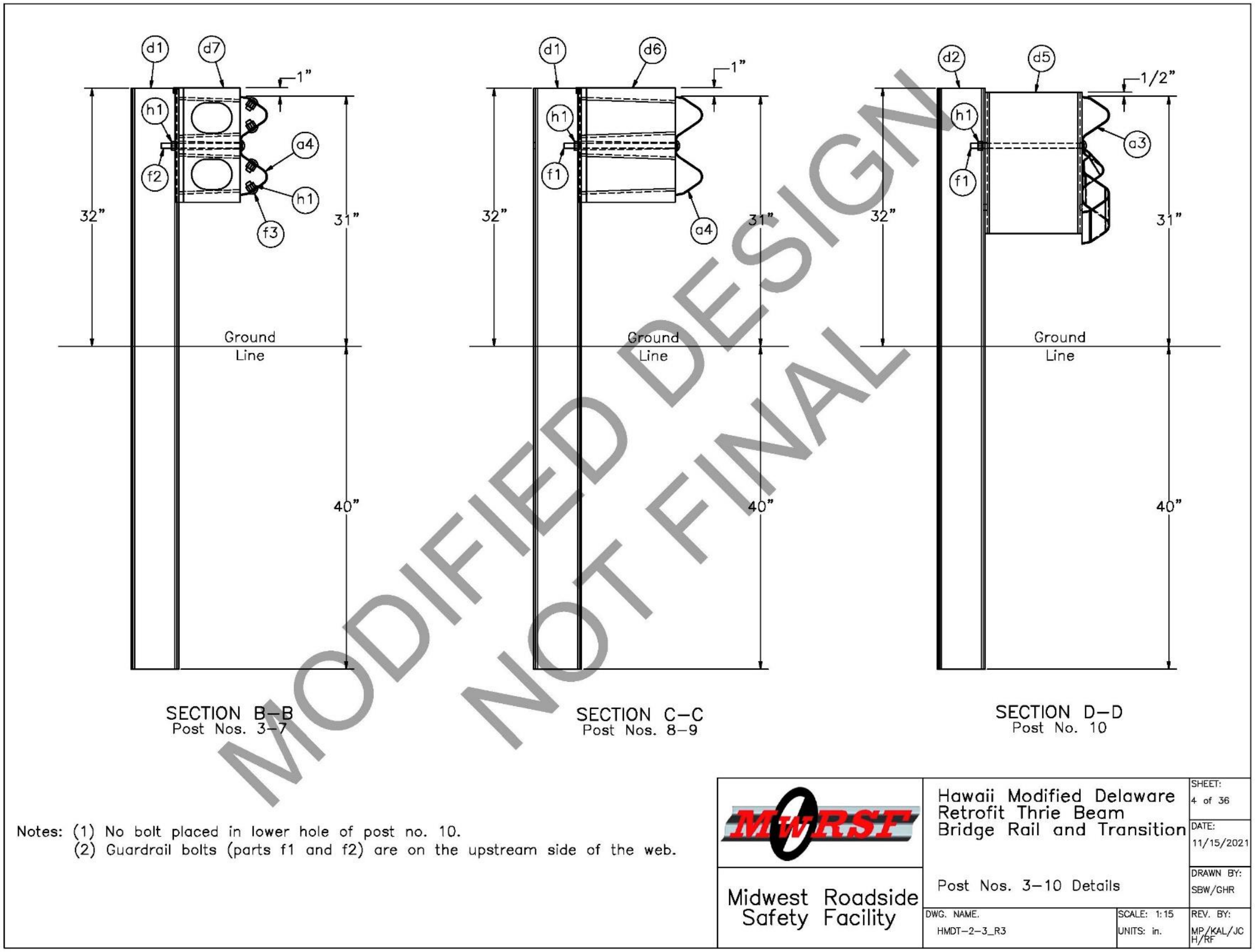



Figure 81. Post Nos. 3 through 10 Details, Test Nos. HMDT-2 and HMDT-3

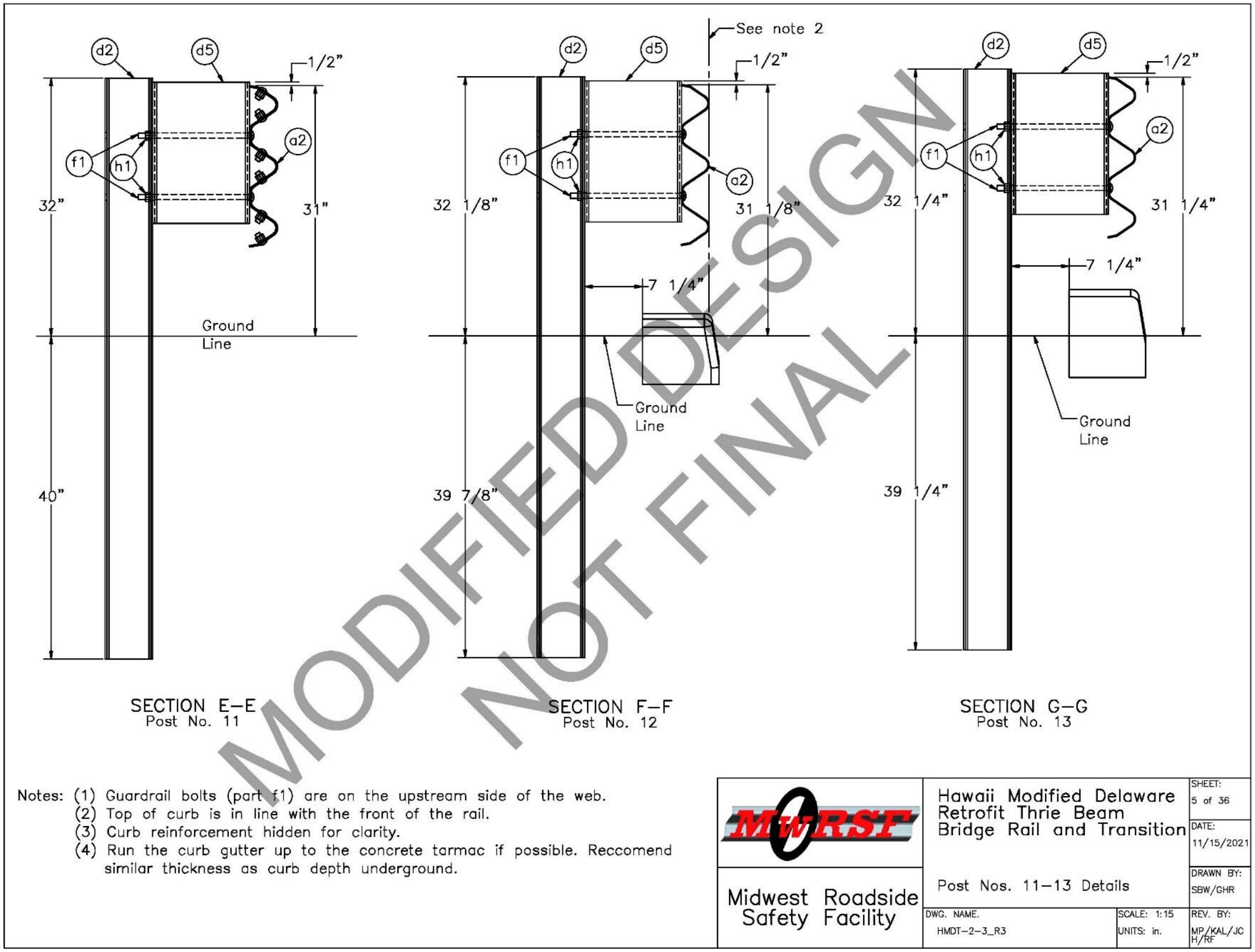



Figure 82. Post Nos. 11 through 13 Details, Test Nos. HMDT-2 and HMDT-3

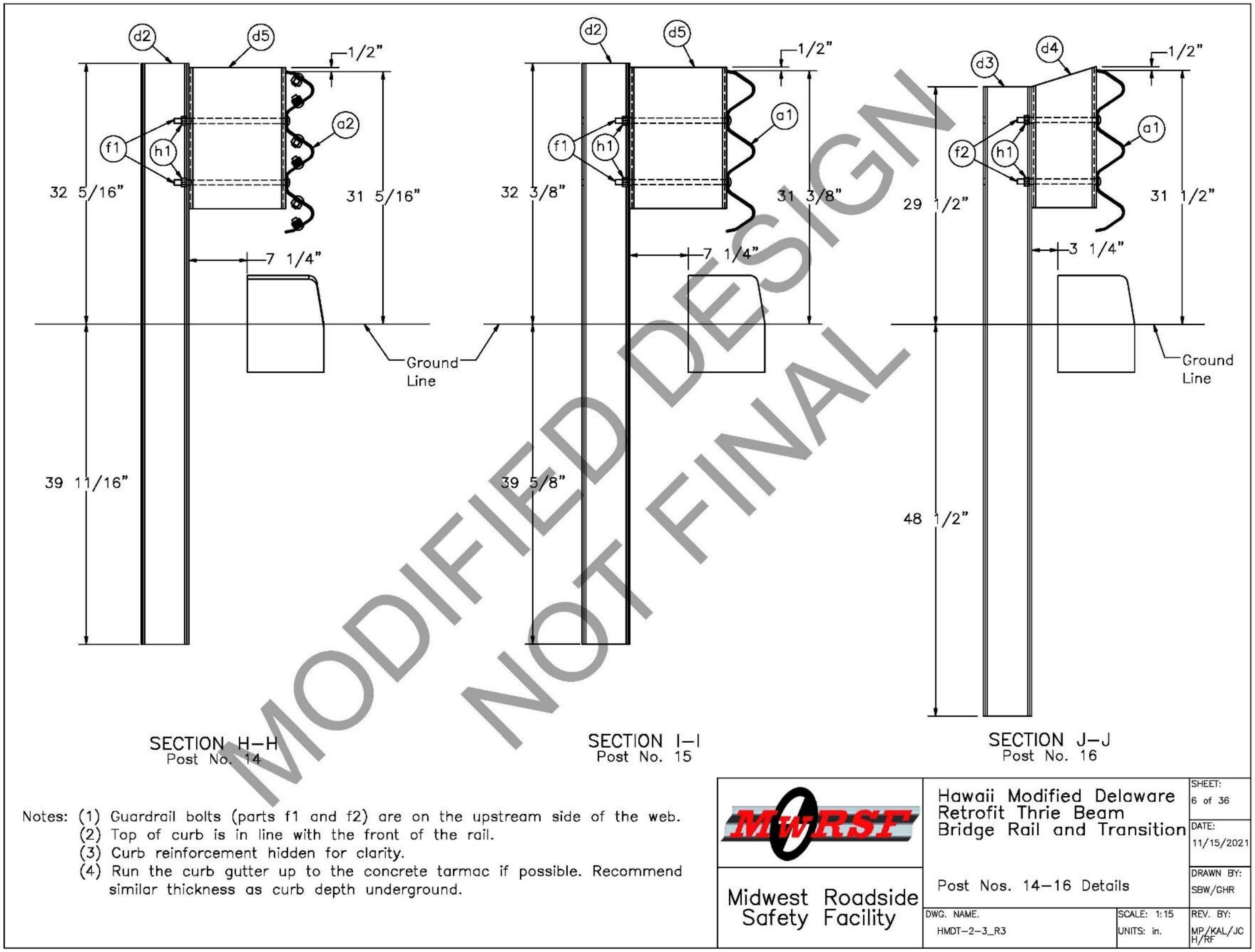



Figure 83. Post Nos. 14 through 16 Details, Test Nos. HMDT-2 and HMDT-3

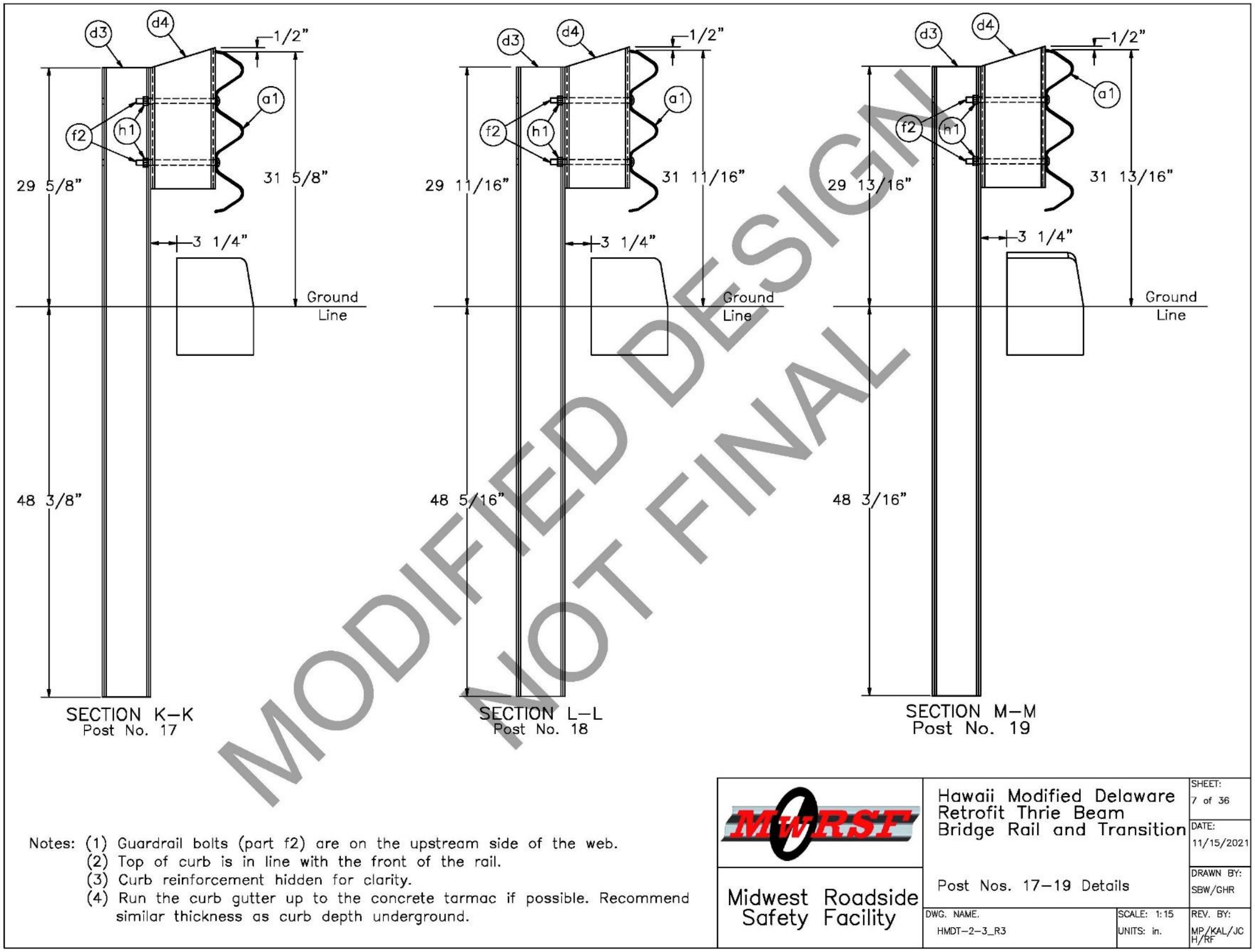



Figure 84. Post Nos. 17 through 19 Details, Test Nos. HMDT-2 and HMDT-3

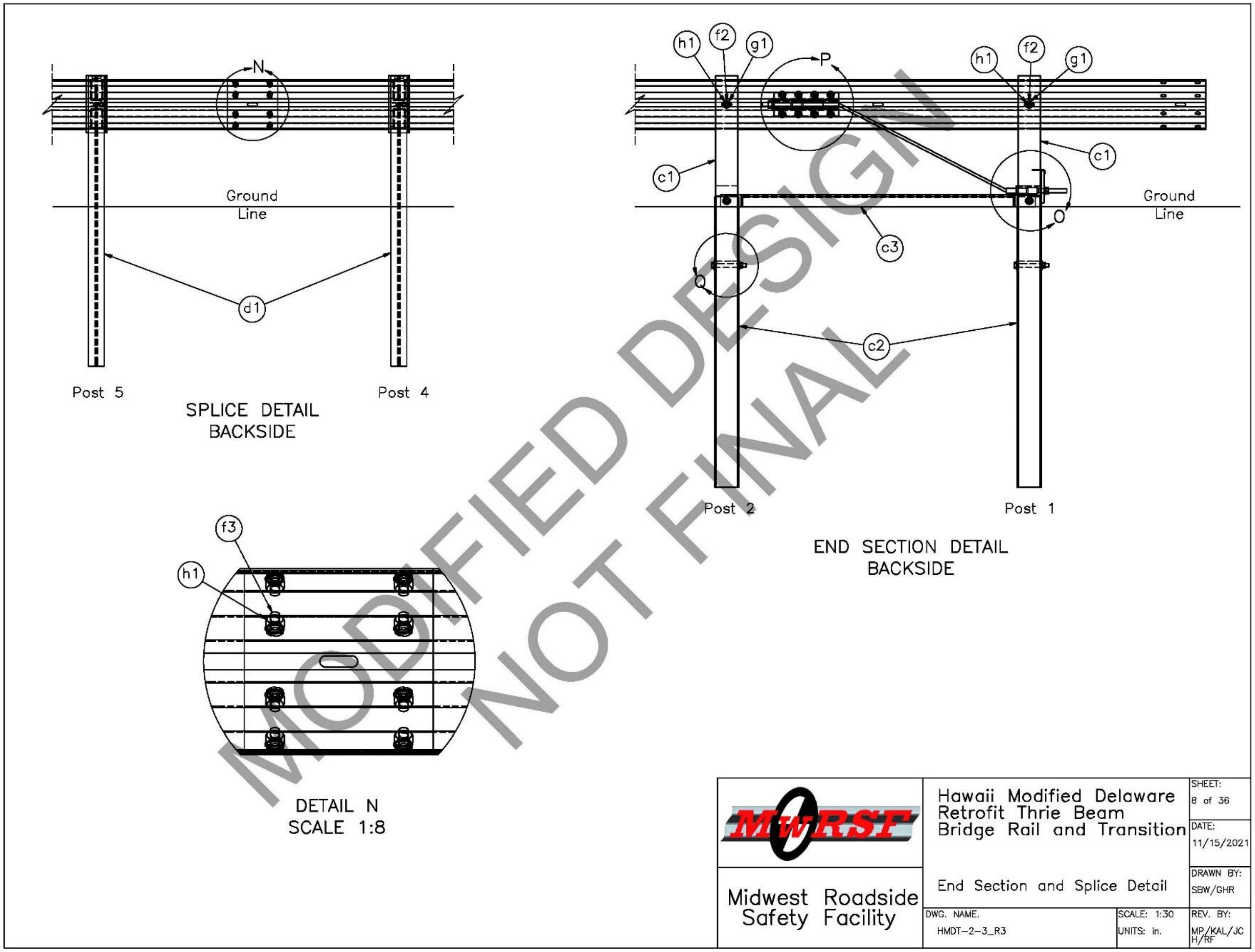



Figure 85. End Section and Splice Detail, Test Nos. HMDT-2 and HMDT-3

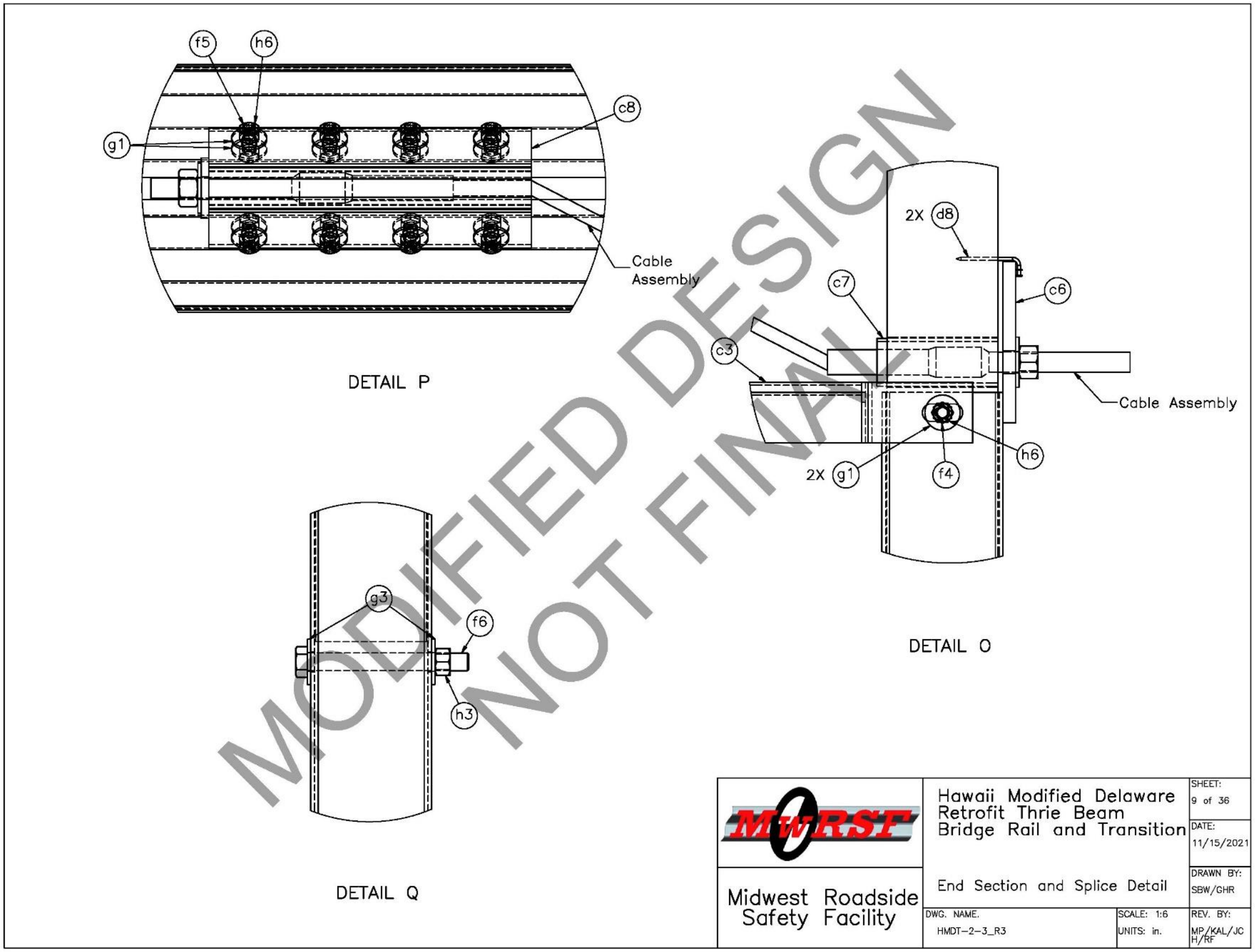



Figure 86. End Selection and Splice Detail, Test Nos. HMDT-2 and HMDT-3

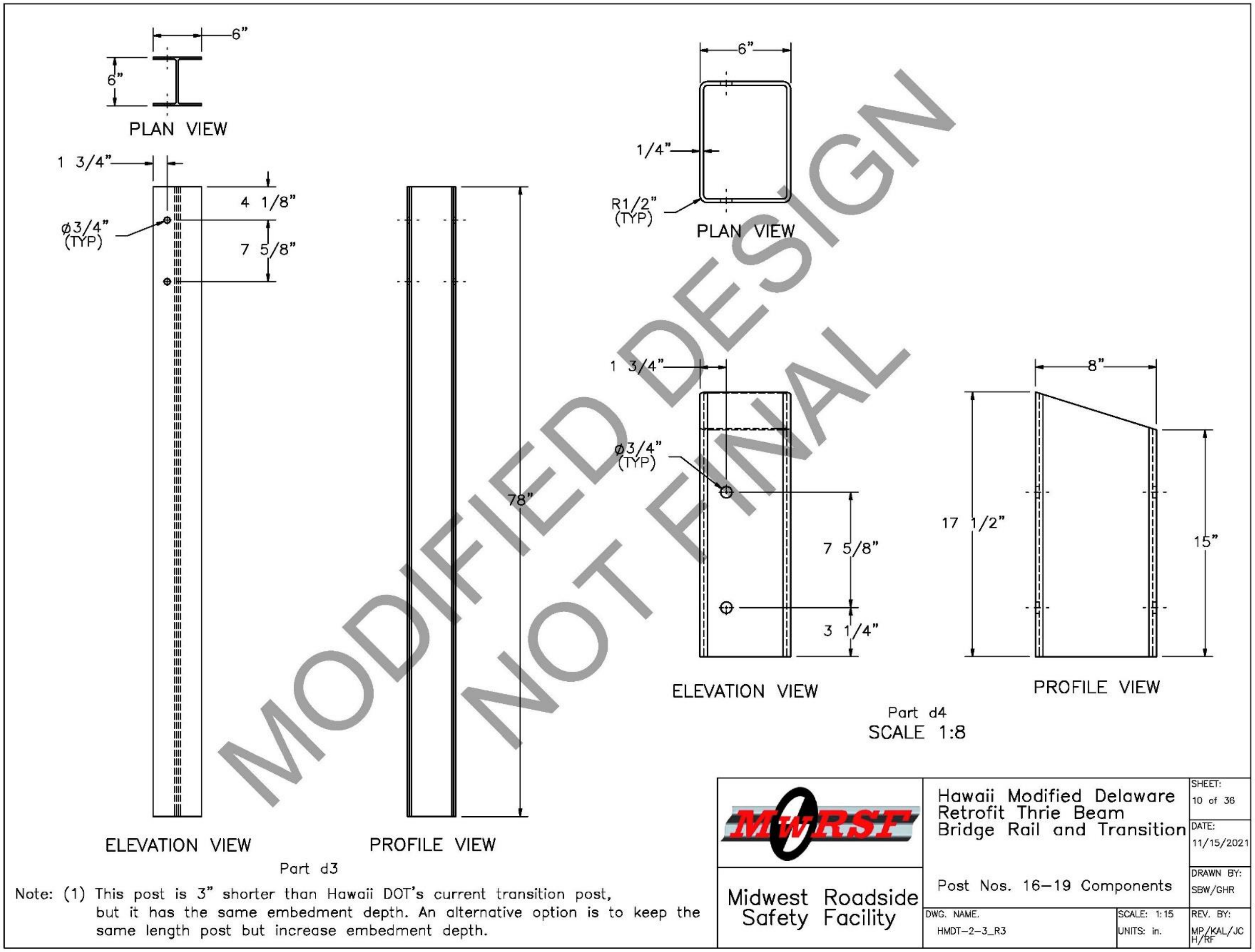



Figure 87. Post Nos. 16 through 19 Components, Test Nos. HMDT-2 and HMDT-3

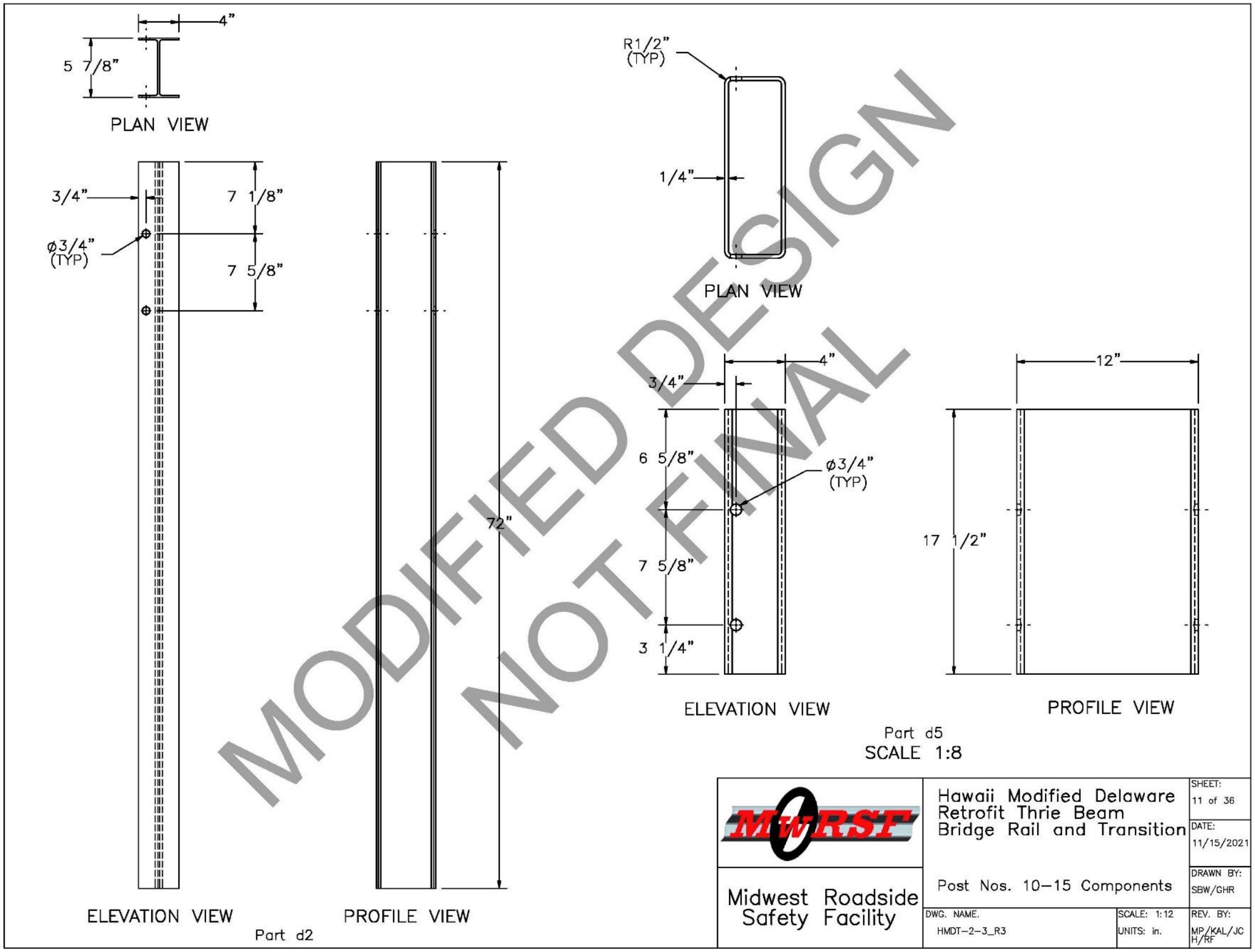



Figure 88. Post Nos. 10 through 15 Components, Test Nos. HMDT-2 and HMDT-3

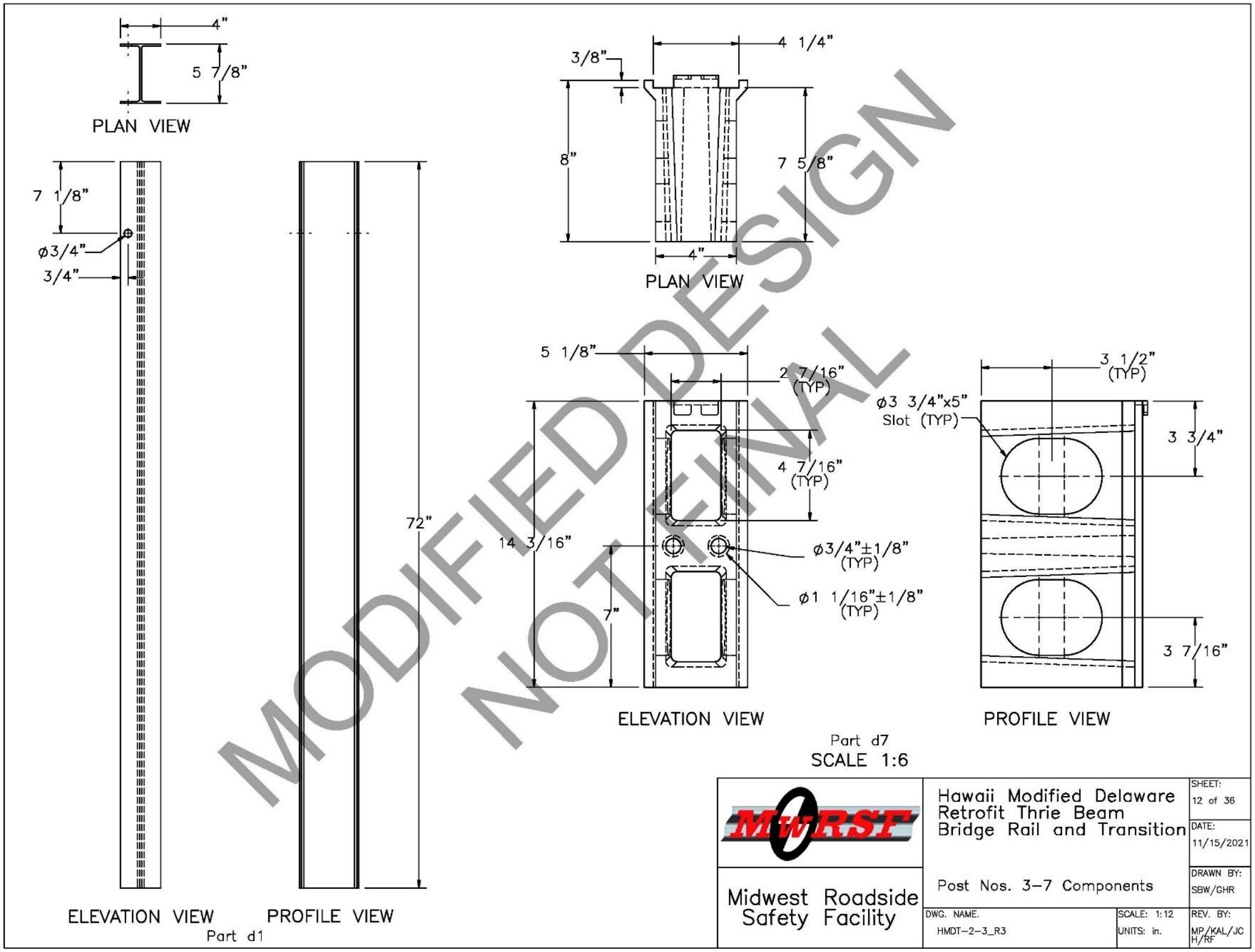



Figure 89. Post Nos. 3 through 7 Components, Test Nos. HMDT-2 and HMDT-3

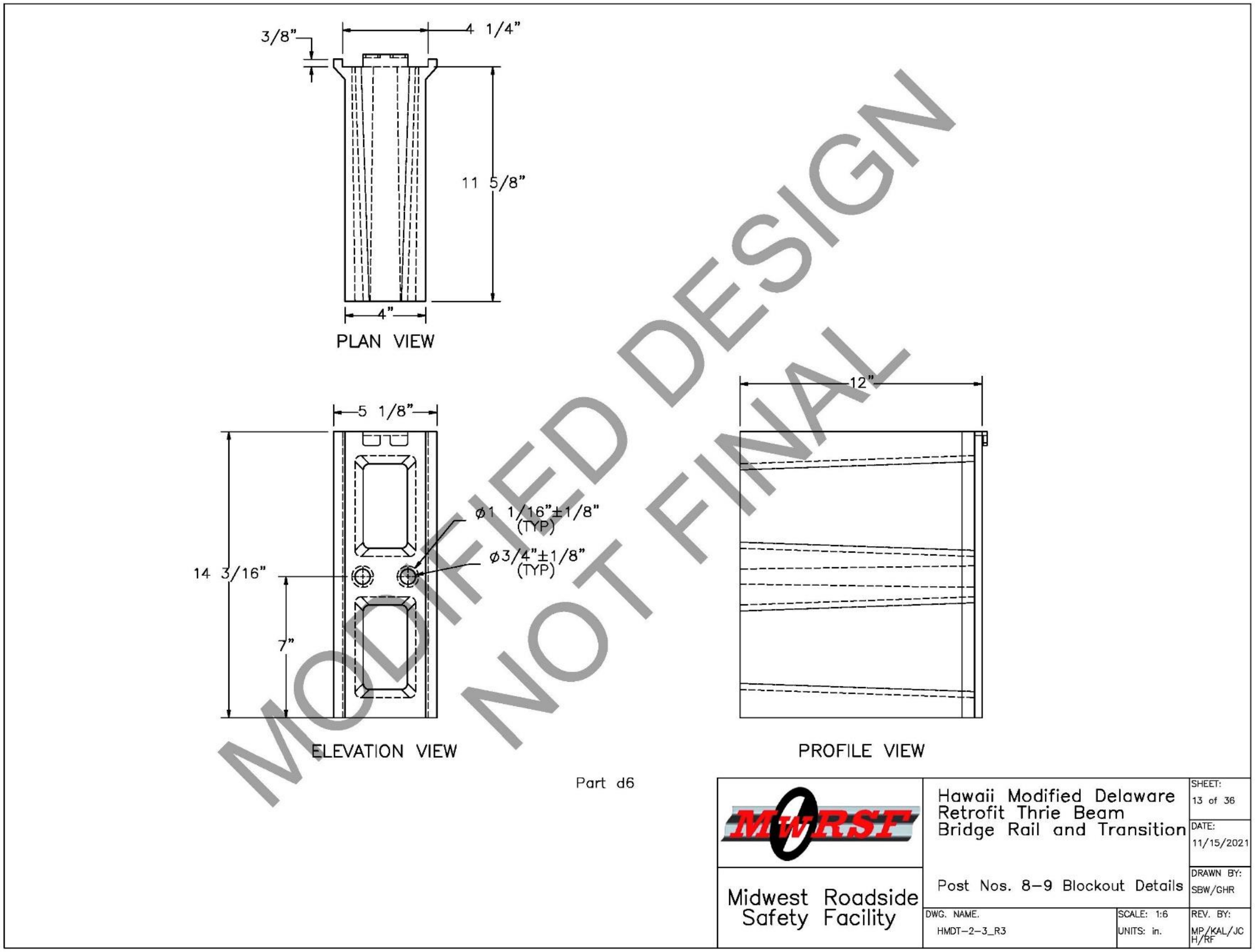



Figure 90. Post Nos. 8 through 9 Blockout Details, Test Nos. HMDT-2 and HMDT-3

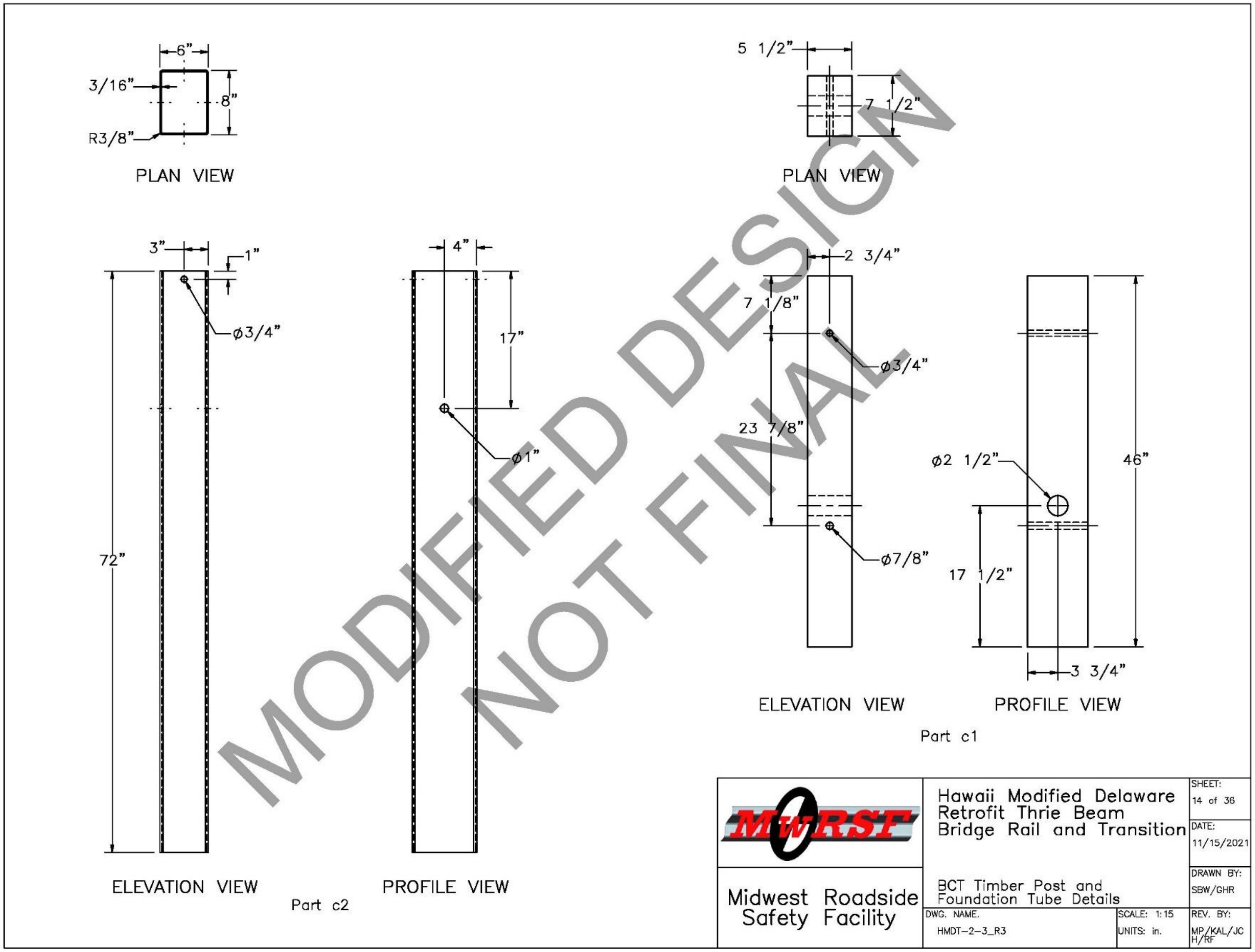



Figure 91. BCT Timber Post and Foundation Tube Details, Test Nos. HMDT-2 and HMDT-3

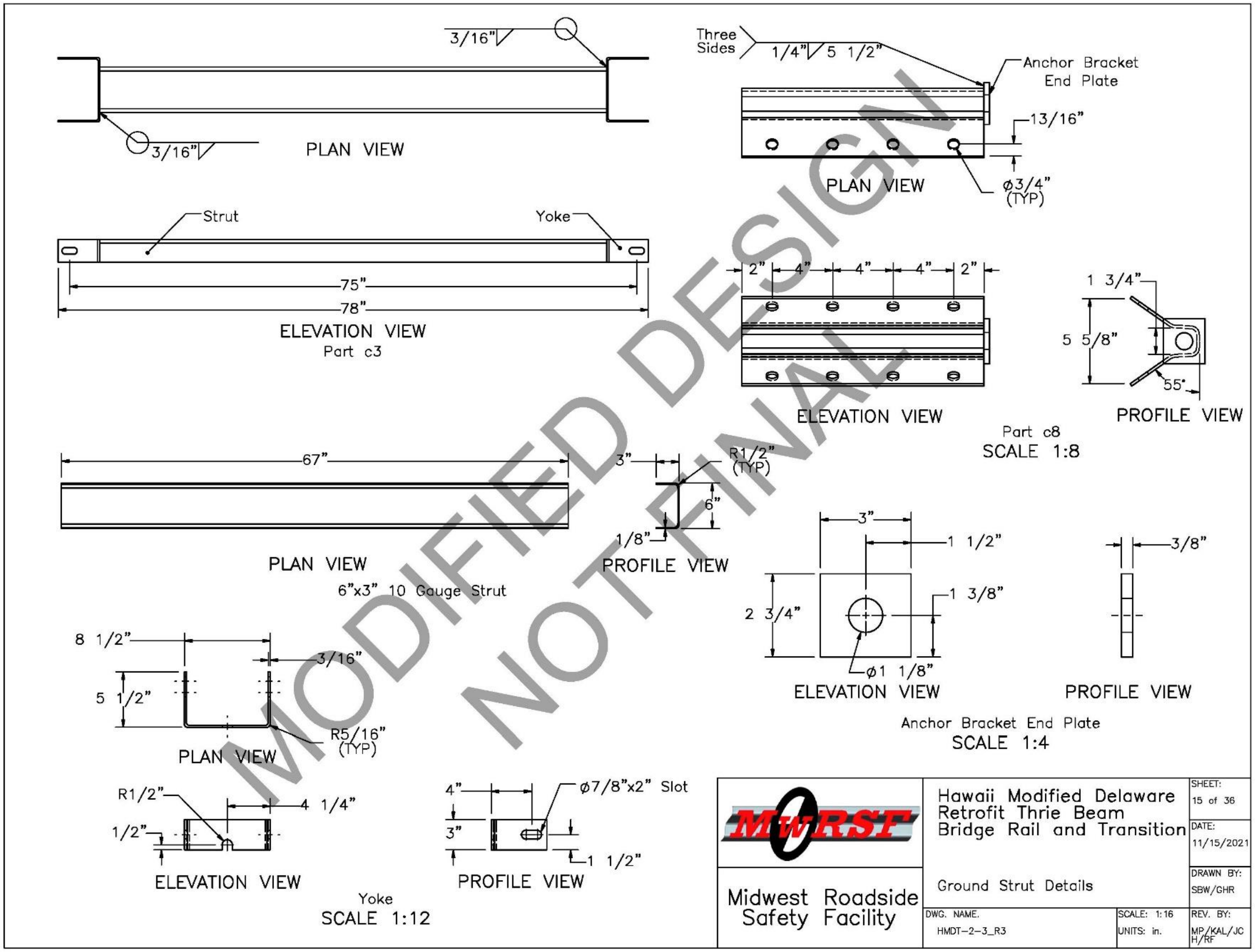
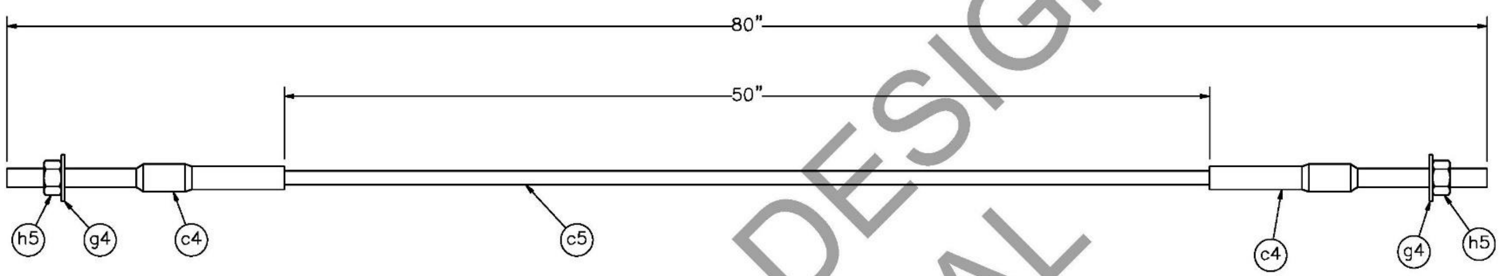



Figure 92. Ground Strut Details, Test Nos. HMDT-2 and HMDT-3






| Item No. | QTY. | Description | Material Specification | Treatment Specification | Hardware Guide |
|---|---|---|---|---|---|
| – | 1 | Cable Assembly | – | – | FCA01 |
| c4 | 2 | BCT Anchor Cable End Swaged Fitting | Fitting – ASTM A576 Gr. 1035<br>Stud – ASTM F568 Class C | Fitting – ASTM A153<br>Stud – ASTM A153 or B695 | – |
| c5 | 1 | 3/4" Dia. 6x19 IWRC IPS Wire Rope | ASTM A741 Type 2 | Class A Coating | – |
| h5 | 2 | 1"–8 UNC Heavy Hex Nut | ASTM A563DH or equivalent | ASTM A153 or B695 Class 55 or F2329 | FNX24b |
| g4 | 2 | 1" Dia. Plain USS Washer | ASTM F844 | ASTM A123 or A153 or F2329 | FWC24a |

MwRSF

Midwest Roadside Safety Facility

Hawaii Modified Delaware Retrofit Thrie Beam Bridge Rail and Transition

BCT Anchor Cable

SHEET: 16 of 36
DATE: 11/15/2021
DRAWN BY: SBW/GHR
DWG. NAME. HMDT–2–3_R3
SCALE: 1:8
UNITS: in.
REV. BY: MP/KAL/JCH/RF

Figure 93. BCT Anchor Cable, Test Nos. HMDT-2 and HMDT-3

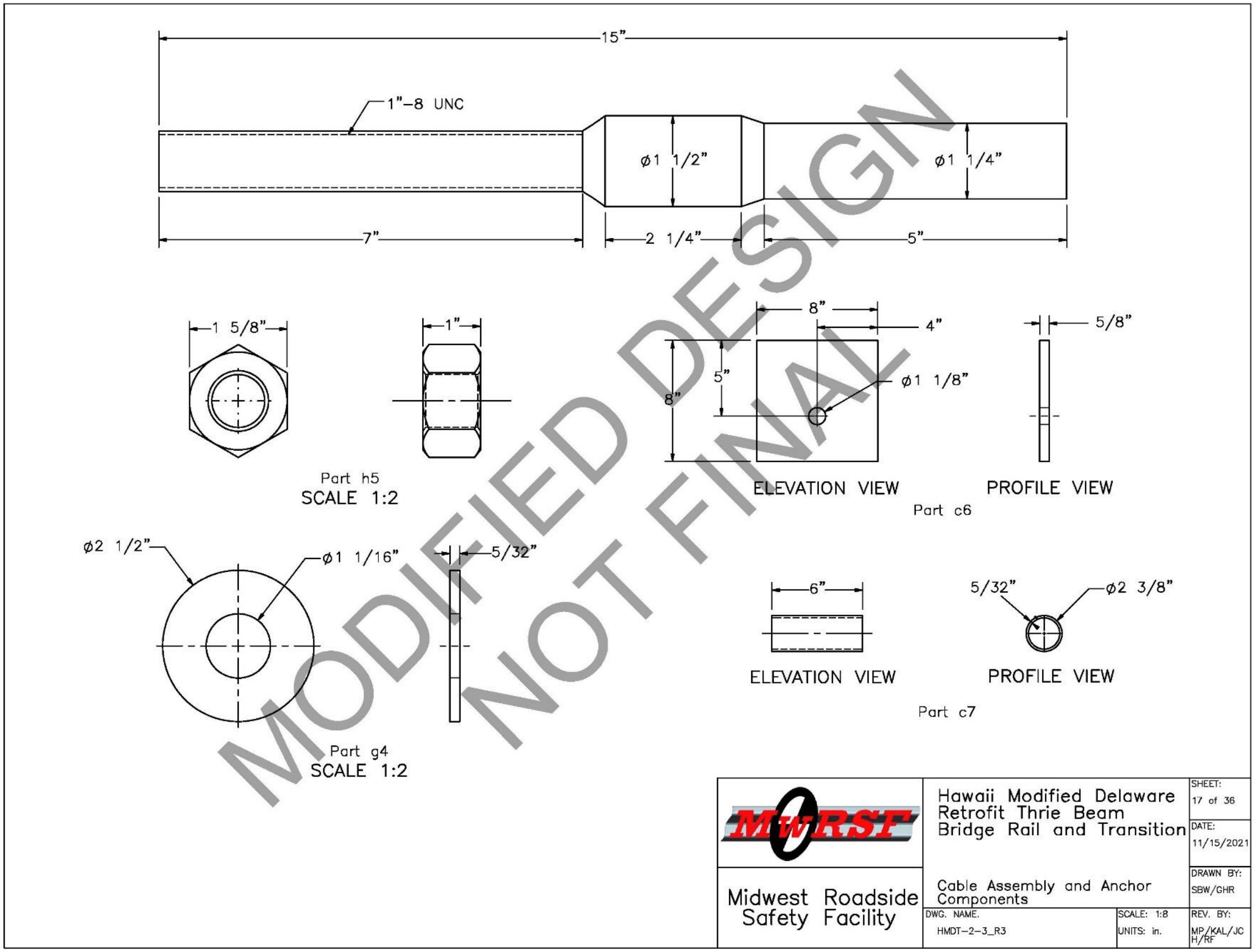



Figure 94. Cable Assembly and Anchor Components, Test Nos. HMDT-2 and HMDT-3

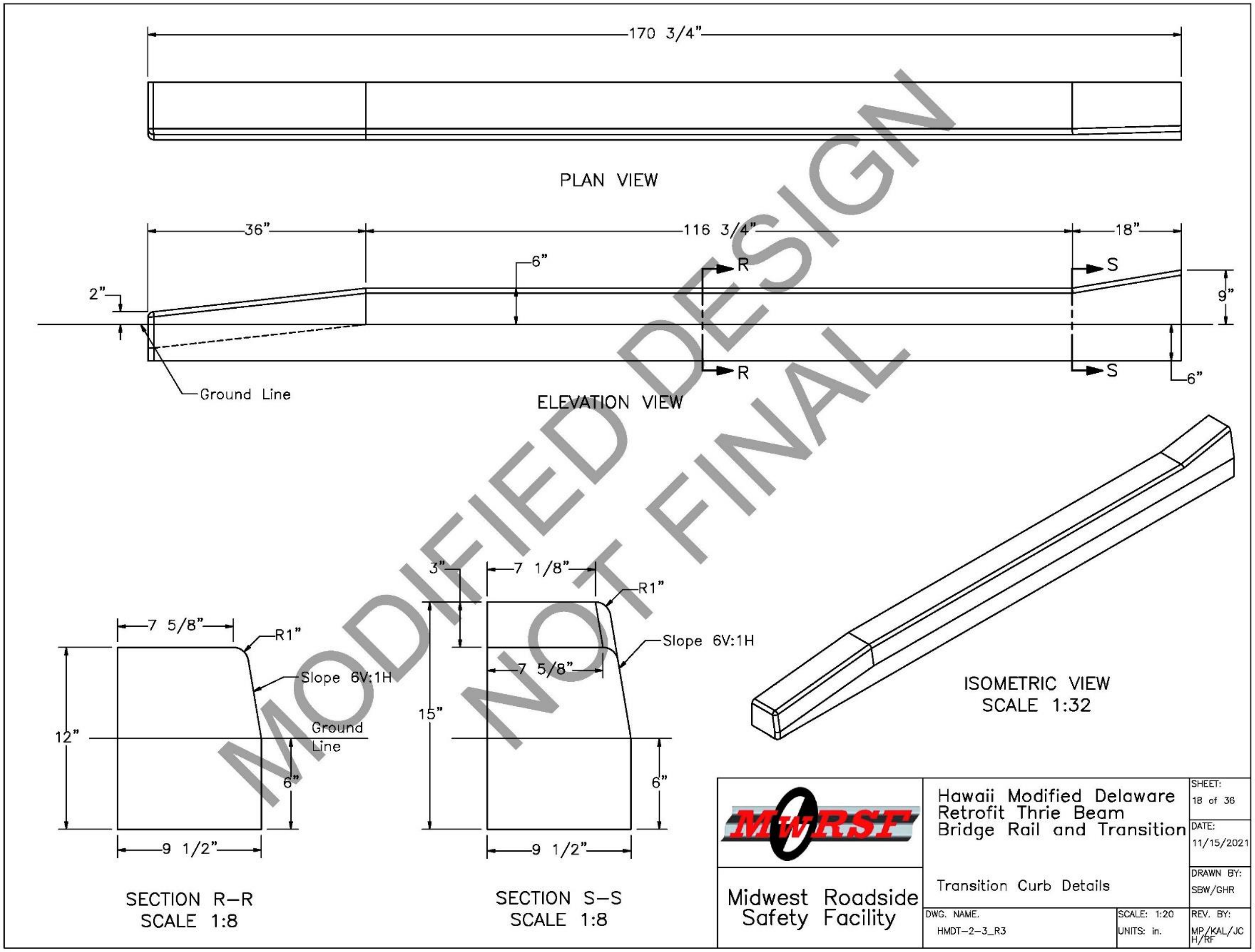



Figure 95. Transition Curb Details, Test Nos. HMDT-2 and HMDT-3

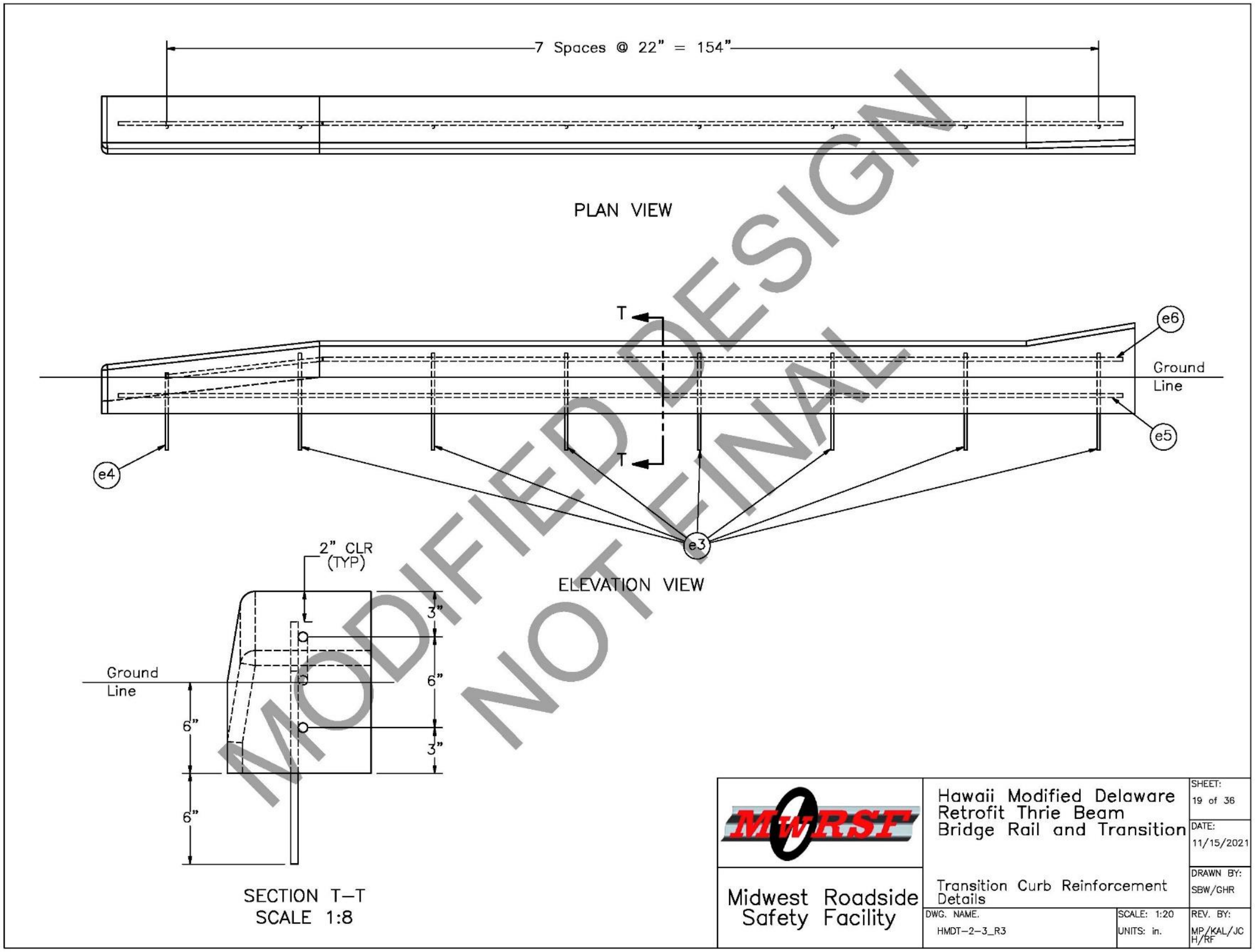
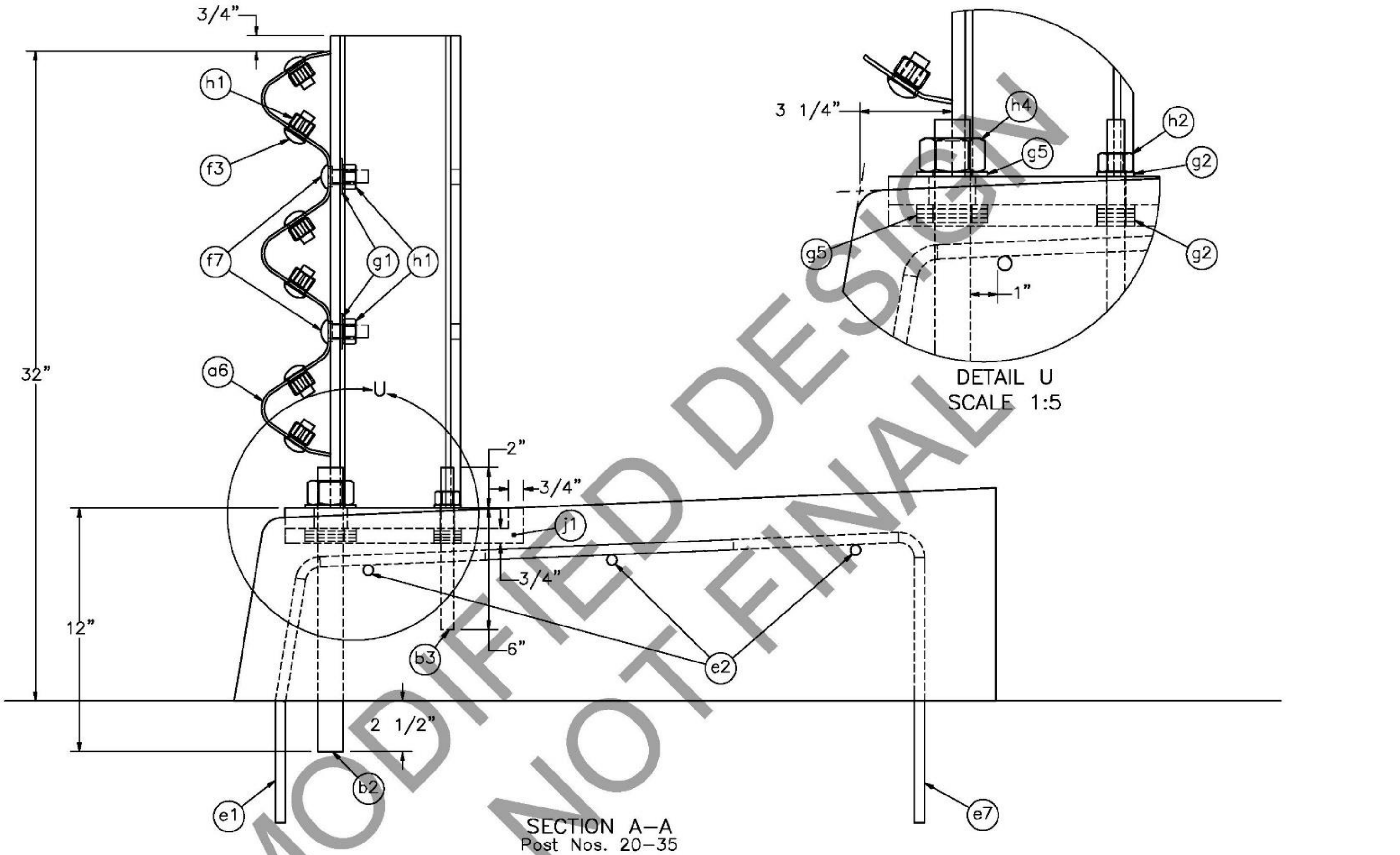



Figure 96. Transition Curb Reinforcement Details, Test Nos. HMDT-2 and HMDT-3




Notes:
(1) Base plate (part b1) should be counter sunk into the sidewalk, slightly over sized, then backfilled with epoxy grout (part k2).
(2) Epoxy grout used to backfill post cavites should be in compliance with ASTM C881 Type IV, Grade I, Class C.
(3) Add washers (parts g2 and g5) to level base plates.
(4) Anchor rods (parts b2 and b3) should be epoxied into the concrete sidewalk and concrete tarmac.
(5) Rebar (parts e1 and e7) should be epoxied into concrete tarmac for a minimum depth of 6".
(6) Anchors and rebar should be epoxied with Hilti HIT RE-500 V3 (part k1) or equivalent, in compliance with Class C, C881.

| MwRSF | Hawaii Modified Delaware Retrofit Thrie Beam Bridge Rail and Transition | | SHEET: 20 of 36 |
|---|---|---|---|
| | | | DATE: 11/15/2021 |
| Midwest Roadside Safety Facility | Bridge Rail Post Details | | DRAWN BY: SBW/GHR |
| | DWG. NAME. HMDT-2-3_R3 | SCALE: 1:7 UNITS: in. | REV. BY: MP/KAL/JCH/RF |

Figure 97. Bridge Rail Post Details, Test Nos. HMDT-2 and HMDT-3

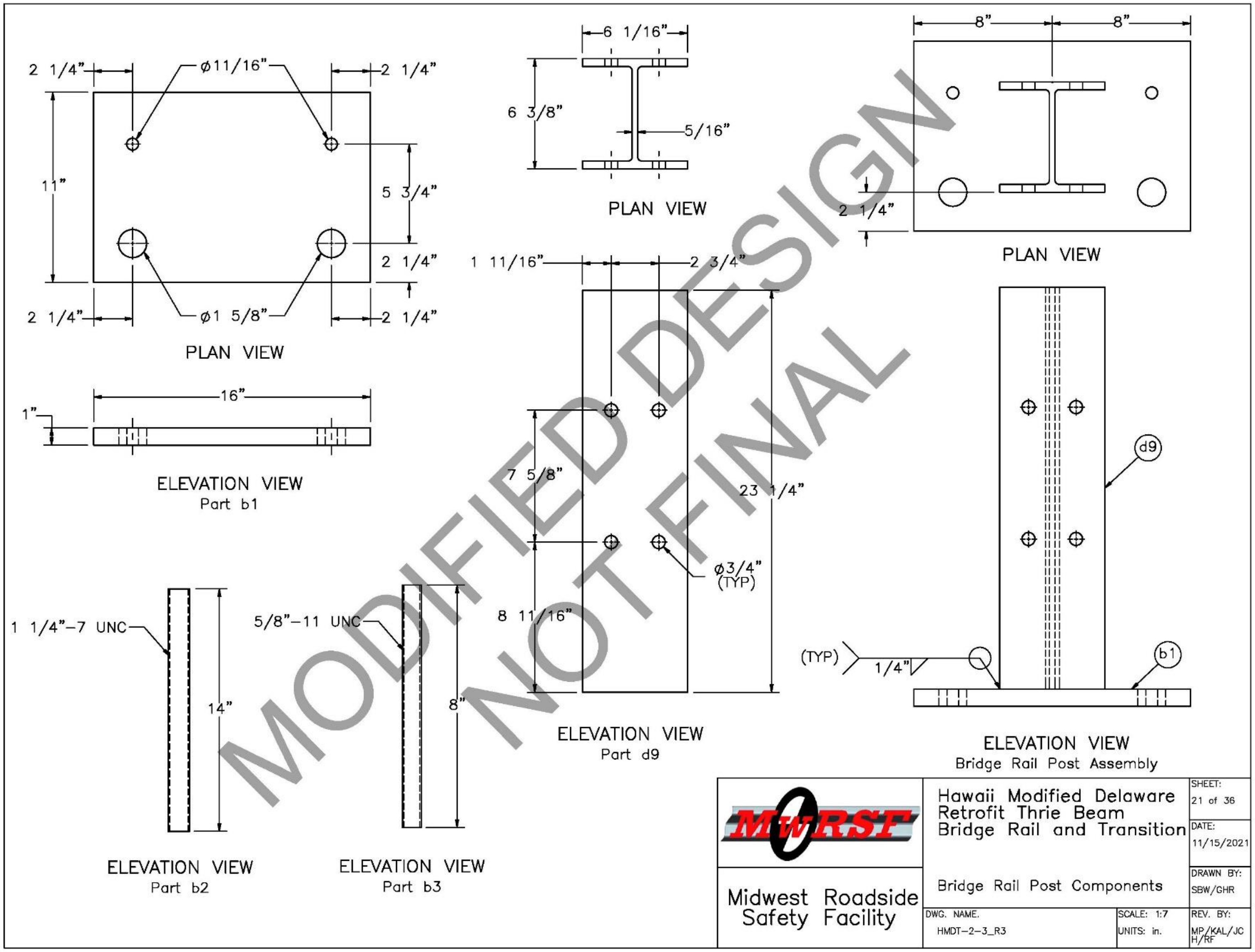



Figure 98. Bridge Rail Post Components, Test Nos. HMDT-2 and HMDT-3

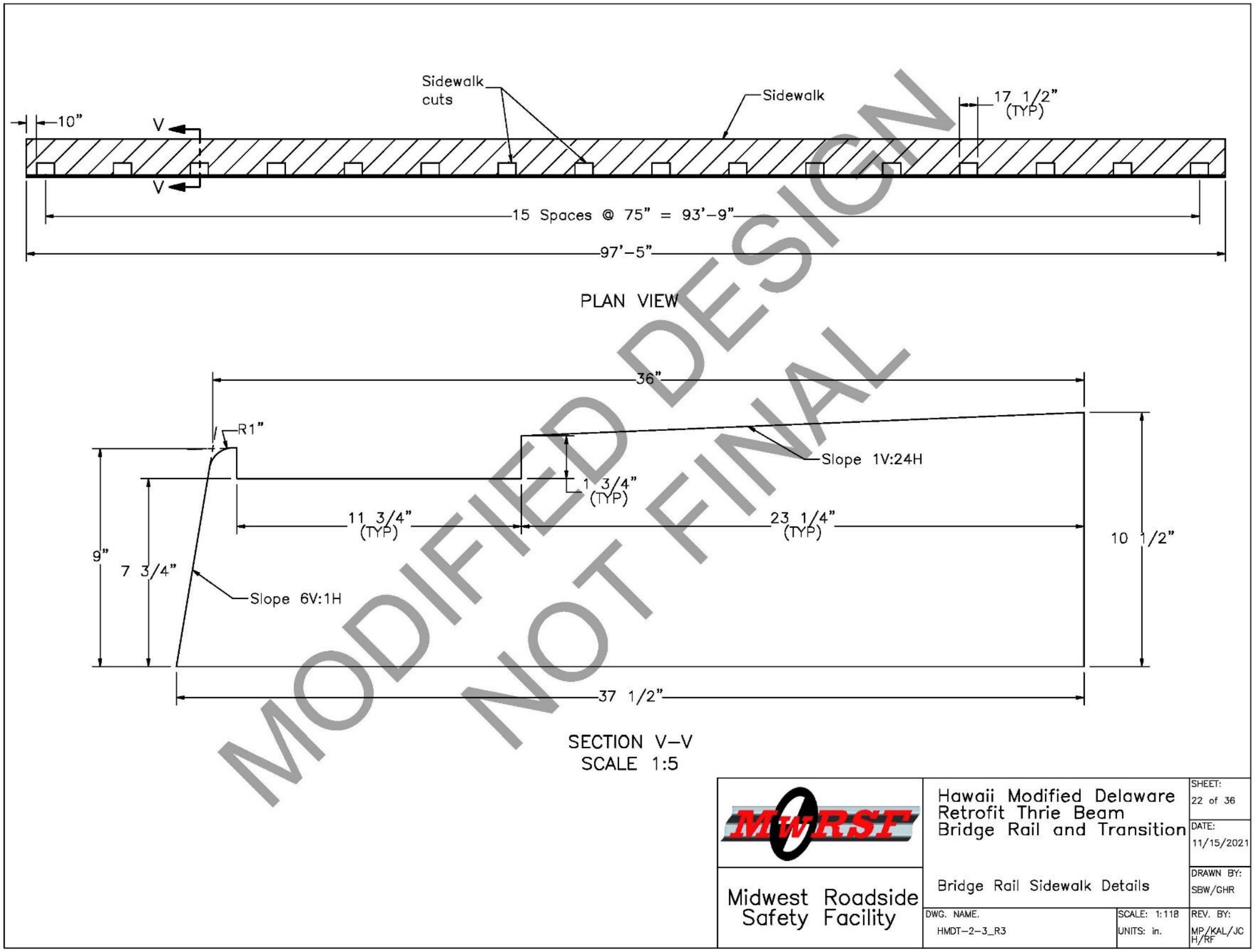



Figure 99. Bridge Rail Sidewalk Details, Test Nos. HMDT-2 and HMDT-3

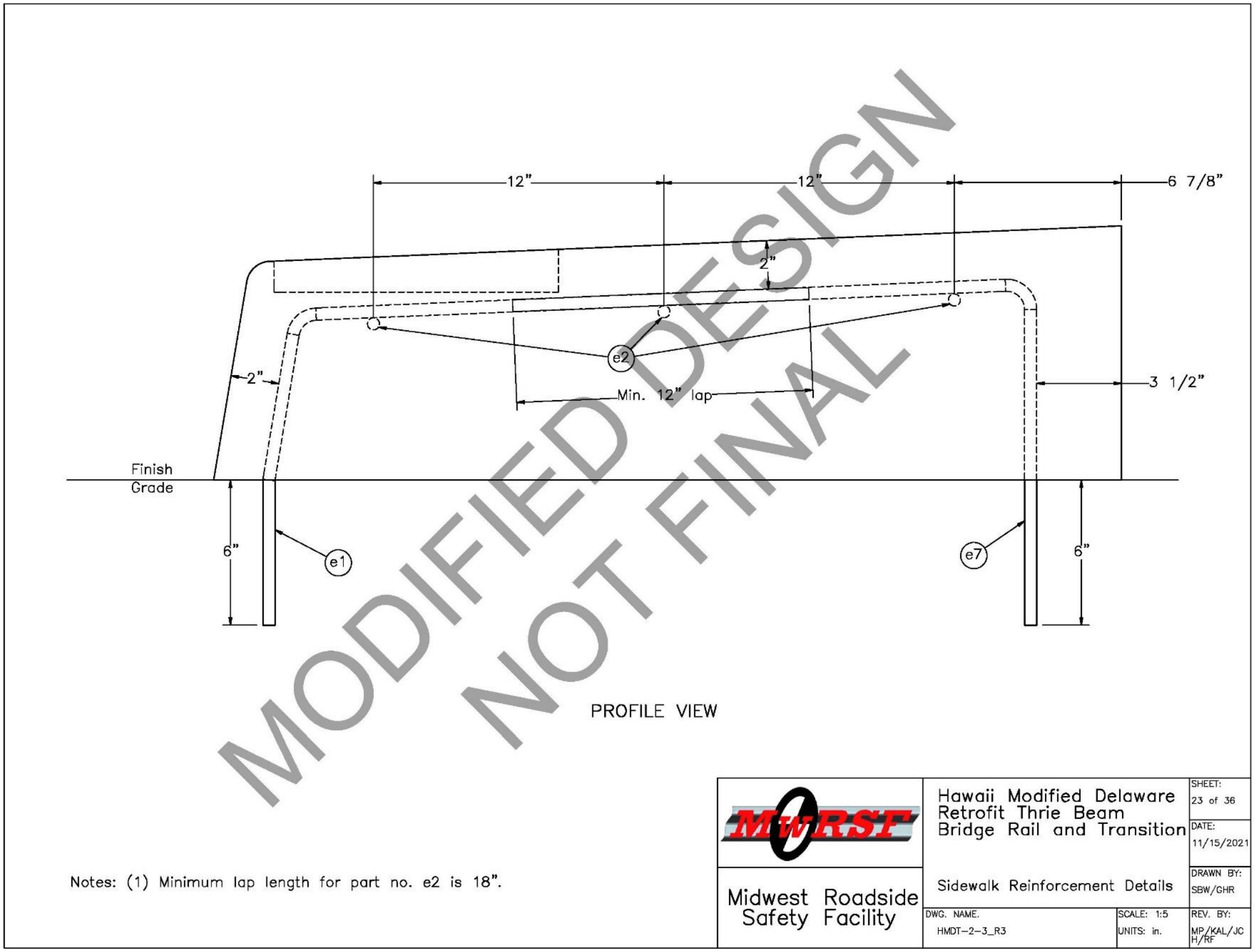



Figure 100. Sidewalk Reinforcement Details, Test Nos. HMDT-2 and HMDT-3

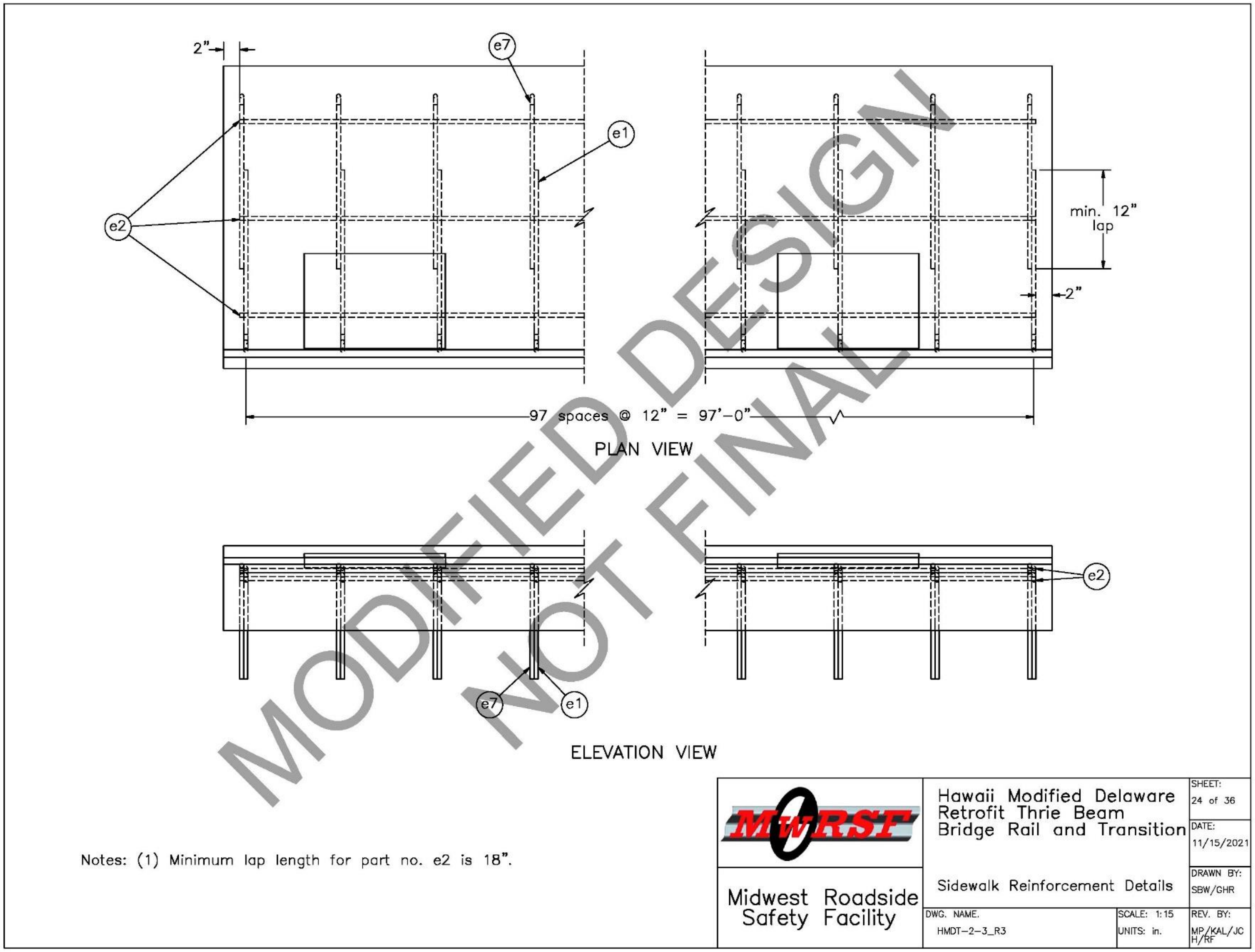
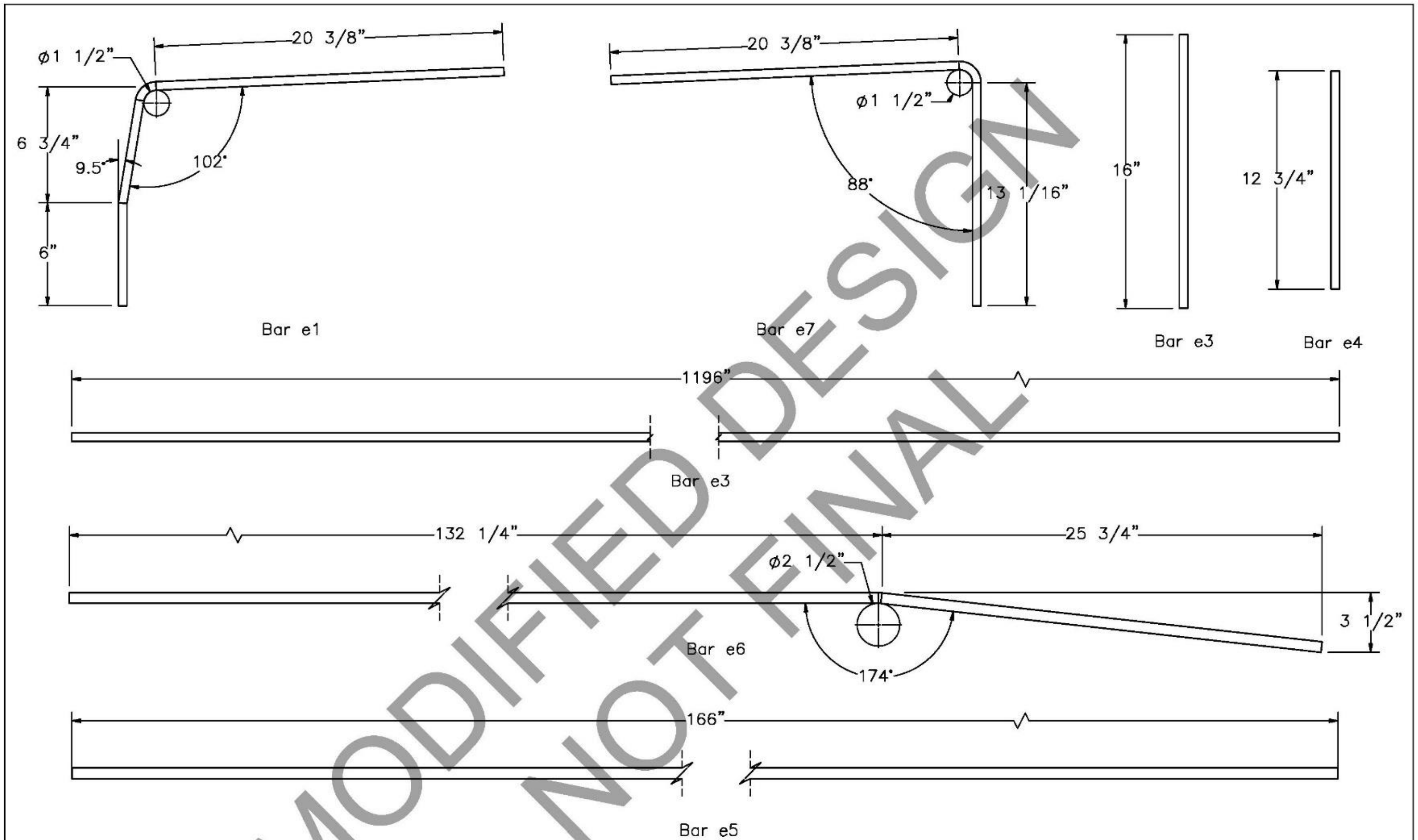



Figure 101. Sidewalk Reinforcement Details, Test Nos. HMDT-2 and HMDT-3




Notes: (1) Minimum lap length for part no. e2 is 18".

| Part No. | Bar No. | Qty. | Unbent Length | Material Specification |
|---|---|---|---|---|
| e1 | #4 | 98 | 33 7/8" | ASTM A615 Gr. 60 |
| e2 | #4 | 3 | 1165" | ASTM A615 Gr. 60 |
| e3 | #4 | 7 | 16" | ASTM A615 Gr. 60 |
| e4 | #4 | 1 | 12 3/4" | ASTM A615 Gr. 60 |
| e5 | #5 | 1 | 166" | ASTM A615 Gr. 60 |
| e6 | #5 | 1 | 158 1/4" | ASTM A615 Gr. 60 |
| e7 | #4 | 98 | 35" | ASTM A615 Gr. 60 |

MwRSF

Midwest Roadside Safety Facility

Hawaii Modified Delaware Retrofit Thrie Beam Bridge Rail and Transition

Curb Reinforcement Details

SHEET: 25 of 36

DATE: 11/15/2021

DRAWN BY: SBW/GHR

DWG. NAME. HMDT-2-3_R3

SCALE: 1:8

UNITS: in.

REV. BY: MP/KAL/JCH/RF

Figure 102. Curb Reinforcement Details, Test Nos. HMDT-2 and HMDT-3

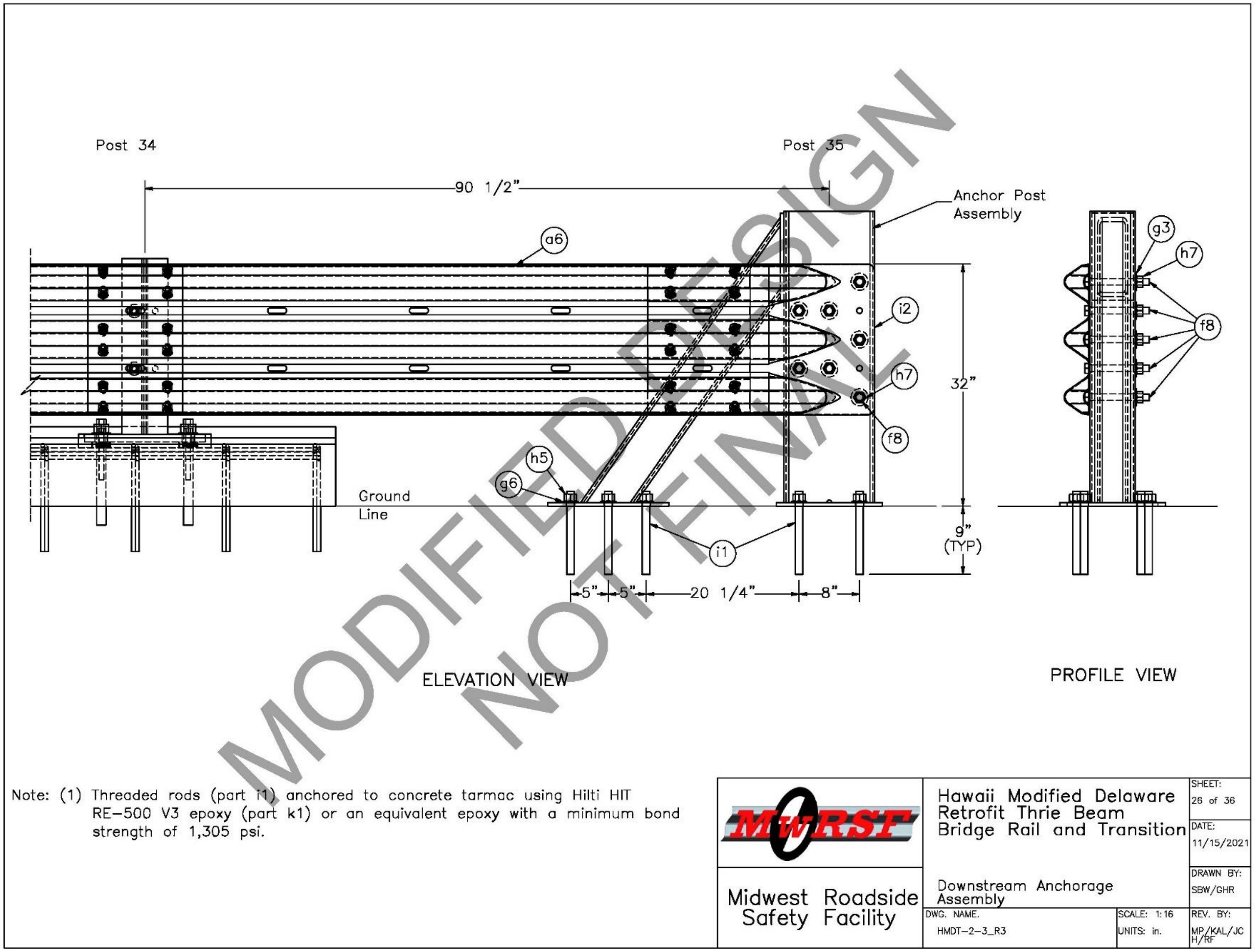



Figure 103. Downstream Anchorage Assembly, Test Nos. HMDT-2 and HMDT-3

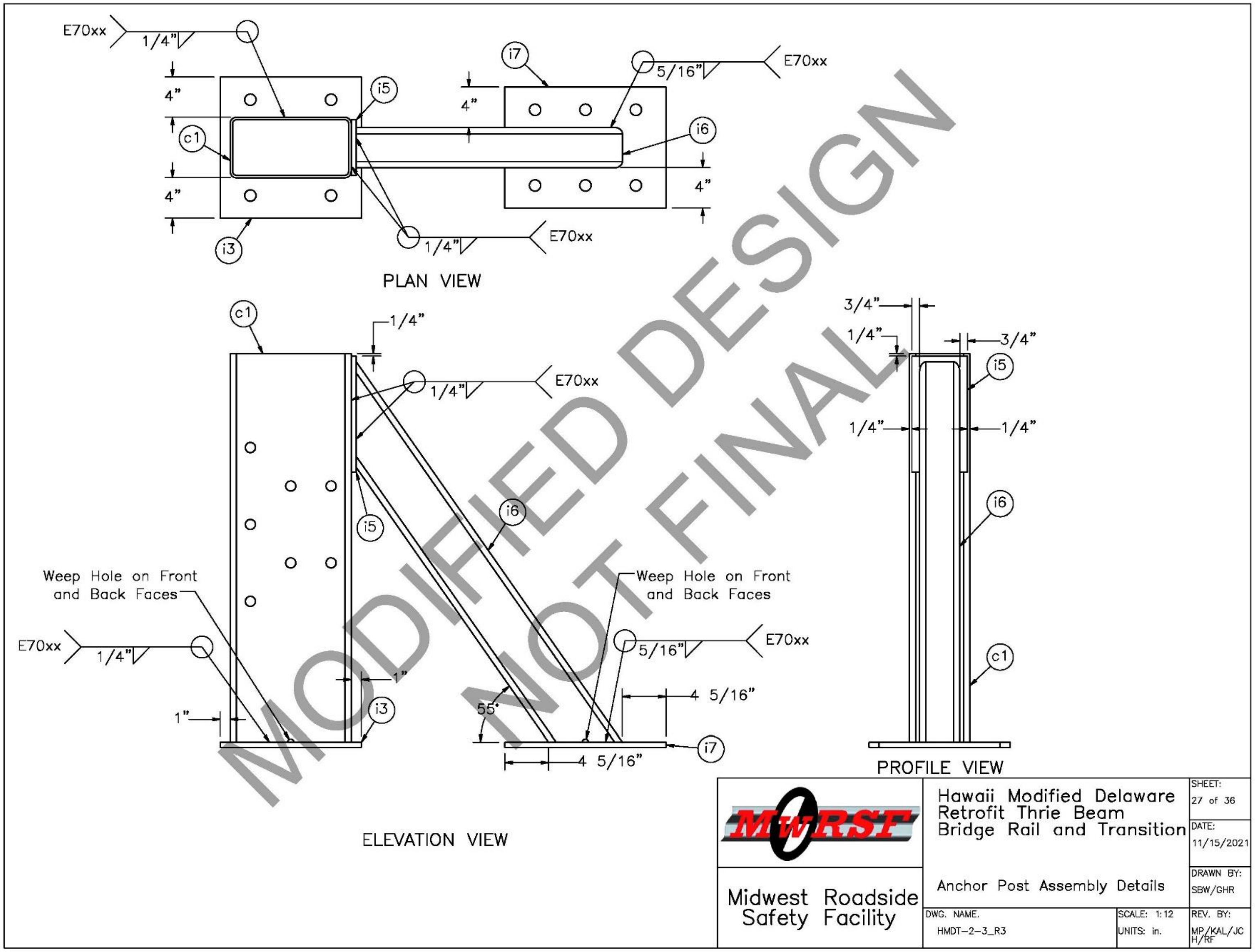



Figure 104. Anchor Post Assembly Details, Test Nos. HMDT-2 and HMDT-3

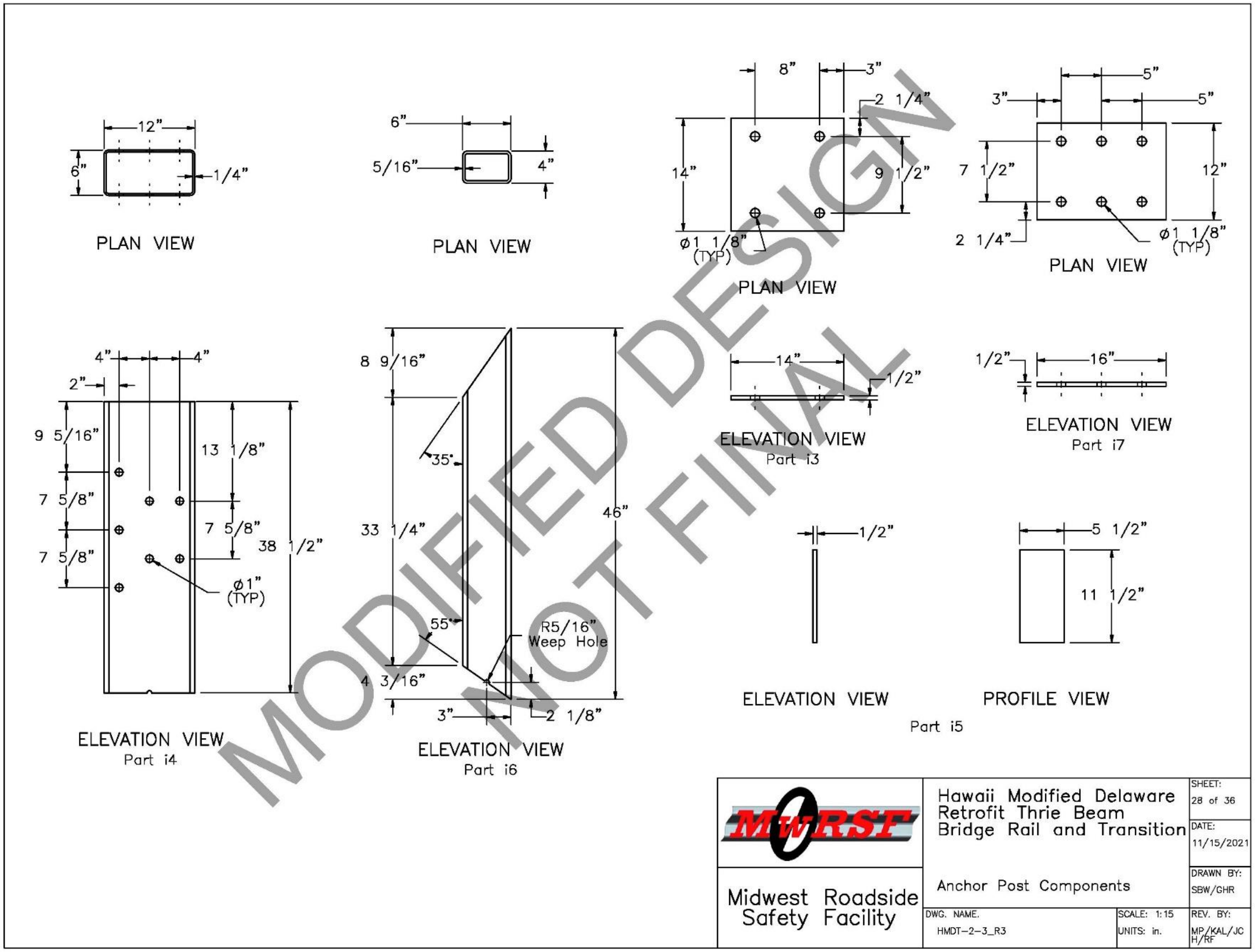



Figure 105. Anchor Post Components, Test Nos. HMDT-2 and HMDT-3

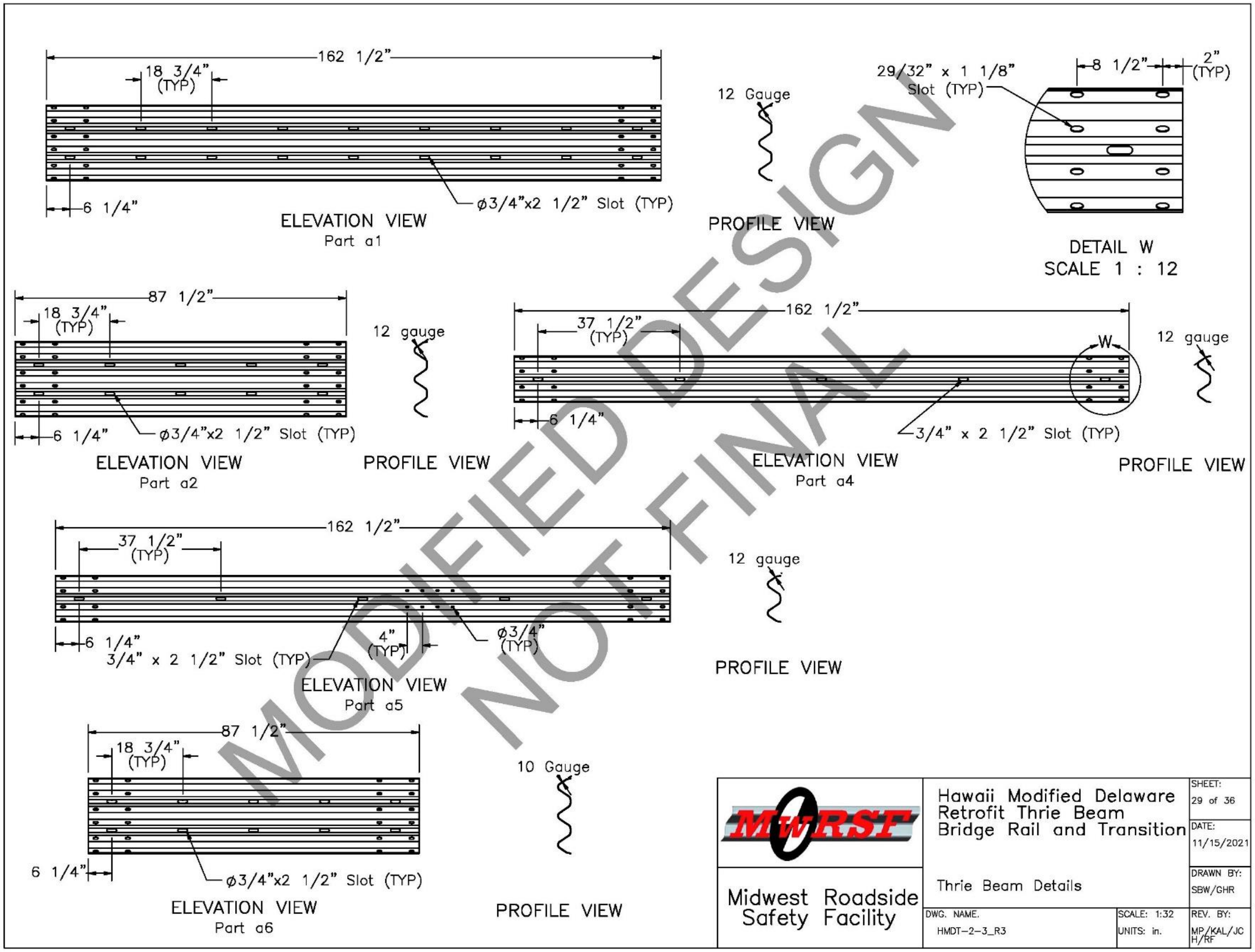



Figure 106. Thrie-Beam Rail Details, Test Nos. HMDT-2 and HMDT-3

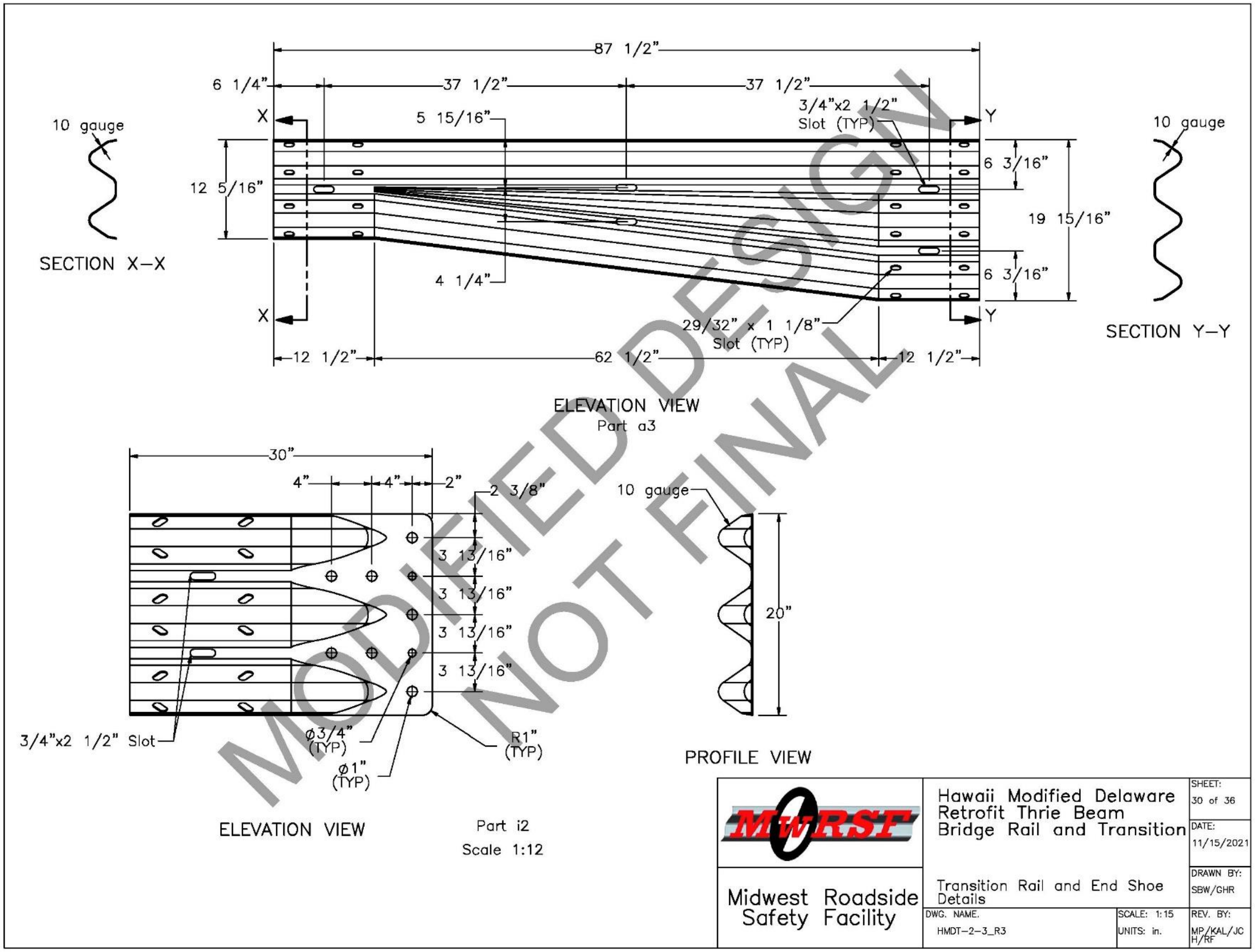



Figure 107. Transition Rail and End Shoe Details, Test Nos. HMDT-2 and HMDT-3

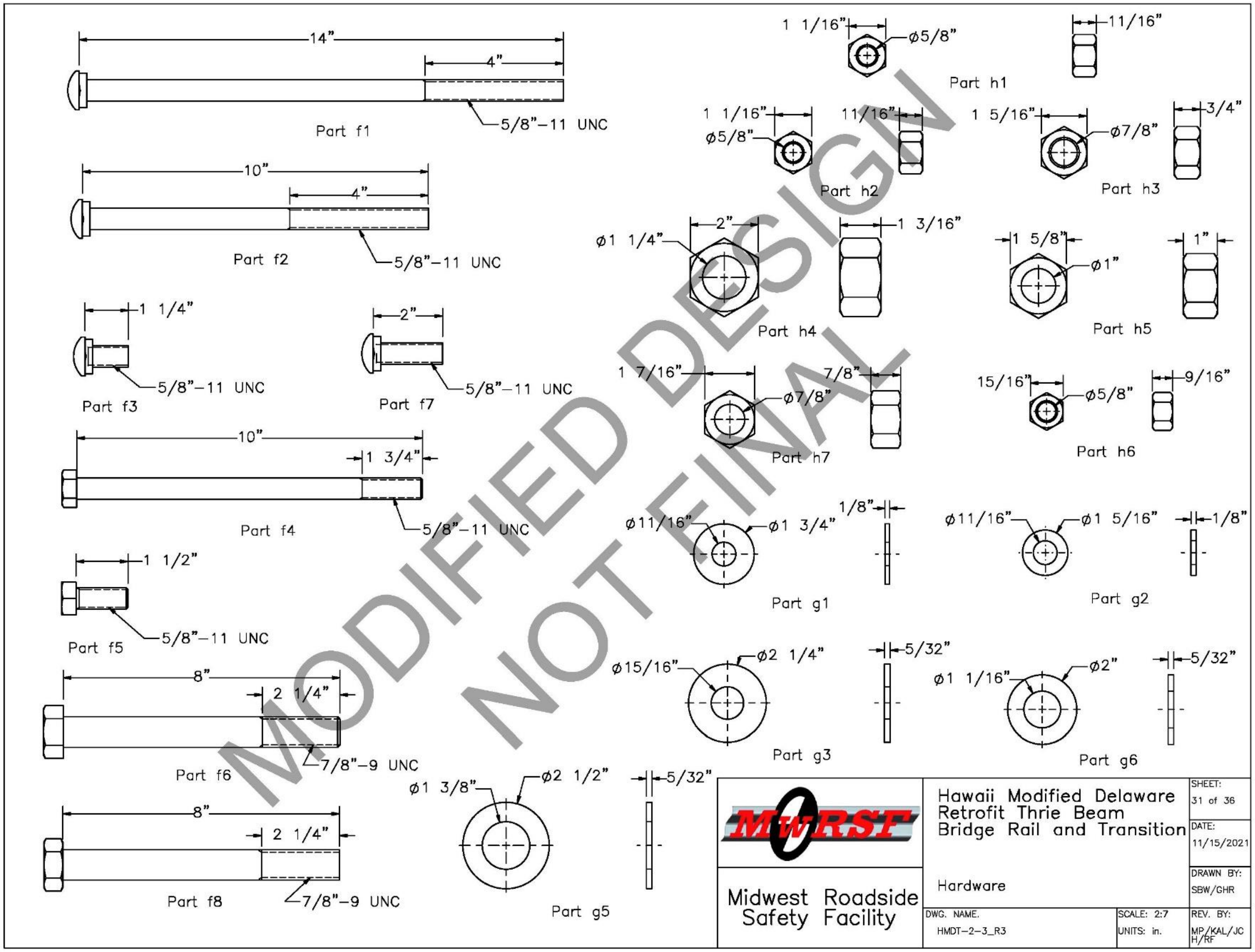



Figure 108. Hardware, Test Nos. HMDT-2 and HMDT-3

| Item No. | QTY. | Description | Material Specification | Treatment Specification | Hardware Guide |
|---|---|---|---|---|---|
| a1 | 2 | 12'–6" 12–gauge Thrie Beam Section | AASHTO M180 | ASTM A123 or A653 | RTM08a |
| a2 | 1 | 6'–3" 12–gauge Thrie Beam Section | AASHTO M180 | ASTM A123 or A653 | RTM19a |
| a3 | 1 | 6'–3" 10–gauge W–Beam to Thrie–Beam Asymmetric Transition Section | AASHTO M180 | ASTM A653 | RWT02 |
| a4 | 3 | 12'–6" 12–gauge W–Beam MGS Section | AASHTO M180 | ASTM A123 or A653 | RWM04a |
| a5 | 1 | 12'–6" 12–gauge W–Beam MGS End Section | AASHTO M180 | ASTM A123 or A653 | RWM14a |
| a6 | 16 | 6'–3" 10–gauge Thrie Beam Section | AASHTO M180 | ASTM A123 or A653 | RTM19a |
| b1 | 16 | 16"x11"x1" Base Plate | ASTM A36 | ASTM A123 | – |
| b2 | 32 | 1 1/4" Dia., 14" Long Anchor Rod | ASTM F1554–15 Grade 105, Class 2A | ASTM F2329 / F2329M–15 | – |
| b3 | 32 | 5/8" Dia., 8" Long Anchor Rod | ASTM F1554–15 Grade 105, Class 2A | ASTM F2329 / F2329M–15 | – |
| c1 | 2 | BCT Timber Post – MGS Height | SYP Grade No. 1 or better (No knots +/– 18" from ground on tension face) | – | PDF01 |
| c2 | 2 | 72" Long Foundation Tube | ASTM A500 Gr. B | ASTM A123 | PTE06 |
| c3 | 1 | Ground Strut Assembly | ASTM A36 | ASTM A123 | PFP02 |
| c4 | 2 | BCT Anchor Cable End Swaged Fitting | Fitting – ASTM A576 Gr. 1035<br>Stud – ASTM F568 Class C | Fitting – ASTM A153<br>Stud – ASTM A153 or B695 | – |
| c5 | 1 | BCT Cable Anchor Assembly | – | – | FCA01 |
| c6 | 1 | 8"x8"x5/8" Anchor Bearing Plate | ASTM A36 | ASTM A123 | FPB01 |
| c7 | 1 | 2 3/8" O.D. x 6" Long BCT Post Sleeve | ASTM A53 Gr. B Schedule 40 | ASTM A123 | FMM02 |
| c8 | 1 | Anchor Bracket Assembly | ASTM A36 | ASTM A123 | FPA01 |
| d1 | 7 | W6x9 or W6x8.5, 72" Long Steel Post | ASTM A992 | ASTM A123* | PWE06 |
| d2 | 6 | W6x9 or W6x8.5, 72" Long Steel Post | ASTM A992 | ASTM A123* | PWE06 |
| d3 | 4 | W6x15, 78" Long Steel Post | ASTM A992 | ASTM A123* | – |
| d4 | 4 | 17 1/2" Long, 8"x6"x1/4" Steel Blockout | ASTM A500 Gr. B | ASTM A123* | – |
| d5 | 6 | 17 1/2" Long, 12"x4"x1/4" Steel Blockout | ASTM A500 Gr. B | ASTM A123* | – |
| d6 | 2 | 14 3/16"x12"x5 1/8" Composite Recycled Blockout | Mondo Polymer MGS14SH or Equivalent | – | – |
| d7 | 5 | 14 3/16"x8"x5 1/8" Composite Recycled Blockout | Mondo Polymer GB14SH2 or Equivalent | – | – |
| d8 | 2 | 16D Double Head Nail | Galvanized | – | – |
| d9 | 16 | W6x25, 23 1/4" Long Steel Post | ASTM A992 | ASTM A123 | – |

* Component does not need to be galvanized for testing purposes

Notes: (1) Quantities listed herein are only for one copy of the system.
(2) Purchase additional materials to repair the barrier system following the first transition test, test no. HMDT–1.



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Hawaii Modified Delaware Retrofit Thrie Beam Bridge Rail and Transition

Bill of Materials

SHEET: 32 of 36
DATE: 11/15/2021
DRAWN BY: SBW/GHR
DWG. NAME. HMDT–2–3_R3
SCALE: None
UNITS: in.
REV. BY: MP/KAL/JCH/RF

Figure 109. Bill of Materials, Test Nos. HMDT-2 and HMDT-3

| Item No. | QTY. | Description | Material Specification | Treatment Specification | Hardware Guide |
|---|---|---|---|---|---|
| e1 | 98 | #4 Rebar, 33 7/8" Total Unbent Length | ASTM A615 Gr. 60 | Epoxy-Coated (ASTM A775 or A934) | – |
| e2 | 3 | #4 Rebar, 97' 1" Total Length* | ASTM A615 Gr. 60 | Epoxy-Coated (ASTM A775 or A934) | – |
| e3 | 7 | #4 Rebar, 16" Total Length | ASTM A615 Gr. 60 | Epoxy-Coated (ASTM A775 or A934) | – |
| e4 | 1 | #4 Rebar, 12 3/4" Total Length | ASTM A615 Gr. 60 | Epoxy-Coated (ASTM A775 or A934) | – |
| e5 | 1 | #5 Rebar, 166" Total Length | ASTM A615 Gr. 60 | Epoxy-Coated (ASTM A775 or A934) | – |
| e6 | 1 | #5 Rebar, 158 1/4" Total Unbent Length | ASTM A615 Gr. 60 | Epoxy-Coated (ASTM A775 or A934) | – |
| e7 | 98 | #4 Rebar, 35" Total Unbent Length | ASTM A615 Gr. 60 | Epoxy-Coated (ASTM A775 or A934) | – |
| f1 | 13 | 5/8"-11 UNC, 14" Long Guardrail Bolt | ASTM A307 Gr. A | ASTM A153 or B695 Class 55 or F2329 | FBB06 |
| f2 | 15 | 5/8"-11 UNC, 10" Long Guardrail Bolt | ASTM A307 Gr. A | ASTM A153 or B695 Class 55 or F2329 | FBB03 |
| f3 | 260 | 5/8"-11 UNC, 1 1/4" Long Guardrail Bolt | ASTM A307 Gr. A | ASTM A153 or B695 Class 55 or F2329 | FBB01 |
| f4 | 2 | 5/8"-11 UNC, 10" Long Hex Head Bolt | ASTM A307 Gr. A or equivalent | ASTM A153 or B695 Class 55 or F2329 | FBX16a |
| f5 | 8 | 5/8"-11 UNC, 1 1/2" Long Hex Head Bolt | ASTM A307 Gr. A or equivalent | ASTM A153 or B695 Class 55 or F2329 | FBX16a |
| f6 | 2 | 7/8"-9 UNC, 8" Long Hex Head Bolt | ASTM A307 Gr. A or equivalent | ASTM A153 or B695 Class 55 or F2329 | – |
| f7 | 32 | 5/8"-11 UNC, 2" Long Guardrail Bolt | ASTM A307 Gr. A | ASTM F2329 | FBB01 |
| f8 | 7 | 7/8" Dia., 8" Long Heavy Hex Head Bolt | ASTM F3125 Gr. A325 Type 1 | ASTM A153 or B695 Class 55 or F1136 Gr. 3 or F2329 or F2833 Gr. 1 | FBX22b |
| g1 | 54 | 5/8" Dia. Plain USS Washer | ASTM F844 | ASTM F2329 | FWC16a |
| g2 | 192 | 5/8" Dia. Hardened Washer | ASTM F436 | ASTM F2329 | FWC16a |
| g3 | 11 | 7/8" Dia. Plain Round Washer | ASTM F844 | ASTM A123 or A153 or F2329 | – |
| g4 | 2 | 1" Dia. Plain USS Washer | ASTM F844 | ASTM A123 or A153 or F2329 | FWC24a |
| g5 | 160 | 1 1/4" Dia. Hardened Washer | ASTM F436 | ASTM F2329 | FWC30a |
| g6 | 10 | 1" Dia. Hardened Flat Washer | ASTM F436 | ASTM A153 or B695 Class 55 or F1136 Gr. 3 or F2329 | FWC24b |
| h1 | 320 | 5/8"-11 UNC Heavy Hex Nut | ASTM A563A or equivalent | ASTM A153 or B695 Class 55 or F2329 | FNX16b |
| h2 | 32 | 5/8"-11 UNC Heavy Hex Nut | ASTM A563-15 Grade DH | ASTM F2329 / F2329U-15 | FNX16b |
| h3 | 2 | 7/8"-9 UNC Hex Nut | ASTM A563A or equivalent | ASTM A153 or B695 Class 55 or F2329 | – |
| h4 | 32 | 1 1/4"-8 UNC Heavy Hex Nut | ASTM A563-15 Grade DH | ASTM F2329 / F2329U-15 | – |
| h5 | 12 | 1" Dia. Heavy Hex Nut | ASTM A563DH or A194 Gr. 2H | ASTM A153 or B633 or B695 Class 55 or F1941 or F2329 | FNX24b |
| h6 | 10 | 5/8"-11 UNC Hex Nut | ASTM A563A or equivalent | ASTM A153 or B695 Class 55 or F2329 | FNX16a |
| h7 | 7 | 7/8" Dia. UNC Heavy Hex Nut | ASTM A563DH or ASTM A194 Gr. 2H | ASTM A153 for Class C or ASTM B695 for Class 50 | – |

* Minimum lap length for part e2 is 18".



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Midwest Roadside Safety Facility

Hawaii Modified Delaware Retrofit Thrie Beam Bridge Rail and Transition

Bill of Materials

| | |
|---|---|
| SHEET: | 33 of 36 |
| DATE: | 11/15/2021 |
| DRAWN BY: | SBW/GHR |
| REV. BY: | MP/KAL/JCH/RF |
| DWG. NAME. | HMDT-2-3_R3 |
| SCALE: | None |
| UNITS: | in. |

Figure 110. Bill of Materials, Test Nos. HMDT-2 and HMDT-3

| Item No. | QTY. | Description | Material Specification | Treatment Specification | Hardware Guide |
|---|---|---|---|---|---|
| i1 | 10 | 1" Dia. UNC, 11" Long Threaded Rod | ASTM A449 or A354 Gr. BC or A193 Gr. B7 | ASTM A153 or B633 or B695 Class 55 or F1941 or F2329 | FRR24b |
| i2 | 1 | 10-gauge Thrie Beam Terminal Connector | AASHTO M180<br>Min. yield strength = 50 ksi<br>Min. tensile strength = 70 ksi | ASTM A123 or A653 | RTE01b |
| i3 | 1 | 14"x14"x1/2" Steel Plate | ASTM A36 or A572 Gr. 50 | ASTM A123* | – |
| c1 | 1 | HSS 6"x12"x1/4" [152x305x6] Tube, 38 1/2" [978] Long | ASTM A500 Gr. B | ASTM A123* | – |
| i5 | 1 | 11 1/2"x5 1/2"x1/2" Steel Plate | ASTM A36 or A572 Gr. 50 | ASTM A123* | – |
| i6 | 1 | HSS 6"x4"x5/16" Tube, 46" Long | ASTM A500 Gr. B | ASTM A123* | – |
| i7 | 1 | 16"x12"x1/2" Steel Plate | ASTM A36 or A572 Gr. 50 | ASTM A123* | – |
| j1 | 1 | Concrete | Min. f'c = 4,000 psi<br>NE Mix 47BD1S/1PF4000HW | – | – |
| k1 | – | Hilti HIT RE-500 V3 Epoxy Adhesive | Class C 881 | – | – |
| k2 | – | SpecChem 500 Epoxy Filler | ASTM C881 Type IV, Grade I, Class C | – | – |

* Component does not need to be galvanized for testing purposes



Notes: (1) Tear out and cut off the entire curb in the transition region at the ground line and redo the curb with updated slope.
(2) Repair concrete breakouts on the sidewalk corners with the high strength epoxy used for front lip of the bridge rail cutouts.

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Hawaii Modified Delaware Retrofit Thrie Beam Bridge Rail and Transition

Bill of Materials

SHEET: 34 of 36
DATE: 11/15/2021
DRAWN BY: SBW/GHR
REV. BY: MP/KAL/JCH/RF
DWG. NAME. HMDT-2-3_R3
SCALE: None
UNITS: in.

Figure 111. Bill of Materials, Test Nos. HMDT-2 and HMDT-3


Figure 112. Test Installation Photographs, Test No. HMDT-2


Figure 113. Test Installation Photographs, Test No. HMDT-2

Figure 114. Test Installation Photographs, Test No. HMDT-3


Figure 115. Test Installation Photographs, Test No. HMDT-3


Figure 116. Test Installation Photographs, Test No. HMDT-3

# 7 FULL-SCALE CRASH TEST NO. HMDT-2

## 7.1 Static Soil Test

Before full-scale crash test no. HMDT-2 was conducted, the strength of the foundation soil was evaluated with a static test, as described in MASH 2016. The static test results, as shown in Appendix D, demonstrated a soil resistance above the baseline test limits. Thus, the soil provided adequate strength, and full-scale crash testing could be conducted on the barrier system.

## 7.2 Weather Conditions

Test no. HMDT-2 was conducted on June 23, 2021 at approximately 12:15 pm. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/LNK) were reported and are shown in Table 11.

Table 11. Weather Conditions, Test No. HMDT-2

| | |
|---|---|
| Temperature | 86° F |
| Humidity | 51% |
| Wind Speed | 16 mph |
| Wind Direction | 190° from True North |
| Sky Conditions | Sunny |
| Visibility | 9.94 Statute Miles |
| Pavement Surface | Dry |
| Previous 3-Day Precipitation | 0.0 in. |
| Previous 7-Day Precipitation | 0.1 in. |

## 7.3 Test Description

Initial vehicle impact was to occur 11 in. upstream from post no. 17, as shown in Figure 117, which was selected using the CIP plots found in Figure 2-17 of MASH 2016 to maximize pocketing and the probability of wheel snag. The 4,981-lb crew cab pickup truck impacted the modified HDOT AGT at a speed of 62.5 mph and at an angle of 24.8 degrees. The actual point of impact was 18.5 in. upstream from post no. 17, or 7.5 in. upstream from the targeted impact location. The vehicle came to rest 203 ft downstream and 77.7 ft laterally behind the impact face of the system after the brakes were applied. The measured I.S. of test no. HMDT-2 was 114.4 kip-ft, which exceeded the 105.6 kip-ft minimum limit, as defined in MASH 2016 for test designation no. 3-21.

A detailed description of the sequential impact events is contained in Table 12. Sequential photographs are shown in Figures 118 and 119. Documentary photographs of the crash test are shown in Figures 120 and 121. The vehicle trajectory and final position are shown in Figure 122.


Figure 117. Impact Location, Test No. HMDT-2

Table 12. Sequential Description of Impact Events, Test No. HMDT-2

| Time sec | Event |
|---|---|
| 0.000 | Vehicle's front bumper and left headlight contacted rail between posts nos. 16 and 17 and deformed. |
| 0.008 | Vehicle's grille contacted rail and deformed. |
| 0.014 | Vehicle's left fender contacted rail and deformed. Vehicle's left-front tire contacted rail. |
| 0.026 | Post nos. 16, 17, 18, 19, and 20 deflected backward. Vehicle's hood deformed and vehicle yawed away from system. |
| 0.029 | Post nos. 14 and 15 deflected backward. |
| 0.033 | Post nos. 7, 8, 9, and 11 deflected downstream, and Post nos. 12 and 13 deflected forward. |
| 0.042 | Post no. 10 deflected downstream. |
| 0.054 | Vehicle's left headlight disengaged, and vehicle's left-front door contacted rail and deformed. |
| 0.062 | Vehicle's left fender disengaged, top of left-front door deformed outward, leaving a gap at top, and vehicle pitched downward. |
| 0.072 | Vehicle rolled toward system, and vehicle's grille disengaged. |
| 0.092 | Vehicle's left-front window and left headlight shattered, and simulated occupant's head exited vehicle. |
| 0.098 | Vehicle's left-front tire deflated. Post nos. 17, 18, and 19 deflected forward. |
| 0.117 | Vehicle's right-front tire became airborne. |
| 0.133 | Vehicle's right-rear tire became airborne. |
| 0.138 | Simulated occupant's head re-entered vehicle. |
| 0.158 | Vehicle's left-rear door contacted rail and deformed. |
| 0.191 | Vehicle was parallel to system at a speed of 49.4 mph. |
| 0.198 | Vehicle's left quarter panel contacted rail and deformed. |
| 0.204 | Vehicle's left taillight contacted rail and deformed. Post nos. 17, 18, and 19 deflected backward. |
| 0.212 | Vehicle's rear bumper and left-rear tire contacted rail. |
| 0.230 | Post nos. 17, 18, and 19 deflected forward. Vehicle yawed toward system. |
| 0.332 | Vehicle exited system at a speed of 47.3 mph and at angle of 6.8 degrees. |
| 0.464 | Vehicle rolled away from system. |
| 0.554 | Vehicle pitched upward. |
| 0.808 | Vehicle's right-front tire regained contact with ground. |
| 0.966 | Vehicle's right-rear tire regained contact with ground. |
| 3.880 | Vehicle came to rest 203 ft downstream from impact and 77.7 ft laterally behind system. |

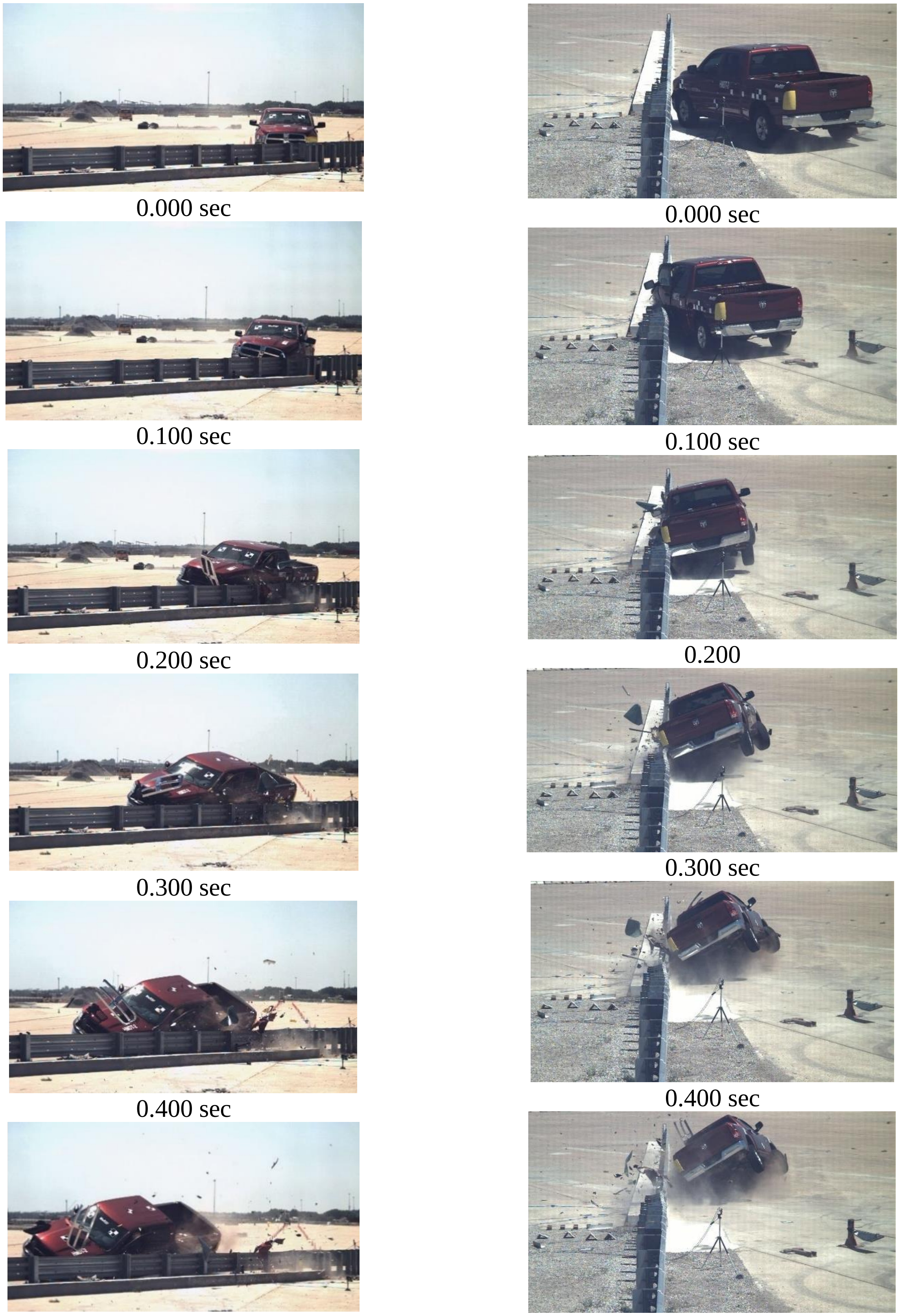

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Figure 118. Sequential Photographs, Test No. HMDT-2

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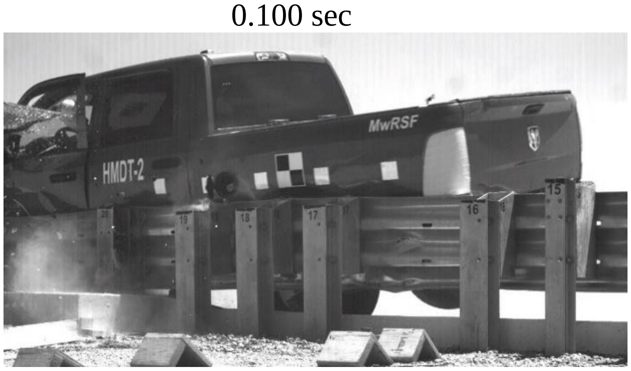


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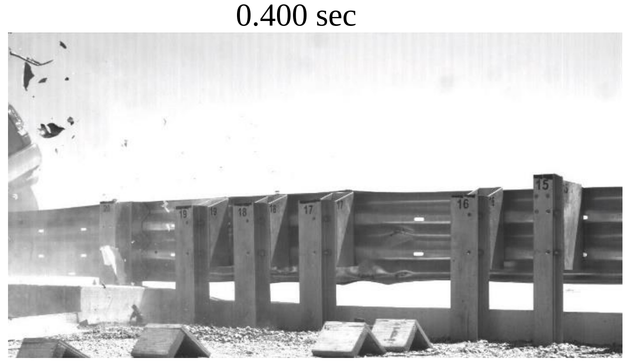

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Figure 119. Sequential Photographs, Test No. HMDT-2

Figure 120. Documentary Photographs, Test No. HMDT-2

Figure 121. Documentary Photographs, Test No. HMDT-2


Figure 122. Vehicle Final Position and Trajectory Marks, Test No. HMDT-2

### 7.4 Barrier Damage

Damage to the barrier was moderate, as shown in Figures 123 through 125. Barrier damage consisted of contact marks, kinks, flattening, and deformation on the thrie-beam rail, contact marks on the front face of the curb, and minor spalling of the concrete sidewalk. The length of vehicle contact along the thrie-beam rail was approximately 176½ in., which spanned from 7¾ in. downstream from post no. 16 to approximately 3¼ in. upstream from post no. 21. There was minor gouging along the top and front face of the curb, starting 17¼ in. upstream from the baseplate edge at post no. 20 and extending 11¼ in. downstream.

The bottom corrugation of the thrie-beam rail was flattened starting 20¼ in. downstream from the centerline of post no. 16 and extending 85¼ in. downstream. The rail was bent backward, starting at the downstream edge of post no. 16 and extending to the upstream edge of post no. 20. There were several kinks on the top and bottom edges of the thrie-beam rail along the length of contact. At the centerline of post no. 17, there was an 8-in. long kink on the top edge and a 4-in. long kink on the bottom edge of the rail. There was a 3½-in. long kink on the bottom edge of the thrie-beam rail 3 in. downstream from post no. 18 and a 5-in. long kink on the bottom edge of the thrie-beam rail 8 in. upstream from the splice between post nos. 20 and 21. There were several dents on the middle corrugation, a ½-in. deep dent starting 16½ in. upstream from post no. 17 and extending 8½ in. downstream, a ¼-in. deep dent starting 2 in. downstream from post no. 17 and extending 9½ in. downstream. Minor contact marks were found on the top edge of post nos. 20 and 21 and blockouts at post nos. 17, 18, and 19.

Post nos. 17, 18, and 19 rotated slightly backward. No other post damage or deflection was observed. Posts nos. 15, 16, and 17 through 19 had minor soil gaps measuring less than ¾ in. in front of and behind the posts. No movement was observed in the upstream anchorage system.


Figure 123. System Damage, Test No. HMDT-2

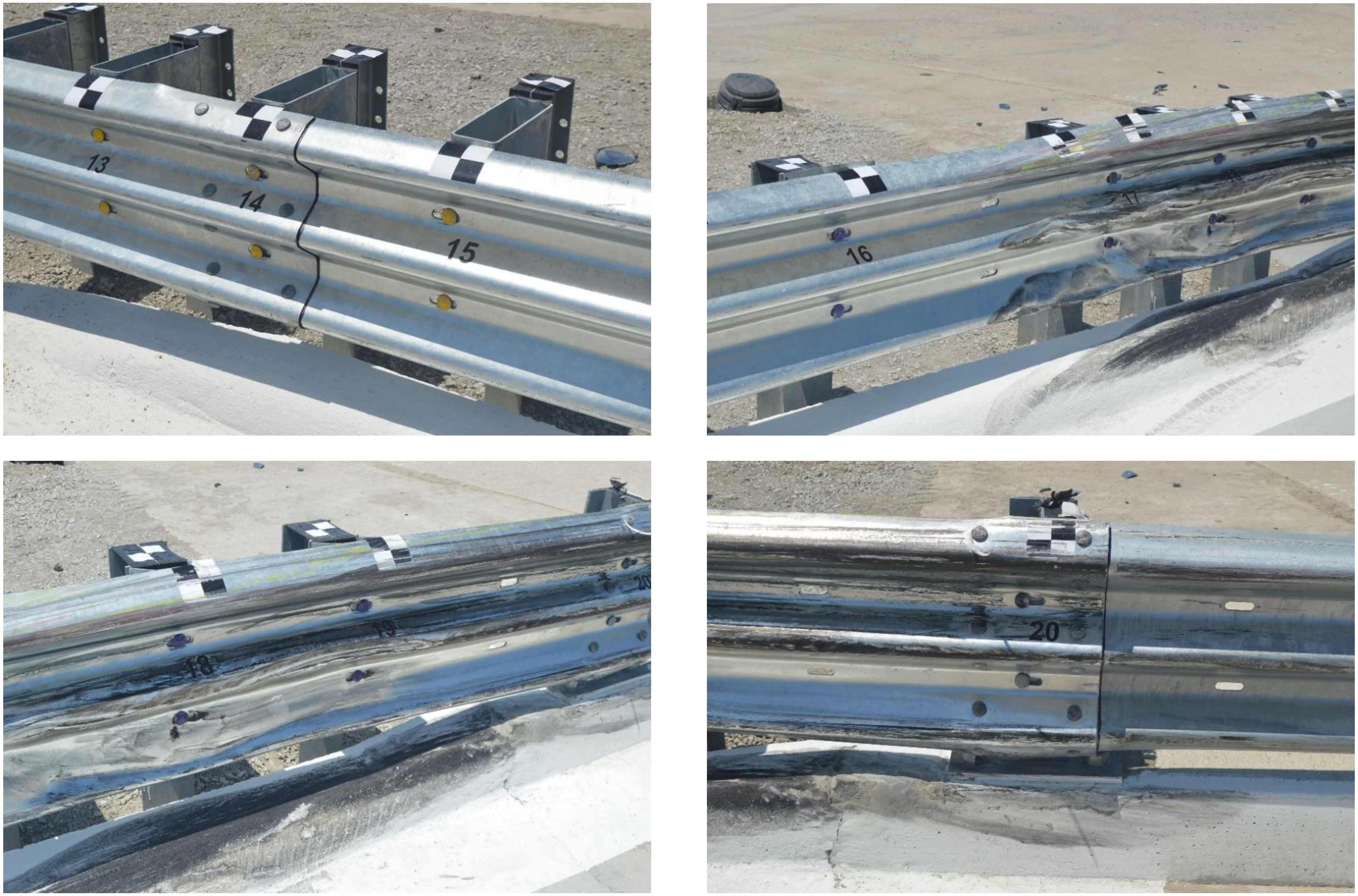


Figure 124. Thrie-Beam Rail Damage, Test No. HMDT-2


Figure 125. Soil Gap and Post Damage, Test No. HMDT-2

The maximum lateral permanent set of the barrier system was 2.4 in., which occurred at the rail at post no. 18, as measured in the field. The maximum lateral dynamic barrier deflection was 4.3 in. at post no. 18, as determined from high-speed digital video analysis. The working width of the system was found to be 22.6 in. at post no. 18, also determined from high-speed digital video analysis. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 126.

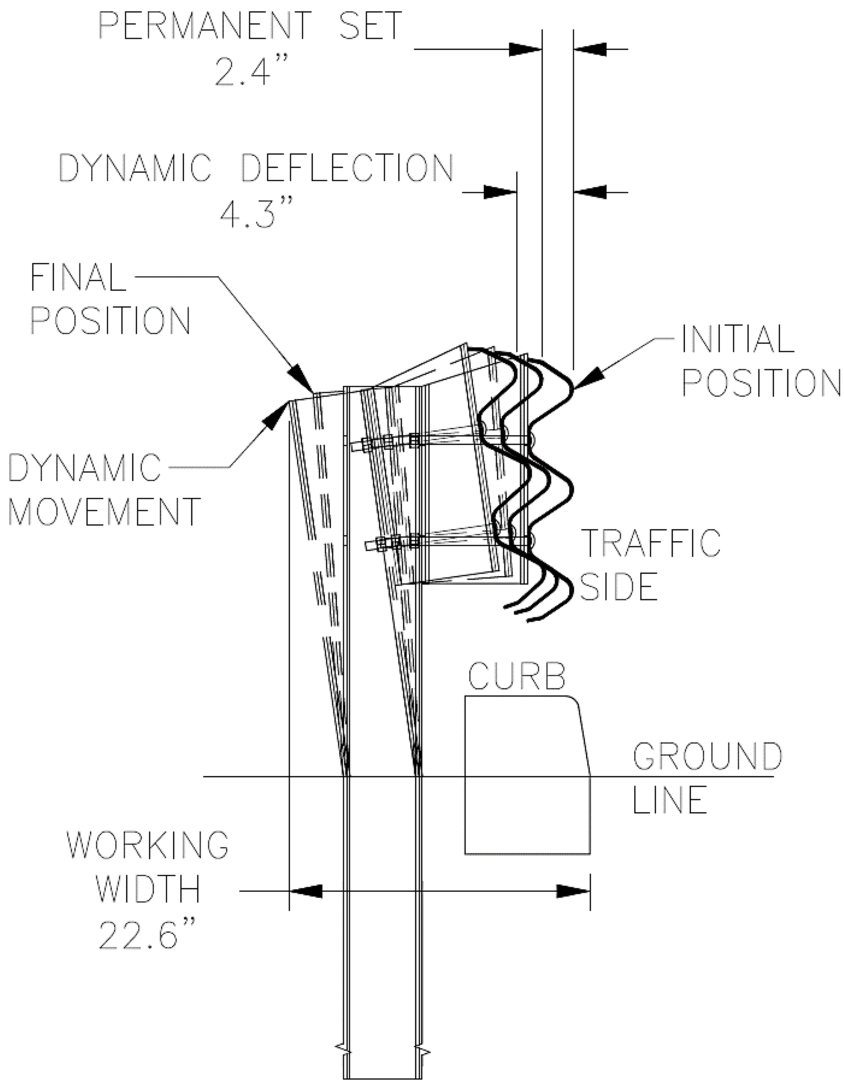


Figure 126. Permanent Set Deflection, Dynamic Deflection, and Working Width, Test No. HMDT-2

## 7.5 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 127 through 129. Majority of the damage was concentrated on the left-front corner and left side of the vehicle where the impact had occurred. The left-front quarter panel was disengaged, and the left-front wheel was pushed backward and inward toward the engine compartment. The left side of the front bumper, left-front headlight, and grille were disengaged. The left-front door was scraped, crushed, and bent outward. The full length of both left-side doors were dented and scraped. The left-front window was shattered. The left-rear quarter panel was scraped and crushed. The left-rear fender and bumper were dented inward.

Undercarriage damage was moderate. The left-front tire was torn, the left shock rod was bent, and the left shock was detached from the lower control arm. The left side end link of the sway bar was detached at the control arm. The upper ball joint of the left control arm fractured, and the left upper control arm was bent rearward. The left inner tie rod was disengaged from the steering rack. The secondary engine cross member buckled downward. The left side of the leading cross member was bent rearward and scraped along the leading edge. The second box mount was bent on both the right and left sides. There was no damage to the oil pan, floor pan, transmission pan, or gas tank.

Windshield damage was minimal, and some cracks on the windshield propagated from the lower-left corner to the upper left side. There was a small tear in the windshield caused by deformations to the vehicle’s front-left side, quarter panel, and lower A-frame, not due to direct contact with the system.

The maximum occupant compartment intrusions are listed in Table 13 along with the intrusion limits established in MASH 2016 for various areas of the occupant compartment. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix E. MASH 2016 defines intrusion or deformation as the occupant compartment being deformed and reduced in size with no observed penetration. There were minimal deformations into the occupant compartment, and none of the established MASH 2016 deformation limits were violated. Outward deformations, which are denoted as negative numbers in Appendix E, are not considered crush toward the occupant, and are not evaluated by MASH 2016 criteria.


Figure 127. Vehicle Damage, Test No. HMDT-2


Figure 128. Vehicle Damage, Test No. HMDT-2

Figure 129. Interior and Undercarriage Damage, Test No. HMDT-2

Table 13. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. HMDT-2

| Location | Maximum Intrusion in. | MASH 2016 Allowable Intrusion in. |
|---|---|---|
| Wheel Well & Toe Pan | 7.5 | ≤ 9 |
| Floor Pan & Transmission Tunnel | 2.9 | ≤ 12 |
| A-Pillar | 0.0 | ≤ 5 |
| A-Pillar (Lateral) | 0.0 | ≤ 3 |
| B-Pillar | 0.2 | ≤ 5 |
| B-Pillar (Lateral) | 0.0 | ≤ 3 |
| Side Front Panel (in Front of A-Pillar) | 3.6 | ≤ 12 |
| Side Door (Above Seat) | 0.0* | ≤ 9 |
| Side Door (Below Seat) | 0.5 | ≤ 12 |
| Roof | 0.0* | ≤ 4 |
| Windshield | 0.0 | ≤ 3 |
| Side Window | Shattered due to contact with simulated occupant's head | No shattering resulting from contact with structural member of test article |
| Dash | 1.7 | N/A |

N/A – No MASH 2016 criteria exist for this location
*Negative value reported as 0.0. See Appendix E for further information.

## 7.6 Occupant Risk

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined from the accelerometer data, are shown in Table 14. Note that the OIVs and ORAs were within suggested limits, as provided in MASH 2016. The calculated THIV, PHD, and ASI values are also shown in Table 14. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix H.

Table 14. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. HMDT-2

| Evaluation Criteria | | Transducer | | MASH 2016 Limits |
|---|---|---|---|---|
| | | **SLICE-1** | **SLICE-2 (primary)** | |
| **OIV ft/s** | Longitudinal | -21.61 | -21.60 | ±40 |
| | Lateral | 23.55 | 26.21 | ±40 |
| **ORA g's** | Longitudinal | -5.57 | -7.16 | ±20.49 |
| | Lateral | 10.69 | 9.22 | ±20.49 |
| **Max Angular Displacement. deg.** | Roll | -32.8 | -29.7 | ±75 |
| | Pitch | -5.8 | -7.9 | ±75 |
| | Yaw | 43.7 | 42.7 | not required |
| **THIV ft/s** | | 32.87 | 33.40 | not required |
| **PHD g's** | | 10.75 | 9.41 | not required |
| **ASI** | | 1.40 | 1.55 | not required |

## 7.7 Discussion

The analysis of the results for test no. HMDT-2 showed that the system adequately contained and redirected the 2270P vehicle with controlled lateral displacements of the barrier. A summary of the test results and sequential photographs are shown in Figure 130. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or work-zone personnel. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did not occur. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix H, were deemed acceptable, because they did not adversely influence occupant risk nor cause rollover. After impact, the vehicle exited the barrier at an angle of 4.4 degrees, and its trajectory did not violate the bounds of the exit box. Therefore, test no. HMDT-2 was determined to be acceptable according to the MASH 2016 safety performance criteria for test designation no. 3-21.


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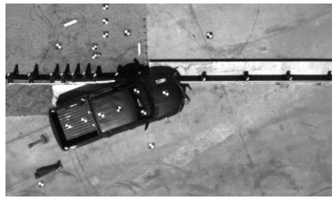
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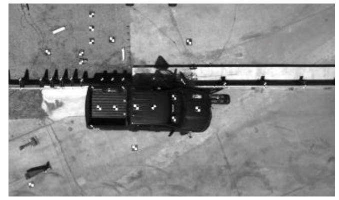
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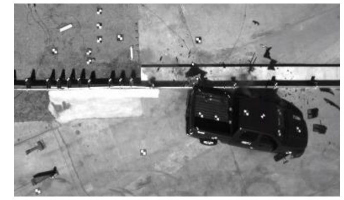
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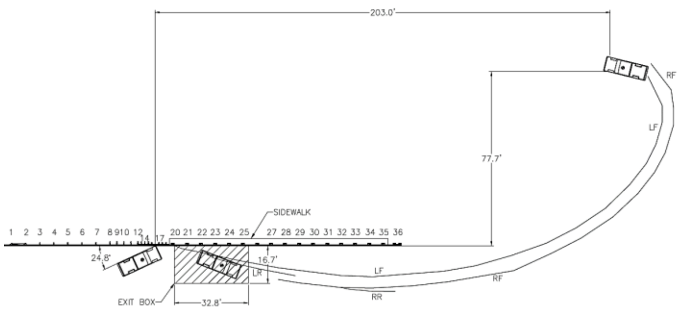
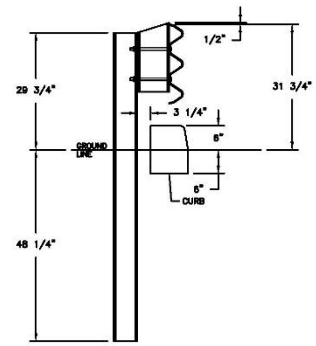



- Test Agency ........ MwRSF
- Test Number ........ HMDT-2
- Date ........ 6/23/2021
- MASH 2016 Test Designation No. ........ 3-21
- Test Article ........ Hawaii Transition to Modified Delaware Retrofit Bridge Rail
- Total Length ........ 177 ft – 6 in.
- Key Component – Thrie-Beam Guardrail
  - Thickness ........ 12 ga.
  - Length ........ 12.5 ft (nested), and 6.25 ft (single ply)
- Key Component – W6x15 Steel Posts
  - Length ........ 78 in.
  - Embedment Depth ........ 48½ in., 48⅜ in, $48^{5}/_{16}$ in., $48^{3}/_{16}$ in. (post nos. 16-19)
  - Spacing ........ 37½ in., 18¾ in.
- Soil Type ........ Coarse, Crushed, Limestone (Well-Graded Gravel)
- Vehicle Make /Model ........ 2015 Dodge RAM 1500 crew cab pickup truck
  - Curb ........ 4,958 lb
  - Test Inertial ........ 4,981 lb
  - Gross Static ........ 5,140 lb
- Impact Conditions
  - Speed ........ 62.5 mph
  - Angle ........ 24.8 degrees
  - Impact Location ........ 18.5 in. upstream from post no. 17
- Impact Severity ........ 114.4 kip-ft > 105.6 kip-ft limit from MASH 2016
- Exit Conditions
  - Speed ........ 47.3 mph
  - Angle ........ 4.4 degrees
- Exit Box Criterion ........ Pass
- Vehicle Stability ........ Satisfactory

Vehicle Stopping Distance ........ 203.0 ft downstream from impact
77.7 ft laterally behind

- Vehicle Damage ........ Moderate
  - VDS [14] ........ 10-LFQ-5
  - CDC [15] ........ 11-LFEW-3
  - Maximum Interior Deformation ........ 7.5 in.≤ 9 in. MASH Limit for the toe pan
- Test Article Damage ........ Minimal
- Maximum Test Article Deflections
  - Permanent Set ........ 2.4 in.
  - Dynamic ........ 4.3 in.
  - Working Width ........ 22.6 in.
- Transducer Data

| Evaluation Criteria | | Transducer | | MASH 2016 Limits |
|---|---|---|---|---|
| | | SLICE-1 | SLICE-2 (primary) | |
| OIV ft/s | Longitudinal | -21.61 | -21.60 | ±40 |
| | Lateral | 23.55 | 26.21 | ±40 |
| ORA g's | Longitudinal | -5.57 | -7.16 | ±20.49 |
| | Lateral | 10.69 | 9.22 | ±20.49 |
| Maximum Angular Displacement deg. | Roll | -32.8 | -29.7 | ±75 |
| | Pitch | -5.8 | -7.9 | ±75 |
| | Yaw | 43.7 | 42.7 | not required |
| THIV – ft/s | | 32.87 | 33.40 | not required |
| PHD – g's | | 10.75 | 9.41 | not required |
| ASI | | 1.40 | 1.55 | not required |

Figure 130. Summary of Test Results and Sequential Photographs, Test No. HMDT-2

# 8 FULL-SCALE CRASH TEST NO. HMDT-3

## 8.1 Static Soil Test

Before full-scale crash test no. HMDT-3 was conducted, the strength of the foundation soil was evaluated with a static test, as described in MASH 2016. The static test results, as shown in Appendix D, demonstrated a soil resistance above the baseline test limits. Thus, the soil provided adequate strength, and full-scale crash testing could be conducted on the barrier system.

## 8.2 Weather Conditions

Test no. HMDT-3 was conducted on July 1, 2021 at approximately 2:00 p.m. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/LNK) were reported and are shown in Table 15.

Table 15. Weather Conditions, Test No. HMDT-3

| | |
|---|---|
| Temperature | 84° F |
| Humidity | 43% |
| Wind Speed | 9 mph |
| Wind Direction | 50° from True North |
| Sky Conditions | Partially Cloudy |
| Visibility | 10 Statute Miles |
| Pavement Surface | Dry |
| Previous 3-Day Precipitation | 0 in. |
| Previous 7-Day Precipitation | 1.07 in. |

## 8.3 Test Description

Initial vehicle impact was to occur 6¾ in. upstream from post no. 18, as shown in Figure 131, which was selected using the CIP plots found in Section 2.3 of MASH 2016 or Table 2.7 of MASH 2016. The 2,430-lb small car impacted the modified HDOT AGT at a speed of 62.3 mph and an angle of 25.1 degrees. The actual point of impact was 1½ in. downstream from post no. 18. The vehicle came to rest 107.4 ft downstream from the impact point and 0.2 ft laterally in front of the system after brakes were applied. The measured I.S. of test no. HMDT-3 was 56.7 kip-ft, which was greater than the minimum limit of 51.1 kip-ft, as defined in MASH 2016 for test designation no. 3-20.

A detailed description of the sequential impact events is contained in Table 16. Sequential photographs are shown in Figures 132 and 133. Documentary photographs of the crash test are shown in Figures 134 and 135. The vehicle trajectory and final position are shown in Figure 136.

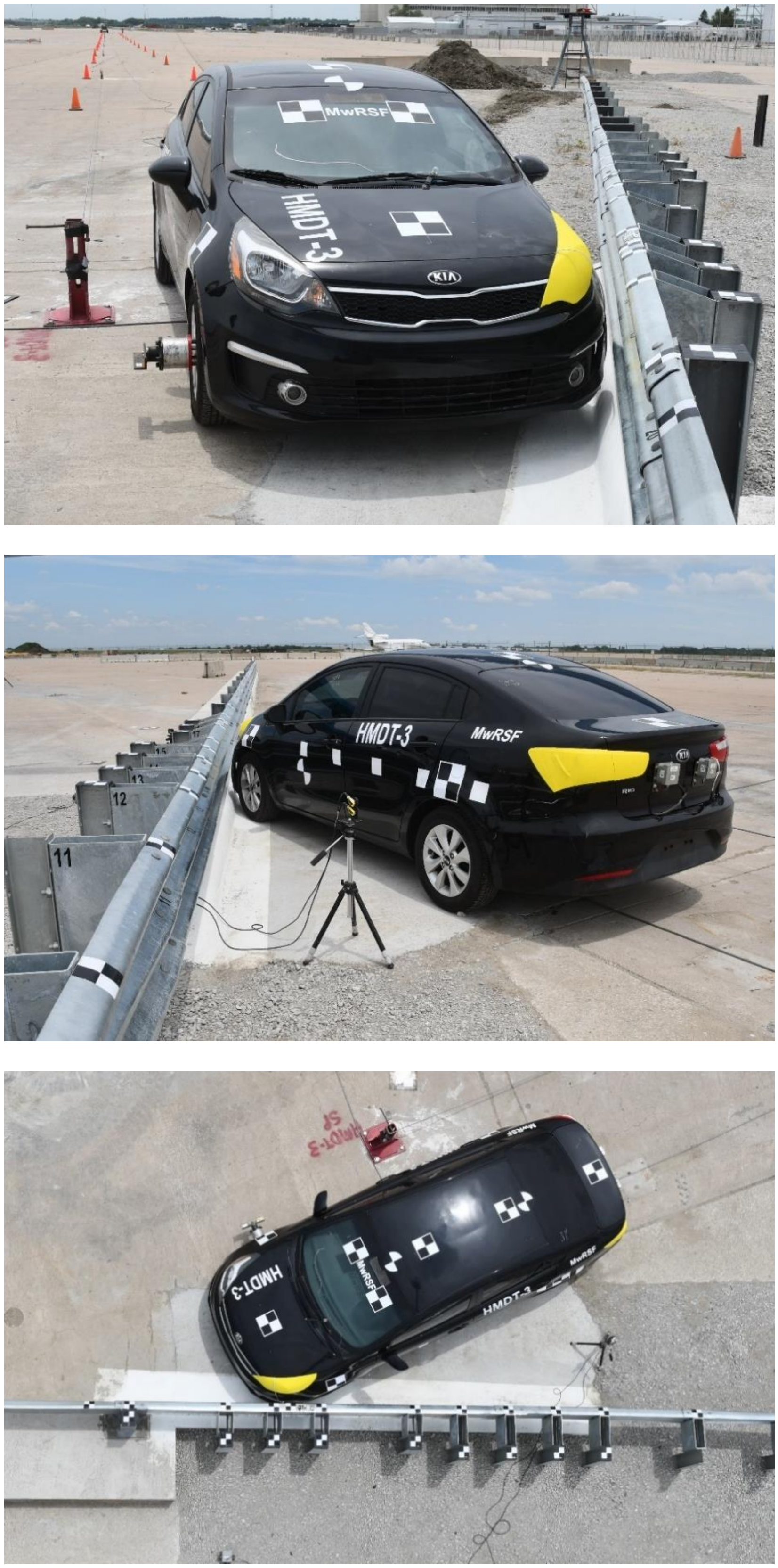
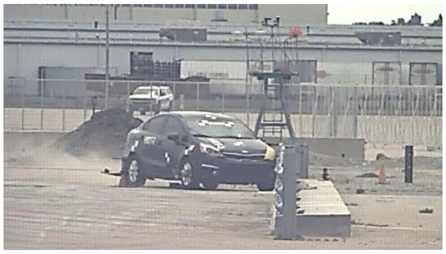



Figure 131. Impact Location, Test No. HMDT-3

Table 16. Sequential Description of Impact Events, Test No. HMDT-3

| Time sec | Event |
|---|---|
| 0.000 | Vehicle’s front bumper contacted rail between post nos. 18 and 19 and deformed. Vehicle’s left-front tire contacted curb. |
| 0.006 | Vehicle’s left-front tire and left headlight contacted rail. |
| 0.014 | Vehicle’s left fender contacted rail and deformed, vehicle’s hood deformed, and vehicle’s left headlight shattered. Post no. 20 deflected backward. |
| 0.020 | Post no. 20 bent backward. Vehicle’s left fender snagged on rail, vehicle’s hood contacted rail, vehicle’s right fender deformed, and vehicle’s left-front tire ruptured. |
| 0.030 | Vehicle’s left A-pillar deformed, and vehicle’s left-front door contacted rail. |
| 0.036 | Post nos. 16, 17, 18, and 19 rotated backward. Vehicle’s left-front door and roof deformed, and vehicle’s windshield shattered. |
| 0.042 | Vehicle’s left mirror contacted rail and deformed. |
| 0.054 | Post no. 15 rotated backward. Left side of vehicle’s frame between A- and B-pillars deformed. |
| 0.062 | Blockouts on post nos. 3, 4, 5, 6, and 7 deflected downstream. Vehicle pitched downward. |
| 0.068 | Top of left-front door deformed outward, leaving a gap between door and frame. |
| 0.074 | Post no. 18 and 19 deflected forward. Vehicle’s right headlight disengaged. Simulated occupant’s head contacted left-front window, and left-front window shattered. |
| 0.080 | Simulated occupant’s head protruded outside left-front window. |
| 0.112 | Vehicle yawed away from system. |
| 0.140 | Vehicle’s right-rear tire became airborne. |
| 0.282 | Vehicle was parallel to system at a speed of 38.3 mph. |
| 0.362 | Vehicle pitched upward. |
| 0.438 | Vehicle’s rear bumper contacted rail. |
| 0.572 | Vehicle exited system at a speed of 35.4 mph and at angle of 8.4 degrees. |
| 2.658 | Vehicle impacted system again. |
| 3.991 | Vehicle came to rest 107.4 ft downstream from impact and 0.2 ft laterally front. |



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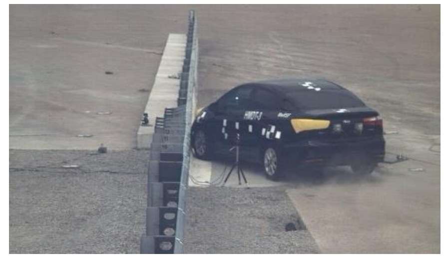

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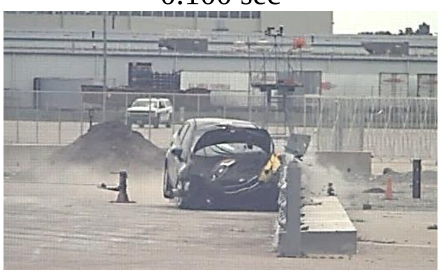

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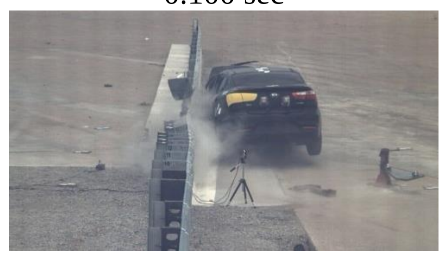

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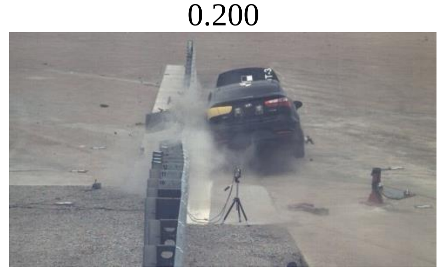

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Figure 132. Sequential Photographs, Test No. HMDT-3

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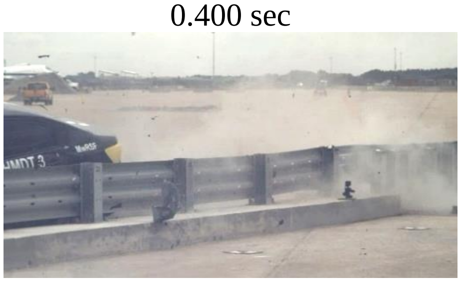

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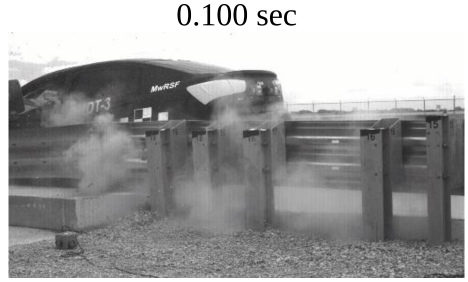

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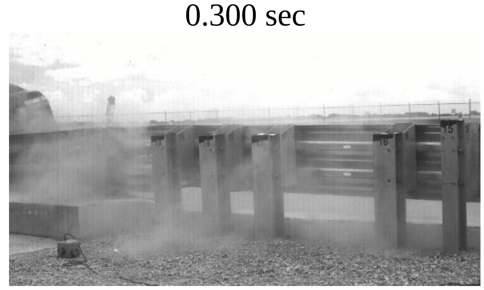

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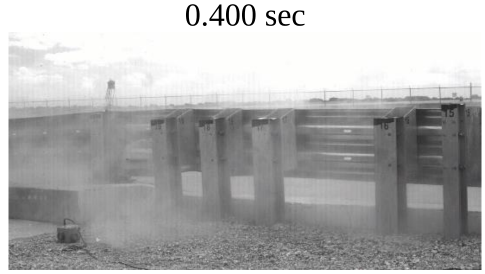

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Figure 133. Sequential Photographs, Test No. HMDT-3

Figure 134. Documentary Photographs, Test No. HMDT-3


Figure 135. Documentary Photographs, Test No. HMDT-3


Figure 136. Vehicle Final Position and Trajectory Marks, Test No. HMDT-3

## 8.4 Barrier Damage

Damage to the barrier was minimal, as shown in Figures 137 through 139. Barrier damage consisted of contact marks on the curb and thrie-beam rail, concrete spalling, and deformation of the thrie-beam rail. The length of vehicle contact was approximately 113 in., which spanned from 7 in. upstream from post no. 18 and to 25¼ in. upstream from post no. 21.

A 67-in. long contact mark on the concrete curb and sidewalk started 12½ in. downstream from post no. 17. A 24-in. long gouge was found along the top and front face of the curb, starting 15 in. downstream from post no. 17. A 7½-in. long minor crack was found on the top face of the curb and extended toward the back of the curb between post nos. 19 and 20. The bottom corrugation of the thrie-beam rail was flattened, starting 2½ in. downstream from post no. 19 and extending 33 in. downstream. Kinks were found on the top and bottom edges of the thrie-beam rail along the length of contact. At post no. 18, there was a 4-in. long kink on the rail bottom corrugation and a 2-in. long kink on the rail top corrugation, starting from 4¼ in. upstream from post no. 21. The upstream, bottom two splice bolts at the splice located at post no. 20 fractured, and the downstream, bottom end of the upstream thrie beam was disengaged from the splice and bent backward.

Post nos. 10 and 11 rotated counterclockwise. Post deflection was minor and limited to post nos. 17 through 19. Post no. 20 bent backward. Posts nos. 17 and 19 had minor soil gaps measuring less than ½ in. between the curb and soil. No movement was observed in the upstream anchorage system.


Figure 137. System Damage, Test No. HMDT-3


Figure 138. Thrie-Beam Rail Damage, Test No. HMDT-3


Figure 139. Curb and Post Damage, Test No. HMDT-3

The maximum lateral permanent set of the barrier system was 2.0 in., located at post no. 18, as measured in the field. The maximum lateral dynamic barrier deflection was 3.7 in. at post no. 19, as determined from high-speed digital video analysis. The working width of the system was found to be 20.9 in. at post no. 19, also determined from high-speed digital video analysis. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 140.

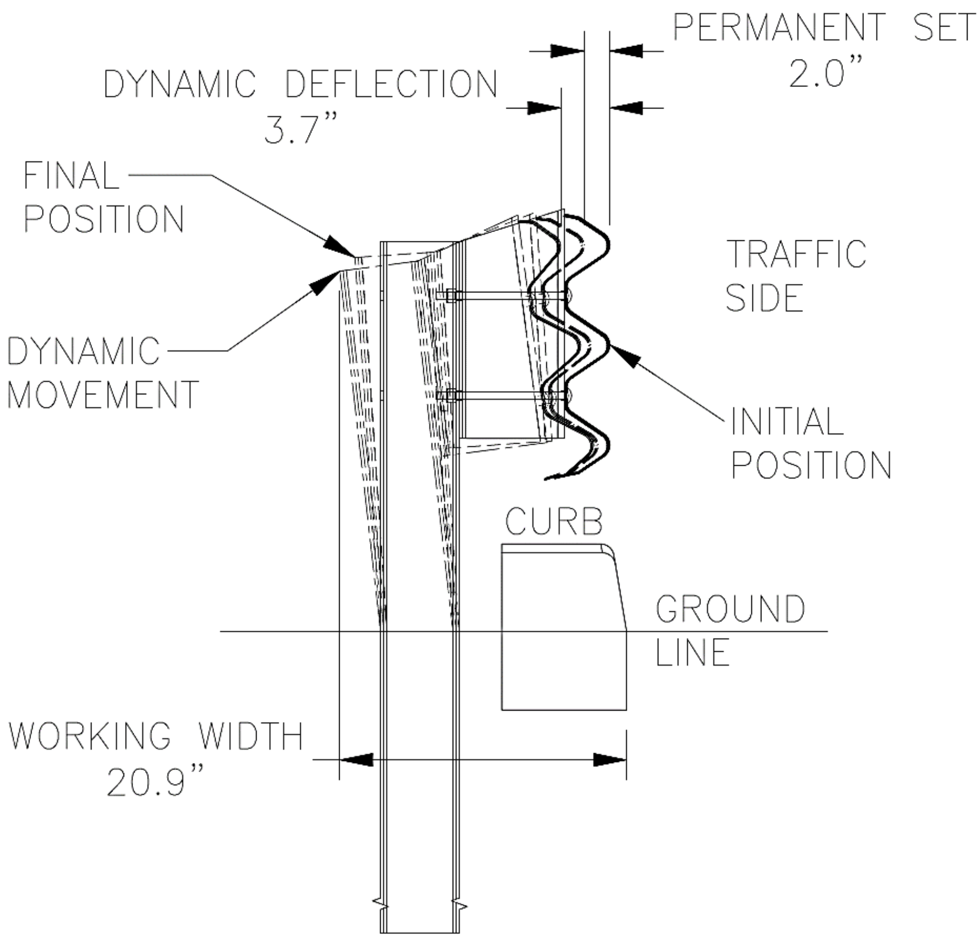



Figure 140. Permanent Set Deflection, Dynamic Deflection, and Working Width, Test No. HMDT-3

## 8.5 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 141 through 143. Majority of the damage was concentrated on the left-front corner and left side of the vehicle. The front bumper was disengaged. The hood was slightly rotated toward the left side, and the front center was dented. Both headlights disengaged. The front side of the left fender was scraped, dented, and crushed inward along the entire length. At the rear side, the left front fender was separated from the A-pillar. The scrapes from the fender continued along the half of the left-front door. The left-front door was shifted backward and bent, leading to a gap between the frame and the door at both the top and bottom of the door. The left-front and left-rear doors were dented at their intersection at the center of the panel. The left-rear door had a dent in the center of the panel. The front half of the roof was dented in several places, including a dent that started at the frame above the left-front door and continued to the center of the roof.

The windshield was cracked across its entire width, with extensive cracking located at the lower left-side corner. The right and left windshield wipers penetrated the windshield. The left-front window was shattered. The left side mirror was disengaged. The left-front tire was deflated and partially separated from the rim with punctures and a tear in the sidewall. The outer side of the front-left wheel rim was bent outward. The front-left wheel was crushed backward and inward, creating an opening in the toe pan and tearing an opening in the undercarriage body panel seams.

Undercarriage damage was moderate. The left side of the front sway bar was bent backward, and the entire assembly was shifted to the right. The left steering knuckle was broken at the lower ball joint. The left-side control arm was disconnected from the steering knuckle, bent rearward and twisted. The outer tie rod of the left steering control arm was bent approximately 90 degrees rearward. There was no damage to the shocks, springs, and rear suspension. The engine and transmission cross members were scraped on the bottom left side. The engine and transmission mounts were stressed but not visibly damaged. The floor pan was dented and creased. The left side of the floor pan was bent upward.

The maximum occupant compartment intrusions are listed in Table 17, along with the intrusion limits established in MASH 2016 for various areas of the occupant compartment. Note that the damage to the vehicle was so severe that post-test vehicle crush measurements were not possible. Instead, the maximum deformation was measured through comparative crush using an undamaged vehicle of the same body style. The maximum intrusion was measured at the side front panel in front of the A-pillar and was 13⅜ in., which exceeded the MASH 2016 limit of 12 in., as shown in Figure 144. Additionally, the left-front wheel penetrated the toe pan area. These penetration and exceedance of the occupant compartment intrusion limits resulted in the failure of test no. HMDT-3 to meet the MASH 2016 criteria.

The other measurable occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix E. MASH 2016 defines intrusion or deformation as the occupant compartment being deformed and reduced in size with no observed penetration. Outward deformations, which are denoted as negative numbers in Appendix E, are not considered crush toward the occupant, and are not evaluated by MASH 2016 criteria.


Figure 141. Vehicle Damage, Test No. HMDT-3


Figure 142. Vehicle Damage, Test No. HMDT-3

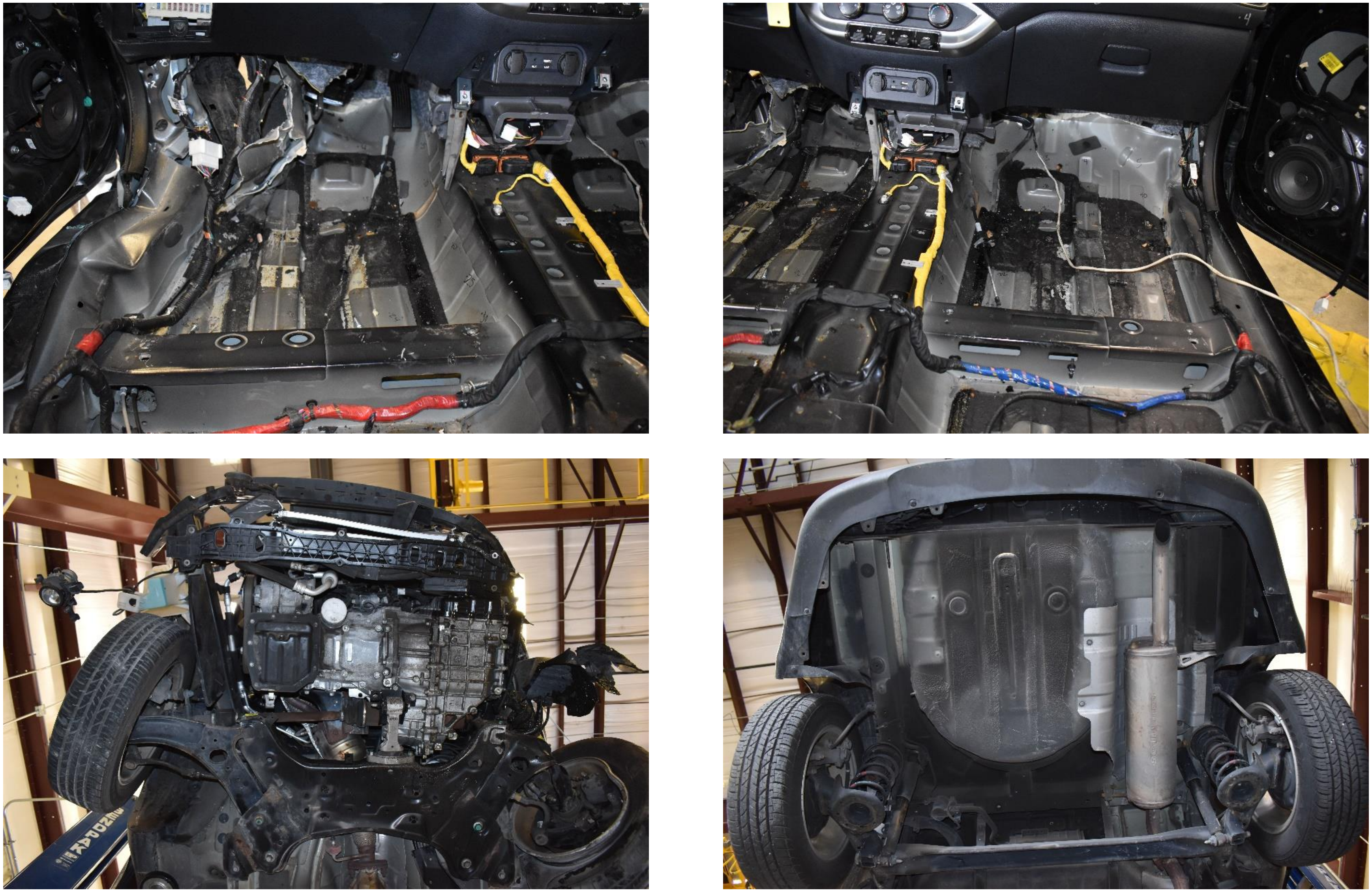


Figure 143. Interior and Undercarriage Damage, Test No. HMDT-3

Figure 144. Comparative Crush Measurements, Test No. HMDT-3

Table 17. Maximum Occupant Compartment Intrusion by Location, Test No. HMDT-3

| Location | Maximum Intrusion in.* | MASH 2016 Allowable Intrusion in. |
|---|---|---|
| Wheel Well & Toe Pan | – | ≤ 9 |
| Floor Pan & Transmission Tunnel | – | ≤ 12 |
| A-Pillar | – | ≤ 5 |
| A-Pillar (Lateral) | – | ≤ 3 |
| B-Pillar | – | ≤ 5 |
| B-Pillar (Lateral) | – | ≤ 3 |
| Side Front Panel (in Front of A-Pillar) | 13.4 | ≤ 12 |
| Side Door (Above Seat) | – | ≤ 9 |
| Side Door (Below Seat) | – | ≤ 12 |
| Roof | – | ≤ 4 |
| Windshield | – | ≤ 3 |
| Side Window | Shattered due to contact with simulated occupant's head | No shattering resulting from contact with structural member of test article |
| Dash | – | N/A |

*The damage to the vehicle was so severe that post-test vehicle crush measurements were not possible. Instead, the maximum deformation was measured through comparative crush using an undamaged vehicle of the same body style.
N/A – No MASH 2016 criteria exist for this location

## 8.6 Occupant Risk

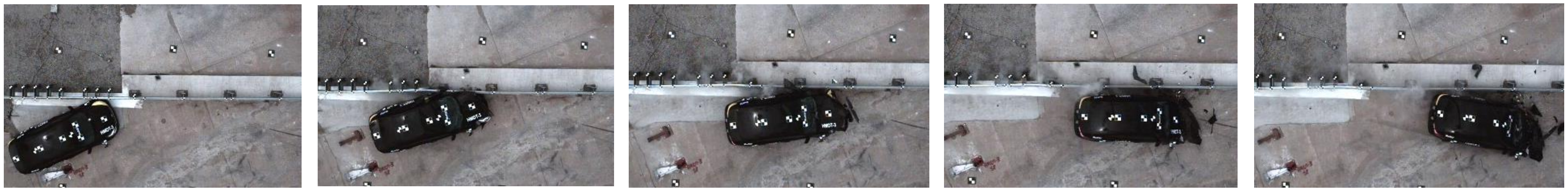
The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined from the accelerometer data, are shown in Table 18. Note that the OIVs and ORAs were within suggested limits, as provided in MASH 2016. The calculated THIV, PHD, and ASI values are also shown in Table 18. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix I.

Table 18. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. HMDT-3

| Evaluation Criteria | | Transducer | | MASH 2016 Limits |
|---|---|---|---|---|
| | | SLICE-1 (primary) | SLICE-2 | |
| **OIV ft/s** | Longitudinal | -33.25 | -33.56 | ±40 |
| | Lateral | 29.24 | 26.79 | ±40 |
| **ORA g's** | Longitudinal | -8.38 | -8.63 | ±20.49 |
| | Lateral | -10.06 | -16.06 | ±20.49 |
| **Max Angular Displacement. deg.** | Roll | -11.2 | 8.7 | ±75 |
| | Pitch | -7.4 | -8.7 | ±75 |
| | Yaw | 52.2 | 51.1 | not required |
| **THIV ft/s** | | 39.62 | 40.62 | not required |
| **PHD g's** | | 10.09 | 16.31 | not required |
| **ASI** | | 2.53 | 2.40 | not required |

## 8.7 Discussion

The analysis of the results for test no. HMDT-3 showed that the modified AGT contained and redirected the 1100C vehicle with controlled lateral displacements of the barrier. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix I, were deemed acceptable, because they did not adversely influence occupant risk nor cause rollover. After impact, the vehicle exited the barrier at an angle of 8.4 degrees, and its trajectory did not violate the bounds of the exit box. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment. However, the left-front wheel was pushed into the toe pan and firewall, which caused a rupture of the floor pan seams and subsequent wheel penetration into the occupant compartment. Additionally, the maximum intrusion measured at the left-side front panel in front of A-pillar was 13⅜ in., which exceeded the MASH 2016 limit of 12 in. Therefore, test no. HMDT-3 was determined to be unacceptable according to the MASH 2016 safety performance criteria for test designation no. 3-20 due to the penetration and excessive toe pan area intrusion. A summary of the test results and sequential photographs are shown in Figure 145.



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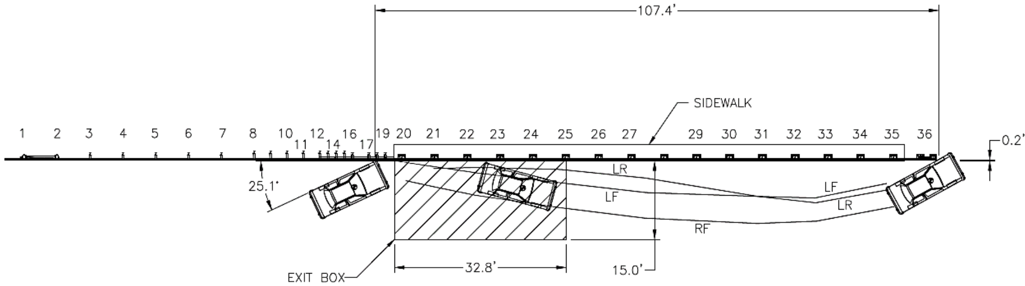
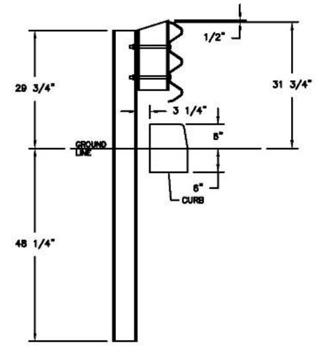



- Test Agency ............ MwRSF
- Test Number ............ HMDT-3
- Date ............ 7/1/2021
- MASH 2016 Test Designation No. ............ 3-20
- Test Article ............ Hawaii Transition to Modified Delaware Retrofit Bridge Rail
- Total Length ............ 177 ft – 6 in.
- Key Component – Thrie-Beam Guardrail
  - Thickness ............ 12 ga.
  - Length ............ 12.5 ft (nested), and 6.25 ft (single ply)
- Key Component – W6x15 Steel Posts
  - Length ............ 78 in.
  - Embedment Depth ............ 48½ in., 48⅜ in, $48^{5}/_{16}$ in., $48^{3}/_{16}$ in. (post nos. 16-19)
  - Spacing ............ 37½ in., 18¾ in.
- Soil Type ............ Coarse, Crushed, Limestone (Well-Graded Gravel)
- Vehicle Make /Model ............ 2016 Kia Rio
  - Curb ............ 2,542 lb
  - Test Inertial ............ 2,430 lb
  - Gross Static ............ 2,585 lb
- Impact Conditions
  - Speed ............ 62.3 mph
  - Angle ............ 25.1 degrees
  - Impact Location ............ 1.5 in. downstream from post no. 18
- Impact Severity ............ 56.7 kip-ft > 51.1 kip-ft limit from MASH 2016
- Exit Conditions
  - Speed ............ 35.4 mph
  - Angle ............ 8.4 degrees
- Exit Box Criterion ............ Pass
- Vehicle Stability ............ Satisfactory
- Vehicle Stopping Distance ............ 107.4 ft. downstream and 0.2 ft laterally in front
- Vehicle Damage ............ Moderate
  - VDS [15] ............ 10-LFQ-6
  - CDC [16] ............ 10-LFEW-4
  - Maximum Interior Deformation .... 13.4 in. ≥ 12 in. MASH 2016 limit for side panel
  - Test Article Damage ............ Minimal
- Maximum Test Article Deflections
  - Permanent Set ............ 2.0 in.
  - Dynamic ............ 3.7 in.
  - Working Width ............ 20.9 in.
- Transducer Data

| Evaluation Criteria | | Transducer | | MASH 2016 Limits |
|---|---|---|---|---|
| | | SLICE-1 | SLICE-2 (primary) | |
| OIV ft/s | Longitudinal | -33.25 | -33.56 | ±40 |
| | Lateral | 29.24 | 26.79 | ±40 |
| ORA g's | Longitudinal | -8.38 | -8.63 | ±20.49 |
| | Lateral | -10.06 | -16.06 | ±20.49 |
| Maximum Angular Displacement deg. | Roll | -11.2 | 8.7 | ±75 |
| | Pitch | -7.4 | -8.7 | ±75 |
| | Yaw | 52.2 | 51.1 | not required |
| THIV – ft/s | | 39.62 | 40.62 | not required |
| PHD – g's | | 10.09 | 16.31 | not required |
| ASI | | 2.53 | 2.40 | not required |

Figure 145. Summary of Test Results and Sequential Photographs, Test No. HMDT-3

# 9 DESIGN MODIFICATIONS – ROUND 2

As previously described, test no. HMDT-3 did not pass the MASH 2016 safety performance criteria for test designation no. 3-20 due to the excessive side front panel deformation and vehicle component penetration of the occupant compartment. During the test, the bottom rail corrugation of the nested thrie beam AGT rails were flattened and formed a sharp kink adjacent to the first bridge rail post (i.e., post no. 20), as shown previously in Figures 137 through 139. These localized rail deformations resulted in the front wheel snagging on the bridge rail post and being pushed toward the occupant compartment. Thus, the AGT rail segments adjacent to the bridge rail post needed to be reinforced against localized deformations (flattening and kinking) to mitigate wheel snag and the corresponding occupant compartment deformation.

To increase the stiffness of the thrie-beam rail, a 43¼-in. long x 16-in. wide x ⅜-in. thick ASTM A36 steel plate was added to the back side of the nested thrie-beam rail between the last transition post and the first bridge rail post. This back-up plate extended from the upstream edge of the transition post (post no. 19) to ¼ in. short of the downstream edge of the bridge rail post's flange. This ¼-in. longitudinal offset from the edge of the post was designed to avoid vehicle snag on that edge during reverse-direction impacts. The plate was attached to the front flange of the bridge rail post using two ⅝-in. diameter by 10-in. long guardrail bolts with heavy hex nuts and plain washers through the existing holes. Note, this attachment used the existing holes in the post and the same attachment bolt as the adjacent transition post. Similarly, the plate was attached to the downstream side of the steel blockout and transition post using the existing attachment bolt. The plate was also connected to the nested thrie-beam rails using two splice bolts (i.e., ⅝-in. diameter by 2-in. long guardrail bolts with heavy hex nuts and plain washers) at the existing slots in the rail section at mid-span. The finalized AGT design is detailed in Figures 146 through 181. Photographs of the test installation are shown in Figures 182 and 183. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix J.

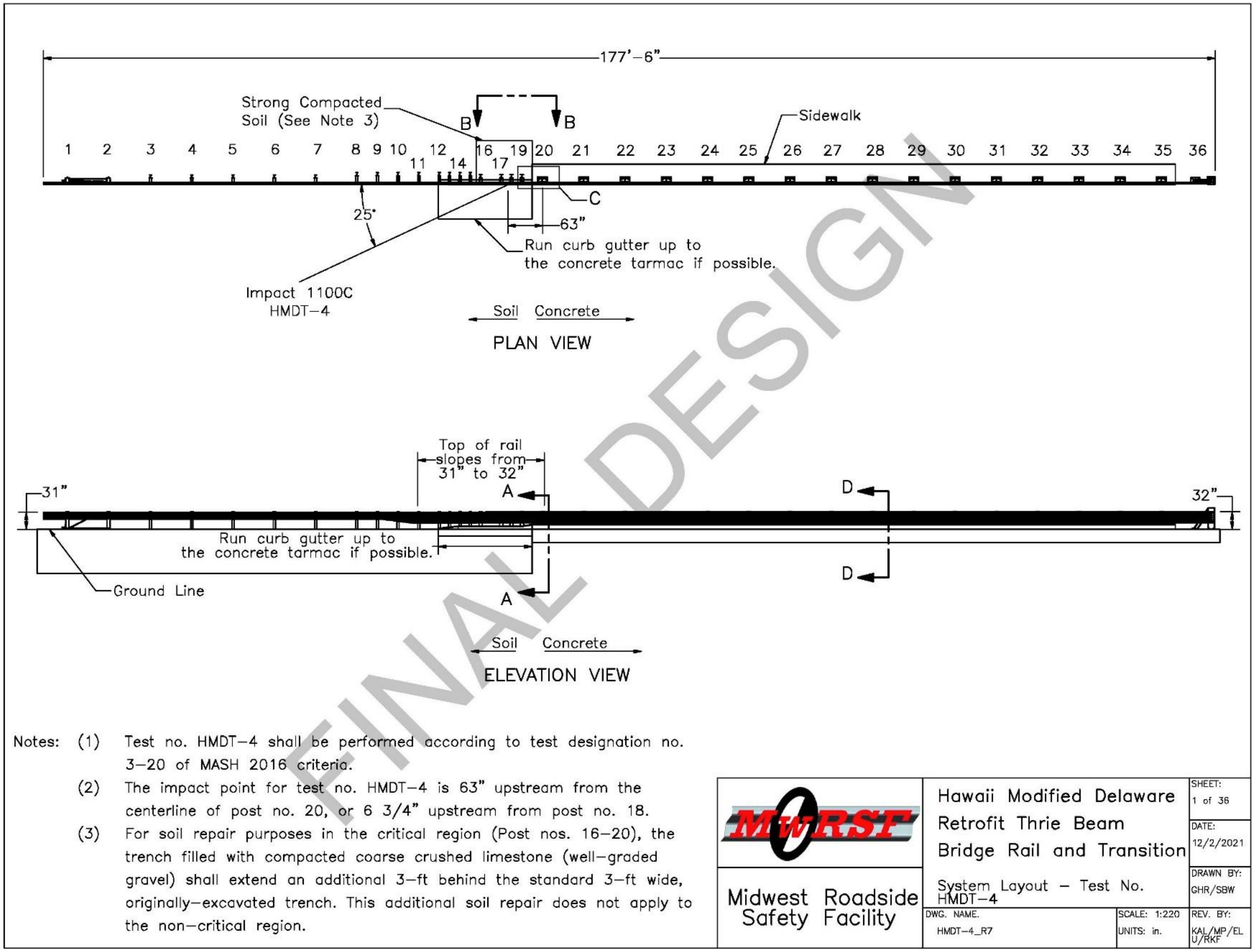



Figure 146. Test Installation Layout, Test No. HMDT-4

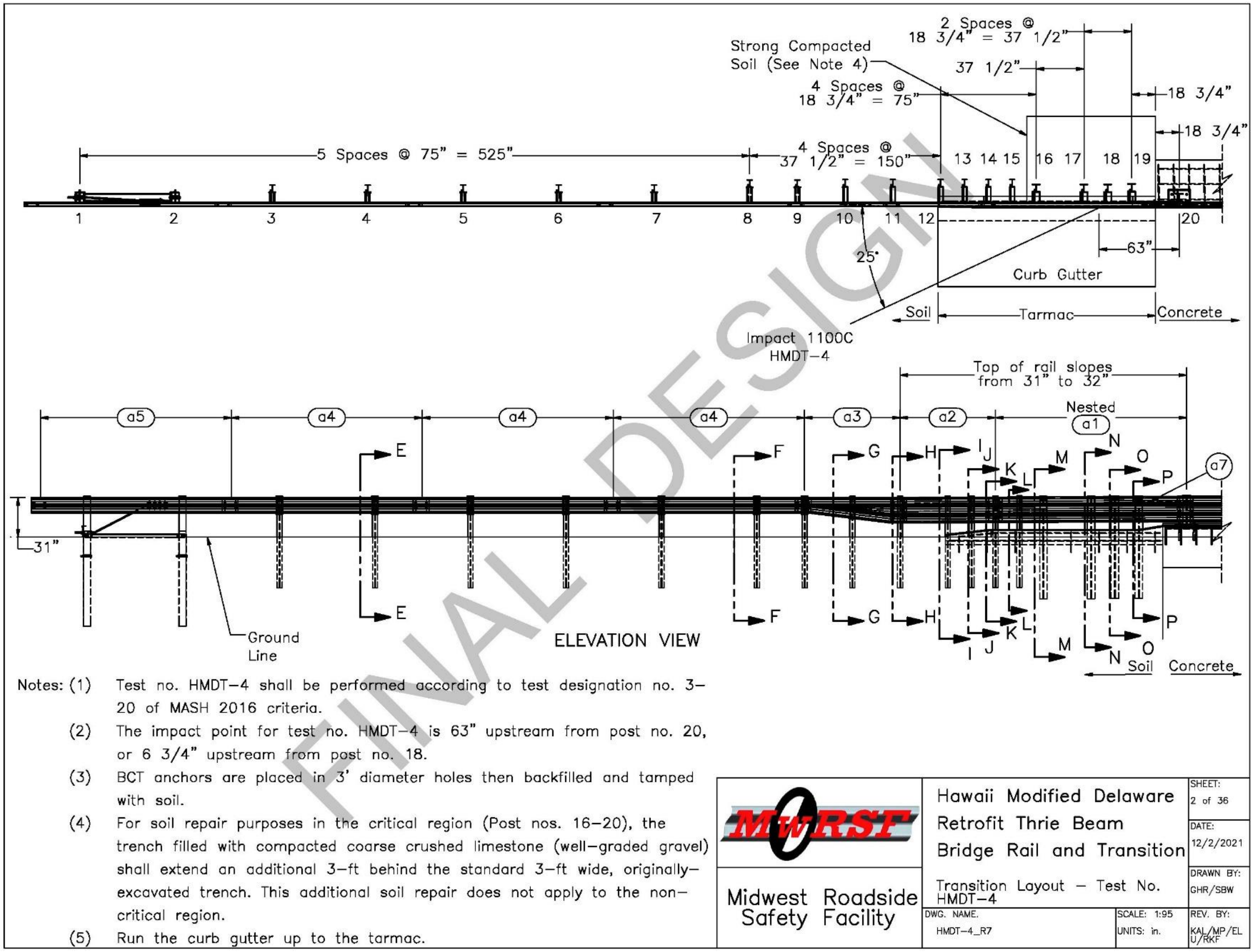
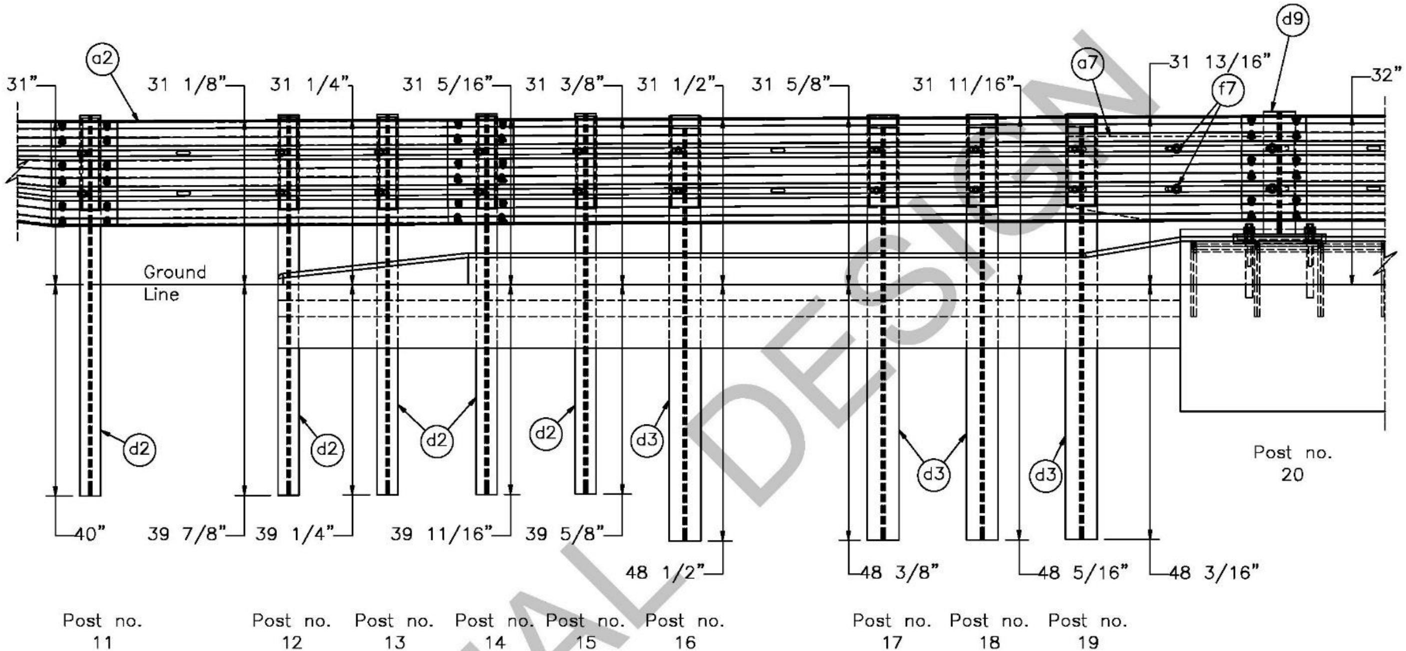



Figure 147. Transition Layout, Test No. HMDT-4




Notes:
(1) Curb reinforcement is hidden for clarity.
(2) Rail height dimensions occur at the center of each post.
(3) Run the curb gutter up to the concrete tarmac if possible. Recommend similar thickness as curb depth underground.
(4) Nut (Part h1) and washer (Part g1) placed on the backside of the bolts (Part f7) attaching the transition back-up plate (Part a7) to the guardrail (Part a2).

| | | | |
|---|---|---|---|
| MwRSF Midwest Roadside Safety Facility | Hawaii Modified Delaware Retrofit Thrie Beam Bridge Rail and Transition | | SHEET: 3 of 36 |
| | | | DATE: 12/2/2021 |
| | Post Nos. 11–20 Embedment Depths and Rail Heights | | DRAWN BY: GHR/SBW |
| | DWG. NAME. HMDT–4_R7 | SCALE: 1:28 UNITS: in. | REV. BY: KAL/MP/EL U/RKF |

Figure 148. Post Nos. 11-20 Embedment Depths and Rail Heights, Test No. HMDT-4

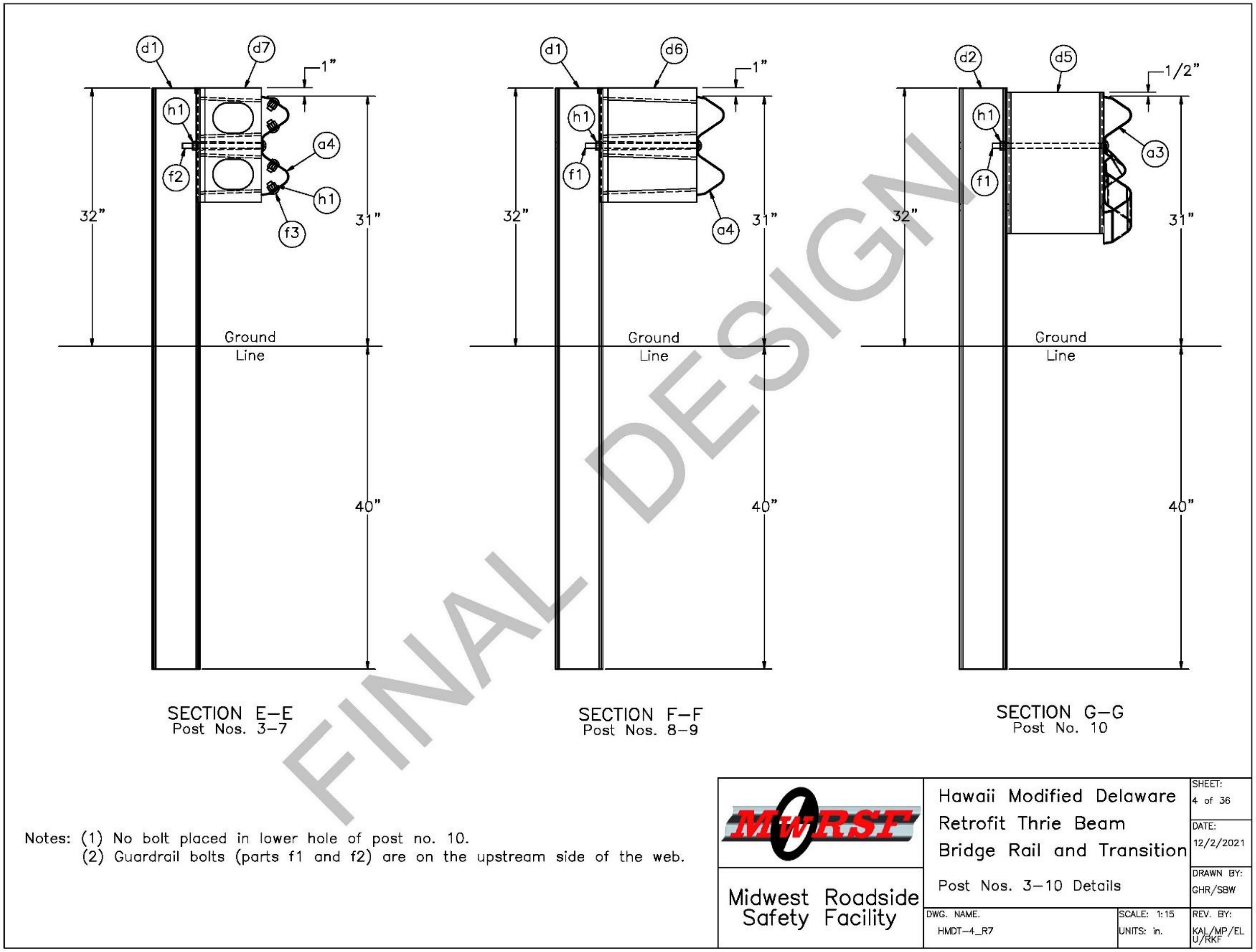



Figure 149. Post Nos. 3 through 10 Details, Test No. HMDT-4

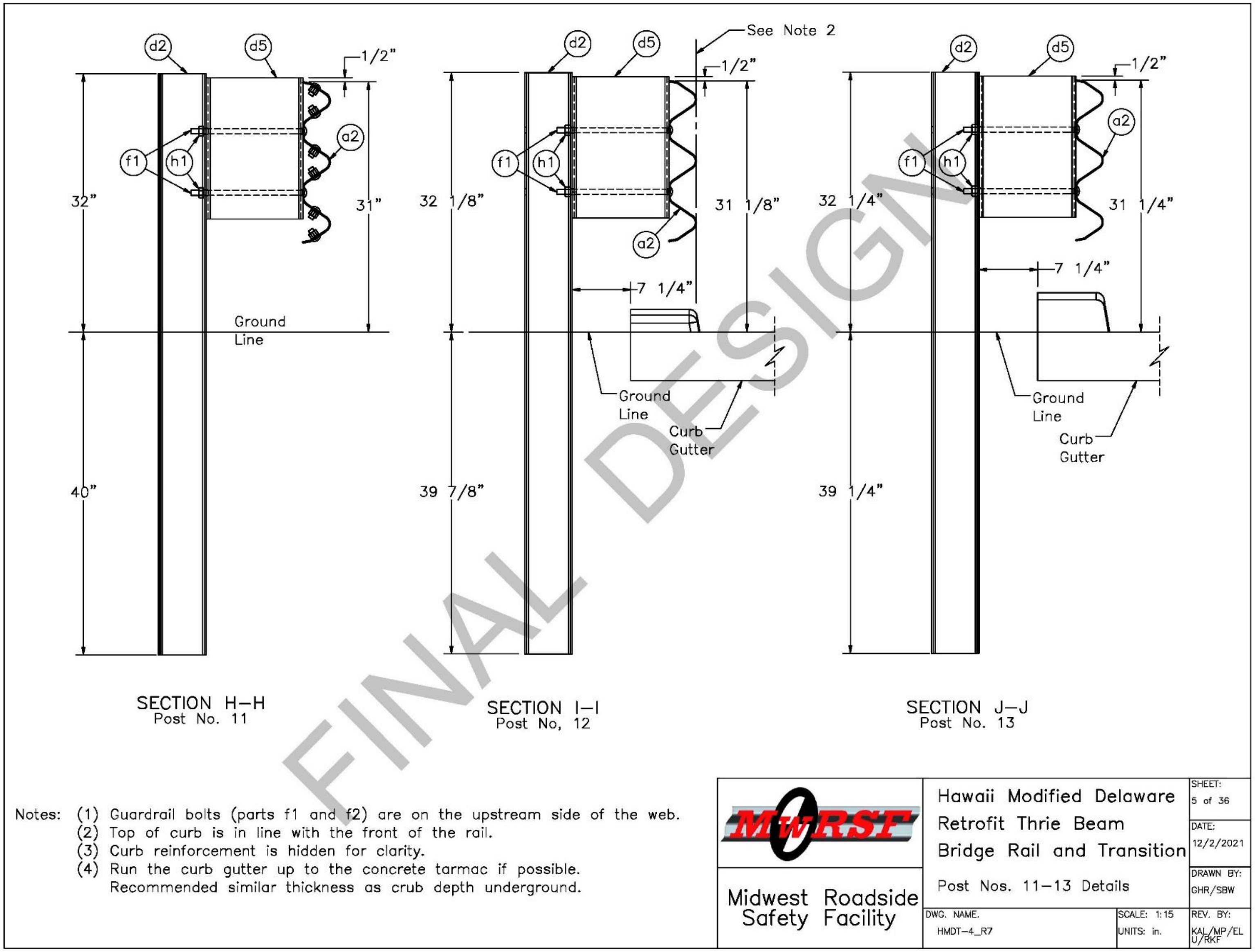



Figure 150. Post Nos. 11 through 13 Details, Test No. HMDT-4

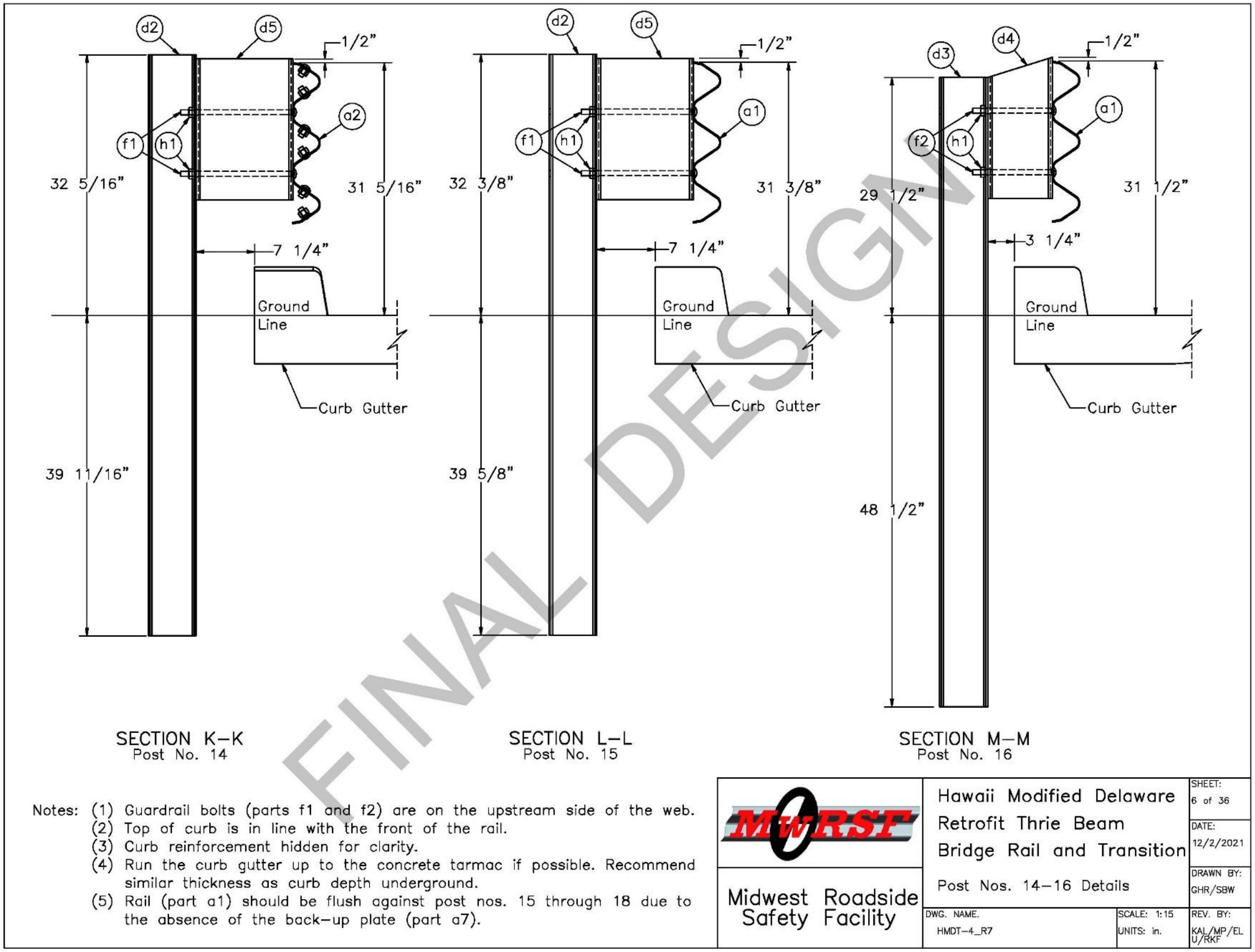



Figure 151. Post Nos. 14 through 16 Details, Test No. HMDT-4

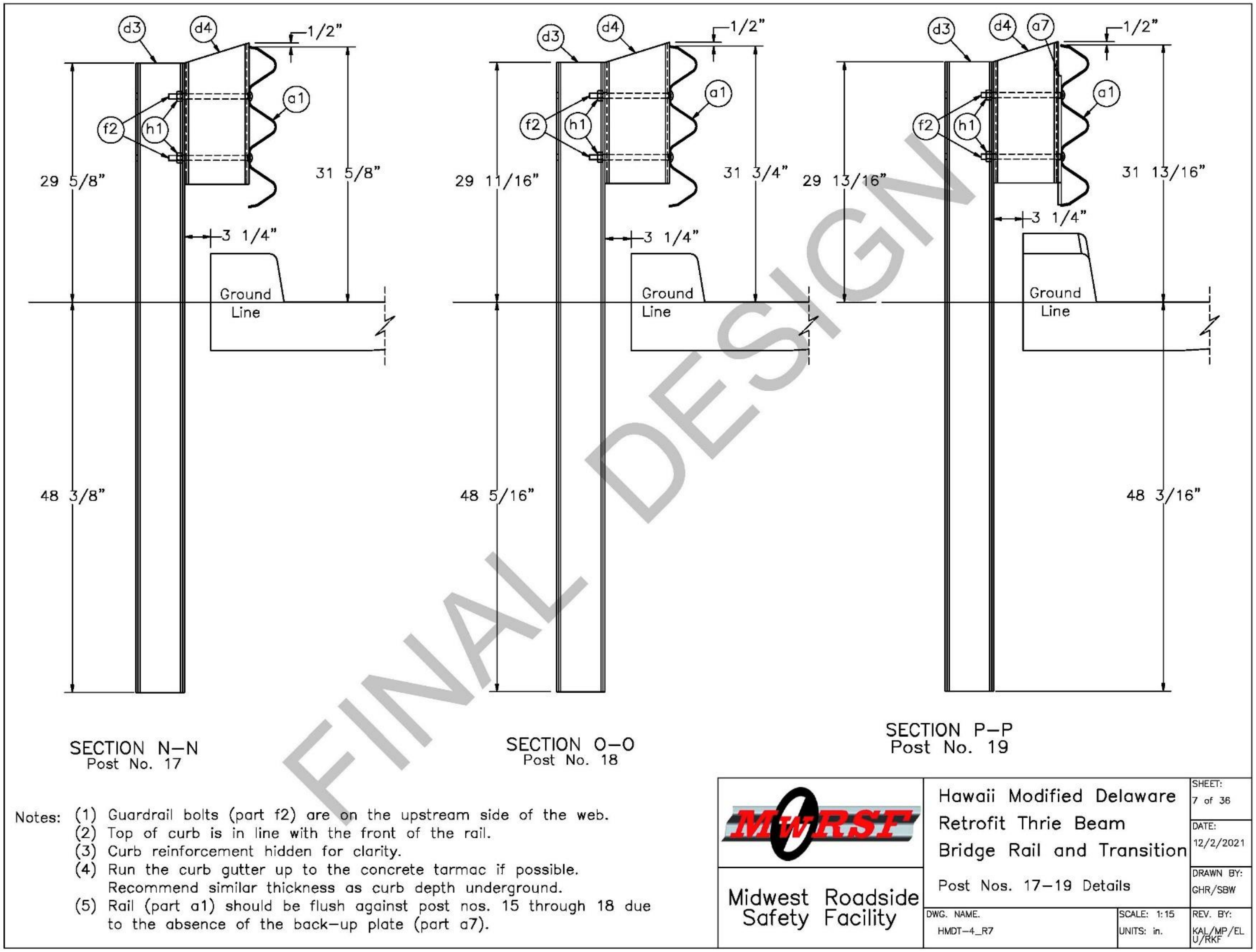



Figure 152. Post Nos. 17 through 19 Details, Test No. HMDT-4

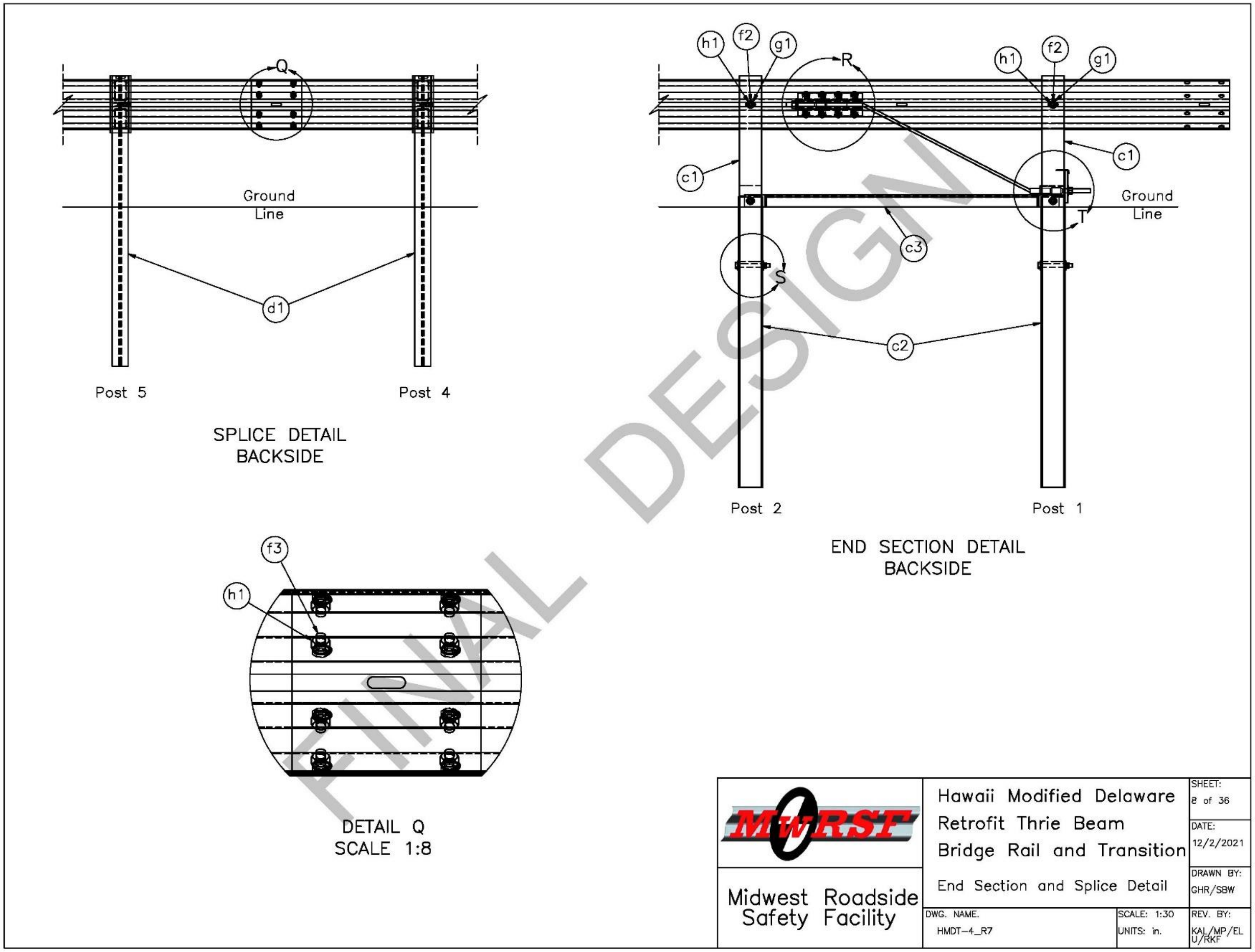



Figure 153. End Section and Splice Detail, Test No. HMDT-4

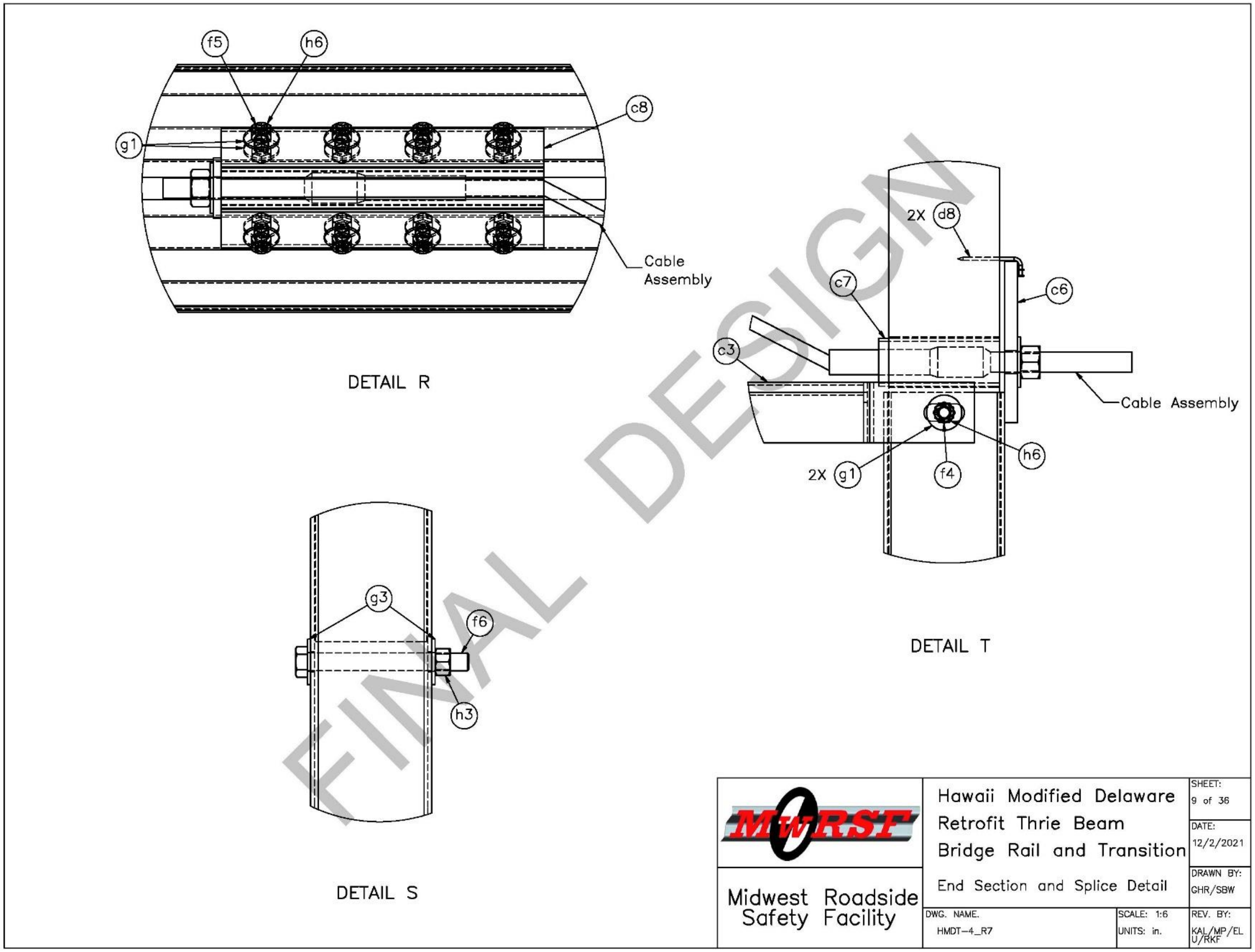



Figure 154. End Section and Splice Detail, Test No. HMDT-4

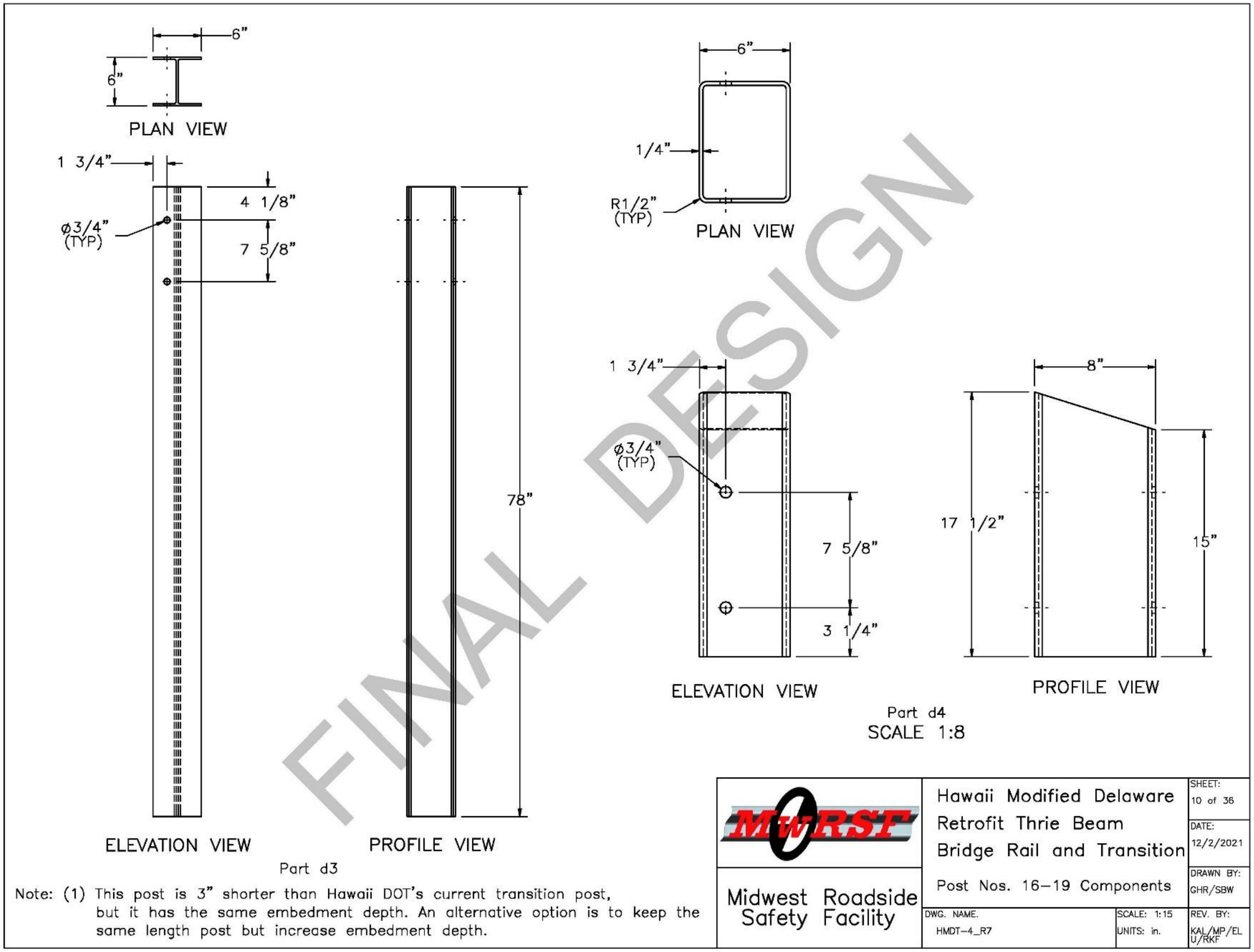



Figure 155. Post Nos. 16 through 19 Components, Test No. HMDT-4

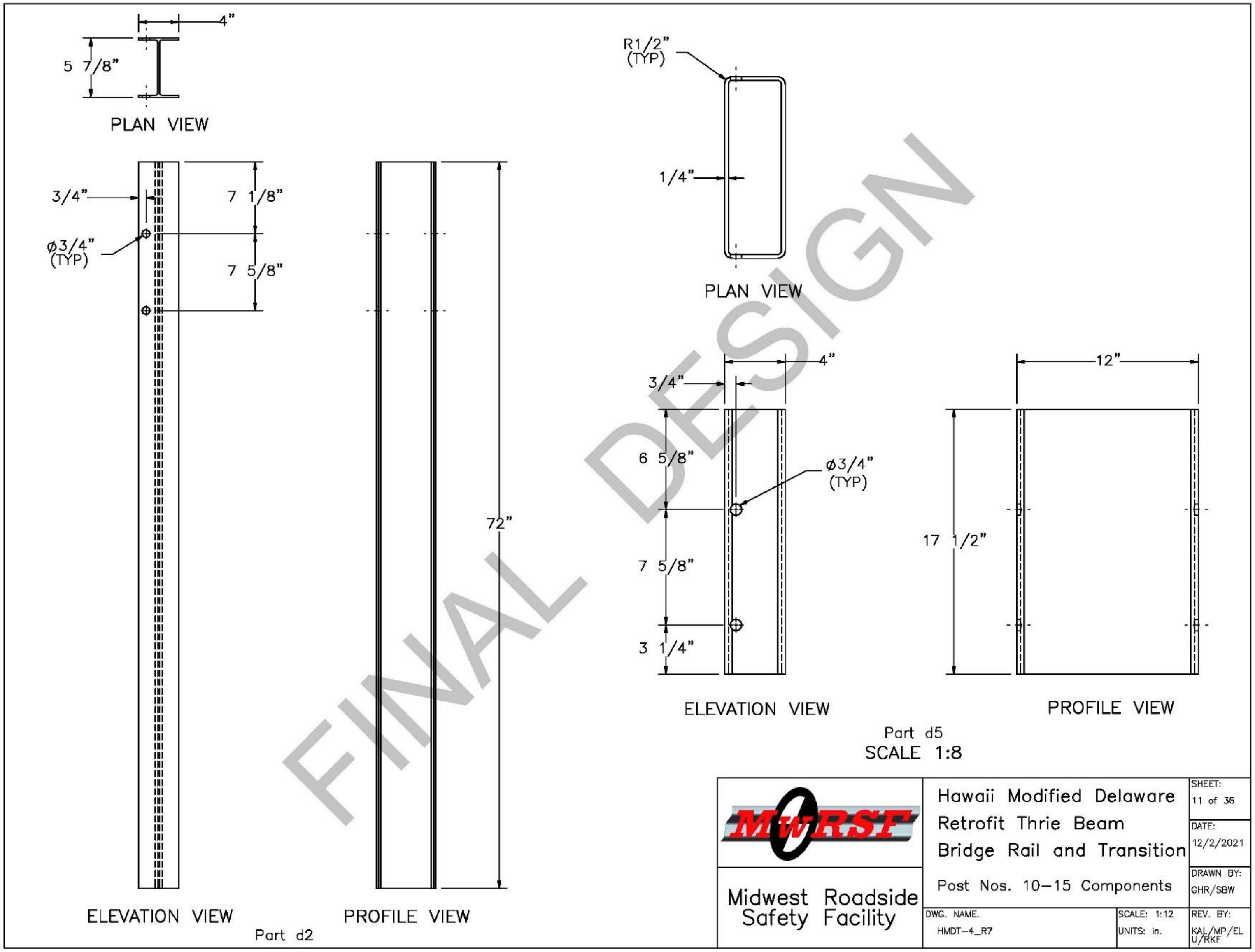



Figure 156. Post Nos. 10 through 15 Components, Test No. HMDT-4

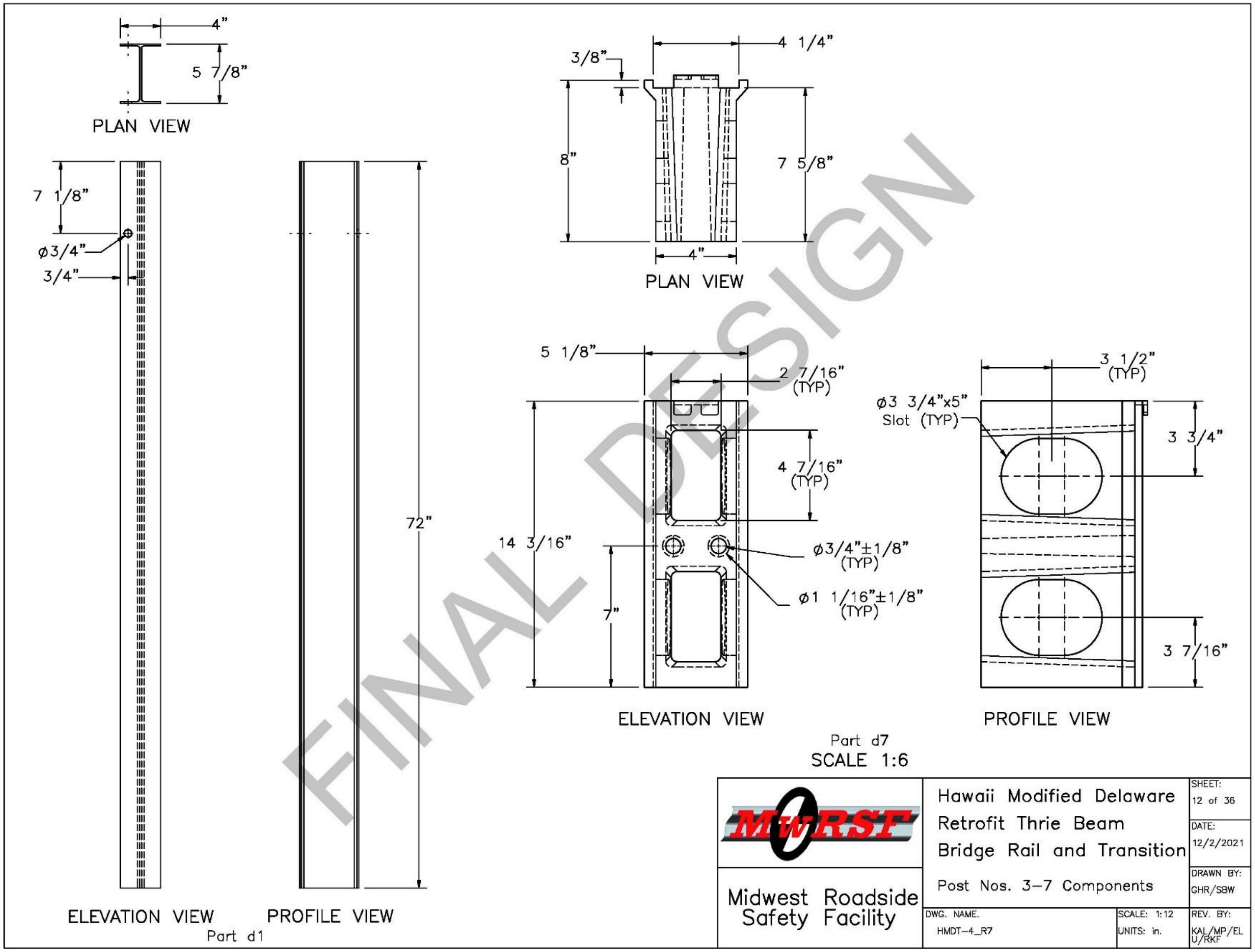



Figure 157. Post Nos. 3 through 7 Components, Test No. HMDT-4

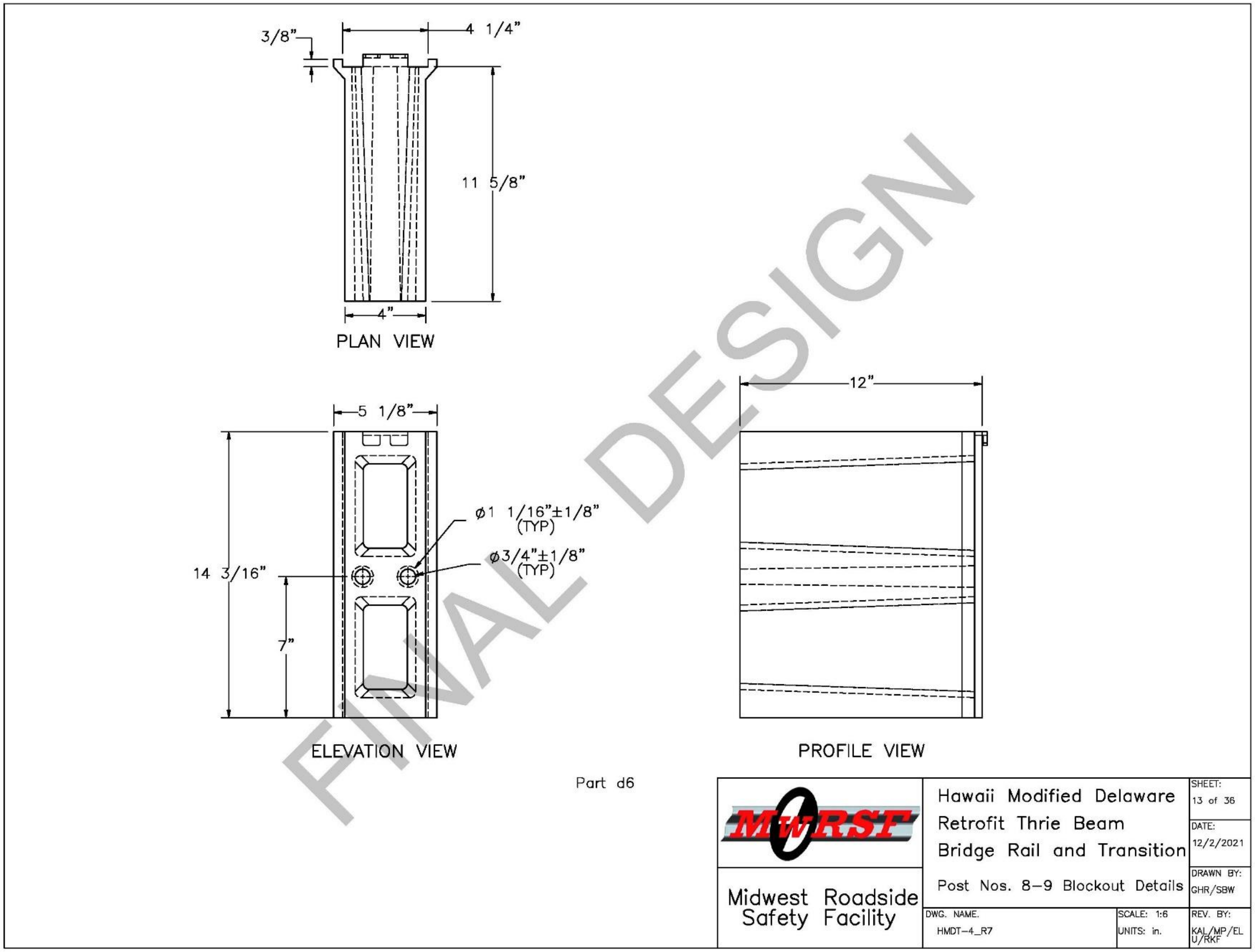



Figure 158. Post Nos. 8 and 9 Blockout Details, Test No. HMDT-4

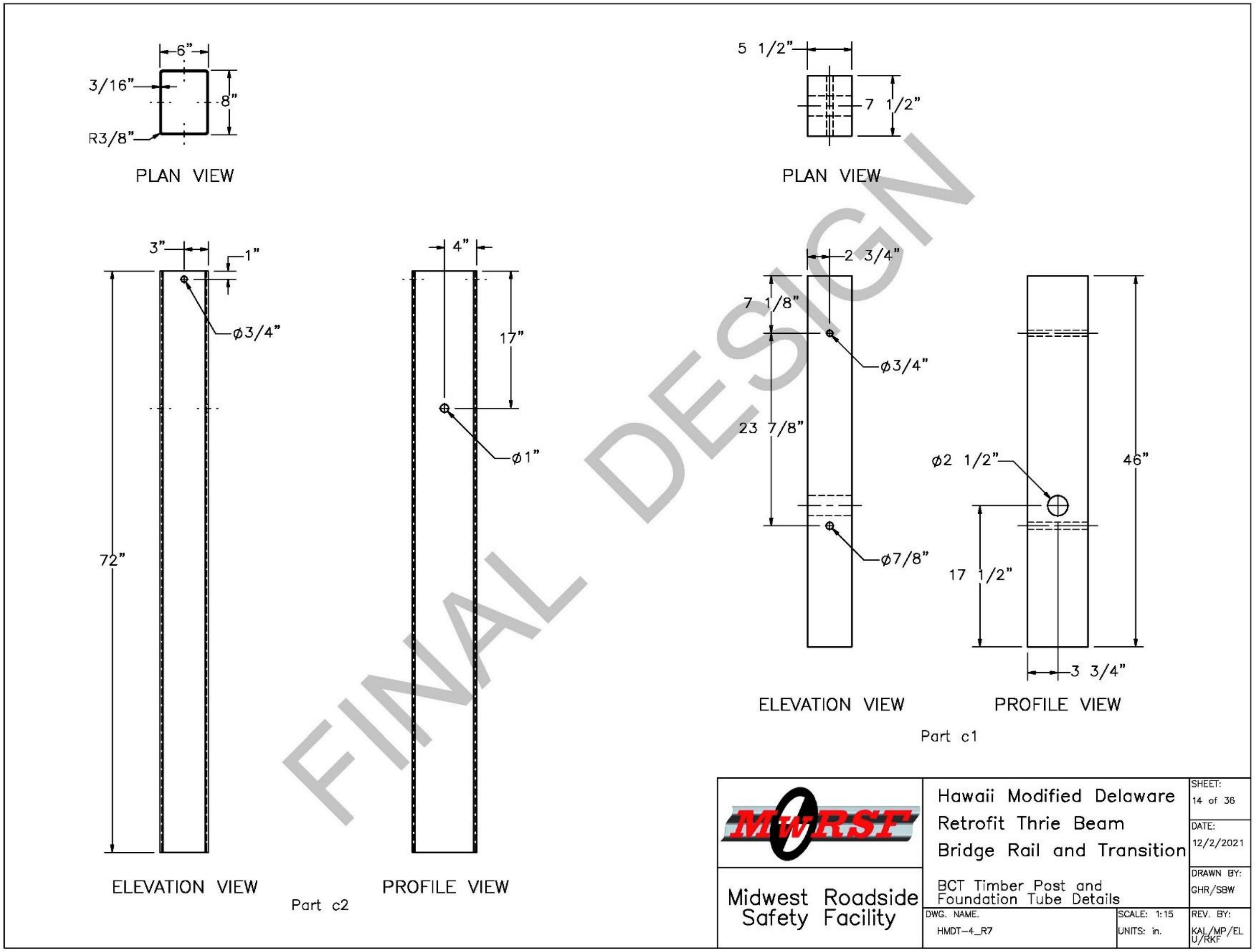



Figure 159. BCT Timber Post and Foundation Tube Details, Test No. HMDT-4

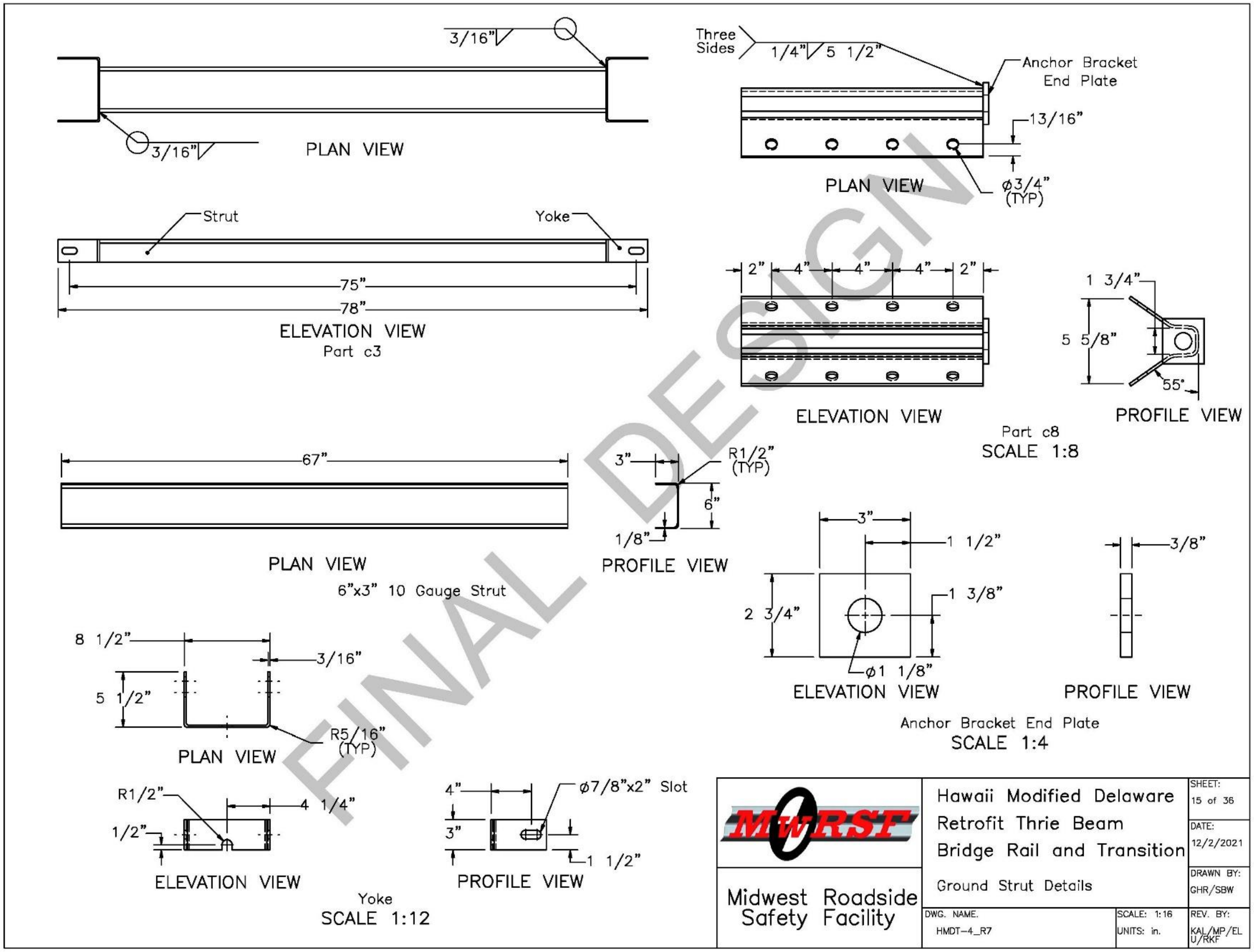
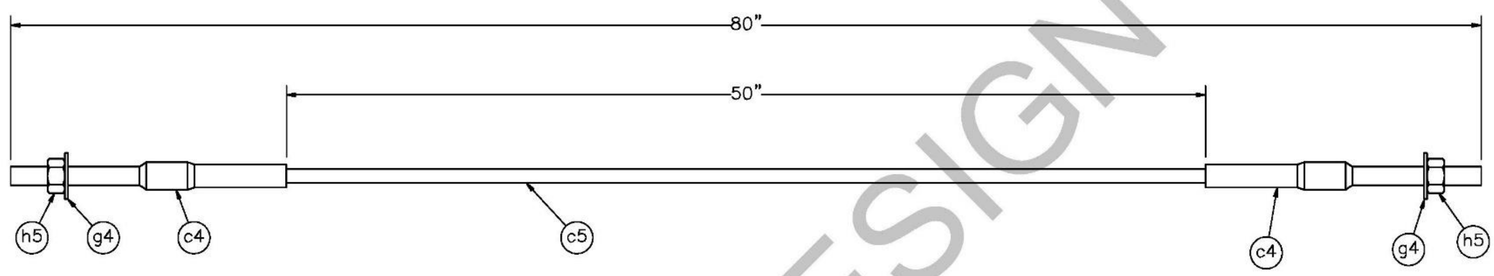



Figure 160. Ground Strut Details, Test No. HMDT-4






| Item No. | QTY. | Description | Material Specification | Treatment Specification | Hardware Guide |
|---|---|---|---|---|---|
| – | 1 | Cable Assembly | – | – | FCA01 |
| c4 | 2 | BCT Anchor Cable End Swaged Fitting | Fitting – ASTM A576 Gr. 1035<br>Stud – ASTM F568 Class C | Fitting – ASTM A153<br>Stud – ASTM A153 or B695 | – |
| c5 | 1 | 3/4" Dia. 6x19 IWRC IPS Wire Rope | ASTM A741 Type 2 | Class A Coating | – |
| h5 | 2 | 1"–8 UNC Heavy Hex Nut | ASTM A563DH or equivalent | ASTM A153 or B695 Class 55 or F2329 | FNX24b |
| g4 | 2 | 1" Dia. Plain USS Washer | ASTM F844 | ASTM A123 or A153 or F2329 | FWC24a |

Midwest Roadside Safety Facility

Hawaii Modified Delaware Retrofit Thrie Beam Bridge Rail and Transition

BCT Anchor Cable

| SHEET: | DATE: | DRAWN BY: | DWG. NAME. | SCALE: | UNITS: | REV. BY: |
|---|---|---|---|---|---|---|
| 16 of 36 | 12/2/2021 | GHR/SBW | HMDT-4_R7 | 1:8 | in. | KAL/MP/EL U/RKF |

Figure 161. BCT Anchor Cable, Test No. HMDT-4

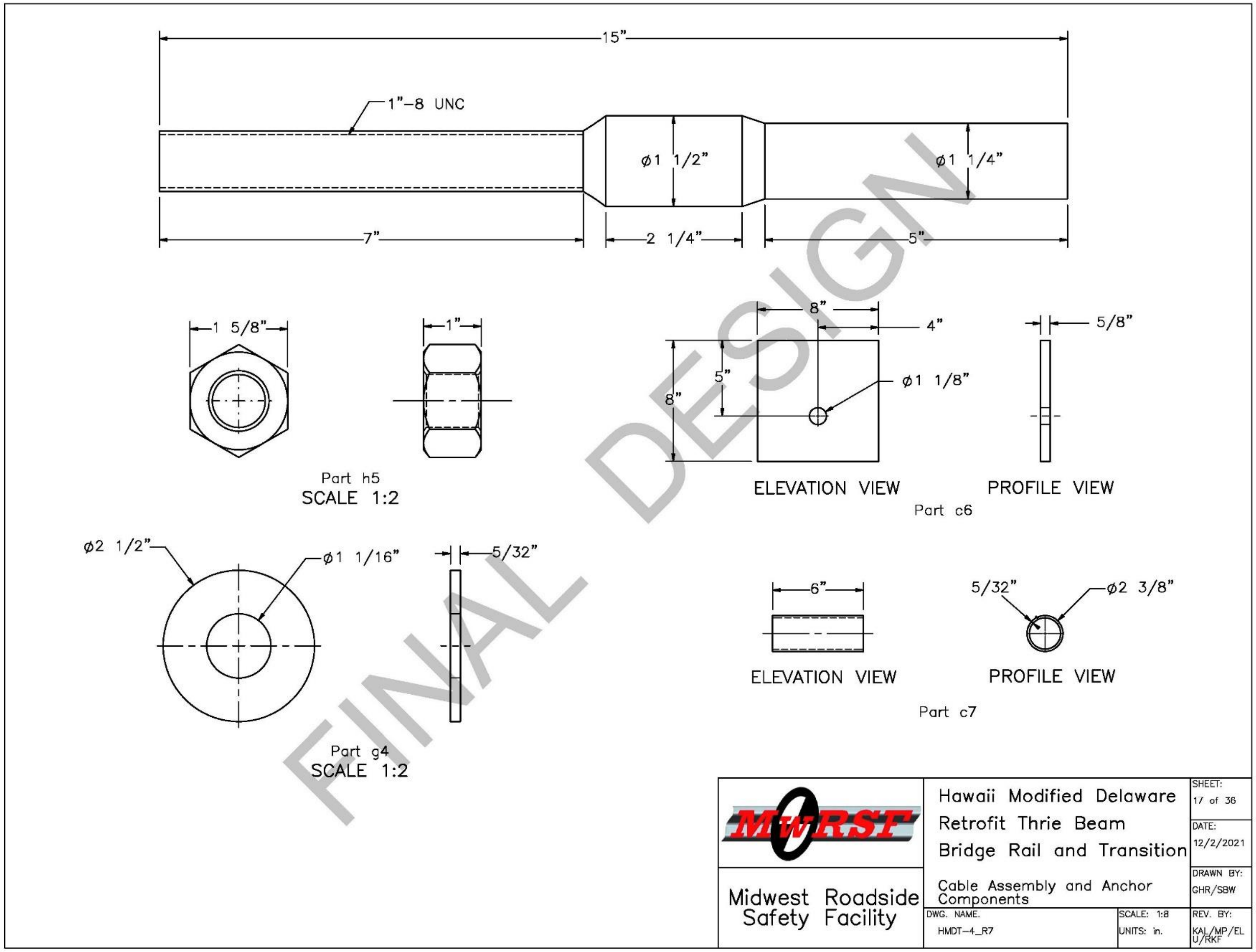



Figure 162. Cable Assembly and Anchor Components, Test No. HMDT-4

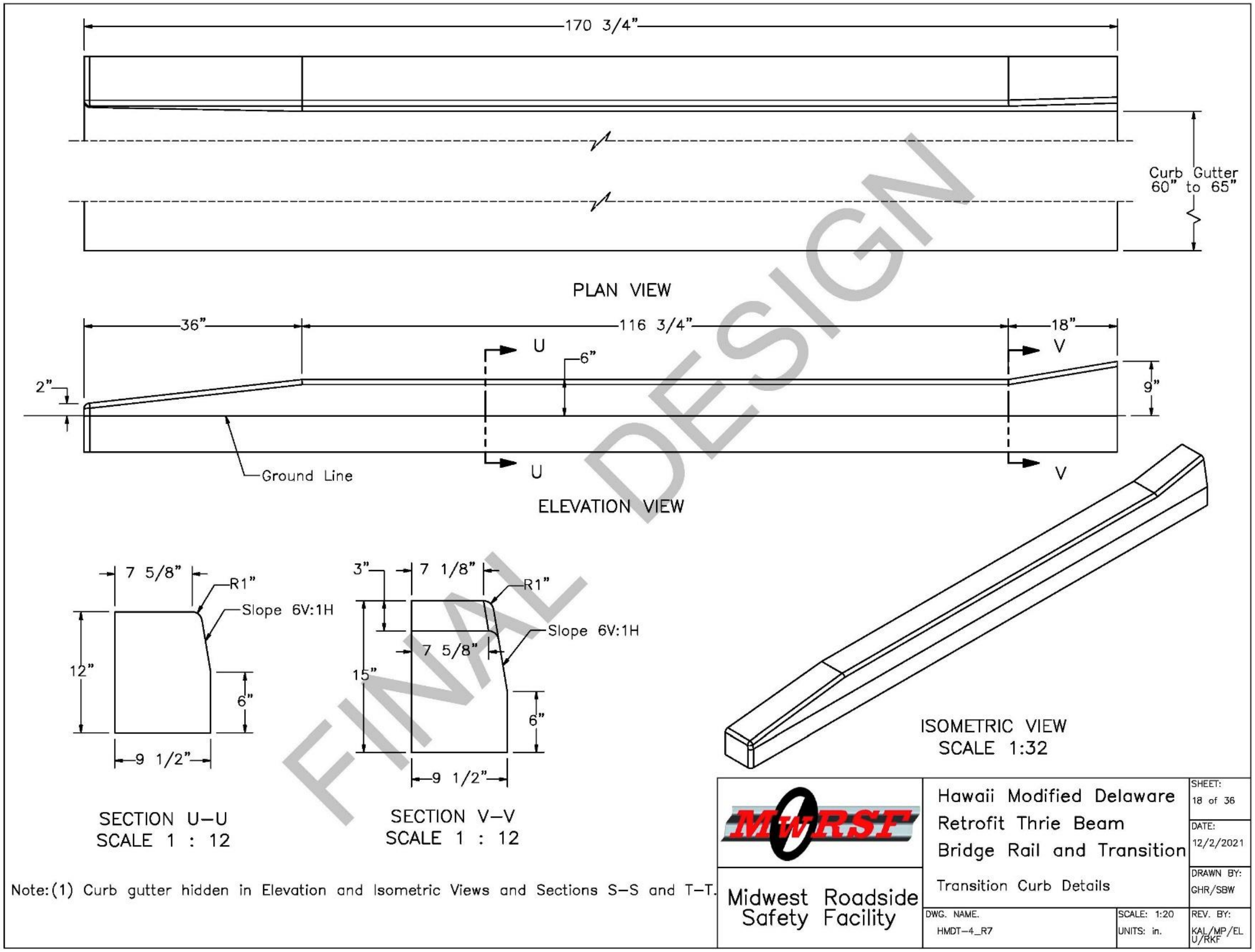



Figure 163. Transition Curb Details, Test No. HMDT-4

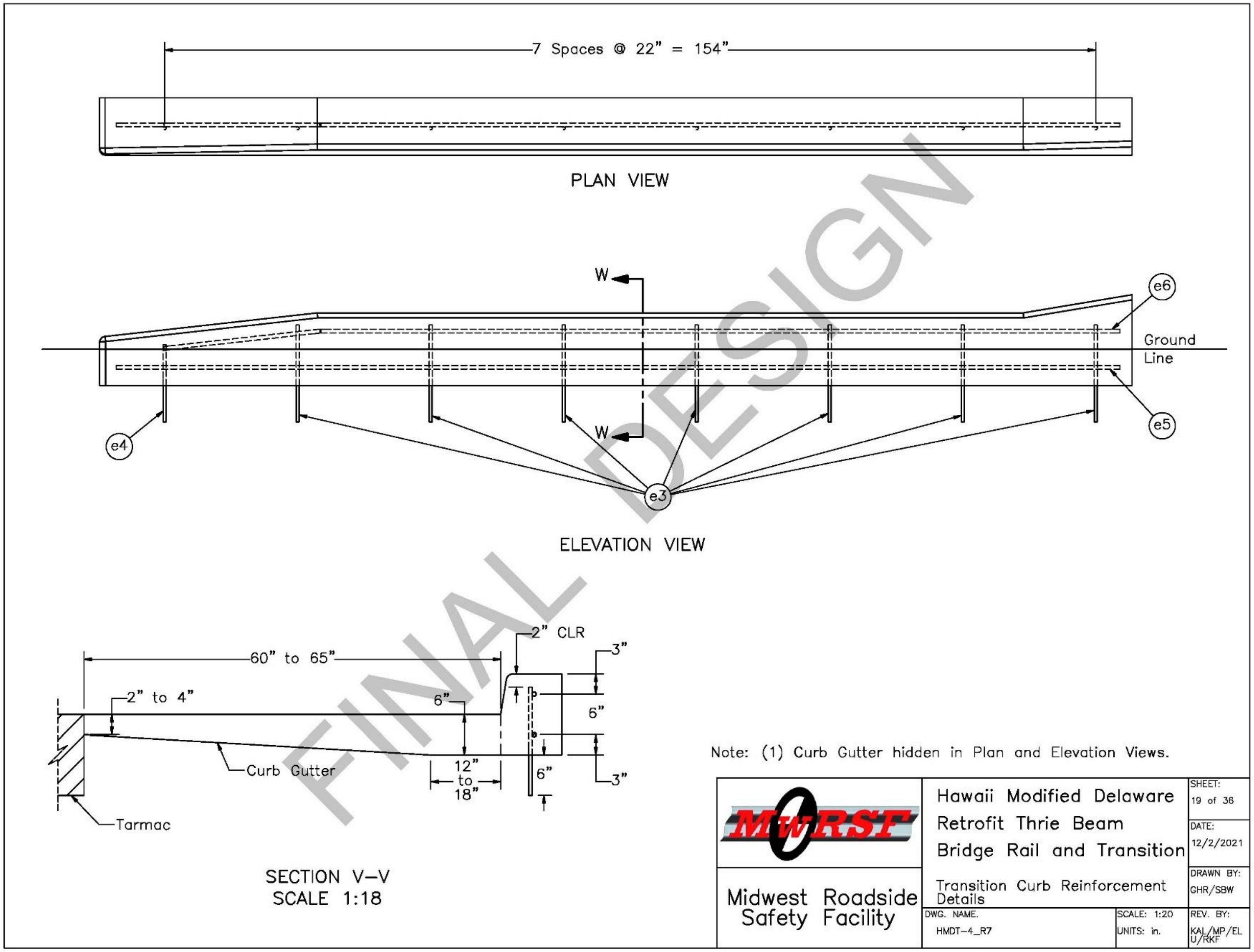
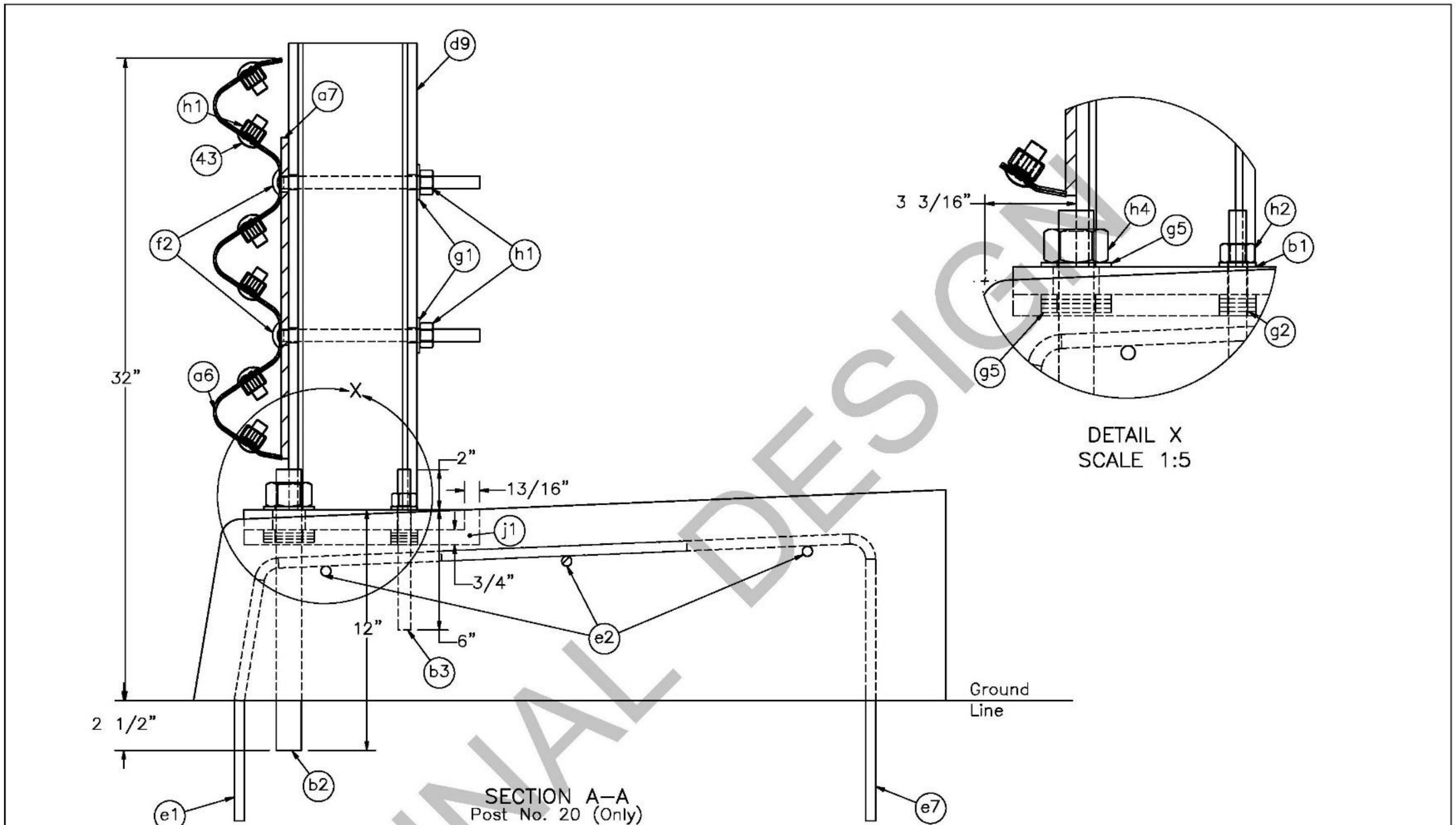



Figure 164. Transition Curb Reinforcement Details, Test No. HMDT-4




Notes: (1) Base plate (part b1) should be counter sunk into the sidewalk, slightly over sized, then backfilled with epoxy grout (part k2).
(2) Epoxy grout used to backfill post cavites should be in compliance with ASTM C881 Type IV, Grade I, Class C.
(3) Add washers (parts g2 and g5) to level base plates.
(4) Anchor rods (parts b2 and b3) should be epoxied into the concrete sidewalk and concrete tarmac.
(5) Rebar (parts e1 and e7) should be epoxied into concrete tarmac for a minimum depth of 6".
(6) Anchors and rebar should be epoxied with Hilti HIT RE–500 V3 (part k1) or equivalent, in compliance with Class C, C881.
(7) Tarmac is hidden in Section A–A.

| | | |
|---|---|---|
| Midwest Roadside Safety Facility | Hawaii Modified Delaware Retrofit Thrie Beam Bridge Rail and Transition | SHEET: 20 of 36 |
| | | DATE: 12/2/2021 |
| | Bridge Rail Post No. 20 Details | DRAWN BY: GHR/SBW |
| | DWG. NAME. HMDT–4_R7 | SCALE: 1:7 UNITS: in. | REV. BY: KAL/MP/EL U/RKF |

Figure 165. Bridge Rail Post No. 20 Details, Test No. HMDT-4

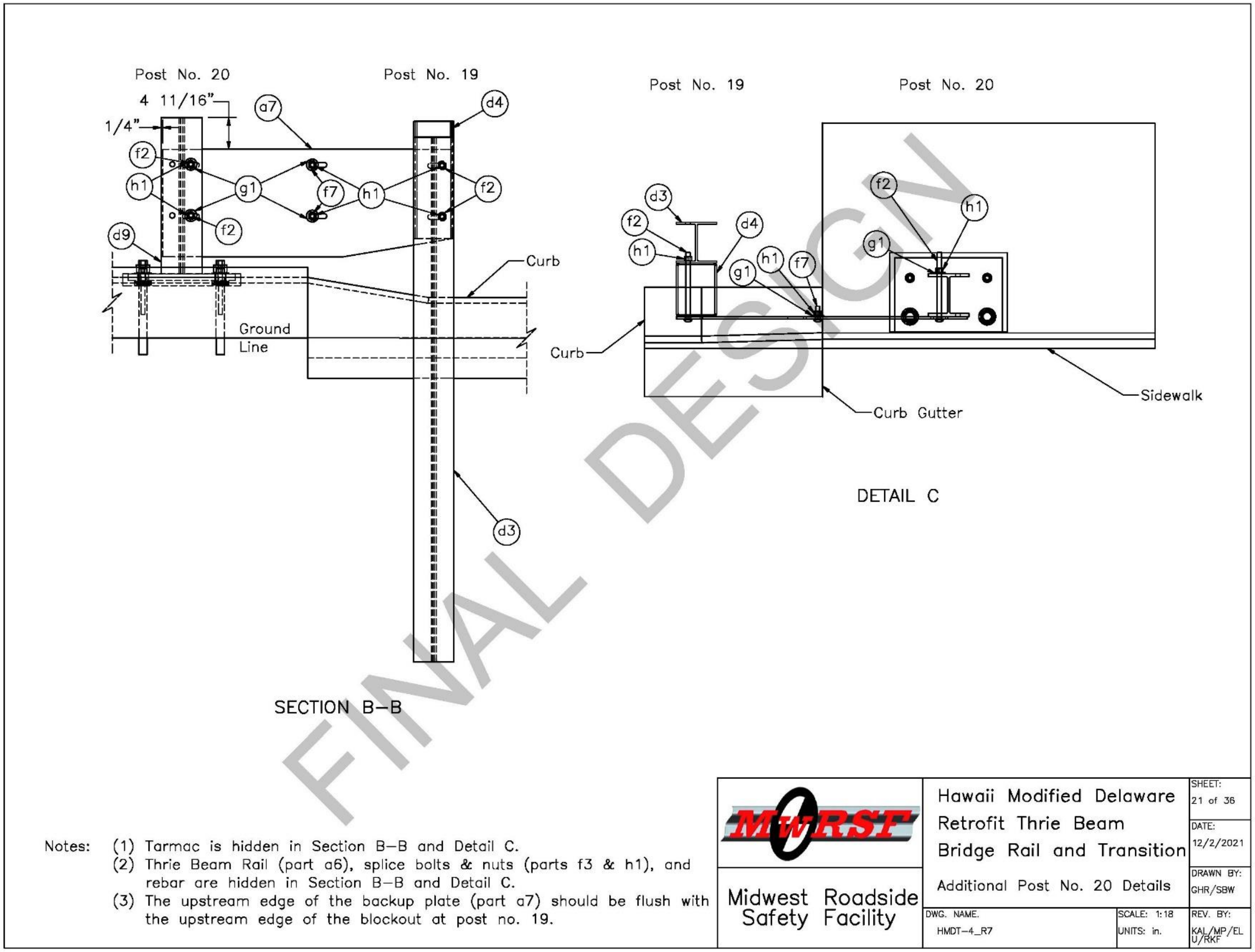
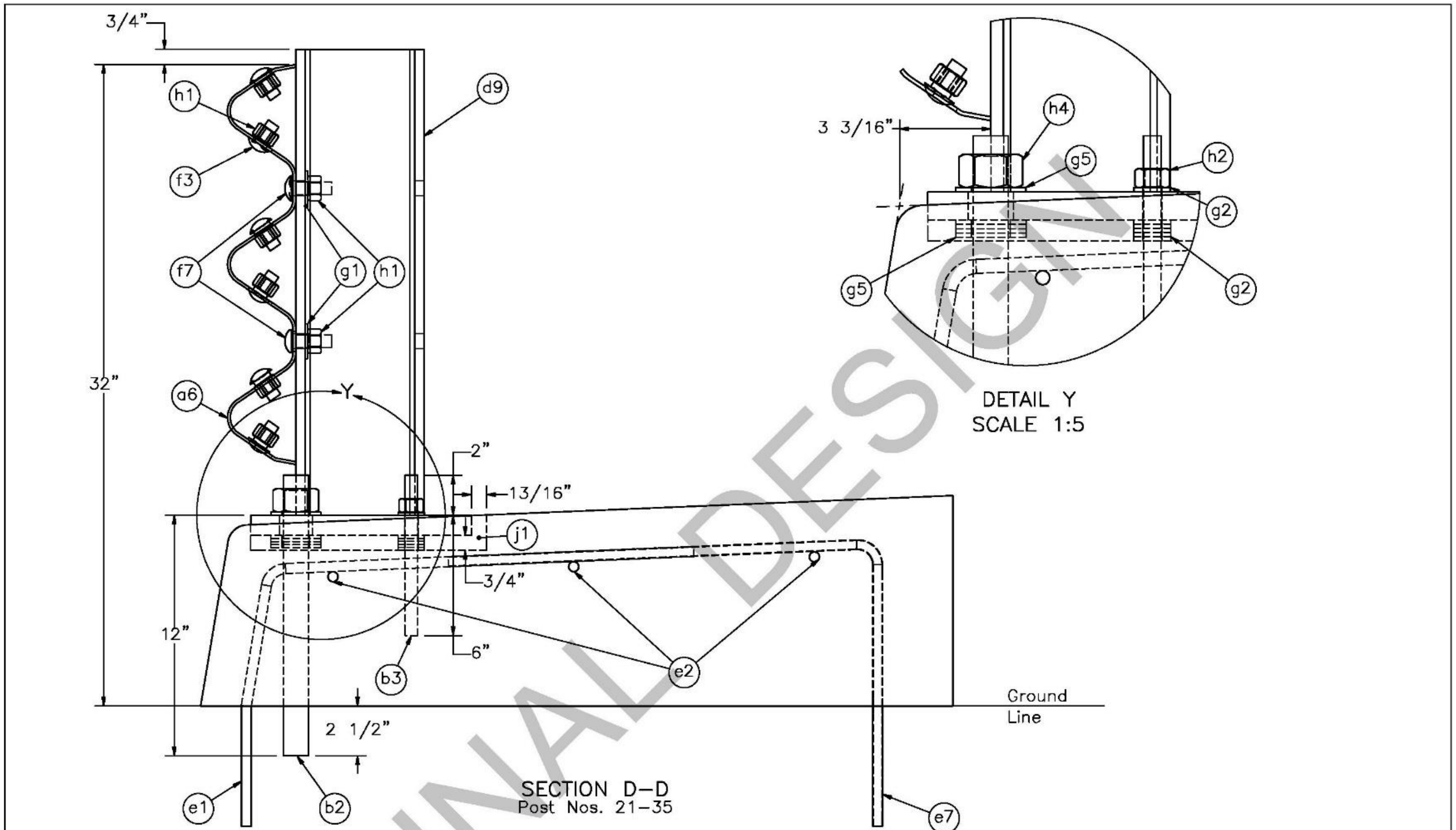



Figure 166. Additional Post No. 20 Details, Test No. HMDT-4




Notes:
(1) Base plate (part b1) should be counter sunk into the sidewalk, slightly over sized, then backfilled with epoxy grout (part k2).
(2) Epoxy grout used to backfill post cavites should be in compliance with ASTM C881 Type IV, Grade I, Class C.
(3) Add washers (parts g2 and g5) to level base plates.
(4) Anchor rods (parts b2 and b3) should be epoxied into the concrete sidewalk and concrete tarmac.
(5) Rebar (parts e1 and e7) should be epoxied into concrete tarmac for a minimum depth of 6".
(6) Anchors and rebar should be epoxied with Hilti HIT RE-500 V3 (part k1) or equivalent, in compliance with Class C, C881.
(7) Tarmac is hidden in Section D–D.

| | | |
|---|---|---|
| Midwest Roadside Safety Facility | Hawaii Modified Delaware Retrofit Thrie Beam Bridge Rail and Transition | SHEET: 22 of 36 |
| | | DATE: 12/2/2021 |
| | Bridge Rail Post Nos. 21–35 Details | DRAWN BY: GHR/SBW |
| | DWG. NAME. HMDT-4_R7 / SCALE: 1:7 / UNITS: in. | REV. BY: KAL/MP/EL U/RKF |

Figure 167. Bridge Rail Post Nos. 21 through 35 Details, Test No. HMDT-4

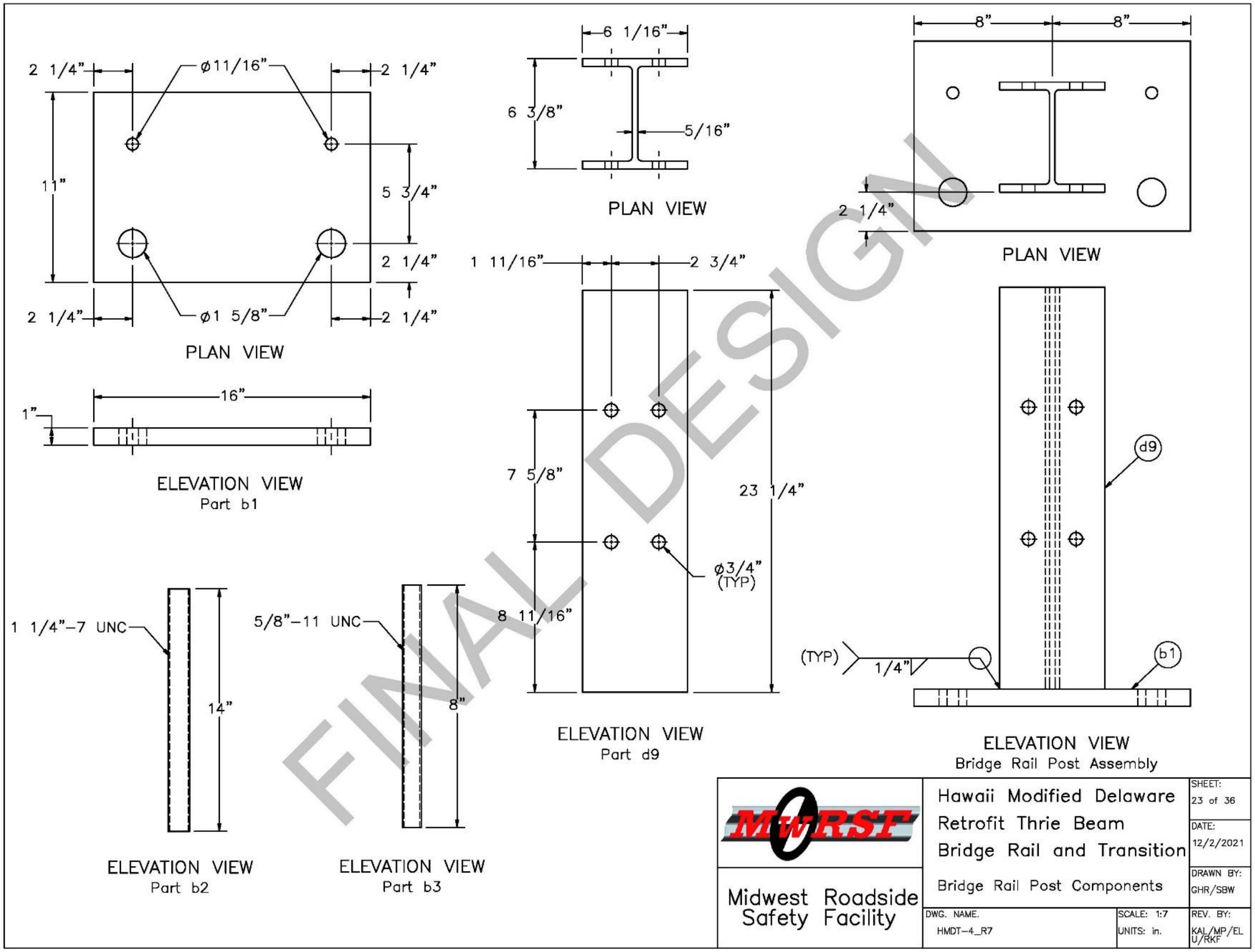



Figure 168. Bridge Rail Post Components, Test No. HMDT-4

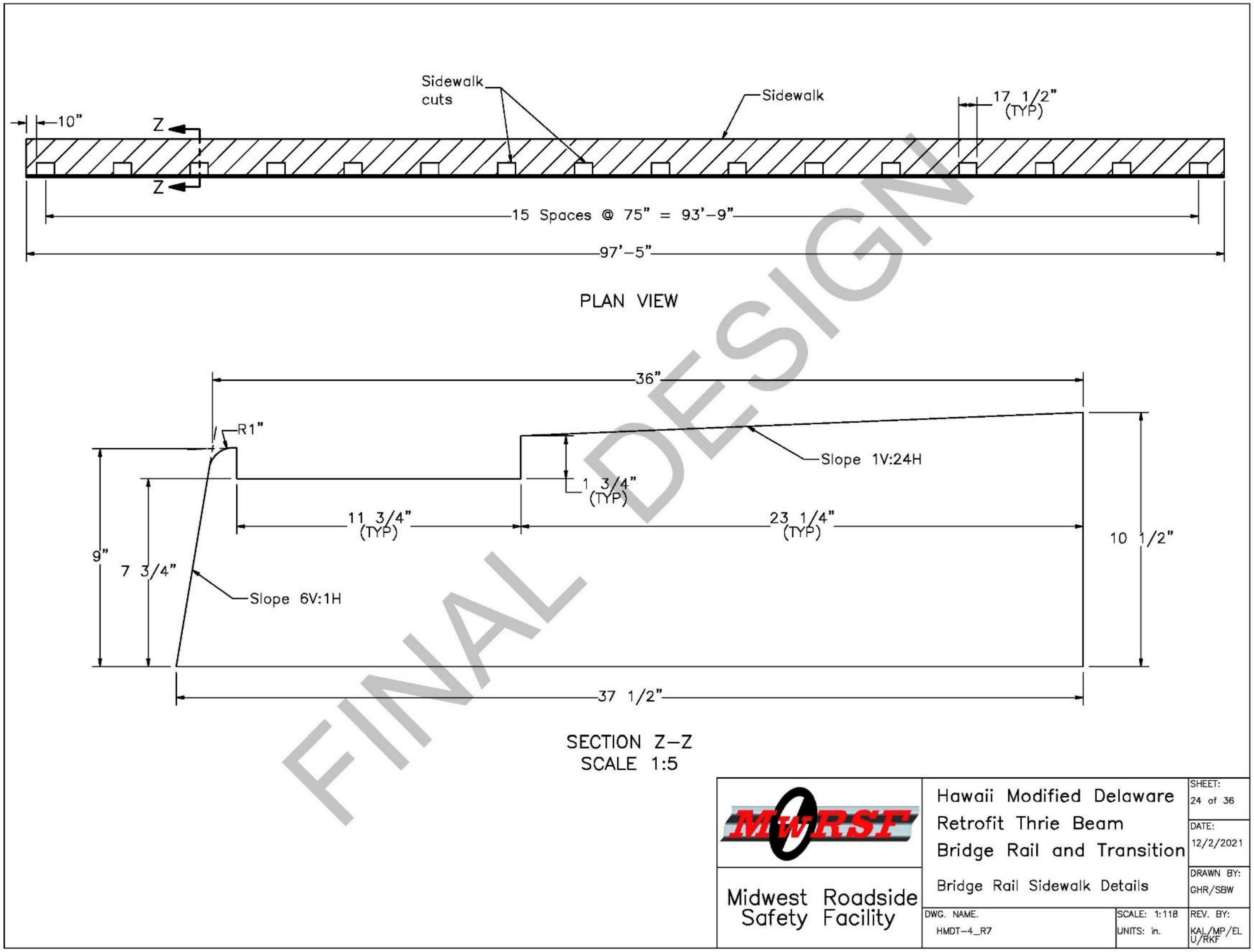



Figure 169. Bridge Rail Sidewalk Details, Test No. HMDT-4

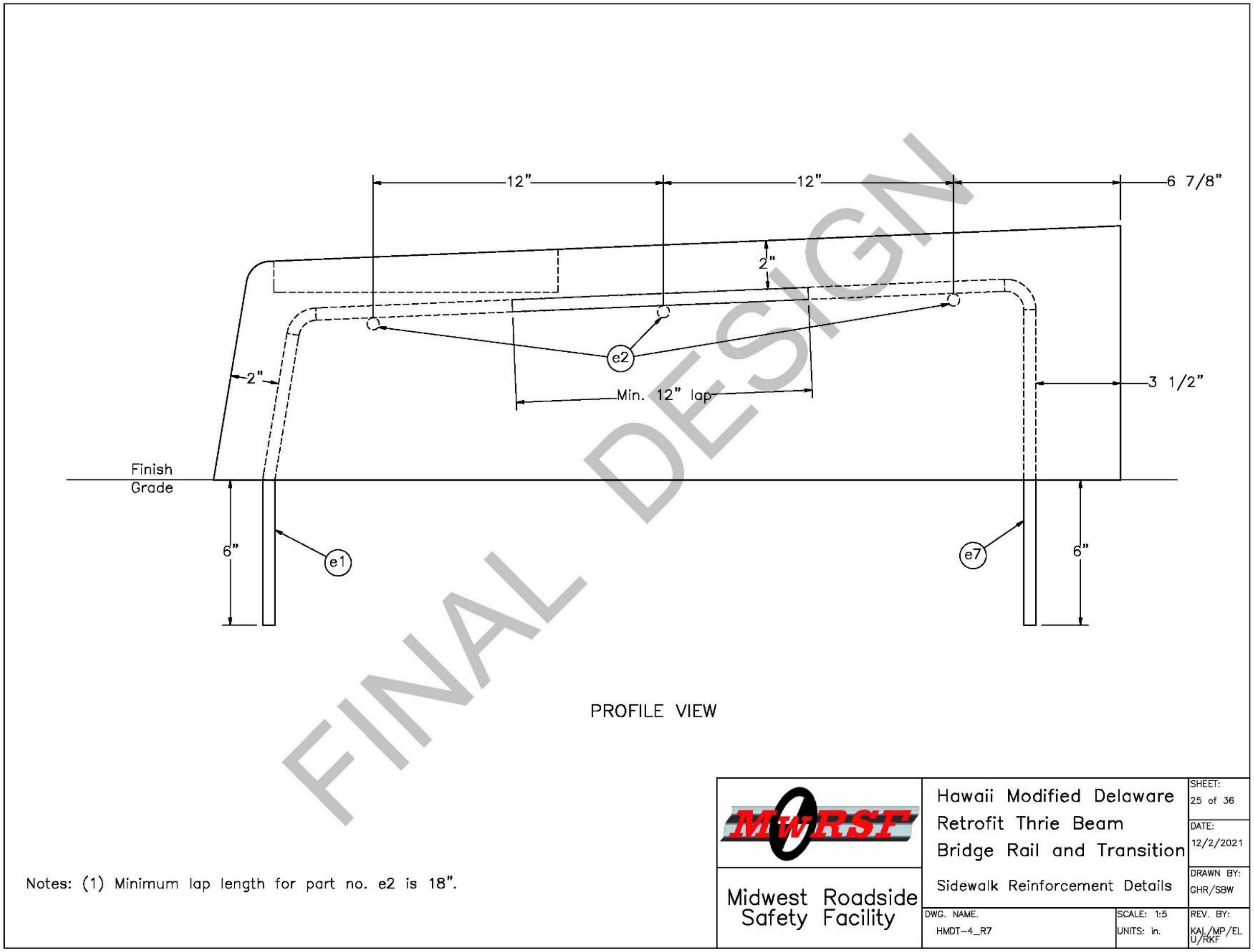



Figure 170. Sidewalk Reinforcement Details, Test No. HMDT-4

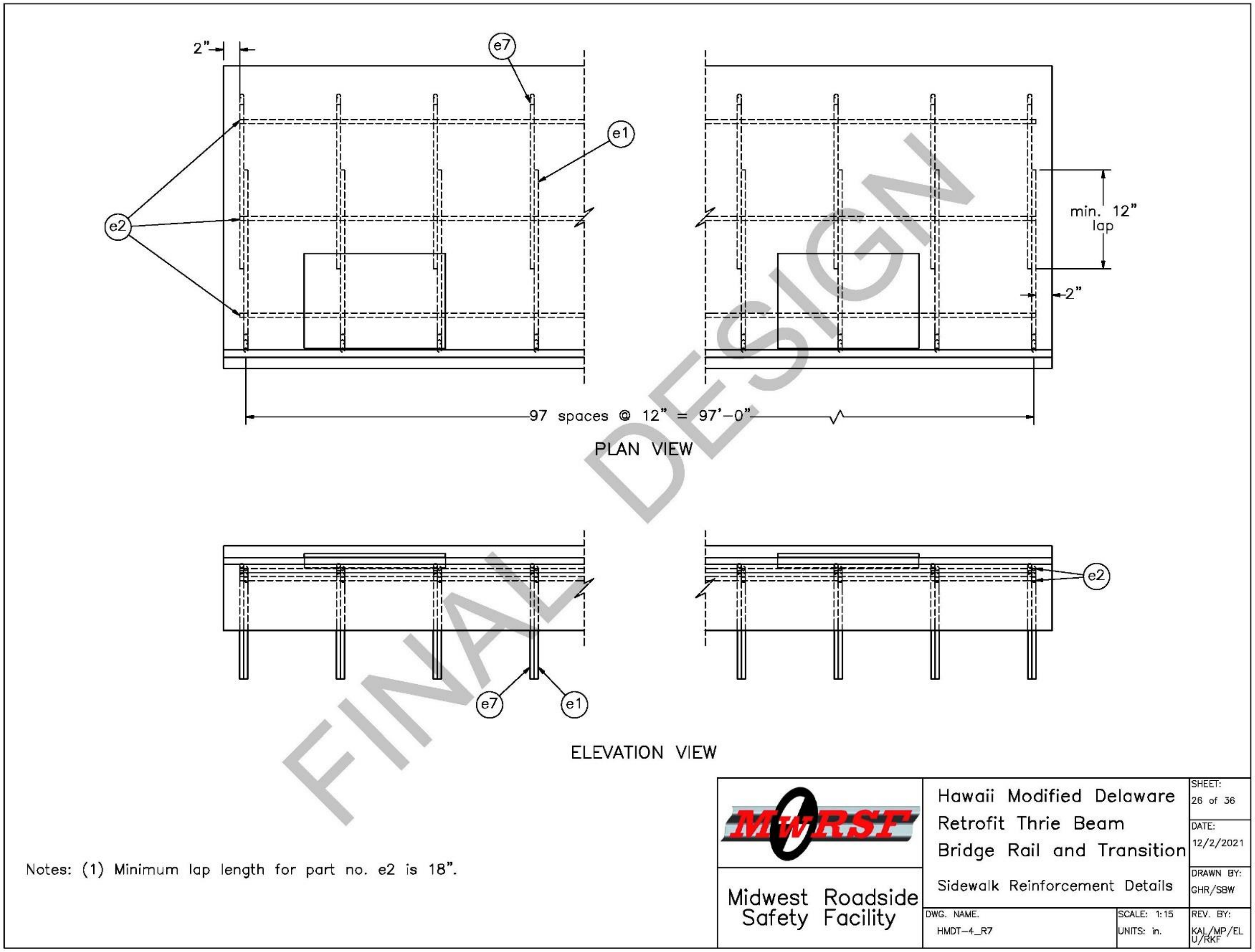
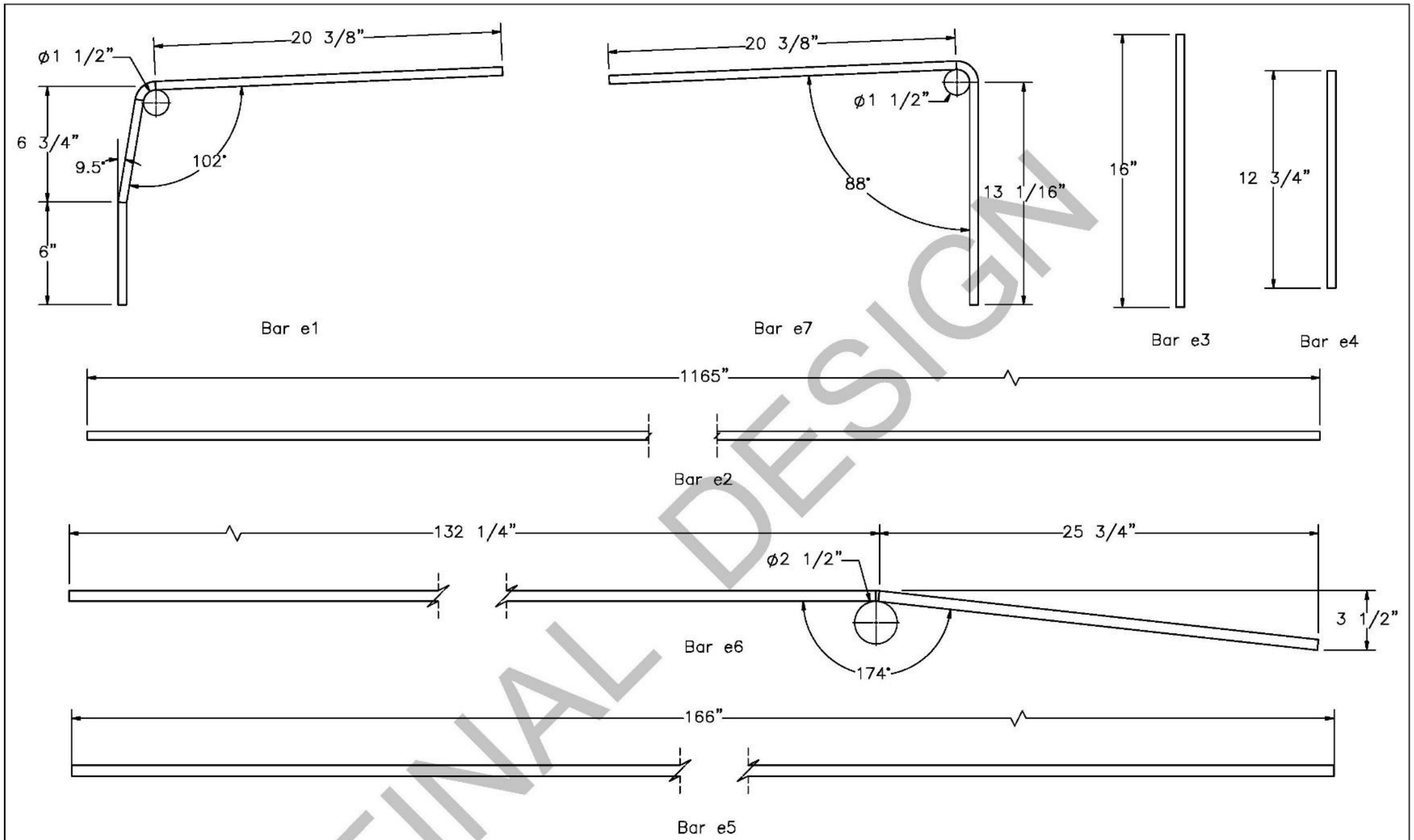



Figure 171. Sidewalk Reinforcement Details, Test No. HMDT-4




Notes: (1) Minimum lap length for part no. e2 is 18".

| Part No. | Bar No. | Qty. | Unbent Length | Material Specification |
|---|---|---|---|---|
| e1 | #4 | 98 | 33 7/8" | ASTM A615 Gr. 60 |
| e2 | #4 | 3 | 1165" | ASTM A615 Gr. 60 |
| e3 | #4 | 7 | 16" | ASTM A615 Gr. 60 |
| e4 | #4 | 1 | 12 3/4" | ASTM A615 Gr. 60 |
| e5 | #5 | 1 | 166" | ASTM A615 Gr. 60 |
| e6 | #5 | 1 | 158 1/4" | ASTM A615 Gr. 60 |
| e7 | #4 | 98 | 35" | ASTM A615 Gr. 60 |

Midwest Roadside Safety Facility

Hawaii Modified Delaware Retrofit Thrie Beam Bridge Rail and Transition

Curb Reinforcement Details

SHEET: 27 of 36
DATE: 12/2/2021
DRAWN BY: GHR/SBW
DWG. NAME. HMDT-4_R7
SCALE: 1:8
UNITS: in.
REV. BY: KAL/MP/EL U/RKF

Figure 172. Curb Reinforcement Details, Test No. HMDT-4

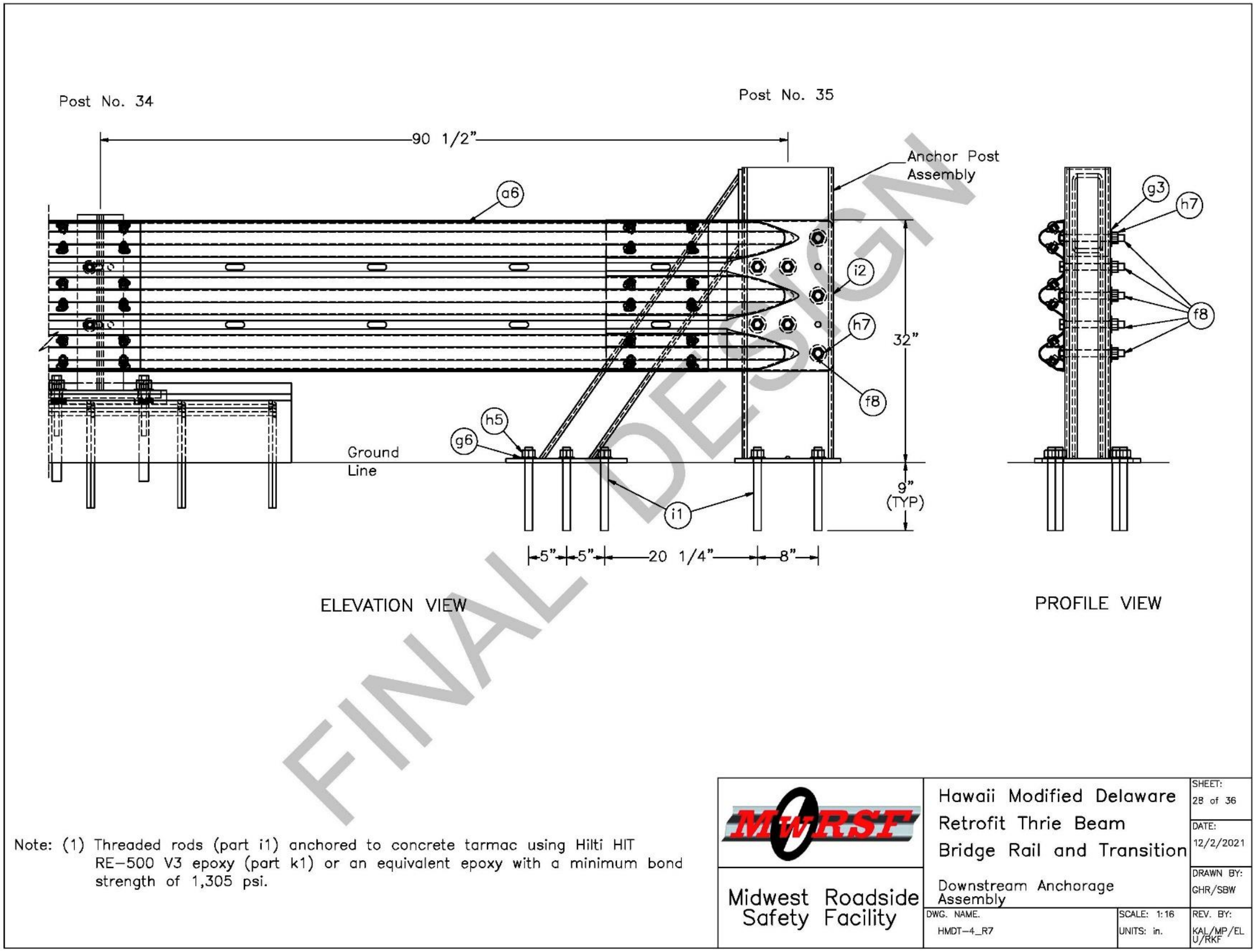



Figure 173. Downstream Anchorage Assembly, Test No. HMDT-4

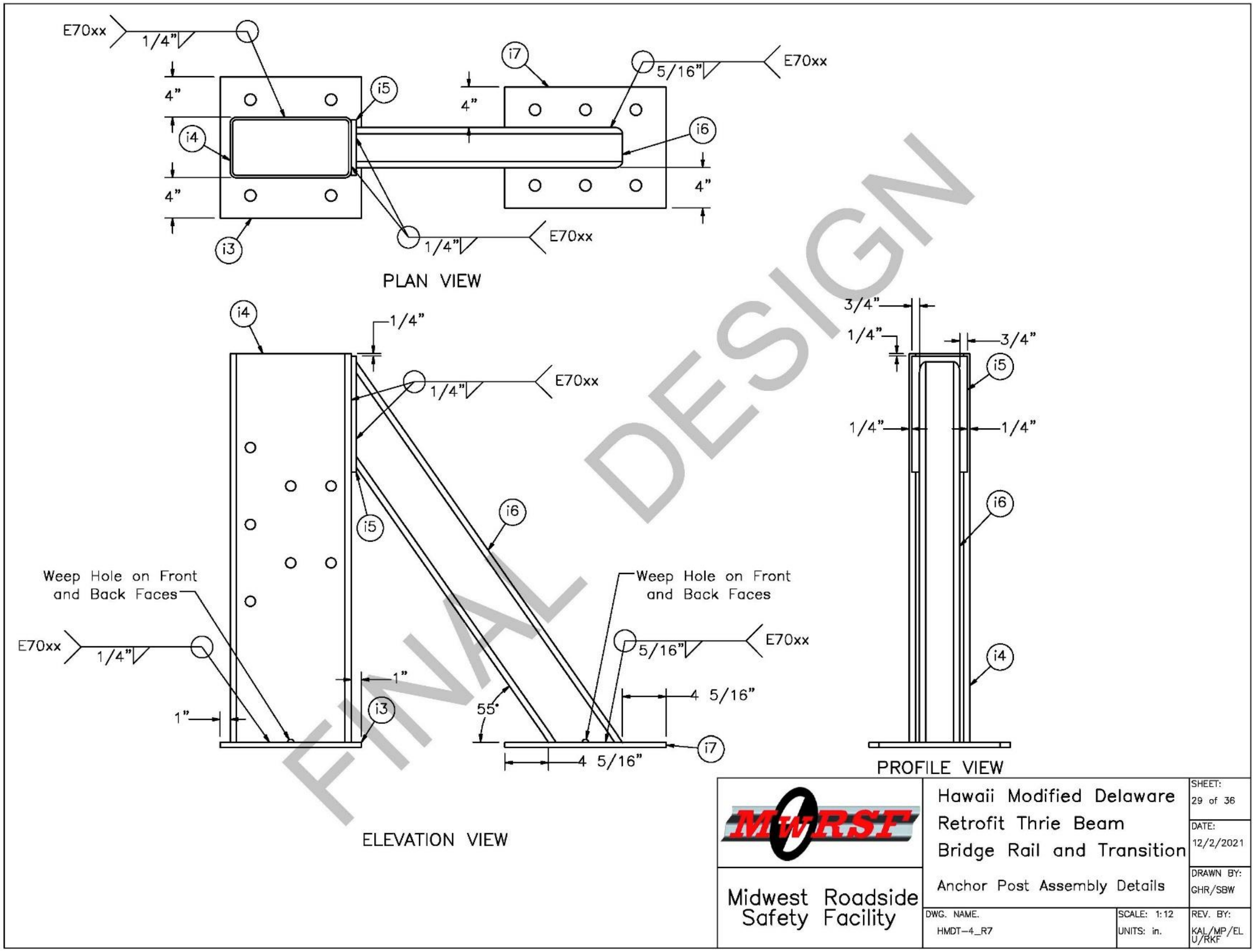



Figure 174. Anchor Post Assembly Details, Test Nos. HMDT-4

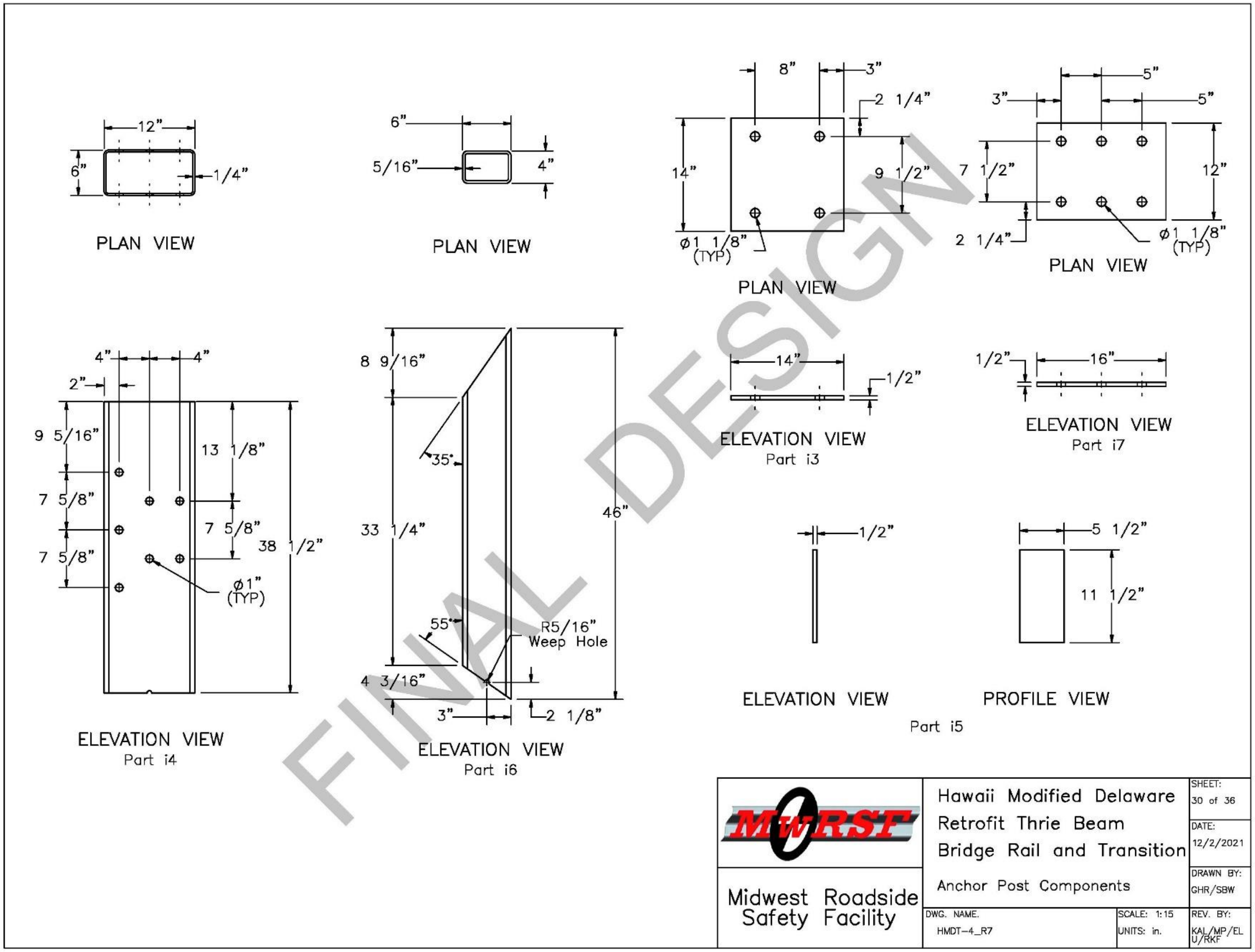



Figure 175. Anchor Post Components, Test No. HMDT-4

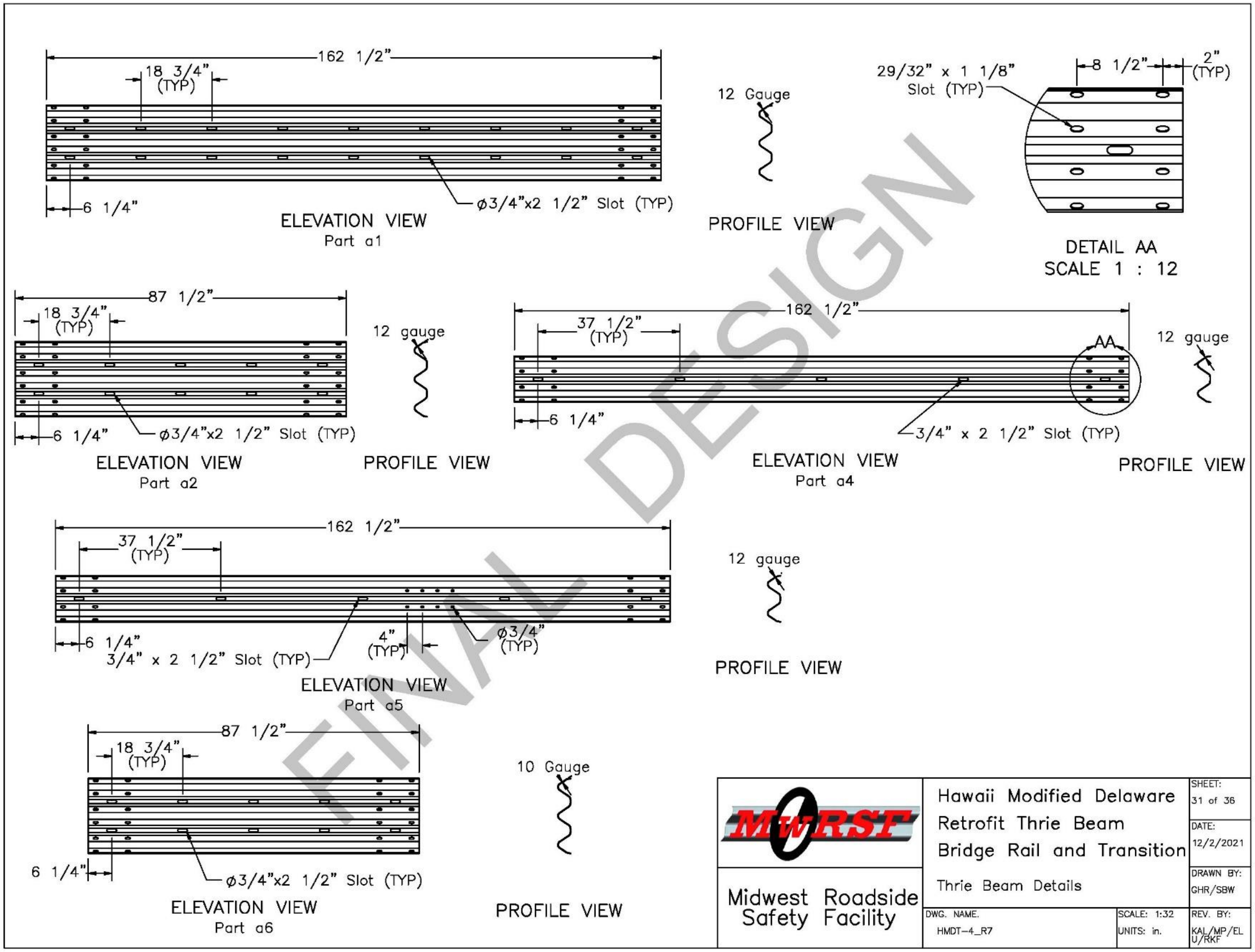



Figure 176. Thrie Beam Details, Test No. HMDT-4

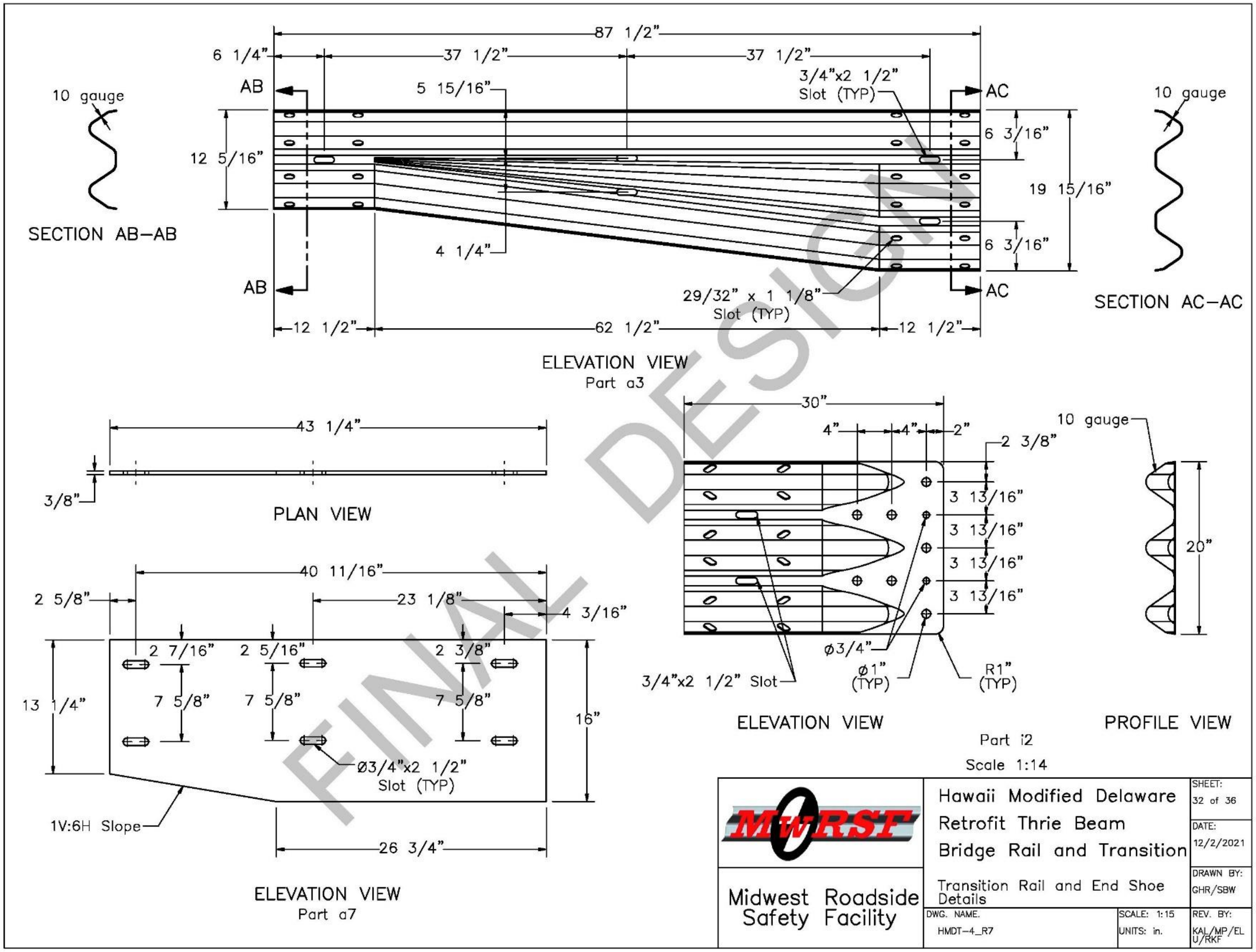



Figure 177. Transition Rail and End Shoe Details, Test No. HMDT-4

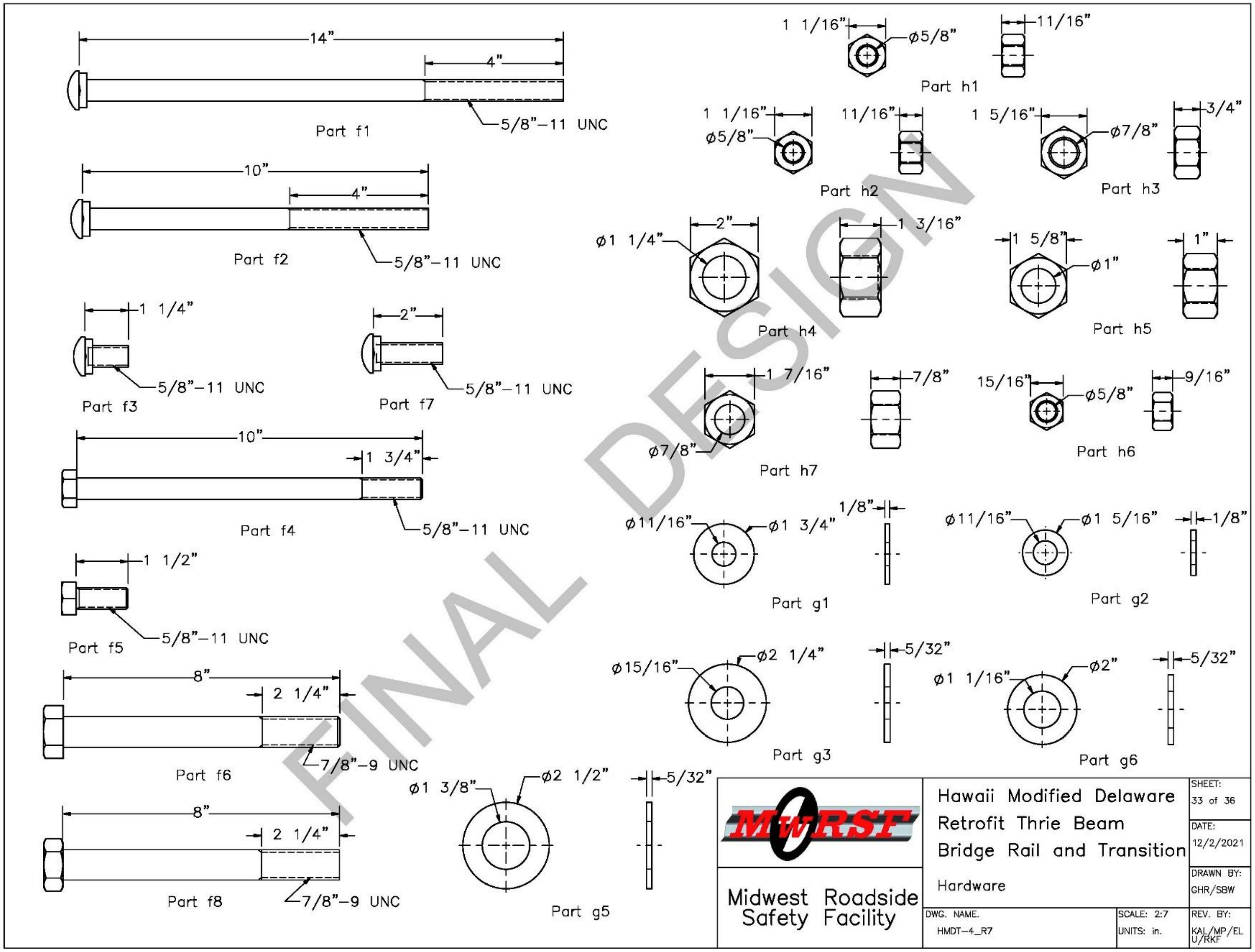



Figure 178. Hardware, Test No. HMDT-4

| Item No. | QTY. | Description | Material Specification | Treatment Specification | Hardware Guide |
|---|---|---|---|---|---|
| a1 | 2 | 12'–6" 12–gauge Thrie Beam Section | AASHTO M180 | ASTM A123 or A653 | RTM08a |
| a2 | 1 | 6'–3" 12–gauge Thrie Beam Section | AASHTO M180 | ASTM A123 or A653 | RTM19a |
| a3 | 1 | 6'–3" 10–gauge W–Beam to Thrie–Beam Asymmetric Transition Section | AASHTO M180 | ASTM A653 | RWT02 |
| a4 | 3 | 12'–6" 12–gauge W–Beam MGS Section | AASHTO M180 | ASTM A123 or A653 | RWM04a |
| a5 | 1 | 12'–6" 12–gauge W–Beam MGS End Section | AASHTO M180 | ASTM A123 or A653 | RWM14a |
| a6 | 16 | 6'–3" 10–gauge Thrie Beam Section | AASHTO M180 | ASTM A123 or A653 | RTM19a |
| a7 | 1 | 43 1/4"x16"x3/8" Transition Back–up Plate | ASTM A36 | ASTM A123 | – |
| b1 | 16 | 16"x11"x1" Base Plate | ASTM A36 | ASTM A123 | – |
| b2 | 32 | 1 1/4" Dia., 15" Long Anchor Rod | ASTM F1554–15 Grade 105, Class 2A | ASTM F2329 / F2329M–15 | – |
| b3 | 32 | 5/8" Dia., 8" Long Anchor Rod | ASTM F1554–15 Grade 105, Class 2A | ASTM F2329 / F2329M–15 | – |
| c1 | 2 | BCT Timber Post – MGS Height | SYP Grade No. 1 or better (No knots +/– 18" from ground on tension face) | – | PDF01 |
| c2 | 2 | 72" Long Foundation Tube | ASTM A500 Gr. B | ASTM A123 | PTE06 |
| c3 | 1 | Ground Strut Assembly | ASTM A36 | ASTM A123 | – |
| c4 | 2 | BCT Anchor Cable End Swaged Fitting | Fitting – ASTM A576 Gr. 1035<br>Stud – ASTM F568 Class C | Fitting – ASTM A153<br>Stud – ASTM A153 or B695 | – |
| c5 | 1 | BCT Cable Anchor Assembly | – | – | FCA01 |
| c6 | 1 | 8"x8"x5/8" Anchor Bearing Plate | ASTM A36 | ASTM A123 | FPB01 |
| c7 | 1 | 2 3/8" O.D. x 6" Long BCT Post Sleeve | ASTM A53 Gr. B Schedule 40 | ASTM A123 | FMM02 |
| c8 | 1 | Anchor Bracket Assembly | ASTM A36 | ASTM A123 | FPA01 |
| d1 | 7 | W6x9 or W6x8.5, 72" Long Steel Post | ASTM A992 | ASTM A123* | PWE06 |
| d2 | 6 | W6x9, 72" Long Steel Post | ASTM A992 | ASTM A123* | PWE06 |
| d3 | 4 | W6x15, 78" Long Steel Post | ASTM A992 | ASTM A123* | – |
| d4 | 4 | 17 1/2" Long, 8"x6"x1/4" Steel Blockout | ASTM A500 Gr. B | ASTM A123* | – |
| d5 | 6 | 17 1/2" Long, 12"x4"x1/4" Steel Blockout | ASTM A500 Gr. B | ASTM A123* | – |
| d6 | 2 | 14 3/16"x12"x5 1/8" Composite Recycled Blockout | Mondo Polymer MGS14SH or Equivalent | – | – |
| d7 | 5 | 14 3/16"x8"x5 1/8" Composite Recycled Blockout | Mondo Polymer GB14SH2 or Equivalent | – | – |
| d8 | 2 | 16D Double Head Nail | Galvanized | – | – |
| d9 | 16 | W6x25, 23 1/4" Long Steel Post | ASTM A992 | ASTM A123 | – |

* Component does not need to be galvanized for testing purposes

Note: (1) Quantities listed herein are only for one copy of the system.

FINAL DESIGN

Midwest Roadside Safety Facility

Hawaii Modified Delaware Retrofit Thrie Beam Bridge Rail and Transition

Bill of Materials

| SHEET: | DATE: | DRAWN BY: | REV. BY: | DWG. NAME. | SCALE: | UNITS: |
|---|---|---|---|---|---|---|
| 34 of 36 | 12/2/2021 | GHR/SBW | KAL/MP/ELU/RKF | HMDT–4_R7 | None | in. |

Figure 179. Bill of Materials, Test No. HMDT-4

| Item No. | QTY. | Description | Material Specification | Treatment Specification | Hardware Guide |
|---|---|---|---|---|---|
| e1 | 98 | #4 Rebar, 33 7/8" Total Unbent Length | ASTM A615 Gr. 60 | Epoxy–Coated (ASTM A775 or A934) | – |
| e2 | 3 | #4 Rebar, 97'–1" Total Length** | ASTM A615 Gr. 60 | Epoxy–Coated (ASTM A775 or A934) | – |
| e3 | 7 | #4 Rebar, 16" Total Length | ASTM A615 Gr. 60 | Epoxy–Coated (ASTM A775 or A934) | – |
| e4 | 1 | #4 Rebar, 12 3/4" Total Length | ASTM A615 Gr. 60 | Epoxy–Coated (ASTM A775 or A934) | – |
| e5 | 1 | #5 Rebar, 166" Total Length | ASTM A615 Gr. 60 | Epoxy–Coated (ASTM A775 or A934) | – |
| e6 | 1 | #5 Rebar, 158 1/4" Total Unbent Length | ASTM A615 Gr. 60 | Epoxy–Coated (ASTM A775 or A934) | – |
| e7 | 98 | #4 Rebar, 35" Total Unbent Length | ASTM A615 Gr. 60 | Epoxy–Coated (ASTM A775 or A934) | – |
| f1 | 13 | 5/8"–11 UNC, 14" Long Guardrail Bolt | ASTM A307 Gr. A | ASTM A153 or B695 Class 55 or F2329 | FBB06 |
| f2 | 17 | 5/8"–11 UNC, 10" Long Guardrail Bolt | ASTM A307 Gr. A | ASTM A153 or B695 Class 55 or F2329 | FBB03 |
| f3 | 260 | 5/8"–11 UNC, 1 1/4" Long Guardrail Bolt | ASTM A307 Gr. A | ASTM A153 or B695 Class 55 or F2329 | FBB01 |
| f4 | 2 | 5/8"–11 UNC, 10" Long Hex Head Bolt | ASTM A307 Gr. A or equivalent | ASTM A153 or B695 Class 55 or F2329 | FBX16a |
| f5 | 8 | 5/8"–11 UNC, 1 1/2" Long Hex Head Bolt | ASTM A307 Gr. A or equivalent | ASTM A153 or B695 Class 55 or F2329 | FBX16a |
| f6 | 2 | 7/8"–9 UNC, 8" Long Hex Head Bolt | ASTM A307 Gr. A or equivalent | ASTM A153 or B695 Class 55 or F2329 | – |
| f7 | 32 | 5/8"–11 UNC, 2" Long Guardrail Bolt | ASTM A307 Gr. A | ASTM F2329 | FBB02 |
| f8 | 7 | 7/8" Dia., 8" Long Heavy Hex Head Bolt | ASTM F3125 Gr. A325 Type 1 | ASTM A153 or B695 Class 55 or F1136 Gr. 3 or F2329 or F2833 Gr. 1 | FBX22b |
| g1 | 56 | 5/8" Dia. Plain USS Washer | ASTM F844 | ASTM F2329 | FWC16a |
| g2 | 192 | 5/8" Dia. Hardened Washer | ASTM F436 | ASTM F2329 | FWC16b |
| g3 | 11 | 7/8" Dia. Plain Round Washer | ASTM F844 | ASTM A123 or A153 or F2329 | – |
| g4 | 2 | 1" Dia. Plain USS Washer | ASTM F844 | ASTM A123 or A153 or F2329 | FWC24a |
| g5 | 160 | 1 1/4" Dia. Hardened Washer | ASTM F436 | ASTM F2329 | FWC30a |
| g6 | 10 | 1" Dia. Hardened Flat Washer | ASTM F436 | ASTM A153 or B695 Class 55 or F1136 Gr. 3 or F2329 | FWC24b |

** Minimum lap length for part e2 is 18".



Midwest Roadside Safety Facility

Hawaii Modified Delaware Retrofit Thrie Beam Bridge Rail and Transition

Bill of Materials

| | |
|---|---|
| SHEET: | 35 of 36 |
| DATE: | 12/2/2021 |
| DRAWN BY: | GHR/SBW |
| DWG. NAME. | HMDT–4_R7 |
| SCALE: | None |
| UNITS: | in. |
| REV. BY: | KAL/MP/ELU/RKF |

Figure 180. Bill of Materials, Test No. HMDT-4

| Item No. | QTY. | Description | Material Specification | Treatment Specification | Hardware Guide |
|---|---|---|---|---|---|
| h1 | 320 | 5/8"–11 UNC Heavy Hex Nut | ASTM A563A or equivalent | ASTM A153 or B695 Class 55 or F2329 | FNX16b |
| h2 | 34 | 5/8"–11 UNC Heavy Hex Nut | ASTM A563–15 Grade DH | ASTM F2329 / F2329U–15 | FNX16b |
| h3 | 2 | 7/8"–9 UNC Hex Nut | ASTM A563A or equivalent | ASTM A153 or B695 Class 55 or F2329 | – |
| h4 | 32 | 1 1/4"–8 UNC Heavy Hex Nut | ASTM A563–15 Grade DH | ASTM F2329 / F2329U–15 | – |
| h5 | 12 | 1"–8 UNC Heavy Hex Nut | ASTM A563DH or equivalent | ASTM A153 or B695 Class 55 or F2329 | FNX24b |
| h6 | 10 | 5/8"–11 UNC Hex Nut | ASTM A563A or equivalent | ASTM A153 or B695 Class 55 or F2329 | FNX16a |
| h7 | 7 | 7/8" Dia. UNC Heavy Hex Nut | ASTM A563DH or ASTM A194 Gr. 2H | ASTM A153 for Class C or ASTM B695 for Class 50 | FNX22b |
| i1 | 10 | 1" Dia. UNC, 11" Long Threaded Rod | ASTM A449 or A354 Gr. BC or A193 Gr. B7 | ASTM A153 or B633 or B695 Class 55 or F1941 or F2329 | FRR24b |
| i2 | 1 | 10–gauge Thrie Beam Terminal Connector | AASHTO M180<br>Min. yield strength = 50 ksi<br>Min. tensile strength = 70 ksi | ASTM A123 or A653 | RTE01b |
| i3 | 1 | 14"x14"x1/2" Steel Plate | ASTM A36 or A572 Gr. 50 | ASTM A123* | – |
| i4 | 1 | HSS 6"x12"x1/4" Tube, 38 1/2" Long | ASTM A500 Gr. B | ASTM A123* | – |
| i5 | 1 | 11 1/2"x5 1/2"x1/2" Steel Plate | ASTM A36 or A572 Gr. 50 | ASTM A123* | – |
| i6 | 1 | HSS 6"x4"x5/16" Tube, 46" Long | ASTM A500 Gr. B | ASTM A123* | – |
| i7 | 1 | 16"x12"x1/2" Steel Plate | ASTM A36 or A572 Gr. 50 | ASTM A123* | – |
| j1 | – | Concrete | Min. f'c = 4,000 psi<br>NE Mix 47BD1S/1PF4000HW | – | – |
| k1 | – | Hilti HIT RE–500 V3 Epoxy Adhesive | Class C 881 | – | – |

* Component does not need to be galvanized for testing purposes

Note: (1) Repair concrete breakouts on the sidewalk corners with the high strength epoxy used for front lip of the bridge rail cutouts

FINAL DESIGN

MwRSF
Midwest Roadside Safety Facility

Hawaii Modified Delaware Retrofit Thrie Beam Bridge Rail and Transition

Bill of Materials

| | |
|---|---|
| SHEET: | 36 of 36 |
| DATE: | 12/2/2021 |
| DRAWN BY: | GHR/SBW |
| DWG. NAME. | HMDT–4_R7 |
| SCALE: | None |
| UNITS: | in. |
| REV. BY: | KAL/MP/EL U/RKF |

Figure 181. Bill of Materials, Test No. HMDT-4


Figure 182. Test Installation, Test No. HMDT-4


Figure 183. Back-Up Plate Between Post Nos. 19 and 20, Test No. HMDT-4

# 10 FULL-SCALE CRASH TEST NO. HMDT-4

## 10.1 Static Soil Test

Before full-scale crash test no. HMDT-4 was conducted, the strength of the foundation soil was evaluated with a static test, as described in MASH 2016. The static test results, as shown in Appendix D, demonstrated a soil resistance above the baseline test limits. Thus, the soil provided adequate strength, and full-scale crash testing could be conducted on the barrier system.

## 10.2 Weather Conditions

Test no. HMDT-4 was conducted on January 28, 2022 at approximately 2:45 p.m. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/LNK) were reported and are shown in Table 19.

Table 19. Weather Conditions, Test No. HMDT-4

| | |
|---|---|
| Temperature | 35° F |
| Humidity | 40% |
| Wind Speed | 9 mph |
| Wind Direction | 200° from True North |
| Sky Conditions | Sunny |
| Visibility | 10 Statute Miles |
| Pavement Surface | Dry |
| Previous 3-Day Precipitation | 0.01 in. |
| Previous 7-Day Precipitation | 0.01 in. |

## 10.3 Test Description

Initial vehicle impact was to occur 63 in. upstream from post no. 20, as shown in Figure 184, which was selected using the CIP plots found in Section 2.3 of MASH 2016. The 2,431-lb small car impacted the finalized design of the transition to the Hawaii Modified Delaware Retrofit Bridge Rail at a speed of 60.5 mph and at an angle of 25.1 degrees. The actual point of impact was 0.05 in. upstream from the targeted impact location. The vehicle came to rest 144.4 ft downstream from the impact point and 39 ft laterally in front of the system after brakes were applied. The measured I.S. of test no. HMDT-4 was 53.5 kip-ft, which was greater than the minimum value of 51.1 kip-ft as defined in MASH 2016 for test designation no. 3-20.

A detailed description of the sequential impact events is contained in Table 20. Sequential photographs are shown in Figures 185 and 186. Documentary photographs of the crash test are shown in Figures 187 and 188. The vehicle trajectory and final position are shown in Figure 189.

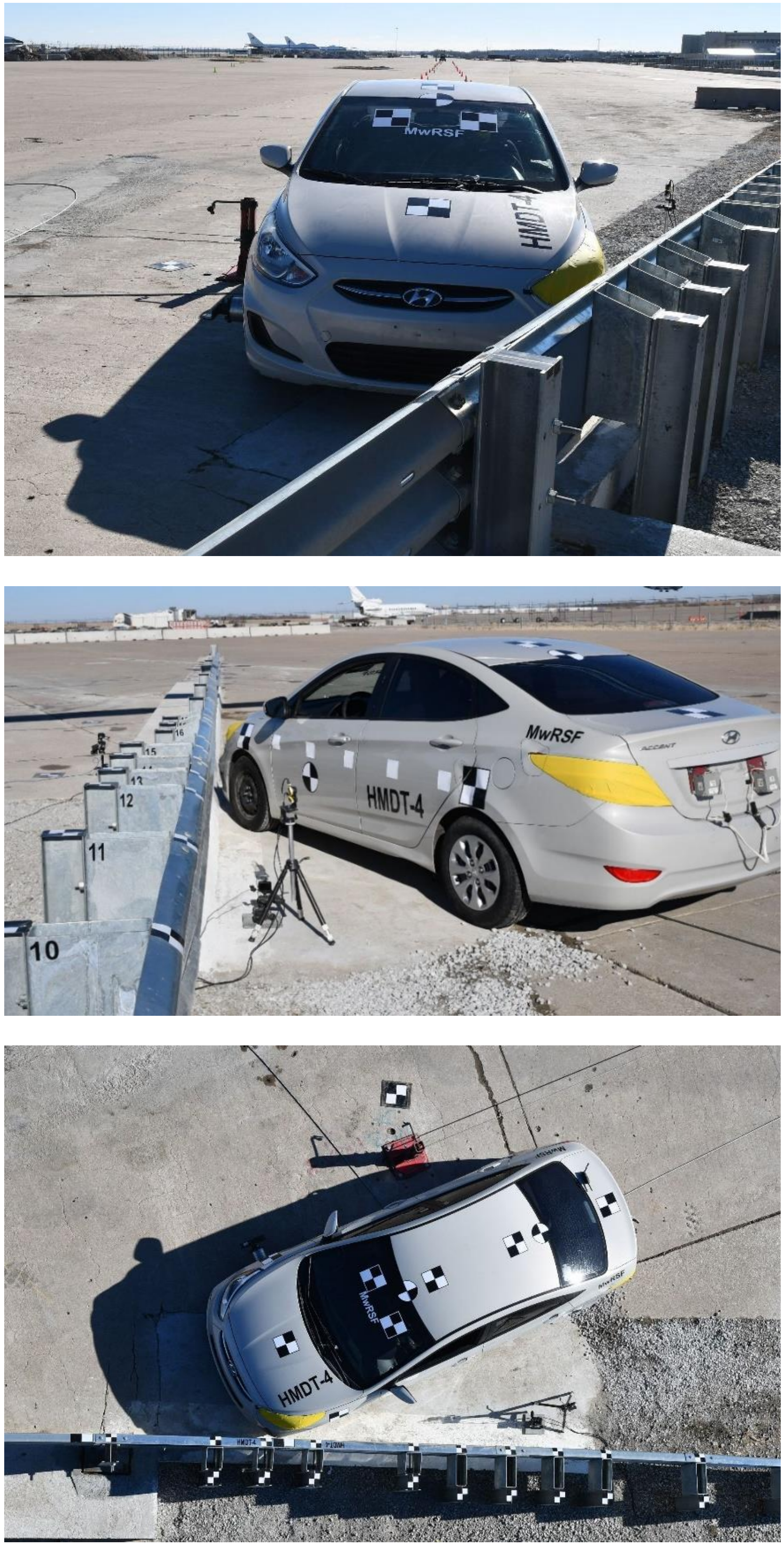
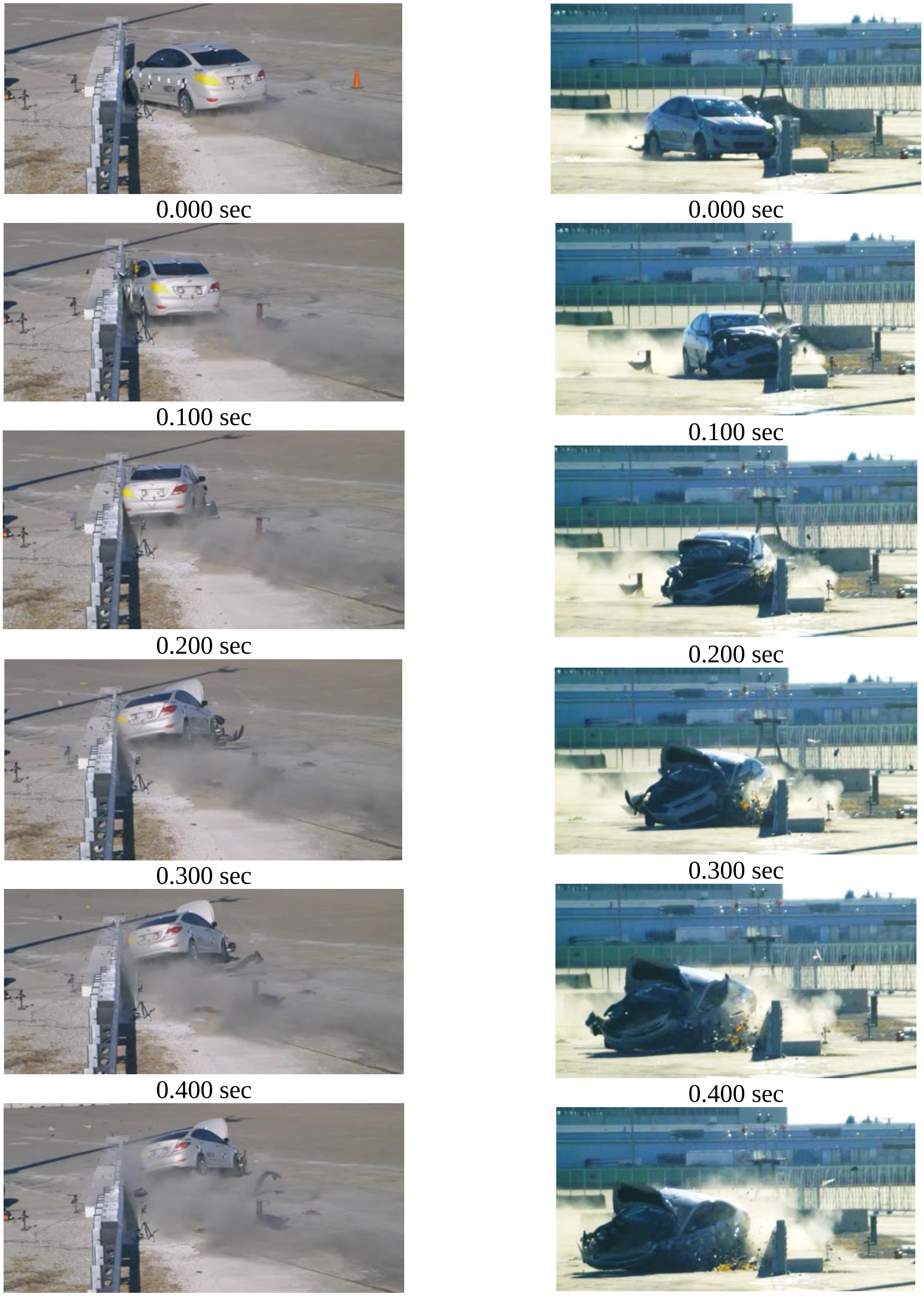



Figure 184. Impact Location, Test No. HMDT-4

Table 20. Sequential Description of Impact Events, Test No. HMDT-4

| Time sec | Event |
|---|---|
| 0.000 | Vehicle’s front bumper contacted rail at post no. 18 and deformed. |
| 0.008 | Vehicle’s left headlight, left fender, and left-front tire contacted rail causing left headlight to shatter and left fender to crush inward. |
| 0.016 | Post nos. 18 and 19 rotated backward, vehicle’s hood contacted rail and crushed inward, and left-front tire ruptured. |
| 0.026 | Post nos. 17 and 20 rotated backward, vehicle rolled and yawed away from barrier. |
| 0.034 | Vehicle’s roof deformed, right headlight deformed and detached, and left-front door contacted rail and crushed inward. |
| 0.046 | Vehicle’s windshield cracked, left-front door became ajar, and left mirror assembly deformed. |
| 0.096 | Surrogate occupant’s head contacted left-front window as vehicle rolled toward barrier. |
| 0.172 | Vehicle became parallel to system at speed of 46.2 mph. |
| 0.192 | Vehicle’s left-rear door, left quarter panel, and rear bumper contacted rail and crushed inward, and front bumper and grille disengaged. |
| 0.252 | Vehicle’s right-rear tire airborne. |
| 0.306 | Vehicle exited system at speed of 44.9 mph and an angle of 10.2 degrees. |
| 0.315 | System came to rest. |
| 0.340 | Vehicle’s right-front tire airborne. |
| 0.542 | Vehicle’s right-front tire contacted ground. |
| 1.410 | Vehicle’s right-rear tire contacted ground. |
| 3.900 | Vehicle came to rest 144.4 ft downstream from impact and 39 ft laterally in front of the system. |



0.000 sec

0.100 sec

0.200 sec

0.300 sec

0.400 sec

0.500 sec

0.000 sec

0.100 sec

0.200 sec

0.300 sec

0.400 sec

0.500 sec

Figure 185. Sequential Photographs, Test No. HMDT-4


0.000 sec


0.100 sec


0.200 sec


0.300 sec


0.400 sec


0.500 sec


0.000 sec


0.100 sec


0.200 sec


0.300 sec


0.400 sec


0.500 sec

Figure 186. Sequential Photographs, Test No. HMDT-4

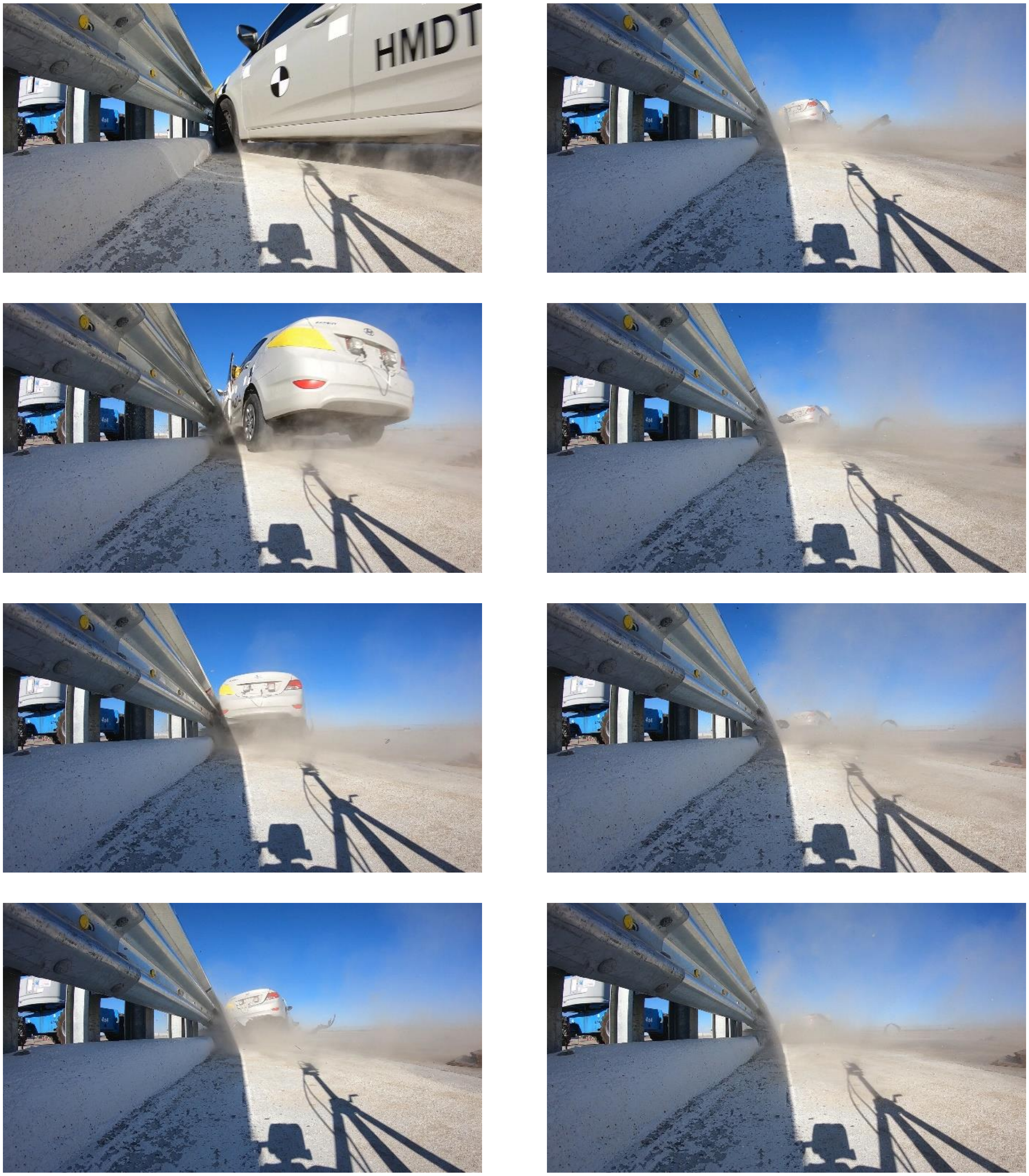



Figure 187. Documentary Photographs, Test No. HMDT-4

Figure 188. Documentary Photographs, Test No. HMDT-4


Figure 189. Vehicle Final Position and Trajectory Marks, Test No. HMDT-4

### 10.4 Barrier Damage

Damage to the barrier was minimal, as shown in Figures 190 and 191. Barrier damage consisted of contact marks on and kinking of the thrie-beam sections, contact marks on the front face of the curb, and minor spalling of the concrete. The total length of vehicle contact along the system was approximately 215 in., which began 3 in. downstream from the center line of post no. 17.

Contact marks on the thrie-beam rail began 8 in. downstream from the centerline of post no. 17, continued 124½ in. downstream to the bridge rail, and extended 57½ in downstream from post no. 20. The thrie-beam rail slightly bent inward for a length of 90 in., starting 17 in. upstream from post no. 17. Multiple kinks were found on the top and bottom of the thrie-beam rail around post nos. 18 and 19. The bottom corrugation of the thrie-beam rail was flattened, beginning 13 in. downstream from post no. 19 and continued to the upstream edge of post no. 20. Dents were found on the bottom corrugation of the thrie-beam rail, starting 12 in. upstream from post no. 19 for a length of 16 in. and starting 23½ in. upstream from post no. 20 for a length of 16¾ in.

A contact mark was found on the concrete curb starting 3 in. downstream from post no. 17 and extending to the concrete sidewalk. A minor gouge was found along the top and front face of the curb, starting 4 in. upstream from post no. 18 and extending 12 in. downstream. A crack on the interface of the concrete curb and sidewalk had occurred in the previous test, test no. HMDT-3. Minor spalling of the concrete was found around that crack.

Post no. 17 had a soil gap of $^{1}/_{16}$ in. on the back of the post, and post no. 19 had soil gaps of ¾ and ¼ in. in front and back of the post, respectively. Post nos. 18 and 19 had a soil heave on the back side and measured 11 in. diameter and 1½ in. high. No post damage or movement occurred to the upstream anchorage system.


Figure 190. System Damage, Test No. HMDT-4


Figure 191. Thrie-Beam Rail Damage, Test No. HMDT-4

The maximum lateral permanent set of the barrier system was 1.3 in., which occurred at the rail between post nos. 19 and 20, as measured in the field. The maximum lateral dynamic barrier deflection was 3.2 in., which occurred at post no. 19, as determined from high-speed digital video analysis. The working width of the system was found to be 21.6 in., also determined from high-speed digital video analysis. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 192.

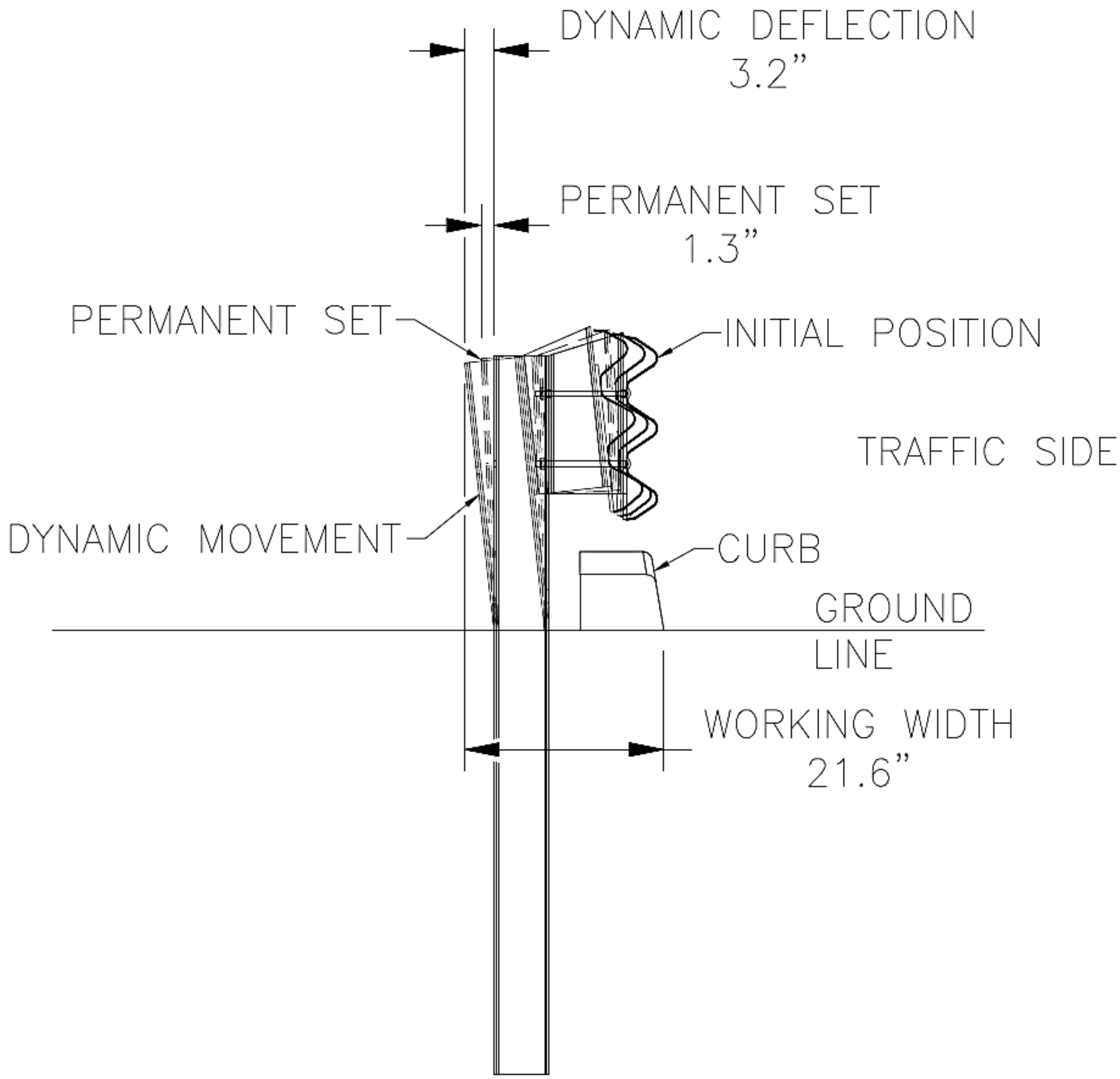



Figure 192. Permanent Set Deflection, Dynamic Deflection, and Working Width, Test No. HMDT-4

## 10.5 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 193 through 195. Majority of the damage was concentrated on the left-front corner and left side of the vehicle where the impact had occurred. The front bumper was disengaged. The hood was slightly warped inward and bent upward. The right-side headlights disengaged from the housing. The vehicle was scraped and crushed inward along the entire left side. The left-front door was shifted slightly backward and bent, leading to a gap between the frame and the door at the top and back side. The left-front door was also dented at the back and the center of the panel. The left-rear fender was displaced inward and bent inward on the back side. The rear bumper was scraped on the left-side. The left-front corner of the roof was dented. The windshield was cracked across the whole surface, with more severe cracking near the bottom and left side corner.

The left-front tire was deflated and partially separated from the rim. The outer side of the left-front wheel rim was bent outward at several places. The left-rear wheel cover fractured and disengaged, but there was no visible damage on the rim. The lower control arm of the left suspension was twisted inward. The left frame rail was bent inward. No other damage to the vehicle's undercarriage was observed.

The maximum occupant compartment intrusions are listed in Table 21, along with the intrusion limits established in MASH 2016 for various areas of the occupant compartment. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix E. MASH 2016 defines intrusion or deformation as the occupant compartment being deformed and reduced in size with no observed penetration. There were no penetrations into the occupant compartment, and none of the established MASH 2016 deformation limits were violated. Outward deformations, which are denoted as negative numbers in Appendix E, are not considered crush toward the occupant, and are not evaluated by MASH 2016 criteria.


Figure 193. Vehicle Damage, Test No. HMDT-4


Figure 194. Vehicle Damage, Test No. HMDT-4


Figure 195. Interior and Undercarriage Damage, Test No. HMDT-4

Table 21. Maximum Occupant Compartment Intrusion by Location, Test No. HMDT-4

| Location | Maximum Intrusion in. | MASH 2016 Allowable Intrusion in. |
|---|---|---|
| Wheel Well & Toe Pan | 2.6 | ≤ 9 |
| Floor Pan & Transmission Tunnel | 1.6 | ≤ 12 |
| A-Pillar | 0.7 | ≤ 5 |
| A-Pillar (Lateral) | 0.0* | ≤ 3 |
| B-Pillar | 0.7 | ≤ 5 |
| B-Pillar (Lateral) | 0.0* | ≤ 3 |
| Side Front Panel (in Front of A-Pillar) | 1.4 | ≤ 12 |
| Side Door (Above Seat) | 0.0* | ≤ 9 |
| Side Door (Below Seat) | 0.0* | ≤ 12 |
| Roof | 0.0 | ≤ 4 |
| Windshield | 1.0 | ≤ 3 |
| Side Window | Intact | No shattering resulting from contact with structural member of test article |
| Dash | 2.3 | N/A |

N/A – No MASH 2016 criteria exist for this location
*Negative value reported as 0.0. See Appendix E for further information.

## 10.6 Occupant Risk

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined from the accelerometer data, are shown in Table 22. Note that the OIVs and ORAs were within suggested limits, as provided in MASH 2016. The calculated THIV, PHD, and ASI values are also shown in Figure 196. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix K.

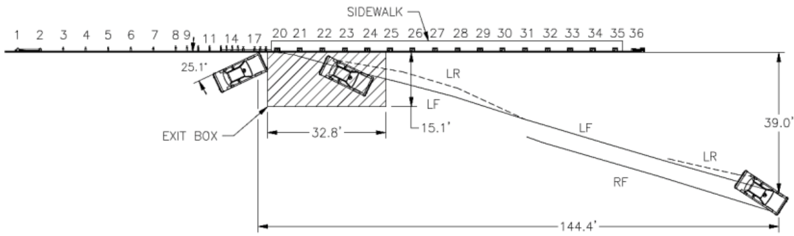
Table 22. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. HMDT-4

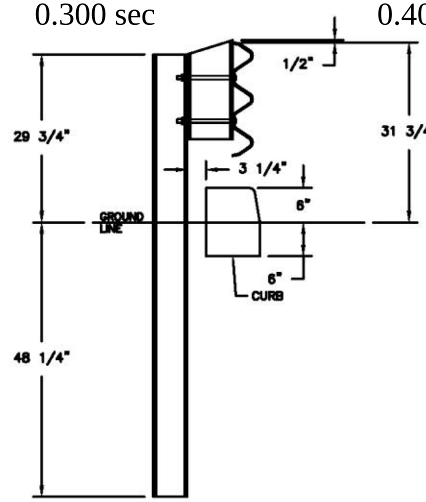
| **Evaluation Criteria** | | **Transducer** | | **MASH 2016 Limits** |
|---|---|---|---|---|
| | | **SLICE-1 (Primary)** | **SLICE-2** | |
| **OIV ft/s** | Longitudinal | -27.92 | -28.33 | ±40 |
| | Lateral | 35.77 | 33.69 | ±40 |
| **ORA g's** | Longitudinal | -8.06 | -5.02 | ±20.49 |
| | Lateral | 7.76 | 10.11 | ±20.49 |
| **Max Angular Displacement. deg.** | Roll | -11.4 | 10.6 | ±75 |
| | Pitch | -3.7 | -6.9 | ±75 |
| | Yaw | 53.0 | 51.8 | not required |
| **THIV ft/s** | | 41.16 | 40.32 | not required |
| **PHD g's** | | 7.86 | 10.37 | not required |
| **ASI** | | 2.74 | 2.63 | not required |

## 10.7 Discussion

The analysis of the results for test no. HMDT-4 showed that the system adequately contained and redirected the 1100C vehicle with controlled lateral displacements of the barrier. A summary of the test results and sequential photographs are shown in Figure 196. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or work-zone personnel. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did not occur. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix K, were deemed acceptable, because they did not adversely influence occupant risk nor cause rollover. After impact, the vehicle exited the barrier at an angle of 10.2 degrees, and its trajectory did not violate the bounds of the exit box. Therefore, test no. HMDT-4 was determined to be acceptable according to the MASH 2016 safety performance criteria for test designation no. 3-20.

0.000 sec 0.100 sec 0.200 sec 0.300 sec 0.400 sec




- Test Agency ........ MwRSF
- Test Number ........ HMDT-4
- Date ........ 1/28/2022
- MASH 2016 Test Designation No. ........ 3-20
- Test Article ........ Hawaii Transition to Modified Delaware Retrofit Bridge Rail
- Total Length ........ 177 ft – 6 in.
- Key Component – Thrie-Beam Guardrail
  - Thickness ........ 12 ga.
  - Length ........ 12.5 ft (nested), and 6.25 ft (single ply)
- Key Component – W6x15 Steel Posts
  - Length ........ 78 in.
  - Embedment Depth ........ $48^{3}/_{16}$ in.
  - Spacing ........ 37½ in.
- Soil Type ........ Coarse, Crushed, Limestone (Well-Graded Gravel)
- Vehicle Make /Model ........ 2016 Hyundai Accent
  - Curb ........ 2,502 lb
  - Test Inertial ........ 2,431 lb
  - Gross Static ........ 2,596 lb
- Impact Conditions
  - Speed ........ 60.5 mph
  - Angle ........ 25.1 degrees
  - Impact Location ........ 63.05 in. upstream from post no. 20
- Impact Severity ........ 53.5 kip-ft > 51.1 kip-ft limit from MASH 2016
- Exit Conditions
  - Speed ........ 44.9 mph
  - Angle ........ 10.2 degrees
- Exit Box Criterion ........ Pass
- Vehicle Stability ........ Satisfactory
- Vehicle Stopping Distance ........ 144.4 ft downstream and 39 ft in front
- Vehicle Damage ........ Moderate
  - VDS [15] ........ 10-LFQ-5
  - CDC [16] ........ 10-LFEW-3
  - Maximum Interior Deformation ........ 2.6 in.≤ 9 in. MASH Limit for the toe pan
- Test Article Damage ........ Minimal
- Maximum Test Article Deflections
  - Permanent Set ........ 1.3 in.
  - Dynamic ........ 3.2 in.
  - Working Width ........ 21.6 in.
- Transducer Data

| Evaluation Criteria | | Transducer | | MASH 2016 Limits |
|---|---|---|---|---|
| | | SLICE-1 (Primary) | SLICE-2 | |
| OIV ft/s | Longitudinal | -27.92 | -28.33 | ±40 |
| | Lateral | 35.77 | 33.69 | ±40 |
| ORA g's | Longitudinal | -8.06 | -5.02 | ±20.49 |
| | Lateral | 7.76 | 10.11 | ±20.49 |
| Maximum Angular Displacement deg. | Roll | -11.4 | 10.6 | ±75 |
| | Pitch | -3.7 | -6.9 | ±75 |
| | Yaw | 53.0 | 51.8 | not required |
| THIV – ft/s | | 0.03 | 0.03 | not required |
| PHD – g's | | 38.60 | 38.39 | not required |
| ASI | | 2.74 | 2.63 | not required |

Figure 196. Summary of Test Results and Sequential Photographs, Test No. HMDT-4

# 11 SUMMARY AND CONCLUSIONS

HDOT desired to test and evaluate its thrie-beam approach guardrail transition to the Hawaii Modified Delaware Retrofit Thrie-Beam Bridge Rail according to MASH 2016 TL-3 criteria. The AGT system connected to the Hawaii Modified Delaware Thrie-Beam Bridge Rail was subjected to full-scale crash testing in accordance with the TL-3 evaluation criteria of MASH 2016 test designation no. 3-21 (test nos. HMDT-1 and HMDT-2) and test designation no. 3-20 (test nos. HMDT-3 and HMDT-4). Summaries of the test evaluations are shown in Table 24.

In test no. HMDT-1, the 5,029-lb pickup truck impacted the preliminary design of the HDOT AGT at a speed of 61.7 mph and an angle of 25.7 degrees at a location 84.6 in. upstream from the first bridge rail post, resulting in an impact severity of 116.9 kip-ft. The vehicle was contained and redirected with moderate damage to the barrier system and the vehicle. All vehicle decelerations, ORAs, and OIVs fell within the recommended safety limits established in MASH 2016. However, in test no. HMDT-1, the vehicle's wheel climbing over the curb along with the large rail deflection in the AGT to the bridge rail transition region resulted in the wheel snagging upon the bridge rail's first post, causing excessive toe pan deformations. The maximum occupant compartment intrusion for the wheel well and toe pan exceeded the MASH 2016 allowable limit. Therefore, test no. HMDT-1 failed to meet the safety performance criteria specified for MASH 2016 test designation no. 3-21.

Two design modifications were incorporated to mitigate the vehicle snag and excessive toe pan deformations. First, a flatter vertical slope for the concrete curb was implemented by reducing the slope from 3H:1V to 6H:1V to mitigate the possibility of vehicle snag. Second, a stiffer AGT was designed adjacent to the bridge rail to decrease the rail deflections in this region by reducing the post spacing adjacent to the bridge rail from 37½ in. to 18¾ in. and adding a W6x15 post between post nos. 17 and 18.

In test no. HMDT-2, the 4,981-lb pickup truck impacted the modified HDOT AGT at a speed of 62.5 mph and an angle of 24.5 degrees at a location 78.5 in. upstream from the first bridge rail post, resulting in an impact severity of 114.4 kip-ft. After impacting the barrier system, the vehicle exited the system at a speed of 47.3 mph and an angle of 6.8 degrees. The vehicle was successfully contained and smoothly redirected with moderate damage to the barrier system and the test vehicle. All vehicle decelerations, ORAs, and OIVs fell within the recommended safety limits established in MASH 2016. The maximum occupant compartment intrusions did not exceed the MASH 2016 allowable limit. Therefore, test no. HMDT-2 was determined to be successful according to the safety performance criteria specified for MASH 2016 test designation no. 3-21.

In test no. HMDT-3, the 2,430-lb small car impacted the modified HDOT AGT at a speed of 62.3 mph and an angle of 25.0 degrees at a location 54.7 in. upstream from the first bridge rail post, resulting in an impact severity of 56.7 kip-ft. After impacting the barrier system, the vehicle exited the system at a speed of 34.4 mph and an angle of 8.2 degrees. The vehicle was contained and redirected with moderate damage to the barrier system and the vehicle. All vehicle decelerations, ORAs, and OIVs fell within the recommended safety limits established in MASH 2016. However, the maximum occupant compartment intrusion for the side front panel exceeded the MASH 2016 allowable limit. Therefore, test no. HMDT-3 failed to meet the safety performance criteria specified for MASH 2016 test designation no. 3-20.

The excessive side front panel deformation in the lateral direction was due to the vehicle tire snagging upon the first bridge rail post (i.e., post no. 20), which was a result of the localized deformation of the nested thire-beam rails, flattening of the bottom corrugations, and kinking of the rails upstream from post no. 20. To prevent these rail deformations, a ⅜-in. thick steel reinforcing plate was added to the backside of the nested rail between the last transition post and the first bridge rail post (post nos. 19 and 20).

In test no. HMDT-4, the 2,431-lb small car impacted the finalized HDOT AGT design at a speed of 60.5 mph and an angle of 25.1 degrees at a location 63.1 in. upstream from the first bridge rail post, resulting in an impact severity of 53.5 kip-ft. After impacting the barrier system, the vehicle exited the system at a speed of 44.9 mph and an angle of 10.2 degrees. The vehicle was successfully contained and smoothly redirected with minimal damage to the barrier system and moderate damage to the vehicle. All vehicle decelerations, ORAs, and OIVs fell within the recommended safety limits established in MASH 2016. The maximum occupant compartment intrusions did not exceed the MASH 2016 allowable limit. Therefore, test no. HMDT-4 passed the safety performance criteria of MASH 2016 test designation no. 3-20.

The addition of the reinforcing plate proved to be key in the prevention of localized rail deformations at the downstream end of the AGT and the prevention of wheel snag on the first bridge rail post. The reinforcing plate did not increase the stiffness or strength of the overall system as it only spanned between two adjacent posts and didn't change the load path between the rail and the support posts. Accordingly, the dynamic deflections and working width of the test articles in test nos. HMDT-3 and HMDT-4 were very similar, as shown in Table 23. Thus, the reinforcing plate did not change the deflections of the AGT barrier system for the MASH 3-20 tests, and it is not expected to change the system deflections observed in HMDT-2 for a MASH 3-21 test.

Table 23. Comparison of MASH 3-20 Test Results

| Test No. | Dynamic Deflection (in.) | Working Width (in.) | Permanent Set (in.) |
|---|---|---|---|
| HMDT-3 | 3.7 | 20.9 | 2.0 |
| HMDT-4 | 3.2 | 21.6 | 1.3 |

Recall, test no. HMDT-2 with the 2270P did not result in localized deformations to the AGT rails like those observed in test no. HMDT-3 with the small car and instead resulted in a satisfactory MASH 3-21 test. Since the addition of the reinforcing plate will not change system stiffness/strength, it is not expected to alter the system performance under MASH test 3-21. Running a MASH 3-21 test on the finalized AGT configuration was deemed unnecessary as its performance would mimic that of test no. HMDT-2. Therefore, based the successful evaluations of test nos. HMDT-2 and HMDT-4, the finalized configuration for Hawaii DOT's AGT to the Modified Delaware Retrofit Thrie-Beam Bridge Rail was deemed crashworthy to MASH TL-3 impact safety standards.

Table 24. Summary of Safety Performance Evaluation

| Evaluation Factors | Evaluation Criteria | Test No. HMDT-1 | Test No. HMDT-2 | Test No. HMDT-3 | Test No. HMDT-4 |
|---|---|---|---|---|---|
| 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. | S | S | S | S |
| Occupant Risk | D. 1. 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. | S | S | S | S |
| | 2. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH 2016. | U | S | U | S |
| | F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees. | S | S | S | S |
| | H. Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:<br>Occupant Impact Velocity Limits<br>Component: Longitudinal and Lateral; Preferred: 30 ft/s; Maximum: 40 ft/s | S | S | S | S |
| | I. The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:<br>Occupant Ridedown Acceleration Limits<br>Component: Longitudinal and Lateral; Preferred: 15.0 g's; Maximum: 20.49 g's | S | S | S | S |
| MASH 2016 Test Designation No. | | 3-21 | 3-21 | 3-20 | 3-20 |
| Final Evaluation (Pass or Fail) | | Fail | Pass | Fail | Pass |

S – Satisfactory U – Unsatisfactory NA - Not Applicable

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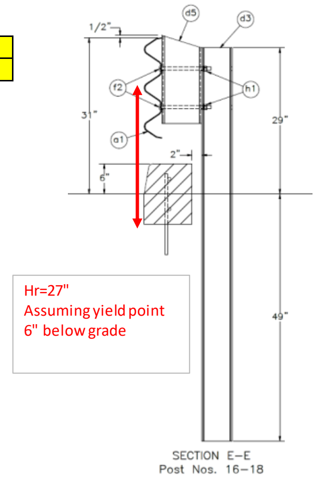
15. *Vehicle Damage Scale for Traffic Investigators*, Second Edition, Technical Bulletin No. 1, Traffic Accident Data (TAD) Project, National Safety Council, Chicago, Illinois, 1971.

16. *Collision Deformation Classification*, SAE International Surface Vehicle Recommended Practice, SAE Standard J224_201702, Society of Automotive Engineers, Warrendale, PA, February 2017.

# 13 APPENDICES

# Appendix A. Critical Impact Point Determination

| Name of System | Hawaii Modified Delaware Bridge Rail Trnasition HMDT w/ 6" curb |
|---|---|
| Test Designation | MASH 3-21 and 3-20 |




**A) Steel Post Fy**

$$F_y = D\left(\frac{\sigma_y Z_p}{H_r}\right) \qquad \text{(Eq. A3-1)}$$

Where:

| | | |
|---|---|---|
| $F_y$ | = | dynamic post yield force for a rigid anchor; |
| $D$ | = | dynamic magnification factor; |
| $\sigma_y$ | = | post yield stress; |
| $Z_p$ | = | post plastic section modulus; and |
| $H_r$ | = | height of highest rail above base of post. |

| | CIP-1 (published values with D=1.5) | CIP-2 (published values with D=1) | Comments |
|---|---|---|---|
| D | 1.5 | 1 | MASH recommends |
| Zp (in^3) | 10.8 | 10.8 | W6x15 |
| σy (ksi) | 50 | 50 | A992 |
| Hr (in) | 27 | 27 | |
| Fy (kips) | 30.00 | 20.00 | |
| | | | |
| Spacing (ft) | 3.125 | 3.125 | Half post spacing |
| Fp (kip/ft) | 9.60 | 6.40 | |

**B) Soil Forces Fs**

$$F_s' = F_s \times \left(\frac{D_e'}{D_e}\right)^2 \qquad \text{(Eq. A3-2)}$$

Where:

| | | |
|---|---|---|
| $D_e'$ | = | soil dynamic yield force at alternate embedment depth, $D_e'$; |
| $F_s$ | = | soil dynamic yield force shown in Table A-3; |
| $D_e'$ | = | alternate embedment depth; and |
| $D_e$ | = | post embedment depth shown in Table A-3. |

| | MASH Data | MwRSF Soil Test Data | Commnets |
|---|---|---|---|
| Fs (kips) | 18.3 | 18.1 | From MASH Table A-3 or MwRSF soil tests |
| De (in) | 44.4 | 44.4 | |
| D'e (in) | 49 | 49 | |
| F's (kips) | 22.29 | 22.04 | |
| Fp (kip/ft) | 7.13 | 7.05 | |

| Smallest of Fy and Fs controls Fp | Fy | |
|---|---|---|
| Fp for CIP-1 | 7.13 | with 1.5 factor MASH Data |
| Fp for CIP-2 | 6.40 | without 1.5 factor - MASH Data |

**C) Rail plastic Moment**

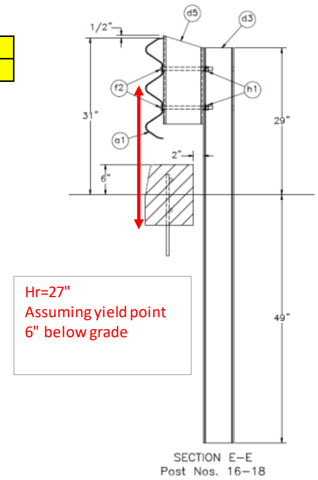
| | MASH Table A-1 | Using actual mill certs | Comments |
|---|---|---|---|
| Zp | 3.07 | 3.07 | 12-gauge thrie beam |
| σy (ksi) | 50 | | |
| Mp | 25.58 | | Nested multiple by 2 |

**D) CIP**

| Test 3-21 | Figure 2-17 | | From Post/splice no. (center) |
|---|---|---|---|
| Fp | 7.13 | X=7.125=86 in. (CIP 1) | 19 |
| Mp | 25.58 | | |
| Fp | 6.40 | X=7.2 ft= 86 in. (CIP 2) | 19 |
| Mp | 25.58 | | |

Figure A-1. CIP Determination, Test Nos. HMDT-1 and HMDT-2

| | |
|---|---|
| Name of System | Hawaii Modified Delaware Bridge Rail Trnasition HMDT w/ 6" curb |
| Test Designation | MASH 3-21 and 3-20 |




**A) Steel Post Fy**

$$F_y = D\left(\frac{\sigma_y Z_p}{H_r}\right) \qquad \text{(Eq. A3-1)}$$

Where:

$F_y$ = dynamic post yield force for a rigid anchor;
$D$ = dynamic magnification factor;
$\sigma_y$ = post yield stress;
$Z_p$ = post plastic section modulus; and
$H_r$ = height of highest rail above base of post.

| | CIP-1 (published values with D=1.5) | CIP-2 (published values with D=1) | Comments |
|---|---|---|---|
| D | 1.5 | 1 | MASH recommends |
| Zp (in^3) | 10.8 | 10.8 | W6x15 |
| σy (ksi) | 50 | 50 | A992 |
| Hr (in) | 27 | 27 | |
| Fy (kips) | 30.00 | 20.00 | |
| | | | |
| Spacing (ft) | 3.125 | 3.125 | Half post spacing |
| Fp (kip/ft) | 9.60 | 6.40 | |

**B) Soil Forces Fs**

$$F_s' = F_s \times \left(\frac{D_e'}{D_e}\right)^2 \qquad \text{(Eq. A3-2)}$$

Where:

$D_e'$ = soil dynamic yield force at alternate embedment depth, $D_e'$;
$F_s$ = soil dynamic yield force shown in Table A-3;

$D_e'$ = alternate embedment depth; and
$D_e$ = post embedment depth shown in Table A-3.

| | MASH Data | MwRSF Soil Test Data | Commnets |
|---|---|---|---|
| Fs (kips) | 18.3 | 18.1 | From MASH Table A-3 or MwRSF soil tests |
| De (in) | 44.4 | 44.4 | |
| D'e (in) | 49 | 49 | |
| F's (kips) | 22.29 | 22.04 | |
| Fp (kip/ft) | 7.13 | 7.05 | |

| Smallest of Fy and Fs controls Fp | Fy | |
|---|---|---|
| Fp for CIP-1 | 7.13 | with 1.5 factor MASH Data |
| Fp for CIP-2 | 6.40 | without 1.5 factor - MASH Data |

**C) Rail plastic Moment**

| | MASH Table A-1 | Using actual mill certs | Comments |
|---|---|---|---|
| Zp | 3.07 | 3.07 | 12-gauge thrie beam |
| σy (ksi) | 50 | | |
| Mp | 25.58 | | Nested multiple by 2 |

**D) CIP**

| **Test 3-20** | Figure 2-14 | | From Post/splice no. (center) |
|---|---|---|---|
| Fp | 7.13 | X=5.175ft= 62 in. (CIP 1) | 19 |
| Mp | 25.58 | | |
| Fp | 6.40 | X=5.25 ft=63 in (CIP 2) | 19 |
| Mp | 25.58 | | |

Figure A-2. CIP Determination, Test Nos. HMDT-3 and HMDT-4

# Appendix B. Material Specifications, Test No. HMDT-1

As discussed in Chapter 3, the drawing set for test no. HMDT-1 included details for the entire system, inclusive of the AGT and bridge rail installation. However, only the AGT was evaluated during in this test, and therefore, only the AGT components are documented in this appendix.

Table B-1. Bill of Materials, Test No. HMDT-1

| Item No. | Description | Material Specification | Reference |
|---|---|---|---|
| a1 | 12'-6" 12-gauge Thrie Beam Section | AASHTO M180 | H#L32420 |
| a2 | 6'-3" 12-gauge Thrie Beam Section | AASHTO M180 | H#L34919 |
| a3 | 6'-3" 10-gauge W-Beam to Thrie-Beam Asymmetric Transition Section | AASHTO M180 | H#240680 |
| a4 | 12'-6" 12-gauge W-Beam MGS Section | AASHTO M180 | H#C85187 |
| a5 | 12'-6" 12-gauge W-Beam MGS End Section | AASHTO M180 | H#C85187 |
| c1 | BCT Timber Post - MGS Height | SYP Grade No. 1 or better (No knots +/- 18" from ground on tension face) | Ch#26224 |
| c2 | 72" Long Foundation Tube | ASTM A500 Gr. B | H#821T08220 |
| c3 | Ground Strut Assembly | ASTM A36 | H#163375 |
| c4 | BCT Anchor Cable End Swaged Fitting | Fitting - ASTM A576 Gr. 1035<br>Stud - ASTM F568 Class C | PO#40299 ASPI# 122160 |
| c5 | BCT Cable Anchor Assembly | - | PO#40299 ASPI# 122160 |
| c6 | 8"x8"x⅝" Anchor Bearing Plate | ASTM A36 | H#4181496 |
| c7 | 2⅜" O.D. x 6" Long BCT Post Sleeve | ASTM A53 Gr. B Schedule 40 | H#B712810 |
| c8 | Anchor Bracket Assembly | ASTM A36 | H#JK16101488 |
| d1 | W6x9 or W6x8.5, 72" Long Steel Post | ASTM A992 | H#55064803.02 |
| d2 | W6x9 or W6x8.5, 72" Long Steel Post | ASTM A992 | H#55064803.02 |
| d3 | W6x15, 78" Long Steel Post | ASTM A992 | H#58042771.02 |
| d4 | 17½" Long, 8"x6"x¼" Steel Blockout | ASTM A500 Gr. B | H#A97575 |
| d5 | 17½" Long, 12"x4"x ¼" Steel Blockout | ASTM A500 Gr. B | H#2202349<br>H#SK1852 |
| d6 | $14^{3}/_{16}$"x12"x5⅛" Composite Recycled Blockout | Mondo Polymer MGS14SH or Equivalent | L#1904/1000 |
| d7 | $14^{3}/_{16}$"x8"x5⅛" Composite Recycled Blockout | Mondo Polymer GB14SH2 or Equivalent | L#1804/1000 |

Table B-2. Bill of Materials, Test No. HMDT-1, Cont.

| Item No. | Description | Material Specification | Reference |
|---|---|---|---|
| d8 | 16D Double Head Nail | Galvanized | Certificate of Compliance for PO E000548963 |
| e3 | #4 Rebar, 16" Total Length | ASTM A615 Gr. 60 | H#7006848 |
| e4 | #4 Rebar, 12¾" Total Length | ASTM A615 Gr. 60 | H#7006848 |
| e5 | #5 Rebar, 166" Total Length | ASTM A615 Gr. 60 | H#62150922/02 |
| e6 | #5 Rebar, 158¼" Total Unbent Length | ASTM A615 Gr. 60 | H#62150922/02 |
| f1 | ⅝"-11 UNC, 14" Long Guardrail Bolt | ASTM A307 Gr. A | H#DL17100590 |
| f2 | ⅝"-11 UNC, 10" Long Guardrail Bolt | ASTM A307 Gr. A | H#1721198 |
| f3 | ⅝"-11 UNC, 1¼ " Long Guardrail Bolt | ASTM A307 Gr. A | H#10657410 |
| f4 | ⅝"-11 UNC, 10" Long Hex Head Bolt | ASTM A307 Gr. A or equivalent | H#JK18104124 |
| f5 | ⅝"-11 UNC, 1½" Long Hex Head Bolt | ASTM A307 Gr. A or equivalent | H#5-01570 |
| f6 | ⅞"-9 UNC, 8" Long Hex Head Bolt | ASTM A307 Gr. A or equivalent | H#489517 |
| g1 | ⅝" Dia. Plain USS Washer | ASTM F844 | P#1133185 C#180164126 L#M-SWE0412454-8 |
| g3 | ⅞" Dia. Plain Round Washer | ASTM F844 | P#33187 C#170089822 L#1844804 |
| g4 | 1" Dia. Plain USS Washer | ASTM F844 | P#33188 C#210151571 |
| h1 | ⅝"-11 UNC Heavy Hex Nut | ASTM A563A or equivalent | H#62151324/02 H#62152527/02 |
| h3 | ⅞"-9 UNC Hex Nut | ASTM A563A or equivalent | P#36717 C#210167591 L#1N18BC001 L#1N1880113 |
| h5 | 1" Dia. Heavy Hex Nut | ASTM A563DH or A194 Gr. 2H | COC Only P#38210 C#210157128 |
| h6 | ⅝"-11 UNC Hex Nut | ASTM A563A or equivalent | H#331608011 |
| j2 | Curb Concrete | Minimum strength f’c = 4,000 psi | Ticket# 1260732 |

# Certified Analysis

Trinity Highway Products LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296
Customer: MIDWEST MACH & SUPPLY CO
P. O. BOX 703

MILFORD, NE 68405
Project: STOCK

Order Number: 1324622 Prod Ln Grp: 0-OE2.0
Customer PO: 3954
BOL Number: 112739 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 6/30/20

| Qty | Part # | Description | Spec | CL | TY | Heat Code/ Heat | Yield | TS | Elg | C | Mn | P | S | Si | Cu | Cb | Cr | Vn | ACW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 40 | 12173G | T12/6'3/4@1'6.75"/S | | | 2 | L34919 | | | | | | | | | | | | | |
| | | | M-180 | A | 2 | 245021 | 64,480 | 83,940 | 22.2 | 0.190 | 0.700 | 0.013 | 0.004 | 0.020 | 0.060 | 0.000 | 0.060 | 0.001 | 4 |
| | | | M-180 | A | 2 | 245984 | 62,860 | 80,840 | 26.2 | 0.190 | 0.720 | 0.008 | 0.003 | 0.010 | 0.080 | 0.000 | 0.050 | 0.000 | 4 |
| 50 | 12365G | T12/12'6/8@1'6.75/S | | | 2 | L32420 | | | | | | | | | | | | | |
| | | | M-180 | A | 2 | 251386 | 62,920 | 81,060 | 24.4 | 0.200 | 0.720 | 0.010 | 0.002 | 0.020 | 0.100 | 0.000 | 0.070 | 0.002 | 4 |
| | | | M-180 | B | 2 | 248862 | 64,080 | 82,460 | 25.1 | 0.180 | 0.730 | 0.011 | 0.001 | 0.020 | 0.100 | 0.000 | 0.060 | 0.001 | 4 |
| | | | M-180 | B | 2 | 249478 | 61,020 | 80,630 | 27.0 | 0.190 | 0.720 | 0.010 | 0.001 | 0.020 | 0.090 | 0.000 | 0.060 | 0.000 | 4 |
| | 12365G | | | | 2 | L31920 | | | | | | | | | | | | | |
| | | | M-180 | A | 2 | 249480 | 63,400 | 81,930 | 25.1 | 0.190 | 0.740 | 0.010 | 0.003 | 0.010 | 0.060 | 0.000 | 0.060 | 0.000 | 4 |
| | | | M-180 | B | 2 | 248862 | 64,080 | 82,460 | 25.1 | 0.180 | 0.730 | 0.011 | 0.001 | 0.020 | 0.100 | 0.000 | 0.060 | 0.001 | 4 |
| 180 | 54043G | 7'0 PST/6X15/DB:3HI | A-572 | | | 59091538 | 62,786 | 81,568 | 20.0 | 0.090 | 1.330 | 0.015 | 0.029 | 0.240 | 0.340 | 0.000 | 0.200 | 0.049 | 4 |

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy QMS-LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT, 23 CFR 635.410.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36 UNLESS OTHERWISE STATED.
ALL COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT", 23 CFR 635.410.
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 (US DOMESTIC SHIPMENTS)
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 & ISO 1461 (INTERNATIONAL SHIPMENTS)

FINISHED GOOD PART NUMBERS ENDING IN SUFFIX B,P, OR S, ARE UNCOATED

2 of 3

Figure B-1. 12-Gauge W-Beam, Test No. HMDT-1 (Item Nos. a1 and a2)

220008-P1

# Certified Test Report

NORTH STAR BLUESCOPE STEEL LLC
6767 County Road 9
Delta Ohio 43515
Telephone: (888) 822-2112

| | | | | | |
|---|---|---|---|---|---|
| **Customer:** | Miami Valley Steel Service Inc. | | | **Ordered Width (mm/in)** | 1295.4 / 51 |
| 201 fox Dr. | | **Order #** | 434020 | **Ordered Gauge (mm/in)** | 3.200 / 0.126 M |
| Piqua, OH 45356 | | **Line Item #** | 1 | **Produced Date/Time** | 6/15/19 17:44 |
| **Customer P.O:** | 081886 | **Heat #** | 240680 | **Coil #** | 1933970 |
| **Cust. Ref/Part #** | M180 | **Material Desc:** | 1018 CQ Modified, Guardrail Type 2 | | |

**Weight(kg/lb)** 19318 / 42589

## Chemical Analysis (wt%)

| Type | C | Mn | P | S | Si | Al | Cu | Cr | Ni | Mo | Sn | N | B | V | Nb | Ti | Ca | Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Heat | 0.20 | 0.73 | 0.008 | 0.004 | 0.02 | 0.03 | 0.11 | 0.06 | 0.04 | 0.01 | 0.00 | 0.006 | 0.0000 | 0.002 | 0.000 | 0.001 | 0.002 | 0.000 |

## Mechanical Test Report

| | Yield Strength | Tensile Strength | % Elongation in 2 inches |
|---|---|---|---|
| Tail | 62100 psi / 428 MPa | 79940 psi / 551 MPa | 27.5% |

This hot rolled steel has been produced to conform to DIN EN 10204:2005 3.1 and has been manufactured to a fully killed fine grain practice. This hot rolled steel has been produced and tested in accordance with each of the following applicable standards:ASTM E1806-09, ASTM E415-14, ASTM A751-14, ASTM A370-14, JIS Z2201:1998, JIS Z2241:2011. Pressure Equipment Directive (PED) 2014/68/EU, Annex I, Paragraph 4.3 Compliant. This report certifies that the above test results are representative of those contained in the records of North Star BlueScope Steel LLC for the material identified in this test report and is intended to comply with the requirements of the material description. North Star BlueScope Steel LLC is not responsible for the inability of this material to meet specific applications. Any modifications to this certification as provided negates the validity of this test report. All reproductions must have the written approval of North Star BlueScope Steel.This product was manufactured, melted, cast, and hot-rolled (min. 3:1 reduction ratio), entirely within the U.S.A at North Star BlueScope Steel LLC, Delta, Ohio. This material was not exposed to Mercury or any alloy which is liquid at ambient temperature during processing or while in North Star BlueScope Steel LLC possession. Test equipment calibration certificates are available upon request. NIST traceability is established through test equipment calibration certificates which are available upon request. Uncertainty calculations are calculated in accordance with NIST standards and are maintained at a 4:1 ratio in accordance with NIST standards. Uncertainty data is available upon request

**John Meece** **Manager Quality Assurance and Technology**

072718

**Date Issued:** Aug 21, 2019 8:58 AM
**Revision#:** 01

Figure B-2. 10-Gauge W-Beam to Thrie-Beam Asymmetric Transition Section, Test No. HMDT-1 (Item No. a3)

GREGORY HIGHWAY PRODUCTS, INC.
4100 13th St. SW
Canton, Ohio 44710

Customer: UNIVERSITY OF NEBRASKA-LINCOLN
401 CANFIELD ADMIN BLDG
P O BOX 880439
LINCOLN,NE,68588-0439

Test Report
Ship Date: 1/26/2018
Customer P O: 36263
Shipped to: UNIVERSITY OF NEBRASKA-LINCOLN
Project:
GHP Order No.: 319AA

| HT # code | Heat # | C. | MN. | P. | S. | Si. | Tensile | Yield | Elong. | Quanity | Class | Type | Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1207 | C85187 | 0.2 | 0.48 | 0.008 | 0.003 | 0.03 | 80433 | 59371 | 16.35 | 150 | A | 2 | 12GA 12FT6IN/3FT1 1/2IN WB T2 |

Bolts comply with ASTM A-307 specifications and are galvanized in accordance with ASTM A-153, unless otherwise stated.
Nuts comply with ASTM A-563 specifications and are galvanized in accordance with ASTM A-153, unless otherwise stated.
All other galvanized material conforms with ASTM-123 & ASTM-653
All Galvanizing has occurred in the United States
All steel used in the manufacture is of Domestic Origin, "Made and Melted in the United States"
All Steel used meets Title 23CFR 635.410 - Buy America
All Guardrail and Terminal Sections meets AASHTO M-180, All structural steel meets AASHTO M-183 & M270
All Bolts and Nuts are of Domestic Origin
All material fabricated in accordance with Nebraska Department of Transportation
All controlled oxidized/corrosion resistant Guardrail and terminal sections meet ASTM A606, Type 4.

Jeffery L Grover

By:
Jeffery Grover, VP of Highway Products Sales & Marketing
Gregory Highway Products, Inc.

NOTARIAL SEAL
STATE OF OHIO

James P Dehnke
Notary Public - State of Ohio
My Commission Expires
October 19, 2019

STATE OF OHIO: COUNTY OF STARK
Sworn to and subscribed before me, a Notary Public, by
Jeffery Grover this 29 day of January, 2018

Notary Public, State of Ohio

Figure B-3. 12 ft – 6 in. 12-Gauge W-Beam MGS Section, Test No. HMDT-1 (Item Nos. a4 and a5)

CNWP
CENTRAL NEBRASKA WOOD PRESERVERS

1098 East Maple St
Sutton, NE 68979
Phone: 402.773.4319
Email: nick@nebraskawood.com

**CERTIFICATE OF COMPLIANCE**

**Shipped To:** Midwest Machinery and Supply
**BOL#** N08525
**Customer PO#** 3644
**Preservative:** CCA – C 0.60D pcf AWPA UC4B

| Part # | Physical Description | # of Pieces | Charge # | Tested Retention |
|---|---|---|---|---|
| GR6819 BLK | 6x8-19″ OCD Block | 168 | 26258 | .657 |
| GR61219 BLK | 6x12-19″ OCD Block | 112 | 26258 | .657 |
| GR61222 BLK | 6x12-22″ OCD Block | 56 | 26260 | .680 |
| GS6846 PST | 5.5x7.5-46″ BCT | 42 | 26224 | .657 |
| | | | | |
| | | | | |
| | | | | |

I certify the above referenced material has been produced, treated and tested in accordance with and conforms to AASHTO M133 & M168 standards.

**VA:** Iowa Wood Preservers certifies that the treated wood products listed above have been treated in accordance with AWPA standards, Section 236 of the VDOT Road & Bridge Specifications and meets the applicable minimum penetration and retention requirements.

Nick Sowl, General Counsel

10/16/18
Date

Figure B-4. BCT Timber Post, Test No. HMDT-1 (Item No. c1)

30460HD6

Atlas Tube Corp (Chicago)
1855 East 122nd Street
Chicago, Illinois, USA
60633
Tel: 773-646-4500
Fax: 773-646-6128

**Atlas Tube**
A DIVISION OF ZEKELMAN INDUSTRIES

Ref.B/L: 80728203
Date: 08.17.2016
Customer: 2908

## MATERIAL TEST REPORT

**Sold to**

Gregory Industries Inc.
4100 13th Street SW.
CANTON OH 44710
USA

**Shipped to**

Tru-Form Steel & Wire
1204 Gilkey Ave
HARTFORD CITY IN 47348
USA

Material: 8.0x6.0x188x27'0"0(2x2)SILDOMUS — Material No: 80060188 — Made in: USA — Melted in: USA

Sales order: 1105121 — Purchase Order: 35569 — Cust Material #: TRB3/16-8-6-27

| Heat No | C | Mn | P | S | Si | Al | Cu | Cb | Mo | Ni | Cr | V | Ti | B | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 616137 | 0.210 | 0.930 | 0.011 | 0.003 | 0.020 | 0.041 | 0.020 | 0.008 | 0.020 | 0.020 | 0.030 | 0.008 | 0.001 | 0.000 | 0.003 |

| Bundle No | PCs | Yield | Tensile | Eln.2in | Certification | CE |
|---|---|---|---|---|---|---|
| M800650076 | 4 | 058210 Psi | 073148 Psi | 32 % | ASTM A500-13 GRADE B&C | 0.38 |

Material Note:
Sales Or.Note:

Material: 8.0x6.0x188x30'0"0(2x3)SILDOMUS — Material No: 80060188 — Made in: USA — Melted in: USA

Sales order: 1105121 — Purchase Order: 35569 — Cust Material #: TRB3/16-8-6-30

| Heat No | C | Mn | P | S | Si | Al | Cu | Cb | Mo | Ni | Cr | V | Ti | B | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 821T08220 | 0.220 | 0.810 | 0.013 | 0.006 | 0.006 | 0.041 | 0.160 | 0.002 | 0.005 | 0.010 | 0.020 | 0.002 | 0.002 | 0.000 | 0.007 |

| Bundle No | PCs | Yield | Tensile | Eln.2in | Certification | CE |
|---|---|---|---|---|---|---|
| M800650038 | 6 | 057275 Psi | 070934 Psi | 32 % | ASTM A500-13 GRADE B&C | 0.37 |

Material Note:
Sales Or.Note:

Material: 8.0x6.0x188x30'0"0(2x3)SILDOMUS — Material No: 80060188 — Made in: USA — Melted in: USA

Sales order: 1105121 — Purchase Order: 35569 — Cust Material #: TRB3/16-8-6-30

| Heat No | C | Mn | P | S | Si | Al | Cu | Cb | Mo | Ni | Cr | V | Ti | B | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 821T08220 | 0.220 | 0.810 | 0.013 | 0.006 | 0.006 | 0.041 | 0.160 | 0.002 | 0.005 | 0.010 | 0.020 | 0.002 | 0.002 | 0.000 | 0.007 |

| Bundle No | PCs | Yield | Tensile | Eln.2in | Certification | CE |
|---|---|---|---|---|---|---|
| M800650039 | 6 | 057275 Psi | 070934 Psi | 32 % | ASTM A500-13 GRADE B&C | 0.37 |

Material Note:
Sales Or.Note:

Jason Richard

Jason Richard

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

Steel Tube Institute OF NORTH AMERICA

Page : 1 Of 6

Metals Service Center Institute

Figure B-5. 72-in. Long Foundation Tube, Test No. HMDT-1 (Item No. c2)

# Certified Analysis

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

Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 703

MILFORD, NE 68405

Project: STOCK

Order Number: 1214903 Prod Ln Grp: 9-End Terminals (Dom)
Customer PO: 2878
BOL Number: 80278 Ship Date:
Document #: 1
Shipped To: NE
Use State: KS

As of: 3/7/14

| Qty | Part # | Description | Spec | CL | TY | Heat Code/ Heat | Yield | TS | Elg | C | Mn | P | S | Si | Cu | Cb | Cr | Vn | ACW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 36 | 749G | TS 8X6X3/16X6'-0" SLEEVE | A-500 | | | 0173175 | 55,871 | 74,495 | 31.0 | 0.160 | 0.610 | 0.012 | 0.009 | 0.010 | 0.030 | 0.000 | 0.030 | 0.000 | 4 |
| 20 | 3000G | CBL 3/4X6'6/DBL | HW | | | 98790 | | | | | | | | | | | | | |
| 22 | 9852A | STRUT & YOKE ASSY | A-1011-SS | | | 163375 | 48,380 | 64,020 | 32.9 | 0.190 | 0.520 | 0.011 | 0.003 | 0.030 | 0.110 | 0.000 | 0.050 | 0.000 | 4 |
| | 9852A | | A-36 | | | 11237730 | 45,500 | 70,000 | 30.0 | 0.170 | 0.500 | 0.010 | 0.008 | 0.020 | 0.080 | 0.000 | 0.070 | 0.001 | 4 |

Ground Strut Green Paint
R#15-0157 September 2014 SMT

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy No. LG-002.
ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36
ALL COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT"
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM-123 (US DOMESTIC SHIPMENTS)
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A123 & ISO 1461 (INTERNATIONAL SHIPMENTS)

FINISHED GOOD PART NUMBERS ENDING IN SUFFIX B,P, OR S, ARE UNCOATED
BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
WASHERS COMPLY WITH ASTM F-436 SPECIFICATION AND/OR F-844 AND ARE GALVANIZED IN ACCORDANCE WITH ASTM F-2329.
3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH – 46000 LB

1 of 2

Figure B-6. Ground Strut Assembly, HMDT-1 (Item No. c3)

ASSEMBLY
SPECIALTY PRODUCTS INC

PH 216.676.5600
FX 216.676.6761
www.assemblyspecialty.com

ISO 9001:2008

14700 Brookpark Rd
Cleveland, OH 44135-5166
customerservice@assemblyspecialty.com

## Certificate of Conformance

**Date:** September 24, 2018

**To:** Gregory Industries, Inc.
Gregory Galv. & Metal Processing
4100 13th St. SW
Canton, OH 44710

We certify that our system and procedures for the control of quality assures that all items furnished on the order will meet applicable tests, requirements and inspection requirements as required by the purchase order and applicable specifications and drawings.

**PURCHASE ORDER #:** 40299
**DATE SHIPPED:** 09/24/18
**ASPI SALES ORDER #:** 122160
**MANUFACTURER:** ASSEMBLY SPECIALTY PRODUCTS, INC.

| QTY | CUST P/N | ASPI P/N | ASPI LOT# | DESCRIPTION |
|---|---|---|---|---|
| 250 | 3012G | C-2028 | 89315 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 89316 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 89318 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 89864 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 89865 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 89866 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 89929 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 89930 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 89931 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 89932 | 6' 6" BCT Cable Assembly |

**REMARKS:** NOMINAL BREAKING STRENGTH: 46,000 lbs
WIRE ROPE MANUFACTURED IN ACCORDANCE WITH AASHTO DESIGNATION: M30-02 and ASTM A741 TYPE 2, CLASS A
FITTINGS GALVANIZED IN ACCORDANCE WITH ASTM A-153 CLASS C.

STEEL USED TO MANUFACTURE THESE ITEMS WAS MELTED AND MANUFACTURED IN THE U.S.A
ALL MANUFACTURING PROCESSES SUPPLIED OR PERFORMED BY ASSEMBLY SPECIALTY PRODUCTS, INC. TOOK PLACE IN THE U.S.A.

Signature:
Certification and Compliance Manager

Figure B-7. BCT Anchor Cable End Swaged Fitting and Cable Anchor Assembly, Test No. HMDT-1 (Item Nos. c4 and c5)

**ASSEMBLY**
SPECIALTY PRODUCTS INC.

PH 216.676.5600
FX 216.676.6761
www.assemblyspecialty.com

ISO 9001:2008

14700 Brookpark Rd
Cleveland, OH 44135-5166
customerservice@assemblyspecialty.com

**Lots continued):**

| QTY | CUST P/N | ASPI P/N | ASPI LOT# | DESCRIPTION |
|---|---|---|---|---|
| 250 | 3012G | C-2028 | 90007 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 90008 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 90009 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 90010 | 6' 6" BCT Cable Assembly |

Figure B-8. BCT Anchor Cable End Swaged Fitting and Cable Anchor Assembly, Test No. HMDT-1, Cont (Item No. c4 and c5)

**GREGORY HIGHWAY PRODUCTS, INC.**
**4100 13th St. SW**
**Canton, Ohio 44710**

MIDWEST MACHINERY & SUPPLY CO.
P. O. BOX 703

MILFORD,NE,68405

Test Report
Ship Date: 11/17/2017
Customer P.O.: 3515
Shipped to: MIDWEST MACHINERY & SUPPLY CO.
Project:
GHP Order No: 128AA

| HT # code | LOT# | C. | Mn. | P. | S. | Si. | Tensile | Yield | Elong. | Quantity | Class | Type | Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A74070 | | 0.21 | 0.46 | 0.012 | 0.002 | 0.03 | 76100 | 58800 | 25.2 | 4 | A | 2 | 12GA TB TRANS. |
| 4181496 | | 0.24 | 0.84 | 0.014 | 0.01 | 0.01 | 72400 | 44800 | 34 | 4 | | 2 | 5/8IN X 8IN X 8IN BRG. PL. |
| 4181489 | | 0.09 | 0.45 | 0.012 | 0.004 | 0.01 | 58000 | 43100 | 27 | 4 | | 2 | 350 STRUT & YOKE |
| 196828BM | | 0.04 | 0.84 | 0.014 | 0.003 | | 76000 | 74000 | 25 | | | 2 | 350 STRUT & YOKE |
| E22985 | | 0.17 | 0.51 | 0.013 | 0.008 | 0.008 | 72510 | 64310 | 29.5 | 4 | | 2 | 2IN X 5 1/2IN PIPE SLEEVE |
| 811T08220 | | 0.22 | 0.81 | 0.013 | 0.006 | 0.005 | 71412 | 56323 | 35 | 8 | | 2 | 3/16IN X 6IN X 8IN X 6FT0IN TUBE SLEEVE |

James P. Dehnke
Notary Public, State of Ohio
My Commission Expires 10-19-2019

All Galvanizing has occurred in the United States
All steel used in the manufacture is of Domestic Origin, "Made and Melted in the United States"
All Steel used meets Title 23CFR 635.410 - Buy America
All Guardrail and Terminal Sections meets AASHTO M-180, All structural steel meets AASHTO M-183 & M270
All Bolts and Nuts are of Domestic Origin
All material fabricated in accordance with Nebraska Department of Transportation
All controlled oxidized/corrosion resistant Guardrail and terminal sections meet ASTM A606, Type 4.

By: ______________________

STATE OF OHIO: COUNTY OF STARK
Sworn to and subscribed before me, a Notary Public, by
Andrew Artar this 21 day of November, 2017

Notary Public, State of Ohio

Figure B-9. Anchor Bearing Plate, Test No. HMDT-1 (Item No. c6)

Atlas Tube (Alabama), Inc.
171 Cleage Dr
Birmingham, Alabama, USA
35217
Tel:
Fax:

Atlas Tube
A DIVISION OF ZEKELMAN INDUSTRIES

Ref.B/L: 80791452
Date: 11.10.2017
Customer: 179

# MATERIAL TEST REPORT

**Sold to**

Steel & Pipe Supply Compan
PO Box 1688
MANHATTAN KS 66505
USA

**Shipped to**

Steel & Pipe Supply Compan
401 New Century Parkway
NEW CENTURY KS 66031
USA

Material: 3.0x2.0x188x40'0"0(5x4). Material No: 0300201884000-B Made in: USA
Melted in: USA
Sales order: 1226976 Purchase Order: 4500296656 Cust Material #: 6630020018840

| Heat No | C | Mn | P | S | Si | Al | Cu | Cb | Mo | Ni | Cr | V | Ti | B | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B704212 | 0.200 | 0.450 | 0.010 | 0.004 | 0.020 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

| Bundle No | PCs | Yield | Tensile | Eln.2in | Certification | CE: 0.28 |
|---|---|---|---|---|---|---|
| 40867002 | 20 | 064649 Psi | 087652 Psi | 24 % | ASTM A500-13 GRADE B&C | |

Material Note:
Sales Or.Note:

Material: 2.375x154x42'0"0(34x1). Material No: R023751544200 Made in: USA
Melted in: USA
Sales order: 1226976 Purchase Order: 4500296656 Cust Material #: 642004042

| Heat No | C | Mn | P | S | Si | Al | Cu | Cb | Mo | Ni | Cr | V | Ti | B | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B712810 | 0.210 | 0.460 | 0.012 | 0.002 | 0.020 | 0.024 | 0.100 | 0.002 | 0.020 | 0.030 | 0.060 | 0.004 | 0.002 | 0.000 | 0.008 |

| Bundle No | PCs | Yield | Tensile | Eln.2in | Rb | Certification | CE: 0.32 |
|---|---|---|---|---|---|---|---|
| MC00006947 | 34 | 063688 Psi | 083220 Psi | 25 % | 91 | ASTM A500-13 GRADE B&C | |

Material Note:
Sales Or.Note:

Material: 2.375x154x42'0"0(34x1). Material No: R023751544200 Made in: USA
Melted in: USA
Sales order: 1226976 Purchase Order: 4500296656 Cust Material #: 642004042

| Heat No | C | Mn | P | S | Si | Al | Cu | Cb | Mo | Ni | Cr | V | Ti | B | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 17037261 | 0.210 | 0.810 | 0.005 | 0.004 | 0.020 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

| Bundle No | PCs | Yield | Tensile | Eln.2in | Certification | CE: 0.35 |
|---|---|---|---|---|---|---|
| 41532001 | 34 | 066144 Psi | 082159 Psi | 27 % | ASTM A500-13 GRADE B&C | |

Material Note:
Sales Or.Note:

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

Steel Tube Institute

Page : 3 Of 4

Metals Service Center Institute

Figure B-10. BCT Post Sleeve, Test No. HMDT-1 (Item No. c7)

# Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296

Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 703

MILFORD, NE 68405

Project: RESALE

Order Number: 1269489 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: 3346
BOL Number: 97457 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 11/7/16

| Qty | Part # | Description | Spec | CL | TY | Heat Code/ Heat | Yield | TS | Elg | C | Mn | P | S | Si | Cu | Cb | Cr | Vn | ACW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 701A | Anchor Box | A-36 | | | JK16101488 | 56,172 | 75,460 | 25.0 | 0.160 | 0.780 | 0.017 | 0.028 | 0.200 | 0.280 | 0.001 | 0.140 | 0.028 | 4 |
| | 701A | | A-36 | | | 535133 | 43,300 | 68,500 | 33.0 | 0.019 | 0.460 | 0.013 | 0.016 | 0.013 | 0.090 | 0.001 | 0.090 | 0.002 | 4 |
| 4 | 729G | TS 8X6X3/16X8'-0" SLEEVE | A-500 | | | A49248 | 64,818 | 78,412 | 32.0 | 0.200 | 0.810 | 0.014 | 0.002 | 0.040 | 0.020 | 0.000 | 0.040 | 0.001 | 4 |
| 20 | 738A | 5'TUBE SL.188X6X8 1/4 /PL | A-36 | | 2 | 4182184 | 45,000 | 67,900 | 31.0 | 0.210 | 0.760 | 0.012 | 0.008 | 0.010 | 0.050 | 0.001 | 0.030 | 0.002 | 4 |
| | 738A | | A-500 | | | A49248 | 64,818 | 78,412 | 32.0 | 0.200 | 0.810 | 0.014 | 0.002 | 0.040 | 0.020 | 0.000 | 0.040 | 0.001 | 4 |
| 6 | 749G | TS 8X6X3/16X6'-0" SLEEVE | A-500 | | | A49248 | 64,818 | 78,412 | 32.0 | 0.200 | 0.810 | 0.014 | 0.002 | 0.040 | 0.020 | 0.000 | 0.040 | 0.001 | 4 |
| 6 | 782G | 5/8"X8"X8" BEAR PL/OF | A-36 | | | DL15103543 | 58,000 | 74,000 | 25.0 | 0.150 | 0.750 | 0.013 | 0.025 | 0.200 | 0.360 | 0.003 | 0.090 | 0.000 | 4 |
| 20 | 783A | 5/8X8X8 BEAR PL 3/16 STP | A-36 | | | PL14107973 | 48,167 | 69,811 | 25.0 | 0.160 | 0.740 | 0.012 | 0.041 | 0.190 | 0.370 | 0.000 | 0.220 | 0.002 | 4 |
| | 783A | | A-36 | | | DL15103543 | 58,000 | 74,000 | 25.0 | 0.150 | 0.750 | 0.013 | 0.025 | 0.200 | 0.360 | 0.003 | 0.090 | 0.000 | 4 |
| 45 | 3000G | CBL 3/4X6'6/DBL | HW | | | 119048 | | | | | | | | | | | | | |
| 7,000 | 3340G | 5/8" GR HEX NUT | HW | | | 0055551-116146 | | | | | | | | | | | | | |
| 4,000 | 3360G | 5/8"X1.25" GR BOLT | HW | | | 0053777-115516 | | | | | | | | | | | | | |
| 450 | 3500G | 5/8"X10" GR BOLT A307 | HW | | | 28971-B | | | | | | | | | | | | | |
| 1,225 | 3540G | 5/8"X14" GR BOLT A307 | HW | | | 29053-B | | | | | | | | | | | | | |

3 of 5

Figure B-11. Anchor Bracket Assembly, Test No. HMDT-1 (Item No. c8)

GERDAU

CERTIFIED MATERIAL TEST REPORT

Page 1 / 1

US-ML-CARTERSVILLE
384 OLD GRASSDALE ROAD NE
CARTERSVILLE, GA 30121
USA

| CUSTOMER SHIP TO | CUSTOMER BILL TO | GRADE | SHAPE / SIZE | DOCUMENT ID: |
|---|---|---|---|---|
| HIGHWAY SAFETY CORP<br>473 W FAIRGROUND ST<br>MARION,OH 43302-1701<br>USA | HIGHWAY SAFETY CORP<br>GLASTONBURY,CT 06033-0358<br>USA | A992/A709-36 | Wide Flange Beam / 6 X 8.5# / 150 X 13.0 | 0000307083 |

| LENGTH | PCS | WEIGHT | HEAT / BATCH |
|---|---|---|---|
| 42'00" | 63 | 22,491 LB | 55064803/02 |

| SALES ORDER | CUSTOMER MATERIAL N° |
|---|---|
| 8525742/000010 | |

| CUSTOMER PURCHASE ORDER NUMBER | BILL OF LADING | DATE |
|---|---|---|
| 1832 | 1323-0000153427 | 03/02/2020 |

SPECIFICATION / DATE or REVISION
ASTM A6-17
ASTM A709-17
ASTM A992-11 (2015)
CSA G40.21-13 345WM

1832138
IB-8010800

CHEMICAL COMPOSITION

| C % | Mn % | P % | S % | Si % | Cu % | Ni % | Cr % | Mo % | Sn % | V % | Nb % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.14 | 0.81 | 0.012 | 0.029 | 0.21 | 0.31 | 0.09 | 0.09 | 0.025 | 0.008 | 0.002 | 0.009 |

MECHANICAL PROPERTIES

| YS 0.2% PSI | UTS PSI | YS MPa | UTS MPa | Y/T ratio % | Elong. % |
|---|---|---|---|---|---|
| 58300 | 76400 | 402 | 527 | 0.760 | 27.50 |
| 55900 | 73900 | 385 | 510 | 0.760 | 24.80 |

COMMENTS / NOTES

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. Weld repair has not been performed on this material. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

Bhaskar

BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 267-1071 Email: Bhaskar.Yalamanchili@gerdau.com

YAN WANG
QUALITY ASSURANCE MGR.
Phone: (770) 387 5718 Email: yan.wang@gerdau.com

Figure B-12. W6x8.5, 72-in. Long Steel Post, Test No. HMDT-1 (Item Nos. d1 and d2)

GERDAU

US-ML-MIDLOTHIAN
300 WARD ROAD
MIDLOTHIAN, TX 76065
USA

**CERTIFIED MATERIAL TEST REPORT**

Page 1 / 1

| CUSTOMER SHIP TO | CUSTOMER BILL TO | GRADE | SHAPE / SIZE | DOCUMENT ID: |
|---|---|---|---|---|
| STEEL AND PIPE SUPPLY CO INC<br>310 SMITH ROAD<br>JONESBURG,MO 63351<br>USA | STEEL AND PIPE SUPPLY CO INC<br>MANHATTAN,KS 66505-1688<br>USA | A992/A572-50 | Wide Flange Beam / 6 X 15# / 150 X 22 5 | 0000470808 |

| LENGTH | PCS | WEIGHT | HEAT / BATCH |
|---|---|---|---|
| 40'00" | 12 | 7,200 LB | **58042771/02** |

| SALES ORDER | CUSTOMER MATERIAL Nº |
|---|---|
| 8995686/000010 | 000000000376150040 |

| CUSTOMER PURCHASE ORDER NUMBER | BILL OF LADING | DATE |
|---|---|---|
| 4500349606 | 1327-0000374754 | 06/26/2020 |

SPECIFICATION / DATE or REVISION
ASTM A6-17
ASTM A709-17
ASTM A992-11 (2015), A572-15
CSA G40.21-13 345WM

CHEMICAL COMPOSITION

| C (%) | Mn (%) | P (%) | S (%) | Si (%) | Cu (%) | Ni (%) | Cr (%) | Mo(%) | Sn (%) | V (%) | Nb (%) | Al (%) | CEqvA6 (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.10 | 0.91 | 0.016 | 0.030 | 0.25 | 0.26 | 0.14 | 0.23 | 0.035 | 0.006 | 0.002 | 0.016 | 0.003 | 0.33 |

MECHANICAL PROPERTIES

| YS 0.2% (PSI) | UTS (PSI) | YS (MPa) | UTS (MPa) | Y/T rati (%) | G/L (Inches) | G/L (mm) | Elong. (%) |
|---|---|---|---|---|---|---|---|
| 55429 | 75865 | 382 | 523 | 0.730 | 8.000 | 200.0 | 24.10 |
| 56366 | 75832 | 389 | 523 | 0.740 | 8.000 | 200.0 | 24.20 |

COMMENTS / NOTES

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. Weld repair has not been performed on this material. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

Bhaskar
BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 267-1071 Email: Bhaskar.Yalamanchili@gerdau.com

Wade A. L.
WADE LUMPKINS
QUALITY ASSURANCE MGR
Phone: 972-779-3118 Email: Wade.Lumpkins@gerdau.com

Figure B-13. W6x15, 78-in. Long Steel Post, Test No. HMDT-1 (Item No. d3)

30Jul20 3: 3 T E S T C E R T I F I C A T E No: MAR 380309

NUCOR TUBULAR PRODUCTS INC.
6226 W. 74TH STREET
CHICAGO, IL 60638
Tel: 708-496-0380 Fax: 708-563-1950

P/O No 01031988
Rel
S/O No MAR 396220-002
B/L No MAR 235650-006 Shp 30Jul20
Inv No Inv

Sold To: ( 1403)
NORFOLK IRON & METAL
P.O. BOX 1129
NORFOLK, NE 68701

Ship To: ( 1)
NORFOLK IRON & METAL
3001 NORTH VICTORY RD
NORFOLK, NE 68702

Tel: 402-371-1810 Fax: 402 379-5409

CERTIFICATE of ANALYSIS and TESTS Cert. No: MAR 380309
24Jul20

Part No 01209
TUBING A500 GRADE B(C)
8" X 6" X 1/4" X 20'

| | Pcs | Wgt |
|---|---|---|
| | 12 | 5,380 |

| Heat Number | Tag No | Pcs | Wgt |
|---|---|---|---|
| A97575 | 914842<br>YLD=58050/TEN=66570/ELG=32.6 | 6 | 2,690 |
| A97575 | 914843 | 6 | 2,690 |

Heat Number *** Chemical Analysis ***
A97575
C=0.0500 Mn=0.4100 P=0.0090 S=0.0030 Si=0.0300 Al=0.0360
Cu=0.1500 Cr=0.0700 Mo=0.0200 V=0.0030 Ni=0.0400 Nb=0.0160
Sn=0.0100 N=0.0070 B=0.0002 Ti=0.0020 Ca=0.0023
MELTED AND MANUFACTURED IN THE USA

THE SPECIFICATIONS LISTED BELOW REPRESENT THE CURRENT ISSUED DATES OF THESE STANDARDS. THIS DOES NOT INDICATE THAT THE MATERIAL ABOVE CONFORMS TO EACH OR ALL OF THE STANDARDS. WE CERTIFY THE MATERIAL ABOVE TO THE SPECIFICATION LISTED IN THE LINE DESCRIPTION.

CURRENT STANDARDS:
A252-19
A500/A500M-20
A513/A513M-20
ASTM A53/A53M-18| ASME SA-53/SA-53M-18
A847/A847M-14
A1085/A1085M-15
IN COMPLIANCE WITH EN 10204 SECTION 4.1
INSPECTION CERTIFICATE TYPE 3.1

Page: 1 .... Last

Figure B-14. 8-in. x 6-in. x ¼-in. Steel Blockout, Test No. HMDT-1 (Item No. d4)

21Jul20 14:35 TEST CERTIFICATE No: MAR 372566

NUCOR TUBULAR PRODUCTS INC.
6226 W. 74TH STREET
CHICAGO, IL 60638
Tel: 708-496-0380 Fax: 708-563-1950

P/O No 01032075
Rel
S/O No MAR 396557-001
B/L No MAR 235002-002 Shp 21Jul20
Inv No Inv

Sold To: ( 1403)
NORFOLK IRON & METAL
P.O. BOX 1129
NORFOLK, NE 68701

Ship To: ( 1)
NORFOLK IRON & METAL
3001 NORTH VICTORY RD
NORFOLK, NE 68702

Tel: 402-371-1810 Fax: 402 379-5409

CERTIFICATE of ANALYSIS and TESTS Cert. No: MAR 372566
13Jul20

Part No 01239
TUBING A500 GRADE B(C)
12" X 4" X 1/4" X 20'

| | Pcs | Wgt |
|---|---|---|
| | 6 | 3,098 |

| Heat Number | Tag No | Pcs | Wgt |
|---|---|---|---|
| 2202349 | 911766 | 6 | 3,098 |

YLD=54380/TEN=70950/ELG=35.8

Heat Number 2202349

*** Chemical Analysis ***
C=0.2100 Mn=0.7600 P=0.0110 S=0.0014 Si=0.0200 Al=0.0400
Cu=0.0700 Cr=0.0400 Mo=0.0100 V=0.0030 Ni=0.0300 Nb=0.0010
Cb=0.0010 Sn=0.0030 N=0.0070 B=0.0000 Ti=0.0020 Sb=0.0000
Ca=0.0010
MELTED AND MANUFACTURED IN THE USA

THE SPECIFICATIONS LISTED BELOW REPRESENT THE CURRENT ISSUED DATES OF THESE STANDARDS. THIS DOES NOT INDICATE THAT THE MATERIAL ABOVE CONFORMS TO EACH OR ALL OF THE STANDARDS. WE CERTIFY THE MATERIAL ABOVE TO THE SPECIFICATION LISTED IN THE LINE DESCRIPTION.

CURRENT STANDARDS:
A252-19
A500/A500M-20
A513/A513M-20
ASTM A53/A53M-18 | ASME SA-53/SA-53M-18
A847/A847M-14
A1085/A1085M-15
IN COMPLIANCE WITH EN 10204 SECTION 4.1
INSPECTION CERTIFICATE TYPE 3.1

Page: 1 .... Last

Figure B-15. 12-in. x 4-in. x ¼-in. Steel Blockout, Test No. HMDT-1 (Item No. d5)

```
14Aug20 22:49            T E S T    C E R T I F I C A T E         No: MAR 390260

     NUCOR TUBULAR PRODUCTS INC.                P/O No 03054005
     6226 W. 74TH STREET                        Rel
     CHICAGO, IL  60638                         S/O No MAR 398647-006
     Tel: 708-496-0380 Fax: 708-563-1950        B/L No MAR 236355-004  Shp  14Aug20
                                                Inv No                 Inv

     Sold To:    (  1403)                       Ship To:    (  3)
     NORFOLK IRON & METAL                       NORFOLK (GREELEY)
     P.O. BOX 1129                              31181 COUNTY RD 39 1/2
     NORFOLK, NE  68701                         970-352-6722
                                                GREELEY, CO  80631

     Tel: 402-371-1810 Fax: 402 379-5409
--------------------------------------------------------------------------------
               CERTIFICATE of ANALYSIS and TESTS            Cert. No: MAR 390260
                                                                       10Aug20
Part No 01239
TUBING A500 GRADE B(C)                                           Pcs       Wgt
12" X 4" X 1/4" X 20'                                              6     3,098

Heat Number     Tag No                                           Pcs       Wgt
SK1852          918868                                             6     3,098
                    YLD=60270/TEN=74590/ELG=33.5

Heat Number            *** Chemical Analysis ***
SK1852          C=0.2000 Mn=0.3900 P=0.0060 S=0.0020 Si=0.0290 Al=0.0320
                Cu=0.1000 Cr=0.0600 Mo=0.0100 V=0.0020 Ni=0.0300 Nb=0.0060
                N=0.0056 B=0.0001 Ti=0.0010 Ca=0.0016
                MELTED AND MANUFACTURED IN THE USA

THE SPECIFICATIONS LISTED BELOW REPRESENT THE
CURRENT ISSUED DATES OF THESE STANDARDS.  THIS
DOES NOT INDICATE THAT THE MATERIAL ABOVE CONFORMS
TO EACH OR ALL OF THE STANDARDS.  WE CERTIFY THE
MATERIAL ABOVE TO THE SPECIFICATION LISTED IN THE
LINE DESCRIPTION.
_________________________________________________
CURRENT STANDARDS:
A252-19
A500/A500M-20
A513/A513M-20
ASTM A53/A53M-18| ASME SA-53/SA-53M-18
A847/A847M-14
A1085/A1085M-15
IN COMPLIANCE WITH EN 10204 SECTION 4.1
INSPECTION CERTIFICATE TYPE 3.1
_________________________________________________

    Page:   1 .... Last
```

Figure B-16. 17½-in. Long, 12-in. x 4-in. x ¼-in. Steel Blockout, Test No. HMDT-1 (Item No. d5)

MONDO POLYMER TECHNOLOGIES INC.
Plastics From Today for Tomorrow...

P.O. BOX 250
27620 ST. RT. 7 NORTH
RENO, OH 45773

Phone: 740-376-9396
Fax: 740-376-9960
(888) 607-4790

## MATERIAL CERTIFICATE

SHIPMENT NUMBER: 34545
PURCHASE ORDER HWTT
SHIPMENT DATE: 4/4/2019

PAGE: 2

**CONSIGNED TO**

Midwest Roadside Safety
4630 NV 36th Street
Lincoln, NE 68524

**SHIP TO**

Midwest Roadside Safety

4630 NW 36th Street
Lincoln, NE 68524

| CONSIGNED | ITEM NUMBER | DESCRIPTION | LOT # | SHIP VIA |
|---|---|---|---|---|
| 4 | MGS14SH | Midwest Composite Block 14" h x 12" d for Steel Post | 1904/1000 | FedEx Freight |

**MADE IN USA**

**The composite guardrail blocks for the Midwest Guardrail System are manufactured by Mondo Polymer Technologies, Inc., and are of the same formulation, composition, and test properties as those which were MASH qualified and and eligible for reimbursement by the Federal Highway Administration under the Federal-aid highway program, Approval #HSST/B-39C.**

**All materials meet required specifications.**

Approved by: Maggie Ellis

Date: 4/4/2019

Print Name: Maggie Ellis

Position: General Manager

Figure B-17. 14$^{3}/_{16}$-in. x 12-in. x 5⅛-in. Composite Recycled Blockout, Test No. HMDT-1 (Item No. d6)

MONDO POLYMER TECHNOLOGIES INC.
Plastics From Today for Tomorrow...

P.O. BOX 250
27620 ST. RT. 7 NORTH
RENO, OH 45773

Phone: 740-376-9396
Fax: 740-376-9960
(888) 607-4790

## MATERIAL CERTIFICATE

SHIPMENT NUMBER: 34545
PURCHASE ORDER HWTT
SHIPMENT DATE: 4/4/2019

PAGE: 1

**CONSIGNED TO**

Midwest Roadside Safety
4630 NV 36th Street
Lincoln, NE 68524

**SHIP TO**

Midwest Roadside Safety

4630 NW 36th Street
Lincoln, NE 68524

| CONSIGNED | ITEM NUMBER | DESCRIPTION | LOT # | SHIP VIA |
|---|---|---|---|---|
| 10 | GB14SH2 | Composite Guardrial Block 14" for Steel Post w/hanger CO | 1804/1000 | FedEx Freight |

**MADE IN USA**

**The composite guardrail offset blocks for the Midwest Guardrail System (MGS), are manufactured by Mondo Polymer Technologies, Inc., and are of the same formulation, composition, and test properties as those which were MASH qualified and eligible for reimbursement by the Federal Highway Administration under the Federal-aid highway program, Approval No. HSST-1/B-278A.**

**All materials meet required specifications.**

Approved by: Maggie Ellis    Date: 4/4/2019

Print Name: Maggie Ellis    Position: General Manager

Figure B-18. $14^{3}/_{16}$-in. x 8-in. x5⅛-in. Composite Recycled Blockout, Test No. HMDT-1 (Item No. d7)

**McMASTER-CARR.**

# Certificate of Compliance

600 N County Line Rd
Elmhurst IL 60126-2081
630-600-3600
chi.sales@mcmaster.com

University of Nebraska
Midwest Roadside Safety Facility
M W R S F
4630 Nw 36TH St
Lincoln NE 68524-1802
Attention: Shaun M Tighe
Midwest Roadside Safety Facility

Purchase Order
**E000548963**

Order Placed By
**Shaun M Tighe**

McMaster-Carr Number
**7204107-01**

Page 1 of 1

08/02/2018

| Line | Product | Ordered | Shipped |
|---|---|---|---|
| 1 | **97812A109** Raised-Head Removable Nails, 16D Penny Size, 3" Long, Packs of 5 | **5 Packs** | **5** |

Certificate of compliance

This is to certify that the above items were supplied in accordance with the description and as illustrated in the catalog. Your order is subject only to our terms and conditions, available at www.mcmaster.com or from our Sales Department.

Sarah Weinberg
Compliance Manager

Figure B-19. 16D Double Head Nail, Test No. HMDT-1 (Item No. d8)

CMC

CMC STEEL TENNESSEE
1919 Tennessee Avenue
Knoxville TN 37921-2686

CERTIFIED MILL TEST REPORT
For additional copies call

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

Jim Hall
Quality Assurance Manager

| | | | | | |
|---|---|---|---|---|---|
| HEAT NO.:7006848<br>SECTION: REBAR 13MM (#4) 60'0" 420/60<br>GRADE:<br>ROLL DATE:<br>MELT DATE: 01/05/2020<br>Cert. No.: 82944733 / 006848L265 | S O L D T O | ABC Coating Co - Tulsa<br><br>2238 S Yukon Ave<br>Tulsa OK<br>US 74107-2765<br>9185852587<br>9185858131 | S H I P T O | CPU Chicago Depot<br><br>13535 S Torrence Ave<br>Chicago IL<br>US 60633-2164<br>7736466363 | Delivery#: 82944733<br>BOL#: 1865847<br>CUST PO#: 010620-Minn<br>CUST P/N:<br>DLVRY LBS / HEAT: 26932.000 LB<br>DLVRY PCS / HEAT: 672 EA |

| Characteristic | Value | Characteristic | Value | Characteristic | Value |
|---|---|---|---|---|---|
| C | 0.27% | Rebar Deformation Avg. Spaci | 0.329IN | | |
| Mn | 0.59% | Rebar Deformation Avg. Heigh | 0.034IN | | |
| P | 0.008% | Rebar Deformation Max. Gap | 0.106IN | | |
| S | 0.048% | | | | |
| Si | 0.20% | | | | |
| Cu | 0.33% | | | | |
| Cr | 0.17% | | | | |
| Ni | 0.11% | | | | |
| Mo | 0.014% | | | | |
| V | 0.002% | | | | |
| Sn | 0.007% | | | | |
| Yield Strength test 1 | 85.9ksi | | | | |
| Yield Strength test 1 (metri | 592MPa | | | | |
| Tensile Strength test 1 | 99.1ksi | | | | |
| Tensile Strength 1 (metric) | 684MPa | | | | |
| Elongation test 1 | 13% | | | | |
| Elongation Gage Lgth test 1 | 8IN | | | | |
| Elongation Gage Lgth 1(metri | 200mm | | | | |
| Bend Test 1 | Passed | | | | |

The Following is true of the material represented by this MTR:
*Material is fully killed
*100% melted and rolled in the USA
*EN10204:2004 3.1 compliant
*Contains no weld repair
*Contains no Mercury contamination
*Manufactured in accordance with the latest version of the plant quality manual
*Meets the "Buy America" requirements of 23 CFR635.410, 49 CFR 661
*Warning: This product can expose you to chemicals which are known to the State of California to cause cancer, birth defects or other reproductive harm. For more information go to www.P65Warnings.ca.gov

REMARKS :

Page 1 OF 1 01/21/2020 09:09:21

Figure B-20. #4 Rebar, Test No. HMDT-1 (Item Nos. e3 and e4)

**CERTIFIED MATERIAL TEST REPORT**

Page 1/1

GERDAU

US-ML-ST PAUL
1678 RED ROCK ROAD
SAINT PAUL, MN 55119
USA

| CUSTOMER SHIP TO | CUSTOMER BILL TO | GRADE | SHAPE / SIZE | DOCUMENT ID: |
|---|---|---|---|---|
| SIMCOTE INC<br>1645 RED ROCK RD<br>SAINT PAUL,MN 55119<br>USA | SIMCOTE INC<br>1645 RED ROCK ROAD<br>SAINT PAUL,MN 55119-6014<br>USA | 60 (420) | Rebar / #5 (16MM) | 0000036750 |

| LENGTH | WEIGHT | HEAT / BATCH |
|---|---|---|
| 40'00" | 8,594 LB | 62150922/02 |

| SALES ORDER | CUSTOMER MATERIAL N° | SPECIFICATION / DATE or REVISION |
|---|---|---|
| 8328518/000050 | | ASTM A615/A615M-16 |

| CUSTOMER PURCHASE ORDER NUMBER | BILL OF LADING | DATE |
|---|---|---|
| MN-3734 | 1332-0000075667 | 11/21/2019 |

CHEMICAL COMPOSITION

| C % | Mn % | P % | S % | Si % | Cu % | Ni % | Cr % | Mo % | Sn % | V % | Nb % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.42 | 1.09 | 0.009 | 0.021 | 0.23 | 0.29 | 0.12 | 0.19 | 0.029 | 0.012 | 0.004 | 0.002 |

MECHANICAL PROPERTIES

| YS PSI | YS MPa | UTS PSI | UTS MPa | G/L Inch | G/L mm |
|---|---|---|---|---|---|
| 68545 | 473 | 107801 | 743 | 8.000 | 203.2 |

MECHANICAL PROPERTIES

| Elong. % | BendTest |
|---|---|
| 13.80 | OK |

GEOMETRIC CHARACTERISTICS

| %Light % | Def Hgt Inch | Def Gap Inch | DefSpace Inch |
|---|---|---|---|
| 1.75 | 0.380 | 0.131 | 0.419 |

COMMENTS / NOTES

Material 100% melted and rolled in the USA. Manufacturing processes for this steel, which may include scrap melted in an electric arc furnace and hot rolling, have been performed at Gerdau St. Paul Mill, 1678 Red Rock Road, Saint Paul, Minnesota, USA. All product produced from strand cast billets. Silicon killed (deoxidized) steel. No weld repairment performed. Steel not exposed to mercury or any liquid alloy which is liquid at ambient temperatures during processing or while in Gerdau St. Paul Mills possession. Any modification to this certification as provided by Gerdau-St. Paul Mill without the expressed written consent of Gerdau St. Paul Mill negates the validity of this test report. This report shall not be reproduced except in full, without the expressed written consent of Gerdau St. Paul Mill. Gerdau St. Paul Mill is not responsible for the inability of this material to meet specific applications.
Roll batch 62150922/02 roll date 8/26/2019

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. Weld repair has not been performed on this material. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 267-1071 Email: Bhaskar.Yalamanchili@gerdau.com

ALEA BRANDENBURG
QUALITY ASSURANCE MGR.
Phone: (651) 731-5662 Email: Alea.Brandenburg@gerdau.com

Figure B-21. #5 Rebar, Test No. HMDT-1 (Item Nos. e5 and e6)

King Steel
5225 East Cook Rd.
Grand Blanc, MI 48439
Tel 810-953-7637
Fax 810-953-1718

# Material Certification

Heat: DL17100590
Heat Code: DL17100590
Grade: 1010
Note: Processed In the USA
Rockford Bolt Rockford, IL
PO# P37885
Weight: 4109

| Material Specification Type | Material Specification | Actual |
|---|---|---|
| Chemical | C | .1 % |
| | Mn | .41 % |
| | P | .005 % |
| | S | .005 % |
| | Si | .05 % |
| | Ni | .02 % |
| | Cr | .03 % |
| | Mo | .011 % |
| | Al | .035 % |
| | Cu | .06 % |
| | V | .003 % |
| | Nb | .003 % |
| | N | .007 % |
| Physical | Tensile Full-Size (PSI) | 58000 psi |
| | Reduction of Area | 66 % |
| | Reduction Ratio: | 141.3:1 |
| | Melted & Manufactured in: | USA |

We hereby certify that chemical analysis and/or physical characteristics shown are a true copy of orignal test reports on file with us from the producing source covering the heat or lot from which this material was taken.

Plex 10/25/17 10:27 AM chetherington Page 1

Figure B-22. ⅝-in. Dia., 14-in. Long Guardrail Bolt, Test No. HMDT-1 (Item No. f1)

# MATERIAL TEST REPORT

PAGE 1

Date Printed: 04/04/2018

Mid American Steel & Wire

Bill to:
KING STEEL
5225 E. COOK ROAD
ap@kingsteelcorp.com
GRAND BLANC, MI 48439-838

Ship to:
KING STEEL
CPU

Grand Blanc, MI 48439-8388

Customer No: 000000006021
PO Number: 025623
Ship Date: 04/04/2018
Order Number: 92649
Load Number: 117036

Item Number: D19321012SHM
Description: 19/32 1012SH ROD

CHEMICAL ANALYSIS

| Heat Number | C | Mn | P | S | Si | Cu | Ni | Cr | Mo | Sn | V | Al | N | B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1721198 | 0.1300 | 0.5100 | 0.0160 | 0.0270 | 0.1900 | 0.1500 | 0.0600 | 0.1200 | 0.0100 | 0.0080 | 0.0020 | 0.0020 | 0.0080 | 0.0002 |

MECHANICAL PROPERTIES

| Heat Number | Yield (Psi) | Tensile (Psi) | Elongation (%) | Reduction (%) | Bend Test Pass/ Fail |
|---|---|---|---|---|---|
| 1721198 | 45781 psi / | 66316 psi / | 23.12 | 60.76 | |

The melting and rolling processes used to manufacture the above described material took place in the United States of America. The material was produced and tested in accordance with ASTM A-510.

Quality Assurance: ______

Figure B-23. ⅝-in. Dia., 10-in. Long Guardrail Bolt, Test No. HMDT-1 (Item No. f2)

**CERTIFICATE OF COMPLIANCE**

**ROCKFORD BOLT & STEEL CO.**
**126 MILL STREET**
**ROCKFORD, IL 61101**
**815-968-0514**

**CUSTOMER NAME:** TRINITY INDUSTRIES

**CUSTOMER PO:** 209038

**SHIPPER #:** 069386
**DATE SHIPPED:** 07/23/2020

**LOT#:** 32756-P

**SPECIFICATION:** ASTM A307, GRADE A MILD CARBON STEEL BOLTS

**TENSILE:** SPEC: 60,000 psi*min RESULTS: 69,800
69,900

**HARDNESS:** 100 max 67.50
68.60

*Pounds Per Square Inch.

**COATING:** ASTM SPECIFICATION F-2329 HOT DIP GALVANIZE
**AZZ GALVANIZING:** 32756-P

**CHEMICAL COMPOSITION**

| MILL | GRADE | HEAT# | C | Mn | P | S | Si |
|---|---|---|---|---|---|---|---|
| CHARTER STEEL | 1010 | 10657410 | .09 | .38 | .007 | .007 | .09 |

**QUANTITY AND DESCRIPTION:**

86,000 PCS 5/8" X 1.25" GUARD RAIL BOLT
P/N 3360G

WE HEREBY CERTIFY THE ABOVE BOLTS HAVE BEEN MANUFACTURED BY ROCKFORD BOLT AND STEEL AT OUR FACILITY IN ROCKFORD, ILLINOIS, USA. THE MATERIAL USED WAS MELTED AND MANUFACTURED IN THE USA. WE FURTHER CERIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIALS SUPPLIER, AND THAT OUR PROCEDURES FOR THE CONTROL OF PRODUCT QUALITY ASSURE THAT ALL ITEMS FURNISHED ON THIS ORDER MEET OR EXCEED ALL APPLICABLE TESTS, PROCESS, AND INSPECTION REQUIREMENT PER ABOVE SPECIFICATION.

STATE OF ILLINOIS
COUNTY OF WINNEBAGO
SIGNED BEFORE ME ON THIS

21st DAY OF July 20 20 — Linda Malomas, APPROVED SIGNATORY — 7/21/2020 DATE

Merry F Shane

Official Seal
Merry F Shane
Notary Public State of Illinois
My Commission Expires 10/03/2022

Figure B-24. ⅝-in. Dia., 1¼-in. Long Guardrail Bolt, Test No. HMDT-1 (Item No. f3)

## Certificate of Compliance

Birmingham Fastener Manufacturing
PO Box 10323
Birmingham, AL 35202
(205) 595-3512

| | | | |
|---|---|---|---|
| Customer | Midwest Machinery & Supply | Date Shipped | 11/28/2018 |
| Customer Order Number | 3664 | BFM Order Number | 1553751 |

### Item Description

Description: 5/8"-11 x 10" Hex Bolt — Qty: 298

Lot #: 81342 — Specification: ASTM A307-14 Gr A — Finish: ASTM F2329

### Raw Material Analysis

Heat#: JK18104124

Chemical Composition (wt% Heat Analysis) By Material Supplier

| C | Mn | P | S | Si | Cu | Ni | Cr | Mo |
|---|---|---|---|---|---|---|---|---|
| 0.18 | 1.19 | 0.012 | 0.034 | 0.20 | 0.29 | 0.13 | 0.11 | 0.04 |

### Mechanical Properties

| Sample # | Hardness | Tensile Strength (lbs) | Tensile Strength (psi) |
|---|---|---|---|
| 1 | 93 HRBW | 22,049 | 99,410 |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |

This information represents the most recent analysis of the product supplied on the stated customer order. The samples tested conform to the ASTM standard listed above.
All steel melted and manufactured in the U.S.A.

Authorized Signature: Brian Hughes, Quality Assurance — Date: 11/29/2018

Figure B-25. ⅝-in. Dia., 10-in. Long Hex Head Bolt, Test No. HMDT-1 (Item No. f4)

# CERTIFIED MATERIAL TEST REPORT
# FOR ASTM A307, GRADE A - MACHINE BOLTS

FACTORY: IFI & MORGAN LTD. REPORT DATE:2019/4/2
ADDRESS: No.583-28, Chang'an North Road, Wuyuan Town, Haiyan, Zhejiang, China MANUFACTURE DATE:2019/3/14

CUSTOMER: FASTENAL MFG LOT NUMBER:M-2019HT138-5
SAMPE SIZE: ACC. TO ASME B18.18 CATEGORY 2-2011; ASTM F1470-12 TABLE 3
MANU QTY: 2450PCS SHIPPED QTY:2400PCS
SIZE: 5/8-11X1 1/2 HDG
HEADMARKS: 307A PLUS NY PO NUMBER:210179696
PART NO:191919

STEEL PROPERTIES:
MATERIAL TYPE:Q195C HEAT NUMBER:5-01570

| CHEMISTRY SPEC: | C %*100 | Mn%*100 | P %*1000 | S %*1000 |
|---|---|---|---|---|
| Grade A ASTM A307-12 | 0.29max | 1.20 max | 0.04max | 0.15max |
| TEST: | 0.07 | 0.33 | 0.015 | 0.022 |

DIMENSIONAL INSPECTIONS Unit:inch SPECIFICATION: ASME B18.2.1 - 2012

| CHARACTERISTICS | SPECIFIED | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|
| ********************** | ************************************ | ******************* | ******** | ******** |
| VISUAL | ASTM F788-2013 | PASSED | 18 | 0 |
| THREAD | ASME B1.1-2003, 3A GO, 2A NO GO | PASSED | 13 | 0 |
| WIDTH A/F | 0.906-0.938 | 0.916-0.928 | 3 | 0 |
| WIDTH A/C | 1.033-1.083 | 1.048-1.057 | 3 | 0 |
| HEAD HEIGHT | 0.378-0.444 | 0.394-0.428 | 3 | 0 |
| BODY DIA. | 0.605-0.642 | 0.617-0.634 | 3 | 0 |
| THREAD LENGTH | 1.420-1.560 | 1.436-1.543 | 13 | 0 |
| LENGTH | 1.420-1.560 | 1.436-1.543 | 13 | 0 |

MECHANICAL PROPERTIES: SPECIFICATION: ASTM A307 - 14e1 GR.A

| CHARACTERISTICS | TEST METHOD | SPECIFIED | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|
| ********************* | ****************** | ****************** | ****************** | ******** | ******** |
| CORE HARDNESS : | ASTM F606/F606M-2016 | 69-100 HRB | 75-80 HRB | 3 | 0 |
| WEDGE TENSILE: | ASTM F606/F606M-2016 | Min 60 KSI | 65-69 KSI | 3 | 0 |

| CHARACTERISTICS | TEST METHOD | SPECIFIED | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|
| COATINGS OF ZINC: | | SPECIFIATION: ASTM F2329/F2329M-2015 | | | |
| HOT DIP GALVANIZED | ASTM B568-98(2014) | Min 0.0017" | 0.0017" -0.0018" | 3 | 0 |

We hereby certify that above products supplied are in compliance with all the requirements of the order.
We here by certify that this MTR is in compliance to DIN EN 10204 3.1 content.
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.
Maker's ISO 9001:2015 SGS Certificate # HK04/0105

IFI & MORGAN LTD. 检验专用章

(SIGNATURE OF Q.A. LAB MGR.)
(NAME OF MANUFACTURER)

Figure B-26. ⅝-in. Dia., 1½-in. Long Hex Head Bolt, Test No. HMDT-1 (Item No. f5)

**Portland Bolt**
**& MANUFACTURING COMPANY**

Phone: 800-547-6758 | Fax: 503-227-4634
3441 NW Guam Street, Portland, OR 97210
Web: www.portlandbolt.com | Email: sales@portlandbolt.com

**CERTIFICATE OF CONFORMANCE**

**For:** MIDWEST ROADSIDE SAFETY FACIL
**PB Invoice#:** 119891
**Cust PO#:** 70ACCT
**Date:** 4/17/2019
**Shipped:** 4/25/2019

**We certify that the following items were manufactured and tested in accordance with the chemical, mechanical, dimensional and thread fit requirements of the specifications referenced.**

**Description:** 7/8 X 8 GALV ASTM A307A HEX BOLT

**Heat#:** 489517 **Base Steel:** A36 **Diam:** 7/8

**Source:** CASCADE STEEL RLG MILL **Proof Load:** 0

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **C :** | .180 | **Mn:** | .680 | **P :** | .013 | **Hardness:** | 0 | | |
| **S :** | .015 | **Si:** | .240 | **Ni:** | .080 | **Tensile:** | 72,500 PSI | **RA:** | 42.00% |
| **Cr:** | .130 | **Mo:** | .028 | **Cu:** | .240 | **Yield:** | 48,800 PSI | **Elon:** | 24.00% |
| **Pb:** | .000 | **V :** | .000 | **Cb:** | .000 | **Sample Length:** | 8 INCH | | |
| **N :** | .000 | | | **CE:** | .3157 | **Charpy:** | | **CVN Temp:** | |

**Coatings:**
ITEMS HOT DIP GALVANIZED PER ASTM F2329/A153C

By:
Certification Department Quality Assurance
Dane McKinnon

Figure B-27. ⅞-in. Dia., 8-in. Long Hex Head Bolt, Test No. HMDT-1 (Item No. f6)

# TEST REPORT

## USS FLAT WASHER, HDG

| | | | |
|---|---|---|---|
| CUSTOMER: | | DATE: | 30/12/2018 |
| PO NUMBER: | 180164126 | MFG LOT NUMBER: | M-SWE0412454-8 |
| SIZE: | 5/8 | PART NO: | 1133185 |
| HEADMARKS: | | QNTY: | 6,000 PCS |

DIMENSIONAL INSPECTIONS — SPECIFICATION: **ASME B18.21.1(2009)**

| CHARACTERISTICS | SPECIFIED | | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|
| ********************** | ************************************ | | ******************* | ******** | ******** |
| APPEARANCE | ASTM F788-07 | | PASSED | 100 | 0 |
| OUTSIDE DIA | 1.743-1.780 | | 1.752-1.756 | 8 | 0 |
| INSIDE DIA | 0.681-0.718 | | 0.700-0.707 | 8 | 0 |
| THICKNESS | 0.108-0.160 | | 0.114-0.119 | 8 | 0 |
| HOT DIP GALVANIZED | ASTM A153 class C.<br>RoHS Compliant | Min 0.0017" | Min 0.0019 In | 8 | 0 |

*ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE ASTM SPECIFICATION.*
*WE CERTIFY THAT THIS DAIA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.*
*MFG ISO 9001:2015 SGS Certificate # HK04/0105*

**We hereby certify that above products supplied are in compliance with all the requirements of the order.**
**We here by certify that this MTR is in compliance to DIN EN 10204 3.1 content.**

IFI & MORGAN LTD. 检验专用章

(SIGNATURE OF Q.A. LAB MGR.)
(NAME OF MANUFACTURER)

*IFI & MORGAN LTD.* *ADDRESS: Chang'an North Road, Wuyuan Town, Haiyan, Zhejiang, China*

Figure B-28. ⅝-in. Dia. Plain USS Washer, Test No. HMDT-1 (Item No. g1)

CERTIFIED MATERIAL TEST REPORT
FOR USS FLAT WASHERS HDG

FACTORY: IFI & Morgan Ltd — REPORT DATE: 23/4/2019
ADDRESS: Chang'an North Road, Wuyuan Town, Haiyan,Zhejiang, China

MFG LOT NUMBER: 1844804

SAMPLING PLAN PER ASME B18.18-11 — PO NUMBER: 170089822
SIZE: USS 7/8 HDG QNTY(Lot size): 7200PCS
HEADMARKS: NO MARK — PART NO: 33187

DIMENSIONAL INSPECTIONS — SPECIFICATION: ASTM B18.21.1-2011

| CHARACTERISTICS | SPECIFIED | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|
| APPEARANCE | ASTM F844 | PASSED | 100 | 0 |
| OUTSIDE DIA | 2.243-2.280 | 2.246-2.254 | 10 | 0 |
| INSIDE DIA | 0.931-0.968 | 0.956-0.965 | 10 | 0 |
| THICKNESS | 0.136-0.192 | 0.136-0.157 | 10 | 0 |

| CHARACTERISTICS | TEST METHOD | SPECIFIED | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|
| HOT DIP GALVANIZED | ASTM F2329-13 | Min 0.0017" | 0.0017-0.0020 in | 8 | 0 |

ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE ASTM SPECIFICATION. WE CERTIFY THAT THIS DAIA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.
ISO 9001:2015 SGS Certificate # HK04/0105

IFI & MORGAN LTD. 检验专用章 QUANLITY CONTROL

(SIGNATURE OF Q.A. LAB MGR.)

Figure B-29. ⅞-in. Dia. Plain Round Washer, Test No. HMDT-1 (Item No. g3)

# CERTIFIED MATERIAL TEST REPORT
# FOR USS FLAT WASHERS HDG

FACTORY: IFI & Morgan Ltd REPORT DATE: 22/10/2018
ADDRESS: Chang'an North Road, Wuyuan Town, Haiyan,Zhejiang, China

SAMPLING PLAN PER ASME B18.18-11 PO NUMBER: 210151571
SIZE: USS 1 HDG QNTY(Lot size): 3240PCS
HEADMARKS: NO MARK PART NO: 33188

DIMENSIONAL INSPECTIONS SPECIFICATION: ASTM B18.21.1-2011

| CHARACTERISTICS | SPECIFIED | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|
| APPEARANCE | ASTM F844 | PASSED | 100 | 0 |
| OUTSIDE DIA | 2.492-2.529 | 2.496-2.504 | 10 | 0 |
| INSIDE DIA | 1.055-1.092 | 1.080-1.089 | 10 | 0 |
| THICKNESS | 0.135-0.192 | 0.135-0.157 | 10 | 0 |

| CHARACTERISTICS | TEST METHOD | SPECIFIED | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|
| HOT DIP GALVANIZED | ASTM F2329-13 | Min 0.0017" | 0.0017-0.0020 in | 8 | 0 |

ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE ASTM SPECIFICATION. WE CERTIFY THAT THIS DAIA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.
ISO 9001:2015 SGS Certificate # HK04/0105

IFI & MORGAN LTD.
检验专用章
QUANLITY CONTROL

(SIGNATURE OF Q.A. LAB MGR.)

Figure B-30. 1-in. Dia. Plain USS Washer, Test No. HMDT-1 (Item No. g4)

GERDAU

**CERTIFIED MATERIAL TEST REPORT** Page 1 / 1

US-ML-ST PAUL
1678 RED ROCK ROAD
SAINT PAUL, MN 55119
USA

| CUSTOMER SHIP TO | CUSTOMER BILL TO | GRADE | SHAPE / SIZE | DOCUMENT ID: |
|---|---|---|---|---|
| UNYTITE INC LASALLE PLANT<br>325 CIVIC ROAD<br>LA SALLE,IL 61301<br>USA | UNYTITE INC<br>1 UNYTITE DR<br>PERU,IL 61354-9710<br>USA | 1045M23FJZN | Round Bar / 1" | 0000038876 |

| LENGTH | WEIGHT | HEAT / BATCH |
|---|---|---|
| 25'01.50" | 35,008 LB | 62151324/02 |

| SALES ORDER | CUSTOMER MATERIAL N° | SPECIFICATION / DATE or REVISION |
|---|---|---|
| 8310712/000010 | B1045SC1.0000 1 | ASTM A29-16<br>ASTM A576-17 |

| CUSTOMER PURCHASE ORDER NUMBER | BILL OF LADING | DATE |
|---|---|---|
| P008845 | 1332-0000077708 | 01/29/2020 |

CHEMICAL COMPOSITION

| C % | Mn % | P % | S % | Si % | Cu % | Ni % | Cr % | Mo % | Sn % | V % | Nb % | Al % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.44 | 0.71 | 0.010 | 0.031 | 0.23 | 0.34 | 0.10 | 0.16 | 0.022 | 0.012 | 0.032 | 0.001 | 0.005 |

HARDENABILITY

| DI A255 Inch |
|---|
| 1.53 |

COMMENTS / NOTES

Material 100% melted and rolled in the USA. Manufacturing processes for this steel, which may include scrap melted in an electric arc furnace and hot rolling, have been performed at Gerdau St. Paul Mill, 1678 Red Rock Road, Saint Paul, Minnesota, USA. All product produced from strand cast billets. Silicon killed (deoxidized) steel. No weld repairmen performed. Steel not exposed to mercury or any liquid alloy which is liquid at ambient temperatures during processing or while in Gerdau St. Paul Mills possession. Any modification to this certification as provided by Gerdau-St. Paul Mill without the expressed written consent of Gerdau St. Paul Mill negates the validity of this test report. This report shall not be reproduced except in full, without the expressed written consent of Gerdau St. Paul Mill. Gerdau St. Paul Mill is not responsible for the inability of this material to meet specific applications.
Roll batch 62151324/02 roll date 10/23/2019 Fine Grain (FG 5-8)
Macro S1 R1 C1 ASTM E381-17 E45-18a Reduction Ration = 38.2 Quality Program Manual Rev. 10, Implemented date 11/8/2019

DEBRA L. KARIESCH
Notary Public-Minnesota
My Commission Expires Jan 31, 2025

Debra L. Kariesch

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. Weld repair has not been performed on this material. This material, including the billets, was melted USA. CMTR complies with EN 10204 3.1.

Bhaskar
BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 267-1071 Email: Bhaskar.Yalamanchili@gerdau.com

ALEA BRANDENBURG
QUALITY ASSURANCE MGR.
Phone: (651) 731-5662 Email: Alea.Brandenburg@gerdau.com

Figure B-31. ⅝-in. Dia. Heavy Hex Nut, Test No. HMDT-1 (Item No. h1)

## GEM-YEAR TESTING LABORATORY
### CERTIFICATE OF INSPECTION

MANUFACTURER GEM-YEAR INDUSTRIAL CO., LTD.
ADDRESS : NO.8 GEM-YEAR ROAD,E.D.Z.,JIASHAN,ZHEJIANG,P.R.CHINA

Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2019/04/23

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 210167591
COMMODITY : FINISHED HEX NUT GR-A
SIZE : 7/8-9 NC O/T 0.56MM
LOT NO : IN18BC001
SHIP QUANTITY : 2,250 PCS
LOT QUANTITY 3,910 PCS
HEADMARKS :
MANUFACTURE DATE : 2018/11/05
COUNTRY OF ORIGIN : CHINA

PACKING NO : GEM181128011
INVOICE NO : GEM/FNL-181212ED-1
PART NO : 36717
SAMPLING PLAN :
ASME B18.18-2017(Category 2)/ASTM F1470-2018
HEAT NO : 18108472-3
MATERIAL : X1008A
FINISH : HOT DIP GALVANIZED PER ASTM A153-2009/ASTM F2329-2013

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A563-2015

| Chemistry | AL% | C% | MN% | P% | S% | SI% |
|---|---|---|---|---|---|---|
| Spec. : MIN. | | | | | | |
| MAX. | | 0.5800 | | 0.1300 | 0.2300 | |
| Test Value | 0.0300 | 0.0700 | 0.2700 | 0.0080 | 0.0050 | 0.0300 |

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.2-2015

SAMPLED BY : YUQIAN

| INSPECTIONS ITEM | SAMPLE | SPECIFIED | | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|---|
| WIDTH ACROSS CORNERS | 4PCS | | 1.4470-1.5160 inch | 1.4730-1.4770 inch | 4 | 0 |
| FIM | 15PCS | ASME B18.2.2-2015 | Max. 0.0250 inch | 0.0010-0.0050 inch | 15 | 0 |
| THICKNESS | 4PCS | | 0.7240-0.7760 inch | 0.7280-0.7480 inch | 4 | 0 |
| WIDTH ACROSS FLATS | 4PCS | | 1.2690-1.3120 inch | 1.2840-1.2990 inch | 4 | 0 |
| SURFACE DISCONTINUITIES | 22PCS | | ASTM F812-2012 | PASSED | 22 | 0 |
| THREAD | 15PCS | | GAGING SYSTEM 21 | PASSED | 15 | 0 |
| MINOR DIAMETER | 15PCS | | 0.7890-0.7970 inch | PASSED | 15 | 0 |

MECHANICAL PROPERTIES : ACCORDING TO ASTM A563-2015

SAMPLED BY : GDAN LIAN

| INSPECTIONS ITEM | SAMPLE | TEST METHOD | REF | SPECIFIED | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|---|---|
| CORE HARDNESS | 13 PCS | ASTM F606-2014 | | 116-302 HRB | 81-82 HRB | 13 | 0 |
| PROOF LOAD | 3 PCS | ASTM F606-2014 | | Min. 90 KSI | OK | 3 | 0 |
| PLATING THICKNESS( μm) | 5 PCS | ASTM B568-1998 | | >=53 | 70.22-75.66 | 5 | 0 |

WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY .WHICH ACCREDITED BY ISO/IEC17025(CERTIFICATE NUMBER:3358.01)
WE CERTIFY THAT THE PRODUCTS SUPPLIED ARE IN COMPLIANCE WITH THE REQUIREMENTS OF THE ORDER
WE CERTIFY THAT ALL PRODUCTS WE SUPPLIED ARE IN COMPLIANCE WITH DIN EN 10204 3.1 CONTENT

Quality Supervisor: Erin

page 1 of 1

Figure B-32. ⅞-in. Dia. Hex Nut, Test No. HMDT-1 (Item No. h3)

## GEM-YEAR TESTING LABORATORY
### CERTIFICATE OF INSPECTION

MANUFACTURER GEM-YEAR INDUSTRIAL CO., LTD.
ADDRESS : NO.8 GEM-YEAR ROAD,E.D.Z.,JIASHAN,ZHEJIANG,P.R.CHINA

Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2019/04/23

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 210167591
COMMODITY : FINISHED HEX NUT GR-A
SIZE : 7/8-9 NC O/T 0.56MM
LOT NO : 1N1880113
SHIP QUANTITY : 2,250 PCS
LOT QUANTITY 31,764 PCS
HEADMARKS :

PACKING NO : GEM181128011
INVOICE NO : GEM/FNL-181212ED-1
PART NO : 36717
SAMPLING PLAN : ASME B18.18-2017(Category.2)/ASTM F1470-2018
HEAT NO : 18108473-3
MATERIAL : X1008A
FINISH : HOT DIP GALVANIZED PER ASTM A153-2009/ASTM F2329-2013

MANUFACTURE DATE : 2018/10/12
COUNTRY OF ORIGIN : CHINA

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A563-2015

| Chemistry | AL% | C% | MN% | P% | S% | SI% |
|---|---|---|---|---|---|---|
| Spec. : MIN. | | | | | | |
| MAX. | | 0.5800 | | 0.1300 | 0.2300 | |
| Test Value | 0.0300 | 0.0600 | 0.2800 | 0.0160 | 0.0060 | 0.0300 |

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.2-2015

SAMPLED BY : WANGYAN

| INSPECTIONS ITEM | SAMPLE | SPECIFIED | | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|---|
| WIDTH ACROSS CORNERS | 4PCS | | 1.4470-1.5160 inch | 1.4650-1.4690 inch | 4 | 0 |
| FIM | 15PCS | ASME B18.2.2-2015 | Max. 0.0250 inch | 0.0040-0.0060 inch | 15 | 0 |
| THICKNESS | 4PCS | | 0.7240-0.7760 inch | 0.7430-0.7460 inch | 4 | 0 |
| WIDTH ACROSS FLATS | 4PCS | | 1.2690-1.3120 inch | 1.2830-1.2840 inch | 4 | 0 |
| SURFACE DISCONTINUITIES | 29PCS | | ASTM F812-2012 | PASSED | 29 | 0 |
| THREAD | 15PCS | | GAGING SYSTEM 21 | PASSED | 15 | 0 |
| MINOR DIAMETER | 15PCS | | 0.7890-0.7970 inch | PASSED | 15 | 0 |

MECHANICAL PROPERTIES : ACCORDING TO ASTM A563-2015

SAMPLED BY : GDAN LIAN

| INSPECTIONS ITEM | SAMPLE | TEST METHOD | REF | SPECIFIED | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|---|---|
| CORE HARDNESS | 13 PCS | ASTM F606-2014 | | 116-302 HRB | 81-82 HRB | 13 | 0 |
| PROOF LOAD | 3 PCS | ASTM F606-2014 | | Min. 90 KSI | OK | 3 | 0 |
| PLATING THICKNESS(μm) | 5 PCS | ASTM B568-1998 | | >=53 | 72.03-95.08 | 5 | 0 |

WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY .WHICH ACCREDITED BY ISO/IEC17025(CERTIFICATE NUMBER:3358.01)
WE CERTIFY THAT THE PRODUCTS SUPPLIED ARE IN COMPLIANCE WITH THE REQUIREMENTS OF THE ORDER
WE CERTIFY THAT ALL PRODUCTS WE SUPPLIED ARE IN COMPLIANCE WITH DIN EN 10204 3.1 CONTENT

Quality Supervisor: Erin

page 1 of 1

Figure B-33. ⅞-in. Dia. Hex Nut, Test No. HMDT-1 (Item No. h3)

Apr. 17. 2019 2:15PM Fastenal-NELIN No. 6648 P. 2

FASTENAL®

# Certificate of Compliance

**Sold To:**

UNL TRANSPORTATION/Midwest Roadside Safe

**Purchase Order:** 70acct BCTAnchorCableHardware

**Job:**

**Invoice Date:** 10/19/2018

THIS IS TO CERTIFY THAT WE HAVE SUPPLIED YOU WITH THE FOLLOWING PARTS.
THESE PARTS WERE PURCHASED TO THE FOLLOWING SPECIFICATIONS.

200 PCS 1" x 2.500" OD Low Carbon Hot Dipped Galvanized Finish Steel USS General Purpose Flat Washer SUPPLIED UNDER OUR TRACE NUMBER 210151571 AND UNDER PART NUMBER 33188

200 PCS 1"-8 Hot Dipped Galvanized A563 Grade DH Heavy Hex Nut Made In USA SUPPLIED UNDER OUR TRACE NUMBER 210157128 AND UNDER PART NUMBER 38210

This is to certify that the above document is true and accurate to the best of my knowledge.

Abigail Ferguson

**Fastenal Account Representative Signature**

Abigail Ferguson

**Printed Name**

4/17/2019

**Date**

Please check current revision to avoid using obsolete copies.

This document was printed on 04/17/2019 and was current at that time.

**Fastenal Store Location/Address**

*3201 N. 23rd Street STE 1*
*LINCOLN, NE 68521*
*Phone #: (402)476-7900*
*Fax #: 402/476-7958*

Page 1 of 1

Figure B-34. 1-in. Dia. Heavy Hex Nut, Test No. HMDT-1 (Item No. h5)

ISO/TS 16949
BUREAU VERITAS
Certification

## GEM-YEAR TESTING LABORATORY
### CERTIFICATE OF INSPECTION

MANUFACTURER :GEM-YEAR INDUSTRIAL CO., LTD.
ADDRESS : NO.8 GEM-YEAR ROAD,E.D.Z.,JIASHAN,ZHEJIANG,P.R.CHINA

Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2017/03/23

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 110216407
COMMODITY : FINISHED HEX NUT GR-A
SIZE : 5/8-11 NC O/T 0.51MM
LOT NO : 1N1680027
SHIP QUANTITY : 23, 400 PCS
LOT QUANTITY 170, 278 PCS
HEADMARKS :
MANUFACTURE DATE : 2016/08/26
COUNTRY OF ORIGIN : CHINA

PACKING NO : GEM160919007
INVOICE NO : GEM/FNL-160929WI
PART NO : 36713
SAMPLING PLAN : ASME B18. 18-2011(Category. 2)/ASTM F1470-2012
HEAT NO : 331608011
MATERIAL : ML08
FINISH : HOT DIP GALVANIZED PER ASTM A153-2009/ASTM F2329-2013

R#17-507 H#331608011
BCT Cable Bracket Nuts

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A563-2007

| Chemistry | AL% | C% | MN% | P% | S% | SI% |
|---|---|---|---|---|---|---|
| Spec. : MIN. | | | | | | |
| MAX. | | 0. 5800 | | 0. 1300 | 0. 2300 | |
| Test Value | 0. 0350 | 0. 0700 | 0. 4100 | 0. 0160 | 0. 0060 | 0. 0500 |

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18. 2. 2-2010

SAMPLED BY : DWTING

| INSPECTIONS ITEM | SAMPLE | SPECIFIED | | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|---|
| WIDTH ACROSS CORNERS | 6 PCS | | 1. 0510-1. 0830 inch | 1. 0560-1. 0690 inch | 6 | 0 |
| FIM | 15 PCS | ASME B18. 2. 2-2010 | Max. 0. 0210 inch | 0. 0020-0. 0040 inch | 15 | 0 |
| THICKNESS | 6 PCS | | 0. 5350-0. 5590 inch | 0. 5390-0. 5570 inch | 6 | 0 |
| WIDTH ACROSS FLATS | 6 PCS | | 0. 9220-0. 9380 inch | 0. 9240-0. 9340 inch | 6 | 0 |
| SURFACE DISCONTINUITIES | 29 PCS | | ASTM F812-2012 | PASSED | 29 | 0 |
| THREAD | 15 PCS | | GAGING SYSTEM 21 | PASSED | 15 | 0 |

MECHANICAL PROPERTIES : ACCORDING TO ASTM A563-2007

SAMPLED BY : GDAN LIAN

| INSPECTIONS ITEM | SAMPLE | TEST METHOD | REF | SPECIFIED | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|---|---|
| CORE HARDNESS | 15 PCS | ASTM F606-2014 | | 68-107 HRB | 79-81 HRB | 15 | 0 |
| PROOF LOAD | 4 PCS | ASTM F606-2014 | | Min. 90 KSI | OK | 4 | 0 |
| PLATING THICKNESS( μm) | 5 PCS | ASTM B568-1998 | | >=53 | 70. 02-75. 81 | 5 | 0 |

WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY .WHICH ACCREDITED BY ISO/IEC17025(CERTIFICATE NUMBER:3358.01)
WE CERTIFY THAT THE PRODUCTS SUPPLIED ARE IN COMPLIANCE WITH THE REQUIREMENTS OF THE ORDER

Quality Supervisor: Grin

page 1 of 1

Figure B-35. ⅝-in. Dia. Hex Nut, Test No. HMDT-1 (Item No. h6)

**Ready Mixed Concrete Company**
6200 Cornhusker Hwy, Lincoln, NE 68529
Phone: (402) 434-1844 Fax: (402) 434-1877

Customer's Signature: ______________________

| PLANT | TRUCK | DRIVER | CUSTOMER | PROJECT | TAX | PO NUMBER | DATE | TIME | TICKET |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 108 | 7596 | 62461 | | | HMDT/FLAGT | 12/16/20 | 10:48 AM | 1260732 |

| Customer | Delivery Address | Special Instructions |
|---|---|---|
| UNL-MIDWEST ROADSIDE SAFETY | 4630 NW 36TH ST | AIRPARK / NORTH OF OLD GOODYEARHANGERS |

| LOAD QUANTITY | CUMULATIVE QUANTITY | ORDERED QUANTITY | PRODUCT CODE | PRODUCT DESCRIPTION | UOM | UNIT PRICE | EXTENDED PRICE |
|---|---|---|---|---|---|---|---|
| 4.00 | 4.00 | 4.00 | NL3S4454 | 47B1S384000HW | yd | $124.25 | $497.00 |
| | | | | MINIMUM HAUL | | | $30.00 |
| | | | | WINTER SERVICE | | | $20.00 |

| Water Added On Job At Customer's Request: | SLUMP | Notes: | | |
|---|---|---|---|---|
| | 3.00 in | | TICKET SUBTOTAL | $547.00 |
| | | | SALES TAX | $0.00 |
| | | | TICKET TOTAL | **$547.00** |
| | | | PREVIOUS TOTAL | |
| | | | **GRAND TOTAL** | **$547.00** |

**CAUTION FRESH CONCRETE**
**KEEP CHILDREN AWAY**

Contains Portland cement. Freshly mixed cement, mortar, concrete or grout may cause skin injury. Avoid prolonged contact with skin. Always wear appropriate Personal Protective Equipment (PPE). In case of contact with eyes or skin, flush thoroughly with water. If irritation persists, seek medical attention promptly.

**Terms & Conditions**

This concrete is produced with the ASTM standard specifications for ready mix concrete. Strengths are based on a 3" slump. Drivers are not permitted to add water to the mix to exceed this slump, except under the authorization of the customer and their acceptance of any decrease in compressive strength and any risk of loss as a result thereof. Cylinder tests must be handled according to ACI/ASTM specifications and drawn by a licensed testing lab and/or certified technician.
Ready Mixed Concrete Company will not deliver any product beyond any curb lines unless expressly told to do so by customer and customer assumes all liability for any personal or property damage that may occur as a result of any such directive.
The purchaser's exceptions and claims shall be deemed waived unless made in writing within 3 days from time of delivery. In such a case, seller shall be given full opportunity to investigate any such claim. Seller's liability shall in no event exceed the purchase price of the materials against which any claims are made.

Figure B-36. Curb Concrete, Test No. HMDT-1 (Item No. j2)

benesch



# Concrete Sample Test Report
## Cylinder Compressive Strength

| | |
|---|---|
| Project Name: | Midwest Roadside Safety - Misc Testing |
| Project Number: | 00110546.00 |
| Client: | Midwest Roadside Safety Facility |
| Location: | MNPD |
| Sample: | 012 |
| Description: | HAWAII_1 HMDT |

### Field Data (ASTM C172, C143, C173/C231, C138, C1064)

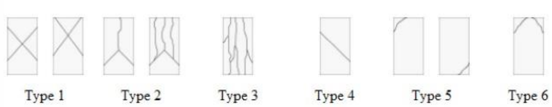
| | | Property | Test Result |
|---|---|---|---|
| Supplier: | | Slump (in): | |
| Mix Name: | | Air Content (%): | |
| Ticket Number: | | Unit Weight (lb/ft³): | |
| Truck Number: | | Air Temp (°F): | |
| Load Volume (yd³): | | Mix Temp (°F): | |
| Mold Date: | 12/16/2020 | Min Temp (°F): | |
| Molded By: | | MaxTemp (°F): | |
| Initial Cure Method: | | | |

### Laboratory Test Data (ASTM C39)

| | | | | | | |
|---|---|---|---|---|---|---|
| Sample Number: | 012 | 012 | | | | |
| Set Number: | HMDT CURB 1 | HMDT CURB 2 | | | | |
| Specimen Number: | 1 | 1 | | | | |
| Age: | 20 | 20 | | | | |
| Length (in): | 12 | 12 | | | | |
| Diameter (in): | 5.99 | 5.98 | | | | |
| Area (in²): | 28.18 | 28.09 | | | | |
| Test Date: | 01/05/2021 | 01/05/2021 | | | | |
| Break Type: | 5 | 5 | | | | |
| Max Load (lbf): | 109,438 | 101,529 | | | | |
| Strength (psi): | 3,880 | 3,610 | | | | |
| Spec Strength (psi): | | | | | | |

Remarks:
Average 20-day Compressive Strength (psi): **3,750**

Date received: 01/05/2021
Curing: ☒ Standard ☐ Field
ASTM C511
Submitted by:




Distribution:

Report Date: 1/5/21

This report shall not be reproduced, except in full, without prior approval of Alfred Benesch & Company. Results relate only to items tested.

825 M Street Suite 100
Lincoln, NE 68508

Alfred Benesch & Company



Figure B-37. Curb Concrete, Test No. HMDT-1 (Item No. j2)

# Appendix C. Vehicle Center of Gravity Determination

**Test Name:** HMDT-1 **VIN:** 1C6RR6FG3FS661207
**Model Year:** 2015 **Make:** Dodge RAM **Model:** 1500 Quad Cab

**Vehicle CG Determination**

| | Vehicle Equipment | Weight (lb) | Vertical CG (in.) | Vertical M (lb-in.) |
|---|---|---|---|---|
| + | Unballasted Truck (Curb) | 4918 | 28.796424 | 141620.81 |
| + | Hub | 19 | 15 | 285 |
| + | Brake activation cylinder & frame | 7 | 27 1/2 | 192.5 |
| + | Pneumatic tank (Nitrogen) | 30 | 26 1/2 | 795 |
| + | Strobe/Brake Battery | 4 | 26 1/2 | 106 |
| + | Brake Receiver/Wires | 5 | 52 1/2 | 262.5 |
| + | CG Plate including DAQ | 30 | 30 7/8 | 926.25 |
| - | Battery | -42 | 43 | -1806 |
| - | Oil | -13 | 18 | -234 |
| - | Interior | -90 | 36 | -3240 |
| - | Fuel | -164 | 19 1/2 | -3198 |
| - | Coolant | -10 | 34 | -340 |
| - | Washer fluid | -5 | 37 | -185 |
| + | Water Ballast (In Fuel Tank) | 233 | 19 1/2 | 4543.5 |
| + | Onboard Supplemental Battery | 4 | 26 1/2 | 106 |
| + | Steel Plates | 103 | 33 7/8 | 3489.125 |
| | | | | 0 |
| | | | | 143323.69 |

Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle

| | |
|---|---|
| Estimated Total Weight (lb) | 5029 |
| Vertical CG Location (in.) | 28.4994 |

**Vehicle Dimensions for C.G. Calculations**

Wheel Base: 140.25 in. Front Track Width: 68.5 in.
Rear Track Width: 67.75 in.

| Center of Gravity | 2270P MASH Targets | Test Inertial | Difference |
|---|---|---|---|
| Test Inertial Weight (lb) | 5000 ± 110 | 5029 | 29.0 |
| Longitudinal CG (in.) | 63 ± 4 | 66.792354 | 3.79235 |
| Lateral CG (in.) | NA | -0.088052 | NA |
| Vertical CG (in.) | 28 or greater | 28.50 | 0.49944 |

Note: Long. CG is measured from front axle of test vehicle

Note: Lateral CG measured from centerline - positive to vehicle right (passenger) side

**CURB WEIGHT (lb.)**

| | Left | Right |
|---|---|---|
| Front | 1373 | 1304 |
| Rear | 1133 | 1108 |

| | | |
|---|---|---|
| FRONT | 2677 | lb |
| REAR | 2241 | lb |
| TOTAL | 4918 | lb |

**TEST INERTIAL WEIGHT (lb.)**

| | Left | Right |
|---|---|---|
| Front | 1324 | 1310 |
| Rear | 1197 | 1198 |

| | | |
|---|---|---|
| FRONT | 2634 | lb |
| REAR | 2395 | lb |
| TOTAL | 5029 | lb |

Figure C-1. Vehicle Mass Distribution, Test No. HMDT-1

| | | | |
|---|---|---|---|
| | **Test Name:** HMDT-2 | **VIN:** | 1C6RR6KG1FS542139 |
| **Model Year:** 2015 | **Make:** Dodge Ram | **Model:** | 1500 Crew Cab |

**Vehicle CG Determination**

| Vehicle Equipment | | Weight (lb) | Vertical CG (in.) | Vertical M (lb-in.) |
|---|---|---|---|---|
| + | Unballasted Truck (Curb) | 4958 | 28.503454 | 141320.13 |
| + | Hub | 19 | 14.75 | 280.25 |
| + | Brake activation cylinder & frame | 7 | 27 | 189 |
| + | Pneumatic tank (Nitrogen) | 30 | 26 3/4 | 802.5 |
| + | Strobe/Brake Battery | 5 | 27 1/2 | 137.5 |
| + | Brake Receiver/Wires | 5 | 53 | 265 |
| + | CG Plate including DAQ | 50 | 30 | 1500 |
| - | Battery | -52 | 41 | -2132 |
| - | Oil | -16 | 18 | -288 |
| - | Interior | -99 | 36 | -3564 |
| - | Fuel | -167 | 18 | -3006 |
| - | Coolant | 0 | 37 | 0 |
| - | Washer fluid | -2 | 35 1/2 | -71 |
| + | Water Ballast (In Fuel Tank) | 236 | 18 | 4248 |
| + | Onboard Supplemental Battery | 5 | 27 1/2 | 137.5 |
| | | | | 0 |
| | | | | 0 |
| Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle | | | | 139818.88 |

| | |
|---|---|
| Estimated Total Weight (lb) | 4979 |
| Vertical CG Location (in.) | 28.0817 |

**Vehicle Dimensions for C.G. Calculations**

Wheel Base: 140.375 in. Front Track Width: 68.125 in.
Rear Track Width: 67.25 in.

| **Center of Gravity** | **2270P MASH Targets** | **Test Inertial** | **Difference** |
|---|---|---|---|
| Test Inertial Weight (lb) | 5000 ± 110 | 4981 | -19.0 |
| Longitudinal CG (in.) | 63 ± 4 | 65.523364 | 2.52336 |
| Lateral CG (in.) | NA | -0.686252 | NA |
| Vertical CG (in.) | 28 or greater | 28.08 | 0.08172 |

Note: Long. CG is measured from front axle of test vehicle

Note: Lateral CG measured from centerline - positive to vehicle right (passenger) side

**CURB WEIGHT (lb.)**

| | Left | Right |
|---|---|---|
| Front | 1388 | 1310 |
| Rear | 1144 | 1116 |

| | | |
|---|---|---|
| FRONT | 2698 | lb |
| REAR | 2260 | lb |
| TOTAL | 4958 | lb |

**TEST INERTIAL WEIGHT (lb.)**

| | Left | Right |
|---|---|---|
| Front | 1361 | 1295 |
| Rear | 1180 | 1145 |

| | | |
|---|---|---|
| FRONT | 2656 | lb |
| REAR | 2325 | lb |
| TOTAL | 4981 | lb |

Figure C-2. Vehicle Mass Distribution, Test No. HMDT-2

| | | | |
|---|---|---|---|
| | | **Test Name:** | **HMDT-3** |
| **VIN:** | **KNADN4A38G6572229** | | |
| **Model Year:** | **2016** | **Make:** | **Kia** |
| **Model:** | **Rio** | | |

**Vehicle CG Determination**

| Vehicle Equipment | | Weight (lb) |
|---|---|---|
| + | Unballasted Car (Curb) | 2542 |
| + | Hub | 19 |
| + | Brake activation cylinder & frame | 7 |
| + | Pneumatic tank (Nitrogen) | 30 |
| + | Strobe/Brake Battery | 5 |
| + | Brake Receiver/Wires | 5 |
| + | CG Plate including DAQ | 20 |
| - | Battery | -32 |
| - | Oil | -12 |
| - | Interior | -112 |
| - | Fuel | -20 |
| - | Coolant | -6 |
| - | Washer fluid | -4 |
| + | Water Ballast (In Fuel Tank) | 0 |
| + | Onboard Supplemental Battery | 5 |
| - | Undercarriage Plastic Covering | -14 |
| | | |

Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle

Estimated Total Weight (lb) 2433

**Vehicle Dimensions for C.G. Calculations**

| | | | |
|---|---|---|---|
| Wheel Base: | 101.5 in. | Front Track Width: | 59.0 in. |
| Roof Height: | 57.375 in. | Rear Track Width: | 58.0 in. |

| **Center of Gravity** | **1100C MASH Targets** | **Test Inertial** | **Difference** |
|---|---|---|---|
| Test Inertial Weight (lb) | 2420 ± 55 | 2430 | 10.0 |
| Longitudinal CG (in.) | 39 ± 4 | 37.634 | -1.366 |
| Lateral CG (in.) | NA | -0.048 | NA |
| Vertical CG (in.) | NA | 22.625 | NA |

Note: Long. CG is measured from front axle of test vehicle

Note: Lateral CG measured from centerline - positive to vehicle right (passenger) side

**CURB WEIGHT (lb)**

| | Left | Right |
|---|---|---|
| Front | 813 | 769 |
| Rear | 484 | 476 |

| | | |
|---|---|---|
| FRONT | 1582 | lb |
| REAR | 960 | lb |
| TOTAL | 2542 | lb |

**TEST INERTIAL WEIGHT (lb)**

| | Left | Right |
|---|---|---|
| Front | 767 | 762 |
| Rear | 450 | 451 |

| | | |
|---|---|---|
| FRONT | 1529 | lb |
| REAR | 901 | lb |
| TOTAL | 2430 | lb |

Figure C-3. Vehicle Mass Distribution, Test No. HMDT-3

| | | | |
|---|---|---|---|
| | Test Name: HMDT-4 | VIN: | KMHCT4AE9GU115037 |
| Model Year: 2016 | Make: Hyundai | Model: | Accent |

**Vehicle CG Determination**

| Vehicle Equipment | | Weight (lb) |
|---|---|---|
| + | Unballasted Car (Curb) | 2502 |
| + | Hub | 19 |
| + | Brake activation cylinder & frame | 7 |
| + | Pneumatic tank (Nitrogen) | 22 |
| + | Strobe/Brake Battery | 10 |
| + | Brake Receiver/Wires | 5 |
| + | CG Plate including DAQ | 20 |
| - | Battery | -42 |
| - | Oil | -5 |
| - | Interior | -82 |
| - | Fuel | -14 |
| - | Coolant | -7 |
| - | Washer fluid | -8 |
| + | Water Ballast (In Fuel Tank) | 0 |
| + | Onboard Supplemental Battery | 0 |
| | | |
| | | |

Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle

Estimated Total Weight (lb) 2427

**Vehicle Dimensions for C.G. Calculations**

| | | | |
|---|---|---|---|
| Wheel Base: | 100.5 in. | Front Track Width: | 59.875 in. |
| Roof Height: | 56.375 in. | Rear Track Width: | 59.625 in. |

| Center of Gravity | 1100C MASH Targets | Test Inertial | Difference |
|---|---|---|---|
| Test Inertial Weight (lb) | 2420 ± 55 | 2431 | 11.0 |
| Longitudinal CG (in.) | 39 ± 4 | 37.744 | -1.256 |
| Lateral CG (in.) | NA | -0.037 | NA |
| Vertical CG (in.) | NA | 21.77 | NA |

Note: Long. CG is measured from front axle of test vehicle

Note: Lateral CG measured from centerline - positive to vehicle right (passenger) side

**CURB WEIGHT (lb)**

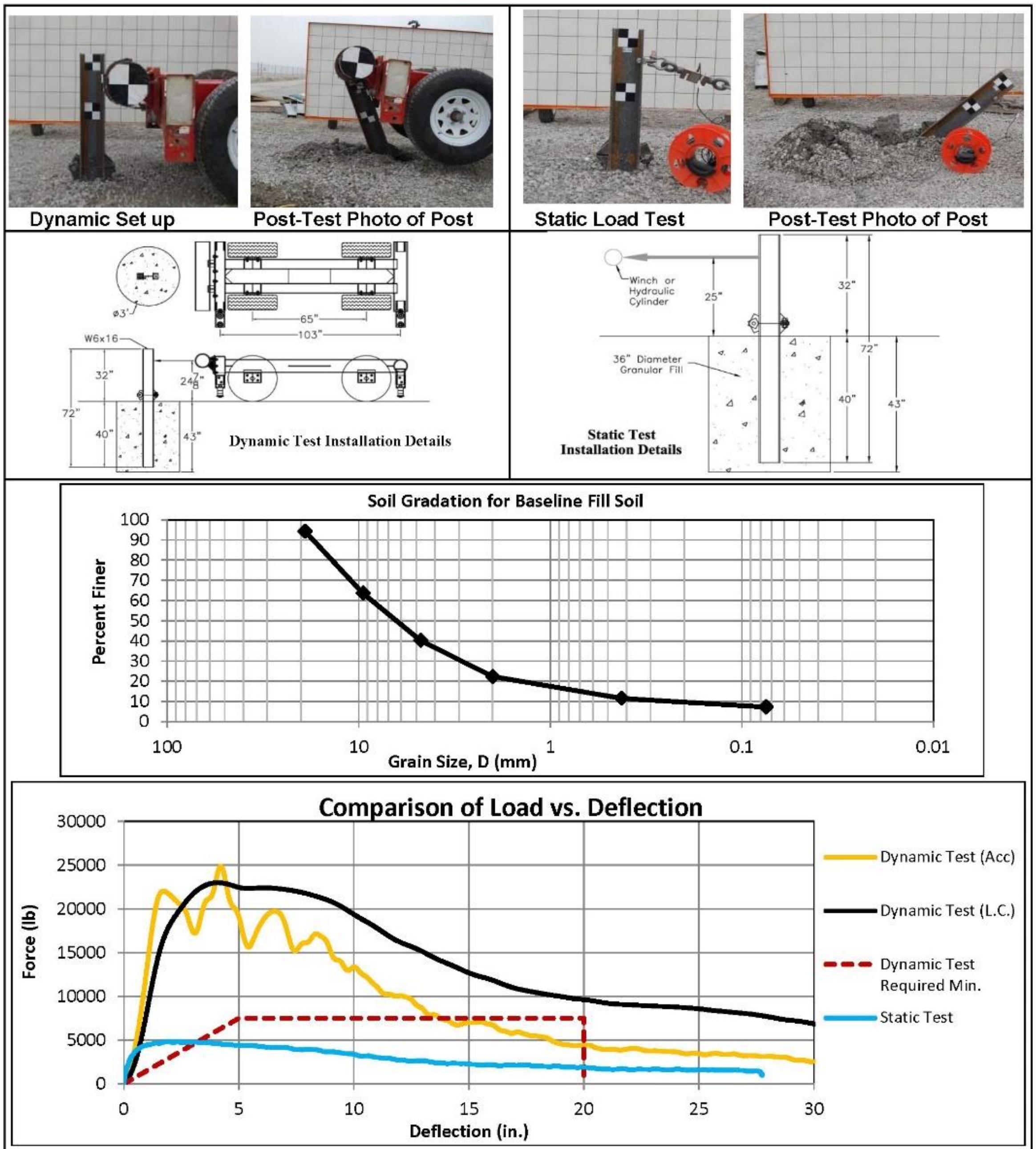
| | Left | Right |
|---|---|---|
| Front | 815 | 747 |
| Rear | 465 | 475 |
| FRONT | 1562 | lb |
| REAR | 940 | lb |
| TOTAL | 2502 | lb |

**TEST INERTIAL WEIGHT (lb)**

| | Left | Right |
|---|---|---|
| Front | 776 | 742 |
| Rear | 441 | 472 |
| FRONT | 1518 | lb |
| REAR | 913 | lb |
| TOTAL | 2431 | lb |

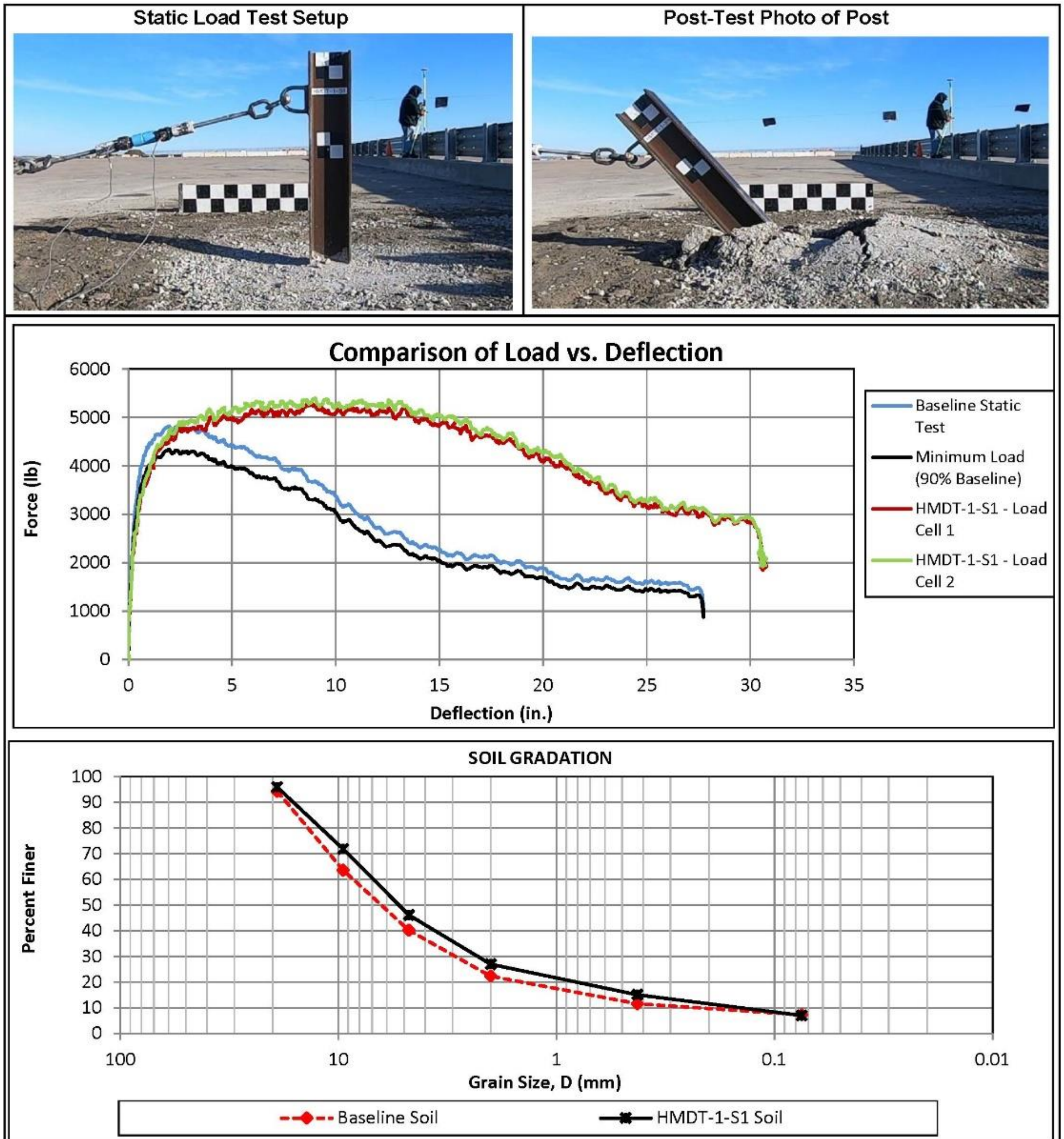
Figure C-4. Vehicle Mass Distribution, Test No. HMDT-4

# Appendix D. Static Soil Test



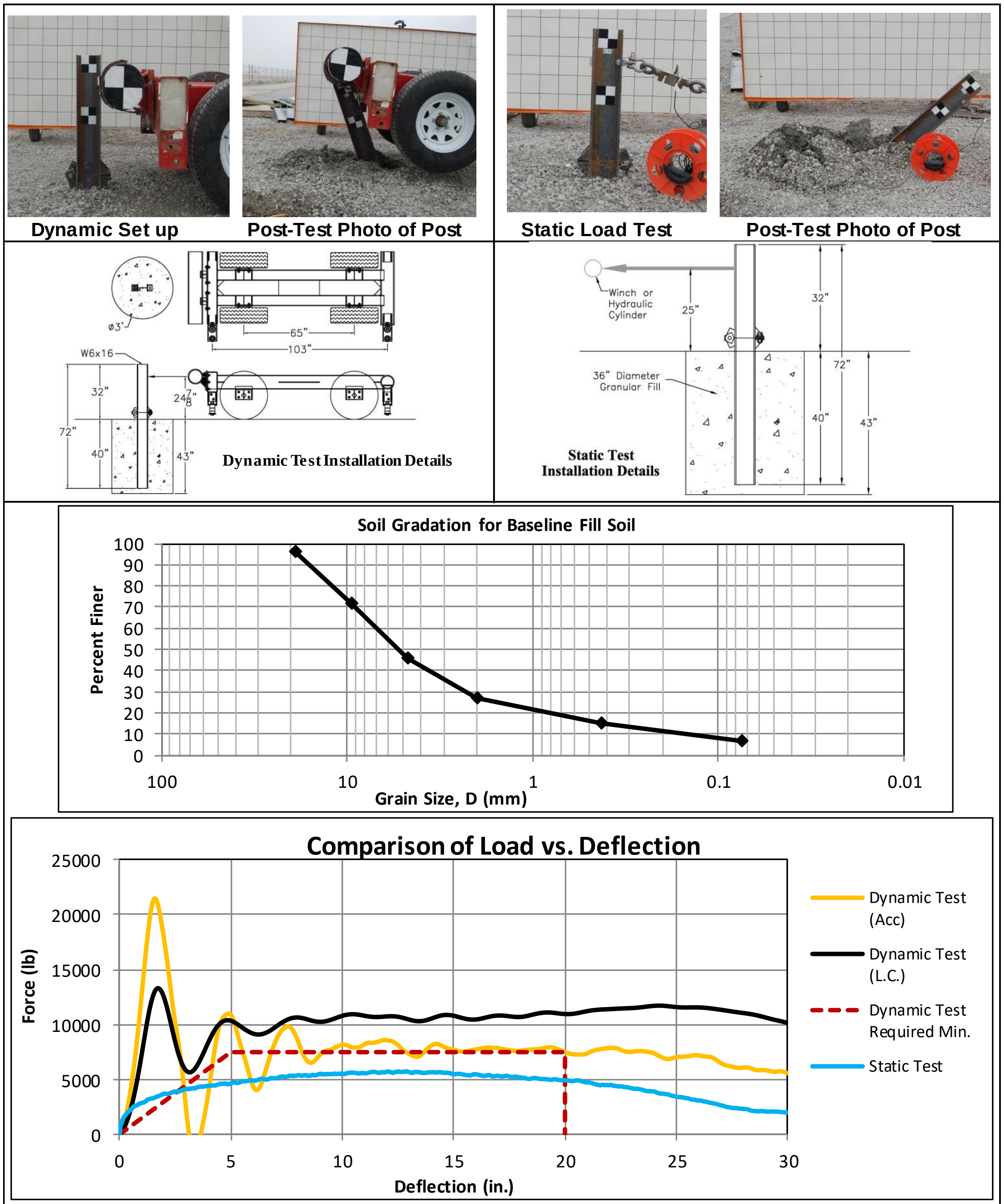

| | | | | |
|---|---|---|---|---|
| **Date**.......................................................... | 2/16/2018 | | | |
| **Test Facility & Site Location**....................... | Midwest Roadside Safety Facility | | | |
| **In situ soil description (ASTM D2487)**........... | Well-Graded Gravel (GW) | | | |
| **Fill material description (ASTM D2487)**......... | Well-Graded Gravel (GW) (see sieve analyses above) | | | |
| **Description of fill placement procedure**........ | H.E.-8 | | | |
| **Bogie Weight**............................................ | 1786 | lb | 810 kg | |
| **Impact Velocity**......................................... | 20.9 | mph | 33.7 km/h | |

Figure D-1. Soil Strength, Baseline Testing




| | |
|---|---|
| **Date**………………………………………………… | 1/13/2021 |
| **Test Facility & Site Location**…………………… | Midwest Roadside Safety Facility |
| **In situ soil description (ASTM D2487)**……….. | Well-Graded Gravel (GW) |
| **Fill material description (ASTM D2487)**……… | Well-Graded Gravel (GW) (see sieve analyses above) |
| **Description of fill placement procedure**…….. | 8-inch lifts tamped with a pneumatic compactor |

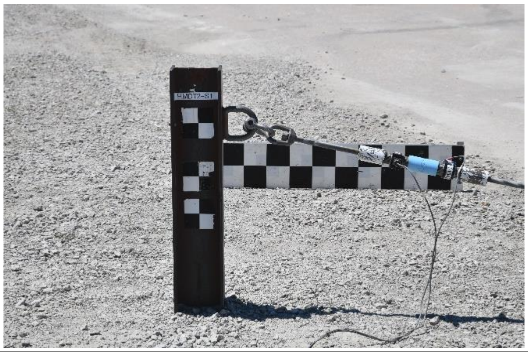
Figure D-2. Static Soil Test, Test No. HMDT-1



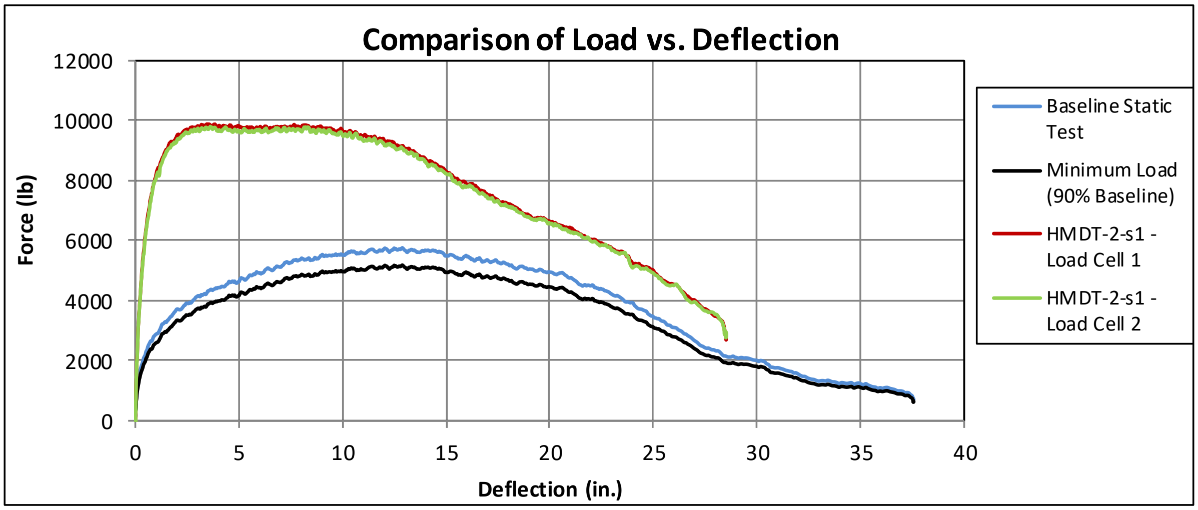

| | |
|---|---|
| **Date**........................................................ | 5/24/2021 |
| **Test Facility & Site Location**...................... | Midwest Roadside Safety Facility |
| **In situ soil description (ASTM D2487)**......... | Well-Graded Gravel (GW) |
| **Fill material description (ASTM D2487)**...... | Well-Graded Gravel (GW) (see sieve analyses above) |
| **Description of fill placement procedure**..... | LE-8 - 4 times around |
| **Bogie Weight**........................................... | 1878 lb 852 kg |
| **Impact Velocity**....................................... | 20.9 mph 33.6 km/h |

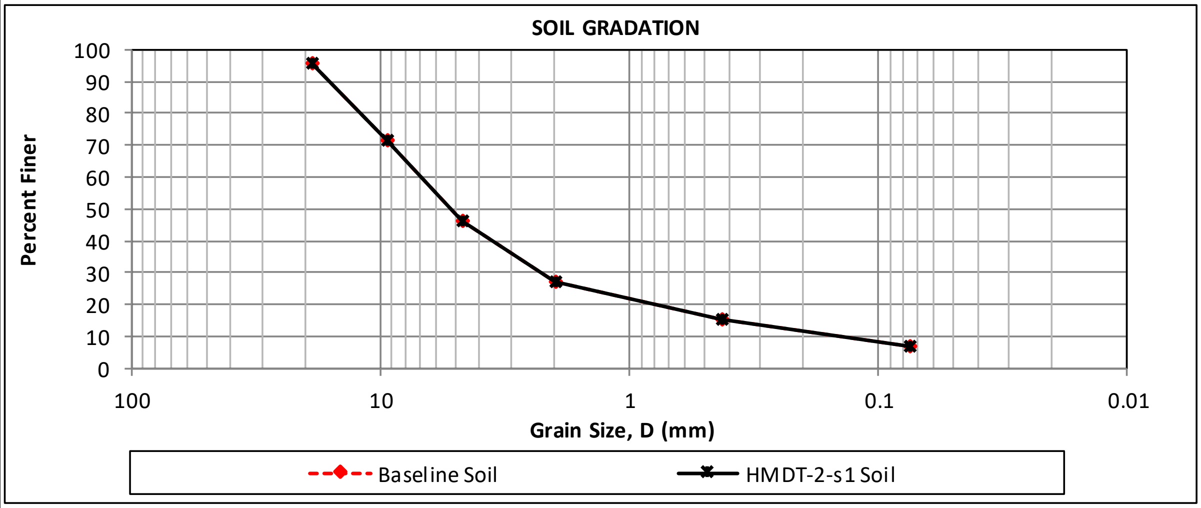
Figure D-3. Soil Strength, Baseline Testing

**Static Load Test Setup**



**Post-Test Photo of Post**



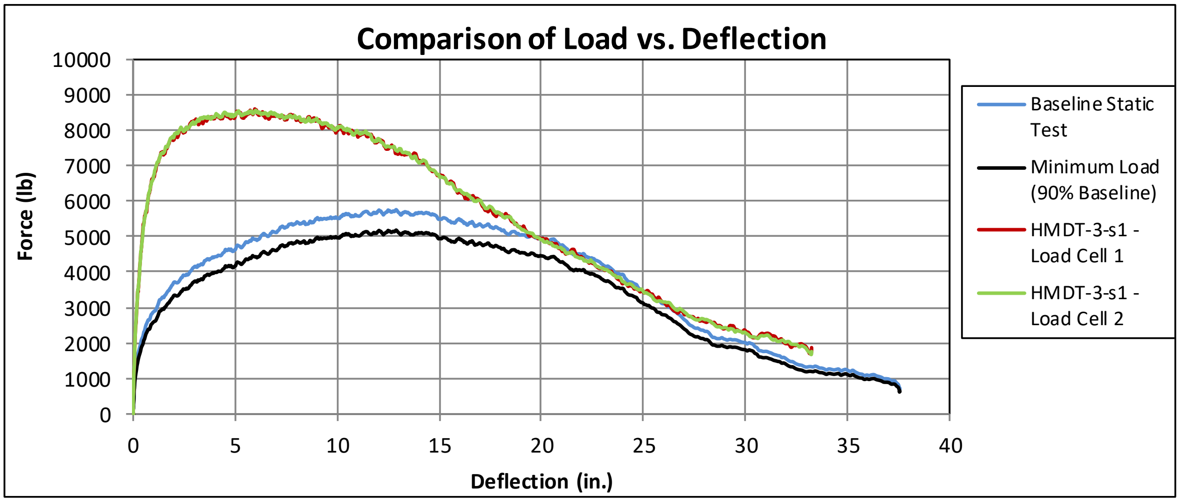



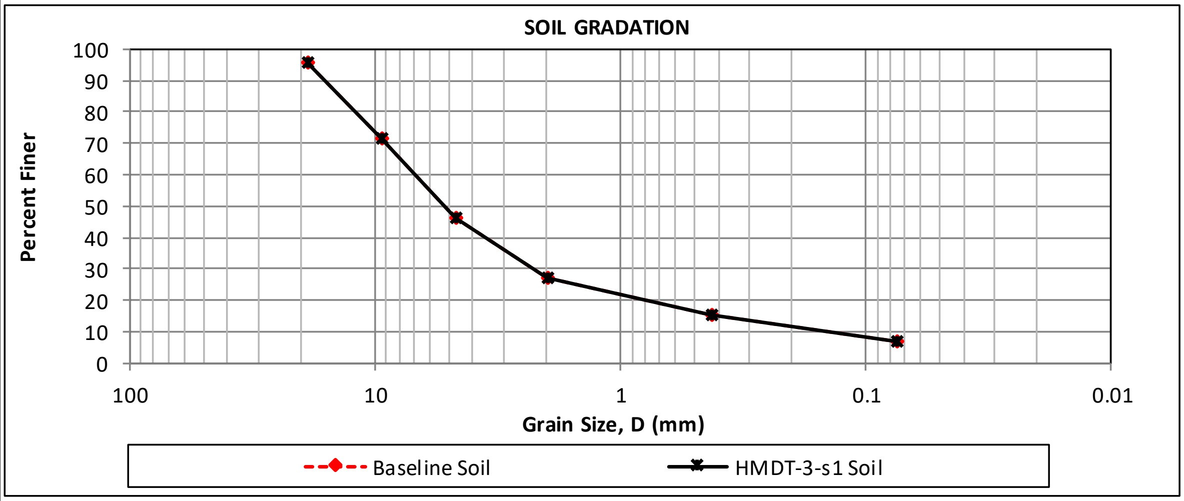

| | |
|---|---|
| **Date**........................................................ | 6/22/2021 |
| **Test Facility & Site Location**..................... | Midwest Roadside Safety Facility |
| **In situ soil description (ASTM D2487)**.......... | Well-Graded Gravel (GW) |
| **Fill material description (ASTM D2487)**...... | Well-Graded Gravel (GW) (see sieve analyses above) |
| **Description of fill placement procedure**..... | 8-inch lifts tamped with a pneumatic compactor |

Figure D-4. Static Soil Test, Test No. HMDT-2

**Static Load Test Setup**

**Post-Test Photo of Post**

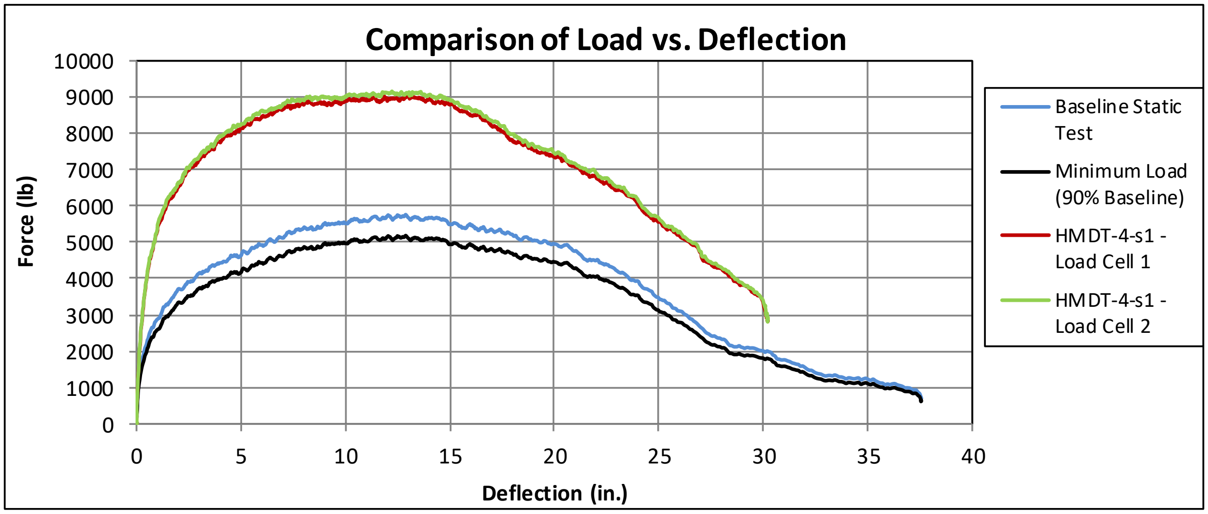


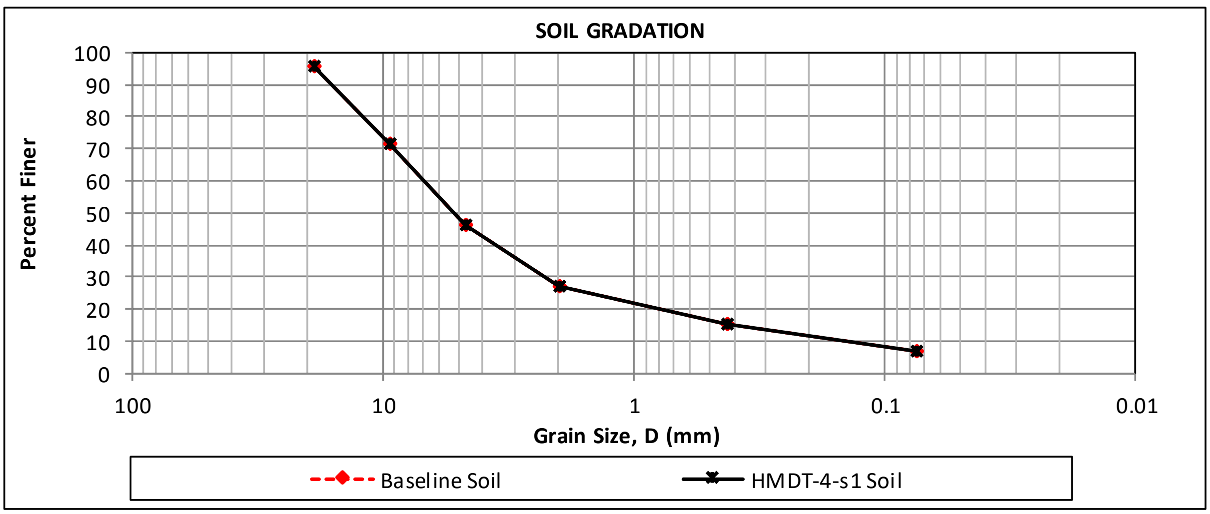




| | |
|---|---|
| **Date**........................................................ | 7/1/2021 |
| **Test Facility & Site Location**..................... | Midwest Roadside Safety Facility |
| **In situ soil description (ASTM D2487)**......... | Well-Graded Gravel (GW) |
| **Fill material description (ASTM D2487)**...... | Well-Graded Gravel (GW) (see sieve analyses above) |
| **Description of fill placement procedure**..... | 8-inch lifts tamped with a pneumatic compactor |

Figure D-5. Static Soil Test, Test No. HMDT-3

| Static Load Test Setup | Post-Test Photo of Post |
|---|---|
|  |  |




| | |
|---|---|
| **Date** | 1/28/2022 |
| **Test Facility & Site Location** | Midwest Roadside Safety Facility |
| **In situ soil description (ASTM D2487)** | Well-Graded Gravel (GW) |
| **Fill material description (ASTM D2487)** | Well-Graded Gravel (GW) (see sieve analyses above) |
| **Description of fill placement procedure** | 8-inch lifts tamped with a pneumatic compactor |

Figure D-6. Static Soil Test, Test No. HMDT-4

# Appendix E. Vehicle Deformation Records

The following figures and tables describe all occupant compartment measurements taken on the test vehicles used in full-scale crash testing herein. MASH 2016 defines intrusion as the occupant compartment being deformed and reduced in size with no penetration. Outward deformations, which are denoted as negative numbers within this Appendix, are not considered as crush toward the occupant, and are not subject to evaluation by MASH 2016 criteria.

Model Year: 2015 | Test Name: HMDT-1 | Make: Dodge RAM | VIN: 1C6RR6FG3FS661207 | Model: 1500 Quad Cab

**VEHICLE DEFORMATION**
**DRIVER SIDE FLOOR PAN - SET 1**

| | POINT | Pretest X (in.) | Pretest Y (in.) | Pretest Z (in.) | Posttest X (in.) | Posttest Y (in.) | Posttest Z (in.) | ΔX^A (in.) | ΔY^A (in.) | ΔZ^A (in.) | Total Δ (in.) | Crush^B (in.) | Directions for Crush^C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TOE PAN - WHEEL WELL (X, Z) | 1 | 55.5588 | -24.1208 | -1.3490 | 48.0352 | -18.8491 | -7.0375 | 7.5236 | 5.2717 | 5.6885 | 10.8053 | 9.4321 | X, Z |
| | 2 | 56.9349 | -20.3301 | -0.3458 | 48.9017 | -15.0378 | -7.0387 | 8.0332 | 5.2923 | 6.6929 | 11.7190 | 10.4560 | X, Z |
| | 3 | 57.6720 | -15.1595 | 0.2235 | 51.6641 | -11.0830 | -4.5897 | 6.0079 | 4.0765 | 4.8132 | 8.7109 | 7.6982 | X, Z |
| | 4 | 56.4100 | -9.0756 | -0.3223 | 54.9881 | -9.3521 | -1.0834 | 1.4219 | -0.2765 | 0.7611 | 1.6363 | 1.6128 | X, Z |
| | 5 | 53.2300 | -2.7319 | -3.7455 | 53.1233 | -2.7904 | -4.3337 | 0.1067 | -0.0585 | 0.5882 | 0.6007 | 0.5978 | X, Z |
| | 6 | 52.1296 | -25.3068 | 3.0168 | 43.7329 | -19.2782 | -3.2717 | 8.3967 | 6.0286 | 6.2885 | 12.0993 | 10.4905 | X, Z |
| | 7 | 51.7484 | -21.0044 | 3.4145 | 43.9178 | -15.4594 | -2.2925 | 7.8306 | 5.5450 | 5.7070 | 11.1640 | 9.6896 | X, Z |
| | 8 | 51.7002 | -15.6072 | 3.3985 | 47.4254 | -12.5243 | 0.5653 | 4.2748 | 3.0829 | 2.8332 | 5.9837 | 5.1284 | X, Z |
| | 9 | 51.8538 | -9.4832 | 3.2748 | 51.1147 | -8.6785 | 3.1155 | 0.7391 | 0.8047 | 0.1593 | 1.1042 | 0.7561 | X, Z |
| | 10 | 50.3491 | -3.4792 | -1.1428 | 50.2278 | -3.4897 | -1.8220 | 0.1213 | -0.0105 | 0.6792 | 0.6900 | 0.6899 | X, Z |
| FLOOR PAN (Z) | 11 | 48.7206 | -24.3188 | 5.0376 | 43.1160 | -19.6345 | -0.7408 | 5.6046 | 4.6843 | 5.7784 | 9.3137 | 5.7784 | Z |
| | 12 | 48.4351 | -20.1232 | 5.1456 | 44.0642 | -16.9649 | 1.3045 | 4.3709 | 3.1583 | 3.8411 | 6.6207 | 3.8411 | Z |
| | 13 | 48.4208 | -15.5466 | 5.1120 | 45.7888 | -13.3875 | 3.5329 | 2.6320 | 2.1591 | 1.5791 | 3.7527 | 1.5791 | Z |
| | 14 | 48.4939 | -10.4217 | 5.0359 | 48.2855 | -9.4733 | 5.6169 | 0.2084 | 0.9484 | -0.5810 | 1.1316 | -0.5810 | Z |
| | 15 | 46.5428 | -3.9092 | 0.0673 | 46.5583 | -3.8213 | -0.4037 | -0.0155 | 0.0879 | 0.4710 | 0.4794 | 0.4710 | Z |
| | 16 | 44.8533 | -24.2471 | 5.5656 | 42.1435 | -21.7810 | 2.5711 | 2.7098 | 2.4661 | 2.9945 | 4.7320 | 2.9945 | Z |
| | 17 | 44.7593 | -19.9120 | 5.5264 | 43.3165 | -18.1609 | 4.6169 | 1.4428 | 1.7511 | 0.9095 | 2.4444 | 0.9095 | Z |
| | 18 | 44.7842 | -15.6858 | 5.5037 | 44.2038 | -14.4132 | 6.2509 | 0.5804 | 1.2726 | -0.7472 | 1.5858 | -0.7472 | Z |
| | 19 | 44.7711 | -10.2116 | 5.4790 | 44.9121 | -9.8185 | 4.6860 | -0.1410 | 0.3931 | 0.7930 | 0.8962 | 0.7930 | Z |
| | 20 | 42.8876 | -4.0984 | 0.4969 | 42.8401 | -4.0662 | -0.0883 | 0.0475 | 0.0322 | 0.5852 | 0.5880 | 0.5852 | Z |
| | 21 | 39.1101 | -24.1677 | 5.5683 | 38.8460 | -23.2615 | 6.3510 | 0.2641 | 0.9062 | -0.7827 | 1.2262 | -0.7827 | Z |
| | 22 | 38.7279 | -19.3707 | 5.5133 | 38.5303 | -18.6874 | 6.4609 | 0.1976 | 0.6833 | -0.9476 | 1.1849 | -0.9476 | Z |
| | 23 | 38.9387 | -15.1860 | 5.4892 | 38.9231 | -14.8281 | 4.7207 | 0.0156 | 0.3579 | 0.7685 | 0.8479 | 0.7685 | Z |
| | 24 | 38.8892 | -10.0539 | 5.4711 | 38.9191 | -9.7929 | 4.7691 | -0.0299 | 0.2610 | 0.7020 | 0.7495 | 0.7020 | Z |
| | 25 | 37.3670 | -4.3497 | 1.1107 | 37.3491 | -4.2878 | 0.6240 | 0.0179 | 0.0619 | 0.4867 | 0.4909 | 0.4867 | Z |
| | 26 | 32.8941 | -24.1937 | 5.2724 | 33.0656 | -23.9792 | 5.6582 | -0.1715 | 0.2145 | -0.3858 | 0.4736 | -0.3858 | Z |
| | 27 | 32.6565 | -19.9591 | 5.1334 | 32.6777 | -19.7913 | 5.3551 | -0.0212 | 0.1678 | -0.2217 | 0.2788 | -0.2217 | Z |
| | 28 | 32.6563 | -15.6499 | 5.1330 | 32.6588 | -15.4163 | 5.1990 | -0.0025 | 0.2336 | -0.0660 | 0.2428 | -0.0660 | Z |
| | 29 | 32.7300 | -10.4555 | 5.1661 | 32.7057 | -10.2230 | 5.1181 | 0.0243 | 0.2325 | 0.0480 | 0.2386 | 0.0480 | Z |
| | 30 | 33.3616 | -4.3938 | 1.1831 | 33.2581 | -4.6491 | 0.6612 | 0.1035 | -0.2553 | 0.5219 | 0.5901 | 0.5219 | Z |

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

| Pretest Floor Pan | Posttest Floor Pan |
|---|---|
|  |  |

Figure E-1. Floor Pan Deformation Data – Set 1, Test No. HMDT-1

Model Year: 2015 | Test Name: HMDT-1 | VIN: 1C6RR6FG3FS661207
Make: Dodge RAM | Model: 1500 Quad Cab

**VEHICLE DEFORMATION**
**DRIVER SIDE FLOOR PAN - SET 2**

| | POINT | Pretest X (in.) | Pretest Y (in.) | Pretest Z (in.) | Posttest X (in.) | Posttest Y (in.) | Posttest Z (in.) | ΔX[A] (in.) | ΔY[A] (in.) | ΔZ[A] (in.) | Total Δ (in.) | Crush[B] (in.) | Directions for Crush[C] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TOE PAN - WHEEL WELL (X, Z) | 1 | 58.9634 | -43.5467 | -5.5649 | 51.4452 | -38.2227 | -11.2215 | 7.5182 | 5.3240 | 5.6566 | 10.8104 | 9.4085 | X, Z |
| | 2 | 60.3376 | -39.7631 | -4.5331 | 52.3139 | -34.4123 | -11.1650 | 8.0237 | 5.3508 | 6.6319 | 11.7044 | 10.4097 | X, Z |
| | 3 | 61.0731 | -34.5965 | -3.9261 | 55.0708 | -30.4950 | -8.6505 | 6.0023 | 4.1015 | 4.7244 | 8.6701 | 7.6386 | X, Z |
| | 4 | 59.8109 | -28.5091 | -4.4304 | 58.3848 | -28.8169 | -5.1093 | 1.4261 | -0.3078 | 0.6789 | 1.6092 | 1.5795 | X, Z |
| | 5 | 56.6341 | -22.1418 | -7.8125 | 56.5340 | -22.2078 | -8.2702 | 0.1001 | -0.0660 | 0.4577 | 0.4731 | 0.4685 | X, Z |
| | 6 | 55.5290 | -44.7643 | -1.2121 | 47.1308 | -38.7035 | -7.4757 | 8.3982 | 6.0608 | 6.2636 | 12.1035 | 10.4768 | X, Z |
| | 7 | 55.1465 | -40.4649 | -0.7842 | 47.3149 | -34.8993 | -6.4409 | 7.8316 | 5.5656 | 5.6567 | 11.1494 | 9.6609 | X, Z |
| | 8 | 55.0975 | -35.0677 | -0.7620 | 50.8152 | -32.0080 | -3.5301 | 4.2823 | 3.0597 | 2.7681 | 5.9466 | 5.0991 | X, Z |
| | 9 | 55.2502 | -28.9430 | -0.8420 | 54.4987 | -28.2016 | -0.9131 | 0.7515 | 0.7414 | 0.0711 | 1.0581 | 0.7549 | X, Z |
| | 10 | 53.7500 | -22.9080 | -5.2188 | 53.6302 | -22.9416 | -5.7780 | 0.1198 | -0.0336 | 0.5592 | 0.5729 | 0.5719 | X, Z |
| FLOOR PAN (Z) | 11 | 52.1172 | -43.7912 | 0.8114 | 46.5058 | -39.0959 | -4.9522 | 5.6114 | 4.6953 | 5.7636 | 9.3141 | 5.7636 | Z |
| | 12 | 51.8309 | -39.5965 | 0.9489 | 47.4492 | -36.4567 | -2.8656 | 4.3817 | 3.1398 | 3.8145 | 6.6036 | 3.8145 | Z |
| | 13 | 51.8159 | -35.0198 | 0.9477 | 49.1688 | -32.9129 | -0.5803 | 2.6471 | 2.1069 | 1.5280 | 3.7123 | 1.5280 | Z |
| | 14 | 51.8882 | -29.8945 | 0.9081 | 51.6612 | -29.0308 | 1.5677 | 0.2270 | 0.8637 | -0.6596 | 1.1102 | -0.6596 | Z |
| | 15 | 49.9423 | -23.3471 | -4.0166 | 49.9561 | -23.2914 | -4.3760 | -0.0138 | 0.0557 | 0.3594 | 0.3640 | 0.3594 | Z |
| | 16 | 48.2493 | -43.7239 | 1.3350 | 45.5217 | -41.2893 | -1.6747 | 2.7276 | 2.4346 | 3.0097 | 4.7355 | 3.0097 | Z |
| | 17 | 48.1546 | -39.3887 | 1.3265 | 46.6904 | -37.6999 | 0.4268 | 1.4642 | 1.6888 | 0.8997 | 2.4094 | 0.8997 | Z |
| | 18 | 48.1788 | -35.1624 | 1.3338 | 47.5747 | -33.9767 | 2.1176 | 0.6041 | 1.1857 | -0.7838 | 1.5444 | -0.7838 | Z |
| | 19 | 48.1648 | -29.6881 | 1.3480 | 48.2906 | -29.3603 | 0.6214 | -0.1258 | 0.3278 | 0.7266 | 0.8070 | 0.7266 | Z |
| | 20 | 46.2866 | -23.5400 | -3.5929 | 46.2368 | -23.5385 | -4.0758 | 0.0498 | 0.0015 | 0.4829 | 0.4855 | 0.4829 | Z |
| | 21 | 42.5060 | -43.6454 | 1.3310 | 42.2115 | -42.8222 | 2.0732 | 0.2945 | 0.8232 | -0.7422 | 1.1468 | -0.7422 | Z |
| | 22 | 42.1231 | -38.8481 | 1.3097 | 41.8981 | -38.2501 | 2.2481 | 0.2250 | 0.5980 | -0.9384 | 1.1353 | -0.9384 | Z |
| | 23 | 42.3332 | -34.6633 | 1.3155 | 42.2985 | -34.3663 | 0.5651 | 0.0347 | 0.2970 | 0.7504 | 0.8078 | 0.7504 | Z |
| | 24 | 42.2829 | -29.5313 | 1.3338 | 42.2973 | -29.3323 | 0.6861 | -0.0144 | 0.1990 | 0.6477 | 0.6777 | 0.6477 | Z |
| | 25 | 40.7653 | -23.7965 | -2.9879 | 40.7434 | -23.7669 | -3.3839 | 0.0219 | 0.0296 | 0.3960 | 0.3977 | 0.3960 | Z |
| | 26 | 36.2904 | -43.6702 | 1.0272 | 36.4329 | -43.5263 | 1.3520 | -0.1425 | 0.1439 | -0.3248 | 0.3828 | -0.3248 | Z |
| | 27 | 36.0523 | -39.4348 | 0.9180 | 36.0484 | -39.3342 | 1.1083 | 0.0039 | 0.1006 | -0.1903 | 0.2153 | -0.1903 | Z |
| | 28 | 36.0514 | -35.1257 | 0.9481 | 36.0325 | -34.9574 | 1.0153 | 0.0189 | 0.1683 | -0.0672 | 0.1822 | -0.0672 | Z |
| | 29 | 36.1242 | -29.9317 | 1.0182 | 36.0826 | -29.7636 | 1.0094 | 0.0416 | 0.1681 | 0.0088 | 0.1734 | 0.0088 | Z |
| | 30 | 36.7597 | -23.8418 | -2.9209 | 36.6521 | -24.1262 | -3.3648 | 0.1076 | -0.2844 | 0.4439 | 0.5381 | 0.4439 | Z |

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

**Pretest Floor Pan**

**Posttest Floor Pan**

Figure E-2. Floor Pan Deformation Data – Set 2, Test No. HMDT-1

Model Year: 2015 | Test Name: HMDT-1 | VIN: 1C6RR6FG3FS661207
Make: Dodge RAM | Model: 1500 Quad Cab

**VEHICLE DEFORMATION**
**DRIVER SIDE INTERIOR CRUSH - SET 1**

| | POINT | Pretest X (in.) | Pretest Y (in.) | Pretest Z (in.) | Posttest X (in.) | Posttest Y (in.) | Posttest Z (in.) | ΔX[A] (in.) | ΔY[A] (in.) | ΔZ[A] (in.) | Total Δ (in.) | Crush[B] (in.) | Directions for Crush[C] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DASH (X, Y, Z) | 1 | 44.0458 | -25.9580 | -26.2741 | 43.6010 | -25.5091 | -28.6859 | 0.4448 | 0.4489 | -2.4118 | 2.4932 | 2.4932 | X, Y, Z |
| | 2 | 40.5737 | -14.9145 | -29.4101 | 40.6333 | -14.2941 | -31.5917 | -0.0596 | 0.6204 | -2.1816 | 2.2689 | 2.2689 | X, Y, Z |
| | 3 | 42.5780 | 3.5812 | -27.7641 | 42.8305 | 4.0635 | -29.0194 | -0.2525 | -0.4823 | -1.2553 | 1.3683 | 1.3683 | X, Y, Z |
| | 4 | 39.5002 | -26.3395 | -15.6032 | 37.8945 | -25.6962 | -18.5368 | 1.6057 | 0.6433 | -2.9336 | 3.4056 | 3.4056 | X, Y, Z |
| | 5 | 37.3603 | -13.7784 | -15.0477 | 35.4376 | -12.8652 | -16.9059 | 1.9227 | 0.9132 | -1.8582 | 2.8255 | 2.8255 | X, Y, Z |
| | 6 | 36.6592 | 4.4581 | -13.3943 | 36.2475 | 4.7811 | -14.8535 | 0.4117 | -0.3230 | -1.4592 | 1.5502 | 1.5502 | X, Y, Z |
| SIDE PANEL (Y) | 7 | 48.1059 | -27.5640 | -2.1184 | 44.1191 | -23.6686 | -4.5178 | 3.9868 | 3.8954 | -2.3994 | 6.0684 | 3.8954 | Y |
| | 8 | 51.7116 | -27.5221 | -2.4733 | 47.0429 | -23.9614 | -4.9296 | 4.6687 | 3.5607 | -2.4563 | 6.3646 | 3.5607 | Y |
| | 9 | 53.1132 | -27.5258 | -5.3166 | 48.9748 | -24.6634 | -7.3574 | 4.1384 | 2.8624 | -2.0408 | 5.4300 | 2.8624 | Y |
| IMPACT SIDE DOOR (Y) | 10 | 13.8450 | -30.2268 | -13.3910 | 12.6563 | -34.5892 | -13.6092 | 1.1887 | -4.3624 | -0.2182 | 4.5267 | -4.3624 | Y |
| | 11 | 24.8445 | -30.3940 | -13.4962 | 22.8939 | -34.4703 | -13.8619 | 1.9506 | -4.0763 | -0.3657 | 4.5337 | -4.0763 | Y |
| | 12 | 33.3897 | -30.0521 | -11.9193 | 31.3748 | -32.2992 | -12.5186 | 2.0149 | -2.2471 | -0.5993 | 3.0771 | -2.2471 | Y |
| | 13 | 15.7062 | -30.7175 | -3.6748 | 13.9398 | -34.5916 | -3.9624 | 1.7664 | -3.8741 | -0.2876 | 4.2675 | -3.8741 | Y |
| | 14 | 26.5081 | -30.3375 | -4.0879 | 24.4775 | -32.1316 | -4.8363 | 2.0306 | -1.7941 | -0.7484 | 2.8111 | -1.7941 | Y |
| | 15 | 33.1915 | -30.9214 | -3.4410 | 31.1067 | -31.3423 | -4.2364 | 2.0848 | -0.4209 | -0.7954 | 2.2707 | -0.4209 | Y |
| ROOF - (Z) | 16 | 31.7369 | -17.6569 | -42.1047 | 32.0691 | -18.0628 | -42.8484 | -0.3322 | -0.4059 | -0.7437 | 0.9101 | -0.7437 | Z |
| | 17 | 33.4080 | -11.0297 | -42.3969 | 33.6912 | -11.3435 | -43.0882 | -0.2832 | -0.3138 | -0.6913 | 0.8103 | -0.6913 | Z |
| | 18 | 34.2467 | -6.4154 | -42.5267 | 34.5369 | -6.8025 | -43.1650 | -0.2902 | -0.3871 | -0.6383 | 0.8009 | -0.6383 | Z |
| | 19 | 34.8589 | -1.3964 | -42.6271 | 35.0164 | -1.7371 | -43.2790 | -0.1575 | -0.3407 | -0.6519 | 0.7522 | -0.6519 | Z |
| | 20 | 34.8910 | 3.2489 | -42.7843 | 35.1664 | 2.9557 | -43.3449 | -0.2754 | 0.2932 | -0.5606 | 0.6900 | -0.5606 | Z |
| | 21 | 25.9671 | -16.5315 | -44.8309 | 26.1842 | -16.8790 | -45.4043 | -0.2171 | -0.3475 | -0.5734 | 0.7048 | -0.5734 | Z |
| | 22 | 27.5123 | -9.4055 | -45.1600 | 27.7508 | -9.7593 | -45.7090 | -0.2385 | -0.3538 | -0.5490 | 0.6953 | -0.5490 | Z |
| | 23 | 28.1650 | -3.8962 | -45.3488 | 28.4056 | -4.2956 | -45.8950 | -0.2406 | -0.3994 | -0.5462 | 0.7182 | -0.5462 | Z |
| | 24 | 28.4296 | 1.1928 | -45.4502 | 28.5927 | 0.8572 | -45.9928 | -0.1631 | 0.3356 | -0.5426 | 0.6585 | -0.5426 | Z |
| | 25 | 28.8017 | 6.9504 | -45.3970 | 28.9055 | 6.6023 | -45.9299 | -0.1038 | 0.3481 | -0.5329 | 0.6449 | -0.5329 | Z |
| | 26 | 19.1218 | -15.6070 | -45.8530 | 19.3223 | -15.9369 | -46.1437 | -0.2005 | -0.3299 | -0.2907 | 0.4833 | -0.2907 | Z |
| | 27 | 19.4394 | -9.1450 | -46.2104 | 19.7234 | -9.4844 | -46.7509 | -0.2840 | -0.3394 | -0.5405 | 0.6986 | -0.5405 | Z |
| | 28 | 19.6459 | -3.4325 | -46.4435 | 19.8826 | -3.7628 | -46.9764 | -0.2367 | -0.3303 | -0.5329 | 0.6702 | -0.5329 | Z |
| | 29 | 19.9667 | 1.6286 | -46.6109 | 20.1450 | 1.2414 | -47.1274 | -0.1783 | 0.3872 | -0.5165 | 0.6697 | -0.5165 | Z |
| | 30 | 20.0850 | 6.4823 | -46.6334 | 20.2886 | 6.1216 | -47.1354 | -0.2036 | 0.3607 | -0.5020 | 0.6508 | -0.5020 | Z |
| A-PILLAR Maximum (X, Y, Z) | 31 | 45.8368 | -26.0164 | -30.1390 | 46.7968 | -26.4659 | -31.8977 | -0.9600 | -0.4495 | -1.7587 | 2.0535 | 0.0000 | NA |
| | 32 | 42.6244 | -25.3728 | -32.6824 | 43.4028 | -25.9166 | -34.2795 | -0.7784 | -0.5438 | -1.5971 | 1.8581 | 0.0000 | NA |
| | 33 | 39.5074 | -24.7488 | -35.0144 | 40.3564 | -25.2765 | -36.3493 | -0.8490 | -0.5277 | -1.3349 | 1.6677 | 0.0000 | NA |
| | 34 | 36.6825 | -24.1861 | -37.0472 | 37.3059 | -24.6582 | -38.2587 | -0.6234 | -0.4721 | -1.2115 | 1.4420 | 0.0000 | NA |
| | 35 | 34.8281 | -23.8105 | -38.1980 | 35.3608 | -24.2547 | -39.3252 | -0.5327 | -0.4442 | -1.1272 | 1.3235 | 0.0000 | NA |
| | 36 | 31.1807 | -23.0268 | -40.1612 | 31.6585 | -23.4455 | -41.0375 | -0.4778 | -0.4187 | -0.8763 | 1.0824 | 0.0000 | NA |
| A-PILLAR Lateral (Y) | 31 | 45.8368 | -26.0164 | -30.1390 | 46.7968 | -26.4659 | -31.8977 | -0.9600 | -0.4495 | -1.7587 | 2.0535 | -0.4495 | Y |
| | 32 | 42.6244 | -25.3728 | -32.6824 | 43.4028 | -25.9166 | -34.2795 | -0.7784 | -0.5438 | -1.5971 | 1.8581 | -0.5438 | Y |
| | 33 | 39.5074 | -24.7488 | -35.0144 | 40.3564 | -25.2765 | -36.3493 | -0.8490 | -0.5277 | -1.3349 | 1.6677 | -0.5277 | Y |
| | 34 | 36.6825 | -24.1861 | -37.0472 | 37.3059 | -24.6582 | -38.2587 | -0.6234 | -0.4721 | -1.2115 | 1.4420 | -0.4721 | Y |
| | 35 | 34.8281 | -23.8105 | -38.1980 | 35.3608 | -24.2547 | -39.3252 | -0.5327 | -0.4442 | -1.1272 | 1.3235 | -0.4442 | Y |
| | 36 | 31.1807 | -23.0268 | -40.1612 | 31.6585 | -23.4455 | -41.0375 | -0.4778 | -0.4187 | -0.8763 | 1.0824 | -0.4187 | Y |
| B-PILLAR Maximum (X, Y, Z) | 37 | 4.2264 | -24.4969 | -36.8585 | 4.3667 | -24.7275 | -36.6618 | -0.1403 | -0.2306 | 0.1967 | 0.3340 | 0.1967 | Z |
| | 38 | 7.4656 | -26.1907 | -32.0404 | 7.6526 | -26.3865 | -31.8061 | -0.1870 | -0.1958 | 0.2343 | 0.3581 | 0.2343 | Z |
| | 39 | 4.6758 | -27.1144 | -28.4968 | 4.9505 | -27.2530 | -28.3212 | -0.2747 | -0.1386 | 0.1756 | 0.3543 | 0.1756 | Z |
| | 40 | 8.2027 | -27.5011 | -24.4720 | 8.5071 | -27.6171 | -24.1986 | -0.3044 | -0.1160 | 0.2734 | 0.4253 | 0.2734 | Z |
| B-PILLAR Lateral (Y) | 37 | 4.2264 | -24.4969 | -36.8585 | 4.3667 | -24.7275 | -36.6618 | -0.1403 | -0.2306 | 0.1967 | 0.3340 | -0.2306 | Y |
| | 38 | 7.4656 | -26.1907 | -32.0404 | 7.6526 | -26.3865 | -31.8061 | -0.1870 | -0.1958 | 0.2343 | 0.3581 | -0.1958 | Y |
| | 39 | 4.6758 | -27.1144 | -28.4968 | 4.9505 | -27.2530 | -28.3212 | -0.2747 | -0.1386 | 0.1756 | 0.3543 | -0.1386 | Y |
| | 40 | 8.2027 | -27.5011 | -24.4720 | 8.5071 | -27.6171 | -24.1986 | -0.3044 | -0.1160 | 0.2734 | 0.4253 | -0.1160 | Y |

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Figure E-3. Occupant Compartment Deformation Data – Set 1, Test No. HMDT-1

Model Year: 2015

Test Name: HMDT-1
Make: Dodge RAM

VIN: 1C6RR6FG3FS661207
Model: 1500 Quad Cab

**VEHICLE DEFORMATION**
**DRIVER SIDE INTERIOR CRUSH - SET 2**

| | POINT | Pretest X (in.) | Pretest Y (in.) | Pretest Z (in.) | Posttest X (in.) | Posttest Y (in.) | Posttest Z (in.) | ΔX[A] (in.) | ΔY[A] (in.) | ΔZ[A] (in.) | Total Δ (in.) | Crush[B] (in.) | Directions for Crush[C] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DASH (X, Y, Z) | 1 | 47.4921 | -45.2158 | -30.4944 | 46.8552 | -44.5307 | -32.9866 | 0.6369 | 0.6851 | -2.4922 | 2.6620 | 2.6620 | X, Y, Z |
| | 2 | 44.0270 | -34.1494 | -33.5567 | 43.8949 | -33.2749 | -35.7385 | 0.1321 | 0.8745 | -2.1818 | 2.3542 | 2.3542 | X, Y, Z |
| | 3 | 46.0305 | -15.6664 | -31.7731 | 46.0812 | -14.9564 | -32.8928 | -0.0507 | 0.7100 | -1.1197 | 1.3268 | 1.3268 | X, Y, Z |
| | 4 | 42.9270 | -45.6739 | -19.8349 | 41.1171 | -44.8659 | -22.8592 | 1.8099 | 0.8080 | -3.0243 | 3.6159 | 3.6159 | X, Y, Z |
| | 5 | 40.7876 | -33.1170 | -19.1923 | 38.6532 | -32.0601 | -21.0496 | 2.1344 | 1.0569 | -1.8573 | 3.0203 | 3.0203 | X, Y, Z |
| | 6 | 40.0856 | -14.8928 | -17.4082 | 39.4541 | -14.4454 | -18.7385 | 0.6315 | 0.4474 | -1.3303 | 1.5390 | 1.5390 | X, Y, Z |
| SIDE PANEL (Y) | 7 | 51.5079 | -46.9972 | -6.3436 | 47.2977 | -43.0415 | -8.7929 | 4.2102 | 3.9557 | -2.4493 | 6.2747 | 3.9557 | Y |
| | 8 | 55.1142 | -46.9533 | -6.6917 | 50.2228 | -43.3280 | -9.1998 | 4.8914 | 3.6253 | -2.5081 | 6.5848 | 3.6253 | Y |
| | 9 | 56.5210 | -46.9365 | -9.5323 | 52.1624 | -43.9945 | -11.6315 | 4.3586 | 2.9420 | -2.0992 | 5.6621 | 2.9420 | Y |
| IMPACT SIDE DOOR (Y) | 10 | 17.2673 | -49.5739 | -17.6978 | 15.8650 | -53.8322 | -18.1401 | 1.4023 | -4.2583 | -0.4423 | 4.5050 | -4.2583 | Y |
| | 11 | 28.2670 | -49.7417 | -17.7840 | 26.1034 | -53.7085 | -18.3591 | 2.1636 | -3.9668 | -0.5751 | 4.5549 | -3.9668 | Y |
| | 12 | 36.8093 | -49.4124 | -16.1891 | 34.5797 | -51.5562 | -16.9579 | 2.2296 | -2.1438 | -0.7688 | 3.1872 | -2.1438 | Y |
| | 13 | 19.1108 | -50.1351 | -7.9820 | 17.1184 | -53.9746 | -8.4904 | 1.9924 | -3.8395 | -0.5084 | 4.3554 | -3.8395 | Y |
| | 14 | 29.9134 | -49.7536 | -8.3726 | 27.6584 | -51.5011 | -9.2955 | 2.2550 | -1.7475 | -0.9229 | 2.9984 | -1.7475 | Y |
| | 15 | 36.5955 | -50.3431 | -7.7178 | 34.2856 | -50.7199 | -8.6636 | 2.3099 | -0.3768 | -0.9458 | 2.5243 | -0.3768 | Y |
| ROOF - (Z) | 16 | 35.2131 | -36.7987 | -46.2870 | 35.3664 | -36.8805 | -47.0753 | -0.1533 | -0.0818 | -0.7883 | 0.8072 | -0.7883 | Z |
| | 17 | 36.8855 | -30.1697 | -46.5281 | 36.9881 | -30.1583 | -47.2124 | -0.1026 | 0.0114 | -0.6843 | 0.6920 | -0.6843 | Z |
| | 18 | 37.7250 | -25.5547 | -46.6230 | 37.8334 | -25.6166 | -47.2206 | -0.1084 | -0.0619 | -0.5976 | 0.6105 | -0.5976 | Z |
| | 19 | 38.3380 | -20.5352 | -46.6859 | 38.3125 | -20.5500 | -47.2594 | 0.0255 | -0.0148 | -0.5735 | 0.5743 | -0.5735 | Z |
| | 20 | 38.3709 | -15.8890 | -46.8094 | 38.4620 | -15.8567 | -47.2567 | -0.0911 | 0.0323 | -0.4473 | 0.4576 | -0.4473 | Z |
| | 21 | 29.4484 | -35.6528 | -49.0155 | 29.4892 | -35.6603 | -49.6321 | -0.0408 | -0.0075 | -0.6166 | 0.6180 | -0.6166 | Z |
| | 22 | 30.9951 | -28.5249 | -49.2901 | 31.0557 | -28.5368 | -49.8284 | -0.0606 | -0.0119 | -0.5383 | 0.5418 | -0.5383 | Z |
| | 23 | 31.6487 | -23.0144 | -49.4379 | 31.7102 | -23.0709 | -49.9330 | -0.0615 | -0.0565 | -0.4951 | 0.5021 | -0.4951 | Z |
| | 24 | 31.9142 | -17.9248 | -49.5019 | 31.8969 | -17.9172 | -49.9553 | 0.0173 | 0.0076 | -0.4534 | 0.4538 | -0.4534 | Z |
| | 25 | 32.2868 | -12.1678 | -49.4063 | 32.2086 | -12.1736 | -49.8079 | 0.0782 | -0.0058 | -0.4016 | 0.4092 | -0.4016 | Z |
| | 26 | 22.6051 | -34.7200 | -50.0434 | 22.6296 | -34.7083 | -50.3792 | -0.0245 | 0.0117 | -0.3358 | 0.3369 | -0.3358 | Z |
| | 27 | 22.9241 | -28.2557 | -50.3534 | 23.0316 | -28.2476 | -50.8912 | -0.1075 | 0.0081 | -0.5378 | 0.5485 | -0.5378 | Z |
| | 28 | 23.1317 | -22.5417 | -50.5447 | 23.1906 | -22.5233 | -51.0330 | -0.0589 | 0.0184 | -0.4883 | 0.4922 | -0.4883 | Z |
| | 29 | 23.4534 | -17.4795 | -50.6749 | 23.4527 | -17.5175 | -51.1105 | 0.0007 | -0.0380 | -0.4356 | 0.4373 | -0.4356 | Z |
| | 30 | 23.5723 | -12.6258 | -50.6620 | 23.5956 | -12.6376 | -51.0471 | -0.0233 | -0.0118 | -0.3851 | 0.3860 | -0.3851 | Z |
| A-PILLAR Maximum (X, Y, Z) | 31 | 49.2902 | -45.2464 | -34.3564 | 50.0611 | -45.4403 | -36.2020 | -0.7709 | -0.1939 | -1.8456 | 2.0095 | 0.0000 | NA |
| | 32 | 46.0825 | -44.5840 | -36.9009 | 46.6745 | -44.8568 | -38.5862 | -0.5920 | -0.2728 | -1.6853 | 1.8070 | 0.0000 | NA |
| | 33 | 42.9699 | -43.9427 | -39.2340 | 43.6345 | -44.1871 | -40.6560 | -0.6646 | -0.2444 | -1.4220 | 1.5886 | 0.0000 | NA |
| | 34 | 40.1487 | -43.3650 | -41.2678 | 40.5898 | -43.5414 | -42.5656 | -0.4411 | -0.1764 | -1.2978 | 1.3820 | 0.0000 | NA |
| | 35 | 38.2965 | -42.9809 | -42.4193 | 38.6480 | -43.1226 | -43.6322 | -0.3515 | -0.1417 | -1.2129 | 1.2707 | 0.0000 | NA |
| | 36 | 34.6528 | -42.1824 | -44.3835 | 34.9509 | -42.2890 | -45.3441 | -0.2981 | -0.1066 | -0.9606 | 1.0114 | 0.0000 | NA |
| A-PILLAR Lateral (Y) | 31 | 49.2902 | -45.2464 | -34.3564 | 50.0611 | -45.4403 | -36.2020 | -0.7709 | -0.1939 | -1.8456 | 2.0095 | -0.1939 | Y |
| | 32 | 46.0825 | -44.5840 | -36.9009 | 46.6745 | -44.8568 | -38.5862 | -0.5920 | -0.2728 | -1.6853 | 1.8070 | -0.2728 | Y |
| | 33 | 42.9699 | -43.9427 | -39.2340 | 43.6345 | -44.1871 | -40.6560 | -0.6646 | -0.2444 | -1.4220 | 1.5886 | -0.2444 | Y |
| | 34 | 40.1487 | -43.3650 | -41.2678 | 40.5898 | -43.5414 | -42.5656 | -0.4411 | -0.1764 | -1.2978 | 1.3820 | -0.1764 | Y |
| | 35 | 38.2965 | -42.9809 | -42.4193 | 38.6480 | -43.1226 | -43.6322 | -0.3515 | -0.1417 | -1.2129 | 1.2707 | -0.1417 | Y |
| | 36 | 34.6528 | -42.1824 | -44.3835 | 34.9509 | -42.2890 | -45.3441 | -0.2981 | -0.1066 | -0.9606 | 1.0114 | -0.1066 | Y |
| B-PILLAR Maximum (X, Y, Z) | 37 | 7.6923 | -43.6729 | -41.1406 | 7.6458 | -43.6373 | -41.0727 | 0.0465 | 0.0356 | 0.0679 | 0.0897 | 0.0897 | X, Y, Z |
| | 38 | 10.9225 | -45.4020 | -36.3290 | 10.9168 | -45.3664 | -36.2314 | 0.0057 | 0.0356 | 0.0976 | 0.1040 | 0.1040 | X, Y, Z |
| | 39 | 8.1261 | -46.3509 | -32.7974 | 8.2040 | -46.2837 | -32.7679 | -0.0779 | 0.0672 | 0.0295 | 0.1070 | 0.0734 | Y, Z |
| | 40 | 11.6456 | -46.7672 | -28.7690 | 11.7478 | -46.7073 | -28.6399 | -0.1022 | 0.0599 | 0.1291 | 0.1752 | 0.1423 | Y, Z |
| B-PILLAR Lateral (Y) | 37 | 7.6923 | -43.6729 | -41.1406 | 7.6458 | -43.6373 | -41.0727 | 0.0465 | 0.0356 | 0.0679 | 0.0897 | 0.0356 | Y |
| | 38 | 10.9225 | -45.4020 | -36.3290 | 10.9168 | -45.3664 | -36.2314 | 0.0057 | 0.0356 | 0.0976 | 0.1040 | 0.0356 | Y |
| | 39 | 8.1261 | -46.3509 | -32.7974 | 8.2040 | -46.2837 | -32.7679 | -0.0779 | 0.0672 | 0.0295 | 0.1070 | 0.0672 | Y |
| | 40 | 11.6456 | -46.7672 | -28.7690 | 11.7478 | -46.7073 | -28.6399 | -0.1022 | 0.0599 | 0.1291 | 0.1752 | 0.0599 | Y |

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Figure E-4. Occupant Compartment Deformation Data – Set 2, Test No. HMDT-1

Test Name: HMDT-1 VIN: 1C6RR6FG3FS661207

Model Year: 2015 Make: Dodge RAM Model: 1500 Quad Cab

**Driver Side Maximum Deformation**

| Reference Set 1 | | | | Reference Set 2 | | | |
|---|---|---|---|---|---|---|---|
| Location | Maximum Deformation[A,B] (in.) | MASH Allowable Deformation (in.) | Directions of Deformation[C] | Location | Maximum Deformation[A,B] (in.) | MASH Allowable Deformation (in.) | Directions of Deformation[C] |
| Roof | -0.7 | ≤ 4 | Z | Roof | -0.8 | ≤ 4 | Z |
| Windshield[D] | 0.0 | ≤ 3 | X, Z | Windshield[D] | NA | ≤ 3 | X, Z |
| A-Pillar Maximum | 0.0 | ≤ 5 | NA | A-Pillar Maximum | 0.0 | ≤ 5 | NA |
| A-Pillar Lateral | -0.5 | ≤ 3 | Y | A-Pillar Lateral | -0.3 | ≤ 3 | Y |
| B-Pillar Maximum | 0.3 | ≤ 5 | Z | B-Pillar Maximum | 0.1 | ≤ 5 | Y, Z |
| B-Pillar Lateral | -0.5 | ≤ 3 | Y | B-Pillar Lateral | 0.1 | ≤ 3 | Y |
| Toe Pan - Wheel Well | 10.5 | ≤ 9 | X, Z | Toe Pan - Wheel Well | 10.5 | ≤ 9 | X, Z |
| Side Front Panel | 3.9 | ≤ 12 | Y | Side Front Panel | 4.0 | ≤ 12 | Y |
| Side Door (above seat) | -4.4 | ≤ 9 | Y | Side Door (above seat) | -4.3 | ≤ 9 | Y |
| Side Door (below seat) | -3.9 | ≤ 12 | Y | Side Door (below seat) | -3.8 | ≤ 12 | Y |
| Floor Pan | 5.8 | ≤ 12 | Z | Floor Pan | 5.8 | ≤ 12 | Z |
| Dash - no MASH requirement | 3.4 | NA | X, Y, Z | Dash - no MASH requirement | 3.4 | NA | X, Y, Z |

[A] Items highlighted in red do not meet MASH allowable deformations.

[B] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[C] For Toe Pan - Wheel Well the direction of defromation may include X and Z direction. For A-Pillar Maximum and B-Pillar Maximum the direction of deformation may include X, Y, and Z directions. The direction of deformation for Toe Pan -Wheel Well, A-Pillar Maximum, and B-Pillar Maximum only include components where the deformation is positive and intruding into the occupant compartment. If direction of deformation is "NA" then no intrusion is recorded and deformation will be 0.

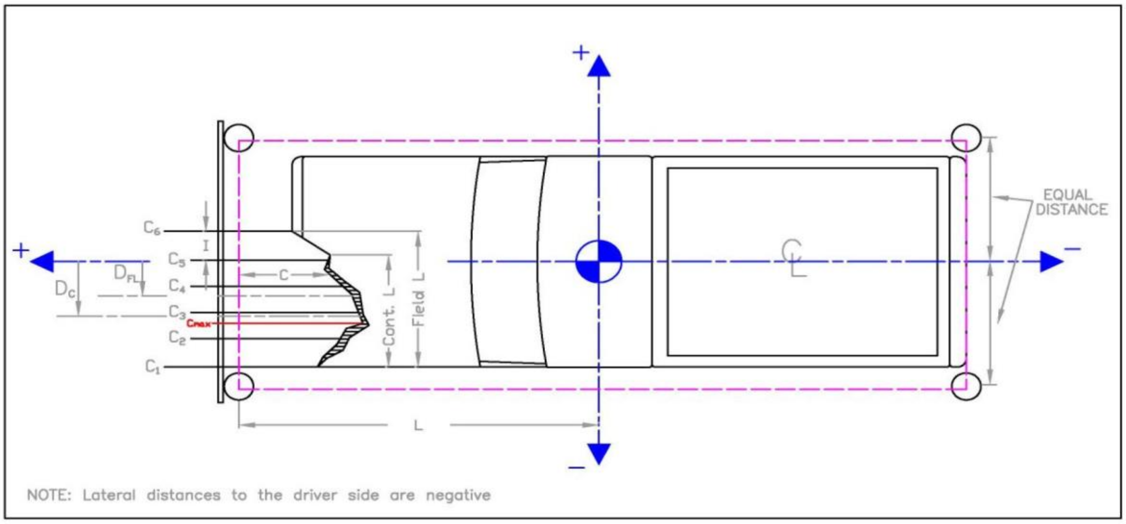
[D] If deformation is observered for the windshield then the windshield deformation is measured posttest with an examplar vehicle, therefore only one set of reference is measured and recorded.

**Notes on vehicle interior crush:**

Figure E-5. Maximum Occupant Compartment Deformation by Location, Test No. HMDT-1

**Date Measured:** 1/19/2021 **Test Name:** HMDT-1 **VIN:** 1C6RR6FG3FS661207

**Model Year:** 2015 **Make:** Dodge RAM **Model:** 1500 Quad Cab



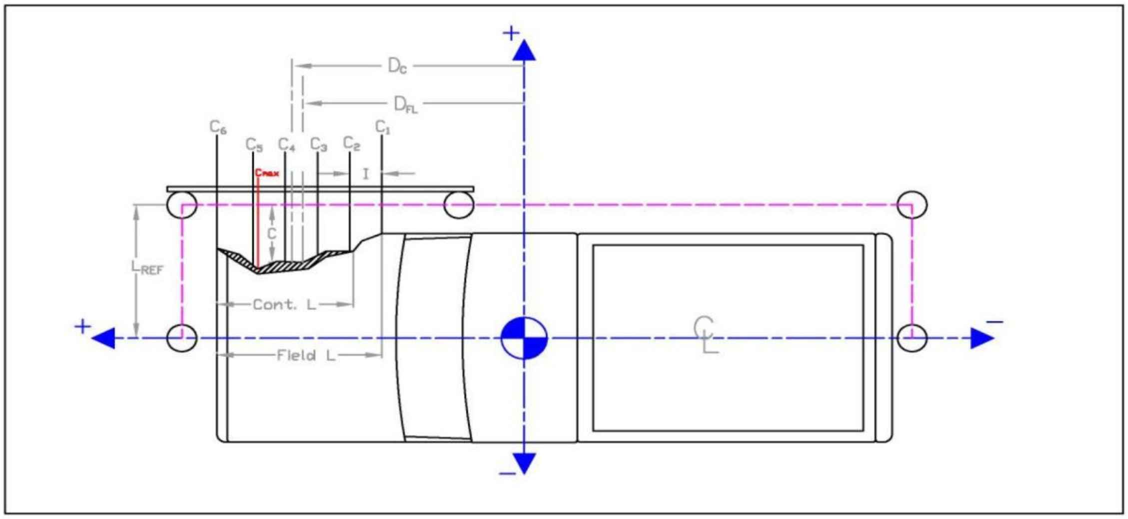

| | in. | (mm) |
|---|---|---|
| Distance from C.G. to reference line - $L_{REF}$: | 112 1/4 | (2851) |
| Total Vehicle Width: | 77 1/2 | (1969) |
| Width of contact and induced crush - Field L: | 77 1/2 | (1969) |
| Crush measurement spacing interval (L/5) - I: | 15 1/2 | (394) |
| Distance from center of vehicle to center of Field L - $D_{FL}$: | 0 | () |
| Width of Contact Damage: | 77 1/2 | (1969) |
| Distance from center of vehicle to center of contact damage - $D_C$: | 0 | () |

NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

| | Crush Measurement | | Lateral Location | | Original Profile Measurement | | Dist. Between Ref. Lines | | Actual Crush | |
|---|---|---|---|---|---|---|---|---|---|---|
| | in. | (mm) | in. | (mm) | in. | (mm) | in. | (mm) | in. | (mm) |
| $C_1$ | N/a | N/A | -38 3/4 | -(984) | 22 1/2 | (572) | 1 1/5 | (30) | N/A | N/A |
| $C_2$ | NA | N/A | -23 1/4 | -(591) | 6 1/2 | (165) | | | N/A | N/A |
| $C_3$ | 11 | (279) | -7 3/4 | -(197) | 4 1/4 | (108) | | | 5 4/7 | (141) |
| $C_4$ | 7 3/8 | (187) | 7 3/4 | (197) | 4 1/4 | (108) | | | 2 | (49) |
| $C_5$ | 6 3/8 | (162) | 23 1/4 | (591) | 6 1/4 | (159) | | | -1 | -(27) |
| $C_6$ | 6 1/2 | (165) | 38 3/4 | (984) | 20 1/2 | (521) | | | -15 1/5 | -(386) |
| $C_{MAX}$ | 23 | (584) | 19 1/2 | (495) | 5 1/2 | (140) | | | 16 1/3 | (414) |

Figure E-6. Exterior Vehicle Crush (NASS) - Front, Test No. HMDT-1

| | | | | | |
|---|---|---|---|---|---|
| **Date Measured:** | 1/19/2021 | **Test Name:** | HMDT-1 | **VIN:** | 1C6RR6FG3FS661207 |
| **Model Year:** | 2015 | **Make:** | Dodge RAM | **Model:** | 1500 Quad Cab |




| | in. | (mm) |
|---|---|---|
| **Distance from centerline to reference line - $L_{REF}$:** | 49 | (1245) |
| **Total Vehicle Length:** | 229 3/8 | (5826) |
| **Distance from vehicle c.g. to 1/2 of Vehicle total length:** | -6 | -(152) |
| **Width of contact and induced crush - Field L:** | 229 3/8 | (5826) |
| **Crush measurement spacing interval (L/5) - I:** | 45 7/8 | (1165) |
| **Distance from vehicle c.g. to center of Field L - $D_{FL}$:** | -6 | -(152) |
| **Width of Contact Damage:** | 229 3/8 | (5826) |
| **Distance from vehicle c.g. to center of contact damage - $D_C$:** | -6 | -(152) |

NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., front of vehicle has been pushed inward or tire has been removed)
NOTE: All values must be filled out above before crush measurements are filled out.

| | Crush Measurement | | Longitudinal Location | | Original Profile Measurement | | Dist. Between Ref. Lines | | Actual | Crush |
|---|---|---|---|---|---|---|---|---|---|---|
| | in. | (mm) | in. | (mm) | in. | (mm) | in. | (mm) | in. | (mm) |
| $C_1$ | n/a | N/A | -120 3/4 | -(3067) | 33 1/2 | (851) | 5 | (127) | N/A | N/A |
| $C_2$ | n/a | N/A | -74 7/8 | -(1902) | 5 1/2 | (140) | | | N/A | N/A |
| $C_3$ | 11 5/8 | (295) | -29 | -(737) | 5 7/8 | (149) | | | 3/4 | (19) |
| $C_4$ | 12 | (305) | 16 7/8 | (429) | 5 | (127) | | | 2 | (51) |
| $C_5$ | n/a | N/A | 62 3/4 | (1594) | 5 3/4 | (146) | | | N/A | N/A |
| $C_6$ | n/a | N/A | 108 5/8 | (2759) | 13 1/4 | (337) | | | N/A | N/A |
| $C_{MAX}$ | 30 3/4 | (781) | 91 | (2311) | 5 3/4 | (146) | | | 20 | (508) |

Figure E-7. Exterior Vehicle Crush (NASS) - Side, Test No. HMDT-1

Model Year: 2015 | Test Name: HMDT-2 | VIN: 1C6RR6KG1FS542139
Make: Dodge Ram | Model: 1500 Crew Cab

**VEHICLE DEFORMATION**
**DRIVER SIDE FLOOR PAN - SET 1**

| | POINT | Pretest X (in.) | Pretest Y (in.) | Pretest Z (in.) | Posttest X (in.) | Posttest Y (in.) | Posttest Z (in.) | ΔX[A] (in.) | ΔY[A] (in.) | ΔZ[A] (in.) | Total Δ (in.) | Crush[B] (in.) | Directions for Crush[C] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TOE PAN - WHEEL WELL (X, Z) | 1 | 62.3243 | -25.6067 | -3.3777 | 58.1631 | -22.3438 | -5.9949 | 4.1612 | 3.2629 | 2.6172 | 5.9002 | 4.9158 | X, Z |
| | 2 | 64.0174 | -21.3159 | -2.2484 | 57.9650 | -17.9009 | -6.6623 | 6.0524 | 3.4150 | 4.4139 | 8.2326 | 7.4909 | X, Z |
| | 3 | 65.2874 | -16.9351 | -1.2531 | 60.6685 | -15.0801 | -4.0532 | 4.6189 | 1.8550 | 2.8001 | 5.7110 | 5.4014 | X, Z |
| | 4 | 64.6443 | -10.8364 | -1.1755 | 63.6156 | -11.7120 | -0.7106 | 1.0287 | -0.8756 | -0.4649 | 1.4286 | 1.0287 | X |
| | 5 | 62.3381 | -4.6810 | -5.3139 | 62.1006 | -5.4882 | -4.4754 | 0.2375 | -0.8072 | -0.8385 | 1.1879 | 0.2375 | X |
| | 6 | 60.4148 | -25.8653 | 0.7440 | 54.8174 | -21.5079 | -2.9783 | 5.5974 | 4.3574 | 3.7223 | 8.0108 | 6.7221 | X, Z |
| | 7 | 60.6069 | -20.9743 | 1.0363 | Bad | Bad | Bad | #VALUE! | #VALUE! | #VALUE! | NA | NA | #VALUE! |
| | 8 | 60.4112 | -16.6776 | 1.1667 | 57.0485 | -15.1703 | -0.1616 | 3.3627 | 1.5073 | 1.3283 | 3.9172 | 3.6155 | X, Z |
| | 9 | 60.4973 | -11.2995 | 1.1378 | 59.7300 | -11.4010 | 2.1836 | 0.7673 | -0.1015 | -1.0458 | 1.3011 | 0.7673 | X |
| | 10 | 58.2732 | -3.4246 | -3.6089 | 58.1621 | -3.9648 | -2.9747 | 0.1111 | -0.5402 | -0.6342 | 0.8405 | 0.1111 | X |
| FLOOR PAN (Z) | 11 | 55.2823 | -25.8768 | 4.2682 | 51.4357 | -23.4069 | 1.3423 | 3.8466 | 2.4699 | 2.9259 | 5.4275 | 2.9259 | Z |
| | 12 | 55.1708 | -20.7532 | 4.2602 | 52.0888 | -19.7119 | 2.8863 | 3.0820 | 1.0413 | 1.3739 | 3.5314 | 1.3739 | Z |
| | 13 | 55.1990 | -15.7888 | 4.2510 | 53.8840 | -15.5721 | 4.8757 | 1.3150 | 0.2167 | -0.6247 | 1.4719 | -0.6247 | Z |
| | 14 | 55.5361 | -10.6848 | 4.1086 | 55.1966 | -10.8523 | 5.5110 | 0.3395 | -0.1675 | -1.4024 | 1.4526 | -1.4024 | Z |
| | 15 | 53.6046 | -4.0337 | -1.6935 | 53.4638 | -4.5231 | -1.2167 | 0.1408 | -0.4894 | -0.4768 | 0.6976 | -0.4768 | Z |
| | 16 | 49.4551 | -25.9008 | 5.4075 | 48.2684 | -24.7336 | 6.2313 | 1.1867 | 1.1672 | -0.8238 | 1.8572 | -0.8238 | Z |
| | 17 | 48.5670 | -20.4918 | 4.7859 | 47.9369 | -20.3304 | 7.7348 | 0.6301 | 0.1614 | -2.9489 | 3.0198 | -2.9489 | Z |
| | 18 | 48.4724 | -15.7938 | 4.7853 | 48.0316 | -15.7096 | 6.9812 | 0.4408 | 0.0842 | -2.1959 | 2.2413 | -2.1959 | Z |
| | 19 | 48.5001 | -10.9361 | 4.7769 | 48.1618 | -10.9703 | 5.9814 | 0.3383 | -0.0342 | -1.2045 | 1.2516 | -1.2045 | Z |
| | 20 | 47.5881 | -4.1184 | -1.0942 | 47.3791 | -4.6460 | -0.8018 | 0.2090 | -0.5276 | -0.2924 | 0.6384 | -0.2924 | Z |
| | 21 | 42.7429 | -25.7451 | 5.2011 | 42.3199 | -25.5594 | 6.7865 | 0.4230 | 0.1857 | -1.5854 | 1.6513 | -1.5854 | Z |
| | 22 | 43.0277 | -19.5665 | 4.8317 | 42.6027 | -19.4813 | 6.7660 | 0.4250 | 0.0852 | -1.9343 | 1.9823 | -1.9343 | Z |
| | 23 | 43.1785 | -15.0702 | 4.8263 | 42.7857 | -15.0953 | 6.1501 | 0.3928 | -0.0251 | -1.3238 | 1.3811 | -1.3238 | Z |
| | 24 | 43.3996 | -9.2883 | 4.8289 | 43.1371 | -9.3139 | 5.4489 | 0.2625 | -0.0256 | -0.6200 | 0.6738 | -0.6200 | Z |
| | 25 | 42.0610 | -4.4237 | -0.1562 | 41.8220 | -4.9922 | -0.0538 | 0.2390 | -0.5685 | -0.1024 | 0.6251 | -0.1024 | Z |
| | 26 | 38.0199 | -25.4964 | 4.0813 | 37.7586 | -25.5781 | 5.3949 | 0.2613 | -0.0817 | -1.3136 | 1.3418 | -1.3136 | Z |
| | 27 | 37.9554 | -18.9968 | 4.1891 | 37.6500 | -19.0608 | 5.1030 | 0.3054 | -0.0640 | -0.9139 | 0.9657 | -0.9139 | Z |
| | 28 | 37.9220 | -14.2149 | 4.1952 | 37.7136 | -14.2502 | 4.8677 | 0.2084 | -0.0353 | -0.6725 | 0.7049 | -0.6725 | Z |
| | 29 | 38.0482 | -9.2056 | 4.1979 | 37.7174 | -9.2899 | 4.7213 | 0.3308 | -0.0843 | -0.5234 | 0.6249 | -0.5234 | Z |
| | 30 | 37.4849 | -4.5542 | -0.2835 | 37.4165 | -4.9279 | -0.2290 | 0.0684 | -0.3737 | -0.0545 | 0.3838 | -0.0545 | Z |

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

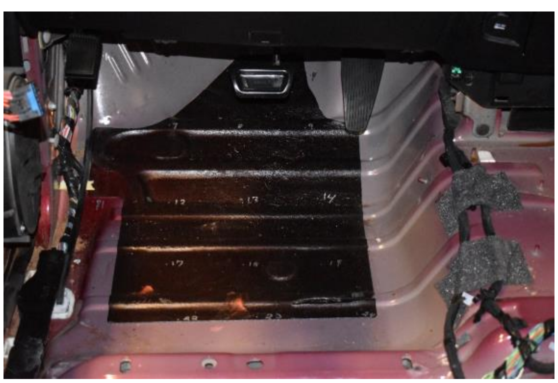
| Pretest Floor Pan | Posttest Floor Pan |
|---|---|
|  |  |

Figure E-8. Floor Pan Deformation Data – Set 1, Test No. HMDT-2

Model Year: 2015

Test Name: HMDT-2
Make: Dodge Ram

VIN: 1C6RR6KG1FS542139
Model: 1500 Crew Cab

**VEHICLE DEFORMATION**
**DRIVER SIDE FLOOR PAN - SET 2**

| | POINT | Pretest X (in.) | Pretest Y (in.) | Pretest Z (in.) | Posttest X (in.) | Posttest Y (in.) | Posttest Z (in.) | ΔX[A] (in.) | ΔY[A] (in.) | ΔZ[A] (in.) | Total Δ (in.) | Crush[B] (in.) | Directions for Crush[C] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TOE PAN - WHEEL WELL (X, Z) | 1 | 64.3260 | -44.9566 | -6.4018 | 60.3040 | -41.1512 | -10.4980 | 4.0220 | 3.8054 | 4.0962 | 6.8874 | 5.7407 | X, Z |
| | 2 | 65.9823 | -40.6506 | -5.2759 | 60.0423 | -36.7107 | -11.1592 | 5.9400 | 3.9399 | 5.8833 | 9.2423 | 8.3604 | X, Z |
| | 3 | 67.2169 | -36.2574 | -4.2901 | 62.7224 | -33.8565 | -8.5624 | 4.4945 | 2.4009 | 4.2723 | 6.6496 | 6.2011 | X, Z |
| | 4 | 66.5418 | -30.1618 | -4.2570 | 65.6429 | -30.4525 | -5.2327 | 0.8989 | -0.2907 | 0.9757 | 1.3581 | 1.3267 | X, Z |
| | 5 | 64.2587 | -24.0428 | -8.4617 | 64.0230 | -24.2458 | -8.9819 | 0.2357 | -0.2030 | 0.5202 | 0.6061 | 0.5711 | X, Z |
| | 6 | 62.3640 | -45.2008 | -2.3038 | 56.9646 | -40.3635 | -7.4615 | 5.3994 | 4.8373 | 5.1577 | 8.8969 | 7.4670 | X, Z |
| | 7 | 62.5274 | -40.3073 | -2.0381 | 35.5195 | Bad | Bad | Bad | #VALUE! | #VALUE! | NA | NA | #VALUE! |
| | 8 | 62.3082 | -36.0110 | -1.9358 | 59.1262 | -33.9995 | -4.6504 | 3.1820 | 2.0115 | 2.7146 | 4.6412 | 4.1826 | X, Z |
| | 9 | 62.3672 | -30.6328 | -1.9954 | 61.7700 | -30.1969 | -2.3162 | 0.5972 | 0.4359 | 0.3208 | 0.8060 | 0.6779 | X, Z |
| | 10 | 60.1654 | -22.7975 | -6.8174 | 60.0729 | -22.7770 | -7.4572 | 0.0925 | 0.0205 | 0.6398 | 0.6468 | 0.6465 | X, Z |
| FLOOR PAN (Z) | 11 | 57.1860 | -45.2183 | 1.1530 | 53.6332 | -42.3124 | -3.1240 | 3.5528 | 2.9059 | 4.2770 | 6.2737 | 4.2770 | Z |
| | 12 | 57.0485 | -40.0954 | 1.1132 | 54.2454 | -38.6106 | -1.5796 | 2.8031 | 1.4848 | 2.6928 | 4.1609 | 2.6928 | Z |
| | 13 | 57.0516 | -35.1311 | 1.0749 | 55.9960 | -34.4491 | 0.4043 | 1.0556 | 0.6820 | 0.6706 | 1.4245 | 0.6706 | Z |
| | 14 | 57.3646 | -30.0263 | 0.9067 | 57.2485 | -29.7127 | 1.0374 | 0.1161 | 0.3136 | -0.1307 | 0.3590 | -0.1307 | Z |
| | 15 | 55.4754 | -23.4194 | -4.9595 | 55.3926 | -23.4003 | -5.6733 | 0.0828 | 0.0191 | 0.7138 | 0.7188 | 0.7138 | Z |
| | 16 | 51.3446 | -45.2656 | 2.2162 | 50.5119 | -43.6867 | 1.7814 | 0.8327 | 1.5789 | 0.4348 | 1.8372 | 0.4348 | Z |
| | 17 | 50.4371 | -39.8651 | 1.5510 | 50.1298 | -39.2899 | 3.2917 | 0.3073 | 0.5752 | -1.7407 | 1.8589 | -1.7407 | Z |
| | 18 | 50.3187 | -35.1677 | 1.5213 | 50.1580 | -34.6675 | 2.5428 | 0.1607 | 0.5002 | -1.0215 | 1.1487 | -1.0215 | Z |
| | 19 | 50.3217 | -30.3100 | 1.4844 | 50.2188 | -29.9258 | 1.5475 | 0.1029 | 0.3842 | -0.0631 | 0.4027 | -0.0631 | Z |
| | 20 | 49.4519 | -23.5317 | -4.4383 | 49.3125 | -23.6055 | -5.2240 | 0.1394 | -0.0738 | 0.7857 | 0.8014 | 0.7857 | Z |
| | 21 | 44.6349 | -45.1458 | 1.9212 | 44.5783 | -44.5930 | 2.3694 | 0.0566 | 0.5528 | -0.4482 | 0.7139 | -0.4482 | Z |
| | 22 | 44.8931 | -38.9681 | 1.5189 | 44.7792 | -38.5117 | 2.3541 | 0.1139 | 0.4564 | -0.8352 | 0.9586 | -0.8352 | Z |
| | 23 | 45.0210 | -34.4712 | 1.4889 | 44.8997 | -34.1230 | 1.7420 | 0.1213 | 0.3482 | -0.2531 | 0.4472 | -0.2531 | Z |
| | 24 | 45.2127 | -28.6883 | 1.4601 | 45.1693 | -28.3367 | 1.0453 | 0.0434 | 0.3516 | 0.4148 | 0.5455 | 0.4148 | Z |
| | 25 | 43.9147 | -23.8600 | -3.5708 | 43.7650 | -24.0273 | -4.4450 | 0.1497 | -0.1673 | 0.8742 | 0.9026 | 0.8742 | Z |
| | 26 | 39.9258 | -44.9281 | 0.7384 | 40.0098 | -44.6717 | 1.0036 | -0.0840 | 0.2564 | -0.2652 | 0.3783 | -0.2652 | Z |
| | 27 | 39.8268 | -38.4284 | 0.8068 | 39.8119 | -38.1562 | 0.7196 | 0.0149 | 0.2722 | 0.0872 | 0.2862 | 0.0872 | Z |
| | 28 | 39.7690 | -33.6468 | 0.7841 | 39.8095 | -33.3449 | 0.4894 | -0.0405 | 0.3019 | 0.2947 | 0.4238 | 0.2947 | Z |
| | 29 | 39.8697 | -28.6370 | 0.7588 | 39.7458 | -28.3849 | 0.3484 | 0.1239 | 0.2521 | 0.4104 | 0.4973 | 0.4104 | Z |
| | 30 | 39.3414 | -24.0149 | -3.7571 | 39.3581 | -24.0221 | -4.5952 | -0.0167 | -0.0072 | 0.8381 | 0.8383 | 0.8381 | Z |

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

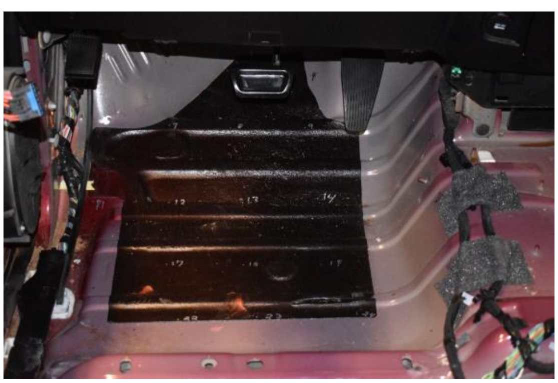
| Pretest Floor Pan | Posttest Floor Pan |
|---|---|
|  |  |

Figure E-9. Floor Pan Deformation Data – Set 2, Test No. HMDT-2

Model Year: 2015

Test Name: HMDT-2
Make: Dodge Ram

VIN: 1C6RR6KG1FS542139
Model: 1500 Crew Cab

**VEHICLE DEFORMATION**
**DRIVER SIDE INTERIOR CRUSH - SET 1**

| | POINT | Pretest X (in.) | Pretest Y (in.) | Pretest Z (in.) | Posttest X (in.) | Posttest Y (in.) | Posttest Z (in.) | ΔX[A] (in.) | ΔY[A] (in.) | ΔZ[A] (in.) | Total Δ (in.) | Crush[B] (in.) | Directions for Crush[C] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DASH (X, Y, Z) | 1 | 50.2334 | -26.2683 | -27.0698 | 50.5988 | -26.2297 | -28.2843 | -0.3654 | 0.0386 | -1.2145 | 1.2689 | 1.2689 | X, Y, Z |
| | 2 | 46.9624 | -14.6202 | -30.0320 | 47.7249 | -14.4263 | -30.9819 | -0.7625 | 0.1939 | -0.9499 | 1.2334 | 1.2334 | X, Y, Z |
| | 3 | 48.9622 | 3.5707 | -27.9384 | 49.8372 | 3.5786 | -28.0083 | -0.8750 | -0.0079 | -0.0699 | 0.8778 | 0.8778 | X, Y, Z |
| | 4 | 45.7388 | -26.2830 | -16.3243 | 45.2295 | -26.2901 | -17.9609 | 0.5093 | -0.0071 | -1.6366 | 1.7140 | 1.7140 | X, Y, Z |
| | 5 | 43.8421 | -14.7146 | -15.8310 | 43.0005 | -14.6482 | -16.4782 | 0.8416 | 0.0664 | -0.6472 | 1.0638 | 1.0638 | X, Y, Z |
| | 6 | 42.8870 | 4.3326 | -16.4064 | 43.0907 | 4.2806 | -16.8209 | -0.2037 | 0.0520 | -0.4145 | 0.4648 | 0.4648 | X, Y, Z |
| SIDE PANEL (Y) | 7 | 54.6335 | -28.0987 | -1.7863 | 52.1418 | -24.4578 | -2.9787 | 2.4917 | 3.6409 | -1.1924 | 4.5702 | 3.6409 | Y |
| | 8 | 57.5682 | -28.2219 | -6.8421 | 55.4101 | -25.8038 | -7.5197 | 2.1581 | 2.4181 | -0.6776 | 3.3112 | 2.4181 | Y |
| | 9 | 57.8488 | -28.1056 | -2.9122 | 55.0104 | -25.5015 | -3.9181 | 2.8384 | 2.6041 | -1.0059 | 3.9812 | 2.6041 | Y |
| IMPACT SIDE DOOR (Y) | 10 | 19.8690 | -30.1457 | -15.1219 | 19.0491 | -32.2508 | -15.0679 | 0.8199 | -2.1051 | 0.0540 | 2.2598 | -2.1051 | Y |
| | 11 | 31.7858 | -30.4872 | -15.0464 | 30.6832 | -33.1050 | -15.0300 | 1.1026 | -2.6178 | 0.0164 | 2.8406 | -2.6178 | Y |
| | 12 | 38.6769 | -30.9715 | -15.3738 | 37.6457 | -32.8287 | -15.4081 | 1.0312 | -1.8572 | -0.0343 | 2.1246 | -1.8572 | Y |
| | 13 | 20.6343 | -30.0442 | -4.3364 | 19.9174 | -31.0746 | -4.4137 | 0.7169 | -1.0304 | -0.0773 | 1.2576 | -1.0304 | Y |
| | 14 | 33.0335 | -30.5383 | -4.8905 | 31.9444 | -30.9080 | -5.0598 | 1.0891 | -0.3697 | -0.1693 | 1.1625 | -0.3697 | Y |
| | 15 | 41.1013 | -30.7819 | -3.8731 | 40.0917 | -30.2858 | -4.0968 | 1.0096 | 0.4961 | -0.2237 | 1.1469 | 0.4961 | Y |
| ROOF - (Z) | 16 | 37.9810 | -17.6016 | -42.5749 | 38.8757 | -17.7467 | -42.3573 | -0.8947 | -0.1451 | 0.2176 | 0.9321 | 0.2176 | Z |
| | 17 | 40.3041 | -8.3558 | -42.9526 | 41.2592 | -8.5191 | -42.5557 | -0.9551 | -0.1633 | 0.3969 | 1.0471 | 0.3969 | Z |
| | 18 | 41.4535 | 2.5651 | -43.1409 | 42.5077 | 2.3569 | -42.5569 | -1.0542 | 0.2082 | 0.5840 | 1.2230 | 0.5840 | Z |
| | 19 | 31.6040 | -17.5740 | -45.2220 | 32.4776 | -17.6120 | -45.0504 | -0.8736 | -0.0380 | 0.1716 | 0.8911 | 0.1716 | Z |
| | 20 | 34.1900 | -7.2957 | -45.6069 | 35.1401 | -7.3558 | -45.2782 | -0.9501 | -0.0601 | 0.3287 | 1.0071 | 0.3287 | Z |
| | 21 | 35.3159 | 3.1467 | -45.6989 | 36.3637 | 3.0232 | -45.2575 | -1.0478 | 0.1235 | 0.4414 | 1.1437 | 0.4414 | Z |
| | 22 | 18.6202 | -15.8759 | -46.4392 | 19.5190 | -15.9110 | -46.4025 | -0.8988 | -0.0351 | 0.0367 | 0.9002 | 0.0367 | Z |
| | 23 | 19.6842 | -5.5611 | -46.9577 | 20.6189 | -5.5484 | -46.8345 | -0.9347 | 0.0127 | 0.1232 | 0.9429 | 0.1232 | Z |
| | 24 | 20.2855 | 4.4526 | -47.1148 | 21.2944 | 4.4866 | -46.9037 | -1.0089 | -0.0340 | 0.2111 | 1.0313 | 0.2111 | Z |
| | 25 | 1.2361 | -15.5497 | -46.6392 | 2.0691 | -15.4355 | -46.8090 | -0.8330 | 0.1142 | -0.1698 | 0.8578 | -0.1698 | Z |
| | 26 | 1.2684 | -6.2626 | -47.0878 | 2.1953 | -6.1453 | -47.2100 | -0.9269 | 0.1173 | -0.1222 | 0.9423 | -0.1222 | Z |
| | 27 | 1.4403 | 4.1660 | -47.2289 | 2.3812 | 4.1989 | -47.3176 | -0.9409 | -0.0329 | -0.0887 | 0.9456 | -0.0887 | Z |
| | 28 | -10.7223 | -15.6483 | -46.3566 | -9.8453 | -15.5202 | -46.6806 | -0.8770 | 0.1281 | -0.3240 | 0.9437 | -0.3240 | Z |
| | 29 | -10.4473 | -4.5537 | -46.7147 | -9.4861 | -4.3501 | -47.0312 | -0.9612 | 0.2036 | -0.3165 | 1.0322 | -0.3165 | Z |
| | 30 | -10.4944 | 4.8395 | -46.7568 | -9.4911 | 5.0362 | -47.0366 | -1.0033 | -0.1967 | -0.2798 | 1.0600 | -0.2798 | Z |
| A-PILLAR Maximum (X, Y, Z) | 31 | 53.6696 | -26.6427 | -28.5786 | 54.5914 | -27.1928 | -28.9774 | -0.9218 | -0.5501 | -0.3988 | 1.1451 | 0.0000 | NA |
| | 32 | 48.8303 | -25.3369 | -32.7863 | 49.7067 | -25.7671 | -33.0131 | -0.8764 | -0.4302 | -0.2268 | 1.0023 | 0.0000 | NA |
| | 33 | 45.9462 | -24.6595 | -34.8356 | 46.7864 | -25.0517 | -35.0106 | -0.8402 | -0.3922 | -0.1750 | 0.9436 | 0.0000 | NA |
| | 34 | 43.6924 | -23.8254 | -36.4475 | 44.4996 | -24.2013 | -36.6050 | -0.8072 | -0.3759 | -0.1575 | 0.9043 | 0.0000 | NA |
| | 35 | 41.6123 | -23.6814 | -37.7178 | 42.3336 | -23.9696 | -37.8296 | -0.7213 | -0.2882 | -0.1118 | 0.7847 | 0.0000 | NA |
| | 36 | 37.8961 | -23.0896 | -40.0593 | 38.6310 | -23.3652 | -40.1256 | -0.7349 | -0.2756 | -0.0663 | 0.7877 | 0.0000 | NA |
| A-PILLAR Lateral (Y) | 31 | 53.6696 | -26.6427 | -28.5786 | 54.5914 | -27.1928 | -28.9774 | -0.9218 | -0.5501 | -0.3988 | 1.1451 | -0.5501 | Y |
| | 32 | 48.8303 | -25.3369 | -32.7863 | 49.7067 | -25.7671 | -33.0131 | -0.8764 | -0.4302 | -0.2268 | 1.0023 | -0.4302 | Y |
| | 33 | 45.9462 | -24.6595 | -34.8356 | 46.7864 | -25.0517 | -35.0106 | -0.8402 | -0.3922 | -0.1750 | 0.9436 | -0.3922 | Y |
| | 34 | 43.6924 | -23.8254 | -36.4475 | 44.4996 | -24.2013 | -36.6050 | -0.8072 | -0.3759 | -0.1575 | 0.9043 | -0.3759 | Y |
| | 35 | 41.6123 | -23.6814 | -37.7178 | 42.3336 | -23.9696 | -37.8296 | -0.7213 | -0.2882 | -0.1118 | 0.7847 | -0.2882 | Y |
| | 36 | 37.8961 | -23.0896 | -40.0593 | 38.6310 | -23.3652 | -40.1256 | -0.7349 | -0.2756 | -0.0663 | 0.7877 | -0.2756 | Y |
| B-PILLAR Maximum (X, Y, Z) | 37 | 9.5688 | -22.6789 | -40.8447 | 10.2960 | -22.5962 | -40.7948 | -0.7272 | 0.0827 | 0.0499 | 0.7336 | 0.0966 | Y, Z |
| | 38 | 12.9717 | -24.7291 | -35.3949 | 13.5993 | -24.6478 | -35.3419 | -0.6276 | 0.0813 | 0.0530 | 0.6351 | 0.0970 | Y, Z |
| | 39 | 10.3364 | -26.2773 | -30.7922 | 10.8148 | -26.1230 | -30.7038 | -0.4784 | 0.1543 | 0.0884 | 0.5104 | 0.1778 | Y, Z |
| | 40 | 13.7312 | -26.8576 | -27.8517 | 14.1698 | -26.7266 | -27.7346 | -0.4386 | 0.1310 | 0.1171 | 0.4725 | 0.1757 | Y, Z |
| B-PILLAR Lateral (Y) | 37 | 9.5688 | -22.6789 | -40.8447 | 10.2960 | -22.5962 | -40.7948 | -0.7272 | 0.0827 | 0.0499 | 0.7336 | 0.0827 | Y |
| | 38 | 12.9717 | -24.7291 | -35.3949 | 13.5993 | -24.6478 | -35.3419 | -0.6276 | 0.0813 | 0.0530 | 0.6351 | 0.0813 | Y |
| | 39 | 10.3364 | -26.2773 | -30.7922 | 10.8148 | -26.1230 | -30.7038 | -0.4784 | 0.1543 | 0.0884 | 0.5104 | 0.1543 | Y |
| | 40 | 13.7312 | -26.8576 | -27.8517 | 14.1698 | -26.7266 | -27.7346 | -0.4386 | 0.1310 | 0.1171 | 0.4725 | 0.1310 | Y |

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Figure E-10. Occupant Compartment Deformation Data – Set 1, Test No. HMDT-2

Test Name: HMDT-2 VIN: 1C6RR6KG1FS542139
Model Year: 2015 Make: Dodge Ram Model: 1500 Crew Cab

**VEHICLE DEFORMATION**
**DRIVER SIDE INTERIOR CRUSH - SET 2**

| | POINT | Pretest X (in.) | Pretest Y (in.) | Pretest Z (in.) | Posttest X (in.) | Posttest Y (in.) | Posttest Z (in.) | ΔX[A] (in.) | ΔY[A] (in.) | ΔZ[A] (in.) | Total Δ (in.) | Crush[B] (in.) | Directions for Crush[C] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DASH (X, Y, Z) | 1 | 52.5745 | -45.9184 | -30.1774 | 52.7370 | -45.1726 | -32.6163 | -0.1625 | 0.7458 | -2.4389 | 2.5556 | 2.5556 | X, Y, Z |
| | 2 | 49.3036 | -34.2943 | -33.2636 | 49.6944 | -33.4119 | -35.3157 | -0.3908 | 0.8824 | -2.0521 | 2.2677 | 2.2677 | X, Y, Z |
| | 3 | 51.2223 | -16.0834 | -31.3037 | 51.5737 | -15.3770 | -32.3679 | -0.3514 | 0.7064 | -1.0642 | 1.3248 | 1.3248 | X, Y, Z |
| | 4 | 47.9704 | -45.8391 | -19.4244 | 47.4053 | -45.2946 | -22.2740 | 0.5651 | 0.5445 | -2.8496 | 2.9557 | 2.9557 | X, Y, Z |
| | 5 | 46.0138 | -34.3078 | -19.0479 | 45.0245 | -33.6822 | -20.7952 | 0.9893 | 0.6256 | -1.7473 | 2.1031 | 2.1031 | X, Y, Z |
| | 6 | 44.9728 | -15.2585 | -19.8525 | 44.8577 | -14.7543 | -21.1575 | 0.1151 | 0.5042 | -1.3050 | 1.4037 | 1.4037 | X, Y, Z |
| SIDE PANEL (Y) | 7 | 56.5967 | -47.4948 | -4.9219 | 54.3449 | -43.3531 | -7.3182 | 2.2518 | 4.1417 | -2.3963 | 5.2883 | 4.1417 | Y |
| | 8 | 59.6474 | -47.6393 | -9.8395 | 57.6150 | -44.6597 | -11.8693 | 2.0324 | 2.9796 | -2.0298 | 4.1387 | 2.9796 | Y |
| | 9 | 59.8087 | -47.4957 | -6.0572 | 57.2240 | -44.3590 | -8.2666 | 2.5847 | 3.1367 | -2.2094 | 4.6261 | 3.1367 | Y |
| IMPACT SIDE DOOR (Y) | 10 | 22.0630 | -49.7833 | -18.6395 | 21.3182 | -51.6053 | -19.2825 | 0.7448 | -1.8220 | -0.6430 | 2.0707 | -1.8220 | Y |
| | 11 | 33.9777 | -50.0467 | -18.4134 | 32.9628 | -52.3022 | -19.2848 | 1.0149 | -2.2555 | -0.8714 | 2.6223 | -2.2555 | Y |
| | 12 | 40.8867 | -50.5237 | -18.6062 | 39.9196 | -51.9323 | -19.6878 | 0.9671 | -1.4086 | -1.0816 | 2.0222 | -1.4086 | Y |
| | 13 | 22.6477 | -49.6182 | -7.8586 | 22.2080 | -50.4061 | -8.6326 | 0.4397 | -0.7879 | -0.7740 | 1.1888 | -0.7879 | Y |
| | 14 | 35.0329 | -50.0477 | -8.1902 | 34.2293 | -50.0778 | -9.3214 | 0.8036 | -0.0301 | -1.1312 | 1.3879 | -0.0301 | Y |
| | 15 | 43.1235 | -50.2421 | -7.1074 | 42.3707 | -49.3445 | -8.3878 | 0.7528 | 0.8976 | -1.2804 | 1.7355 | 0.8976 | Y |
| ROOF - (Z) | 16 | 40.4472 | -37.2840 | -45.9690 | 40.8510 | -36.8637 | -46.6565 | -0.4038 | 0.4203 | -0.6875 | 0.9013 | -0.6875 | Z |
| | 17 | 42.7364 | -28.0616 | -46.3602 | 43.1088 | -27.6049 | -46.8727 | -0.3724 | 0.4567 | -0.5125 | 0.7810 | -0.5125 | Z |
| | 18 | 43.8335 | -17.1645 | -46.5944 | 44.2103 | -16.7130 | -46.8893 | -0.3768 | 0.4515 | -0.2949 | 0.6579 | -0.2949 | Z |
| | 19 | 34.1375 | -37.3223 | -48.6755 | 34.4422 | -36.8182 | -49.3271 | -0.3047 | 0.5041 | -0.6516 | 0.8784 | -0.6516 | Z |
| | 20 | 36.6324 | -27.0406 | -49.1003 | 36.9650 | -26.5273 | -49.5747 | -0.3326 | 0.5133 | -0.4744 | 0.7741 | -0.4744 | Z |
| | 21 | 37.7432 | -16.6247 | -49.2342 | 38.0483 | -16.1327 | -49.5689 | -0.3051 | 0.4920 | -0.3347 | 0.6687 | -0.3347 | Z |
| | 22 | 21.1247 | -35.7787 | -50.0749 | 21.4571 | -35.2939 | -50.6352 | -0.3324 | 0.4848 | -0.5603 | 0.8121 | -0.5603 | Z |
| | 23 | 22.1965 | -25.4227 | -50.6446 | 22.4153 | -24.9178 | -51.0816 | -0.2188 | 0.5049 | -0.4370 | 0.7027 | -0.4370 | Z |
| | 24 | 22.7825 | -15.3636 | -50.8516 | 22.9549 | -14.8747 | -51.1634 | -0.1724 | 0.4889 | -0.3118 | 0.6049 | -0.3118 | Z |
| | 25 | 3.7498 | -35.5277 | -50.5041 | 4.0010 | -35.0546 | -50.9806 | -0.2512 | 0.4731 | -0.4765 | 0.7169 | -0.4765 | Z |
| | 26 | 3.7624 | -26.1846 | -51.0284 | 4.0003 | -25.7639 | -51.3914 | -0.2379 | 0.4207 | -0.3630 | 0.6044 | -0.3630 | Z |
| | 27 | 3.8373 | -15.8111 | -51.2395 | 4.0461 | -15.4183 | -51.5102 | -0.2088 | 0.3928 | -0.2707 | 0.5207 | -0.2707 | Z |
| | 28 | -8.2192 | -35.6931 | -50.3706 | -7.9106 | -35.3001 | -50.8101 | -0.3086 | 0.3930 | -0.4395 | 0.6655 | -0.4395 | Z |
| | 29 | -8.0276 | -24.4995 | -50.7941 | -7.7036 | -24.1266 | -51.1732 | -0.3240 | 0.3729 | -0.3791 | 0.6227 | -0.3791 | Z |
| | 30 | -8.1261 | -15.1250 | -50.9069 | -7.8354 | -14.7412 | -51.1882 | -0.2907 | 0.3838 | -0.2813 | 0.5576 | -0.2813 | Z |
| A-PILLAR Maximum (X, Y, Z) | 31 | 55.9656 | -46.1998 | -31.6886 | 56.7398 | -46.0824 | -33.3225 | -0.7742 | 0.1174 | -1.6339 | 1.8118 | 0.1174 | Y |
| | 32 | 51.1755 | -44.9343 | -35.9794 | 51.8222 | -44.7271 | -37.3424 | -0.6467 | 0.2072 | -1.3630 | 1.5228 | 0.2072 | Y |
| | 33 | 48.3009 | -44.2654 | -38.0574 | 48.8854 | -44.0533 | -39.3303 | -0.5845 | 0.2121 | -1.2729 | 1.4167 | 0.2121 | Y |
| | 34 | 46.0205 | -43.4606 | -39.7614 | 46.5817 | -43.2357 | -40.9175 | -0.5612 | 0.2249 | -1.1561 | 1.3046 | 0.2249 | Y |
| | 35 | 43.9515 | -43.3457 | -41.0775 | 44.4085 | -43.0344 | -42.1347 | -0.4570 | 0.3113 | -1.0572 | 1.1931 | 0.3113 | Y |
| | 36 | 40.2684 | -42.7658 | -43.4705 | 40.6900 | -42.4826 | -44.4182 | -0.4216 | 0.2832 | -0.9477 | 1.0752 | 0.2832 | Y |
| A-PILLAR Lateral (Y) | 31 | 55.9656 | -46.1998 | -31.6886 | 56.7398 | -46.0824 | -33.3225 | -0.7742 | 0.1174 | -1.6339 | 1.8118 | 0.1174 | Y |
| | 32 | 51.1755 | -44.9343 | -35.9794 | 51.8222 | -44.7271 | -37.3424 | -0.6467 | 0.2072 | -1.3630 | 1.5228 | 0.2072 | Y |
| | 33 | 48.3009 | -44.2654 | -38.0574 | 48.8854 | -44.0533 | -39.3303 | -0.5845 | 0.2121 | -1.2729 | 1.4167 | 0.2121 | Y |
| | 34 | 46.0205 | -43.4606 | -39.7614 | 46.5817 | -43.2357 | -40.9175 | -0.5612 | 0.2249 | -1.1561 | 1.3046 | 0.2249 | Y |
| | 35 | 43.9515 | -43.3457 | -41.0775 | 44.4085 | -43.0344 | -42.1347 | -0.4570 | 0.3113 | -1.0572 | 1.1931 | 0.3113 | Y |
| | 36 | 40.2684 | -42.7658 | -43.4705 | 40.6900 | -42.4826 | -44.4182 | -0.4216 | 0.2832 | -0.9477 | 1.0752 | 0.2832 | Y |
| B-PILLAR Maximum (X, Y, Z) | 37 | 12.0644 | -42.5429 | -44.5518 | 12.3450 | -42.0972 | -44.9882 | -0.2806 | 0.4457 | -0.4364 | 0.6840 | 0.4457 | Y |
| | 38 | 15.4642 | -44.5412 | -39.0749 | 15.6949 | -44.0981 | -39.5449 | -0.2307 | 0.4431 | -0.4700 | 0.6859 | 0.4431 | Y |
| | 39 | 12.7547 | -46.0759 | -34.4959 | 12.9469 | -45.6059 | -34.8955 | -0.1922 | 0.4700 | -0.3996 | 0.6462 | 0.4700 | Y |
| | 40 | 16.1029 | -46.6184 | -31.5172 | 16.3202 | -46.1610 | -31.9376 | -0.2173 | 0.4574 | -0.4204 | 0.6582 | 0.4574 | Y |
| B-PILLAR Lateral (Y) | 37 | 12.0644 | -42.5429 | -44.5518 | 12.3450 | -42.0972 | -44.9882 | -0.2806 | 0.4457 | -0.4364 | 0.6840 | 0.4457 | Y |
| | 38 | 15.4642 | -44.5412 | -39.0749 | 15.6949 | -44.0981 | -39.5449 | -0.2307 | 0.4431 | -0.4700 | 0.6859 | 0.4431 | Y |
| | 39 | 12.7547 | -46.0759 | -34.4959 | 12.9469 | -45.6059 | -34.8955 | -0.1922 | 0.4700 | -0.3996 | 0.6462 | 0.4700 | Y |
| | 40 | 16.1029 | -46.6184 | -31.5172 | 16.3202 | -46.1610 | -31.9376 | -0.2173 | 0.4574 | -0.4204 | 0.6582 | 0.4574 | Y |

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Figure E-11. Occupant Compartment Deformation Data – Set 2, Test No. HMDT-2

| | |
|---|---|
| Test Name: | HMDT-2 |
| VIN: | 1C6RR6KG1FS542139 |
| Model Year: | 2015 |
| Make: | Dodge Ram |
| Model: | 1500 Crew Cab |

**Driver Side Maximum Deformation**

| **Reference Set 1** | | | | **Reference Set 2** | | | |
|---|---|---|---|---|---|---|---|
| Location | Maximum Deformation[A,B] (in.) | MASH Allowable Deformation (in.) | Directions of Deformation[C] | Location | Maximum Deformation[A,B] (in.) | MASH Allowable Deformation (in.) | Directions of Deformation[C] |
| Roof | 0.6 | ≤ 4 | Z | Roof | -0.7 | ≤ 4 | Z |
| Windshield[D] | 0.0 | ≤ 3 | X, Z | Windshield[D] | NA | ≤ 3 | X, Z |
| A-Pillar Maximum | 0.0 | ≤ 5 | NA | A-Pillar Maximum | 0.3 | ≤ 5 | Y |
| A-Pillar Lateral | -0.6 | ≤ 3 | Y | A-Pillar Lateral | 0.3 | ≤ 3 | Y |
| B-Pillar Maximum | 0.2 | ≤ 5 | Y, Z | B-Pillar Maximum | 0.5 | ≤ 5 | Y |
| B-Pillar Lateral | -0.6 | ≤ 3 | Y | B-Pillar Lateral | 0.5 | ≤ 3 | Y |
| Toe Pan - Wheel Well | 7.5 | ≤ 9 | X, Z | Toe Pan - Wheel Well | 8.4 | ≤ 9 | X, Z |
| Side Front Panel | 3.6 | ≤ 12 | Y | Side Front Panel | 4.1 | ≤ 12 | Y |
| Side Door (above seat) | -2.6 | ≤ 9 | Y | Side Door (above seat) | -2.3 | ≤ 9 | Y |
| Side Door (below seat) | 0.5 | ≤ 12 | Y | Side Door (below seat) | 0.9 | ≤ 12 | Y |
| Floor Pan | 2.9 | ≤ 12 | Z | Floor Pan | 4.3 | ≤ 12 | Z |
| Dash - no MASH requirement | 1.7 | NA | X, Y, Z | Dash - no MASH requirement | 1.7 | NA | X, Y, Z |

[A] Items highlighted in red do not meet MASH allowable deformations.

[B] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

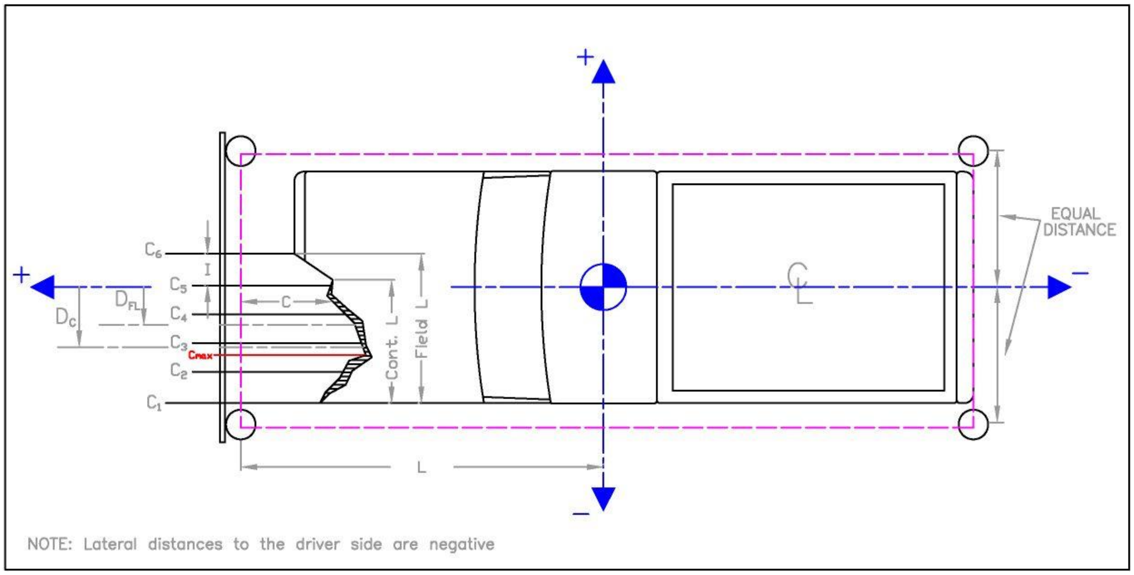
[C] For Toe Pan - Wheel Well the direction of defromation may include X and Z direction. For A-Pillar Maximum and B-Pillar Maximum the direction of deformation may include X, Y, and Z directions. The direction of deformation for Toe Pan -Wheel Well, A-Pillar Maximum, and B-Pillar Maximum only include components where the deformation is positive and intruding into the occupant compartment. If direction of deformation is "NA" then no intrusion is recorded and deformation will be 0.

[D] If deformation is observered for the windshield then the windshield deformation is measured posttest with an examplar vehicle, therefore only one set of reference is measured and recorded.

**Notes on vehicle interior crush:**

Figure E-12. Maximum Occupant Compartment Deformation by Location, Test No. HMDT-2

| | | | | | |
|---|---|---|---|---|---|
| **Date Measured:** | 6/25/2021 | **Test Name:** | HMDT-2 | **VIN:** | 1C6RR6KG1FS542139 |
| **Model Year:** | 2015 | **Make:** | Dodge Ram | **Model:** | 1500 Crew Cab |



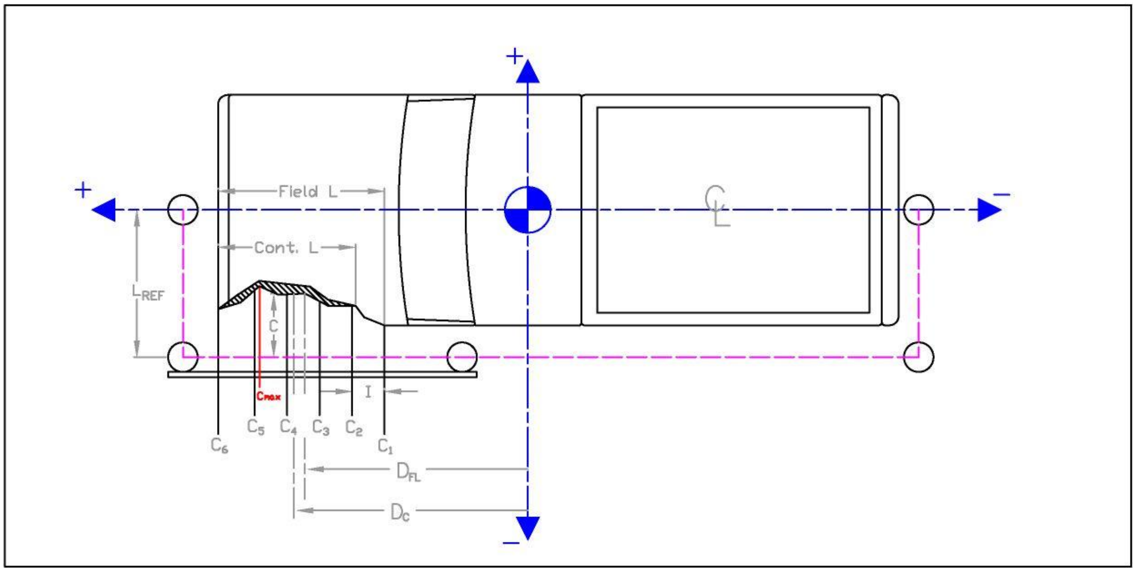

| | in. | (mm) |
|---|---|---|
| Distance from C.G. to reference line - $L_{REF}$: | 114 | (2896) |
| Total Vehicle Width: | 76 7/8 | (1953) |
| Width of contact and induced crush - Field L: | 76 7/8 | (1953) |
| Crush measurement spacing interval (L/5) - I: | 15 3/8 | (391) |
| Distance from center of vehicle to center of Field L - $D_{FL}$: | 0 | () |
| Width of Contact Damage: | 22 4/9 | (570) |
| Distance from center of vehicle to center of contact damage - $D_C$: | -27 1/3 | -(694) |

NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

| | Crush Measurement | | Lateral Location | | Original Profile Measurement | | Dist. Between Ref. Lines | | Actual Crush | |
|---|---|---|---|---|---|---|---|---|---|---|
| | in. | (mm) | in. | (mm) | in. | (mm) | in. | (mm) | in. | (mm) |
| $C_1$ | n/a | N/A | -38 1/2 | -(978) | 22 1/2 | (572) | 4 3/8 | (111) | N/A | N/A |
| $C_2$ | 34 | (864) | -23 1/8 | -(587) | 6 1/2 | (165) | | | 23 1/8 | (587) |
| $C_3$ | 8 3/4 | (222) | -7 3/4 | -(197) | 4 1/4 | (108) | | | 1/8 | (3) |
| $C_4$ | 6 | (152) | 7 5/8 | (194) | 4 1/4 | (108) | | | -2 5/8 | -(67) |
| $C_5$ | 9 3/4 | (248) | 23 | (584) | 6 1/8 | (156) | | | - 3/4 | -(19) |
| $C_6$ | n/a | N/A | 38 3/8 | (975) | 20 1/2 | (521) | | | N/A | N/A |
| $C_{MAX}$ | 34 | (864) | -23 1/8 | -(587) | 6 1/2 | (165) | | | 23 1/8 | (587) |

Figure E-13. Exterior Vehicle Crush (NASS) - Front, Test No. HMDT-2

| | | | | | |
|---|---|---|---|---|---|
| **Date Measured:** | 6/25/2021 | **Test Name:** | HMDT-2 | **VIN:** | 1C6RR6KG1FS542139 |
| **Model Year:** | 2015 | **Make:** | Dodge Ram | **Model:** | 1500 Crew Cab |




| | in. | (mm) |
|---|---|---|
| Distance from centerline to reference line - $L_{REF}$: | 47 | (1194) |
| Total Vehicle Length: | 229 | (5817) |
| Distance from vehicle c.g. to 1/2 of Vehicle total length: | -9 1/4 | -(235) |
| Width of contact and induced crush - Field L: | 229 | (5817) |
| Crush measurement spacing interval (L/5) - I: | 45 3/4 | (1162) |
| Distance from vehicle c.g. to center of Field L - $D_{FL}$: | -9 1/4 | -(235) |
| Width of Contact Damage: | 229 | (5817) |
| Distance from vehicle c.g. to center of contact damage - $D_C$: | -9 1/4 | -(235) |

NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., front of vehicle has been pushed inward or tire has been removed)
NOTE: All values must be filled out above before crush measurements are filled out.

| | Crush Measurement | | Longitudinal Location | | Original Profile Measurement | | Dist. Between Ref. Lines | | Actual | Crush |
|---|---|---|---|---|---|---|---|---|---|---|
| | in. | (mm) | in. | (mm) | in. | (mm) | in. | (mm) | in. | (mm) |
| $C_1$ | n/a | N/A | -123 3/4 | -(3143) | 33 1/2 | (851) | 3 | (76) | N/A | N/A |
| $C_2$ | n/a | N/A | -78 | -(1981) | 5 1/2 | (140) | | | N/A | N/A |
| $C_3$ | 8 1/2 | (216) | -32 1/4 | -(819) | 5 3/4 | (146) | | | - 1/4 | -(6) |
| $C_4$ | 8 1/2 | (216) | 13 1/2 | (343) | 5 | (127) | | | 1/2 | (13) |
| $C_5$ | n/a | N/A | 59 1/4 | (1505) | 5 5/8 | (143) | | | N/A | N/A |
| $C_6$ | 33 1/2 | (851) | 105 | (2667) | 8 7/8 | (225) | | | 21 5/8 | (549) |
| $C_{MAX}$ | 33 1/2 | (851) | 105 | (2667) | 8 7/8 | (225) | | | 21 5/8 | (549) |

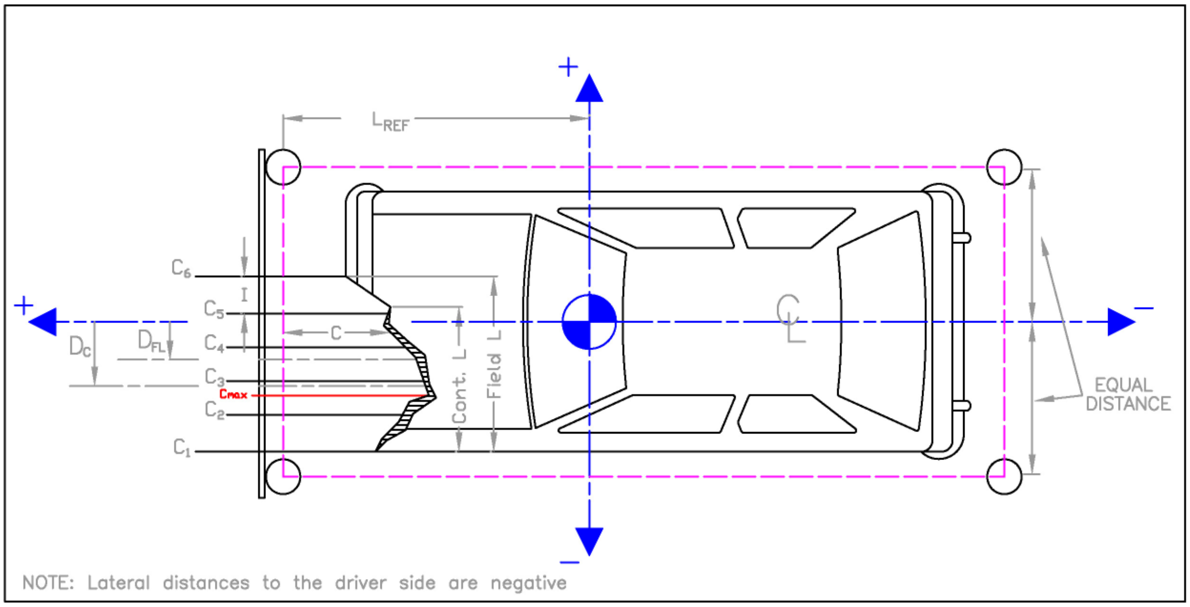
Figure E-14. Exterior Vehicle Crush (NASS) - Side, Test No. HMDT-2

Note, damage to the occupant compartment including the floor pan on the impact side was extensive and reference measurements could not be made to pre-test data points for test no. HMDT-3. An exemplar vehicle and occupant compartment floorpan were used to estimate the occupant compartment deformation.

Figure E-15. Maximum Occupant Compartment Deformation by Location, Test No. HMDT-3

Using an undamaged vehicle of the same body style, several areas of deformation were analyzed. The maximum lateral deformation was 13⅜ in. at the side front panel.

| | | | | | |
|---|---|---|---|---|---|
| **Date Measured** | 7/7/21 | | **HMDT-3** | **VIN:** | **KNADN4A38G6572229** |
| **Model Year:** | **2016** | **Make:** | **Kia** | **Model:** | **Rio** |




| | in. | (mm) |
|---|---|---|
| **Distance from C.G. to reference line - $L_{REF}$:** | 76 | (1930) |
| **Total Width of Vehicle:** | 66 1/4 | (1683) |
| **Width of contact and induced crush - Field L:** | 66 1/4 | (1683) |
| **Crush measurement spacing interval (L/5) - I:** | 13 1/4 | (337) |
| **Distance from center of vehicle to center of Field L - $D_{FL}$:** | 0 | () |
| **Width of Contact Damage:** | 66 1/4 | (1683) |
| **Distance from center of vehicle to center of contact damage - $D_C$:** | 0 | () |

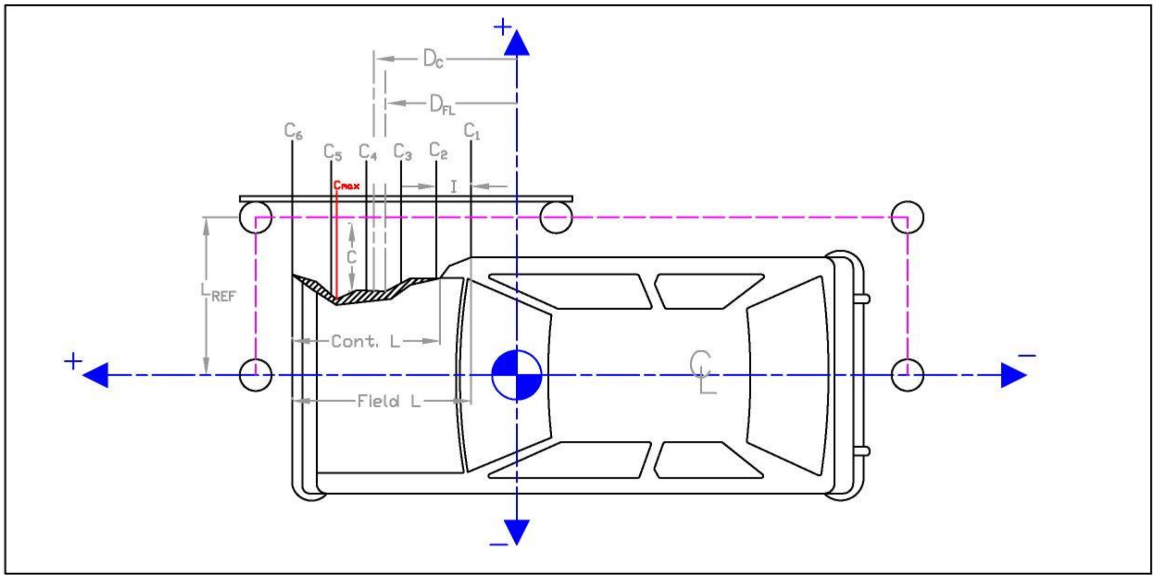
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

| Crush Measurement | | | Lateral Location | | Original Profile Measurement | | Dist. Between Ref. Lines | | Actual Crush | |
|---|---|---|---|---|---|---|---|---|---|---|
| | in. | (mm) | in. | (mm) | in. | (mm) | in. | (mm) | in. | (mm) |
| $C_1$ | N/A | NA | -33 1/8 | -(841) | 24 1/8 | (613) | -2 3/4 | -(70) | NA | NA |
| $C_2$ | N/A | NA | -19 7/8 | -(505) | 11 5/8 | (295) | | | NA | NA |
| $C_3$ | 12 1/4 | (311) | -6 5/8 | -(168) | 8 7/8 | (225) | | | 6 1/8 | (156) |
| $C_4$ | 8 3/8 | (213) | 6 5/8 | (168) | 8 7/8 | (225) | | | 2 1/4 | (57) |
| $C_5$ | 9 1/2 | (241) | 19 7/8 | (505) | 11 1/2 | (292) | | | 3/4 | (19) |
| $C_6$ | 16 1/2 | (419) | 33 1/8 | (841) | 24 1/8 | (613) | | | -4 7/8 | -(124) |
| $C_{MAX}$ | 19 1/2 | (495) | -18 | -(457) | 10 7/8 | (276) | | | 11 3/8 | (289) |

Figure E-16. Exterior Vehicle Crush (NASS) - Front, Test No. HMDT-3

**Date Measured** 7/7/21 **Test Name:** HMDT-3 **VIN:** KNADN4A38G6572229

**Model Year:** 2016 **Make:** Kia **Model:** Rio




| | in. | (mm) |
|---|---|---|
| Distance from centerline to reference line - $L_{REF}$: | 39 1/2 | (1003) |
| Total Vehicle Length: | 171 3/4 | (4362) |
| Distance from vehicle c.g. to 1/2 of Vehicle total length: | -16 1/2 | -(419) |
| Width of contact and induced crush - Field L: | 91 1/8 | (2315) |
| Crush measurement spacing interval (L/5) - I: | 18 1/4 | (464) |
| Distance from vehicle c.g. to center of Field L - $D_{FL}$: | 23 4/5 | (605) |
| Width of Contact Damage: | 69 3/8 | (1762) |
| Distance from vehicle c.g. to center of contact damage - $D_C$: | 40 2/3 | (1033) |

NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., front of vehicle has been pushed inward or tire has been removed)
NOTE: All values must be filled out above before crush measurements are filled out.

| | Crush Measurement | | Longitudinal Location | | Original Profile Measurement | | Dist. Between Ref. Lines | | Actual Crush | |
|---|---|---|---|---|---|---|---|---|---|---|
| | in. | (mm) | in. | (mm) | in. | (mm) | in. | (mm) | in. | (mm) |
| $C_1$ | 5 3/8 | (137) | -21 3/4 | -(552) | 6 3/8 | (162) | 0 | () | -1 | -(25) |
| $C_2$ | 6 | (152) | -3 1/2 | -(89) | 6 1/2 | (165) | | | - 1/2 | -(13) |
| $C_3$ | 9 1/8 | (232) | 14 3/4 | (375) | 6 1/4 | (159) | | | 2 7/8 | (73) |
| $C_4$ | N/A | NA | 33 | (838) | 7 | (178) | | | NA | NA |
| $C_5$ | 22 1/4 | (565) | 51 1/4 | (1302) | 6 1/8 | (156) | | | 16 1/8 | (410) |
| $C_6$ | N/A | NA | 69 1/2 | (1765) | 18 7/8 | (479) | | | NA | NA |
| $C_{MAX}$ | 22 1/4 | (565) | 51 1/4 | (1302) | 6 1/8 | (156) | | | 16 1/8 | (410) |

Figure E-17. Exterior Vehicle Crush (NASS) - Side, Test No. HMDT-3

Model Year: 2016 | Test Name: HMDT-4 | VIN: KMHCT4AE9GU115037
Make: Hyundai | Model: Accent

**VEHICLE DEFORMATION**
**DRIVER SIDE FLOOR PAN - SET 1**

| | POINT | Pretest X (in.) | Pretest Y (in.) | Pretest Z (in.) | Posttest X (in.) | Posttest Y (in.) | Posttest Z (in.) | ΔX[A] (in.) | ΔY[A] (in.) | ΔZ[A] (in.) | Total Δ (in.) | Crush[B] (in.) | Directions for Crush[C] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TOE PAN - WHEEL WELL (X, Z) | 1 | 73.4979 | -22.7247 | -2.6372 | 72.2295 | -21.2517 | -4.9178 | 1.2684 | 1.4730 | 2.2806 | 2.9966 | 2.6096 | X, Z |
| | 2 | 76.9671 | -17.7384 | -0.7151 | 76.3541 | -16.8805 | -2.7585 | 0.6130 | 0.8579 | 2.0434 | 2.2994 | 2.1334 | X, Z |
| | 3 | 76.4274 | -11.7314 | 1.6315 | 75.9567 | -11.7069 | -0.0947 | 0.4707 | 0.0245 | 1.7262 | 1.7894 | 1.7892 | X, Z |
| | 4 | 74.9370 | -6.9634 | 1.8261 | 74.7180 | -6.9062 | 0.2137 | 0.2190 | 0.0572 | 1.6124 | 1.6282 | 1.6272 | X, Z |
| | 5 | 73.5392 | -2.6446 | 0.2240 | 73.5065 | -2.7263 | -1.4078 | 0.0327 | -0.0817 | 1.6318 | 1.6342 | 1.6321 | X, Z |
| | 6 | 68.3833 | -23.0595 | 5.5185 | 68.3428 | -22.7102 | 3.6266 | 0.0405 | 0.3493 | 1.8919 | 1.9243 | 1.8923 | X, Z |
| | 7 | 67.6368 | -17.9644 | 5.8893 | 67.7194 | -17.7054 | 4.4278 | -0.0826 | 0.2590 | 1.4615 | 1.4866 | 1.4615 | Z |
| | 8 | 67.2273 | -12.4893 | 6.0999 | 67.2211 | -12.2955 | 4.7229 | 0.0062 | 0.1938 | 1.3770 | 1.3906 | 1.3770 | X, Z |
| | 9 | 67.3837 | -7.0870 | 6.1058 | 67.3681 | -6.9590 | 4.4593 | 0.0156 | 0.1280 | 1.6465 | 1.6515 | 1.6466 | X, Z |
| | 10 | 66.5989 | -2.8355 | 2.9782 | 66.6053 | -2.9233 | 1.4128 | -0.0064 | -0.0878 | 1.5654 | 1.5679 | 1.5654 | Z |
| FLOOR PAN (Z) | 11 | 63.4969 | -23.6251 | 6.5570 | 63.4970 | -23.2766 | 4.9249 | -0.0001 | 0.3485 | 1.6321 | 1.6689 | 1.6321 | Z |
| | 12 | 63.2634 | -17.5454 | 6.7386 | 63.3196 | -17.3170 | 5.4026 | -0.0562 | 0.2284 | 1.3360 | 1.3565 | 1.3360 | Z |
| | 13 | 63.3860 | -12.6725 | 6.6479 | 63.4083 | -12.4816 | 5.3911 | -0.0223 | 0.1909 | 1.2568 | 1.2714 | 1.2568 | Z |
| | 14 | 62.7995 | -6.7227 | 6.4557 | 62.8521 | -6.6571 | 4.9710 | -0.0526 | 0.0656 | 1.4847 | 1.4871 | 1.4847 | Z |
| | 15 | 63.4087 | -2.8397 | 3.0798 | 63.3691 | -2.9388 | 1.5523 | 0.0396 | -0.0991 | 1.5275 | 1.5312 | 1.5275 | Z |
| | 16 | 59.3906 | -23.4764 | 6.6855 | 59.4295 | -23.2631 | 5.1755 | -0.0389 | 0.2133 | 1.5100 | 1.5255 | 1.5100 | Z |
| | 17 | 58.1691 | -17.4558 | 6.8443 | 58.1747 | -17.2328 | 5.5942 | -0.0056 | 0.2230 | 1.2501 | 1.2698 | 1.2501 | Z |
| | 18 | 57.7516 | -12.5339 | 6.7562 | 57.7747 | -12.2913 | 5.5820 | -0.0231 | 0.2426 | 1.1742 | 1.1992 | 1.1742 | Z |
| | 19 | 57.2005 | -6.3826 | 6.7073 | 57.2158 | -6.2169 | 5.2912 | -0.0153 | 0.1657 | 1.4161 | 1.4258 | 1.4161 | Z |
| | 20 | 58.5668 | -2.4531 | 2.7288 | 58.6014 | -2.4779 | 1.1914 | -0.0346 | -0.0248 | 1.5374 | 1.5380 | 1.5374 | Z |
| | 21 | 53.6738 | -23.5561 | 7.0342 | 53.7208 | -23.3833 | 5.7280 | -0.0470 | 0.1728 | 1.3062 | 1.3184 | 1.3062 | Z |
| | 22 | 53.4747 | -17.5623 | 7.0830 | 53.5332 | -17.4831 | 5.8857 | -0.0585 | 0.0792 | 1.1973 | 1.2013 | 1.1973 | Z |
| | 23 | 53.4775 | -12.4063 | 7.0372 | 53.4774 | -12.2457 | 5.9574 | 0.0001 | 0.1606 | 1.0798 | 1.0917 | 1.0798 | Z |
| | 24 | 53.4087 | -6.2553 | 6.9700 | 53.4187 | -6.1197 | 5.5831 | -0.0100 | 0.1356 | 1.3869 | 1.3935 | 1.3869 | Z |
| | 25 | 54.7750 | -2.2217 | 2.3841 | 54.7886 | -2.2096 | 0.9334 | -0.0136 | 0.0121 | 1.4507 | 1.4508 | 1.4507 | Z |
| | 26 | 51.1127 | -23.6451 | 7.1775 | 51.1453 | -23.4207 | 5.9610 | -0.0326 | 0.2244 | 1.2165 | 1.2375 | 1.2165 | Z |
| | 27 | 51.1375 | -17.3763 | 7.1947 | 51.1794 | -17.3211 | 6.0243 | -0.0419 | 0.0552 | 1.1704 | 1.1724 | 1.1704 | Z |
| | 28 | 50.5948 | -12.4232 | 7.1784 | 50.6491 | -12.3458 | 6.0200 | -0.0543 | 0.0774 | 1.1584 | 1.1623 | 1.1584 | Z |
| | 29 | 50.7738 | -5.8238 | 7.0991 | 50.7506 | -5.6702 | 5.7478 | 0.0232 | 0.1536 | 1.3513 | 1.3602 | 1.3513 | Z |
| | 30 | 51.2459 | -2.0849 | 2.3552 | 51.1955 | -2.0517 | 0.9623 | 0.0504 | 0.0332 | 1.3929 | 1.3942 | 1.3929 | Z |

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

| Pretest Floor Pan | Posttest Floor Pan |
|---|---|
|  |  |

Figure E-18. Floor Pan Deformation Data – Set 1, Test No. HMDT-4

Model Year: 2016 | Test Name: HMDT-4 | VIN: KMHCT4AE9GU115037
Make: Hyundai | Model: Accent

**VEHICLE DEFORMATION**
**DRIVER SIDE INTERIOR CRUSH - SET 1**

| | POINT | Pretest X (in.) | Pretest Y (in.) | Pretest Z (in.) | Posttest X (in.) | Posttest Y (in.) | Posttest Z (in.) | ΔX[A] (in.) | ΔY[A] (in.) | ΔZ[A] (in.) | Total Δ (in.) | Crush[B] (in.) | Directions for Crush[C] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DASH (X, Y, Z) | 1 | 61.8788 | -23.2614 | -21.3513 | 61.2586 | -23.2021 | -23.5050 | 0.6202 | 0.0593 | -2.1537 | 2.2420 | 2.2420 | X, Y, Z |
| | 2 | 58.0667 | -11.9092 | -25.4575 | 57.5995 | -11.7049 | -27.3709 | 0.4672 | 0.2043 | -1.9134 | 1.9802 | 1.9802 | X, Y, Z |
| | 3 | 61.0863 | 2.1752 | -22.6280 | 60.7614 | 2.2140 | -24.2832 | 0.3249 | -0.0388 | -1.6552 | 1.6872 | 1.6872 | X, Y, Z |
| | 4 | 58.4389 | -20.7502 | -13.5066 | 57.8212 | -20.6279 | -15.6937 | 0.6177 | 0.1223 | -2.1871 | 2.2759 | 2.2759 | X, Y, Z |
| | 5 | 60.1913 | -12.2540 | -10.3225 | 59.8090 | -12.2695 | -12.1664 | 0.3823 | -0.0155 | -1.8439 | 1.8832 | 1.8832 | X, Y, Z |
| | 6 | 56.0044 | 1.8761 | -13.2410 | 55.7907 | 1.8634 | -14.8199 | 0.2137 | 0.0127 | -1.5789 | 1.5933 | 1.5933 | X, Y, Z |
| SIDE PANEL (Y) | 7 | 66.5741 | -25.2580 | -3.1981 | 65.8702 | -24.6764 | -5.3735 | 0.7039 | 0.5816 | -2.1754 | 2.3593 | 0.5816 | Y |
| | 8 | 66.2628 | -25.2643 | -0.7816 | 65.7854 | -24.7049 | -2.9365 | 0.4774 | 0.5594 | -2.1549 | 2.2769 | 0.5594 | Y |
| | 9 | 70.3797 | -25.3178 | -0.3142 | 69.4350 | -23.9085 | -2.4410 | 0.9447 | 1.4093 | -2.1268 | 2.7206 | 1.4093 | Y |
| IMPACT SIDE DOOR (Y) | 10 | 32.4059 | -26.6889 | -18.4509 | 31.6150 | -29.0880 | -19.0388 | 0.7909 | -2.3991 | -0.5879 | 2.5936 | -2.3991 | Y |
| | 11 | 47.6647 | -26.8535 | -17.0137 | 46.7154 | -28.6760 | -18.1812 | 0.9493 | -1.8225 | -1.1675 | 2.3634 | -1.8225 | Y |
| | 12 | 57.0836 | -26.7509 | -17.6871 | 56.0310 | -27.6302 | -19.2599 | 1.0526 | -0.8793 | -1.5728 | 2.0868 | -0.8793 | Y |
| | 13 | 34.2348 | -26.5222 | -3.1762 | 34.1830 | -27.2907 | -4.0828 | 0.0518 | -0.7685 | -0.9066 | 1.1896 | -0.7685 | Y |
| | 14 | 50.2610 | -27.1765 | -0.2128 | 50.2777 | -28.5704 | -1.6274 | -0.0167 | -1.3939 | -1.4146 | 1.9860 | -1.3939 | Y |
| | 15 | 60.6738 | -26.7540 | -0.6064 | 60.3017 | -27.1661 | -2.3963 | 0.3721 | -0.4121 | -1.7899 | 1.8740 | -0.4121 | Y |
| ROOF - (Z) | 16 | 47.3398 | -18.0241 | -36.7393 | 46.6401 | -18.3466 | -38.1644 | 0.6997 | -0.3225 | -1.4251 | 1.6200 | -1.4251 | Z |
| | 17 | 48.9935 | -9.0845 | -37.0968 | 48.2706 | -9.4221 | -38.4296 | 0.7229 | -0.3376 | -1.3328 | 1.5534 | -1.3328 | Z |
| | 18 | 49.4598 | 1.6087 | -37.2165 | 48.6983 | 1.3093 | -38.4216 | 0.7615 | 0.2994 | -1.2051 | 1.4566 | -1.2051 | Z |
| | 19 | 41.4069 | -17.9248 | -38.8244 | 40.6364 | -18.1780 | -40.0400 | 0.7705 | -0.2532 | -1.2156 | 1.4613 | -1.2156 | Z |
| | 20 | 43.0506 | -8.5066 | -39.1912 | 42.2799 | -8.7711 | -40.3670 | 0.7707 | -0.2645 | -1.1758 | 1.4305 | -1.1758 | Z |
| | 21 | 43.7409 | 1.2081 | -39.3136 | 43.0042 | 0.8724 | -40.3881 | 0.7367 | 0.3357 | -1.0745 | 1.3454 | -1.0745 | Z |
| | 22 | 26.7616 | -16.9377 | -40.1398 | 25.9684 | -17.1089 | -40.6121 | 0.7932 | -0.1712 | -0.4723 | 0.9389 | -0.4723 | Z |
| | 23 | 26.5534 | -8.7966 | -40.7023 | 25.7433 | -9.0009 | -41.4454 | 0.8101 | -0.2043 | -0.7431 | 1.1181 | -0.7431 | Z |
| | 24 | 26.4062 | -0.2794 | -40.9528 | 25.5768 | -0.4679 | -41.6418 | 0.8294 | -0.1885 | -0.6890 | 1.0946 | -0.6890 | Z |
| | 25 | 10.4216 | -16.4474 | -39.4173 | 9.5975 | -16.6756 | -39.6251 | 0.8241 | -0.2282 | -0.2078 | 0.8800 | -0.2078 | Z |
| | 26 | 10.3140 | -9.2030 | -39.9228 | 9.5093 | -9.3418 | -40.2117 | 0.8047 | -0.1388 | -0.2889 | 0.8662 | -0.2889 | Z |
| | 27 | 10.0590 | -0.8764 | -40.1661 | 9.2994 | -1.0688 | -40.4385 | 0.7596 | -0.1924 | -0.2724 | 0.8296 | -0.2724 | Z |
| | 28 | -2.5308 | -16.2233 | -37.2469 | -3.3145 | -16.3738 | -37.2348 | 0.7837 | -0.1505 | 0.0121 | 0.7981 | 0.0121 | Z |
| | 29 | -3.4047 | -10.0195 | -37.5810 | -4.1667 | -10.1636 | -37.5510 | 0.7620 | -0.1441 | 0.0300 | 0.7761 | 0.0300 | Z |
| | 30 | -3.9513 | -1.5982 | -37.8082 | -4.6877 | -1.7441 | -37.7665 | 0.7364 | -0.1459 | 0.0417 | 0.7519 | 0.0417 | Z |
| A-PILLAR Maximum (X, Y, Z) | 31 | 68.6827 | -24.6917 | -25.4574 | 68.2548 | -24.8611 | -27.4677 | 0.4279 | -0.1694 | -2.0103 | 2.0623 | 0.4279 | X |
| | 32 | 64.0156 | -23.8142 | -27.3176 | 63.6124 | -23.9828 | -29.3750 | 0.4032 | -0.1686 | -2.0574 | 2.1033 | 0.4032 | X |
| | 33 | 59.6072 | -22.9028 | -29.6350 | 59.0811 | -23.4704 | -31.6836 | 0.5261 | -0.5676 | -2.0486 | 2.1899 | 0.5261 | X |
| | 34 | 57.2269 | -22.3310 | -31.3704 | 56.7049 | -22.7324 | -33.3157 | 0.5220 | -0.4014 | -1.9453 | 2.0537 | 0.5220 | X |
| | 35 | 54.7116 | -21.7637 | -32.4624 | 54.0822 | -22.1201 | -34.2684 | 0.6294 | -0.3564 | -1.8060 | 1.9455 | 0.6294 | X |
| | 36 | 49.8961 | -20.7752 | -35.0428 | 49.1661 | -21.1218 | -36.6769 | 0.7300 | -0.3466 | -1.6341 | 1.8230 | 0.7300 | X |
| A-PILLAR Lateral (Y) | 31 | 68.6827 | -24.6917 | -25.4574 | 68.2548 | -24.8611 | -27.4677 | 0.4279 | -0.1694 | -2.0103 | 2.0623 | -0.1694 | Y |
| | 32 | 64.0156 | -23.8142 | -27.3176 | 63.6124 | -23.9828 | -29.3750 | 0.4032 | -0.1686 | -2.0574 | 2.1033 | -0.1686 | Y |
| | 33 | 59.6072 | -22.9028 | -29.6350 | 59.0811 | -23.4704 | -31.6836 | 0.5261 | -0.5676 | -2.0486 | 2.1899 | -0.5676 | Y |
| | 34 | 57.2269 | -22.3310 | -31.3704 | 56.7049 | -22.7324 | -33.3157 | 0.5220 | -0.4014 | -1.9453 | 2.0537 | -0.4014 | Y |
| | 35 | 54.7116 | -21.7637 | -32.4624 | 54.0822 | -22.1201 | -34.2684 | 0.6294 | -0.3564 | -1.8060 | 1.9455 | -0.3564 | Y |
| | 36 | 49.8961 | -20.7752 | -35.0428 | 49.1661 | -21.1218 | -36.6769 | 0.7300 | -0.3466 | -1.6341 | 1.8230 | -0.3466 | Y |
| B-PILLAR Maximum (X, Y, Z) | 37 | 23.0019 | -20.8545 | -33.4280 | 22.3279 | -21.0965 | -34.0088 | 0.6740 | -0.2420 | -0.5808 | 0.9220 | 0.6740 | X |
| | 38 | 25.9120 | -21.6163 | -31.7953 | 25.2771 | -21.9015 | -32.4058 | 0.6349 | -0.2852 | -0.6105 | 0.9258 | 0.6349 | X |
| | 39 | 23.4303 | -22.3249 | -29.8510 | 22.7832 | -22.5539 | -30.4372 | 0.6471 | -0.2290 | -0.5862 | 0.9027 | 0.6471 | X |
| | 40 | 27.2689 | -23.8569 | -25.9538 | 26.6684 | -24.1214 | -26.5892 | 0.6005 | -0.2645 | -0.6354 | 0.9134 | 0.6005 | X |
| B-PILLAR Lateral (Y) | 37 | 23.0019 | -20.8545 | -33.4280 | 22.3279 | -21.0965 | -34.0088 | 0.6740 | -0.2420 | -0.5808 | 0.9220 | -0.2420 | Y |
| | 38 | 25.9120 | -21.6163 | -31.7953 | 25.2771 | -21.9015 | -32.4058 | 0.6349 | -0.2852 | -0.6105 | 0.9258 | -0.2852 | Y |
| | 39 | 23.4303 | -22.3249 | -29.8510 | 22.7832 | -22.5539 | -30.4372 | 0.6471 | -0.2290 | -0.5862 | 0.9027 | -0.2290 | Y |
| | 40 | 27.2689 | -23.8569 | -25.9538 | 26.6684 | -24.1214 | -26.5892 | 0.6005 | -0.2645 | -0.6354 | 0.9134 | -0.2645 | Y |

[A] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[B] Crush calculations that use multiple directional components will disregard components that are negative and only include positive values where the component is deforming inward toward the occupant compartment.

[C] Direction for Crush column denotes which directions are included in the crush calculations. If "NA" then no intrusion is recorded, and Crush will be 0.

Figure E-19. Occupant Compartment Deformation Data – Set 1, Test No. HMDT-4

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Model Year: 2016 | | Test Name: HMDT-4 | | VIN: KMHCT4AE9GU115037 | | | |
| | | Make: Hyundai | | Model: Accent | | | |

| Driver Side Maximum Deformations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Reference Set 1 | | | | | Reference Set 2 | | | |
| Location | Maximum Deformation[A,B] (in.) | MASH Allowable Deformation (in.) | Directions of Deformation[C] | | Location | Maximum Deformation[A,B] (in.) | MASH Allowable Deformation (in.) | Directions of Deformation[C] |
| Roof | 0.0 | ≤ 4 | Z | | Roof | 0.0 | ≤ 4 | Z |
| Windshield[D] | 1.0 | ≤ 3 | X, Z | | Windshield[D] | NA | ≤ 3 | X, Z |
| A-Pillar Maximum | 0.7 | ≤ 5 | X | | A-Pillar Maximum | 0.0 | ≤ 5 | NA |
| A-Pillar Lateral | -0.6 | ≤ 3 | Y | | A-Pillar Lateral | 0.0 | ≤ 3 | Y |
| B-Pillar Maximum | 0.7 | ≤ 5 | X | | B-Pillar Maximum | 0.0 | ≤ 5 | NA |
| B-Pillar Lateral | -0.6 | ≤ 3 | Y | | B-Pillar Lateral | 0.0 | ≤ 3 | Y |
| Toe Pan - Wheel Well | 2.6 | ≤ 9 | X, Z | | Toe Pan - Wheel Well | 0.0 | ≤ 9 | NA |
| Side Front Panel | 1.4 | ≤ 12 | Y | | Side Front Panel | 0.0 | ≤ 12 | Y |
| Side Door (above seat) | -2.4 | ≤ 9 | Y | | Side Door (above seat) | 0.0 | ≤ 9 | Y |
| Side Door (below seat) | -1.4 | ≤ 12 | Y | | Side Door (below seat) | 0.0 | ≤ 12 | Y |
| Floor Pan | 1.6 | ≤ 12 | Z | | Floor Pan | 0.0 | ≤ 12 | Z |
| Dash - no MASH requirement | 2.3 | NA | X, Y, Z | | Dash - no MASH requirement | 2.3 | NA | X, Y, Z |

[A] Items highlighted in red do not meet MASH allowable deformations.

[B] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

[C] For Toe Pan - Wheel Well the direction of defromation may include X and Z direction. For A-Pillar Maximum and B-Pillar Maximum the direction of deformation may include X, Y, and Z directions. The direction of deformation for Toe Pan -Wheel Well, A-Pillar Maximum, and B-Pillar Maximum only include components where the deformation is positive and intruding into the occupant compartment. If direction of deformation is "NA" then no intrusion is recorded and deformation will be 0.

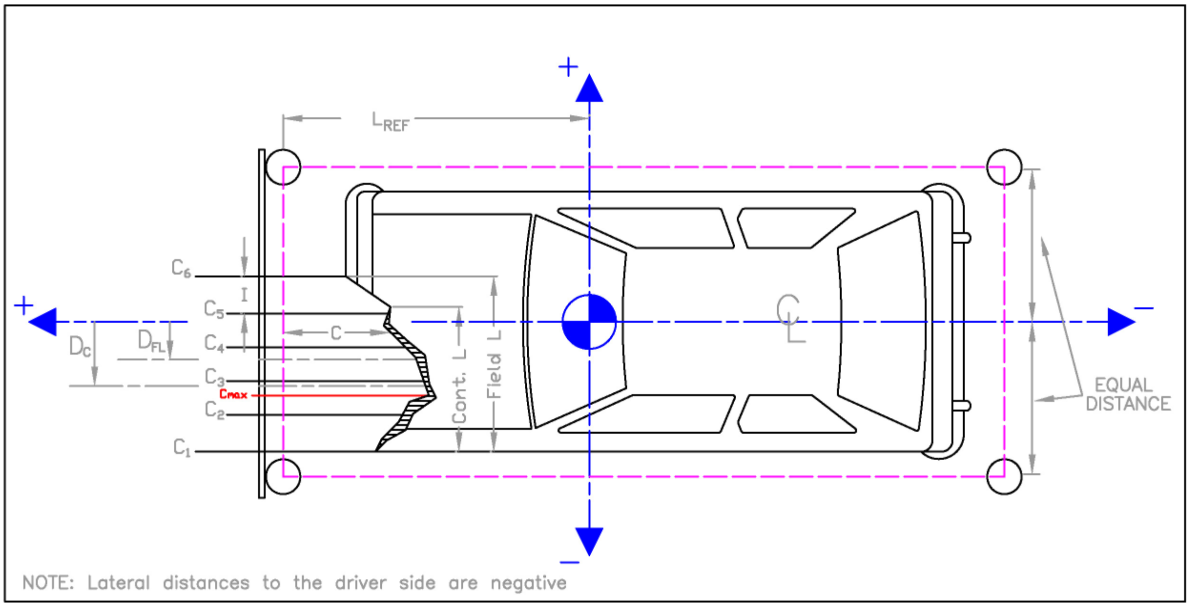
[D] If deformation is observered for the windshield then the windshield deformation is measured posttest with an examplar vehicle, therefore only one set of reference is measured and recorded.

**Notes on vehicle crush:**

The secondary set of reference points were compromised and therefore measurements were omitted.

Figure E-20. Maximum Occupant Compartment Deformation by Location, Test No. HMDT-4

| | | | | | |
|---|---|---|---|---|---|
| | | Test Name: | HMDT-4 | VIN: | KMHCT4AE9GU115037 |
| Model Year: | 2016 | Make: | Hyundai | Model: | Accent |



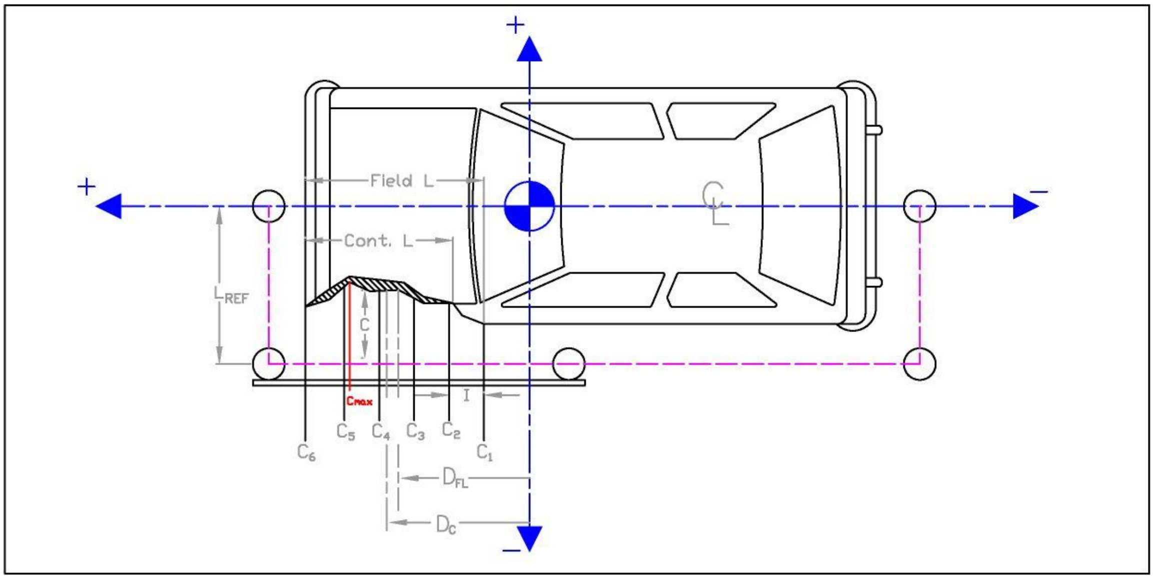

| | in. | (mm) |
|---|---|---|
| Distance from C.G. to reference line - $L_{REF}$: | 84 | (2134) |
| Total Width of Vehicle: | 66 1/4 | (1683) |
| Width of contact and induced crush - Field L: | 66 1/4 | (1683) |
| Crush measurement spacing interval (L/5) - I: | 13 1/4 | (337) |
| Distance from center of vehicle to center of Field L - $D_{FL}$: | 0 | () |
| Width of Contact Damage: | 66 1/4 | (1683) |
| Distance from center of vehicle to center of contact damage - $D_C$: | 0 | () |

NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

| Crush Measurement | | | Lateral Location | | Original Profile Measurement | | Dist. Between Ref. Lines | | Actual Crush | |
|---|---|---|---|---|---|---|---|---|---|---|
| | in. | (mm) | in. | (mm) | in. | (mm) | in. | (mm) | in. | (mm) |
| $C_1$ | N/A | NA | -33 1/8 | -(841) | 15 5/8 | (397) | 9 1/4 | (235) | NA | NA |
| $C_2$ | 22 5/8 | (575) | -19 7/8 | -(505) | 6 7/8 | (175) | | | 6 1/2 | (165) |
| $C_3$ | 18 3/8 | (467) | -6 5/8 | -(168) | 4 3/8 | (111) | | | 4 3/4 | (121) |
| $C_4$ | 16 7/8 | (429) | 6 5/8 | (168) | 4 1/2 | (114) | | | 3 1/8 | (79) |
| $C_5$ | 17 1/4 | (438) | 19 7/8 | (505) | 6 3/4 | (171) | | | 1 1/4 | (32) |
| $C_6$ | N/A | NA | 33 1/8 | (841) | 15 5/8 | (397) | | | NA | NA |
| $C_{MAX}$ | 33 3/4 | (857) | 23 3/4 | (603) | 8 5/8 | (219) | | | 15 7/8 | (403) |

Figure E-21. Exterior Vehicle Crush (NASS) - Front, Test No. HMDT-4

| | | | | | |
|---|---|---|---|---|---|
| | | Test Name: | HMDT-4 | VIN: | KMHCT4AE9GU115037 |
| Model Year: | 2016 | Make: | Hyundai | Model: | Accent |




| | in. | (mm) |
|---|---|---|
| Distance from centerline to reference line - $L_{REF}$: | 38 | (965) |
| Total Vehicle Length: | 171 7/8 | (4366) |
| Distance from vehicle c.g. to 1/2 of Vehicle total length: | -16 1/3 | -(414) |
| Width of contact and induced crush - Field L: | 171 7/8 | (4366) |
| Crush measurement spacing interval (L/5) - I: | 34 3/8 | (873) |
| Distance from vehicle c.g. to center of Field L - $D_{FL}$: | -16 1/3 | -(415) |
| Width of Contact Damage: | 171 7/8 | (4366) |
| Distance from vehicle c.g. to center of contact damage - $D_C$: | -16 1/3 | -(415) |

NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., front of vehicle has been pushed inward or tire has been removed)
NOTE: All values must be filled out above before crush measurements are filled out.

| | Crush Measurement | | Longitudinal Location | | Original Profile Measurement | | Dist. Between Ref. Lines | | Actual Crush | |
|---|---|---|---|---|---|---|---|---|---|---|
| | in. | (mm) | in. | (mm) | in. | (mm) | in. | (mm) | in. | (mm) |
| $C_1$ | N/A | NA | -102 1/4 | -(2597) | 41 1/4 | (1048) | -3 1/4 | -(83) | NA | NA |
| $C_2$ | N/A | NA | -67 7/8 | -(1724) | 7 | (178) | | | NA | NA |
| $C_3$ | 4 1/4 | (108) | -33 1/2 | -(851) | 8 1/8 | (206) | | | - 5/8 | -(16) |
| $C_4$ | 2 3/8 | (60) | 7/8 | (22) | 8 1/4 | (210) | | | -2 5/8 | -(67) |
| $C_5$ | N/A | NA | 35 1/4 | (895) | 7 | (178) | | | NA | NA |
| $C_6$ | N/A | NA | 69 5/8 | (1768) | 27 1/2 | (699) | | | NA | NA |
| $C_{MAX}$ | 19 | (483) | 57 | (1448) | 9 | (229) | | | 13 1/4 | (337) |

Figure E-22. Exterior Vehicle Crush (NASS) - Side, Test No. HMDT-4

# Appendix F. Accelerometer and Rate Transducer Data Plots, Test No. HMDT-1

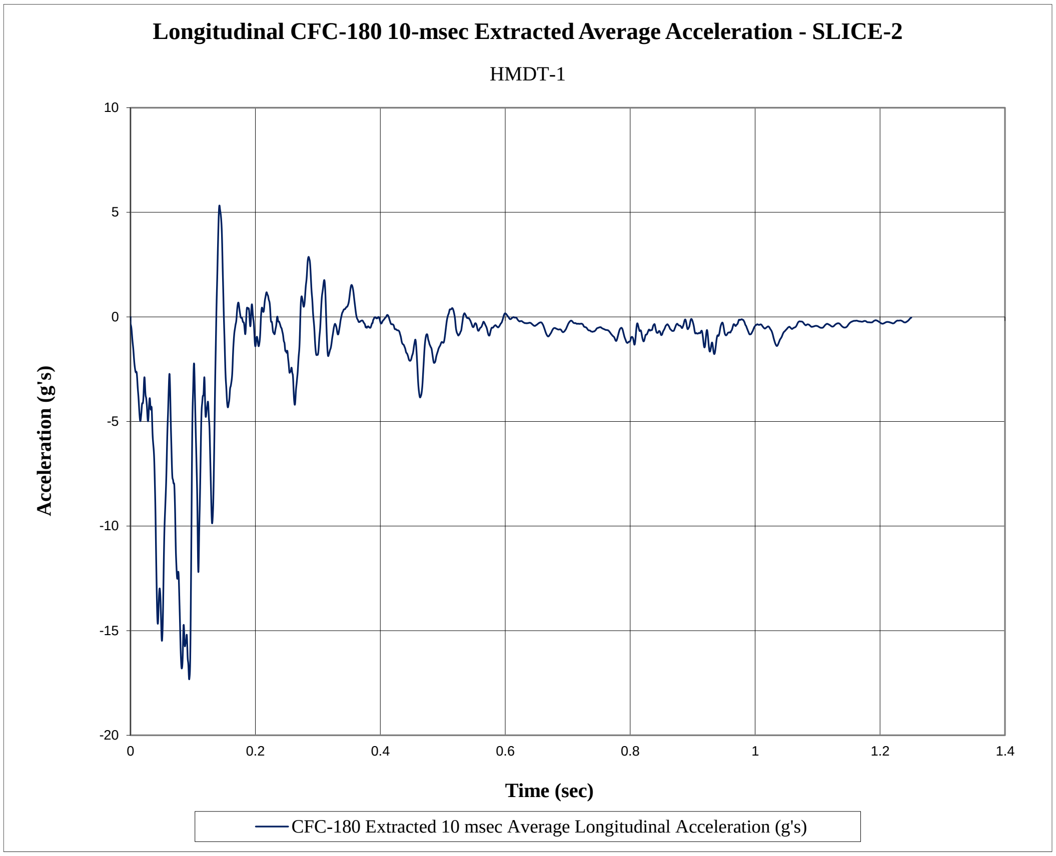



Figure F-1. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. HMDT-1

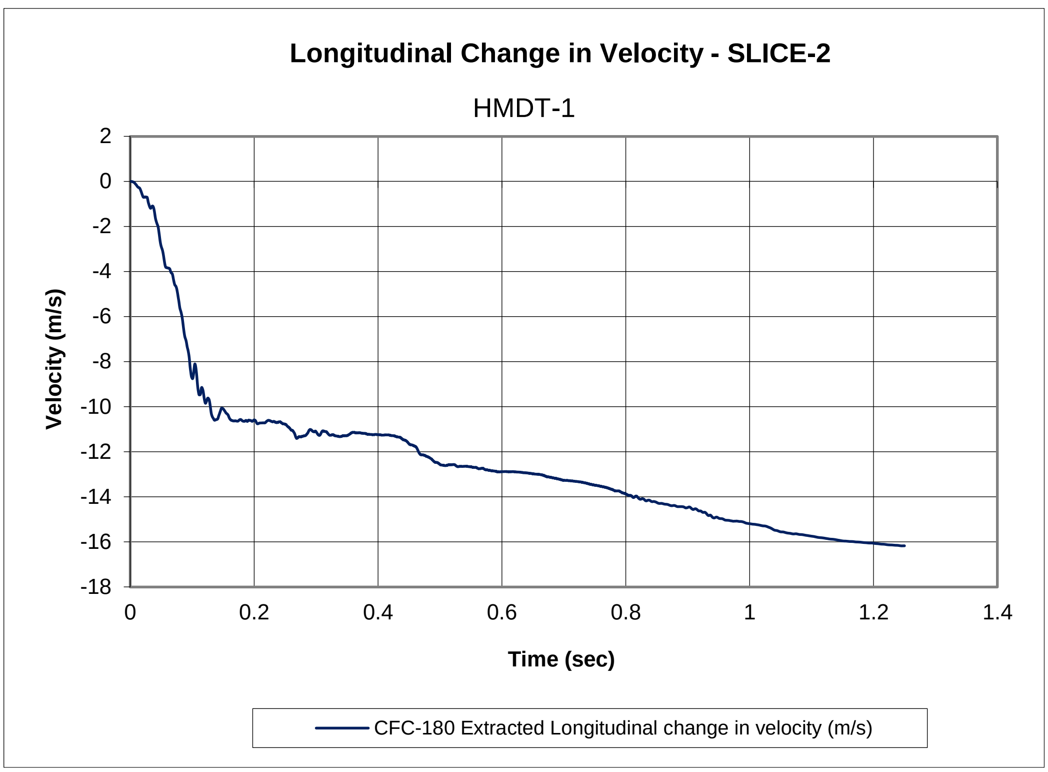



Figure F-2. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. HMDT-1

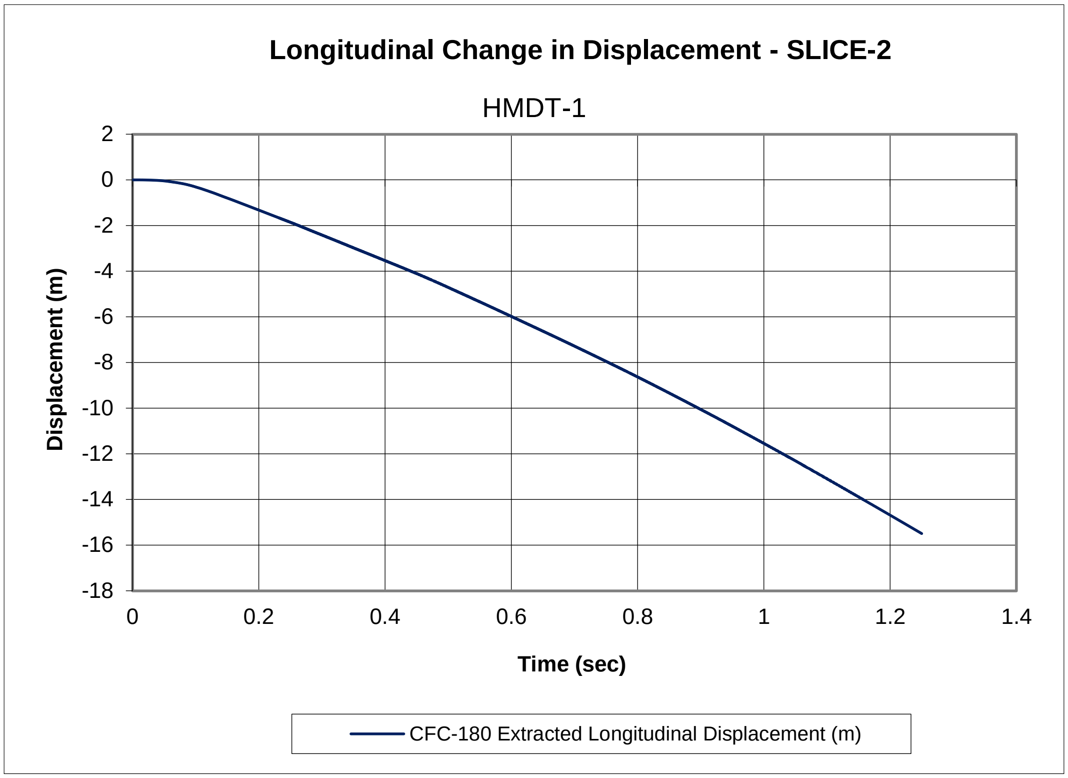



Figure F-3. Longitudinal Occupant Displacement (SLICE-2), Test No. HMDT-1

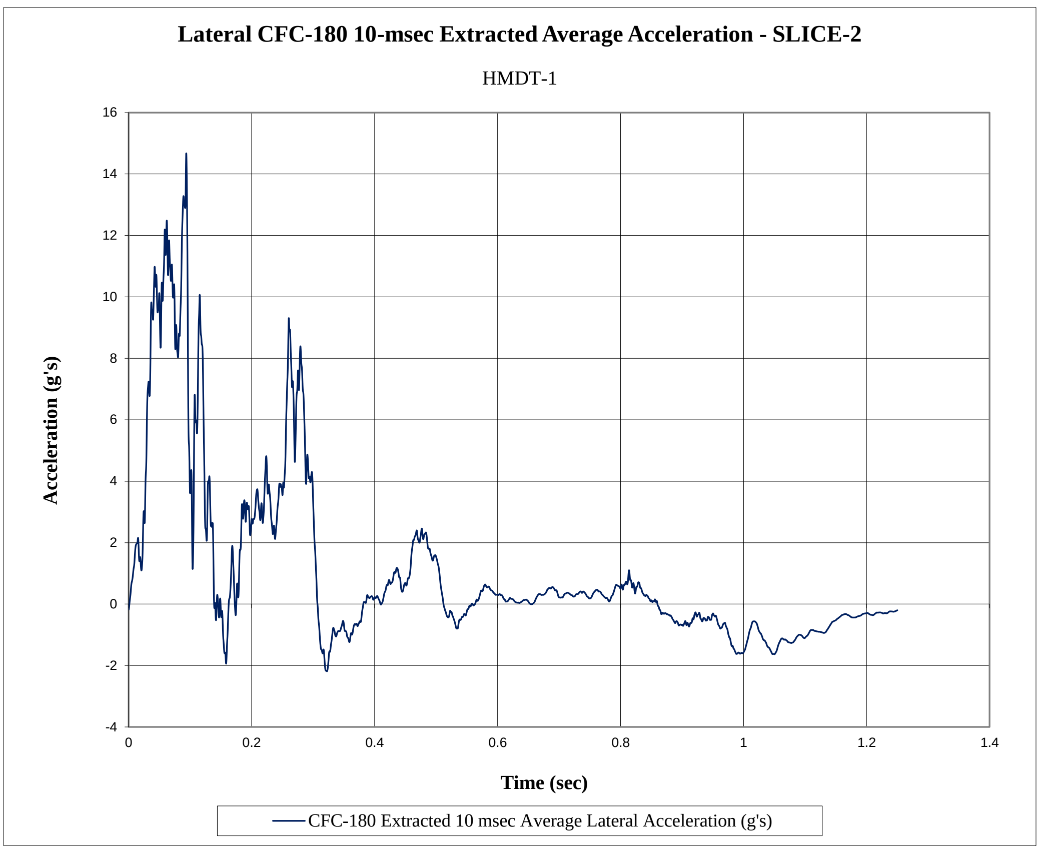



Figure F-4. 10-ms Average Lateral Deceleration (SLICE-2), Test No. HMDT-1

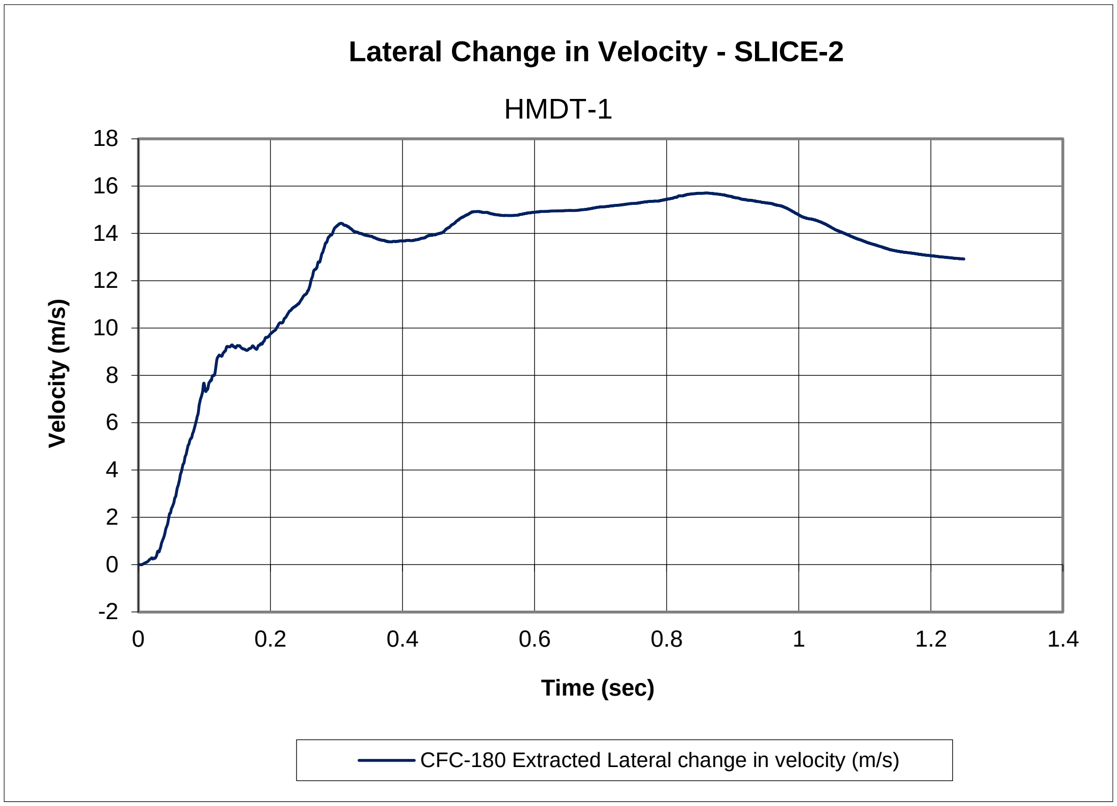



Figure F-5. Lateral Occupant Impact Velocity (SLICE-2), Test No. HMDT-1

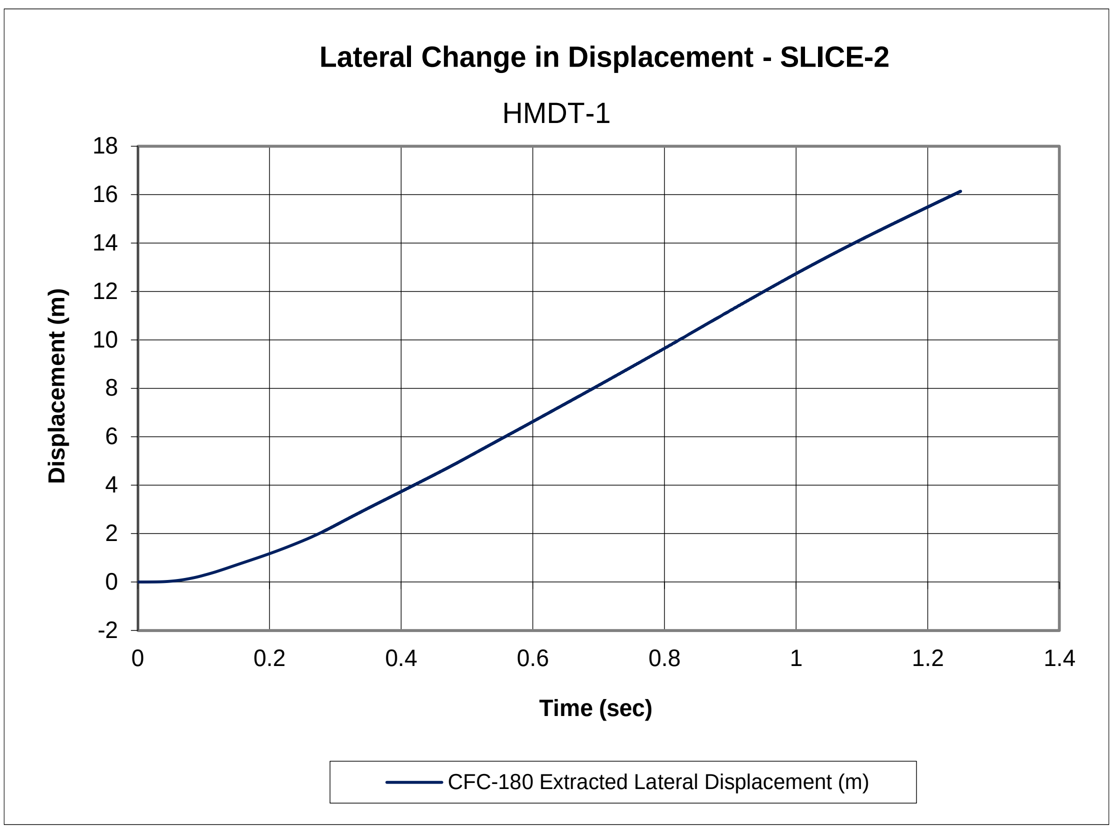



Figure F-6. Lateral Occupant Displacement (SLICE-2), Test No. HMDT-1

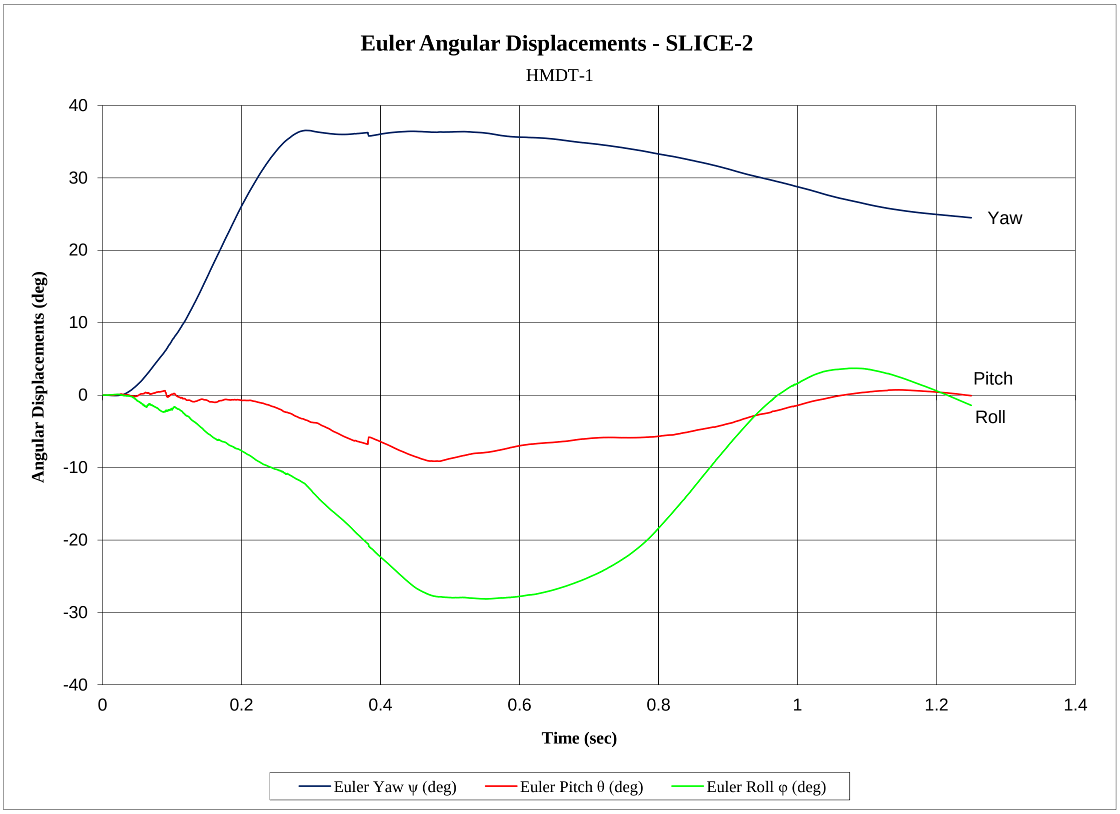



Figure F-7. Vehicle Angular Displacements (SLICE-2), Test No. HMDT-1

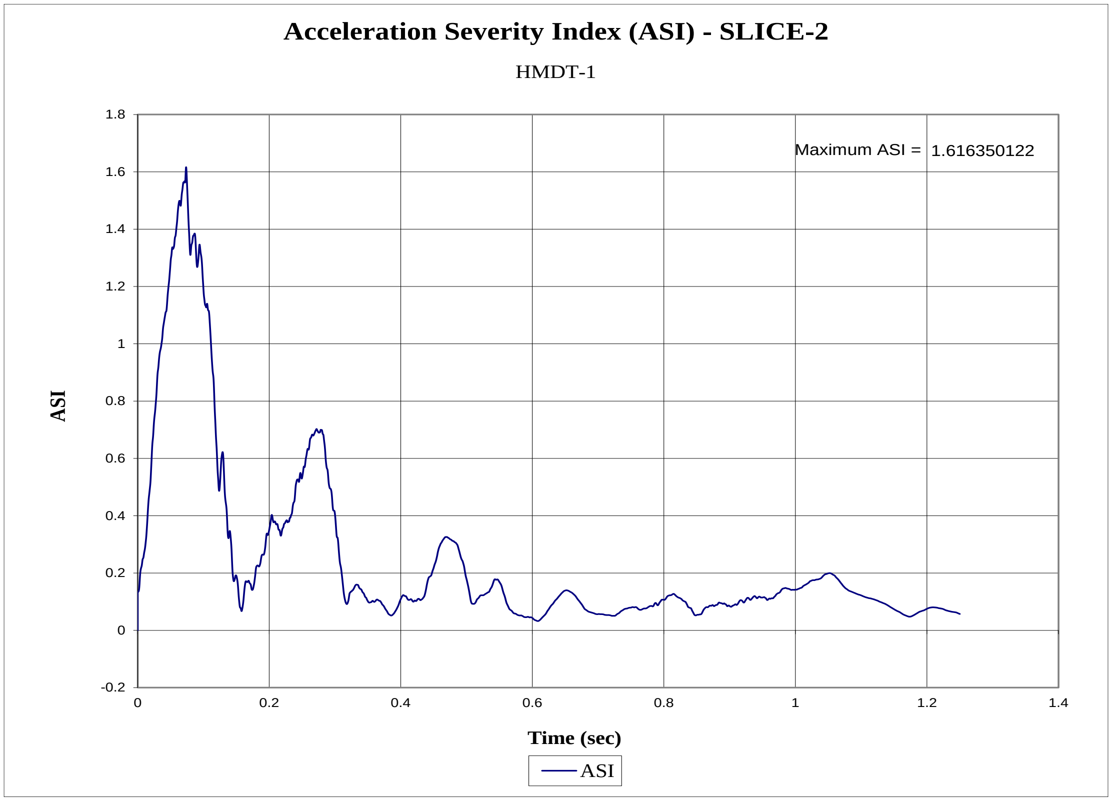



Figure F-8. Acceleration Severity Index (SLICE-2), Test No. HMDT-1

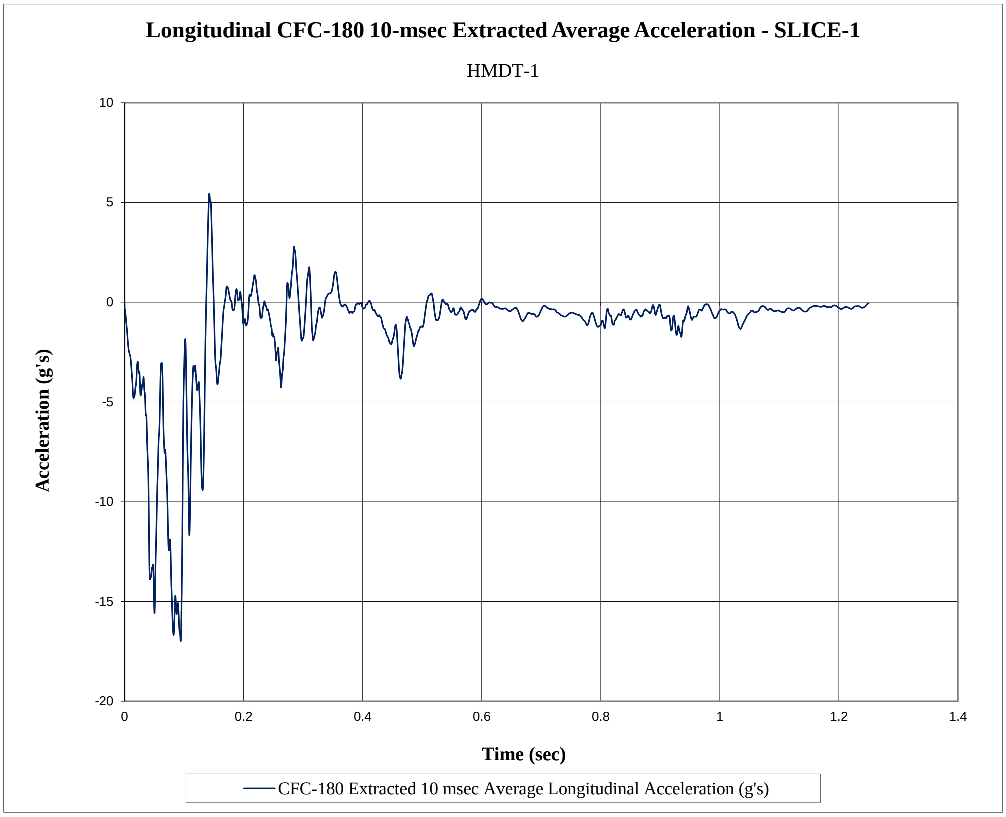



Figure F-9. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. HMDT-1

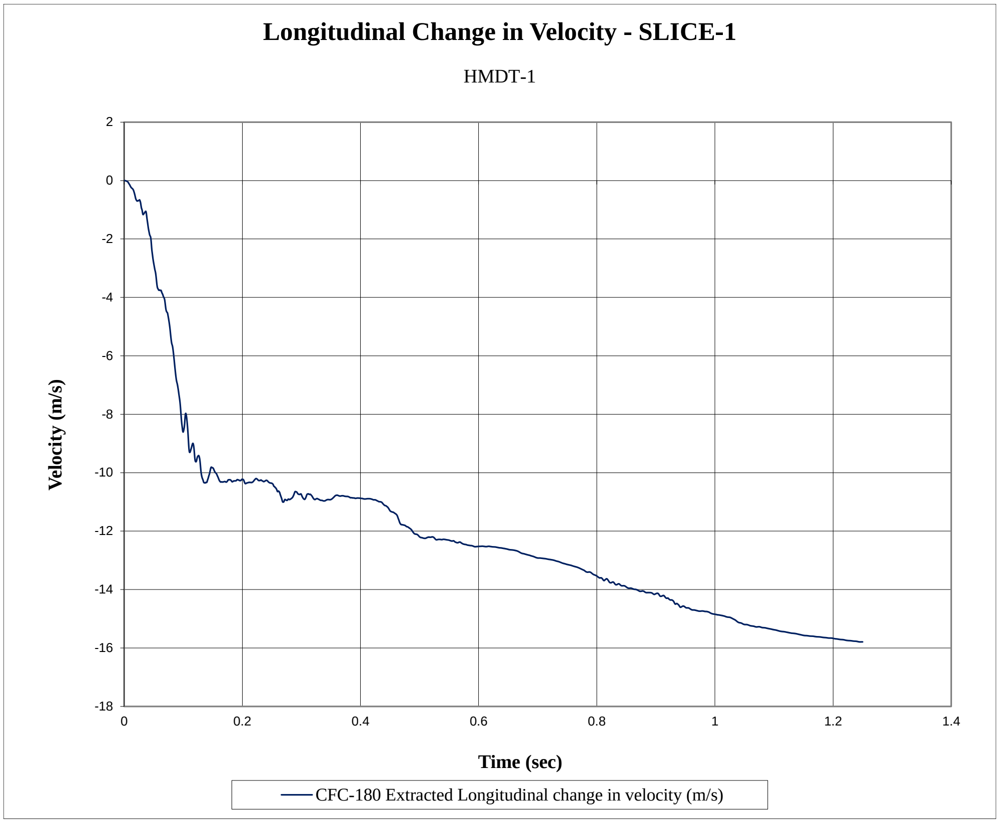



Figure F-10. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. HMDT-1

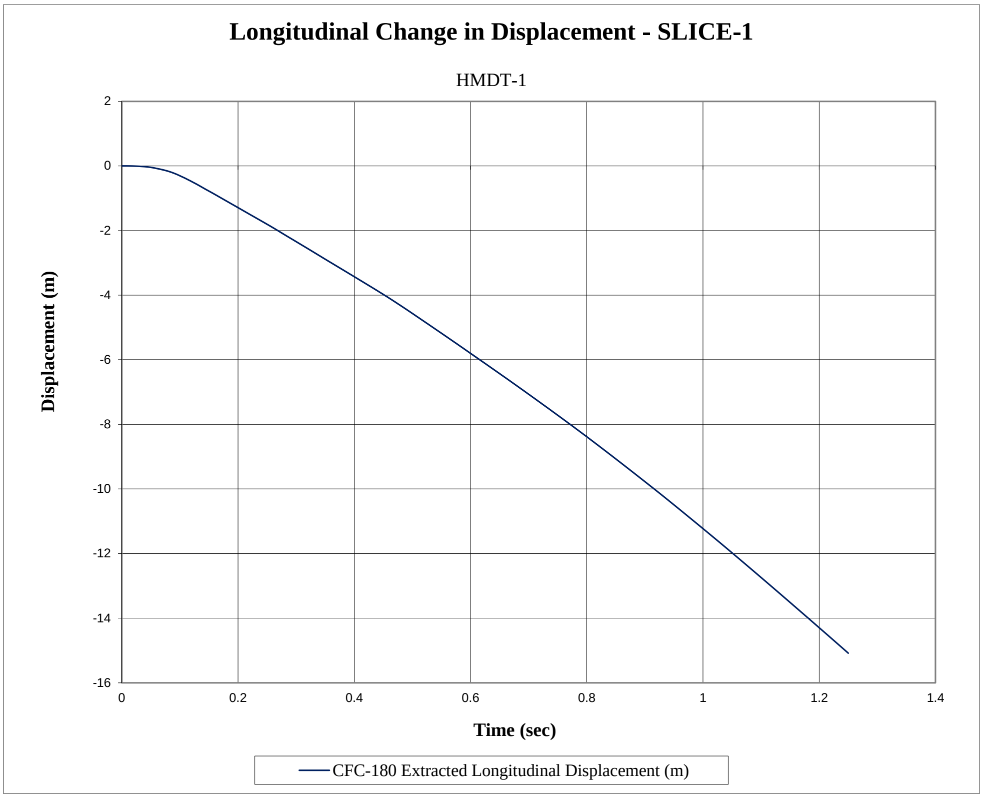



Figure F-11. Longitudinal Occupant Displacement (SLICE-1), Test No. HMDT-1

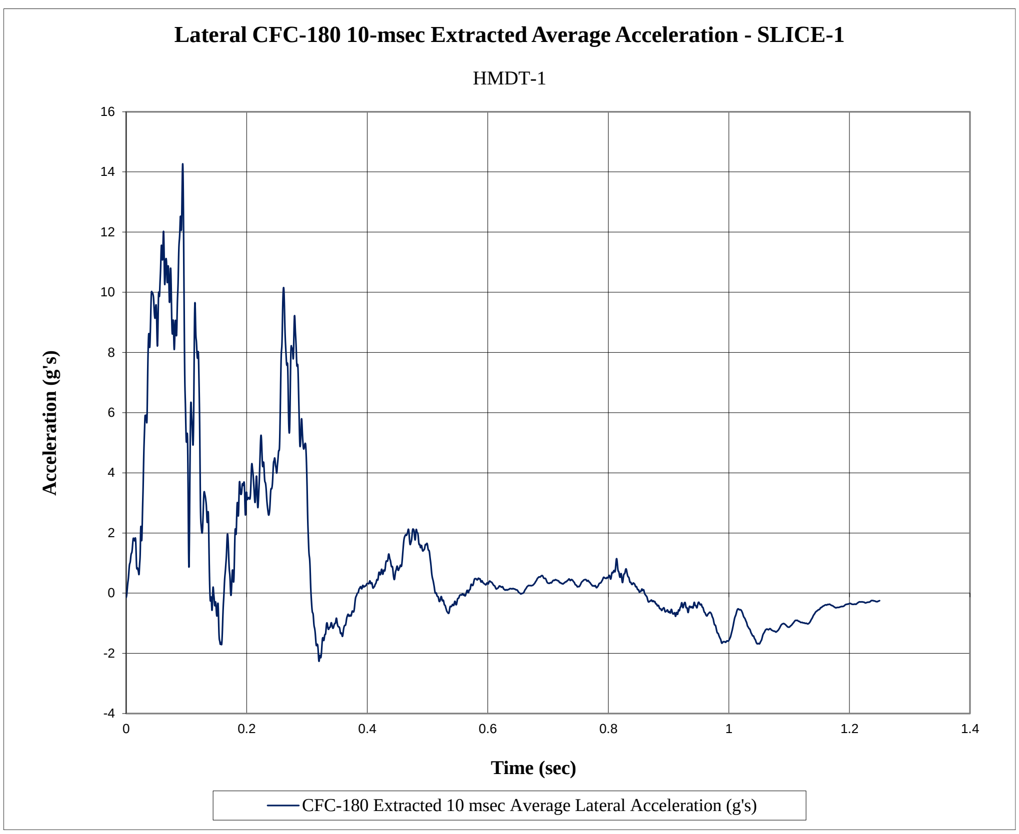



Figure F-12. 10-ms Average Lateral Deceleration (SLICE-1), Test No. HMDT-1

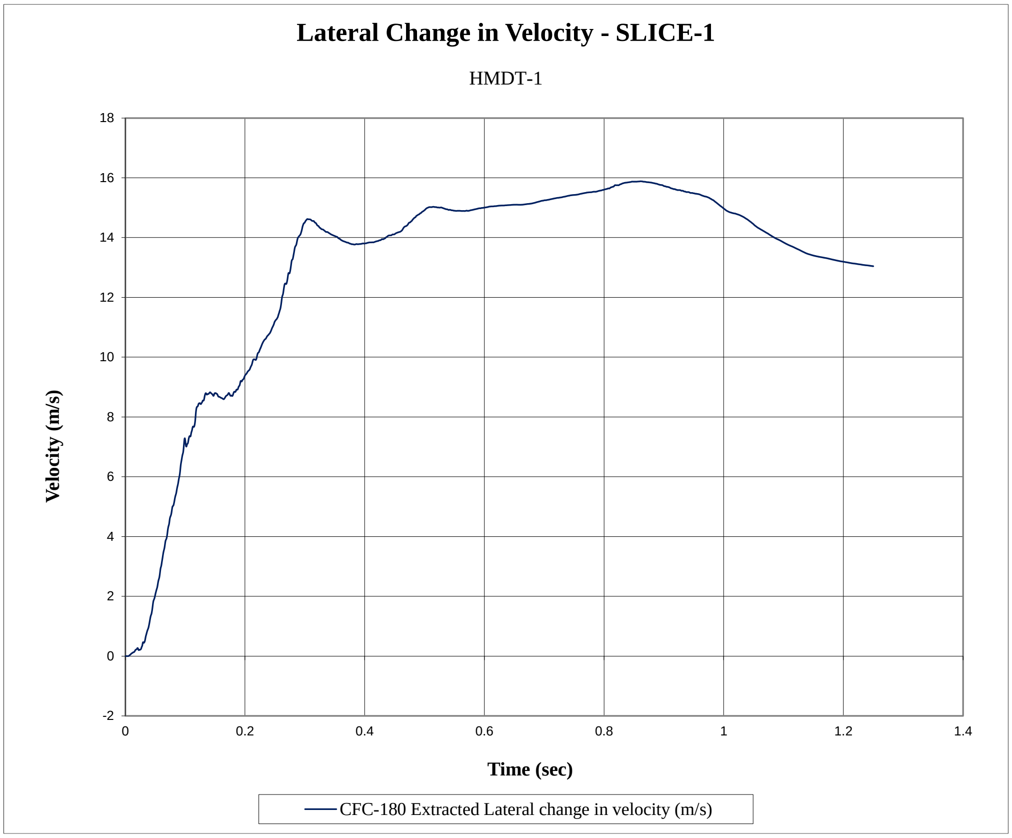



Figure F-13. Lateral Occupant Impact Velocity (SLICE-1), Test No. HMDT-1

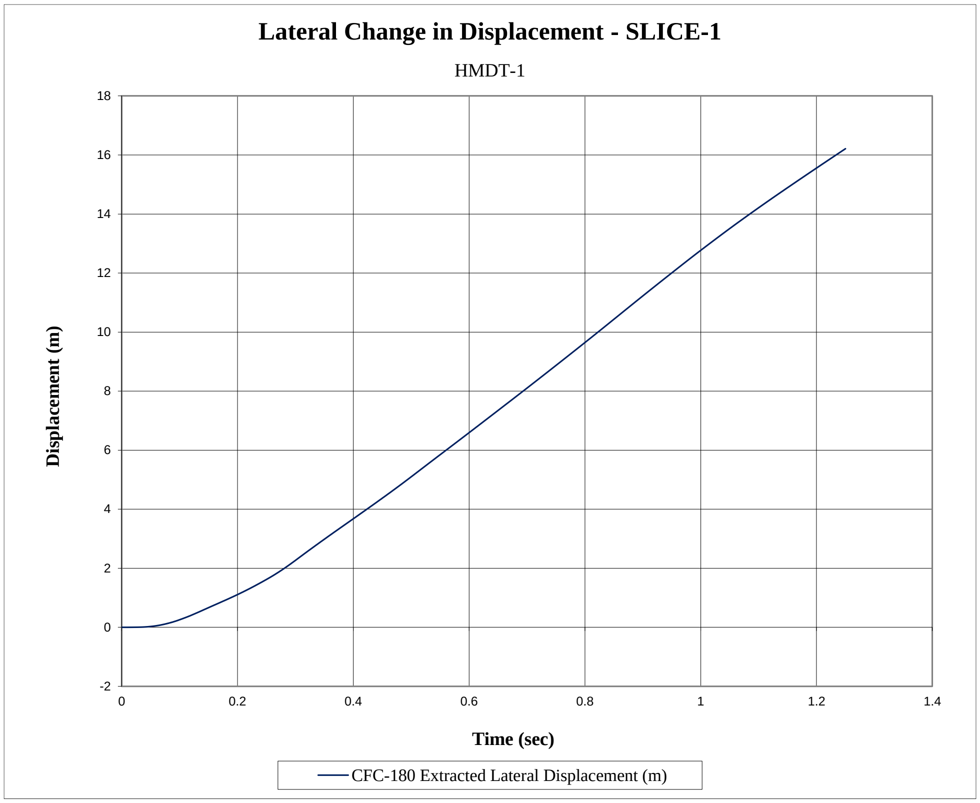



Figure F-14. Lateral Occupant Displacement (SLICE-1), Test No. HMDT-1

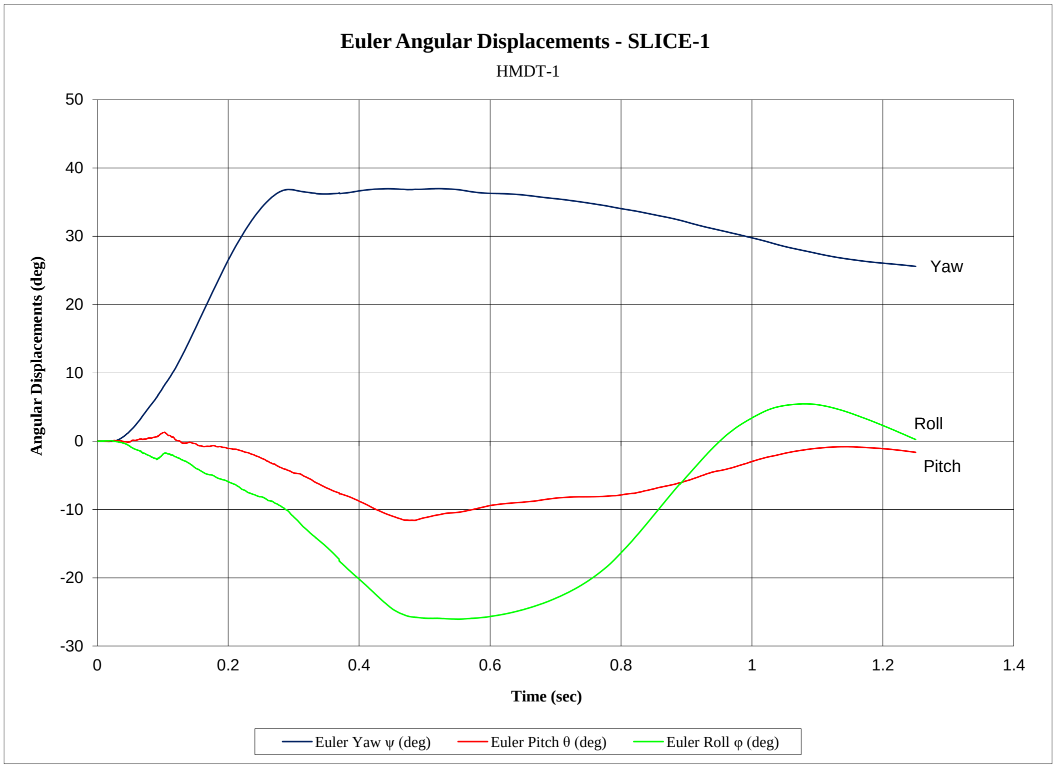



Figure F-15. Vehicle Angular Displacements (SLICE-1), Test No. HMDT-1

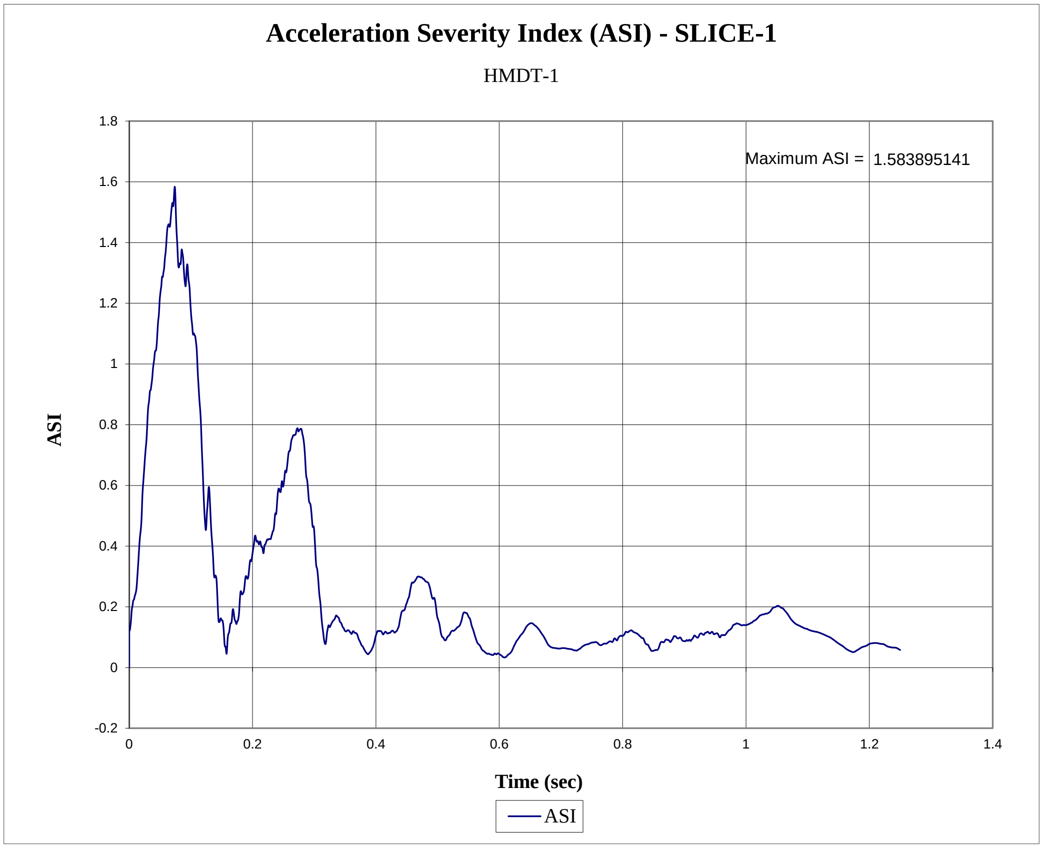



Figure F-16. Acceleration Severity Index (SLICE-1), Test No. HMDT-1

# Appendix G. Material Specifications, Test No. HMDT-2 and HMDT-3

Table G-1. Bill of Materials, Test Nos. HMDT-2 and HMDT-3

| Item No. | Description | Material Specification | Reference |
|---|---|---|---|
| a1 | 12'-6" 12-gauge Thrie Beam Section | AASHTO M180 | H#L32420 |
| a2 | 6'-3" 12-gauge Thrie Beam Section | AASHTO M180 | H#L34919 |
| a3 | 6'-3" 10-gauge W-Beam to Thrie-Beam Asymmetric Transition Section | AASHTO M180 | H#240680 |
| a4 | 12'-6" 12-gauge W-Beam MGS Section | AASHTO M180 | H#C85187 |
| a5 | 12'-6" 12-gauge W-Beam MGS End Section | AASHTO M180 | H#C85187 |
| c1 | BCT Timber Post - MGS Height | SYP Grade No. 1 or better (No knots +/- 18" from ground on tension face) | Ch#26224 |
| c2 | 72" Long Foundation Tube | ASTM A500 Gr. B | H#821T08220 |
| c3 | Ground Strut Assembly | ASTM A36 | H#163375 |
| c4 | BCT Anchor Cable End Swaged Fitting | Fitting - ASTM A576 Gr. 1035; Stud - ASTM F568 Class C | PO#40299<br>ASPI# 122160 |
| c5 | BCT Cable Anchor Assembly | - | PO#40299<br>ASPI# 122160 |
| c6 | 8"x8"x⅝" Anchor Bearing Plate | ASTM A36 | H#4181496 |
| c7 | 2⅜" O.D. x 6" Long BCT Post Sleeve | ASTM A53 Gr. B Schedule 40 | H#B712810 |
| c8 | Anchor Bracket Assembly | ASTM A36 | H#JK16101488 |
| d1 | W6x9 or W6x8.5, 72" Long Steel Post | ASTM A992 | H#55064803.02 |
| d2 | W6x9 or W6x8.5, 72" Long Steel Post | ASTM A992 | H#5564803.02 |
| d3 | W6x15, 78" Long Steel Post | ASTM A992 | H#58042771.02 |
| d4 | 17½" Long, 8"x6"x¼" Steel Blockout | ASTM A500 Gr. B | H#A97575 |
| d5 | 17½" Long, 12"x4"x¼" Steel Blockout | ASTM A500 Gr. B | H#2202349<br>H#SK1852 |
| d6 | 14³⁄₁₆"x12"x5⅛" Composite Recycled Blockout | Mondo Polymer MGS14SH or Equivalent | L#1904/1000 |
| d7 | 14³⁄₁₆"x8"x5⅛" Composite Recycled Blockout | Mondo Polymer GB14SH2 or Equivalent | L#1804/1000 |
| d8 | 16D Double Head Nail | Galvanized | Certificate of Compliance for PO E000548963 |
| e3 | #4 Rebar, 16" Total Length | ASTM A615 Gr. 60 | H#7006848 |
| e4 | #4 Rebar, 12¾" Total Length | ASTM A615 Gr. 60 | H#7006848 |
| e5 | #5 Rebar, 166" Total Length | ASTM A615 Gr. 60 | H#3600014140<br>H#62150922.02 |

Table G-2. Bill of Materials, Test Nos. HMDT-2 and HMDT-3, Cont.

| Item No. | Description | Material Specification | Reference |
|---|---|---|---|
| e6 | #5 Rebar, 158¼" Total Unbent Length | ASTM A615 Gr. 60 | H#3600014140<br>H#62150922.02 |
| f1 | ⅝"-11 UNC, 14" Long Guardrail Bolt | ASTM A307 Gr. A | H#DL17100590<br>H#100104009 |
| f2 | ⅝"-11 UNC, 10" Long Guardrail Bolt | ASTM A307 Gr. A | H#1721198 |
| f3 | ⅝"-11 UNC, 1 1/4" Long Guardrail Bolt | ASTM A307 Gr. A | H#10657410 |
| f4 | ⅝"-11 UNC, 10" Long Hex Head Bolt | ASTM A307 Gr. A or equivalent | H#JK18104124 |
| f5 | ⅝"-11 UNC, 1 1/2" Long Hex Head Bolt | ASTM A307 Gr. A or equivalent | H#5-01570 |
| f6 | ⅞"-9 UNC, 8" Long Hex Head Bolt | ASTM A307 Gr. A or equivalent | H#489517 |
| g1 | ⅝" Dia. Plain USS Washer | ASTM F844 | P#1133185<br>C#180164126<br>L#M-SWE0412454-8 |
| g3 | ⅞" Dia. Plain Round Washer | ASTM F844 | P#33187<br>C#170089822<br>L#1844804 |
| g4 | 1" Dia. Plain USS Washer | ASTM F844 | P#33188<br>C#210151571 |
| h1 | ⅝"-11 UNC Heavy Hex Nut | ASTM A563A or equivalent | H#62151324.02<br>H#62152527.02 |
| h3 | ⅞"-9 UNC Hex Nut | ASTM A563A or equivalent | P#36717<br>C#210167591<br>L#1N18BC001<br>L#1N1880113 |
| h5 | 1"-8 UNC Heavy Hex Nut | ASTM A563DH or A194 Gr. 2H | COC Only<br>P#38210<br>C#210157128 |
| h6 | ⅝"-11 UNC Hex Nut | ASTM A563A or equivalent | H#331608011 |
| j2 | Curb Concrete, Test No. HMDT-2 | Minimum strength<br>f'c = 4,000 psi | Ticket# 1260732 |
| j2 | Curb Concrete, Test No. HMDT-3 | Minimum strength<br>f'c = 4,000 psi | Ticket# 1265745 |

# Certified Analysis

Trinity Highway Products LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296
Customer: MIDWEST MACH & SUPPLY CO
P. O. BOX 703

MILFORD, NE 68405
Project: STOCK

Order Number: 1324622 Prod Ln Grp: 0-OE2.0
Customer PO: 3954
BOL Number: 112739 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 6/30/20

| Qty | Part # | Description | Spec | CL | TY | Heat Code/ Heat | Yield | TS | Elg | C | Mn | P | S | Si | Cu | Cb | Cr | Vn | ACW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 40 | 12173G | T12/6'3/4@1'6.75"/S | | | 2 | L34919 | | | | | | | | | | | | | |
| | | | M-180 | A | 2 | 245021 | 64,480 | 83,940 | 22.2 | 0.190 | 0.700 | 0.013 | 0.004 | 0.020 | 0.060 | 0.000 | 0.060 | 0.001 | 4 |
| | | | M-180 | A | 2 | 245984 | 62,860 | 80,840 | 26.2 | 0.190 | 0.720 | 0.008 | 0.003 | 0.010 | 0.080 | 0.000 | 0.050 | 0.000 | 4 |
| 50 | 12365G | T12/12'6/8@1'6.75/S | | | 2 | L32420 | | | | | | | | | | | | | |
| | | | M-180 | A | 2 | 251386 | 62,920 | 81,060 | 24.4 | 0.200 | 0.720 | 0.010 | 0.002 | 0.020 | 0.100 | 0.000 | 0.070 | 0.002 | 4 |
| | | | M-180 | B | 2 | 248862 | 64,080 | 82,460 | 25.1 | 0.180 | 0.730 | 0.011 | 0.001 | 0.020 | 0.100 | 0.000 | 0.060 | 0.001 | 4 |
| | | | M-180 | B | 2 | 249478 | 61,020 | 80,630 | 27.0 | 0.190 | 0.720 | 0.010 | 0.001 | 0.020 | 0.090 | 0.000 | 0.060 | 0.000 | 4 |
| | 12365G | | | | 2 | L31920 | | | | | | | | | | | | | |
| | | | M-180 | A | 2 | 249480 | 63,400 | 81,930 | 25.1 | 0.190 | 0.740 | 0.010 | 0.003 | 0.010 | 0.060 | 0.000 | 0.060 | 0.000 | 4 |
| | | | M-180 | B | 2 | 248862 | 64,080 | 82,460 | 25.1 | 0.180 | 0.730 | 0.011 | 0.001 | 0.020 | 0.100 | 0.000 | 0.060 | 0.001 | 4 |
| 180 | 54043G | 7'0 PST/6X15/DB:3HI | A-572 | | | 59091538 | 62,786 | 81,568 | 20.0 | 0.090 | 1.330 | 0.015 | 0.029 | 0.240 | 0.340 | 0.000 | 0.200 | 0.049 | 4 |

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy QMS-LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT, 23 CFR 635.410.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36 UNLESS OTHERWISE STATED.
ALL COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT", 23 CFR 635.410.
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 (US DOMESTIC SHIPMENTS)
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 & ISO 1461 (INTERNATIONAL SHIPMENTS)

FINISHED GOOD PART NUMBERS ENDING IN SUFFIX B,P, OR S, ARE UNCOATED

Figure G-1. 12-Gauge Thrie-Beam, Test Nos. HMDT-2 and HMDT-3 (Item No. a1)

# Certified Analysis

Trinity Highway Products LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296
Customer: MIDWEST MACH & SUPPLY CO
P. O. BOX 703

MILFORD, NE 68405
Project: STOCK

Order Number: 1326783 Prod Ln Grp: 0-OE2.0
Customer PO: 3974
BOL Number: 113032 Ship Date: 7/31/2020
Document #: 1
Shipped To: NE
Use State: NE

As of: 8/11/20

| Qty | Part # | Description | Spec | CL | TY | Heat Code/ Heat | Yield | TS | Elg | C | Mn | P | S | Si | Cu | Cb | Cr | Vn | ACW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 40 | 980G | T10/END SHOE/SLANT | A-1011 | | | 95839 | 50,900 | 628,000 | 35.4 | 0.060 | 0.490 | 0.010 | 0.001 | 0.030 | 0.110 | 0.000 | 0.070 | 0.001 | 4 |
| 70 | 12173G | T12/6'3/4@1'6.75"/S | | | 2 | L34919 | | | | | | | | | | | | | |
| | | | M-180 | A | 2 | 245021 | 64,480 | 83,940 | 22.2 | 0.190 | 0.700 | 0.013 | 0.004 | 0.020 | 0.060 | 0.000 | 0.060 | 0.001 | 4 |
| | | | M-180 | A | 2 | 245984 | 62,860 | 80,840 | 26.2 | 0.190 | 0.720 | 0.008 | 0.003 | 0.010 | 0.080 | 0.000 | 0.050 | 0.000 | 4 |
| 140 | 12365G | T12/12'6/8@1'6.75/S | | | 2 | L30520 | | | | | | | | | | | | | |
| | | | M-180 | A | 2 | 245984 | 62,860 | 80,840 | 26.2 | 0.190 | 0.720 | 0.008 | 0.003 | 0.010 | 0.080 | 0.000 | 0.050 | 0.000 | 4 |
| | | | M-180 | A | 2 | 248105 | 61,520 | 80,800 | 24.4 | 0.200 | 0.730 | 0.012 | 0.004 | 0.020 | 0.100 | 0.000 | 0.060 | 0.002 | 4 |
| | | | M-180 | A | 2 | 248106 | 62,360 | 81,270 | 28.1 | 0.190 | 0.720 | 0.013 | 0.003 | 0.020 | 0.120 | 0.000 | 0.060 | 0.001 | 4 |
| | 12365G | | | | 2 | L32520 | | | | | | | | | | | | | |
| | | | M-180 | A | 2 | 251386 | 62,920 | 81,060 | 24.4 | 0.200 | 0.720 | 0.010 | 0.002 | 0.020 | 0.100 | 0.000 | 0.070 | 0.002 | 4 |
| | | | M-180 | A | 2 | 252079 | 63,050 | 81,000 | 26.3 | 0.190 | 0.720 | 0.015 | 0.003 | 0.020 | 0.130 | 0.000 | 0.070 | 0.002 | 4 |
| 20 | 32218G | T10/TRAN/TB:WB/ASYM/R | M-180 | B | 2 | 42014850 | 50,000 | 70,000 | 28.0 | 0.040 | 0.770 | 0.014 | 0.001 | 0.040 | 0.120 | 0.000 | 0.070 | 0.003 | 4 |
| 30 | 32219G | T10/TRAN/TB:WB/ASYM/LT | M-180 | B | 2 | 248834 | 59,940 | 78,890 | 27.2 | 0.210 | 0.720 | 0.013 | 0.003 | 0.020 | 0.100 | 0.000 | 0.050 | 0.000 | 4 |
| 120 | 54043G | 70 PST/6X15/DB:3HI | A-572 | | | 59091919 | 59,367 | 78,866 | 24.0 | 0.100 | 0.920 | 0.016 | 0.035 | 0.210 | 0.350 | 0.015 | 0.180 | 0.001 | 4 |

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy QMS-LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT, 23 CFR 635.410.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36 UNLESS OTHERWISE STATED.

ALL COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT", 23 CFR 635.410.
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 (US DOMESTIC SHIPMENTS)
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 & ISO 1461 (INTERNATIONAL SHIPMENTS)

FINISHED GOOD PART NUMBERS ENDING IN SUFFIX B,P, OR S, ARE UNCOATED

Figure G-2. 12-Gauge Thrie-Beam, Test Nos. HMDT-2 and HMDT-3 (Item No. a2)

220008-P1

# Certified Test Report

NORTH STAR BLUESCOPE STEEL LLC
6767 County Road 9
Delta Ohio 43515
Telephone: (888) 822-2112

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Customer:** | Miami Valley Steel Service Inc. | | | **Ordered Width (mm/in)** | 1295.4 / 51 | | **Weight(kg/lb)** |
| 201 fox Dr. | | **Order #** | 434020 | **Ordered Gauge (mm/in)** | 3.200 / 0.126 | M | 19318 / 42589 |
| Piqua, OH 45356 | | **Line Item #** | 1 | **Produced Date/Time** | 6/15/19 17:44 | | |
| **Customer P.O:** | 081886 | **Heat #** | 240680 | **Coil #** | 1933970 | | |
| **Cust. Ref/Part #** | M180 | **Material Desc:** | 1018 CQ Modified, Guardrail Type 2 | | | | |

## Chemical Analysis (wt%)

| Type | C | Mn | P | S | Si | Al | Cu | Cr | Ni | Mo | Sn | N | B | V | Nb | Ti | Ca | Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Heat | 0.20 | 0.73 | 0.008 | 0.004 | 0.02 | 0.03 | 0.11 | 0.06 | 0.04 | 0.01 | 0.00 | 0.006 | 0.0000 | 0.002 | 0.000 | 0.001 | 0.002 | 0.000 |

## Mechanical Test Report

| | Yield Strength | Tensile Strength | % Elongation in 2 inches |
|---|---|---|---|
| Tail | 62100 psi / 428 MPa | 79940 psi / 551 MPa | 27.5% |

This hot rolled steel has been produced to conform to DIN EN 10204:2005 3.1 and has been manufactured to a fully killed fine grain practice. This hot rolled steel has been produced and tested in accordance with each of the following applicable standards:ASTM E1806-09, ASTM E415-14, ASTM A751-14, ASTM A370-14, JIS Z2201:1998, JIS Z2241:2011. Pressure Equipment Directive (PED) 2014/68/EU, Annex I, Paragraph 4.3 Compliant. This report certifies that the above test results are representative of those contained in the records of North Star BlueScope Steel LLC for the material identified in this test report and is intended to comply with the requirements of the material description. North Star BlueScope Steel LLC is not responsible for the inability of this material to meet specific applications. Any modifications to this certification as provided negates the validity of this test report. All reproductions must have the written approval of North Star BlueScope Steel.This product was manufactured, melted, cast, and hot-rolled (min. 3:1 reduction ratio), entirely within the U.S.A at North Star BlueScope Steel LLC, Delta, Ohio. This material was not exposed to Mercury or any alloy which is liquid at ambient temperature during processing or while in North Star BlueScope Steel LLC possession. Test equipment calibration certificates are available upon request. NIST traceability is established through test equipment calibration certificates which are available upon request. Uncertainty calculations are calculated in accordance with NIST standards and are maintained at a 4:1 ratio in accordance with NIST standards. Uncertainty data is available upon request

John Meece
072718

Manager Quality Assurance and Technology

**Date Issued:** Aug 21, 2019 8:58 AM
**Revision#:** 01

Figure G-3. 10-Gauge W-Beam to Thrie-Beam Asymmetric Transition Section, Test Nos. HMDT-2 and HMDT-3 (Item No. a3)

**GREGORY HIGHWAY PRODUCTS, INC.**
**4100 13th St. SW**
**Canton, Ohio 44710**

**Customer:** UNIVERSITY OF NEBRASKA-LINCOLN
401 CANFIELD ADMIN BLDG
P O BOX 880439
LINCOLN,NE,68588-0439

Test Report
Ship Date: 1/26/2018
Customer P O: 36263
Shipped to: UNIVERSITY OF NEBRASKA-LINCOLN
Project:
GHP Order No.: 319AA

| HT # code | Heat # | C. | MN. | P. | S. | Si. | Tensile | Yield | Elong. | Quanity | Class | Type | Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1207 | C85187 | 0.2 | 0.48 | 0.008 | 0.003 | 0.03 | 80433 | 59371 | 16.35 | 150 | A | 2 | 12GA 12FT6IN/3FT1 1/2IN WB T2 |

Bolts comply with ASTM A-307 specifications and are galvanized in accordance with ASTM A-153, unless otherwise stated.
Nuts comply with ASTM A-563 specifications and are galvanized in accordance with ASTM A-153, unless otherwise stated.
All other galvanized material conforms with ASTM-123 & ASTM-653
All Galvanizing has occurred in the United States
All steel used in the manufacture is of Domestic Origin, "Made and Melted in the United States"
All Steel used meets Title 23CFR 635.410 - Buy America
All Guardrail and Terminal Sections meets AASHTO M-180, All structural steel meets AASHTO M-183 & M270
All Bolts and Nuts are of Domestic Origin
All material fabricated in accordance with Nebraska Department of Transportation
All controlled oxidized/corrosion resistant Guardrail and terminal sections meet ASTM A606, Type 4.

Jeffery L Grover

By: Jeffery Grover, VP of Highway Products Sales & Marketing
Gregory Highway Products, Inc.

NOTARIAL SEAL
STATE OF OHIO

James P Dehnke
Notary Public - State of Ohio
My Commission Expires
October 19, 2019

STATE OF OHIO: COUNTY OF STARK
Sworn to and subscribed before me, a Notary Public, by
Jeffery Grover this 29 day of January, 2018

Notary Public, State of Ohio

Figure G-4. 12 ft – 6 in. Long, 12-Gauge W-Beam MGS Section, Test Nos. HMDT-2 and HMDT-3 (Item Nos. a4 and a5)

CNWP
CENTRAL NEBRASKA WOOD PRESERVERS

1098 East Maple St
Sutton, NE 68979
Phone: 402.773.4319
Email: nick@nebraskawood.com

**CERTIFICATE OF COMPLIANCE**

**Shipped To:** Midwest Machinery and Supply
**BOL#** N08525
**Customer PO#** 3644
**Preservative:** CCA – C 0.60D pcf AWPA UC4B

| Part # | Physical Description | # of Pieces | Charge # | Tested Retention |
|---|---|---|---|---|
| GR6819 BLK | 6x8-19" OCD Block | 168 | 26258 | .657 |
| GR61219 BLK | 6x12-19" OCD Block | 112 | 26258 | .657 |
| GR61222 BLK | 6x12-22" OCD Block | 56 | 26260 | .680 |
| GS6846 PST | 5.5x7.5-46" BCT | 42 | 26224 | .657 |
| | | | | |
| | | | | |
| | | | | |

I certify the above referenced material has been produced, treated and tested in accordance with and conforms to AASHTO M133 & M168 standards.

VA: Iowa Wood Preservers certifies that the treated wood products listed above have been treated in accordance with AWPA standards, Section 236 of the VDOT Road & Bridge Specifications and meets the applicable minimum penetration and retention requirements.

Nick Sowl, General Counsel

10/16/18
Date

Figure G-5. BCT Timber Post, Test Nos. HMDT-2 and HMDT-3 (Item No. c1)

30460HD6

Atlas Tube Corp (Chicago)
1855 East 122nd Street
Chicago, Illinois, USA
60633
Tel: 773-646-4500
Fax: 773-646-6128

Atlas Tube
A DIVISION OF ZEKELMAN INDUSTRIES

Ref.B/L: 80728203
Date: 08.17.2016
Customer: 2908

## MATERIAL TEST REPORT

**Sold to**

Gregory Industries Inc.
4100 13th Street SW.
CANTON OH 44710
USA

**Shipped to**

Tru-Form Steel & Wire
1204 Gilkey Ave
HARTFORD CITY IN 47348
USA

Material: 8.0x6.0x188x27'0"0(2x2)SILDOMUS — Material No: 80060188 — Made in: USA — Melted in: USA

Sales order: 1105121 — Purchase Order: 35569 — Cust Material #: TRB3/16-8-6-27

| Heat No | C | Mn | P | S | Si | Al | Cu | Cb | Mo | Ni | Cr | V | Ti | B | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 616137 | 0.210 | 0.930 | 0.011 | 0.003 | 0.020 | 0.041 | 0.020 | 0.008 | 0.020 | 0.020 | 0.030 | 0.008 | 0.001 | 0.000 | 0.003 |

| Bundle No | PCs | Yield | Tensile | Eln.2in | Certification | CE: 0.38 |
|---|---|---|---|---|---|---|
| M800650076 | 4 | 058210 Psi | 073148 Psi | 32 % | ASTM A500-13 GRADE B&C | |

Material Note:
Sales Or.Note:

Material: 8.0x6.0x188x30'0"0(2x3)SILDOMUS — Material No: 80060188 — Made in: USA — Melted in: USA

Sales order: 1105121 — Purchase Order: 35569 — Cust Material #: TRB3/16-8-6-30

| Heat No | C | Mn | P | S | Si | Al | Cu | Cb | Mo | Ni | Cr | V | Ti | B | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 821T08220 | 0.220 | 0.810 | 0.013 | 0.006 | 0.006 | 0.041 | 0.160 | 0.002 | 0.005 | 0.010 | 0.020 | 0.002 | 0.002 | 0.000 | 0.007 |

| Bundle No | PCs | Yield | Tensile | Eln.2in | Certification | CE: 0.37 |
|---|---|---|---|---|---|---|
| M800650038 | 6 | 057275 Psi | 070934 Psi | 32 % | ASTM A500-13 GRADE B&C | |

Material Note:
Sales Or.Note:

Material: 8.0x6.0x188x30'0"0(2x3)SILDOMUS — Material No: 80060188 — Made in: USA — Melted in: USA

Sales order: 1105121 — Purchase Order: 35569 — Cust Material #: TRB3/16-8-6-30

| Heat No | C | Mn | P | S | Si | Al | Cu | Cb | Mo | Ni | Cr | V | Ti | B | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 821T08220 | 0.220 | 0.810 | 0.013 | 0.006 | 0.006 | 0.041 | 0.160 | 0.002 | 0.005 | 0.010 | 0.020 | 0.002 | 0.002 | 0.000 | 0.007 |

| Bundle No | PCs | Yield | Tensile | Eln.2in | Certification | CE: 0.37 |
|---|---|---|---|---|---|---|
| M800650039 | 6 | 057275 Psi | 070934 Psi | 32 % | ASTM A500-13 GRADE B&C | |

Material Note:
Sales Or.Note:

Jason Richard
Jason Richard

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

Steel Tube Institute OF NORTH AMERICA

Page : 1 Of 6

Metals Service Center Institute

Figure G-6. 72-in. Long Foundation Tube, Test Nos. HMDT-2 and HMDT-3 (Item No. c2

# Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 703

MILFORD, NE 68405
Project: STOCK

Order Number: 1214903 Prod Ln Grp: 9-End Terminals (Dom)
Customer PO: 2878
BOL Number: 80278 Ship Date:
Document #: 1
Shipped To: NE
Use State: KS

As of: 3/7/14

| Qty | Part # | Description | Spec | CL | TY | Heat Code/ Heat | Yield | TS | Elg | C | Mn | P | S | Si | Cu | Cb | Cr | Vn | ACW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 36 | 749G | TS 8X6X3/16X6'-0" SLEEVE | A-500 | | | 0173175 | 55,871 | 74,495 | 31.0 | 0.160 | 0.610 | 0.012 | 0.009 | 0.010 | 0.030 | 0.000 | 0.030 | 0.000 | 4 |
| 20 | 3000G | CBL 3/4X6'6/DBL | HW | | | 98790 | | | | | | | | | | | | | |
| 22 | 9852A | STRUT & YOKE ASSY | A-1011-SS | | | 163375 | 48,380 | 64,020 | 32.9 | 0.190 | 0.520 | 0.011 | 0.003 | 0.030 | 0.110 | 0.000 | 0.050 | 0.000 | 4 |
| | 9852A | | A-36 | | | 11237730 | 45,500 | 70,000 | 30.0 | 0.170 | 0.500 | 0.010 | 0.008 | 0.020 | 0.080 | 0.000 | 0.070 | 0.001 | 4 |

Ground Strut Green Paint
R#15-0157 September 2014 SMT

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

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

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

FINISHED GOOD PART NUMBERS ENDING IN SUFFIX B,P, OR S, ARE UNCOATED
BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.

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

1 of 2

Figure G-7. Ground Strut Assembly, Test Nos. HMDT-2 and HMDT-3 (Item No. c3)

PH 216.676.5600
FX 216.676.6761
www.assemblyspecialty.com

ASSEMBLY
SPECIALTY PRODUCTS INC

ISO 9001:2008

14700 Brookpark Rd
Cleveland, OH 44135-5166
customerservice@assemblyspecialty.com

## Certificate of Conformance

**Date:** September 24, 2018

**To:** Gregory Industries, Inc.
Gregory Galv. & Metal Processing
4100 13th St. SW
Canton, OH 44710

We certify that our system and procedures for the control of quality assures that all items furnished on the order will meet applicable tests, requirements and inspection requirements as required by the purchase order and applicable specifications and drawings.

**PURCHASE ORDER #:** 40299
**DATE SHIPPED:** 09/24/18
**ASPI SALES ORDER #:** 122160
**MANUFACTURER:** ASSEMBLY SPECIALTY PRODUCTS, INC.

| QTY | CUST P/N | ASPI P/N | ASPI LOT# | DESCRIPTION |
|---|---|---|---|---|
| 250 | 3012G | C-2028 | 89315 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 89316 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 89318 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 89864 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 89865 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 89866 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 89929 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 89930 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 89931 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 89932 | 6' 6" BCT Cable Assembly |

**REMARKS:** NOMINAL BREAKING STRENGTH: 46,000 lbs
WIRE ROPE MANUFACTURED IN ACCORDANCE WITH AASHTO DESIGNATION: M30-02 and ASTM A741 TYPE 2, CLASS A
FITTINGS GALVANIZED IN ACCORDANCE WITH ASTM A-153 CLASS C.

STEEL USED TO MANUFACTURE THESE ITEMS WAS MELTED AND MANUFACTURED IN THE U.S.A
ALL MANUFACTURING PROCESSES SUPPLIED OR PERFORMED BY ASSEMBLY SPECIALTY PRODUCTS, INC. TOOK PLACE IN THE U.S.A.

Signature:
Certification and Compliance Manager

Figure G-8. BCT Anchor Cable End Swaged Fitting and Cable Anchor Assembly, Test Nos. HMDT-2 and HMDT-3 (Item Nos. c4 and c5)

PH 216.676.5600
FX 216.676.6761
www.assemblyspecialty.com

ASSEMBLY
SPECIALTY PRODUCTS INC.

ISO 9001:2008

14700 Brookpark Rd
Cleveland, OH 44135-5166
customerservice@assemblyspecialty.com

**Lots continued):**

| QTY | CUST P/N | ASPI P/N | ASPI LOT# | DESCRIPTION |
|---|---|---|---|---|
| 250 | 3012G | C-2028 | 90007 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 90008 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 90009 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 90010 | 6' 6" BCT Cable Assembly |

Figure G-9. BCT Anchor Cable End Swaged Fitting and Cable Anchor Assembly, Test Nos. HMDT-2 and HMDT-3 (Item Nos. c4 and c5)

**GREGORY HIGHWAY PRODUCTS, INC.**
**4100 13th St. SW**
**Canton, Ohio 44710**

MIDWEST MACHINERY & SUPPLY CO.
P. O. BOX 703

MILFORD,NE,68405

Test Report
Ship Date: 11/17/2017
Customer P.O.: 3515
Shipped to: MIDWEST MACHINERY & SUPPLY CO.
Project:
GHP Order No: 128AA

| HT # code | LOT# | C. | Mn. | P. | S. | Si. | Tensile | Yield | Elong. | Quantity | Class | Type | Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A74070 | | 0.21 | 0.46 | 0.012 | 0.002 | 0.03 | 76100 | 58800 | 25.2 | 4 | A | 2 | 12GA TB TRANS. |
| 4181496 | | 0.24 | 0.84 | 0.014 | 0.01 | 0.01 | 72400 | 44800 | 34 | 4 | | 2 | 5/8IN X 8IN X 8IN BRG. PL. |
| 4181489 | | 0.09 | 0.45 | 0.012 | 0.004 | 0.01 | 58000 | 43100 | 27 | 4 | | 2 | 350 STRUT & YOKE |
| 196828BM | | 0.04 | 0.84 | 0.014 | 0.003 | | 76000 | 74000 | 25 | | | 2 | 350 STRUT & YOKE |
| E22985 | | 0.17 | 0.51 | 0.013 | 0.008 | 0.008 | 72510 | 64310 | 29.5 | 4 | | 2 | 2IN X 5 1/2IN PIPE SLEEVE |
| 811T08220 | | 0.22 | 0.81 | 0.013 | 0.006 | 0.005 | 71412 | 56323 | 35 | 8 | | 2 | 3/16IN X 6IN X 8IN X 6FT0IN TUBE SLEEVE |

All Galvanizing has occurred in the United States
All steel used in the manufacture is of Domestic Origin, "Made and Melted in the United States"
All Steel used meets Title 23CFR 635.410 - Buy America
All Guardrail and Terminal Sections meets AASHTO M-180, All structural steel meets AASHTO M-183 & M270
All Bolts and Nuts are of Domestic Origin
All material fabricated in accordance with Nebraska Department of Transportation
All controlled oxidized/corrosion resistant Guardrail and terminal sections meet ASTM A606, Type 4.

By:

James P. Dehnke
Notary Public, State of Ohio
My Commission Expires 10-19-2019

STATE OF OHIO: COUNTY OF STARK
Sworn to and subscribed before me, a Notary Public, by Andrew Artar this 21 day of November, 2017

Notary Public, State of Ohio

Figure G-10. Anchor Bearing Plate, Test Nos. HMDT-2 and HMDT-3 (Item No. c6)

Atlas Tube (Alabama), Inc.
171 Cleage Dr
Birmingham, Alabama, USA
35217
Tel:
Fax:

Atlas Tube
A DIVISION OF ZEKELMAN INDUSTRIES

Ref.B/L: 80791452
Date: 11.10.2017
Customer: 179

## MATERIAL TEST REPORT

**Sold to**

Steel & Pipe Supply Compan
PO Box 1688
MANHATTAN KS 66505
USA

**Shipped to**

Steel & Pipe Supply Compan
401 New Century Parkway
NEW CENTURY KS 66031
USA

Material: 3.0x2.0x188x40'0"0(5x4). Material No: 0300201884000-B Made in: USA
Melted in: USA
Sales order: 1226976 Purchase Order: 4500296656 Cust Material #: 6630020018840

| Heat No | C | Mn | P | S | Si | Al | Cu | Cb | Mo | Ni | Cr | V | Ti | B | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B704212 | 0.200 | 0.450 | 0.010 | 0.004 | 0.020 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

| Bundle No | PCs | Yield | Tensile | Eln.2in | Certification | CE: 0.28 |
|---|---|---|---|---|---|---|
| 40867002 | 20 | 064649 Psi | 087652 Psi | 24 % | ASTM A500-13 GRADE B&C | |

Material Note:
Sales Or.Note:

Material: 2.375x154x42'0"0(34x1). Material No: R023751544200 Made in: USA
Melted in: USA
Sales order: 1226976 Purchase Order: 4500296656 Cust Material #: 642004042

| Heat No | C | Mn | P | S | Si | Al | Cu | Cb | Mo | Ni | Cr | V | Ti | B | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B712810 | 0.210 | 0.460 | 0.012 | 0.002 | 0.020 | 0.024 | 0.100 | 0.002 | 0.020 | 0.030 | 0.060 | 0.004 | 0.002 | 0.000 | 0.008 |

| Bundle No | PCs | Yield | Tensile | Eln.2in | Rb | Certification | CE: 0.32 |
|---|---|---|---|---|---|---|---|
| MC00006947 | 34 | 063688 Psi | 083220 Psi | 25 % | 91 | ASTM A500-13 GRADE B&C | |

Material Note:
Sales Or.Note:

Material: 2.375x154x42'0"0(34x1). Material No: R023751544200 Made in: USA
Melted in: USA
Sales order: 1226976 Purchase Order: 4500296656 Cust Material #: 642004042

| Heat No | C | Mn | P | S | Si | Al | Cu | Cb | Mo | Ni | Cr | V | Ti | B | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 17037261 | 0.210 | 0.810 | 0.005 | 0.004 | 0.020 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

| Bundle No | PCs | Yield | Tensile | Eln.2in | Certification | CE: 0.35 |
|---|---|---|---|---|---|---|
| 41532001 | 34 | 066144 Psi | 082159 Psi | 27 % | ASTM A500-13 GRADE B&C | |

Material Note:
Sales Or.Note:

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

Steel Tube Institute

Page : 3 Of 4

Metals Service Center Institute

Figure G-11. BCT Post Sleeve, Test Nos. HMDT-2 and HMDT-3 (Item No. c7)

# Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 703

MILFORD, NE 68405
Project: RESALE

Order Number: 1269489 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: 3346
BOL Number: 97457 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 11/7/16

| Qty | Part # | Description | Spec | CL | TY | Heat Code/ Heat | Yield | TS | Elg | C | Mn | P | S | Si | Cu | Cb | Cr | Vn | ACW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 701A | Anchor Box | A-36 | | | JK16101488 | 56,172 | 75,460 | 25.0 | 0.160 | 0.780 | 0.017 | 0.028 | 0.200 | 0.280 | 0.001 | 0.140 | 0.028 | 4 |
| | 701A | | A-36 | | | 535133 | 43,300 | 68,500 | 33.0 | 0.019 | 0.460 | 0.013 | 0.016 | 0.013 | 0.090 | 0.001 | 0.090 | 0.002 | 4 |
| 4 | 729G | TS 8X6X3/16X8'-0" SLEEVE | A-500 | | | A49248 | 64,818 | 78,412 | 32.0 | 0.200 | 0.810 | 0.014 | 0.002 | 0.040 | 0.020 | 0.000 | 0.040 | 0.001 | 4 |
| 20 | 738A | 5'TUBE SL.188X6X8 1/4 /PL | A-36 | | 2 | 4182184 | 45,000 | 67,900 | 31.0 | 0.210 | 0.760 | 0.012 | 0.008 | 0.010 | 0.050 | 0.001 | 0.030 | 0.002 | 4 |
| | 738A | | A-500 | | | A49248 | 64,818 | 78,412 | 32.0 | 0.200 | 0.810 | 0.014 | 0.002 | 0.040 | 0.020 | 0.000 | 0.040 | 0.001 | 4 |
| 6 | 749G | TS 8X6X3/16X6'-0" SLEEVE | A-500 | | | A49248 | 64,818 | 78,412 | 32.0 | 0.200 | 0.810 | 0.014 | 0.002 | 0.040 | 0.020 | 0.000 | 0.040 | 0.001 | 4 |
| 6 | 782G | 5/8"X8"X8" BEAR PL/OF | A-36 | | | DL15103543 | 58,000 | 74,000 | 25.0 | 0.150 | 0.750 | 0.013 | 0.025 | 0.200 | 0.360 | 0.003 | 0.090 | 0.000 | 4 |
| 20 | 783A | 5/8X8X8 BEAR PL 3/16 STP | A-36 | | | PL14107973 | 48,167 | 69,811 | 25.0 | 0.160 | 0.740 | 0.012 | 0.041 | 0.190 | 0.370 | 0.000 | 0.220 | 0.002 | 4 |
| | 783A | | A-36 | | | DL15103543 | 58,000 | 74,000 | 25.0 | 0.150 | 0.750 | 0.013 | 0.025 | 0.200 | 0.360 | 0.003 | 0.090 | 0.000 | 4 |
| 45 | 3000G | CBL 3/4X6'6/DBL | HW | | | 119048 | | | | | | | | | | | | | |
| 7,000 | 3340G | 5/8" GR HEX NUT | HW | | | 0055551-116146 | | | | | | | | | | | | | |
| 4,000 | 3360G | 5/8"X1.25" GR BOLT | HW | | | 0053777-115516 | | | | | | | | | | | | | |
| 450 | 3500G | 5/8"X10" GR BOLT A307 | HW | | | 28971-B | | | | | | | | | | | | | |
| 1,225 | 3540G | 5/8"X14" GR BOLT A307 | HW | | | 29053-B | | | | | | | | | | | | | |

Figure G-12. Anchor Bracket Assembly, Test Nos. HMDT-2 and HMDT-3 (Item No. c8)

GERDAU

**CERTIFIED MATERIAL TEST REPORT**

Page 1 / 1

US-ML-CARTERSVILLE
384 OLD GRASSDALE ROAD NE
CARTERSVILLE, GA 30121
USA

| CUSTOMER SHIP TO | CUSTOMER BILL TO | GRADE | SHAPE / SIZE | DOCUMENT ID: |
|---|---|---|---|---|
| HIGHWAY SAFETY CORP<br>473 W FAIRGROUND ST<br>MARION,OH 43302-1701<br>USA | HIGHWAY SAFETY CORP<br>GLASTONBURY,CT 06033-0358<br>USA | A992/A709-36 | Wide Flange Beam / 6 X 8.5# / 150 X 13.0 | 0000307083 |

| LENGTH | PCS | WEIGHT | HEAT / BATCH |
|---|---|---|---|
| 42'00" | 63 | 22,491 LB | 55064803/02 |

| SALES ORDER | CUSTOMER MATERIAL N° |
|---|---|
| 8525742/000010 | |

| CUSTOMER PURCHASE ORDER NUMBER | BILL OF LADING | DATE |
|---|---|---|
| 1832 | 1323-0000153427 | 03/02/2020 |

SPECIFICATION / DATE or REVISION
ASTM A6-17
ASTM A709-17
ASTM A992-11 (2015)
CSA G40.21-13 345WM

1832138
IB-BC00800

CHEMICAL COMPOSITION

| C % | Mn % | P % | S % | Si % | Cu % | Ni % | Cr % | Mo % | Sn % | V % | Nb % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.14 | 0.81 | 0.012 | 0.029 | 0.21 | 0.31 | 0.09 | 0.09 | 0.025 | 0.008 | 0.002 | 0.009 |

MECHANICAL PROPERTIES

| YS 0.2% PSI | UTS PSI | YS MPa | UTS MPa | Y/T ratio % | Elong. % |
|---|---|---|---|---|---|
| 58300 | 76400 | 402 | 527 | 0.760 | 27.50 |
| 55900 | 73900 | 385 | 510 | 0.760 | 24.80 |

COMMENTS / NOTES

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. Weld repair has not been performed on this material. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

Bhaskar
BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 267-1071 Email: Bhaskar.Yalamanchili@gerdau.com

YAN WANG
QUALITY ASSURANCE MGR.
Phone: (770) 387 5718 Email: yan.wang@gerdau.com

Figure G-13. W6x8.5, 72-in. Long Steel Post, Test Nos. HMDT-2 and HMDT-3 (Item Nos. d1 and d2)

CERTIFIED MATERIAL TEST REPORT

Page 1 / 1

GERDAU

US-ML-MIDLOTHIAN
300 WARD ROAD
MIDLOTHIAN, TX 76065
USA

| CUSTOMER SHIP TO | CUSTOMER BILL TO | GRADE | SHAPE / SIZE | DOCUMENT ID: |
|---|---|---|---|---|
| STEEL AND PIPE SUPPLY CO INC<br>310 SMITH ROAD<br>JONESBURG,MO 63351<br>USA | STEEL AND PIPE SUPPLY CO INC<br>MANHATTAN,KS 66505-1688<br>USA | A992/A572-50 | Wide Flange Beam / 6 X 15# / 150 X 22 5 | 0000470808 |

| LENGTH | PCS | WEIGHT | HEAT / BATCH |
|---|---|---|---|
| 40'00" | 12 | 7,200 LB | **58042771/02** |

| SALES ORDER | CUSTOMER MATERIAL N° |
|---|---|
| 8995686/000010 | 000000000376150040 |

| CUSTOMER PURCHASE ORDER NUMBER | BILL OF LADING | DATE |
|---|---|---|
| 4500349606 | 1327-0000374754 | 06/26/2020 |

SPECIFICATION / DATE or REVISION
ASTM A6-17
ASTM A709-17
ASTM A992-11 (2015), A572-15
CSA G40.21-13 345WM

CHEMICAL COMPOSITION

| C (%) | Mn (%) | P (%) | S (%) | Si (%) | Cu (%) | Ni (%) | Cr (%) | Mo(%) | Sn (%) | V (%) | Nb (%) | Al (%) | CEqvA6 (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.10 | 0.91 | 0.016 | 0.030 | 0.25 | 0.26 | 0.14 | 0.23 | 0.035 | 0.006 | 0.002 | 0.016 | 0.003 | 0.33 |

MECHANICAL PROPERTIES

| YS 0.2% (PSI) | UTS (PSI) | YS (MPa) | UTS (MPa) | Y/T rati (%) | G/L (Inches) | G/L (mm) | Elong. (%) |
|---|---|---|---|---|---|---|---|
| 55429 | 75865 | 382 | 523 | 0.730 | 8.000 | 200.0 | 24.10 |
| 56366 | 75832 | 389 | 523 | 0.740 | 8.000 | 200.0 | 24.20 |

COMMENTS / NOTES

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. Weld repair has not been performed on this material. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

Bhaskar

BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 267-1071 Email: Bhaskar.Yalamanchili@gerdau.com

Wade A. L

WADE LUMPKINS
QUALITY ASSURANCE MGR
Phone: 972-779-3118 Email: Wade.Lumpkins@gerdau.com

Figure G-14. W6x15, 78-in. Long Steel Post, Test Nos. HMDT-2 and HMDT-3 (Item No. d3)

30Jul20 3: 3 T E S T C E R T I F I C A T E No: MAR 380309

NUCOR TUBULAR PRODUCTS INC.
6226 W. 74TH STREET
CHICAGO, IL 60638
Tel: 708-496-0380 Fax: 708-563-1950

P/O No 01031988
Rel
S/O No MAR 396220-002
B/L No MAR 235650-006 Shp 30Jul20
Inv No Inv

Sold To: ( 1403)
NORFOLK IRON & METAL
P.O. BOX 1129
NORFOLK, NE 68701

Ship To: ( 1)
NORFOLK IRON & METAL
3001 NORTH VICTORY RD
NORFOLK, NE 68702

Tel: 402-371-1810 Fax: 402 379-5409

CERTIFICATE of ANALYSIS and TESTS Cert. No: MAR 380309
24Jul20

Part No 01209
TUBING A500 GRADE B(C)
8" X 6" X 1/4" X 20'

| Pcs | Wgt |
|---|---|
| 12 | 5,380 |

| Heat Number | Tag No | Pcs | Wgt |
|---|---|---|---|
| A97575 | 914842 | 6 | 2,690 |
| | YLD=58050/TEN=66570/ELG=32.6 | | |
| A97575 | 914843 | 6 | 2,690 |

Heat Number *** Chemical Analysis ***
A97575 C=0.0500 Mn=0.4100 P=0.0090 S=0.0030 Si=0.0300 Al=0.0360
Cu=0.1500 Cr=0.0700 Mo=0.0200 V=0.0030 Ni=0.0400 Nb=0.0160
Sn=0.0100 N=0.0070 B=0.0002 Ti=0.0020 Ca=0.0023
MELTED AND MANUFACTURED IN THE USA

THE SPECIFICATIONS LISTED BELOW REPRESENT THE CURRENT ISSUED DATES OF THESE STANDARDS. THIS DOES NOT INDICATE THAT THE MATERIAL ABOVE CONFORMS TO EACH OR ALL OF THE STANDARDS. WE CERTIFY THE MATERIAL ABOVE TO THE SPECIFICATION LISTED IN THE LINE DESCRIPTION.

CURRENT STANDARDS:
A252-19
A500/A500M-20
A513/A513M-20
ASTM A53/A53M-18| ASME SA-53/SA-53M-18
A847/A847M-14
A1085/A1085M-15
IN COMPLIANCE WITH EN 10204 SECTION 4.1
INSPECTION CERTIFICATE TYPE 3.1

Page: 1 .... Last

Figure G-15. 8-in. x 6-in. x ¼ -in. Steel Blockout, Test Nos. HMDT-2 and HMDT-3 (Item No. d4)

21Jul20 14:35 T E S T C E R T I F I C A T E No: MAR 372566

NUCOR TUBULAR PRODUCTS INC.
6226 W. 74TH STREET
CHICAGO, IL 60638
Tel: 708-496-0380 Fax: 708-563-1950

P/O No 01032075
Rel
S/O No MAR 396557-001
B/L No MAR 235002-002 Shp 21Jul20
Inv No Inv

Sold To: ( 1403)
NORFOLK IRON & METAL
P.O. BOX 1129
NORFOLK, NE 68701

Ship To: ( 1)
NORFOLK IRON & METAL
3001 NORTH VICTORY RD
NORFOLK, NE 68702

Tel: 402-371-1810 Fax: 402 379-5409

CERTIFICATE of ANALYSIS and TESTS Cert. No: MAR 372566
13Jul20

Part No 01239
TUBING A500 GRADE B(C)
12" X 4" X 1/4" X 20'

| | Pcs | Wgt |
|---|---|---|
| Part No 01239 TUBING A500 GRADE B(C) 12" X 4" X 1/4" X 20' | 6 | 3,098 |

| Heat Number | Tag No | Pcs | Wgt |
|---|---|---|---|
| 2202349 | 911766 | 6 | 3,098 |

YLD=54380/TEN=70950/ELG=35.8

Heat Number *** Chemical Analysis ***
2202349 C=0.2100 Mn=0.7600 P=0.0110 S=0.0014 Si=0.0200 Al=0.0400
Cu=0.0700 Cr=0.0400 Mo=0.0100 V=0.0030 Ni=0.0300 Nb=0.0010
Cb=0.0010 Sn=0.0030 N=0.0070 B=0.0000 Ti=0.0020 Sb=0.0000
Ca=0.0010
MELTED AND MANUFACTURED IN THE USA

THE SPECIFICATIONS LISTED BELOW REPRESENT THE CURRENT ISSUED DATES OF THESE STANDARDS. THIS DOES NOT INDICATE THAT THE MATERIAL ABOVE CONFORMS TO EACH OR ALL OF THE STANDARDS. WE CERTIFY THE MATERIAL ABOVE TO THE SPECIFICATION LISTED IN THE LINE DESCRIPTION.

CURRENT STANDARDS:
A252-19
A500/A500M-20
A513/A513M-20
ASTM A53/A53M-18| ASME SA-53/SA-53M-18
A847/A847M-14
A1085/A1085M-15
IN COMPLIANCE WITH EN 10204 SECTION 4.1
INSPECTION CERTIFICATE TYPE 3.1

Page: 1 .... Last

Figure G-16. 12-in. x 4-in. x ¼-in. Steel Blockout, Test Nos. HMDT-2 and HMDT-3 (Item No. d5)

```
14Aug20 22:49          T E S T   C E R T I F I C A T E         No: MAR 390260

     NUCOR TUBULAR PRODUCTS INC.                P/O No 03054005
     6226 W. 74TH STREET                        Rel
     CHICAGO, IL  60638                         S/O No MAR 398647-006
     Tel: 708-496-0380 Fax: 708-563-1950        B/L No MAR 236355-004  Shp  14Aug20
                                                Inv No                 Inv

     Sold To:   ( 1403)                         Ship To:   (  3)
     NORFOLK IRON & METAL                       NORFOLK (GREELEY)
     P.O. BOX 1129                              31181 COUNTY RD 39 1/2
     NORFOLK, NE  68701                         970-352-6722
                                                GREELEY, CO  80631

     Tel: 402-371-1810 Fax: 402 379-5409
--------------------------------------------------------------------------------
               CERTIFICATE of ANALYSIS and TESTS            Cert. No: MAR 390260
                                                                      10Aug20
Part No 01239
TUBING A500 GRADE B(C)                                          Pcs        Wgt
12" X 4" X 1/4" X 20'                                             6      3,098

Heat Number      Tag No                                         Pcs        Wgt
SK1852           918868                                           6      3,098
                    YLD=60270/TEN=74590/ELG=33.5

Heat Number           *** Chemical Analysis ***
SK1852           C=0.2000 Mn=0.3900 P=0.0060 S=0.0020 Si=0.0290 Al=0.0320
                 Cu=0.1000 Cr=0.0600 Mo=0.0100 V=0.0020 Ni=0.0300 Nb=0.0060
                 N=0.0056 B=0.0001 Ti=0.0010 Ca=0.0016
                 MELTED AND MANUFACTURED IN THE USA

THE SPECIFICATIONS LISTED BELOW REPRESENT THE
CURRENT ISSUED DATES OF THESE STANDARDS.  THIS
DOES NOT INDICATE THAT THE MATERIAL ABOVE CONFORMS
TO EACH OR ALL OF THE STANDARDS.  WE CERTIFY THE
MATERIAL ABOVE TO THE SPECIFICATION LISTED IN THE
LINE DESCRIPTION.
__________________________________________________
CURRENT STANDARDS:
A252-19
A500/A500M-20
A513/A513M-20
ASTM A53/A53M-18| ASME SA-53/SA-53M-18
A847/A847M-14
A1085/A1085M-15
IN COMPLIANCE WITH EN 10204 SECTION 4.1
INSPECTION CERTIFICATE TYPE 3.1
__________________________________________________

     Page:   1 .... Last
```

Figure G-17. 17½-in. Long, 12-in. x 4-in. x ¼-in. Steel Blockout, Test Nos. HMDT-2 and HMDT-3 (Item No. d5)

MONDO POLYMER TECHNOLOGIES INC.
Plastics From Today for Tomorrow...

P.O. BOX 250
27620 ST. RT. 7 NORTH
RENO, OH 45773

Phone: 740-376-9396
Fax: 740-376-9960
(888) 607-4790

**MATERIAL CERTIFICATE**

SHIPMENT NUMBER: 34545
PURCHASE ORDER HWTT
SHIPMENT DATE: 4/4/2019

PAGE: 2

**CONSIGNED TO**

Midwest Roadside Safety
4630 NV 36th Street
Lincoln, NE 68524

**SHIP TO**

Midwest Roadside Safety

4630 NW 36th Street
Lincoln, NE 68524

| CONSIGNED | ITEM NUMBER | DESCRIPTION | LOT # | SHIP VIA |
|---|---|---|---|---|
| 4 | MGS14SH | Midwest Composite Block 14" h x 12" d for Steel Post | 1904/1000 | FedEx Freight |

**MADE IN USA**

**The composite guardrail blocks for the Midwest Guardrail System are manufactured by Mondo Polymer Technologies, Inc., and are of the same formulation, composition, and test properties as those which were MASH qualified and and eligible for reimbursement by the Federal Highway Administration under the Federal-aid highway program, Approval #HSST/B-39C.**

**All materials meet required specifications.**

Approved by: Maggie Ellis

Date: 4/4/2019

Print Name: Maggie Ellis

Position: General Manager

Figure G-18. $14^{3}/_{16}$-in. x 12-in. x $5^{1}/_{8}$-in. Composite Recycled Blockout, Test Nos. HMDT-2 and HMDT-3 (Item No. d6)

**MONDO POLYMER TECHNOLOGIES INC.**
Plastics From Today for Tomorrow...

P.O. BOX 250
27620 ST. RT. 7 NORTH
RENO, OH 45773

Phone: 740-376-9396
Fax: 740-376-9960
(888) 607-4790

## MATERIAL CERTIFICATE

SHIPMENT NUMBER: 34545
PURCHASE ORDER HWTT
SHIPMENT DATE: 4/4/2019

PAGE: 1

**CONSIGNED TO**

Midwest Roadside Safety
4630 NV 36th Street
Lincoln, NE 68524

**SHIP TO**

Midwest Roadside Safety

4630 NW 36th Street
Lincoln, NE 68524

| CONSIGNED | ITEM NUMBER | DESCRIPTION | LOT # | SHIP VIA |
|---|---|---|---|---|
| 10 | GB14SH2 | Composite Guardrial Block 14" for Steel Post w/hanger CO | 1804/1000 | FedEx Freight |

**MADE IN USA**

**The composite guardrail offset blocks for the Midwest Guardrail System (MGS), are manufactured by Mondo Polymer Technologies, Inc., and are of the same formulation, composition, and test properties as those which were MASH qualified and eligible for reimbursement by the Federal Highway Administration under the Federal-aid highway program, Approval No. HSST-1/B-278A.**

**All materials meet required specifications.**

Approved by: Maggie Ellis

Date: 4/4/2019

Print Name: Maggie Ellis

Position: General Manager

Figure G-19. $14^{3}/_{16}$-in. x 8-in. x5⅛-in. Composite Recycled Blockout, Test Nos. HMDT-2 and HMDT-3 (Item No. d7)

**McMASTER-CARR.** Certificate of Compliance

600 N County Line Rd
Elmhurst IL 60126-2081
630-600-3600
chi.sales@mcmaster.com

University of Nebraska
Midwest Roadside Safety Facility
M W R S F
4630 Nw 36TH St
Lincoln NE 68524-1802
Attention: Shaun M Tighe
Midwest Roadside Safety Facility

Purchase Order
**E000548963**

Order Placed By
**Shaun M Tighe**

McMaster-Carr Number
**7204107-01**

Page 1 of 1

08/02/2018

| Line | Product | Ordered | Shipped |
|---|---|---|---|
| 1 | **97812A109** Raised-Head Removable Nails, 16D Penny Size, 3" Long, Packs of 5 | **5 Packs** | **5** |

Certificate of compliance

This is to certify that the above items were supplied in accordance with the description and as illustrated in the catalog. Your order is subject only to our terms and conditions, available at www.mcmaster.com or from our Sales Department.

Sarah Weinberg
Compliance Manager

Figure G-20. 16D Double Head Nail, Test Nos. HMDT-2 and HMDT-3 (Item No. d8)

CMC STEEL TENNESSEE
1919 Tennessee Avenue
Knoxville TN 37921-2686

CERTIFIED MILL TEST REPORT
For additional copies call

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

Jim Hall
Quality Assurance Manager

| | | | | |
|---|---|---|---|---|
| HEAT NO.:7006848<br>SECTION: REBAR 13MM (#4) 60'0" 420/60<br>GRADE:<br>ROLL DATE:<br>MELT DATE: 01/05/2020<br>Cert. No.: 82944733 / 006848L265 | SOLD TO | ABC Coating Co - Tulsa<br><br>2238 S Yukon Ave<br>Tulsa OK<br>US 74107-2765<br>9185852587<br>9185858131 | SHIP TO | CPU Chicago Depot<br><br>13535 S Torrence Ave<br>Chicago IL<br>US 60633-2164<br>7736466363 | Delivery#: 82944733<br>BOL#: 1865847<br>CUST PO#: 010620-Minn<br>CUST P/N:<br>DLVRY LBS / HEAT: 26932.000 LB<br>DLVRY PCS / HEAT: 672 EA |

| Characteristic | Value | Characteristic | Value | Characteristic | Value |
|---|---|---|---|---|---|
| C | 0.27% | Rebar Deformation Avg. Spaci | 0.329IN | | |
| Mn | 0.59% | Rebar Deformation Avg. Heigh | 0.034IN | | |
| P | 0.008% | Rebar Deformation Max. Gap | 0.106IN | | |
| S | 0.048% | | | | |
| Si | 0.20% | | | | |
| Cu | 0.33% | | | | |
| Cr | 0.17% | | | | |
| Ni | 0.11% | | | | |
| Mo | 0.014% | | | | |
| V | 0.002% | | | | |
| Sn | 0.007% | | | | |
| Yield Strength test 1 | 85.9ksi | | | | |
| Yield Strength test 1 (metri | 592MPa | | | | |
| Tensile Strength test 1 | 99.1ksi | | | | |
| Tensile Strength 1 (metric) | 684MPa | | | | |
| Elongation test 1 | 13% | | | | |
| Elongation Gage Lgth test 1 | 8IN | | | | |
| Elongation Gage Lgth 1(metri | 200mm | | | | |
| Bend Test 1 | Passed | | | | |

The Following is true of the material represented by this MTR:
*Material is fully killed
*100% melted and rolled in the USA
*EN10204:2004 3.1 compliant
*Contains no weld repair
*Contains no Mercury contamination
*Manufactured in accordance with the latest version of the plant quality manual
*Meets the "Buy America" requirements of 23 CFR635.410, 49 CFR 661
*Warning: This product can expose you to chemicals which are known to the State of California to cause cancer, birth defects or other reproductive harm. For more information go to www.P65Warnings.ca.gov

REMARKS :

Page 1 OF 1 01/21/2020 09:09:21

Figure G-21. #4 Rebar, Test Nos. HMDT-2 and HMDT-3 (Item Nos. e3 and e4)

# Mill Certification

08/26/2020

MTR#:454619-1
Lot #:360001414020
ONE NUCOR WAY
BOURBONNAIS, IL 60914 US
815 937-3131
Fax: 815 939-5599

Sold To: SIMCOTE INC
1645 RED ROCK RD
ST PAUL, MN 55119 US

Ship To: SIMCOTE INC
1645 RED ROCK RD
ST PAUL, MN 55119 US

| | | | |
|---|---|---|---|
| Customer PO | MN-3748 | Sales Order # | 36013225 - 2.10 |
| Product Group | Rebar | Product # | 2110230 |
| Grade | A615 Gr 60/AASHTO M31 | Lot # | 360001414020 |
| Size | #5 | Heat # | 3600014140 |
| BOL # | BOL-562924 | Load # | 454619 |
| Description | Rebar #5/16mm A615 Gr 60/AASHTO M31 40' 0" [480"] 4001-8000 lbs | Customer Part # | |
| Production Date | 07/17/2020 | Qty Shipped LBS | 45060 |
| Product Country Of Origin | United States | Qty Shipped EA | 1080 |
| Original Item Description | | Original Item Number | |

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.

Melt Country of Origin : United States    Melting Date: 07/14/2020

| C (%) | Mn (%) | P (%) | S (%) | Si (%) | Ni (%) | Cr (%) | Mo (%) | Cu (%) | V (%) | Nb (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.36 | 0.94 | 0.012 | 0.048 | 0.215 | 0.23 | 0.14 | 0.08 | 0.37 | 0.009 | 0.002 |

**Other Test Results**

Yield (PSI) : 66700
Tensile (PSI) : 101600
Average Deformation Height (IN) : 0.043
Elongation in 8" (%) : 13.1
Bend Test : Pass
Weight Percent Variance (%) : -2.40

**Comments:**

All manufacturing processes of the steel materials in this product, including melting, have occurred within the United States. Products produced are weld free. Mercury, in any form, has not been used in the production or testing of this material.

Figure G-22. #5 Rebar, Test Nos. HMDT-2 and HMDT-3 (Item Nos. e5 and e6)

GERDAU

US-ML-ST PAUL
1678 RED ROCK ROAD
SAINT PAUL, MN 55119
USA

CERTIFIED MATERIAL TEST REPORT

Page 1/1

| CUSTOMER SHIP TO | CUSTOMER BILL TO | GRADE | SHAPE / SIZE | DOCUMENT ID: |
|---|---|---|---|---|
| SIMCOTE INC<br>1645 RED ROCK RD<br>SAINT PAUL,MN 55119<br>USA | SIMCOTE INC<br>1645 RED ROCK ROAD<br>SAINT PAUL,MN 55119-6014<br>USA | 60 (420) | Rebar / #5 (16MM) | 0000036750 |

| LENGTH | WEIGHT | HEAT / BATCH |
|---|---|---|
| 40'00" | 8,594 LB | **62150922**/02 |

| SALES ORDER | CUSTOMER MATERIAL N° | SPECIFICATION / DATE or REVISION |
|---|---|---|
| 8328518/000050 | | ASTM A615/A615M-16 |

| CUSTOMER PURCHASE ORDER NUMBER | BILL OF LADING | DATE |
|---|---|---|
| MN-3734 | 1332-0000075667 | 11/21/2019 |

CHEMICAL COMPOSITION

| C % | Mn % | P % | S % | Si % | Cu % | Ni % | Cr % | Mo % | Sn % | V % | Nb % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.42 | 1.09 | 0.009 | 0.021 | 0.23 | 0.29 | 0.12 | 0.19 | 0.029 | 0.012 | 0.004 | 0.002 |

MECHANICAL PROPERTIES

| YS PSI | YS MPa | UTS PSI | UTS MPa | G/L Inch | G/L mm |
|---|---|---|---|---|---|
| 68545 | 473 | 107801 | 743 | 8.000 | 203.2 |

MECHANICAL PROPERTIES

| Elong. % | BendTest |
|---|---|
| 13.80 | OK |

GEOMETRIC CHARACTERISTICS

| %Light % | Def Hgt Inch | Def Gap Inch | DefSpace Inch |
|---|---|---|---|
| 1.75 | 0.380 | 0.131 | 0.419 |

COMMENTS / NOTES

Material 100% melted and rolled in the USA. Manufacturing processes for this steel, which may include scrap melted in an electric arc furnace and hot rolling, have been performed at Gerdau St. Paul Mill, 1678 Red Rock Road, Saint Paul, Minnesota, USA. All product produced from strand cast billets. Silicon killed (deoxidized) steel. No weld repairment performed. Steel not exposed to mercury or any liquid alloy which is liquid at ambient temperatures during processing or while in Gerdau St. Paul Mills possession. Any modification to this certification as provided by Gerdau-St. Paul Mill without the expressed written consent of Gerdau St. Paul Mill negates the validity of this test report. This report shall not be reproduced except in full, without the expressed written consent of Gerdau St. Paul Mill. Gerdau St. Paul Mill is not responsible for the inability of this material to meet specific applications.
Roll batch 62150922/02 roll date 8/26/2019

Figure G-23. #5 Rebar, Test Nos. HMDT-2 and HMDT-3 (Item Nos. e5 and e6)

**CERTIFICATE OF COMPLIANCE**

**ROCKFORD BOLT & STEEL CO.**
**126 MILL STREET**
**ROCKFORD, IL 61101**
**815-968-0514 FAX# 815-968-3111**

**CUSTOMER NAME:** TRINITY INDUSTRIES

**CUSTOMER PO:** 187087

**SHIPPER #:** 061972
**DATE SHIPPED:** 11/06/2017

**LOT#:** 30361-P

**SPECIFICATION:** ASTM A307, GRADE A MILD CARBON STEEL BOLTS

| | | | | |
|---|---|---|---|---|
| **TENSILE:** | SPEC: | 60,000 psi*min | RESULTS: | 66,566<br>66,832 |
| **HARDNESS:** | | 100 max | | 82.60<br>82.70 |

*Pounds Per Square Inch.

**COATING:** ASTM SPECIFICATION F-2329 HOT DIP GALVANIZE
**ROGERS GALVANIZE:** 30361-P

**CHEMICAL COMPOSITION**

| MILL | GRADE | HEAT# | C | Mn | P | S | Si |
|---|---|---|---|---|---|---|---|
| NUCOR | 1010 | DL17100590 | .10 | .41 | .005 | .005 | .05 |

**QUANTITY AND DESCRIPTION:**

**4,825** PCS 5/8" X 14" GUARD RAIL BOLT
P/N 3540G

WE HEREBY CERTIFY THE ABOVE BOLTS HAVE BEEN MANUFACTURED BY ROCKFORD BOLT AND STEEL AT OUR FACILITY IN ROCKFORD, ILLINOIS, USA. THE MATERIAL USED WAS MELTED AND MANUFACTURED IN THE USA. WE FURTHER CERIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIALS SUPPLIER, AND THAT OUR PROCEDURES FOR THE CONTROL OF PRODUCT QUALITY ASSURE THAT ALL ITEMS FURNISHED ON THIS ORDER MEET OR EXCEED ALL APPLICABLE TESTS, PROCESS, AND INSPECTION REQUIREMENT PER ABOVE SPECIFICATION.

STATE OF ILLINOIS
COUNTY OF WINNEBAGO
SIGNED BEFORE ME ON THIS

6th DAY OF November, 2017 — Linda McComas — 11/6/17

APPROVED SIGNATORY — DATE

Merry F. Shane

OFFICIAL SEAL
MERRY F. SHANE
NOTARY PUBLIC – STATE OF ILLINOIS
MY COMMISSION EXPIRES OCTOBER 3, 2018

Figure G-24. ⅝-in. Dia., 14-in. Long Guardrail Bolt, Test Nos. HMDT-2 and HMDT-3 (Item No. f1)

# MATERIAL TEST REPORT

PAGE 1

Date Printed: 04/04/2018

Mid American Steel & Wire

Bill to:
KING STEEL
5225 E. COOK ROAD
ap@kingsteelcorp.com
GRAND BLANC, MI 48439-838

Ship to:
KING STEEL
CPU
Grand Blanc, MI 48439-8388

Customer No: 000000006021
PO Number: 025623
Ship Date: 04/04/2018
Order Number: 92649
Load Number: 117036

| Item Number | Description |
|---|---|
| D19321012SHM | 19/32 1012SH ROD |

CHEMICAL ANALYSIS

| Heat Number | C | Mn | P | S | Si | Cu | Ni | Cr | Mo | Sn | V | Al | N | B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1721198 | 0.1300 | 0.5100 | 0.0160 | 0.0270 | 0.1900 | 0.1500 | 0.0600 | 0.1200 | 0.0100 | 0.0080 | 0.0020 | 0.0020 | 0.0080 | 0.0002 |

MECHANICAL PROPERTIES

| Heat Number | Yield (Psi) | Tensile (Psi) | Elongation (%) | Reduction (%) | Bend Test Pass/ Fail |
|---|---|---|---|---|---|
| 1721198 | 45781 psi / | 66316 psi / | 23.12 | 60.76 | |

The melting and rolling processes used to manufacture the above described material took place in the United States of America. The material was produced and tested in accordance with ASTM A-510.

Quality Assurance: 

Figure G-25. ⅝-in. Dia., 10-in. Long Guardrail Bolt, Test Nos. HMDT-2 and HMDT-3 (Item No. f2)

**CERTIFICATE OF COMPLIANCE**

**ROCKFORD BOLT & STEEL CO.**
**126 MILL STREET**
**ROCKFORD, IL 61101**
**815-968-0514**

**CUSTOMER NAME:** TRINITY INDUSTRIES

**CUSTOMER PO:** 209038

**SHIPPER #:** 069386
**DATE SHIPPED:** 07/23/2020

**LOT#:** 32756-P

**SPECIFICATION:** ASTM A307, GRADE A MILD CARBON STEEL BOLTS

**TENSILE:** SPEC: 60,000 psi*min RESULTS: 69,800
69,900

**HARDNESS:** 100 max 67.50
68.60

*Pounds Per Square Inch.

**COATING:** ASTM SPECIFICATION F-2329 HOT DIP GALVANIZE
**AZZ GALVANIZING:** 32756-P

**CHEMICAL COMPOSITION**

| MILL | GRADE | HEAT# | C | Mn | P | S | Si |
|---|---|---|---|---|---|---|---|
| CHARTER STEEL | 1010 | 10657410 | .09 | .38 | .007 | .007 | .09 |

**QUANTITY AND DESCRIPTION:**

86,000 PCS 5/8" X 1.25" GUARD RAIL BOLT
P/N 3360G

WE HEREBY CERTIFY THE ABOVE BOLTS HAVE BEEN MANUFACTURED BY ROCKFORD BOLT AND STEEL AT OUR FACILITY IN ROCKFORD, ILLINOIS, USA. THE MATERIAL USED WAS MELTED AND MANUFACTURED IN THE USA. WE FURTHER CERIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIALS SUPPLIER, AND THAT OUR PROCEDURES FOR THE CONTROL OF PRODUCT QUALITY ASSURE THAT ALL ITEMS FURNISHED ON THIS ORDER MEET OR EXCEED ALL APPLICABLE TESTS, PROCESS, AND INSPECTION REQUIREMENT PER ABOVE SPECIFICATION.

STATE OF ILLINOIS
COUNTY OF WINNEBAGO
SIGNED BEFORE ME ON THIS

21st DAY OF July 20 20 Linda Mclomas 7/21/2020
APPROVED SIGNATORY DATE

Merry F Shane

Official Seal
Merry F Shane
Notary Public State of Illinois
My Commission Expires 10/03/2022

Figure G-26. ⅝-in. Dia., 1¼-in. Long Guardrail Bolt, Test Nos. HMDT-2 and HMDT-3 (Item No. f3)

## Certificate of Compliance

Birmingham Fastener Manufacturing
PO Box 10323
Birmingham, AL 35202
(205) 595-3512

| | | | |
|---|---|---|---|
| Customer | Midwest Machinery & Supply | Date Shipped | 11/28/2018 |
| Customer Order Number | 3664 | BFM Order Number | 1553751 |

### Item Description

| | | | | | |
|---|---|---|---|---|---|
| Description | 5/8"-11 x 10" Hex Bolt | | | Qty | 298 |
| Lot # | 81342 | Specification | ASTM A307-14 Gr A | Finish | ASTM F2329 |

### Raw Material Analysis

Heat# JK18104124

Chemical Composition (wt% Heat Analysis) By Material Supplier

| C | Mn | P | S | Si | Cu | Ni | Cr | Mo |
|---|---|---|---|---|---|---|---|---|
| 0.18 | 1.19 | 0.012 | 0.034 | 0.20 | 0.29 | 0.13 | 0.11 | 0.04 |

### Mechanical Properties

| Sample # | Hardness | Tensile Strength (lbs) | Tensile Strength (psi) |
|---|---|---|---|
| 1 | 93 HRBW | 22,049 | 99,410 |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |

This information represents the most recent analysis of the product supplied on the stated customer order. The samples tested conform to the ASTM standard listed above.
All steel melted and manufactured in the U.S.A.

Authorized Signature: Brian Hughes
Quality Assurance

Date: 11/29/2018

Figure G-27. ⅝-in. Dia., 10-in. Long Hex Head Bolt, Test Nos. HMDT-2 and HMDT-3 (Item No. f4)

# CERTIFIED MATERIAL TEST REPORT
# FOR ASTM A307, GRADE A - MACHINE BOLTS

FACTORY: IFI & MORGAN LTD. REPORT DATE:2019/4/2
ADDRESS: No.583-28, Chang'an North Road, Wuyuan Town, Haiyan, Zhejiang, China MANUFACTURE DATE:2019/3/14

CUSTOMER: FASTENAL MFG LOT NUMBER:M-2019HT138-5
SAMPE SIZE: ACC. TO ASME B18.18 CATEGORY 2-2011; ASTM F1470-12 TABLE 3
MANU QTY: 2450PCS SHIPPED QTY:2400PCS
SIZE: 5/8-11X1 1/2 HDG
HEADMARKS: 307A PLUS NY PO NUMBER:210179696
PART NO:191919

STEEL PROPERTIES:
MATERIAL TYPE:Q195C HEAT NUMBER:5-01570

| CHEMISTRY SPEC: | C %*100 | Mn%*100 | P %*1000 | S %*1000 |
|---|---|---|---|---|
| Grade A ASTM A307-12 | 0.29max | 1.20 max | 0.04max | 0.15max |
| TEST: | 0.07 | 0.33 | 0.015 | 0.022 |

DIMENSIONAL INSPECTIONS Unit:inch SPECIFICATION: ASME B18.2.1 - 2012

| CHARACTERISTICS | SPECIFIED | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|
| ********************** | ************************************ | ****************** | ******** | ******** |
| VISUAL | ASTM F788-2013 | PASSED | 18 | 0 |
| THREAD | ASME B1.1-2003, 3A GO, 2A NO GO | PASSED | 13 | 0 |
| WIDTH A/F | 0.906-0.938 | 0.916-0.928 | 3 | 0 |
| WIDTH A/C | 1.033-1.083 | 1.048-1.057 | 3 | 0 |
| HEAD HEIGHT | 0.378-0.444 | 0.394-0.428 | 3 | 0 |
| BODY DIA. | 0.605-0.642 | 0.617-0.634 | 3 | 0 |
| THREAD LENGTH | 1.420-1.560 | 1.436-1.543 | 13 | 0 |
| LENGTH | 1.420-1.560 | 1.436-1.543 | 13 | 0 |

MECHANICAL PROPERTIES: SPECIFICATION: ASTM A307 - 14e1 GR.A

| CHARACTERISTICS | TEST METHOD | SPECIFIED | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|
| ********************* | ****************** | ****************** | ****************** | ******** | ******** |
| CORE HARDNESS : | ASTM F606/F606M-2016 | 69-100 HRB | 75-80 HRB | 3 | 0 |
| WEDGE TENSILE: | ASTM F606/F606M-2016 | Min 60 KSI | 65-69 KSI | 3 | 0 |

| CHARACTERISTICS | TEST METHOD | SPECIFIED | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|
| COATINGS OF ZINC: | | SPECIFIATION: ASTM F2329/F2329M-2015 | | | |
| HOT DIP GALVANIZED | ASTM B568-98(2014) | Min 0.0017" | 0.0017" -0.0018" | 3 | 0 |

We hereby certify that above products supplied are in compliance with all the requirements of the order.
We here by certify that this MTR is in compliance to DIN EN 10204 3.1 content.
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.
Maker's ISO 9001:2015 SGS Certificate # HK04/0105

IFI & MORGAN LTD.
检验专用章

(SIGNATURE OF Q.A. LAB MGR.)
(NAME OF MANUFACTURER)

Figure G-28. ⅝-in. Dia., 1½-in. Long Hex Head Bolt, Test Nos. HMDT-2 and HMDT-3 (Item No. f5)

**Portland Bolt**
**& MANUFACTURING COMPANY**

Phone: 800-547-6758 | Fax: 503-227-4634
3441 NW Guam Street, Portland, OR 97210
Web: www.portlandbolt.com | Email: sales@portlandbolt.com

**CERTIFICATE OF CONFORMANCE**

**For:** MIDWEST ROADSIDE SAFETY FACIL
**PB Invoice#:** 119891
**Cust PO#:** 70ACCT
**Date:** 4/17/2019
**Shipped:** 4/25/2019

**We certify that the following items were manufactured and tested in accordance with the chemical, mechanical, dimensional and thread fit requirements of the specifications referenced.**

**Description:** 7/8 X 8 GALV ASTM A307A HEX BOLT

**Heat#:** 489517 **Base Steel:** A36 **Diam:** 7/8

**Source:** CASCADE STEEL RLG MILL **Proof Load:** 0

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **C :** | .180 | **Mn:** | .680 | **P :** | .013 | **Hardness:** | 0 | | | | |
| **S :** | .015 | **Si:** | .240 | **Ni:** | .080 | **Tensile:** | 72,500 PSI | **RA:** | 42.00% | | |
| **Cr:** | .130 | **Mo:** | .028 | **Cu:** | .240 | **Yield:** | 48,800 PSI | **Elon:** | 24.00% | | |
| **Pb:** | .000 | **V :** | .000 | **Cb:** | .000 | **Sample Length:** | 8 INCH | | | | |
| **N :** | .000 | | | **CE:** | .3157 | **Charpy:** | | **CVN Temp:** | | | |

**Coatings:**
ITEMS HOT DIP GALVANIZED PER ASTM F2329/A153C

By: 
Certification Department Quality Assurance
Dane McKinnon

Figure G-29. ⅞-in. Dia., 8-in. Long Hex Head Bolt, Test Nos. HMDT-2 and HMDT-3 (Item No. f6)

# TEST REPORT

## USS FLAT WASHER, HDG

| | |
|---|---|
| CUSTOMER: | DATE: 30/12/2018 |
| PO NUMBER: 180164126 | MFG LOT NUMBER: M-SWE0412454-8 |
| SIZE: 5/8 | PART NO: 1133185 |
| HEADMARKS: | QNTY: 6,000 PCS |

DIMENSIONAL INSPECTIONS — SPECIFICATION: **ASME B18.21.1(2009)**

| CHARACTERISTICS | SPECIFIED | | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|
| APPEARANCE | ASTM F788-07 | | PASSED | 100 | 0 |
| OUTSIDE DIA | 1.743-1.780 | | 1.752-1.756 | 8 | 0 |
| INSIDE DIA | 0.681-0.718 | | 0.700-0.707 | 8 | 0 |
| THICKNESS | 0.108-0.160 | | 0.114-0.119 | 8 | 0 |
| HOT DIP GALVANIZED | ASTM A153 class C. RoHS Compliant | Min 0.0017" | Min 0.0019 In | 8 | 0 |

*ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE ASTM SPECIFICATION.*
*WE CERTIFY THAT THIS DAIA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.*
*MFG ISO 9001:2015 SGS Certificate # HK04/0105*
**We hereby certify that above products supplied are in compliance with all the requirements of the order.**
**We here by certify that this MTR is in compliance to DIN EN 10204 3.1 content.**

IFI & MORGAN LTD. 检验专用章

(SIGNATURE OF Q.A. LAB MGR.)
(NAME OF MANUFACTURER)

*IFI & MORGAN LTD.* *ADDRESS: Chang'an North Road, Wuyuan Town, Haiyan, Zhejiang, China*

Figure G-30. ⅝-in. Dia. Plain USS Washer, Test Nos. HMDT-2 and HMDT-3 (Item No. g1)

CERTIFIED MATERIAL TEST REPORT
FOR USS FLAT WASHERS HDG

FACTORY: IFI & Morgan Ltd REPORT DATE: 23/4/2019
ADDRESS: Chang'an North Road, Wuyuan Town, Haiyan,Zhejiang, China

MFG LOT NUMBER: 1844804

SAMPLING PLAN PER ASME B18.18-11 PO NUMBER: 170089822
SIZE: USS 7/8 HDG QNTY(Lot size): 7200PCS
HEADMARKS: NO MARK PART NO: 33187

DIMENSIONAL INSPECTIONS SPECIFICATION: ASTM B18.21.1-2011

| CHARACTERISTICS | SPECIFIED | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|
| APPEARANCE | ASTM F844 | PASSED | 100 | 0 |
| OUTSIDE DIA | 2.243-2.280 | 2.246-2.254 | 10 | 0 |
| INSIDE DIA | 0.931-0.968 | 0.956-0.965 | 10 | 0 |
| THICKNESS | 0.136-0.192 | 0.136-0.157 | 10 | 0 |

| CHARACTERISTICS | TEST METHOD | SPECIFIED | ACTUAL RESULT | | ACC. | REJ. |
|---|---|---|---|---|---|---|
| HOT DIP GALVANIZED | ASTM F2329-13 | Min 0.0017" | 0.0017-0.0020 | in | 8 | 0 |

ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE ASTM SPECIFICATION. WE CERTIFY THAT THIS DAIA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.
ISO 9001:2015 SGS Certificate # HK04/0105

IFI & MORGAN LTD.
检验专用章
QUANLITY CONTROL

(SIGNATURE OF Q.A. LAB MGR.)

Figure G-31. ⅞-in. Dia. Plain Round Washer, Test Nos. HMDT-2 and HMDT-3 (Item No. g3)

# CERTIFIED MATERIAL TEST REPORT
## FOR USS FLAT WASHERS HDG

FACTORY: IFI & Morgan Ltd  REPORT DATE: 22/10/2018
ADDRESS: Chang'an North Road, Wuyuan Town, Haiyan,Zhejiang, China

SAMPLING PLAN PER ASME B18.18-11  PO NUMBER: 210151571
SIZE: USS 1 HDG  QNTY(Lot size): 3240PCS
HEADMARKS: NO MARK  PART NO: 33188

DIMENSIONAL INSPECTIONS  SPECIFICATION: ASTM B18.21.1-2011

| CHARACTERISTICS | SPECIFIED | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|
| ********************* | ************************************ | ******************** | ******** | ******** |
| APPEARANCE | ASTM F844 | PASSED | 100 | 0 |
| OUTSIDE DIA | 2.492-2.529 | 2.496-2.504 | 10 | 0 |
| INSIDE DIA | 1.055-1.092 | 1.080-1.089 | 10 | 0 |
| THICKNESS | 0.135-0.192 | 0.135-0.157 | 10 | 0 |

| CHARACTERISTICS | TEST METHOD | SPECIFIED | ACTUAL RESULT | | ACC. | REJ. |
|---|---|---|---|---|---|---|
| ********************* | ****************** | ****************** | ****************** | | ******** | ******** |
| HOT DIP GALVANIZED | ASTM F2329-13 | Min 0.0017" | 0.0017-0.0020 | in | 8 | 0 |

ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE ASTM SPECIFICATION. WE CERTIFY THAT THIS DAIA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.
ISO 9001:2015 SGS Certificate # HK04/0105

IFI & MORGAN LTD.
检验专用章
QUANLITY CONTROL

(SIGNATURE OF Q.A. LAB MGR.)

Figure G-32. 1-in. Dia. Plain USS Washer, Test Nos. HMDT-2 and HMDT-3 (Item No. g4)

GERDAU

CERTIFIED MATERIAL TEST REPORT

Page 1 / 1

US-ML-ST PAUL
1678 RED ROCK ROAD
SAINT PAUL, MN 55119
USA

| CUSTOMER SHIP TO | CUSTOMER BILL TO | GRADE | SHAPE / SIZE | DOCUMENT ID: |
|---|---|---|---|---|
| UNYTITE INC LASALLE PLANT<br>325 CIVIC ROAD<br>LA SALLE,IL 61301<br>USA | UNYTITE INC<br>1 UNYTITE DR<br>PERU,IL 61354-9710<br>USA | 1045M23FJZN | Round Bar / 1" | 0000038876 |

| LENGTH | WEIGHT | HEAT / BATCH |
|---|---|---|
| 25'01.50" | 35,008 LB | 62151324/02 |

| SALES ORDER | CUSTOMER MATERIAL N° | SPECIFICATION / DATE or REVISION |
|---|---|---|
| 8310712/000010 | B1045SC1.0000 1 | ASTM A29-16<br>ASTM A576-17 |

| CUSTOMER PURCHASE ORDER NUMBER | BILL OF LADING | DATE |
|---|---|---|
| P008845 | 1332-0000077708 | 01/29/2020 |

CHEMICAL COMPOSITION

| C % | Mn % | P % | S % | Si % | Cu % | Ni % | Cr % | Mo % | Sn % | V % | Nb % | Al % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.44 | 0.71 | 0.010 | 0.031 | 0.23 | 0.34 | 0.10 | 0.16 | 0.022 | 0.012 | 0.032 | 0.001 | 0.005 |

HARDENABILITY

| DI A255 Inch |
|---|
| 1.53 |

COMMENTS / NOTES

Material 100% melted and rolled in the USA. Manufacturing processes for this steel, which may include scrap melted in an electric arc furnace and hot rolling, have been performed at Gerdau St. Paul Mill, 1678 Red Rock Road, Saint Paul, Minnesota, USA. All product produced from strand cast billets. Silicon killed (deoxidized) steel. No weld repairmen performed. Steel not exposed to mercury or any liquid alloy which is liquid at ambient temperatures during processing or while in Gerdau St. Paul Mills possession. Any modification to this certification as provided by Gerdau-St. Paul Mill without the expressed written consent of Gerdau St. Paul Mill negates the validity of this test report. This report shall not be reproduced except in full, without the expressed written consent of Gerdau St. Paul Mill. Gerdau St. Paul Mill is not responsible for the inability of this material to meet specific applications.
Roll batch 62151324/02 roll date 10/23/2019 Fine Grain (FG 5-8)
Macro S1 R1 C1 ASTM E381-17 E45-18a Reduction Ration = 38.2 Quality Program Manual Rev. 10, Implemented date 11/8/2019

DEBRA L. KARIESCH
Notary Public-Minnesota
My Commission Expires Jan 31, 2025

Debra L. Kariesch

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. Weld repair has not been performed on this material. This material, including the billets, was melted USA. CMTR complies with EN 10204 3.1.

Bhaskar
BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 267-1071 Email: Bhaskar.Yalamanchili@gerdau.com

ALEA BRANDENBURG
QUALITY ASSURANCE MGR.
Phone: (651) 731-5662 Email: Alea.Brandenburg@gerdau.com

Figure G-33. ⅝-in. Dia. Heavy Hex Nut, Test Nos. HMDT-2 and HMDT-3 (Item No. h1)

CERTIFIED MATERIAL TEST REPORT

Page 1 / 1

GERDAU

US-ML-ST PAUL
1678 RED ROCK ROAD
SAINT PAUL, MN 55119
USA

| CUSTOMER SHIP TO | CUSTOMER BILL TO | GRADE | SHAPE / SIZE | DOCUMENT ID: |
|---|---|---|---|---|
| UNYTITE INC LASALLE PLANT<br>325 CIVIC ROAD<br>LA SALLE,IL 61301<br>USA | UNYTITE INC<br>1 UNYTITE DR<br>PERU,IL 61354-9710<br>USA | 1045M23FJZN | Round Bar / 1" | 0000043064 |

| LENGTH | WEIGHT | HEAT / BATCH |
|---|---|---|
| 25'01.50" | 46,290 LB | 62152527/02 |

| SALES ORDER | CUSTOMER MATERIAL N° |
|---|---|
| 8563324/000020 | B1045SC1.0000 B |

SPECIFICATION / DATE or REVISION
ASTM A29-16
ASTM A576-17

| CUSTOMER PURCHASE ORDER NUMBER | BILL OF LADING | DATE |
|---|---|---|
| P008976 | 1332-0000080054 | 04/15/2020 |

CHEMICAL COMPOSITION

| C % | Mn % | P % | S % | Si % | Cu % | Ni % | Cr % | Mo % | Sn % | V % | Nb % | Al % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.44 | 0.68 | 0.006 | 0.027 | 0.19 | 0.30 | 0.07 | 0.08 | 0.017 | 0.009 | 0.030 | 0.000 | 0.005 |

HARDENABILITY

| DI A255 Inch |
|---|
| 1.21 |

COMMENTS / NOTES

Material 100% melted and rolled in the USA. Manufacturing processes for this steel, which may include scrap melted in an electric arc furnace and hot rolling, have been performed at Gerdau St. Paul Mill, 1678 Red Rock Road, Saint Paul, Minnesota, USA. All product produced from strand cast billets. Silicon killed (deoxidized) steel. No weld repairmen performed. Steel not exposed to mercury or any liquid alloy which is liquid at ambient temperatures during processing or while in Gerdau St. Paul Mills possession. Any modification to this certification as provided by Gerdau-St. Paul Mill without the expressed written consent of Gerdau St. Paul Mill negates the validity of this test report. This report shall not be reproduced except in full, without the expressed written consent of Gerdau St. Paul Mill. Gerdau St. Paul Mill is not responsible for the inability of this material to meet specific applications.
Roll batch 62152527/02 roll date 3/17/2020 Fine Grain FG 5-8
Macro S1 R1 C1 ASTM E381-17 Reduction Ratio 38.2 Quality Program Manual Rev. 10, Implemented date 11/8/2019

DEBRA L. KARIESCH
Notary Public-Minnesota
My Commission Expires Jan 31, 2025

Debra L. Kariesch

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. Weld repair has not been performed on this material. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

Bhaskar
BHASKAR YALAMANCHILI
QUALITY DIRECTOR

ALEA BRANDENBURG
QUALITY ASSURANCE MGR.

Phone: (409) 267-1071 Email: Bhaskar.Yalamanchili@gerdau.com

Phone: (651) 731-5662 Email: Alea.Brandenburg@gerdau.com

Figure G-34. ⅝-in. Dia. Heavy Hex Nut, Test Nos. HMDT-2 and HMDT-3 (Item No. h1)

## GEM-YEAR TESTING LABORATORY
### CERTIFICATE OF INSPECTION

MANUFACTURER GEM-YEAR INDUSTRIAL CO., LTD.
ADDRESS : NO.8 GEM-YEAR ROAD,E.D.Z.,JIASHAN,ZHEJIANG,P.R.CHINA

Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2019/04/23

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 210167591
COMMODITY : FINISHED HEX NUT GR-A
SIZE : 7/8-9 NC O/T 0.56MM
LOT NO : 1N18BC001
SHIP QUANTITY : 2,250 PCS
LOT QUANTITY 3,910 PCS
HEADMARKS :
MANUFACTURE DATE : 2018/11/05
COUNTRY OF ORIGIN : CHINA

PACKING NO : GEM181128011
INVOICE NO : GEM/FNL-181212ED-1
PART NO : 36717
SAMPLING PLAN :
ASME B18.18-2017(Category 2)/ASTM F1470-2018
HEAT NO : 18108472-3
MATERIAL : X1008A
FINISH : HOT DIP GALVANIZED PER ASTM A153-2009/ASTM F2329-2013

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A563-2015

| Chemistry | AL% | C% | MN% | P% | S% | SI% |
|---|---|---|---|---|---|---|
| Spec. : MIN. | | | | | | |
| MAX. | | 0.5800 | | 0.1300 | 0.2300 | |
| Test Value | 0.0300 | 0.0700 | 0.2700 | 0.0080 | 0.0050 | 0.0300 |

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.2-2015

SAMPLED BY : YUQIAN

| INSPECTIONS ITEM | SAMPLE | SPECIFIED | | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|---|
| WIDTH ACROSS CORNERS | 4PCS | ASME B18.2.2-2015 | 1.4470-1.5160 inch | 1.4730-1.4770 inch | 4 | 0 |
| FIM | 15PCS | | Max. 0.0250 inch | 0.0010-0.0050 inch | 15 | 0 |
| THICKNESS | 4PCS | | 0.7240-0.7760 inch | 0.7280-0.7480 inch | 4 | 0 |
| WIDTH ACROSS FLATS | 4PCS | | 1.2690-1.3120 inch | 1.2840-1.2990 inch | 4 | 0 |
| SURFACE DISCONTINUITIES | 22PCS | | ASTM F812-2012 | PASSED | 22 | 0 |
| THREAD | 15PCS | | GAGING SYSTEM 21 | PASSED | 15 | 0 |
| MINOR DIAMETER | 15PCS | | 0.7890-0.7970 inch | PASSED | 15 | 0 |

MECHANICAL PROPERTIES : ACCORDING TO ASTM A563-2015

SAMPLED BY : GDAN LIAN

| INSPECTIONS ITEM | SAMPLE | TEST METHOD | REF | SPECIFIED | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|---|---|
| CORE HARDNESS | 13 PCS | ASTM F606-2014 | | 116-302 HRB | 81-82 HRB | 13 | 0 |
| PROOF LOAD | 3 PCS | ASTM F606-2014 | | Min. 90 KSI | OK | 3 | 0 |
| PLATING THICKNESS( μm) | 5 PCS | ASTM B568-1998 | | >=53 | 70.22-75.66 | 5 | 0 |

WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY .WHICH ACCREDITED BY ISO/IEC17025(CERTIFICATE NUMBER:3358.01)
WE CERTIFY THAT THE PRODUCTS SUPPLIED ARE IN COMPLIANCE WITH THE REQUIREMENTS OF THE ORDER
WE CERTIFY THAT ALL PRODUCTS WE SUPPLIED ARE IN COMPLIANCE WITH DIN EN 10204 3.1 CONTENT

Quality Supervisor: Grin

Figure G-35. ⅞-in. Dia. Hex Nut, Test Nos. HMDT-2 and HMDT-3 (Item No. h3)

# GEM-YEAR TESTING LABORATORY
## CERTIFICATE OF INSPECTION

MANUFACTURER GEM-YEAR INDUSTRIAL CO., LTD.
ADDRESS : NO.8 GEM-YEAR ROAD,E.D.Z.,JIASHAN,ZHEJIANG,P.R.CHINA

Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2019/04/23

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 210167591
COMMODITY : FINISHED HEX NUT GR-A
SIZE : 7/8-9 NC O/T 0.56MM
LOT NO : 1N1880113
SHIP QUANTITY : 2,250 PCS
LOT QUANTITY 31,764 PCS
HEADMARKS :
MANUFACTURE DATE : 2018/10/12
COUNTRY OF ORIGIN : CHINA

PACKING NO : GEM181128011
INVOICE NO : GEM/FNL-181212ED-1
PART NO : 36717
SAMPLING PLAN : ASME B18.18-2017(Category.2)/ASTM F1470-2018
HEAT NO : 18108473-3
MATERIAL : X1008A
FINISH : HOT DIP GALVANIZED PER ASTM A153-2009/ASTM F2329-2013

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A563-2015

| Chemistry | AL% | C% | MN% | P% | S% | SI% |
|---|---|---|---|---|---|---|
| Spec. : MIN. | | | | | | |
| MAX. | | 0.5800 | | 0.1300 | 0.2300 | |
| Test Value | 0.0300 | 0.0600 | 0.2800 | 0.0160 | 0.0060 | 0.0300 |

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.2-2015

SAMPLED BY : WANGYAN

| INSPECTIONS ITEM | SAMPLE | SPECIFIED | | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|---|
| WIDTH ACROSS CORNERS | 4PCS | | 1.4470-1.5160 inch | 1.4650-1.4690 inch | 4 | 0 |
| FIM | 15PCS | ASME B18.2.2-2015 | Max. 0.0250 inch | 0.0040-0.0060 inch | 15 | 0 |
| THICKNESS | 4PCS | | 0.7240-0.7760 inch | 0.7430-0.7460 inch | 4 | 0 |
| WIDTH ACROSS FLATS | 4PCS | | 1.2690-1.3120 inch | 1.2830-1.2840 inch | 4 | 0 |
| SURFACE DISCONTINUITIES | 29PCS | | ASTM F812-2012 | PASSED | 29 | 0 |
| THREAD | 15PCS | | GAGING SYSTEM 21 | PASSED | 15 | 0 |
| MINOR DIAMETER | 15PCS | | 0.7890-0.7970 inch | PASSED | 15 | 0 |

MECHANICAL PROPERTIES : ACCORDING TO ASTM A563-2015

SAMPLED BY : GDAN LIAN

| INSPECTIONS ITEM | SAMPLE | TEST METHOD | REF | SPECIFIED | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|---|---|
| CORE HARDNESS | 13 PCS | ASTM F606-2014 | | 116-302 HRB | 81-82 HRB | 13 | 0 |
| PROOF LOAD | 3 PCS | ASTM F606-2014 | | Min. 90 KSI | OK | 3 | 0 |
| PLATING THICKNESS(μm) | 5 PCS | ASTM B568-1998 | | >=53 | 72.03-95.08 | 5 | 0 |

WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY .WHICH ACCREDITED BY ISO/IEC17025(CERTIFICATE NUMBER:3358.01)
WE CERTIFY THAT THE PRODUCTS SUPPLIED ARE IN COMPLIANCE WITH THE REQUIREMENTS OF THE ORDER
WE CERTIFY THAT ALL PRODUCTS WE SUPPLIED ARE IN COMPLIANCE WITH DIN EN 10204 3.1 CONTENT

Quality Supervisor: Erin

Figure G-36. ⅞-in. Dia. Hex Nut, Test Nos. HMDT-2 and HMDT-3 (Item No. h3)

Apr. 17. 2019 2:15PM Fastenal-NELIN No. 6648 P. 2

FASTENAL®

## Certificate of Compliance

| | | | |
|---|---|---|---|
| **Sold To:** | | **Purchase Order:** | 70acct BCTAnchorCableHardware |
| UNL TRANSPORTATION/Midwest Roadside Safe | | **Job:** | |
| | | **Invoice Date:** | 10/19/2018 |

THIS IS TO CERTIFY THAT WE HAVE SUPPLIED YOU WITH THE FOLLOWING PARTS.
THESE PARTS WERE PURCHASED TO THE FOLLOWING SPECIFICATIONS.

200 PCS 1" x 2.500" OD Low Carbon Hot Dipped Galvanized Finish Steel USS General Purpose Flat Washer SUPPLIED UNDER OUR TRACE NUMBER 210151571 AND UNDER PART NUMBER 33188

200 PCS 1"-8 Hot Dipped Galvanized A563 Grade DH Heavy Hex Nut Made In USA SUPPLIED UNDER OUR TRACE NUMBER 210157128 AND UNDER PART NUMBER 38210

This is to certify that the above document is true and accurate to the best of my knowledge.

AFerguson

**Fastenal Account Representative Signature**

Abigail Ferguson

**Printed Name**

4/17/2019

**Date**

Please check current revision to avoid using obsolete copies.

This document was printed on 04/17/2019 and was current at that time.

**Fastenal Store Location/Address**

*3201 N. 23rd Street STE 1*
*LINCOLN, NE 68521*
*Phone #: (402)476-7900*
*Fax #: 402/476-7958*

Page 1 of 1

Figure G-37. 1-in. Dia. Heavy Hex Nut, Test Nos. HMDT-2 and HMDT-3 (Item No. h5)

ISO/TS 16949
BUREAU VERITAS
Certification

## GEM-YEAR TESTING LABORATORY
### CERTIFICATE OF INSPECTION

MANUFACTURER :GEM-YEAR INDUSTRIAL CO., LTD.
ADDRESS : NO.8 GEM-YEAR ROAD,E.D.Z.,JIASHAN,ZHEJIANG,P.R.CHINA

Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2017/03/23

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 110216407
COMMODITY : FINISHED HEX NUT GR-A
SIZE : 5/8-11 NC O/T 0.51MM
LOT NO : 1N1680027
SHIP QUANTITY : 23,400 PCS
LOT QUANTITY 170,278 PCS
HEADMARKS :
MANUFACTURE DATE : 2016/08/26
COUNTRY OF ORIGIN : CHINA

PACKING NO : GEM160919007
INVOICE NO : GEM/FNL-160929WI
PART NO : 36713
SAMPLING PLAN : ASME B18.18-2011(Category.2)/ASTM F1470-2012
HEAT NO : 331608011
MATERIAL : ML08
FINISH : HOT DIP GALVANIZED PER ASTM A153-2009/ASTM F2329-2013

R#17-507 H#331608011
BCT Cable Bracket Nuts

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A563-2007

| Chemistry | AL% | C% | MN% | P% | S% | SI% |
|---|---|---|---|---|---|---|
| Spec. : MIN. | | | | | | |
| MAX. | | 0.5800 | | 0.1300 | 0.2300 | |
| Test Value | 0.0350 | 0.0700 | 0.4100 | 0.0160 | 0.0060 | 0.0500 |

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.2-2010

SAMPLED BY : DWTING

| INSPECTIONS ITEM | SAMPLE | SPECIFIED | | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|---|
| WIDTH ACROSS CORNERS | 6PCS | | 1.0510-1.0830 inch | 1.0560-1.0690 inch | 6 | 0 |
| FIM | 15PCS | ASME B18.2.2-2010 | Max. 0.0210 inch | 0.0020-0.0040 inch | 15 | 0 |
| THICKNESS | 6PCS | | 0.5350-0.5590 inch | 0.5390-0.5570 inch | 6 | 0 |
| WIDTH ACROSS FLATS | 6PCS | | 0.9220-0.9380 inch | 0.9240-0.9340 inch | 6 | 0 |
| SURFACE DISCONTINUITIES | 29PCS | | ASTM F812-2012 | PASSED | 29 | 0 |
| THREAD | 15PCS | | GAGING SYSTEM 21 | PASSED | 15 | 0 |

MECHANICAL PROPERTIES : ACCORDING TO ASTM A563-2007

SAMPLED BY : GDAN LIAN

| INSPECTIONS ITEM | SAMPLE | TEST METHOD | REF | SPECIFIED | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|---|---|
| CORE HARDNESS | 15PCS | ASTM F606-2014 | | 68-107 HRB | 79-81 HRB | 15 | 0 |
| PROOF LOAD | 4PCS | ASTM F606-2014 | | Min. 90 KSI | OK | 4 | 0 |
| PLATING THICKNESS( μm) | 5PCS | ASTM B568-1998 | | >=53 | 70.02-75.81 | 5 | 0 |

WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY .WHICH ACCREDITED BY ISO/IEC17025(CERTIFICATE NUMBER:3358.01)
WE CERTIFY THAT THE PRODUCTS SUPPLIED ARE IN COMPLIANCE WITH THE REQUIREMENTS OF THE ORDER

Quality Supervisor: Grin

Figure G-38. ⅝-in. Dia. Hex Nut, Test Nos. HMDT-2 and HMDT-3 (Item No. h6)

**Ready Mixed Concrete Company**
6200 Cornhusker Hwy, Lincoln, NE 68529
Phone: (402) 434-1844 Fax: (402) 434-1877

Customer's Signature: ____________________

| PLANT | TRUCK | DRIVER | CUSTOMER | PROJECT | TAX | PO NUMBER | DATE | TIME | TICKET |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 251 | 9827 | 62461 | | N01 | HAWAII | 6/14/21 | 11:07 AM | 1265745 |

| Customer | Delivery Address | Special Instructions |
|---|---|---|
| UNL-MIDWEST ROADSIDE SAFETY | 4630 NW 36TH ST | AIRPARK / NORTH OF OLD GOODYEARHANGERS |

| LOAD QUANTITY | CUMULATIVE QUANTITY | ORDERED QUANTITY | PRODUCT CODE | PRODUCT DESCRIPTION | UOM | UNIT PRICE | EXTENDED PRICE |
|---|---|---|---|---|---|---|---|
| 2.00 | 2.00 | 2.00 | QL324504 | LNK47B1PF4000HW | yd | $132.50 | $265.00 |
| | | | | MINIMUM HAUL | | | $50.00 |

| Water Added On Job At Customer's Request: | SLUMP | Notes: | | |
|---|---|---|---|---|
| | 3.00 in | | TICKET SUBTOTAL | $315.00 |
| | | | SALES TAX | $0.00 |
| | | | TICKET TOTAL | $315.00 |
| | | | PREVIOUS TOTAL | |
| | | | GRAND TOTAL | $315.00 |

**CAUTION FRESH CONCRETE**
**KEEP CHILDREN AWAY**

Contains Portland cement. Freshly mixed cement, mortar, concrete or grout may cause skin injury. Avoid prolonged contact with skin. Always wear appropriate Personal Protective Equipment (PPE). In case of contact with eyes or skin, flush thoroughly with water. If irritation persists, seek medical attention promptly.

**Terms & Conditions**

This concrete is produced with the ASTM standard specifications for ready mix concrete. Strengths are based on a 3" slump. Drivers are not permitted to add water to the mix to exceed this slump, except under the authorization of the customer and their acceptance of any decrease in compressive strength and any risk of loss as a result thereof. Cylinder tests must be handled according to ACI/ASTM specifications and drawn by a licensed testing lab and/or certified technician.
Ready Mixed Concrete Company will not deliver any product beyond any curb lines unless expressly told to do so by customer and customer assumes all liability for any personal or property damage that may occur as a result of any such directive.
The purchaser's exceptions and claims shall be deemed waived unless made in writing within 3 days from time of delivery. In such a case, seller shall be given full opportunity to investigate any such claim. Seller's liability shall in no event exceed the purchase price of the materials against which any claims are made.

Figure G-39. Curb Concrete, Test Nos. HMDT-2 and HMDT-3 (Item No. j2)

benesch



# Concrete Sample Test Report
## Cylinder Compressive Strength

| | |
|---|---|
| Project Name: | Midwest Roadside Safety - Misc Testing |
| Project Number: | 00110546.00 |
| Client: | Midwest Roadside Safety Facility |
| Location: | MNPD |
| Sample: | 022 |
| Description: | HMDT (Curb) |

## Field Data (ASTM C172, C143, C173/C231, C138, C1064)

| | | Property | Test Result |
|---|---|---|---|
| Supplier: | | | |
| Mix Name: | | Slump (in): | |
| Ticket Number: | | Air Content (%): | |
| Truck Number: | | Unit Weight (lb/ft³): | |
| Load Volume (yd³): | | Air Temp (°F): | |
| Mold Date: | 06/14/2021 | Mix Temp (°F): | |
| Molded By: | | Min Temp (°F): | |
| Initial Cure Method: | | MaxTemp (°F): | |

## Laboratory Test Data (ASTM C39)

| | | | | | | |
|---|---|---|---|---|---|---|
| Sample Number: | 022 | 022 | | | | |
| Set Number: | 001 | 002 | | | | |
| Specimen Number: | 1 | 1 | | | | |
| Age: | 2 | 2 | | | | |
| Length (in): | 12 | 12 | | | | |
| Diameter (in): | 5.98 | 5.99 | | | | |
| Area (in²): | 28.09 | 28.18 | | | | |
| Test Date: | 06/16/2021 | 06/16/2021 | | | | |
| Break Type: | 5 | 2 | | | | |
| Max Load (lbf): | 93,499 | 96,537 | | | | |
| Strength (psi): | 3,330 | 3,430 | | | | |
| Spec Strength (psi): | | | | | | |
| Excl in Avg Strength: | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

Remarks:
Average 2-day Compressive Strength (psi): 3,380

Date received: 06/16/2021
Curing: ☒ Standard ☐ Field
ASTM C511
Submitted by: Matt Roesler

Distribution:

Report Date: 6/16/21

Type 1 Type 2 Type 3 Type 4 Type 5 Type 6



825 M Street Suite 100
Lincoln, NE 68508

Alfred Benesch & Company



Figure G-40. Curb Concrete, Test Nos. HMDT-2 and HMDT-3 (Item No. j2)

# Appendix H. Accelerometer and Rate Transducer Data Plots, Test No. HMDT-2

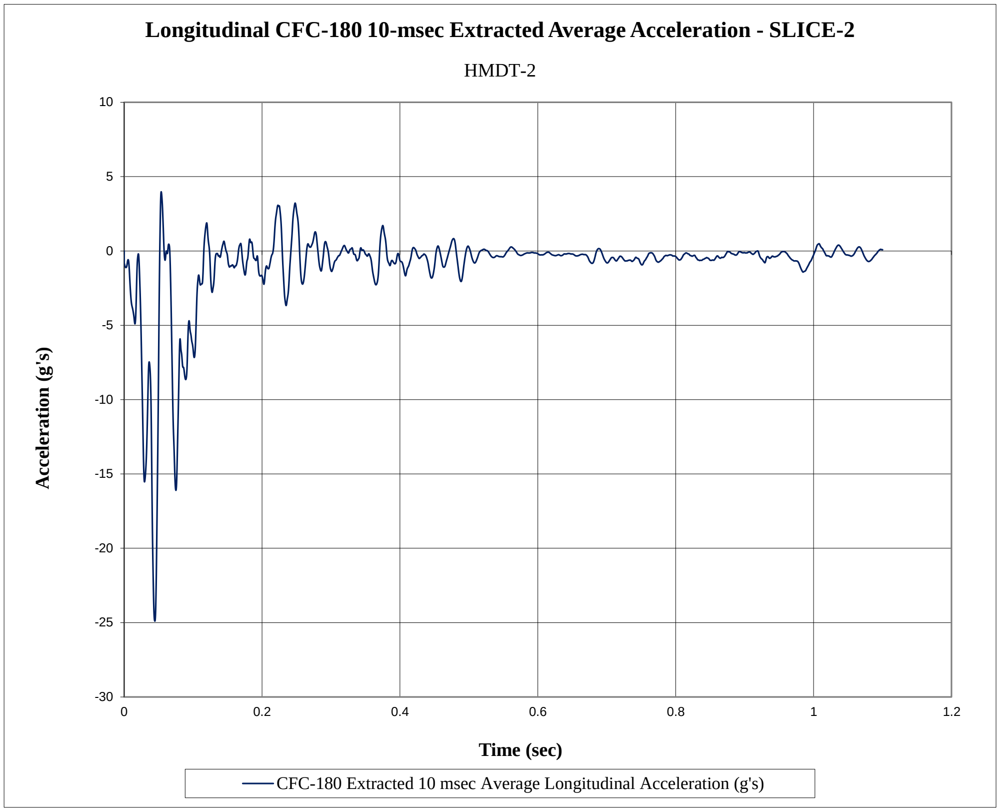



Figure H-1. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. HMDT-2

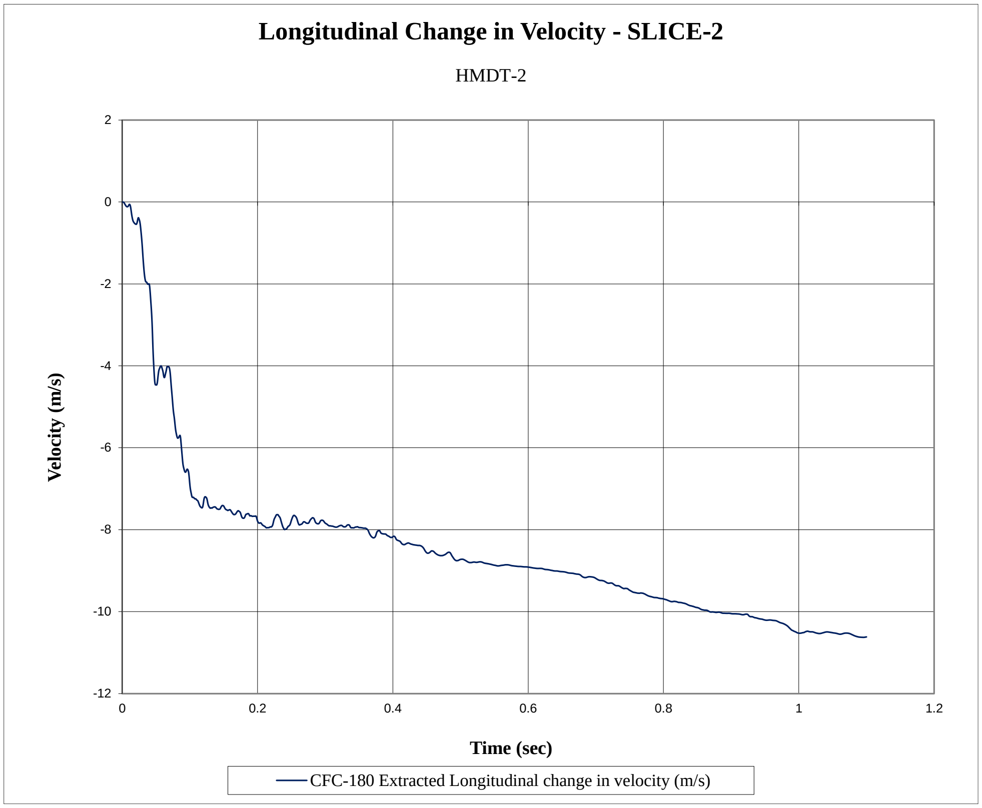



Figure H-2. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. HMDT-2

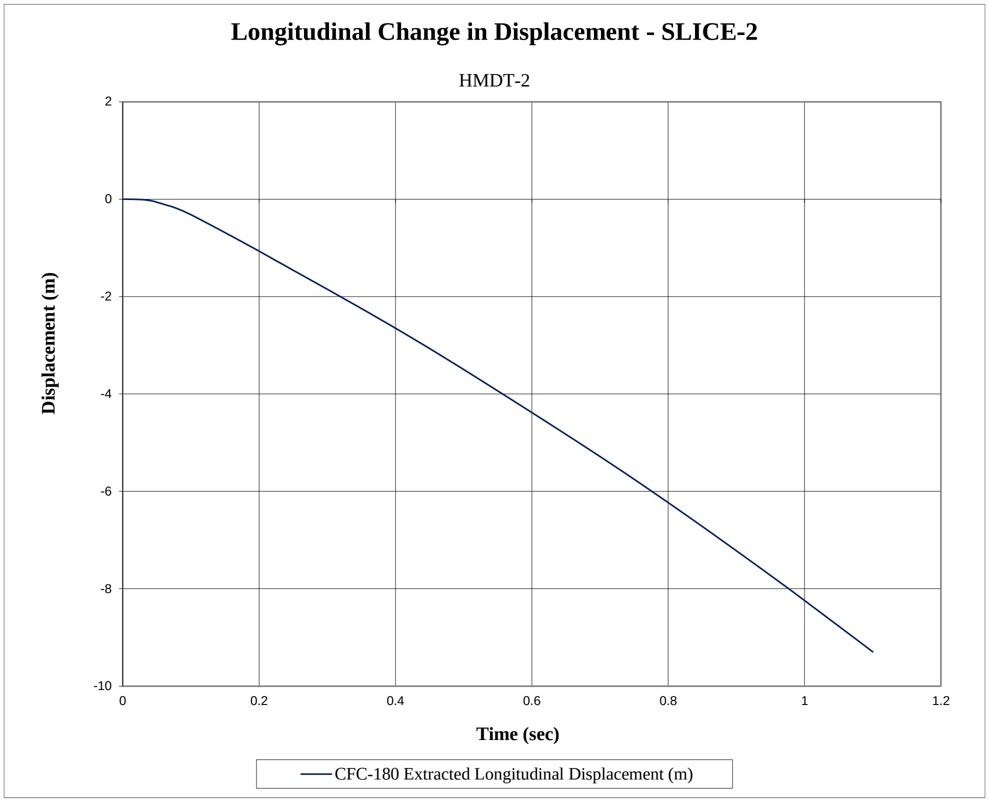



Figure H-3. Longitudinal Occupant Displacement (SLICE-2), Test No. HMDT-2

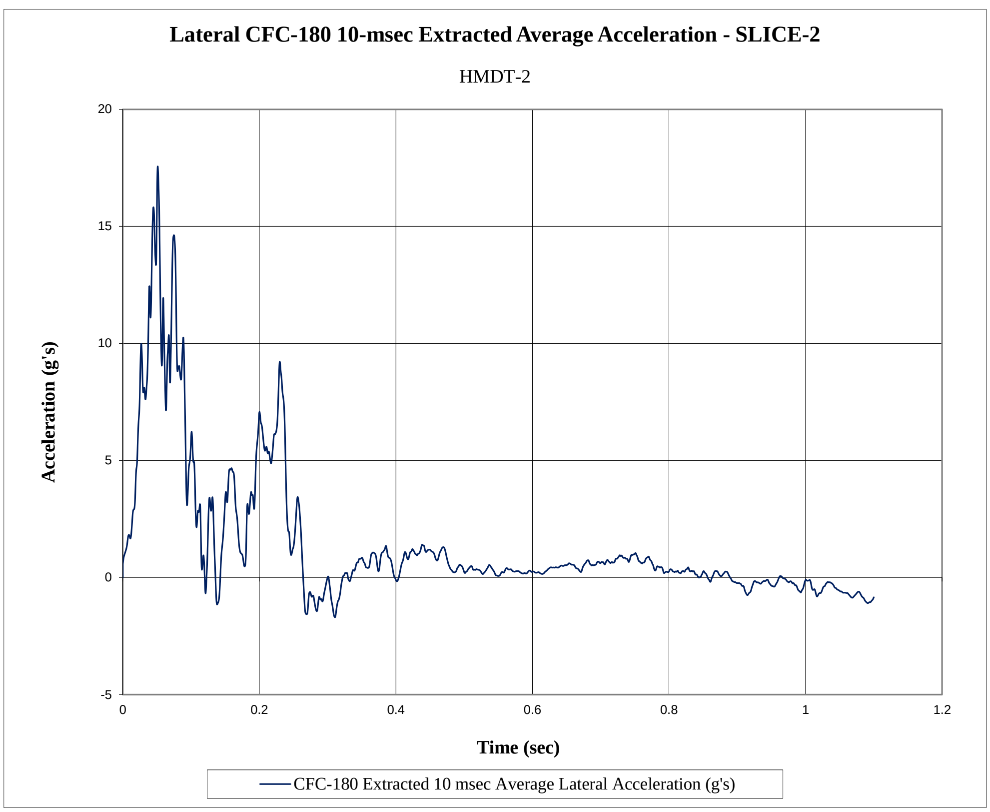



Figure H-4. 10-ms Average Lateral Deceleration (SLICE-2), Test No. HMDT-2

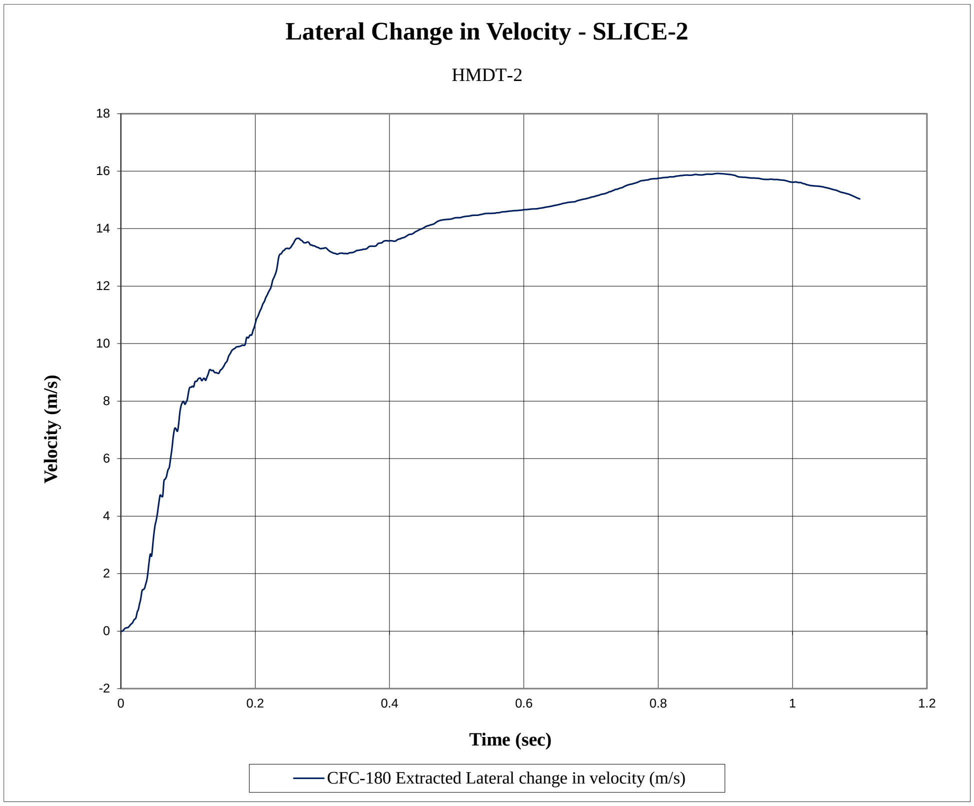



Figure H-5. Lateral Occupant Impact Velocity (SLICE-2), Test No. HMDT-2

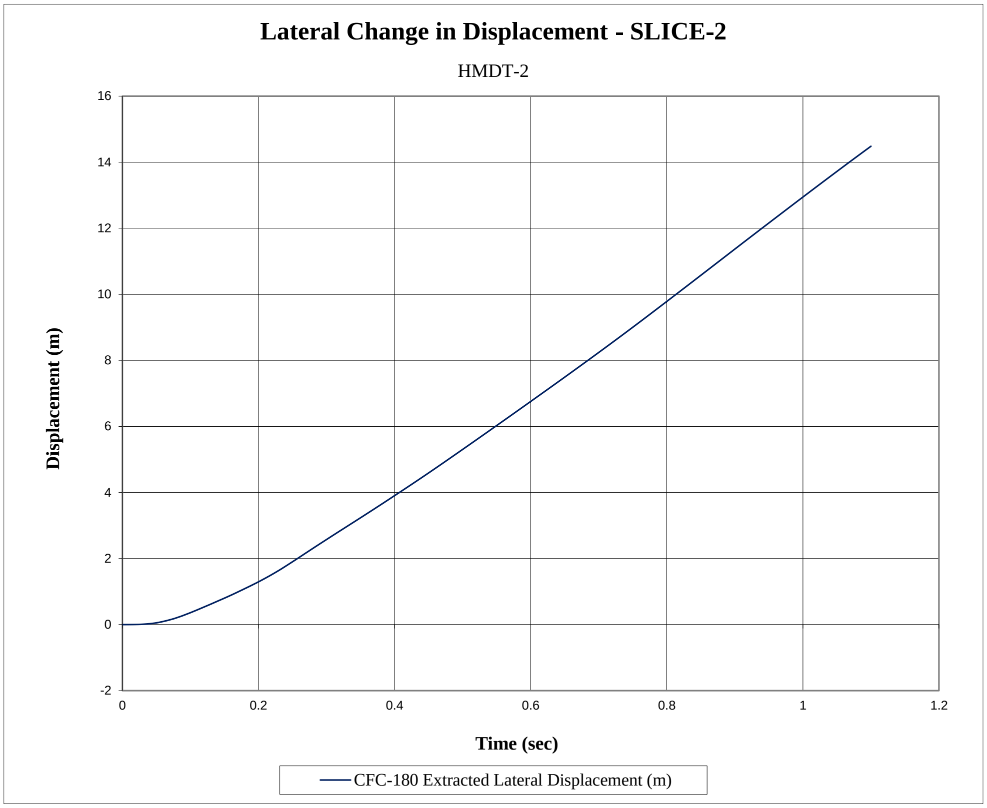



Figure H-6. Lateral Occupant Displacement (SLICE-2), Test No. HMDT-2

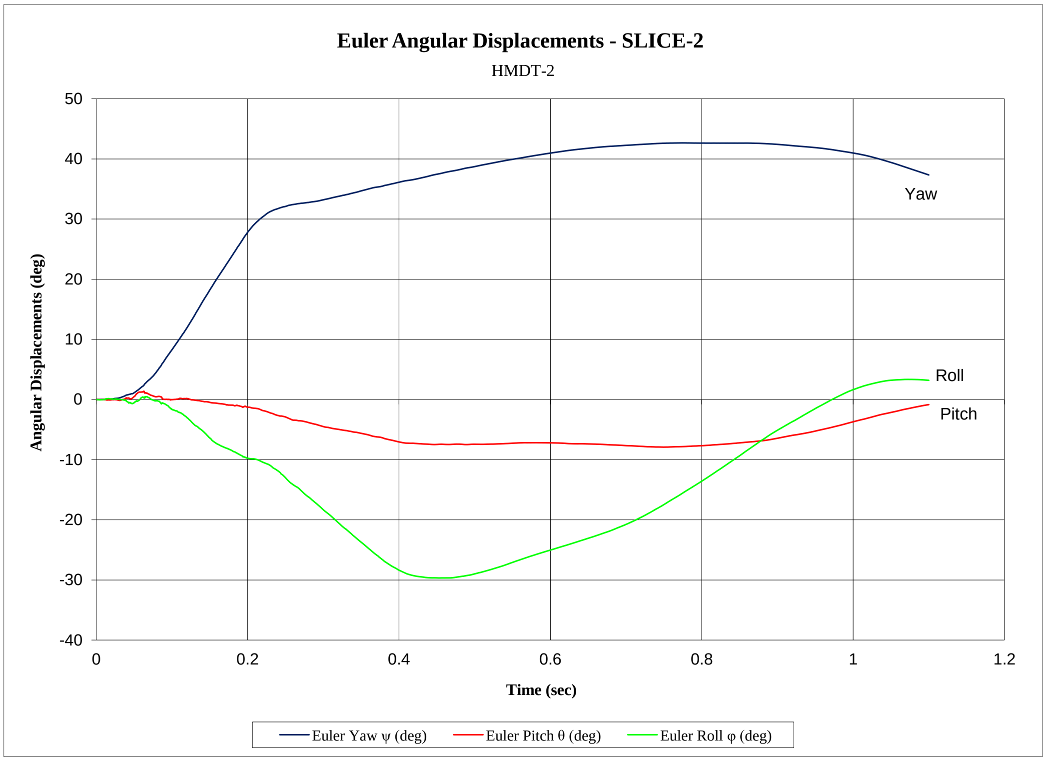



Figure H-7. Vehicle Angular Displacements (SLICE-2), Test No. HMDT-2

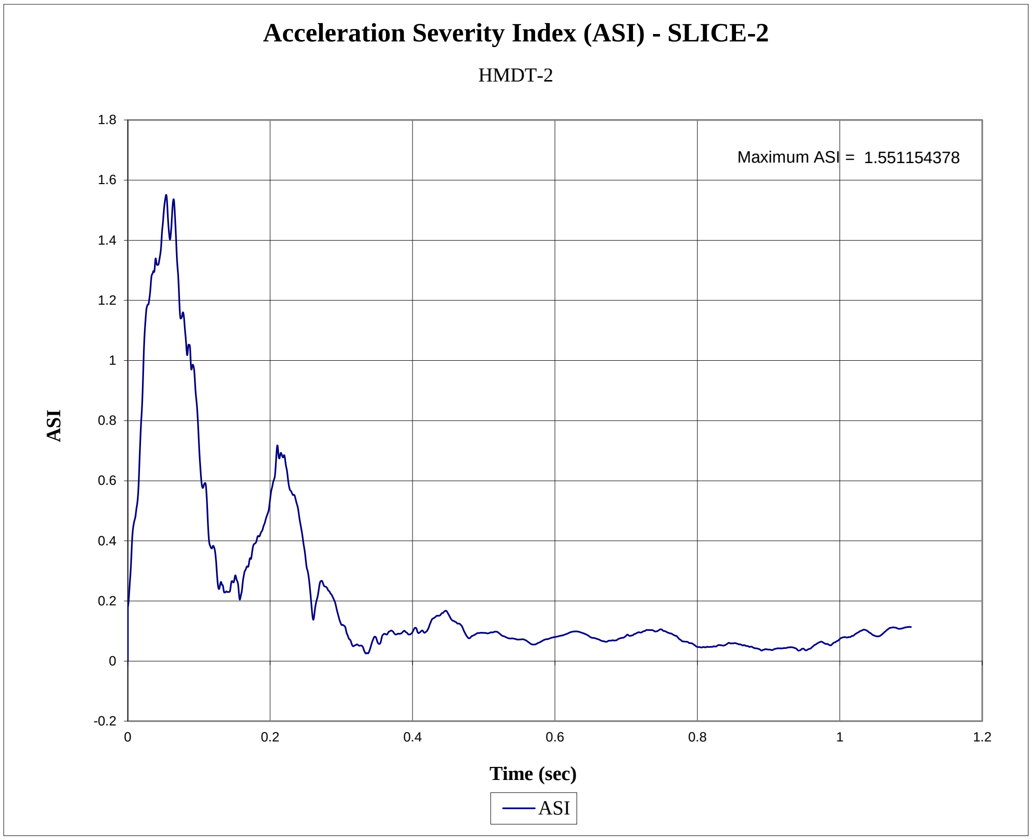



Figure H-8. Acceleration Severity Index (SLICE-2), Test No. HMDT-2

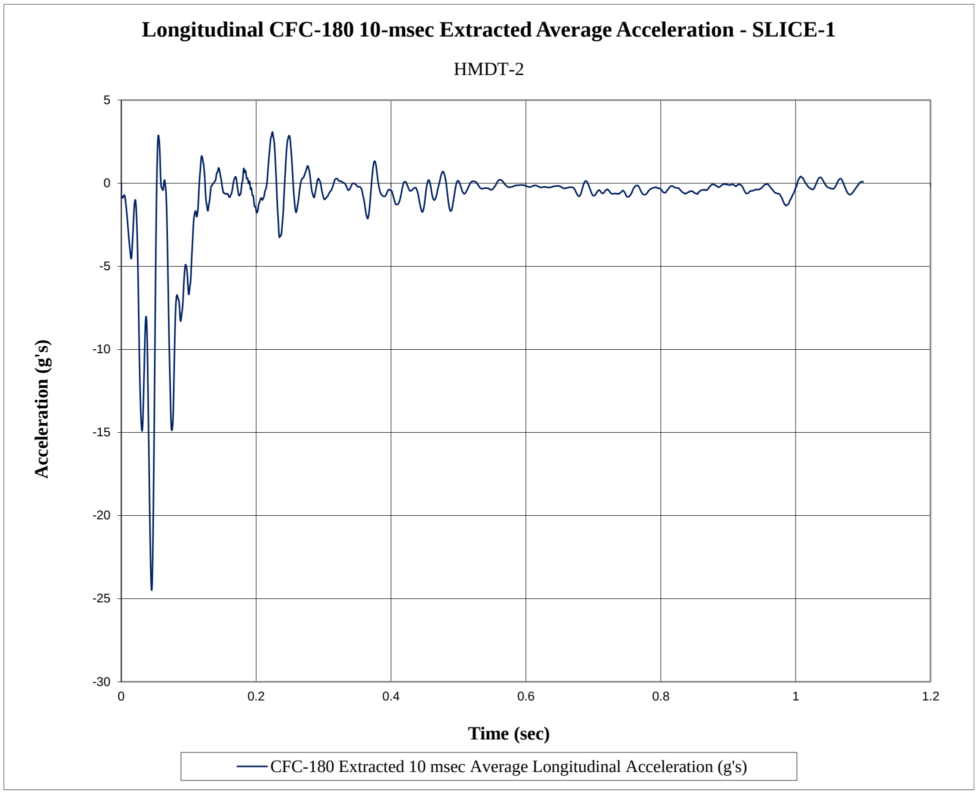



Figure H-9. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. HMDT-2

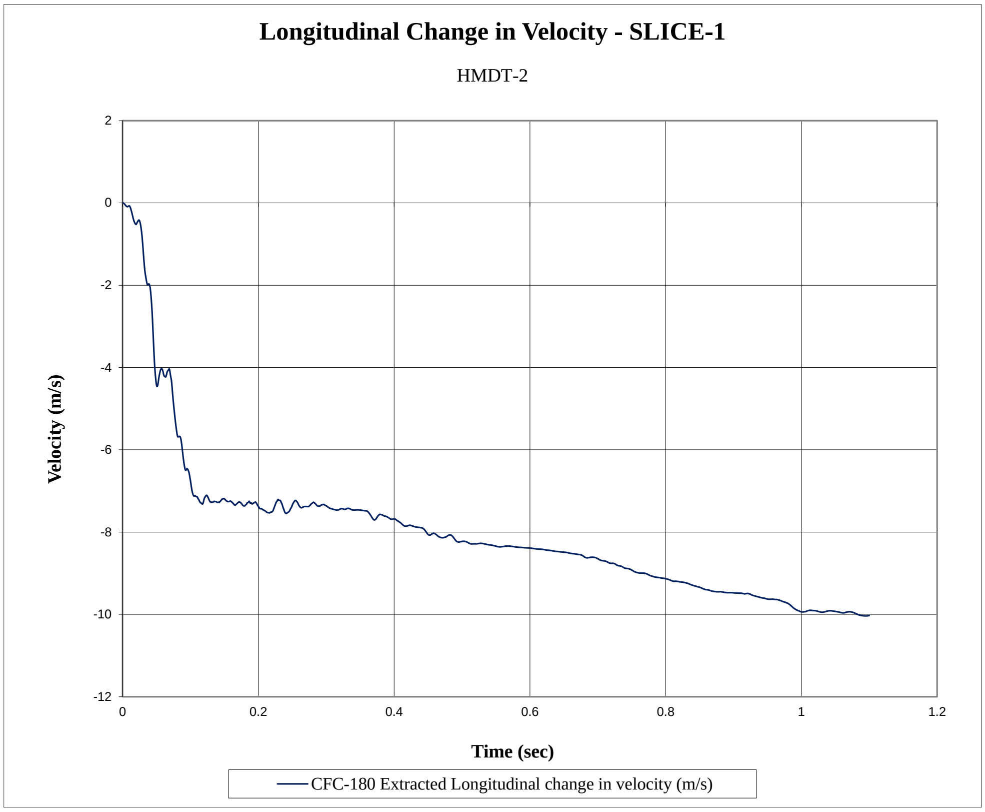



Figure H-10. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. HMDT-2

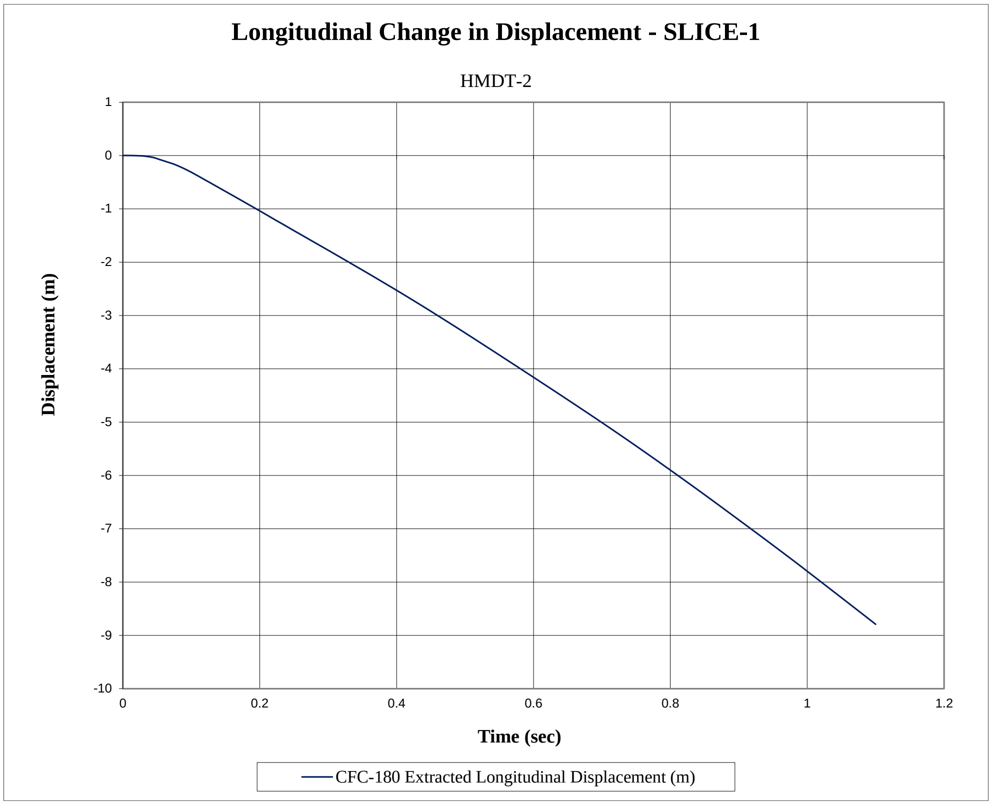



Figure H-11. Longitudinal Occupant Displacement (SLICE-1), Test No. HMDT-2

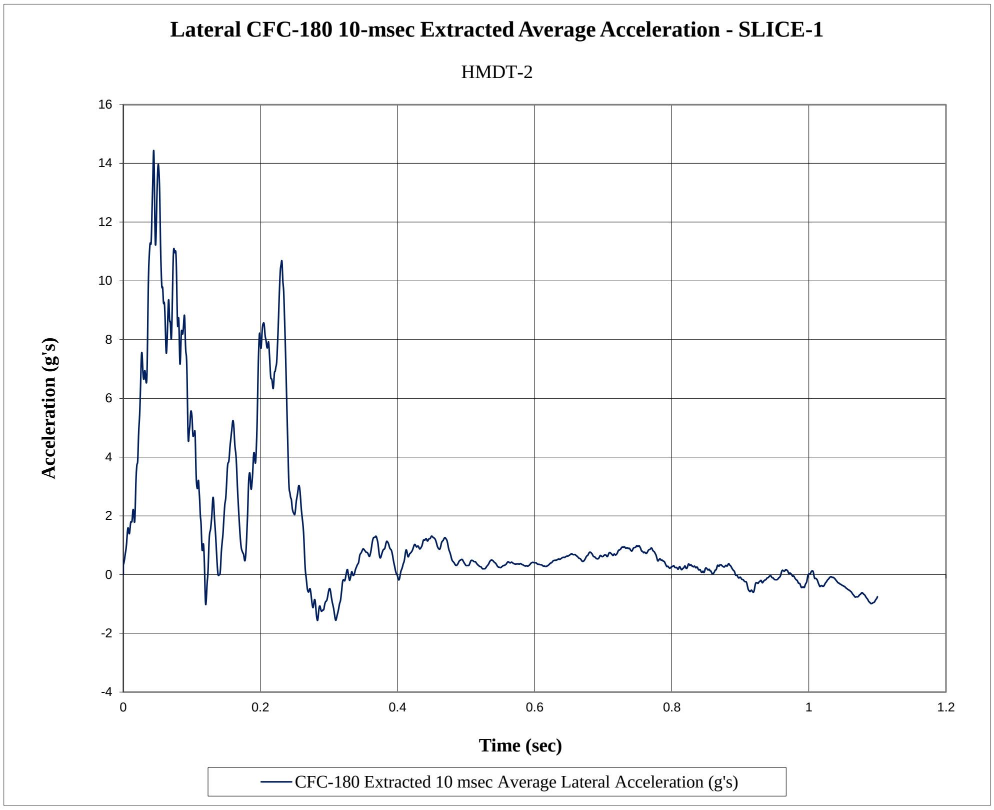



Figure H-12. 10-ms Average Lateral Deceleration (SLICE-1), Test No. HMDT-2

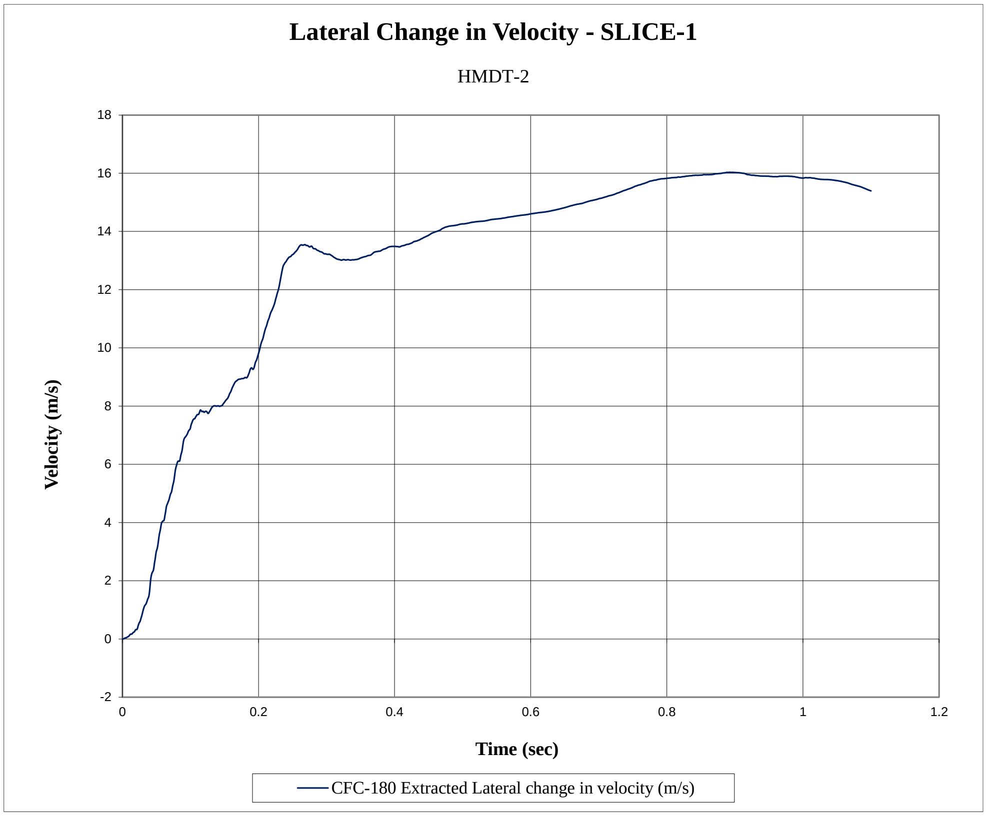



Figure H-13. Lateral Occupant Impact Velocity (SLICE-1), Test No. HMDT-2

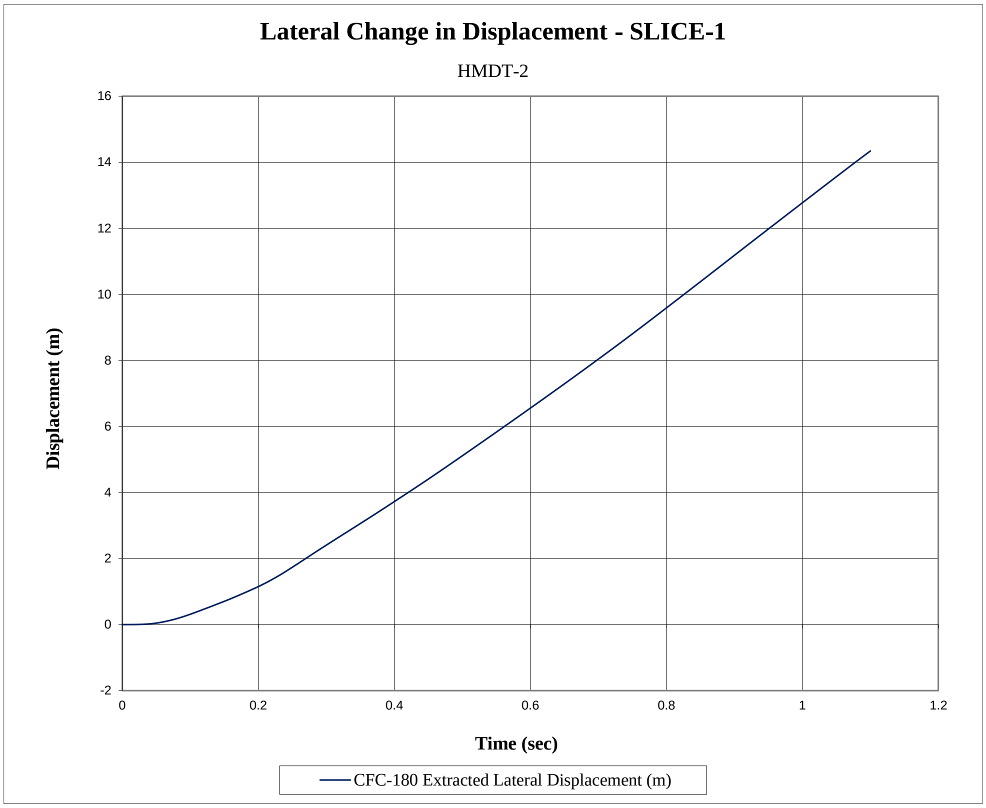



Figure H-14. Lateral Occupant Displacement (SLICE-1), Test No. HMDT-2

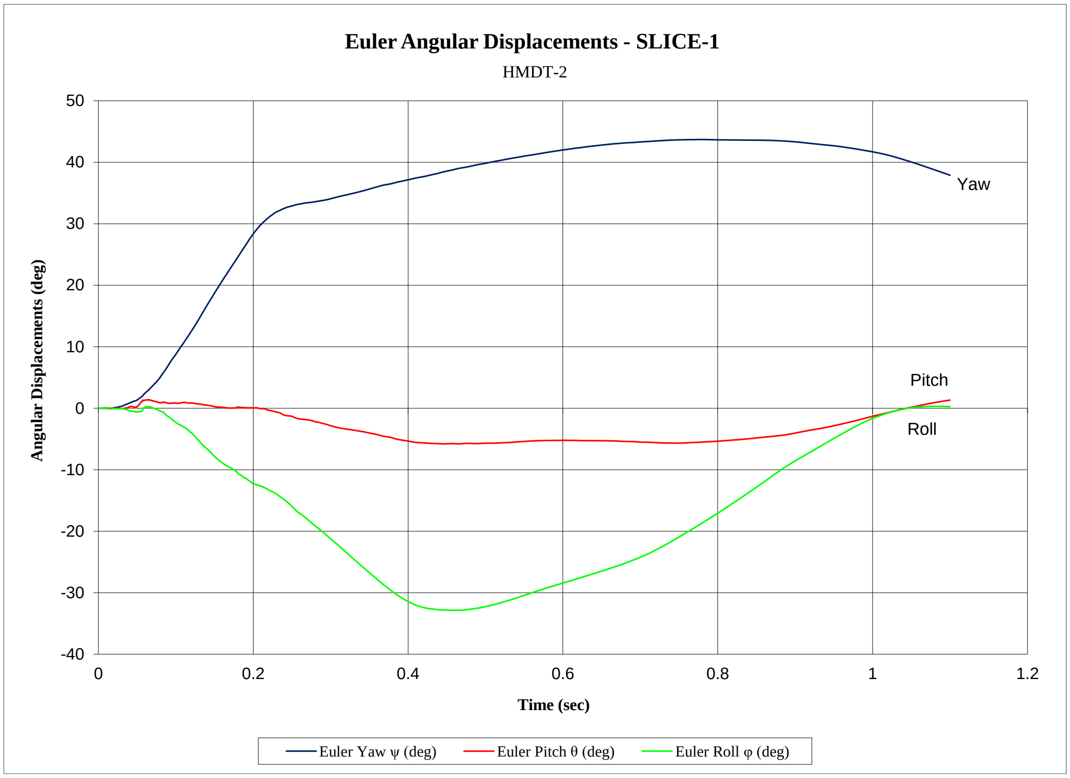



Figure H-15. Vehicle Angular Displacements (SLICE-1), Test No. HMDT-2

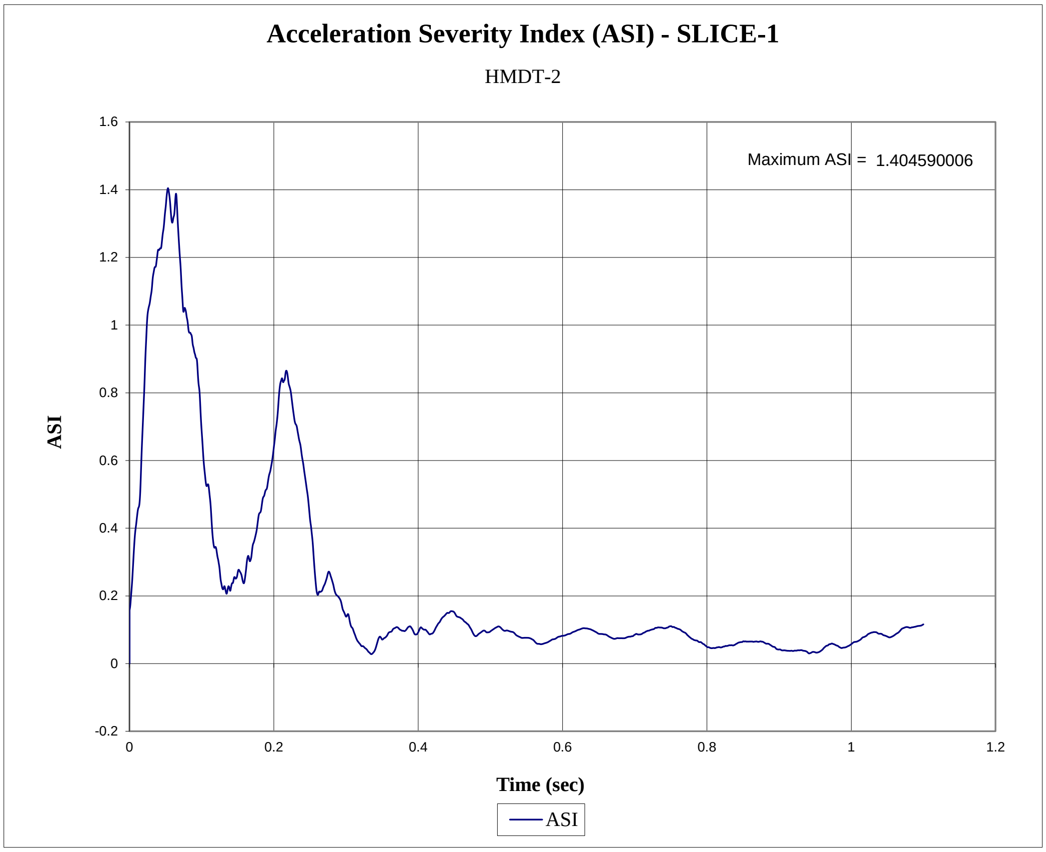



Figure H-16. Acceleration Severity Index (SLICE-1), Test No. HMDT-2

# Appendix I. Accelerometer and Rate Transducer Data Plots, Test No. HMDT-3

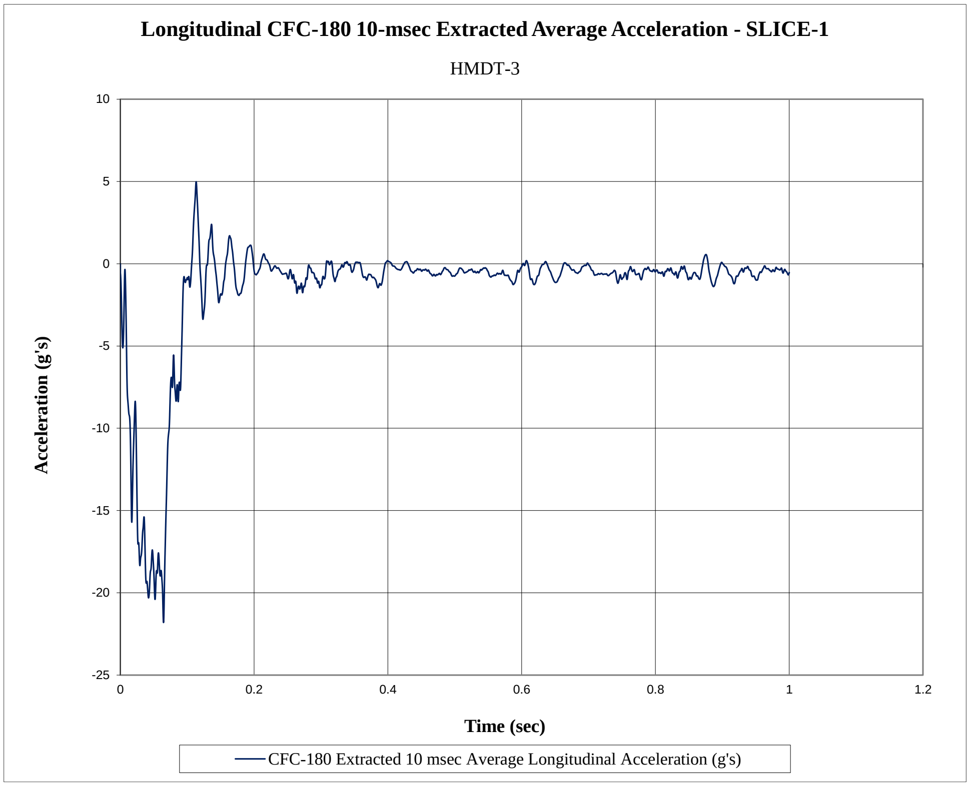



Figure I-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. HMDT-3

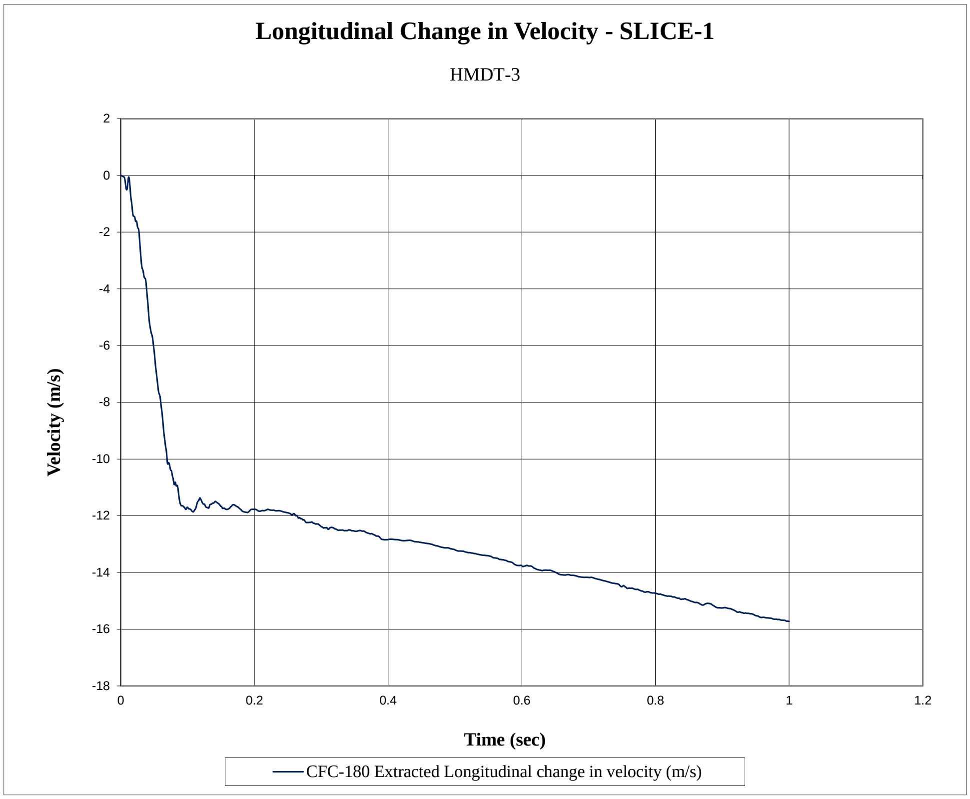



Figure I-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. HMDT-3

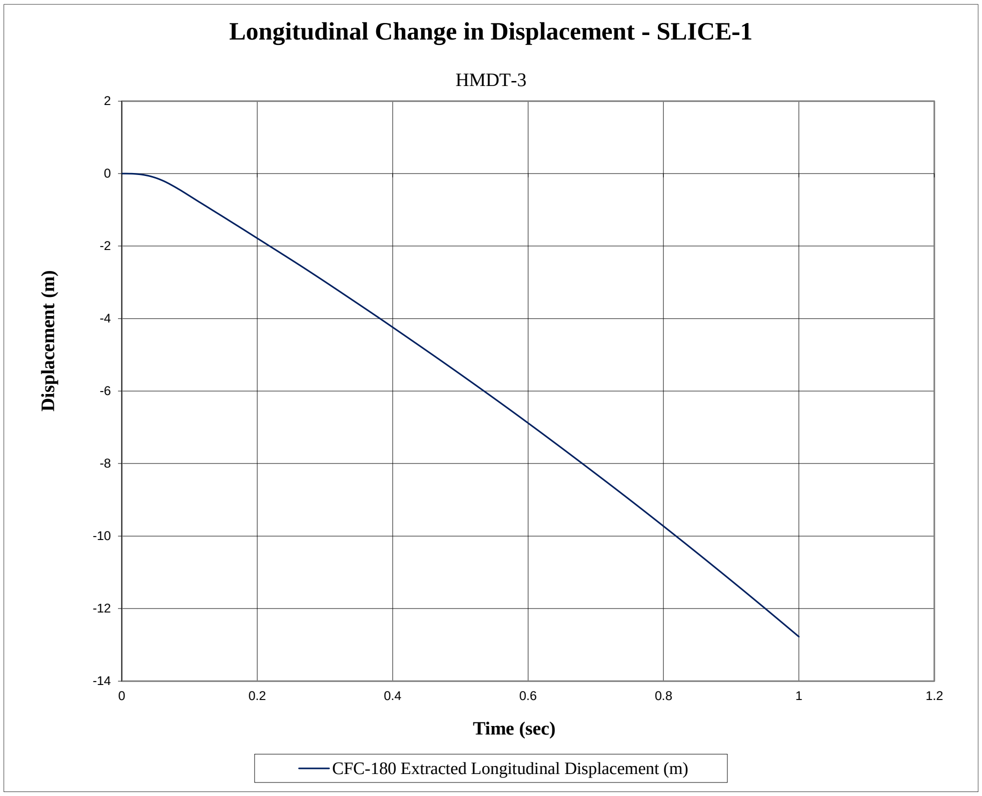



Figure I-3. Longitudinal Occupant Displacement (SLICE-1), Test No. HMDT-3

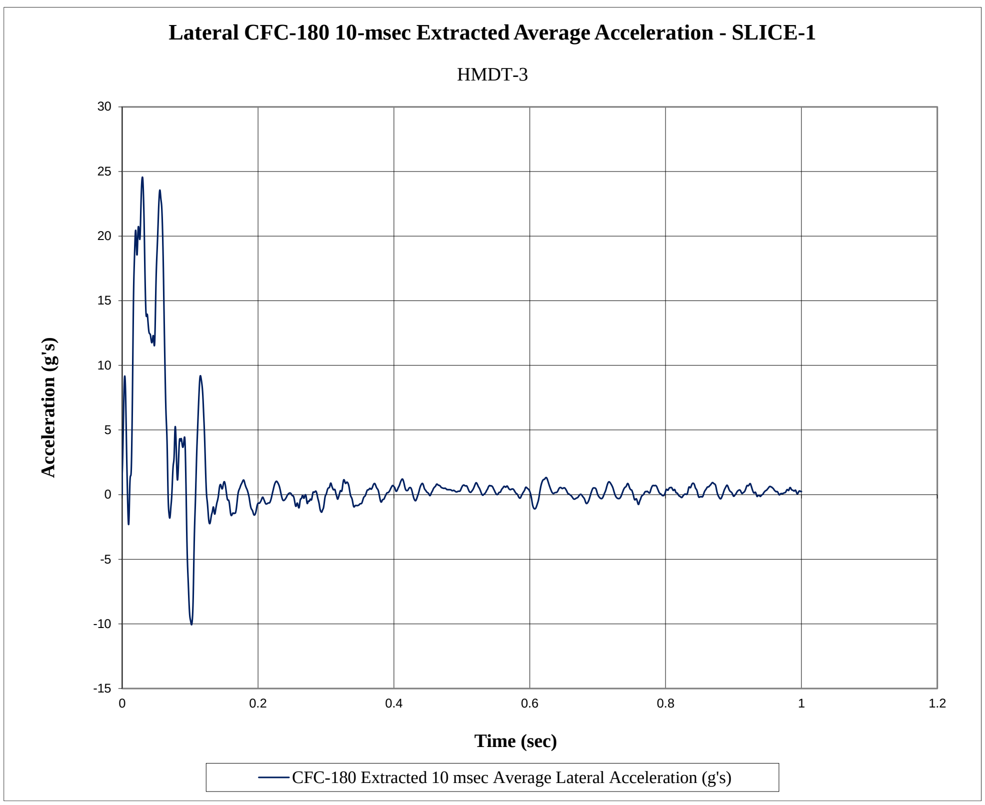



Figure I-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. HMDT-3

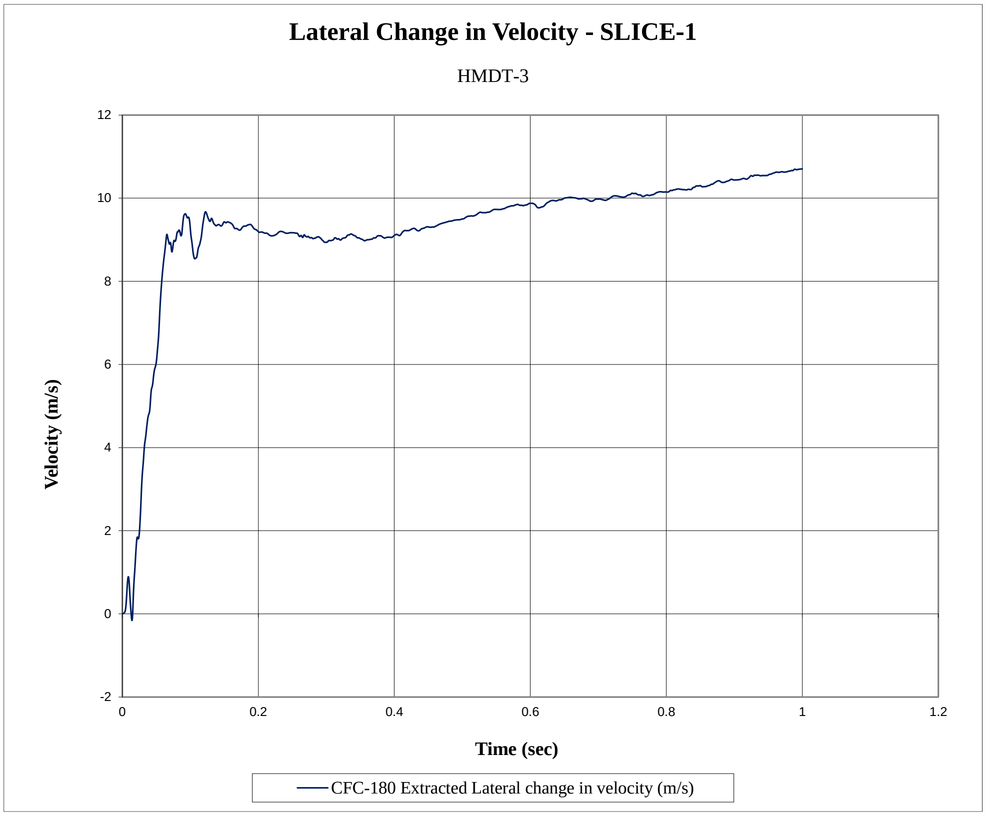



Figure I-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. HMDT-3

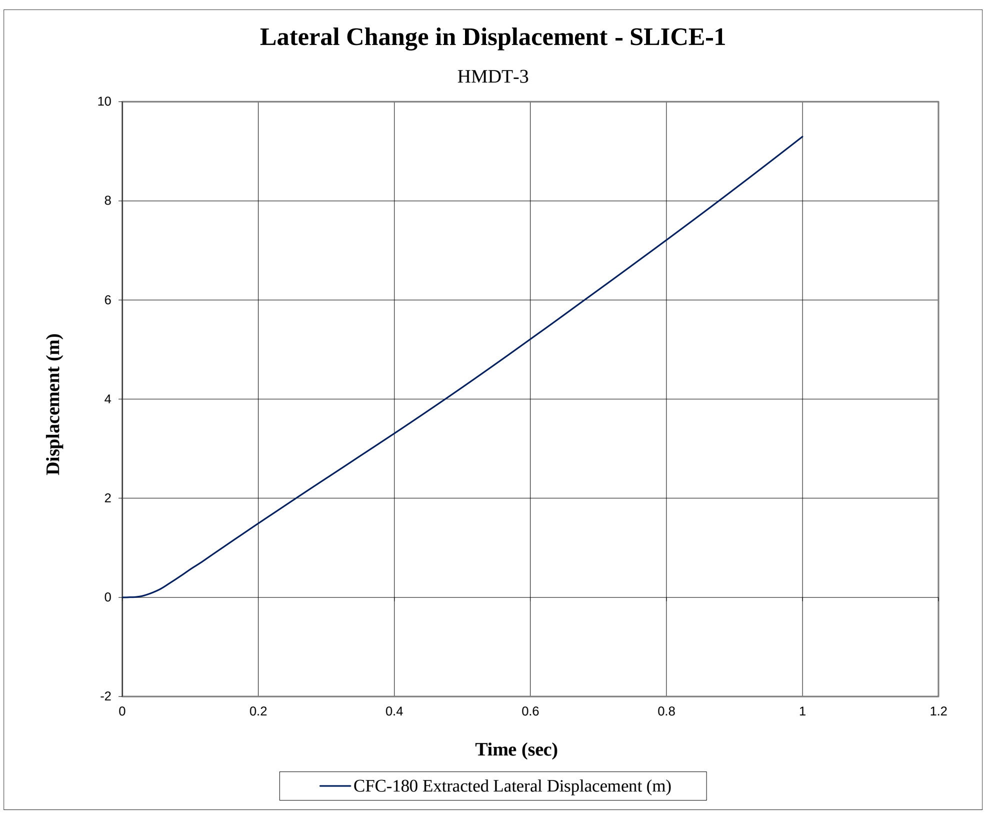



Figure I-6. Lateral Occupant Displacement (SLICE-1), Test No. HMDT-3

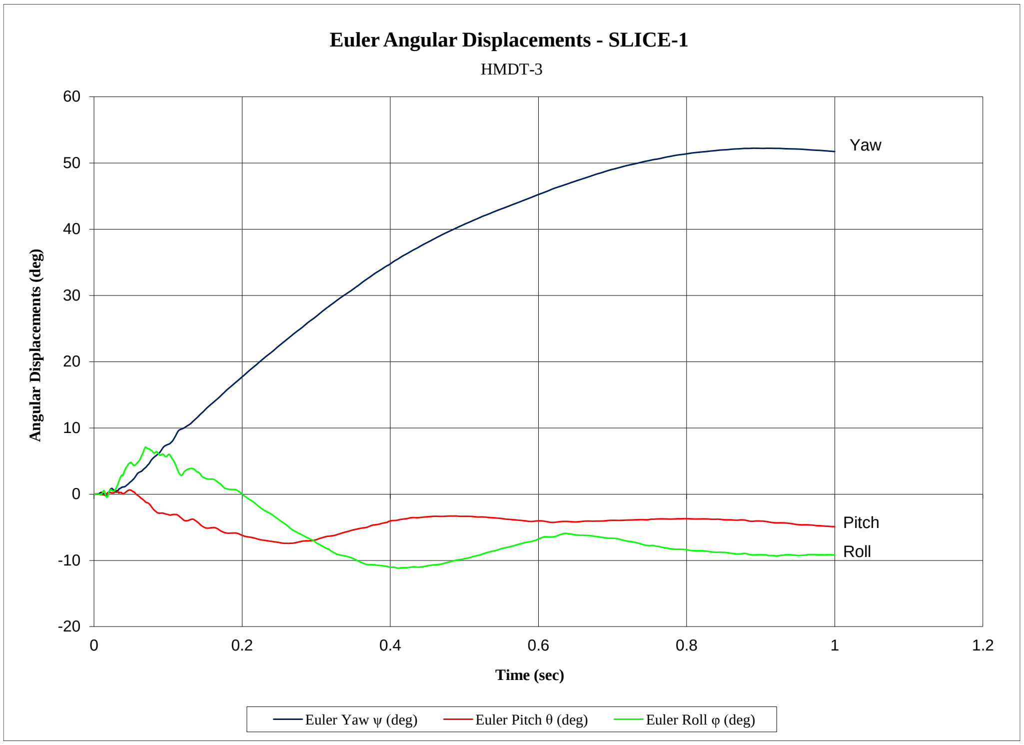



Figure I-7. Vehicle Angular Displacements (SLICE-1), Test No. HMDT-3

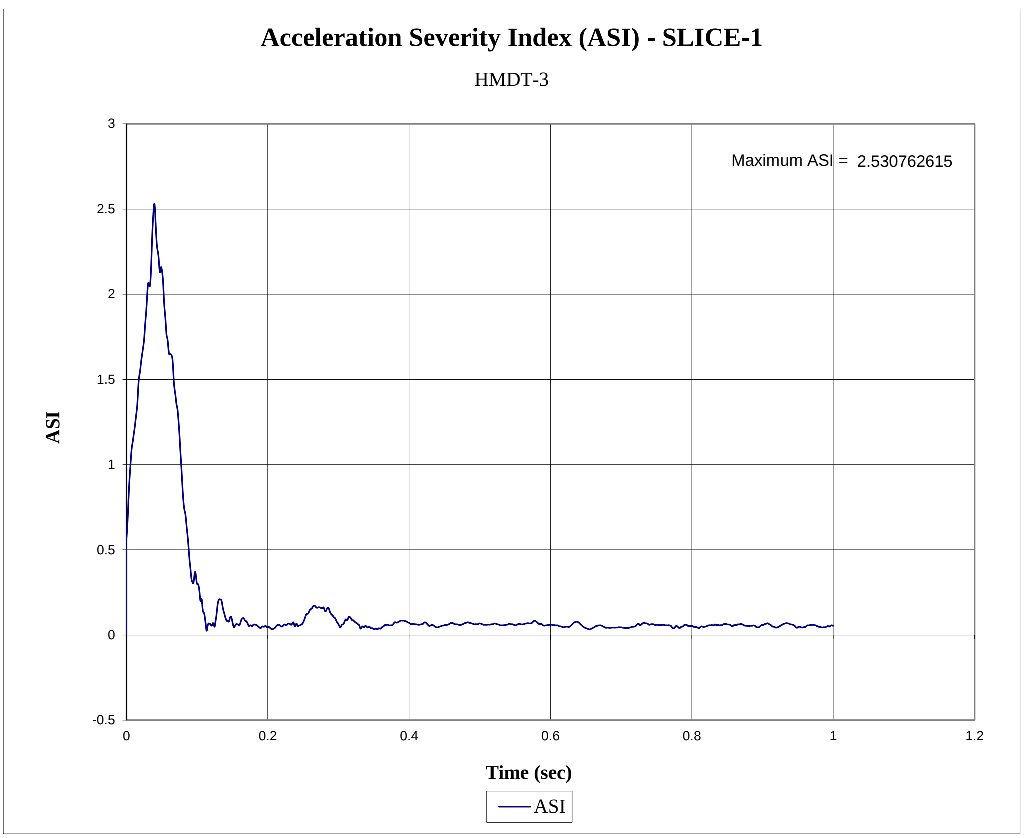



Figure I-8. Acceleration Severity Index (SLICE-1), Test No. HMDT-3

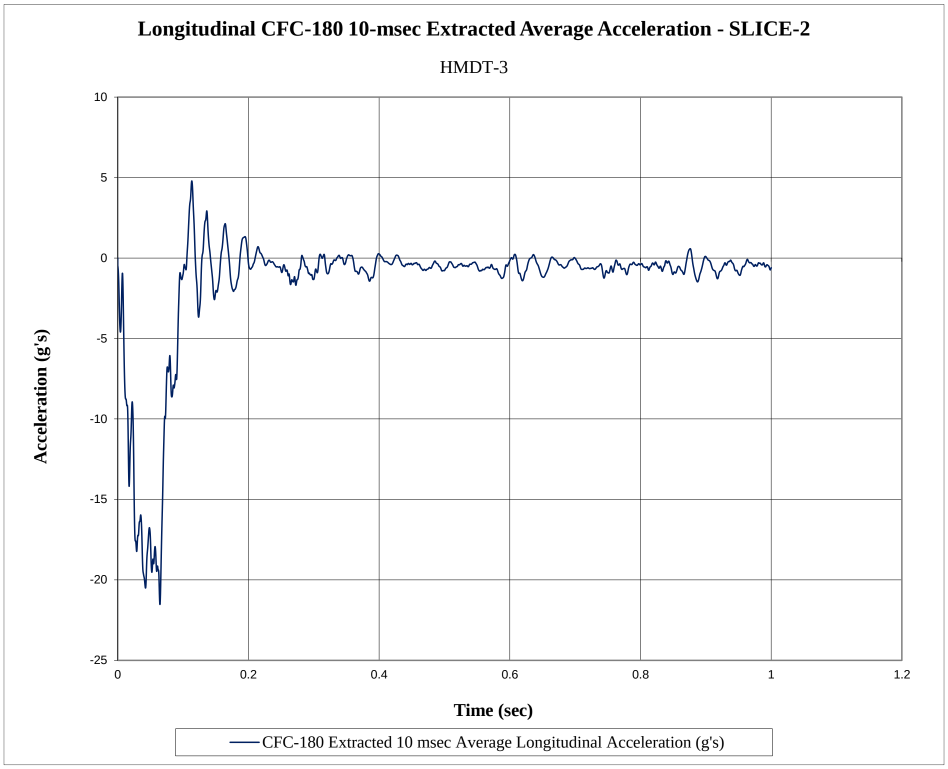



Figure I-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. HMDT-3

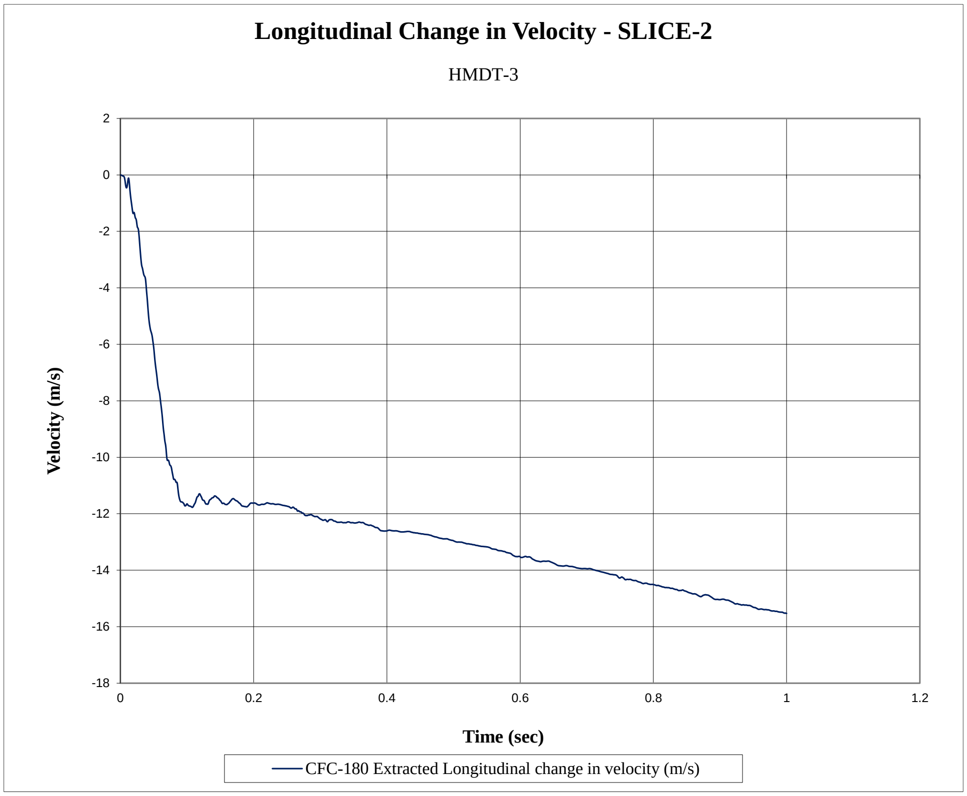



Figure I-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. HMDT-3

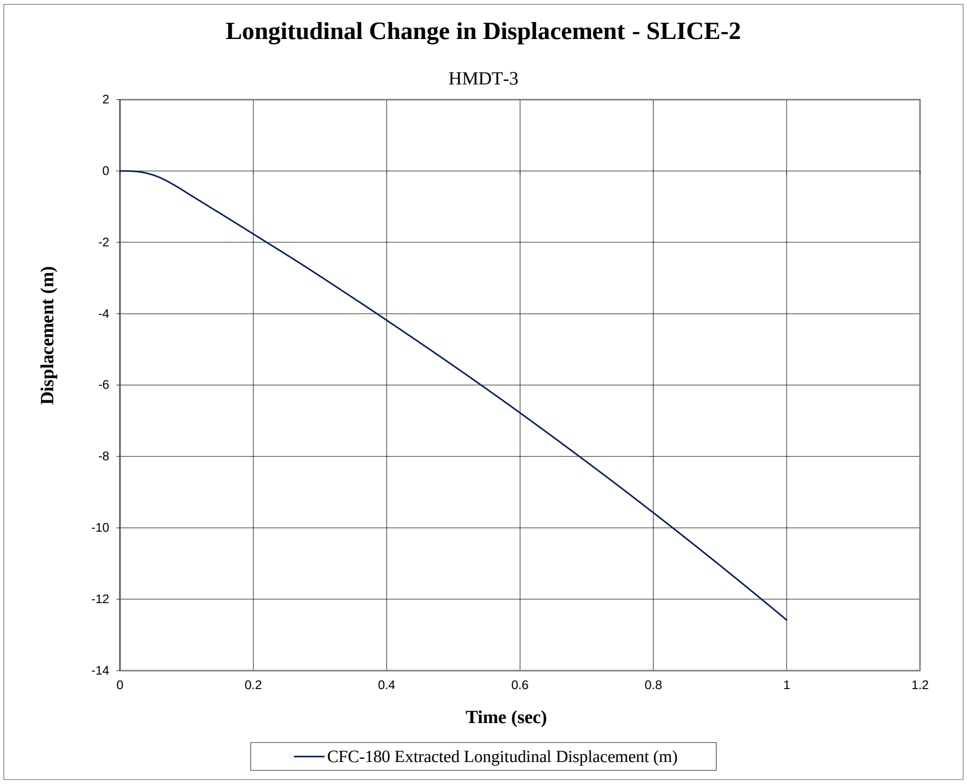



Figure I-11. Longitudinal Occupant Displacement (SLICE-2), Test No. HMDT-3

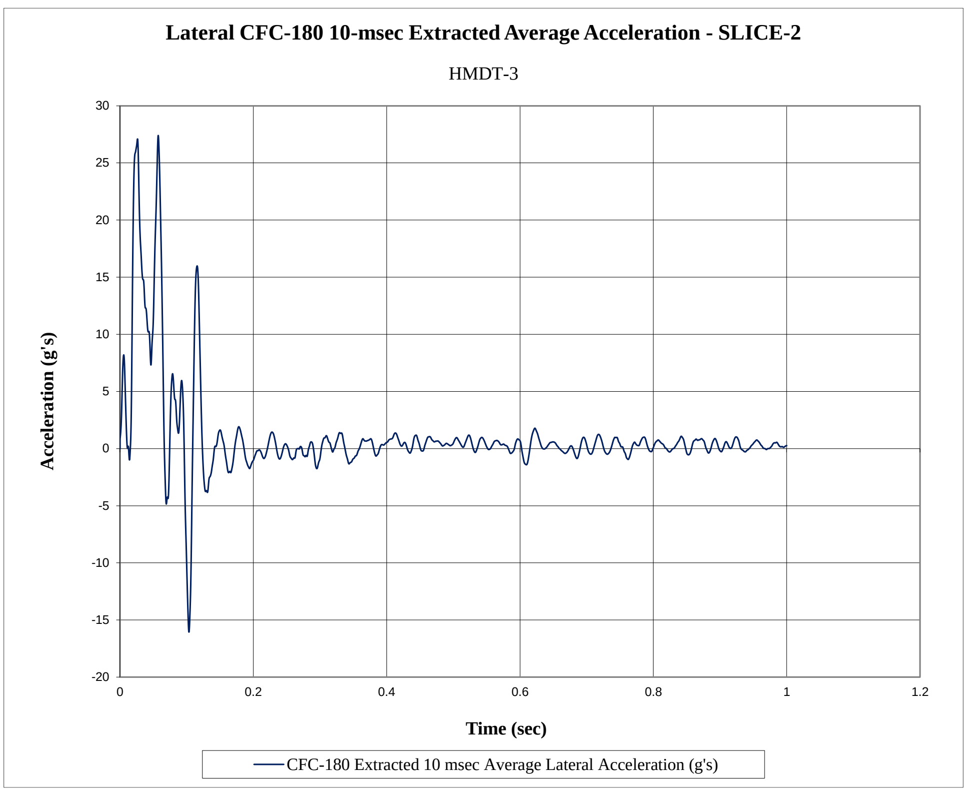



Figure I-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. HMDT-3

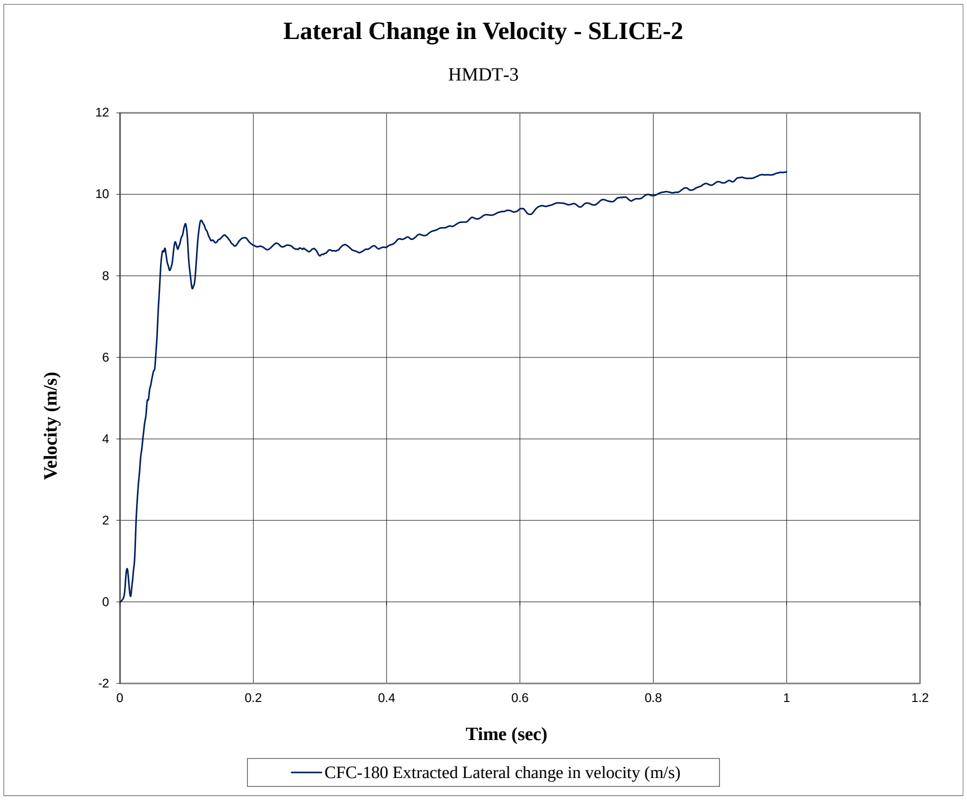



Figure I-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. HMDT-3

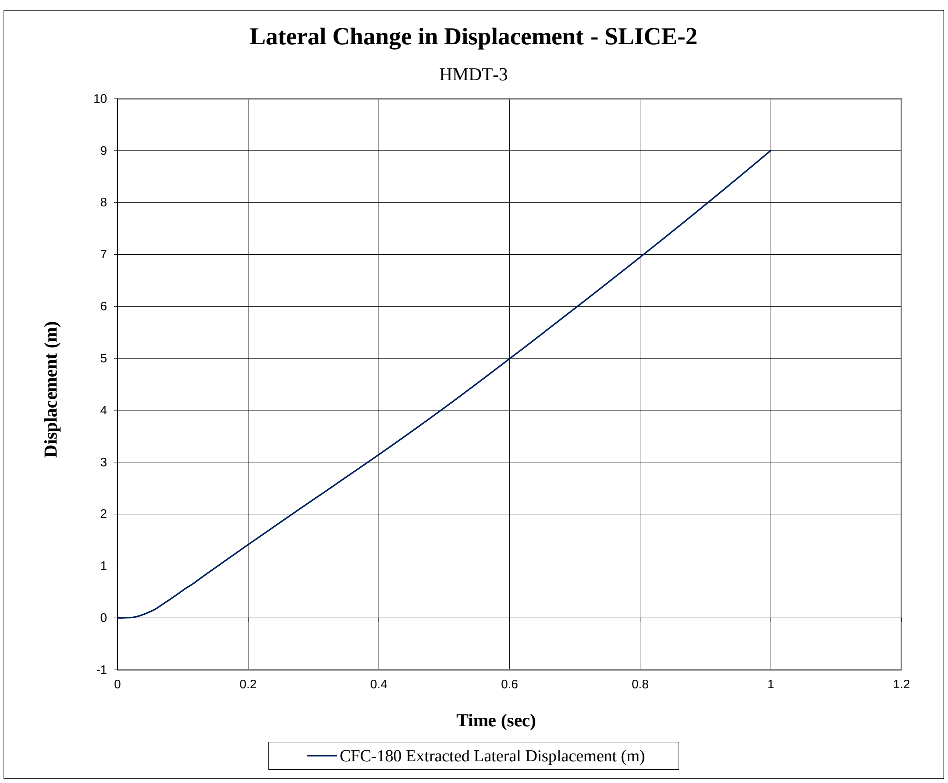



Figure I-14. Lateral Occupant Displacement (SLICE-2), Test No. HMDT-3

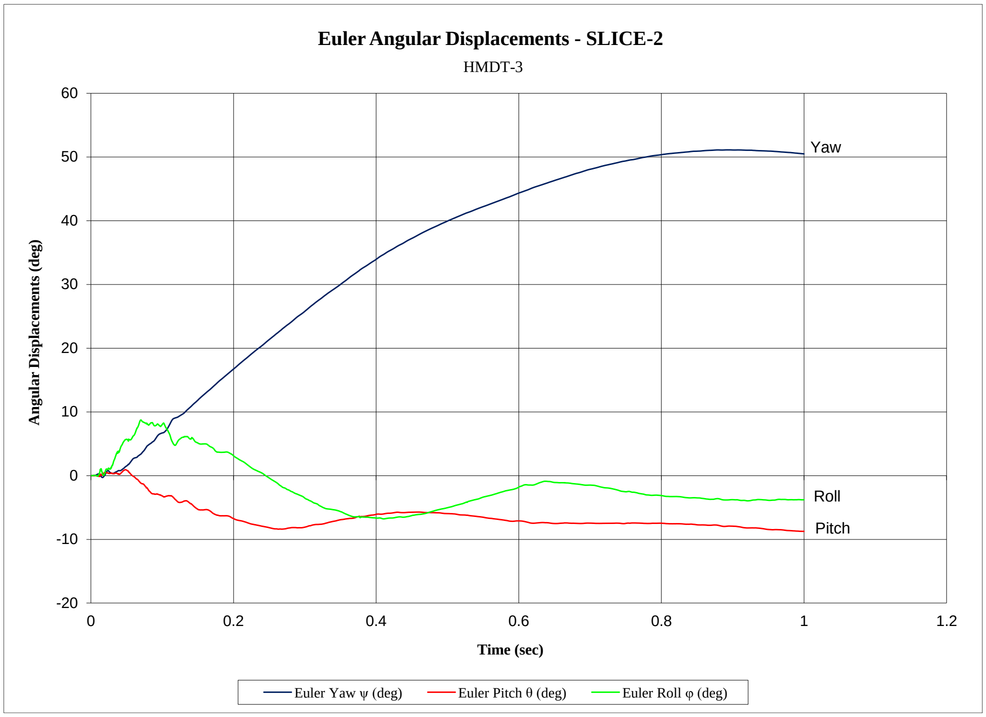



Figure I-15. Vehicle Angular Displacements (SLICE-2), Test No. HMDT-3

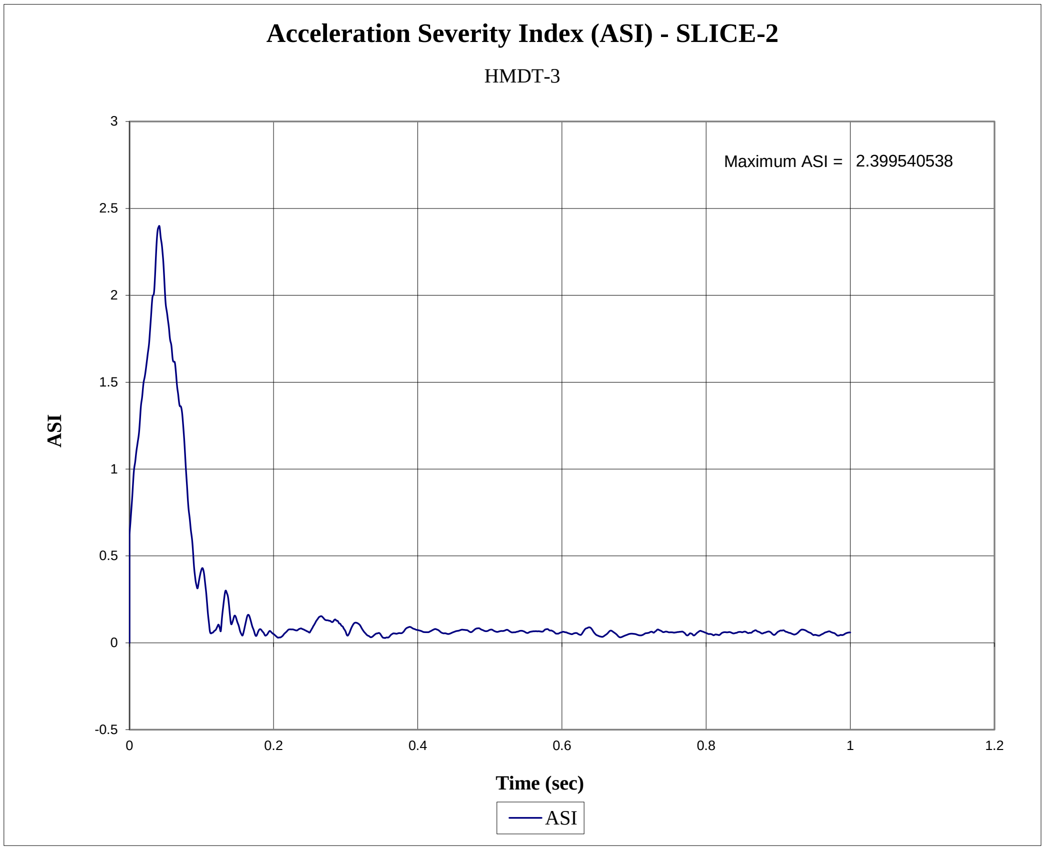



Figure I-16. Acceleration Severity Index (SLICE-2), Test No. HMDT-3

# Appendix J. Material Specifications, Test No. HMDT-4

Table J-1. Bill of Materials, HMDT-4

| Item No. | Description | Material Specification | Reference |
|---|---|---|---|
| a1 | 12'-6" 12-gauge Thrie Beam Section | AASHTO M180 | H#L33720 |
| a2 | 6'-3" 12-gauge Thrie Beam Section | AASHTO M180 | H#L34919 |
| a3 | 6'-3" 10-gauge W-Beam to Thrie-Beam Asymmetric Transition Section | AASHTO M180 | H#240680 |
| a4 | 12'-6" 12-gauge W-Beam MGS Section | AASHTO M180 | H#C84187 |
| a5 | 12'-6" 12-gauge W-Beam MGS End Section | AASHTO M180 | H#C84187 |
| a6 | 6'-3" 10-gauge Thrie Beam Section | AASHTO M180 | H#11000960 |
| a7 | 43¼"x16"x⅜" Transition Back-up Plate | ASTM A36 | H#NLK2156215 |
| c1 | BCT Timber Post - MGS Height | SYP Grade No. 1 or better (No knots ±18" from ground on tension face) | Ch#4697 |
| c2 | 72" Long Foundation Tube | ASTM A500 Gr. B | H#821T08220 |
| c3 | Ground Strut Assembly | ASTM A36 | H#163375 |
| c4 | BCT Anchor Cable End Swaged Fitting | Fitting - ASTM A576 Gr. 1035<br>Stud - ASTM F568 Class C | PO#40299<br>ASPI# 122160 |
| c5 | BCT Cable Anchor Assembly | - | PO#40299<br>ASPI# 122160 |
| c6 | 8"x8"x⅝" Anchor Bearing Plate | ASTM A36 | H#4181496 |
| c7 | 2⅜" O.D. x 6" Long BCT Post Sleeve | ASTM A53 Gr. B Schedule 40 | H#B712810 |
| c8 | Anchor Bracket Assembly | ASTM A36 | H#JK16101488 |
| d1 | W6x9 or W6x8.5, 72" Long Steel Post | ASTM A992 | H#55064803.02 |
| d2 | W6x9 or W6x8.5, 72" Long Steel Post | ASTM A992 | H#55064803.02 |
| d3 | W6x15, 78" Long Steel Post | ASTM A992 | H#58042771.02 |
| d4 | 17½" Long, 8"x6"x¼" Steel Blockout | ASTM A500 Gr. B | H#A97575 |
| d5 | 17½" Long, 12"x4"x¼" Steel Blockout | ASTM A500 Gr. B | H#2202349<br>H#SK1852 |
| d6 | 14$^{3}/_{16}$"x12"x5⅛" Composite Recycled Blockout | Mondo Polymer MGS14SH or Equivalent | L#1904/1000 |

Table J-2. Bill of Materials, HMDT-4, Cont.

| Item No. | Description | Material Specification | Reference |
|---|---|---|---|
| d7 | $14^{3}/_{16}$"x8"x5⅛" Composite Recycled Blockout | Mondo Polymer GB14SH2 or equivalent | L#1804/1000 |
| d8 | 16D Double Head Nail | Galvanized | COC for PO E000548963 |
| e3 | #4 Rebar, 16" Total Length | ASTM A615 Gr. 60 | H#7006848 |
| e4 | #4 Rebar, 12¾" Total Length | ASTM A615 Gr. 60 | H#7006848 |
| e5 | #5 Rebar, 166" Total Length | ASTM A615 Gr. 60 | H#3600014140 |
| e6 | #5 Rebar, 158¼" Total Unbent Length | ASTM A615 Gr. 60 | H#3600014140 |
| f1 | ⅝"-11 UNC, 14" Long Guardrail Bolt | ASTM A307 Gr. A | H#100104009 |
| f2 | ⅝"-11 UNC, 10" Long Guardrail Bolt | ASTM A307 Gr. A | H#1721198<br>H#10666100 |
| f3 | ⅝"-11 UNC, 1¼" Long Guardrail Bolt | ASTM A307 Gr. A | H#10657410<br>H#10684020 |
| f4 | ⅝"-11 UNC, 10" Long Hex Head Bolt | ASTM A307 Gr. A or equivalent | H#JK18104124 |
| f5 | ⅝"-11 UNC, 1½" Long Hex Head Bolt | ASTM A307 Gr. A or equivalent | H#5-01570 |
| f6 | ⅞"-9 UNC, 8" Long Hex Head Bolt | ASTM A307 Gr. A or equivalent | H#489517 |
| g1 | ⅝" Dia. Plain USS Washer | ASTM F844 | P#1133185<br>C#180164126<br>L#M-SWE0412454-8 |
| g3 | ⅞" Dia. Plain Round Washer | ASTM F844 | P#33187<br>C#170089822<br>L#1844804 |
| g4 | 1" Dia. Plain USS Washer | ASTM F844 | P#33188<br>C#210151571 |
| h1 | ⅝"-11 UNC Heavy Hex Nut | ASTM A563A or equivalent | H#62151324<br>H#62152527 |
| h3 | ⅞"-9 UNC Hex Nut | ASTM A563A or equivalent | P#36717<br>C#210167591<br>L#1N18BC001<br>L#1N1880113 |
| h5 | 1"-8 UNC Heavy Hex Nut | ASTM A563DH or A194 Gr. 2H | H#100106331<br>COC Only P#38210 |
| h6 | ⅝"-11 UNC Hex Nut | ASTM A563A or equivalent | H#331608011 |
| j2 | Curb Concrete | Minimum strength<br>f'c = 4,000 psi | Ticket# 1260732 |

H#L33720 R#21-197 12'-6" 12-gauge Thrie Beam Section

# Certified Analysis

Trinity Highway Products LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296
Customer: MIDWEST MACH & SUPPLY CO
P. O. BOX 703

MILFORD, NE 68405
Project: STOCK

Order Number: 1328797 Prod Ln Grp: 0-OE2.0
Customer PO: 4006
BOL Number: 113647 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 9/30/20

| Qty | Part # | Description | Spec | CL | TY | Heat Code/ Heat | Yield | TS | Elg | C | Mn | P | S | Si | Cu | Cb | Cr | Vn | ACW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | M-180 | A | 2 | 245021 | 64,480 | 83,940 | 22.2 | 0.190 | 0.700 | 0.013 | 0.004 | 0.020 | 0.060 | 0.000 | 0.060 | 0.001 | 4 |
| | | | M-180 | A | 2 | 245984 | 62,860 | 80,840 | 26.2 | 0.190 | 0.720 | 0.008 | 0.003 | 0.010 | 0.080 | 0.000 | 0.050 | 0.000 | 4 |
| 155 | 12365G | T12/12'6/8@1'6.75/S | | | 2 | L33720 | | | | | | | | | | | | | |
| | | | M-180 | A | 2 | 254833 | 62,344 | 82,251 | 25.5 | 0.190 | 0.720 | 0.015 | 0.002 | 0.020 | 0.150 | 0.000 | 0.070 | 0.002 | 4 |
| | | | M-180 | A | 2 | 255300 | 62,065 | 80,722 | 24.9 | 0.200 | 0.730 | 0.008 | 0.004 | 0.010 | 0.060 | 0.000 | 0.040 | 0.002 | 4 |
| 27 | 32218G | T10/TRAN/TB:WB/ASYM/R | M-180 | B | 2 | 833M66260 | 66,600 | 74,800 | 29.0 | 0.060 | 0.820 | 0.015 | 0.005 | 0.029 | 0.019 | 0.042 | 0.030 | 0.001 | 4 |
| 22 | 32219G | T10/TRAN/TB:WB/ASYM/LT | M-180 | B | 2 | 248834 | 59,940 | 78,890 | 27.2 | 0.210 | 0.720 | 0.013 | 0.003 | 0.020 | 0.100 | 0.000 | 0.050 | 0.000 | 4 |

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy QMS-LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT, 23 CFR 635.410.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36 UNLESS OTHERWISE STATED.
ALL COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT", 23 CFR 635.410.
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 (US DOMESTIC SHIPMENTS)
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 & ISO 1461 (INTERNATIONAL SHIPMENTS)
FINISHED GOOD PART NUMBERS ENDING IN SUFFIX B,P, OR S, ARE UNCOATED
BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
WASHERS COMPLY WITH ASTM F-436 SPECIFICATION AND/OR F-844 AND ARE GALVANIZED IN ACCORDANCE WITH ASTM F-2329, UNLESS OTHERWISE STATED.
3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH – 46000 LB

Figure J-1. 12-Gauge W-Beam, Test No. HMDT-4 (Item No. a1)

# Certified Analysis

Trinity Highway Products LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296
Customer: MIDWEST MACH & SUPPLY CO
P. O. BOX 703

MILFORD, NE 68405
Project: STOCK

Order Number: 1326783 Prod Ln Grp: 0-OE2.0
Customer PO: 3974
BOL Number: 113032 Ship Date: 7/31/2020
Document #: 1
Shipped To: NE
Use State: NE

As of: 8/11/20

| Qty | Part # | Description | Spec | CL | TY | Heat Code/ Heat | Yield | TS | Elg | C | Mn | P | S | Si | Cu | Cb | Cr | Vn | ACW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 40 | 980G | T10/END SHOE/SLANT | A-1011 | | | 95839 | 50,900 | 628,000 | 35.4 | 0.060 | 0.490 | 0.010 | 0.001 | 0.030 | 0.110 | 0.000 | 0.070 | 0.001 | 4 |
| 70 | 12173G | T12/6'3/4@1'6.75"/S | | | 2 | L34919 | | | | | | | | | | | | | |
| | | | M-180 | A | 2 | 245021 | 64,480 | 83,940 | 22.2 | 0.190 | 0.700 | 0.013 | 0.004 | 0.020 | 0.060 | 0.000 | 0.060 | 0.001 | 4 |
| | | | M-180 | A | 2 | 245984 | 62,860 | 80,840 | 26.2 | 0.190 | 0.720 | 0.008 | 0.003 | 0.010 | 0.080 | 0.000 | 0.050 | 0.000 | 4 |
| 140 | 12365G | T12/12'6/8@1'6.75/S | | | 2 | L30520 | | | | | | | | | | | | | |
| | | | M-180 | A | 2 | 245984 | 62,860 | 80,840 | 26.2 | 0.190 | 0.720 | 0.008 | 0.003 | 0.010 | 0.080 | 0.000 | 0.050 | 0.000 | 4 |
| | | | M-180 | A | 2 | 248105 | 61,520 | 80,800 | 24.4 | 0.200 | 0.730 | 0.012 | 0.004 | 0.020 | 0.100 | 0.000 | 0.060 | 0.002 | 4 |
| | | | M-180 | A | 2 | 248106 | 62,360 | 81,270 | 28.1 | 0.190 | 0.720 | 0.013 | 0.003 | 0.020 | 0.120 | 0.000 | 0.060 | 0.001 | 4 |
| | 12365G | | | | 2 | L32520 | | | | | | | | | | | | | |
| | | | M-180 | A | 2 | 251386 | 62,920 | 81,060 | 24.4 | 0.200 | 0.720 | 0.010 | 0.002 | 0.020 | 0.100 | 0.000 | 0.070 | 0.002 | 4 |
| | | | M-180 | A | 2 | 252079 | 63,050 | 81,000 | 26.3 | 0.190 | 0.720 | 0.015 | 0.003 | 0.020 | 0.130 | 0.000 | 0.070 | 0.002 | 4 |
| 20 | 32218G | T10/TRAN/TB:WB/ASYM/R | M-180 | B | 2 | 42014850 | 50,000 | 70,000 | 28.0 | 0.040 | 0.770 | 0.014 | 0.001 | 0.040 | 0.120 | 0.000 | 0.070 | 0.003 | 4 |
| 30 | 32219G | T10/TRAN/TB:WB/ASYM/LT | M-180 | B | 2 | 248834 | 59,940 | 78,890 | 27.2 | 0.210 | 0.720 | 0.013 | 0.003 | 0.020 | 0.100 | 0.000 | 0.050 | 0.000 | 4 |
| 120 | 54043G | 70 PST/6X15/DB:3HI | A-572 | | | 59091919 | 59,367 | 78,866 | 24.0 | 0.100 | 0.920 | 0.016 | 0.035 | 0.210 | 0.350 | 0.015 | 0.180 | 0.001 | 4 |

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy QMS-LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT, 23 CFR 635.410.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36 UNLESS OTHERWISE STATED.

ALL COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT", 23 CFR 635.410.
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 (US DOMESTIC SHIPMENTS)
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 & ISO 1461 (INTERNATIONAL SHIPMENTS)

FINISHED GOOD PART NUMBERS ENDING IN SUFFIX B,P, OR S, ARE UNCOATED

Figure J-2. 12-Gauge W-Beam, Test No. HMDT-4 (Item No. a2)

# Certified Test Report

220008-P1

**NORTH STAR BLUESCOPE STEEL LLC**
6767 County Road 9
Delta Ohio 43515
Telephone: (888) 822-2112

| | | | | | |
|---|---|---|---|---|---|
| **Customer:** | Miami Valley Steel Service Inc. | | | **Ordered Width (mm/in)** | 1295.4 / 51 |
| 201 fox Dr. | | **Order #** | 434020 | **Ordered Gauge (mm/in)** | 3.200 / 0.126 M |
| Piqua, OH 45356 | | **Line Item #** | 1 | **Produced Date/Time** | 6/15/19 17:44 |
| **Customer P.O:** | 081886 | **Heat #** | 240680 | **Coil #** | 1933970 |
| **Cust. Ref/Part #** | M180 | **Material Desc:** | 1018 CQ Modified, Guardrail Type 2 | | |

**Weight(kg/lb)** 19318 / 42589

## Chemical Analysis (wt%)

| Type | C | Mn | P | S | Si | Al | Cu | Cr | Ni | Mo | Sn | N | B | V | Nb | Ti | Ca | Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Heat | 0.20 | 0.73 | 0.008 | 0.004 | 0.02 | 0.03 | 0.11 | 0.06 | 0.04 | 0.01 | 0.00 | 0.006 | 0.0000 | 0.002 | 0.000 | 0.001 | 0.002 | 0.000 |

## Mechanical Test Report

| | Yield Strength | Tensile Strength | % Elongation in 2 inches |
|---|---|---|---|
| Tail | 62100 psi / 428 MPa | 79940 psi / 551 MPa | 27.5% |

This hot rolled steel has been produced to conform to DIN EN 10204:2005 3.1 and has been manufactured to a fully killed fine grain practice. This hot rolled steel has been produced and tested in accordance with each of the following applicable standards:ASTM E1806-09, ASTM E415-14, ASTM A751-14, ASTM A370-14, JIS Z2201:1998, JIS Z2241:2011. Pressure Equipment Directive (PED) 2014/68/EU, Annex I, Paragraph 4.3 Compliant. This report certifies that the above test results are representative of those contained in the records of North Star BlueScope Steel LLC for the material identified in this test report and is intended to comply with the requirements of the material description. North Star BlueScope Steel LLC is not responsible for the inability of this material to meet specific applications. Any modifications to this certification as provided negates the validity of this test report. All reproductions must have the written approval of North Star BlueScope Steel.This product was manufactured, melted, cast, and hot-rolled (min. 3:1 reduction ratio), entirely within the U.S.A at North Star BlueScope Steel LLC, Delta, Ohio. This material was not exposed to Mercury or any alloy which is liquid at ambient temperature during processing or while in North Star BlueScope Steel LLC possession. Test equipment calibration certificates are available upon request. NIST traceability is established through test equipment calibration certificates which are available upon request. Uncertainty calculations are calculated in accordance with NIST standards and are maintained at a 4:1 ratio in accordance with NIST standards. Uncertainty data is available upon request

**John Meece** — Manager Quality Assurance and Technology
072718

**Date Issued:** Aug 21, 2019 8:58 AM
**Revision#:** 01

Figure J-3. 10-Gauge W-Beam to Thrie-Beam Asymmetric Transition Section, Test No. HMDT-4 (Item No. a3)

GREGORY HIGHWAY PRODUCTS, INC.
4100 13th St. SW
Canton, Ohio 44710

**Customer:** UNIVERSITY OF NEBRASKA-LINCOLN
401 CANFIELD ADMIN BLDG
P O BOX 880439
LINCOLN,NE,68588-0439

Test Report
Ship Date: 1/26/2018
Customer P O: 36263
Shipped to: UNIVERSITY OF NEBRASKA-LINCOLN
Project:
GHP Order No.: 319AA

| HT # code | Heat # | C. | MN. | P. | S. | Si. | Tensile | Yield | Elong. | Quanity | Class | Type | Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1207 | C85187 | 0.2 | 0.48 | 0.008 | 0.003 | 0.03 | 80433 | 59371 | 16.35 | 150 | A | 2 | 12GA 12FT6IN/3FT1 1/2IN WB T2 |

Bolts comply with ASTM A-307 specifications and are galvanized in accordance with ASTM A-153, unless otherwise stated.
Nuts comply with ASTM A-563 specifications and are galvanized in accordance with ASTM A-153, unless otherwise stated.
All other galvanized material conforms with ASTM-123 & ASTM-653
All Galvanizing has occurred in the United States
All steel used in the manufacture is of Domestic Origin, "Made and Melted in the United States"
All Steel used meets Title 23CFR 635.410 - Buy America
All Guardrail and Terminal Sections meets AASHTO M-180, All structural steel meets AASHTO M-183 & M270
All Bolts and Nuts are of Domestic Origin
All material fabricated in accordance with Nebraska Department of Transportation
All controlled oxidized/corrosion resistant Guardrail and terminal sections meet ASTM A606, Type 4.

Jeffery L Grover

By:
Jeffery Grover, VP of Highway Products Sales & Marketing
Gregory Highway Products, Inc.

NOTARIAL SEAL
STATE OF OHIO

James P Dehnke
Notary Public - State of Ohio
My Commission Expires
October 19, 2019

STATE OF OHIO: COUNTY OF STARK
Sworn to and subscribed before me, a Notary Public, by
Jeffery Grover this 29 day of January, 2018

Notary Public, State of Ohio

Figure J-4. 12 ft – 6 in. Long, 12-Gauge W-Beam MGS Section, Test No. HMDT-4 (Item Nos. a4 and a5)

Steel Dynamics®
Steel Dynamics Sales North America, Inc.
Flat Roll Division

4500 County Road 59
Butler, IN 46721 USA
Telephone (260) 868-8000
Fax (260) 868-8955

# CHEMICAL/PHYSICAL CERTIFICATION

**SHIP TO**
Alta / Steelco - Rail
for Universal Roll Forming
Zone 05 Track 748 Spot 3
Salt Lake City, UT 84104
United States

**SOLD TO**
Universal Roll Forming, Inc.
Div. of Universal Industrial S
P.O. Box 699
Pleasant Grove, UT 84062
United States

Karl Johnson
Purchasing
801-785-9792
1-801-785-9781

**Load ID**
1126802

| Customer # | Part # | Po # | Order # | Line Item # | Coil # | Heat # | Coil Weight (lbs) |
|---|---|---|---|---|---|---|---|
| 1192 | | 166 - 2 | 215854 | 2 | 10B492134 | 11000960 | 45,330 |

| Width (In) | Gauge (In) | Length(ft) | Material Specification | Product Description |
|---|---|---|---|---|
| 59.25 - mill edge | 0.1271 - Min | 1,712 | ASTM A 1011 SS GRADE 57 MODIFIED - 09a | Prime Hot Rolled Band |

**Chem Treat :** No **Oiled :**

### Ladle Chemical Analysis %

| C | Mn | P | S | Si | Al | Cu | Ni | Cr | Mo | Sn | N | V | Nb | Ti | B | Ca | Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.20 | 0.87 | 0.012 | 0.006 | 0.03 | 0.027 | 0.12 | 0.05 | 0.06 | 0.02 | 0.007 | 0.009 | 0.002 | 0.014 | 0.001 | 0.0000 | 0.002 | 0.00 |

### Mechanical Properties

| Yield Strength (PSI) | Tensile Strength (PSI) | Percent Elongation | Rockwell Result |
|---|---|---|---|
| 68,630 | 85,669 | 27.0 | 88 |

Made in USA
Shipped from Butler, IN, United States
Melted , thin slab cast and rolled by proud Americans in Butler , IN.
All tests were performed according to applicable standards and are correct as contained in the records of the company.
Quality Assurance________________

Retrieved on : 01/11/10 14:46:02 *Steel Dynamics, Inc. Rev. Level 5.1 [1003]* Page 1 of 4

Figure J-5. 6 ft – 3 in. Long, 10-Gauge Thrie-Beam Section, Test No. HMDT-4 (Item No. a6)

NLMK Indiana

NLMK INDIANA
6500 SOUTH BOUNDARY ROAD
PORTAGE, IN 46368
PHONE: 219.787.8200

07/22/2021 13:50
CSTM8105
Page 1 of 1

CERTIFICATE OF TEST FOR COIL 6329687 HEAT# NLK2156215

SOLD TO: STATE STEEL SUPPLY
208 COURT STREET
PO BOX 3224
SIOUX CITY, IA 51102

SHIP TO: STATE STEEL SUPPLY
208 COURT STREET
SIOUX CITY, IA 51102

ORDER SPECIFICATIONS

CUSTOMER PO: P10419BL,013-2
RESULTS FOR COIL: 6329687
PRODUCT TYPE: HR
PRODUCT CATEGORY: HA .030 SI MAX
ORDERED GRADE: 1012
ORDERED GAUGE: 0.3700 MIN
GAUGE TOL: +0.0300/-0.0000
ORDERED WIDTH: 48.0000 MIN
WIDTH TOL: +1.1250/-0.0000

ORDER: 3070614
EDGE: MILL
FINISH: BLACK
HARDNESS: NA
HARDNESS RANGE: NA
YIELD:
TENSILE:
ELONGATION:
BEND:

ITEM: 41229655
INDUSTRY SPEC:
CUSTOMER SPEC: NA
CUSTOMER PART #:
CERT #: 1
CUSTOMER NOTE:

| JOB # | COIL # | SIZE (Inches) | WGT(pounds) |
|---|---|---|---|
| 3070614-01 | 6329687 | 0.3700 x 48.0000 | 48330 |

HEAT# NLK2156215 (Country of Origin: RUSSIA)

C: .13 - MN: .34 - P: .012 - S: .009 - SI: .01 - AL: .041 - CU: .03 - NI: .01 - CR: .02 - MO: * - SN: * - TI: .001 - V: .001 - NB: .002 - N: .004 - B: .0001 - CA: * - CE: * - ZR: * - AS: * - SB: *

*P10929JL02101*

*NLK2156215*

Manufactured in the United States of America - 'BUY AMERICAN' Compliant.

ELEMENTS ABOVE ARE REPORTED IN WEIGHT PERCENT (i.e. C .06 = .06% weight carbon)

Elements with a reported value of "*" were undetected, and thus are less than .001%.
NLMK INDIANA certifies that the material listed herein has been tested in accordance with the methods prescribed in the governing specifications. Based upon the results of such testing, the material conforms to the specifications. All testing has been performed using the current revision of the testing specifications.

Jasond Jones
Product Engineer

Figure J-6. 43¼-in. x 16-in. x ⅜-in. Transition Back-Up Plate, Test No. HMDT-4 (Item No. a7)

CNWP
CENTRAL NEBRASKA WOOD PRESERVERS

1098 East Maple St
Sutton, NE 68979
Phone: 402.773.4319
Email: nick@nebraskawood.com

# CERTIFICATE OF COMPLIANCE

**Shipped To:** Midwest Machinery and Supply
**BOL#** N45211
**Customer PO#** 5055
**Preservative:** CCA – C 0.60D pcf AWPA UC4

| Part # | Physical Description | # Pieces | Charge # | Retention |
|---|---|---|---|---|
| GS6846PST | 5.5x7.5-46" BCT | 42 | 4697 | .615 |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

I certify the above referenced material has been produced, treated and tested in accordance with and conforms to AASHTO M133 & M168 standards.

VA: Iowa Wood Preservers certifies that the treated wood products listed above have been treated in accordance with AWPA standards, Section 236 of the VDOT Road & Bridge Specifications and meets the applicable minimum penetration and retention requirements.

Nick Sowl, General Counsel

7/20/21
Date

Rebecca A Becker

GENERAL NOTARY - State of Nebraska
REBECCA A. BECKER
My Comm. Exp. May 21, 2023

Figure J-7. BCT Timber Post, Test No. HMDT-4 (Item No. c1)

30460HD6

Atlas Tube Corp (Chicago)
1855 East 122nd Street
Chicago, Illinois, USA
60633
Tel: 773-646-4500
Fax: 773-646-6128

Atlas Tube
A DIVISION OF ZEKELMAN INDUSTRIES

Ref.B/L: 80728203
Date: 08.17.2016
Customer: 2908

## MATERIAL TEST REPORT

**Sold to**

Gregory Industries Inc.
4100 13th Street SW.
CANTON OH 44710
USA

**Shipped to**

Tru-Form Steel & Wire
1204 Gilkey Ave
HARTFORD CITY IN 47348
USA

Material: 8.0x6.0x188x27'0"0(2x2)SILDOMUS | Material No: 80060188 | Made in: USA | Melted in: USA

Sales order: 1105121 | Purchase Order: 35569 | Cust Material #: TRB3/16-8-6-27

| Heat No | C | Mn | P | S | Si | Al | Cu | Cb | Mo | Ni | Cr | V | Ti | B | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 616137 | 0.210 | 0.930 | 0.011 | 0.003 | 0.020 | 0.041 | 0.020 | 0.008 | 0.020 | 0.020 | 0.030 | 0.008 | 0.001 | 0.000 | 0.003 |

| Bundle No | PCs | Yield | Tensile | Eln.2in | Certification | CE |
|---|---|---|---|---|---|---|
| M800650076 | 4 | 058210 Psi | 073148 Psi | 32 % | ASTM A500-13 GRADE B&C | 0.38 |

Material Note:
Sales Or.Note:

Material: 8.0x6.0x188x30'0"0(2x3)SILDOMUS | Material No: 80060188 | Made in: USA | Melted in: USA

Sales order: 1105121 | Purchase Order: 35569 | Cust Material #: TRB3/16-8-6-30

| Heat No | C | Mn | P | S | Si | Al | Cu | Cb | Mo | Ni | Cr | V | Ti | B | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 821T08220 | 0.220 | 0.810 | 0.013 | 0.006 | 0.006 | 0.041 | 0.160 | 0.002 | 0.005 | 0.010 | 0.020 | 0.002 | 0.002 | 0.000 | 0.007 |

| Bundle No | PCs | Yield | Tensile | Eln.2in | Certification | CE |
|---|---|---|---|---|---|---|
| M800650038 | 6 | 057275 Psi | 070934 Psi | 32 % | ASTM A500-13 GRADE B&C | 0.37 |

Material Note:
Sales Or.Note:

Material: 8.0x6.0x188x30'0"0(2x3)SILDOMUS | Material No: 80060188 | Made in: USA | Melted in: USA

Sales order: 1105121 | Purchase Order: 35569 | Cust Material #: TRB3/16-8-6-30

| Heat No | C | Mn | P | S | Si | Al | Cu | Cb | Mo | Ni | Cr | V | Ti | B | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 821T08220 | 0.220 | 0.810 | 0.013 | 0.006 | 0.006 | 0.041 | 0.160 | 0.002 | 0.005 | 0.010 | 0.020 | 0.002 | 0.002 | 0.000 | 0.007 |

| Bundle No | PCs | Yield | Tensile | Eln.2in | Certification | CE |
|---|---|---|---|---|---|---|
| M800650039 | 6 | 057275 Psi | 070934 Psi | 32 % | ASTM A500-13 GRADE B&C | 0.37 |

Material Note:
Sales Or.Note:

Jason Richard

Jason Richard

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

Steel Tube Institute OF NORTH AMERICA

Page : 1 Of 6

Metals Service Center Institute

Figure J-8. 72-in. Long Foundation Tube, Test No. HMDT-4 (Item No. c2)

# Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 703

MILFORD, NE 68405
Project: STOCK

Order Number: 1214903 Prod Ln Grp: 9-End Terminals (Dom)
Customer PO: 2878
BOL Number: 80278 Ship Date:
Document #: 1
Shipped To: NE
Use State: KS

As of: 3/7/14

| Qty | Part # | Description | Spec | CL | TY | Heat Code/ Heat | Yield | TS | Elg | C | Mn | P | S | Si | Cu | Cb | Cr | Vn | ACW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 36 | 749G | TS 8X6X3/16X6'-0" SLEEVE | A-500 | | | 0173175 | 55,871 | 74,495 | 31.0 | 0.160 | 0.610 | 0.012 | 0.009 | 0.010 | 0.030 | 0.000 | 0.030 | 0.000 | 4 |
| 20 | 3000G | CBL 3/4X6'6/DBL | HW | | | 98790 | | | | | | | | | | | | | |
| 22 | 9852A | STRUT & YOKE ASSY | A-1011-SS | | | 163375 | 48,380 | 64,020 | 32.9 | 0.190 | 0.520 | 0.011 | 0.003 | 0.030 | 0.110 | 0.000 | 0.050 | 0.000 | 4 |
| | 9852A | | A-36 | | | 11237730 | 45,500 | 70,000 | 30.0 | 0.170 | 0.500 | 0.010 | 0.008 | 0.020 | 0.080 | 0.000 | 0.070 | 0.001 | 4 |

Ground Strut Green Paint
R#15-0157 September 2014 SMT

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

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

FINISHED GOOD PART NUMBERS ENDING IN SUFFIX B,P, OR S, ARE UNCOATED
BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
WASHERS COMPLY WITH ASTM F-436 SPECIFICATION AND/OR F-844 AND ARE GALVANIZED IN ACCORDANCE WITH ASTM F-2329.
3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH – 46000 LB

1 of 2

Figure J-9. Ground Strut Assembly, Test No. HMDT-4 (Item No. c3)

ASSEMBLY
SPECIALTY PRODUCTS INC

PH 216.676.5600
FX 216.676.6761
www.assemblyspecialty.com

ISO 9001:2008

14700 Brookpark Rd
Cleveland, OH 44135-5166
customerservice@assemblyspecialty.com

## Certificate of Conformance

**Date:** September 24, 2018

**To:** Gregory Industries, Inc.
Gregory Galv. & Metal Processing
4100 13th St. SW
Canton, OH 44710

We certify that our system and procedures for the control of quality assures that all items furnished on the order will meet applicable tests, requirements and inspection requirements as required by the purchase order and applicable specifications and drawings.

**PURCHASE ORDER #:** 40299
**DATE SHIPPED:** 09/24/18
**ASPI SALES ORDER #:** 122160
**MANUFACTURER:** ASSEMBLY SPECIALTY PRODUCTS, INC.

| QTY | CUST P/N | ASPI P/N | ASPI LOT# | DESCRIPTION |
|---|---|---|---|---|
| 250 | 3012G | C-2028 | 89315 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 89316 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 89318 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 89864 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 89865 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 89866 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 89929 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 89930 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 89931 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 89932 | 6' 6" BCT Cable Assembly |

**REMARKS:** NOMINAL BREAKING STRENGTH: 46,000 lbs
WIRE ROPE MANUFACTURED IN ACCORDANCE WITH AASHTO DESIGNATION: M30-02 and ASTM A741 TYPE 2, CLASS A
FITTINGS GALVANIZED IN ACCORDANCE WITH ASTM A-153 CLASS C.

STEEL USED TO MANUFACTURE THESE ITEMS WAS MELTED AND MANUFACTURED IN THE U.S.A
ALL MANUFACTURING PROCESSES SUPPLIED OR PERFORMED BY ASSEMBLY SPECIALTY PRODUCTS, INC. TOOK PLACE IN THE U.S.A.

Signature: 
Certification and Compliance Manager

Figure J-10. BCT Anchor Cable End Swaged Fitting and Cable Anchor Assembly, Test No. HMDT-4 (Item Nos. c4 and c5)

**ASSEMBLY**
SPECIALTY PRODUCTS INC.

PH 216.676.5600
FX 216.676.6761
www.assemblyspecialty.com

ISO 9001:2008

14700 Brookpark Rd
Cleveland, OH 44135-5166
customerservice@assemblyspecialty.com

**Lots continued):**

| QTY | CUST P/N | ASPI P/N | ASPI LOT# | DESCRIPTION |
|---|---|---|---|---|
| 250 | 3012G | C-2028 | 90007 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 90008 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 90009 | 6' 6" BCT Cable Assembly |
| 250 | 3012G | C-2028 | 90010 | 6' 6" BCT Cable Assembly |

Figure J-11. BCT Anchor Cable End Swaged Fitting and Cable Anchor Assembly, Test No. HMDT-4 (Item Nos. c4 and c5)

**GREGORY HIGHWAY PRODUCTS, INC.**
**4100 13th St. SW**
**Canton, Ohio 44710**

MIDWEST MACHINERY & SUPPLY CO.
P. O. BOX 703

MILFORD,NE,68405

Test Report
Ship Date: 11/17/2017
Customer P.O.: 3515
Shipped to: MIDWEST MACHINERY & SUPPLY CO.
Project:
GHP Order No: 128AA

| HT # code | LOT# | C. | Mn. | P. | S. | Si. | Tensile | Yield | Elong. | Quantity | Class | Type | Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A74070 | | 0.21 | 0.46 | 0.012 | 0.002 | 0.03 | 76100 | 58800 | 25.2 | 4 | A | 2 | 12GA TB TRANS. |
| 4181496 | | 0.24 | 0.84 | 0.014 | 0.01 | 0.01 | 72400 | 44800 | 34 | 4 | | 2 | 5/8IN X 8IN X 8IN BRG. PL. |
| 4181489 | | 0.09 | 0.45 | 0.012 | 0.004 | 0.01 | 58000 | 43100 | 27 | 4 | | 2 | 350 STRUT & YOKE |
| 196828BM | | 0.04 | 0.84 | 0.014 | 0.003 | | 76000 | 74000 | 25 | | | 2 | 350 STRUT & YOKE |
| E22985 | | 0.17 | 0.51 | 0.013 | 0.008 | 0.008 | 72510 | 64310 | 29.5 | 4 | | 2 | 2IN X 5 1/2IN PIPE SLEEVE |
| 811T08220 | | 0.22 | 0.81 | 0.013 | 0.006 | 0.005 | 71412 | 56323 | 35 | 8 | | 2 | 3/16IN X 6IN X 8IN X 6FT0IN TUBE SLEEVE |

James P. Dehnke
Notary Public, State of Ohio
My Commission Expires 10-19-2019

All Galvanizing has occurred in the United States
All steel used in the manufacture is of Domestic Origin, "Made and Melted in the United States"
All Steel used meets Title 23CFR 635.410 - Buy America
All Guardrail and Terminal Sections meets AASHTO M-180, All structural steel meets AASHTO M-183 & M270
All Bolts and Nuts are of Domestic Origin
All material fabricated in accordance with Nebraska Department of Transportation
All controlled oxidized/corrosion resistant Guardrail and terminal sections meet ASTM A606, Type 4.

By:

STATE OF OHIO: COUNTY OF STARK
Sworn to and subscribed before me, a Notary Public, by
Andrew Artar this 21 day of November, 2017

Notary Public, State of Ohio

Figure J-12. Anchor Bearing Plate, Test No. HMDT-4 (Item No. c6)

Atlas Tube (Alabama), Inc.
171 Cleage Dr
Birmingham, Alabama, USA
35217
Tel:
Fax:

**Atlas** Tube
A DIVISION OF ZEKELMAN INDUSTRIES

Ref.B/L: 80791452
Date: 11.10.2017
Customer: 179

## MATERIAL TEST REPORT

**Sold to**

Steel & Pipe Supply Compan
PO Box 1688
MANHATTAN KS 66505
USA

**Shipped to**

Steel & Pipe Supply Compan
401 New Century Parkway
NEW CENTURY KS 66031
USA

Material: 3.0x2.0x188x40'0"0(5x4). Material No: 0300201884000-B Made in: USA
Melted in: USA
Sales order: 1226976 Purchase Order: 4500296656 Cust Material #: 6630020018840

| Heat No | C | Mn | P | S | Si | Al | Cu | Cb | Mo | Ni | Cr | V | Ti | B | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B704212 | 0.200 | 0.450 | 0.010 | 0.004 | 0.020 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

| Bundle No | PCs | Yield | Tensile | Eln.2in | Certification | CE: 0.28 |
|---|---|---|---|---|---|---|
| 40867002 | 20 | 064649 Psi | 087652 Psi | 24 % | ASTM A500-13 GRADE B&C | |

Material Note:
Sales Or.Note:

Material: 2.375x154x42'0"0(34x1). Material No: R023751544200 Made in: USA
Melted in: USA
Sales order: 1226976 Purchase Order: 4500296656 Cust Material #: 642004042

| Heat No | C | Mn | P | S | Si | Al | Cu | Cb | Mo | Ni | Cr | V | Ti | B | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B712810 | 0.210 | 0.460 | 0.012 | 0.002 | 0.020 | 0.024 | 0.100 | 0.002 | 0.020 | 0.030 | 0.060 | 0.004 | 0.002 | 0.000 | 0.008 |

| Bundle No | PCs | Yield | Tensile | Eln.2in | Rb | Certification | CE: 0.32 |
|---|---|---|---|---|---|---|---|
| MC00006947 | 34 | 063688 Psi | 083220 Psi | 25 % | 91 | ASTM A500-13 GRADE B&C | |

Material Note:
Sales Or.Note:

Material: 2.375x154x42'0"0(34x1). Material No: R023751544200 Made in: USA
Melted in: USA
Sales order: 1226976 Purchase Order: 4500296656 Cust Material #: 642004042

| Heat No | C | Mn | P | S | Si | Al | Cu | Cb | Mo | Ni | Cr | V | Ti | B | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 17037261 | 0.210 | 0.810 | 0.005 | 0.004 | 0.020 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

| Bundle No | PCs | Yield | Tensile | Eln.2in | Certification | CE: 0.35 |
|---|---|---|---|---|---|---|
| 41532001 | 34 | 066144 Psi | 082159 Psi | 27 % | ASTM A500-13 GRADE B&C | |

Material Note:
Sales Or.Note:

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

Steel Tube Institute

Page : 3 Of 4

Metals Service Center Institute

Figure J-13. BCT Post Sleeve, Test No. HMDT-4 (Item No. c7)

# Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 703

MILFORD, NE 68405
Project: RESALE

Order Number: 1269489 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: 3346
BOL Number: 97457 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 11/7/16

| Qty | Part # | Description | Spec | CL | TY | Heat Code/ Heat | Yield | TS | Elg | C | Mn | P | S | Si | Cu | Cb | Cr | Vn | ACW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 701A | Anchor Box | A-36 | | | JK16101488 | 56,172 | 75,460 | 25.0 | 0.160 | 0.780 | 0.017 | 0.028 | 0.200 | 0.280 | 0.001 | 0.140 | 0.028 | 4 |
| | 701A | | A-36 | | | 535133 | 43,300 | 68,500 | 33.0 | 0.019 | 0.460 | 0.013 | 0.016 | 0.013 | 0.090 | 0.001 | 0.090 | 0.002 | 4 |
| 4 | 729G | TS 8X6X3/16X8'-0" SLEEVE | A-500 | | | A49248 | 64,818 | 78,412 | 32.0 | 0.200 | 0.810 | 0.014 | 0.002 | 0.040 | 0.020 | 0.000 | 0.040 | 0.001 | 4 |
| 20 | 738A | 5'TUBE SL.188X6X8 1/4 /PL | A-36 | | 2 | 4182184 | 45,000 | 67,900 | 31.0 | 0.210 | 0.760 | 0.012 | 0.008 | 0.010 | 0.050 | 0.001 | 0.030 | 0.002 | 4 |
| | 738A | | A-500 | | | A49248 | 64,818 | 78,412 | 32.0 | 0.200 | 0.810 | 0.014 | 0.002 | 0.040 | 0.020 | 0.000 | 0.040 | 0.001 | 4 |
| 6 | 749G | TS 8X6X3/16X6'-0" SLEEVE | A-500 | | | A49248 | 64,818 | 78,412 | 32.0 | 0.200 | 0.810 | 0.014 | 0.002 | 0.040 | 0.020 | 0.000 | 0.040 | 0.001 | 4 |
| 6 | 782G | 5/8"X8"X8" BEAR PL/OF | A-36 | | | DL15103543 | 58,000 | 74,000 | 25.0 | 0.150 | 0.750 | 0.013 | 0.025 | 0.200 | 0.360 | 0.003 | 0.090 | 0.000 | 4 |
| 20 | 783A | 5/8X8X8 BEAR PL 3/16 STP | A-36 | | | PL14107973 | 48,167 | 69,811 | 25.0 | 0.160 | 0.740 | 0.012 | 0.041 | 0.190 | 0.370 | 0.000 | 0.220 | 0.002 | 4 |
| | 783A | | A-36 | | | DL15103543 | 58,000 | 74,000 | 25.0 | 0.150 | 0.750 | 0.013 | 0.025 | 0.200 | 0.360 | 0.003 | 0.090 | 0.000 | 4 |
| 45 | 3000G | CBL 3/4X6'6/DBL | HW | | | 119048 | | | | | | | | | | | | | |
| 7,000 | 3340G | 5/8" GR HEX NUT | HW | | | 0055551-116146 | | | | | | | | | | | | | |
| 4,000 | 3360G | 5/8"X1.25" GR BOLT | HW | | | 0053777-115516 | | | | | | | | | | | | | |
| 450 | 3500G | 5/8"X10" GR BOLT A307 | HW | | | 28971-B | | | | | | | | | | | | | |
| 1,225 | 3540G | 5/8"X14" GR BOLT A307 | HW | | | 29053-B | | | | | | | | | | | | | |

Figure J-14. Anchor Bracket Assembly, Test No. HMDT-4 (Item No. c8)

GERDAU

US-ML-CARTERSVILLE
384 OLD GRASSDALE ROAD NE
CARTERSVILLE, GA 30121
USA

CERTIFIED MATERIAL TEST REPORT

Page 1 / 1

| CUSTOMER SHIP TO | CUSTOMER BILL TO | GRADE | SHAPE / SIZE | DOCUMENT ID: |
|---|---|---|---|---|
| HIGHWAY SAFETY CORP<br>473 W FAIRGROUND ST<br>MARION,OH 43302-1701<br>USA | HIGHWAY SAFETY CORP<br>GLASTONBURY,CT 06033-0358<br>USA | A992/A709-36 | Wide Flange Beam / 6 X 8.5# / 150 X 13.0 | 0000307408 |

| LENGTH | PCS | WEIGHT | HEAT / BATCH |
|---|---|---|---|
| 42'00" | 21 | 7,497 LB | 65064804/02 |

| SALES ORDER | CUSTOMER MATERIAL Nº |
|---|---|
| 8525742/000010 | |

| CUSTOMER PURCHASE ORDER NUMBER | BILL OF LADING | DATE |
|---|---|---|
| 1832 | 1323-0000153521 | 03/03/2020 |

SPECIFICATION / DATE or REVISION
ASTM A6-17
ASTM A709-17
ASTM A992-11 (2015)
CSA G40.21-13 345WM

1832140
IB-80600800

CHEMICAL COMPOSITION

| C % | Mn % | P % | S % | Si % | Cu % | Ni % | Cr % | Mo % | Sn % | V % | Nb % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.13 | 0.84 | 0.012 | 0.030 | 0.20 | 0.29 | 0.08 | 0.10 | 0.022 | 0.007 | 0.001 | 0.008 |

MECHANICAL PROPERTIES

| YS 0.2% PSI | UTS PSI | YS MPa | UTS MPa | Y/T ratio % | Elong. % |
|---|---|---|---|---|---|
| 59300 | 77800 | 409 | 536 | 0.760 | 25.40 |
| 57000 | 75800 | 393 | 523 | 0.750 | 24.80 |

COMMENTS / NOTES

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. Weld repair has not been performed on this material. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

Bhaskar
BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 267-1071 Email: Bhaskar.Yalamanchili@gerdau.com

YAN WANG
QUALITY ASSURANCE MGR.
Phone: (770) 387 5718 Email: yan.wang@gerdau.com

Figure J-15. W6x8.5, 72-in. Long Steel Post, Test No. HMDT-4 (Item Nos. d1 and d2)

CERTIFIED MATERIAL TEST REPORT

Page 1 / 1

GERDAU

US-ML-MIDLOTHIAN
300 WARD ROAD
MIDLOTHIAN, TX 76065
USA

| CUSTOMER SHIP TO | CUSTOMER BILL TO | GRADE | SHAPE / SIZE | DOCUMENT ID: |
|---|---|---|---|---|
| STEEL AND PIPE SUPPLY CO INC<br>310 SMITH ROAD<br>JONESBURG,MO 63351<br>USA | STEEL AND PIPE SUPPLY CO INC<br>MANHATTAN,KS 66505-1688<br>USA | A992/A572-50 | Wide Flange Beam / 6 X 15# / 150 X 22 5 | 0000470808 |

| LENGTH | PCS | WEIGHT | HEAT / BATCH |
|---|---|---|---|
| 40'00" | 12 | 7,200 LB | **58042771/02** |

| SALES ORDER | CUSTOMER MATERIAL N° |
|---|---|
| 8995686/000010 | 0000000003761150040 |

SPECIFICATION / DATE or REVISION
ASTM A6-17
ASTM A709-17
ASTM A992-11 (2015), A572-15
CSA G40.21-13 345WM

| CUSTOMER PURCHASE ORDER NUMBER | BILL OF LADING | DATE |
|---|---|---|
| 4500349606 | 1327-0000374754 | 06/26/2020 |

CHEMICAL COMPOSITION

| C (%) | Mn (%) | P (%) | S (%) | Si (%) | Cu (%) | Ni (%) | Cr (%) | Mo(%) | Sn (%) | V (%) | Nb (%) | Al (%) | CEqvA6 (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.10 | 0.91 | 0.016 | 0.030 | 0.25 | 0.26 | 0.14 | 0.23 | 0.035 | 0.006 | 0.002 | 0.016 | 0.003 | 0.33 |

MECHANICAL PROPERTIES

| YS 0.2% (PSI) | UTS (PSI) | YS (MPa) | UTS (MPa) | Y/T rati (%) | G/L (Inches) | G/L (mm) | Elong. (%) |
|---|---|---|---|---|---|---|---|
| 55429 | 75865 | 382 | 523 | 0.730 | 8.000 | 200.0 | 24.10 |
| 56366 | 75832 | 389 | 523 | 0.740 | 8.000 | 200.0 | 24.20 |

COMMENTS / NOTES

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. Weld repair has not been performed on this material. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

Bhaskar
BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 267-1071 Email: Bhaskar.Yalamanchili@gerdau.com

Wade A. L
WADE LUMPKINS
QUALITY ASSURANCE MGR
Phone: 972-779-3118 Email: Wade.Lumpkins@gerdau.com

Figure J-16. W6x15, 78-in. Long Steel Post, Test No. HMDT-4 (Item No. d3)

30Jul20 3: 3 TEST CERTIFICATE No: MAR 380309

NUCOR TUBULAR PRODUCTS INC.
6226 W. 74TH STREET
CHICAGO, IL 60638
Tel: 708-496-0380 Fax: 708-563-1950

P/O No 01031988
Rel
S/O No MAR 396220-002
B/L No MAR 235650-006 Shp 30Jul20
Inv No Inv

Sold To: ( 1403)
NORFOLK IRON & METAL
P.O. BOX 1129
NORFOLK, NE 68701

Ship To: ( 1)
NORFOLK IRON & METAL
3001 NORTH VICTORY RD
NORFOLK, NE 68702

Tel: 402-371-1810 Fax: 402 379-5409

CERTIFICATE of ANALYSIS and TESTS Cert. No: MAR 380309
24Jul20

Part No 01209
TUBING A500 GRADE B(C)
8" X 6" X 1/4" X 20'

| | | Pcs | Wgt |
|---|---|---|---|
| | | 12 | 5,380 |

| Heat Number | Tag No | Pcs | Wgt |
|---|---|---|---|
| A97575 | 914842 | 6 | 2,690 |
| | YLD=58050/TEN=66570/ELG=32.6 | | |
| A97575 | 914843 | 6 | 2,690 |

Heat Number *** Chemical Analysis ***
A97575 C=0.0500 Mn=0.4100 P=0.0090 S=0.0030 Si=0.0300 Al=0.0360
Cu=0.1500 Cr=0.0700 Mo=0.0200 V=0.0030 Ni=0.0400 Nb=0.0160
Sn=0.0100 N=0.0070 B=0.0002 Ti=0.0020 Ca=0.0023
MELTED AND MANUFACTURED IN THE USA

THE SPECIFICATIONS LISTED BELOW REPRESENT THE CURRENT ISSUED DATES OF THESE STANDARDS. THIS DOES NOT INDICATE THAT THE MATERIAL ABOVE CONFORMS TO EACH OR ALL OF THE STANDARDS. WE CERTIFY THE MATERIAL ABOVE TO THE SPECIFICATION LISTED IN THE LINE DESCRIPTION.

CURRENT STANDARDS:
A252-19
A500/A500M-20
A513/A513M-20
ASTM A53/A53M-18| ASME SA-53/SA-53M-18
A847/A847M-14
A1085/A1085M-15
IN COMPLIANCE WITH EN 10204 SECTION 4.1
INSPECTION CERTIFICATE TYPE 3.1

Page: 1 .... Last

Figure J-17. 8-in. x 6-in. x ¼ -in. Steel Blockout, Test No. HMDT-4 (Item No. d4)

21Jul20 14:35 T E S T C E R T I F I C A T E No: MAR 372566

NUCOR TUBULAR PRODUCTS INC.
6226 W. 74TH STREET
CHICAGO, IL 60638
Tel: 708-496-0380 Fax: 708-563-1950

P/O No 01032075
Rel
S/O No MAR 396557-001
B/L No MAR 235002-002 Shp 21Jul20
Inv No Inv

Sold To: ( 1403)
NORFOLK IRON & METAL
P.O. BOX 1129
NORFOLK, NE 68701

Ship To: ( 1)
NORFOLK IRON & METAL
3001 NORTH VICTORY RD
NORFOLK, NE 68702

Tel: 402-371-1810 Fax: 402 379-5409

CERTIFICATE of ANALYSIS and TESTS Cert. No: MAR 372566
13Jul20

Part No 01239
TUBING A500 GRADE B(C)
12" X 4" X 1/4" X 20'

| | Pcs | Wgt |
|---|---|---|
| | 6 | 3,098 |

| Heat Number | Tag No | Pcs | Wgt |
|---|---|---|---|
| 2202349 | 911766 | 6 | 3,098 |

YLD=54380/TEN=70950/ELG=35.8

Heat Number *** Chemical Analysis ***
2202349
C=0.2100 Mn=0.7600 P=0.0110 S=0.0014 Si=0.0200 Al=0.0400
Cu=0.0700 Cr=0.0400 Mo=0.0100 V=0.0030 Ni=0.0300 Nb=0.0010
Cb=0.0010 Sn=0.0030 N=0.0070 B=0.0000 Ti=0.0020 Sb=0.0000
Ca=0.0010
MELTED AND MANUFACTURED IN THE USA

THE SPECIFICATIONS LISTED BELOW REPRESENT THE CURRENT ISSUED DATES OF THESE STANDARDS. THIS DOES NOT INDICATE THAT THE MATERIAL ABOVE CONFORMS TO EACH OR ALL OF THE STANDARDS. WE CERTIFY THE MATERIAL ABOVE TO THE SPECIFICATION LISTED IN THE LINE DESCRIPTION.

CURRENT STANDARDS:
A252-19
A500/A500M-20
A513/A513M-20
ASTM A53/A53M-18| ASME SA-53/SA-53M-18
A847/A847M-14
A1085/A1085M-15
IN COMPLIANCE WITH EN 10204 SECTION 4.1
INSPECTION CERTIFICATE TYPE 3.1

Page: 1 .... Last

Figure J-18. 12-in. x 4-in. x ¼-in. Steel Blockout, Test No. HMDT-4 (Item No. d5)

14Aug20 22:49 TEST CERTIFICATE No: MAR 390260

NUCOR TUBULAR PRODUCTS INC.
6226 W. 74TH STREET
CHICAGO, IL 60638
Tel: 708-496-0380 Fax: 708-563-1950

P/O No 03054005
Rel
S/O No MAR 398647-006
B/L No MAR 236355-004 Shp 14Aug20
Inv No Inv

Sold To: ( 1403)
NORFOLK IRON & METAL
P.O. BOX 1129
NORFOLK, NE 68701

Tel: 402-371-1810 Fax: 402 379-5409

Ship To: ( 3)
NORFOLK (GREELEY)
31181 COUNTY RD 39 1/2
970-352-6722
GREELEY, CO 80631

CERTIFICATE of ANALYSIS and TESTS Cert. No: MAR 390260
10Aug20

Part No 01239
TUBING A500 GRADE B(C)
12" X 4" X 1/4" X 20'

| Pcs | Wgt |
|---|---|
| 6 | 3,098 |

| Heat Number | Tag No | Pcs | Wgt |
|---|---|---|---|
| SK1852 | 918868 | 6 | 3,098 |

YLD=60270/TEN=74590/ELG=33.5

Heat Number *** Chemical Analysis ***
SK1852 C=0.2000 Mn=0.3900 P=0.0060 S=0.0020 Si=0.0290 Al=0.0320
Cu=0.1000 Cr=0.0600 Mo=0.0100 V=0.0020 Ni=0.0300 Nb=0.0060
N=0.0056 B=0.0001 Ti=0.0010 Ca=0.0016
MELTED AND MANUFACTURED IN THE USA

THE SPECIFICATIONS LISTED BELOW REPRESENT THE CURRENT ISSUED DATES OF THESE STANDARDS. THIS DOES NOT INDICATE THAT THE MATERIAL ABOVE CONFORMS TO EACH OR ALL OF THE STANDARDS. WE CERTIFY THE MATERIAL ABOVE TO THE SPECIFICATION LISTED IN THE LINE DESCRIPTION.

CURRENT STANDARDS:
A252-19
A500/A500M-20
A513/A513M-20
ASTM A53/A53M-18| ASME SA-53/SA-53M-18
A847/A847M-14
A1085/A1085M-15
IN COMPLIANCE WITH EN 10204 SECTION 4.1
INSPECTION CERTIFICATE TYPE 3.1

Page: 1 .... Last

Figure J-19. 17½-in. Long, 12-in. x 4-in. x ¼-in. Steel Blockout, Test No. HMDT-4 (Item No. d5)

**MONDO POLYMER TECHNOLOGIES INC.**
Plastics From Today for Tomorrow...

**P.O. BOX 250**
**27620 ST. RT. 7 NORTH**
**RENO, OH 45773**

**Phone: 740-376-9396**
**Fax: 740-376-9960**
**(888) 607-4790**

## MATERIAL CERTIFICATE

SHIPMENT NUMBER: 34545
PURCHASE ORDER HWTT
SHIPMENT DATE: 4/4/2019

PAGE: 2

**CONSIGNED TO**

Midwest Roadside Safety
4630 NV 36th Street
Lincoln, NE 68524

**SHIP TO**

Midwest Roadside Safety

4630 NW 36th Street
Lincoln, NE 68524

| CONSIGNED | ITEM NUMBER | DESCRIPTION | LOT # | SHIP VIA |
|---|---|---|---|---|
| 4 | MGS14SH | Midwest Composite Block 14" h x 12" d for Steel Post | 1904/1000 | FedEx Freight |

**MADE IN USA**

**The composite guardrail blocks for the Midwest Guardrail System are manufactured by Mondo Polymer Technologies, Inc., and are of the same formulation, composition, and test properties as those which were MASH qualified and and eligible for reimbursement by the Federal Highway Administration under the Federal-aid highway program, Approval #HSST/B-39C.**

**All materials meet required specifications.**

**Approved by:** Maggie Ellis **Date:** 4/4/2019

**Print Name:** Maggie Ellis **Position:** General Manager

Figure J-20. 14$^{3}/_{16}$-in. x 12-in. x 5⅛-in. Composite Recycled Blockout, Test No. HMDT-4 (Item No. d6)

MONDO POLYMER TECHNOLOGIES INC.
Plastics From Today for Tomorrow...

P.O. BOX 250
27620 ST. RT. 7 NORTH
RENO, OH 45773

Phone: 740-376-9396
Fax: 740-376-9960
(888) 607-4790

**MATERIAL CERTIFICATE**

SHIPMENT NUMBER: 34545
PURCHASE ORDER HWTT
SHIPMENT DATE: 4/4/2019

PAGE: 1

**CONSIGNED TO**

Midwest Roadside Safety
4630 NV 36th Street
Lincoln, NE 68524

**SHIP TO**

Midwest Roadside Safety

4630 NW 36th Street
Lincoln, NE 68524

| CONSIGNED | ITEM NUMBER | DESCRIPTION | LOT # | SHIP VIA |
|---|---|---|---|---|
| 10 | GB14SH2 | Composite Guardrial Block 14" for Steel Post w/hanger CO | 1804/1000 | FedEx Freight |

**MADE IN USA**

**The composite guardrail offset blocks for the Midwest Guardrail System (MGS), are manufactured by Mondo Polymer Technologies, Inc., and are of the same formulation, composition, and test properties as those which were MASH qualified and eligible for reimbursement by the Federal Highway Administration under the Federal-aid highway program, Approval No. HSST-1/B-278A.**

**All materials meet required specifications.**

Approved by: Maggie Ellis

Date: 4/4/2019

Print Name: Maggie Ellis

Position: General Manager

Figure J-21. 14$^{3}/_{16}$-in. x 8-in. x5⅛-in. Composite Recycled Blockout, Test No. HMDT-4 (Item No. d7)

McMASTER-CARR.

# Certificate of Compliance

600 N County Line Rd
Elmhurst IL 60126-2081
630-600-3600
chi.sales@mcmaster.com

University of Nebraska
Midwest Roadside Safety Facility
M W R S F
4630 Nw 36TH St
Lincoln NE 68524-1802
Attention: Shaun M Tighe
Midwest Roadside Safety Facility

Purchase Order
**E000548963**

Order Placed By
**Shaun M Tighe**

McMaster-Carr Number
**7204107-01**

Page 1 of 1

08/02/2018

| Line | Product | Ordered | Shipped |
|---|---|---|---|
| 1 | **97812A109** Raised-Head Removable Nails, 16D Penny Size, 3" Long, Packs of 5 | **5 Packs** | **5** |

Certificate of compliance

This is to certify that the above items were supplied in accordance with the description and as illustrated in the catalog. Your order is subject only to our terms and conditions, available at www.mcmaster.com or from our Sales Department.

Sarah Weinberg
Compliance Manager

Figure J-22. 16D Double Head Nail, Test No. HMDT-4 (Item No. d8)

CMC STEEL TENNESSEE
1919 Tennessee Avenue
Knoxville TN 37921-2686

CERTIFIED MILL TEST REPORT
For additional copies call

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

Jim Hall
Quality Assurance Manager

| | | | | | | |
|---|---|---|---|---|---|---|
| HEAT NO.:7006848<br>SECTION: REBAR 13MM (#4) 60'0" 420/60<br>GRADE:<br>ROLL DATE:<br>MELT DATE: 01/05/2020<br>Cert. No.: 82944733 / 006848L265 | S O L D T O | ABC Coating Co - Tulsa<br><br>2236 S Yukon Ave<br>Tulsa OK<br>US 74107-2765<br>9185852587<br>9185858131 | S H I P T O | CPU Chicago Depot<br><br>13535 S Torrence Ave<br>Chicago IL<br>US 60633-2164<br>7736466363 | Delivery#: 82944733<br>BOL#: 1865847<br>CUST PO#: 010620-Minn<br>CUST P/N:<br>DLVRY LBS / HEAT: 26932.000 LB<br>DLVRY PCS / HEAT: 672 EA | |

| Characteristic | Value | Characteristic | Value | Characteristic | Value |
|---|---|---|---|---|---|
| C | 0.27% | Rebar Deformation Avg. Spaci | 0.329IN | | |
| Mn | 0.59% | Rebar Deformation Avg. Heigh | 0.034IN | | |
| P | 0.008% | Rebar Deformation Max. Gap | 0.106IN | | |
| S | 0.048% | | | | |
| Si | 0.20% | | | | |
| Cu | 0.33% | | | | |
| Cr | 0.17% | | | | |
| Ni | 0.11% | | | | |
| Mo | 0.014% | | | | |
| V | 0.002% | | | | |
| Sn | 0.007% | | | | |
| Yield Strength test 1 | 85.9ksi | | | | |
| Yield Strength test 1 (metri | 592MPa | | | | |
| Tensile Strength test 1 | 99.1ksi | | | | |
| Tensile Strength 1 (metric) | 684MPa | | | | |
| Elongation test 1 | 13% | | | | |
| Elongation Gage Lgth test 1 | 8IN | | | | |
| Elongation Gage Lgth 1(metri | 200mm | | | | |
| Bend Test 1 | Passed | | | | |

The Following is true of the material represented by this MTR:
*Material is fully killed
*100% melted and rolled in the USA
*EN10204:2004 3.1 compliant
*Contains no weld repair
*Contains no Mercury contamination
*Manufactured in accordance with the latest version of the plant quality manual
*Meets the "Buy America" requirements of 23 CFR635.410, 49 CFR 661
*Warning: This product can expose you to chemicals which are known to the State of California to cause cancer, birth defects or other reproductive harm. For more information go to www.P65Warnings.ca.gov

REMARKS :

Page 1 OF 1 01/21/2020 09:09:21

Figure J-23. #4 Rebar, Test No. HMDT-4 (Item Nos. e3 and e4)

NUCOR

# Mill Certification

08/26/2020

MTR#:454619-1
Lot #:360001414020
ONE NUCOR WAY
BOURBONNAIS, IL 60914 US
815 937-3131
Fax: 815 939-5599

Sold To: SIMCOTE INC
1645 RED ROCK RD
ST PAUL, MN 55119 US

Ship To: SIMCOTE INC
1645 RED ROCK RD
ST PAUL, MN 55119 US

| | | | |
|---|---|---|---|
| Customer PO | MN-3748 | Sales Order # | 36013225 - 2.10 |
| Product Group | Rebar | Product # | 2110230 |
| Grade | A615 Gr 60/AASHTO M31 | Lot # | 360001414020 |
| Size | #5 | Heat # | 3600014140 |
| BOL # | BOL-562924 | Load # | 454619 |
| Description | Rebar #5/16mm A615 Gr 60/AASHTO M31 40' 0" [480"] 4001-8000 lbs | Customer Part # | |
| Production Date | 07/17/2020 | Qty Shipped LBS | 45060 |
| Product Country Of Origin | United States | Qty Shipped EA | 1080 |
| Original Item Description | | Original Item Number | |

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.

Melt Country of Origin : United States

Melting Date: 07/14/2020

| C (%) | Mn (%) | P (%) | S (%) | Si (%) | Ni (%) | Cr (%) | Mo (%) | Cu (%) | V (%) | Nb (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.36 | 0.94 | 0.012 | 0.048 | 0.215 | 0.23 | 0.14 | 0.08 | 0.37 | 0.009 | 0.002 |

**Other Test Results**

Yield (PSI) : 66700

Tensile (PSI) : 101600

Average Deformation Height (IN) : 0.043

Elongation in 8" (%) : 13.1

Bend Test : Pass

Weight Percent Variance (%) : -2.40

**Comments:**

All manufacturing processes of the steel materials in this product, including melting, have occurred within the United States. Products produced are weld free. Mercury, in any form, has not been used in the production or testing of this material.

Figure J-24. #5 Rebar, Test No. HMDT-4 (Item Nos. e5 and e6)

**CERTIFICATE OF COMPLIANCE**

ROCKFORD BOLT & STEEL CO.
126 MILL STREET
ROCKFORD, IL 61101
815-968-0514

**CUSTOMER NAME:** TRINITY INDUSTRIES

**CUSTOMER PO:** 209794

**SHIPPER #:** 069663
**DATE SHIPPED:** 08/27/2020

**LOT#:** 33076

**SPECIFICATION:** ASTM A307, GRADE A MILD CARBON STEEL BOLTS

**TENSILE:** SPEC: 60,000 psi*min RESULTS: 75,000 74,500

**HARDNESS:** 100 max 84.30 84.70

*Pounds Per Square Inch.

**COATING:** ASTM SPECIFICATION F-2329 HOT DIP GALVANIZE
**AZZ GALVANIZING:** 33076

**CHEMICAL COMPOSITION**

| MILL | GRADE | HEAT# | C | Mn | P | S | SI |
|---|---|---|---|---|---|---|---|
| NUCOR | 1010 | 100104009 | .11 | .52 | .011 | .016 | .174 |

4,550 PCS 5/8" X 14" GUARD RAIL BOLT
P/N 3540G

WE HEREBY CERTIFY THE ABOVE BOLTS HAVE BEEN MANUFACTURED BY ROCKFORD BOLT AND STEEL AT OUR FACILITY IN ROCKFORD, ILLINOIS, USA. THE MATERIAL USED WAS MELTED AND MANUFACTURED IN THE USA. WE FURTHER CERIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIALS SUPPLIER, AND THAT OUR PROCEDURES FOR THE CONTROL OF PRODUCT QUALITY ASSURE THAT ALL ITEMS FURNISHED ON THIS ORDER MEET OR EXCEED ALL APPLICABLE TESTS, PROCESS, AND INSPECTION REQUIREMENT PER ABOVE SPECIFICATION.

STATE OF ILLINOIS
COUNTY OF WINNEBAGO
SIGNED BEFORE ME ON THIS
24th DAY OF August, 20 20

Merry F Shane

Linda McComas
APPROVED SIGNATORY

8/24/2020
DATE

Official Seal
Merry F Shane
Notary Public State of Illinois
My Commission Expires 10/03/2022

Figure J-25. ⅝-in. Dia., 14-in. Long Guardrail Bolt, Test No. HMDT-4 (Item No. f1)

# MATERIAL TEST REPORT

PAGE 1

Date Printed: 04/04/2018

Mid American Steel & Wire

| Bill to: | Ship to: |
|---|---|
| KING STEEL | KING STEEL |
| 5225 E. COOK ROAD | CPU |
| ap@kingsteelcorp.com | |
| GRAND BLANC, MI 48439-838 | Grand Blanc, MI 48439-8388 |

Customer No: 000000006021
PO Number: 025623
Ship Date: 04/04/2018
Order Number: 92649
Load Number: 117036

| Item Number | Description |
|---|---|
| D19321012SHM | 19/32 1012SH ROD |

## CHEMICAL ANALYSIS

| Heat Number | C | Mn | P | S | Si | Cu | Ni | Cr | Mo | Sn | V | Al | N | B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1721198 | 0.1300 | 0.5100 | 0.0160 | 0.0270 | 0.1900 | 0.1500 | 0.0600 | 0.1200 | 0.0100 | 0.0080 | 0.0020 | 0.0020 | 0.0080 | 0.0002 |

## MECHANICAL PROPERTIES

| Heat Number | Yield (Psi) | Tensile (Psi) | Elongation (%) | Reduction (%) | Bend Test Pass/ Fail |
|---|---|---|---|---|---|
| 1721198 | 45781 psi / | 66316 psi / | 23.12 | 60.76 | |

The melting and rolling processes used to manufacture the above described material took place in the United States of America. The material was produced and tested in accordance with ASTM A-510.

Quality Assurance:

Figure J-26. ⅝-in. Dia., 10-in. Long Guardrail Bolt, Test No. HMDT-4 (Item No. f2)

CHARTER STEEL

A Division of Charter Manufacturing Company, Inc.

EMAIL

1658 Cold Springs Road
Saukville, Wisconsin 53080
(262) 268-2400
1-800-437-8789
Fax (262) 268-2570

Melted in USA Manufactured in USA

**CHARTER STEEL TEST REPORT**

Fastenal Company
5800 Industrial Ave,
Loves Park,IL-61111

| | |
|---|---|
| Cust P.O. | 040050254-1 |
| Customer Part # | 09007018 |
| Charter Sales Order | 70097624 |
| Heat # | 10666100 |
| Ship Lot # | 4647440 |
| Grade | 1018 R SK FG RHQ 19/32 RNDCOIL |
| Process | HRCC |
| Finish Size | 19/32 |
| Ship date | 31-JUL-20 |

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed below and that it satisfies these requirements. The recording of false, fictitious and fraudulent statements or entries on this document may be punishable as a felony under federal statute.

Test results of Heat Lot # 10666100

Lab Code: 7388

| CHEM | C | MN | P | S | SI | NI | CR | MO | CU | SN | V |
|---|---|---|---|---|---|---|---|---|---|---|---|
| %Wt | .16 | .75 | .008 | .011 | .170 | .03 | .06 | .02 | .06 | .004 | .003 |
| | AL | N | B | TI | NB | | | | | | |
| | .039 | .0080 | .0001 | .001 | .001 | | | | | | |

JOMINY(HRC)

| J1 | J2 | J3 |
|---|---|---|
| 42 | 22 | 20 |

JOMINY SAMPLE TYPE ENGLISH=C

Test results of Rolling Lot # 1299051

| | # of Tests | Min Value | Max Value | Mean Value | |
|---|---|---|---|---|---|
| TENSILE (KSI) | 1 | 69.7 | 69.7 | 69.7 | TENSILE LAB = 0368-02 |
| REDUCTION OF AREA (%) | 1 | 44 | 44 | 44 | RA LAB = 0368-02 |
| ROCKWELL B (HRBW) | 1 | 75 | 75 | 75 | RB LAB = 0368-02 |

REDUCTION RATIO=109:1

Specifications: Manufactured per Charter Steel Quality Manual Rev Date 05/12/17
Charter Steel certifies this product is indistinguishable from background radiation levels by having process radiation detectors in place to measure for the presence of radiation within our process & products.
Meets customer specifications with any applicable Charter Steel exceptions for the following customer documents:
Customer Document = ASTM F2282 Revision = 18 Dated = 01-MAY-19

Additional Comments:

Figure J-27. ⅝-in. Dia., 10-in. Long Guardrail Bolt, Test No. HMDT-4 (Item No. f2)

**CERTIFICATE OF COMPLIANCE**

**ROCKFORD BOLT & STEEL CO.**
**126 MILL STREET**
**ROCKFORD, IL 61101**
**815-968-0514**

**CUSTOMER NAME:** TRINITY INDUSTRIES

**CUSTOMER PO:** 209038

**SHIPPER #:** 069386
**DATE SHIPPED:** 07/23/2020

**LOT#:** 32756-P

**SPECIFICATION:** ASTM A307, GRADE A MILD CARBON STEEL BOLTS

**TENSILE:** SPEC: 60,000 psi*min RESULTS: 69,800
69,900

**HARDNESS:** 100 max 67.50
68.60

*Pounds Per Square Inch.

**COATING:** ASTM SPECIFICATION F-2329 HOT DIP GALVANIZE
**AZZ GALVANIZING:** 32756-P

**CHEMICAL COMPOSITION**

| MILL | GRADE | HEAT# | C | Mn | P | S | Si |
|---|---|---|---|---|---|---|---|
| CHARTER STEEL | 1010 | 10657410 | .09 | .38 | .007 | .007 | .09 |

**QUANTITY AND DESCRIPTION:**

86,000 PCS 5/8" X 1.25" GUARD RAIL BOLT
P/N 3360G

WE HEREBY CERTIFY THE ABOVE BOLTS HAVE BEEN MANUFACTURED BY ROCKFORD BOLT AND STEEL AT OUR FACILITY IN ROCKFORD, ILLINOIS, USA. THE MATERIAL USED WAS MELTED AND MANUFACTURED IN THE USA. WE FURTHER CERIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIALS SUPPLIER, AND THAT OUR PROCEDURES FOR THE CONTROL OF PRODUCT QUALITY ASSURE THAT ALL ITEMS FURNISHED ON THIS ORDER MEET OR EXCEED ALL APPLICABLE TESTS, PROCESS, AND INSPECTION REQUIREMENT PER ABOVE SPECIFICATION.

STATE OF ILLINOIS
COUNTY OF WINNEBAGO
SIGNED BEFORE ME ON THIS

21st DAY OF July 20 20 Linda Melomas 7/21/2020
APPROVED SIGNATORY DATE

Merry F Shane

Official Seal
Merry F Shane
Notary Public State of Illinois
My Commission Expires 10/03/2022

Figure J-28. ⅝-in. Dia., 1¼-in. Long Guardrail Bolt, Test No. HMDT-4 (Item No. f3)

CERTIFICATE OF COMPLIANCE

ROCKFORD BOLT & STEEL CO.
126 MILL STREET
ROCKFORD, IL 61101
815-968-0514

**CUSTOMER NAME:** GREGORY INDUSTRIES

**CUSTOMER PO:** 49996

**SHIPPER #:** 071888
**DATE SHIPPED:** 07/29/2021

**LOT#:** 33278-P

**SPECIFICATION:** ASTM A307, GRADE A MILD CARBON STEEL BOLTS

**TENSILE:** SPEC: 60,000 psi*min RESULTS: 70,400 71,400

**HARDNESS:** 100 max 71.80 72.30

*Pounds Per Square Inch.

**COATING:** ASTM SPECIFICATION F-2329 HOT DIP GALVANIZE
**AZZ GALVANIZING:** 33278-P

**CHEMICAL COMPOSITION**

| MILL | GRADE | HEAT# | C | Mn | P | S | Si |
|---|---|---|---|---|---|---|---|
| CHARTER STEEL | 1010 | 10684020 | .11 | .43 | .006 | .010 | .09 |

**QUANTITY AND DESCRIPTION:**

6,000 PCS 5/8" X 1.25" GUARD RAIL BOLT
P/N 1001G

WE HEREBY CERTIFY THE ABOVE BOLTS HAVE BEEN MANUFACTURED BY ROCKFORD BOLT AND STEEL AT OUR FACILITY IN ROCKFORD, ILLINOIS, USA. THE MATERIAL USED WAS MELTED AND MANUFACTURED IN THE USA. WE FURTHER CERIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIALS SUPPLIER, AND THAT OUR PROCEDURES FOR THE CONTROL OF PRODUCT QUALITY ASSURE THAT ALL ITEMS FURNISHED ON THIS ORDER MEET OR EXCEED ALL APPLICABLE TESTS, PROCESS, AND INSPECTION REQUIREMENT PER ABOVE SPECIFICATION.

STATE OF ILLINOIS
COUNTY OF WINNEBAGO
SIGNED BEFORE ME ON THIS

24th DAY OF August, 20 21

Merry F Shane

APPROVED SIGNATORY

8-24-2021
DATE

Official Seal
Merry F Shane
Notary Public State of Illinois
My Commission Expires 10/03/2022

Figure J-29. ⅝-in. Dia., 1¼-in. Long Guardrail Bolt, Test No. HMDT-4 (Item No. f3)

## Certificate of Compliance

Birmingham Fastener Manufacturing
PO Box 10323
Birmingham, AL 35202
(205) 595-3512

Customer: Midwest Machinery & Supply | Date Shipped: 11/28/2018

Customer Order Number: 3664 | BFM Order Number: 1553751

### Item Description

Description: 5/8"-11 x 10" Hex Bolt | Qty: 298

Lot #: 81342 | Specification: ASTM A307-14 Gr A | Finish: ASTM F2329

### Raw Material Analysis

Heat#: JK18104124

Chemical Composition (wt% Heat Analysis) By Material Supplier

| C | Mn | P | S | Si | Cu | Ni | Cr | Mo |
|---|---|---|---|---|---|---|---|---|
| 0.18 | 1.19 | 0.012 | 0.034 | 0.20 | 0.29 | 0.13 | 0.11 | 0.04 |

### Mechanical Properties

| Sample # | Hardness | Tensile Strength (lbs) | Tensile Strength (psi) |
|---|---|---|---|
| 1 | 93 HRBW | 22,049 | 99,410 |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |

This information represents the most recent analysis of the product supplied on the stated customer order. The samples tested conform to the ASTM standard listed above.
All steel melted and manufactured in the U.S.A.

Authorized Signature: Brian Hughes, Quality Assurance | Date: 11/29/2018

Figure J-30. ⅝-in. Dia., 10-in. Long Hex Head Bolt, Test No. HMDT-4 (Item No. f4)

# CERTIFIED MATERIAL TEST REPORT
# FOR ASTM A307, GRADE A - MACHINE BOLTS

FACTORY: IFI & MORGAN LTD. REPORT DATE:2019/4/2
ADDRESS: No.583-28, Chang'an North Road, Wuyuan Town, Haiyan, Zhejiang, China MANUFACTURE DATE:2019/3/14

CUSTOMER: FASTENAL MFG LOT NUMBER:M-2019HT138-5
SAMPE SIZE: ACC. TO ASME B18.18 CATEGORY 2-2011; ASTM F1470-12 TABLE 3
MANU QTY: 2450PCS SHIPPED QTY:2400PCS
SIZE: 5/8-11X1 1/2 HDG
HEADMARKS: 307A PLUS NY PO NUMBER:210179696
PART NO:1191919

STEEL PROPERTIES:
MATERIAL TYPE:Q195C HEAT NUMBER:5-01570

| CHEMISTRY SPEC: | C %*100 | Mn%*100 | P %*1000 | S %*1000 |
|---|---|---|---|---|
| Grade A ASTM A307-12 | 0.29max | 1.20 max | 0.04max | 0.15max |
| TEST: | 0.07 | 0.33 | 0.015 | 0.022 |

DIMENSIONAL INSPECTIONS **Unit:inch** SPECIFICATION: ASME B18.2.1 - 2012

| CHARACTERISTICS | SPECIFIED | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|
| ********************** | ************************************ | ******************* | ******** | ******** |
| VISUAL | ASTM F788-2013 | PASSED | 18 | 0 |
| THREAD | ASME B1.1-2003, 3A GO, 2A NO GO | PASSED | 13 | 0 |
| WIDTH A/F | 0.906-0.938 | 0.916-0.928 | 3 | 0 |
| WIDTH A/C | 1.033-1.083 | 1.048-1.057 | 3 | 0 |
| HEAD HEIGHT | 0.378-0.444 | 0.394-0.428 | 3 | 0 |
| BODY DIA. | 0.605-0.642 | 0.617-0.634 | 3 | 0 |
| THREAD LENGTH | 1.420-1.560 | 1.436-1.543 | 13 | 0 |
| LENGTH | 1.420-1.560 | 1.436-1.543 | 13 | 0 |

MECHANICAL PROPERTIES: SPECIFICATION: ASTM A307 - 14e1 GR.A

| CHARACTERISTICS | TEST METHOD | SPECIFIED | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|
| ********************* | ****************** | ****************** | ****************** | ******** | ******** |
| CORE HARDNESS : | ASTM F606/F606M-2016 | 69-100 HRB | 75-80 HRB | 3 | 0 |
| WEDGE TENSILE: | ASTM F606/F606M-2016 | Min 60 KSI | 65-69 KSI | 3 | 0 |
| CHARACTERISTICS | TEST METHOD | SPECIFIED | ACTUAL RESULT | ACC. | REJ. |
| COATINGS OF ZINC: | | SPECIFIATION: ASTM F2329/F2329M-2015 | | | |
| HOT DIP GALVANIZED | ASTM B568-98(2014) | Min 0.0017" | 0.0017" -0.0018" | 3 | 0 |

We hereby certify that above products supplied are in compliance with all the requirements of the order.
We here by certify that this MTR is in compliance to DIN EN 10204 3.1 content.
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.
Maker's ISO 9001:2015 SGS Certificate # HK04/0105

IFI & MORGAN LTD.
检验专用章

(SIGNATURE OF Q.A. LAB MGR.)
(NAME OF MANUFACTURER)

Figure J-31. ⅝-in. Dia., 1½-in. Long Hex Head Bolt, Test No. HMDT-4 (Item No. f5)

**Portland Bolt**
**& MANUFACTURING COMPANY**

Phone: 800-547-6758 | Fax: 503-227-4634
3441 NW Guam Street, Portland, OR 97210
Web: www.portlandbolt.com | Email: sales@portlandbolt.com

**CERTIFICATE OF CONFORMANCE**

**For:** MIDWEST ROADSIDE SAFETY FACIL
**PB Invoice#:** 119891
**Cust PO#:** 70ACCT
**Date:** 4/17/2019
**Shipped:** 4/25/2019

**We certify that the following items were manufactured and tested in accordance with the chemical, mechanical, dimensional and thread fit requirements of the specifications referenced.**

**Description:** 7/8 X 8 GALV ASTM A307A HEX BOLT

**Heat#:** 489517 **Base Steel:** A36 **Diam:** 7/8

**Source:** CASCADE STEEL RLG MILL **Proof Load:** 0

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **C :** | .180 | **Mn:** | .680 | **P :** | .013 | **Hardness:** | 0 | | |
| **S :** | .015 | **Si:** | .240 | **Ni:** | .080 | **Tensile:** | 72,500 PSI | **RA:** | 42.00% |
| **Cr:** | .130 | **Mo:** | .028 | **Cu:** | .240 | **Yield:** | 48,800 PSI | **Elon:** | 24.00% |
| **Pb:** | .000 | **V :** | .000 | **Cb:** | .000 | **Sample Length:** | 8 INCH | | |
| **N :** | .000 | | | **CE:** | .3157 | **Charpy:** | | **CVN Temp:** | |

**Coatings:**
ITEMS HOT DIP GALVANIZED PER ASTM F2329/A153C

By: Certification Department Quality Assurance
Dane McKinnon

Figure J-32. ⅞-in. Dia., 8-in. Long Hex Head Bolt, Test No. HMDT-4 (Item No. f6)

# TEST REPORT

## USS FLAT WASHER, HDG

CUSTOMER:

PO NUMBER: 180164126

SIZE: 5/8

HEADMARKS:

DATE: 30/12/2018

MFG LOT NUMBER: M-SWE0412454-8

PART NO: 1133185

QNTY: 6,000 PCS

DIMENSIONAL INSPECTIONS — SPECIFICATION: ASME B18.21.1(2009)

| CHARACTERISTICS | SPECIFIED | | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|
| ********************** | ************************************* | | ******************* | ******** | ******** |
| APPEARANCE | ASTM F788-07 | | PASSED | 100 | 0 |
| OUTSIDE DIA | 1.743-1.780 | | 1.752-1.756 | 8 | 0 |
| INSIDE DIA | 0.681-0.718 | | 0.700-0.707 | 8 | 0 |
| THICKNESS | 0.108-0.160 | | 0.114-0.119 | 8 | 0 |
| HOT DIP GALVANIZED | ASTM A153 class C. RoHS Compliant | Min 0.0017" | Min 0.0019 In | 8 | 0 |

*ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE ASTM SPECIFICATION.*
*WE CERTIFY THAT THIS DAIA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.*
*MFG ISO 9001:2015 SGS Certificate # HK04/0105*

**We hereby certify that above products supplied are in compliance with all the requirements of the order.**
**We here by certify that this MTR is in compliance to DIN EN 10204 3.1 content.**

IFI & MORGAN LTD.
检验专用章

(SIGNATURE OF Q.A. LAB MGR.)
(NAME OF MANUFACTURER)

*IFI & MORGAN LTD.* *ADDRESS: Chang'an North Road, Wuyuan Town, Haiyan, Zhejiang, China*

Figure J-33. ⅝-in. Dia. Plain USS Washer, Test No. HMDT-4 (Item No. g1)

CERTIFIED MATERIAL TEST REPORT
FOR USS FLAT WASHERS HDG

FACTORY: IFI & Morgan Ltd REPORT DATE: 23/4/2019
ADDRESS: Chang'an North Road, Wuyuan Town, Haiyan,Zhejiang, China

MFG LOT NUMBER: 1844804

SAMPLING PLAN PER ASME B18.18-11 PO NUMBER: 170089822
SIZE: USS 7/8 HDG QNTY(Lot size): 7200PCS
HEADMARKS: NO MARK PART NO: 33187

DIMENSIONAL INSPECTIONS SPECIFICATION: ASTM B18.21.1-2011

| CHARACTERISTICS | SPECIFIED | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|
| APPEARANCE | ASTM F844 | PASSED | 100 | 0 |
| OUTSIDE DIA | 2.243-2.280 | 2.246-2.254 | 10 | 0 |
| INSIDE DIA | 0.931-0.968 | 0.956-0.965 | 10 | 0 |
| THICKNESS | 0.136-0.192 | 0.136-0.157 | 10 | 0 |

| CHARACTERISTICS | TEST METHOD | SPECIFIED | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|
| HOT DIP GALVANIZED | ASTM F2329-13 | Min 0.0017" | 0.0017-0.0020 in | 8 | 0 |

ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE ASTM SPECIFICATION. WE CERTIFY THAT THIS DAIA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.
ISO 9001:2015 SGS Certificate # HK04/0105

IFI & MORGAN LTD.
检验专用章
QUANLITY CONTROL

(SIGNATURE OF Q.A. LAB MGR.)

Figure J-34. ⅞-in. Dia. Plain Round Washer, Test No. HMDT-4 (Item No. g3)

# CERTIFIED MATERIAL TEST REPORT
## FOR USS FLAT WASHERS HDG

FACTORY: IFI & Morgan Ltd REPORT DATE: 22/10/2018
ADDRESS: Chang'an North Road, Wuyuan Town, Haiyan,Zhejiang, China

SAMPLING PLAN PER ASME B18.18-11 PO NUMBER: 210151571
SIZE: USS 1 HDG QNTY(Lot size): 3240PCS
HEADMARKS: NO MARK PART NO: 33188

DIMENSIONAL INSPECTIONS SPECIFICATION: ASTM B18.21.1-2011

| CHARACTERISTICS | SPECIFIED | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|
| APPEARANCE | ASTM F844 | PASSED | 100 | 0 |
| OUTSIDE DIA | 2.492-2.529 | 2.496-2.504 | 10 | 0 |
| INSIDE DIA | 1.055-1.092 | 1.080-1.089 | 10 | 0 |
| THICKNESS | 0.135-0.192 | 0.135-0.157 | 10 | 0 |

| CHARACTERISTICS | TEST METHOD | SPECIFIED | ACTUAL RESULT | | ACC. | REJ. |
|---|---|---|---|---|---|---|
| HOT DIP GALVANIZED | ASTM F2329-13 | Min 0.0017" | 0.0017-0.0020 | in | 8 | 0 |

ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE ASTM SPECIFICATION. WE CERTIFY THAT THIS DAIA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.
ISO 9001:2015 SGS Certificate # HK04/0105

IFI & MORGAN LTD.
检验专用章
QUANLITY CONTROL

(SIGNATURE OF Q.A. LAB MGR.)

Figure J-35. 1-in. Dia. Plain USS Washer, Test No. HMDT-4 (Item No. g4)

GERDAU

US-ML-ST PAUL
1678 RED ROCK ROAD
SAINT PAUL, MN 55119
USA

**CERTIFIED MATERIAL TEST REPORT**

Page 1 / 1

| CUSTOMER SHIP TO | CUSTOMER BILL TO | GRADE | SHAPE / SIZE | DOCUMENT ID: |
|---|---|---|---|---|
| UNYTITE INC LASALLE PLANT<br>325 CIVIC ROAD<br>LA SALLE,IL 61301<br>USA | UNYTITE INC<br>1 UNYTITE DR<br>PERU,IL 61354-9710<br>USA | 1045M23FJZN | Round Bar / 1" | 0000038876 |

| LENGTH | WEIGHT | HEAT / BATCH |
|---|---|---|
| 25'01.50" | 35,008 LB | 62151324/02 |

| SALES ORDER | CUSTOMER MATERIAL N° |
|---|---|
| 8310712/000010 | B1045SC1.0000 1 |

SPECIFICATION / DATE or REVISION
ASTM A29-16
ASTM A576-17

| CUSTOMER PURCHASE ORDER NUMBER | BILL OF LADING | DATE |
|---|---|---|
| P008845 | 1332-0000077708 | 01/29/2020 |

CHEMICAL COMPOSITION

| C % | Mn % | P % | S % | Si % | Cu % | Ni % | Cr % | Mo % | Sn % | V % | Nb % | Al % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.44 | 0.71 | 0.010 | 0.031 | 0.23 | 0.34 | 0.10 | 0.16 | 0.022 | 0.012 | 0.032 | 0.001 | 0.005 |

HARDENABILITY

| DI A255 Inch |
|---|
| 1.53 |

COMMENTS / NOTES

Material 100% melted and rolled in the USA. Manufacturing processes for this steel, which may include scrap melted in an electric arc furnace and hot rolling, have been performed at Gerdau St. Paul Mill, 1678 Red Rock Road, Saint Paul, Minnesota, USA. All product produced from strand cast billets. Silicon killed (deoxidized) steel. No weld repairmen performed. Steel not exposed to mercury or any liquid alloy which is liquid at ambient temperatures during processing or while in Gerdau St. Paul Mills possession. Any modification to this certification as provided by Gerdau-St. Paul Mill without the expressed written consent of Gerdau St. Paul Mill negates the validity of this test report. This report shall not be reproduced except in full, without the expressed written consent of Gerdau St. Paul Mill. Gerdau St. Paul Mill is not responsible for the inability of this material to meet specific applications.
Roll batch 62151324/02 roll date 10/23/2019 Fine Grain (FG 5-8)
Macro S1 R1 C1 ASTM E381-17 E45-18a Reduction Ration = 38.2 Quality Program Manual Rev. 10, Implemented date 11/8/2019

DEBRA L. KARIESCH
Notary Public-Minnesota
My Commission Expires Jan 31, 2025

Debra L. Kariesch

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. Weld repair has not been performed on this material. This material, including the billets, was melted USA. CMTR complies with EN 10204 3.1.

Bhaskar
BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 267-1071 Email: Bhaskar.Yalamanchili@gerdau.com

ALEA BRANDENBURG
QUALITY ASSURANCE MGR.
Phone: (651) 731-5662 Email: Alea.Brandenburg@gerdau.com

Figure J-36. ⅝-in. Dia. Heavy Hex Nut, Test No. HMDT-4 (Item No. h1)

**GERDAU**

US-ML-ST PAUL
1678 RED ROCK ROAD
SAINT PAUL, MN 55119
USA

**CERTIFIED MATERIAL TEST REPORT**

Page 1 / 1

| CUSTOMER SHIP TO | CUSTOMER BILL TO | GRADE | SHAPE / SIZE | DOCUMENT ID: |
|---|---|---|---|---|
| UNYTITE INC LASALLE PLANT<br>325 CIVIC ROAD<br>LA SALLE,IL 61301<br>USA | UNYTITE INC<br>1 UNYTITE DR<br>PERU,IL 61354-9710<br>USA | 1045M23FJZN | Round Bar / 1" | 0000043064 |

| LENGTH | WEIGHT | HEAT / BATCH |
|---|---|---|
| 25'01.50" | 46,290 LB | 62152527/02 |

| SALES ORDER | CUSTOMER MATERIAL N° | SPECIFICATION / DATE or REVISION |
|---|---|---|
| 8563324/000020 | B1045SC1.0000 B | ASTM A29-16<br>ASTM A576-17 |

| CUSTOMER PURCHASE ORDER NUMBER | BILL OF LADING | DATE |
|---|---|---|
| P008976 | 1332-0000080054 | 04/15/2020 |

CHEMICAL COMPOSITION

| C % | Mn % | P % | S % | Si % | Cu % | Ni % | Cr % | Mo % | Sn % | V % | Nb % | Al % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.44 | 0.68 | 0.006 | 0.027 | 0.19 | 0.30 | 0.07 | 0.08 | 0.017 | 0.009 | 0.030 | 0.000 | 0.005 |

HARDENABILITY

| DI A255 Inch |
|---|
| 1.21 |

COMMENTS / NOTES

Material 100% melted and rolled in the USA. Manufacturing processes for this steel, which may include scrap melted in an electric arc furnace and hot rolling, have been performed at Gerdau St. Paul Mill, 1678 Red Rock Road, Saint Paul, Minnesota, USA. All product produced from strand cast billets. Silicon killed (deoxidized) steel. No weld repairmen performed. Steel not exposed to mercury or any liquid alloy which is liquid at ambient temperatures during processing or while in Gerdau St. Paul Mills possession. Any modification to this certification as provided by Gerdau-St. Paul Mill without the expressed written consent of Gerdau St. Paul Mill negates the validity of this test report. This report shall not be reproduced except in full, without the expressed written consent of Gerdau St. Paul Mill. Gerdau St. Paul Mill is not responsible for the inability of this material to meet specific applications.
Roll batch 62152527/02 roll date 3/17/2020 Fine Grain FG 5-8
Macro S1 R1 C1 ASTM E381-17 Reduction Ratio 38.2 Quality Program Manual Rev. 10, Implemented date 11/8/2019

DEBRA L. KARIESCH
Notary Public-Minnesota
My Commission Expires Jan 31, 2025

Debra L. Kariesch

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. Weld repair has not been performed on this material. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

Bhaskar
BHASKAR YALAMANCHILI
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ALEA BRANDENBURG
QUALITY ASSURANCE MGR.
Phone: (651) 731-5662 Email: Alea.Brandenburg@gerdau.com

Figure J-37. ⅝-in. Dia. Heavy Hex Nut, Test No. HMDT-4 (Item No. h1)

## GEM-YEAR TESTING LABORATORY
### CERTIFICATE OF INSPECTION

MANUFACTURER GEM-YEAR INDUSTRIAL CO., LTD.
ADDRESS : NO.8 GEM-YEAR ROAD,E.D.Z.,JIASHAN,ZHEJIANG,P.R.CHINA

Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2019/04/23

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 210167591
COMMODITY : FINISHED HEX NUT GR-A
SIZE : 7/8-9 NC O/T 0.56MM
LOT NO : IN18BC001
SHIP QUANTITY : 2,250 PCS
LOT QUANTITY 3,910 PCS
HEADMARKS :

PACKING NO : GEM181128011
INVOICE NO : GEM/FNL-181212ED-1
PART NO : 36717
SAMPLING PLAN :
ASME B18.18-2017(Category 2)/ASTM F1470-2018
HEAT NO : 18108472-3
MATERIAL : X1008A
FINISH : HOT DIP GALVANIZED PER ASTM A153-2009/ASTM F2329-2013

MANUFACTURE DATE : 2018/11/05
COUNTRY OF ORIGIN : CHINA

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A563-2015

| Chemistry | AL% | C% | MN% | P% | S% | SI% |
|---|---|---|---|---|---|---|
| Spec. : MIN. | | | | | | |
| MAX. | | 0.5800 | | 0.1300 | 0.2300 | |
| Test Value | 0.0300 | 0.0700 | 0.2700 | 0.0080 | 0.0050 | 0.0300 |

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.2-2015

SAMPLED BY : YUQIAN

| INSPECTIONS ITEM | SAMPLE | SPECIFIED | | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|---|
| WIDTH ACROSS CORNERS | 4PCS | | 1.4470-1.5160 inch | 1.4730-1.4770 inch | 4 | 0 |
| FIM | 15PCS | ASME B18.2.2-2015 | Max. 0.0250 inch | 0.0010-0.0050 inch | 15 | 0 |
| THICKNESS | 4PCS | | 0.7240-0.7760 inch | 0.7280-0.7480 inch | 4 | 0 |
| WIDTH ACROSS FLATS | 4PCS | | 1.2690-1.3120 inch | 1.2840-1.2990 inch | 4 | 0 |
| SURFACE DISCONTINUITIES | 22PCS | | ASTM F812-2012 | PASSED | 22 | 0 |
| THREAD | 15PCS | | GAGING SYSTEM 21 | PASSED | 15 | 0 |
| MINOR DIAMETER | 15PCS | | 0.7890-0.7970 inch | PASSED | 15 | 0 |

MECHANICAL PROPERTIES : ACCORDING TO ASTM A563-2015

SAMPLED BY : GDAN LIAN

| INSPECTIONS ITEM | SAMPLE | TEST METHOD | REF | SPECIFIED | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|---|---|
| CORE HARDNESS | 13 PCS | ASTM F606-2014 | | 116-302 HRB | 81-82 HRB | 13 | 0 |
| PROOF LOAD | 3 PCS | ASTM F606-2014 | | Min. 90 KSI | OK | 3 | 0 |
| PLATING THICKNESS( μm) | 5 PCS | ASTM B568-1998 | | >=53 | 70.22-75.66 | 5 | 0 |

WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY .WHICH ACCREDITED BY ISO/IEC17025(CERTIFICATE NUMBER:3358.01)
WE CERTIFY THAT THE PRODUCTS SUPPLIED ARE IN COMPLIANCE WITH THE REQUIREMENTS OF THE ORDER
WE CERTIFY THAT ALL PRODUCTS WE SUPPLIED ARE IN COMPLIANCE WITH DIN EN 10204 3.1 CONTENT

Quality Supervisor: Grin

Figure J-38. ⅞-in. Dia. Hex Nut, Test No. HMDT-4 (Item No. h3)

## GEM-YEAR TESTING LABORATORY
### CERTIFICATE OF INSPECTION

MANUFACTURER GEM-YEAR INDUSTRIAL CO., LTD.
ADDRESS : NO.8 GEM-YEAR ROAD,E.D.Z.,JIASHAN,ZHEJIANG,P.R.CHINA

Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2019/04/23

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 210167591
COMMODITY : FINISHED HEX NUT GR-A
SIZE : 7/8-9 NC O/T 0.56MM
LOT NO : 1N1880113
SHIP QUANTITY : 2,250 PCS
LOT QUANTITY 31,764 PCS
HEADMARKS :

PACKING NO : GEM181128011
INVOICE NO : GEM/FNL-181212ED-1
PART NO : 36717
SAMPLING PLAN : ASME B18.18-2017(Category.2)/ASTM F1470-2018
HEAT NO : 18108473-3
MATERIAL : X1008A
FINISH : HOT DIP GALVANIZED PER ASTM A153-2009/ASTM F2329-2013

MANUFACTURE DATE : 2018/10/12
COUNTRY OF ORIGIN : CHINA

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A563-2015

| Chemistry | AL% | C% | MN% | P% | S% | SI% |
|---|---|---|---|---|---|---|
| Spec. : MIN. | | | | | | |
| MAX. | | 0.5800 | | 0.1300 | 0.2300 | |
| Test Value | 0.0300 | 0.0600 | 0.2800 | 0.0160 | 0.0060 | 0.0300 |

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.2-2015

SAMPLED BY : WANGYAN

| INSPECTIONS ITEM | SAMPLE | SPECIFIED | | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|---|
| WIDTH ACROSS CORNERS | 4PCS | | 1.4470-1.5160 inch | 1.4650-1.4690 inch | 4 | 0 |
| FIM | 15PCS | ASME B18.2.2-2015 | Max. 0.0250 inch | 0.0040-0.0060 inch | 15 | 0 |
| THICKNESS | 4PCS | | 0.7240-0.7760 inch | 0.7430-0.7460 inch | 4 | 0 |
| WIDTH ACROSS FLATS | 4PCS | | 1.2690-1.3120 inch | 1.2830-1.2840 inch | 4 | 0 |
| SURFACE DISCONTINUITIES | 29PCS | | ASTM F812-2012 | PASSED | 29 | 0 |
| THREAD | 15PCS | | GAGING SYSTEM 21 | PASSED | 15 | 0 |
| MINOR DIAMETER | 15PCS | | 0.7890-0.7970 inch | PASSED | 15 | 0 |

MECHANICAL PROPERTIES : ACCORDING TO ASTM A563-2015

SAMPLED BY : GDAN LIAN

| INSPECTIONS ITEM | SAMPLE | TEST METHOD | REF | SPECIFIED | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|---|---|
| CORE HARDNESS | 13 PCS | ASTM F606-2014 | | 116-302 HRB | 81-82 HRB | 13 | 0 |
| PROOF LOAD | 3 PCS | ASTM F606-2014 | | Min. 90 KSI | OK | 3 | 0 |
| PLATING THICKNESS(μm) | 5 PCS | ASTM B568-1998 | | >=53 | 72.03-95.08 | 5 | 0 |

WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY .WHICH ACCREDITED BY ISO/IEC17025(CERTIFICATE NUMBER:3358.01)
WE CERTIFY THAT THE PRODUCTS SUPPLIED ARE IN COMPLIANCE WITH THE REQUIREMENTS OF THE ORDER
WE CERTIFY THAT ALL PRODUCTS WE SUPPLIED ARE IN COMPLIANCE WITH DIN EN 10204 3.1 CONTENT

Quality Supervisor: Erin

Figure J-39. ⅞-in. Dia. Hex Nut, Test No. HMDT-4 (Item No. h3)

Apr. 17. 2019 2:15PM Fastenal-NELIN No. 6648 P. 2

FASTENAL®

# Certificate of Compliance

**Sold To:**

UNL TRANSPORTATION/Midwest Roadside Safe

**Purchase Order:** 70acct BCTAnchorCableHardware

**Job:**

**Invoice Date:** 10/19/2018

THIS IS TO CERTIFY THAT WE HAVE SUPPLIED YOU WITH THE FOLLOWING PARTS.
THESE PARTS WERE PURCHASED TO THE FOLLOWING SPECIFICATIONS.

200 PCS 1" x 2.500" OD Low Carbon Hot Dipped Galvanized Finish Steel USS General Purpose Flat Washer SUPPLIED UNDER OUR TRACE NUMBER 210151571 AND UNDER PART NUMBER 33188

200 PCS 1"-8 Hot Dipped Galvanized A563 Grade DH Heavy Hex Nut Made In USA SUPPLIED UNDER OUR TRACE NUMBER 210157128 AND UNDER PART NUMBER 38210

This is to certify that the above document is true and accurate to the best of my knowledge.

AFerguson

**Fastenal Account Representative Signature**

Abigail Ferguson

**Printed Name**

4/17/2019

**Date**

Please check current revision to avoid using obsolete copies.

This document was printed on 04/17/2019 and was current at that time.

**Fastenal Store Location/Address**

*3201 N. 23rd Street STE 1*
*LINCOLN, NE 68521*
*Phone #: (402)476-7900*
*Fax #: 402/476-7958*

Page 1 of 1

Figure J-40. 1-in. Dia. Heavy Hex Nut, Test No. HMDT-4 (Item No. h5)

ISO/TS 16949 BUREAU VERITAS Certification

# GEM-YEAR TESTING LABORATORY
## CERTIFICATE OF INSPECTION

MANUFACTURER :GEM-YEAR INDUSTRIAL CO., LTD.
ADDRESS : NO.8 GEM-YEAR ROAD,E.D.Z.,JIASHAN,ZHEJIANG,P.R.CHINA

Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2017/03/23

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 110216407
COMMODITY : FINISHED HEX NUT GR-A
SIZE : 5/8-11 NC O/T 0.51MM
LOT NO : 1N1680027
SHIP QUANTITY : 23,400 PCS
LOT QUANTITY 170,278 PCS
HEADMARKS :
MANUFACTURE DATE : 2016/08/26
COUNTRY OF ORIGIN : CHINA

PACKING NO : GEM160919007
INVOICE NO : GEM/FNL-160929WI
PART NO : 36713
SAMPLING PLAN : ASME B18.18-2011(Category.2)/ASTM F1470-2012
HEAT NO : 331608011
MATERIAL : ML08
FINISH : HOT DIP GALVANIZED PER ASTM A153-2009/ASTM F2329-2013

R#17-507 H#331608011
BCT Cable Bracket Nuts

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A563-2007

| Chemistry | AL% | C% | MN% | P% | S% | SI% |
|---|---|---|---|---|---|---|
| Spec. : MIN. | | | | | | |
| MAX. | | 0.5800 | | 0.1300 | 0.2300 | |
| Test Value | 0.0350 | 0.0700 | 0.4100 | 0.0160 | 0.0060 | 0.0500 |

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.2-2010

SAMPLED BY : DWTING

| INSPECTIONS ITEM | SAMPLE | SPECIFIED | | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|---|
| WIDTH ACROSS CORNERS | 6PCS | | 1.0510-1.0830 inch | 1.0560-1.0690 inch | 6 | 0 |
| FIM | 15PCS | ASME B18.2.2-2010 | Max. 0.0210 inch | 0.0020-0.0040 inch | 15 | 0 |
| THICKNESS | 6PCS | | 0.5350-0.5590 inch | 0.5390-0.5570 inch | 6 | 0 |
| WIDTH ACROSS FLATS | 6PCS | | 0.9220-0.9380 inch | 0.9240-0.9340 inch | 6 | 0 |
| SURFACE DISCONTINUITIES | 29PCS | | ASTM F812-2012 | PASSED | 29 | 0 |
| THREAD | 15PCS | | GAGING SYSTEM 21 | PASSED | 15 | 0 |

MECHANICAL PROPERTIES : ACCORDING TO ASTM A563-2007

SAMPLED BY : GDAN LIAN

| INSPECTIONS ITEM | SAMPLE | TEST METHOD | REF | SPECIFIED | ACTUAL RESULT | ACC. | REJ. |
|---|---|---|---|---|---|---|---|
| CORE HARDNESS | 15PCS | ASTM F606-2014 | | 68-107 HRB | 79-81 HRB | 15 | 0 |
| PROOF LOAD | 4PCS | ASTM F606-2014 | | Min. 90 KSI | OK | 4 | 0 |
| PLATING THICKNESS( μm) | 5PCS | ASTM B568-1998 | | >=53 | 70.02-75.81 | 5 | 0 |

WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY .WHICH ACCREDITED BY ISO/IEC17025(CERTIFICATE NUMBER:3358.01)
WE CERTIFY THAT THE PRODUCTS SUPPLIED ARE IN COMPLIANCE WITH THE REQUIREMENTS OF THE ORDER

Quality Supervisor: Erin

Figure J-41. ⅝-in. Dia. Hex Nut, Test No. HMDT-4 (Item No. h6)

benesch

Page 1 of 1

# Concrete Sample Test Report
## Cylinder Compressive Strength

| | |
|---|---|
| Project Name: | Midwest Roadside Safety - Misc Testing |
| Project Number: | 00110546.00 |
| Client: | Midwest Roadside Safety Facility |
| Location: | MNPD |
| Sample: | 012 |
| Description: | HAWAII_1 HMDT |

### Field Data (ASTM C172, C143, C173/C231, C138, C1064)

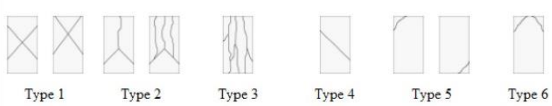
| | | Property | Test Result |
|---|---|---|---|
| Supplier: | | Slump (in): | |
| Mix Name: | | Air Content (%): | |
| Ticket Number: | | Unit Weight (lb/ft³): | |
| Truck Number: | | Air Temp (°F): | |
| Load Volume (yd³): | | Mix Temp (°F): | |
| Mold Date: | 12/16/2020 | Min Temp (°F): | |
| Molded By: | | MaxTemp (°F): | |
| Initial Cure Method: | | | |

### Laboratory Test Data (ASTM C39)

| | | | | | | |
|---|---|---|---|---|---|---|
| Sample Number: | 012 | 012 | | | | |
| Set Number: | HMDT CURB 1 | HMDT CURB 2 | | | | |
| Specimen Number: | 1 | 1 | | | | |
| Age: | 20 | 20 | | | | |
| Length (in): | 12 | 12 | | | | |
| Diameter (in): | 5.99 | 5.98 | | | | |
| Area (in²): | 28.18 | 28.09 | | | | |
| Test Date: | 01/05/2021 | 01/05/2021 | | | | |
| Break Type: | 5 | 5 | | | | |
| Max Load (lbf): | 109,438 | 101,529 | | | | |
| Strength (psi): | 3,880 | 3,610 | | | | |
| Spec Strength (psi): | | | | | | |

Remarks:
Average 20-day Compressive Strength (psi): **3,750**

Date received: 01/05/2021
Curing: ☒ Standard ☐ Field
ASTM C511
Submitted by:




Distribution:

Report Date: 1/5/21



825 M Street Suite 100
Lincoln, NE 68508

Alfred Benesch & Company



Figure J-42. Curb Concrete, Test No. HMDT-4 (Item No. j2)

# Appendix K. Accelerometer and Rate Transducer Data Plots, Test No. HMDT-4

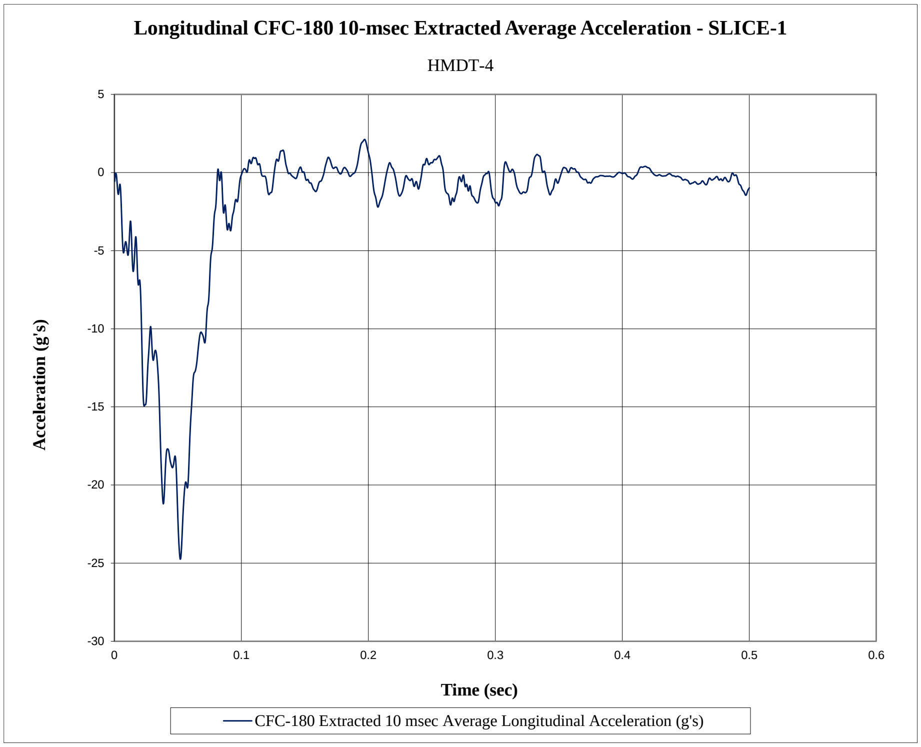



Figure K-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. HMDT-4

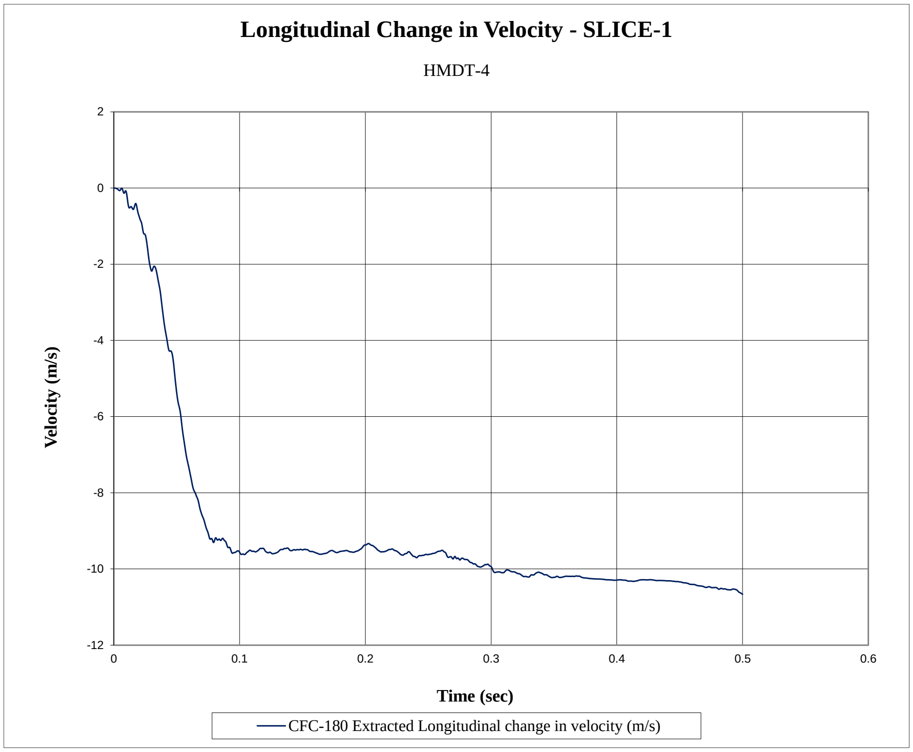



Figure K-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. HMDT-4

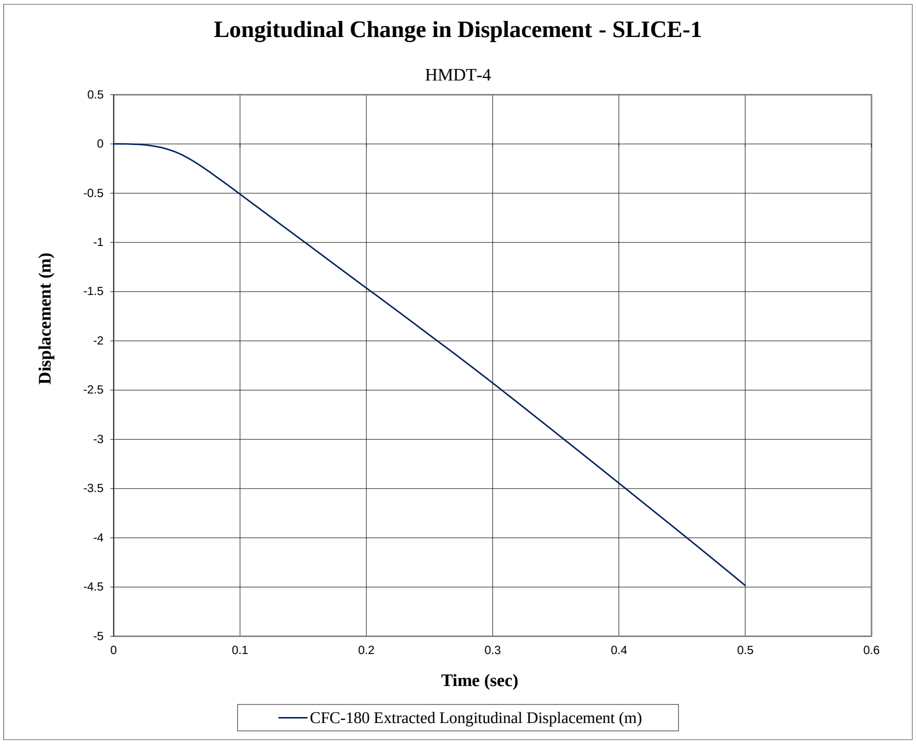



Figure K-3. Longitudinal Occupant Displacement (SLICE-1), Test No. HMDT-4

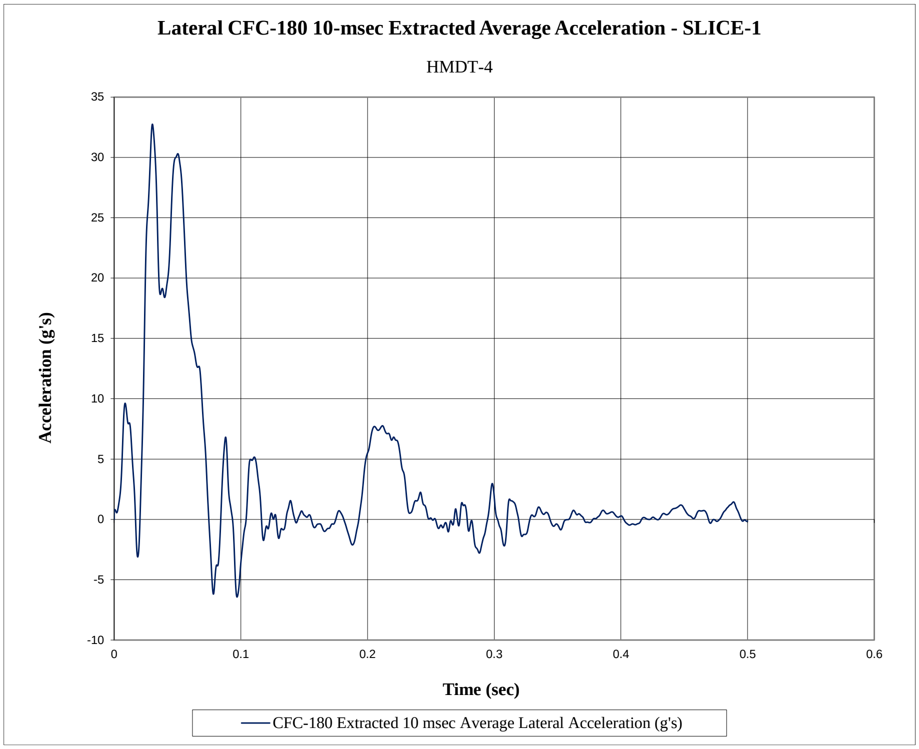



Figure K-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. HMDT-4

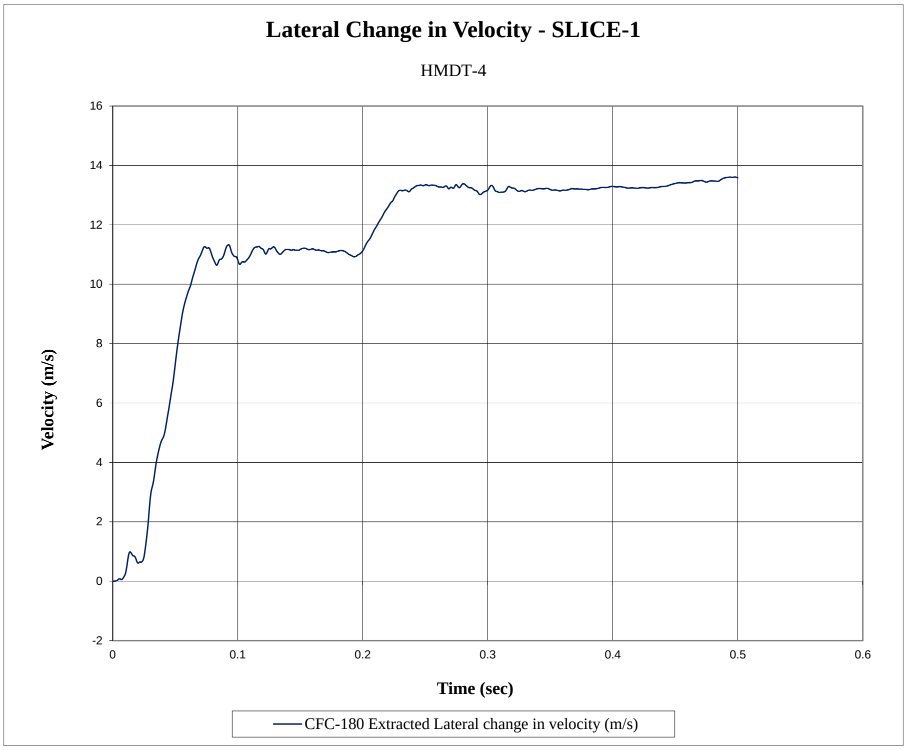



Figure K-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. HMDT-4

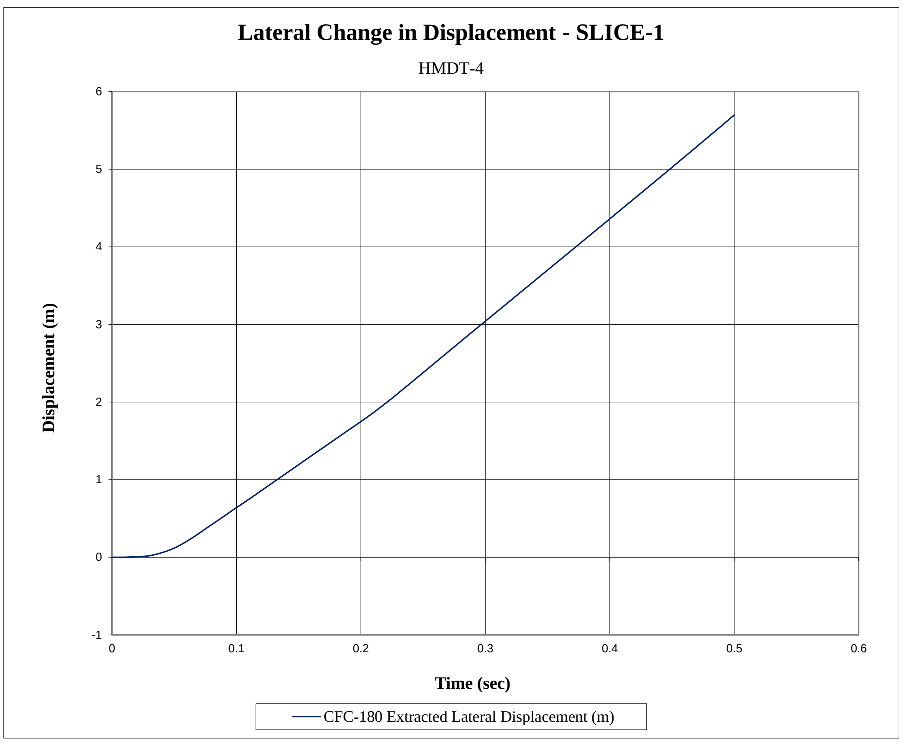



Figure K-6. Lateral Occupant Displacement (SLICE-1), Test No. HMDT-4

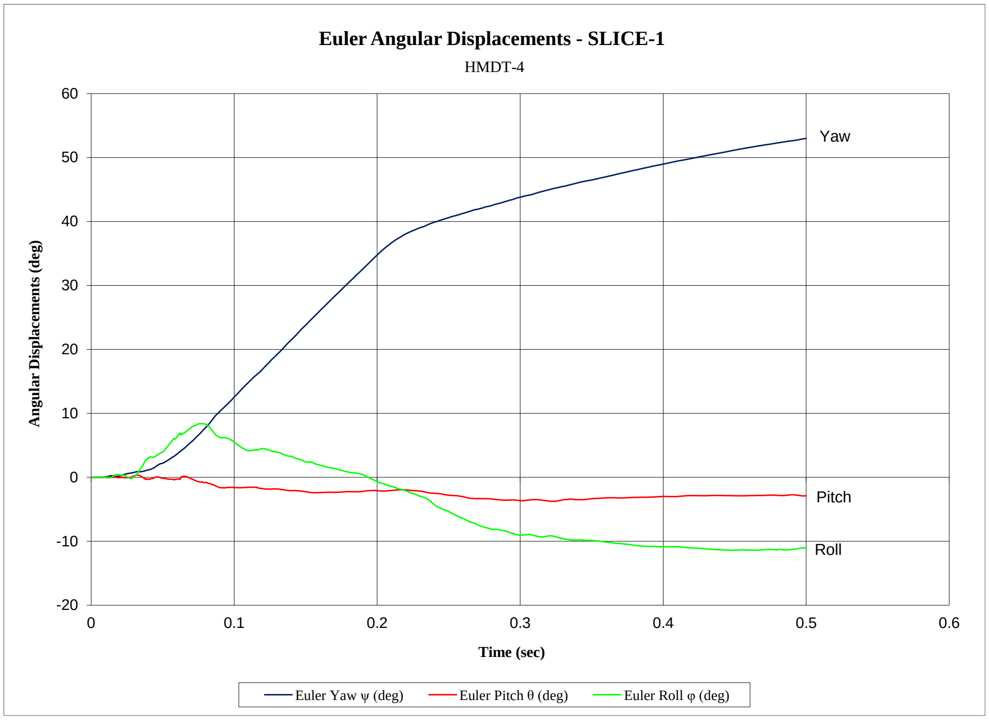



Figure K-7. Vehicle Angular Displacements (SLICE-1), Test No. HMDT-4

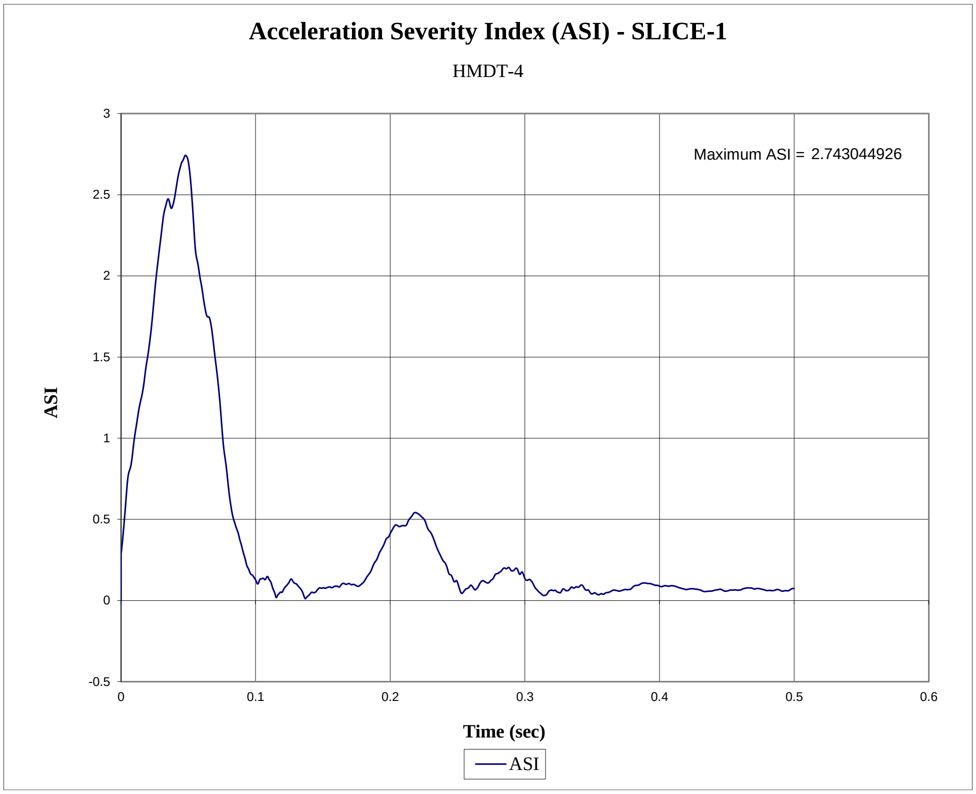



Figure K-8. Acceleration Severity Index (SLICE-1), Test No. HMDT-4

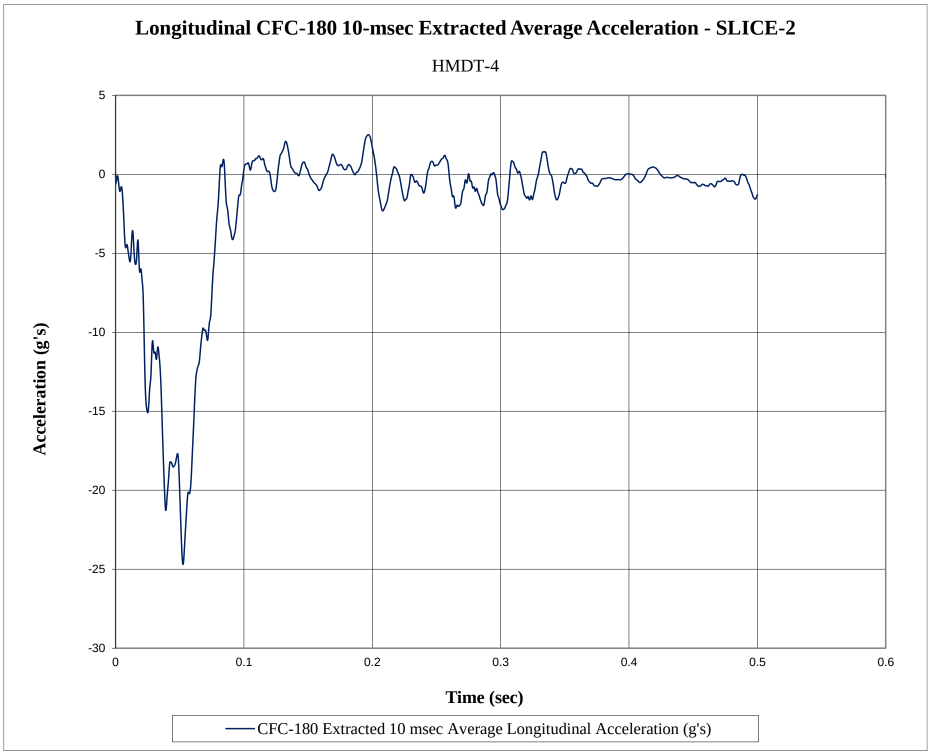



Figure K-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. HMDT-4

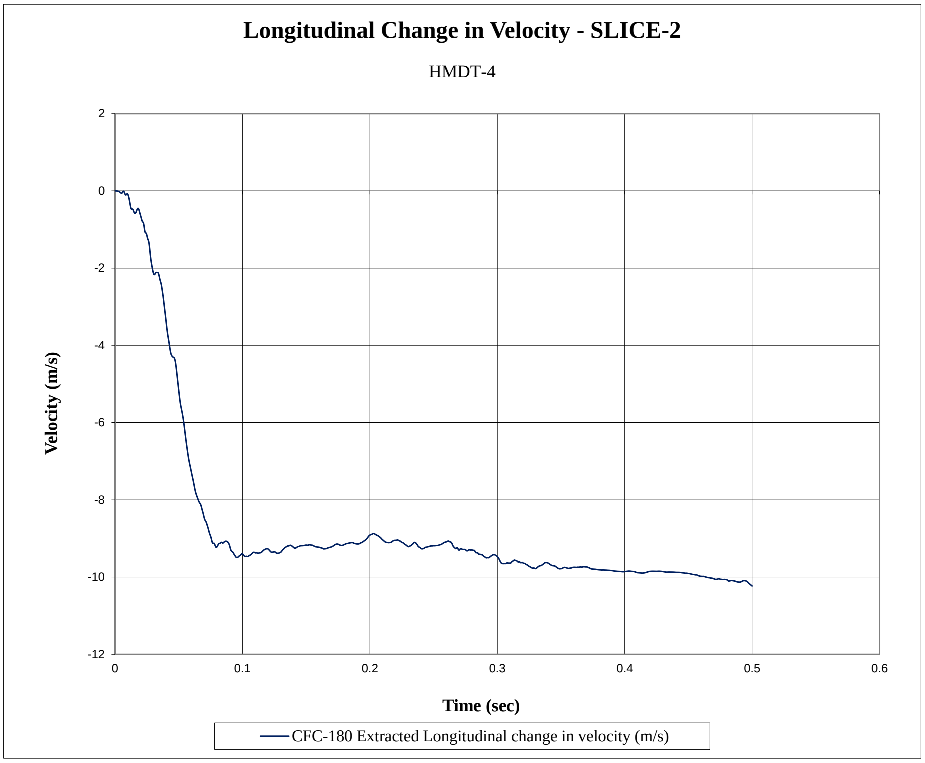



Figure K-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. HMDT-4

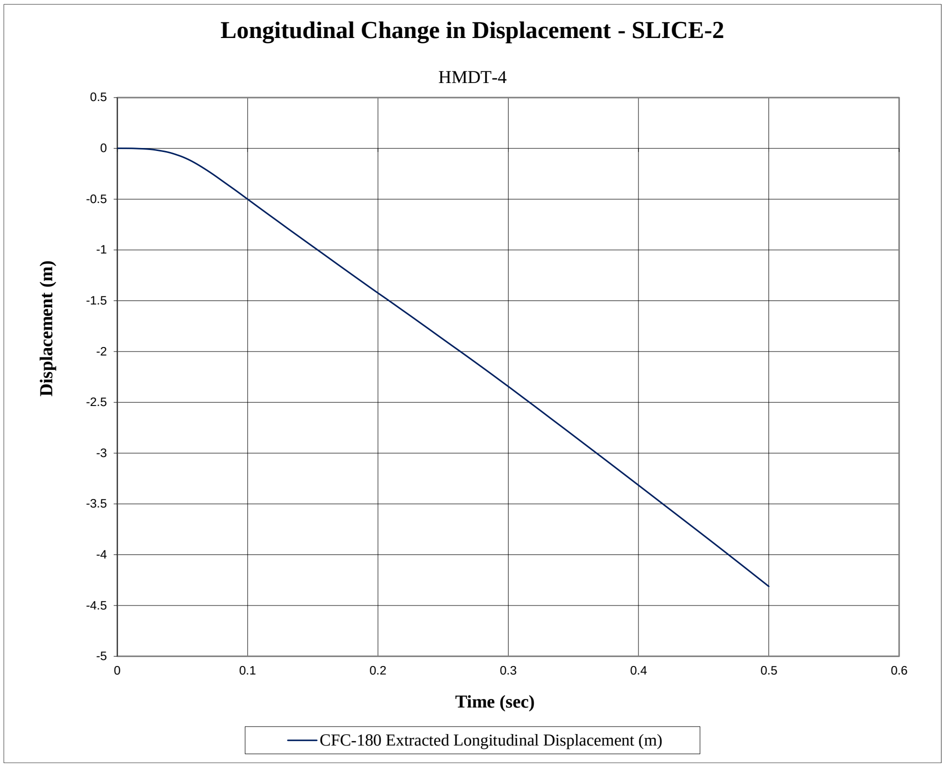



Figure K-11. Longitudinal Occupant Displacement (SLICE-2), Test No. HMDT-4

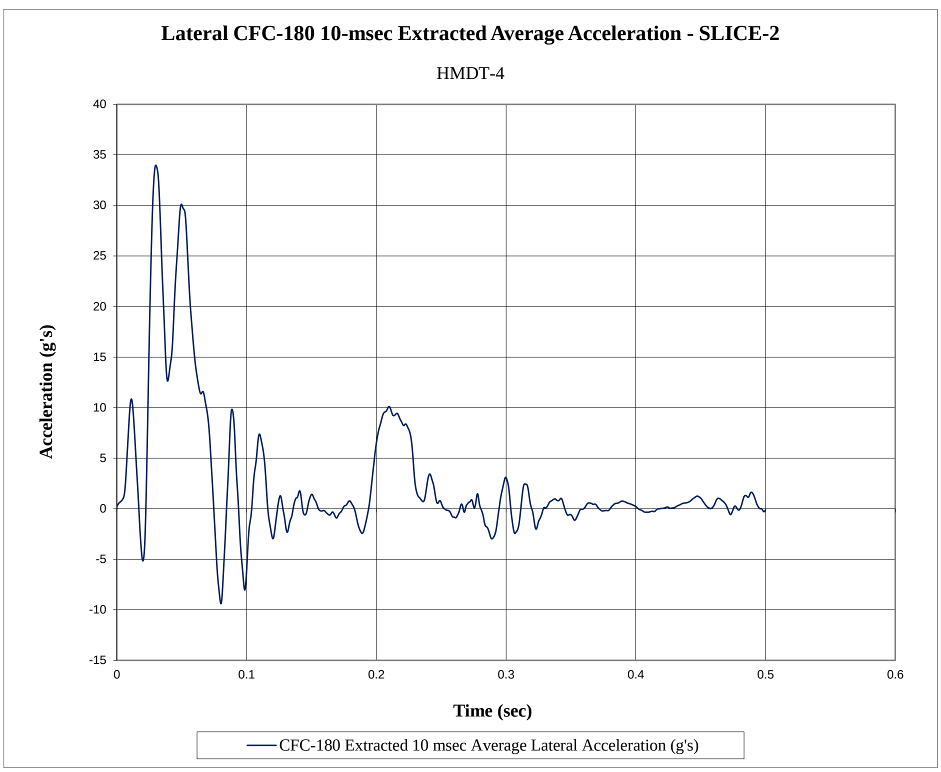



Figure K-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. HMDT-4

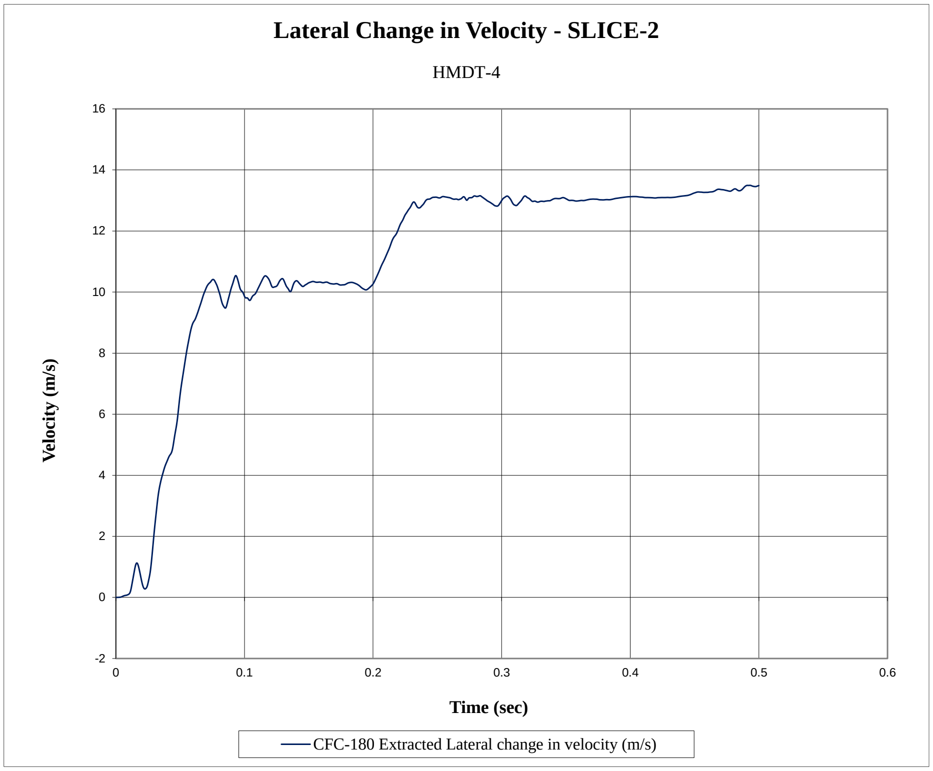



Figure K-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. HMDT-4

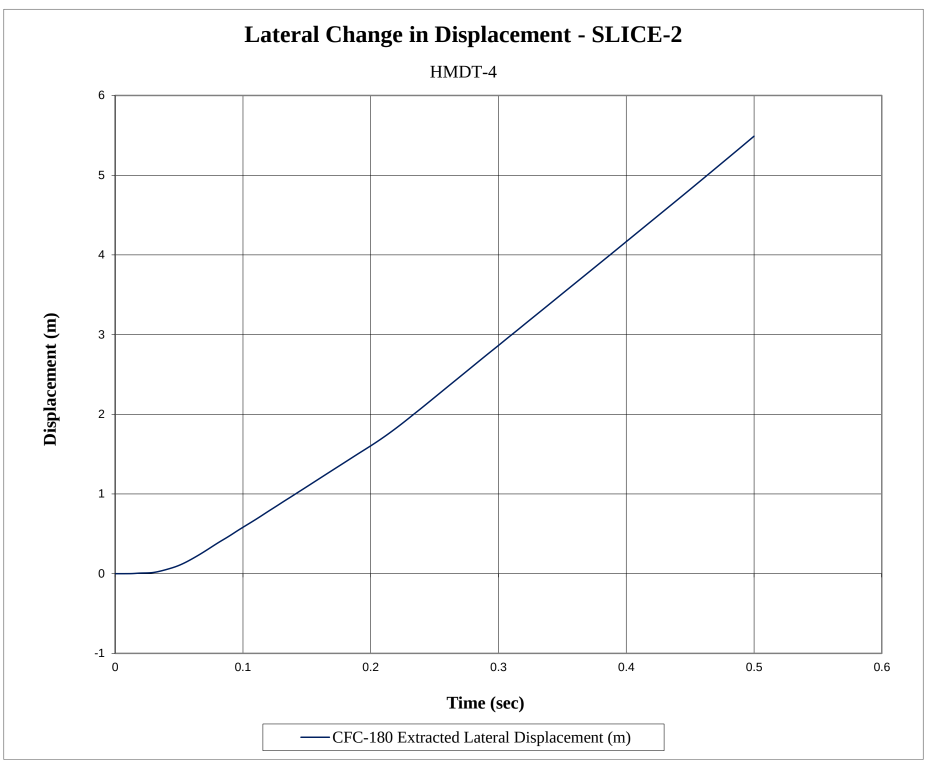



Figure K-14. Lateral Occupant Displacement (SLICE-2), Test No. HMDT-4

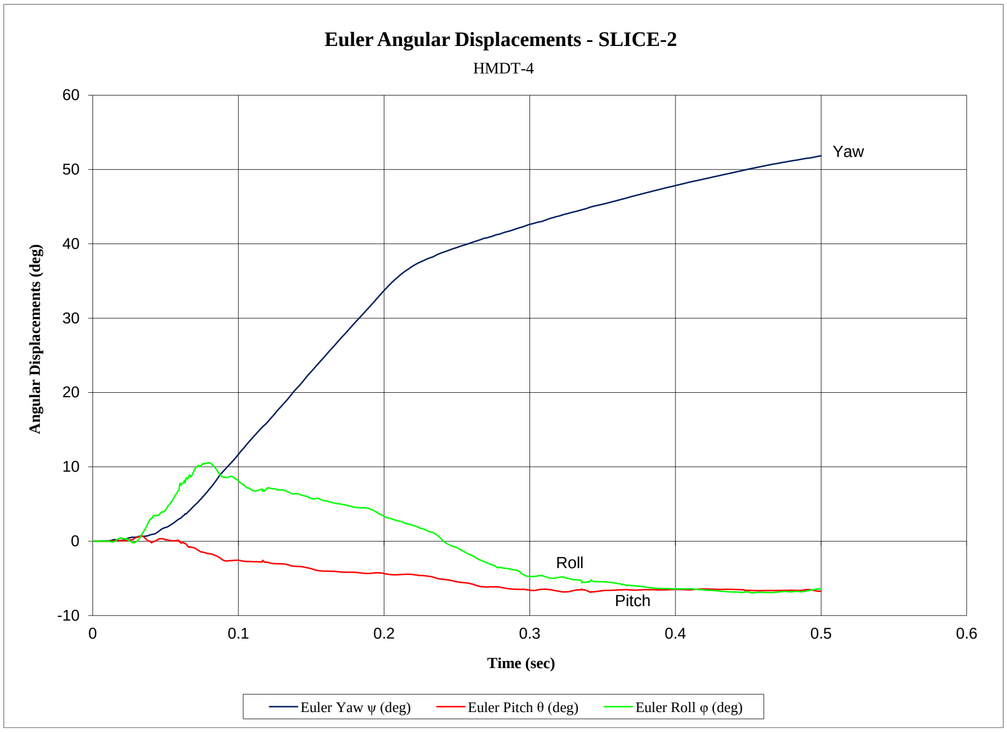



Figure K-15. Vehicle Angular Displacements (SLICE-2), Test No. HMDT-4

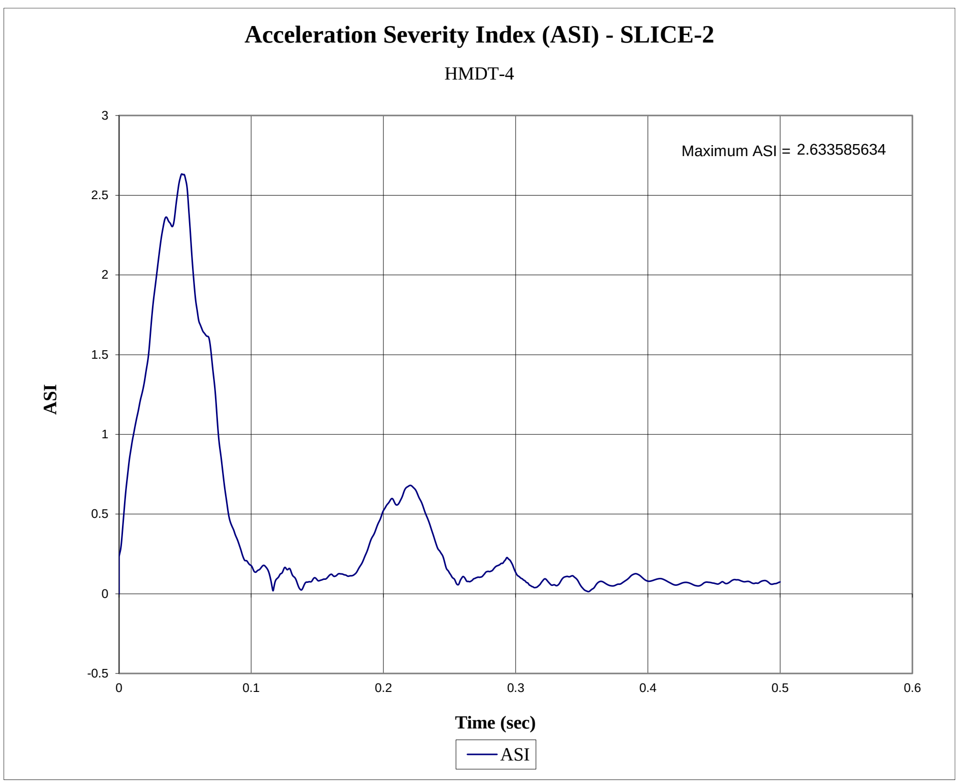



Figure K-16. Acceleration Severity Index (SLICE-2), Test No. HMDT-4

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