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HAWAII DOT FLARED BURIED-IN-BACKSLOPE GUARDRAIL END TERMINAL PART 1 – STANDARD DIRECTION TESTS



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16. Abstract

The Hawaii Department of Transportation's (HDOT's) Buried-in-Backslope system was evaluated according to *Manual for Assessing Safety Hardware* (MASH) Test Level 3 (TL-3) impact conditions. The system consisted of Midwest Guardrail System (MGS) W-beam railing supported by W6x8.5 and W6x9 steel posts and 8-in. deep recycled plastic blockouts, with a lower W-beam rubrail attached to the post. The terminal had a 13:1 flare (4.4 degrees) from a tangent roadside system between post nos. 29 and 10, and a second 7.4:1 flare (6.8 degrees) between post no. 10 and the upstream anchor block. The system passed through a V-ditch with a 120-in. wide, 6H:1V foreslope and a 2:1 backslope.

During test no. HBIB-1, conducted according to MASH test designation 3-32, an 1100C passenger car impacted the system 12 in. downstream from the edge of the anchor block. The right-front tire snagged on post nos. 3 through 6, resulting in a longitudinal occupant ridedown acceleration (ORA) of 27.56 g's. The vehicle's right A-pillar deformed laterally 4.2 in., which exceeded lateral MASH limit of 3 in. Excessive ORA and A-pillar deformation resulted in test failure. Consequently, the HBIB system was redesigned to reduce the propensity for vehicle snag and excessive A-pillar deformation.

The redesigned system followed the ditch profile from post no. 17 through the upstream anchor block, resulting in decreasing system height. Steel tube blockouts were added to the rubrail to mitigate wheel snag. The modified system was successfully retested in test no. HBIB-2. Therefore, test no. HBIB-2 was considered successful. Following the successful test of the redesigned buried-in-backslope system, the remaining required full-scale crash tests, test designation nos. 3-33, 3-34, and 3-35, run as test nos. HBIB-3 through HBIB-5, respectively, were conducted and all satisfied MASH TL-3 safety criteria. This report describes standard direction testing to MASH criteria, while a second report describes reverse-direction testing.

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This material is based upon work supported by the Federal Highway Administration, U.S. Department of Transportation and the Hawaii Department of Transportation under Research Project 67167. The contents of this report reflect the views and opinions of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the University of Nebraska-Lincoln, Hawaii Department of Transportation nor the Federal Highway Administration, U.S. Department of Transportation. This report does not constitute a standard, specification, or regulation. Trade or manufacturers' names, which may appear in this report, are cited only because they are considered essential to the objectives of the report. The United States (U.S.) government and the States of Nebraska and Hawaii do not endorse products or manufacturers.

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.

A2LA ACCREDITATION

The tests reported herein are within the scope of MwRSF's A2LA Accreditation. MwRSF's accreditation documentation can be found in Appendix A.

INDEPENDENT APPROVING AUTHORITY

The Independent Approving Authority for the data contained herein was Mr. Brandon Perry, Research Engineer.

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1 INTRODUCTION

1.1 Background

The Hawaii Department of Transportation (HDOT) utilizes a buried-in-backslope (BIB) guardrail end terminal, referred to as the Modified Type A-1 flared BIB guardrail end terminal. The Hawaii buried-in-backslope (HBIB) system consists of a guardrail end terminal anchored into a reinforced concrete block that is inset into a roadside cut slope; continues with a flared, strong-post, W-beam guardrail system with a rubrail through a section of sloped roadside terrain; and then continues with a strong-post, W-beam guardrail system along the roadway shoulder. However, the crashworthiness of this system under current impact safety standards has not been demonstrated. This report documents the system modifications and full-scale crash testing conducted to evaluate the safety performance of the modified Type A-1 flare system according to the American Association of State Highway and Transportation (AASHTO) *Manual for Assessing Safety Hardware, Second Edition* (MASH) criteria [1] in standard direction for run-off-road impacts.

HDOT provided the research team with four system configurations that varied the location of the end anchorage block. Option 1 consisted of the least offset from the roadway and utilized a single flare rate, terminating in an anchor block. The flare rate of Option 1 was dependent on the design speed of the roadway. Option 2 utilized the same flared configuration as Option 1 but added an additional 7.4:1 flare rate before terminating the system. Options 3 and 4 added additional steepening flare rates to the upstream end of the previous options. Of the four options, HDOT indicated that Option 1 was the most common (estimated 75%) and Option 2 was the second most common (20-25%). Few, if any, actual installations used Options 3 and 4. Thus, while Options 3 and 4 were possibly more severe, they may not be used in practice. Thus, the most severe configuration that would be used on the roadway was Option 2, shown in the system plans provided by HDOT in Figures 1 through 3.

1.2 Objective

The objective of this research was to conduct full-scale crash testing of the HDOT buried-in-backslope system according to MASH Test Level 3 (TL-3) impact safety standards. This report describes the performance of the HBIB system in the standard direction of impact; a second report describes testing of the system in the reverse direction.

1.3 Scope

The research objective was performed through the completion of several tasks. The first task included a comprehensive literature review of the existing BIB roadside safety features. The research team identified potential design revisions to improve constructability and standardization. System plans were developed, and a ditch with a 6:1 foreslope and 2:1 backslope was constructed to model an HDOT roadside ditch. The system was constructed and subjected to five full-scale crash tests in accordance with MASH test designation nos. 3-32 through 3-35. The full-scale vehicle crash test results were analyzed, evaluated, and documented. Additional full-scale crash tests for reverse direction impacts will be detailed in a subsequent report. Conclusions and recommendations were then made pertaining to the safety performance of the HBIB guardrail, rubrail, and end anchorage.

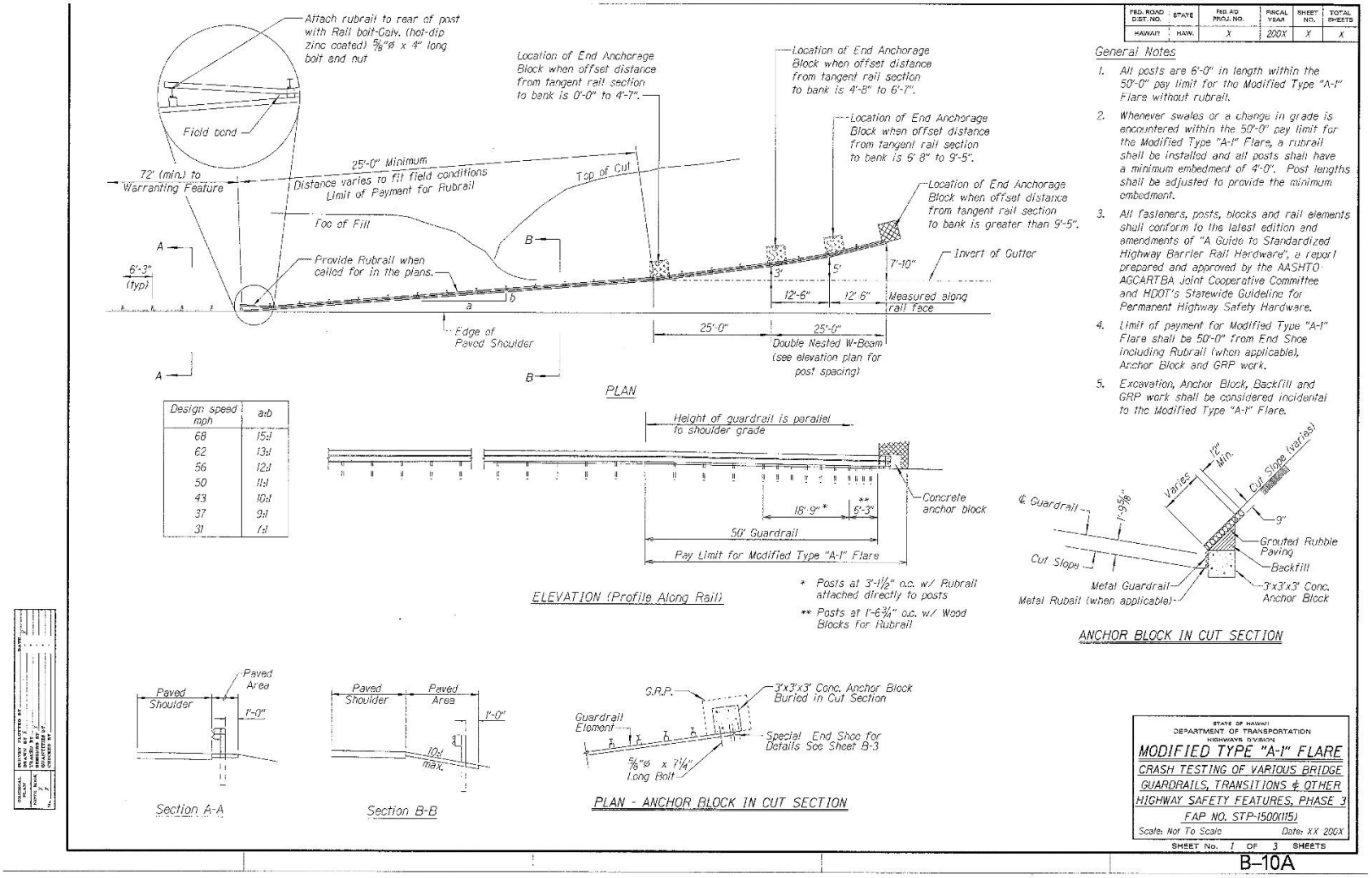


Figure 1. HDOT Standard Plans - HBIB Modified Type A-1 Flare, Sheet 1

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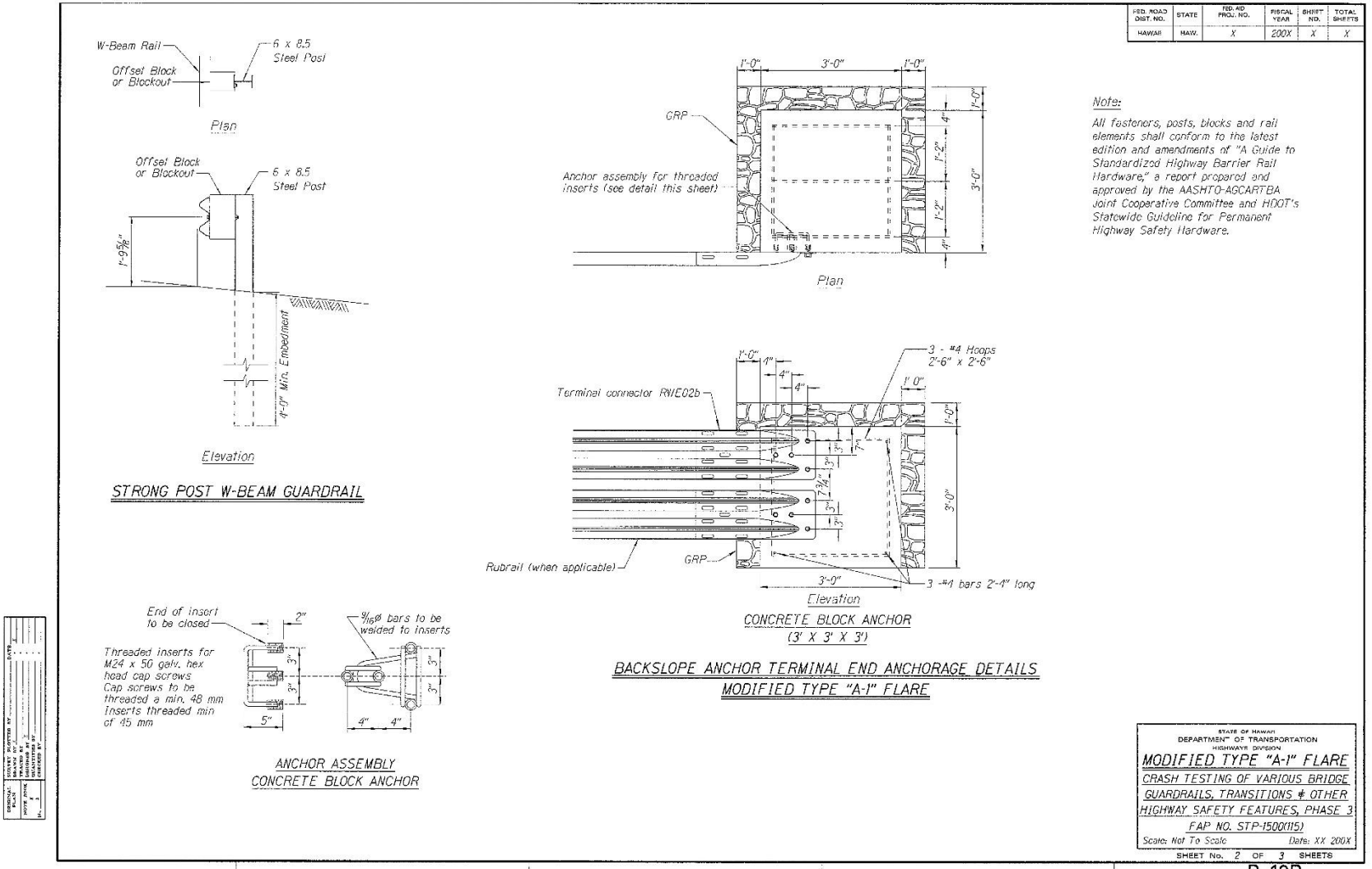


Figure 2. HDOT Standard Plans - HBIB Modified Type A-1 Flare, Sheet 2

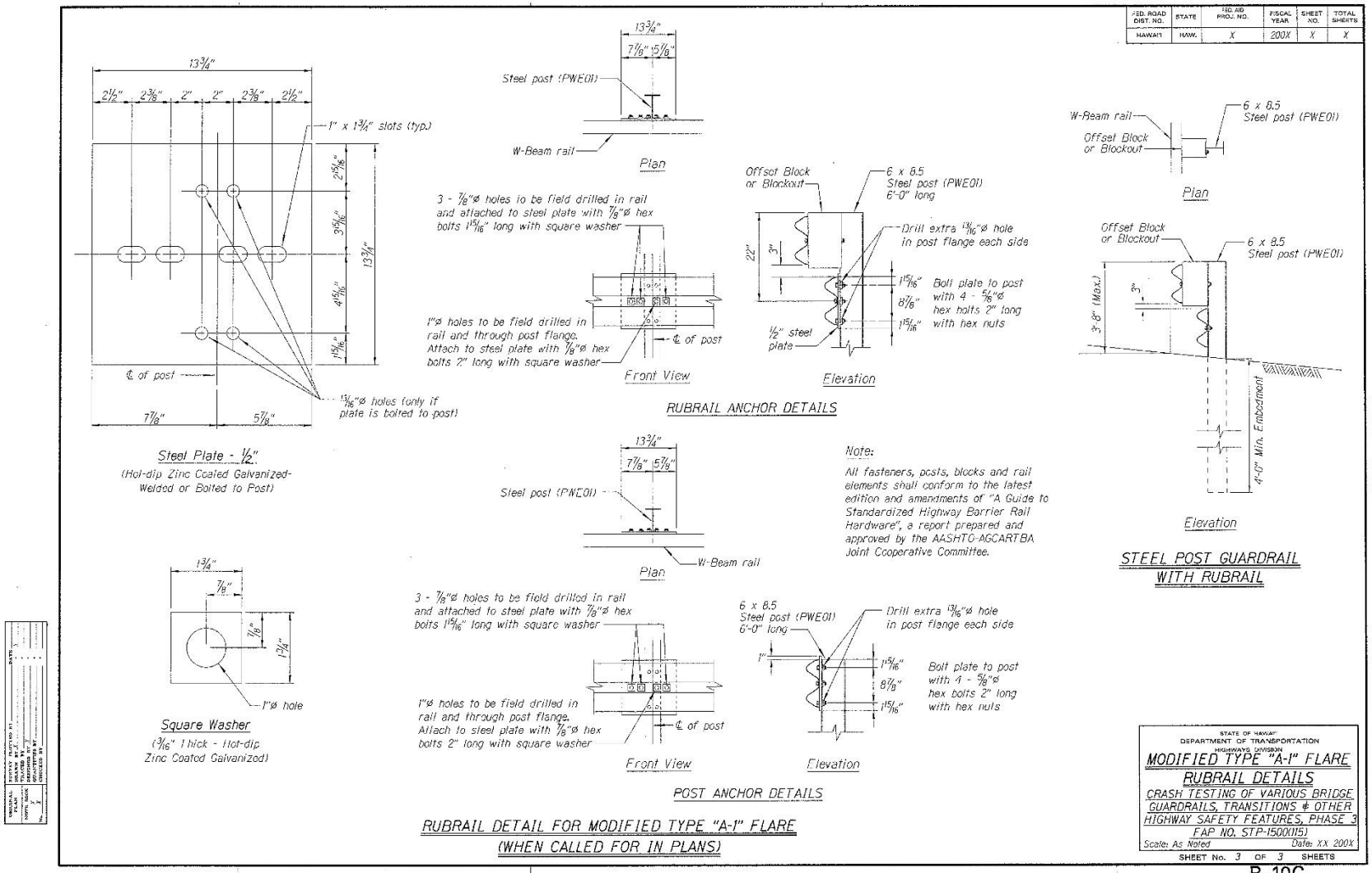


Figure 3. HDOT Standard Plans - HBIB Modified Type A-1 Flare, Sheet 3

2 LITERATURE REVIEW

A literature review was performed on previously crash-tested BIB systems that were considered relevant to the HDOT system. The literature review was separated into three topics: (1) BIB full-scale crash testing; (2) W-beam-to-bridge rail transition full-scale crash testing; and (3) W-to-thrie-beam transition full-scale crash testing. An evaluation of the similarities and differences between the tested systems and the current HDOT BIB Midwest Guardrail System (MGS) design is discussed in each section.

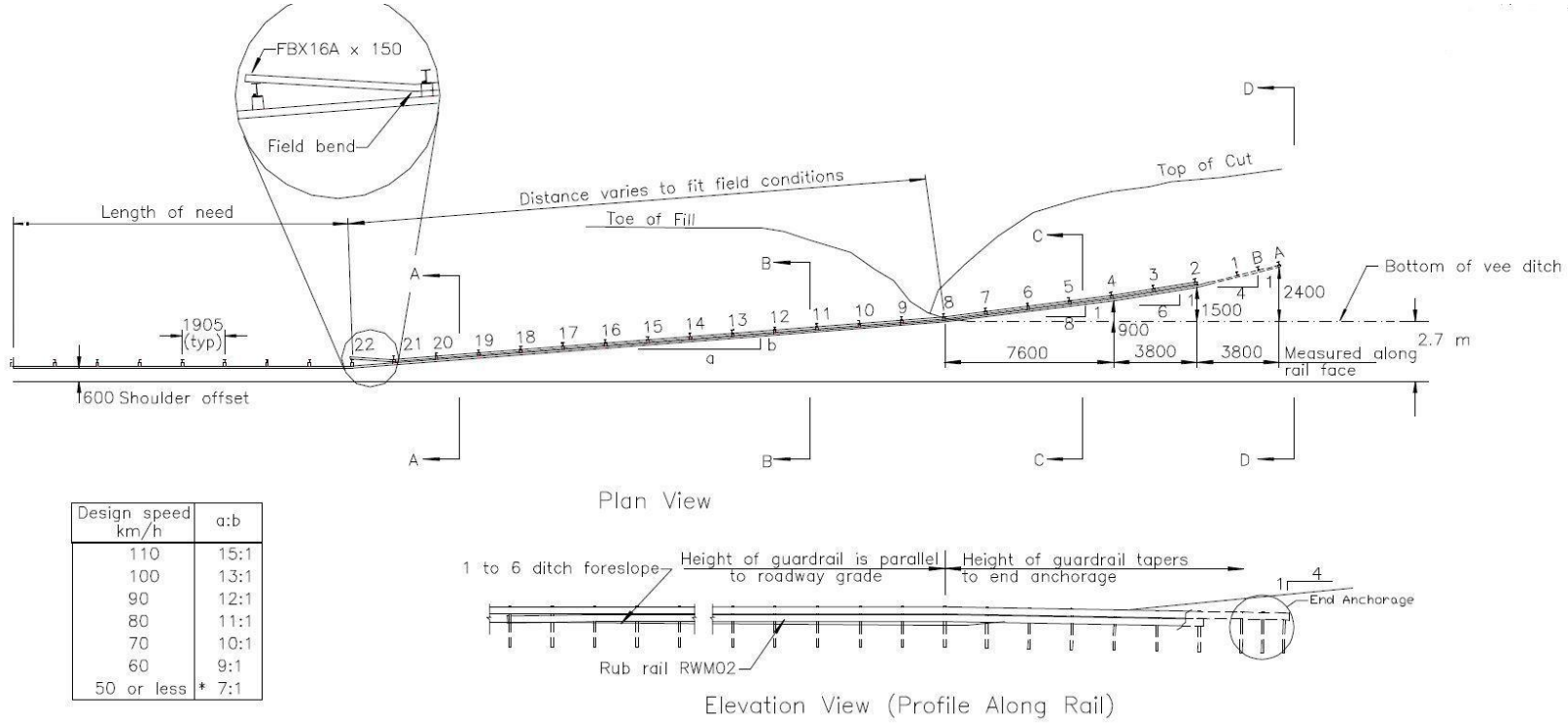
2.1 Buried-in-Backslope Terminal Testing

A literature review of previously crash-tested BIB systems was completed to inform researchers on design details of failed and successful systems. Upstream and downstream W-beam anchorage details, impact points, ditch configurations, and rail heights were considered for previously-evaluated systems. The majority of systems were evaluated to National Cooperative Highway Research Program (NCHRP) Report No. 350 TL-3 impact conditions and evaluation criteria, and one system was evaluated to MASH TL-3 impact conditions.

2.1.1 Buried-in-Backslope Terminal with 6:1 V-Ditch (1998)

The Texas A&M Transportation Institute (TTI) evaluated the crashworthiness of a BIB terminal according to crash test evaluation criteria [2] described in National Cooperative Highway Research Program (NCHRP) Report No. 350 [3]. The BIB terminal system was installed adjacent to a V-ditch with a 6:1 foreslope and a 4:1 backslope. The ditch was constructed with a flat (zero-grade) paved shoulder followed by a 6:1 slope extending 8 ft – 10¼ in. laterally to a maximum depth of 1 ft – 5½ in., and a 4:1 backslope that extended approximately 20 ft laterally from the ditch bottom. The guardrail system crossed the center of the V-ditch 2 ft – 3⅞ in. upstream from post no. 8.

The BIB guardrail system consisted of W-beam guardrail with a W-beam rubrail attached to W6x9 steel posts. Timber blockouts supporting the upper rail measured 6 in. x 8 in. x 14 in. tall and were routed to fit over the steel post flanges. The guardrail beginning at post no. 22 was parallel to the travel way. The top of the posts in this section was 26½ in. measured from the shoulder grade. At the upstream end of the system, post "A" was buried 11.8 in. below the surface of the backslope and anchored the upper W-beam rail. The 12-gauge W-beam guardrail was attached to the 8-ft long W6x9 steel posts with 8-in. deep blockouts. The guardrail was flared at a 4:1 flare rate between posts A, B, 1, and 2, which were numbered sequentially beginning at the upstream end anchor. The W-beam rail was flared 6:1 between post nos. 2 through 4, 8:1 between post nos. 4 through 8, and 13:1 from post nos. 8 through 22. From post no. 22 to the downstream end of the system, the guardrail was parallel to the travel way. The W-beam rubrail was mounted to the front face of the posts using ⅝-in. bolts and was located 3 in. below the bottom of the upper rail. The rubrail extended from post no. 2 to 22. The upstream end of the rubrail was anchored using a plate bracket attached to post no. 2. The downstream end of the rubrail was terminated at the back side of post no. 22 using a ⅝-in. dia. bolt and spacer sleeve. The system layout is shown in Figure 4 and the system installation is shown in Figure 5.



Design speed km/h	a:b
110	15:1
100	13:1
90	12:1
80	11:1
70	10:1
60	9:1
50 or less	* 7:1

Figure 4. Buried-in-Backslope Terminal with 6:1 V-Ditch Installation Schematic [2]

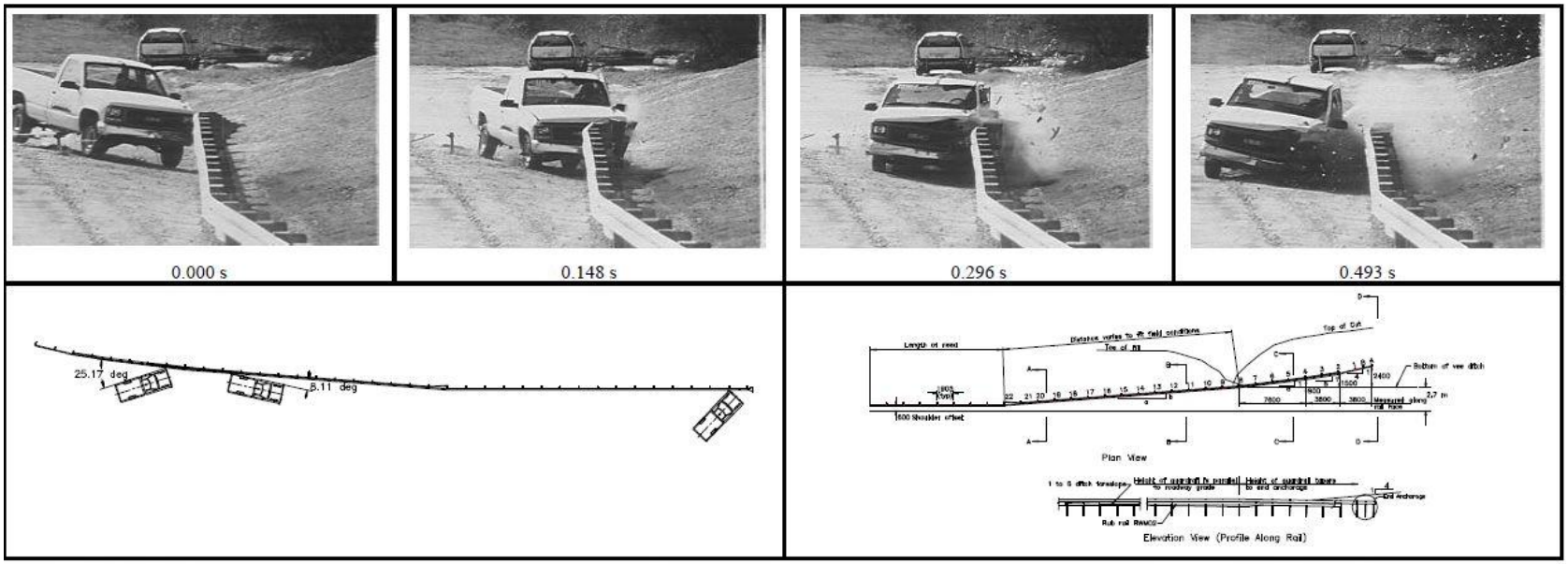


Figure 5. Buried-in-Backslope Terminal with 6:1 V-Ditch and Rubrail Installation [2]

Test no. 404211-1 was conducted according to NCHRP Report No. 350 test designation no. 3-35, consisting of a 2000P pickup truck impacting the system at approximately 62 mph and an angle of 25 degrees at the critical impact point (CIP), which was located at post no. 8. During test no. 404211-1, the vehicle impacted the BIB system 3½ in. downstream from post no. 8 at 60.4 mph and an angle of 25.2 degrees. The test vehicle was smoothly redirected and came to a stop 219 ft – 3 in. downstream from impact. After the test, deformation of the upper and lower W-beam guardrail extended from post nos. 8 through 11, as shown in Figure 6. No penetration, override, or underride was observed after the test. NCHRP Report No. 350 test designation no. 3-34 was not performed on the BIB system. Test no. 404211-1 was the first BIB end anchorage to successfully meet NCHRP Report No. 350 criteria. The test evaluation summary is shown in Figure 7.



Figure 6. Buried-in-Backslope Terminal with 6:1 V-Ditch, System Damage, Test No. 404211-1 [2]



General Information

Test Agency	Texas Transportation Institute
Test No.	404211-1
Date	01/29/98

Test Article

Type	Terminal
Name	W-beam Buried in Backslope
Installation Length (m)	76.2
Material or Key Elements	W-beam Guardrail on Steel Posts w/WoodBlockouts, Rub rail, 6:1 Ditch
Soil Type and Condition	Standard Soil, Damp

Test Vehicle

Type	Production
Designation	2000P
Model	1995 GMC 2500 Pickup Truck
Mass (kg) Curb	1933
Test Inertial	2000
Dummy	76
Gross Static	2076

Impact Conditions

Speed (km/h)	97.2
Angle (deg)	25.2

Exit Conditions

Speed (km/h)	70.6
Angle (deg)	8.1

Occupant Risk Values

Impact Velocity (m/s)	
x-direction	7.2
y-direction	7.2
THIV	25.0
Ridedown Accelerations (g's)	
x-direction	-9.4
y-direction	8.6
PHD (g's)	9.3
ASI	1.15
Max. 0.050-s Average (g's)	
x-direction	-6.0
y-direction	8.8
z-direction	-9.3

Test Article Deflections (m)

Dynamic	0.67
Permanent	0.41

Vehicle Damage

Exterior	
VDS	11LFQ4
CDC	11FLEK2 &11LYEW3
Maximum Exterior Vehicle Crush (mm)	520
Interior	
OCDI	FS0100002
Max. Occ. Compart. Deformation (mm)	45

Post-Impact Behavior

(during 1.0 s after impact)	
Max. Yaw Angle (deg)	32
Max. Pitch Angle (deg)	11
Max. Roll Angle (deg)	38

Figure 7. Evaluation Summary of Buried-in-Backslope Terminal with 6:1 V-Ditch, Test No. 404211-1 [2]

2.1.2 Buried-in-Backslope Terminal with 4:1 Slope (2000)

TTI evaluated the crashworthiness of a modified version of the BIB terminal with a steeper, 4:1 V-ditch according to safety criteria described in NCHRP Report 350 [2]. Posts A, B, 1, and 2, numbered sequentially beginning at the end anchor, were fully embedded below grade in the backslope at a minimum of 11.8 in. Post nos. 3 through 5 were partially embedded such that the upstream end of the guardrail and rubrail was buried in the soil. As shown in Figure 8, the guardrail system was flared at four rates: 4:1 between post nos. A, B, 1, and 2, 6:1 between post nos. 2 through 4, 8:1 between post nos. 4 through 8, and 13:1 between post nos. 8 through 20. The V-ditch consisted of a 4:1 foreslope which was 6 ft wide with a 2:1 backslope continuing behind the rail. The top of the rail for the length of need was 27¾ in. above the shoulder grade.

A W-beam rubrail was installed 3 in. below the upper rail and extended from post nos. 2 to 20. The rubrail was mounted to the posts with ⅝-in. diameter bolts. The rubrail was connected to post no. 2, and the downstream end of the rubrail was connected to the back of post no. 20 with a ⅝-in. diameter bolt. Post nos. A, B, and 1 were connected to the guardrail using ½-in. x 30-in. x 29⅞-in. steel plates. The system installation is shown in Figure 8 and the system layout is shown in Figure 9.

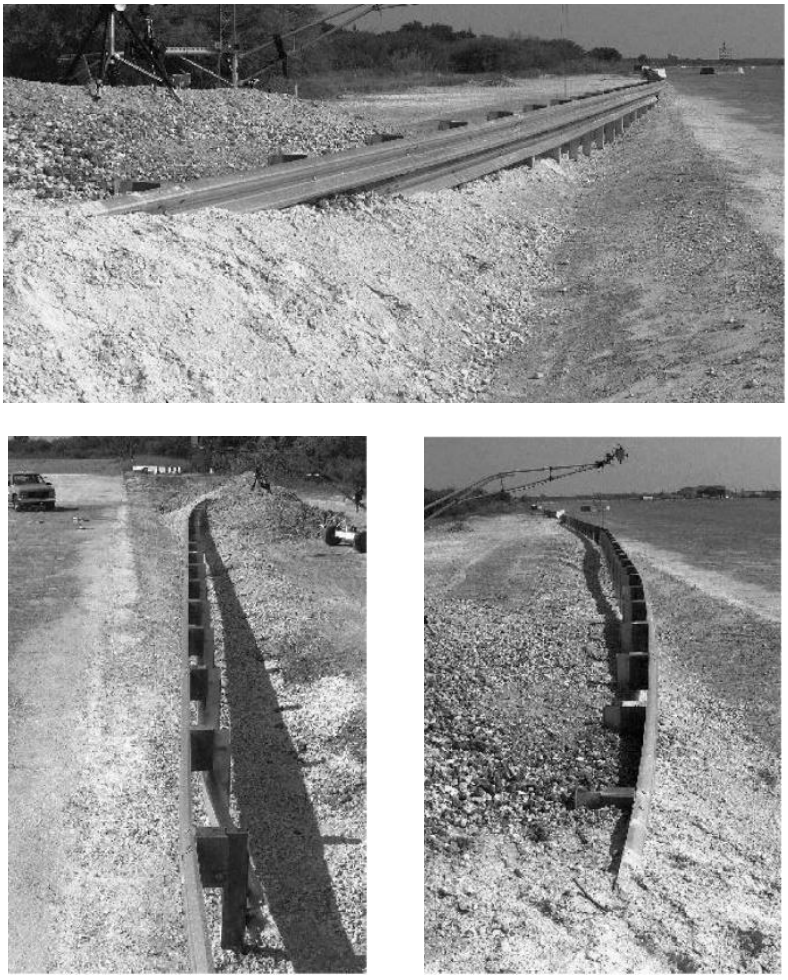


Figure 8. Buried-in-Backslope Terminal with 4:1 Slope Installation, Test No. 404211-13 [2]

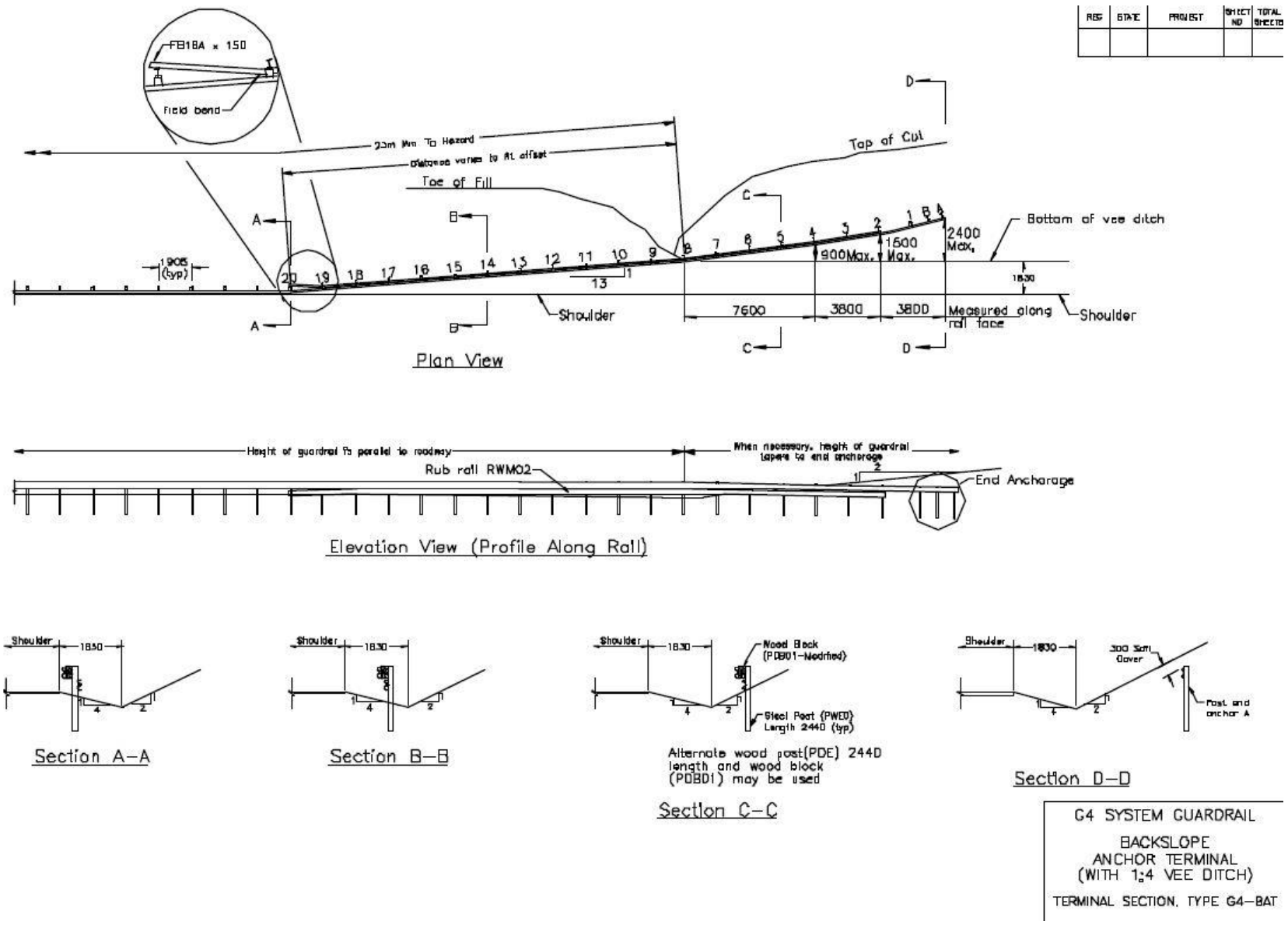
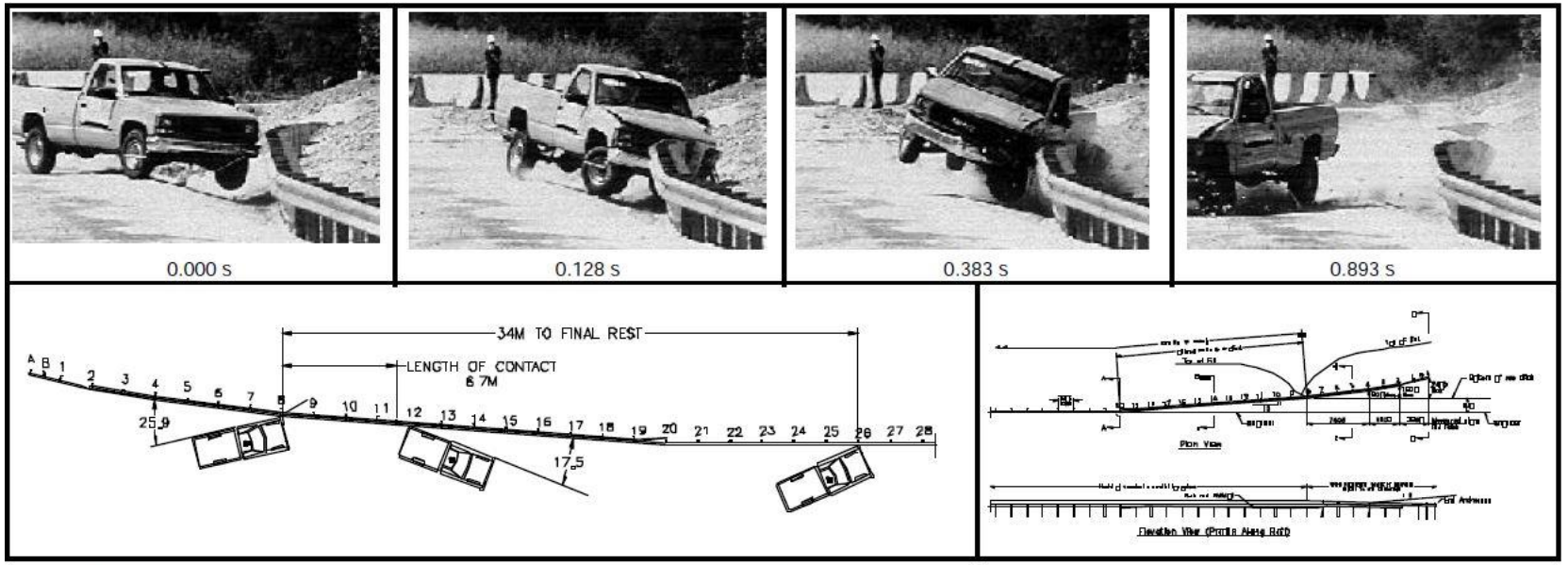


Figure 9. Buried-in-Backslope Terminal with 4:1 Slope Installation, Test No. 404211-13 [2]

Test no. 404211-13 was conducted according to NCHRP Report No.350 test designation no. 3-35. The 2000P vehicle impacted the system at post no. 8, corresponding to the beginning of the Length of Need (LON). The vehicle was smoothly redirected and came to rest 111 ft – 6.6 in. downstream from impact, satisfying all NCHRP Report No. 350 evaluation criteria. The damage to the system was deemed moderate considering the deformation of both rails. The maximum dynamic deflection was 2.8 ft and the permanent set for the rubrail and top rail were 17½ and 27⅜ in., respectively. The system damage is shown in Figure 10. The test report summary page is shown in Figure 11. Test no. 404211-13 was determined to be successful according to NCHRP Report No. 350 test designation no. 3-35.



Figure 10. Buried-in-Backslope Terminal with 4:1 Slope, System Damage, Test No. 404211-13 [2]



General Information

Test Agency	Texas Transportation Institute
Test No.	404211-13
Date	07/27/00

Test Article

Type	Terminal
Name	Buried-in-Backslope w/4 to 1 slope
Installation Length (m)	38.2
Material or Key Elements	W-beam Guardrail on Steel posts w/wood blockouts, Rubrail, 4 to 1 Slope
Soil Type and Condition	Standard Soil, Dry

Test Vehicle

Type	Production
Designation	2000P
Model	1995 GMC 2500 Pickup Truck
Mass (kg)	
Curb	2107
Test Inertial	2000
Dummy	75
Gross Static	2075

Impact Conditions

Speed (km/h)	101.1
Angle (deg)	25.9

Exit Conditions

Speed (km/h)	65.0
Angle (deg)	17.5

Occupant Risk Values

Impact Velocity (m/s)	
x-direction	5.4
y-direction	6.5
THIV (km/h)	28.5
Ridedown Accelerations (g's)	
x-direction	-8.3
y-direction	7.9
PHD (g's)	10.9
ASI	0.99
Max. 0.050-s Average (g's)	
x-direction	-6.5
y-direction	7.7
z-direction	-4.7

Test Article Deflections (m)

Dynamic	0.861
Permanent	0.695
Working Width	1.087

Vehicle Damage

Exterior	
VDS	11LFQ4
CDC	11FLEK2 &11LYEW3
Maximum Exterior Vehicle Crush (mm)	550
Interior	
OCDI	LF0102000
Max. Occ. Compart. Deformation (mm)	125

Post-Impact Behavior (during 1.0 s after impact)

Max. Yaw Angle (deg)	43
Max. Pitch Angle (deg)	7
Max. Roll Angle (deg)	-18

Figure 11. Evaluation Summary of Buried-in-Backslope Terminal with 4:1 Slope, Test No. 404211-13 [2]

2.1.3 Testing and Evaluation of W-beam Buried-in-Backslope with Ditch (1999)

Following the successful performance of the BIB system in a 6:1 V-ditch, TTI evaluated alternative anchorage options for a W-beam BIB system [4]. The anchor block was buried with 11.8 in. minimum cover which transitioned into a V-ditch with a $70^{13}/_{16}$-in. wide, 10:1 foreslope and a 35½-in. flat ditch followed by a 2:1 backslope. The BIB system utilized W-beam guardrail and strong steel posts. The guardrail was flared at 8:1 between post nos. 1 through 6 and 13:1 between post nos. 6 through 22. Beginning at post no. 22, the guardrail was parallel to the travel way and extended for 100 ft. The height of the upper rail was 27⅞ in. measured from the shoulder grade and held constant throughout the system. The BIB end treatment included standard W-beams connected to W6x8.5 steel posts using wood blockouts and ⅝-in. dia. button-head bolts. All posts were spaced 75 in. on center. An RWE02 terminal connector was used in this installation to connect the W-beam to the concrete anchor block. Four M24 x 50 galvanized hex head cap screws were used to connect the terminal connector to the concrete block anchor. The connector was spliced to the W-beam with eight ⅝-in. diameter bolts, and the rubrail was centered 13¾ in. below the center of the W-beam. The BIB system was flared 13:1 through the ditch, with the bottom of the ditch located between post nos. 8 and 9. The system installation is shown in Figure 12.

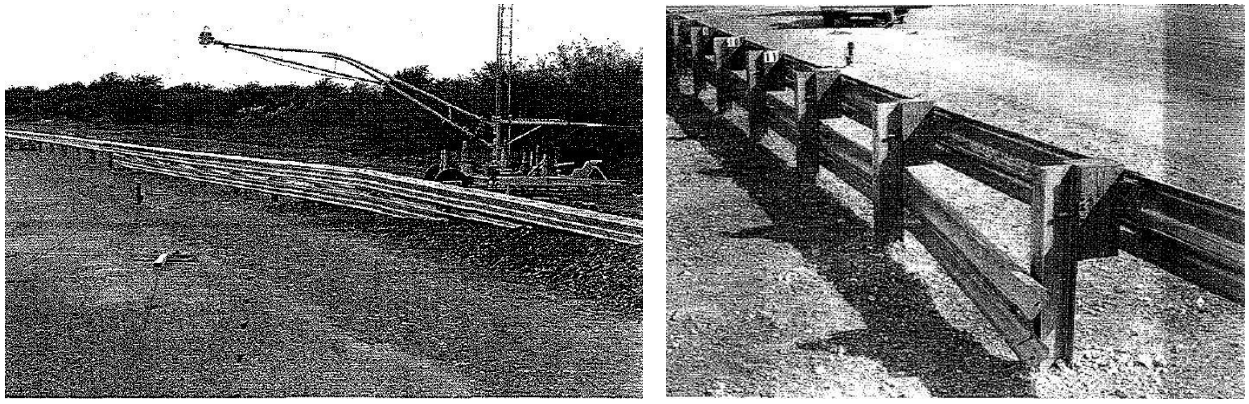


Figure 12. BIB Terminal with Ditch Guardrail Installation, Test No. 405521-1 [4]

Test no. 405521-1, was conducted according to NCHRP Report No. 350 test designation no. 3-35. A Chevrolet 2500 pickup truck impacted the system at a speed of 61 mph and an impact angle of 21.3 degrees to the tangent section of the guardrail, approximately 7 in. upstream from post no. 8. The vehicle was smoothly contained and redirected and came to a controlled stop 173 ft – 10 in. downstream from the point of impact. Test no. 405521-1 was successful according to NCHRP Report No. 350 criteria for test designation no. 3-35. The vehicle's length of contact with the guardrail elements was 20 ft. The system was damaged between post nos. 7 through 12. The maximum post deflection of 19⅝ in. occurred at post no. 7. The system damage is shown in Figure 13 and a summary of the test results is shown in Figure 14.

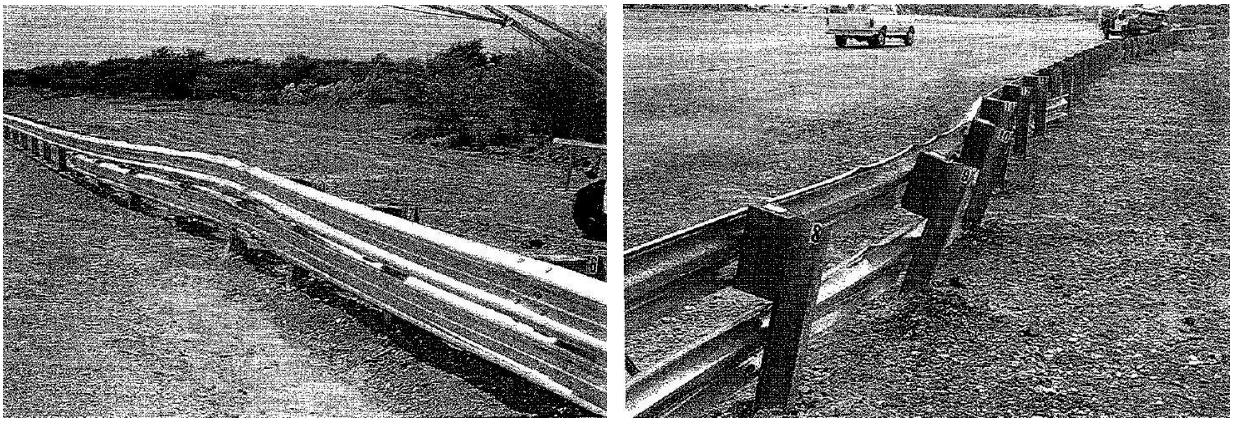
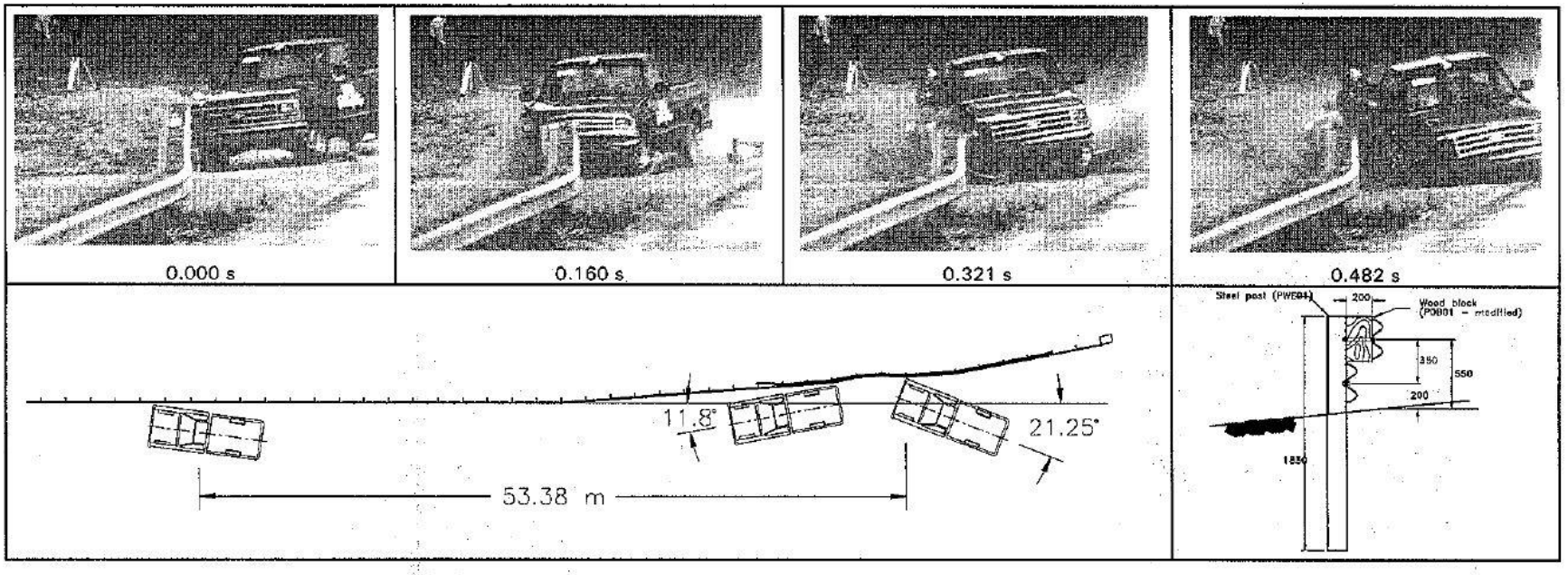


Figure 13. Buried-in-Backslope Terminal Damage, Test No. 405521-1 [4]



General Information
- Test Agency . . . . . Texas Transportation Institute
- Test No. 405521-1
- Date 10/03/96

Test Article
- Type . . . . . Terminal
- Name . . . . . W-beam Buried-in-backslope
- Installation Length (m) 114.3
- Size and/or dimension and material of key elements . . . . . W-beam guardrail on steel posts w/wood blockouts, rubrail, ditch
- Soil Type and Condition . . . . . Standard soil, dry

Test Vehicle
- Type . . . . . Production
- Designation 2000P
- Model . . . . . 1991 Chevrolet 2500 pickup
- Mass (kg) Curb 1947
- Test Inertial 2000
- Dummy 76
- Gross Static 2076

Impact Conditions
- Speed (km/h) 98.12
- Angle (deg) 21.25

Exit Conditions
- Speed (km/h) 72.31
- Angle (deg) 11.80

Occupant Risk Values
- Impact Velocity (m/s)
  - x-direction 7.41
  - y-direction 5.85
- Ridedown Accelerations (g's)
  - x-direction . . . . . -5.59
  - y-direction . . . . . -8.92
- Max. 0.050-s Average (g's)
  - x-direction . . . . . -6.08
  - y-direction . . . . . -7.54
  - z-direction . . . . . -3.12

Test Article Deflections (m)
- Dynamic 0.75
- Permanent 0.24

Vehicle Damage
- Exterior
  - VDS 01RFQ5
  - CDC 01FREW3
- Maximum Exterior Vehicle Crush (mm) 500
- Interior
  - OCDI RF0103000
- Max. Occ. Compart. Deformation (mm) 66

Post-Impact Behavior (during 1.0 s after impact)
- Max. Roll Angle (deg) . . . . . -29.44
- Max. Pitch Angle (deg) . . . . -5.94
- Max. Yaw Angle (deg) . . . . -35.11

Figure 14. Summary of Results for Test No. 405521-1 [4]

2.1.4 Testing of W-beam Buried-in-Backslope with Drop Inlet (1999)

A system involving a drop inlet instead of a V-ditch was also evaluated by TTI [4]. The system consisted of standard W-beam guardrail flared across the ditch with the end anchored to a BIB concrete block. The guardrail between post nos. 1 through 6 was flared at 8:1, and the rail between post nos. 6 through 22 was flared at 13:1. The top of the guardrail between post nos. 1 through 6 was tapered from 27⅞ in., measured from the shoulder grade at post no. 6, to 9½ in. at the concrete block for the end treatment with the drop inlet. The guardrail beginning at post no. 22 was parallel to the travel way, and extended for 100 ft. The top of the rail was 27¾ in. high measured from the shoulder grade. Posts were spaced at 75 in. on center. The BIB concrete anchor block was attached to the rail using a terminal connector. The rubrail spanned from post nos. 2 through 14, with the downstream end of the rubrail connected to the back of the flange of post no. 14.

For the drop inlet configuration, the ditch was graded at a 10:1 slope for 8 ft – 10 in. after which the 2:1 backslope began. The BIB concrete block was anchored with a 11.8-in. minimum cover. The system installation is shown in Figure 15 and the system layout is shown in Figure 16.

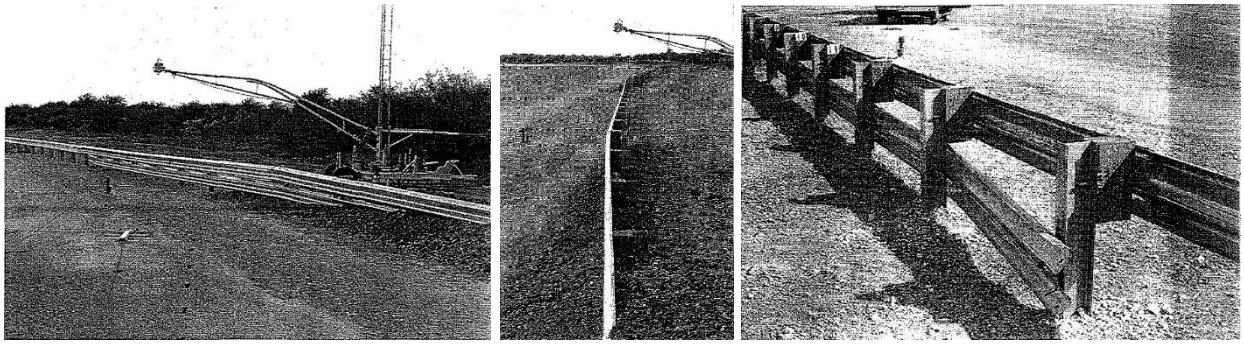


Figure 15. W-beam Buried-in-Backslope with Drop Inlet Installation, Test No. 405521-2 [4]

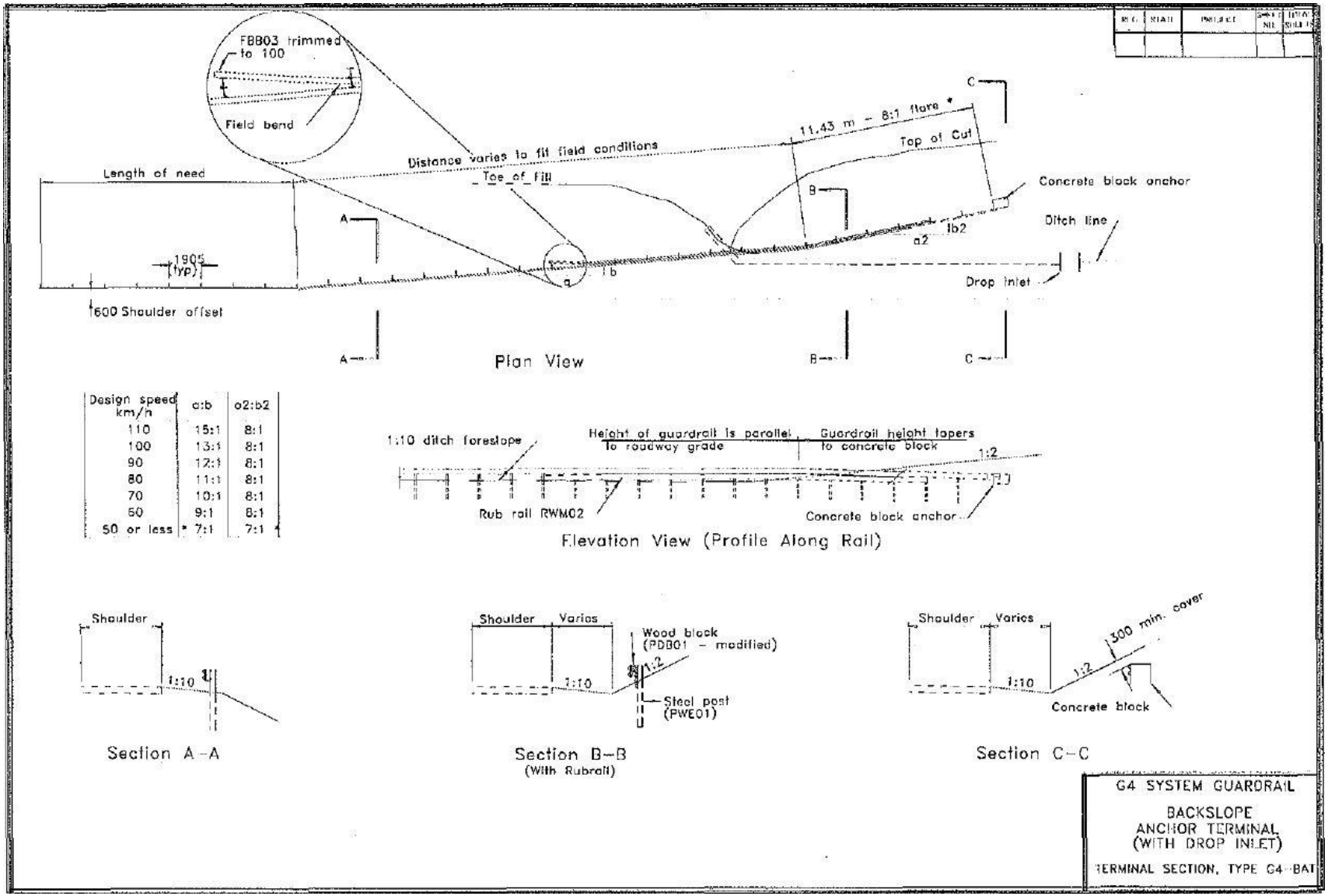


Figure 16. W-beam Buried-in-Backslope with Drop Inlet Schematics, Test No. 405521-2 [4]

Test no. 405521-2 was conducted according to NCHRP Report No. 350 test designation no. 3-35. A Chevrolet 2500 pickup truck impacted the system at a speed of 60.3 mph and an angle of 22 degrees at post no. 8. The vehicle was smoothly redirected and came to rest 137 ft – 9½ in. downstream from the point of impact. Test no. 405521-2 was successful according to NCHRP Report No. 350 criteria for test designation no. 3-35. The length of vehicle contact with the system was approximately 24 ft – 3⅜ in. The maximum dynamic deflection of the W-beam rail was 2 ft – 7½ in. between post nos. 9 through 10. The maximum permanent deformation of the rail elements was 1 ft – 7½ in. at post no. 9. The system damage is shown in Figure 17 and a test summary is shown in Figure 18.

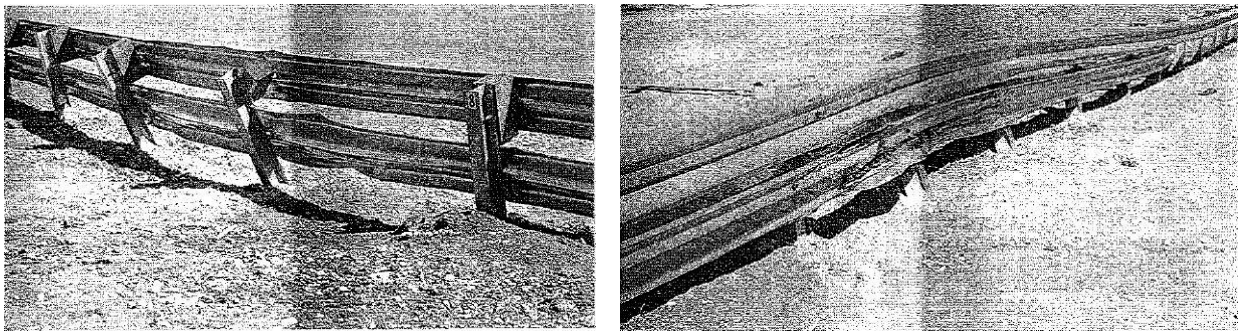
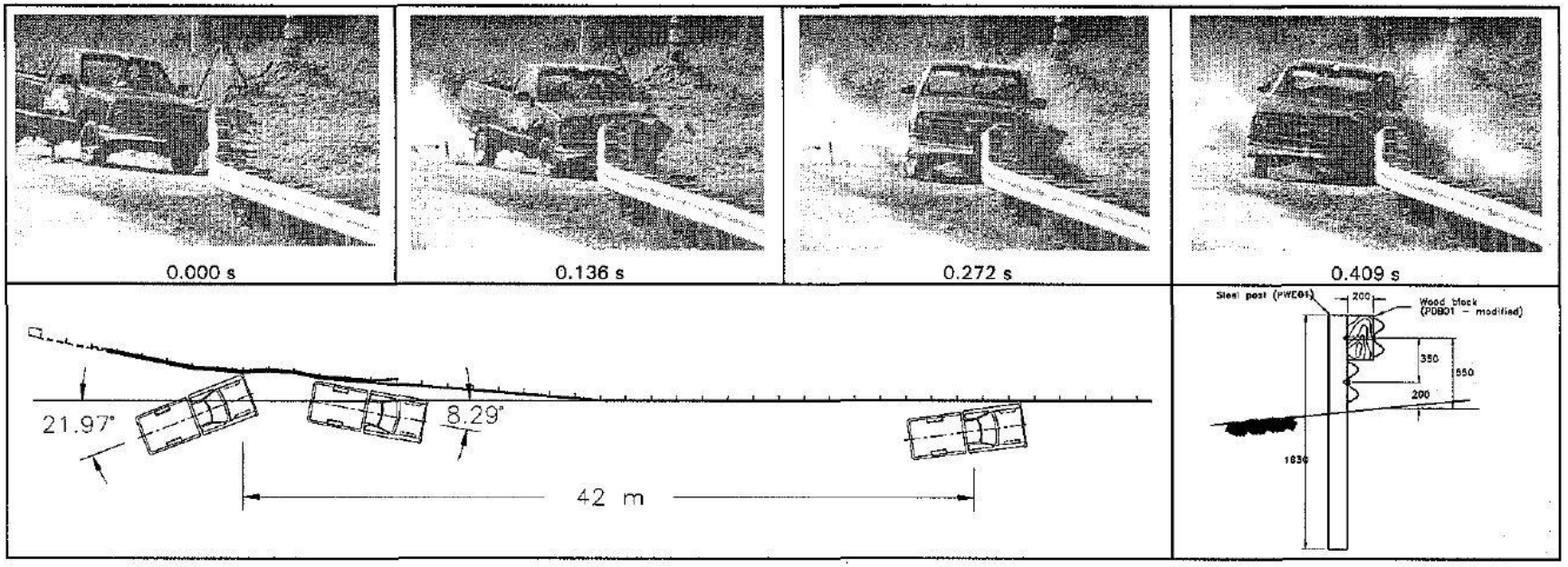


Figure 17. W-beam Buried-in-Backslope with Drop Inlet, Guardrail Damage, Test No. 405521-2 [4]



General Information
- Test Agency . . . . . Texas Transportation Institute
- Test No. 405521-2
- Date 10/03/96

Test Article
- Type . . . . . Terminal
- Name . . . . . W-beam Buried in backslope
- Installation Length (m) 114.3
- Size and/or dimension and material of key elements . . . . . W-beam guardrail on steel posts w/wood blockouts, rubrail, drop inlet

Soil Type and Condition . . . . . Standard soil, dry

Test Vehicle
- Type . . . . . Production
- Designation 2000P
- Model . . . . . 1990 Chevrolet 2500 pickup
- Mass (kg) Curb 1955
- Test Inertial 2000
- Dummy 76
- Gross Static 2076

Impact Conditions
- Speed (km/h) 97.00
- Angle (deg) 21.97

Exit Conditions
- Speed (km/h) 61.71
- Angle (deg) 8.29

Occupant Risk Values
- Impact Velocity (m/s)
  - x-direction 7.73
  - y-direction 5.53
- Ridedown Accelerations (g's)
  - x-direction . . . . . -7.56
  - y-direction 7.27
- Max. 0.050-s Average (g's)
  - x-direction . . . . . -5.97
  - y-direction 6.17
  - z-direction . . . . . -5.21

Test Article Deflections (m)
- Dynamic 0.80
- Permanent 0.50

Vehicle Damage
- Exterior
  - VDS 01LFQ5
  - CDC 01FLEW3
- Maximum Exterior
  - Vehicle Crush (mm) 600
- Interior
  - OCDI LF0100000
- Max. Occ. Compart. Deformation (mm) 33

Post-Impact Behavior (during 1.0 s after impact)
- Max. Roll Angle (deg) 41.30
- Max. Pitch Angle (deg) . . . . -4.68
- Max. Yaw Angle (deg) 36.74

Figure 18. Summary of Results, Test No. 405521-2 [4]

2.1.5 Buried-in-Backslope Terminal with MGS (2018)

In 2018, TTI redesigned the BIB terminal using standardMGS [5]. The installation consisted of a tangent MGS guardrail system connected to a flared, BIB terminal with a constant 31-in. top mounting height relative to the roadway between post nos. 10 through 40. The V-ditch had a 72-in. wide, 4:1 foreslope that initiated from the edge of the pavement, and a 2:1 backslope with a maximum height of 66 in. measured from the bottom of the ditch. The bottom of the ditch crossed the rail terminal between post nos. 9 and 10. The upstream end of the system was designed by the Texas Department of Transportation (TxDOT). The guardrail was flared across a V-ditch, while the end was anchored to three 72-in. long steel posts. Post nos. 1 through 3 were spaced at 37½ in. on center while all other posts were spaced at 75-in. on center. W-beam guardrail was attached to 72-in. long W6x8.5 posts and 6-in. x 8-in. timber blockouts using 10-in. long, ⅝-in. diameter guardrail bolts.

The BIB system incorporated three flare rates. At the downstream end of the rubrail, the guardrail was flared at a 13:1 rate between post nos. 10 through 22. The rail was flared at an 8:1 rate between post nos. 6 through 10, and a 6:1 rate between post nos. 4 through 6. The rail was terminated at post nos. 1 through 4 with a 4:1 flare rate. The system sloped downward starting at post no. 10. Post nos. 5 and 6 were partially buried in the backslope and post nos. 1 through 4 were fully buried in backslope. The system layout is shown in Figure 19 and the system installation is shown in Figure 20.

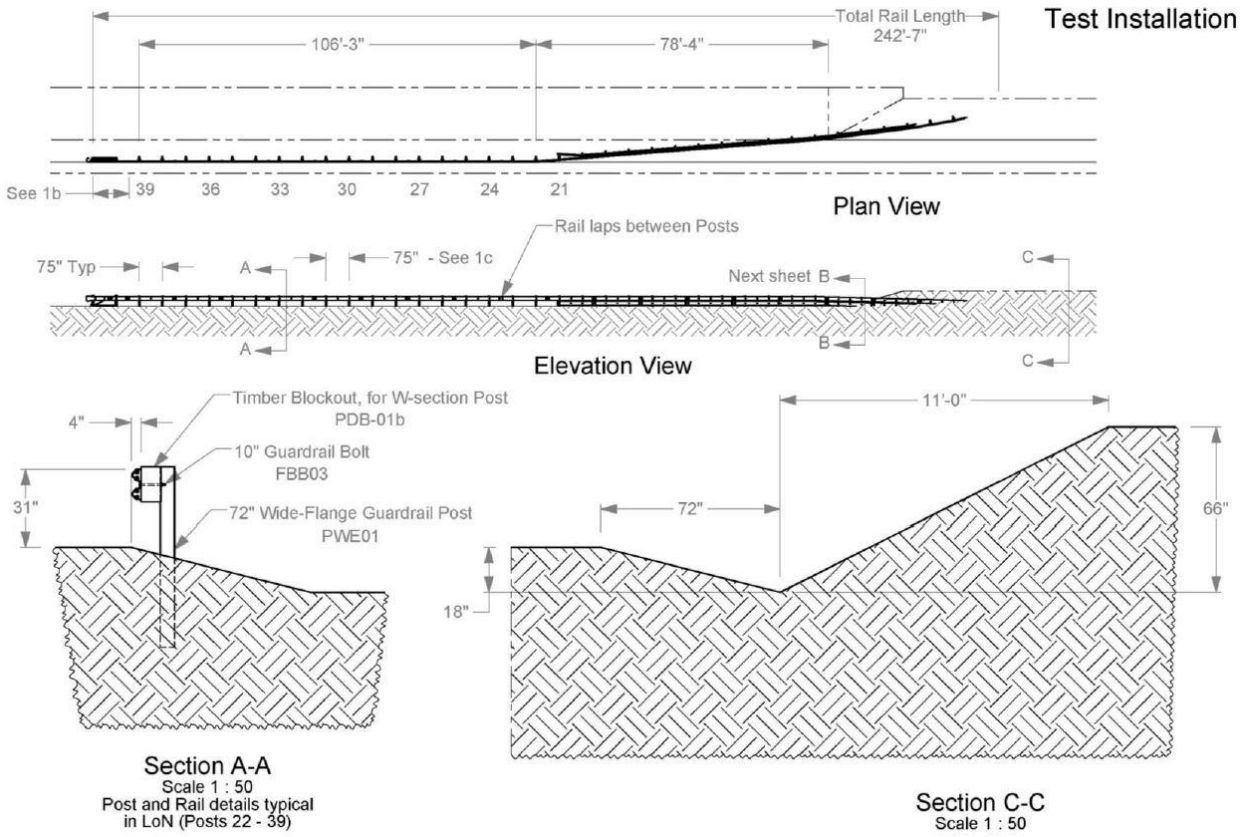


Figure 19. 31-in. Tall BIB Terminal with MGS Layout [5]

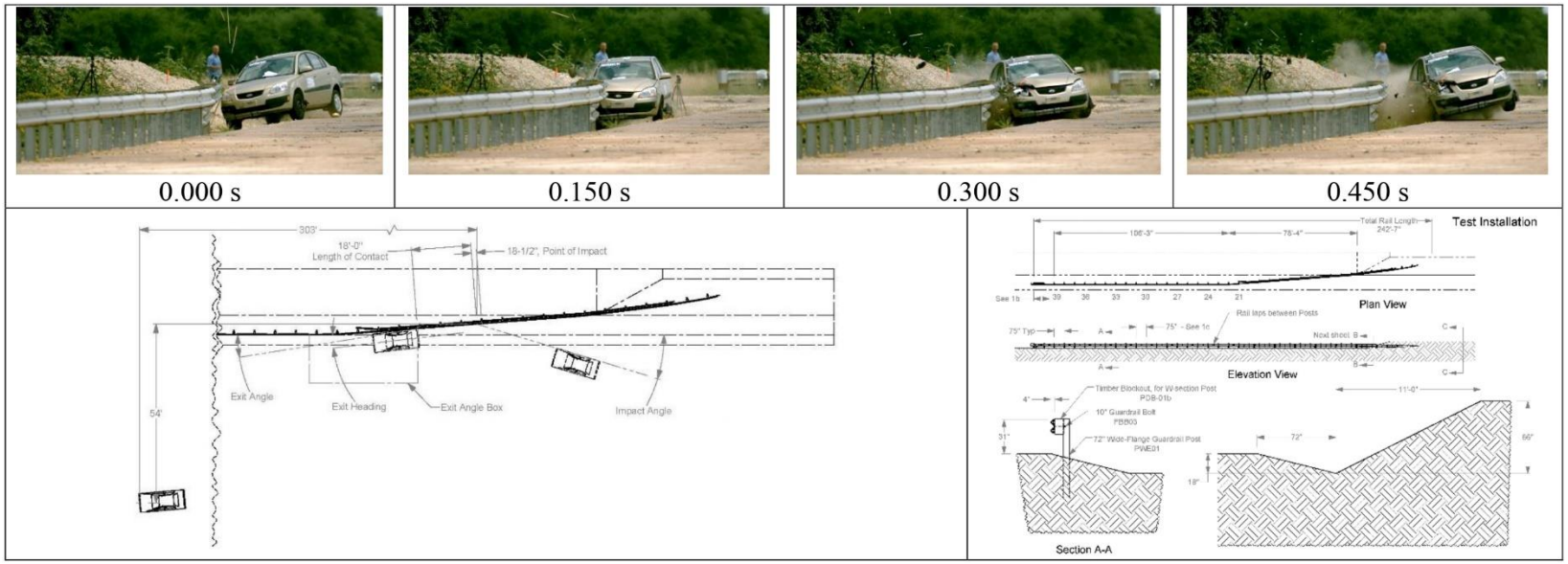


Figure 20. Pre-test Photographs, Test No. 608431-01-2 [5]

Test no. 608431-01-2 was conducted according to MASH test designation no. 3-34. The 1100C test vehicle impacted the system 18½ in. downstream from post no. 9, corresponding to the beginning of LON of the terminal, at a speed of 64.1 mph and the angle of 14.5 degrees. Due to the vehicle's interaction with the slope as it traveled into the ditch, the actual impact angle was 17.8 degrees to the roadway and 24.9 degrees with respect to the travel tangent line. The vehicle was smoothly redirected by the system and came to rest 303 ft downstream from the impact point and 45 ft toward traffic. Damage to the test article was limited, consisting of bent and deformed posts, flattened W-beam guardrail, and posts and blockouts that disengaged from the rail. The maximum dynamic deflection was $19^{15}/_{16}$ in. at post no. 9, and the maximum plastic deformation was 5½ in at post no. 10. Post-test damage photographs are shown in Figure 21. The performance of the BIB system with MGS was determined to be successful according to MASH test designation no. 3-34. A summary of the test results is shown in Figure 22.



Figure 21. Installation Damage, Test No. 608431-01-2 [5]



General Information
- Test Agency ..... Texas A&M Transportation Institute (TTI)
- Test Standard Test No. ..... MASH Test 3-34
- TTI Test No. 608431-01-2
- Test Date 2018-06-01

Test Article
- Type ..... Terminal
- Name ..... Buried-in-Backslope Terminal
- Installation Length ..... 242 ft 7 inches
- Material or Key Elements ... W-Beam Terminal flared back at 4 different angles, for total setback of 14 ft, 31-inch rail height to the paved road; splices between posts; 4:1 foreslope; 2:1 backslope; W-beam rubrail
- **Soil Type and Condition** ..... AASHTO M147-65(2004), grading B Soil (crushed limestone), Damp

Test Vehicle
- Type/Designation 1100C
- Make and Model ..... 2009 Kia Rio
- Curb ..... 2475 lb
- Test Inertial ..... 2427 lb
- Dummy ..... 165 lb
- Gross Static ..... 2592 lb

Impact Conditions
- Speed ..... 64.1 mi/h
- Angle* ..... 14.5° / 17.8° / 24.9°
- Location/Orientation ..... 18.5 inches dwnstrm of post 9
- **Impact Severity**** ..... 31 kip-ft / 59 kip-ft

Exit Conditions
- Speed ..... 49.9 mi/h
- Exit Trajectory Angle ..... 9.1°
- Exit Heading Angle ..... 6.7°

Occupant Risk Values
- Longitudinal OIV ..... 14.1 ft/s
- Lateral OIV ..... 20.3 ft/s
- Longitudinal Ridedown ..... 7.5 g
- Lateral Ridedown ..... 8.5 g
- THIV ..... 26.0 km/h
- PHD ..... 10.3 g
- ASI 0.96

Max. 0.050-s Average
- Longitudinal ..... -5.7 g
- Lateral ..... -7.4 g
- Vertical ..... -2.8 g

Post-Impact Trajectory
- Stopping Distance ..... 303 ft downstream 54 ft toward traffic

Vehicle Stability
- Maximum Yaw Angle ..... 44°
- Maximum Pitch Angle ..... 6°
- Maximum Roll Angle ..... 17°
- Vehicle Snagging ..... No
- Vehicle Pocketing ..... No

Test Article Deflections
- Dynamic ..... 19.9 inches
- Permanent ..... 5.5 inches
- Working Width ..... 25.3 inches
- Height of Working Width ..... 32.0 inches

Vehicle Damage
- VDS 01RFQ4
- CDC 01FREW4
- Max. Exterior Deformation ..... 8.0 inches
- OCDI RS0000000
- Max. Occupant Compartment Deformation ..... None

Figure 22. 31-in. Buried-in-Backslope Terminal Results Summary, Test No. 608431-01-2 [5]

A second full-scale crash was conducted according to MASH TL-3 test designation no. 3-35 [5]. Test no. 608431-01-1 evaluated the system's robustness at the beginning of the LON, which was determined to be 19 in. downstream from post no. 9, corresponding to the point where the system crossed the bottom of the V-ditch. The system and the point of impact are shown in Figure 23.

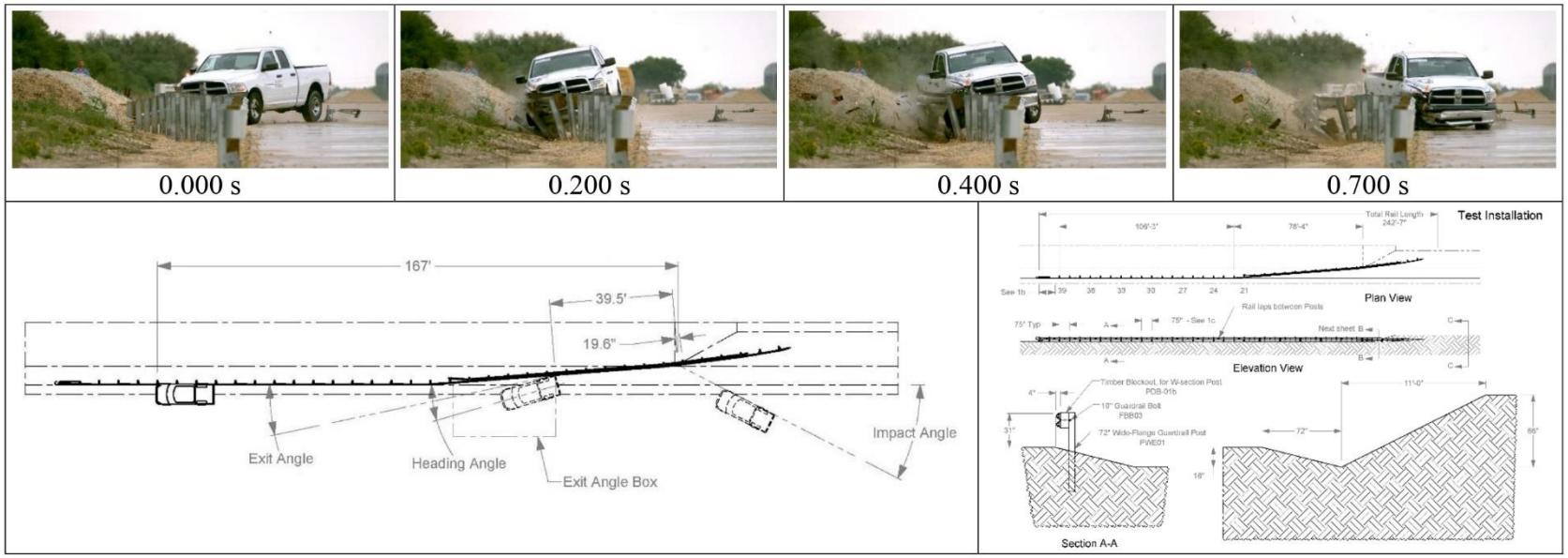


Figure 23. Impact Location for Test No. 608431-01-1 [5]

A 2012 RAM 1500 pickup impacted the system 19⅝ in. downstream from post no. 9 at a speed of 63.3 mph and an angle of 25.4 degrees. Due to the vehicle's interaction with the slope as it traveled into the ditch, the actual impact angle was 27.2 degrees to the roadway and 34.3 degrees with respect to the travel tangent line. The vehicle was smoothly contained and redirected and came to rest 167 ft downstream from the impact point. During impact, a 4½-in. tear occurred in the rubrail at the splice between post nos. 11 and 12. The upper and lower W-beam rails detached from post nos. 12 through 15. The maximum dynamic and permanent deflections of the system were both $51^{7}/_{16}$ in. Overall system damage is shown in Figure 24. Test no. 608431-01-1 was deemed successful and all MASH TL-3 safety criteria for test designation no. 3-35 were satisfied. A summary of the test results is shown in Figure 25.



Figure 24. Installation Damage, Test No. 608431-01-1 [5]



General Information
- Test Agency ..... Texas A&M Transportation Institute (TTI)
- Test Standard Test No. ..... MASH Test 3-35
- TTI Test No. 608431-01-1
- Test Date 2018-04-30

Test Article
- Type ..... Terminal
- Name ..... Buried-in-Backslope Terminal
- Installation Length ..... 242 ft 7 inches
- Material or Key Elements ... W-Beam Terminal flared back at 4 different angles, for total setback of 14 ft, 31-inch rail height to the paved road; splice between posts; 4:1 foreslope; 2:1 backslope; W-beam rubrail
- **Soil Type and Condition** ..... AASHTO M147-65(2004), grading B Soil (crushed limestone), Damp

Test Vehicle
- Type/Designation 2270P
- Make and Model ..... 2012 Dodge RAM 1500 Pickup
- Curb ..... 4968 lb
- Test Inertial ..... 5035 lb
- Dummy ..... 165 lb
- Gross Static ..... 5200 lb

Impact Conditions
- Speed ..... 63.3 mi/h
- Angle* ..... 25.4° / 27.2° / 34.3°
- Location/Orientation ..... 19.6 inches dwnstrm of post 9
- **Impact Severity**** ..... 141 kip-ft / 214 kip-ft

Exit Conditions
- Speed ..... 36.0 mi/h
- Angle ..... 11.8°

Occupant Risk Values
- Longitudinal OIV ..... 17.4 ft/s
- Lateral OIV ..... 16.4 ft/s
- Longitudinal Ridedown ..... 5.4 g
- Lateral Ridedown ..... 8.8 g
- THIV ..... 24.8 km/h
- PHD ..... 9.2 g
- ASI 0.83
- Max. 0.050-s Average
  - Longitudinal ..... −5.3 g
  - Lateral ..... −7.0 g
  - Vertical ..... 2.4 g

Post-Impact Trajectory
- Stopping Distance ..... 167 ft dwnstrm 3 ft twd traffic

Vehicle Stability
- Maximum Yaw Angle ..... 36°
- Maximum Pitch Angle ..... 3°
- Maximum Roll Angle ..... 6°
- Vehicle Snagging ..... No
- Vehicle Pocketing ..... No

Test Article Deflections
- Dynamic ..... 51.4 inches
- Permanent ..... 51.4 inches
- Working Width ..... 62.7 inches
- Height of Working Width ..... 54.7 inches

Vehicle Damage
- VDS 01RFQ5
- CDC 01FREW4
- Max. Exterior Deformation ..... 10.0 inches
- OCDI RF000000
- Max. Occupant Compartment Deformation ..... None

Figure 25. Summary of 31-in. Buried-in-Backslope Terminal Results, Test No. 608431-01-1 [5]

2.1.6 Discussion

The majority of BIB W-beam end terminal designs were evaluated to NCHRP Report No. 350 impact criteria and included a rubrail attached to historic G4(1S) strong, steel-post W-beam guardrail. Impact conditions utilized with the BIB system were generally consistent with NCHRP Report No. 350 test designations 3-33 and 3-34, or MASH test designations 3-33 or 3-34 [5].

To date, no impacts have been evaluated near the upstream end anchorage (i.e., upstream from post no. 8). Little is known regarding potential vulnerabilities of the system when impacts occur very close to the end anchorage. Additionally, the system has not been evaluated in any reverse-direction impacts, although the BIB system is considered a terminal system and should be evaluated according to MASH TL-3 test designation nos. 3-30 through 3-37. Therefore, it is not recommended to utilize the BiB in locations where reverse-direction impacts could occur; this includes locations within the clear zones of opposing travel lanes as well as using BiB terminals for trailing end installations

2.2 W-beam-to-Bridge Rail Transitions

The HDOT BIB system includes an upper W-beam guardrail and lower W-beam rubrail attached to an embedded anchor block. Given the similarities, crash testing of W-beam-to-bridge rail transitions were of interest.

2.2.1 Vertical Wall Transition – Test 2 (1998)

The crashworthiness of a vertical wall transition was tested by TTI according to NCHRP Report 350 test designation no. 3-21 [2]. The system consisted of standard W-beam guardrail with steel posts and wood blockouts transitioned over a length of 12 ft – 5½ in. to a concrete parapet wall. The vertical center of the nested W-beam was 21⅝ in. above the ground.

The system utilized a reinforced concrete parapet wall with a spread footing at the upstream end of the system that had a total height of 31⅞ in. from the roadway surface. The block was tapered from a vertical face at the rail transition to a bridge rail over 10 ft – $5^{15}/_{16}$ in. The top of the spread footing was $17^{11}/_{16}$ in. below the roadway surface and was 35½ in. deep. A 94½-in. long by $31^{15}/_{16}$-in. high F-shape simulated bridge rail was constructed adjacent to the parapet wall. The height of the concrete parapet was 31⅞ in. measured from the ground. Both the upper W-beam guardrail and lower W-beam rubrail were nested and connected to the concrete parapet wall using eight standard guardrail connector bolts. Four M22 x 250 mm high strength hex bolts and a standard bearing plate terminal connector were used to attach the end connector to the parapet wall.

The rubrail center was mounted 7½ in. above the surface of the ground. The upper W-beam rail and rubrail were connected to post no. 4 using a guardrail bolt with a rectangular plate washer under the bolt head and a steel washer under the recess nut; post nos. 1, 2, 3, 5, and 7 were not connected to the upper or lower W-beam rails. The post spacing between the parapet wall, post nos. 1, 2, 3, and 4 was $18^{11}/_{16}$ in., and the spacing for post nos. 4, 5, 6, 7, and 8 was 37½ in. For the standard section of the rail, the post spacing was 75 in. Routed wood blockouts measuring 5⅛-in. x 7⅞-in. x 14¼-in. long were used behind the rail. The blockouts for the rubrail at post nos. 1

through 4 were tapered to allow the rubrail to be flush at the parapet wall and attached behind post no. 6. The system installation and layout are shown in Figures 26 and 27, respectively.



Figure 26. TL-2 W-beam Transition, Test No. 404211-2 [2]

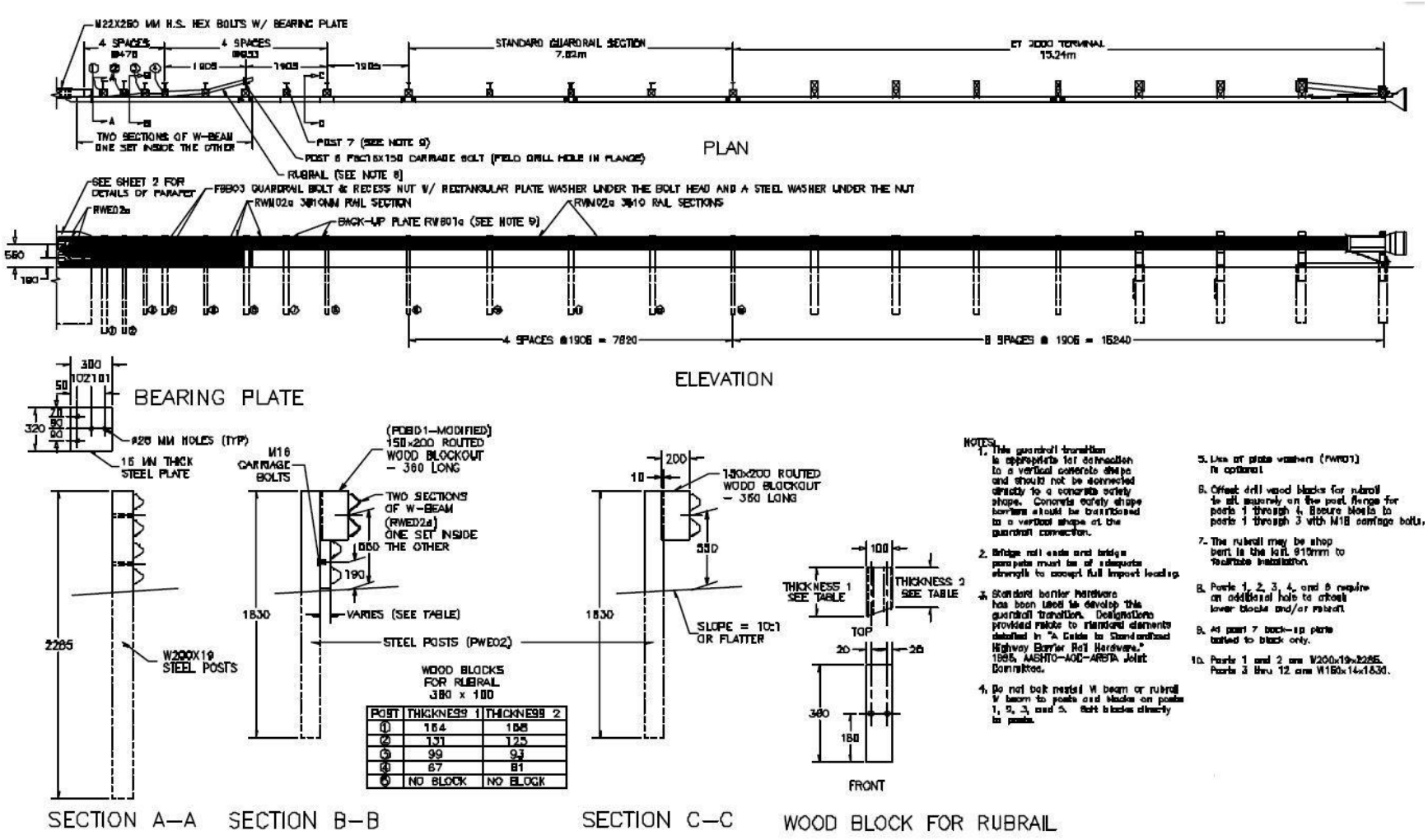


Figure 27. System Installation Details, Test No. 404211-2 [2]

BARRIER VII simulations were used to determine the CIP, which was 4 ft – 11 in. upstream from the end of the concrete parapet [2]. During test no. 404211-2, which was conducted according to NCHRP Report No. 350 test designation no. 3-21, the Chevrolet 2500 pickup truck impacted the system 4 ft – 11 in. upstream from the end of the bridge parapet at a speed of 60.6 mph and an angle of 25.5 degrees. The system contained and redirected the vehicle, however, the vehicle rolled, coming to rest 145 ft downstream from impact on its right side and 9 ft – 10 in. towards traffic. The W-beam's upper and lower rails were flattened near the point of impact and upstream from the parapet, as shown in Figure 28. The blockout on the upper rail at post no. 1 was split and disengaged from the post and the blockout on the upper rail at post no. 2 was gouged. The test was deemed unsuccessful due to vehicle rollover. The test vehicle snagged on the system resulting in vehicle rollover. A summary of the test results is shown in Figure 29.

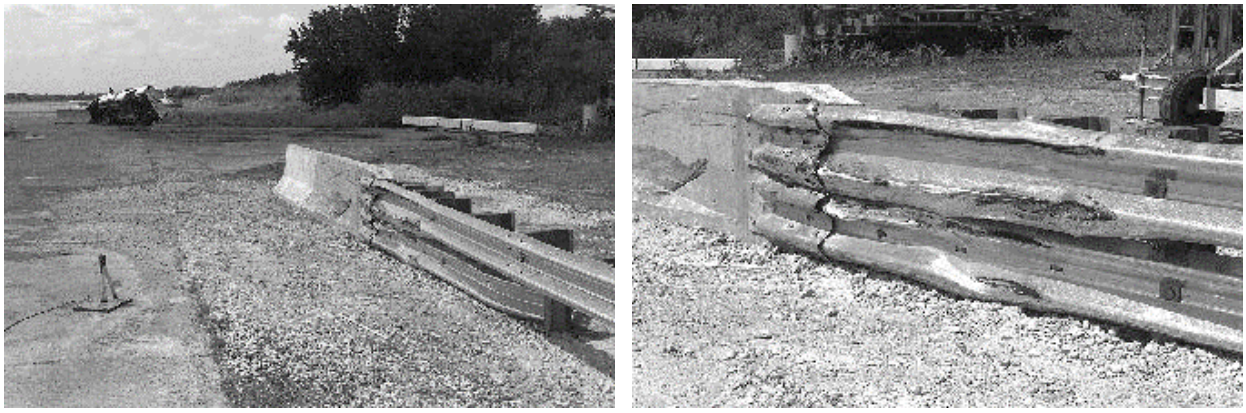
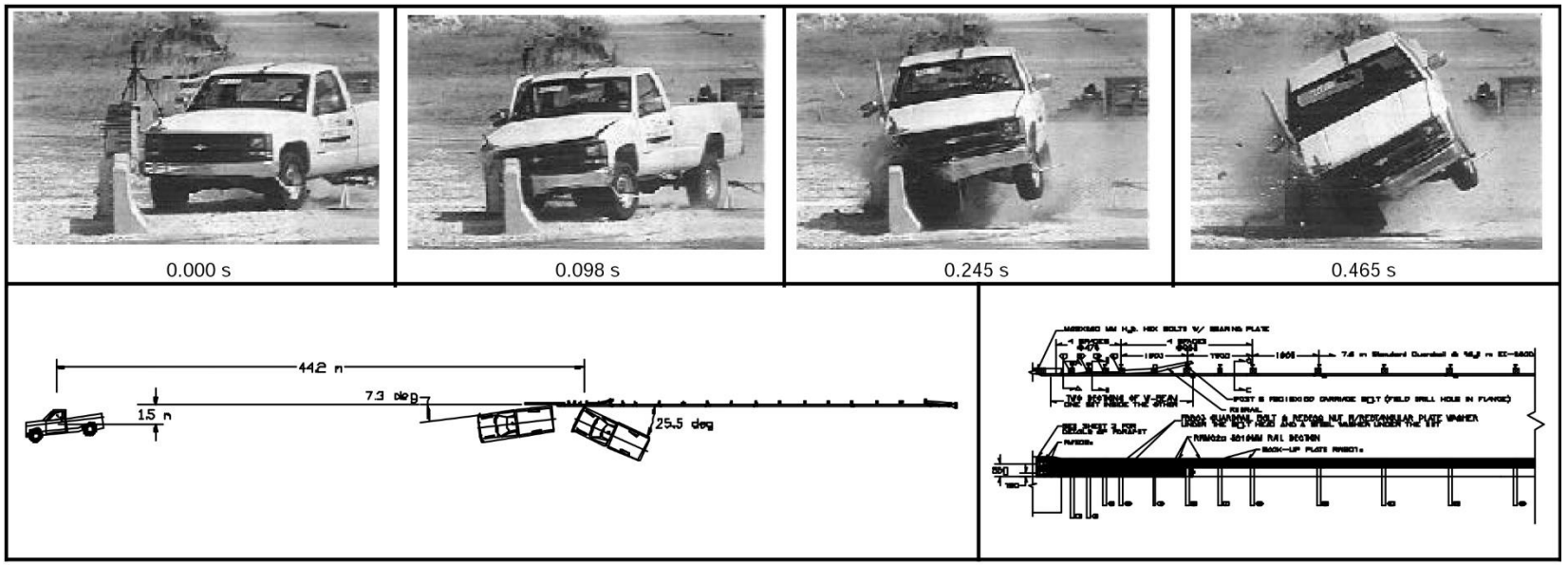


Figure 28. Installation Damage, Test No. 404211-2 [2]



General Information
- Test Agency . . . . . Texas Transportation Institute
- Test No. 404211-2
- Date 07/27/98

Test Article
- Type . . . . . Transition
- Name . . . . . Vertical Wall Transition
- Installation Length (m) 35.3
- Material or Key Elements . W-beam with W-beam Rub Rail & Steel Posts to Vertical Concrete Bridge Rail

Soil Type and Condition . Standard Soil, Dry

Test Vehicle
- Type . . . . . Production
- Designation 2000
- Model . . . . . 1995 Chevrolet Pickup Truck
- Mass (kg)
  - Curb 2056
  - Test Inertial 2000
  - Dummy 74
  - Gross Static 2074

Impact Conditions
- Speed (km/h) 97.5
- Angle (deg) 25.5

Exit Conditions
- Speed (km/h) 52.5
- Angle (deg) 7.3

Occupant Risk Values
- Impact Velocity (m/s)
  - x-direction 9.1
  - y-direction 7.8
- THIV (km/h) 38.6
- Ridedown Accelerations (g's)
  - x-direction . . . . . -15.1
  - y-direction 12.5
- PHD (g's) 14.8
- ASI 1.70
- Max. 0.050-s Average (g's)
  - x-direction . . . . . -12.1
  - y-direction . . . . . -13.3
  - z-direction 6.7

Test Article Deflections (m)
- Dynamic . . . . . N/A
- Permanent 0.09

Vehicle Damage
- Exterior
  - VDS 01RFQ5
  - CDC . . . . . 01FREK4 & 01RDEW4
- Maximum Exterior
  - Vehicle Crush (mm) 540
- Interior
  - OCDI FS0113000
- Max. Occ. Compart.
  - Deformation (mm) 97

Post-Impact Behavior
(during 1.0 s after impact)
- Max. Yaw Angle (deg) . . . . . -34
- Max. Pitch Angle (deg) . . . . . -9
- Max. Roll Angle (deg) 45

Figure 29. Summary of Test Results, Test No. 404211-2 [2]

2.2.2 W-beam Transition – Test 12 (1998)

Test no. 404211-12 was a re-test of test no. 404211-2. TTI modified the system to reduce the propensity for wheel snag and pocketing. The main reason for vehicle rollover during test no. 404211-2 was the vehicle snagging to the end connector. Therefore, this component installation and design were modified to prevent snagging. The end terminal connector was modified to fit while lapped under the W-beam. The terminal connector's holes were enlarged so splice bolts could be installed with the terminal connector lapped under the W-beam. The terminal connector was then bolted through holes in the parapet wall with four M22x250-mm high strength hex bolts with a standard terminal connector bearing plate on the back of the parapet wall. The modified transition is shown in Figure 30.

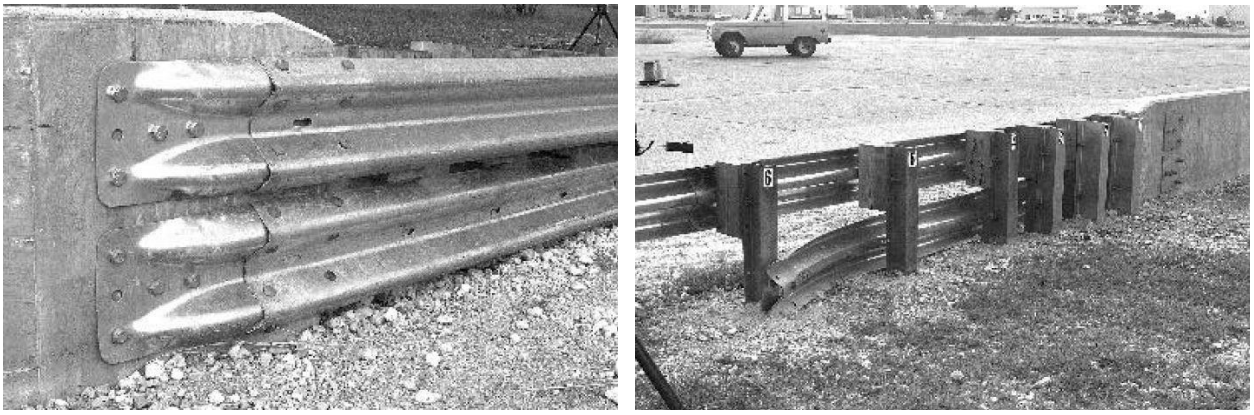


Figure 30. Modified Vertical Wall Transition End Connector, Test No. 404211-12 [2]

During test no. 404211-12, a 1994 Chevrolet 2500 pickup truck impacted the system at a speed of 62.9 mph and the angle of 24.2 degrees in accordance with NCHRP Report No. 350 test designation no. 3-21. The impact point was 63 in. upstream from the end of the vertical concrete parapet wall. The vehicle was smoothly redirected and came to rest 177 ft – 6 in. downstream from the impact point. The maximum deformation in the top rail and rubrail elements were 1 in. and ⅝ in., respectively. The installation damage was minimal, as shown in Figure 31. Test no. 404211-12 was determined to be successful according to NCHRP Report No. 350 test designation no. 3-21. The test summary is shown in Figure 32.

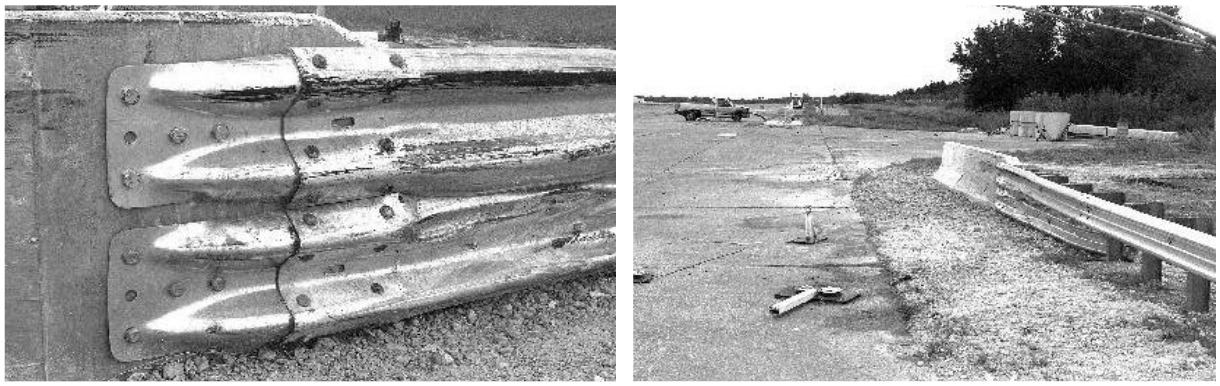
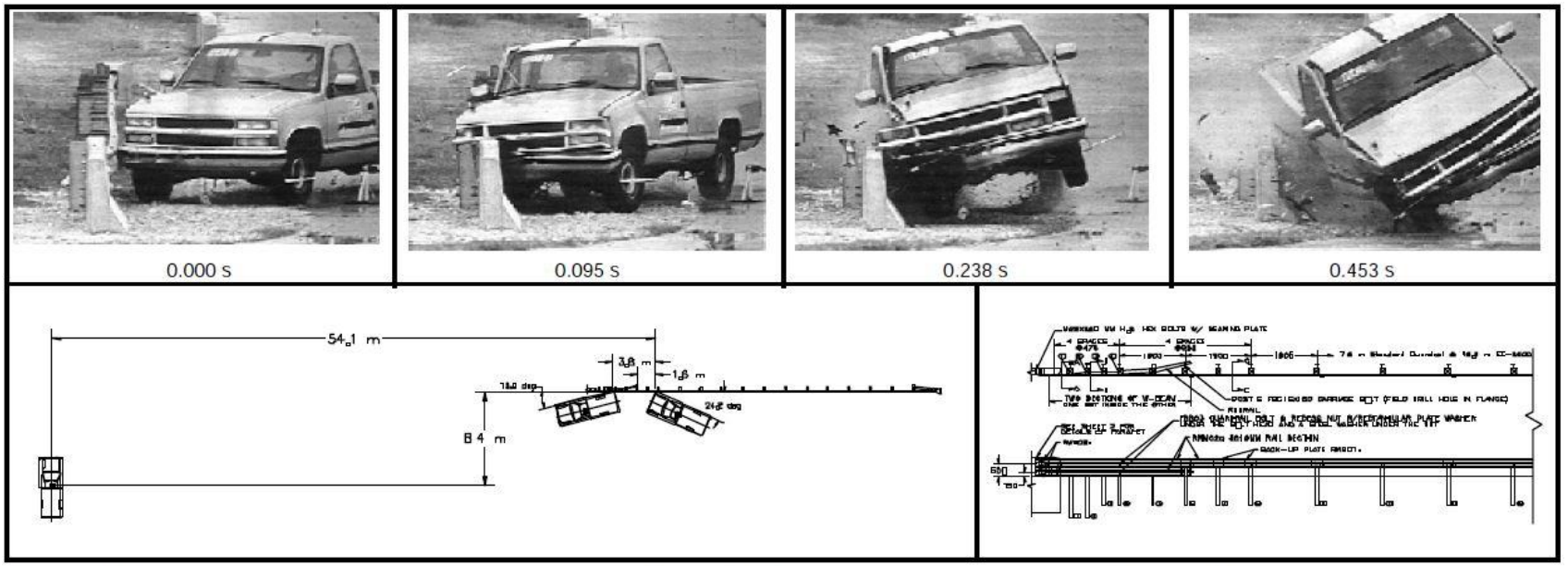


Figure 31. System Damage, Test No. 404211-12 [2]



General Information
- Test Agency ..... Texas Transportation Institute
- Test No. 404211-12
- Date 11/05/98

Test Article
- Type ..... Transition
- Name ..... Vertical Wall Transition
- Installation Length (m) 35.3
- Material or Key Elements . W-Beam With W-Beam Rub Rail & Steel Posts to Vertical Concrete Bridge Rail

Soil Type and Condition . Standard Soil, Damp

Test Vehicle
- Type ..... Production
- Designation 2000P
- Model ..... 1994 Chevrolet 2500 Pickup Truck
- Mass (kg)
  - Curb 1925
  - Test Inertial 2000
  - Dummy 77
  - Gross Static 2077

Impact Conditions
- Speed (km/h) 101.3
- Angle (deg) 24.2

Exit Conditions
- Speed (km/h) 73.3
- Angle (deg) 13.9

Occupant Risk Values
- Impact Velocity (m/s)
  - x-direction 7.3
  - y-direction 7.8
- THIV (km/h) 35.6
- Ridedown Accelerations (g's)
  - x-direction ..... -6.7
  - y-direction ..... -10.1
- PHD (g's) 10.6
- ASI 1.85
- Max. 0.050-s Average (g's)
  - x-direction ..... -10.9
  - y-direction ..... -13.9
  - z-direction ..... -9.5

Test Article Deflections (m)
- Dynamic 0.07
- Permanent 0.03

Vehicle Damage
- Exterior
  - VDS 01RFQ4
  - CDC ..... 01FYEK2 & 01RDEW3
- Maximum Exterior
  - Vehicle Crush (mm) 500
- Interior
  - OCDI RF0104000
- Max. Occ. Compart.
  - Deformation (mm) 90

Post-Impact Behavior
(during 1.0 s after impact)
- Max. Yaw Angle (deg) ..... -50
- Max. Pitch Angle (deg) 8
- Max. Roll Angle (deg) 25

Figure 32. Summary of Test Results, Test No. 404211-12 [2]

2.2.3 Stacked W-beam Transition for 31-in. Guardrail (2016)

A stacked W-beam transition was evaluated by TTI in 2016 [6] according to MASH test designation 3-21 safety criteria. The system consisted of standard 12-gauge W-beam mounted 31 in. above the ground level, which transitioned to an F-shape concrete parapet. The W-beam was nested starting from post no. 13 to the concrete parapet. The rubrail was positioned between the nested guardrail and the terrain level at the centerline elevation of 10⅞ in. above grade and was also nested from post no. 13 to the concrete parapet. The terminal connector was then bolted through formed holes in the parapet wall with four M22x250 mm high strength hex bolts with a standard FPB02 terminal connector bearing plate on the back of the parapet wall. The system layout details are shown in Figures 33 and 34 and the system installation is shown in Figure 35.

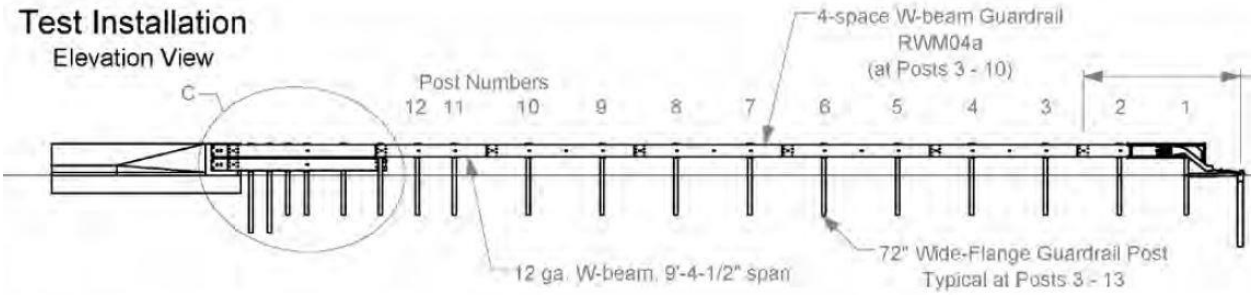


Figure 33. Layout Details, Stacked W-beam Transition for 31-in. Guardrail [6]

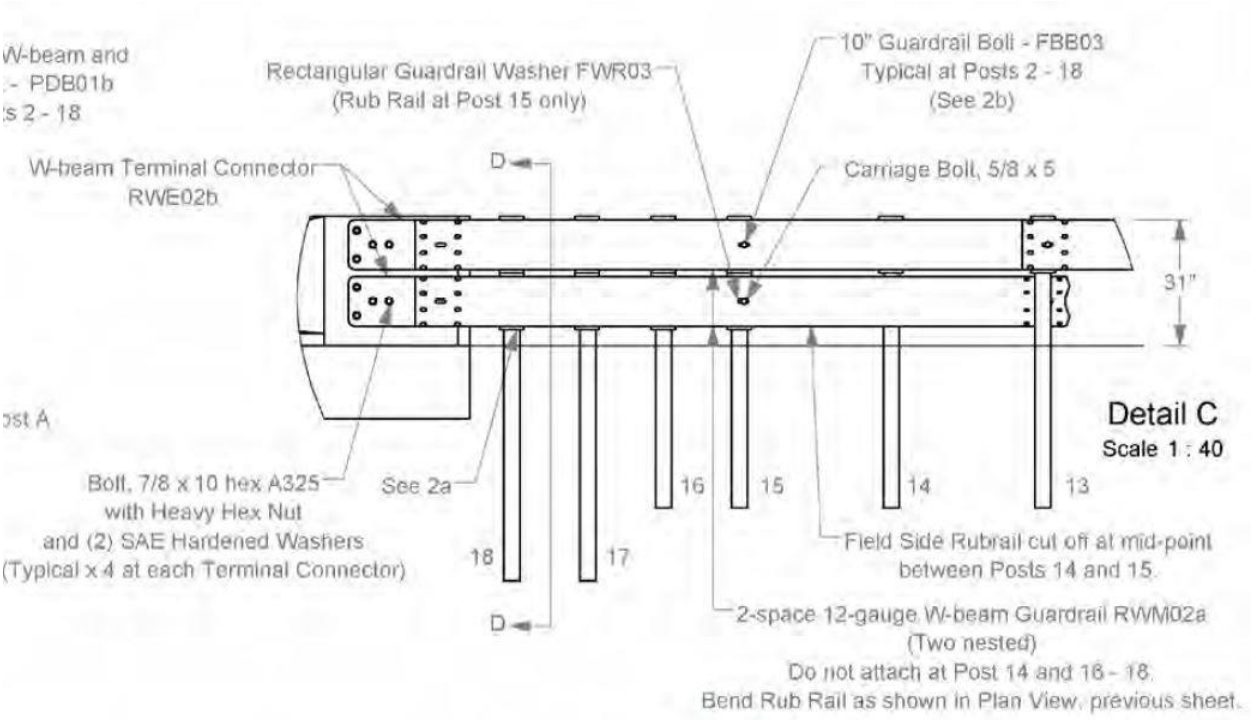


Figure 34. Rubrail Attachment Configuration, Stacked W-beam Transition [6]

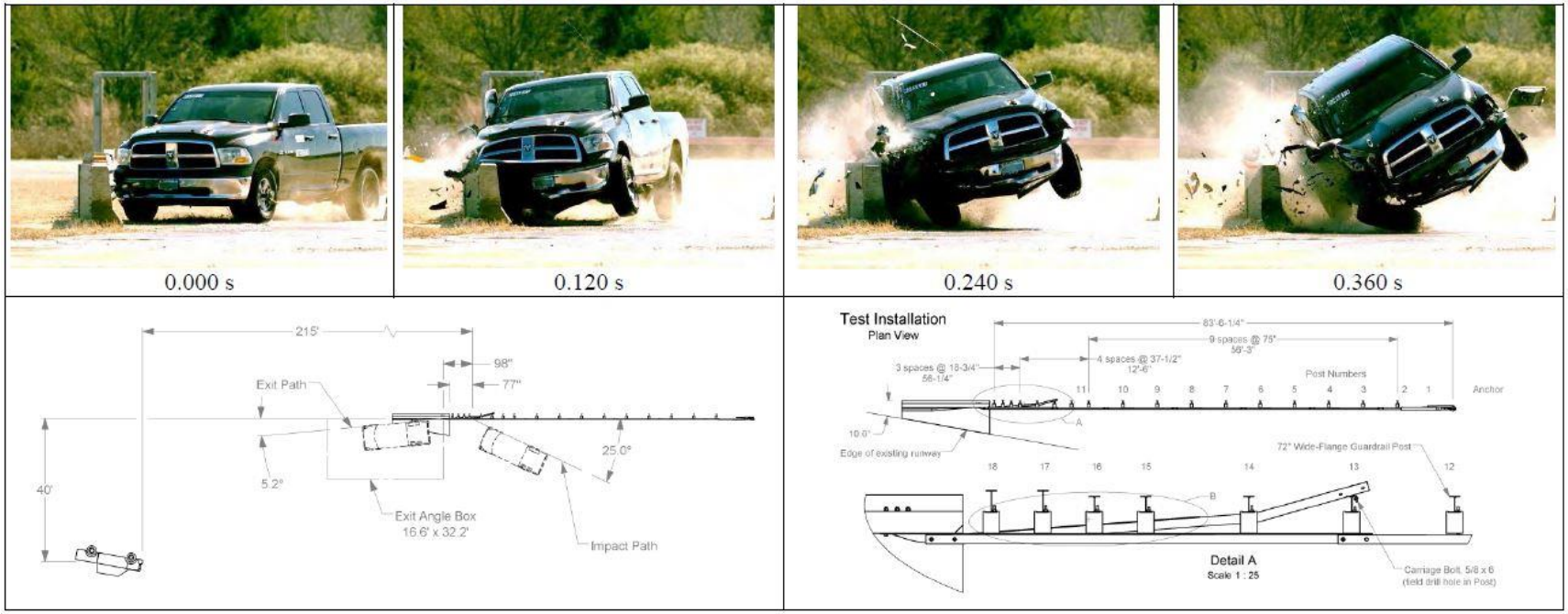


Figure 35. System Installation Details, Stacked W-beam Transition [6]

TTI crash tested the system under MASH test designation 3-21, in test no. 604581-1. The 2270P truck impacted the installation 5 ft - 7 in. from the upstream end of concrete parapet at 64.0 mph and 25.0 degrees. The system damage after the impact is illustrated in Figure 36. The vehicle was smoothly contained and redirected but rolled onto its right side downstream from the transition. The vehicle came to rest on its right side 215 ft downstream of impact and 40 ft toward traffic lanes. The maximum dynamic deflection and permanent set of the system were 4.0 in. and 2½ in., respectively, both of which occurred at post no. 16. A summary of the test results is shown in Figure 37. Due to the vehicle rollover, the occupant risk safety criteria for test designation 3-21 were not satisfied and test no. 604581-1 was deemed unsuccessful.



Figure 36. System Damage, Test No. 604581-1 [6]



General Information
- Test Agency ..... Texas A&M Transportation Institute (TTI)
- Test Standard Test No. ..... MASH Test 3-21
- TTI Test No. 604581-1
- Date 2016-01-28

Test Article
- Type ..... Transition
- Name ..... Stacked W-Beam Transition
- Installation Length ..... 100 ft-8 inches
- Material or Key Elements ..... 31-inch tall stacked W-beam transition to 32-inch tall concrete parapet wall
- **Soil Type and Condition** ..... Standard AASHTO M147-65(2004) Grade B Soil, Dry

Test Vehicle
- Type/Designation 2270P
- Make and Model ..... 2010 Dodge Ram 1500 Pickup Truck
- Curb ..... 4962 lb
- Test Inertial ..... 5005 lb
- Dummy ..... No dummy
- Gross Static ..... 5005 lb

Impact Conditions
- Speed ..... 64.0 mi/h
- Angle ..... 25.0 degrees
- Location/Orientation ..... CIP

Impact Severity ..... 122 kip-ft

Exit Conditions
- Speed ..... 52.4 mi/h
- Angle ..... 5.2 degrees

Occupant Risk Values
- Longitudinal OIV ..... 19.4 ft/s
- Lateral OIV ..... 29.9 ft/s
- Longitudinal RDA ..... 5.6 g
- Lateral RDA ..... 15.0 g
- THIV ..... 24.1 mi/h
- PHD ..... 15.0 g
- ASI 1.98

Max. 0.050-s Average
- Longitudinal ..... −10.0 g
- Lateral ..... −15.4 g
- Vertical ..... −3.9 g

Post-Impact Trajectory
- Stopping Distance ..... 215 ft dwnstrm
40 ft twd traffic

Vehicle Stability
- Maximum Yaw Angle ..... 85 degrees
- Maximum Pitch Angle ..... 5 degrees
- Maximum Roll Angle ..... 90 degrees
- Vehicle Snagging ..... No
- Vehicle Pocketing ..... No

Test Article Deflections
- Dynamic ..... 4.0 inches
- Permanent ..... 2.5 inches
- Working Width ..... 24.3 inches

Vehicle Damage
- VDS 01RD4
- CDC 01FROA3
- Max. Exterior Deformation ..... 17.0 inches
- OCDI RF0020000
- Max. Occupant Compartment Deformation ..... 5.0 inches

Figure 37. Summary of Test Results, Test No. 604581-1 [6]

2.2.4 Median Transition to Concrete Barrier (2020)

A stacked W-beam median barrier transition was evaluated at TTI, which was similar to the single-sided stacked W-beam transition [7]. The system consisted of a double-sided, 31-in. tall W-beam median guardrail attached to a concrete terminal barrier via W-beam terminal connectors. A W-beam rubrail was installed 2 in. below the guardrail system on both sides extending 14 ft upstream from the concrete terminal barrier. Nested W-beam was used for the top rail starting at post no. 15 and continuing to the concrete parapet. Two W-beam end connectors were used to attach both rails to the concrete parapet using ⅞-in. diameter x 1½-in. long hex bolts. W6x8.5 steel posts were used at various spacings: 10-in. spacing between post no. 19 and the anchor, 18¾ in. between post nos. 15 through 19, 37½ in. between post nos. 10 through 15, and 75 in. between post nos. 1 through 10. Wood blockouts were used to offset the guardrail for post nos. 2 through 18 and measured 14-in. tall x 6-in. wide x 7⅞-in. deep. The system layout and installation are shown in Figures 38 and 39, respectively.

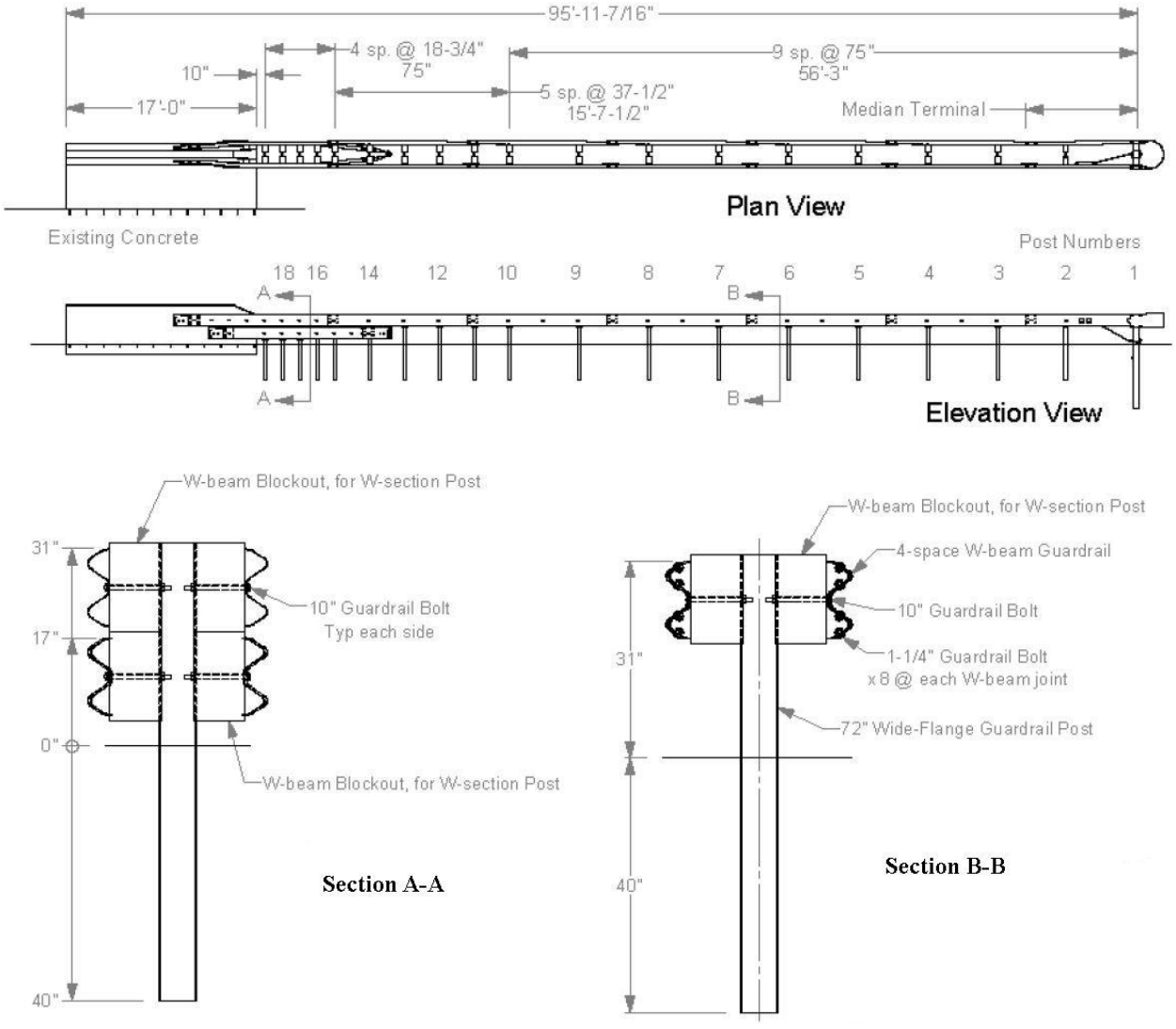


Figure 38. Schematic of Median Transition to Concrete Barrier, Test No. 469900-01-1 [7]



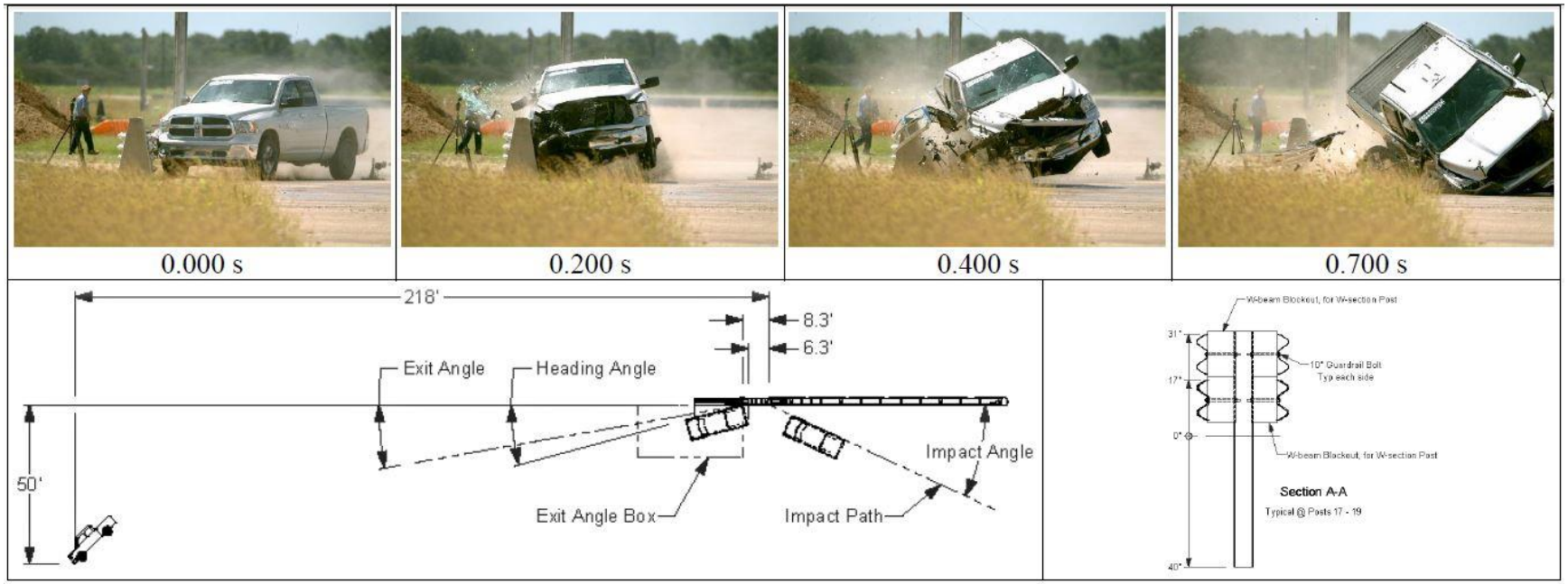
Figure 39. Median Transition to Concrete Barrier Installation, Test No. 469900-01-1 [7]

Computer simulations were used to determine the system's CIP. Three impact regions were considered: (a) the transition from median guardrail with rub rail and quarter post spacing to median concrete parapet; (b) the transition from median guardrail with half post spacing to median guardrail with rubrail and quarter post spacing; and (c) the transition from median guardrail with full post spacing to median guardrail with half post spacing. Simulation results indicated that the CIP was located 76 in. upstream from the concrete parapet face.

Test no. 469900-01-1 was conducted in accordance with MASH test designation no. 3-21. The vehicle impacted the system 6 ft – $3^{5}/_{16}$ in. upstream from the end of the concrete parapet at a speed of approximately 63.3 mph and an angle of 25.1 degrees. After impact, the vehicle rolled 90 degrees onto its right side and came to rest 218 ft downstream from the impact point and 50 ft laterally in front of the system. The system contained and redirected the vehicle and no penetration, underride, or override were observed during the impact. However, pocketing in the rubrail caused the wheel to snag and the vehicle rolled 90 degrees onto its right side after losing contact with the system, resulting in test failure. The system damage is shown in Figure 40 and a summary of the test results is reported in Figure 41.



Figure 40. Vehicle Final Position and System Damage, Test No. 469900-01-1 [7]



General Information
- Test Agency ..... Texas A&M Transportation Institute (TTI)
- Test Standard Test No. ... *MASH* Test 3-21
- TTI Test No. 469900-01-1
- Test Date 2020-06-18

Test Article
- Type ..... Transition
- Name ..... Median Transition
- Installation Length ..... 95 ft $11^{7}/_{16}$ inches
- Material or Key Elements ..... Steel W-beam guardrail and posts, concrete barrier with steel rebar

Soil Type and Condition .. AASHTO M147-65, Grade B soil (crushed limestone)

Test Vehicle
- Type/Designation 2270P
- Make and Model ..... 2014 RAM 1500 pickup truck
- Curb ..... 4947 lb
- Test Inertial ..... 5002 lb
- Dummy ..... 165 lb
- Gross Static ..... 5167 lb

Impact Conditions
- Speed ..... 63.3 mi/h
- Angle ..... 25.1°
- Location/Orientation ..... 6.3 ft upstream of end of parapet

Impact Severity ..... 121 kip-ft

Exit Conditions
- Speed ..... 49.5 mi/h
- Trajectory/Heading Angle ..... 4.2°/8.4°

Occupant Risk Values
- Longitudinal OIV ..... 21.0 ft/s
- Lateral OIV ..... 25.9 ft/s
- Longitudinal Ridedown ..... 11.6 g
- Lateral Ridedown ..... 12.4 g
- THIV ..... 10.0 m/s
- ASI 1.4

Max. 0.050-s Average
- Longitudinal ..... −8.9 g
- Lateral ..... −11.7 g
- Vertical ..... −3.0 g

Post-Impact Trajectory
- Stopping Distance ..... 218 ft downstream 50 ft twd traffic

Vehicle Stability
- Maximum Roll Angle ..... 53°
- Maximum Pitch Angle ..... 18°
- Maximum Yaw Angle ..... 70°
- Vehicle Snagging ..... Yes
- Vehicle Pocketing ..... No

Test Article Deflections
- Dynamic ..... 3.3 inches
- Permanent ..... Undetermined
- Working Width ..... 33.3 inches
- Height of Working Width ..... 28.5 inches

Vehicle Damage
- VDS 01RFQ5
- CDC 01FREW4
- Max. Exterior Deformation ..... 16.0 inches
- OCDI RF0020000
- Max. Occupant Compartment Deformation ..... 7.0 inches

Figure 41. Summary of Test Results, Test No. 469900-01-1 [7]

2.2.5 Modified Median Transition to Concrete Barrier MASH (2020)

Following the failure of test no. 469900-01-1, TTI modified the stacked W-beam median barrier transition to reduce rubrail pocketing by laterally offsetting the rubrail to be flush with the traffic-side face of the concrete parapet [7].. Thus, the rubrail had no end connector attached to the concrete parapet. Additionally, an extra post was added upstream from the quarter-post spacing section to gradually transition the system stiffness between the half-spaced posts and the quarter-spaced posts, and a vertical taper was added to the toe at the end of the concrete parapet. The modified stacked W-beam median transition is shown in Figure 42 and photographs of the system installation are shown in Figure 43.

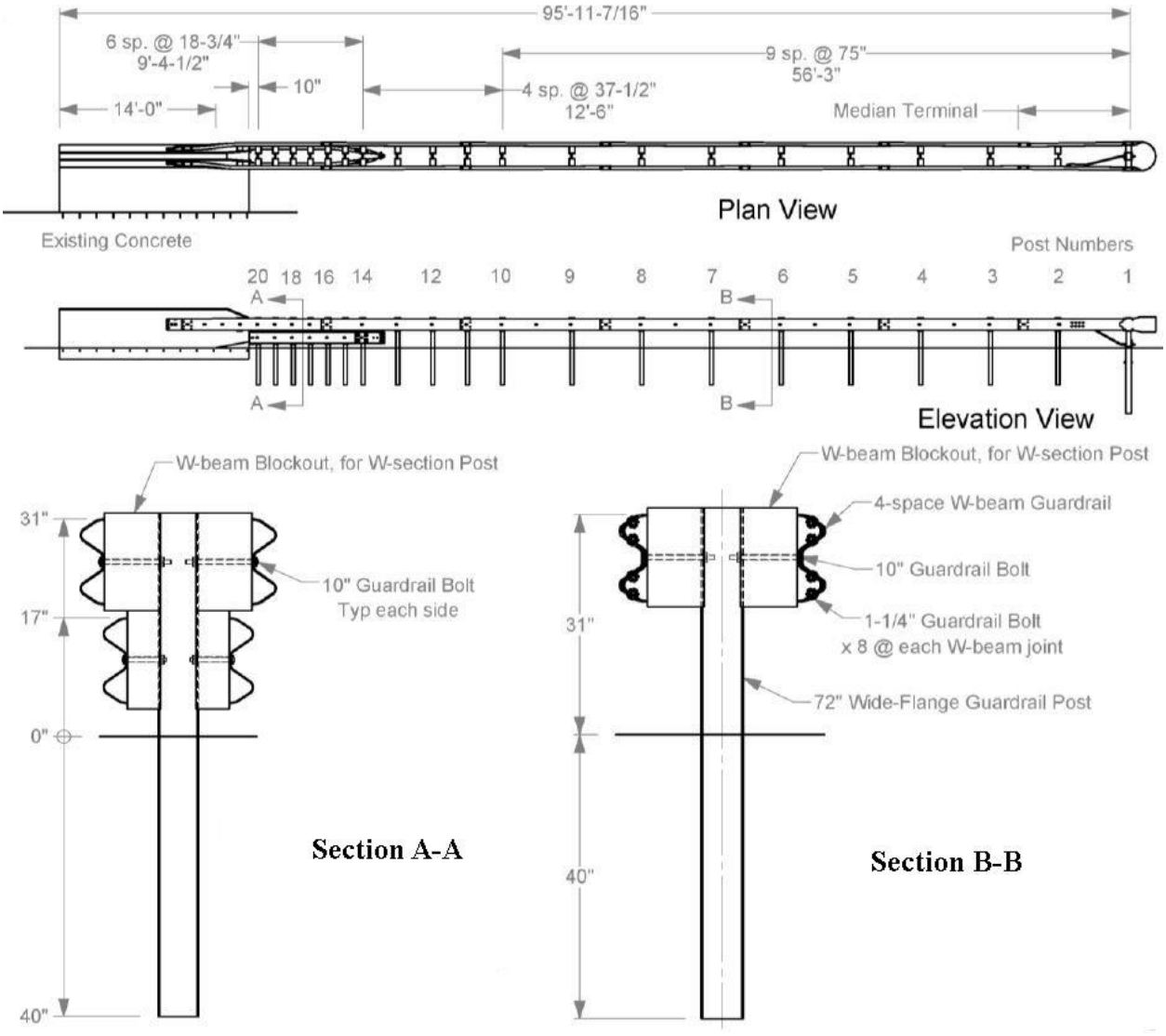


Figure 42. Schematic of Modified Median Barrier Transition, Test No. 469900-01-2 [7]

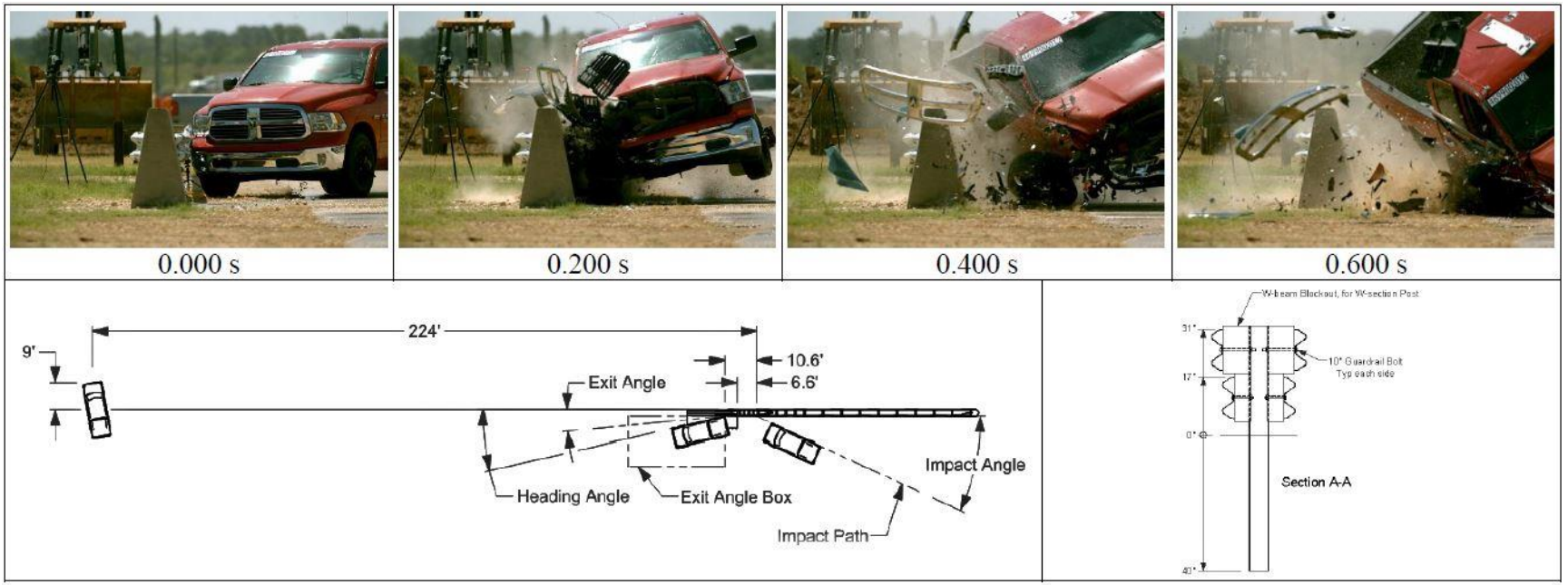


Figure 43. Modified Median Barrier Transition System, Test No. 469900-01-2 [7]

Test no. 469900-01-2 was conducted in accordance with MASH test designation no. 3-21. During test no. 469900-01-2, the 2270P vehicle impacted the system at a speed of 61.9 mph and an angle of 24.7 degrees, respectively. The impact point was 6 ft – $7^{3}/_{16}$ in. upstream from the end of the concrete parapet. The vehicle was contained and redirected, coming to rest 224 ft downstream from the impact point and 9 ft and laterally in front of the barrier. The W-beam guardrail was partially flattened and deformed at the point of impact and extended to the upstream face of the concrete parapet. The maximum dynamic and permanent deformations of the system were 5¼ in. and 2¾ in., respectively. The test vehicle's final position and system damage are shown in Figure 44. Test no. 469900-01-2 was deemed to be successful, and all MASH TL-3 safety criteria were satisfied. A summary of test no. 469900-01-2 is shown in Figure 45.



Figure 44. Vehicle Final Position and System Damage, Test No. 469900-01-2 [7]



General Information

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 3-21
TTI Test No.	469900-01-2
Test Date	2020-08-13

Test Article

Type	Transition
Name	Modified Median Transition
Installation Length	95 ft $11^{7}/_{16}$ inches
Material or Key Elements	Steel W-beam guardrail and posts, steel rebar reinforced concrete barrier
Soil Type and Condition	AASHTO M147-65, Grade B soil (crushed limestone)

Test Vehicle

Type/Designation	2270P
Make and Model	2014 RAM 1500 pickup truck
Curb	5089 lb
Test Inertial	5008 lb
Dummy	165 lb
Gross Static	5173 lb

Impact Conditions

Speed	61.9 mi/h
Angle	24.7°
Location/Orientation	6.6 ft upstream of end of parapet
Impact Severity	112 kip-ft

Exit Conditions

Speed	45.9 mi/h
Trajectory/Heading Angle	5.3°/12.8°

Occupant Risk Values

Longitudinal OIV	20.7 ft/s
Lateral OIV	25.6 ft/s
Longitudinal Ridedown	7.1 g
Lateral Ridedown	7.3 g
THIV	10.5 m/s
ASI	1.7
Max. 0.050-s Average	
Longitudinal	−9.3 g
Lateral	−12.7 g
Vertical	−2.4 g

Post-Impact Trajectory

Stopping Distance	224 ft downstream 9 ft twd field side

Vehicle Stability

Maximum Roll Angle	37°
Maximum Pitch Angle	44°
Maximum Yaw Angle	42°
Vehicle Snagging	No
Vehicle Pocketing	No

Test Article Deflections

Dynamic	5.4 inches
Permanent	2.75 inches
Working Width	33.0 inches
Height of Working Width	28.7 inches

Vehicle Damage

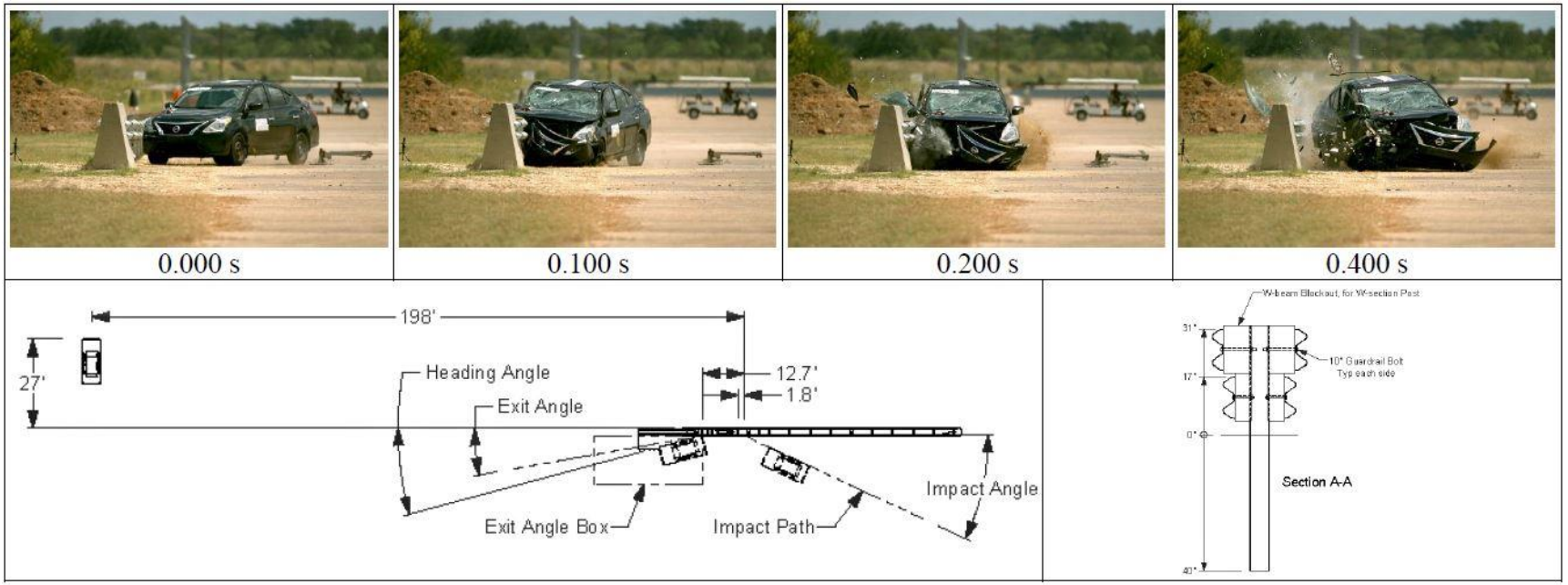
VDS	01RFQ5
CDC	01FREW4
Max. Exterior Deformation	16.0 inches
OCDI	RF0021200
Max. Occupant Compartment Deformation	5.5 inches

Figure 45. Summary of Test Results, Test No. 469900-01-2 [7]

This system was also evaluated according to MASH test designation no. 3-20 [7], in test no. 469900-01-3. The 1100C test vehicle impacted the transition system $20^{11}/_{16}$ in. upstream from the centerline of post no. 13 at a speed of 62.9 mph and an angle of 25.2 degrees. The vehicle snagged on the upstream face of the lap splice at the upstream W-beam end shoe. The vehicle was smoothly contained and redirected and came to rest 198 ft downstream from the point of impact and 27 ft towards the field side. The maximum dynamic deflection and permanent set of the barrier were 5¼ in. and 1¼ in., respectively. The system was determined to be successful according to MASH safety criteria for test designation no. 3-20. Post-test photographs of the vehicle's final position and system damage are shown in Figure 46 and a summary of test results is shown in Figure 47.



Figure 46. Vehicle's Final Position and System Damage, Test No. 469900-01-3 [7]



General Information

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 3-20
TTI Test No.	469900-01-3
Test Date	2020-08-25

Test Article

Type	Transition
Name	Modified Median Transition
Installation Length	95 ft $11^{7}/_{16}$ inches
Material or Key Elements	Steel W-beam guardrail with posts, steel rebar reinforced concrete barrier
Soil Type and Condition	AASHTO M147-65, Grade B soil (crushed limestone)

Test Vehicle

Type/Designation	1100C
Make and Model	2015 Nissan Versa
Curb	2371 lb
Test Inertial	2420 lb
Dummy	165 lb
Gross Static	2585 lb

Impact Conditions

Speed	62.9 mi/h
Angle	25.2°
Location/Orientation	20.7 inches upstream of post 13
Impact Severity	58 kip-ft

Exit Conditions

Speed	46.6 mi/h
Trajectory/Heading Angle	6.3°/12.4°

Occupant Risk Values

Longitudinal OIV	23.6 ft/s
Lateral OIV	26.2 ft/s
Longitudinal Ridedown	5.5 g
Lateral Ridedown	14.7 g
THIV	11.5 m/s
ASI	2.1
Max. 0.050-s Average	
Longitudinal	−11.8 g
Lateral	−15.5 g
Vertical	−2.7 g

Post-Impact Trajectory

Stopping Distance	198 ft downstream 27 ft twd field side

Vehicle Stability

Maximum Roll Angle	6°
Maximum Pitch Angle	3°
Maximum Yaw Angle	47°
Vehicle Snagging	No
Vehicle Pocketing	No

Test Article Deflections

Dynamic	5.2 inches
Permanent	1.25 inches
Working Width	32.1 inches
Height of Working Width	28.5 inches

Vehicle Damage

VDS	01RFQ5
CDC	01FREW4
Max. Exterior Deformation	12.0 inches
OCDI	RF0000000
Max. Occupant Compartment Deformation	4.5 inches

Figure 47. Summary of Test Results, Test No. 469900-01-3 [7]

2.2.6 Discussion

Many approach guardrail transitions utilize a W-to-thrie beam transition piece because connections to rigid objects must be shielded over a broad range of heights. The W-beam systems utilized upstream from rigid obstacles, such as bridge parapets, are economical guardrail systems with crashworthy end treatments. It is desirable to have W-beam end termination options that do not incorporate a transition to thrie-beams, because the change in system stiffness has led to significant system design challenges and some failures. However, W-beam stiffness transitions also pose challenges associated with the rail stiffness and locations where the rail needs to shield rigid obstructions, such as the toe of a parapet.

Designs that were successfully evaluated by the Texas A&M Transportation Institute utilized a rubrail which terminated at the upstream face of the rigid concrete parapet. Rails upstream from the rigid obstruction were nested, and the rubrail performed better when offset laterally from the front face of the upper W-beam rail. Additionally, designs performed better when the rails adjacent to the rigid obstruction were nested for increased stiffness. However, testing was limited to a small number of CIPs, and additional critical impact points may exist which could result in pocketing or vehicle instability.

2.3 W-to-Thrie-beam Transitions

2.3.1 MGS Stiffness Transition with Curb, Test No. MWTC-1 (2012)

The MGS stiffness transition with curb was tested by MwRSF according to MASH 2009 test designation no. 3-20 [8, 9]. The 31-in. tall system consisted of five major structural components: (1) a 12 ft – 6 in. long thrie-beam and channel bridge railing system; (2) 12-ft 6-in. long nested 12-gauge thrie-beam guardrail; (3) 6-ft 3-in. long standard 12-gauge thrie-beam guardrail; (4) a 6-ft 3-in. long asymmetrical 10-gauge W-beam to thrie-beam transition element; and (5) 50-ft long standard 12-gauge W-beam rail attached to a simulated anchorage device. Post nos. 1 and 2 were wooden posts placed in 6-ft long steel foundation tubes to anchor the system. Post nos. 3 through 15 were 6-ft long W6x8.5 steel posts, and post nos. 16 through 18 were 7-ft long W6x15 steel posts. Various post spacings were used in this system, as shown in Figure 48. The system installation is shown in Figure 49.

During test no. MWTC-1, the 1100C small car impacted the system at speed of 62.9 mph and an angle of 25.0 degrees in accordance with MASH 2009 TL-3 safety criteria test designation no. 3-20. Impact occurred 14¾ in. downstream from post no. 7, 4 in. upstream of the target location. The system did not safely redirect the vehicle, and some components of the vehicle penetrated under the system, while the wheel climbed up the curb. The presence of a curb under the MGS near a stiff transition likely changed the load direction and magnitude applied to the guardrail in advance of the splice location. In addition, the wheel interaction with the curb surface and curb back side edge may have contributed to a slightly altered vehicle trajectory from that observed in the successful small car crash test on the system without a curb. The interaction between the vehicle and the system resulted in the rupture of the rail at the splice to the W-to-thrie transition element. Due to vehicle penetration under the barrier and rail rupture, test no. MWTC-1 was determined to be unacceptable according to the MASH safety performance criteria for test designation no. 3-20. The vehicle and system damage are show in Figure 50. A summary of test no. MWTC-1 is shown in Figure 51.

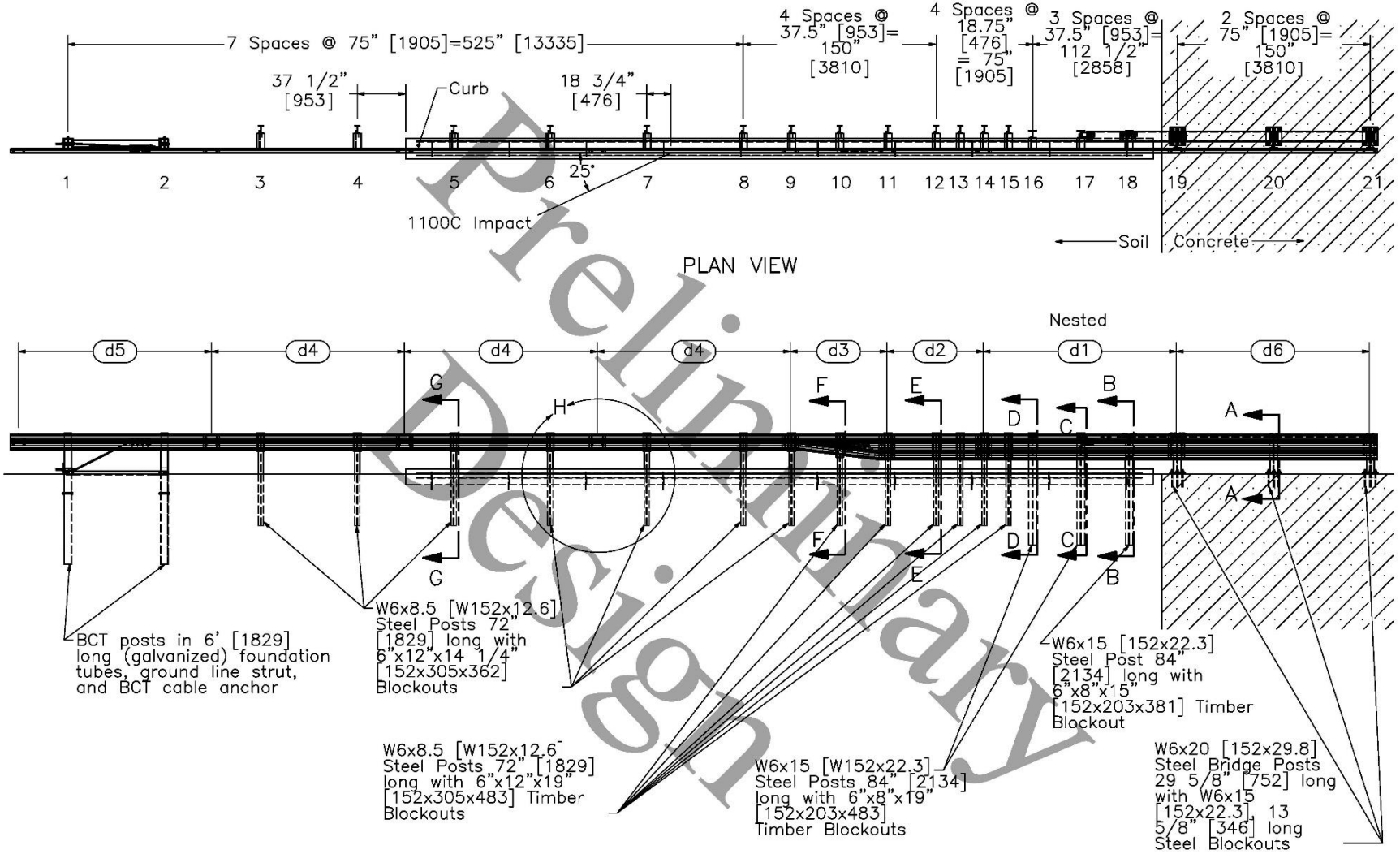


Figure 48. System Design for Test No. MWTC-1 [9]

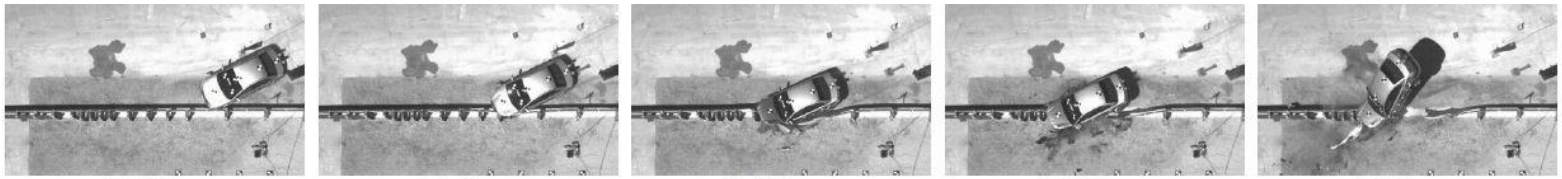
Preliminary Design



Figure 49. MGS Stiffness Transition with Curb System Installation, Test No. MWTC-1 [9]

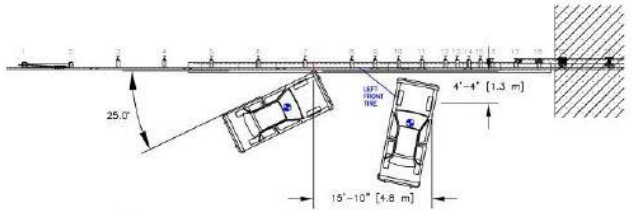


Figure 50. MGS Stiffness Transition with Curb, Vehicle and System Damage, Test No. MWTC-1 [9]



0.000 sec 0.044 sec 0.152 sec 0.248 sec 0.710 sec

- Test Agency ..... MwRSF
- Test Number MWTC-1
- Date 8/10/12
- MASH Test Designation 3-20
- Test Article ..... Stiffness Transition between MGS and Thrie Beam Transition with Curb
- Total Length ..... 87.5 ft (26.7 m)
- Height to Top of Rail ..... 31 in. (787 mm)
- Steel 12 gauge (2.66 mm) W-Beam Guardrail
  - Segment Location - Single ..... Post nos. 1 to 9
- Steel 10 gauge (3.42 mm) W-Beam to Thrie Beam Transition
  - Segment Location ..... Post nos. 9 to 11
- Steel 12 gauge (2.66 mm) Thrie Beam Guardrail
  - Segment Location - Single ..... Post nos. 11 to 14 and 19 to 21
  - Segment Location - Nested ..... Post nos. 14 to 19
- Guardrail Posts
  - Post Nos. 1-2 ..... 46 in. (1,168 mm) long, BCT timber posts
  - Post Nos. 3-15 ..... 72 in. (1,829 mm) long, W6x8.5 (W152x12.6)
  - Post Nos. 16-18 ..... 84 in. (2,134 mm) long, W6x15 (W152x22.3)
  - Post Nos. 19-21 ..... 29⅝ in. (752 mm) long, W6x20 (W152x29.8)
- Post Spacing
  - Post Nos. 1-8, 19-21 ..... 75 in. (1,905 mm)
  - Post Nos. 8-12, 16-19 ..... 37½ in. (953 mm)
  - Post Nos. 12-16 ..... 18¾ in. (476 mm)
- Soil Type ..... AASHTO Grade B
- Vehicle
  - Make and Model ..... 2007 Kia Rio
  - Test Inertial ..... 2,457 lb (1,114 kg)
  - Gross Static ..... 2,623 lb (1,190 kg)
  - Curb ..... 2,468 lb (1,119 kg)
- Impact Conditions
  - Speed ..... 62.9 mph (101.2 km/h)
  - Angle ..... 25.0 deg
  - Impact Severity (IS) ..... 58.0 kip-ft (78.6 kJ) > 51.0 kip-ft (69.1 kJ)
  - Impact Location ..... 14¾ in. (375 mm) downstream of post no. 7
- Exit Conditions
  - Speed ..... NA
  - Angle ..... NA
- Exit Box Criterion ..... NA
- Vehicle Stability ..... Satisfactory



- Vehicle Stopping Distance ..... 15.8 ft (4.8 m) downstream of impact
  4.3 ft (1.3 m) laterally in front of system
- Vehicle Damage ..... Moderate
  - VDS[7] 11-LFQ-5
  - CDC[8] 11-LFEW2
  - Maximum Interior Deformation ..... ¾ in. (19 mm)
- Test Article Damage ..... Severe (rail ruptured)
- Maximum Test Article Deflections
  - Permanent Set ..... NA (rail ruptured)
  - Dynamic ..... NA (rail ruptured)
  - Working Width ..... NA (rail ruptured)
- Maximum Angular Displacements
  - Roll ..... 13.7° < 75°
  - Pitch ..... -36.3° < 75°
  - Yaw ..... -54.1°
- Transducer Data

Evaluation Criteria		Transducer			MASH Limit
		DTS	DTS SLICE	EDR-3	
OIV ft/s (m/s)	Longitudinal	-35.86 (-10.93)	-32.56 (-9.92)	-37.52 (-11.44)	≤ 40 (12.2)
	Lateral	16.45 (5.01)	17.59 (5.36)	16.01 (4.88)	≤ 40 (12.2)
ORA g's	Longitudinal	-21.76	-22.25	-21.23	≤ 20.49
	Lateral	-8.70	-8.51	-8.42	≤ 20.49
THIV – ft/s (m/s)		38.78 (11.82)	36.88 (11.24)	NA	not required
PHD – g's		23.29	23.79	NA	not required
ASI		1.23	1.26	1.26	not required

Figure 51. Summary of Test Results, Test No. MWTC-1 [9]

2.3.2 MGS Stiffness Transition with Curb, Test Nos. MWTC-2 and MWTC-3 (2012)

Due to the rail rupture and subsequent system failure experienced during test no. MWTC-1, design modifications were required to strengthen the rail near the upstream end of the asymmetrical transition element. The modifications included an additional 12-gauge W-beam segment that was incorporated into the system such that 12 ft – 6 in. of nested W-beam guardrail preceded the 10-gauge W-to-thrie transition segment [9]. The system layouts for test nos. MWTC-2 and MWTC-3, the re-run of the small car test and the pickup truck test, respectively, were nearly identical to that of test no. MWTC-1 with the addition of the 12 ft – 6 in. nested W-beam section prior to the W-to-thrie transition segment.

The crashworthiness of the modified MGS stiffness transition with curb system was tested by MwRSF during full-scale crash test nos. MWTC-2 and MWTC-3 according to MASH TL-3 safety criteria for test designation nos. 3-20 and 3-21, respectively. The system layout and installation for test nos. MWTC-2 and MWTC-3 are shown in Figures 52 and 53, respectively.

During test no. MWTC-2, the 1100C test vehicle targeted the same impact point, 18¾ in. downstream of post no. 7, but actually impacted 7½ in. further upstream. The impact occurred at the speed and angle of 61.3 mph and 25.6 degrees, respectively. The system adequately contained and redirected the 1100C vehicle with controlled lateral displacements of the barrier. The system damage is shown in Figure 54. Test no. MWTC-2 was determined to be successful according to MASH test designation no. 3-20.

During test no. MWTC-3, the 4,969-lb pickup truck impacted the W-to-thrie-beam transition system with curb at a speed of 61.0 mph and at an angle of 24.4 degrees. The impact location, 75 in. upstream from the centerline of post no. 9, matched targeted location. During the test, the damage to the barrier was deemed moderate and consisted of deformed guardrail and posts, fractured wooden posts, displaced soil, gouged wooden spacer blockouts, and contact marks on the guardrail. The length of vehicle contact along the barrier was approximately 18 ft – 2 in., which spanned from the impact point to 7½ in. upstream from post no. 14. The system adequately contained and redirected the 2270P vehicle with controlled lateral displacements of the barrier. The system damage for test no. MWTC-3 is shown in Figure 55. Test no. MWTC-3 was determined to be successful according to MASH test designation no. 3-21. A summary of the results for test nos. MWTC-2 and MWTC-3 are shown in Figures 56 and 57, respectively.

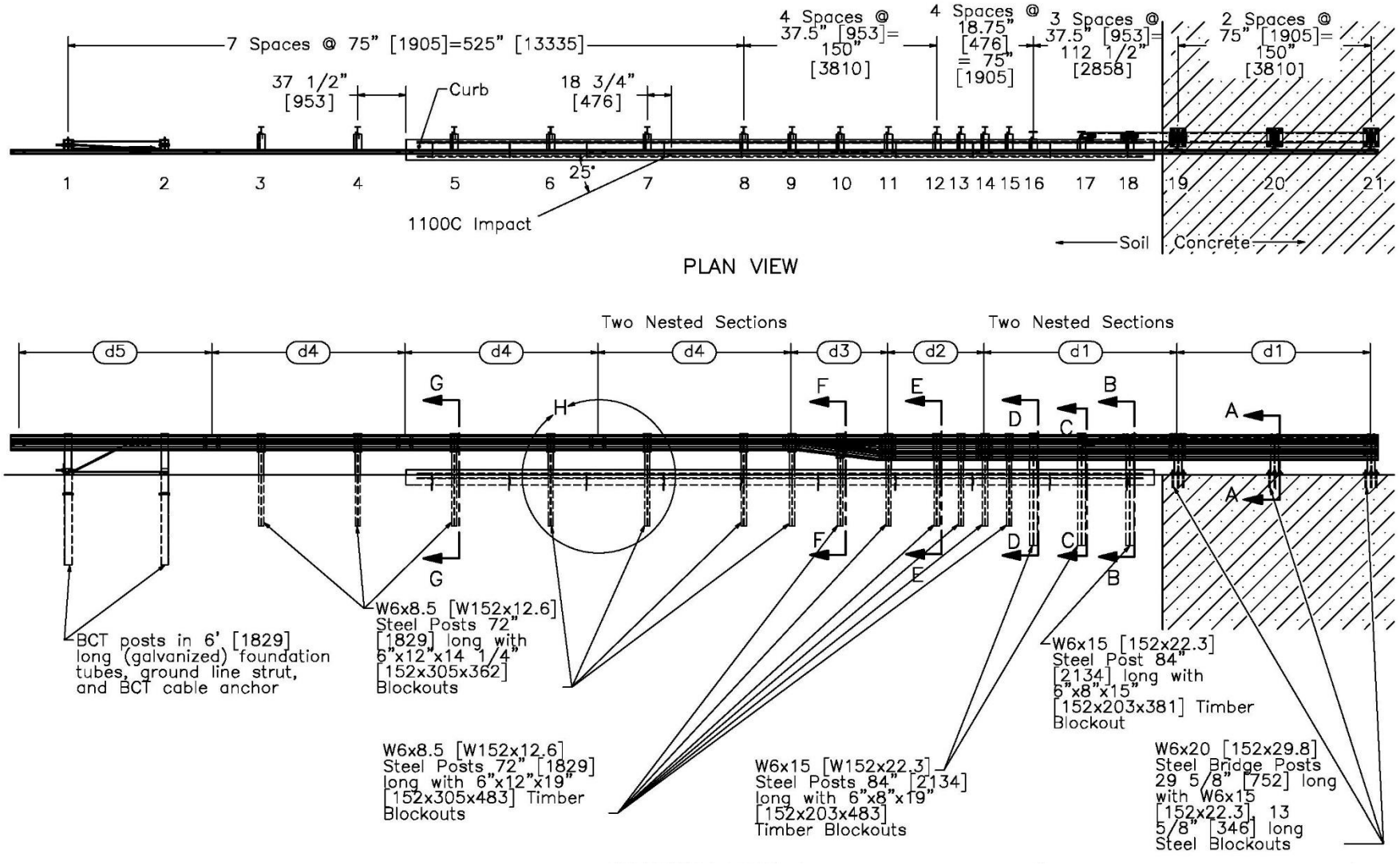


Figure 52. Modified MGS Stiffness Transition with Curb System Design, Test Nos. MWTC-2 and MWTC-3 [9]



Figure 53. Modified MGS Stiffness Transition with Curb, System Installation, Test No. MWTC-2 and MWTC-3 [9]

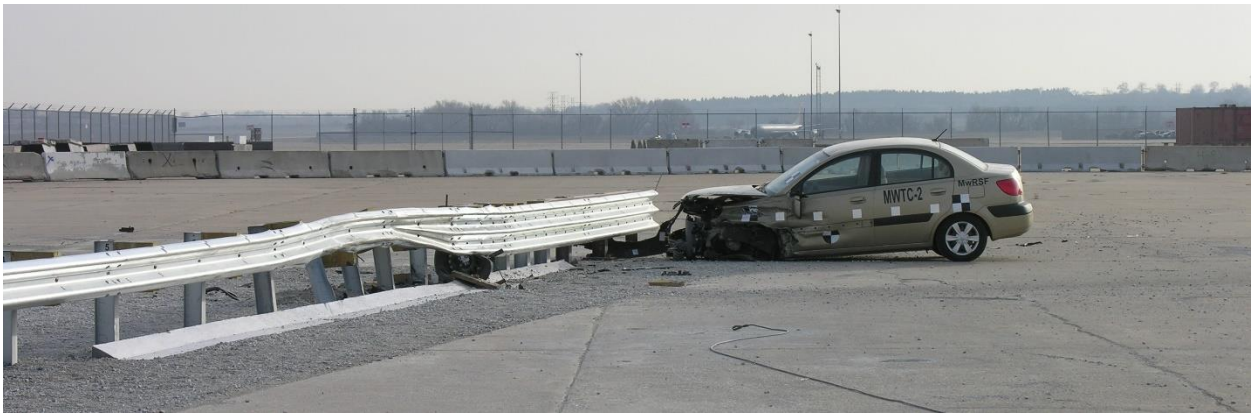


Figure 54. Modified MGS Stiffness Transition with Curb, Vehicle and System Damage, Test No. MWTC-2 [9]

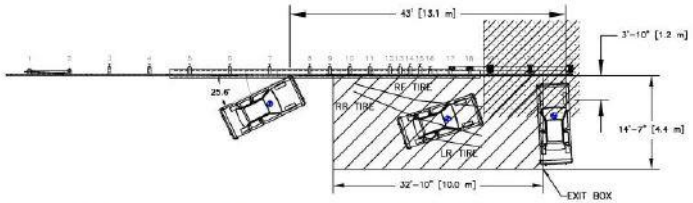


Figure 55. Modified MGS Stiffness Transition with Curb, Vehicle and System Damage, Test No. MWTC-3 [9]



0.000 sec 0.162 sec 0.412 sec 0.558 sec 0.772 sec

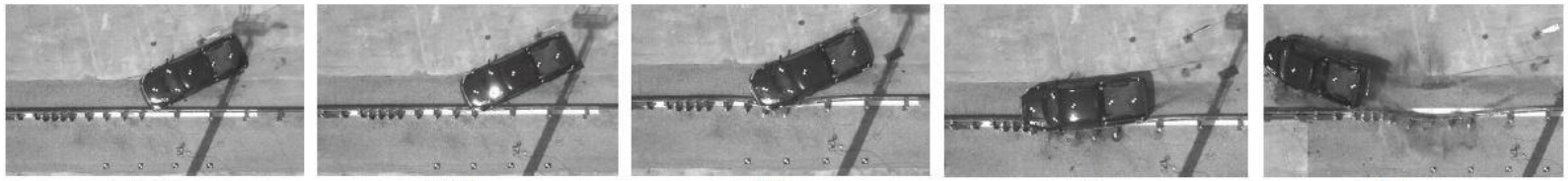
- Test Agency ..... MwRSF
- Test Number MWTC-2
- Date 11/30/12
- MASH Test Designation 3-20
- Test Article ..... Stiffness Transition between MGS and Thrie Beam Transition with Curb
- Total Length ..... 87.5 ft (26.7 m)
- Height to Top of Rail ..... 31 in. (787 mm)
- Steel 12 gauge (2.66 mm) W-Beam Guardrail
  - Segment Location - Single ..... Post no. 1 to Splice 6/7
  - Segment Location - Nested ..... Splice 6/7 to Post no. 9
- Steel 10 gauge (3.42 mm) W-Beam to Thrie Beam Transition
  - Segment Location ..... Post nos. 9 to 11
- Steel 12 gauge (2.66 mm) Thrie Beam Guardrail
  - Segment Location - Single ..... Post nos. 11 to 14 and 19 to 21
  - Segment Location - Nested ..... Post nos. 14 to 19
- Guardrail Posts
  - Post Nos. 1-2 ..... 46 in. (1,168 mm) long, BCT timber posts
  - Post Nos. 3-15 ..... 72 in. (1,829 mm) long, W6x8.5 (W152x12.6)
  - Post Nos. 16-18 ..... 84 in. (2,134 mm) long, W6x15 (W152x22.3)
  - Post Nos. 19-21 ..... 29⅝ in. (752 mm) long, W6x20 (W152x29.8)
- Post Spacing
  - Post Nos. 1-8, 19-21 ..... 75 in. (1,905 mm)
  - Post Nos. 8-12, 16-19 ..... 37½ in. (953 mm)
  - Post Nos. 12-16 ..... 18¾ in. (476 mm)
- Soil Type ..... AASHTO Grade B
- Vehicle
  - Make and Model ..... 2007 Kia Rio
  - Test Inertial ..... 2,410 lb (1,093 kg)
  - Gross Static ..... 2,575 lb (1,168 kg)
  - Curb ..... 2,390 lb (1,084 kg)
- Impact Conditions
  - Speed ..... 61.3 mph (98.7 km/h)
  - Angle ..... 25.6 deg
  - Impact Severity (IS) ..... 56.5 kip-ft (76.6 kJ) > 51.0 kip-ft (69.1 kJ)
  - Impact Location ..... 11¼ in. (286 mm) downstream of post no. 7
- Exit Conditions
  - Speed ..... 19.6 mph (31.5 km/h)
  - Angle ..... 11.0 deg
- Exit Box Criterion ..... Passed
- Vehicle Stability ..... Satisfactory



- Vehicle Stopping Distance ..... 43.0 ft (13.1 m) downstream of impact
  ..... 3.8 ft (1.2 m) laterally in front of system
- Vehicle Damage ..... Moderate
  VDS[7] 11-LFQ5
  CDC[8] 11-LFEW2
  Maximum Interior Deformation ..... 1 in. (25 mm)
- Test Article Damage ..... Moderate
- Maximum Test Article Deflections
  - Permanent Set ..... 16.1 in. (409 mm)
  - Dynamic ..... 16.4 in. (417 mm)
  - Working Width ..... 32.5 in. (826 mm)
- Maximum Angular Displacements
  - Roll ..... -13.7° < 75°
  - Pitch ..... -8.6° < 75°
  - Yaw ..... -70.7°
- Transducer Data

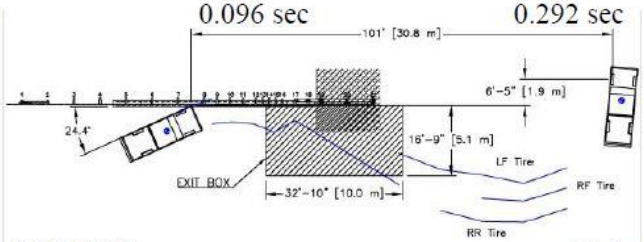
Evaluation Criteria		Transducer			MASH Limit
		DTS	DTS SLICE	EDR-3	
OIV ft/s (m/s)	Longitudinal	-22.23 (6.78)	-23.04 (-7.02)	-24.21 (-7.38)	≤ 40 (12.2)
	Lateral	22.53 (6.87)	24.14 (7.36)	21.19 (6.46)	≤ 40 (12.2)
ORA g's	Longitudinal	-15.65	-16.58	-11.72	≤ 20.49
	Lateral	13.45	12.45	10.88	≤ 20.49
THIV – ft/s (m/s)		31.66 (9.65)	31.79 (9.69)	NA	not required
PHD – g's		15.69	18.84	NA	not required
ASI		1.32	1.40	1.27	not required

Figure 56. Summary of Test Results, Test No. MWTC-2 [9]



0.000 sec 0.013 sec 0.035 sec 0.096 sec 0.292 sec

- Test Agency ..... MwRSF
- Test Number MWTC-3
- Date 5/16/13
- MASH Test Designation 3-21
- Test Article ..... Stiffness Transition between MGS and Thrie Beam Transition with Curb
- Total Length ..... 87.5 ft (26.7 m)
- Height to Top of Rail ..... 31 in. (787 mm)
- Steel 12 gauge (2.66 mm) W-Beam Guardrail
  - Segment Location - Single ..... Post no. 1 to Splice 6/7
  - Segment Location - Nested ..... Splice 6/7 to Post no. 9
- Steel 10 gauge (3.42 mm) W-Beam to Thrie Beam Transition
  - Segment Location ..... Post nos. 9 to 11
- Steel 12 gauge (2.66 mm) Thrie Beam Guardrail
  - Segment Location - Single ..... Post nos. 11 to 14 and 19 to 21
  - Segment Location - Nested ..... Post nos. 14 to 19
- Guardrail Posts
  - Post Nos. 1-2 ..... 46 in. (1,168 mm) long, BCT timber posts
  - Post Nos. 3-15 ..... 72 in. (1,829 mm) long, W6x9 (W152x13.4)
  - Post Nos. 16-18 ..... 84 in. (2,134 mm) long, W6x15 (W152x22.3)
  - Post Nos. 19-21 ..... 29⅝ in. (752 mm) long, W6x20 (W152x29.8)
- Post Spacing
  - Post Nos. 1-8, 19-21 ..... 75 in. (1,905 mm)
  - Post Nos. 8-12, 16-19 ..... 37½ in. (953 mm)
  - Post Nos. 12-16 ..... 18¾ in. (476 mm)
- Soil Type ..... AASHTO Grade B
- Vehicle
  - Make and Model ..... 2006 Dodge Ram 1500 Quad Cab
  - Test Inertial ..... 4,969 lb (2,254 kg)
  - Gross Static ..... 5,135 lb (2,329 kg)
  - Curb ..... 5,134 lb (2,329 kg)
- Impact Conditions
  - Speed ..... 61.0 mph (98.1 km/h)
  - Angle ..... 24.4 deg
  - Impact Severity ..... 105.8 kip-ft (143.4 kJ) > 105.6 kip-ft (143.2 kJ)
  - Impact Location ..... 75 in. (1,905 mm) Upstream of Post No. 9
- Exit Conditions
  - Speed ..... 38.3 mph (61.7 km/h)
  - Angle ..... 11.7 deg
- Exit Box Criterion ..... Passed



- Vehicle Stability ..... Satisfactory
- Vehicle Stopping Distance ..... 101 ft (30.8 m) downstream of impact
  ..... 6.4 ft (2.0 m) laterally behind system
- Vehicle Damage ..... Moderate
  VDS[7] 11-LFQ4
  CDC[8] 11-LFEW2
  Maximum Interior Deformation ..... 2½ in. (64 mm)
- Test Article Damage ..... Moderate
- Maximum Test Article Deflections
  - Permanent Set ..... 17.8 in. (452 mm)
  - Dynamic ..... 23.9 in. (607 mm)
  - Working Width ..... 40.8 in. (1,036 mm)
- Maximum Angular Displacements
  - Roll ..... -21.8° < 75°
  - Pitch ..... -10.8° < 75°
  - Yaw ..... 55.4°
- Transducer Data

Evaluation Criteria		Transducer			MASH Limit
		DTS	DTS SLICE	DTS	
OIV ft/s (m/s)	Longitudinal	-17.62 (-5.37)	-17.46 (-5.32)	-18.77 (-5.72)	≤ 40 (12.2)
	Lateral	16.31 (4.97)	17.79 (5.42)	17.11 (5.22)	≤ 40 (12.2)
ORA g's	Longitudinal	-12.52	-12.29	-13.07	≤ 20.49
	Lateral	10.94	9.18	10.12	≤ 20.49
THIV – ft/s (m/s)		23.02 (7.02)	23.75 (7.24)	NA	not required
PHD – g's		15.21	14.83	NA	not required
ASI		0.88	0.93	0.92	not required

Figure 57. Summary of Test Results, Test No. MWTC-3 [9]

2.3.3 34-in. Tall Thrie-beam Transition to Concrete Buttress, Test Nos. 34AGT-1 and 34AGT-2 (2017)

The crashworthiness of a vertical wall transition was tested by MwRSF during full-scale crash test nos. 34AGT-1 and 34AGT-2, according to MASH test designation nos. 3-21 and 3-20, respectively. During these tests, the existing Nebraska Department of Transportation (NDOT) standard guardrail transition provided the basis for the new approach guardrail transition (AGT) design [10]. The system consisted of 31-in. tall, nested thrie-beam rails supported by W6x15 posts spaced at 37.5 in. on center. The upstream end of the NDOT transition utilized the MASH-crashworthy MGS stiffness transition, which transitions from standard MGS guardrail to stiffened thrie-beam AGTs with the use of an asymmetrical W-to-thrie transition segment and 6-ft long W6x8.5 posts. In order to account for future overlays, the thrie-beam rail segments of the AGT were raised 3 in. to achieve a top mounting height of 34 in. The post embedment depths for the system were 52 in. and 40 in. for the W6x15 and W6x8.5 steel posts, respectively. To connect the 34-in. tall thrie-beam to the 31-in. tall MGS, the asymmetric W-to-thrie transition segment within the MGS stiffness transition was replaced with the symmetric transition rail segment. The system layout and the installation system are shown in Figures 58 through 60.

The CIP was determined to be 89 in. and 63 in. upstream from the concrete buttress for test nos. 34AGT-1 and 34AGT-2, respectively. During test no. 34AGT-1, the 5,024-lb pickup truck impacted the AGT 90½ in. upstream from the concrete buttress at a speed of 62.2 mph and an angle of 24.8 degrees. The vehicle was contained and smoothly redirected and the test was deemed successful according to MASH test designation no. 3-21 safety criteria. System damage is shown in Figure 61 and a summary of test results in shown in Figure 63.

During test no. 34AGT-2, the 2,420-lb small car impacted the AGT 65¾ in. upstream from the concrete buttress at the speed and angle of 62.1 mph 25.5 degrees, respectively. The vehicle was contained and smoothly redirected. The test vehicle did not penetrate nor override the barrier and remained upright during and after the collision and test no. 34AGT-2 was determined to be acceptable according to the MASH safety performance criteria for test designation no. 3-20. System damage is shown in Figures 61 and 62 and summaries of test results are shown in Figures 63 and 64.

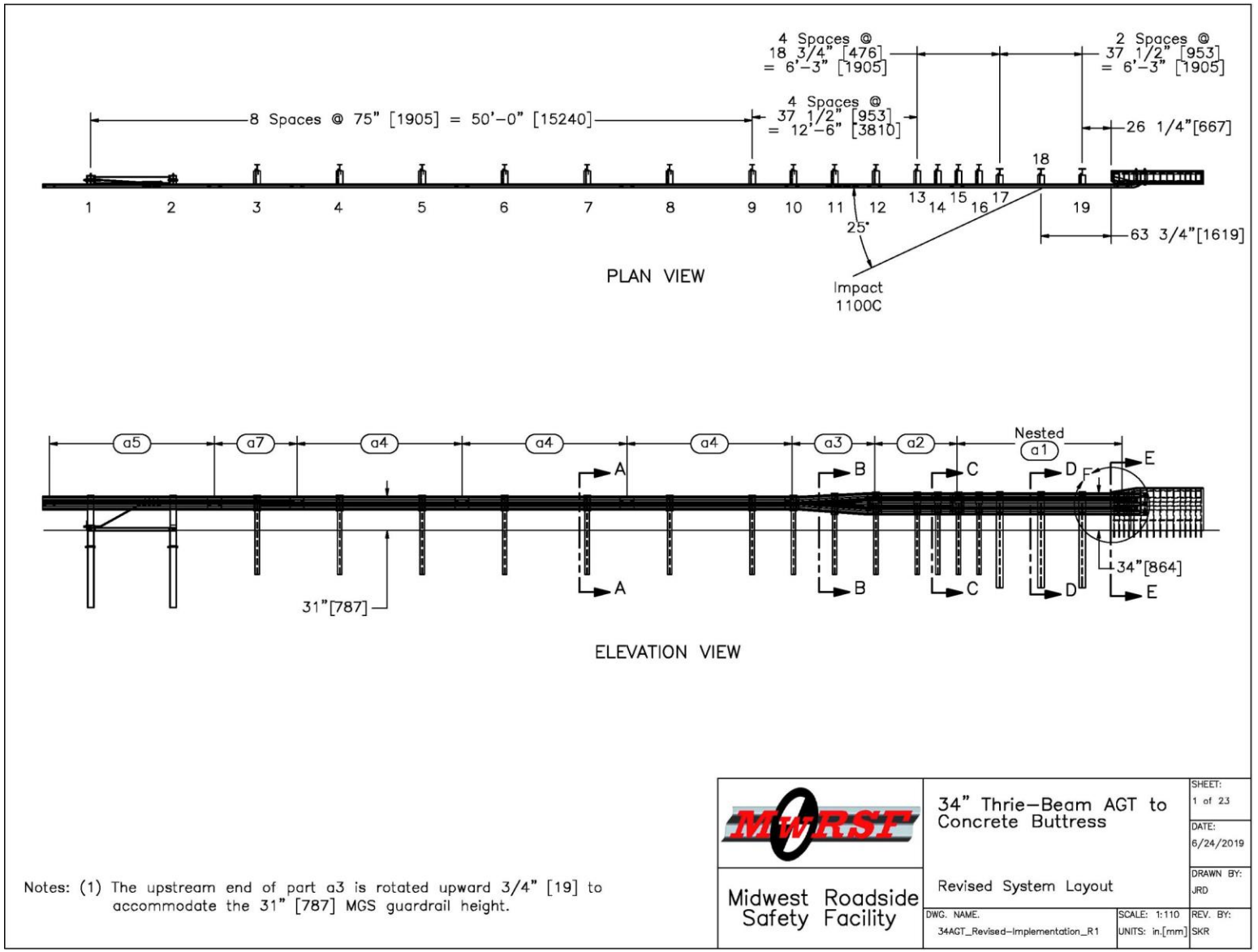


Figure 58. 34-in. Tall Thrie-beam Transition to Concrete Buttress, System Layout, Test Nos. 34AGT-1 and 34AGT-2 [10]

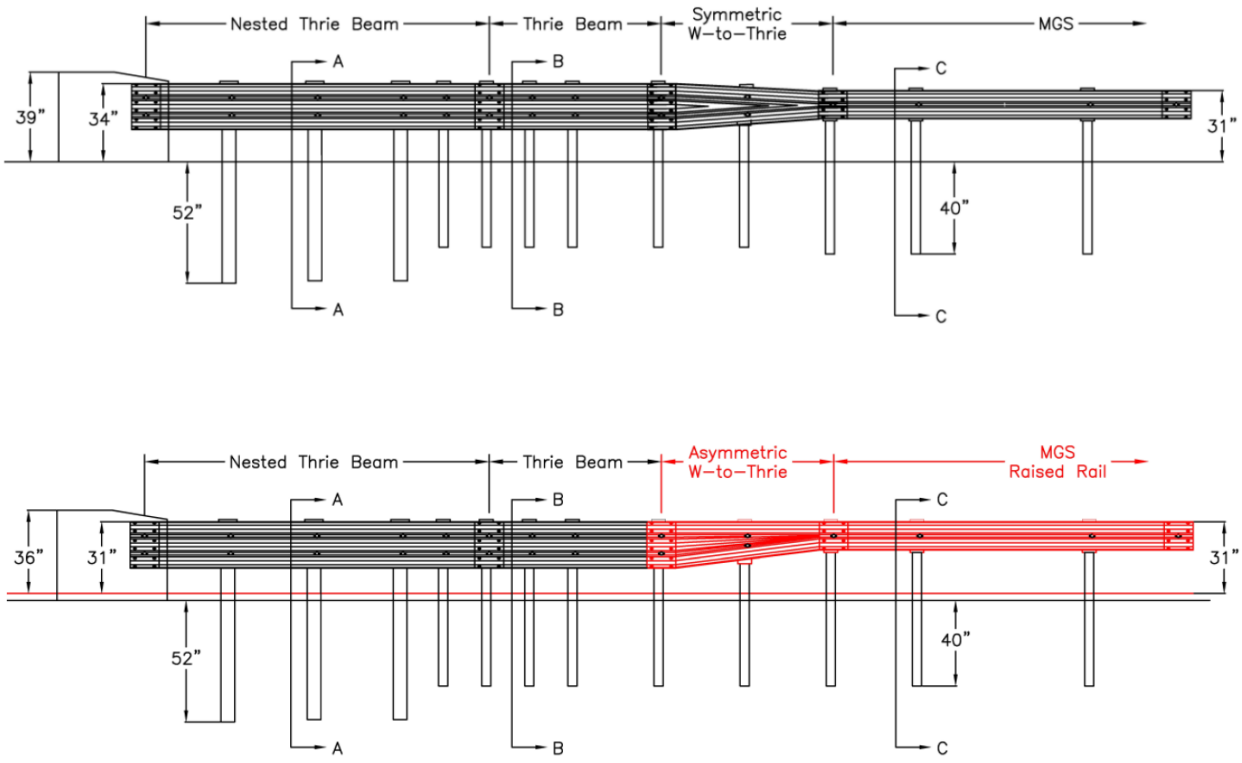


Figure 59. 34-in. Tall AGT Installation: (Top) Initial Installation with No Overlay, (Bottom) Installation after 3-in. Roadway Overlay [10]



Figure 60. 34-in. Tall AGT System Installation, Test Nos. 34AGT-1 and 34AGT-2 [10]

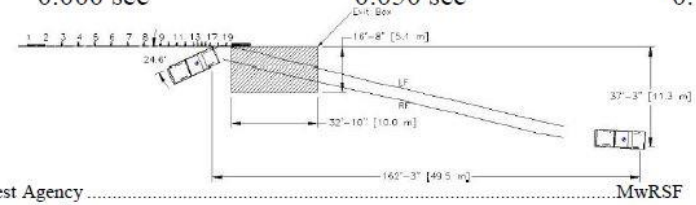


Figure 61. 34-in. Tall AGT System Damage, Test No. 34AGT-1 [10]

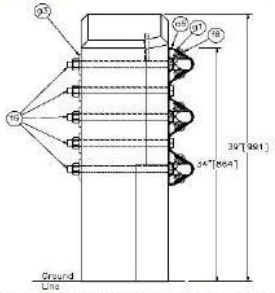


Figure 62. 34-in. Tall AGT System Damage, Test No. 34AGT-2 [10]





- Test Agency ..... MwRSF
- Test Number 34AGT-1
- Date 3/17/17
- MASH 2016 Test Designation No. 3-21
- Test Article ..... 34-in. (864-mm) Tall Thrie Beam AGT
- Total Length ..... 87 ft – 11¼ in. (26.8 m)
- Key Component – Thrie beam Guardrail
  - Thickness ..... 12 ga. (2.7 mm)
  - Mounting Height ..... 34 in. (864 mm)
- Key Component –W6x15 Steel Post
  - Length ..... 84 in. (2,134 mm)
  - Embedment Depth ..... 52 in. (1,321 mm)
  - Spacing ..... 37½ in. (953 mm)
- Key Component – Concrete Transition Buttress
  - Length ..... 84 in. (2,134 mm)
  - Width ..... 12 in. (305 mm)
  - Height ..... 39 in. (991 mm)
- Soil Type ..... Coarse Crushed Limestone
- Vehicle Make /Model ..... Dodge Ram 1500
  - Curb ..... 5,085 lb (2,307 kg)
  - Test Inertial ..... 5,024 lb (2,279 kg)
  - Gross Static ..... 5,189 lb (2,354 kg)
- Impact Conditions
  - Speed ..... 62.2 mph (100.1 km/h)
  - Angle ..... 24.8 deg.
  - Impact Location ..... 90½ in. (2,299 mm) upstream from buttress
- Impact Severity (IS) ..... 114 kip-ft (155 kJ) > 106 kip-ft (144 kJ) MASH 2016 limit
- Exit Conditions
  - Speed ..... 42.1 mph (67.8 km/h)
  - Angle ..... -10.8 deg.
- Exit Box Criterion ..... Pass
- Vehicle Stability ..... Satisfactory
- Vehicle Stopping Distance ..... 162.3 ft (49.5 m) downstream and 37.3 ft (11.4 m) in front

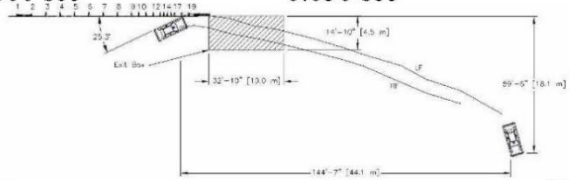


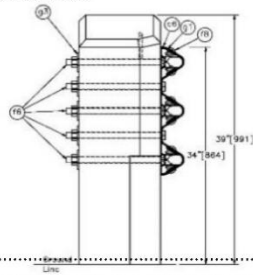
- Vehicle Damage ..... Moderate
  - VDS [33] 11-LFQ-6
  - CDC [34] 11-FLEW-4
  - Maximum Interior Deformation ..... 6⅝ in. (168 mm)
- Test Article Damage ..... Moderate
- Maximum Test Article Deflections
  - Permanent Set ..... 5¾ in. (146 mm)
  - Dynamic ..... 7.8 in. (198 mm)
  - Working Width ..... 24.7 in. (627 mm)
- Transducer Data

Evaluation Criteria		Transducer		MASH 2016 Limit
		SLICE-1	SLICE-2 (primary)	
OIV ft/s (m/s)	Longitudinal	-21.06 (-6.42)	-20.18 (-6.15)	±40 (12.2)
	Lateral	24.62 (7.50)	25.92 (7.90)	±40 (12.2)
ORA g's	Longitudinal	-10.05	-10.77	±20.49
	Lateral	10.44	8.85	±20.49
MAX ANGULAR DISP. deg.	Roll	-15.1	-12.0	±75
	Pitch	-3.3	-4.4	±75
	Yaw	39.6	38.9	not required
THIV – ft/s (m/s)		30.78 (9.38)	31.50 (9.60)	not required
PHD – g's		10.71	11.15	not required
ASI		1.49	1.59	not required

Figure 63. Summary of Test Results, Test No. 34AGT-1 [10]







- Test Agency ..... MwRSF
- Test Number 34AGT-2
- Date 5/9/17
- MASH 2016 Test Designation No. 3-20
- Test Article ..... 34-in. (864-mm) Tall Thrie Beam AGT
- Total Length ..... 87 ft – 11¼ in. (26.8 m)
- Key Component – Thrie beam Guardrail
  - Thickness ..... 12 ga. (2.7 mm)
  - Mounting Height ..... 34 in. (864 mm)
- Key Component – ASTM A992 W6x15 Steel Post
  - Length ..... 84 in. (2,134 mm)
  - Embedment Depth ..... 52 in. (1,321 mm)
  - Spacing ..... 37½ in. (953 mm)
- Key Component – 4,000 psi Concrete Buttress
  - Length ..... 84 in. (2134 mm)
  - Width ..... 12 in. (305 mm)
  - Height ..... 39 in. (991 mm)
- Soil Type ..... Coarse Crushed Limestone
- Vehicle Make /Model ..... Kia Rio
  - Curb ..... 2,331 lb (1,057 kg)
  - Test Inertial ..... 2,420 lb (1,098 kg)
  - Gross Static ..... 2,580 lb (1,170 kg)
- Impact Conditions
  - Speed ..... 62.1 mph (99.9 km/h)
  - Angle ..... 25.5 deg
  - Impact Location ..... 2 in. (51 mm) upstream from post no. 18
- Impact Severity (IS) ... 57.7 kip-ft (78.3 kJ) > 51 kip-ft (69.7 kJ) limit from MASII 2016
- Exit Conditions
  - Speed ..... 40.7 mph (65.5 km/h)
  - Angle ..... -6.4 deg
- Exit Box Criterion ..... Pass
- Vehicle Stability ..... Satisfactory
- Vehicle Stopping Distance ..... 144.6 ft (44.1 m) downstream and 69.5 ft (21.2) in front
- Vehicle Damage ..... Moderate
  - VDS 11-LFQ-6
  - CDC 11-FLEW-4
  - Maximum Interior Deformation ..... 7 in. (178 mm)
- Test Article Damage ..... Minimal
- Maximum Test Article Deflections
  - Permanent Set ..... ¾ in. (19 mm)
  - Dynamic ..... 2.7 in. (69 mm)
  - Working Width ..... 19.9 in. (505 mm)
- Transducer Data

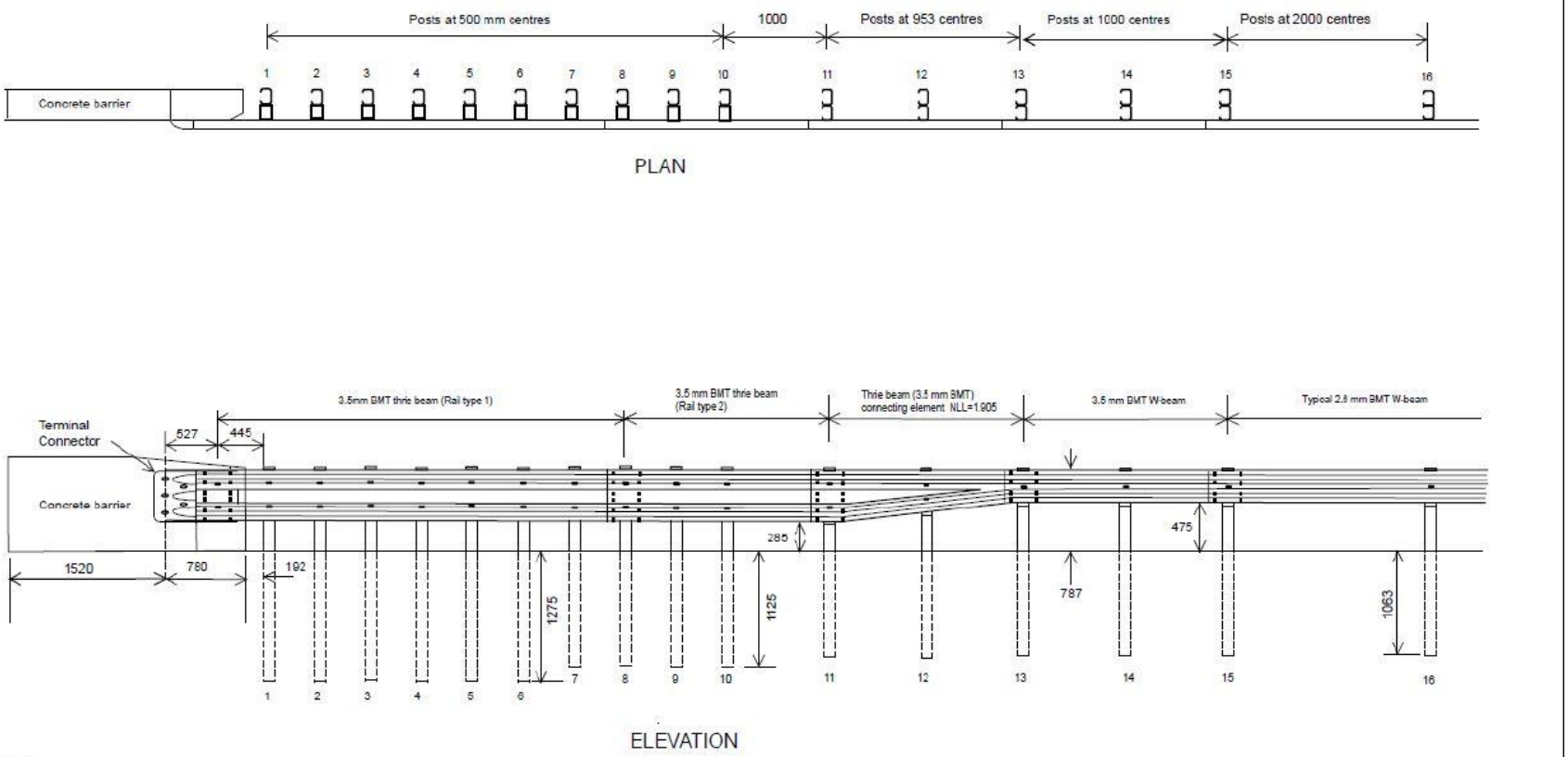
Evaluation Criteria		Transducer		MASII 2016 Limit
		SLICE-1	SLICE-2 (primary)	
OIV ft/s (m/s)	Longitudinal	-20.54 (-6.26)	-22.65 (-6.90)	±40 (12.2)
	Lateral	35.29 (10.76)	32.71 (9.97)	±40 (12.2)
ORA g's	Longitudinal	-25.55	-10.84	±20.49
	Lateral	-12.69	14.70	±20.49
MAX ANGULAR DISP. deg.	Roll	-15.3	-10.0	±75
	Pitch	-6.0	-5.5	±75
	Yaw	96.4	94.9	not required
THIV – ft/s (m/s)		38.39 (11.70)	36.65 (11.17)	not required
PHD – g's		13.44	15.07	not required
ASI		2.43	2.30	not required

Figure 64. Summary of Test Results, Test No. 34AGT-2 [10]

2.3.4 Thrie-Beam AGT to Concrete Barrier, Test No. B19005

In 2019, Crashlab evaluated the crashworthiness of the thrie-beam AGT to concrete barrier system according to MASH test designation no. 3-21 [11-12]. In test no. B19005, the system consisted of a concrete block located upstream of the system, and 21 Charlie C steel posts attached to the thrie-beam and W-beam. Total length of the system was 78 ft – 8 in. Post nos. 1 through 11 were attached to the 10-gauge thrie-beam, post nos. 11 through 13 were attached to the W-to-thrie-beam transition, post nos. 13 through 19 were attached to the 12-gauge W-beam, and post nos. 20 and 21 were attached to a W-beam trailing end anchor. Varying types of steel blockouts were implemented in this installation, including 15 mm x 100 mm x 6 mm steel blockouts for post nos. 1 through 10 and modified Charlie section steel blockouts for post nos. 11 through 20. Post nos. 1 through 10 were spaced at 19⅝ in. on center, post nos. 10 and 11 were spaced at 39⅜ in. on center, post nos. 11 through 13 were spaced at 37½ in. on center, post nos. 13 through 15 were spaced at 39⅜ in. on center, and post nos. 15 through 20 were spaced at 78¾ in on center. Post nos. 1 through 6, post nos. 7 to 10, and post nos. 11 through 21 were embedded at depths of 50⅛ in., 44⅜ in., and $41^{15}/_{16}$ in., respectively. The total system height was 31 in., the thrie-beam was 30¾ in. at post no. 4, 30⅜ in. at post no. 5, and 30½ in. at the impact point. Impact occurred $82^{11}/_{16}$ in. upstream from the concrete anchor block, between post nos. 4 and 5. The system layout and installation are shown in Figures 65 and 66, respectively.

During test no. B19005, the 2270P pickup truck impacted the barrier system at speed of 64.2 mph and an angle of 25.6 degrees, in accordance with MASH test designation no. 3-21. The vehicle came to rest 114 ft – 10 in. downstream from the impact point with an 85 ft – 4 in. lateral offset from the tangential line of the system. The system contained and redirected the vehicle during the test; however, the vehicle rolled after exiting the barrier, which resulted in failure of the test. The damage to the test vehicle was deemed moderate due to vehicle rollover. System damage, which is shown in Figure 67, was deemed minimal. A summary of test results is shown in Figure 68.



Notes:
1. Posts 1 to 6 are 2000 long
2. Posts 11 to 16 are 1850 long
3. Blockouts on posts 1 to 10 are RHS
4. Blockouts on post 11 is TMR P004
5. Blockout on post 12 is a modified C section
6. Blockouts on posts 13 to 16 are C section TMR P002
7. W-beam and thrie beam ticknesses are shown

Austroads

W-beam to thrie beam to concrete barrier transition configuration for testing

Austroads	Drawn: R J Troutbeck
Not to scale	Date: 8 January 2019
General arrangement	Drawing: 2 of 7

Figure 65. System Layout, Test No. B19005 [11]



Figure 66. Thrie-beam AGT to Concrete Barrier Transition Installation, Test No. B19005 [1211]



Figure 67. Thrie-beam AGT to Concrete Barrier Transition, System Damage, Test No. B19005 [11]



Test article	W-beam to Thrie-beam to concrete transition Barrier	
Installation length	24 m	
Height of barrier	775 mm (at impact)	
Number of posts	21	
Terminals	Trailing end anchorage terminal used	
Installation conditions	Spray sealed surface, AAHSTO specification ground.	
Impact point	2.1m upstream from end of concrete transition	
Test vehicle	2013 Dodge RAM 1500 Quad Cab pickup	
Designation	2270P	
Test inertial mass	2251.5 kg	
Velocities	Impact: 103.3 km/h	Exit: 79.4km/h
Angles	Impact: 25.6 degrees	Exit: 13.2 degrees
Impact severity	173.4 kJ	
Stopping distance	35m downstream from impact point, 26m laterally to the leftt of impact point	
Vehicle stability	Vehicle rolled after exit	
Vehicle snagging	None	
Vehicle pocketing	None	

Occupant Impact Velocity	Longitudinal (Vx)	7.0 m/s
	Lateral (Vy)	8.5 m/s
Occupant Ridedown Acceleration	Longitudinal (Gx)	-8.8 g
	Lateral (Gy)	-14.9 g
ASI	1.65	
THIV	38.6 km/h *(exceeded maximum reference value)*	
PHD	14.9 g	
Maximum roll angle	>75 degrees at 1651ms, 23.1 degrees (during contact) 436 degrees at 4799ms	
Maximum pitch angle	-7.9 degrees (during contact) -58.9 degrees at 2327ms	
Exterior vehicle damage	CDC	01FRA05
	VDS	011RT5
Interior deformation (max.)	OCDI	n/a
Barrier end deflection	x-direction	0mm
Static deflection, top of barrier (max.)	y-direction	120mm
Dynamic deflection, top of barrier (max.)	y-direction	190mm
Working width	y-direction	549mm

Figure 68. Summary of Test Results, Test No. B19005 [11]

2.3.5 Thrie-Beam AGT to Concrete Barrier, Test No. B19008

Following the failure of test no. B19005, the AGT system was modified and reevaluated. In test no. B19008, the crashworthiness of the modified thrie-beam AGT to concrete barrier system was evaluated by Crashlab according to MASH test designation no. 3-21 [11-12]. Modifications included replacing the original post nos. 1 through 6 with 100-mm universal columns (100UC) steel posts bolted to 200 mm x 100 mm x 5 mm rectangular hollow section (RHS) blockouts which attached to 3.5 mm BMT thrie-beam. Post nos. 1 through 11 were attached to the 10-gauge thrie-beam, 11 through 13 were attached to the thrie-beam to W-beam transition, 13 through 15 were attached to the 10-gauge W-beam, 16 through 19 were attached to the 12-gauge W-beam, and 19 through 21 were attached to the W-beam trailing end anchor. All posts were attached to the rails using RHS blockouts. The post spacing and embedment depths used in this installation remained the same as in test no. B19005. The total height of the thrie-beam was 30¾ in. at post no. 4, $30^{9}/_{16}$ in. at post no. 5, and 30¾ in. at the impact point, which was $82^{11}/_{16}$ in. upstream from the concrete anchor block, between post nos. 4 and 5. The system layout and the installation are shown in Figures 69 and 70, respectively.

During test no. B19008, the 2270P pickup truck impacted the barrier system at 63.6 mph and an angle of 25.2 degrees, in accordance with MASH test designation no. 3-21. The selected impact point was $82^{11}/_{16}$ in. upstream from the downstream edge of the concrete anchor block, between post nos. 4 and 5. The vehicle was found to be within 11 in. of the impact point. The system contained and redirected the vehicle during the test with compliant level of occupant risk; however, the vehicle rolled after exiting the barrier which resulted in failure of the test. The damage to the test vehicle was deemed moderate due to the vehicle rolling over after the test. System damage, which is shown in Figure 71, was deemed minimal. The test summary is shown in Figure 72.

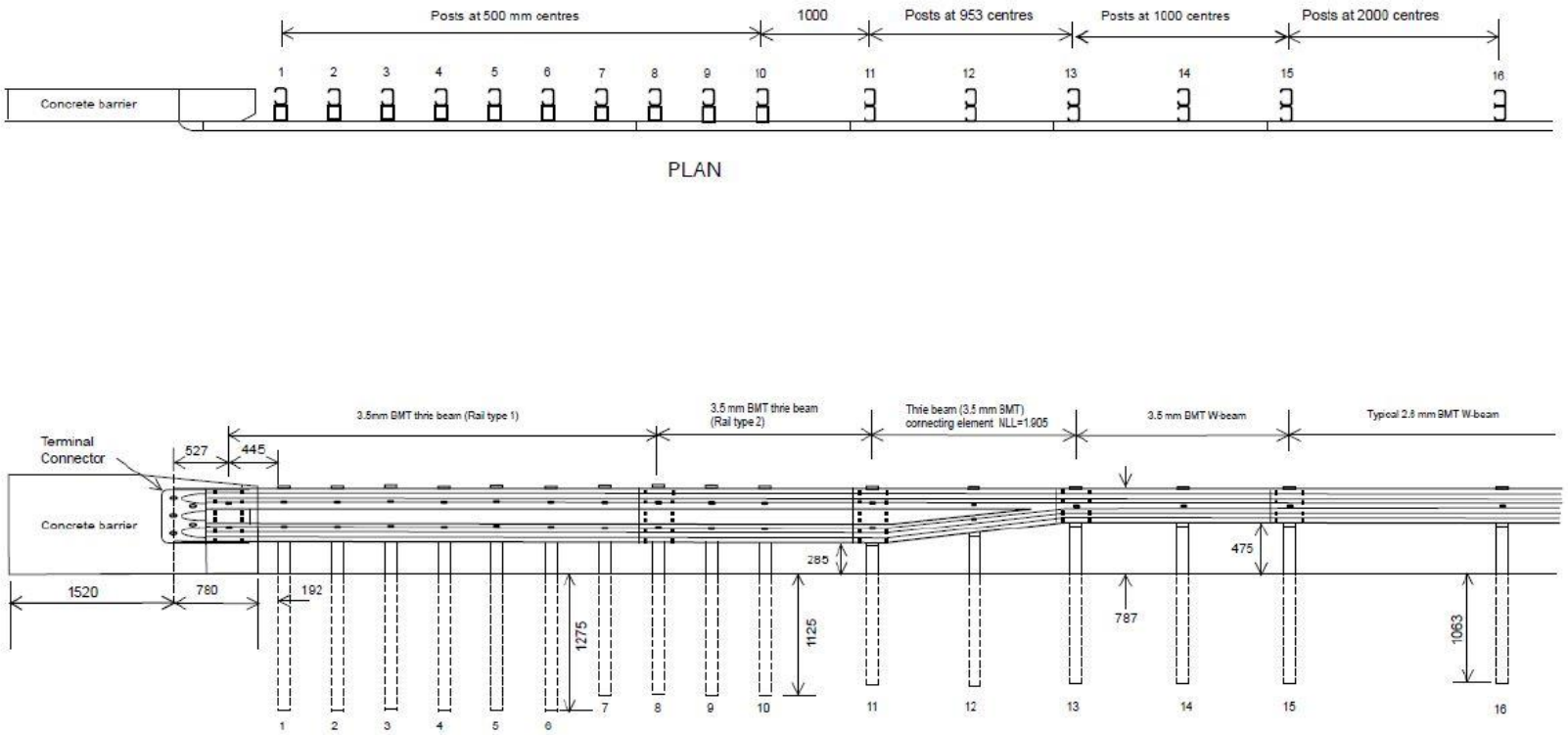


Figure 69. System Layout, Test No. B19008 [11]



Figure 70. Thrie-beam AGT to Concrete Barrier Transition Installation, Test No. B19008 [11]



Figure 71. Thrie-beam AGT to Concrete Barrier Transition, System Damage, Test No. B19008 [11]



Test article	W-beam to Thrie-beam to concrete transition Barrier	
Installation length	24 m	
Height of barrier	780 mm (at impact)	
Number of posts	21	
Terminals	Trailing end anchorage terminal used	
Installation conditions	Spray sealed surface (except from posts 1 to 8), AAHSTO specification ground.	
Impact point	2.1m upstream from end of concrete transition	
Test vehicle	2012 Dodge RAM 1500 Quad Cab pickup	
Designation	2270P	
Test inertial mass	2249 kg	
Velocities	Impact: 102.3 km/h	Exit: 73km/h
Angles	Impact: 25.2 degrees	Exit: 11.5 degrees
Impact severity	164.6 kJ	
Stopping distance	35m downstream from impact point, 23m laterally to the left of impact point	
Vehicle stability	Vehicle rolled twice onto roof after exit	
Vehicle snagging	None	
Vehicle pocketing	None	

Occupant Impact Velocity	Longitudinal (Vx)	6.9 m/s
	Lateral (Vy)	8.1 m/s
Occupant Ridedown Acceleration	Longitudinal (Gx)	-13.4 g
	Lateral (Gy)	-11.2 g
ASI	1.85	
THIV	37.2 km/h *(exceeded maximum reference value)*	
PHD	15.1 g	
Maximum roll angle[1]	>75 degrees at 940ms, 23.7 degrees (during contact) 159.6 degrees at 2000ms	
Maximum pitch angle	-8.6 degrees (during contact) -89.1 degrees at 2000ms	
Exterior vehicle damage	CDC	01FRA08
	VDS	011RT7
Interior deformation (max.)	OCDI	n/a
Barrier end deflection	x-direction	0mm
Static deflection, top of barrier (max.)	y-direction	80mm
Dynamic deflection, top of barrier (max.)	y-direction	140mm
Working width	y-direction	451mm

Note: 1. Vehicle rolled 1¾ times. Data only recorded to 2000ms.

Figure 72. Summary of Test Results, Test No. B19008 [11]

2.3.6 Thrie-Beam AGT to Concrete Barrier, Test No. AGTB-2

The crashworthiness of the thrie-beam AGT system was evaluated by MwRSF according to MASH test designation no. 3-21 [13]. The test installation for test no. AGTB-2 was approximately 82 ft long and consisted of four main components: (1) a concrete transition buttress, (2) a thrie-beam AGT, (3) standard MGS, and (4) a guardrail anchorage system. The downstream end of the installation consisted of the standardized concrete buttress. The buttress was 7 ft long and 36 in. tall, corresponding to a typical height for MASH TL-4 concrete barriers. To prevent vehicle snag above the thrie-beam rail, the upstream end of the buttress was 32 in. tall and incorporated a 4-in. tall x 24-in. long slope to bring the barrier height up to 36 in. The buttress utilized a dual-tapered, or dual-chamfer, design along its front edge. The lower taper measured 4½ in. deep x 18 in. long x 14 in. tall and was designed to reduce wheel snagging on the parapet. The upper taper measured 3 in. x 4 in. and extended from the lower taper to the top of the buttress. The upper taper was designed to limit vehicle snag on the buttress, to prevent the rail from bending around a rigid corner, and to limit the unsupported span length of the rail upstream from the buttress.

The thrie-beam AGT and adjacent MGS consisted of 12 ft – 6 in. of nested 12-gauge thrie-beam, 6 ft – 3 in. of single ply 12-gauge thrie-beam, a 6 ft – 3 in. long 10-gauge asymmetric W-to-thrie transition rail segment, and 50 ft of 12-gauge W-beam. All rail segments were mounted with a top height of 31 in. The first six posts adjacent to the buttress were 6 ft – 6 in. long W6x8.5 posts spaced at 18¾ in. on-center and embedded 49 in. into the soil. The remaining steel posts were 6-ft long W6x8.5 posts embedded 40 in. into the soil, utilized 12-in. deep wood blockouts, and were spaced at various intervals. A guardrail anchorage system typically utilized as a trailing-end terminal was utilized to anchor the upstream end of the test installation. The guardrail anchorage system was originally designed to simulate the strength of other crashworthy end terminals. The anchorage system consisted of timber posts, foundation tubes, anchor cables, bearing plates, rail brackets, and channel struts. The system layout and installation are shown in Figures 73 and 74, respectively.

During test no. AGTB-2, the 2270P pickup truck impacted the thrie-beam AGT 86 in. upstream from the concrete buttress at a speed of 62.6 mph and an angle of 25.4 degrees in accordance with MASH test designation no. 3-21. The vehicle was contained and redirected and the vehicle remained stable throughout the impact event. Vehicle deformations were within limits described in MASH. Therefore, test no. AGTB-2 was determined to be acceptable according to the MASH safety performance criteria for test designation no. 3-21. System damage and a summary of test results are shown in Figures 75 and 76, respectively.

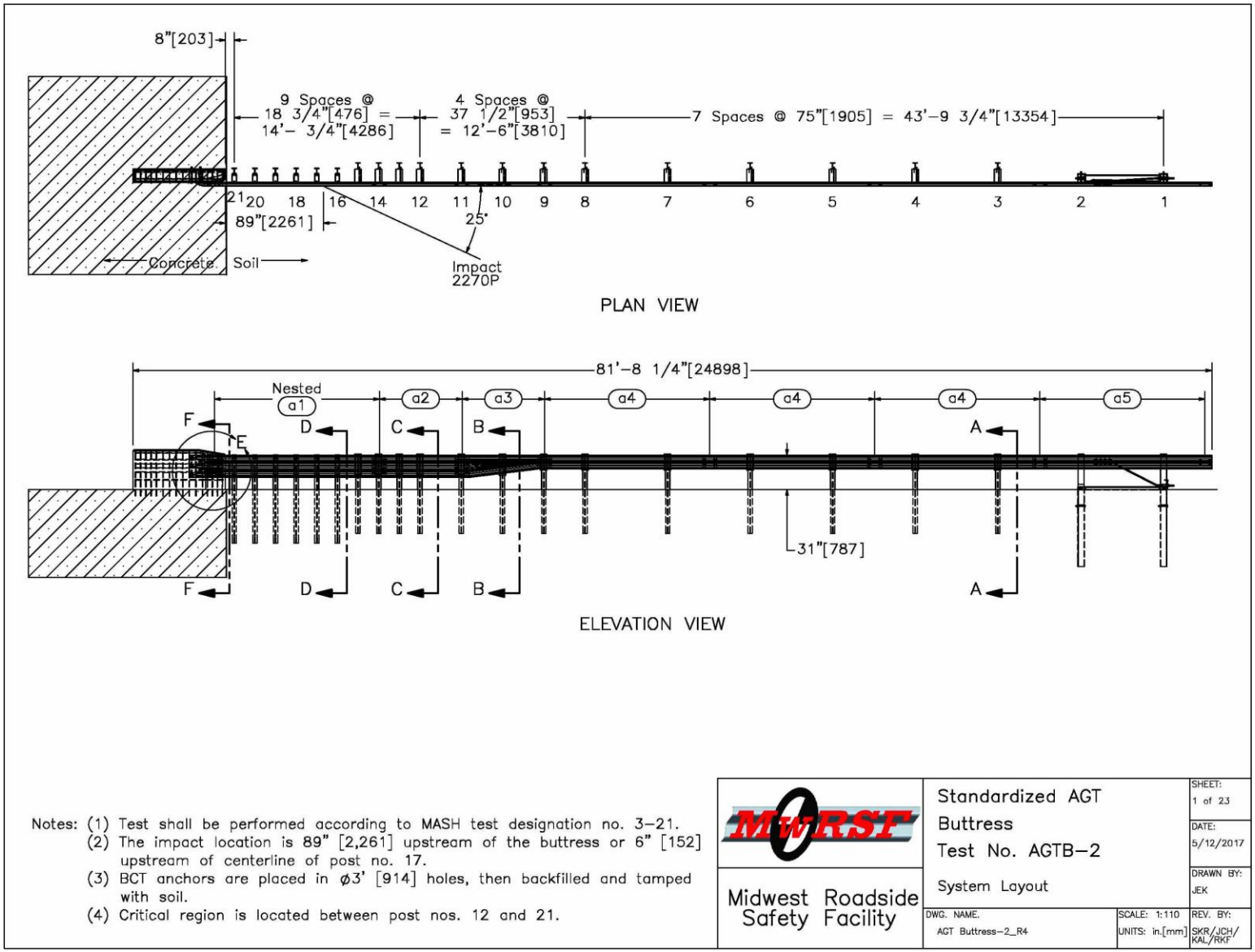


Figure 73. System Layout, Test No. AGTB-2 [12]

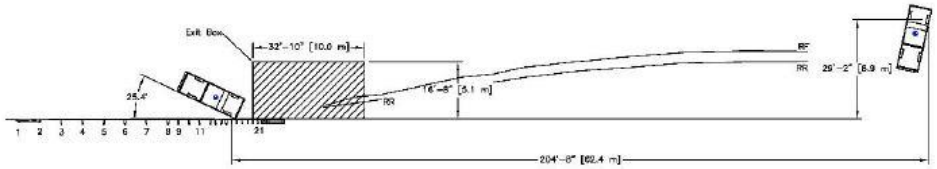


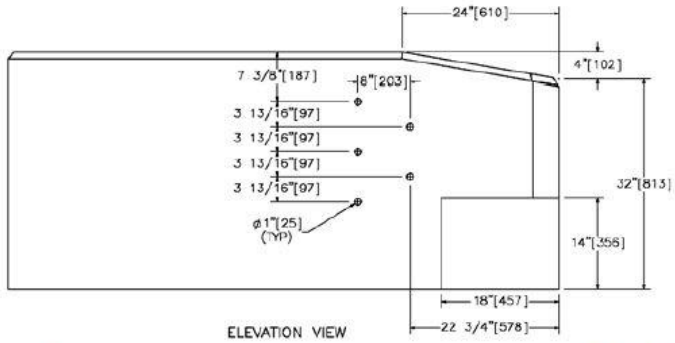
Figure 74. Thrie-Beam AGT to Concrete Barrier Installation, Test No. AGTB-2 [12]



Figure 75. Thrie-Beam AGT to Concrete Barrier System Damage, Test No. AGTB-2 [12]







- Test Agency ..... MwRSF
- Test Number AGTB-2
- Date 7/19/2017
- MASH Test Designation No. 3-21
- Test Article ..... Standardized Buttress for AGT
- Total Length ..... 81 ft - 8¼ in.
- Key Components – Guardrail AGT
  - Nested Thrie beam ..... 12 gauge
  - Asymmetric W-to-Thrie Transition Segment ..... 10 gauge
  - Thrie Beam Terminal Connector ..... 10 gauge
  - Concrete Buttress (*l* x *w* x *h*) ..... 84 x 12 x 36 in.
- Soil Type ..... Coarse Crushed Limestone
- Vehicle Make /Model ..... 2010 Dodge Ram 1500
  - Curb ..... 5,097 lb
  - Test Inertial ..... 4,998 lb
  - Gross Static ..... 5,160 lb
- Impact Conditions
  - Speed ..... 62.7 mph
  - Angle ..... 25.4 deg
  - Impact Location ..... 86 in. upstream from the end buttress
- Impact Severity (IS) ..... 120.84 kip-ft > 106 kip-ft
- Exit Conditions
  - Speed ..... 48.9 mph
  - Angle ..... -9.0 deg
- Exit Box Criterion ..... Pass
- Vehicle Stability ..... Satisfactory
- Vehicle Stopping Distance ..... 204 ft – 8 in.
- Vehicle Damage ..... Moderate
  - VDS [47] 1-RFQ-5
  - CDC [48] 01-RFEE-4
  - Maximum Interior Deformation ..... 6⅜ in.
- Test Article Damage ..... Minimal
- Maximum Test Article Deflections
  - Permanent Set ..... 2¾ in.
  - Dynamic ..... 5.3 in.
  - Working Width ..... 26.0 in.
- Transducer Data

Evaluation Criteria		Transducer		MASH Limit
		SLICE-1	SLICE-2 (primary)	
OIV (ft/s)	Longitudinal	-20.68	-20.28	±40
	Lateral	-23.08	-24.61	±40
ORA (g's)	Longitudinal	-6.95	-7.06	±20.49
	Lateral	-12.57	-10.40	±20.49
MAXIMUM ANGULAR DISP. (deg.)	Roll	24.56	21.25	±75
	Pitch	-5.38	-6.30	±75
	Yaw	-39.19	-39.58	Not required
THIV – (ft/s)		30.46	30.95	Not required
PHD – (g's)		13.65	12.53	Not required
ASI		1.30	1.37	Not required

Figure 76. Summary of Test Results, Test No. AGTB-2 [12]

2.3.7 Discussion

The design of the HDOT buried-in-backslope terminal system utilized a W-beam transition to a rigid, concrete anchor block. Full-scale crash tests of W-beam transitions were utilized to identify common practice for the design of W-beam transitions as well as design considerations to improve the likelihood of successful vehicle redirections in the transition region.

During the course of full-scale testing with the HDOT BIB system, design options were considered that involved a transition between W-beam and thrie beam rail options. The use of thrie beam was proposed as a means of increasing the system stiffness and reducing vehicle engagement with posts beneath the rubrail. Thus, researchers also reviewed W-beam to thrie beam transitions to understand the potential challenges and risks associated with introducing a W-beam to thrie beam transition within the rail section.

Results indicated that stiffness transitions would be required for any transition, and that W-beam transitions to rigid parapets have historically posed a challenge for successful crash testing to MASH evaluation conditions. At the time of this study, it was unknown if the combination of a W-beam transition, V-ditch, and flare away from the adjacent travel way would be crashworthy. However, the design of the HDOT BIB system was consistent with designs which have been historically evaluated with some success. If a thrie beam retrofit is required to improve the performance of the rubrail in the ditch, the design will need to integrate considerations for the stiffness transition upstream of the W-beam to thrie beam transition piece, similar to what was observed in testing.

3 TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1 Test Requirements

End terminals, such as the HDOT BIB system, must satisfy impact safety standards to be declared eligible for federal reimbursement by the Federal Highway Administration (FHWA) for use on the National Highway System. For new hardware, these safety standards consist of the guidelines and procedures published in MASH. According to TL-3 of MASH, end terminals systems must be subjected to ten full-scale vehicle crash tests, as summarized in Table 1.

Table 1. MASH TL-3 Crash Test Conditions for Non-Gating End Terminals

Test Article	Test Designation No.	Test Vehicle	Vehicle Weight lb	Impact Conditions		Evaluation Criteria [1]
				Speed mph	Angle deg.	
Non-Gating End Terminal	3-30	1100C	2,420	62	0	A,D,F,H,I
	3-31	2270P	5,000	62	0	A,D,F,H,I
	3-32	1100C	2,420	62	5-15	A,D,F,H,I
	3-33	2270P	5,000	62	5-15	A,D,F,H,I
	3-34	1100C	2,420	62	15	A,D,F,H,I
	3-35	2270P	5,000	62	25	A,D,F,H,I
	3-36	2270P	5,000	62	25	A,D,F,H,I
	3-37a	2270P	5,000	62	25	A,D,F,H,I
	3-37b	1100C	2,420	62	25	A,D,F,H,I
	3-38	1500A	3,300	62	0	A,D,F,H,I

[1] Evaluation criteria explained in Table 2.

Nine full-scale crash tests were conducted to evaluate the HDOT BIB system, consisting of test designation nos. 3-32, 3-33, 3-34, 3-35, 3-37a and 3-37b in the standard direction of travel and the addition of test designation nos. 3-37a and 3-37b run in the reverse travel direction. Since the 0-degree impact angle was not practical for this installation, test designation nos. 3-30, 3-31, and 3-38 were not considered. Additionally, test designation no. 3-36 is recommended for terminals directedly attached to the stiff barrier, which was not applicable for this system. It should be noted that the test matrix detailed herein represents the researchers' best engineering judgement with respect to the MASH safety requirements and their internal evaluation of critical tests necessary to evaluate the crashworthiness of the 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 criteria.

3.2 Evaluation Criteria

Evaluation criteria for full-scale vehicle crash testing are based on three appraisal areas: (1) structural adequacy; (2) occupant risk; and (3) vehicle trajectory after collision. Criteria for structural adequacy are intended to evaluate the ability of the longitudinal barrier 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. The full-scale vehicle crash tests documented herein were conducted and reported in accordance with the procedures provided in MASH.

Table 2. MASH Evaluation Criteria for Non-Gating End Terminals

<table>
<tr><td>Structural Adequacy</td><td>A.</td><td colspan="4">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="6">Occupant Risk</td><td>D.</td><td colspan="4">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.</td></tr>
<tr><td>F.</td><td colspan="4">The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 deg.</td></tr>
<tr><td rowspan="3">H.</td><td colspan="4">Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 of MASH for calculation procedure) should satisfy the following limits:</td></tr>
<tr><td colspan="4">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="3">I.</td><td colspan="4">The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH for calculation procedure) should satisfy the following limits:</td></tr>
<tr><td colspan="4">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>

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.

3.3 Soil Strength Requirements

In accordance with MASH, 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 using 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 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 .

4 TEST MATRICES AND CONDITIONS

4.1 General

Full-scale crash tests are a recommended method for assessing evaluation criteria, which encompass occupant risk, vehicle trajectory, and structural adequacy. Several key principles define a full-scale crash test, including vehicle velocity, impact angle, test vehicle mass, and impact location. These parameters are carefully selected to simulate the most challenging real-world scenarios for roadside safety features' crash performance.

In terms of impact speed and angle, the criteria traditionally target the 85th percentile level to ensure robust testing. Test vehicles are typically chosen based on their body style and weight, with weight approximating the 2nd and 90th percentile levels for passenger vehicles.

When it comes to selecting impact locations on safety features, these are strategically chosen to represent a critical impact point (CIP) that poses the highest likelihood of test failure. Therefore, the combination of criteria involving the 85th percentile impact speed, 85th percentile impact angle, 5th and 95th percentile vehicle weight, and critical impact point is considered a comprehensive assessment of the worst practical conditions for evaluating crashworthiness.

4.2 Impact Conditions

Based on the most reliable data obtained from the reconstruction of passenger vehicle crashes on high-speed roadways [14, 15], it was determined that an impact speed of 62 mph and an impact angle of 25 degrees closely represent the 85th percentile of real-world impact conditions for passenger vehicles. For end terminal impacts, reduced impact angles of 5 to 15 degrees are also considered to determine if end terminals experience a change in behavior. The variation of 5 to 15 degrees addresses different anchor conditions where either narrower or wider impact angles may cause critical behavior. For the HBIB system, 15 degrees was considered the more critical orientation because the end anchor is very stiff and not expected to experience large deflections. As a result, a comprehensive series of full-scale crash tests, encompassing scenarios with a 62-mph impact speed and impact angles of both 25 and 15 degrees, has been identified as essential to evaluate the crashworthiness of HDOT's BIB (HBIB) system.

The severity of an impact is normally measured in terms of impact severity factor (ISF) for tests involving vehicle redirection. The other factor is kinetic energy (KE) for crash tests involving end-on impact or breakaway devices. ISF is an indicator of the magnitude of loading on the barrier systems, which is defined as:

$$ISF = \frac{1}{2} M(Vsin(\theta))^2 \quad (1\text{-}4)$$

where, ISF is the impact severity (kJ). M, V, and θ are vehicle mass (kg), impact speed (m/s), and impact angle (degrees), respectively. The KE parameter is defined as:

$$KE = \frac{1}{2} MV^2 \quad (2\text{-}4)$$

where, KE is the kinetic energy (kJ or kips-ft). Note that for the head-on or end-on crash tests such as end terminals, the KE can be a better indicator of the impact severity. For full-scale crash tests, ISF values for tests involving vehicular redirection and KE values for high-speed crash tests, including end-on impacts, should be no more than 8 percent below the target values. KE values were not utilized to evaluate the crash tests for this system because no 0-degree impacts were applicable or practical per section 3.1 of this report. The HBIB system's unique design excluded this typical method of evaluating end terminal tests. Note that the ISF and KE values are calculated based upon the vehicle's inertia mass, excluding the mass of the surrogate occupant.

MASH Section 5.3 provides guidance for addressing geometric features. As the system tested in current research efforts included a ditch in front of the guardrail system for all of the evaluated impacts, criteria provided in MASH are outlined below and were addressed accordingly:

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

(b) Compute average accelerations in the longitudinal and lateral directions for each consecutive 50-ms period for the duration of the event.

(c) If the average longitudinal or lateral acceleration computed in Step b exceeds 2 g's during any 50-ms period, calculate the OIV and RA values at the beginning of the period over which the average acceleration was computed, and evaluate the results according to Criteria H and I of Table 5-l B.

4.3 Critical Impact Point Location

Critical impact points (CIPs) are locations on the system where an impacting vehicle may experience localized critical behaviors. CIP examples include transitions of barrier stiffness, shape, or height, or where changes in the stiffness of the system could contribute to pocketing in the rail, high lateral or longitudinal accelerations, and snag on system components. Changes in the stiffness of a system may lead to localized pocketing or potential for a stiff component or a wheel of an impacting vehicle to snag and experience large forces. As a result, CIPs represent the locations on a barrier system that could maximize the risk of test failure.

The process of choosing the impact location in most full-scale crash tests is a key point to replicate critical conditions that are most likely to result in test failure. For end terminals and longitudinal barriers, the CIPs are basically selected to maximize the loading at specific areas such as rail splices, transition regions, and posts. These selections take into account the potential for wheel snag, vehicle pocketing, and rail rupture, which are significant factors of system failure.

The choice of CIPs may also be influenced by the system's height, which can affect the potential for vehicle override. It is essential to highlight that, in the case of post-and-beam type end terminals, the CIPs are specifically chosen to represent the point at which the system is expected to transition from gating to re-directive behavior. This transition point is a crucial aspect of assessing the performance of these safety systems. MASH allows the selection of CIPs to be estimated analytically or determined using computer simulation programs such as BARRIER VII and LS-DYNA. The analytical procedure described in MASH estimates CIPs based on barrier stiffness parameters associated with posts, rail, and foundations. Parameters include post dynamic

yield force per unit length of barrier, F_p, and the effective plastic moment of all barrier rail elements, M_p.

The post strength is calculated by the weaker of the two parameters: soil resistive forces and the plastic bending strength of the guardrail posts. The post strength per unit length of system, F_p, is determined by:

$$F_p = \frac{F_y}{S} \tag{3-4}$$

In which S is the post spacing on the system and F_y represents the dynamic yield force of a single post. The value for F_y is given by weaker of two calculations: the post plastic bending strength and the total soil force acting on the post at the height of the rail, F_s. The soil contribution to posts depends on post size and embedment depth. Many scenarios involve posts with varying embedment depths, such as posts installed in ditches or on slopes. For these scenarios, the estimated contribution of soil force is provided in MASH using a baseline scenario of a W6x9 steel post embedded 40 in. in MASH strong soil:

$$F_s' = F_s \left(\frac{D_e'}{D_e}\right)^2 \tag{4-4}$$

in which F_s' and F_s denote soil dynamic yield force at the alternative embedment depth and soil dynamic yield force extracted from MASH table A-3, respectively. Likewise, the embedment depths of D_e' and D_e correspond to the embedment depth of the post contribution being estimated and the nominal embedment depth of 40 in., using data provided in MASH table A-3. It should be noted that the values of F_s' can be determined by the bogie testing, which is usually conducted before a full-scale crash test.

The effective plastic moment of a multiple rail system is the sum of the plastic moment of the highest beam and the plastic moments of lower beams reduced by a ratio of the heights of the highest and lowest rail elements:

$$M_p = M_h + \sum M_i \frac{H_i}{H_h} \tag{5-4}$$

where M_h and M_i are, respectively, the plastic moment of highest rail element above ground or deck, and the plastic moment of a lower barrier rail element. H_i and H_h represent height of a lower rail element and height of the highest rail element, respectively. It is worth mentioning that for the systems in which rails are constructed by nested W- or thrie-beam, the M_p of system components should be multiplied by appropriate scale factors (e.g., 2.0) to represent the total effective plastic moment capacity.

After calculating the values for F_p and M_p, the location of the CIP can be defined using the figures provided in MASH. The location of the CIP is defined by the distance *x* from the length-of-need portion of post-and-beam type barrier system. The *x* distance is shown in Figure 77, and a summary of recommended CIP offsets from critical barrier features which are provided in MASH are shown in Figures 79 and 80.

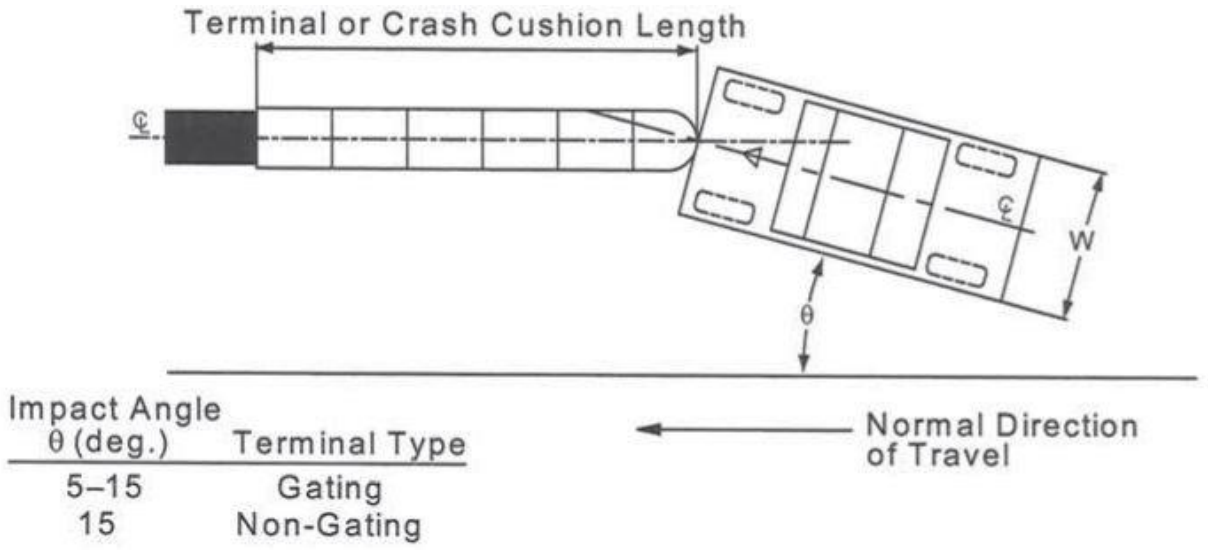


Figure 77. CIP Distance and Test Conditions, Test Level 3, Test Designation Nos. 3-32 and 3-33

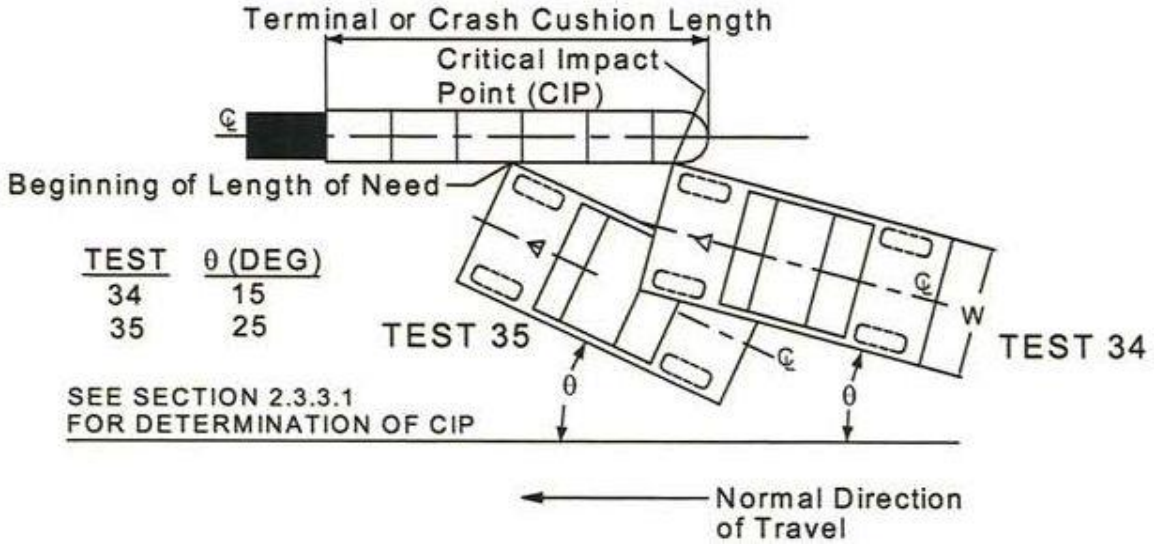


Figure 78. CIP Distance and Test Conditions, Test Level 3, Test Designation Nos. 3-34 and 3-35

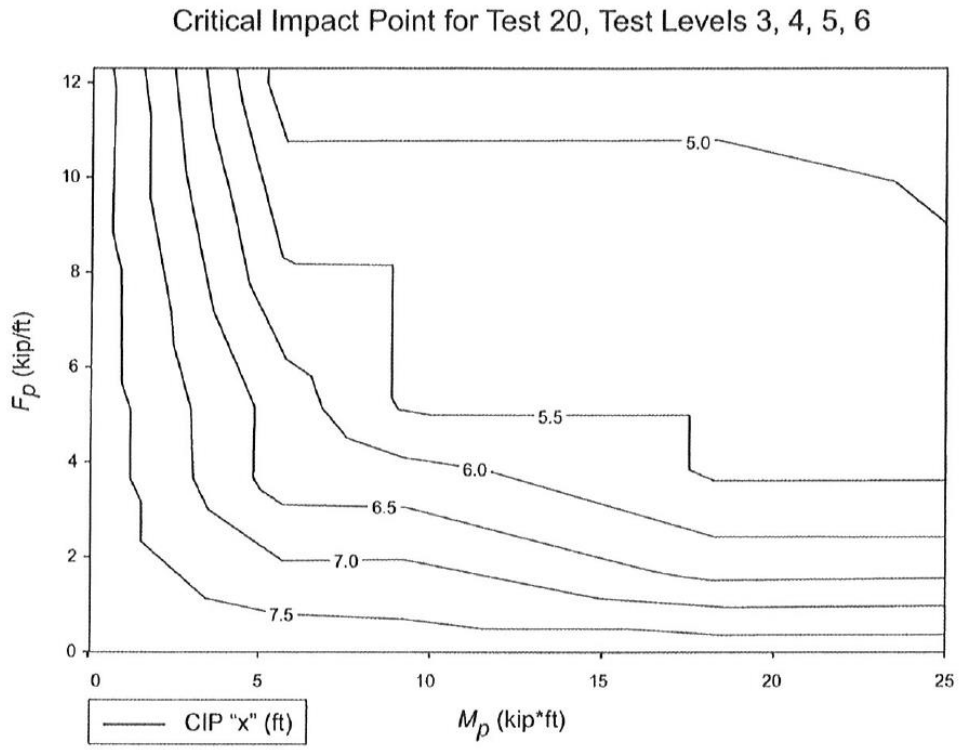


Figure 79. Critical Impact Point Selection for MASH Test Designation 3-20 [8]

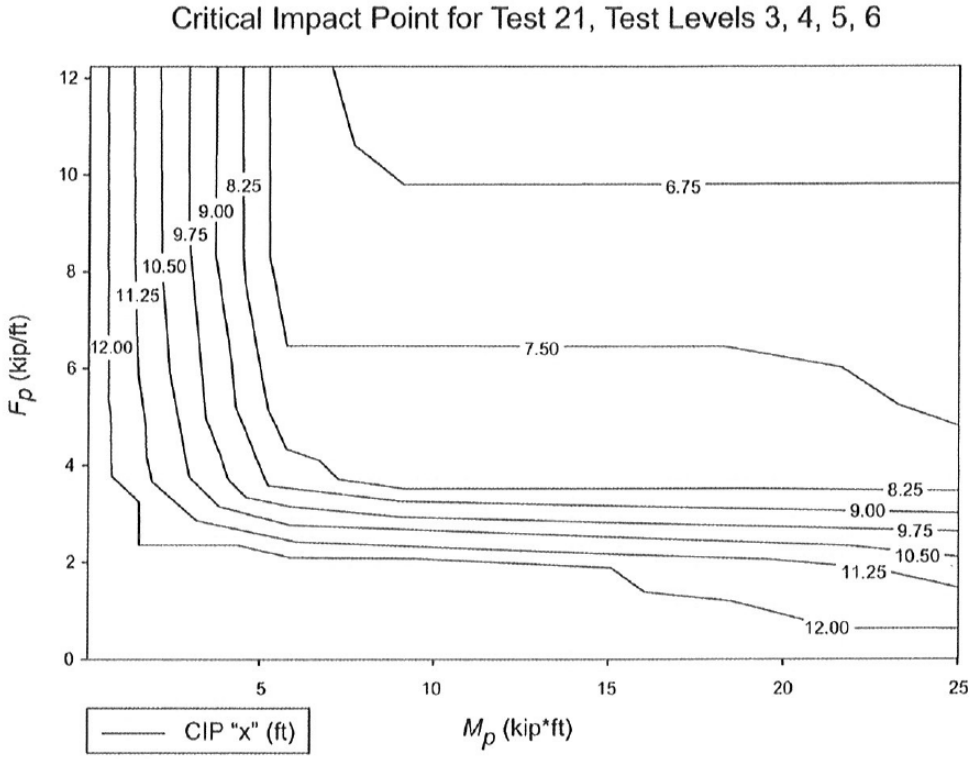


Figure 80. Critical Impact Point Selection for MASH Test Designation 3-21 [8]

A total of four CIPs were prioritized for the standard traffic direction, and four CIPs were identified for the reverse-direction impacts. The CIPs are summarized in Table 3 and denoted by "X." The final locations of the impact points are shown in Figure 82. Because the HBIB-1 crash test failed, it was rerun as HBIB-2, the impact location for HBIB-1 and -2 are identical in the figure. Detailed information about the process of CIP calculations is presented in Appendix C.

Posts used in the HBIB system were common W6x8.5 steel posts. The average force per unit length at different locations in the HBIB system was calculated using post spacings that varied from 6 ft – 3 in. (full post spacing) to 18¾ in. (quarter post spacing), with a post plastic section modulus of 6.3 in^3. and an estimated yield stress of 36 ksi. A dynamic magnification factor of 1.5 was used to estimate dynamic rate effects on post stiffness. The stiffness of a single W-beam rail for standard MGS was 8.1 kip-ft. Splice locations, the point at which two W-beams are lapped together, were treated as double the stiffness of the standard W-beam rail (e.g., 16.2 kip-ft). Likewise, nested W-beam was also treated as two W-beam rails, and the nested splice of the W-beam was treated as four separate W-beam rails with a net stiffness of 32.4 kip-ft. The upstream anchor block was assumed to be rigid (i.e., have infinite stiffness).

Table 3. CIP Calculation and Locations for Different System Sections

	Section 1	**Section 2**	**Section 3**	**Section 4**	**Section 5**
Fp (kips)	6.36	2.78	2.61	1.13	1.59
Fs' (kips)	17.58	14.73	13.36	10.14	17.66
Mp (kip.ft)	32.85	33.00	16.53	16.60	8
X (ft) 3-20	5.3	5.5	5.9	7.3	7.3
X (ft) 3-21	7.3	9.8	11.3	12.2	12.8

All sections are shown in Figure 81. See the following description for each section:

Section 1: post nos. 1 through 4 - system has nested upper rails and rubrails at quarter post spacing (1.5625 ft or 18¾ in.)

Section 2: post nos. 4 through 6 - system has nested upper rails and rubrails and half post spacing (3 ft – 1½ in.)

Section 3: from post nos. 6 through 10 - system has both upper rail and rubrail at half post spacing

Section 4: from post nos. 10 through 29 - system has upper rail and rubrail using full post spacing (6.25 ft or 6 ft – 3 in.)

Section 5: from post nos. 29 through 40 - system is consistent with standard, tangent MGS with full post spacing

For test designation nos. 3-32 and 3-33, the CIP was determined based on MASH impact condition recommendations from MASH Figure 2-3A since the anchor block was the end terminal of the system. The impact location is recommended to be at the beginning of the system (i.e., the "nose" of the system) where the anchor block was buried in the backslope. Since the concrete anchor block was out of the clear zone and the zero-degree impact was not practical for this system, the impact angle was selected to be 15 degrees to the downstream end of the anchor block. This impact location would require that the vehicle traverse the ditch before impacting the rail. To reduce the potential that the vehicle would change direction in the ditch prior to impacting the rail and subsequently impacting the anchor block, the location of the CIP was moved 12 in. downstream from the downstream end of the anchor block.

The following concerns and parameters were considered during the detection of the CIPs to evaluate downstream performance of the system using MASH Figure 2-11:

- Maximum clearance between the lower corrugation of the rubrail and the terrain (maximum risk of underride) near the center of the V-ditch;

- Maximized potential for the small car to underride the system using results of 15- and 25-degree trajectories into V-ditches described by Mongiardini [16];

- Maximized potential for the pickup truck to override the system using results of 25-degree trajectories into V-ditches described by Mongiardini; and

- The system transition from the first flare (13:1) into second flare (7.4:1), which occurred at post no. 10.

Note that the point at which the system crossed the bottom of the ditch was approximately located at post no. 8. Based on results from Mongiardini et al., the practical worst CIP for the small car and pickup truck were approximately located at post no. 8 for MASH test designation nos. 3-34 and 3-35.

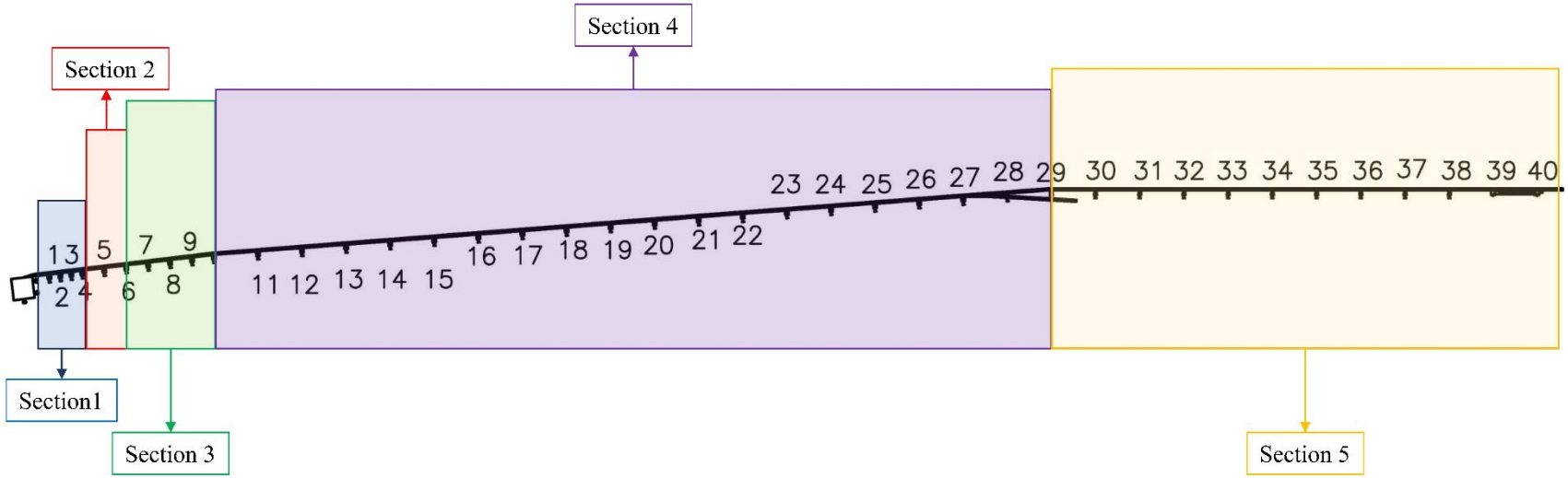


Figure 81. System Sections Based on System Stiffness and Post Spacing

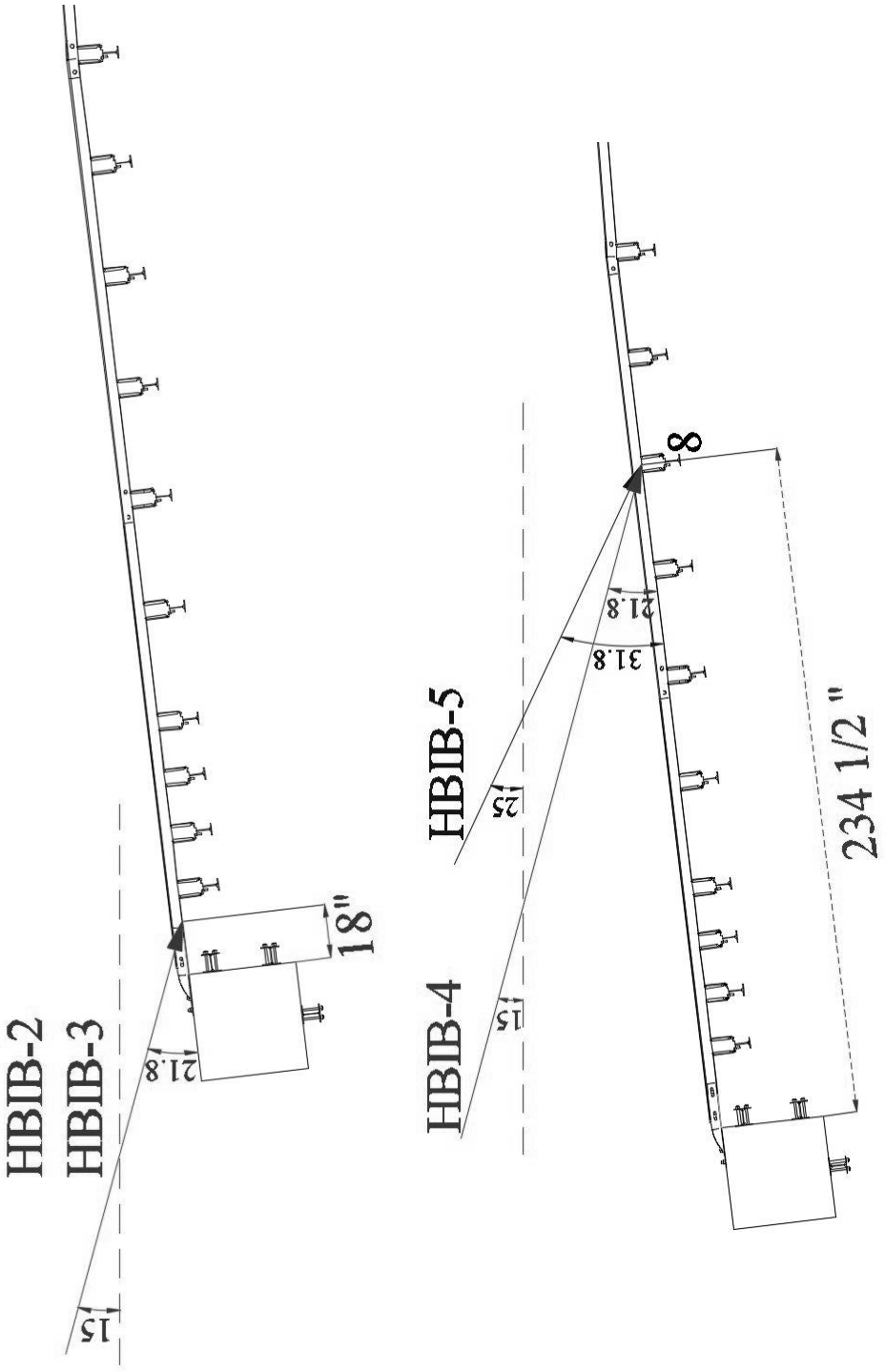


Figure 82. CIP Locations for HBIB Full-scale Crash Test Matrix, Standard Direction

4.4 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 5 miles northwest of the University of Nebraska-Lincoln.

4.5 Vehicle Tow and Guidance System

A reverse-cable, tow system with a 1:2 mechanical advantage was used to propel the test vehicle. The distance traveled and the speed of the tow vehicle were one-half that of the test vehicle. The test vehicle was released from the 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 [17] was used to steer the test vehicle. A guide flag, attached to the left-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.

4.6 Test Vehicles

For test no. HBIB-1, a 2017 Hyundai Accent (1100C small car) was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 2,459 lb, 2,411 lb, and 2,569 lb, respectively. The test vehicle is shown in Figures 83 and 84, and vehicle dimensions are shown in Figure 85. Note that for all vehicles, the passenger's side of the vehicle is referred to as the vehicle's right side throughout this report. The driver's side is referred to as the vehicle's left side.

For test no. HBIB-2, a 2017 Kia Rio (1100C small car) was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 2,540 lb, 2,462 lb, and 2,625 lb, respectively. The test vehicle is shown in Figures 86 and 87, and vehicle dimensions are shown in Figure 88.

For test no. HBIB-3, a 2017 Ram 1500 crew cab (2270P pickup truck) was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 5,384 lb, 5,068 lb, and 5,228 lb, respectively. The test vehicle is shown in Figures 89 and 90, and vehicle dimensions are shown in Figure 91.

For test no. HBIB-4, a 2017 Hyundai Accent (1100C small car) was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 2,457 lb, 2,418 lb, and 2,580 lb, respectively. The test vehicle is shown in Figures 92 and 93, and vehicle dimensions are shown in Figure 94.

For test no. HBIB-5, a 2018 Ram 1500 quad cab (2270P pickup truck) was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 5,013 lb, 4,998 lb, and 5,160 lb, respectively. The test vehicle is shown in Figures 95 and 96, and vehicle dimensions are shown in Figure 97.



Figure 83. Test Vehicle Photographs, Test No. HBIB-1

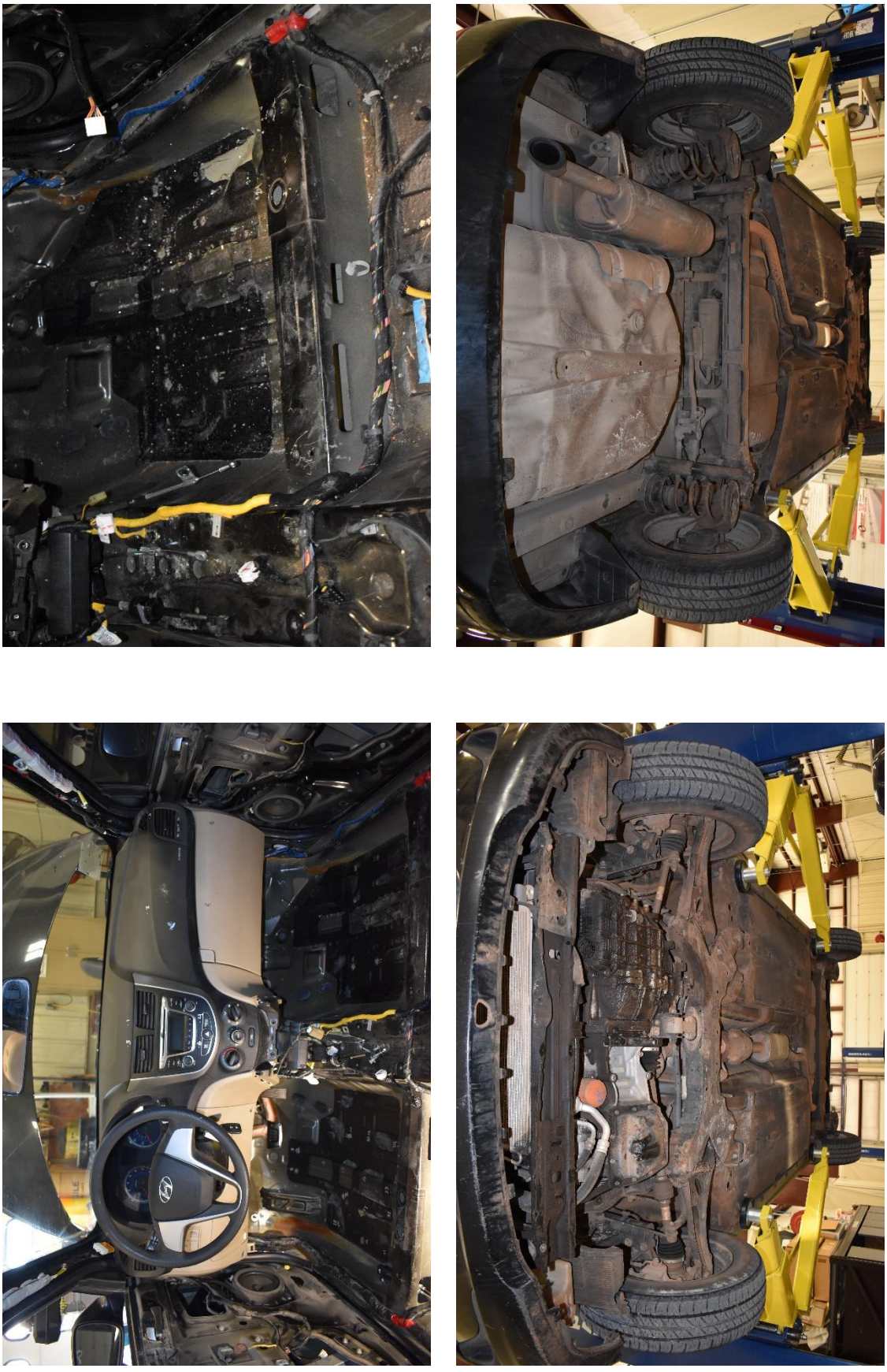
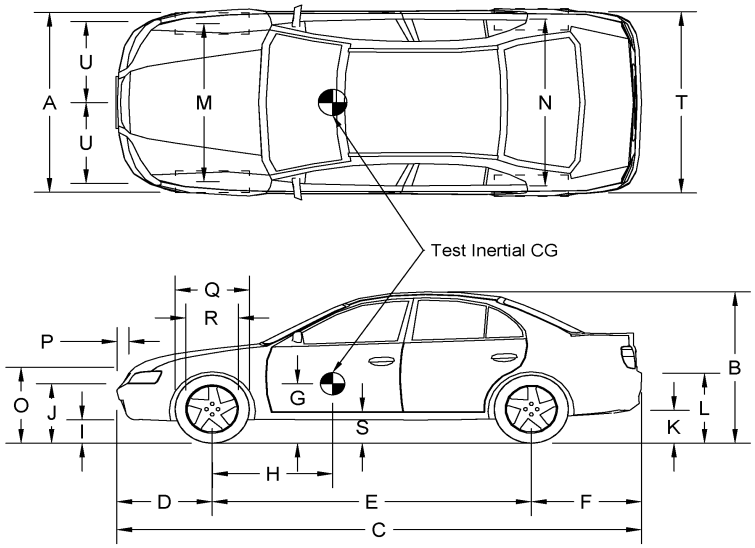


Figure 84. Test Vehicle Interior Floorboards and Undercarriage, Test No. HBIB-1

Test Name:	HBIB-1		**VIN No:**	KMHCT4AEXHU272805	
Model Year:	2017	**Make:**	Hyundai	**Model:**	Accent
Tire Size:	175/70R14	**Tire Inflation Pressure:**	33 psi	**Odometer:**	107913



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

A:	66 1/2 (1689) 65±3 (1650±75)	**B:**	56 1/2 (1435)
C:	171 1/4 (4350) 169±8 (4300±200)	**D:**	33 7/8 (860) 35±4 (900±100)
E:	101 1/8 (2569) 98±5 (2500±125)	**F:**	36 1/4 (921)
G:	22 1/4 (565)	**H:**	38 (965) 39±4 (990±100)
I:	7 1/2 (191)	**J:**	20 1/2 (521)
K:	10 1/4 (260)	**L:**	25 1/2 (648)
M:	59 3/8 (1508) 59±2 (1498±50)	**N:**	59 5/8 (1514) 59±2 (1425±50)
O:	28 1/4 (718) 28±4 (711±100)	**P:**	5 1/2 (140)
Q:	23 (584)	**R:**	15 1/4 (387)
S:	10 1/2 (267)	**T:**	66 1/4 (1683)
		U (impact width):	30 5/8 (778)

Mass Distribution - lb (kg)

Gross Static	**LF**	809 (367)	**RF**	776 (352)
	LR	474 (215)	**RR**	510 (231)

Weights lb (kg)	**Curb**	**Test Inertial**	**Gross Static**
W-front	1544 (700)	1505 (683)	1585 (719)
W-rear	915 (415)	906 (411)	984 (446)
W-total	2459 (1115)	2411 (1094) 2420±55 (1100±25)	2569 (1165) 2585±55 (1175±50)

Top of radiator core support:	28 (711)
Wheel Center Height (Front):	11 (279)
Wheel Center Height (Rear):	11 1/4 (286)
Wheel Well Clearance (Front):	24 5/8 (625)
Wheel Well Clearance (Rear):	25 1/8 (638)
Bottom Frame Height (Front):	15 1/8 (384)
Bottom Frame Height (Rear):	15 3/4 (400)
Engine Type:	Gasoline
Engine Size:	1.6L
Transmission Type:	Automatic
Drive Type:	FWD

GVWR Ratings lb

Front	1874
Rear	1852
Total	3527

Surrogate Occupant Data

Type:	Hybrid II
Mass:	161 lb
Seat Position:	Right

Note any damage prior to test: Right rear bumper cover is fractured belowe tail light, hail damage, dent on hood

Figure 85. Vehicle Dimensions, Test No. HBIB-1

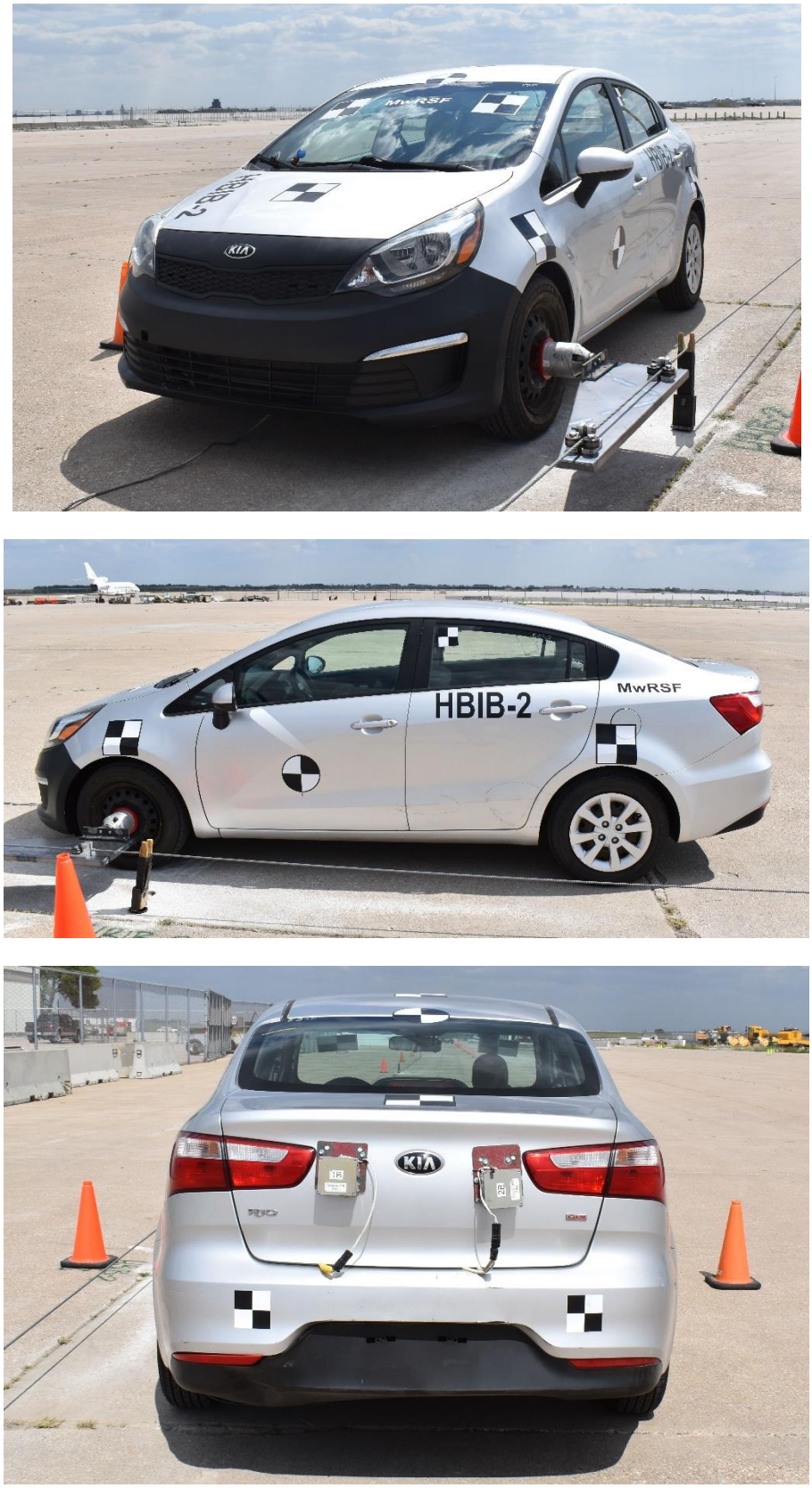


Figure 86. Test Vehicle Photographs, Test No. HBIB-2

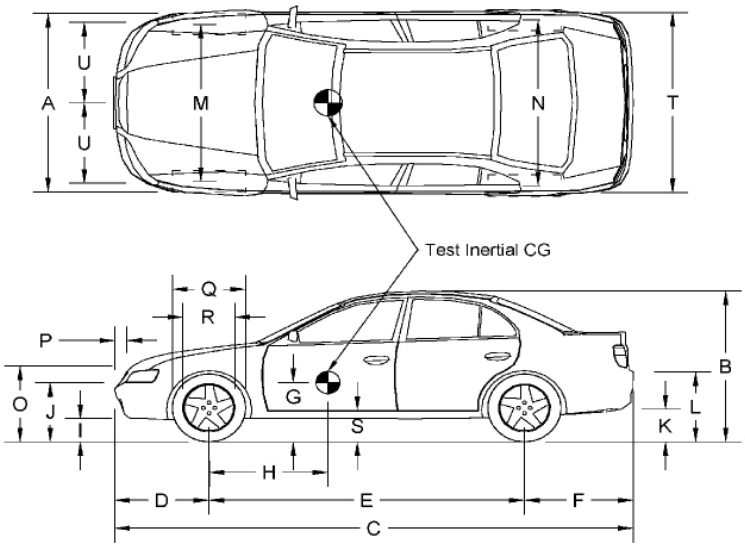


Figure 87. Test Vehicle Interior Floorboards and Undercarriage, Test No. HBIB-2

Test Name: HBIB-2 VIN No: KNADM4A32H6015837

Model Year: 2017 Make: Kia Model: Rio

Tire Size: 185/65R15 Tire Inflation Pressure: 33 psi Odometer: 147709



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

A:	66 3/4 (1695)	B:	57 1/4 (1454)
	65±3 (1650±75)		
C:	172 1/8 (4372)	D:	32 7/8 (835)
	169±8 (4300±200)		35±4 (900±100)
E:	101 1/4 (2572)	F:	38 (965)
	98±5 (2500±125)		
G:	22 11/16 (576)	H:	38 5/16 (973)
			39±4 (990±100)
I:	8 (203)	J:	22 (559)
K:	13 1/2 (343)	L:	26 1/4 (667)
M:	59 7/8 (1521)	N:	60 1/8 (1527)
	59±2 (1498±50)		59±2 (1425±50)
O:	32 (813)	P:	5 1/2 (140)
	28±4 (711±100)		
Q:	24 (610)	R:	16 1/2 (419)
S:	10 3/4 (273)	T:	66 7/8 (1699)

U (impact width): 33 1/8 (841)

Mass Distribution - lb (kg)

Gross Static LF 822 (373) RF 796 (361)
LR 489 (222) RR 518 (235)

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	1586 (719)	1531 (694)	1618 (734)
W-rear	954 (433)	931 (422)	1007 (457)
W-total	2540 (1152)	2462 (1117)	2625 (1191)
		2420±55 (1100±25)	2585±55 (1175±50)

Top of radiator core support:	29 1/8 (740)
Wheel Center Height (Front):	11 1/2 (292)
Wheel Center Height (Rear):	11 3/4 (298)
Wheel Well Clearance (Front):	25 3/4 (654)
Wheel Well Clearance (Rear):	26 1/8 (664)
Bottom Frame Height (Front):	16 (406)
Bottom Frame Height (Rear):	16 1/2 (419)
Engine Type:	Gasoline
Engine Size:	1.6L 4 cyl
Transmission Type:	Automatic
Drive Type:	FWD

GVWR Ratings lb

Front	2028
Rear	1852
Total	3660

Surrogate Occupant Data

Type:	Hybrid II
Mass:	163 lb
Seat Position:	Passenger

Note any damage prior to test: Slight denting on both right side doors at the bottom of the panel,at the door to door seam.

Figure 88. Vehicle Dimensions, Test No. HBIB-2







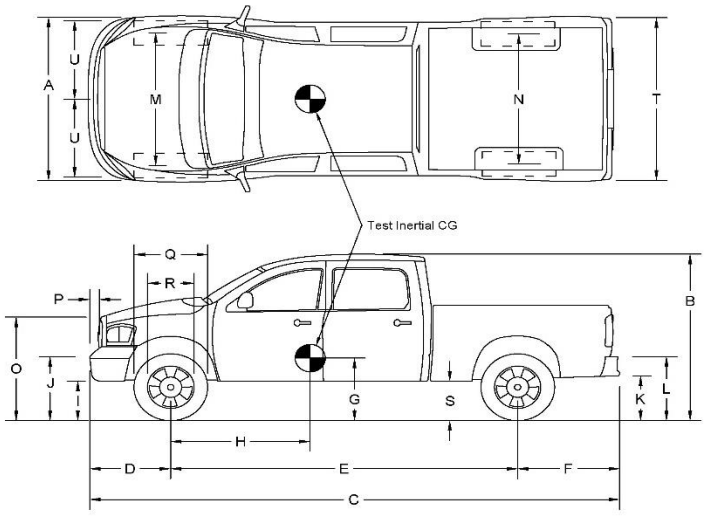
Figure 89. Test Vehicle Photographs, Test No. HBIB-3






Figure 90. Test Vehicle Interior Floorboards and Undercarriage, Test No. HBIB-3

Test Name:	HBIB-3			VIN No:	1C6RR6LT5HS722979
Model Year:	2017	Make:	Dodge	Model:	Ram 1500
Tire Size:	275/60R20	Tire Inflation Pressure:	39 psi	Odometer:	282549



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

A:	76 5/8	1946 11/40	B:	75 9/16	1919 23/80		
	78±2 (1950±50)						
C:	229 3/8	5826 1/8	D:	41 1/8	1044 23/40		
	237±13 (6020±325)			39±3 (1000±75)			
E:	139 7/8	3552 33/40	F:	48 1/2	1231 9/10		
	148±12 (3760±300)						
G:	29 3/8	746 1/8	H:	59 1/8	1501 31/40		
	min: 28 (710)			63±4 (1575±100)			
I:	14	355 3/5	J:	24 1/2	622 3/10		
K:	21 1/2	546 1/10	L:	29 5/8	752 19/40		
M:	68 9/16	1741 39/80	N:	68	1727 1/5		
	67±1.5 (1700±38)			67±1.5 (1700±38)			
O:	45 1/2	1155 7/10	P:	4 1/2	114 3/10		
	43±4 (1100±75)						
Q:	31 3/4	806 9/20	R:	21 1/4	539 3/4		
S:	16.125.	--	T:	76 1/4	1936 3/4		

U (impact width): 37 1/8 942 39/40

Mass Distribution - lb (kg)

Gross Static	LF	1497	(679)	RF	1526	(692)	
	LR	1084	(492)	RR	1121	(508)	

Weights lb (kg)	Curb		Test Inertial		Gross Static	
W-front	3028	(1373)	2925	(1327)	3023	(1371)
W-rear	2356	(1069)	2143	(972)	2205	(1000)
W-total	5384	(2442)	5068	(2299)	5228	(2371)
			5000±110 (2270±50)		5165±110 (2343±50)	

Wheel Center Height (Front):	15 5/8 396 7/8
Wheel Center Height (Rear):	15 3/4 400 1/20
Wheel Well Clearance (Front):	35 13/16 909 51/80
Wheel Well Clearance (Rear):	38 11/16 982 53/80
Bottom Frame Height (Front):	19 482 3/5
Bottom Frame Height (Rear):	26 1/8 663 23/40
Engine Type:	Gasoline
Engine Size:	5.7L V8
Transmission Type:	Automatic
Drive Type:	RWD
Cab Style:	Crew Cab
Bed Length:	67"

GVWR Ratings - lb

Front	3700
Rear	3900
Total	6900

Surrogate Occupant Data

Type:	Hybrid II
Mass:	160 lb
Seat Position:	Right/Passenger

Note any damage prior to test: Dent in right box side above wheel opening.

Figure 91. Vehicle Dimensions, Test No. HBIB-3

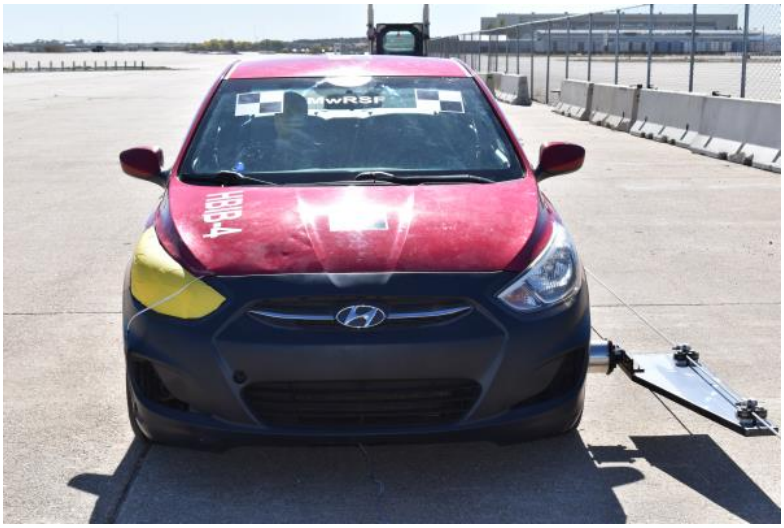






Figure 92. Test Vehicle Photographs, Test No. HBIB-4







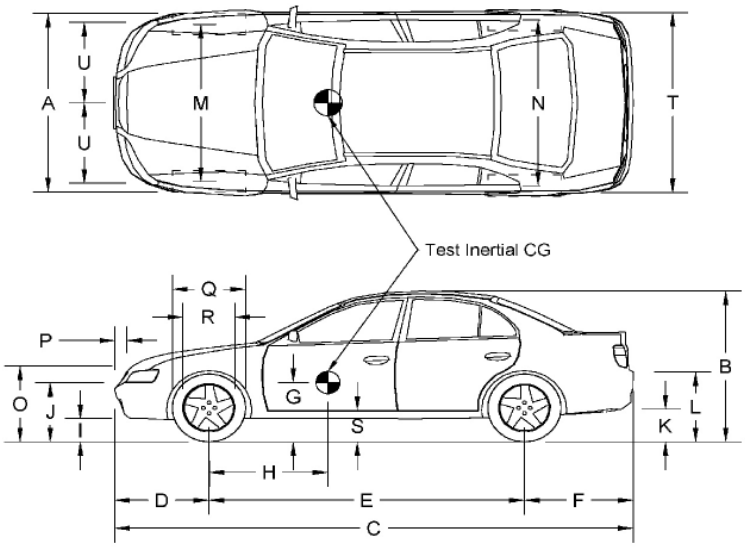


Figure 93. Test Vehicle Interior Floorboards and Undercarriage, Test No. HBIB-4

Test Name: HBIB-4 VIN No: KMHCT4AE0HU266110

Model Year: 2017 Make: Hyundai Model: Accent

Tire Size: 175/70R14 Tire Inflation Pressure: 33 psi Odometer: 130347



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

A:	66 1/4 (1683)	B:	56 3/4 (1441)
	65±3 (1650±75)		
C:	172 (4369)	D:	32 7/8 (835)
	169±8 (4300±200)		35±4 (900±100)
E:	101 1/8 (2569)	F:	38 (965)
	98±5 (2500±125)		
G:	22 3/16 (564)	H:	38 1/8 (968)
			39±4 (990±100)
I:	7 3/4 (197)	J:	20 3/4 (527)
K:	11 (279)	L:	25 1/2 (648)
M:	59 3/8 (1508)	N:	59 3/8 (1508)
	59±2 (1498±50)		59±2 (1425±50)
O:	29 1/4 (743)	P:	4 1/2 (114)
	28±4 (711±100)		
Q:	23 1/4 (591)	R:	15 3/8 (391)
S:	10 7/8 (276)	T:	66 1/8 (1680)

U (impact width): 30 13/16 (783)

Mass Distribution - lb (kg)

Gross Static LF 813 (369) RF 776 (352)
LR 519 (235) RR 472 (214)

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	1552 (704)	1507 (684)	1589 (721)
W-rear	905 (411)	911 (413)	991 (450)
W-total	2457 (1114)	2418 (1097)	2580 (1170)
		2420±55 (1100±25)	2585±55 (1175±50)

Top of radiator core support:	28 1/4 (718)
Wheel Center Height (Front):	11 (279)
Wheel Center Height (Rear):	11 1/4 (286)
Wheel Well Clearance (Front):	24 5/8 (625)
Wheel Well Clearance (Rear):	25 (635)
Bottom Frame Height (Front):	15 3/8 (391)
Bottom Frame Height (Rear):	15 5/8 (397)
Engine Type:	Gasoline
Engine Size:	1.6L 4 cyl
Transmission Type:	Automatic
Drive Type:	FWD

GVWR Ratings lb

Front	1874
Rear	1852
Total	3527

Surrogate Occupant Data

Type:	Hybrid II
Mass:	162 lb
Seat Position:	Passenger

Note any damage prior to test: Small dent in hood by right headlight.

Figure 94. Vehicle Dimensions, Test No. HBIB-4



Figure 95. Test Vehicle Photographs, Test No. HBIB-5







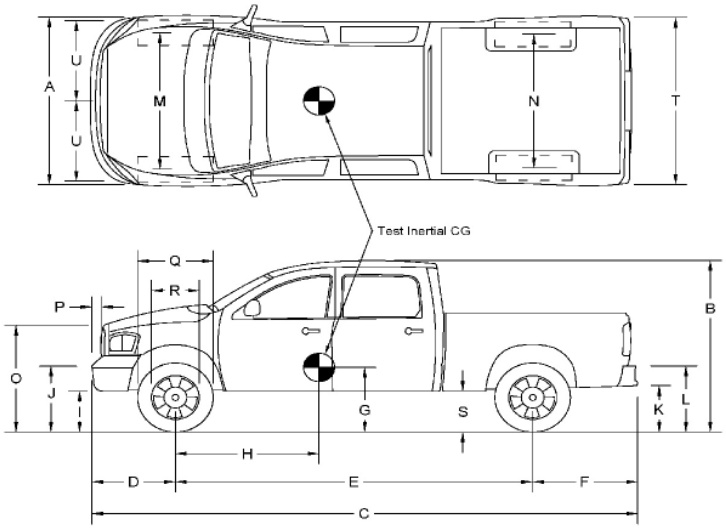


Figure 96. Test Vehicle Interior Floorboards and Undercarriage, Test No. HBIB-5

Test Name: HBIB-5 VIN No: 1C6RR6FG2JS324827

Model Year: 2018 Make: Dodge Model: Ram 1500

Tire Size: 265/70R17 Tire Inflation Pressure: 40 psi Odometer: 213116



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

A:	76 3/4	1949 9/20		B:	74 1/4	1885 19/20	
	78±2 (1950±50)						
C:	229 1/4	5822 19/20		D:	39 7/8	1012 33/40	
	237±13 (6020±325)				39±3 (1000±75)		
E:	140 1/2	3568 7/10		F:	48 7/8	1241 17/40	
	148±12 (3760±300)						
G:	28 1/8	714 3/8		H:	65 1/4	1657 7/20	
	min: 28 (710)				63±4 (1575±100)		
I:	13 3/4	349 1/4		J:	26	660 2/5	
K:	20 1/2	520 7/10		L:	28 3/4	730 1/4	
M:	68 1/8	1730 3/8		N:	67 5/8	1717 27/40	
	67±1.5 (1700±38)				67±1.5 (1700±38)		
O:	45	1143		P:	4 1/2	114 3/10	
	43±4 (1100±75)						
Q:	30 1/2	774 7/10		R:	18 1/2	469 9/10	
S:	14	355 3/5		T:	76	1930 2/5	

U (impact width): 36 5/8 930 11/40

Mass Distribution - lb (kg)

Gross Static	LF	1379 (626)	RF	1395 (633)
	LR	1211 (549)	RR	1175 (533)

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	2750 (1247)	2677 (1214)	2774 (1258)
W-rear	2263 (1026)	2321 (1053)	2386 (1082)
W-total	5013 (2274)	4998 (2267)	5160 (2341)
		5000±110 (2270±50)	5165±110 (2343±50)

Wheel Center Height (Front):	14 7/8 377 33/40
Wheel Center Height (Rear):	15 381
Wheel Well Clearance (Front):	35 1/4 895 7/20
Wheel Well Clearance (Rear):	37 3/4 958 17/20
Bottom Frame Height (Front):	18 1/2 469 9/10
Bottom Frame Height (Rear):	25 635
Engine Type:	Gasoline
Engine Size:	3.6L
Transmission Type:	Automatic
Drive Type:	RWD
Cab Style:	Quad Cab
Bed Length:	76"

GVWR Ratings - lb

Front	3700
Rear	3900
Total	6800

Surrogate Occupant Data

Type:	Hybrid II
Mass:	162 lb
Seat Position:	Right

Note any damage prior to test: Small dent is left box side.

Figure 97. Vehicle Dimensions, Test No. HBIB-5

The longitudinal component of the center of gravity (c.g.) was determined using the measured axle weights. The Suspension Method [18] was used to determine the vertical component of the c.g. for the 2270P vehicles. 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 [19]. The location of the final c.g. for the test vehicles for test nos. HBIB-1 through HBIB-5 are shown in Figures 98 through 102. Data used to calculate the locations of the vehicles' c.g. and ballast information for both vehicles are shown in Appendix C.

Square, black- and white-checkered targets were placed on the vehicles for reference to be viewed from the high-speed digital video cameras and aid in the video analysis, as shown in Figures 98 through 102. Round, checkered targets were placed at the c.g. on the left-side door, the right-side door, and the roof of the vehicle.

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 each vehicle's windshield wiper for test nos. HBIB-1 through HBIB-5. The flash bulb 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 the test vehicles so the vehicles could be brought safely to a stop after the test.

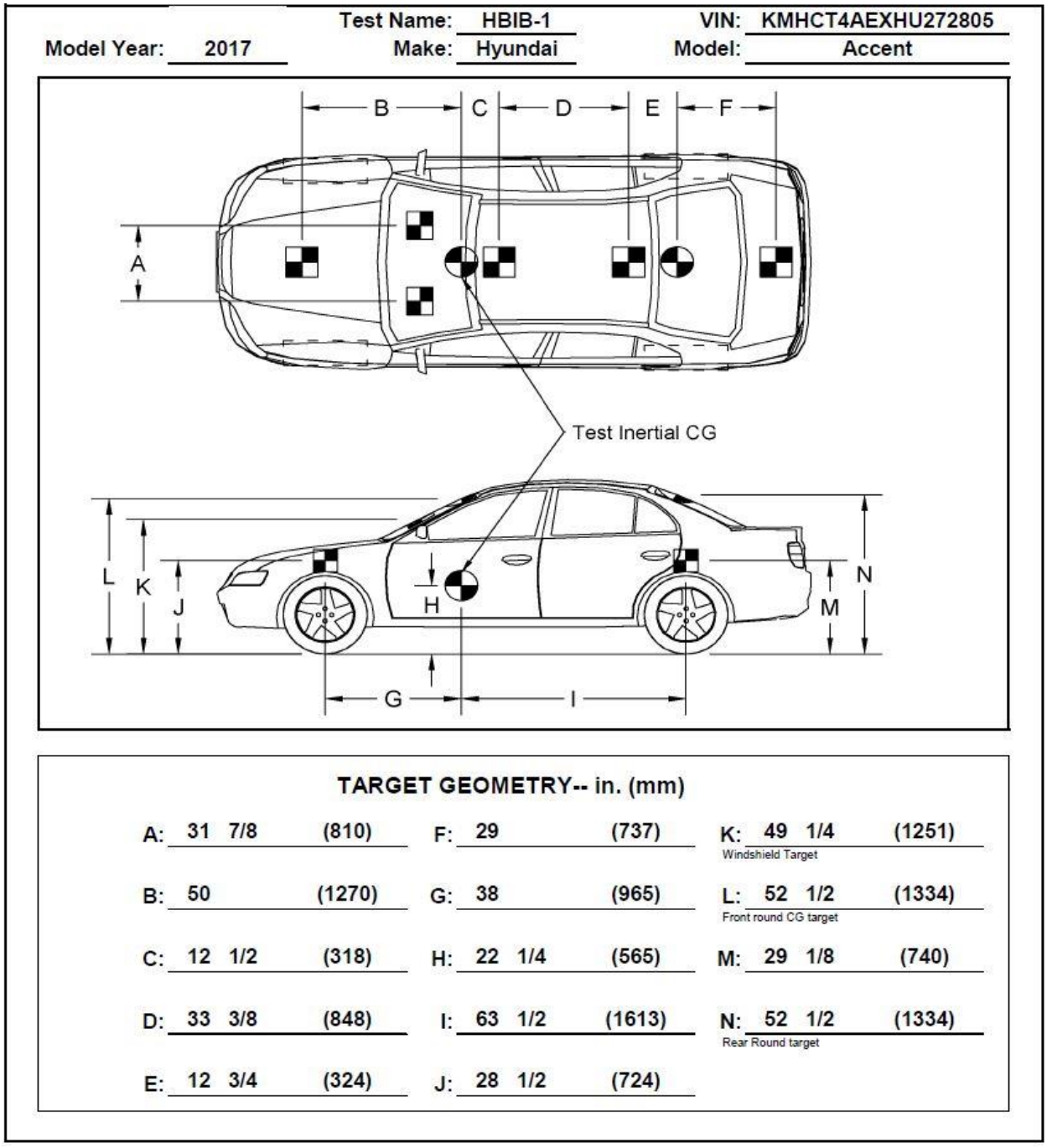
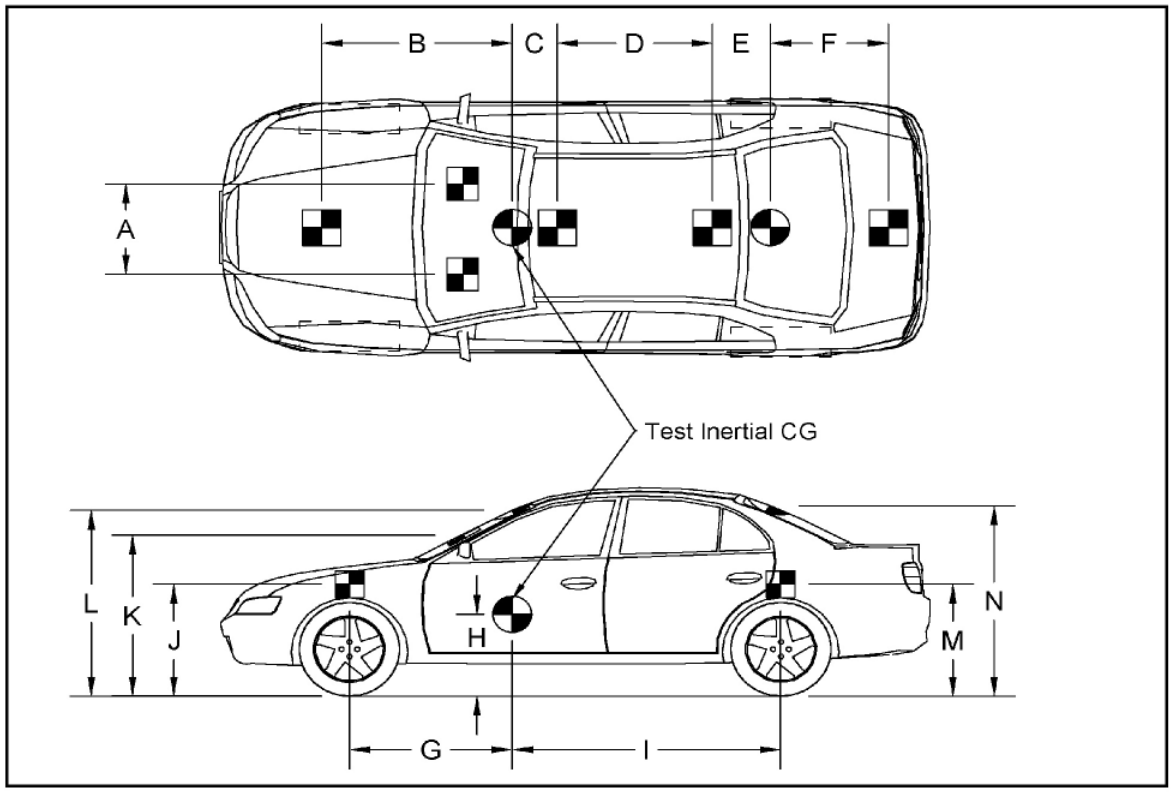


Figure 98. Target Geometry, Test No HBIB-1

Test Name: HBIB-2 VIN: KNADM4A32H6015837
Model Year: 2017 Make: Kia Model: Rio



TARGET GEOMETRY-- in. (mm)

A:	31 3/4	(806)	F:	30 3/4	(781)	K:	48 3/4	(1238)
						Windshield Target		
B:	48 5/8	(1235)	G:	38 5/16	(973)	L:	54	(1372)
						Front round CG target		
C:	17	(432)	H:	22 11/16	(576)	M:	30 1/4	(768)
D:	24 9/16	(624)	I:	63 5/16	(1608)	N:	54	(1372)
						Rear Round target		
E:	17 1/2	(445)	J:	29 3/4	(756)			

Figure 99. Target Geometry, Test No HBIB-2

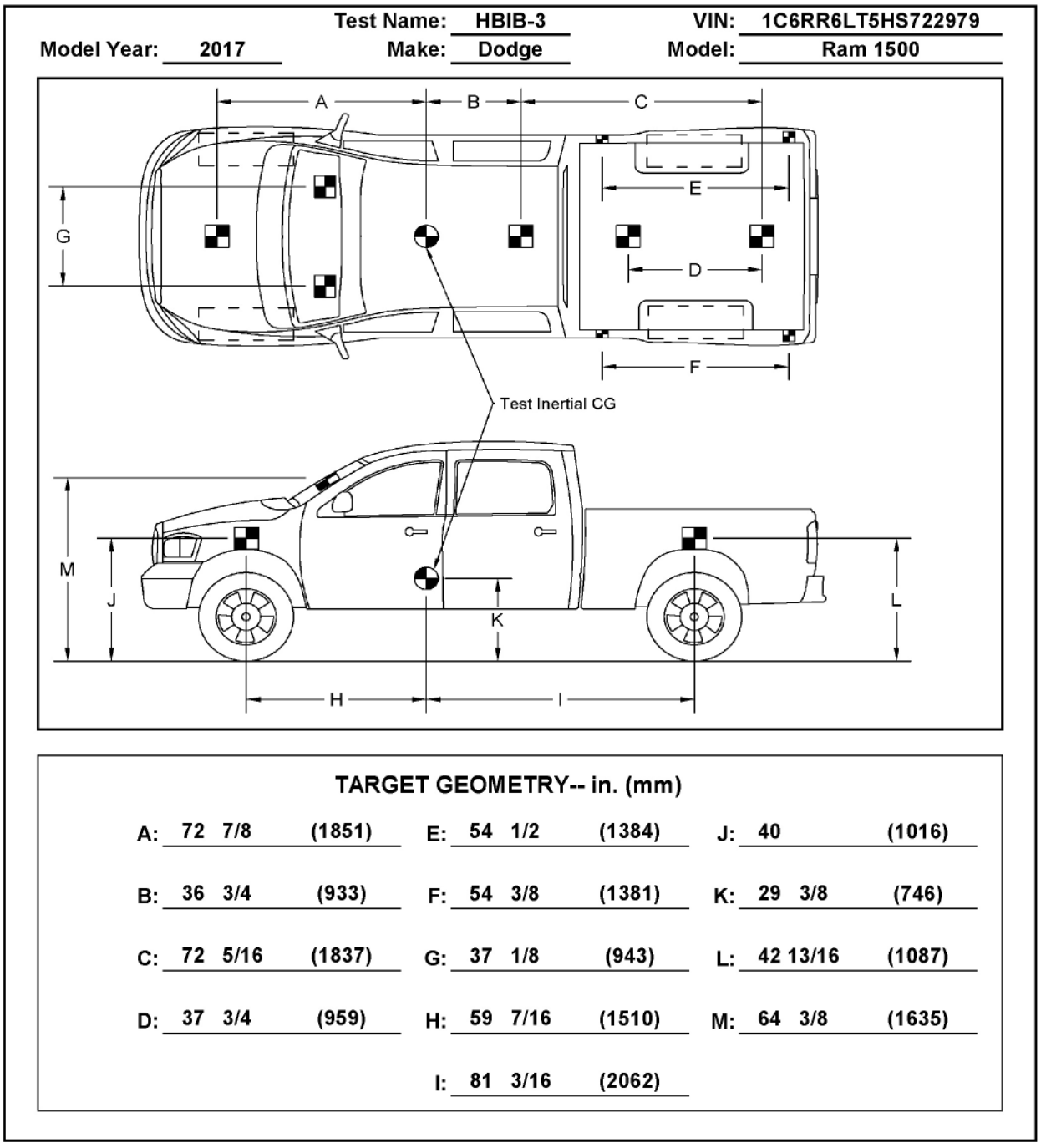
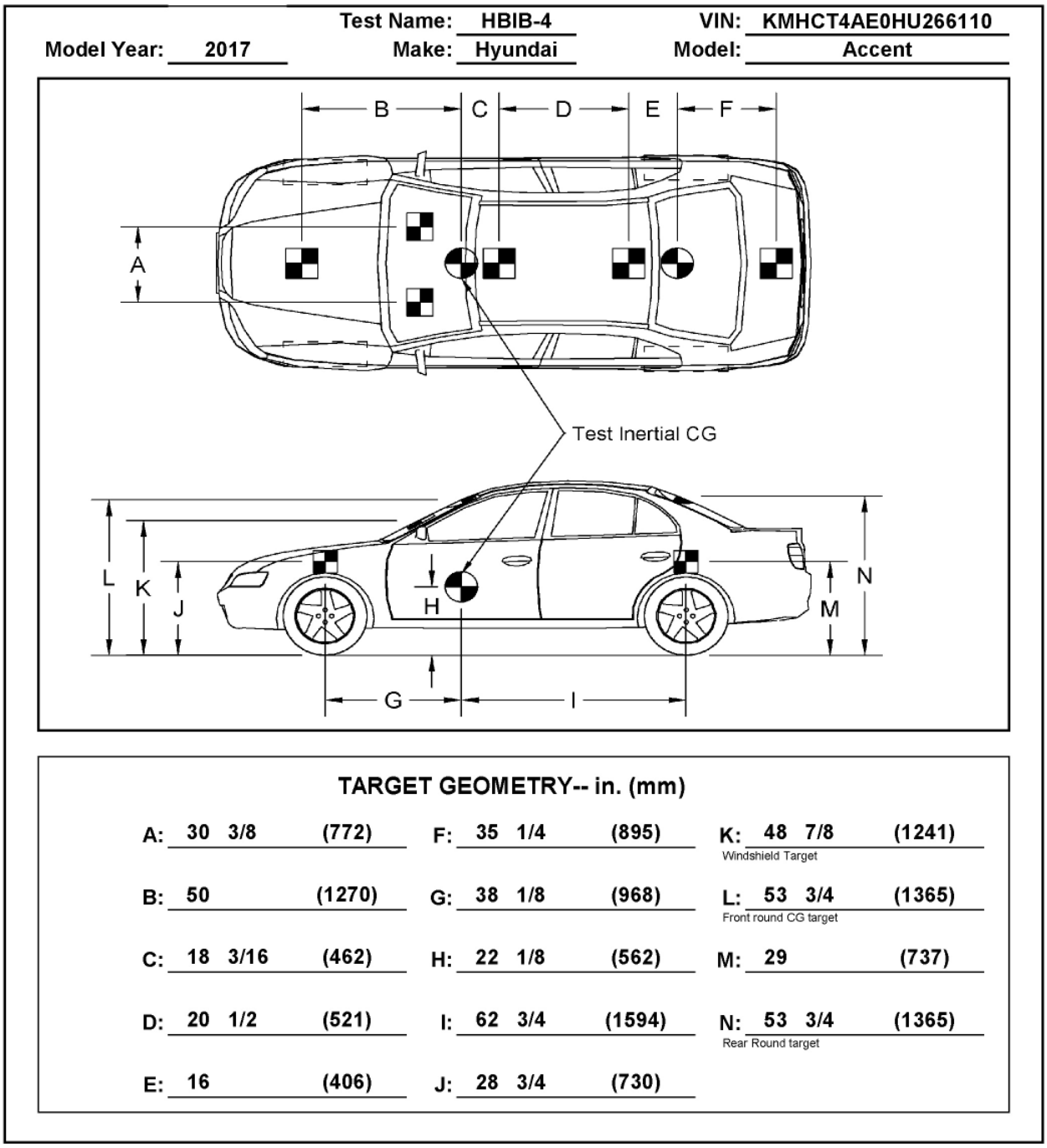


Figure 100. Target Geometry, Test No HBIB-3



TARGET GEOMETRY-- in. (mm)

A:	30 3/8	(772)	F:	35 1/4	(895)	K:	48 7/8	(1241)
						Windshield Target		
B:	50	(1270)	G:	38 1/8	(968)	L:	53 3/4	(1365)
						Front round CG target		
C:	18 3/16	(462)	H:	22 1/8	(562)	M:	29	(737)
D:	20 1/2	(521)	I:	62 3/4	(1594)	N:	53 3/4	(1365)
						Rear Round target		
E:	16	(406)	J:	28 3/4	(730)			

Figure 101. Target Geometry, Test No HBIB-4

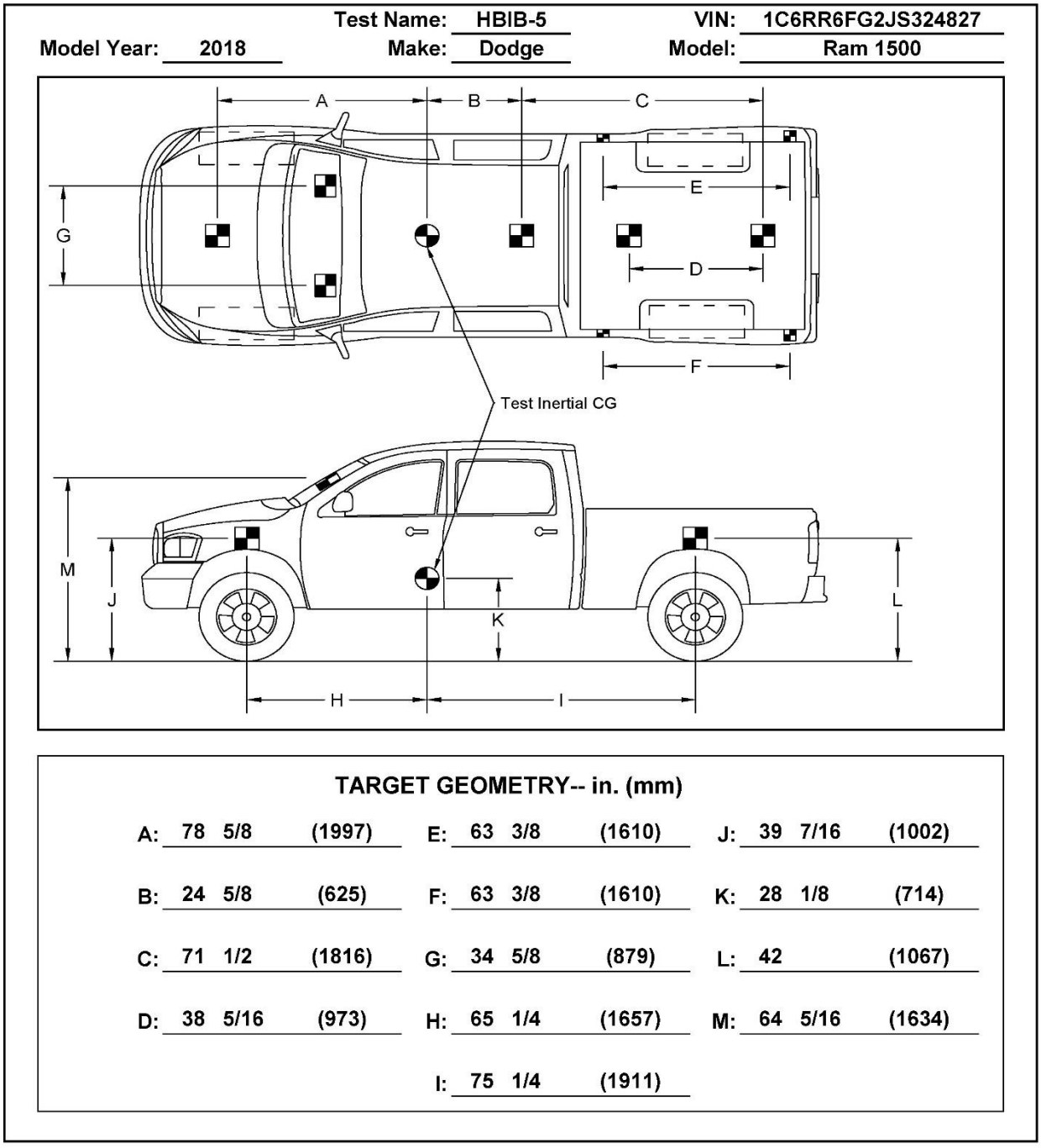


Figure 102. Target Geometry, Test No HBIB-5

4.7 Surrogate Occupant

For test nos. HBIB-1 through HBIB-5, a Hybrid II 50th-Percentile, Adult Male Dummy equipped with footwear was placed in the right-front seat of the test vehicles with the seat belt fastened. The surrogate occupant's final weights for each test are detailed in Table 4. As recommended by MASH, the surrogate occupant was not included in calculating the c.g. location for any of the tests.

Table 4. Surrogate Occupant Weight, Test Nos. HBIB-1 through HBIB-5

Test No.	Weight lb
HBIB-1	161
HBIB-2	163
HBIB-3	160
HBIB-4	162
HBIB-5	162

4.8 Data Acquisition Systems

4.8.1 Accelerometers

The accelerometer and rate transducer systems used in the full-scale crash testing were the SLICE-1 and SLICE-2 units described below. Units were positioned near the c.g. of the test vehicle and the SLICE-1 unit was designated as primary for test nos. HBIB-1, HBIB-2, and HBIB-4. The SLICE-2 unit was designated as primary for test nos. HBIB-3 and HBIB-5. Data obtained in dynamic testing was filtered using the SAE Class 60 and the SAE Class 180 Butterworth filter conforming to the SAEJ211/1 specifications [20].

The SLICE-1 and SLICE-2 units were modular data acquisition systems manufactured by Diversified Technical Systems, Inc. of Seal Beach, California. Triaxial acceleration and angular rate sensor modules were mounted inside the bodies of custom-built SLICE 6DX event data recorders equipped with 7GB of non-volatile flash memory and recorded data at 10,000 Hz to the onboard microprocessor. The accelerometers had a range of ±500g's in each of three directions (longitudinal, lateral, and vertical) and a 1,650 Hz (CFC 1000) anti-aliasing filter. The SLICE MICRO Triax ARS had a range of 1,500 degrees/sec in each of three directions (roll, pitch, and yaw). The raw angular rate measurements were 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 both the accelerometer and angular rate sensor data.

4.8.2 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 vehicles. 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.

4.8.3 Retroreflective Optic Speed Trap

A retroreflective optic speed trap was used to determine the speed of the test vehicles before impact. Five retroreflective targets, spaced at approximately 18-in. intervals, were applied to the sides 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 only used as a backup in the event that vehicle speeds cannot be determined from electronic data.

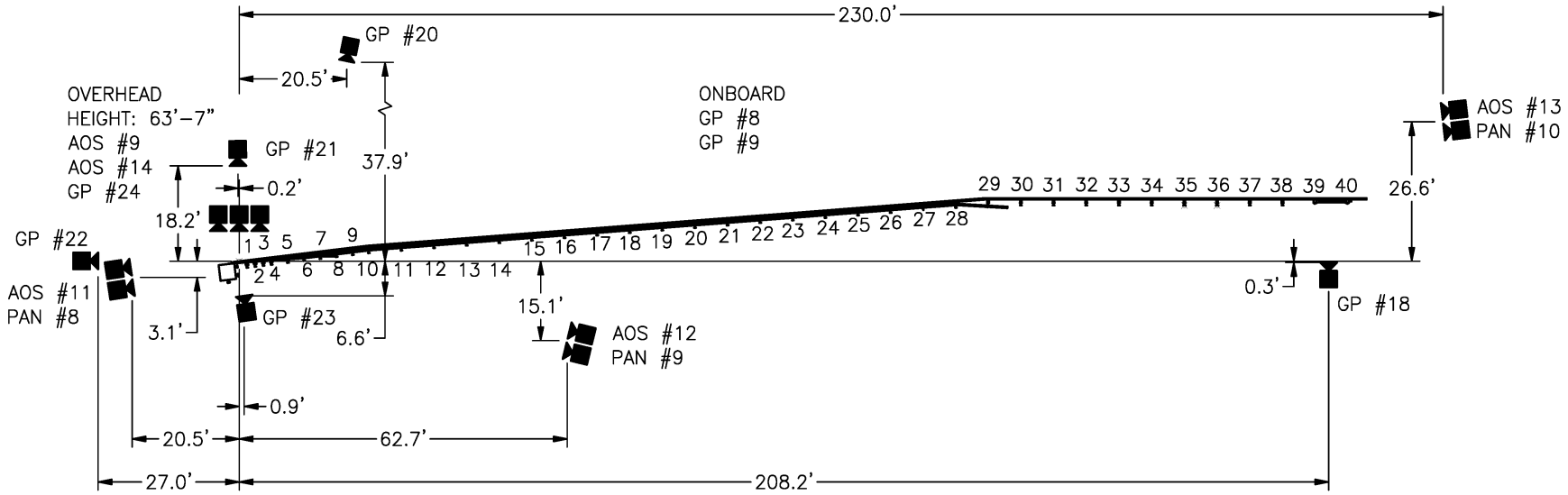
4.8.4 Digital Photography

AOS high-speed digital video cameras, GoPro digital video cameras, Panasonic digital video cameras, and Ubiquiti digital video cameras were used to film test nos. HBIB-1 through HBIB-5, as summarized in Table 5. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system are shown in Figures 103 through 107.

Table 5. Digital Video Camera Usage for Test Nos. HBIB-1 through HBIB-5

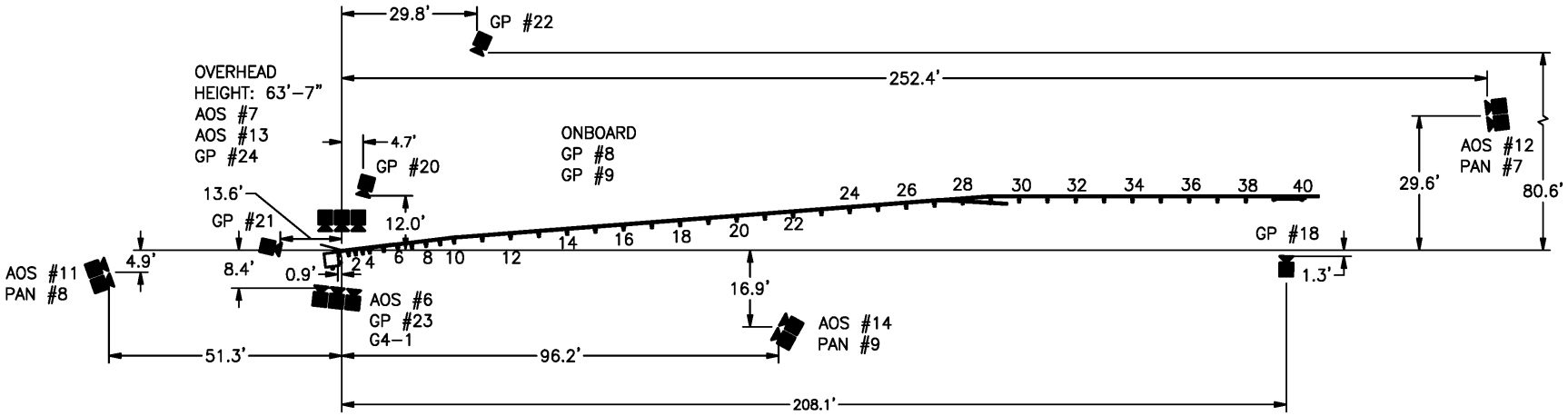
Test No.	Detailed Information	Number of Cameras			
		AOS	GoPro	Panasonic	Ubiquiti
HBIB-1	Figure 103	5	8	3	0
HBIB-2	Figure 104	6	8	3	1
HBIB-3	Figure 105	5	7	3	2
HBIB-4	Figure 106	5	7	3	2
HBIB-5	Figure 107	5	6	4	1

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 tests.



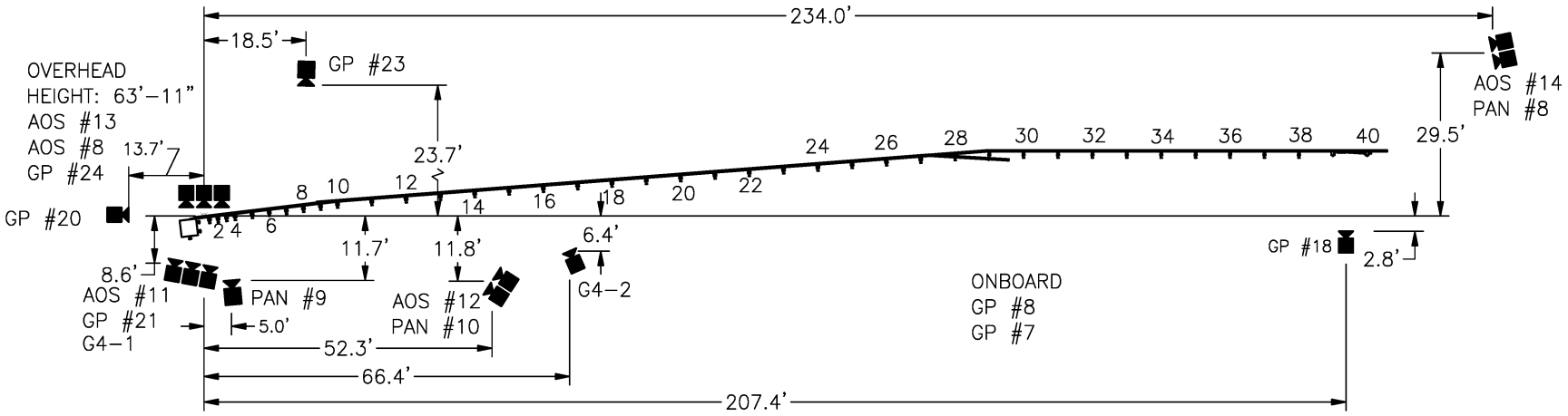
No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-9	AOS TRI-VIT 2236	500	Kowa 12 mm Fixed	-
AOS-11	AOS J-PRI	500	Sigma 17-50	17
AOS-12	AOS J-PRI	500	Nikon 50 mm Fixed	-
AOS-13	AOS J-PRI	500	Nikon 100 mm Fixed	-
AOS-14	AOS J-PRI	500	Rokinon 12 mm Fixed	-
GP-8	GoPro Hero 4	120		
GP-9	GoPro Hero 4	120		
GP-18	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-8	Panasonic HC-VX981	120		
PAN-9	Panasonic HC-VX981	120		
PAN-10	Panasonic HC-VX981	120		

Figure 103. Camera Locations, Speeds, and Lens Settings, Test No. HBIB-1



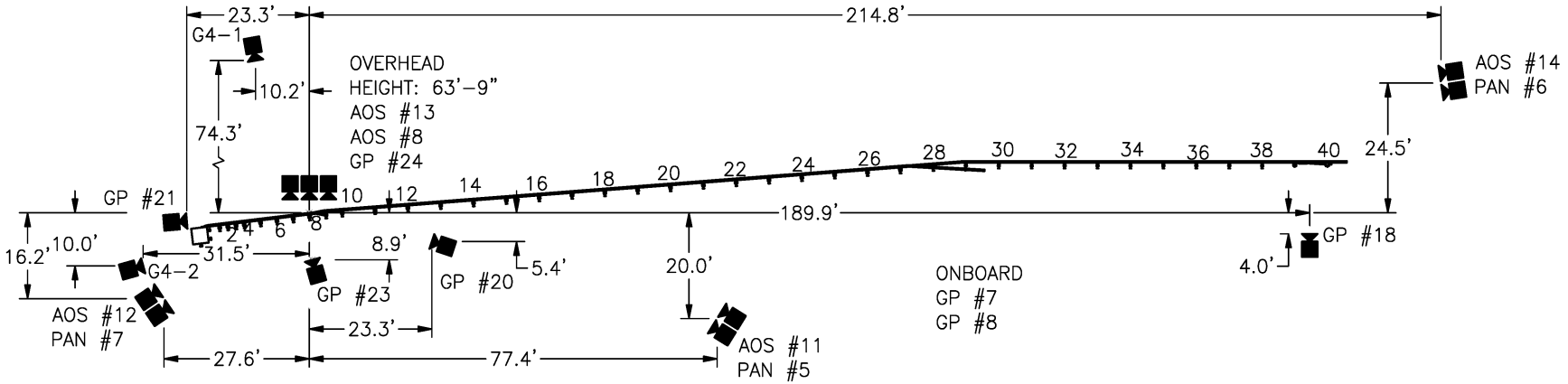
No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-6	AOS X-PRI	500	Kowa 16mm Fixed	-
AOS-7	AOS X-PRI	500	Kowa 12mm Fixed	-
AOS-11	AOS J-PRI	500	Sigma 17-50	50
AOS-12	AOS J-PRI	500	Sigma 24-135	24
AOS-13	AOS J-PRI	500	Canon EF 14mm Fixed	-
AOS-14	AOS J-PRI	500	Canon EF 24-70	70
GP-8	GoPro Hero 4	120		
GP-9	GoPro Hero 4	120		
GP-18	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-8	Panasonic HC-VX981	120		
PAN-9	Panasonic HC-VX981	120		
PAN-10	Panasonic HC-VX981	120		
G4-1	Ubiquiti G4 Plus	20		

Figure 104. Camera Locations, Speeds, and Lens Settings, Test No. HBIB-2



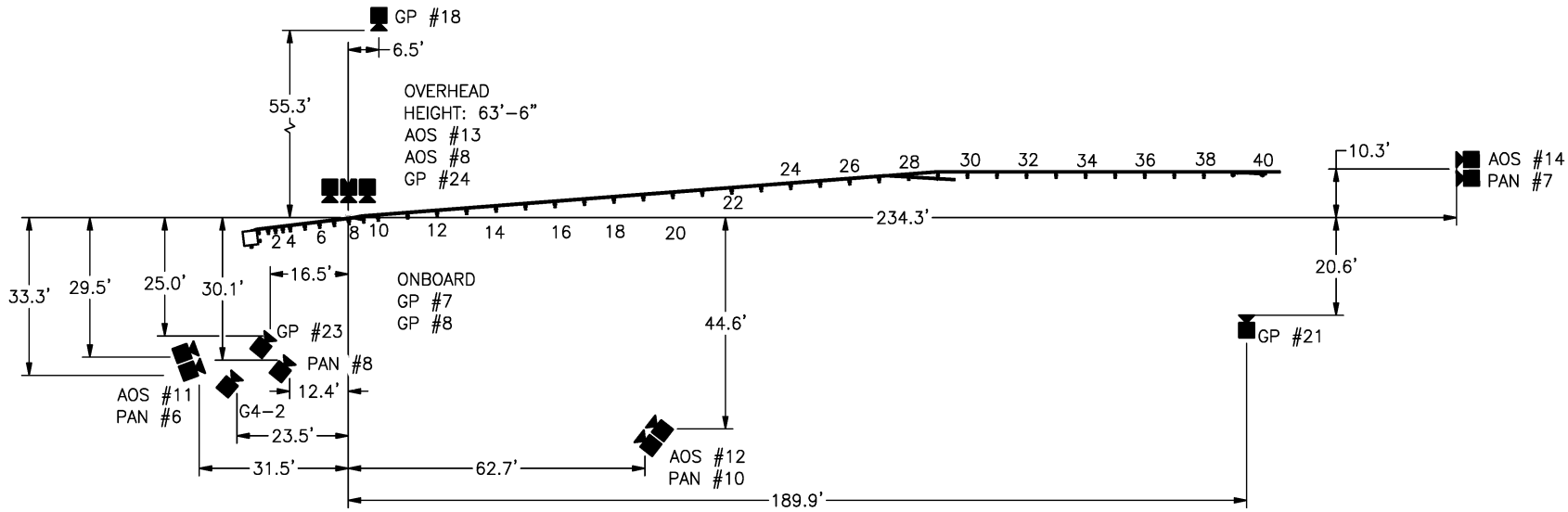
No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-8	AOS TRI-VIT 2236	500	Kowa 12 mm Fixed	-
AOS-11	AOS J-PRI	500	Sigma 17-50	17
AOS-12	AOS J-PRI	500	Sigma 24-135	70
AOS-13	AOS J-PRI	500	Canon EF 14mm Fixed	-
AOS-14	AOS J-PRI	500	Canon EF 24-70	24
GP-7	GoPro Hero 4	120		
GP-8	GoPro Hero 4	120		
GP-18	GoPro Hero 6	240		
GP-20	GoPro Hero 6	240		
GP-21	GoPro Hero 6	240		
GP-23	GoPro Hero 7	240		
GP-24	GoPro Hero 7	240		
PAN-8	Panasonic HC-VX981	120		
PAN-9	Panasonic HC-VX981	120		
PAN-10	Panasonic HC-VX981	120		
G4-1	Ubiquiti G4 Plus	20		
G4-2	Ubiquiti G4 Plus	20		

Figure 105. Camera Locations, Speeds, and Lens Settings, Test No. HBIB-3



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-8	AOS S-VIT 1531	500	Kowa 12mm Fixed	-
AOS-11	AOS J-PRI	500	Sigma 17-50	50
AOS-12	AOS J-PRI	500	Nikon 50mm Fixed	-
AOS-13	AOS J-PRI	500	Canon EF 14mm Fixed	-
AOS-14	AOS J-PRI	500	Canon EF 24-70	70
GP-7	GoPro Hero 4	120		
GP-8	GoPro Hero 4	120		
GP-18	GoPro Hero 6	240		
GP-20	GoPro Hero 6	240		
GP-21	GoPro Hero 6	240		
GP-23	GoPro Hero 7	240		
GP-24	GoPro Hero 7	240		
PAN-5	Panasonic HC-VX981	120		
PAN-6	Panasonic HC-VX981	120		
PAN-7	Panasonic HC-VX981	120		
G4-1	Ubiquiti G4 Plus	20		
G4-2	Ubiquiti G4 Plus	20		

Figure 106. Camera Locations, Speeds, and Lens Settings, Test No. HBIB-4



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-8	AOS S-VIT 1531	500	Kowa 12mm Fixed	-
AOS-11	AOS J-PRI	500	Sigma 17-50	17
AOS-12	AOS J-PRI	500	Sigma 24-135	28
AOS-13	AOS J-PRI	500	Rokinon 12mm Fixed	-
AOS-14	AOS J-PRI	100	Canon EF 24-70	70
GP-7	GoPro Hero 4	120		
GP-8	GoPro Hero 4	120		
GP-18	GoPro Hero 6	30		
GP-21	GoPro Hero 6	240		
GP-23	GoPro Hero 7	240		
GP-24	GoPro Hero 7	240		
PAN-5	Panasonic HC-VX981	30		
PAN-7	Panasonic HC-VX981	120		
PAN-8	Panasonic HC-VX981	30		
PAN-10	Panasonic HC-VX981	120		
G4-2	Ubiquiti G4 Plus	20		

Figure 107. Camera Locations, Speeds, and Lens Settings, Test No. HBIB-5

5 DESIGN DETAILS

5.1 HDOT Design Modifications

The HDOT BIB system was very similar to the as-tested configuration from full-scale testing in the literature review [3-5]. Systems tested under criteria established in NCHRP Report No. 350 had a top rail height of 27¾ in.; however, the top rail height of the MGS installation was 31 in. A lower top rail height was more conducive to maintaining a constant height through the ditch, as well as to maintaining a single, constant post length. However, with the increased MGS rail mounting height and decreased post embedment, the HDOT system was modified by increasing the post length from 6 ft to 8 ft throughout the ditch region where the post embedment of a 6-ft long post would be less than 30 in.

Additionally, the anchor block was placed into the backslope, which consisted of native soil fill. Typically, above-grade anchors are used when it is not practical to bury an anchor, such as in soil with significant rock or igneous lava flow. These soil conditions may be significantly more stiff than native soil or MASH strong soil conditions. Thus, additional soil reinforcement was added to the anchor block to simulate conditions in use.

5.2 Upper and Lower Rails

The total length of the system installation was 219 ft – 3⅞ in. spanning between an upstream anchorage at a concrete anchor block to a downstream MGS trailing end anchorage at post no. 40. The upstream anchor was connected to nested W-beam and nested W-beam rubrails using W-beam terminal connectors, and a W-beam rubrail extended from the upstream anchor block to post no. 29. Upper W-beam rails and lower rubrails consisted of 12-ft 6-in. long segments of W-beam, except for a 6-ft 3-in. long section of upper W-beam rail at post no. 38. The height of the upper rail was constant from post no. 1 to 40 and was 31 in. above the travelway. The lower rubrail was installed 3 in. below the bottom edge of the upper rail between post nos. 1 and 29.

The system utilized two flare rates. The first flare extended between post nos. 1 and 10, which had an effective flare rate of 6.8 degrees with respect to the travelway. The second flare extended between post nos. 10 and 29, with a 12:1 lateral flare rate or a 4.4 degree flare angle with respect to the travelway. System installation details for test no. HBIB-1 are shown in Figures 108 through 141. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix A.

5.3 Posts and Blockouts

For test no. HBIB-1, two W6x15, 120-in. long steel posts were used to support the anchor block and improve its stiffness. Post nos. 1 through 24 were 96-in. long W6x8.5 steel posts and post nos. 25 through 38 were 72-in. long W6x8.5 steel posts. For the end of the installation, where the system was anchored to the terrain, two BCT timber posts were used. Post embedment varied throughout the system.

The post spacing was different for each section of the system. Measuring from the upstream end of the installation, the post spacing was as follows, with more detailed information about the post layouts shown in Figure 112

- **Section 1:** post nos. 1 through 4 in which the system had nested upper rails and rubrails at quarter post spacing (18¾ in.)

- **Section 2:** post nos. 4 through 6 in which the system had nested upper rails and rubrails at half post spacing (3 ft – 1½ in.)

- **Section 3:** post nos. 6 through 10 in which the system had upper rail and rubrail at half post spacing (3 ft – 1½ in.)

- **Section 4:** post nos. 10 through 29 in which the system had upper rail and rubrail at full post spacing (6 ft – 3 in.)

- **Section 5:** post nos. 29 through 40 in which the system was consistent with standard, tangent MGS at full post spacing

Recycled plastic blockouts measuring $^{3}/_{16}$ in. x 8 in. x 5⅛ in. were used to support the upper rail throughout the BIB system. Tapered timber blocks were used to space the rubrail from the front face of the posts between post nos. 1 through 4, and the rubrail was installed at the front face of the posts between post nos. 5 and 28. More details about the recycled blockouts and the tapered timber blockouts are provided in Figures 117 and 118.

Posts were embedded in a compacted, coarse, crushed limestone material, alternatively classified as well-graded gravel by the Unified Soil Classification System, that met American Association of State Highway and Transportation Officials (AASHTO) standard soil designation M147 Grade B.

5.4 End Anchor Block

HDOT typically utilizes an aesthetic stone-faced exterior of the anchor block. The block was represented by a 6-in. thick fascia added to the upstream, top, and downstream faces of the concrete anchor block. Typically, anchor blocks are installed in a cut backslope and a stone fascia is added to the top and downstream sides to match the slope of the surrounding backslope and environment. The stone fascia consists of aesthetic stone pieces grouted to the concrete using low-strength concrete, low-aggregate sandy concrete, or a grout mixture. For test nos. HBIB-1 through HBIB-5, the fascia was simulated using a small-aggregate concrete mix with a nominal compressive strength of 1,500 psi.

The originally designed anchor block for use with the buried-in-backslope system was designed for a guardrail with less than 31 in. top mounting height. To support connection to the MGS, which had a top rail height of 31 in., and a constant rail height through the ditch, the height of the anchor block above the ditch bottom was increased to 3 ft. Since the 2H:1V backslope did not provide significant soil anchorage in the system which may be consistent with significant igneous rock backfill, three W6x9 reinforcement posts were added to the back side and the downstream side of the anchor.

After the modifications, a 3 ft x 3 ft x 3 ft concrete block with hoop reinforcement was used to anchor the system. The original block design is shown in Figure 115 while the actual system installation is shown in Figures 143 through 145.

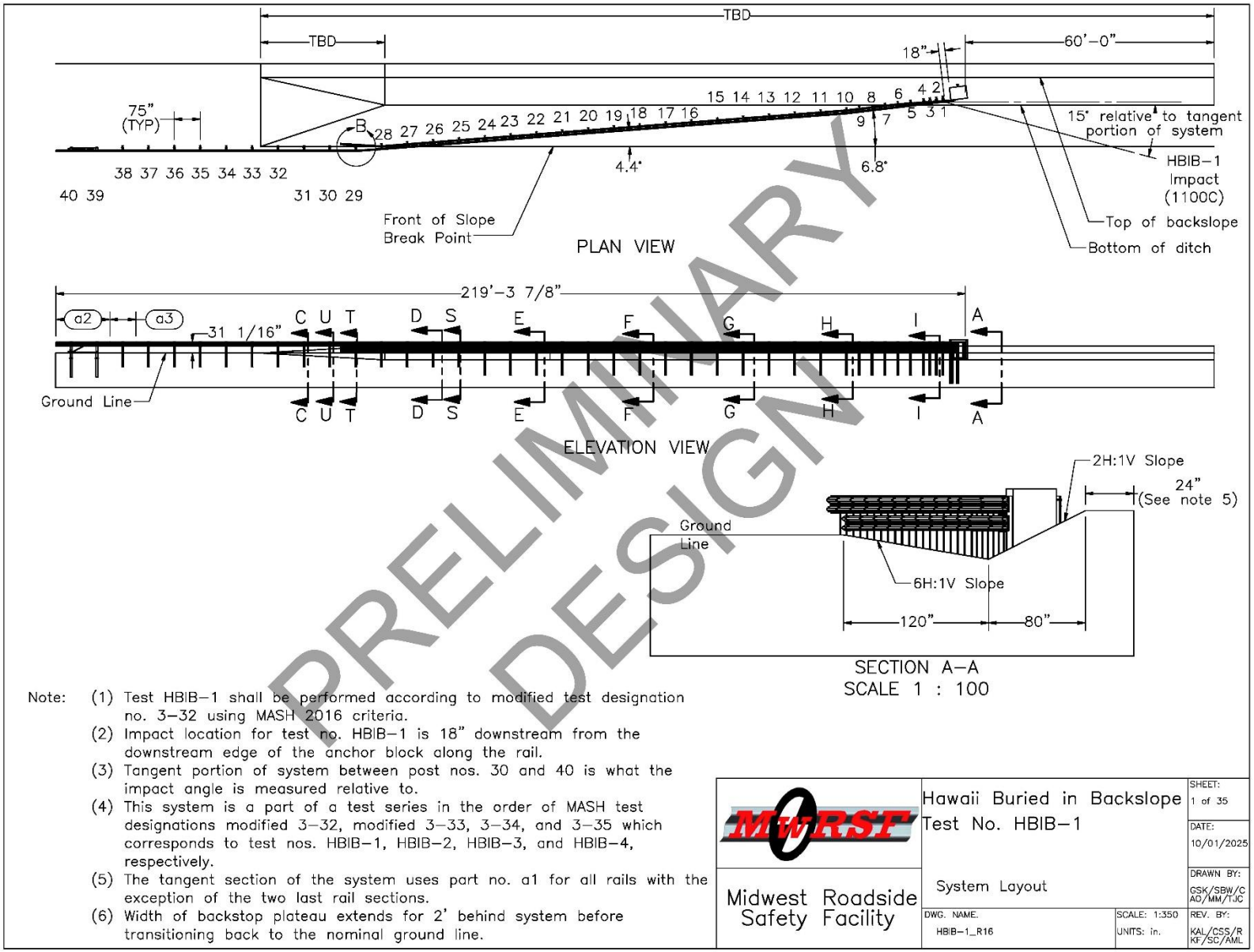


Figure 108. System Layout, Test No. HBIB-1

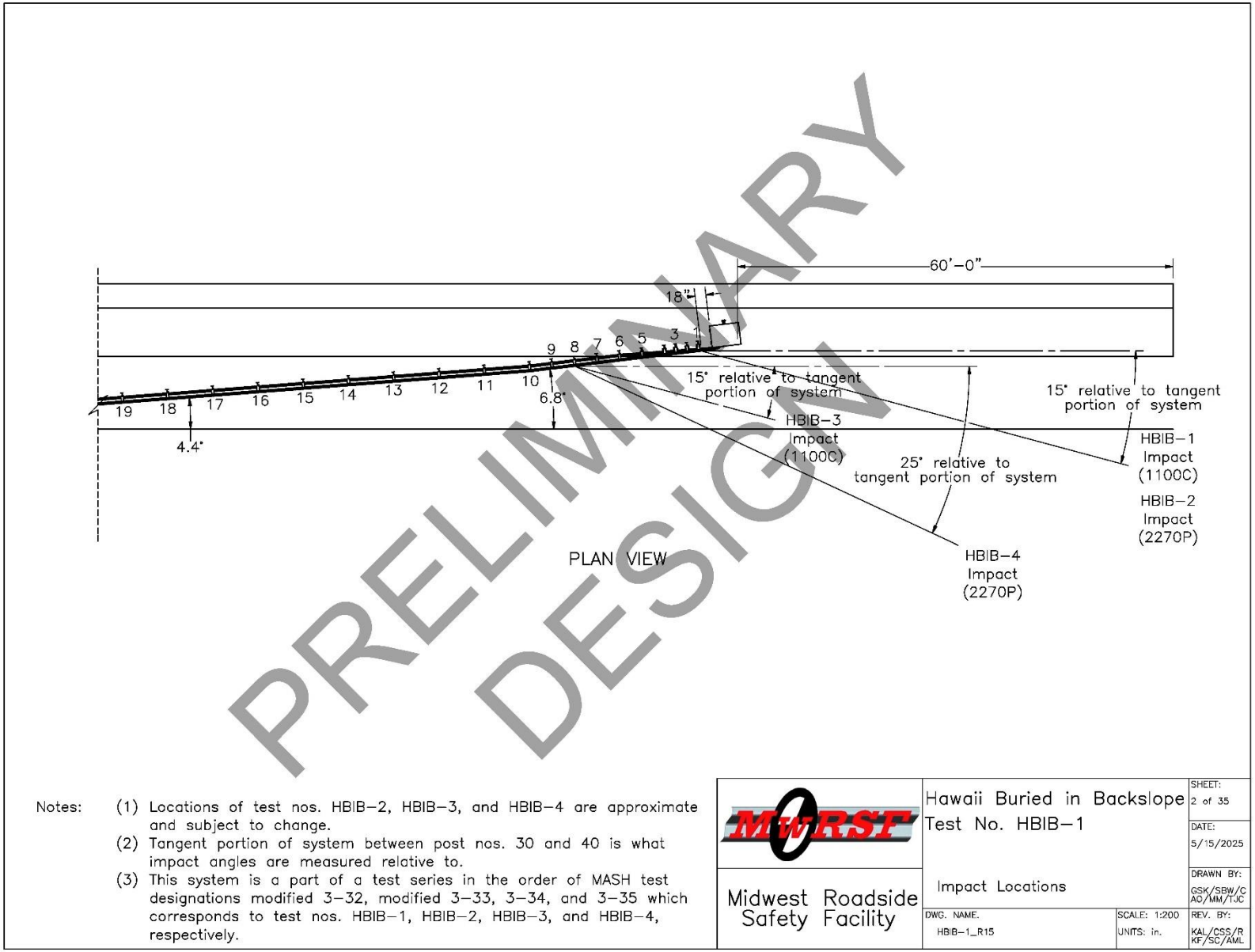


Figure 109. Impact Location, Test No. HBIB-1

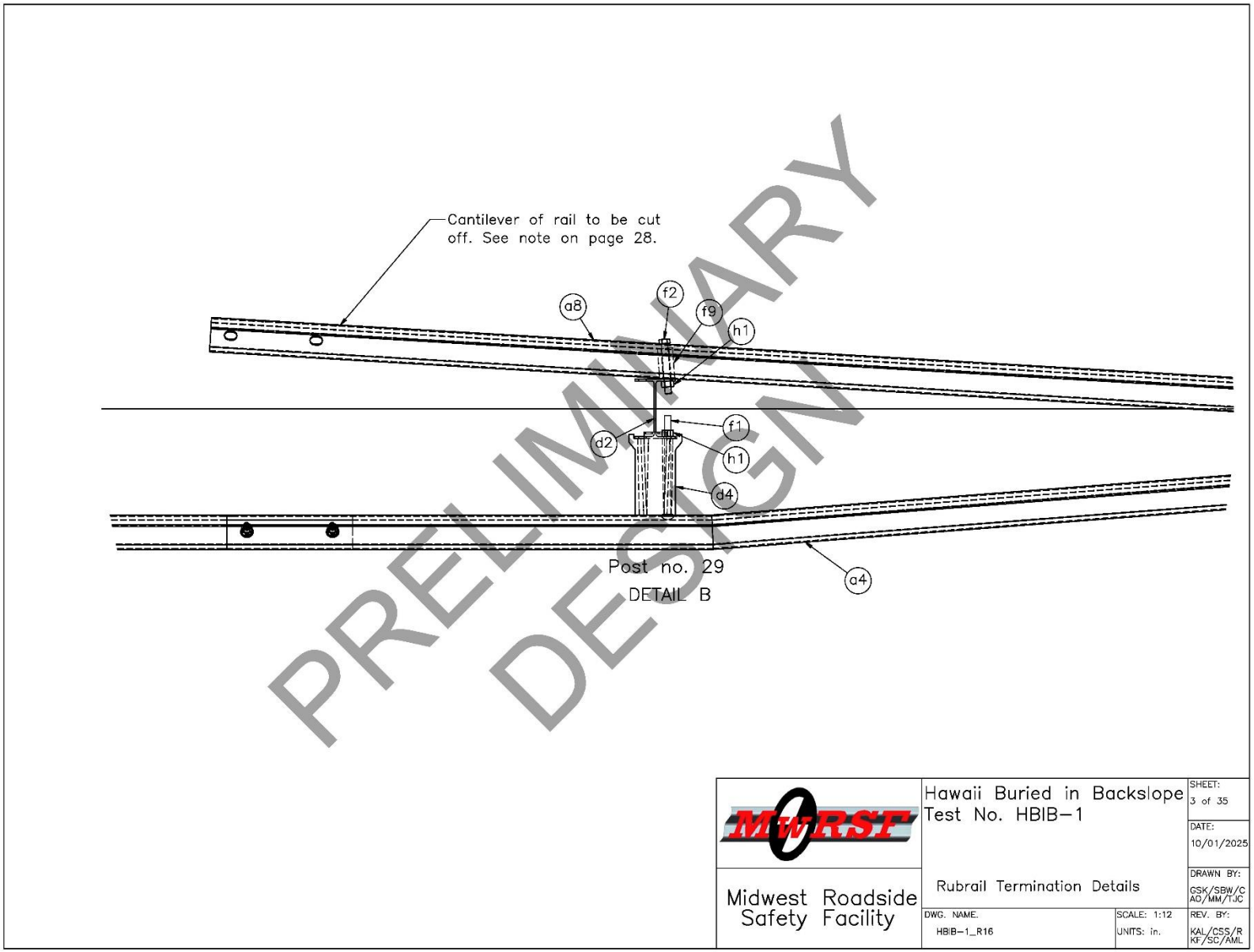


Figure 110. Rubrail Termination Details, First Deviations Point, Test No. HBIB-1

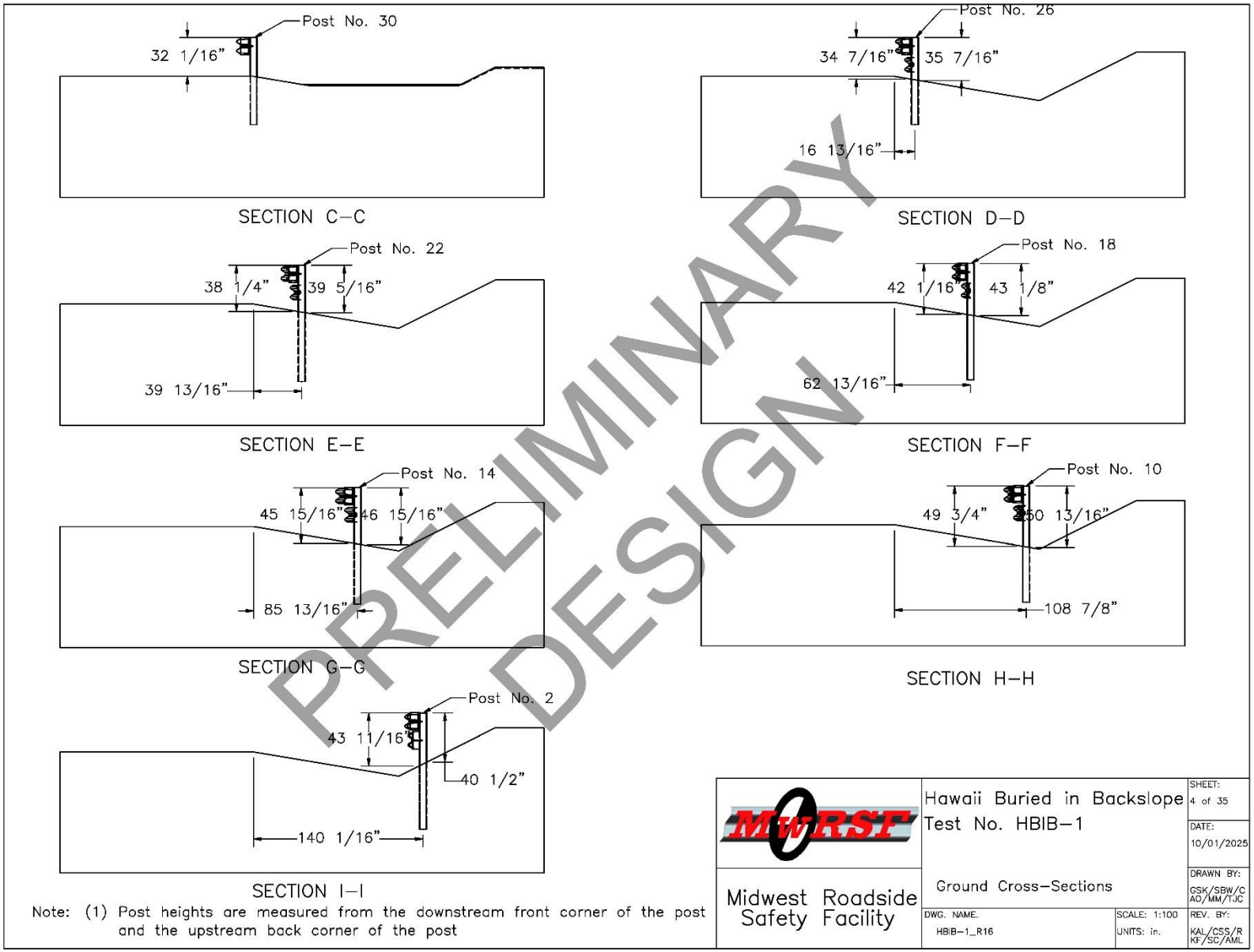
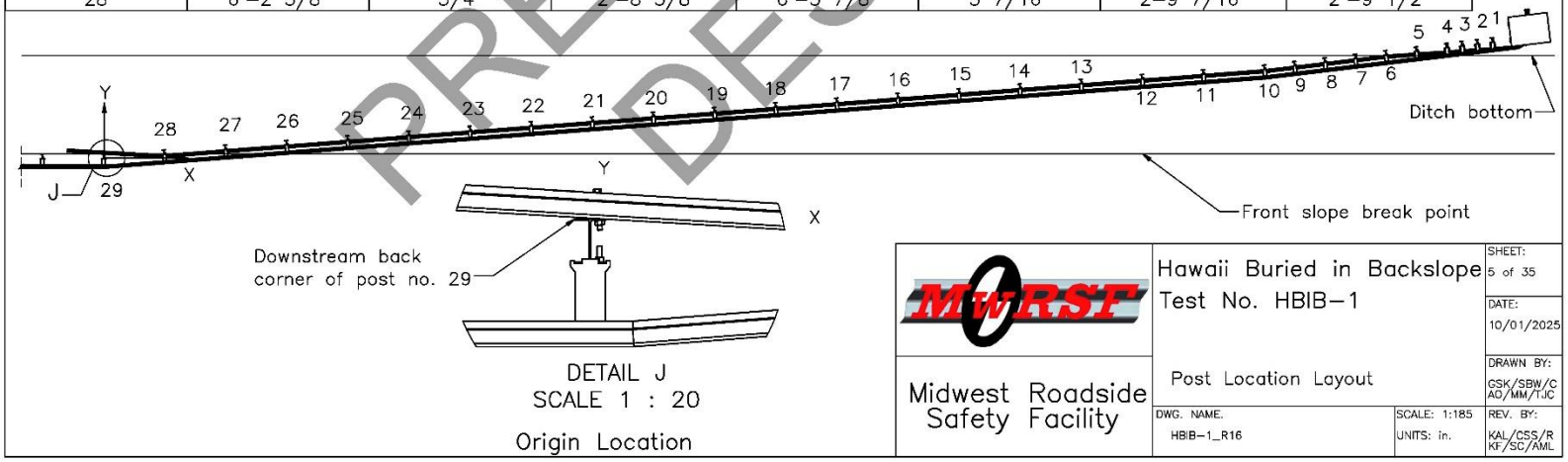


Figure 111. Ground Cross Sections, Test No. HBIB-1

Post No.	Downstream Front of Post			Upstream Back of Post			Top of the back side centerline post to ditch
	X	Y	Top of the post to ground	X	Y	Top of the post to ground	
1	141'–7 1/4"	11'–4 3/16"	3'–6 1/4"	141'–10 9/16"	11'–10 1/2"	3–3 5/16"	3'–3 13/32"
2	140'–5/8"	11'–1 15/16"	3'–7 9/16"	140'–3 15/16"	11'–8 1/4"	3'–4 7/16"	3'–4 21/32"
3	138'–6"	10'–11 3/4"	3'–8 3/8"	138'–6"	10'–11 3/4'	3'–5 9/16"	3'–5 3/4"
4	136'–11 7/16"	10'–9 1/2"	3'–9 7/8"	137"–2 11/16"	11'–3 13/16"	3'–6 3/4"	3'–6 7/8"
5	133'–10 3/16"	10'–5"	4'–1/8"	134'–1 7/16"	10'– 11 5/16'	3'–8 15/16"	3'–9 3/32"
6	130'–8 15/16"	10'–9/16"	4'–2 5/16"	130'–8 15/16"	10'–9/16'	3'–11 3/16"	3'–11 11/32"
7	127'–7 11/16"	9'–8 1/16"	4'–3 5/16"	127'–11"	10'–2 3/8"	4'–1 7/16"	4'–1 9/16"
8	124'–6 1/2"	9'–3 5/8"	4'–3 3/16"	124'–9 3/4"	9'–9 15/16"	4'–3 5/8"	4'–3 13/16"
9	121'–5 1/4"	8'–11 3 1/6"	4'–2 7/16"	121'–8 1/2"	9'–5 1/2"	4'–3 1/2"	4'–3 15/32"
10	118'–4 3/8"	8'–6 13/16"	4'–1 5/8"	118'–7 15/16"	9'–1"	4'–2 11/16"	4'–2 3/4"
11	112'–1 5/8"	8'–1 1/16"	4'–11/16"	112'–5 1/8"	8'–7 1/4"	4'–1 3/4"	4'–1 13/16"
12	105'–10 13/16"	7'–7 5 1/6"	3'–11 3/4'	106'–2 3/8"	8'–1 1/2"	4'–3/4"	4'–27/32"
13	99'–8 1/16"	7'–1 9/16"	3'–10 13/16"	99'–11 9/16"	7'–7 3/4"	3'–11 13/16"	3'–11 29/32"
14	93'–5 1/4"	6'–7 13/16"	3'–9 13/16"	93'–8 13/16"	7'–2'	3'–10 7/8"	3'–10 15/16"
15	87'–2 1/2"	6'–2 1/16"	3'–8 7/8"	87'–6"	6'–8 1/4"	3'–9 7/8"	3'–9 31/32"
16	80'–11 11/16"	5'–8 5/16"	3'–7 15/16"	81'3 1/4"	6'–2 1/2"	3'–8 15/16"	3'–9"
17	74'–8 15/16"	5'–2 9/16"	3'–6 15/16"	75'–7/16"	5'–8 3/4"	3'–8"	3'–8 1/16"
18	68"–6 1/8"	4'–8 13/16"	3'–6"	68'–9 11/16"	5'–3'	3'–7"	3'–7 3/32"
19	62'–3 3/8"	4'–3 1/16"	3'–5'	62'–6 15/16"	4'–9 1/4"	3'–6 1/16"	3'–6 5/32"
20	56'–9/16"	3'–9 5/16"	3'–4 1/16"	56'–4 1/8"	4'–3 1/2"	3'–5 1/8"	3'–5 3/16"
21	49'–9 13/16"	3'–3 9/16"	3'–3 1/8"	50'–1 3/8"	3'–9 3/4"	3'–4 1/8"	3'–4 1/4"
22	43'–7 1/16"	2'– 9 13/16"	3'–2 3/16"	43'–10 9/16"	3'–4"	3'–3 3/16"	3'–3 9/32"
23	37'–4 1/4"	2'–4 1/16"	3'–1 3/16'	37'–7 13/16"	2'–10 1/4"	3'–2 1/4"	3'–2 1/4"
24	31'–1/12"	1'–10 5/16"	3'–1/4"	31'–5"	2'–4 1/2'	3'–1 1/4"	3'–1 3/8"
25	24'–10 11/16"	1'–4 9/16'	2'–11 1/4"	25'–2 1/4"	1'–10 11/16"	3'–5/16"	3'–3/8"
26	18'–7 15/16	10 13/16"	2'–10 5/16"	18'–11 7/16"	1'–4 15/16"	2'–11 3/8"	2'–11 15/32"
27	12'–5 1/8"	5 1/16"	2'–9 3/8"	12'–8 11/16"	11 3/16"	2'–10 3/8"	2'–10 15/32"
28	6'–2 3/8"	3/4"	2'–8 3/8	6'–5 7/8"	5 7/16"	2–9 7/16"	2'–9 1/2"



PRELIMINARY DESIGN

MwRSF	Hawaii Buried in Backslope Test No. HBIB–1	SHEET: 5 of 35
		DATE: 10/01/2025
Midwest Roadside Safety Facility	Post Location Layout	DRAWN BY: GSK/SBW/CAO/MM/TJC
	DWG. NAME. HBIB–1_R16 SCALE: 1:185 UNITS: in.	REV. BY: KAL/CSS/RKF/SC/AML

Figure 112. Post Location Layout, Test No. HBIB-1

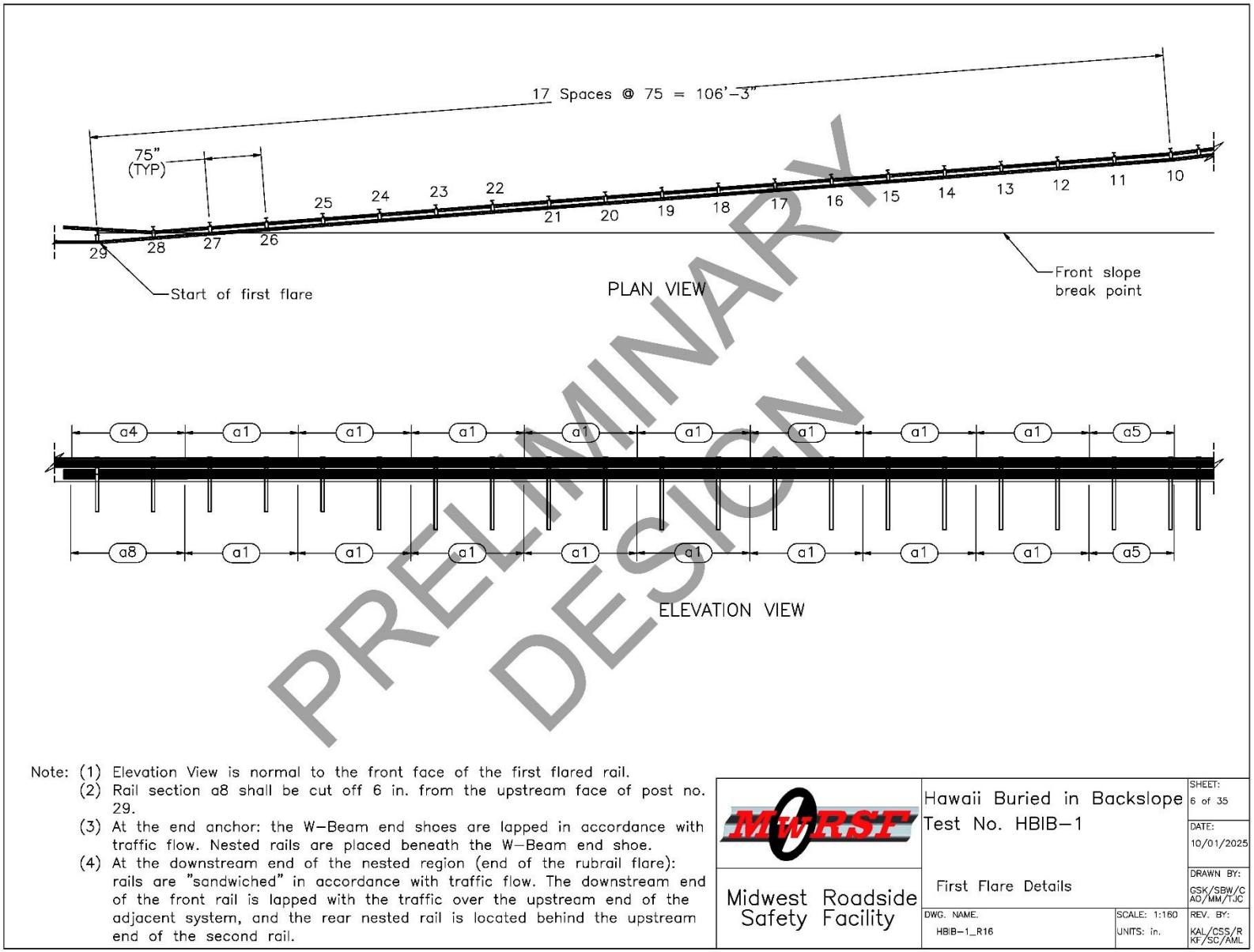


Figure 113. First Flare Details, Test No. HBIB-1

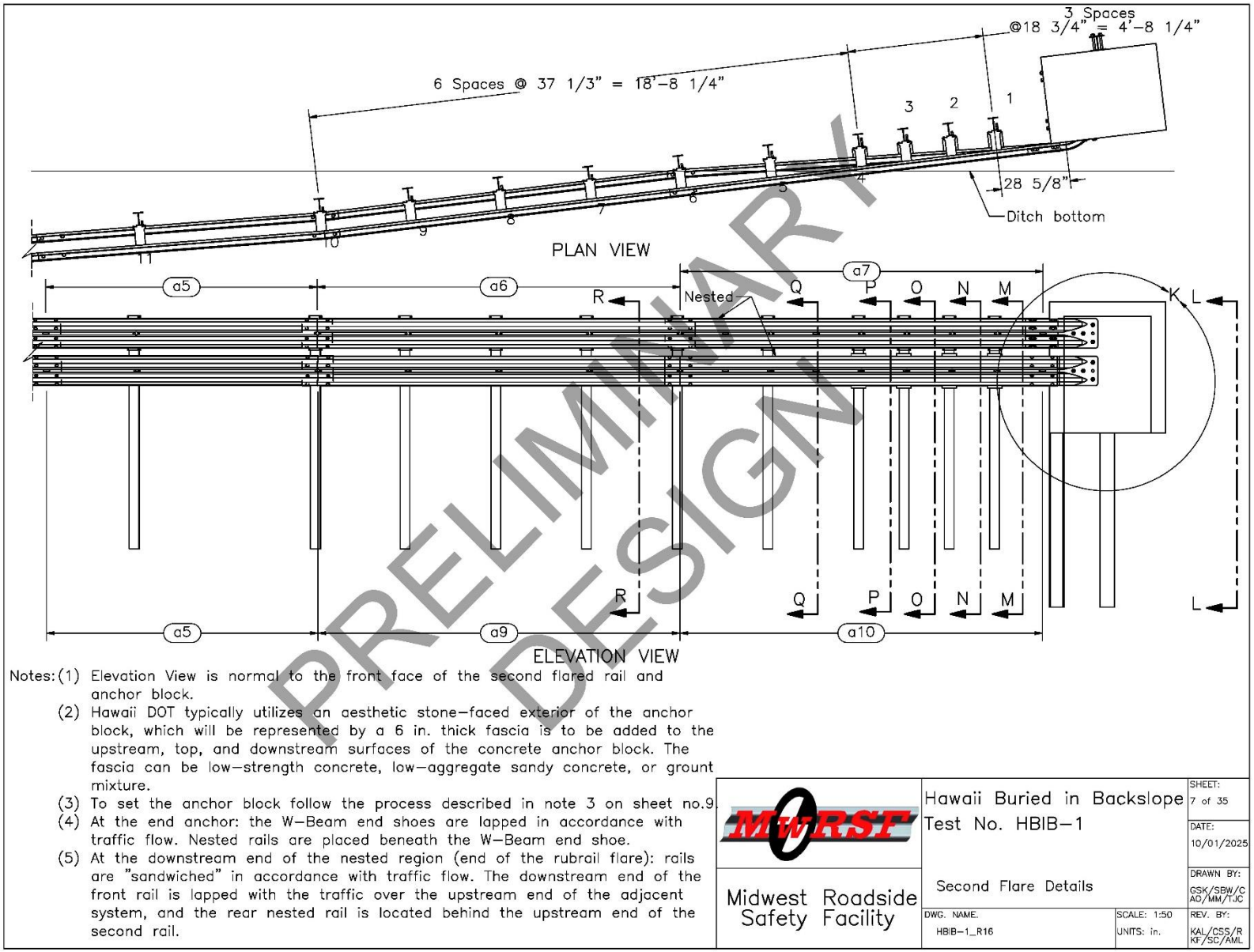


Figure 114. Second Flare Details, Test No. HBIB-1

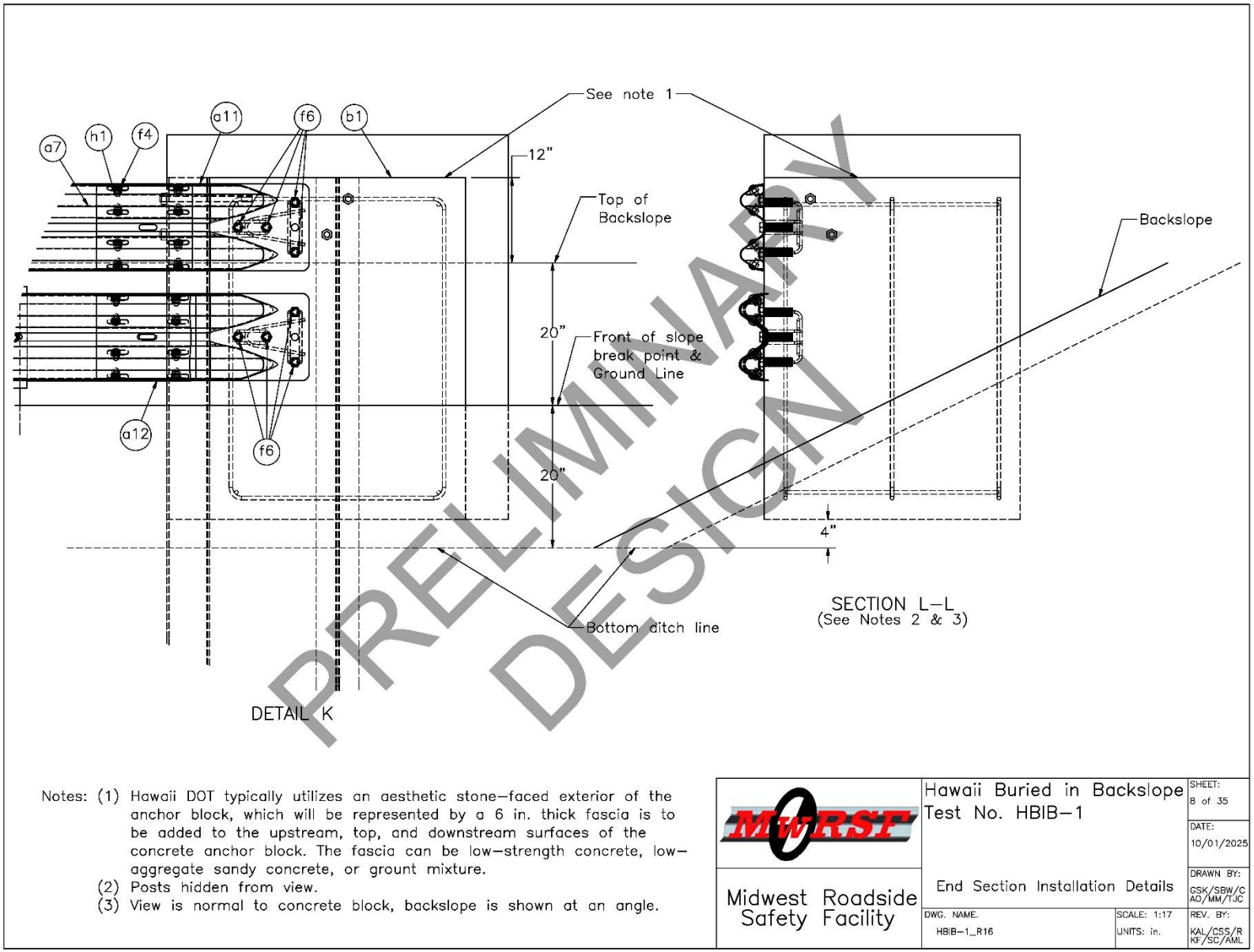


Figure 115. End Section Installation Details, Test No. HBIB-1

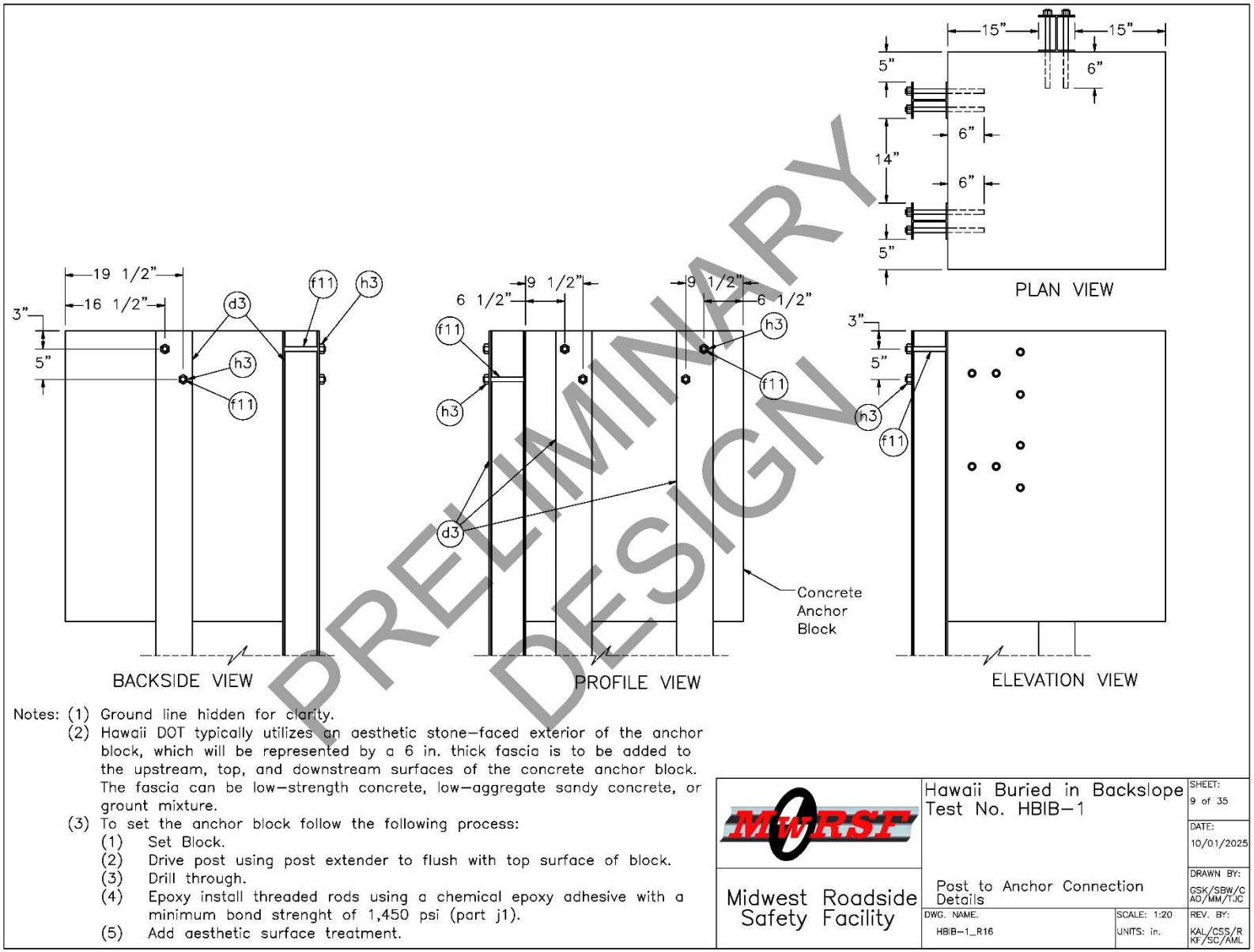


Figure 116. Post to Anchor Connection, Test No. HBIB-1

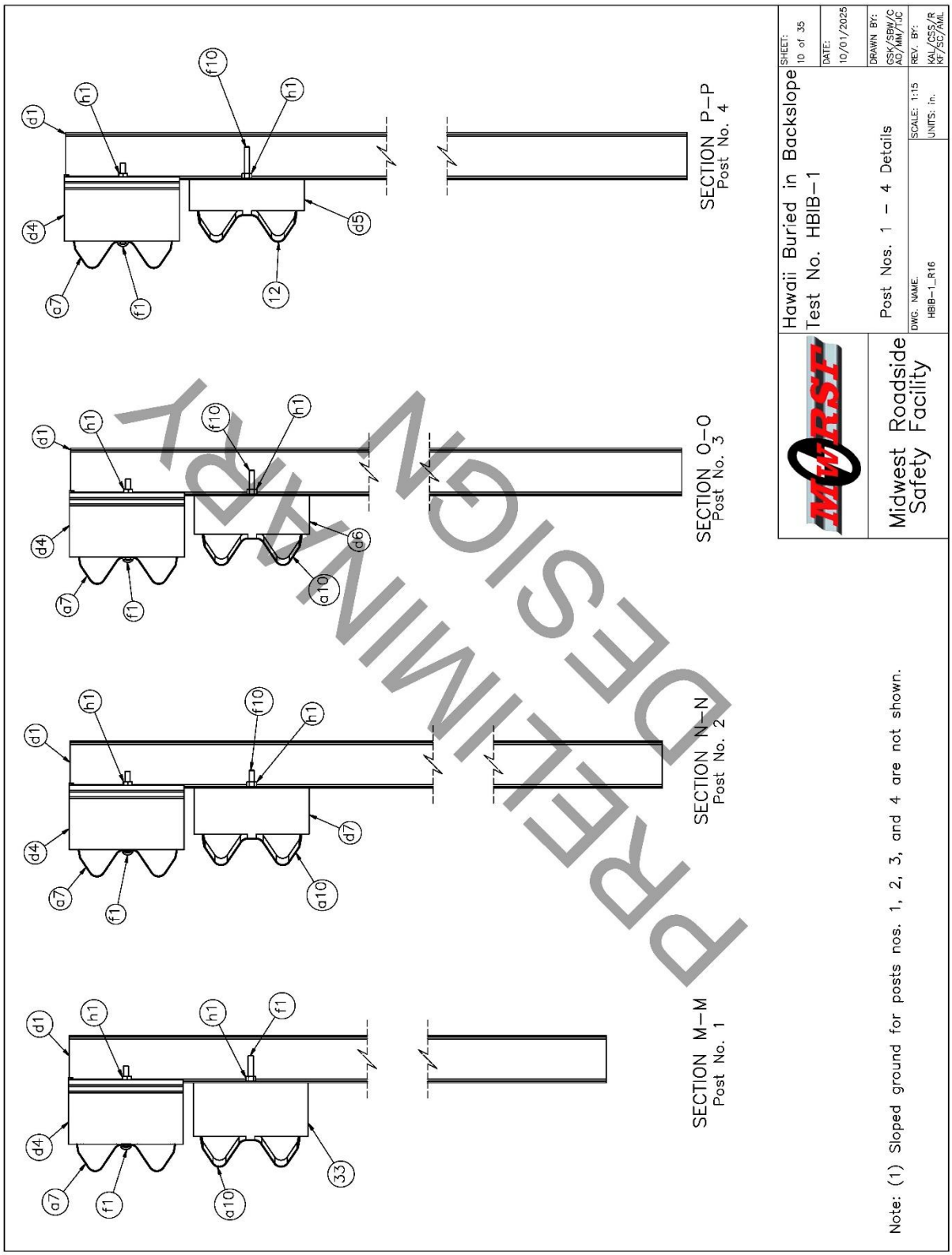


Figure 117. Post Details, Post Nos. 1 through 4, Test No. HBIB-1

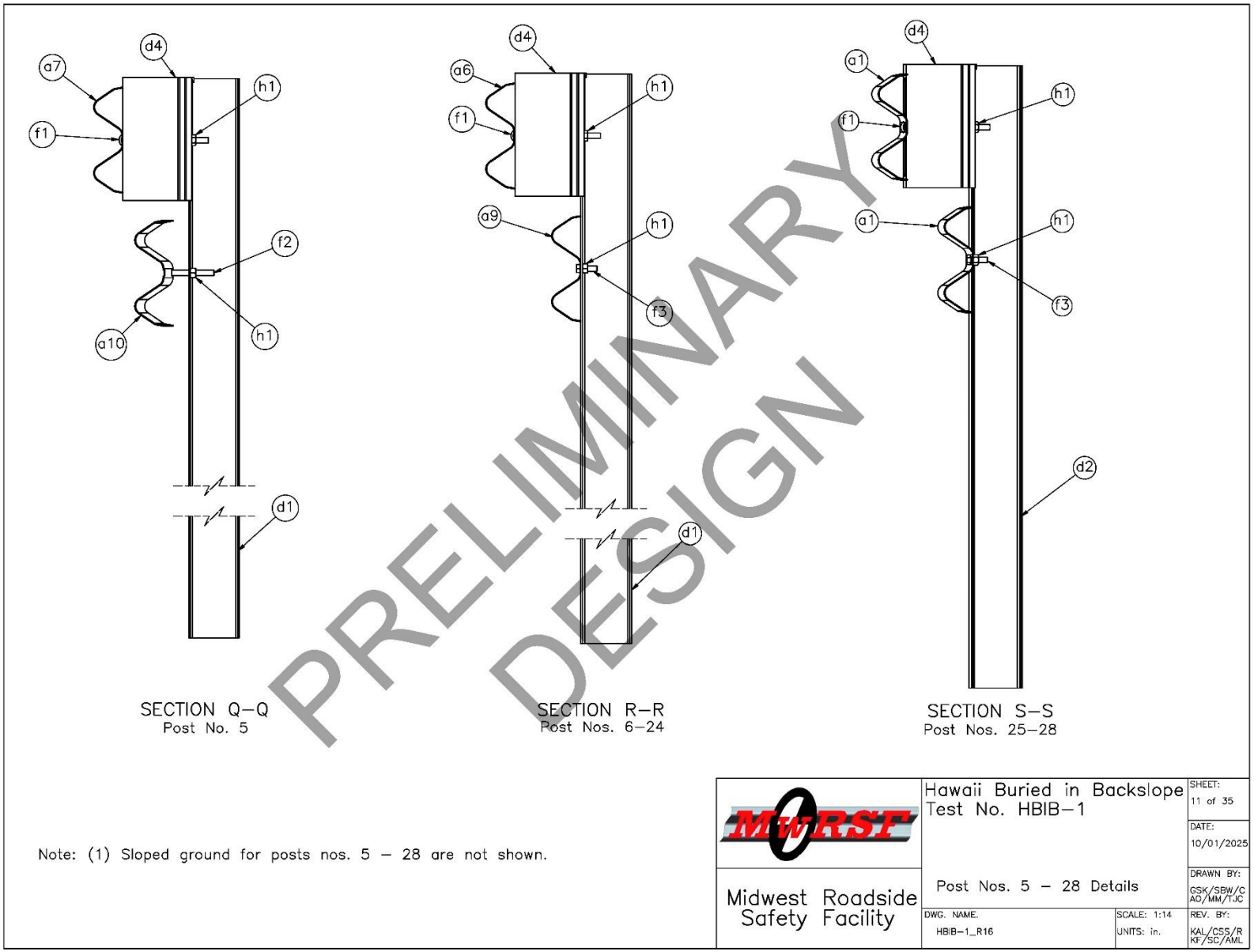


Figure 118. Post Details, Post Nos. 5 through 28, Test No. HBIB-1

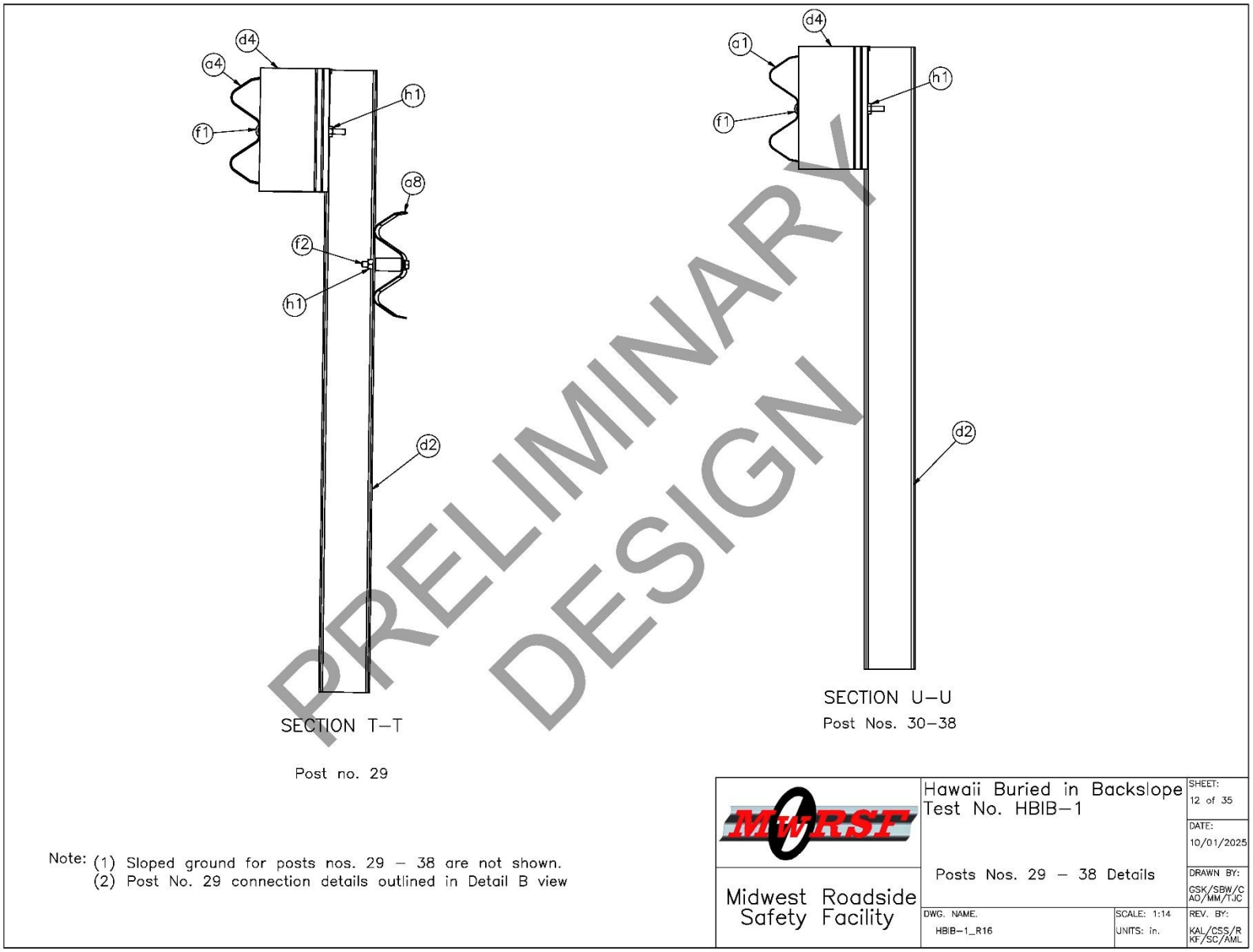


Figure 119. Post Details, Post Nos. 29 through 38, Test No. HBIB-1

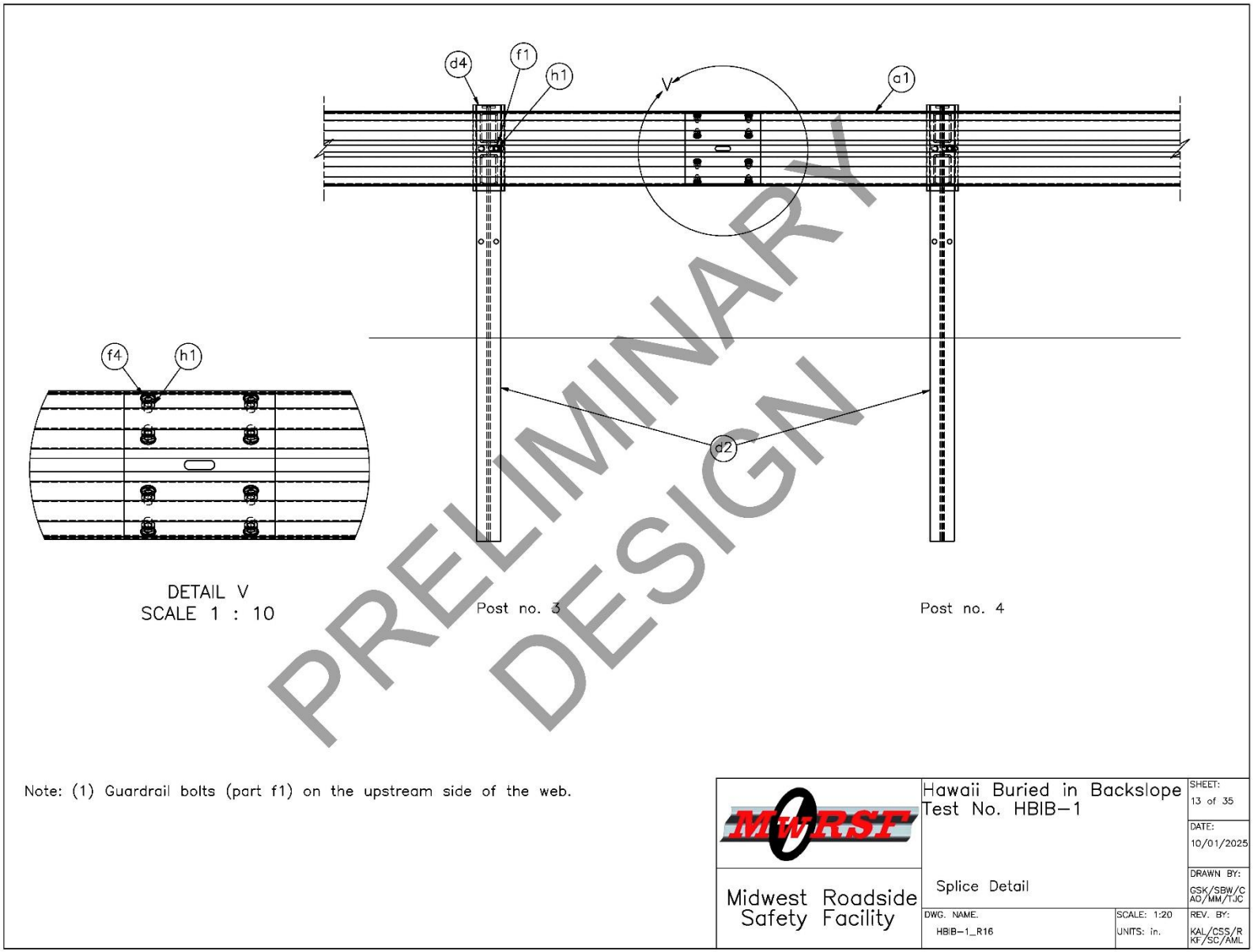


Figure 120. Splice Details, Test No. HBIB-1

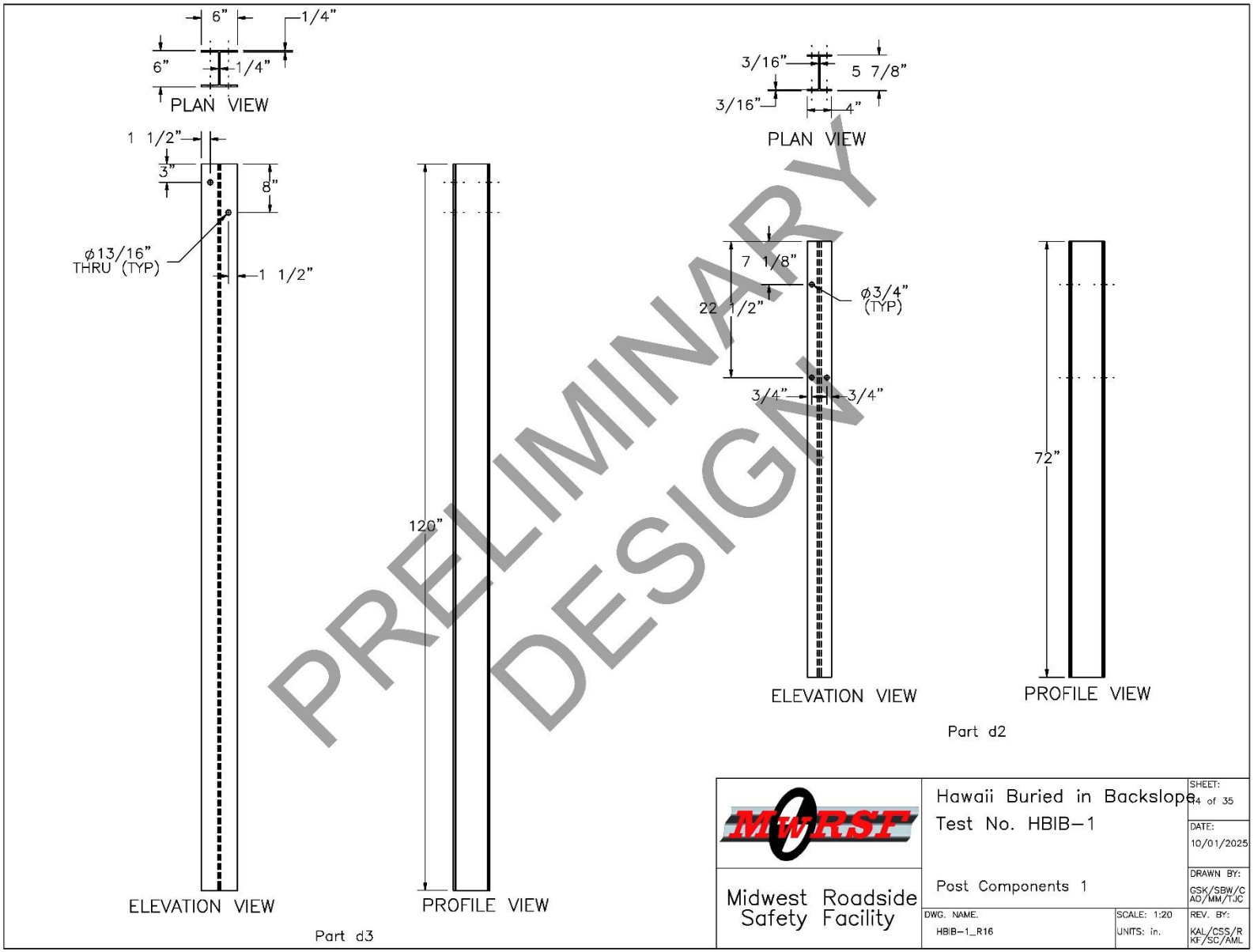


Figure 121. Post Component Details, Page 1, Test No. HBIB-1

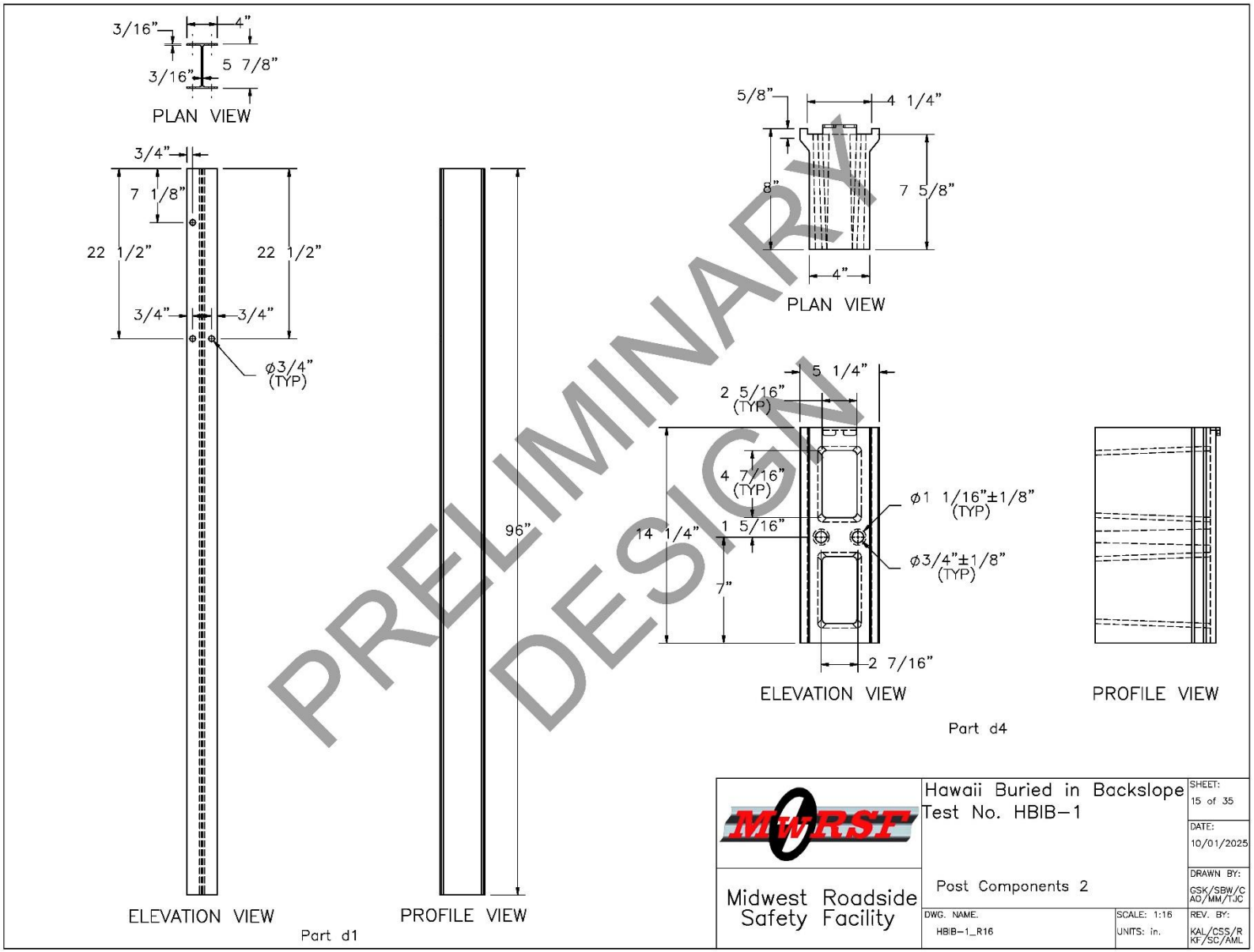


Figure 122. Post Component Details, Page 2, Test No. HBIB-1

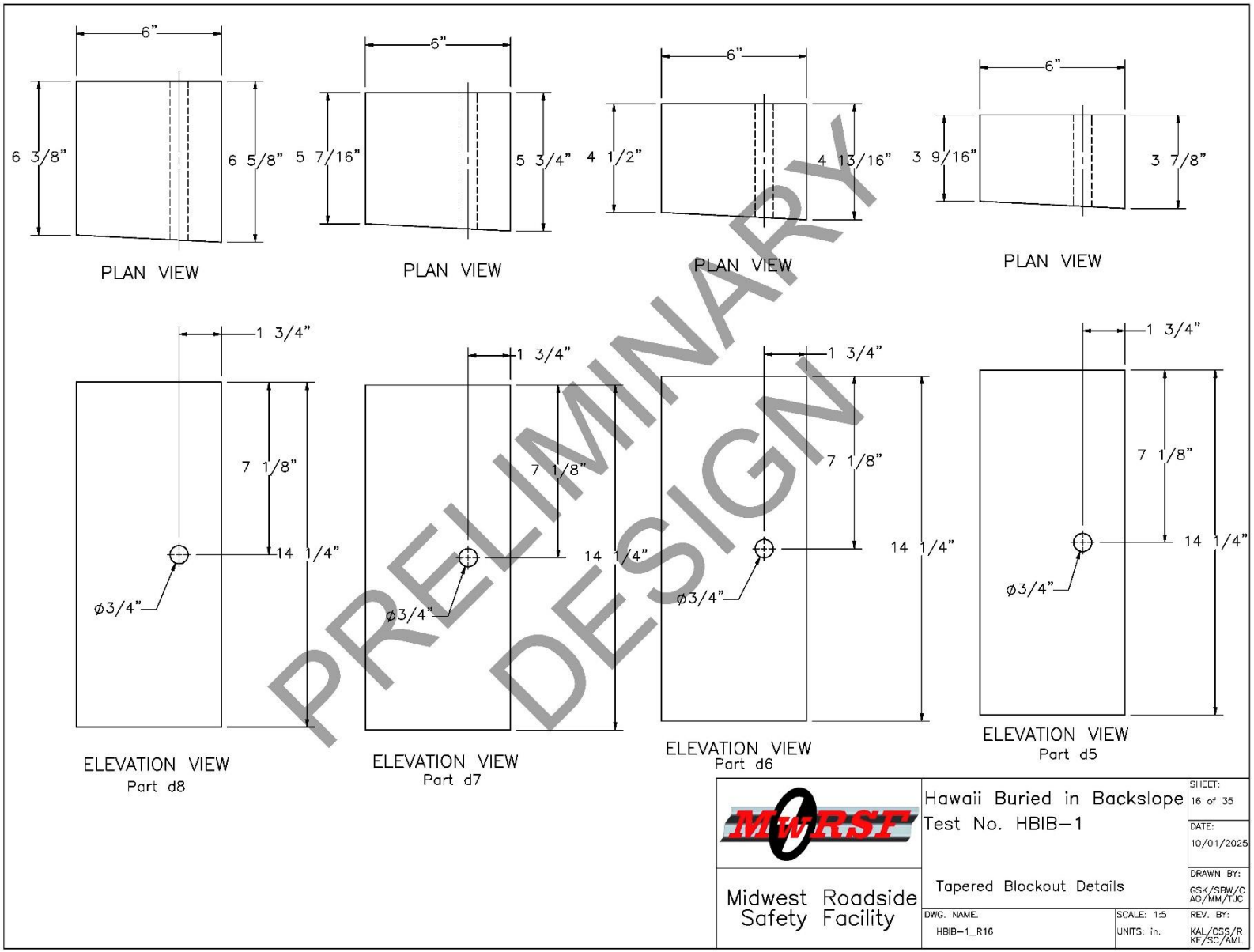


Figure 123. Tapered Blockout Details, Test No. HBIB-1

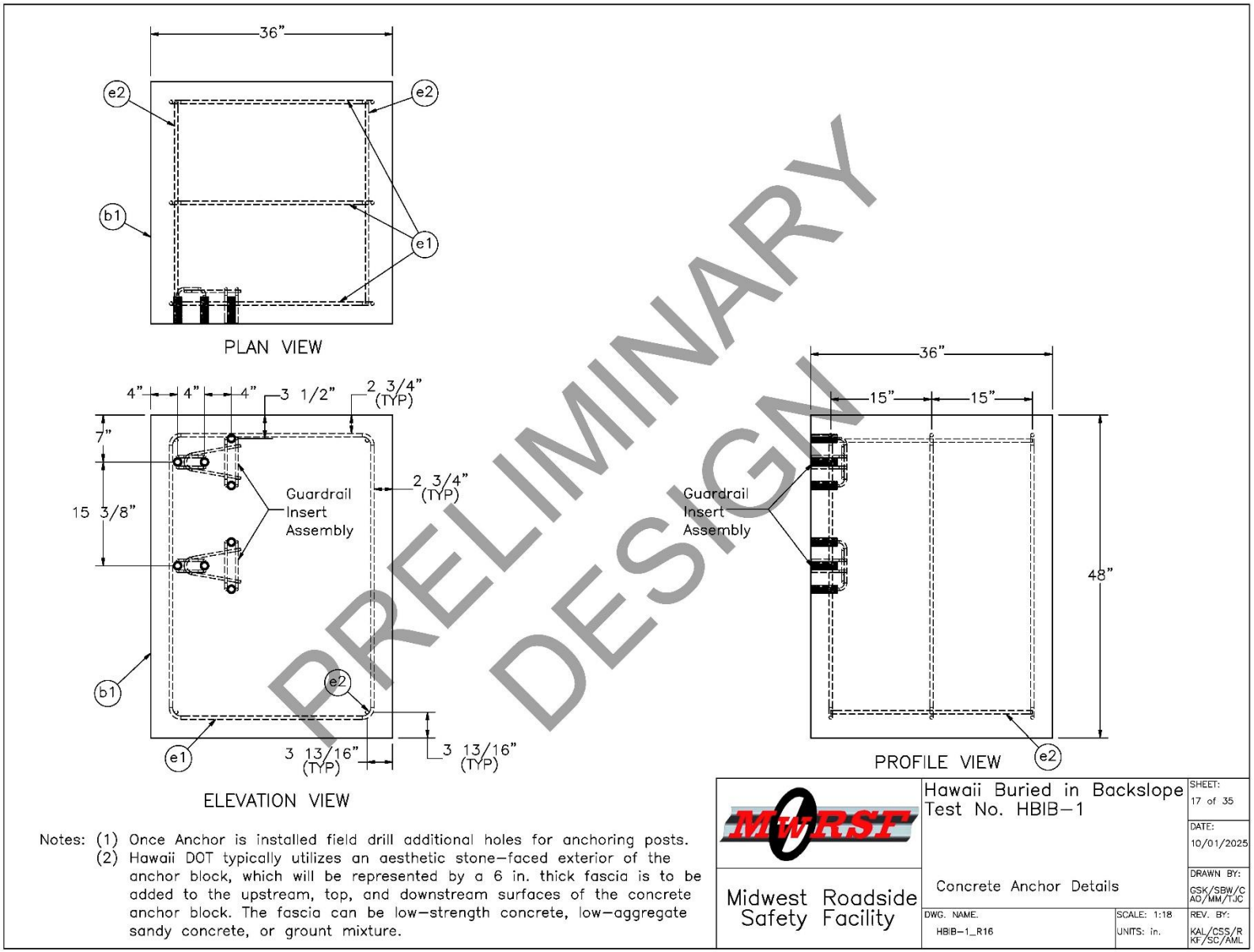
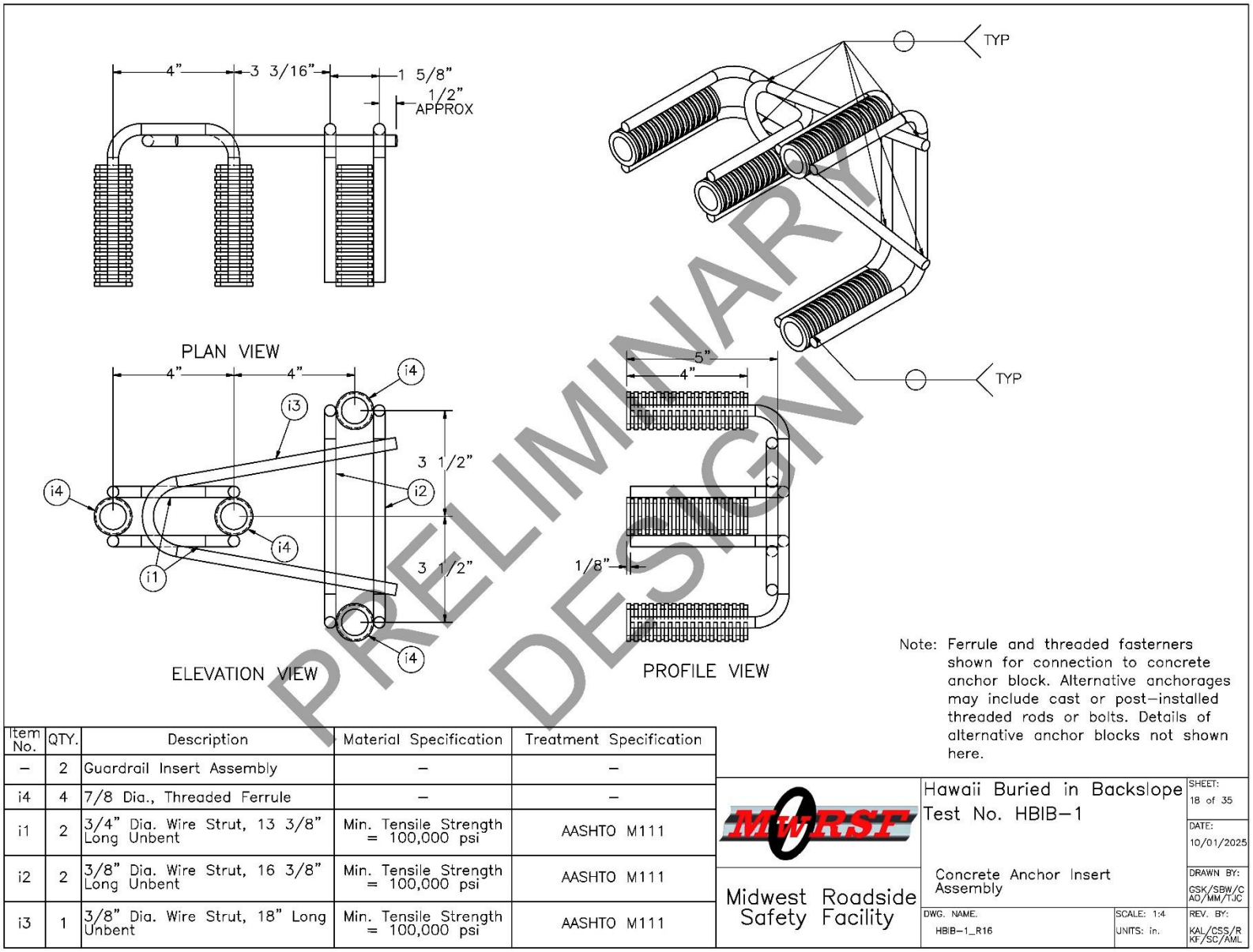


Figure 124. Concrete Anchor Details, Test No. HBIB-1



Item No.	QTY.	Description	Material Specification	Treatment Specification
–	2	Guardrail Insert Assembly	–	–
i4	4	7/8 Dia., Threaded Ferrule	–	–
i1	2	3/4" Dia. Wire Strut, 13 3/8" Long Unbent	Min. Tensile Strength = 100,000 psi	AASHTO M111
i2	2	3/8" Dia. Wire Strut, 16 3/8" Long Unbent	Min. Tensile Strength = 100,000 psi	AASHTO M111
i3	1	3/8" Dia. Wire Strut, 18" Long Unbent	Min. Tensile Strength = 100,000 psi	AASHTO M111

MwRSF

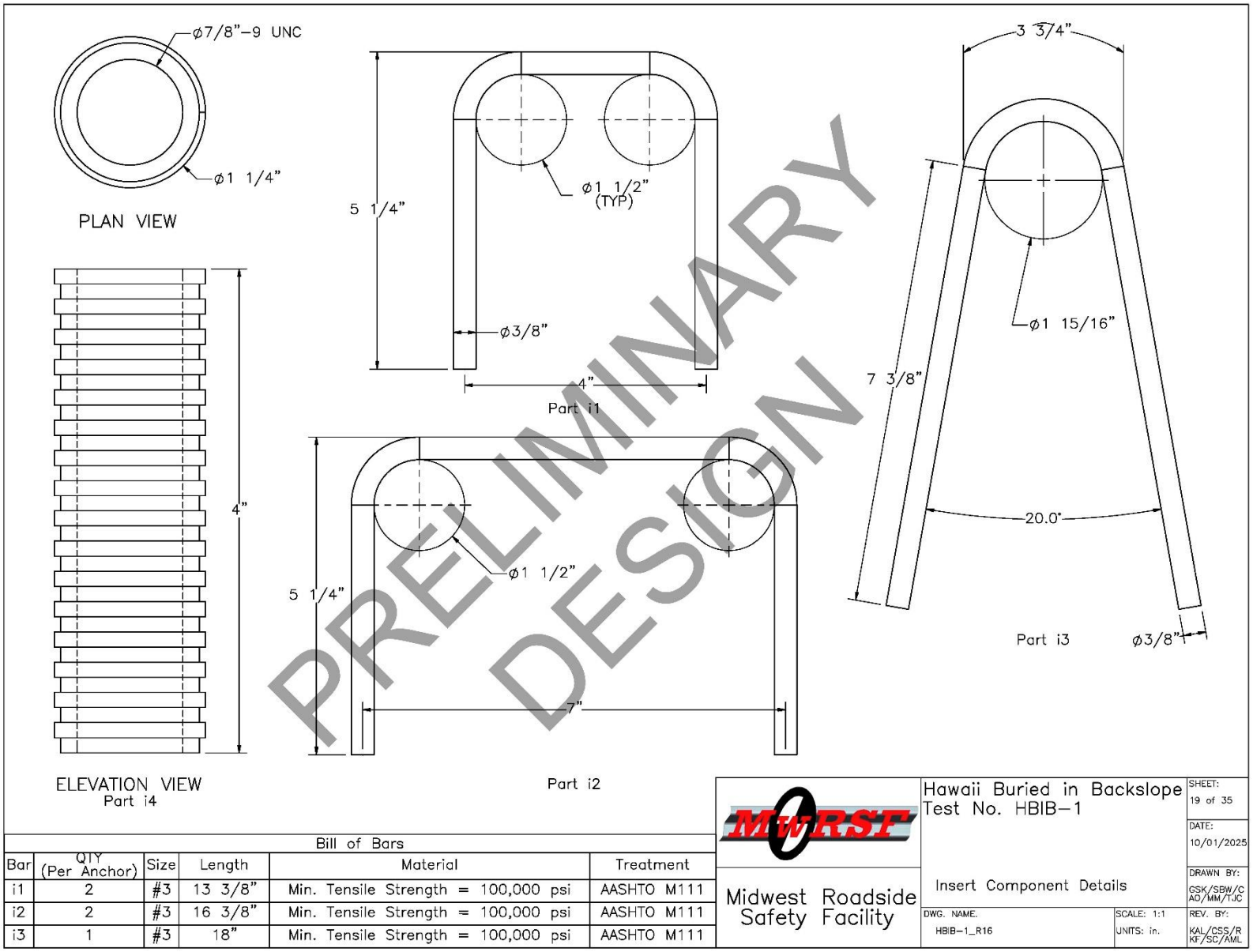
Midwest Roadside Safety Facility

Hawaii Buried in Backslope
Test No. HBIB-1

Concrete Anchor Insert Assembly

SHEET: 18 of 35
DATE: 10/01/2025
DRAWN BY: GSK/SBW/CAO/MM/TJC
REV. BY: KAL/CSS/RKF/SC/AML
DWG. NAME. HBIB-1_R16
SCALE: 1:4
UNITS: in.

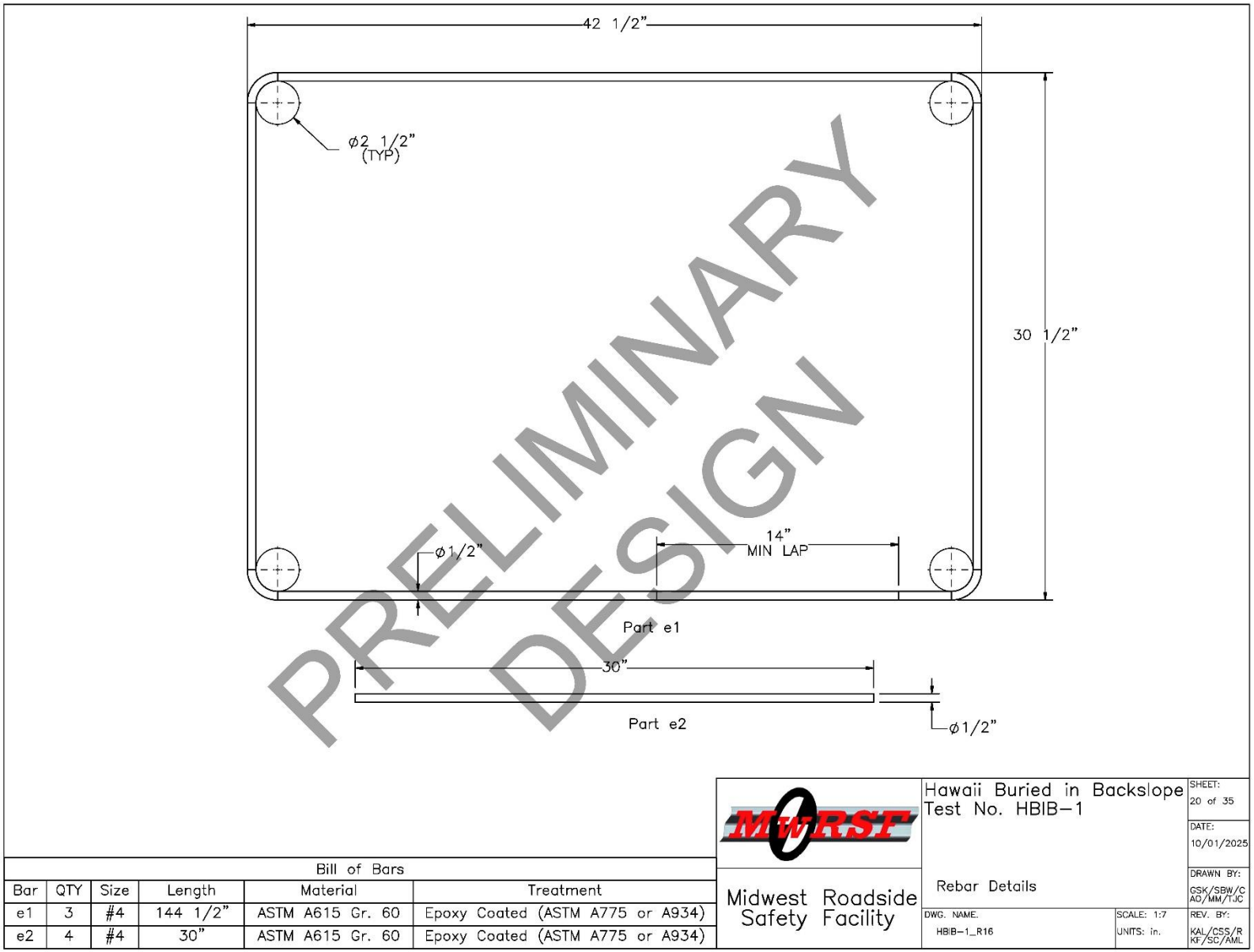
Figure 125. Concrete Anchor Insert Details, Test No. HBIB-1



Bill of Bars

Bar	QTY (Per Anchor)	Size	Length	Material	Treatment
i1	2	#3	13 3/8"	Min. Tensile Strength = 100,000 psi	AASHTO M111
i2	2	#3	16 3/8"	Min. Tensile Strength = 100,000 psi	AASHTO M111
i3	1	#3	18"	Min. Tensile Strength = 100,000 psi	AASHTO M111

Figure 126. Insert Component Details, Test No. HBIB-1



Bill of Bars					
Bar	QTY	Size	Length	Material	Treatment
e1	3	#4	144 1/2"	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)
e2	4	#4	30"	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)

Midwest Roadside Safety Facility

Hawaii Buried in Backslope
Test No. HBIB-1

Rebar Details

SHEET: 20 of 35
DATE: 10/01/2025
DRAWN BY: GSK/SBW/CAO/MM/TJC
REV. BY: KAL/CSS/RKF/SC/AML
DWG. NAME. HBIB-1_R16
SCALE: 1:7
UNITS: in.

Figure 127. Rebar Details, Test No. HBIB-1

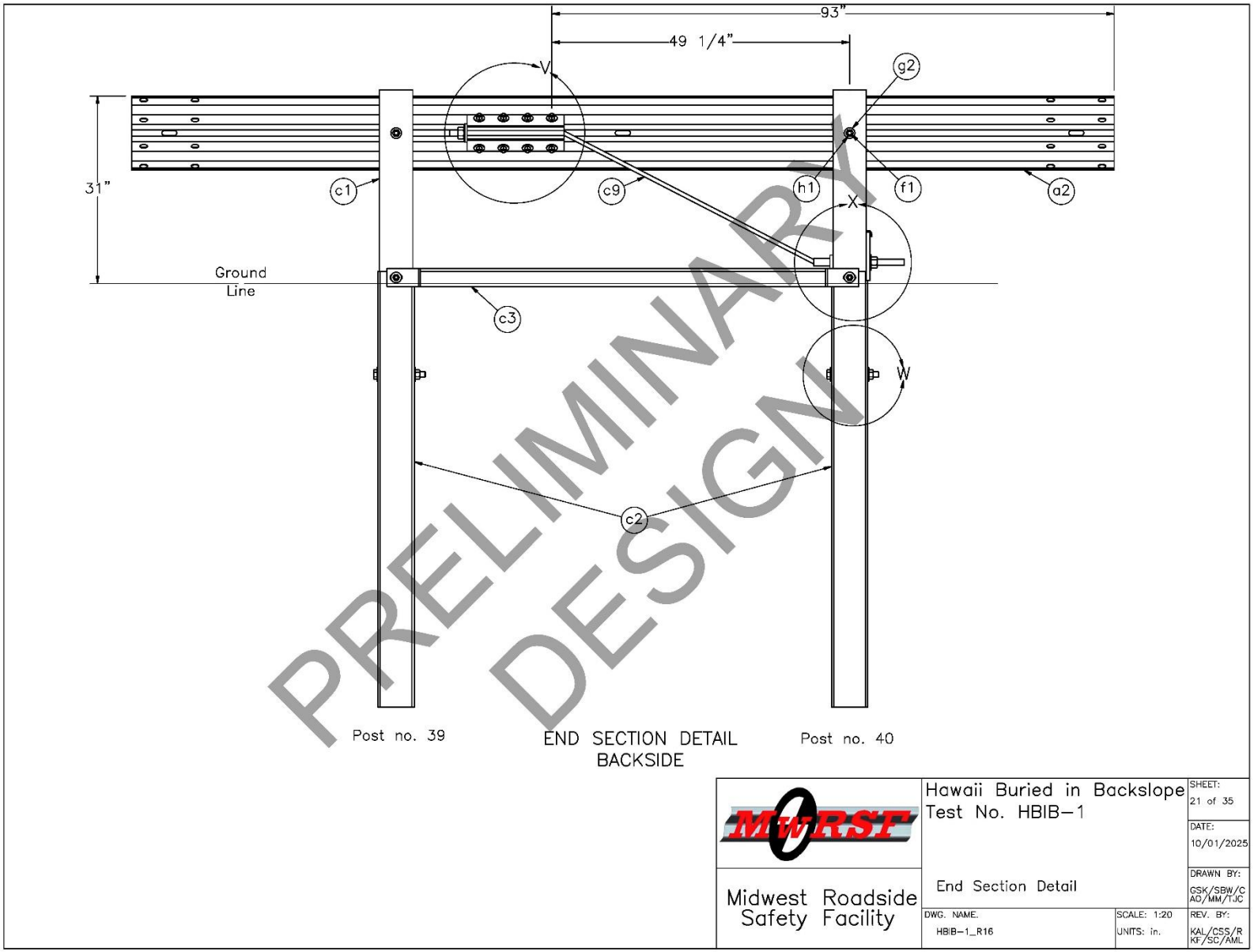


Figure 128. End Section Details, Test No. HBIB-1

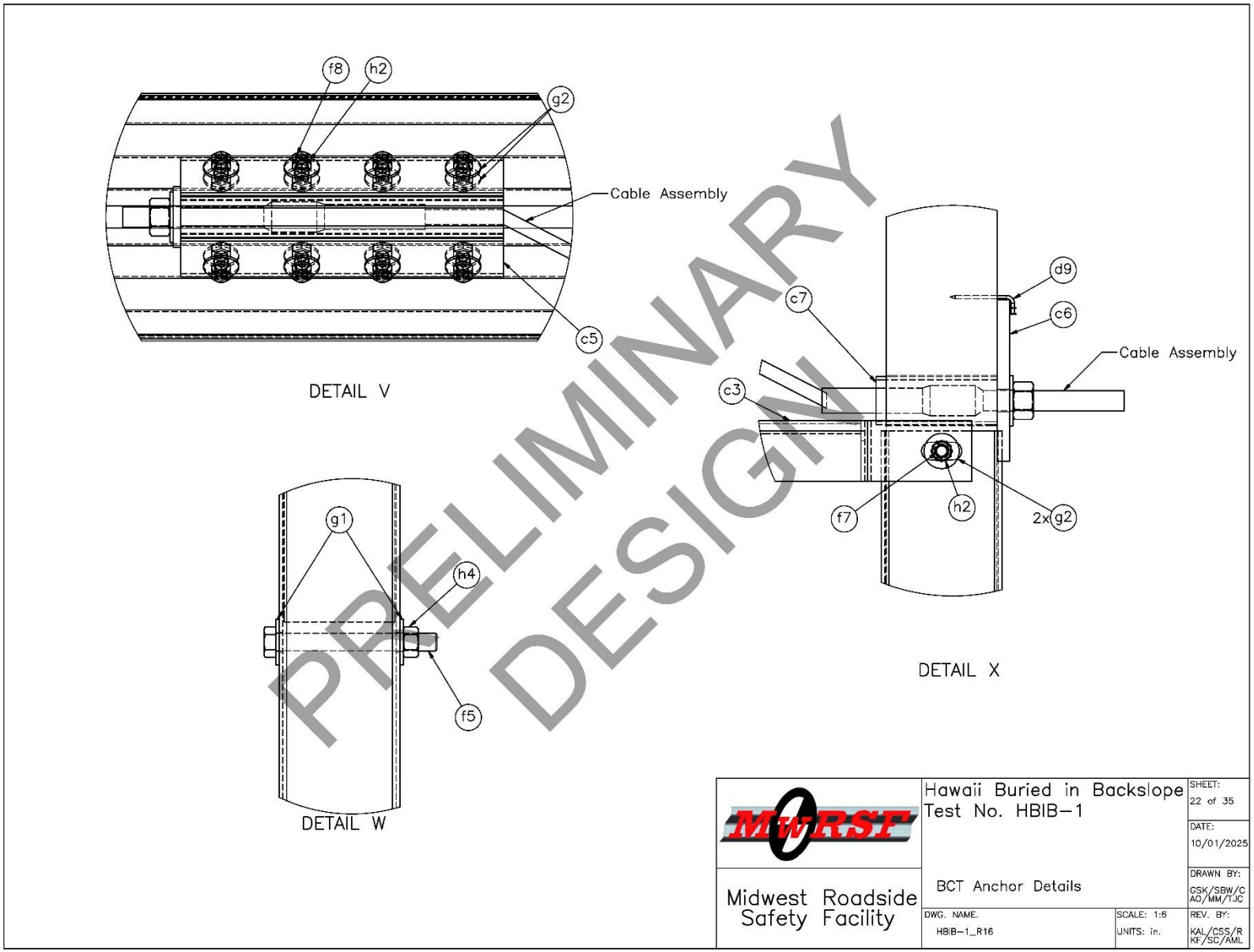


Figure 129. BCT Anchor Details, Test No. HBIB-1

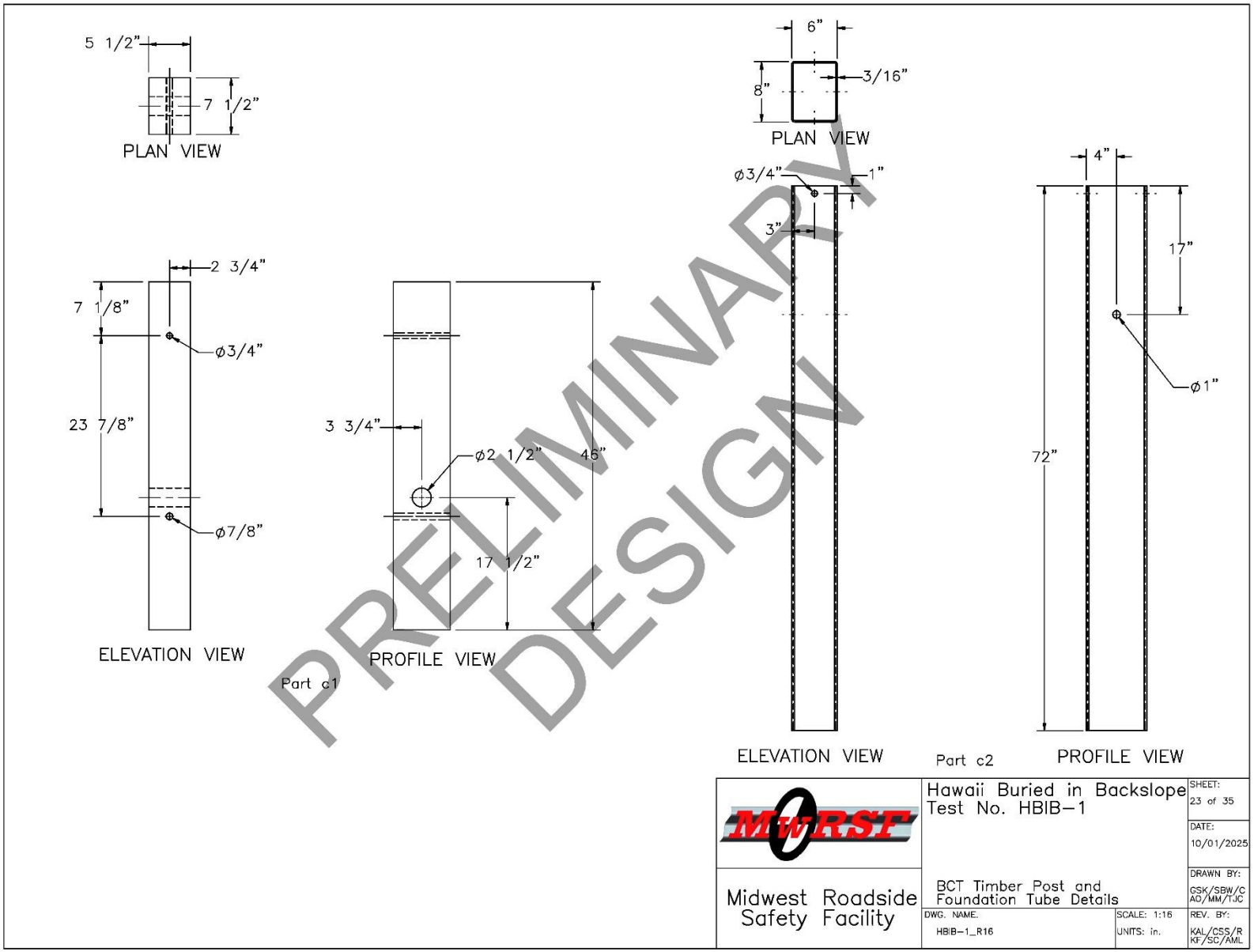


Figure 130. BCT Timber Post and Foundation Tube Details, Test No. HBIB-1

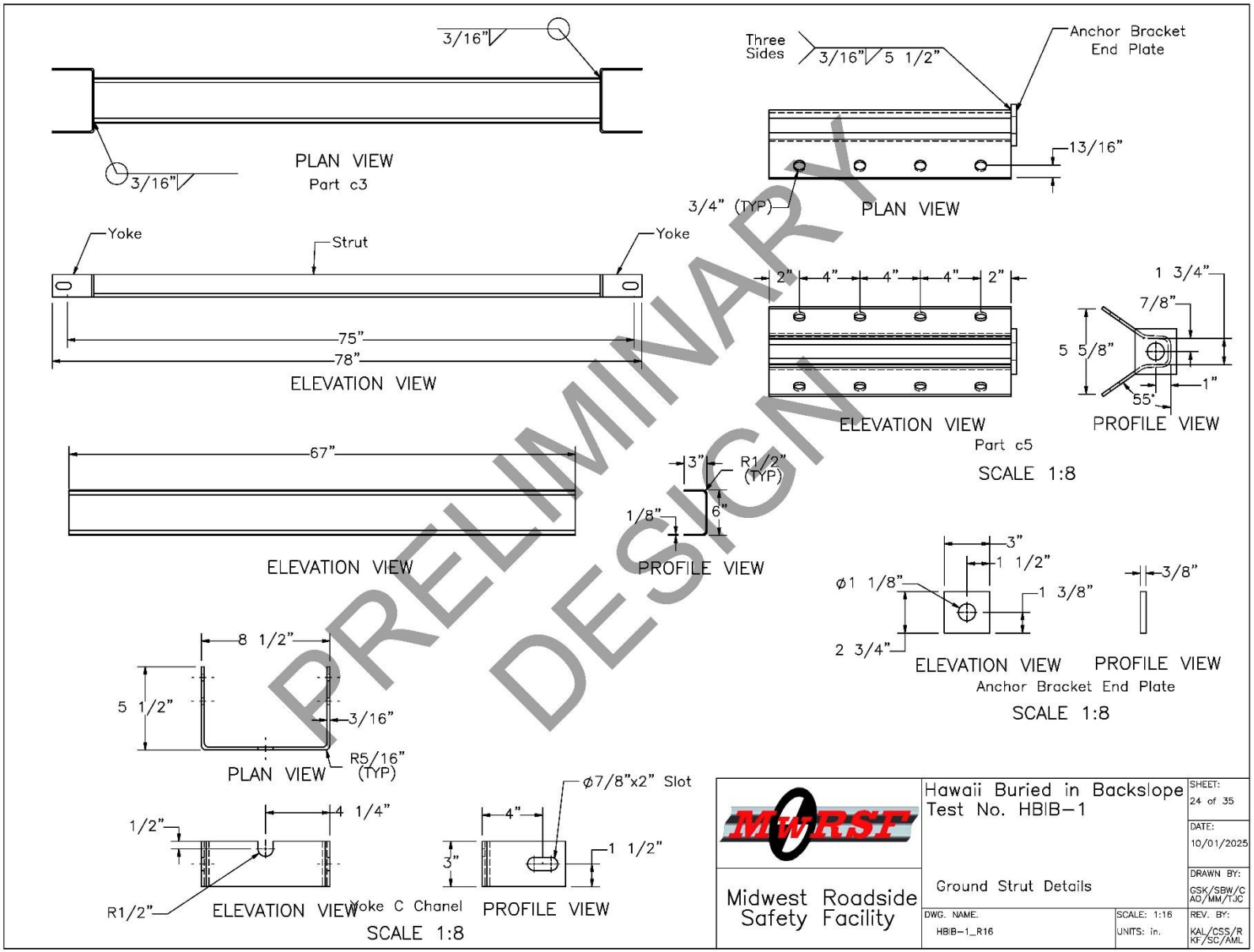


Figure 131. Ground Strut Details, Test No. HBIB-1

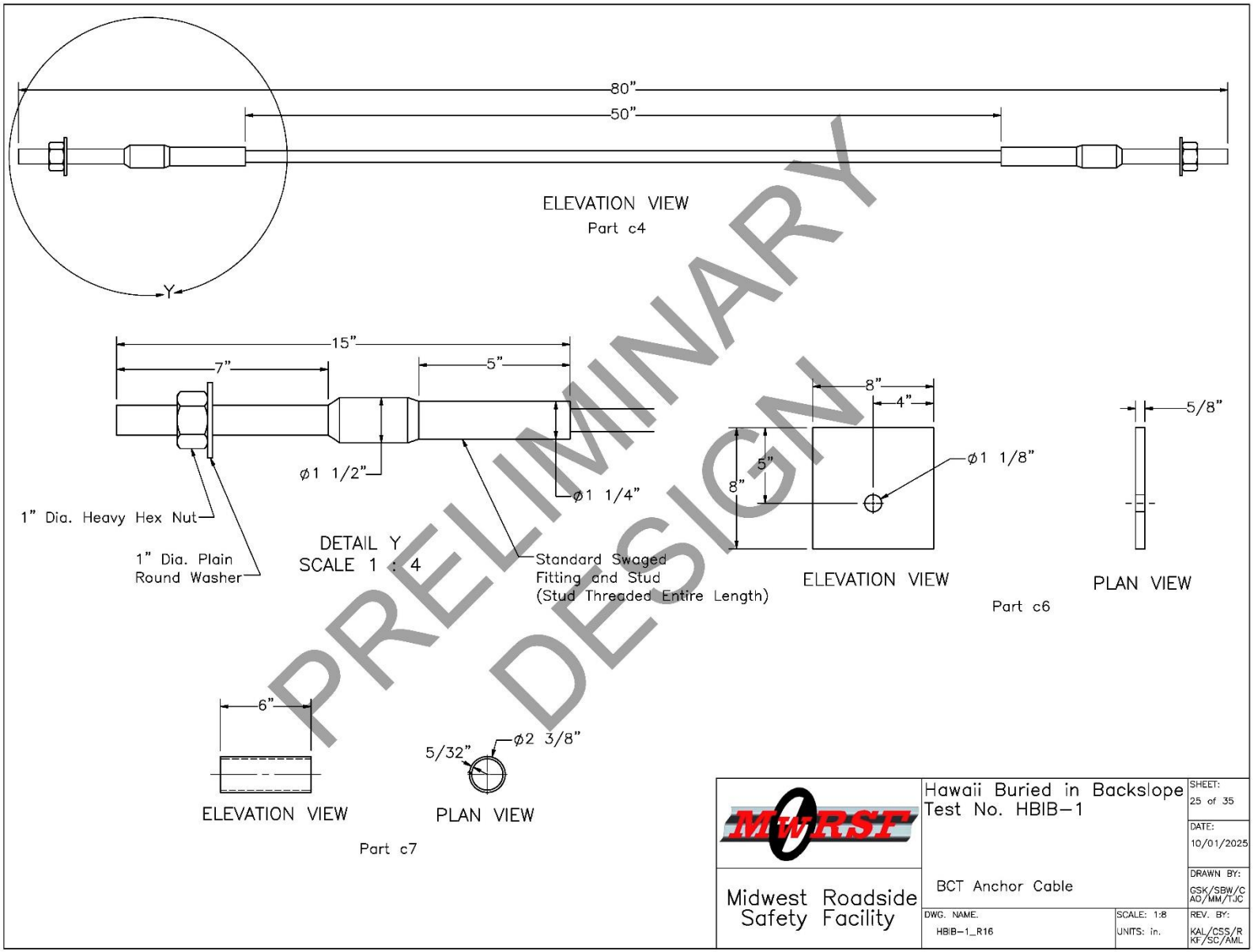


Figure 132. BCT Anchor Cable Details, Test No. HBIB-1

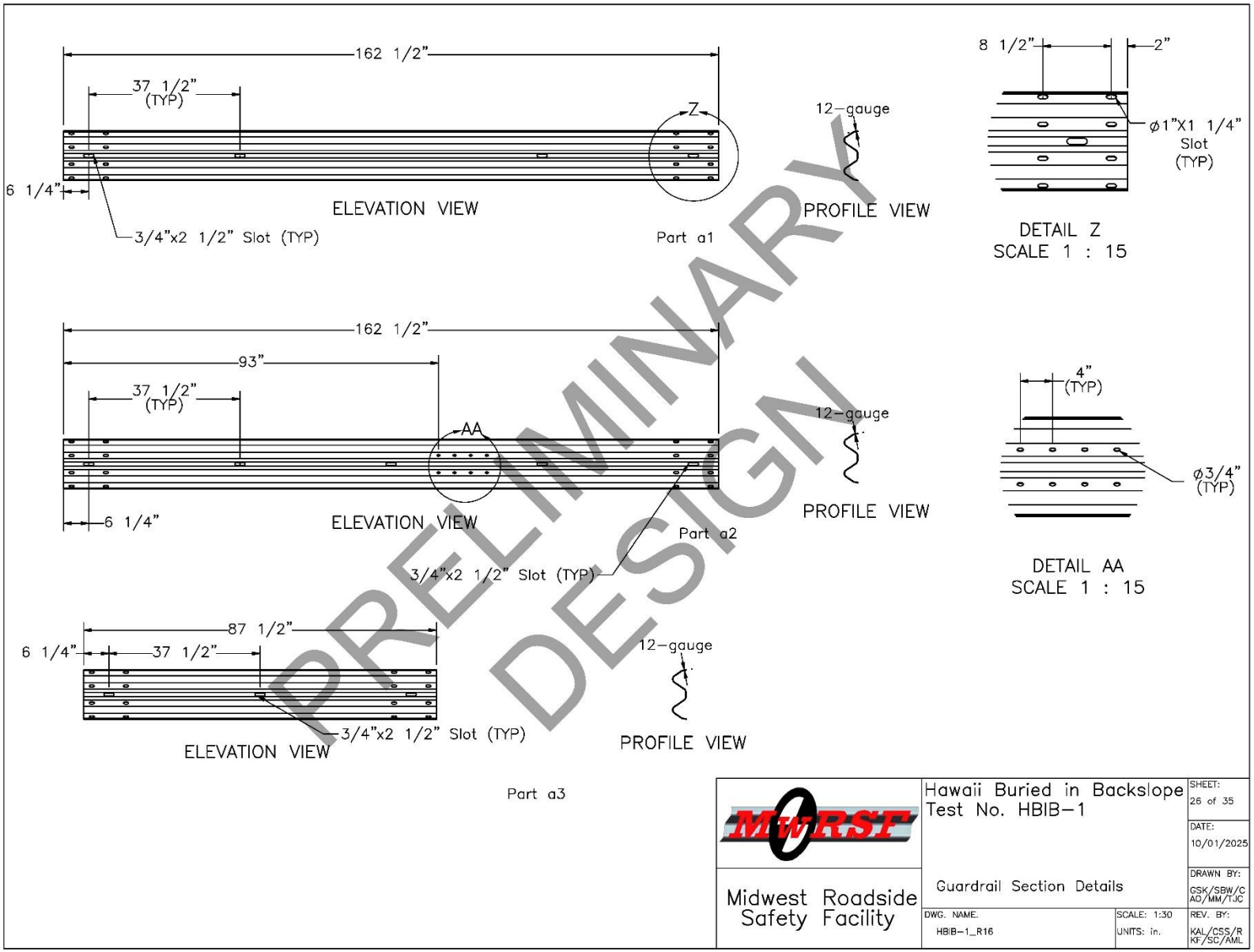


Figure 133. Guardrail Section Details, Page 1, Test No. HBIB-1

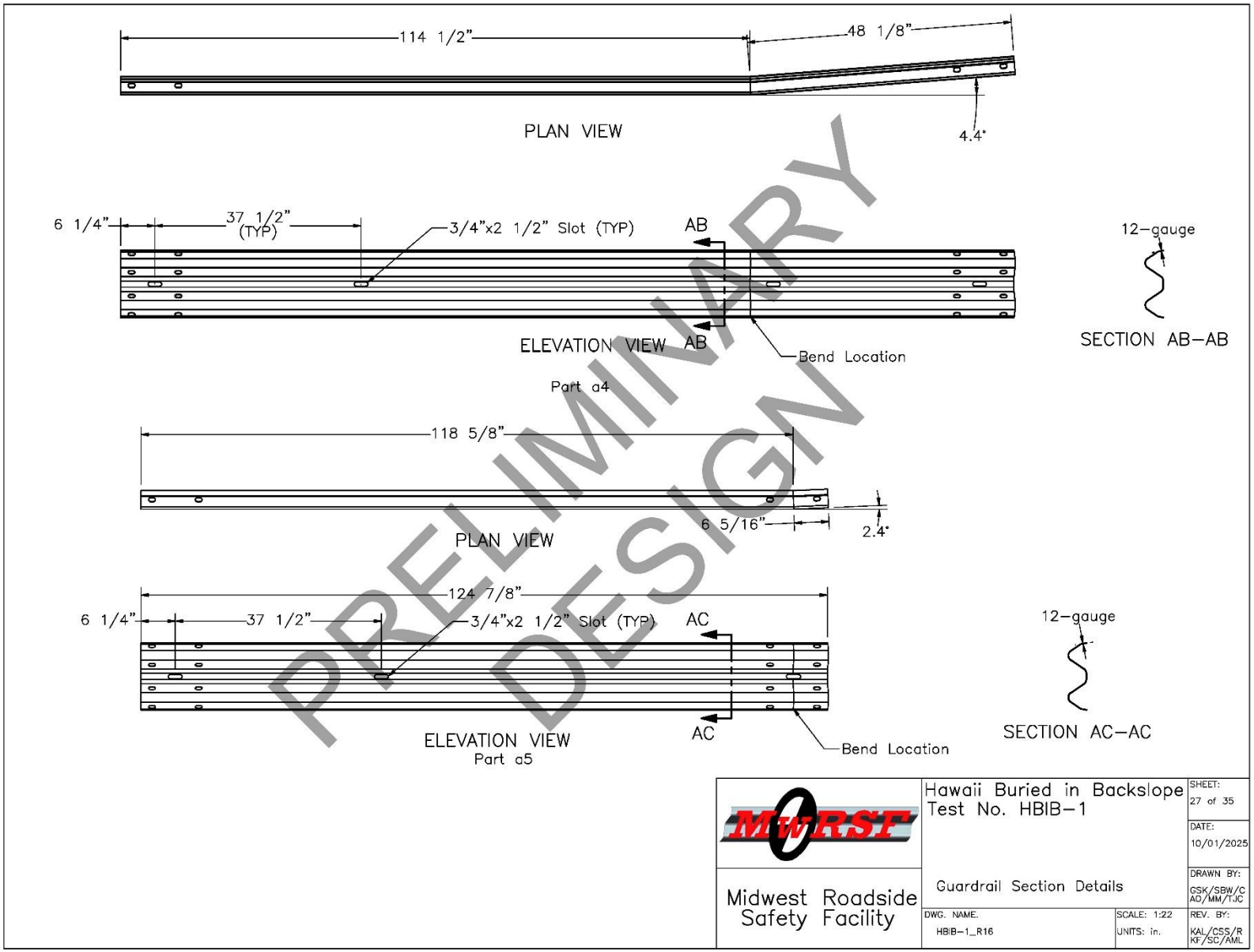


Figure 134. Guardrail Section Details, Page 2, Test No. HBIB-1

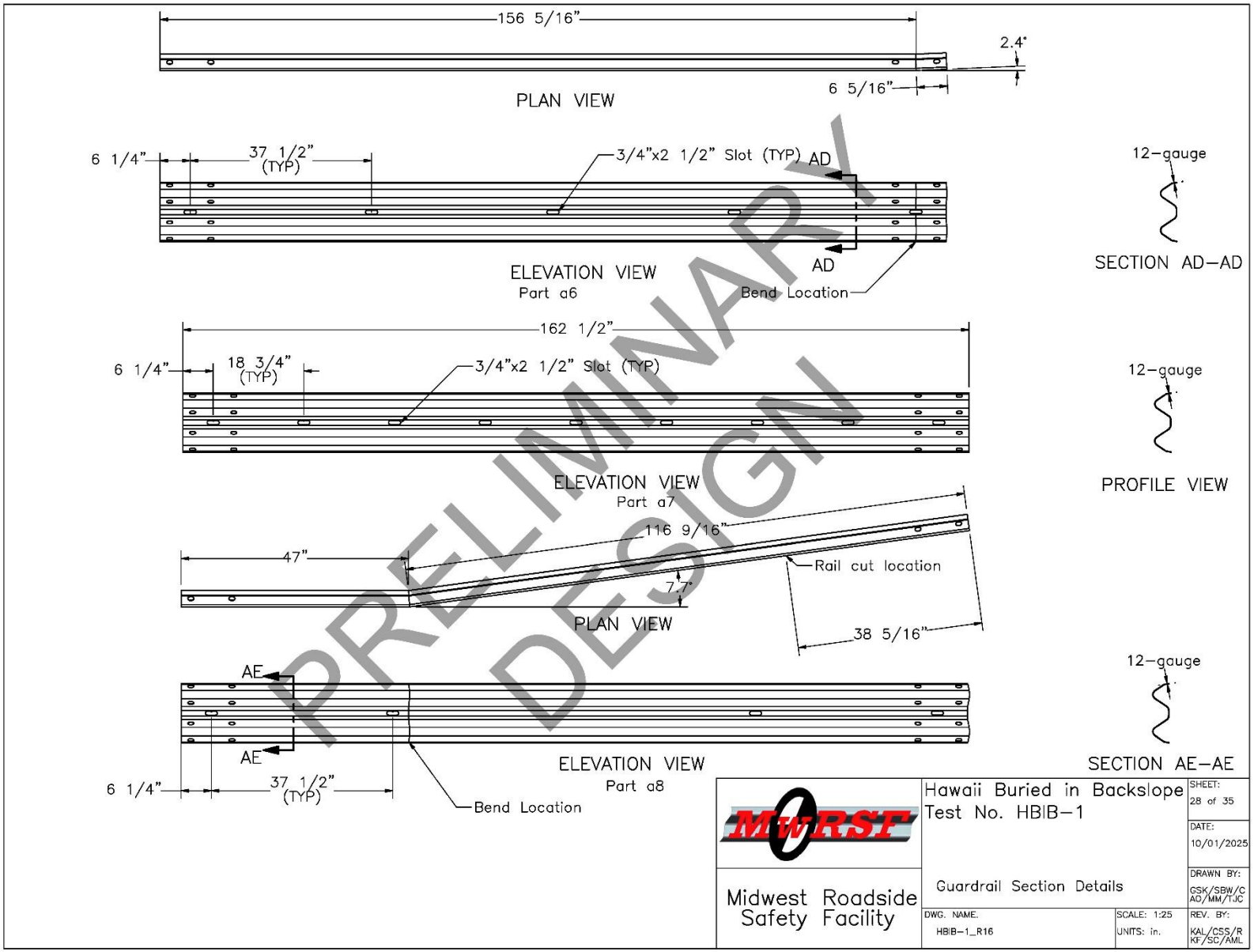


Figure 135. Guardrail Section Details, Page 3, Test No. HBIB-1

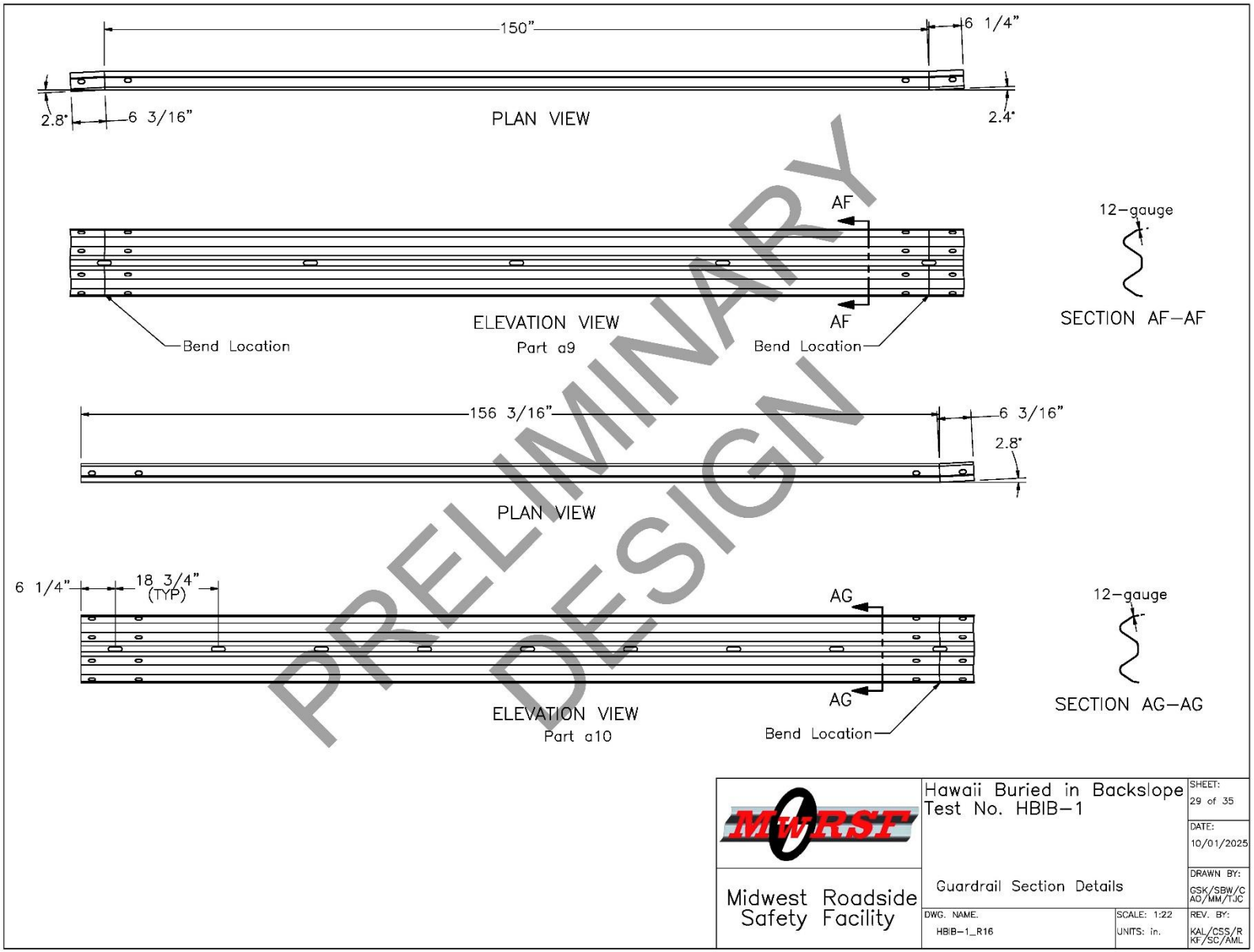


Figure 136. Guardrail Section Details, Page 4, Test No. HBIB-1

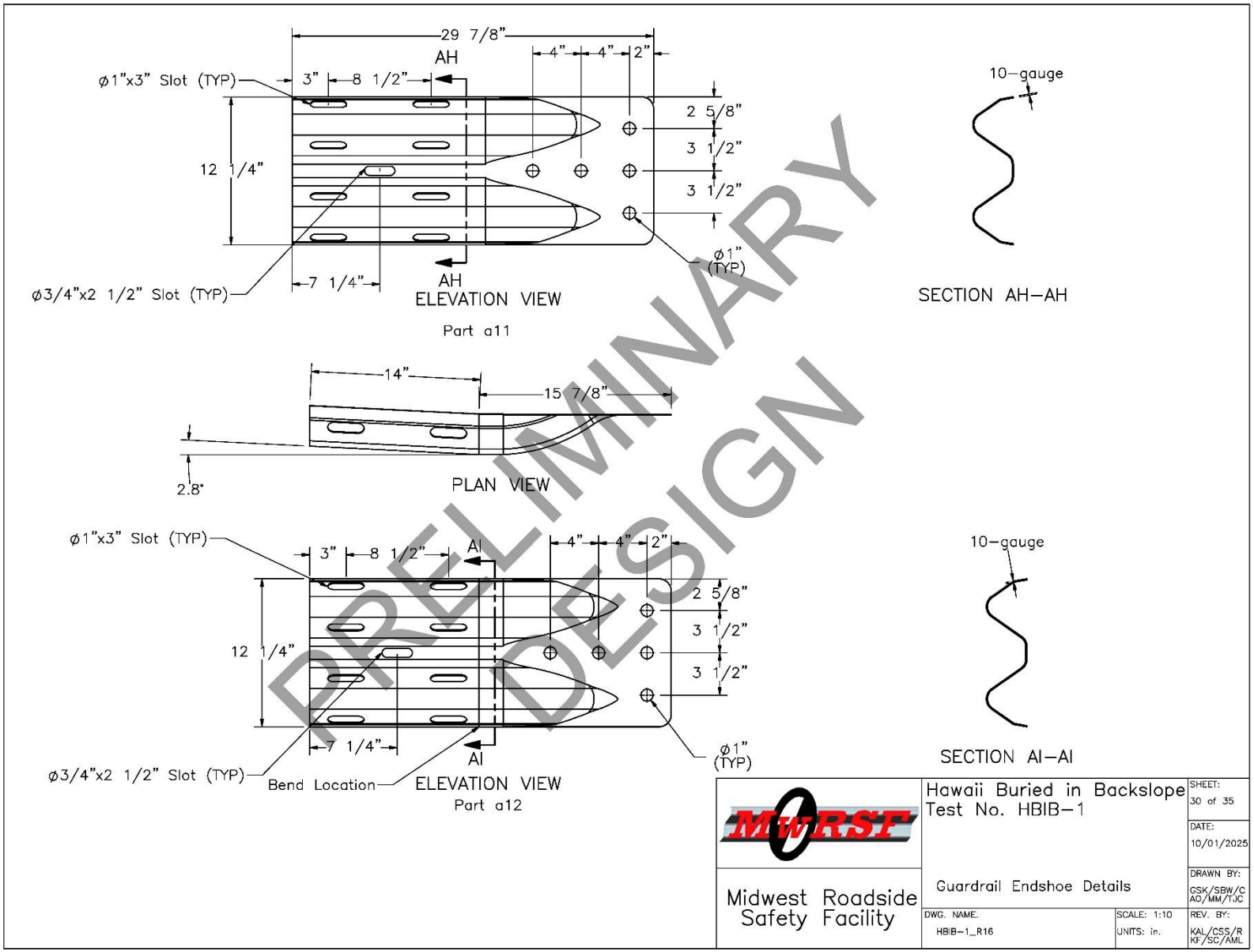


Figure 137. Guardrail End Connector Details, Test No. HBIB-1

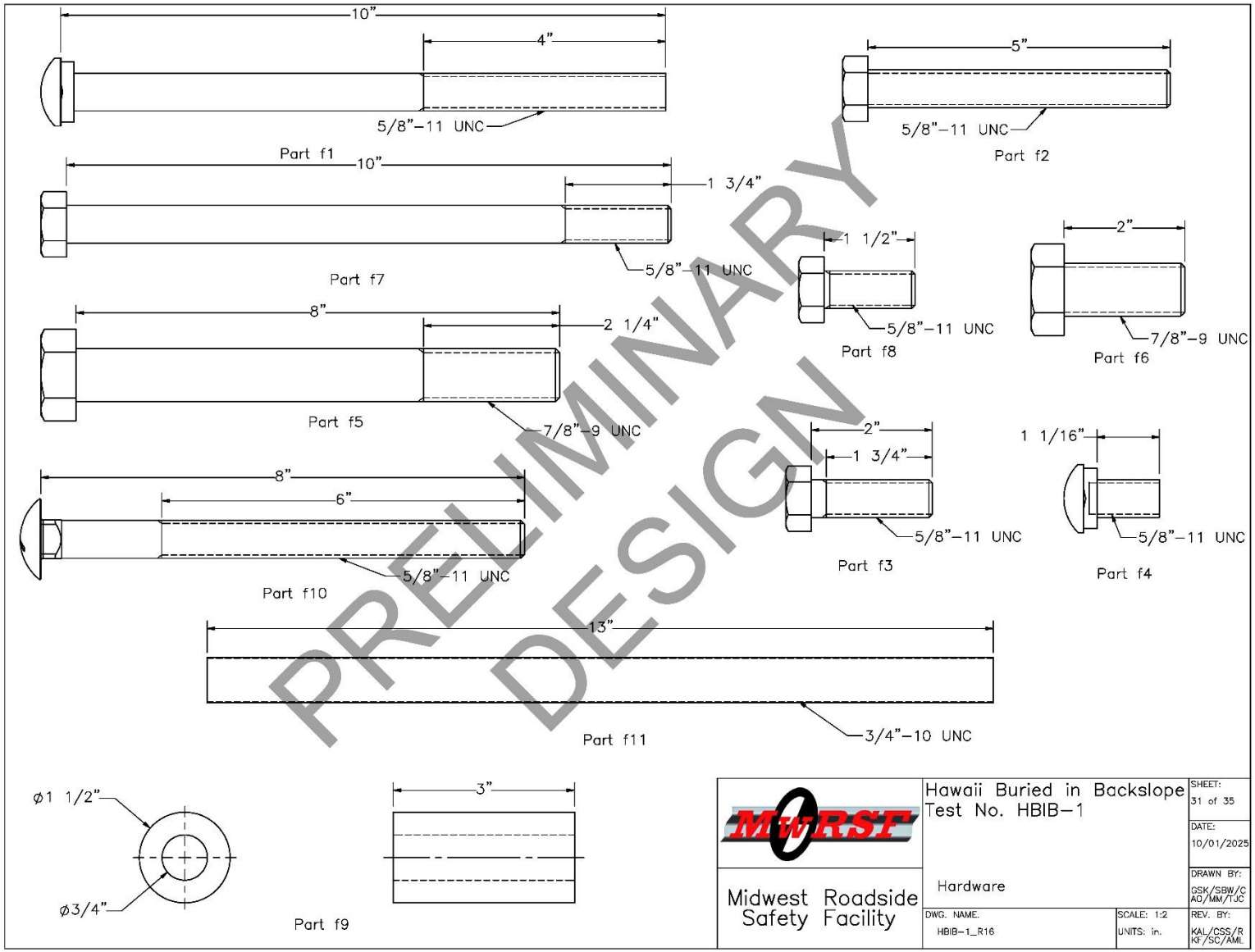


Figure 138. Hardware Details, Page 1, Test No. HBIB-1

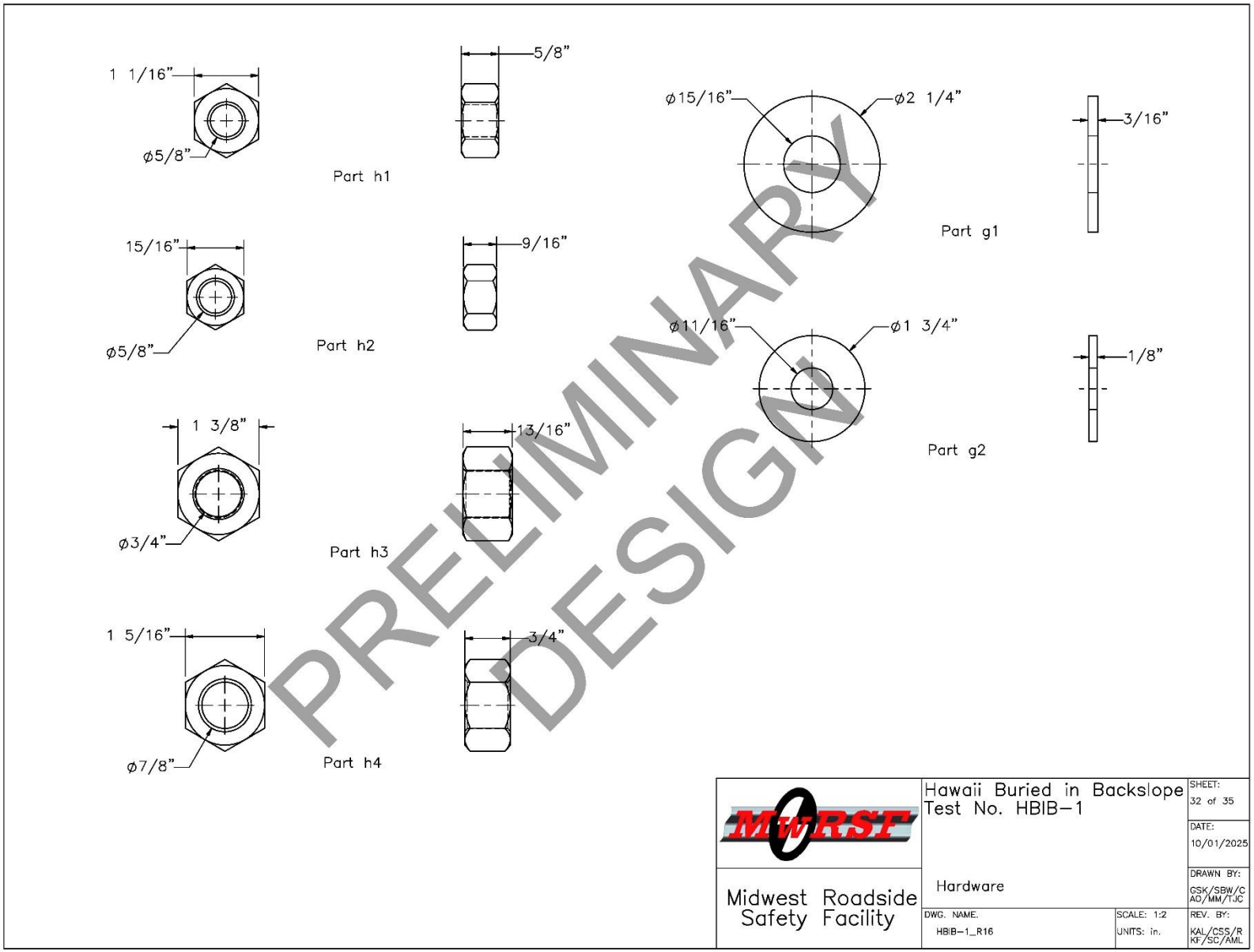


Figure 139. Hardware Details, Page 2, Test No. HBIB-1

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
a1	20	12'–6" 12–gauge W–Beam MGS Section	AASHTO M180	ASTM A123 or A653	RWM04a
a2	1	12'–6" 12–gauge W–Beam MGS End Section	AASHTO M180	ASTM A123 or A653	RWM14a
a3	1	6'–3" 12–Gauge W–Beam Section	AASHTO M180	ASTM A123 or A653	RWM01b
a4	1	12'–6" 12–gauge Bent W–Beam	AASHTO M180	ASTM A123 or A653	–
a5	2	9'–4 1/2" 12–gauge Bent W–Beam	AASHTO M180	ASTM A123 or A653	–
a6	1	12'–6" 12–gauge Bent W–Beam	AASHTO M180	ASTM A123 or A653	–
a7	2	12'–6" W–Beam Section – 1/4 Post Spacing	AASHTO M180	ASTM A123 or A653	RWM04a
a8	1	12'–6" 12–gauge Bent W–Beam	AASHTO M180	ASTM A123 or A653	–
a9	1	12'–6" 12–gauge Bent W–Beam	AASHTO M180	ASTM A123 or A653	–
a10	2	12'–6" 12–gauge Bent W–Beam	AASHTO M180	ASTM A123 or A653	–
a11	1	W–Beam End Shoe Section	AASHTO M180	ASTM A123 or A653	RWE02b
a12	1	W–Beam Bent End Shoe Section	AASHTO M180		RWE02b
b1	1	3'x3'x3' Concrete Block Anchor	Min. f'c = 4,000 psi	–	–
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 Assembly with Heavy Hex Nuts and Washers	Fitting–ASTM A576 Gr.1035 Stud–ASTM F568 Class C Cable, Nut, Washer	Fitting–ASTM A153 Stud–ASTM A153 or B695, Cable, Nut, Washer	FCA01
c5	1	Anchor Bracket Assembly	ASTM A36	ASTM A123	FPA01
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

PRELIMINARY DESIGN

Midwest Roadside Safety Facility

Hawaii Buried in Backslope
Test No. HBIB–1
Bill of Materials

SHEET: 33 of 35
DATE: 10/01/2025
DRAWN BY: GSK/SBW/CAO/MM/TJC
REV. BY: KAL/CSS/RKF/SC/AML
DWG. NAME. HBIB–1_R16
SCALE: 1:768
UNITS: in.

Figure 140. Bill of Materials, Test No. HBIB-1

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
d1	24	W6x8.5 or W6x9, 96" Long Steel Post	ASTM A992 Gr. 50	ASTM A123	PWE06
d2	14	W6x8.5 or W6x9, 72" Long Steel Post	ASTM A992 Gr. 50	ASTM A123	PWE06
d3	3	W6x15, 120" Long Steel Post	ASTM A992 Gr. 50	ASTM A123	–
d4	38	14 3/16"x8"x5 1/8" Composite Recycled Blockout	Mondo Polymer GB14SH2 or equivalent	–	–
d5	1	6x12x14 1/4" Tapered Timber Blockout	SYP Grade No.1 or better		–
d6	1	6x12x14 1/4" Tapered Timber Blockout	SYP Grade No.1 or better		–
d7	1	6x12x14 1/4" Tapered Timber Blockout	SYP Grade No.1 or better		–
d8	1	6x12x14 1/4" Tapered Timber Blockout	SYP Grade No.1 or better		–
d9	2	16D Double Head Nail	–	–	–
e1	3	144 1/2" Unbent Length #4 Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
e2	4	28" Long #4 Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
f1	41	5/8" Dia. UNC, 10" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBB03
f2	2	5/8 Dia. UNC, 5" Long Hex Head Bolt	ASTM A449 Gr. 5 or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f3	23	5/8" Dia. UNC, 2" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f4	240	5/8" Dia. UNC, 1 1/4" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBB01
f5	2	7/8" Dia. UNC, 8" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX22a
f6	8	7/8" Dia. UNC, 2" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX22a
f7	2	5/8" Dia. UNC, 10" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f8	8	5/8" Dia. UNC, 1 1/2" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a

PRELIMINARY DESIGN

Midwest Roadside Safety Facility

Hawaii Buried in Backslope
Test No. HBIB–1

Bill of Materials

SHEET: 34 of 35
DATE: 10/01/2025
DRAWN BY: GSK/SBW/CAO/MM/TJC
REV. BY: KAL/CSS/RKF/SC/AML
DWG. NAME. HBIB–1_R16
SCALE: 1:14
UNITS: in.

Figure 141. Bill of Materials, Continued, Test No. HBIB-1

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
f9	1	3/4 Dia, Unthreaded Spacer Sleeve	ASTM A53 Gr. B	ASTM A123	FMM03-04
f10	3	5/8" Dia, UNC, 8" Long Carriage Bolts	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	–
f11	6	3/4" Dia. UNC, 13" Long Fully Threaded Rod	ASTM A193 Gr. B7	ASTM A153 of B695 Class 55 or F2329	–
g1	4	7/8" Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC20a
g2	22	5/8" Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC16a
h1	309	5/8" Dia. UNC Heavy Hex Nut	ASTM A563A	ASTM A153 (AASHTO M232) for Class C or ASTM B695 (AASHTO M298) for Class 50	FNX16a
h2	10	5/8" Dia. UNC Hex Nut	ASTM A563A	ASTM A153 (AASHTO M232) for Class C or ASTM B695 (AASHTO M298) for Class 50	FNX16a
h3	6	3/4" Dia. UNC Heavy Hex Nut	ASTM A563DH or equivalent	ASMT A153 or B695 Class 55 or F2329	FNX20b
h4	2	7/8" Dia. UNC Hex Nut	ASTM A307A or equivalent	ASTM A153 (AASHTO M232) for Class C or ASTM B695 (AASHTO M298) for Class 50	–
i1	4	3/4" Dia. Wire Strut, 13 3/8" Long Unbent	Min. Tensile Strength = 100,000 psi	AASHTO M111	
i2	4	3/8" Dia. Wire Strut, 16 3/8" Long Unbent	Min. Tensile Strength = 100,000 psi	AASHTO M111	–
i3	2	3/8" Dia. Wire Strut, 18" Long Unbent	Min. Tensile Strength = 100,000 psi	AASHTO M111	–
i4	8	7/8 Dia., Threaded Ferrule	–	–	–
j1	–	Epoxy Adhesive	Min. Bond Strength = 1450 psi	–	–
k1	–	Soil	–	–	–

PRELIMINARY DESIGN

Midwest Roadside Safety Facility

Hawaii Buried in Backslope
Test No. HBIB-1

Bill of Materials

SHEET: 35 of 35
DATE: 10/01/2025
DRAWN BY: GSK/SBW/CAO/MM/TJC
REV. BY: KAL/CSS/RKF/SC/AML
DWG. NAME. HBIB-1_R16
SCALE: 1:14
UNITS: in.

Figure 142. Bill of Materials, Continued, Test No. HBIB-1





Figure 143. Test Installation Photographs, Test No. HBIB-1



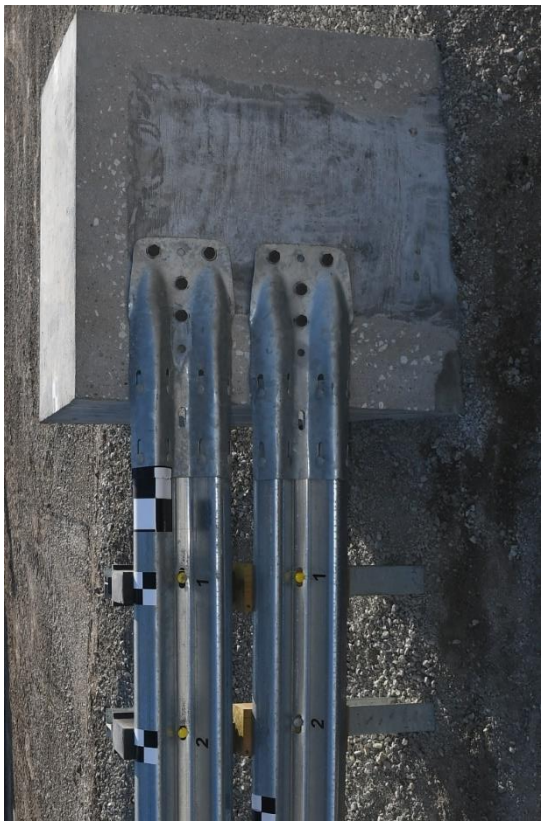
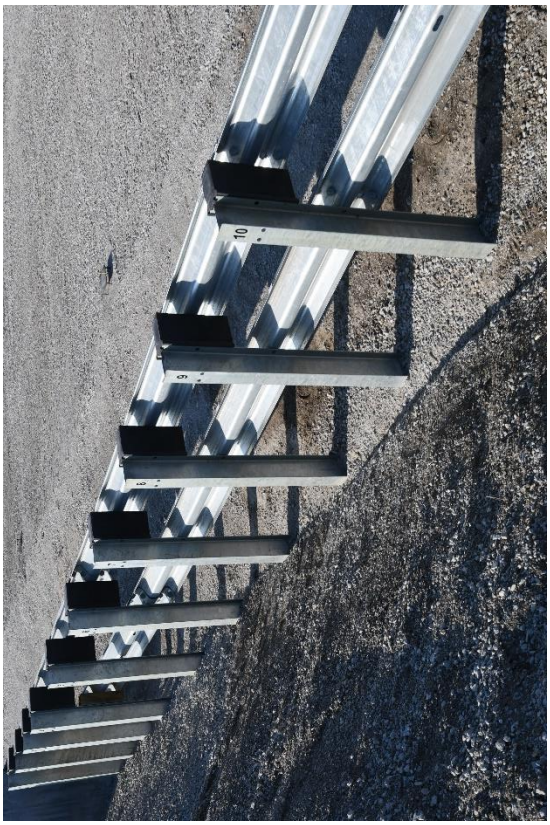






Figure 144. Test Installation Photographs, Test No. HBIB-1







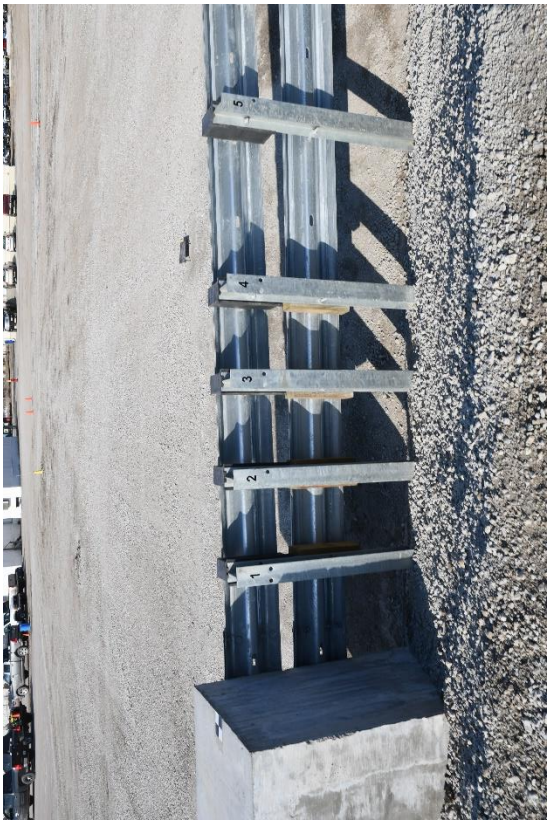


Figure 145. Test Installation Photographs, Test No. HBIB-1

6 FULL-SCALE CRASH TEST NO. HBIB-1

6.1 Static Soil Test

Before full-scale crash test no. HBIB-1 was conducted, the strength of the foundation soil was evaluated with a static test, as described in MASH. The static test results, as shown in Appendix E, 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.

6.2 Weather Conditions

Test no. HBIB-1 was conducted on March 21, 2023, at approximately 2:00 p.m. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/KLNK) were reported and are shown in Table 6.

Table 6. Weather Conditions, Test No. HBIB-1

Temperature	48°F
Humidity	71%
Wind Speed	16 mph
Wind Direction	160° from True North
Sky Conditions	Cloudy
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.00 in.
Previous 7-Day Precipitation	0.71 in.

6.3 Test Description

Initial vehicle impact was to occur 12 in. downstream from the downstream end of the concrete anchor block, as shown in Figure 146, which was selected using the recommended TL-3 test matrix in section 2-3 of MASH. For the non-gating, re-directive HBIB system, the critical impact angle and velocity were selected to maximize the lateral load on the system, the risk that the test vehicle would gate through the system, and the occupant risk measures.

MASH Section 5.3 provides guidance for addressing geometric features. As the system tested in current research efforts included a ditch in front of the guardrail system for all of the evaluated impacts, criteria provided in MASH are outlined below and were addressed accordingly:

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

E: Compute average accelerations in the longitudinal and lateral directions for each consecutive 50-ms period for the duration of the event.

F: If the average longitudinal or lateral acceleration computed in Step b exceeds 2 g's during any 50-ms period, calculate the OIV and RA values at the beginning of the period over which the average acceleration was computed, and evaluate the results according to Criteria H and I of Table 5-l B.

The average acceleration of the vehicle did not exceed 2 g's until the point of impact with the system, therefore t* determination began at the time the vehicle impacted the system. Note that "t*" refers to the time at which a theoretical occupant located in the occupant compartment would impact either the front or side of the vehicle based on a presumed longitudinal and lateral offset. In test no. HBIB-1, a 2,411-lb small car impacted the slope of the HBIB system at a speed of 61.7 mph and at an angle of 15.0 degrees. The actual point of impact was 12.3 in. downstream from the downstream end of the concrete block. During the test, the test vehicle followed the trajectory of the ditch and the wheels remained engaged with the ground. The vehicle decelerated rapidly and experienced minimal yaw prior to redirecting out of the system, coming to rest at the top of the ditch slope after brakes were applied, 100 ft – 7.2 in. downstream and 10.8 in. laterally behind the initial point of impact.

A detailed description of the sequential impact events is contained in Table 7. Sequential photographs are shown in Figure 147 and documentary photographs of the crash test are shown in Figure 148. The vehicle trajectory and final position are shown in Figure 149.

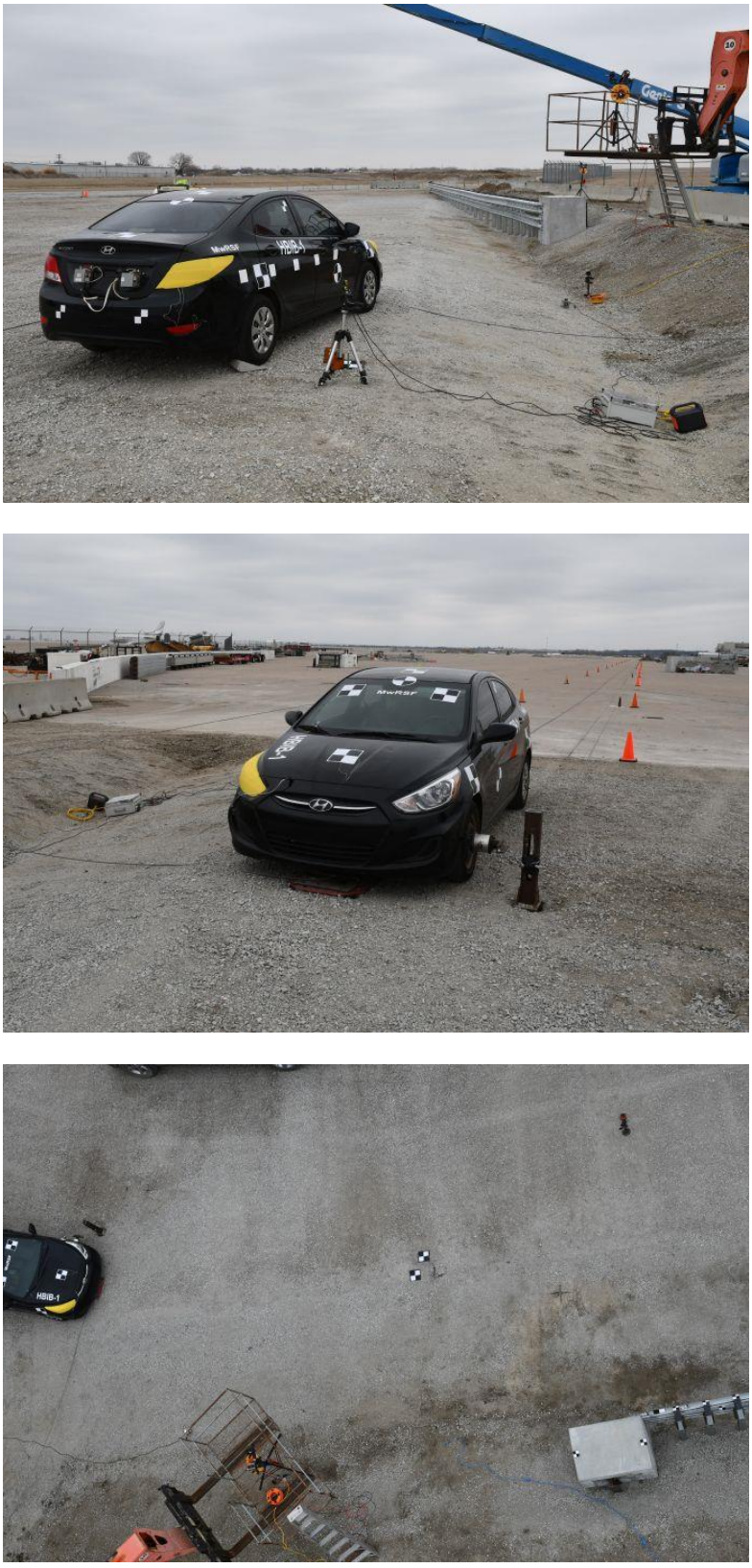


Figure 146. Impact Location, Test No. HBIB-1

Table 7. Sequential Description of Impact Events, Test No. HBIB-1

Time (sec)	Event
-0.532	Vehicle's right-front tire crossed slope break point.
-0.398	Vehicle's right-front tire became airborne.
-0.354	Vehicle pitched downward.
-0.206	Vehicle's right-front tire contacted ground.
-0.156	Vehicle's left-front tire became airborne.
0.000	Vehicle's front bumper contacted barrier and detached. Vehicle's right headlight and right door mirror contacted barrier and shattered. Vehicle rolled away from barrier and pitched downward.
0.012	Post nos. 1, 2, 3, and 4 rotated backward. Vehicle's right a-pillar contacted barrier and crushed. Windshield cracked.
0.016	Vehicle's right-front door contacted barrier and deformed. Vehicle's left fender and roof deformed.
0.030	Vehicle yawed away from barrier. Post no. 5 rotated backward. Post nos.3 and 4 twisted counterclockwise.
0.044	Vehicle's right-front tire contacted barrier, deflated, and was pushed backward into wheel well. Vehicle's left headlight disengaged.
0.058	Occupant head contacted vehicle's right-front door window, which shattered.
0.078	Post no. 5 twisted clockwise.
0.089	Vehicle's left-front tire deflated.
0.140	Post no. 5 rotated downstream. Blockout at post no. 5 disengaged from rail and post.
0.148	Vehicle's right-rear door contacted barrier and deformed.
0.182	Post no. 6 twisted counterclockwise.
0.188	Post no. 6 twisted clockwise.
0.238	Post no. 6 rotated downstream.
0.270	Vehicle exited system at a speed of 29.4 mph and an angle of 12.3 degrees.
0.340	Vehicle yawed toward barrier.
0.816	Vehicle yawed away from barrier.
2.350	Vehicle came to rest.


0.000 sec


-0.532 sec


0.100 sec


0.000 sec


0.200 sec


0.100 sec


0.300 sec


0.200 sec


0.400 sec


0.300 sec


0.500 sec


0.400 sec

Figure 147. Sequential Photographs, Test No. HBIB-1



Figure 148. Documentary Photographs, Test No. HBIB-1



Figure 149. Vehicle Final Position and Trajectory Marks, Test No. HBIB-1

6.4 Barrier Damage

Damage to the barrier was minimal, as shown in Figures 150 and 151. No contact with the upstream concrete anchor block was observed during the impact. System damage consisted of contact marks and kinks on both the upper rail and rubrail, and post damage and detachment. The total length of the vehicle's primary contact with the rail was approximately 13 ft – 11 in. beginning 52 in. downstream from the upstream edge of the concrete block and extending to approximately the center of post no. 7.

Contact marks on the upper rail, including kinks and marks, began at the centerline of post no. 1 and continued downstream to post no. 6. Damage to the upper rail was minor. Kinks ½-in. deep were found on the upper rail 3 in. and 18 in. upstream from the centerline of post no. 3. Kinks ⅛ in. deep were found at the center of post no. 4 and 26 in. upstream from the centerline of post no. 1. A ¼-in. deep kink occurred 25½ in. upstream from post no. 1. A bend began in the upper rail located 13½ in. upstream from the centerline of post no. 1.

Due to the vehicle's bumper and right-front door contacting the rubrail and posts, the post attachment components were damaged, including bolts and nuts. Post no. 5 detached from the rail and bent backward and downstream. Blockouts from post nos. 4 and 5 disengaged from the rail and their respective posts. Bolt hole deformation occurred at the top and bottom bolt holes of post nos. 3 through 5. On post nos. 3 through 6, clockwise rotations and twisting occurred due to the right-front wheel contacting the posts.



Figure 150. System Damage, Test No. HBIB-1



Figure 151. Posts and Blockout Damage, Test No. HBIB-1

The maximum lateral permanent set of the system was 0.7 in., which occurred in post no. 5, as measured in the field. The maximum lateral dynamic barrier deflection was 6.2 in. at post no. 5, as determined from high-speed digital video analysis. The working width of the system was found to be 23.1 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 152.

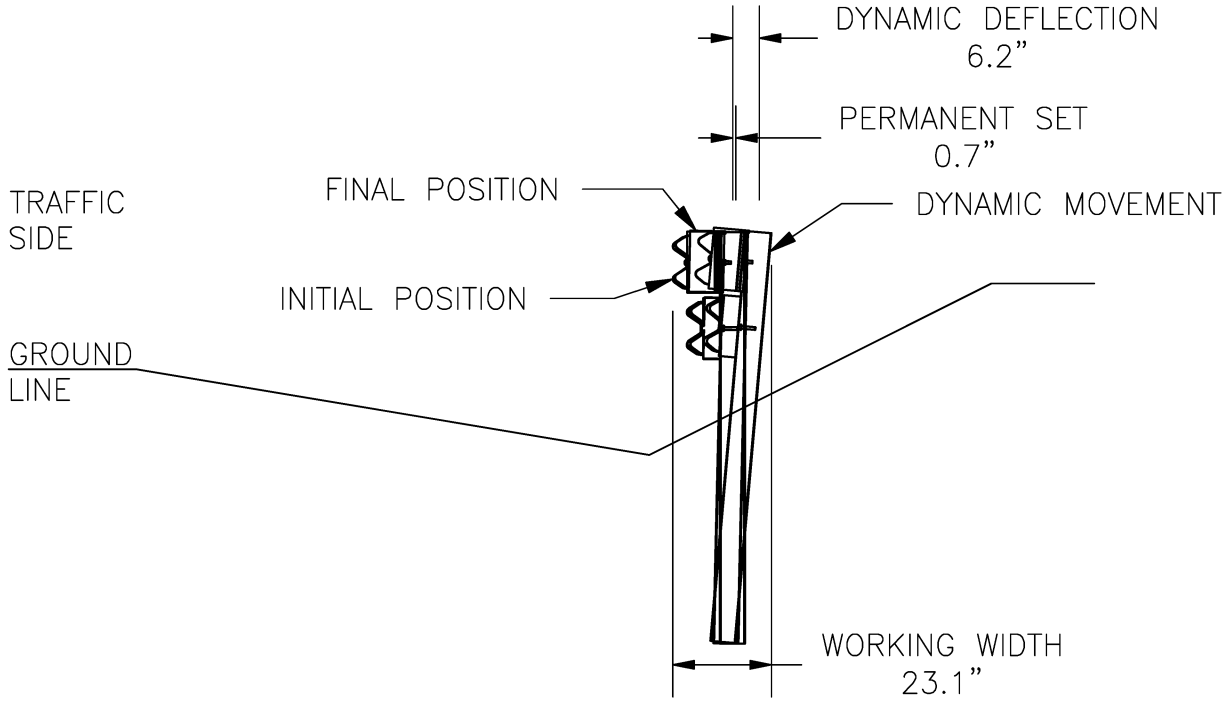


Figure 152. Permanent Set Deflection, Dynamic Deflection, and Working Width, Test No. HBIB-1

6.5 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 153 through 155. Note, the impact side of the vehicle, or the passenger's side, is referred to as the vehicle's right side. The non-impact side, or driver's side, is referred to as the vehicle's left side.

Majority of the damage was concentrated on the right-front corner and right side of the vehicle where the impact occurred. The right side of the vehicle's hood was severely crushed on the right side, wrinkling and shifting the hood. The front bumper cover was detached from the vehicle, and the right-front fender was severely crushed, ripped, and partially disengaged. The right-front tire of the vehicle was pushed back into the wheel opening after snagging on post nos. 3 through 6.

The front windshield was cracked, deformed, and torn near the hood, and the right-front window was shattered. Windshield deformation was due to the excessive deformation in the right A-pillar and the right-front window was shattered due to contact with the surrogate occupant's head. The roof of the vehicle had a large dent along the back half, likely due to A-pillar deformation.

Undercarriage damage was moderate. The right control arm was severely bent rearward and broke away from the cross member. The right spring and shock were severely bent and crushed rearward and outward. The left-front lower control arm twisted toward the left side, but both front lower control arms remained attached to the vehicle frame. The right end link was stressed, and the CV shaft was detached from the steering knuckle. The right-side outer tie rod was bent, and the front cross member was bent and crushed inward. The brake caliper disengaged, and the brake line became detached on the right side.

The maximum occupant compartment intrusions are listed in Table 8, along with the intrusion limits established in MASH for various areas of the occupant compartment. Complete occupant compartment, vehicle intrusions, and the corresponding locations of the deformations are provided in Appendix F. MASH defines intrusion as the occupant compartment being deformed and reduced in size with no penetration. Outward deformations, which are denoted as negative numbers in Appendix F, are not considered as crush toward the occupant, and are not subject to evaluation by MASH criteria. It should be noted that only one reference set was used to measure the occupant compartment intrusions due to the shifting of the second reference set during testing. As seen in Table 8, the lateral deformation of the A-pillar exceeded MASH limits, resulting in test failure. The maximum A-pillar deformation was 4.7 in., which is marginally acceptable based on the MASH A-pillar deformation maximum of 5 in.







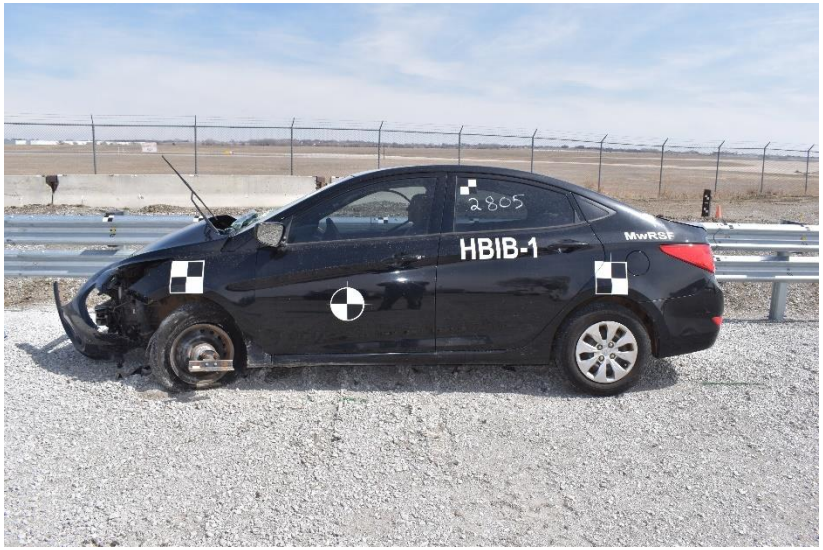
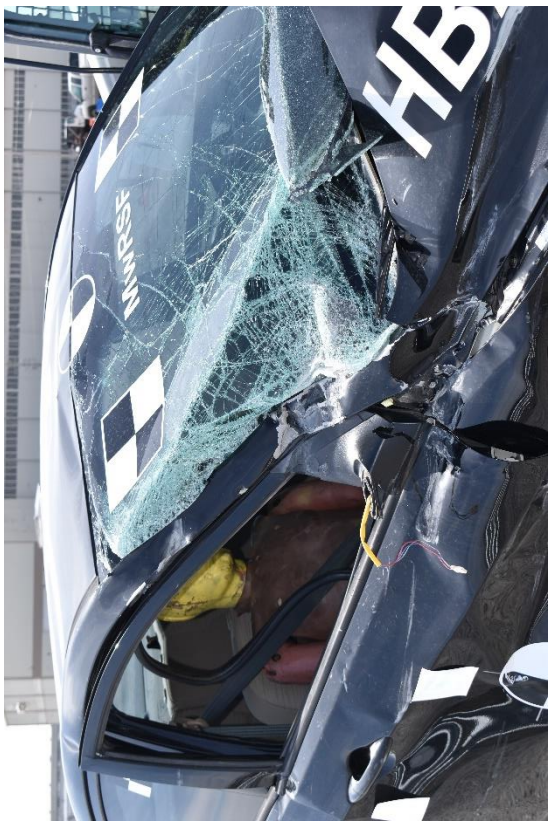
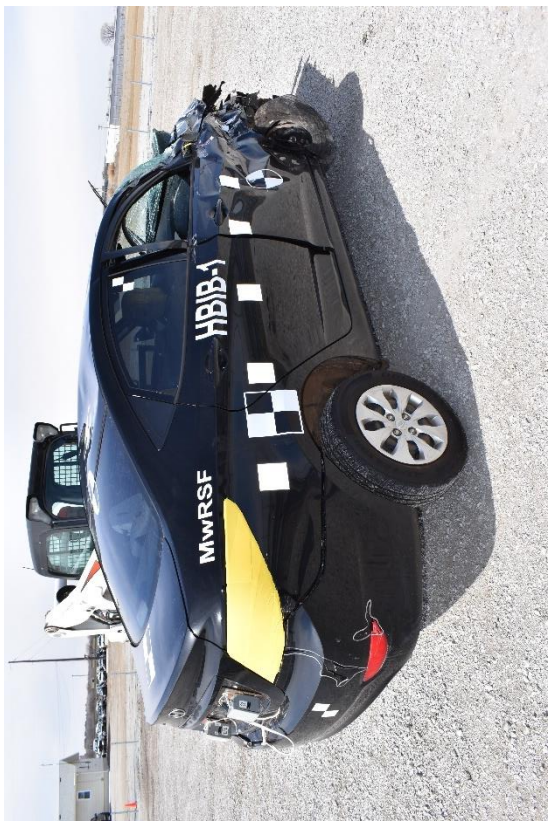


Figure 153. Vehicle Damage, Test No. HBIB-1





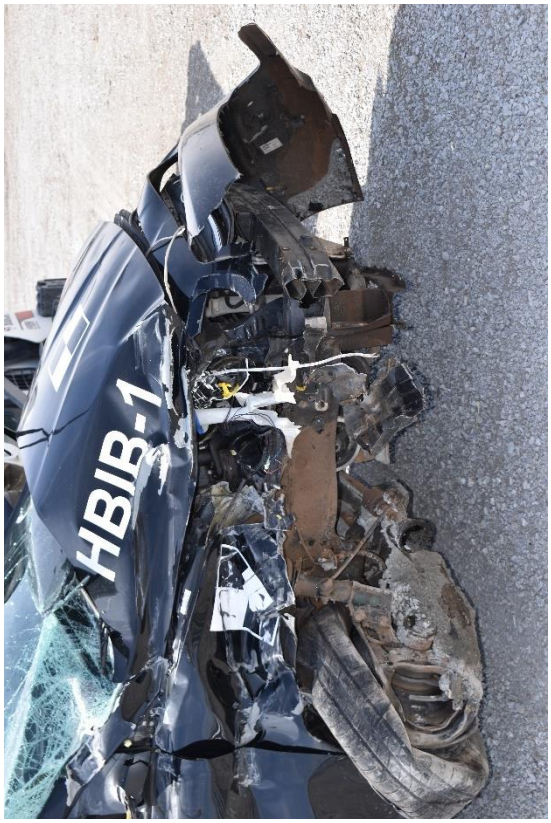




Figure 154. Vehicle Damage, Test No. HBIB-1



Figure 155. Vehicle Interior and Undercarriage Damage, Test No. HBIB-1

Table 8. Maximum Occupant Compartment Intrusion by Location, Test No. HBIB-1

Location	Maximum Intrusion in.	MASH Allowable Intrusion in.
Wheel Well & Toe Pan	1.2	≤ 9
Floor Pan & Transmission Tunnel	0.0*	≤ 12
A-Pillar	4.7	≤ 5
A-Pillar (Lateral)	4.2	≤ 3
B-Pillar	0.8	≤ 5
B-Pillar (Lateral)	0.0*	≤ 3
Side Front Panel (in Front of A-Pillar)	1.7	≤ 12
Side Door (Above Seat)	2.3	≤ 9
Side Door (Below Seat)	0.3	≤ 12
Roof	1.7	≤ 4
Windshield	0.0	≤ 3
Side Window	Shattered due to contact with surrogate occupant's head	No shattering resulting from contact with structural member of test article
Dash	2.4	N/A

N/A – Not applicable
*Negative value reported as 0.0. See Appendix F for further information.

6.6 Occupant Risk

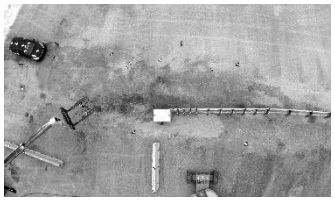
The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined by accelerometer data, are shown in Table 9. Note that the OIVs and ORAs were within suggested limits, as provided in MASH, except for the ORA in the longitudinal direction, which exceeded the MASH limits, resulting in test failure. The calculated THIV, PHD, and ASI values are also shown in Table 9. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix G.

Table 9. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. HBIB-1

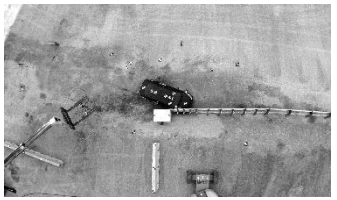
Evaluation Criteria		Transducer		MASH Limits
		SLICE-1 (primary)	SLICE-2 (backup)	
OIV ft/s	Longitudinal	-20.95	-22.68	±40
	Lateral	-25.59	-24.60	±40
ORA g's	Longitudinal	-27.56	-27.33	±20.49
	Lateral	12.45	-16.66	±20.49
Maximum Angular Displacement deg.	Roll	18.3	19.7	±75
	Pitch	-7.6	-5.9	±75
	Yaw	-17.7	-19.5	not required
THIV ft/s		32.67	27.80	not required
PHD g's		27.52	28.01	not required
ASI		1.77	1.75	not required

6.7 Discussion

Analysis of the test results for test no. HBIB-1 showed that the 1100C vehicle impact with the system resulted in test failure. A summary of the test results and sequential photographs are shown in Figure 156. Due to the severity of the impact to the top rail, the lateral deformation of the A-pillar measured 4.2 in., which exceeded the MASH safety limits of 3.0 in. 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 longitudinal ORA values exceeded the MASH limitations of ±20.49 g's. The test vehicle did not penetrate nor override the barrier and remained upright during and after the collision. The right-front wheel snagged on posts nos. 3 through 6. Vehicle roll, pitch, and yaw angular displacements were deemed acceptable as they did not adversely influence occupant risk nor cause rollover. After impact, the vehicle exited the barrier at an angle of 12.3 degrees, and its trajectory did not violate the bounds of the exit box. Therefore, test no. HBIB-1 was determined to be unsuccessful according to MASH safety performance criteria for test designation no. 3-32.



-0.532 sec



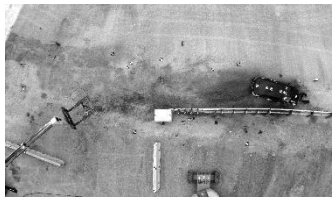
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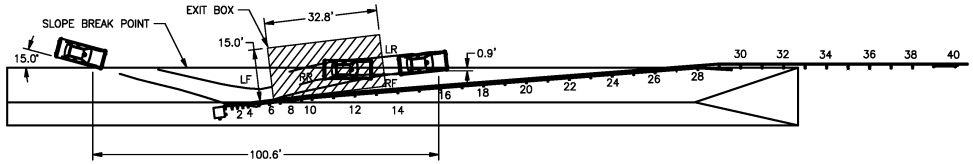
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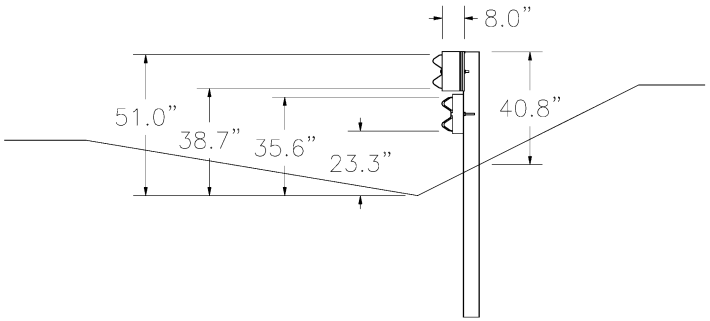


0.400 sec



0.600 sec





- Test Agency ..... MwRSF
- Test Number HBIB-1
- Date 3/21/2023
- MASH Test Designation No. 3-32
- Test Article ..... HDOT Buried in Backslope
- Total Length ..... 219 ft – 3⅞ in.
- Key Component – Steel W-beam Guardrail
  - Thickness ..... 12 gauge
  - Top Mounting Height ..... 32 in.
- Key Component – Steel Post
  - Shape W6x8.5
  - Length ..... 96 in.
  - Embedment Depth ..... 64 in.
  - Spacing ..... 75 in.
- Key Component – Composite Recycled Blockout (Post Nos. 1-38)
  - Shape ..... $14^{3}/_{16}$ x 8 x 5⅛ in.
- Soil Type ..... Coarse, Crushed Limestone (Well-Graded Gravel)
- Vehicle Make / Model ..... 2017 Hyundai Accent
  - Curb ..... 2,459 lb
  - Test Inertial ..... 2,411 lb (MASH limit 2,420 ± 55 lb)
  - Gross Static ..... 2,569 lb (MASH limit 2,585 ± 55 lb)
- Impact Conditions
  - Speed ..... 61.7 mph (MASH limit 62 ± 2.5 mph)
  - Angle ..... 15.0 deg. (MASH limit 15 ± 1.5 deg.)
  - Impact Location ..... 12.3 in. downstream from concrete anchor's downstream edge
- Impact Kinetic Energy ..... 305.4 kip-ft ≥ 288 kip-ft minimum from MASH
- Exit Conditions
  - Speed ..... 29.4 mph
  - Angle ..... 12.3 deg.
- Vehicle Stability ..... Satisfactory
- Vehicle Stopping Distance ..... 100.6 ft downstream from impact, 0.9 ft laterally behind slope break point
- Exit Box Criterion ..... Pass
- Vehicle Damage ..... Moderate
  - VDS [21] 1-RFQ-5
  - CDC [22] 01-FDEW-9
  - Maximum Interior Deformation ... 4.7 in. at A-pillar (maximum) ≥ 5 in. MASH limit
- Test Article Damage ..... Minimal
- Maximum Test Article Deflections
  - Permanent Set ..... 0.7 in.
  - Dynamic ..... 6.2 in.
- Transducer Data

Evaluation Criteria		Transducer		MASH Limit
		SLICE-1 (primary)	SLICE-2	
OIV ft/s	Longitudinal	-20.95	-22.68	±40
	Lateral	-25.59	-24.60	±40
ORA g's	Longitudinal	-27.56	-27.33	±20.49
	Lateral	12.45	-16.66	±20.49
Maximum Angular Displacement deg.	Roll	18.3	19.7	±75
	Pitch	-7.6	-5.9	±75
	Yaw	-17.7	-19.5	not required
THIV – ft/s		32.67	27.80	not required
PHD – g's		27.52	28.01	not required
ASI		1.77	1.75	not required

Figure 156. Summary of Test Results and Sequential Photographs, Test No. HBIB-1

7 DESIGN MODIFICATIONS

7.1 Introduction

After the failure of test no. HBIB-1, the system was modified to improve its crashworthiness. Two primary factors led to the failure of test no. HBIB-1, one of which was the right-front wheel snagging on post nos. 3 through 6. The gap between the terrain and the rubrail's lower corrugation allowed the test vehicle's right-front wheel to contact the front flange of post nos. 3 through 6, resulting in the vehicle underriding the rubrail. The snag on the posts' flanges caused the Occupant Ridedown Acceleration (ORA) limit to exceed MASH TL-3 safety criteria. The second reason the test failed was excessive deformation of the vehicle's right A-pillar caused by direct contact between the A-pillar and the lower corrugation of the upper W-beam.

It was observed that the potential for A-pillar crush and wheel extension beneath the rubrail would both be reduced by decreasing the system height. However, decreasing the system height in the ditch could lead to challenging capture for vehicles entering the ditch at increased departure angles; this test condition is evaluated for MASH test designations 3-33 and 3-35, which involves a 2270P pickup truck impacting the system at a 25-degree angle.

The research team investigated the potential optimization opportunities for rail configurations in the ditch that could result in acceptable vehicle capture and redirection for test conditions 3-32, 3-33, 3-34, and 3-35. The following sections discuss the system modifications in detail.

7.2 System Height Determination

The optimized height of the HBIB system would be sufficiently tall to capture the 2270P impacting at 25 degrees near the anchor as well as the small car impacting at 15 degrees near the anchor. Researchers investigated critical zones of both the 1100C and 2270P vehicles and the estimated heights of the bumper and A-pillar for both angular impact conditions.

In previous research conducted by MwRSF, LS-DYNA simulations were developed to model the 2270P vehicle's bumper trajectories and vehicle kinematics in different configurations of ditch widths and slopes [16]. The ditch utilized in this study had a 6H:1V foreslope and a 2H:1V backslope, but for the majority of the vehicle's trajectory, was similar to a vehicle entering a 6:1 V-ditch. Thus, researchers reviewed and extracted the trajectory of the 2270P vehicle entering a 6H:1V ditch and overlaid the trajectory on the ditch profile, as shown in Figure 157 [16].

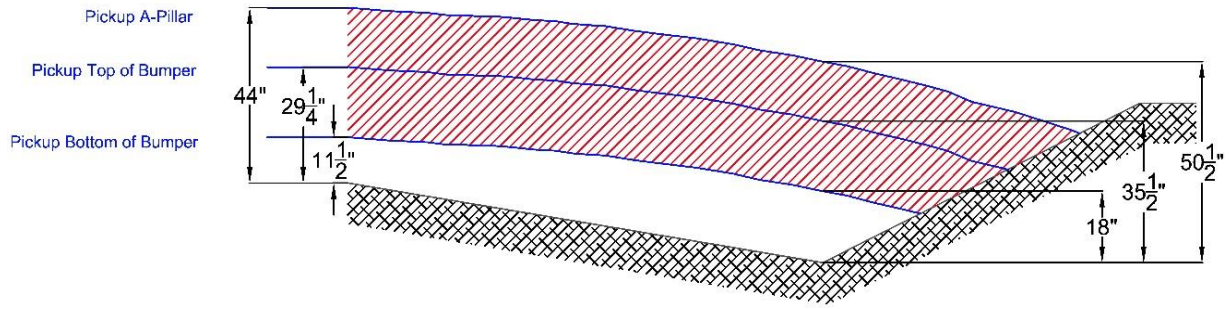


Figure 157. 2270P Pickup Truck Trajectory in 6:1 V-Ditch [16]

The optimal region of the vehicle to stably capture the pickup truck was near the front bumper and quarter panel. The nominal height of the top of the truck's bumper on level ground is approximately 29¼ in. and the nominal height of the base of the A-pillar of the pickup truck is 44 in. With a roadside departure speed of 62 mph and an angle of 25 degrees, the maximum height of the pickup truck bumper above the ditch bottom was estimated to be 35½ in.

During test no. HBIB-1, the test vehicle remained very close to the ground after entering the V-ditch. Therefore, the trajectory of the small car was simplified as a series of parallel lines extending from the ditch surface to the small car's bumper and A-pillar. The nominal heights of the small car's bumper top surface and bottom of the A-pillar were 20¾ and 39 in., respectively, and the effective height at the bottom of the ditch were approximately 21 and 39½ in., respectively. The projected trajectory of critical locations on the small car mapped to the ditch surface are shown in Figure 158.

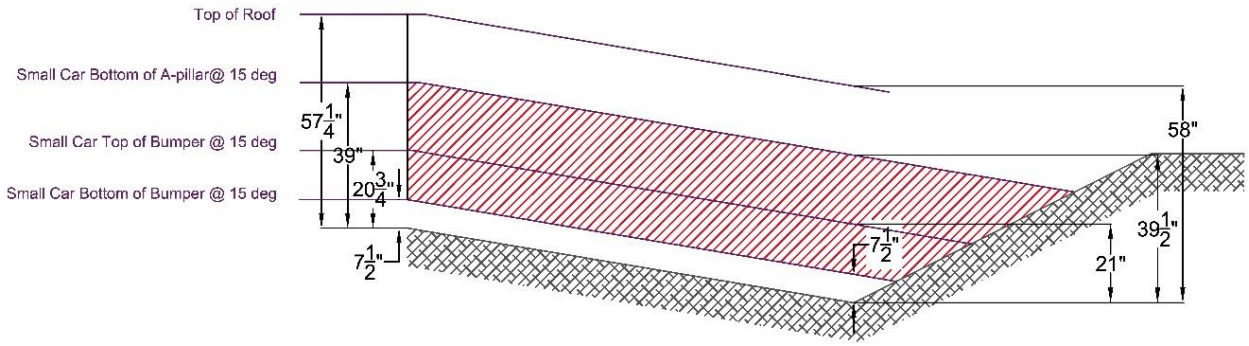


Figure 158. Trajectory of Selected Points on 1100C Small Car, Test No. HBIB-1

The small car and pickup truck trajectories were overlaid and compared, as shown in Figure 159. The critical area of the barrier placement was identified extending from a maximum height of the top surface of the pickup truck's bumper to a minimum height of the bottom surface of the small car's bumper. The primary structural features of the barriers should remain within the critical area to maximize the probability of successfully capturing both vehicles. Thus, researchers proposed several modifications of the system evaluated during test no. HBIB-1 to improve overall performance. The possible design options are discussed in the following section.

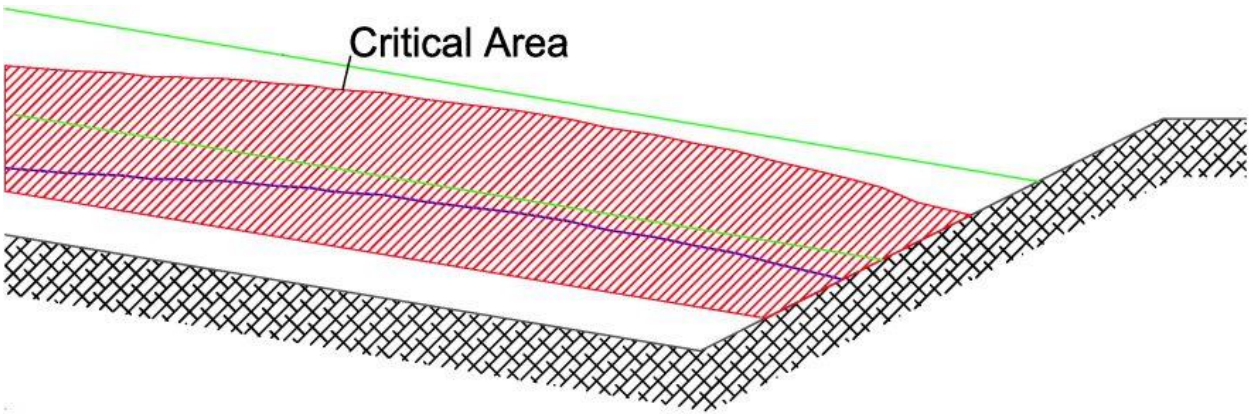


Figure 159. Critical Area for Consideration in System Redesign

7.3 Design Alternatives

7.3.1 HBIB System Redesign – Option 1a

The first proposed modification to the system to maximize the coverage of the buried-in-backslope system was to convert the rubrail from a W-beam to a thrie-beam. The proposed modification would add additional stiffness near the bottom of the system and increase the coverage of the exposed region of rail. Additionally, the height of the upper W-beam rail was aligned such that the "valley" of the W-beam approximately followed the envelope of the critical area. Additionally, both the thrie-beam and W-beam rubrail were offset from the post by a blockout. Note that because of the limited ground clearance beneath the rail at the anchor block, the research team did not utilize nested thrie beam at the upstream end of the rail, which could accumulate debris, soil, or may have partial clipping into the ground or surrounding area.

The height of the system was adjusted to match the critical area. For the standard MGS adjacent to the roadway, the rail was mounted with a top rail height of 31 in. The rubrail adjacent to the ditch and the start of the buried in backslope system flare was installed with a constant difference of 3 in. between the top of the rubrail and the bottom of the W-beam. The rubrail is offset from the surface of the posts using blockouts, which reduced exposure beneath the system. The 13:1 flare through the V-ditch was maintained for a design speed of 60 mph. The system height remained constant for the first 60 in. of lateral displacement through the ditch. Beyond 60 in., the post was lengthened to 7 ft to increase the post embedment depth in the soil to approximately 40 in., and a constant system height was maintained above the ditch surface until it reached the anchor block. This required the system to vertically slope downward through part of the ditch. Finally, at the anchor block where the post spacing is decreased to half and quarter-post spacing and the rail was nested, the system height was maintained at a constant elevation. The increased post length provided 42 in. of soil embedment which was consistent with standard MGS guardrail post embedment lengths. A schematic of the upstream view of Option 1a is shown in Figure 160. The location of the transition of posts lengths is shown schematically in Figure 161.

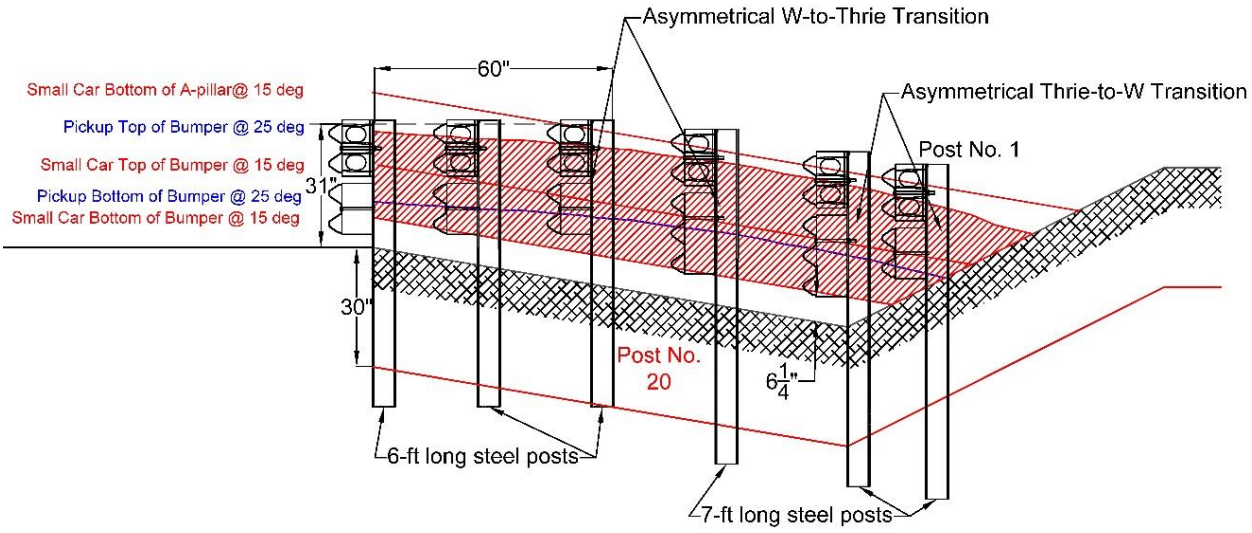


Figure 160. Schematic of HBIB Redesign Option 1a

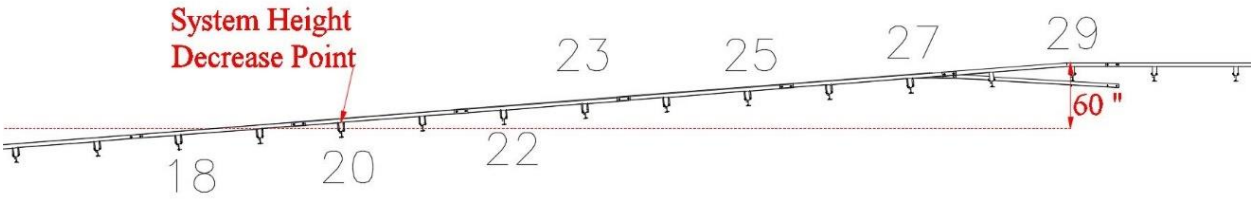


Figure 161. Location of 7-ft Steel Post Implementation

As noted, Option 1a utilized a thrie-beam rubrail instead of W-beam. The majority of the rubrail was thrie-beam, but in locations where ground clearance to the bottom of the thrie-beam may promote the accumulation of debris or become difficult to maintain, the rail was transitioned to W-beam. As a result, both the upstream and downstream ends of the rubrail were W-beam, and the interior was thrie-beam. For Option 1a, the W-beam at the anchor block was transitioned to thrie-beam starting at the 8th post downstream from the anchor block; as a result, the splice locations of the W-beam and thrie-beam would occur at the same locations. Additionally, it placed the W-to-thrie-beam transition at the bottom of the ditch. The W-to-thrie-beam transition is shown schematically in Figure 162. An overview of the layout of the different rail sections is shown in Figure 163.

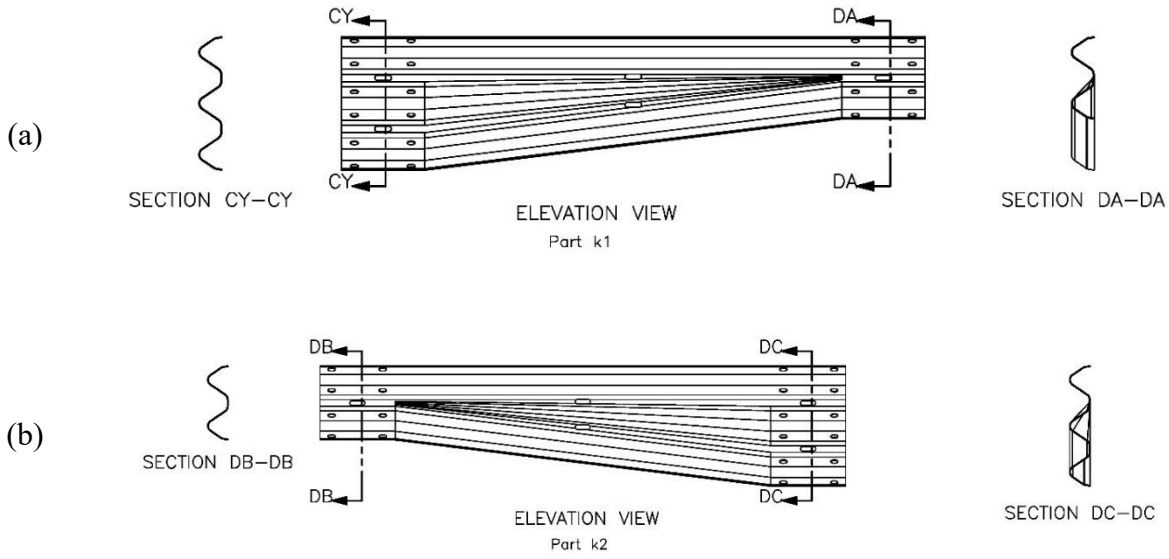


Figure 162. Transition Sections, (a) W-to-Thrie-Beam, (b) Thrie-to-W Beam

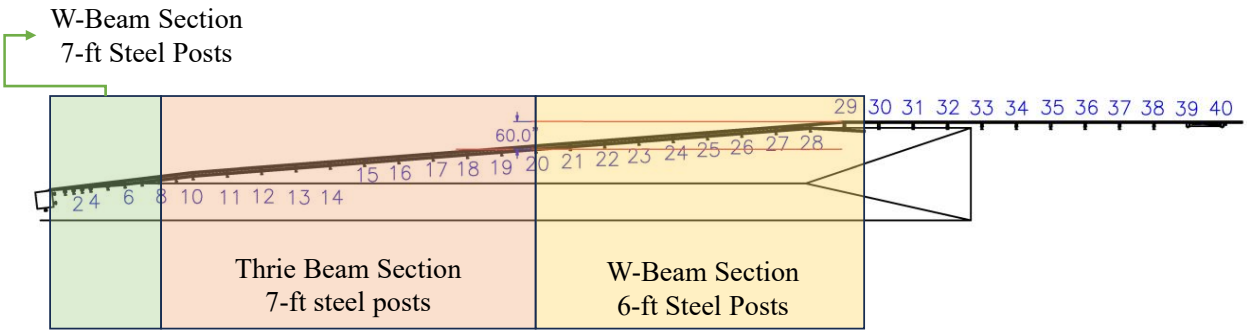


Figure 163. W-to-Thrie-beam Transition at Lower Rail Location, Option 1a

It was noted that the rubrail would benefit from blockouts spacing the rail from the face of the post. Blocking out the rail provides more of a "wall" surface for the vehicle to impact, reduces the clearance between the rubrail and ditch surface, and decreases the potential for a wheel impacting the rubrail to contact the face of a post and snag. The W-beam blockout used in the system was a recycled plastic block with a top mounting tab; to support the thrie-beam, tubular steel blockouts were used instead of the plastic upper blocks. Details and dimensions of the proposed blockouts are shown in Figure 164.

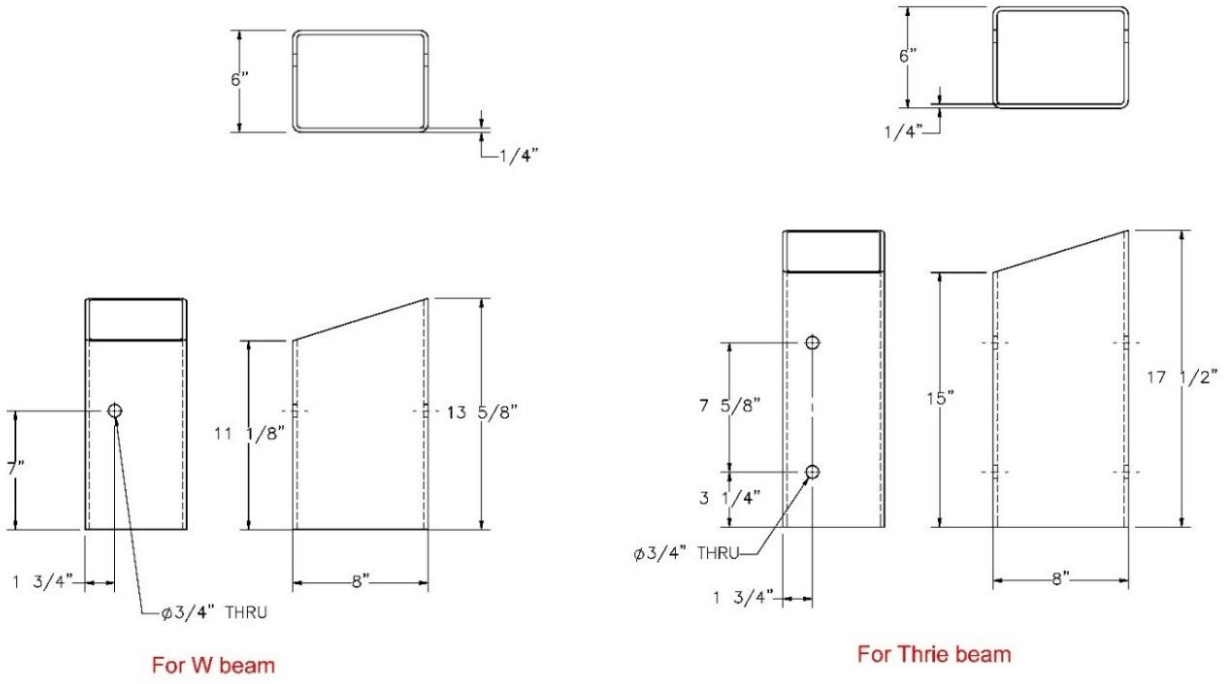


Figure 164. Tube Steel Blockout Details, Redesign Options 1a

7.3.2 HBIB System Redesign – Option 1b

The second option for the rubrail was similar to Option 1a. The second redesign option included all modifications detailed in the Option 1a with the only major difference being that the

nested W-beam adjacent to the anchor block was directly connected to the upstream side of the W-to-thrie-beam transition piece. Option 1b is shown in Figure 165. The W-to-thrie-beam transition was placed upstream from the bottom of the ditch.

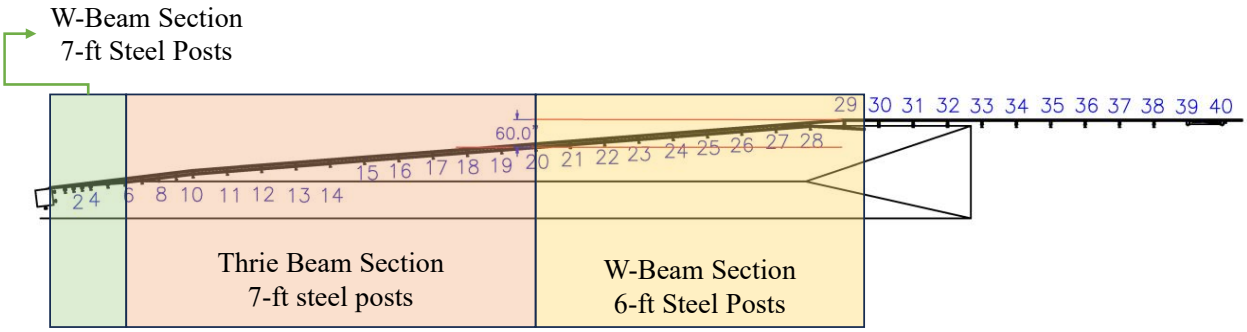


Figure 165. W-to-Thrie-beam Transition at Lower Rail Location, Option 1b

7.3.3 HBIB System Redesign – Option 2

Option 2 for the system did not utilize thrie-beam. The system top height was set the same as for Options 1a and 1b, which resulted in a larger exposure beneath the rubrail for Option 2. However, the exposure of the post below the rubrail was similar for Option 2 compared to typical MGS systems on level terrain, and vehicles impacting at increased angles and speeds were more likely to be elevated at the time of impact rather than extending below the rail. Impacts more likely to extend below the rail would be at lower speed and angle combinations which would ultimately reduce the risk of vehicle-to-post snagging. A schematic of the proposed layout of Option 2 is shown in Figure 166. A plan view of Option 2 is shown in Figure 167.

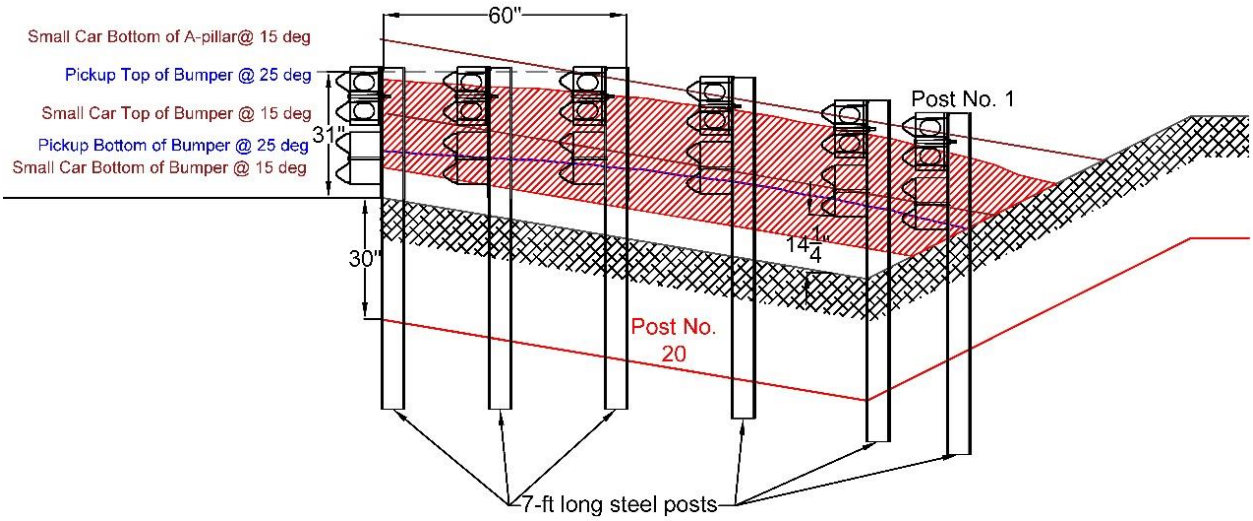


Figure 166. Schematic of System Installation, Option 2

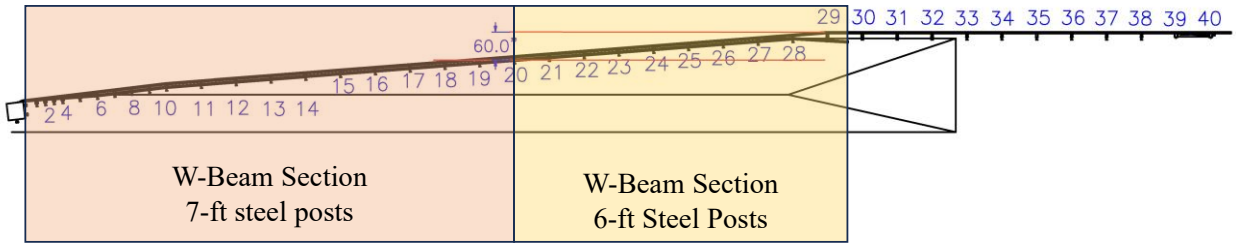


Figure 167. 7-ft Steel Post Implementation, Option 2

7.4 Summary and Conclusion

Two major system modifications were proposed to address the causes of failure observed in test no. HBIB-1, which were contact between the lower corrugation of the upper W-beam with the small car A-pillar and the wheel extension below the rubrail and snagging on exposed posts. It was believed that by reducing the height of the rails with respect to the ditch surface, both contributions to the system performance could be improved. Two design options and one design option alternative were suggested. For both options, the rail height remained level with the roadway for a lateral offset of the posts measuring 60 in., and a system height which followed the elevation of the ditch through the end of the system.

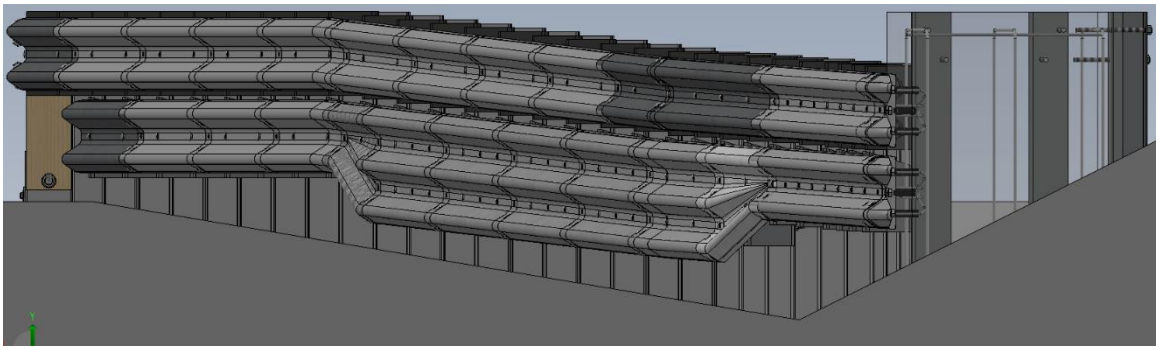
The system design options did not address a critical interface between the anchor block and the backslope. To date, no research has been performed on the traversability and crashworthiness of the upstream anchor block. Further evaluation of the BIB system subjected to reverse-direction impacts will be provided in a future report.

For this research effort, the ditch profile selected for evaluation consisted of a 6H:1V foreslope and a 2H:1V backslope. The system evaluated during test no. HBIB-1 did not vary with ditch foreslope and was only limited to a maximum ditch depth of 18 in. The recommended configuration may be more flexible to accommodate a broader width and depth of ditches, but crash testing would be required to confirm that other configurations, such as deeper ditch profiles and wider foreslopes, would be acceptable. Note also that if ditches utilize foreslopes shallower than 6H:1V, the recommendations provided for the system height in Options 1 and 2 would remain in effect. The recommended system heights are:

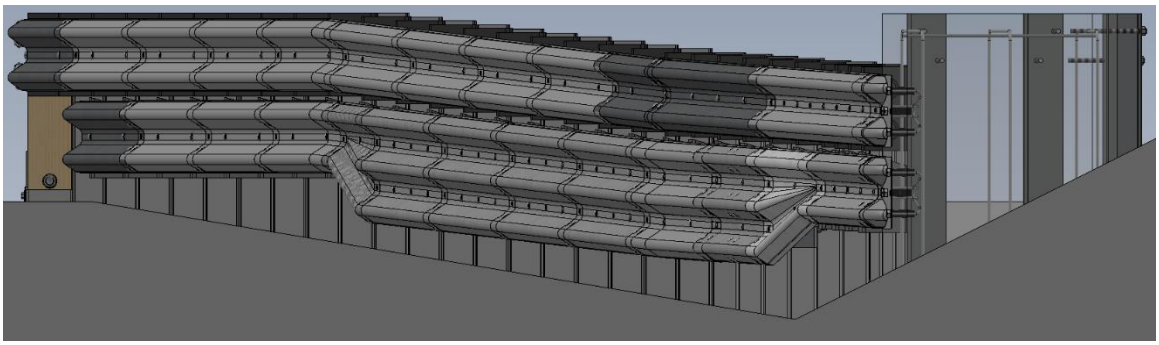
1. Nominal 31-in. tall MGS for posts located within 60 in. of the slope breakpoint; and
2. Constant height of W-beam in the transition section adjacent to the anchor block; and
3. Constant height of the system above the ditch between the anchor block and the standard MGS height.

The three design options are shown graphically in Figure 168. Details of the system layout for all three options are shown in Figures 169 through 171. A summary of the differences between these redesign options is shown in Table 10.

(a)



(b)



(c)

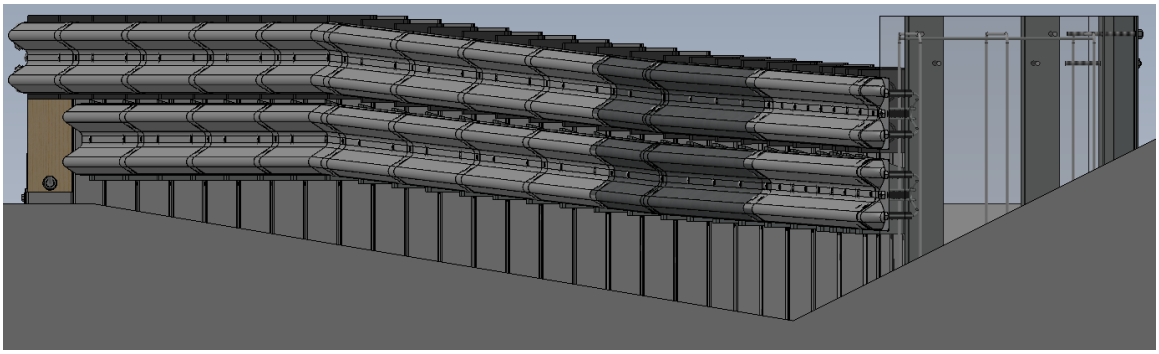


Figure 168. 3D Views of (a) Option 1a, (b) Option 1b, and (c) Option 2

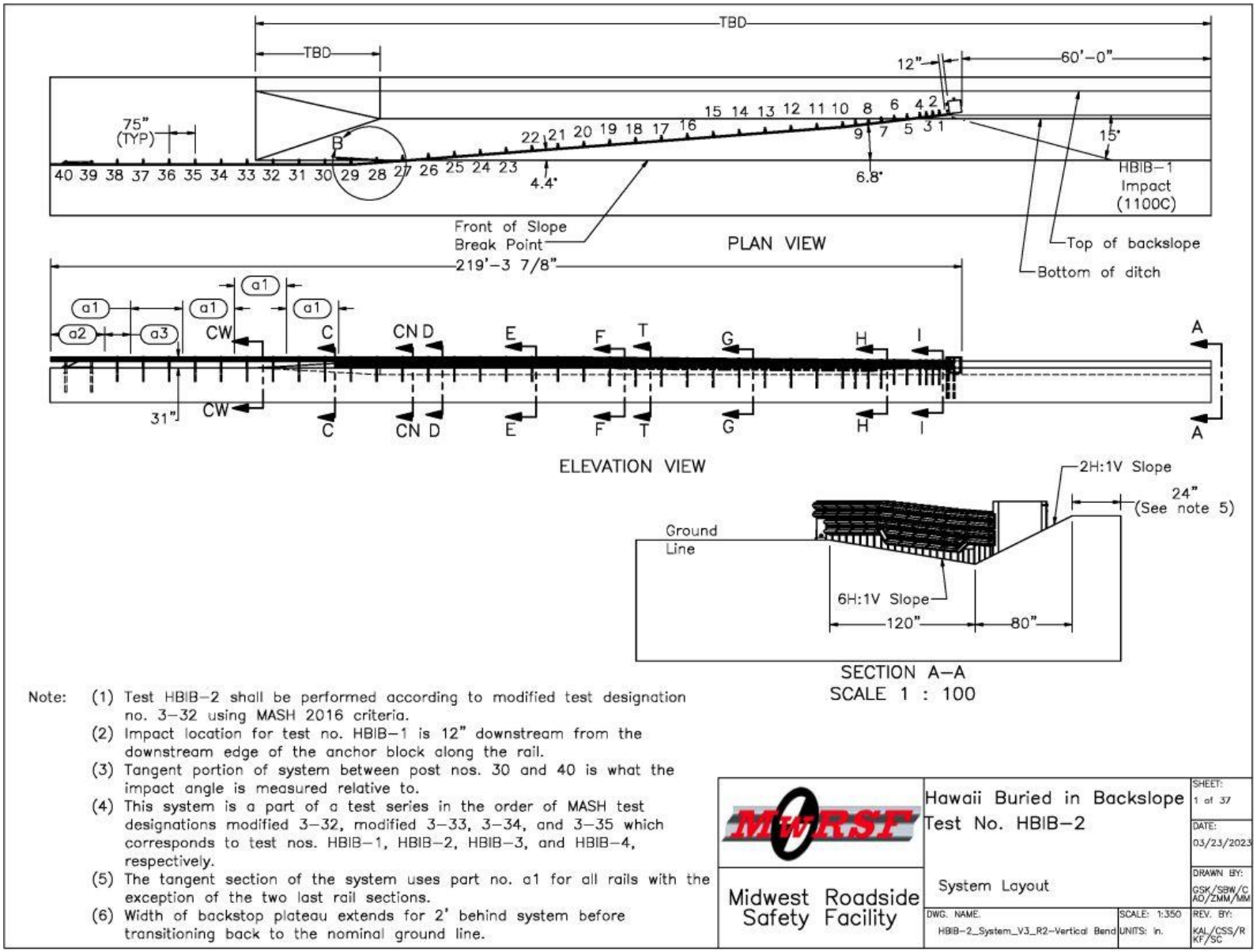


Figure 169. System Layout, Option 1a

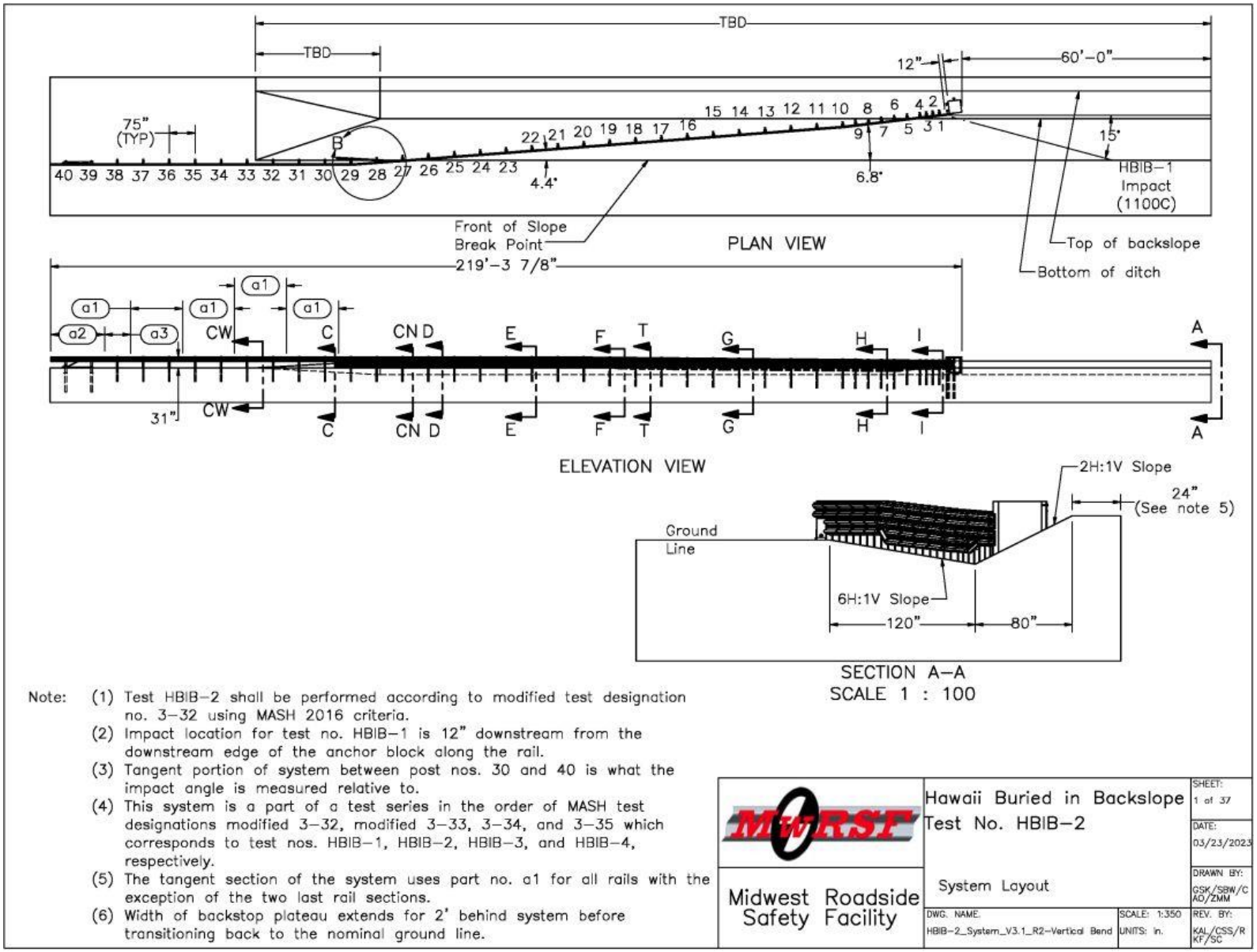


Figure 170. System Layout, Option 1b

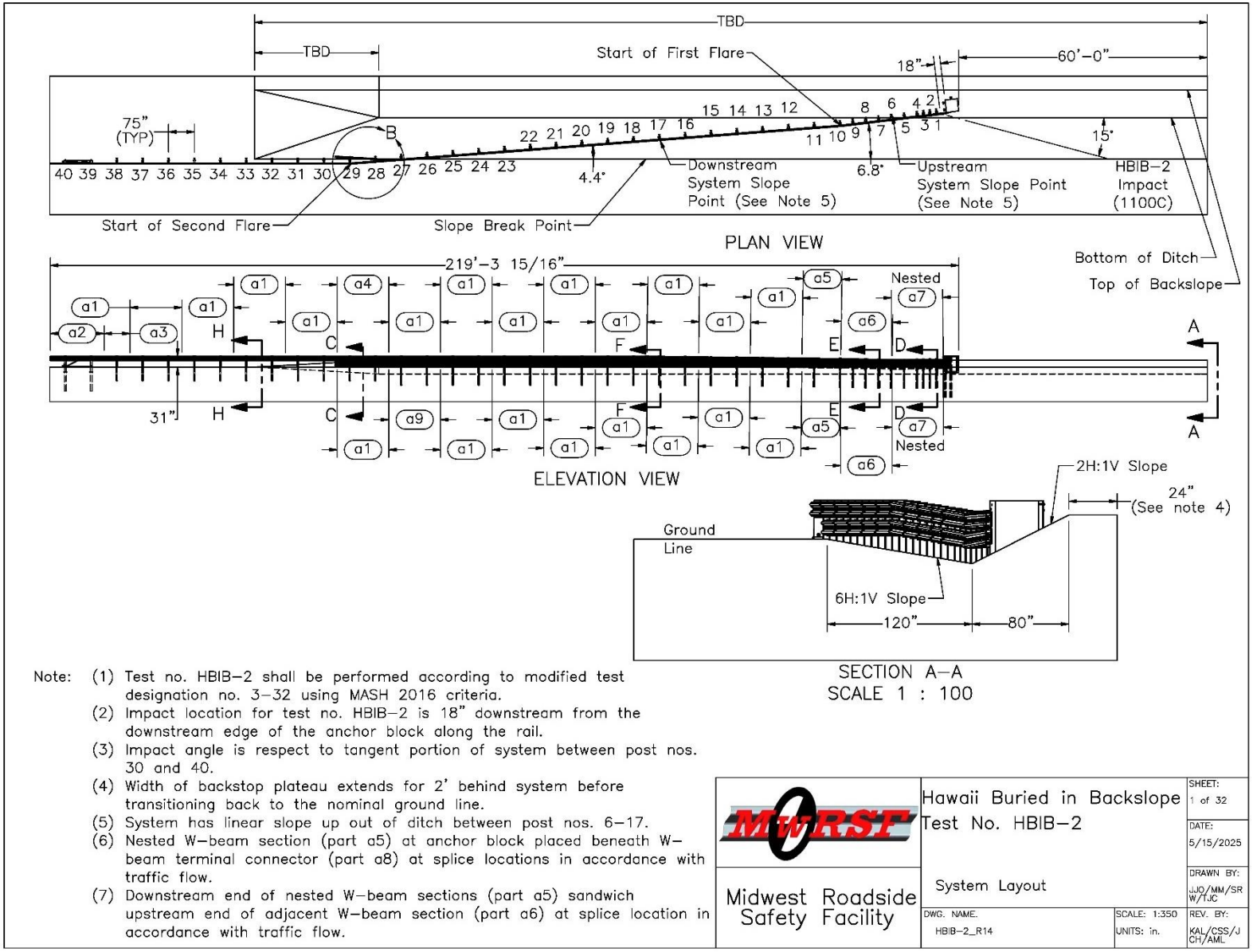


Figure 171. System Layout, Option 2

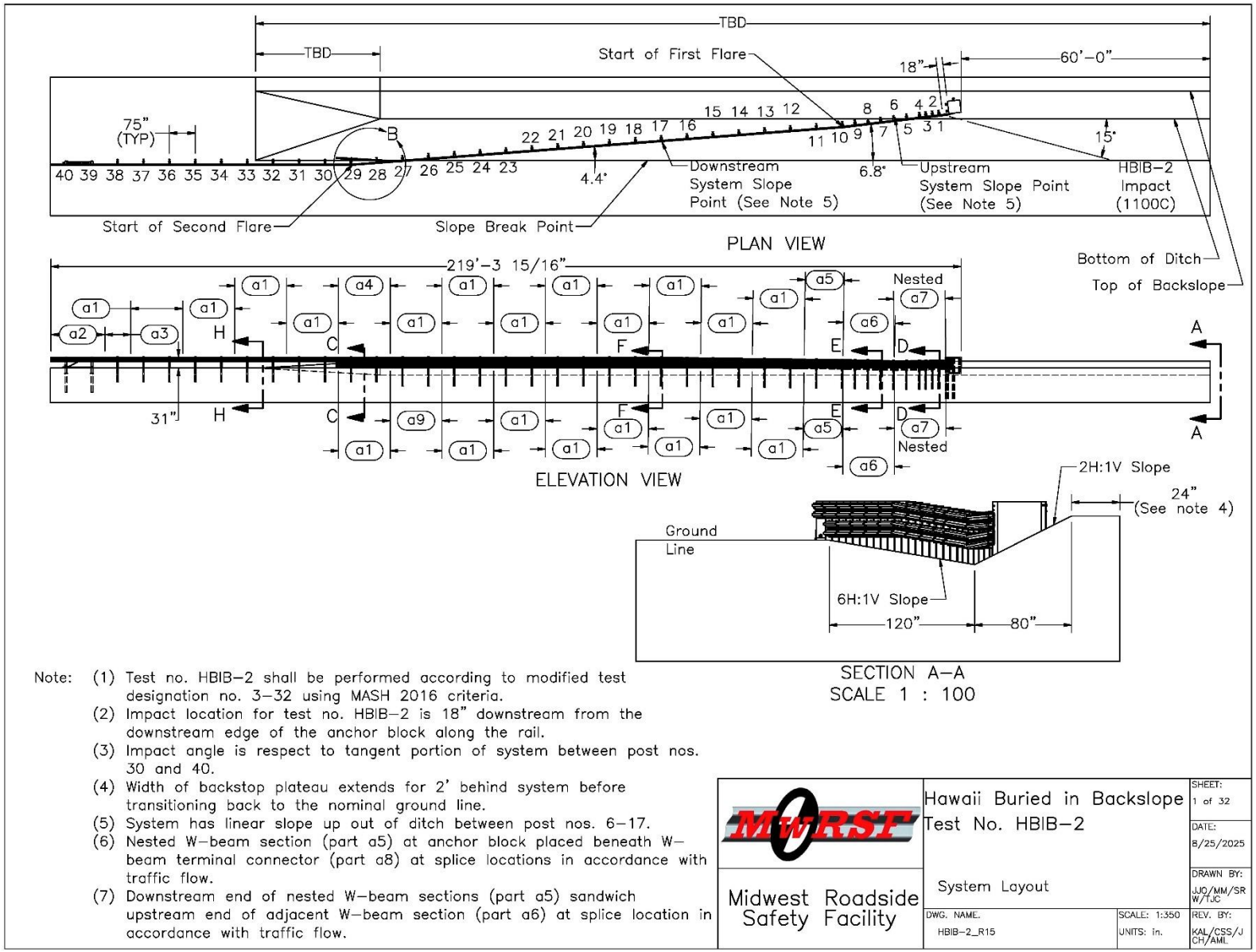
Table 10. Summary of System Modification Options

Comparison with HBIB-1 System	**Option 1a**	**Option 1b**	**Option 2**
Number of Unique Components Compared to HBIB-1	2x W-to-Thrie Transitions Tubular blockouts for W-beam Tubular blockouts for Thrie-beam	2x W-to-Thrie Transitions Tubular blockouts for W-beam Tubular blockouts for Thrie-beam	Tubular blockouts for W-beam
Maximum Gap Below Rubrail (in.)	14¼	9½	14¼
Rubrail W-to-Thrie Transition Locations	Post nos. 17-18 Post nos. 6-8	Post nos. 17-18 Post nos. 3-5	N/A
Cost Increase vs. HBIB-1 System	Thrie-beam, transition, blockouts, & post-rail fasteners	Thrie-beam, transition, blockouts, & post-rail fasteners	Blockouts & post-rail fasteners

8 MODIFIED DESIGN DETAILS

After analyzing the three possible designs discussed in the previous chapter and consulting with HDOT, Option 2 was selected to be tested. The modified system was evaluated according to MASH TL-3 safety criteria test designation nos. 3-32, 3-33, 3-34, and 3-35, run as test nos. HBIB-2 through HBIB-5, respectively. System drawings are shown in Figures 173 through 202 and photographs of the system installation, which was identical for test nos. HBIB-2 through HBIB-5, are shown in Figures 204 and 205.

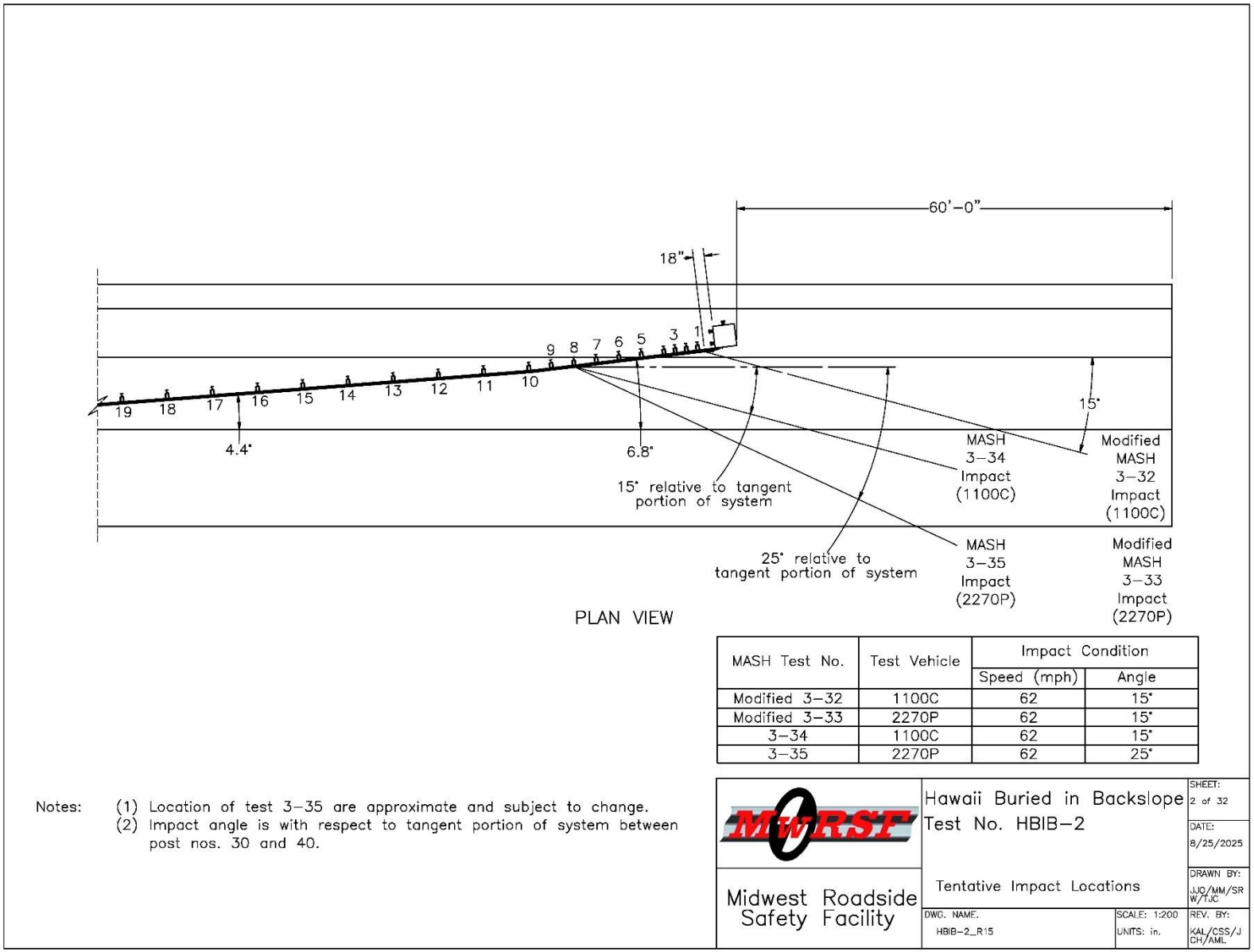
The layout for the system crash tested in test nos. HBIB-2 through HBIB-5 was nearly identical to the layout chosen for test no. HBIB-1. The primary differences between the two systems were post lengths and rail heights. Post nos. 28 through 38 were 6 ft long, and post nos. 1 through 27 were 7 ft long. The height of the top of the rail was 31 in. above the roadway surface for post nos. 17 through 39. The rail maintained a constant height above the ditch between post nos. 6 and 16. Lastly, the rail was horizontal and at a constant height between post nos. 1 and 6. However, because the anchor block from test no. 1 was reused, new holes were drilled into the anchor block and post-installed anchors were used to attach the rail end shoes to the anchor block. One of the existing ferrule openings was reused to accommodate the updated rail placement on the block. This change resulted in a slight inclination of the rail between post nos. 1 and 6.



Note:
(1) Test no. HBIB-2 shall be performed according to modified test designation no. 3-32 using MASH 2016 criteria.
(2) Impact location for test no. HBIB-2 is 18" downstream from the downstream edge of the anchor block along the rail.
(3) Impact angle is respect to tangent portion of system between post nos. 30 and 40.
(4) Width of backstop plateau extends for 2' behind system before transitioning back to the nominal ground line.
(5) System has linear slope up out of ditch between post nos. 6-17.
(6) Nested W-beam section (part a5) at anchor block placed beneath W-beam terminal connector (part a8) at splice locations in accordance with traffic flow.
(7) Downstream end of nested W-beam sections (part a5) sandwich upstream end of adjacent W-beam section (part a6) at splice location in accordance with traffic flow.

MwRSF Midwest Roadside Safety Facility	Hawaii Buried in Backslope Test No. HBIB-2 System Layout	SHEET: 1 of 32 DATE: 8/25/2025 DRAWN BY: JJO/MM/SR W/TJC REV. BY: KAL/CSS/J CH/AML
	DWG. NAME. HBIB-2_R15	SCALE: 1:350 UNITS: in.

Figure 172. System Layout, Test Nos. HBIB-2 through HBIB-5



MASH Test No.	Test Vehicle	Impact Condition	
		Speed (mph)	Angle
Modified 3-32	1100C	62	15°
Modified 3-33	2270P	62	15°
3-34	1100C	62	15°
3-35	2270P	62	25°

Notes:
(1) Location of test 3-35 are approximate and subject to change.
(2) Impact angle is with respect to tangent portion of system between post nos. 30 and 40.

MwRSF	Hawaii Buried in Backslope Test No. HBIB-2	SHEET: 2 of 32
		DATE: 8/25/2025
Midwest Roadside Safety Facility	Tentative Impact Locations	DRAWN BY: JJO/MM/SRW/TJC
	DWG. NAME: HBIB-2_R15 / SCALE: 1:200 / UNITS: in.	REV. BY: KAL/CSS/JCH/AML

Figure 173. Tentative Impact Location, Test Nos. HBIB-2 through HBIB-5

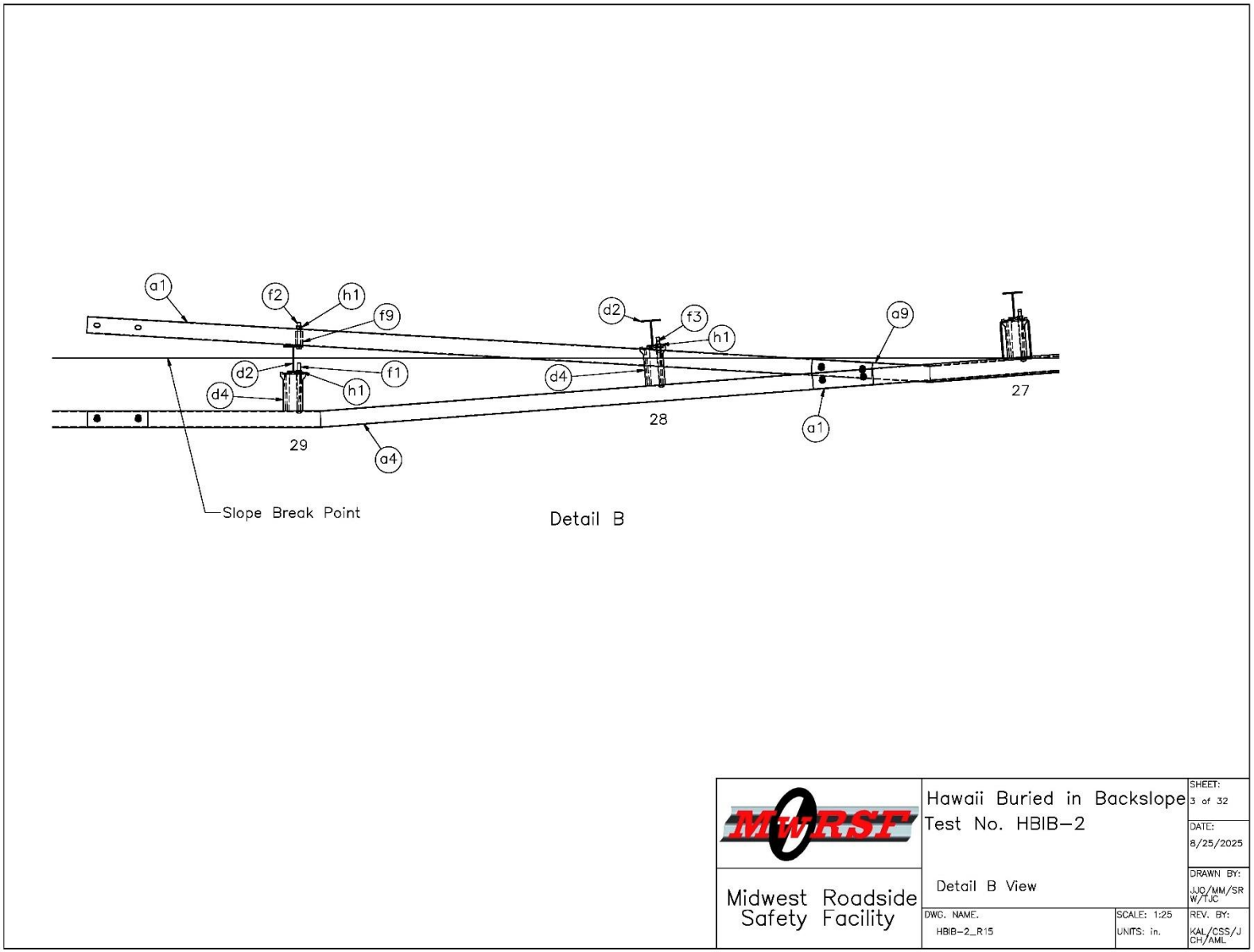


Figure 174. Rubrail Termination Details, First Deviations Point, Test No. HBIB-2

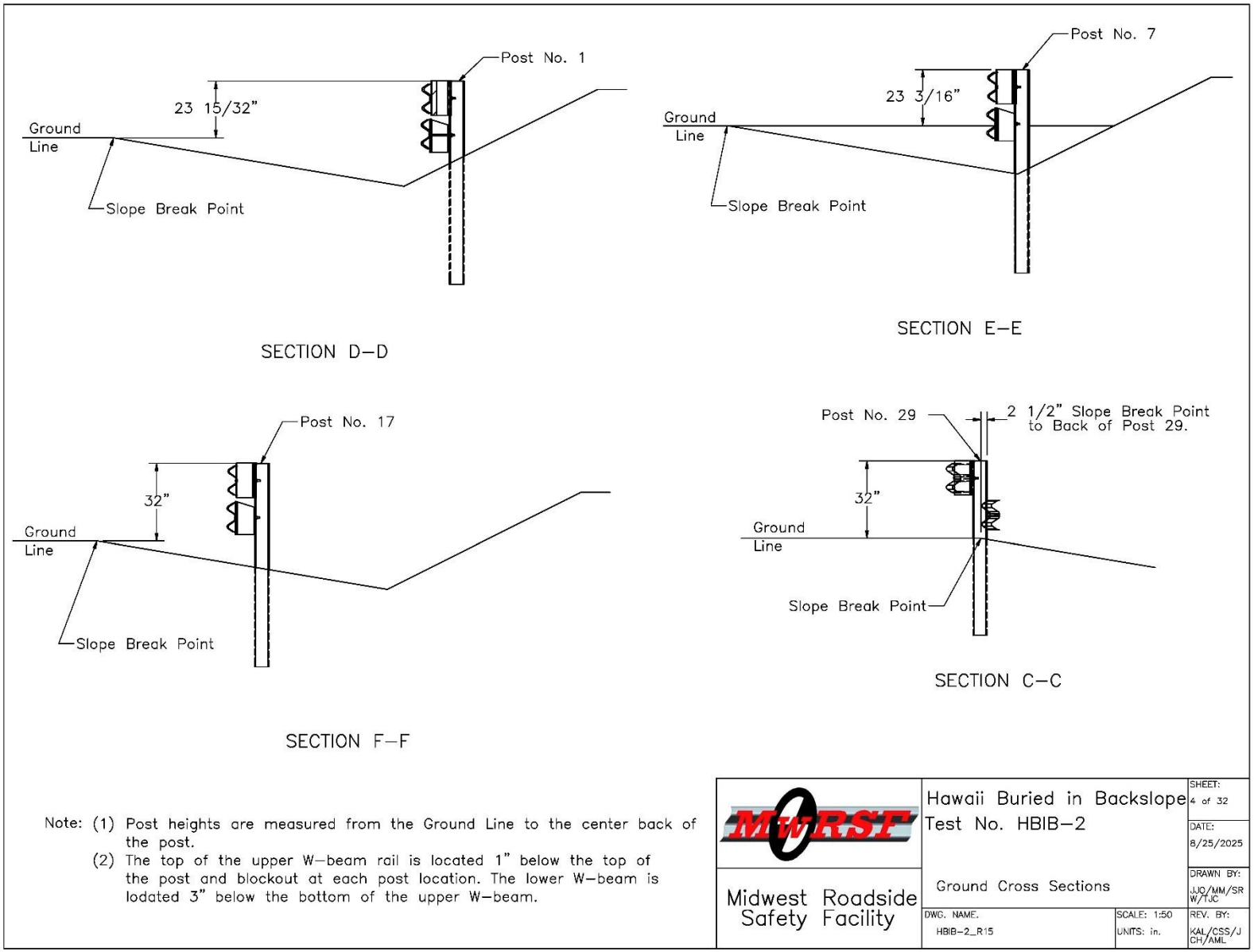


Figure 175. Ground Cross Sections, Test No. HBIB-2

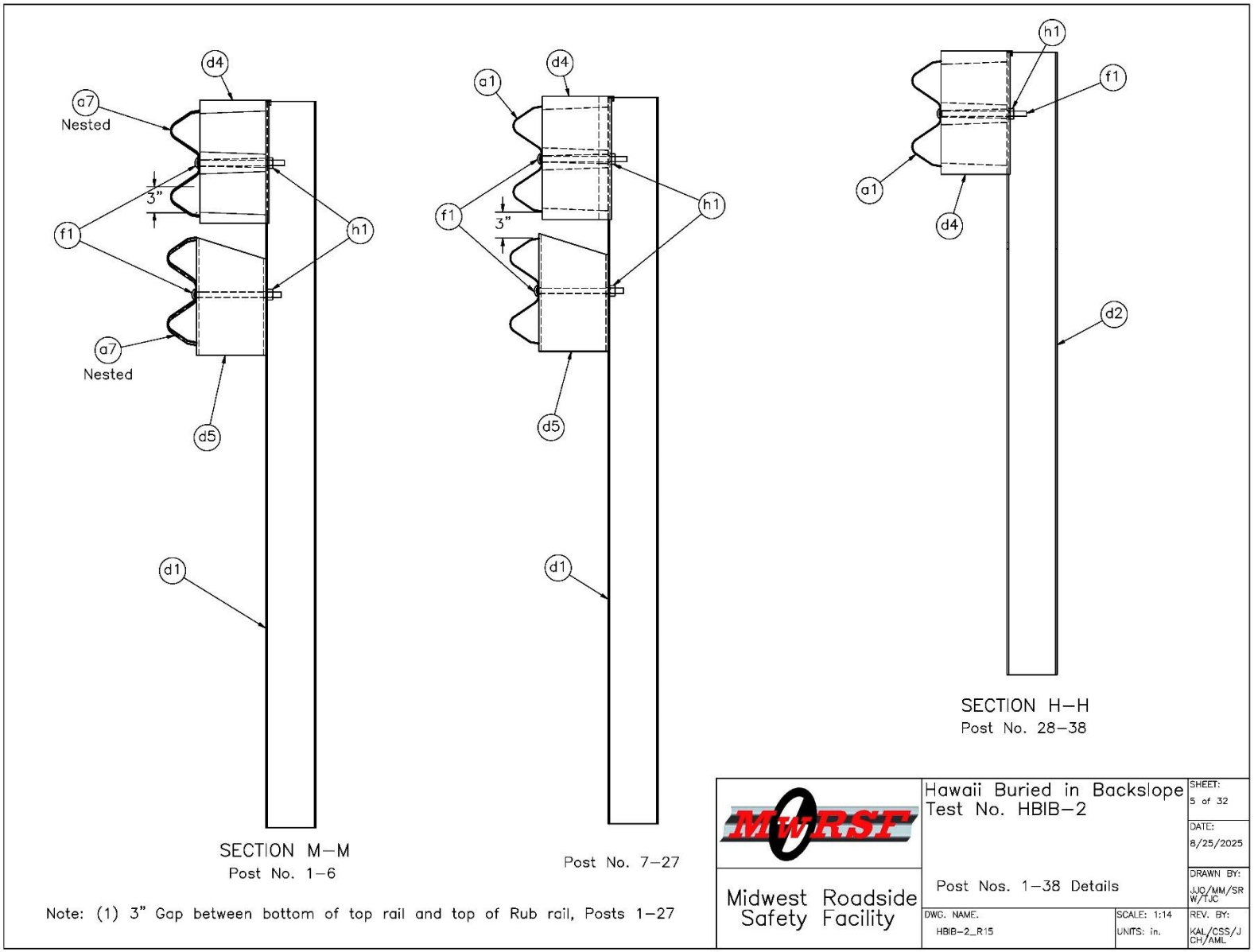
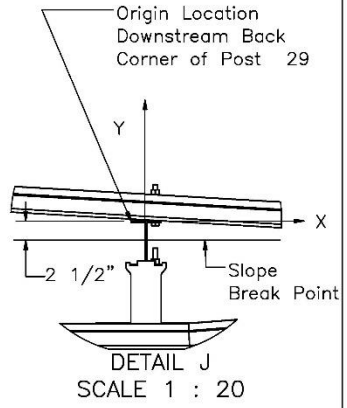
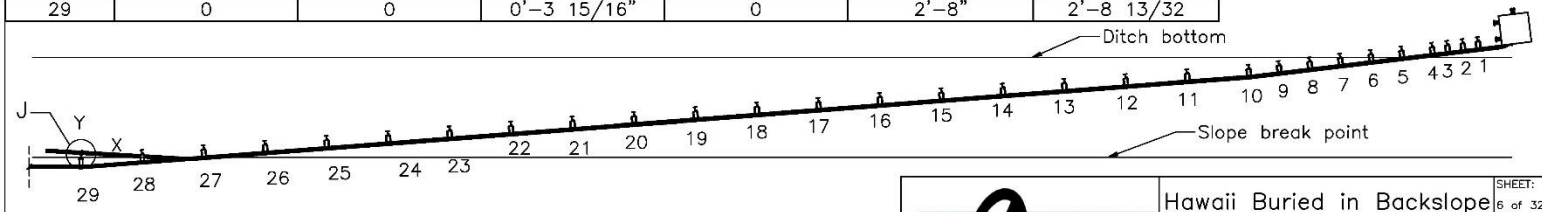


Figure 176. Post Nos. 1 through 38 Details, Test No. HBIB-2

Post Locations						
Post No.	Downstream Back Corner of Post		Upstream Back Corner of Post		Top of the post to ground line	Top of the Back Side Centerline Post to Ditch
	X	Y	X	Y		
1	141'–6 5/8'	11'–9 63/64"	141'–10 35/64"	11'–10 29/64"	1'–11 15/32"	2'–7 1/8"
2	140'–0 1/64	11'–7 49/64"	140'–3 59/64"	11'–8 15/64"	1'–11 9/32"	2'– 8 1/8"
3	138'–5 25/64"	11'–5 33/64"	138'–9 19/64"	11'–5 63/64	1'–10 29/32"	2'–8 3/4"
4	136'–10 25/32"	11'–3 19/64"	137'–2 11/16"	11'–3 49/64"	1'–10 51/64"	2'–9 25/32"
5	133'–9 35/64"	10'–10 13/16"	134'–1 29/64"	10'–11 19/64"	1'–10 27/64"	2'–11 19/32"
6	130'–8 5/16"	10'–6 23/64"	131'–0 7/32"	10'–6 53/64	1'–10 5/16"	3'–1 29/32"
7	127'–7 5/64"	10'–1 57/64"	127'–10 63/64"	10'–2 23/64"	1'–11 1/16"	3'–4 31/32"
8	124'–5 27/32"	9'–9 7/16"	124'–9 3/4"	9'–9 29/32"	1'–11 13/16"	3'–7 25/32"
9	121'–4 39/64"	9'–4 61/64"	121'–8 33/64"	9'–5 7/16"	2'–0 35/64"	3'–7 27/32"
10	118'–3 29/32"	9'–0 45/64"	118'–7 53/64"	9'–1"	2'–1 19/64"	3'–7 27/32"
11	112'–1"	8'–6 15/16"	112'–4 15/16"	8'–7 15/64"	2'–2 1/4"	3'–7 27/32"
12	105'–10 23/64"	8'–1 3/16"	106'–2 9/32	8'–1 31/64"	2'–3 13/64"	3'–7 27/32"
13	99'–7 37/64"	7'–7 7/16"	99'–11 33/64	7'–7 47/64"	2'–4 5/32"	3'–7 27/32"
14	93'–4 13/16"	7'–1 11/16"	93'–8 47/64"	7'–1 63/64"	2'–5 1/8"	3'–7 7/8"
15	87'–2 3/64"	6'–7 15/16"	87'–5 61/64"	6'–8 15/64"	2'–6 5/64"	3'–7 27/32"
16	80'–11 9/32'	6'–2 3/16"	81'–3 13/64	6'–2 31/64"	2'–7 3/64"	3'–7 7/8"
17	74'–8 1/2"	5'–8 27/64"	75'–0 27/64	5'–8 23/32	2'–8"	3'–7 27/32"
18	68'–5 23/32"	5'–2 43/64"	68'–9 41/64"	5'–2 31/32"	2'–8"	3'–6 15/16"
19	62'–2 15/16"	4'–8 29/32"	62'–6 55/64"	4'–9 7/32"	2'–8"	3'–5 29/32"
20	56'–0 5/32"	4'–3 5/32"	56'–4 3/32"	4'–3 29/64	2'–8"	3'–5"
21	49'–9 3/8"	3'–9 13/32"	50'–1 5/16"	3'–9 45/64"	2'–8"	3'–4 1/32"
22	43'–6 19/32"	3'–3 21/32"	43'–10 17/32"	3'–3 61/64"	2'–8"	3'–3 1/32"
23	37'–3 13/16"	2'–9 29/32"	37'–7 3/4"	2'–10 13/64"	2'–8"	3'–2 3/32"
24	31'–1 3/64"	2'–4 9/64"	31'–4 31/32"	2'–4 29/64"	2'–8"	3'–1 5/32"
25	24'–10 9/32"	1'–10 25/64"	25'–2 13/64"	1'–10 11/16"	2'–8"	3'–3/16"
26	18'–7 18/32"	1' 4 41/64"	18'–11 13/32"	1'–4 15/16"	2'–8"	2'–11 7/32"
27	12'–4 45/64"	0–10 7/8"	12'–8 5/8"	0'–11 3/16"	2'–8"	2'–10 1/4"
28	6'–1 29/32"	0–5 9/64"	6"–5 27/32"	0'–5 29/64"	2'–8"	2'–9 9/32"
29	0	0	0'–3 15/16"	0	2'–8"	2'–8 13/32





Note: (1) Post x,y,z dimensions are measured from downstream back corner of post 29. Vertical dimensions are from the top of the front slope break point to the top of the post.
(2) Post no. 17 through No. 29 do not change in height from the top of the post to the ground line.

MwRSF	Hawaii Buried in Backslope Test No. HBIB–2	SHEET: 6 of 32
		DATE: 8/25/2025
Midwest Roadside Safety Facility	Post Location Layout	DRAWN BY: JJO/MM/SR W/TJC
	DWG. NAME. HBIB–2_R15 SCALE: 1:185 UNITS: in.	REV. BY: KAL/CSS/J CH/AML

Figure 177. Post Location Layout, Test No. HBIB-2

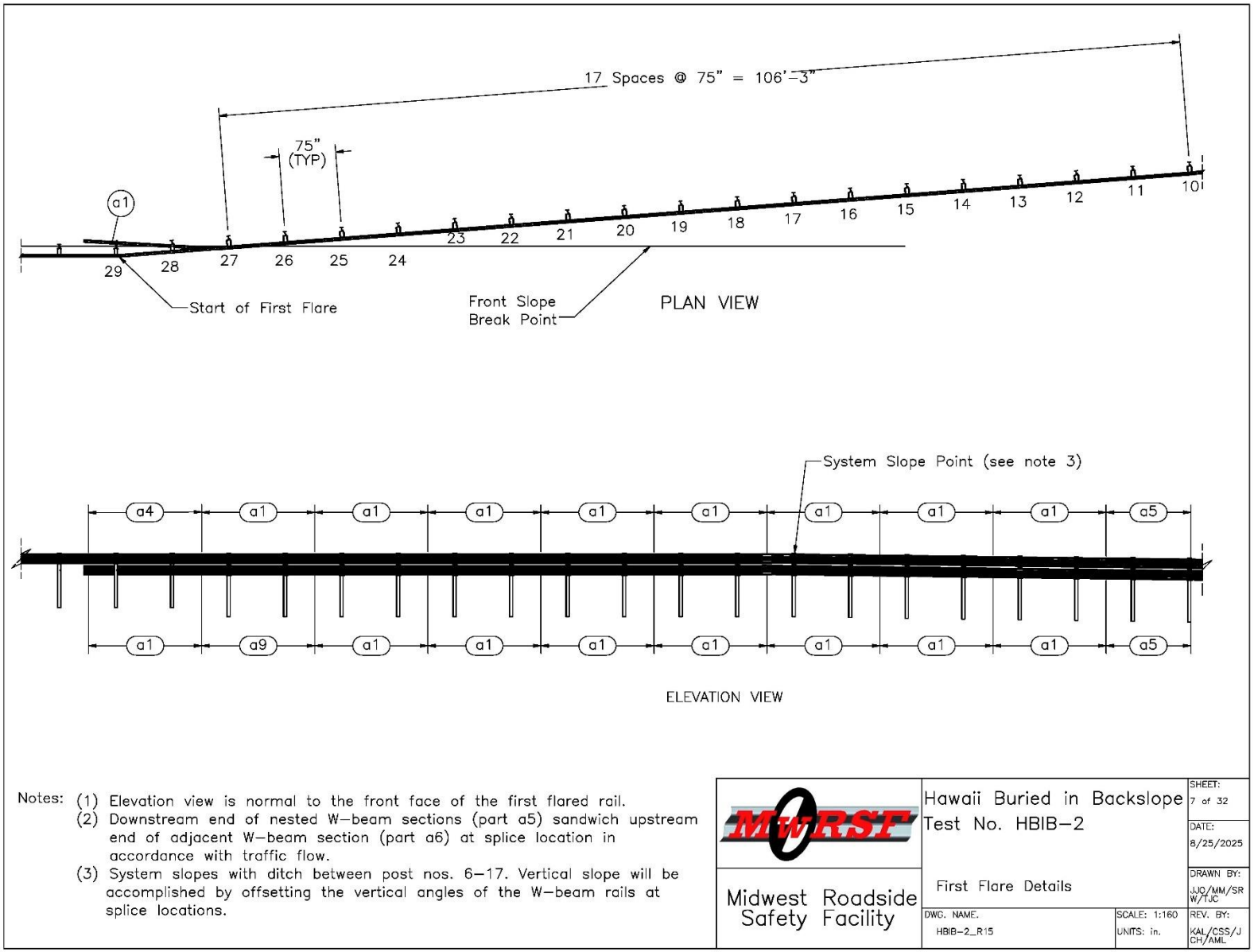


Figure 178. First Flare Details, Test No. HBIB-2

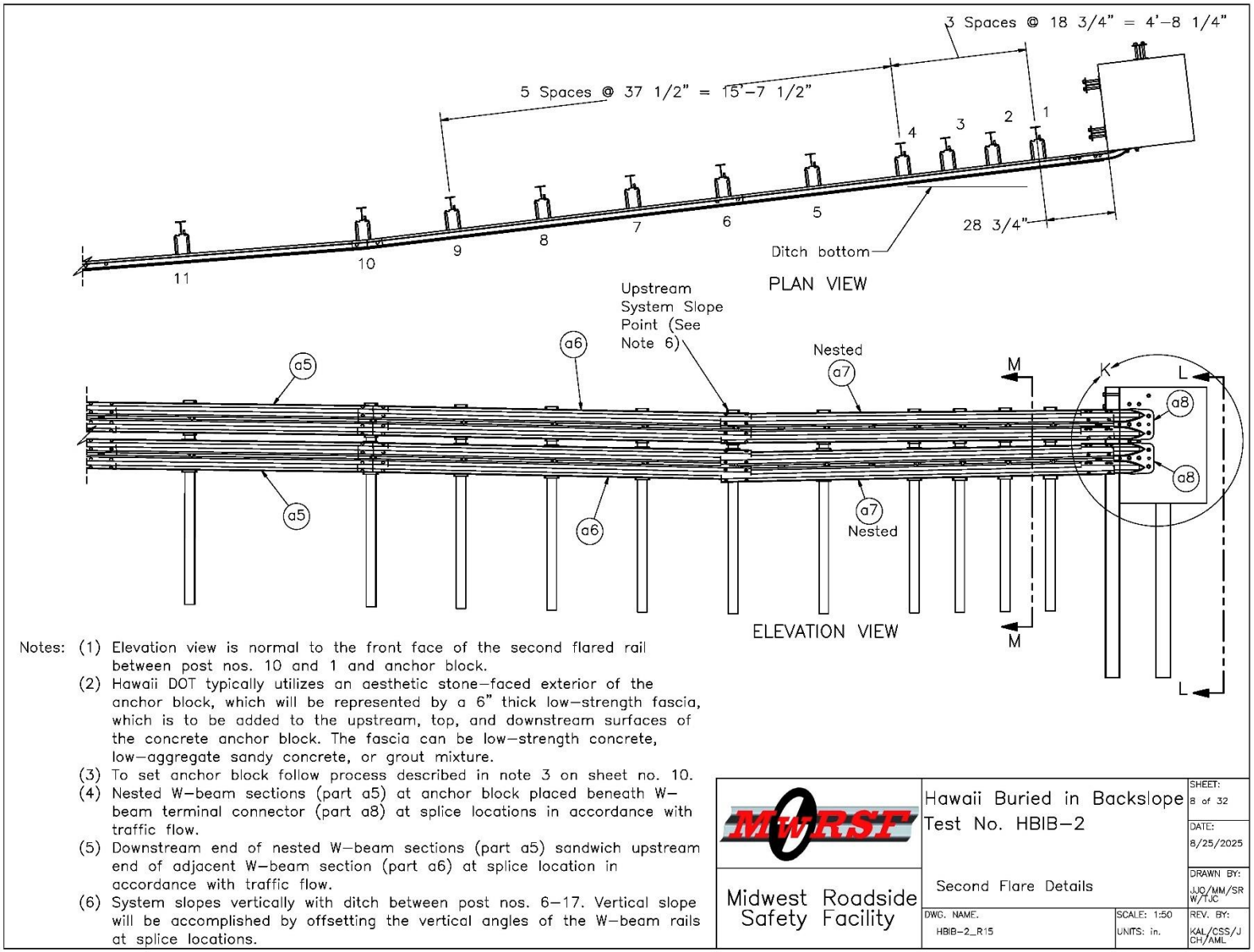


Figure 179. Second Flare Details, Test No. HBIB-2

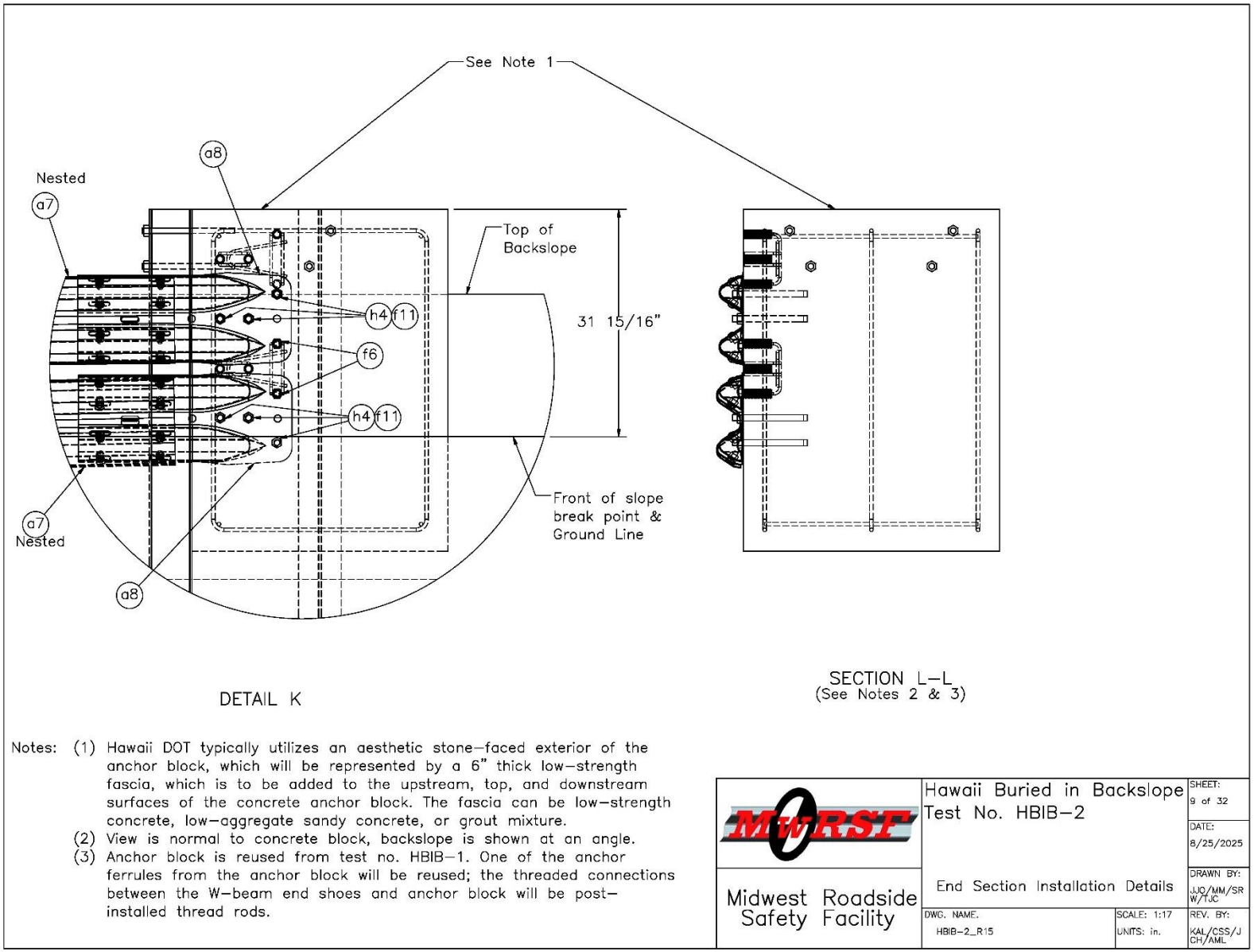


Figure 180. End Section Installation Details, Test No. HBIB-2

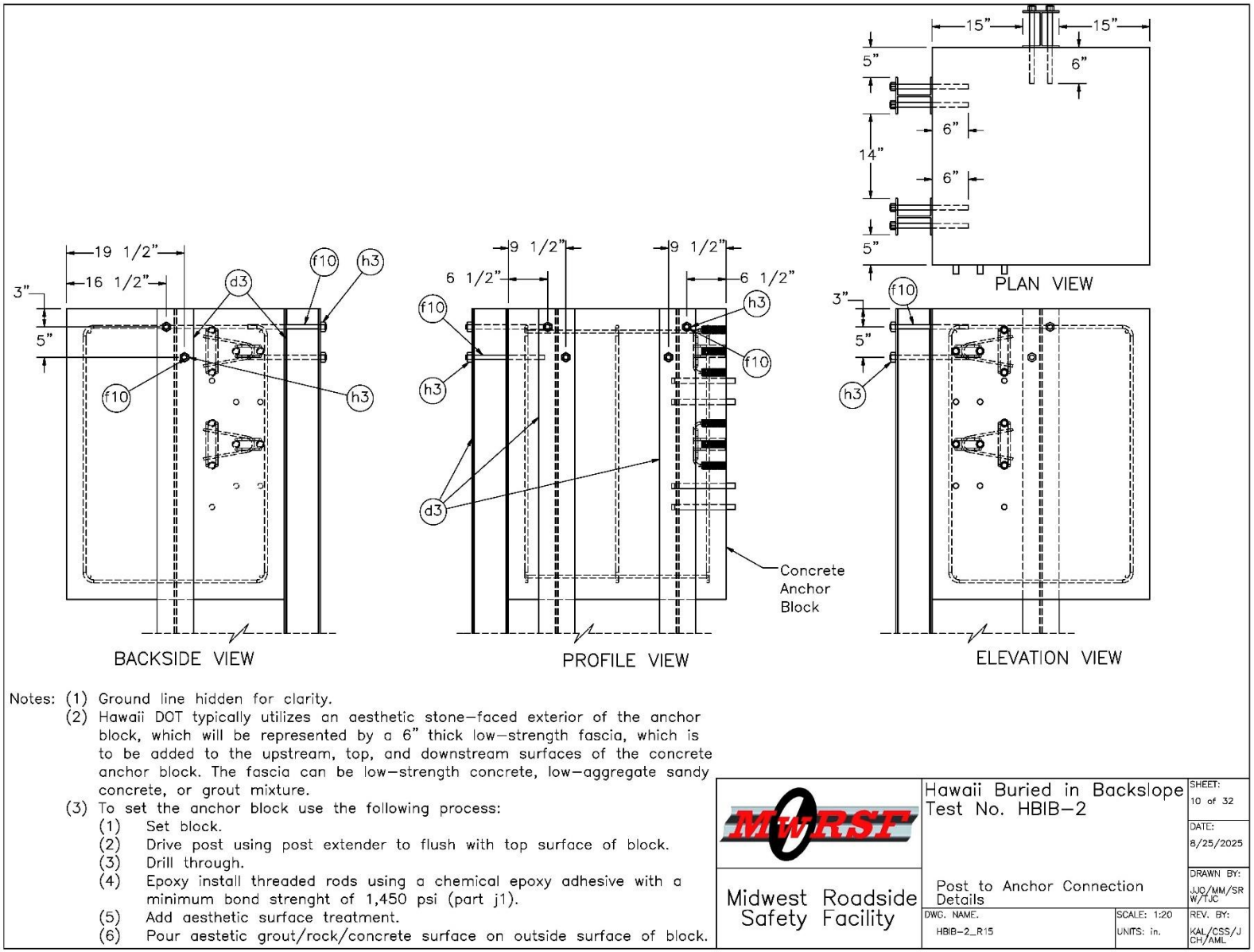


Figure 181. Post to Anchor Connection, Test No. HBIB-2

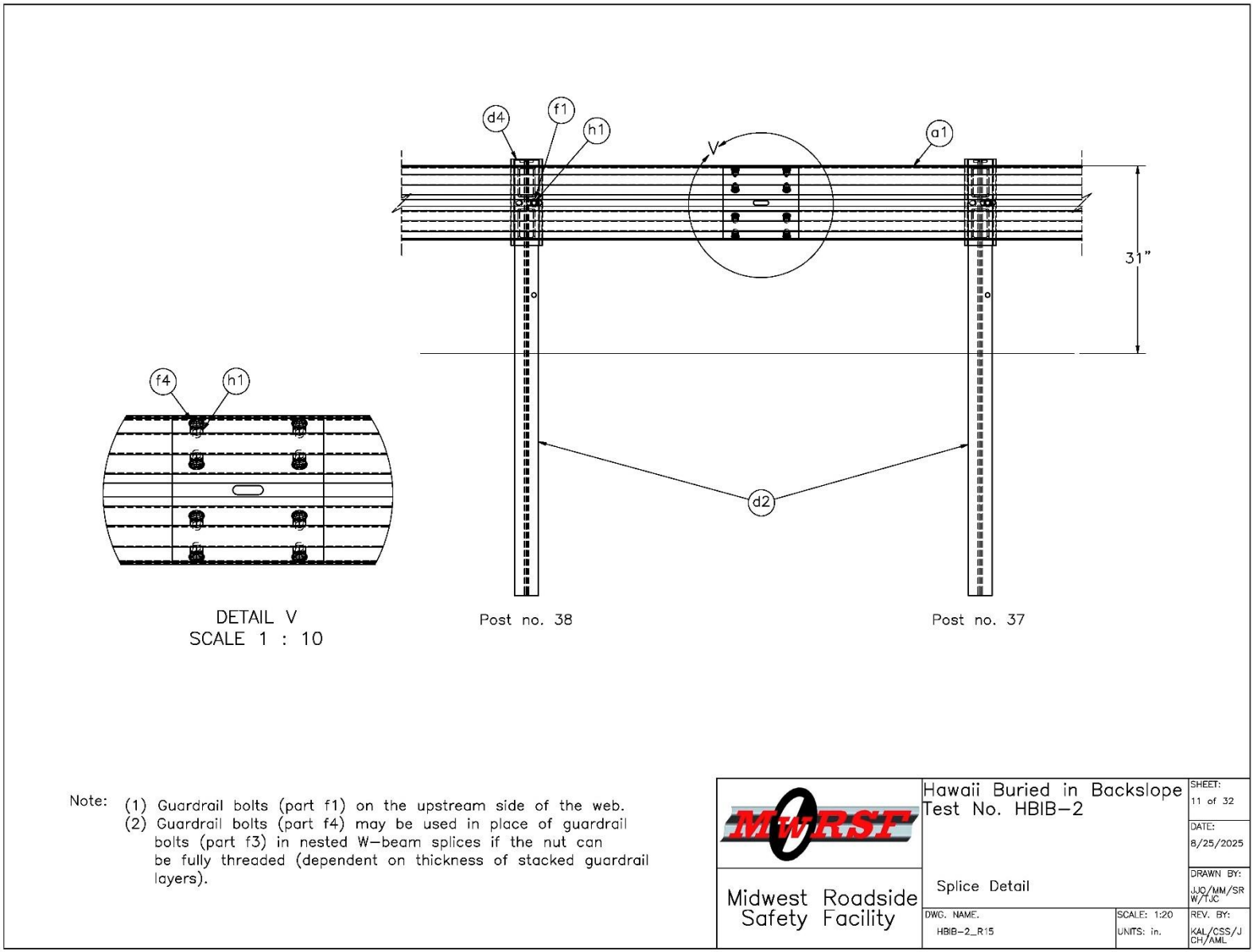


Figure 182. Splice Details, Test No. HBIB-2

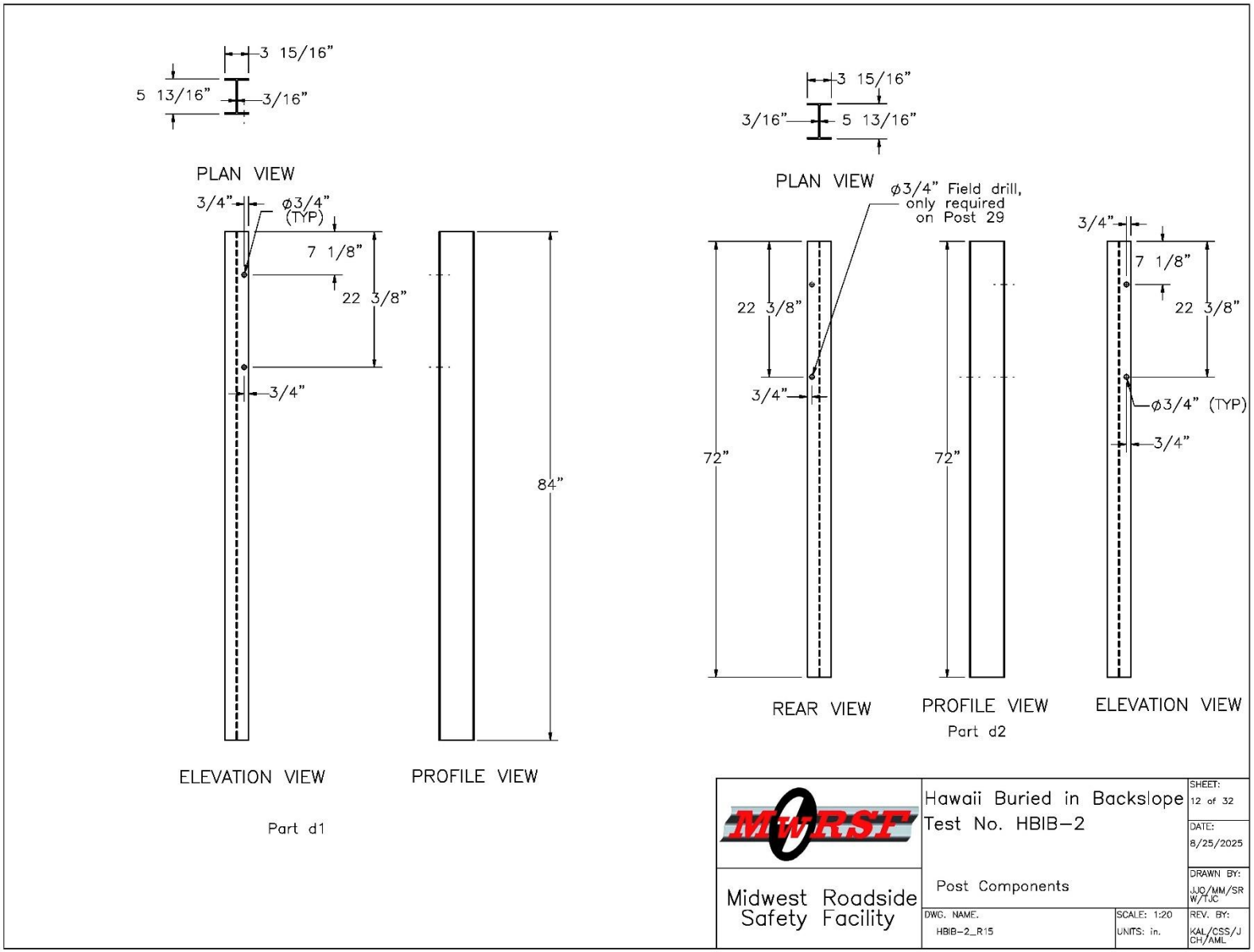


Figure 183. Post Components Details, Test No. HBIB-2

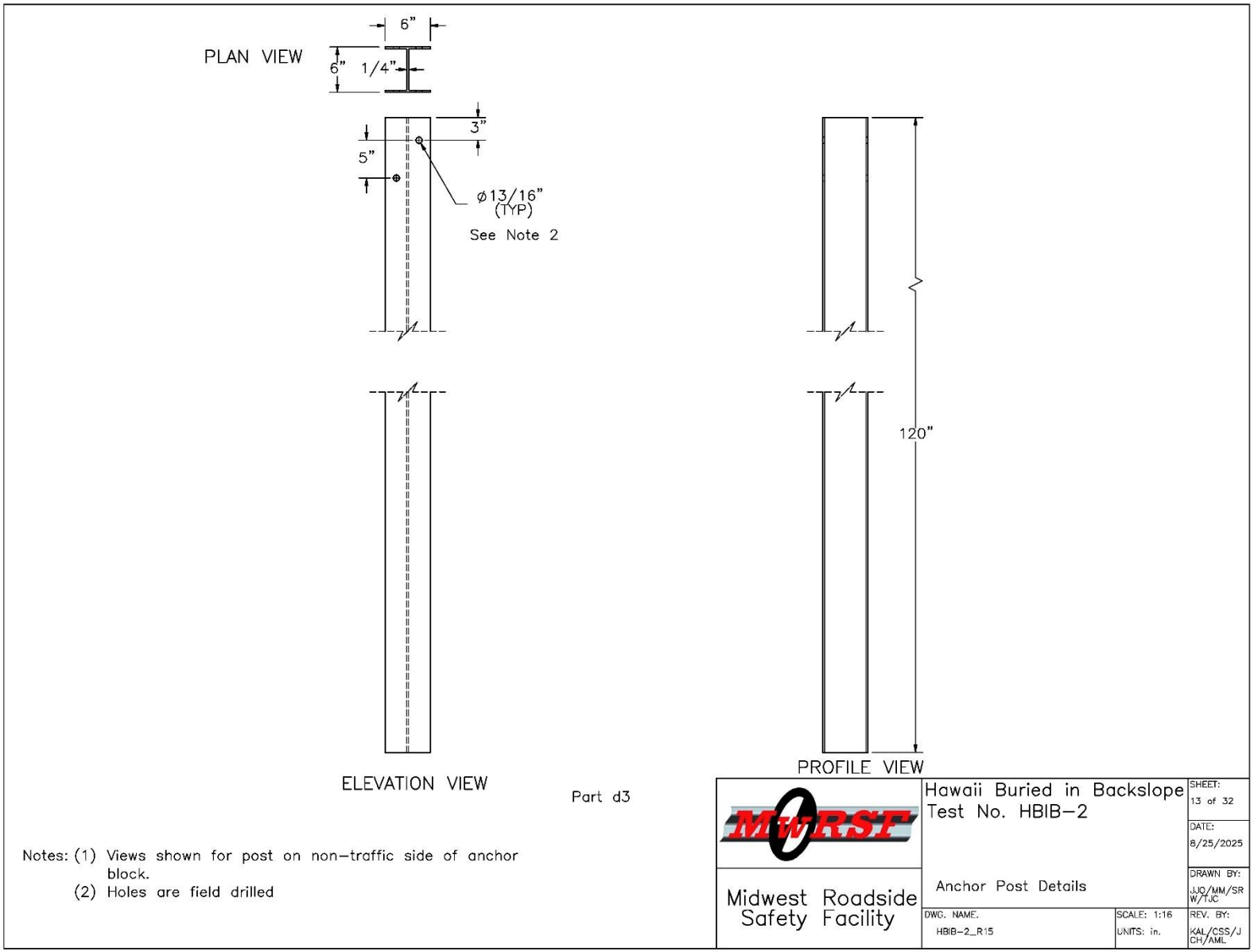


Figure 184. Post Components Details, Test No. HBIB-2

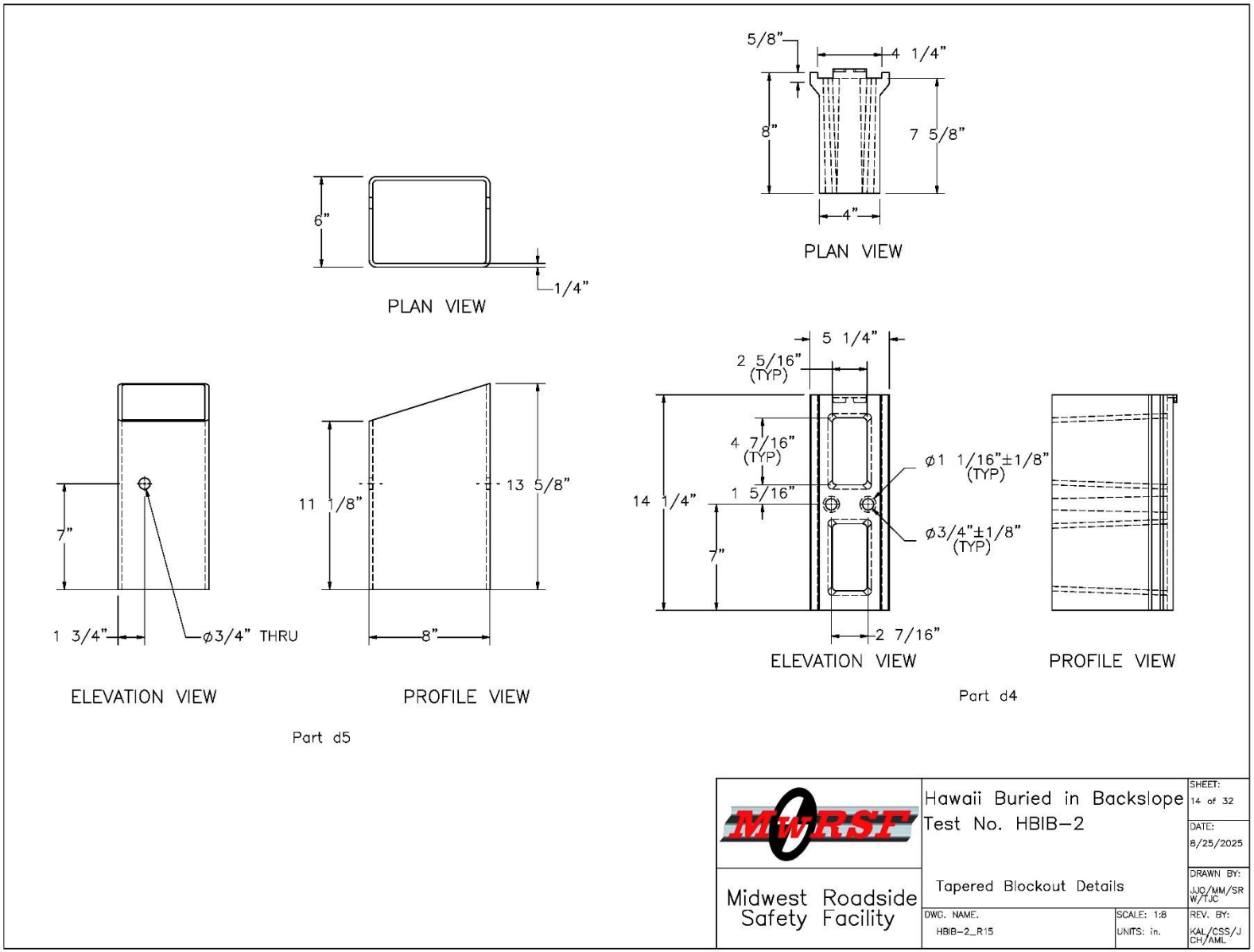


Figure 185. Tapered Blockout Details, Test No. HBIB-2

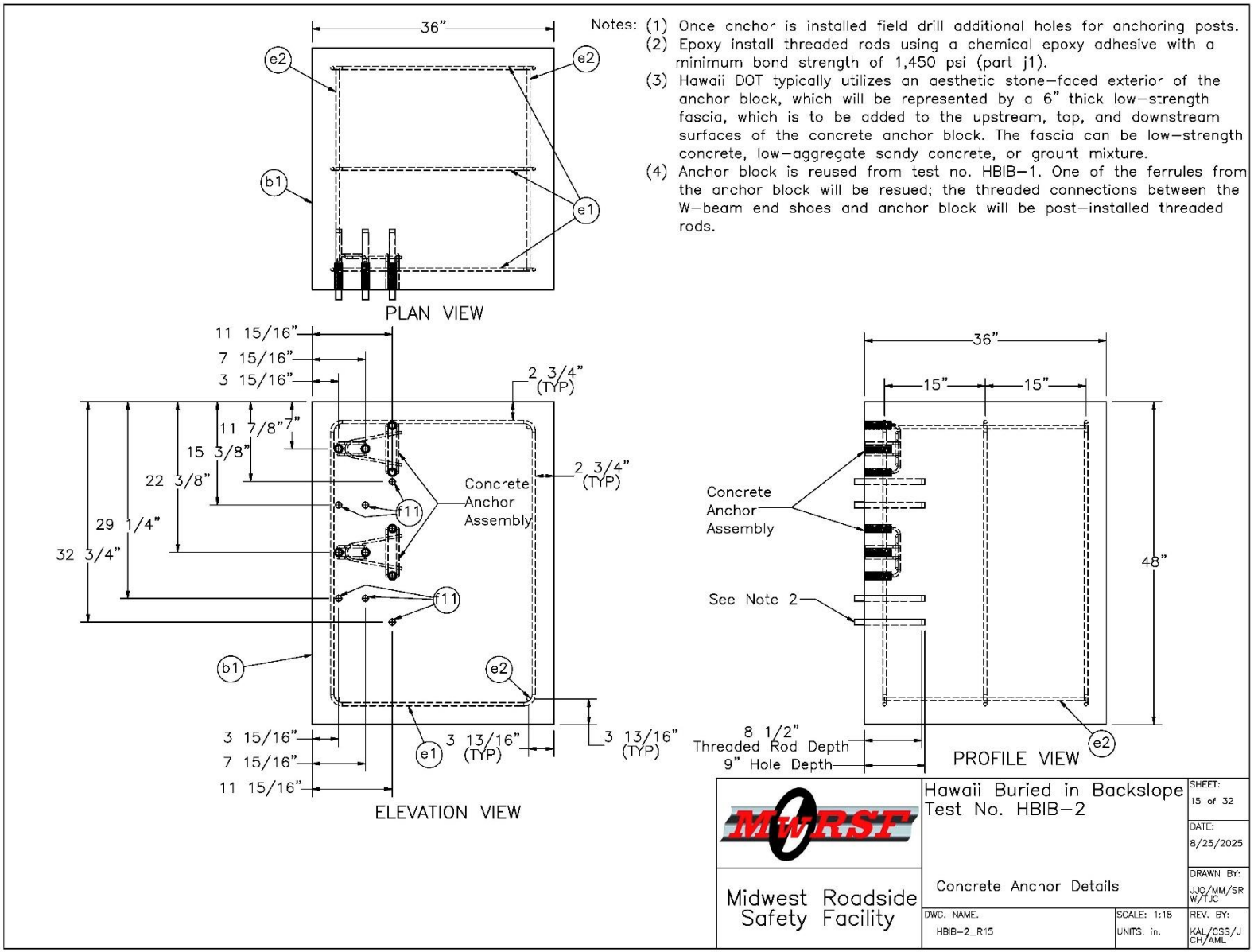
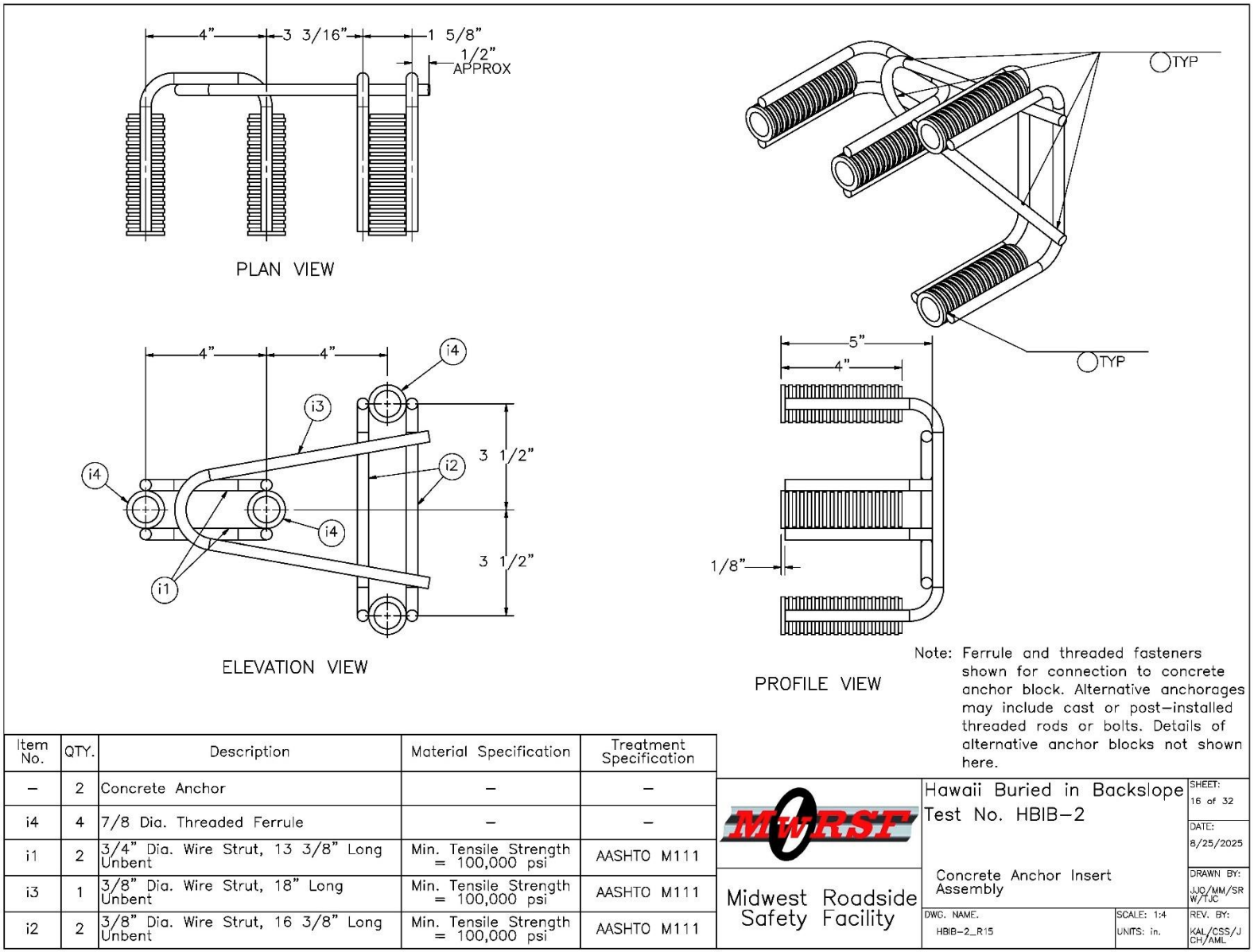


Figure 186. Concrete Anchor Details, Test No. HBIB-2



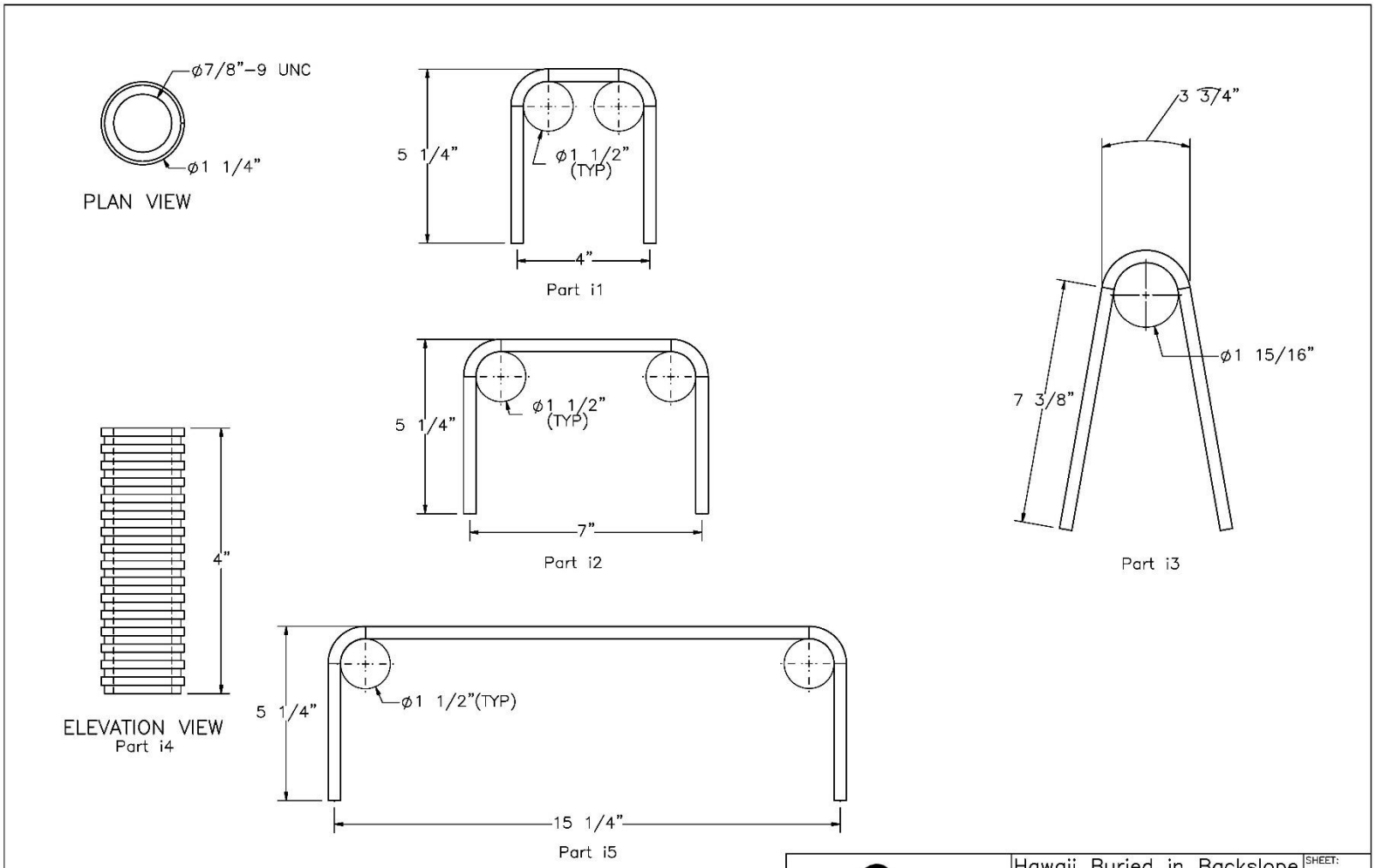
Item No.	QTY.	Description	Material Specification	Treatment Specification
–	2	Concrete Anchor	–	–
i4	4	7/8 Dia. Threaded Ferrule	–	–
i1	2	3/4" Dia. Wire Strut, 13 3/8" Long Unbent	Min. Tensile Strength = 100,000 psi	AASHTO M111
i3	1	3/8" Dia. Wire Strut, 18" Long Unbent	Min. Tensile Strength = 100,000 psi	AASHTO M111
i2	2	3/8" Dia. Wire Strut, 16 3/8" Long Unbent	Min. Tensile Strength = 100,000 psi	AASHTO M111

MwRSF
Midwest Roadside Safety Facility

Hawaii Buried in Backslope
Test No. HBIB-2
Concrete Anchor Insert Assembly

SHEET: 16 of 32
DATE: 8/25/2025
DRAWN BY: JJO/MM/SR W/TJC
REV. BY: KAL/CSS/J CH/AML
DWG. NAME: HBIB-2_R15
SCALE: 1:4
UNITS: in.

Figure 187. Concrete Anchor Insert Details, Test No. HBIB-2



Bill of Bars

Bar	QTY (Per Anchor)	Bar Size	Length	Material	Treatment
i1	2	#3	13 3/8"	Min. Tensile Strength = 100,000 psi	AASHTO M111
i2	2	#3	16 3/8"	Min. Tensile Strength = 100,000 psi	AASHTO M111
i3	1	#3	18"	Min. Tensile Strength = 100,000 psi	AASHTO M111

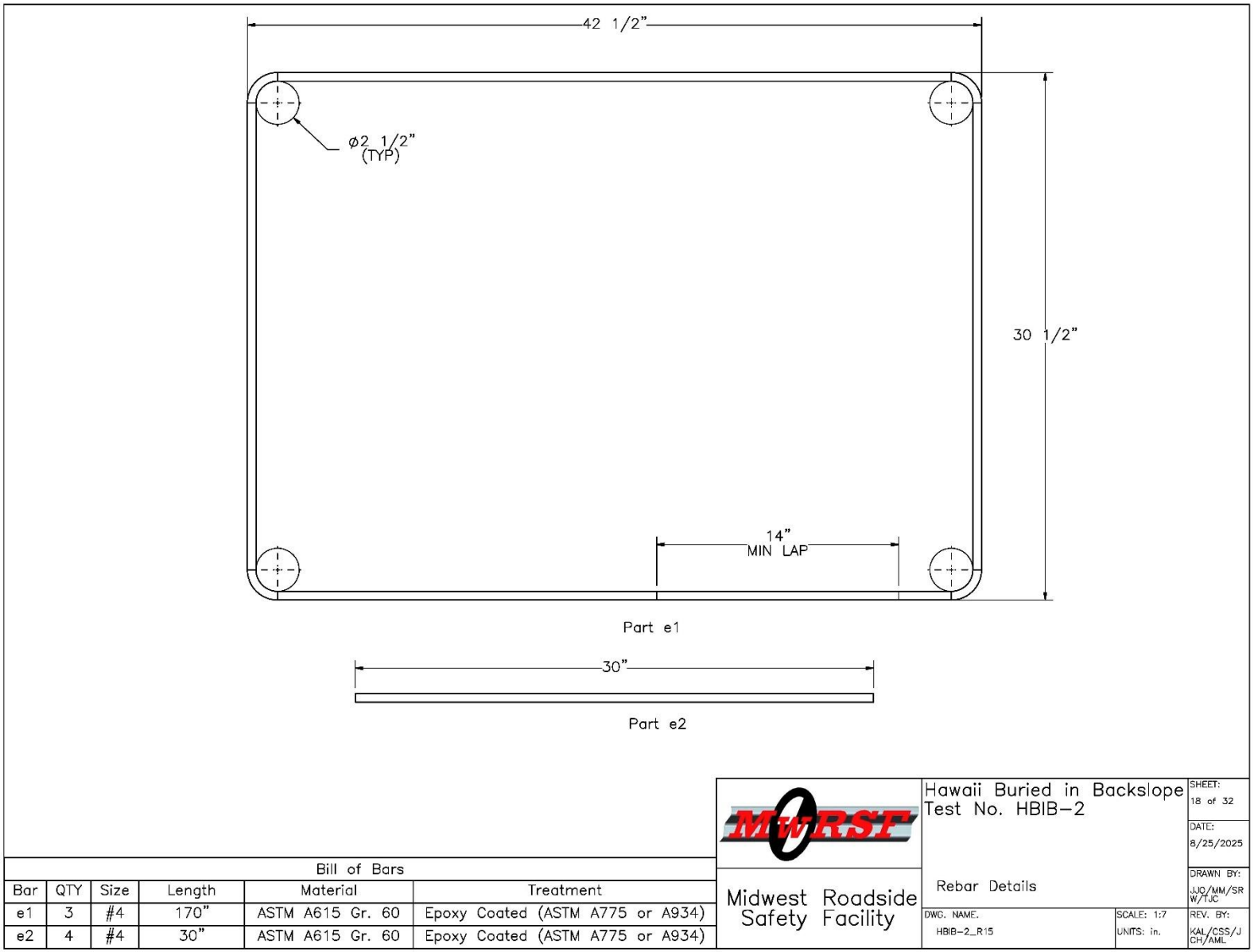
Midwest Roadside Safety Facility

Hawaii Buried in Backslope
Test No. HBIB–2

Insert Component Details

SHEET: 17 of 32
DATE: 8/25/2025
DRAWN BY: JJO/MM/SRW/TJC
REV. BY: KAL/CSS/JCH/AML
DWG. NAME: HBIB–2_R15
SCALE: 1:2
UNITS: in.

Figure 188. Insert Component Details, Test No. HBIB-2



Bill of Bars					
Bar	QTY	Size	Length	Material	Treatment
e1	3	#4	170"	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)
e2	4	#4	30"	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)

Midwest Roadside Safety Facility

Hawaii Buried in Backslope
Test No. HBIB-2

Rebar Details

DWG. NAME: HBIB-2_R15
SCALE: 1:7
UNITS: in.

SHEET: 18 of 32
DATE: 8/25/2025
DRAWN BY: JJO/MM/SR W/TJC
REV. BY: KAL/CSS/J CH/AML

Figure 189. Rebar Details, Test No. HBIB-2

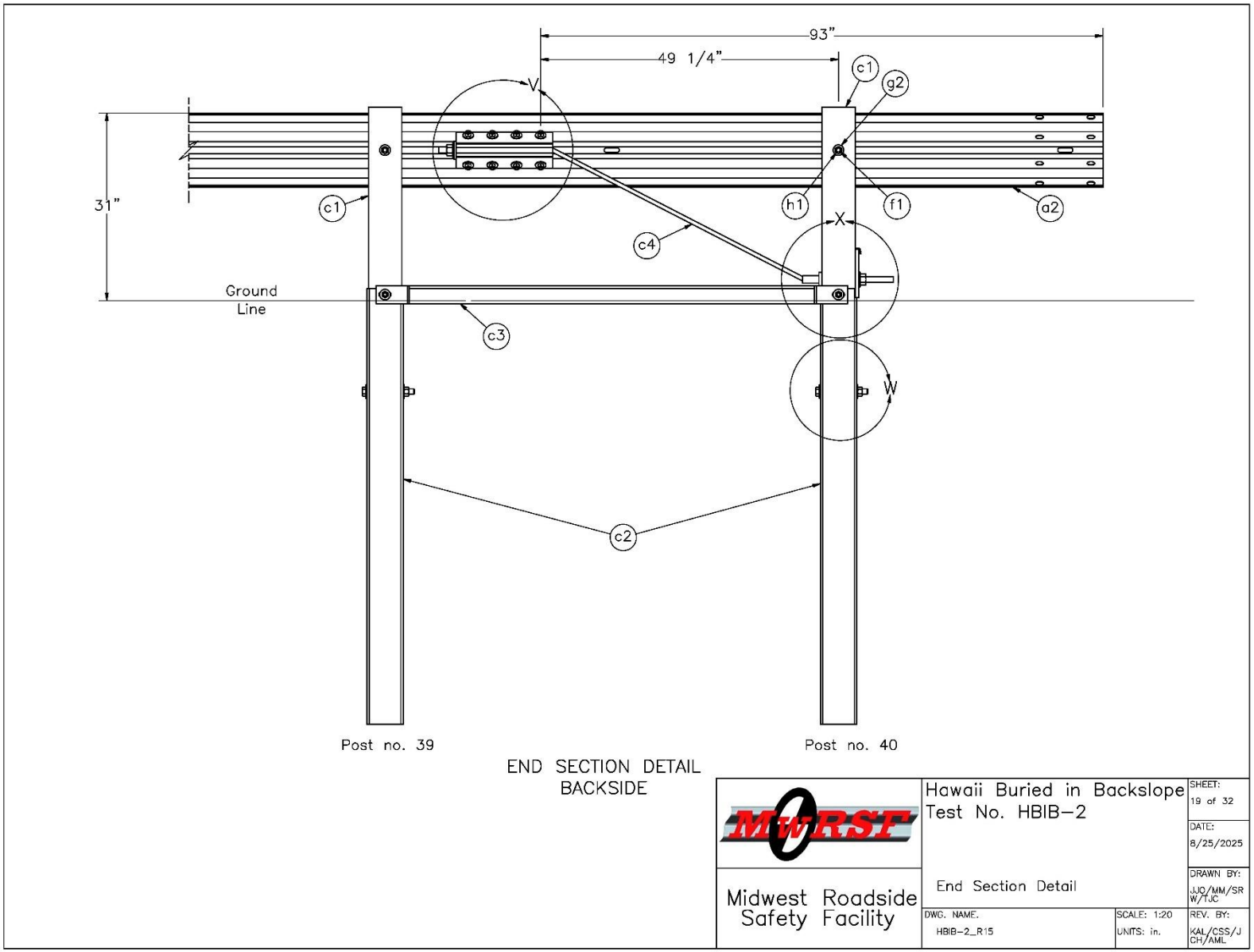


Figure 190. End Section Details, Test No. HBIB-2

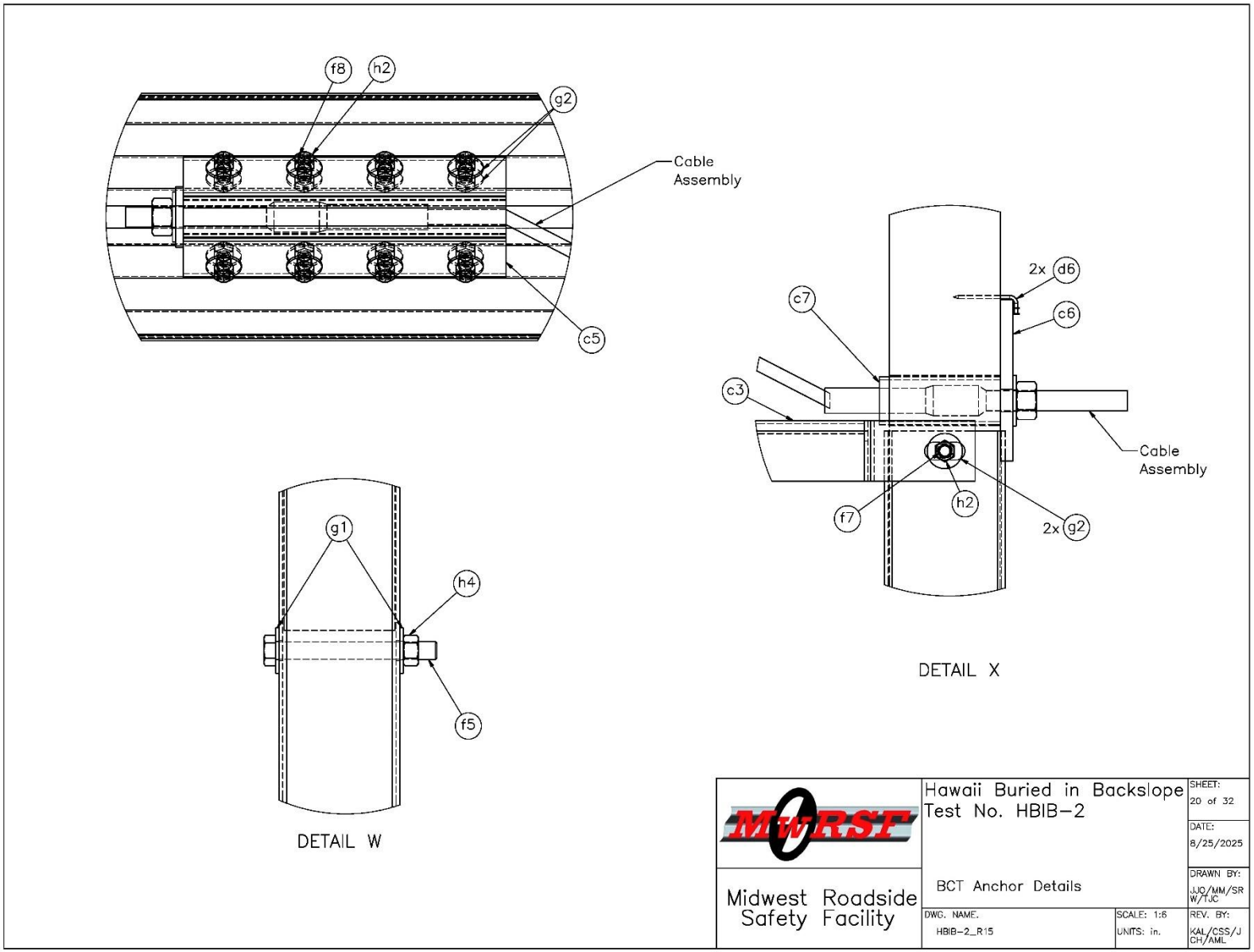


Figure 191. BCT Anchor Details, Test No. HBIB-2

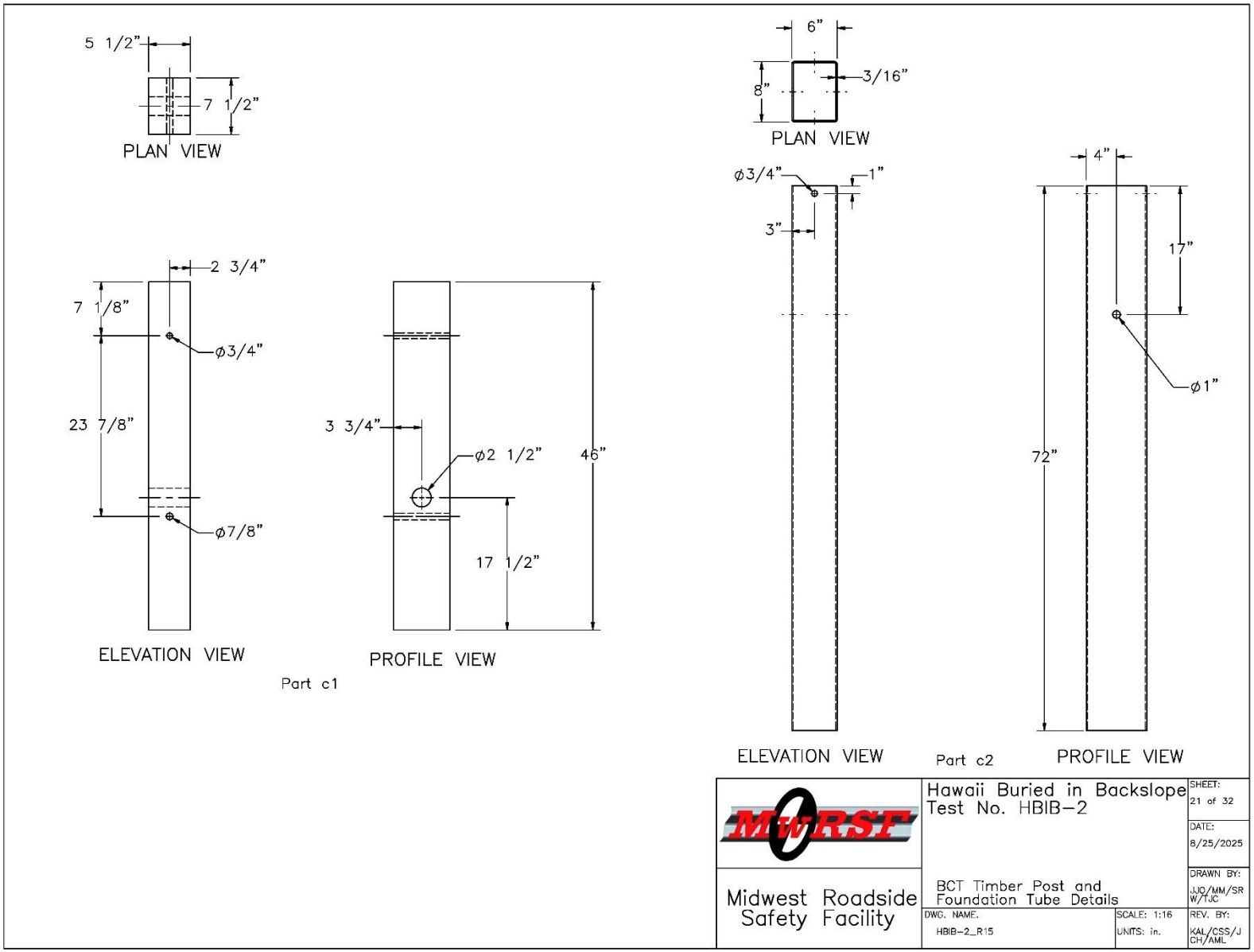


Figure 192. BCT Timber Post and Foundation Tube Details, Test No. HBIB-2

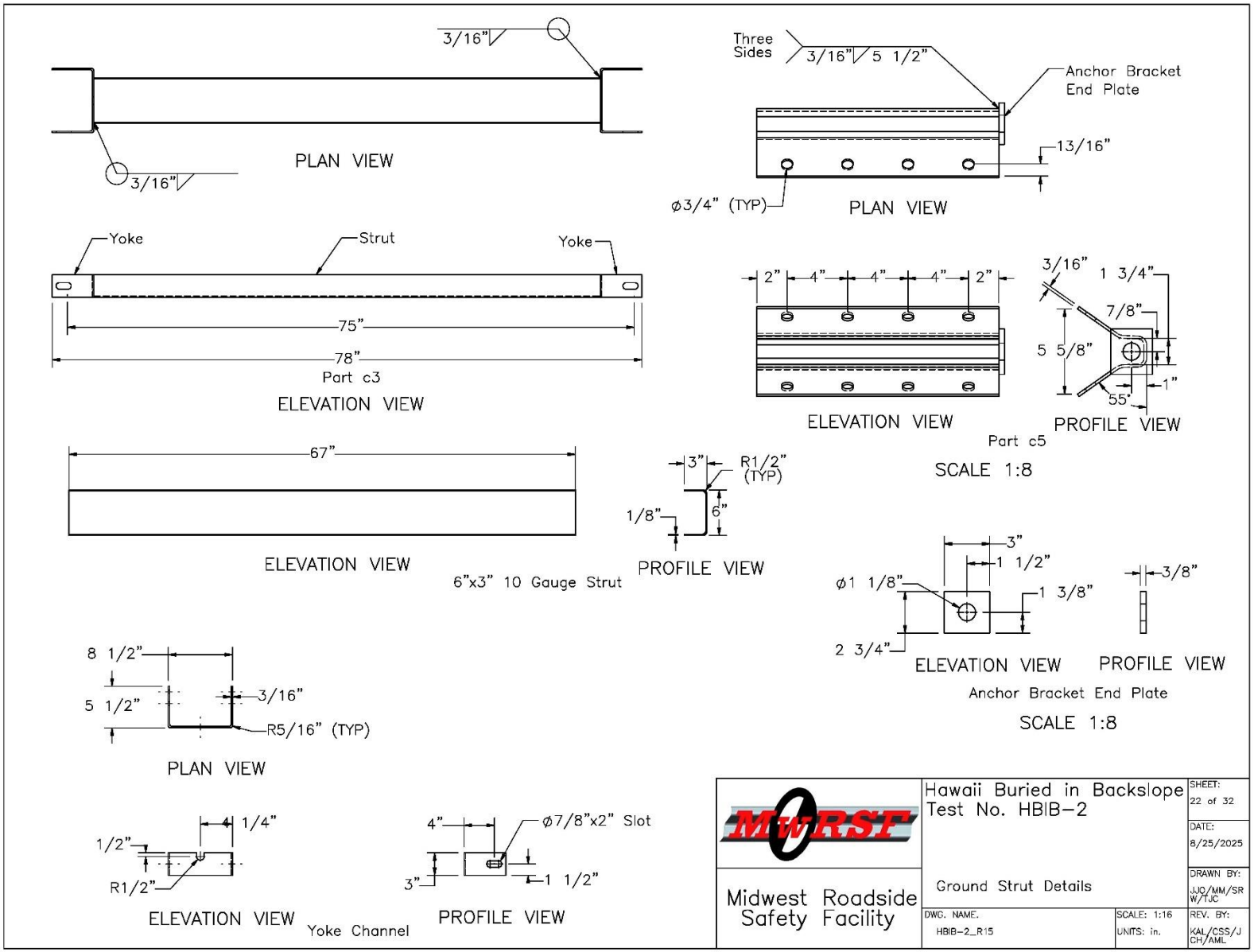


Figure 193. Ground Strut Details, Test No. HBIB-2

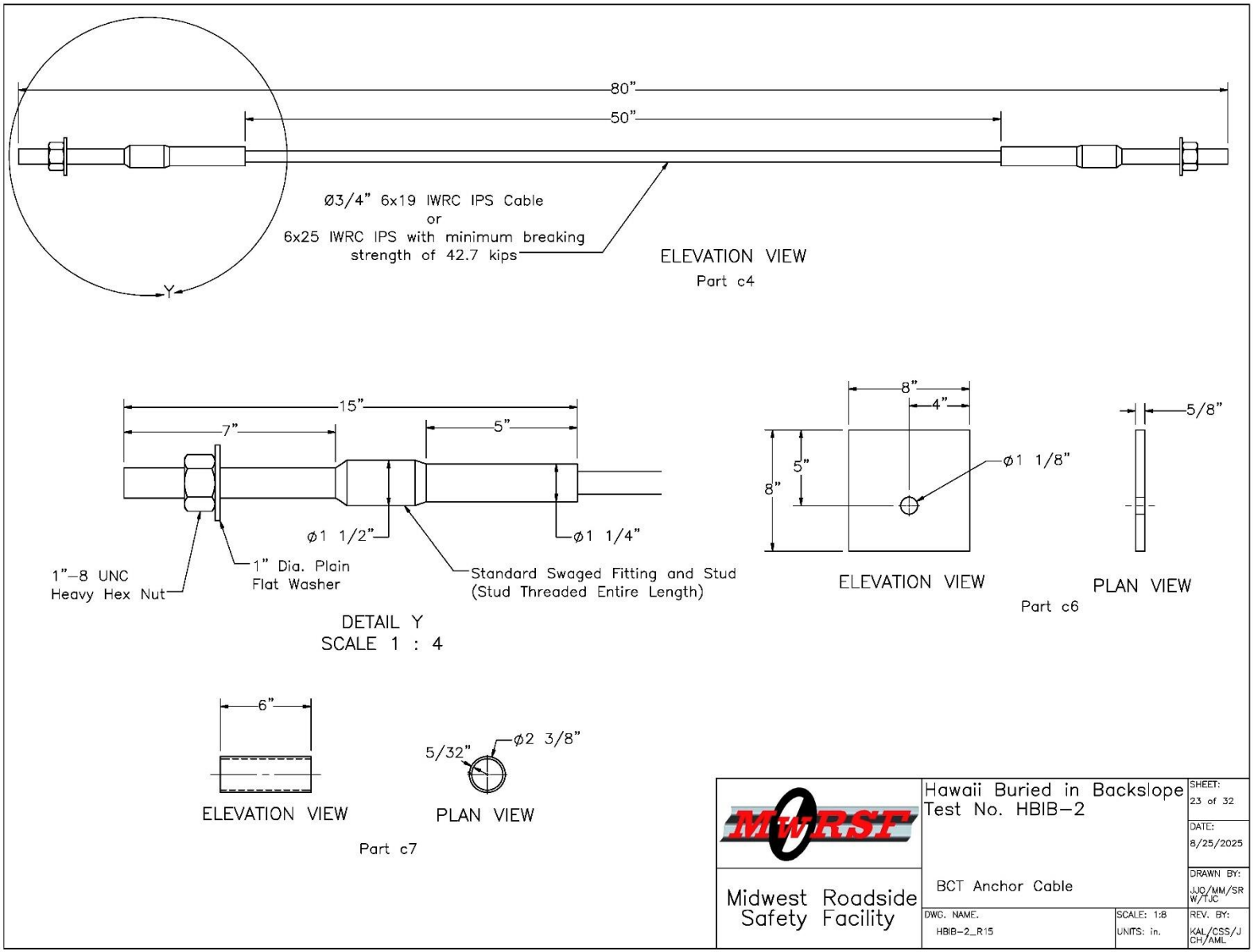


Figure 194. BCT Anchor Cable Details, Test No. HBIB-2

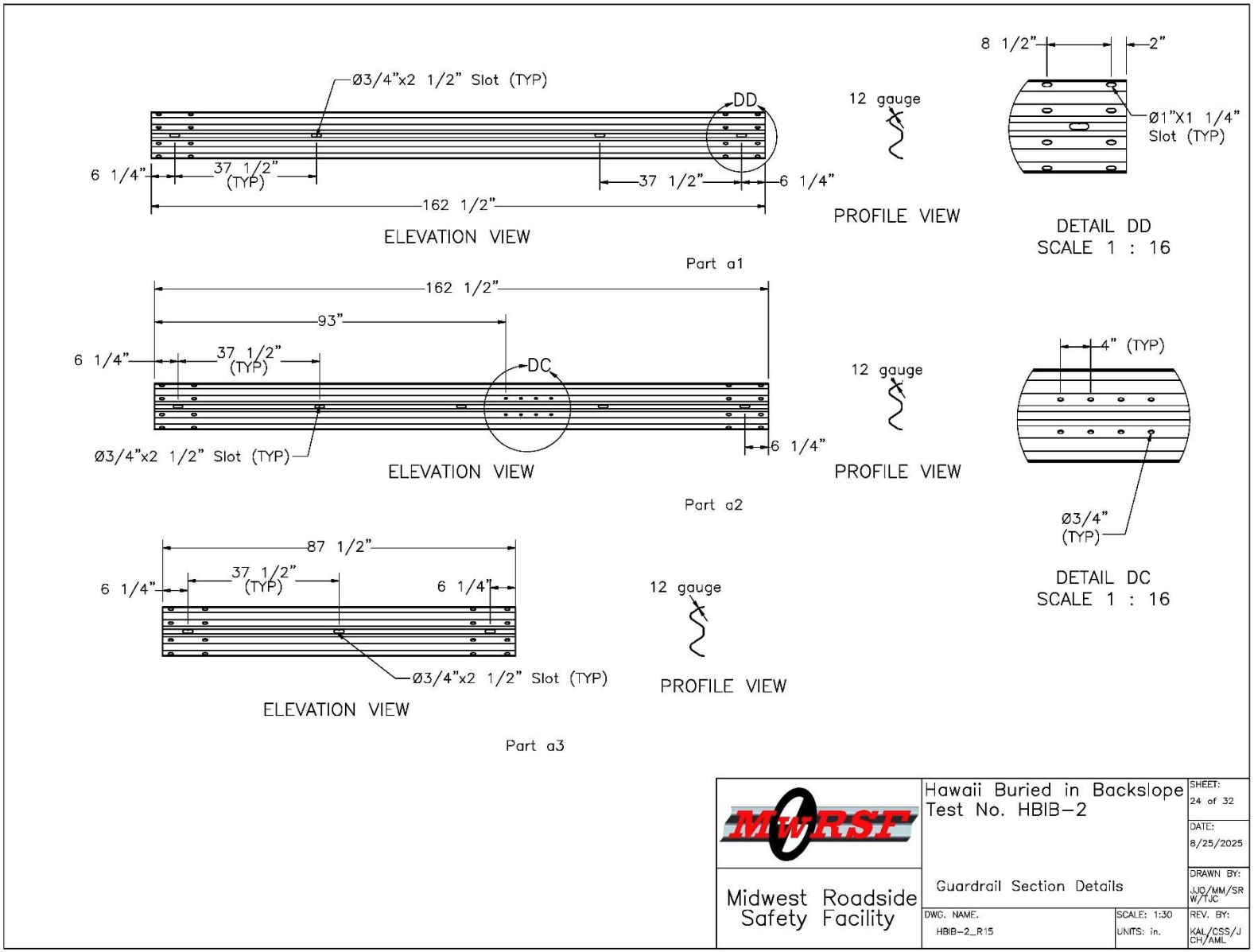


Figure 195. Guardrail Section Details, Test No. HBIB-2

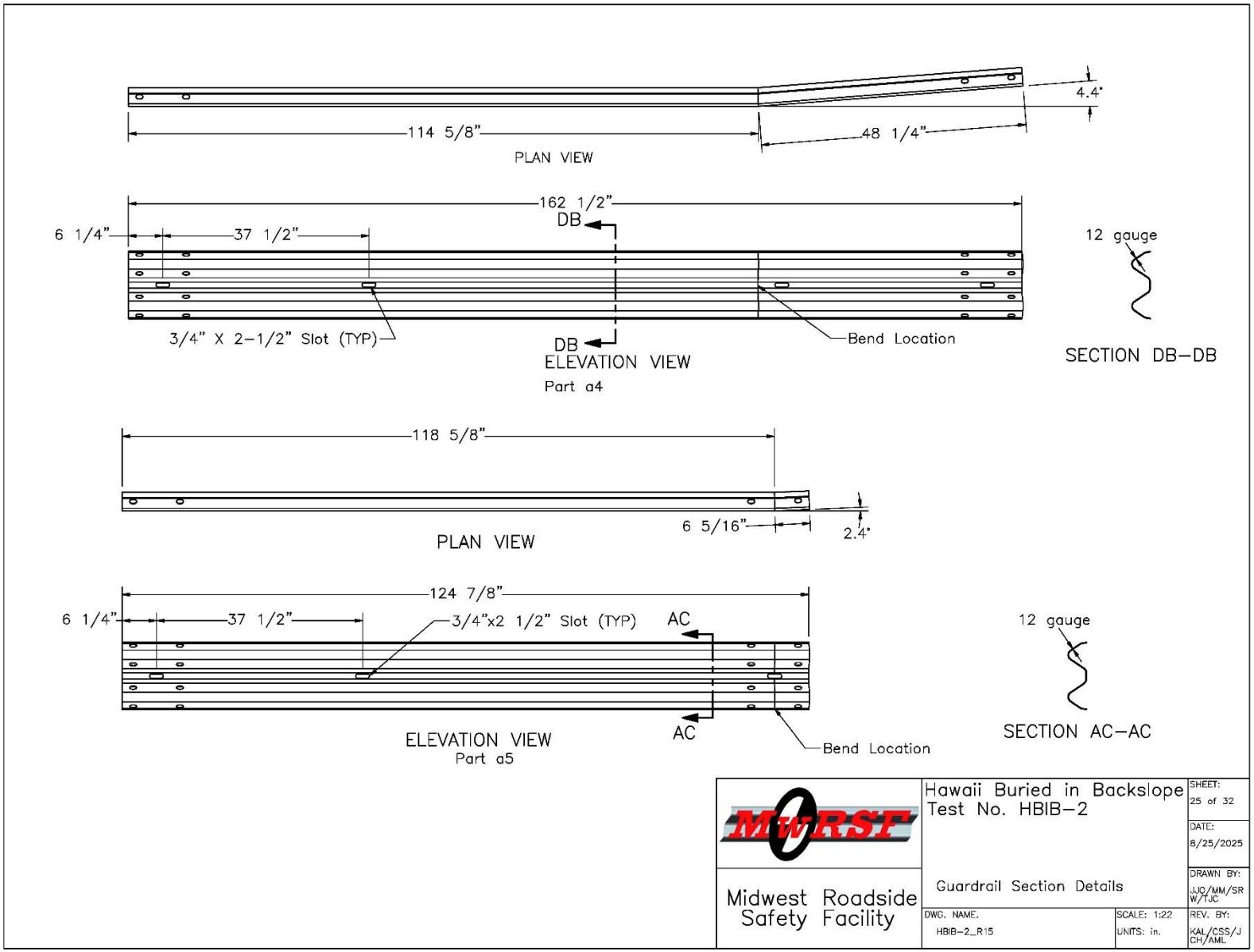


Figure 196. Guardrail Section Details, Test No. HBIB-2

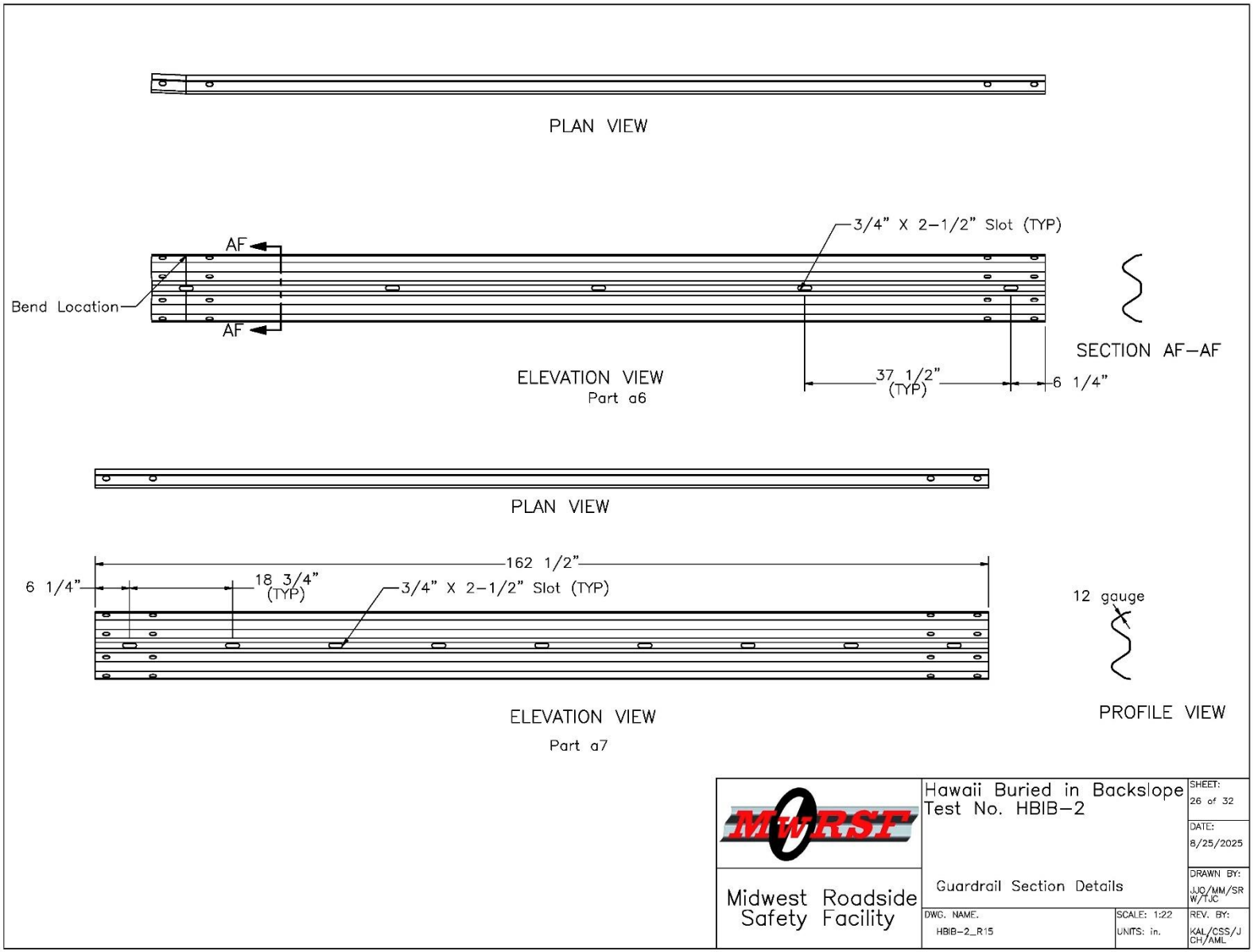


Figure 197. Guardrail Section Details, Test No. HBIB-2

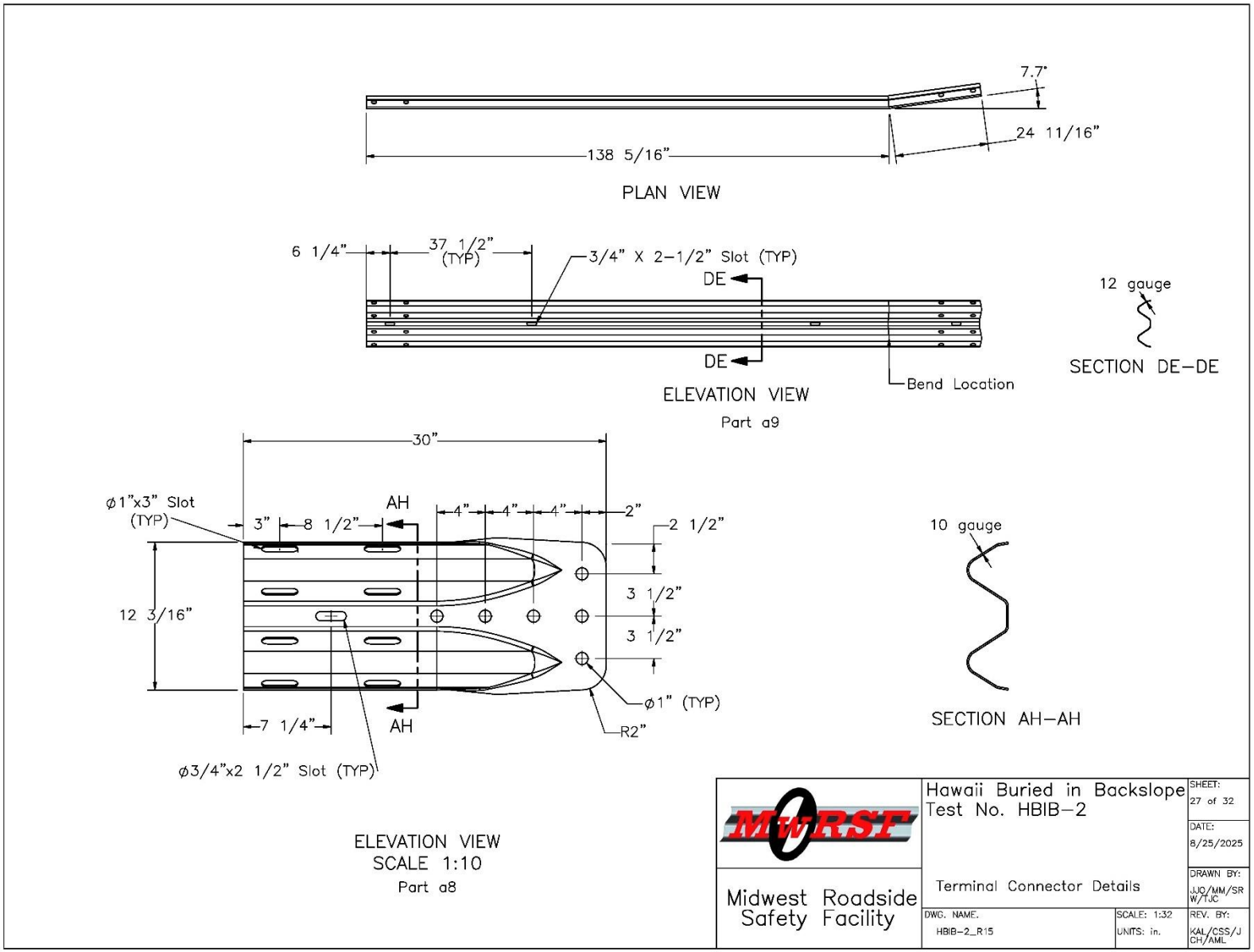


Figure 198. Guardrail End Connector Details, Test No. HBIB-2

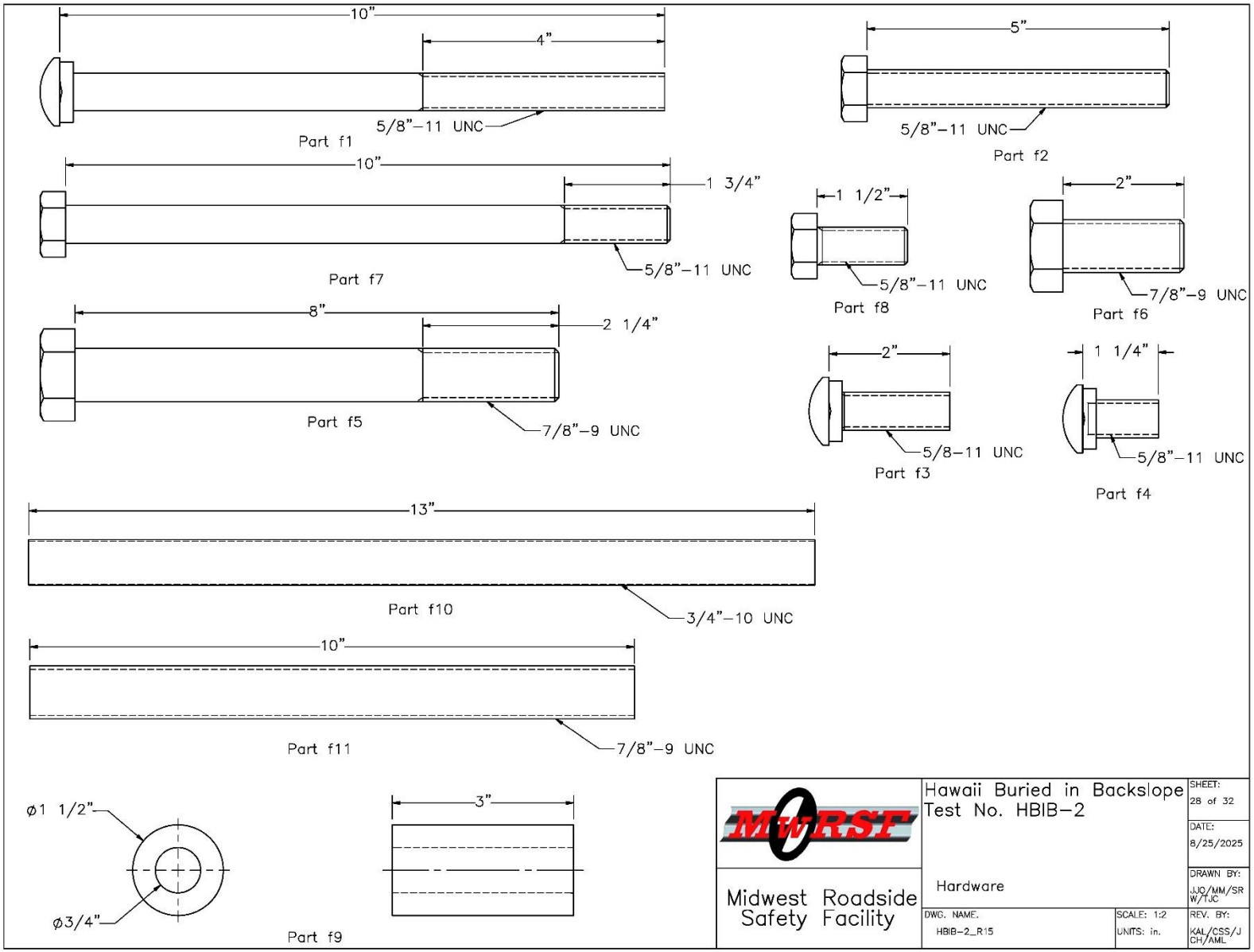


Figure 199. Hardware Details, Test No. HBIB-2

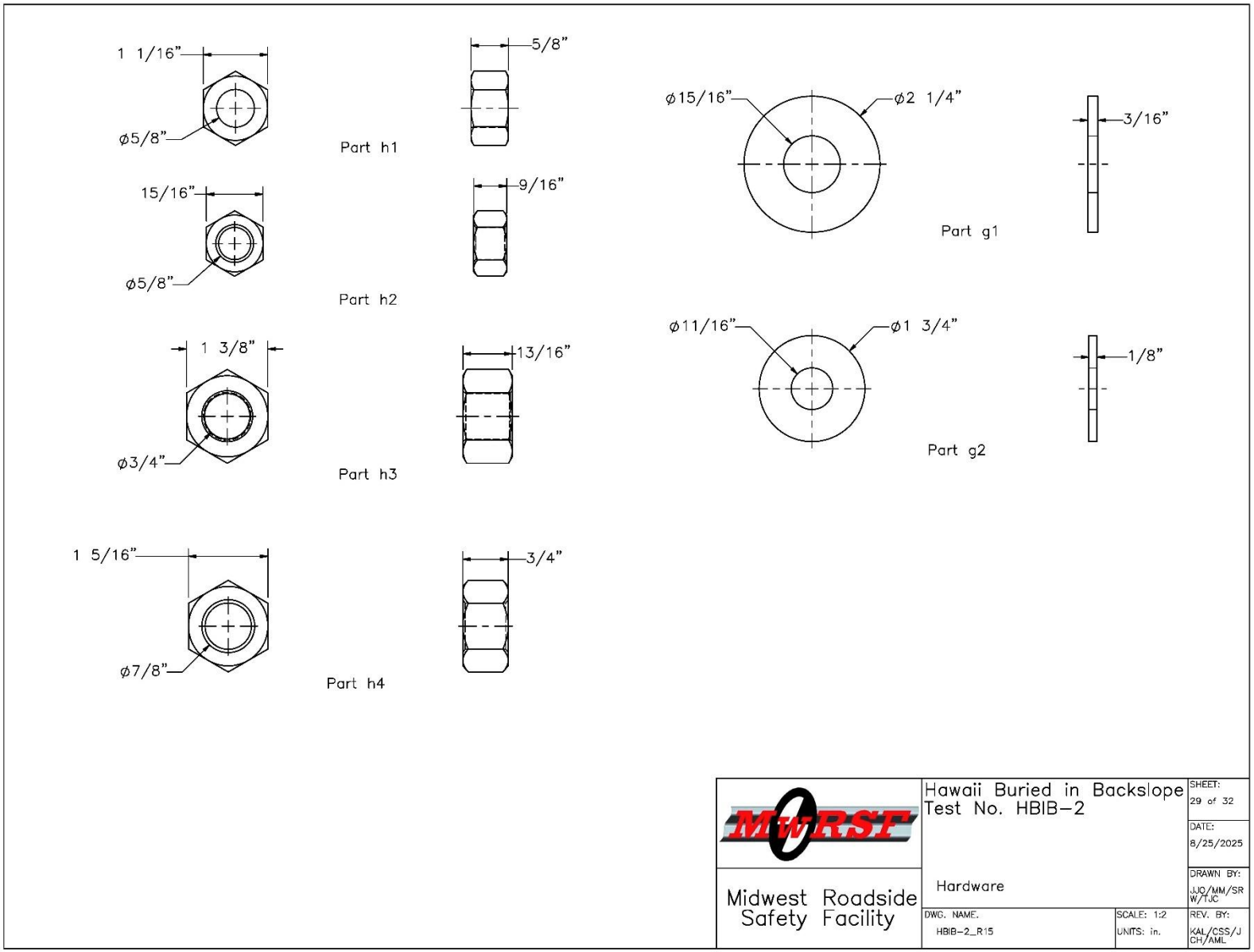


Figure 200. Hardware Details, Test No. HBIB-2

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
a1	20	12'–6" 12–gauge W–Beam MGS Section	AASHTO M180	ASTM A123 or A653	RWM04a
a2	1	12'–6" 12–gauge W–Beam MGS End Section	AASHTO M180	ASTM A123 or A653	RWM14a
a3	1	6'–3" 12–gauge W–Beam Section	AASHTO M180	ASTM A123 or A653	RWM01b
a4	1	12'–6" 12–gauge Bent W–Beam [4.4 deg]	AASHTO M180	ASTM A123 or A653	–
a5	2	9'–4 1/2" 12–gauge Bent W–Beam [2.4 deg]	AASHTO M180	ASTM A123 or A653	–
a6	2	12'–6" 12–gauge Bent W–Beam [2.4 deg]	AASHTO M180	ASTM A123 or A653	–
a7	4	12'–6" 12–gauge W–Beam Section – 1/4 Post Spacing	AASHTO M180	ASTM A123 or A653	RWM04a
a8	2	W–Beam Terminal Connector	AASHTO M180	ASTM A123 or A653	RWE02b
a9	1	12'–6" 12–gauge Bent W–Beam [7.7 deg]	AASHTO M180	ASTM A123 or A653	–
b1	1	3'x3'x3' Concrete Block Anchor	Min. f'c = 4,000 psi	–	–
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	1	BCT Anchor Cable Assembly with Heavy Hex Nuts and Washers	Fitting–ASTM A576 Gr. 1035 Stud–ASTM F568 Class C	Fitting–ASTM A153 Cable,Nut,Wahser & Stud–ASTM A153 or B695	FCA01
c5	1	Ground Anchor Bracket Assembly	ASTM A36	ASTM A123	FPA01
c6	1	8"x8"x5/8" Anchor Bearing Plate	ASTM A36	ASTM A123	FPB01
c7	1	2 3/8" O.D. 6" Long BCT Post Sleeve	ASTM A53 Gr. B Schedule 40	ASTM A123	FMM02

Midwest Roadside Safety Facility

Hawaii Buried in Backslope
Test No. HBIB–2
Bill of Materials

SHEET: 30 of 32
DATE: 8/25/2025
DRAWN BY: JJO/MM/SRW/TJC
REV. BY: KAL/CSS/JCH/AML
DWG. NAME: HBIB–2_R15
SCALE: None
UNITS: in.

Figure 201. Bill of Materials, Test No. HBIB-2

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
d1	27	W6x8.5 or W6x9, 84" Long Steel Post	ASTM A992 Gr. 50	ASTM A123	PWE06
d2	11	W6x8.5 or W6x9, 72" Long Steel Post	ASTM A992 Gr. 50	ASTM A123	PWE06
d3	3	W6x15, 120" Long Steel Post	ASTM A992 Gr. 50	ASTM A123	–
d4	38	14 3/16"x8"x5 1/8" Composite Recycled Blockout	Mondo Polymer GB14SH2 or Equivalent	–	–
d5	27	13 5/8" [346] Long, 8"x6"x1/4" [203x152x6] Steel Blockout	ASTM A500 Gr. B	ASTM A123	–
d6	2	16D Double Head Nail	–	–	–
e1	3	170" Unbent Length #4 Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
e2	4	30" Long #4 Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
f1	67	5/8" Dia. UNC, 10" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBB03
f2	1	5/8" Dia. UNC, 5" Long Hex Head Bolt	ASTM A449 Gr. 5 or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f3	1	5/8" Dia. UNC, 2" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBB01
f4	240	5/8" Dia. UNC, 1 1/4" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBB01
f5	2	7/8" Dia. UNC, 8" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX22a
f6	2	7/8" Dia. UNC, 2" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX22a
f7	2	5/8" Dia. UNC, 10" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f8	8	5/8" Dia. UNC, 1 1/2" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f9	1	3/4" Dia, Unthreaded Spacer Sleeve	ASTM A53 Gr. B	ASTM A123	FMM03–04
f10	6	3/4" Dia. UNC, 13" Long Fully Threaded Rod	ASTM A193 Gr. B7	ASTM A153 of B695 Class 55 or F2329	–
f11	6	7/8" Dia. UNC, 10" Long Fully Threaded Rod	ASTM A307 Gr. A or equivalent	ASTM A153 of B695 Class 55 or F2329	–

Midwest Roadside Safety Facility

Hawaii Buried in Backslope
Test No. HBIB–2

Bill of Materials

SHEET: 31 of 32
DATE: 8/25/2025
DRAWN BY: JJO/MM/SRW/TJC
REV. BY: KAL/CSS/JCH/AML
DWG. NAME: HBIB–2_R15
SCALE: None
UNITS: in.

Figure 202. Bill of Materials, Test No. HBIB-2

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
g1	4	7/8" Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC20a
g2	22	5/8" Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC16a
h1	309	5/8" Dia. UNC Heavy Hex Nut	ASTM A563A or equivalent	ASTM A153 (AASHTO M232) for Class C or ASTM B695 (AASHTO M298) for Class 50	FNX16b
h2	10	5/8" Dia. UNC Hex Nut	ASTM A563A	ASTM A153 (AASHTO M232) for Class C or ASTM B695 (AASHTO M298) for Class 50	FNX16a
h3	6	3/4" Dia. UNC Heavy Hex Nut	ASTM A563DH or equivalent	ASMT A153 or B695 Class 55 or F2329	FNX20b
h4	8	7/8" Dia. UNC Hex Nut	ASTM A563A or equivalent	ASTM A153 (AASHTO M232) for Class C or ASTM B695 (AASHTO M298) for Class 50	–
i1	4	3/4" Dia. Wire Strut, 13 3/8" Long Unbent	Min. Tensile Strength = 100,000 psi	AASHTO M111	
i2	4	3/8" Dia. Wire Strut, 16 3/8" Long Unbent	Min. Tensile Strength = 100,000 psi	AASHTO M111	–
i3	2	3/8" Dia. Wire Strut, 18" Long Unbent	Min. Tensile Strength = 100,000 psi	AASHTO M111	–
i4	8	7/8 Dia. Threaded Ferrule	–	–	–
j1	–	Epoxy Adhesive	Min. Bond Strength = 1,450 psi	–	–
k1	–	Soil	–	–	–

Midwest Roadside Safety Facility	Hawaii Buried in Backslope Test No. HBIB–2 Bill of Materials	SHEET: 32 of 32 DATE: 8/25/2025 DRAWN BY: JJO/MM/SRW/TJC REV. BY: KAL/CSS/JCH/AML
	DWG. NAME: HBIB–2_R15	SCALE: 1:768 UNITS: in.

Figure 203. Bill of Materials, Test No. HBIB-2





Figure 204. Test Installation Photographs, Test No. HBIB-2

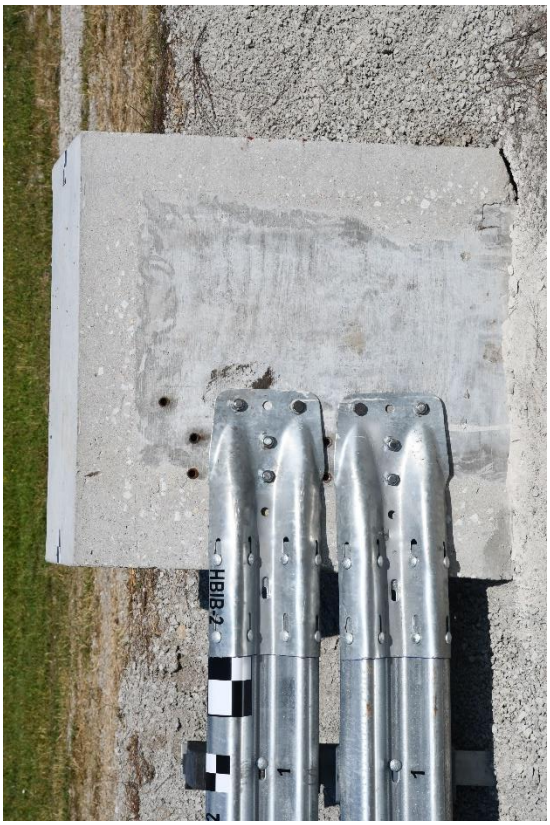








Figure 205. Test Installation Photographs, Test No. HBIB-2

9 FULL-SCALE CRASH TEST NO. HBIB-2

9.1 Static Soil Test

Before full-scale crash test no. HBIB-2 was conducted, the strength of the foundation soil was evaluated with a static test, as described in MASH. The static test results, as shown in Appendix E, 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.

9.2 Weather Conditions

Test no. HBIB-2 was conducted on September 13, 2023, at approximately 1:45 p.m. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/KLNK) were reported and are shown in Table 11.

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

Temperature	78°F
Humidity	33%
Wind Speed	14 mph
Wind Direction	170° from True North
Sky Conditions	Partly cloudy
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.05 in.
Previous 7-Day Precipitation	0.24 in.

9.3 Test Description

Due to the failure of test no. HBIB-1, MASH test designation no. 3-32 was rerun on the modified system as test no. HBIB-2. Similar to test no. HBIB-1, initial vehicle impact was to occur 12 in. downstream from the downstream end of the concrete anchor block, as shown in Figure 206. For the non-gating, re-directive HBIB system, the critical impact angle and velocity were selected to maximize the lateral load on the system, the risk that the test vehicle will gate through the system, and the occupant risk measures.

In test no. HBIB-2, a 2,462-lb passenger car impacted the slope of the HBIB system at a speed of 61.7 mph and at an angle of 15.0 degrees. The actual point of impact on the system was 9.9 in. downstream from the downstream end of the concrete anchor block. After brakes were applied, the vehicle came to rest at 291.2 ft downstream and 154.1 ft laterally in front of the system impact point.

A detailed description of the sequential impact events is reported in Table 12. Sequential photographs are shown in Figures 207 and 208. Documentary photographs of the crash test are shown in Figure 209. The vehicle trajectory and final position are shown in Figure 210.







Figure 206. Impact Location and Test Vehicle, Test No. HBIB-2

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

TIME (sec)	EVENT
-0.426	Vehicle's right-front tire crossed slope break point.
-0.360	Vehicle pitched downward.
-0.294	Vehicle rolled toward system. Vehicle's right-front tire airborne.
-0.176	Vehicle's right-front tire contacted ground.
-0.026	Vehicle rolled away from system.
0.000	Vehicle's front bumper, right fender, and headlight contacted barrier and deformed.
0.017	Vehicle's hood contacted barrier and crushed. Vehicle yawed away from system.
0.024	Vehicle's right-front door and right mirror contacted barrier. Mirror disengaged and door was dented.
0.024	Post nos. 1, 2, 3, 4, and 5 deflected backward. Vehicle's right-front door contacted barrier and was dented. Vehicle's windshield cracked.
0.034	Vehicle's roof deformed.
0.067	Occupant's head contacted right-front window, which shattered.
0.098	Vehicle rolled toward system.
0.126	Vehicle was parallel to system at a speed of 45.6 mph.
0.137	Vehicles' left headlight disengaged. Vehicle pitched upward.
0.176	Vehicles' right-rear door and right quarter panel contacted barrier and was severely dented. Vehicles' right taillight contacted barrier and shattered.
0.182	Vehicles' rear bumper contacted barrier and deformed.
0.193	Post no. 6 deflected backward. Vehicle's front bumper disengaged.
0.256	Vehicle exited system at a speed of 42.2 mph and an angle of 11.2 degrees.
0.416	Vehicle rolled away from system.
0.434	Vehicle pitched downward.
9.518	Vehicle came to rest.


-0.426 sec


0.000 sec


0.000 sec


0.100 sec


0.200 sec


0.200 sec


0.400 sec


0.300 sec


0.600 sec


0.400 sec

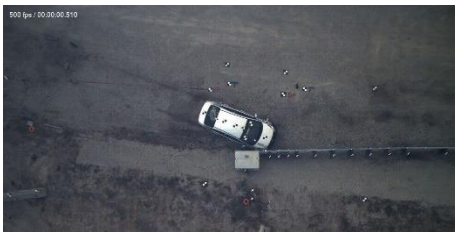

0.800 sec


0.500 sec

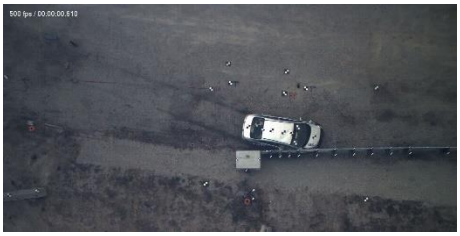
Figure 207. Sequential Photographs, Test No. HBIB-2


-0.426 sec

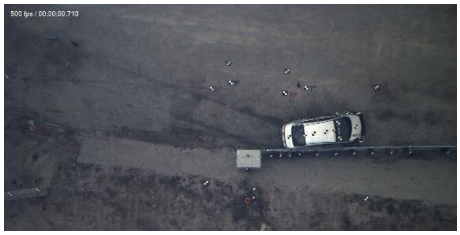

-0.426 sec


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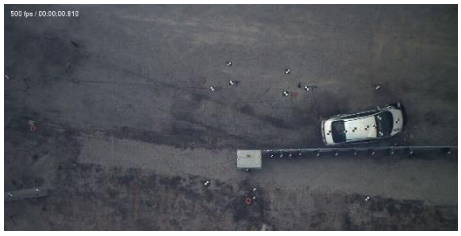

0.000 sec


0.100 sec


0.100 sec


0.200 sec


0.200 sec


0.300 sec


0.300 sec


0.400 sec


0.400 sec

Figure 208. Sequential Photographs, Test No. HBIB-2



Figure 209. Documentary Photographs, Test No. HBIB-2



Figure 210. Vehicle Final Position and Trajectory Marks, Test No. HBIB-2

9.4 Barrier Damage

The damage to the barrier was minimal, as shown in Figures 211 through 213. The posts were undamaged with negligible deflections; all damage to the barrier was along the rails of the system. The length of the vehicle's primary contact with the system started 27 in. upstream from post no. 1 and extended 155 in. downstream. The primary contact consisted of several individual contact marks on the front face of the rail. A contact mark was recorded 20 in. upstream of post no. 1 on the bottom flange of the rubrail and extended 10 ft - 2 in. downstream. The other contact mark on the rubrail's bottom flange was observed 14.5 in. upstream from post no. 6 and extended 8 in. downstream. A contact mark was recorded on the upper flange of the rubrail 27 in. upstream from post no. 1 and extended 125 in. downstream. Two contact marks were recorded on the upper rail. One mark started 21 in. upstream from post no. 1 and extended 139 in. downstream along the bottom flange of the upper rail. The second contact mark on the upper rail was observed 10.5 in. upstream from post no. 1 and extended 131 in. downstream.

Denting occurred on the lower flange of the rubrail at 11 in. and 5 in. downstream of post no. 1, and extended 6 in. and 5 in. downstream of the rubrail, respectively. Denting along the upper flange of the rubrail was recorded at 2 in. and 4 in. downstream from post nos. 1 and 4, respectively. The overall length of these contact marks was 3 in. and 42 in., respectively.

The maximum lateral permanent set of the system was 0.6 in., which occurred at the rail between post nos. 4 and 5, as measured in the field. The maximum lateral dynamic barrier deflection was 3.7 in. at the rail between post nos. 4 and 5, as determined from high-speed digital video analysis. The working width of the system was found to be 20.3 in., also determined from high-speed digital video analysis. A schematic of the permanent set, dynamic deflection, and working width is shown in Figure 214.

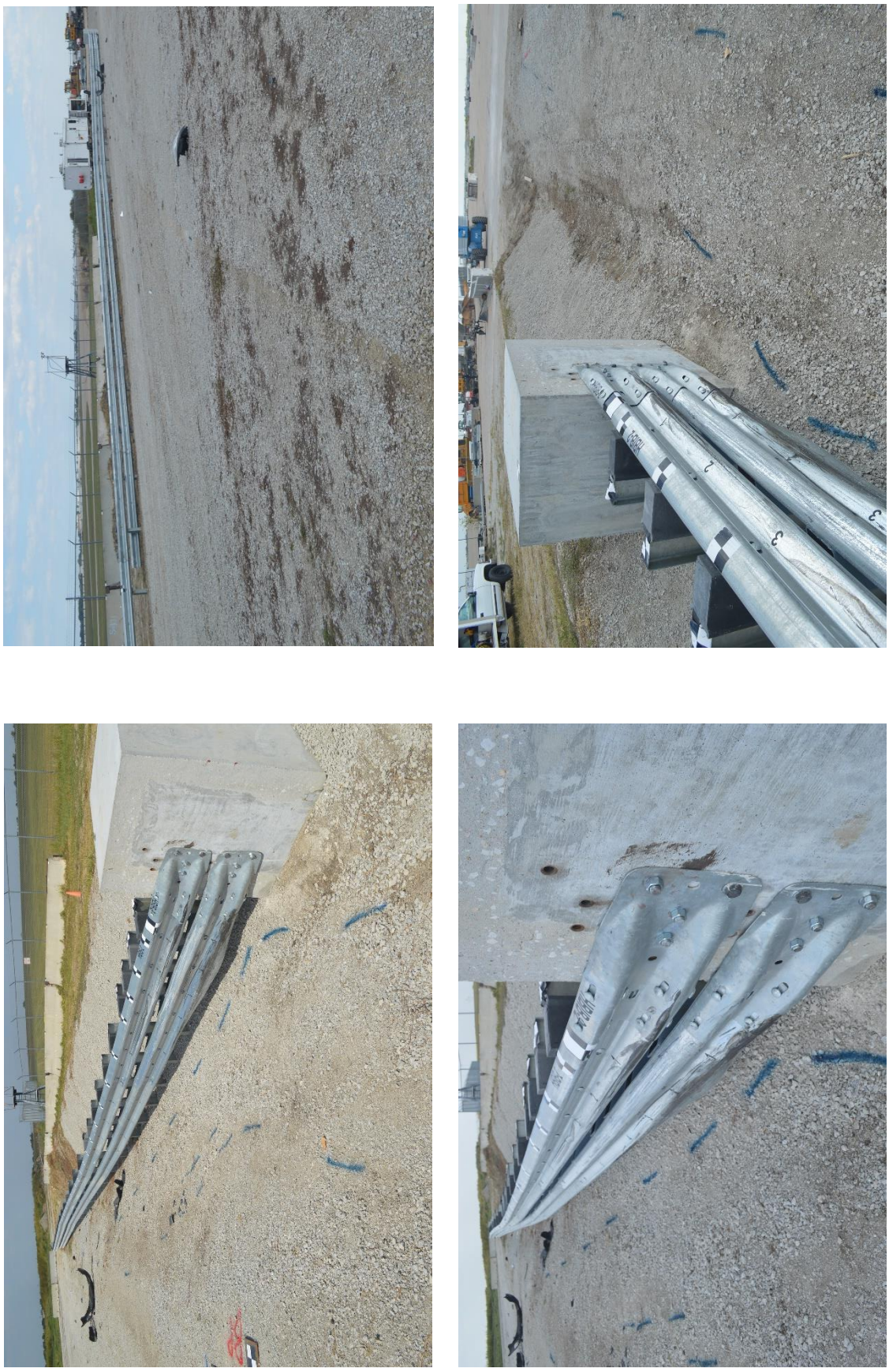


Figure 211. Overall System Damage, Test No. HBIB-2



Figure 212. Upper Rail and Rubrail Damage, Test No. HBIB-2



Figure 213. Rail Connection Terminal and Buttress and Post Damage, Test No. HBIB-2

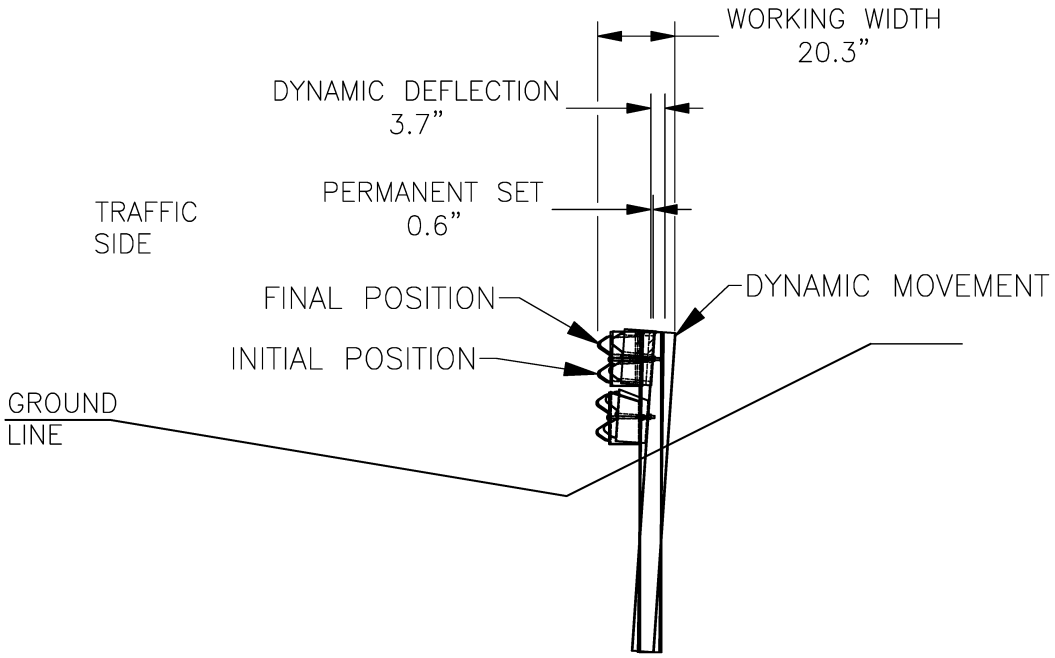


Figure 214. Permanent Set Deflection, Dynamic Deflection, and Working Width, Test No. HBIB-2

9.5 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 215 through 217. The majority of the damage was concentrated on the right-front corner and right side of the vehicle where the impact occurred. The windshield suffered severe damage, being severely crushed along its right side. The bottom-right corner of the windshield sustained the most damage due to crush by the vehicle's hood. The right side of the vehicle's hood was crushed, creating a kink along the left-rear side of the hood. Scraping and crushing were recorded on the right-side doors, front fender, rear quarter panel, and along the right end of the rear bumper cover. The front bumper cover was disengaged. The right headlight was crushed and shattered, and the left headlight disengaged from the vehicle during impact. The right-side mirror disengaged, and the right-front side window shattered due to contact with the surrogate occupant's head. Ripple dents occurred throughout the roof of the vehicle.

Undercarriage damage was minimal. The right control arm was bent near its center point. The outer tie rod on the right side of the vehicle bent slightly. The right-front lower strut was bent inward at the knuckle, and the lower bumper brackets were bent rearward on both horns. The transmission pan was cracked at the lower leading edge, and the oil pan was slightly scraped.

Maximum occupant compartment intrusions are listed in Table 13, along with the intrusion limits established in MASH for various areas of the occupant compartment. Complete occupant compartment, vehicle intrusions, and the corresponding locations of the deformations are provided in Appendix F. MASH defines intrusion as the occupant compartment being deformed and reduced in size with no penetration. Outward deformations, which are denoted as negative numbers in Appendix F, are not considered as crush toward the occupant, and are not subject to evaluation by MASH criteria.









Figure 215. Vehicle Damage, Test No. HBIB-2









Figure 216. Vehicle Damage, Test No. HBIB-2



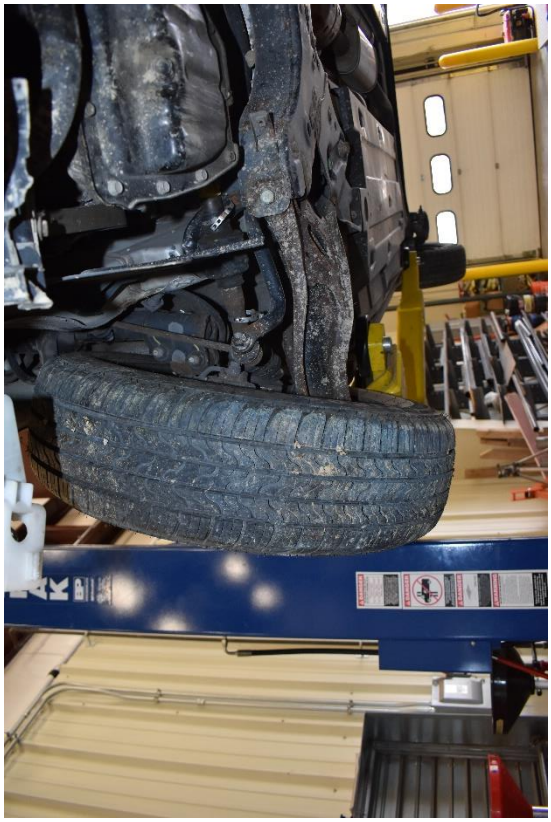






Figure 217. Vehicle Interior and Undercarriage Damage, Test No. HBIB-2

Table 13. Maximum Occupant Compartment Intrusion by Location, Test No. HBIB-2

Location	Maximum Intrusion in.	MASH Allowable Intrusion in.
Wheel Well & Toe Pan	0.3	≤ 9
Floor Pan & Transmission Tunnel	0.0*	≤ 12
A-Pillar	1.1	≤ 5
A-Pillar (Lateral)	1.1	≤ 3
B-Pillar	0.1	≤ 5
B-Pillar (Lateral)	0.0*	≤ 3
Side Front Panel (in Front of A-Pillar)	0.7	≤ 12
Side Door (Above Seat)	0.0*	≤ 9
Side Door (Below Seat)	0.0*	≤ 12
Roof	0.2	≤ 4
Windshield	2.0	≤ 3
Side Window	Shattered due to contact with surrogate occupant's head	No shattering resulting from contact with structural member of test article
Dash	0.5	N/A

N/A – Not applicable
*Negative value reported as 0.0. See Appendix F for further information.

9.6 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 by accelerometer data, are shown in Table 14. Note that the OIVs and ORAs were within suggested limits, as provided in MASH. 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.

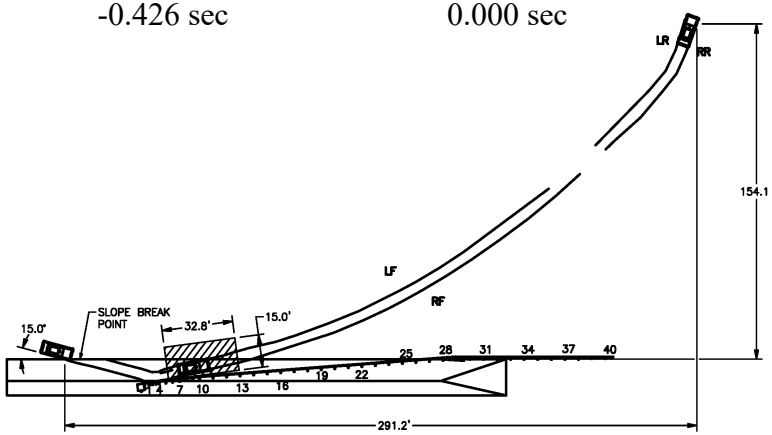
Table 14. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. HBIB-2

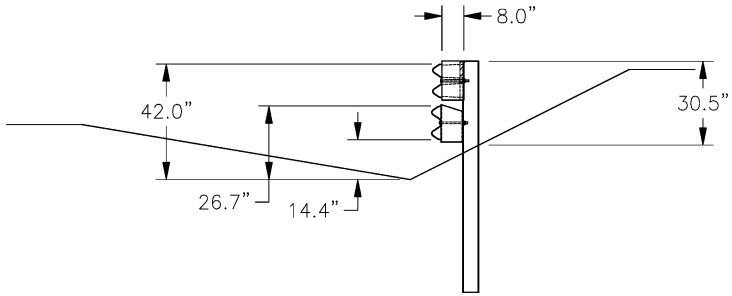
Evaluation Criteria		Transducer		MASH Limits
		SLICE-1 (primary)	SLICE-2 (backup)	
OIV ft/s	Longitudinal	-20.25	-20.08	±40
	Lateral	-29.96	-27.57	±40
ORA g's	Longitudinal	-5.30	-4.99	±20.49
	Lateral	-10.39	-12.53	±20.49
Maximum Angular Displacement deg.	Roll	17.5	15.5	±75
	Pitch	-6.2	-6.3	±75
	Yaw	-30.4	-31.1	not required
THIV ft/s		30.88	28.63	not required
PHD g's		10.43	12.54	not required
ASI		2.09	1.94	not required

9.7 Discussion

The analysis of the test results for test no. HBIB-2 showed that the system adequately contained and redirected the 1100C vehicle with controlled lateral displacements of the system. A summary of the test results and sequential photographs are shown in Figure 218. 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 system at an angle of 11.2 degrees, and its trajectory did not violate the bounds of the exit box. Therefore, test no. HBIB-2 was determined to be acceptable according to the MASH safety performance criteria for test designation no. 3-32.







- Test Agency ..... MwRSF
- Test Number HBIB-2
- Date 9/13/2023
- MASH Test Designation No. 3-32
- Test Article ..... Hawaii DOT Buried in Backslope
- Total Length ..... 219 ft – $3^{15}/_{16}$ in.
- Key Component – Steel W-beam Guardrail
  - Thickness ..... 12 gauge
  - Top Mounting Height ..... 32 in.
- Key Component – Steel Post
  - Shape W6x8.5
  - Length ..... 96 in.
  - Embedment Depth ..... 64 in.
  - Spacing ..... 75 in.
- Key Component – Composite Recycled Blockout (Post Nos. 1-38)
  - Shape ..... $14^{3}/_{16}$ x 8 x 5⅛
- Soil Type ..... Coarse, Crushed Limestone (Well-Graded Gravel)
- Vehicle Make / Model ..... 2017 Kia Rio
  - Curb ..... 2,540 lb
  - Test Inertial ..... 2,462 lb (MASH Limit 2,420 ± 55 lb)
  - Gross Static ..... 2,625 lb (MASH Limit 2,585 ± 55 lb)
- Impact Conditions
  - Speed ..... 61.7 mph (MASH Limit 62 ± 2.5 mph)
  - Angle ..... 15.0 deg. (MASH Limit 15 ± 1.5 deg.)
  - Impact Location ..... 9.9 in. downstream from concrete anchor's downstream edge
- Impact Kinetic Energy ..... 313.3 kip-ft ≥ 288 kip-ft minimum from MASH
- Exit Conditions
  - Speed ..... 42.2 mph
  - Angle ..... 11.2 deg.
- Vehicle Stability ..... Satisfactory
- Vehicle Stopping Distance ..... 291.2 ft downstream, 154.1 ft laterally in front
- Exit Box Criterion ..... Pass
- Vehicle Damage ..... Moderate
  - VDS [21] 1-RFQ-5
  - CDC [22] 01-FDEW-9
  - Maximum Interior Deformation ..... 2.0 in. at windshield ≤ 3-in. MASH Limit
- Test Article Damage ..... Minimal
- Maximum Test Article Deflections
  - Permanent Set ..... 0.6 in.
  - Dynamic ..... 3.7 in.
  - Working Width ..... 20.3 in.
- Transducer Data

Evaluation Criteria		Transducer		MASH Limit
		SLICE-1 (primary)	SLICE-2	
OIV ft/s	Longitudinal	-20.25	-20.08	±40
	Lateral	-29.96	-27.57	±40
ORA g's	Longitudinal	-5.30	-4.99	±20.49
	Lateral	-10.39	-12.53	±20.49
Maximum Angular Displacement deg.	Roll	17.5	15.5	±75
	Pitch	-6.2	-6.3	±75
	Yaw	-30.4	-31.1	not required
THIV – ft/s		30.88	28.63	not required
PHD – g's		10.43	12.54	not required
ASI		2.09	1.94	not required

Figure 218. Summary of Test Results and Sequential Photographs, Test No. HBIB-2

10 FULL-SCALE CRASH TEST NO. HBIB-3

10.1 Static Soil Test

Before full-scale crash test no. HBIB-3 was conducted, the strength of the foundation soil was evaluated with a static test, as described in MASH. The static test results, as shown in Appendix E, 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. HBIB-3 was conducted on September 27, 2023, at approximately 2:15 p.m. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/KLNK) were reported and are shown in Table 15.

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

Temperature	77°F
Humidity	43%
Wind Speed	5 mph
Wind Direction	120° from True North
Sky Conditions	Sunny
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.00 in.
Previous 7-Day Precipitation	0.22 in.

10.3 Test Description

Initial vehicle impact was to occur 12 in. downstream from the end of the concrete anchor block, as shown in Figure 219, which was selected using the recommended TL-3 test matrix Tables 2-2D and 2-3 of MASH. The CIP plots found in MASH Section 2.3 were implemented to maximize the probability of pocketing and vehicle snagging on the concrete parapet. The 5,068-lb quad cab pickup truck impacted the slope of the HBIB system at a speed of 62.5 mph and at an angle of 15.0 degrees. During the test, the vehicle followed the terrain trajectory before the impact. The actual impact point was measured 19.2 in. downstream from the upstream edge of the concrete block. The impact position in test no. HBIB-3 is shown in Figure 219. After brakes were applied, the vehicle came to rest 169 ft downstream and 0.3 ft laterally in front the system impact point.

A detailed description of the sequential impact events is reported in Table 16. Sequential photographs are shown in Figures 220 and 221. Documentary photographs of the crash test are shown in Figure 222. The vehicle trajectory and final position are shown in Figure 223.



Figure 219. Impact Location, Test No. HBIB-3

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

TIME (sec)	EVENT
-0.450	Vehicle's right-front tire crossed the slope break point.
-0.350	Vehicle pitched downward.
-0.322	Vehicle rolled toward the system.
0.000	Vehicle's front bumper contacted rail and was severely crushed inward and rearward.
0.005	Vehicle's right headlight contacted rail and was crushed. Vehicle's hood contacted rail and buckled. Vehicle's right fender contacted rail and was severely crushed inward and rearward. Post nos. 1, 2, 3, 4, and 5 deflected backward.
0.022	Vehicle's grille contacted rail and disengaged. Vehicle's right mirror contacted upstream concrete block anchor and disengaged.
0.032	Post no. 6 deflected backward.
0.045	Vehicle's windshield cracked. Vehicle's right-front tire contacted rail, deflated, and crushed rearward.
0.068	Vehicle yawed away from system. Vehicle's left headlight disengaged. Vehicle's right-front door contacted rail, crushed rearward, and became ajar at the top.
0.094	Occupant's head contacted right-front door window glass, which shattered.
0.182	Vehicle's right-rear door contacted rail and dented. Vehicle was parallel to system at a speed of 43.6 mph.
0.242	Vehicle's right taillight and quarter panel contacted rail, taillight cracked and quarter panel dented.
0.314	Vehicle rolled away from system.
0.412	Vehicle exited system at a speed of 38.3 mph and an angle of 8.0 degrees.
1.132	Vehicle's left-front tire deflated.
2.066	Vehicle recontacted system between post nos. 23 and 24.
3.264	Vehicle came to rest.


-0.450 sec


0.000 sec


0.200 sec


0.400 sec


0.600 sec


0.800 sec


0.000 sec


0.100 sec


0.200 sec



0.300 sec


0.400 sec


0.500 sec

Figure 220. Sequential Photographs, Test No. HBIB-3

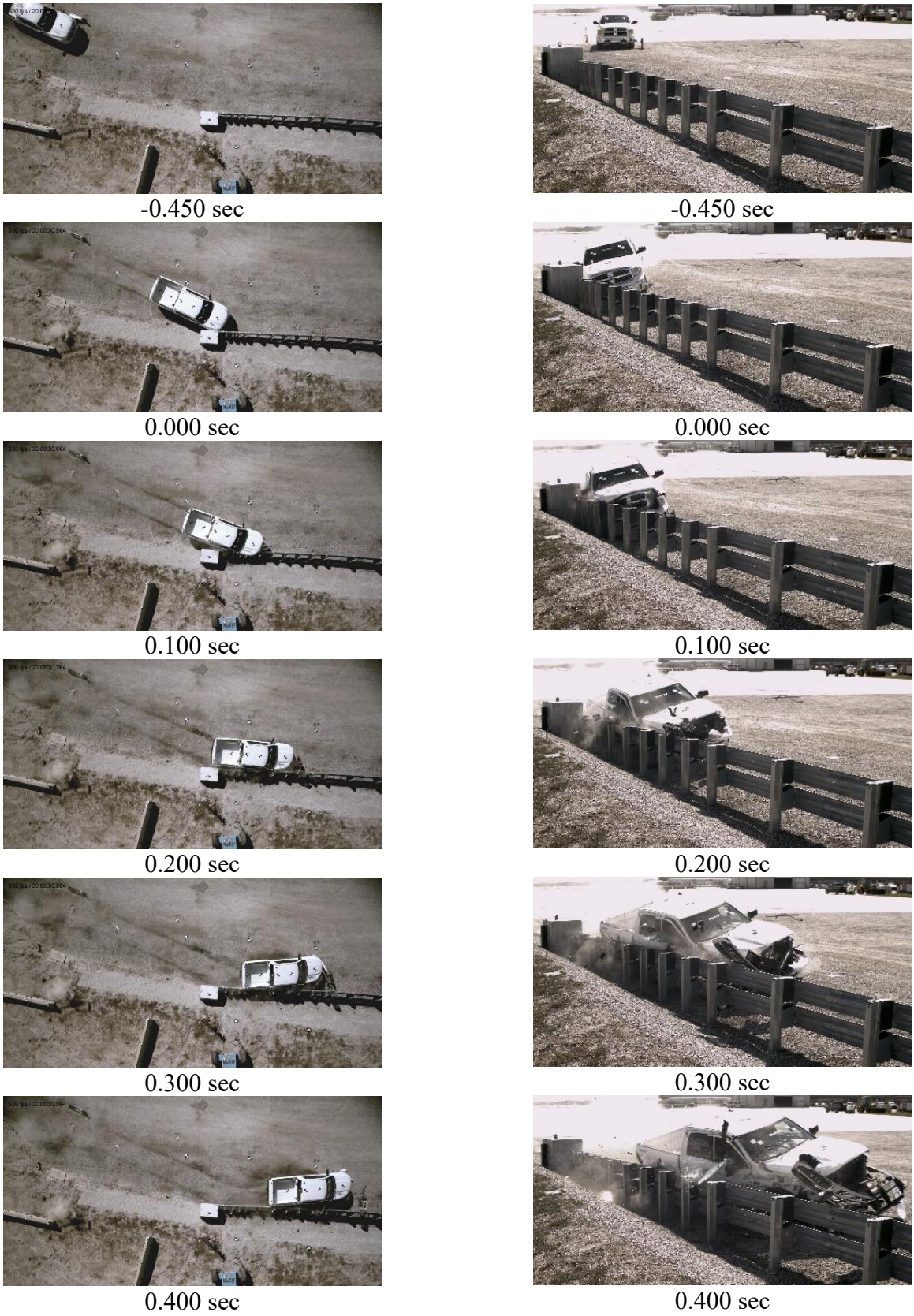


Figure 221. Sequential Photographs, Test No. HBIB-3



Figure 222. Documentary Photographs, Test No. HBIB-3





Figure 223. Vehicle Final Position and Trajectory Marks, Test No. HBIB-3

10.4 Barrier Damage

Damage to the barrier was minimal, as shown in Figures 224 through 226. Barrier damage consisted of contact marks on the front face of the concrete anchor block and the upper rail and rubrail, and gouging, tearing, bending, and kinking of the guardrails. The length of vehicle contact along the barrier, including contact to the anchor block, was approximately 18 ft – 4 in., which spanned from 5 ft – 10 in. upstream from the center line of the midpoint of post no. 1. Secondary contact of the vehicle to the barrier was approximately 22 ft – 9 in., which spanned from 2 ft – 5 in. downstream from the center line of the midpoint of post no. 23.

Gouges were observed along the rubrail terminal connector at locations 28 in. and 34 in. upstream from post no. 1. Additional gouging was observed along the lower edge of the rubrail 18 in. upstream from post no. 5. The whole face of the rubrail was flattened 31 in. upstream from the center line of post no. 1. Kinks were observed on the upper edge of the rubrail 1 in. upstream from post no. 1. Tearing was observed at the bolt holes on the rubrail at post nos. 2 and 3. The bottom edge of the upper rail was bent about 11 in. upstream from post no. 1. The secondary contact to the system caused bending of the lower edge of the rubrail measuring 25 in. x 2 in. x ¼ in. located 25 in. upstream from post no. 24. Posts nos. 1 through 4 were kinked along their front flanges on their upstream and downstream edges.









Figure 224. Overall System Damage, Test No. HBIB-3



Figure 225. Upper Rail and Rubrail Damage, Test No. HBIB-3



Figure 226. Rail Connection Terminal, Buttress and Post Damage, Test No. HBIB-3

The maximum lateral permanent set of the system was 1.2 in., which occurred in post no. 4, as measured in the field. The maximum lateral dynamic barrier deflection was 5.2 in. at post no. 1, as determined from high-speed digital video analysis. The working width of the system was found to be 22.0 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 227.

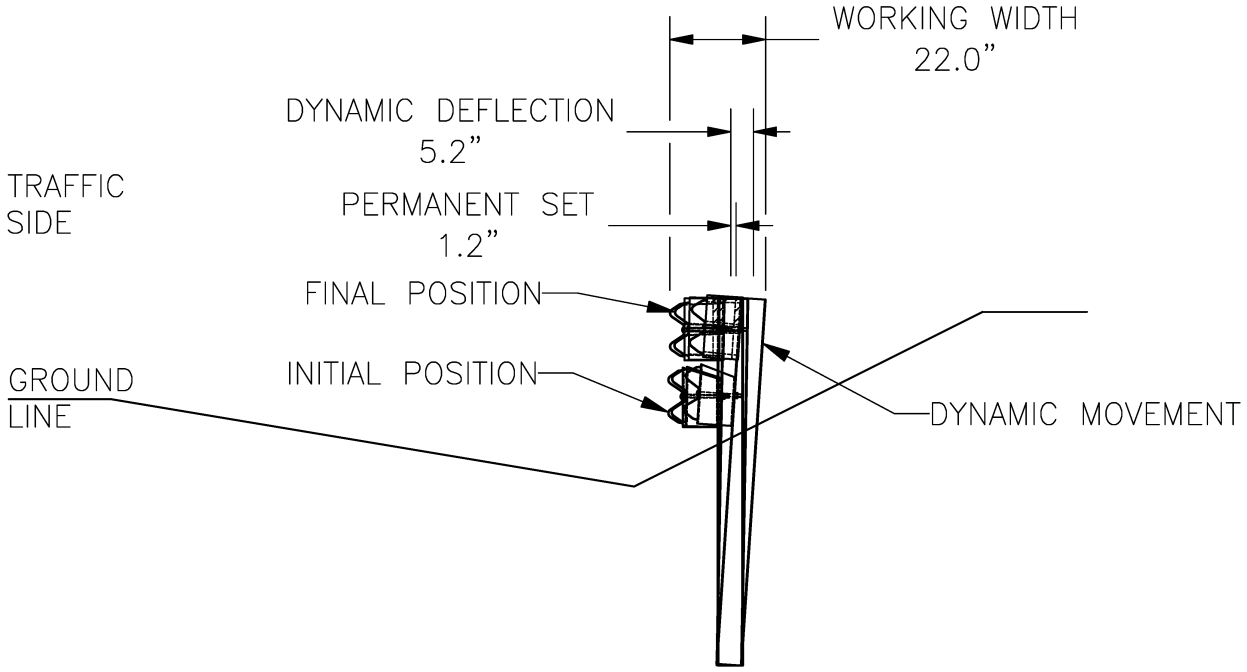


Figure 227. Permanent Set Deflection, Dynamic Deflection, and Working Width, Test No. HBIB-3

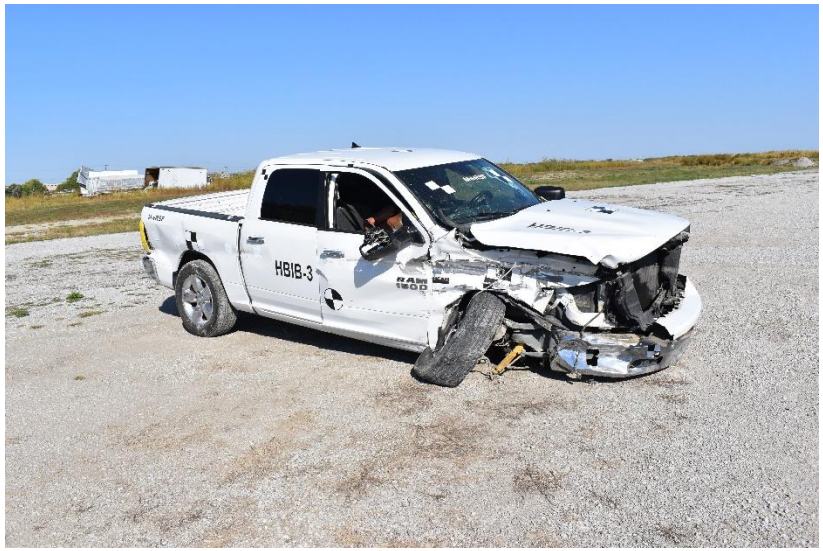
10.5 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 228 through 230. The majority of the damage was concentrated on the right-front corner and right side of the vehicle where the impact occurred. The right side of the front bumper was severely crushed inward and rearward from the vehicle's body and buckled in the middle. The right-front fender was crushed and scraped across its entire length and shoved rearward and inward due to contact to the upper rail. The right-front tire was crushed rearward, and the reinforcement bar was crushed rearward and inward. The headlights and front grille were disengaged from the vehicle. The hood was crushed inward on its right edge. The right-front door was crushed rearward, causing several dents to form throughout the door. Scrapping occurred throughout the front-right fender panel, across the right-front and right-rear doors, and along the ride-side box of the vehicle. The right side of the bed had several dents along its entire exterior. The right taillight was crushed but did not disengage. The right side of the rear bumper was slightly dented and scraped. The windshield had severe cracking across its right side. The right-front side window was shattered due to contact with the surrogate occupant's head.

On the undercarriage, the right-front shock was detached from the lower control arm, and the spring was disengaged. The right-side lower control arm was disengaged from the vehicle's

body, and the upper control arm was bent at the ball joint. The right-side tie rod was detached and bent and the right-side end link was broken at the lower control arm and bent rearward. Scrapes were observed on the lower edge of the main cross member. The right frame horn was bent inward, and the right front body mount was twisted.

The maximum occupant compartment intrusions are listed in Table 17, along with the intrusion limits established in MASH for various areas of the occupant compartment. Complete occupant compartment, vehicle intrusions, and the corresponding locations of the deformations are provided in Appendix F. MASH defines intrusion as the occupant compartment being deformed and reduced in size with no penetration. Outward deformations, which are denoted as negative numbers in Appendix F, are not considered as crush toward the occupant, and are not subject to evaluation by MASH criteria.







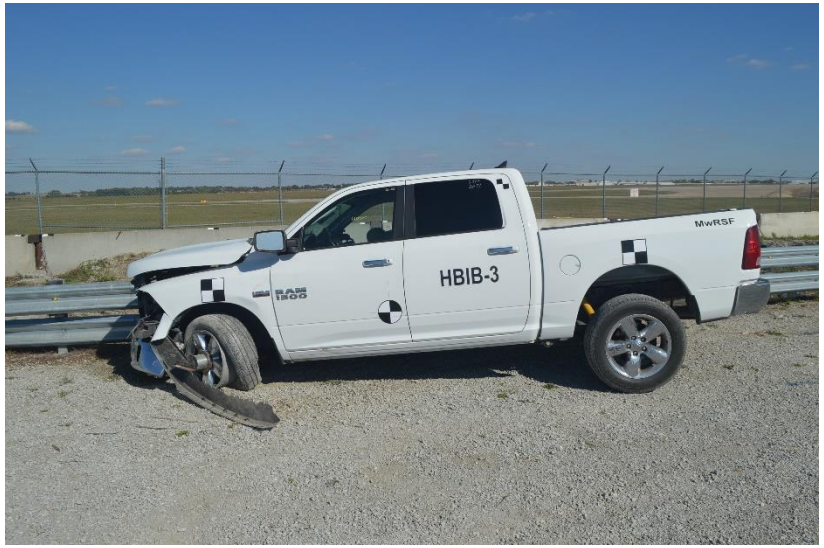


Figure 228. Vehicle Damage, Test No. HBIB-3



Figure 229. Vehicle Damage, Test No. HBIB-3



Figure 230. Interior and Undercarriage Damage, Test No. HBIB-3

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

Location	Maximum Intrusion in.	MASH Allowable Intrusion in.
Wheel Well & Toe Pan	6.5	≤ 9
Floor Pan & Transmission Tunnel	0.8	≤ 12
A-Pillar	0.6	≤ 5
A-Pillar (Lateral)	0.6	≤ 3
B-Pillar	0.2	≤ 5
B-Pillar (Lateral)	0.2	≤ 3
Side Front Panel (in Front of A-Pillar)	3.1	≤ 12
Side Door (Above Seat)	1.3	≤ 9
Side Door (Below Seat)	0.3	≤ 12
Roof	0.0*	≤ 4
Windshield	0.0	≤ 3
Side Window	Shattered due to contact with surrogate occupant's head	No shattering resulting from contact with structural member of test article
Dash	1.6	N/A

N/A – Not applicable
*Negative value reported as 0.0. See Appendix F 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 by accelerometer data, are shown in Table 18. Note that the OIVs and ORAs were within suggested limits, as provided in MASH. 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. HBIB-3

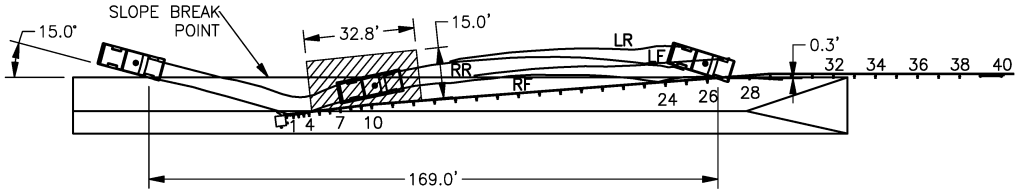
Evaluation Criteria		Transducer		MASH Limits
		SLICE-1 (backup)	SLICE-2 (primary)	
OIV ft/s	Longitudinal	-22.08	-20.82	±40
	Lateral	-22.28	-23.38	±40
ORA g's	Longitudinal	-12.12	-17.81	±20.49
	Lateral	-10.30	-13.67	±20.49
Maximum Angular Displacement deg.	Roll	17.8	*	±75
	Pitch	-6.7	*	±75
	Yaw	-29.6	*	not required
THIV ft/s		29.90	*	not required
PHD g's		19.99	*	not required
ASI		1.39	1.51	not required

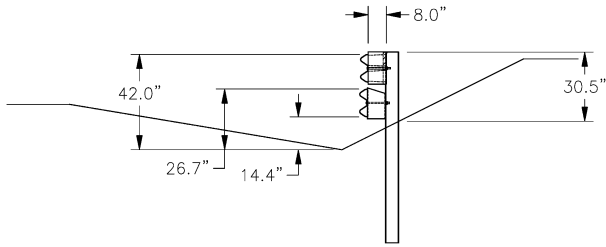
* - Value unavailable due to technical difficulties with angular data collection.

10.7 Discussion

The analysis of the test results for test no. HBIB-3 showed that the system adequately contained and redirected the 2270P vehicle with controlled lateral displacements of the system. A summary of the test results and sequential photographs are shown in Figure 231. 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 I, were deemed acceptable because they did not adversely influence occupant risk nor cause rollover. After impact, the vehicle exited the system at an angle of 8.0 degrees, and its trajectory did not violate the bounds of the exit box. Therefore, test no. HBIB-3 was determined to be acceptable according to the MASH safety performance criteria for test designation no. 3-33.







- Test Agency ..... MwRSF
- Test Number HBIB-3
- Date 9/27/23
- MASH Test Designation No. 3-33
- Test Article ..... Hawaii DOT Buried in Backslope
- Total Length ..... 219 ft – $3^{15}/_{16}$ in.
- Key Component – Steel W-beam Guardrail
  - Thickness ..... 12 gauge
  - Top Mounting Height ..... 32 in.
- Key Component – Steel Post
  - Shape W6x8.5
  - Length ..... 96 in.
  - Embedment Depth ..... 64 in.
  - Spacing ..... 75 in.
- Key Component – Composite Recycled Blockout (Post Nos. 1-38)
  - Shape ..... $14^{3}/_{16}$ x 8 x 5⅛
- Soil Type ..... Coarse, Crushed Limestone (Well-Graded Gravel)
- Vehicle Make / Model ..... 2017 Ram 1500
  - Curb ..... 5,384 lb
  - Test Inertial ..... 5,068 lb (MASH Limit 5,000 ± 110 lb)
  - Gross Static ..... 5,228 lb (MASH Limit 5,165 ± 110 lb)
- Impact Conditions
  - Speed ..... 62.5 mph (MASH Limit 62 ± 2.5 mph)
  - Angle ..... 15.0 deg. (MASH Limit 15 ± 1.5 deg.)
  - Impact Location ..... 19.2 in. DS from US edge of concrete anchor block
- Impact Kinetic Energy ..... 661.8 kip-ft ≥ 594 kip-ft minimum from MASH
- Exit Conditions
  - Speed ..... 38.3 mph
  - Angle ..... 8.0 deg.
- Vehicle Stability ..... Satisfactory
- Vehicle Stopping Distance ..... 169 ft downstream, 0.3 ft. laterally behind
- Exit Box Criterion ..... Pass
- Vehicle Damage ..... Moderate
  - VDS [21] 1-RFQ-5
  - CDC [22] 01-FDEW-9
- Maximum Interior Deformation ..... 6.5 in. at wheel well & toe pan ≤ 9-in. MASH Limit
- Test Article Damage ..... Minimal
- Maximum Test Article Deflections
  - Permanent Set ..... 1.2 in.
  - Dynamic ..... 5.2 in.
  - Working Width ..... 22.0 in.
- Transducer Data

Evaluation Criteria		Transducer		MASH Limit
		SLICE-1 (primary)	SLICE-2	
OIV ft/s	Longitudinal	-22.08	-20.82	±40
	Lateral	-22.28	-23.38	±40
ORA g's	Longitudinal	-12.12	-17.82	±20.49
	Lateral	-10.30	-13.67	±20.49
Maximum Angular Displacement deg.	Roll	17.8	*	±75
	Pitch	-6.7	*	±75
	Yaw	-29.6	*	not required
THIV – ft/s		29.90	*	not required
PHD – g's		19.99	*	not required
ASI		1.39	1.51	not required

* - Value unavailable due to technical difficulties with angular data collection.

Figure 231. Summary of Test Results and Sequential Photographs, Test No. HBIB-3

11 FULL-SCALE CRASH TEST NO. HBIB-4

11.1 Static Soil Test

Before full-scale crash test no. HBIB-4 was conducted, the strength of the foundation soil was evaluated with a static test, as described in MASH. The static test results, as shown in Appendix E, 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.

11.2 Weather Conditions

Test no. HBIB-4 was conducted on October 20, 2023, at approximately 2:00 p.m. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/KLNK) were reported and are shown in Table 19.

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

Temperature	84°F
Humidity	25%
Wind Speed	11 mph
Wind Direction	240° from True North
Sky Conditions	Sunny
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.00 in.
Previous 7-Day Precipitation	0.13 in.

11.3 Test Description

The initial vehicle impact was to occur along the centerline of post no. 8 at an impact speed of 62 mph and an angle of 15 degrees, as shown in Figure 232, which was selected using the recommended TL-3 test matrix tables 2-2D and 2-3 of MASH. The CIP plots found in MASH Section 2.3 were implemented to maximize the probability of pocketing and vehicle snagging on the concrete parapet. The 2,418-lb small car impacted the slope of the HBIB system at a speed of 62.1 mph and at an angle of 15.1 degrees. The actual point of impact was 0.4 in. upstream from the centerline of post no. 8. The impact position in test no. HBIB-4 is shown in Figure 232. After brakes were applied, the vehicle came to rest at 191.6 ft downstream and 70.4 ft laterally in front of the system impact point.

A detailed description of the sequential impact events is reported in Table 20. Sequential photographs are shown in Figures 233 and 234. Documentary photographs of the crash test are shown in Figure 235. The vehicle trajectory and final position are shown in Figure 236.



Figure 232. Impact Location, Test No. HBIB-4

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

TIME (sec)	EVENT
-0.380	Vehicle's right-front tire crossed slope break point.
-0.292	Vehicle rolled toward system.
-0.034	Vehicle left-front tire airborne.
0.000	Vehicle's front bumper, right fender, and right headlight contacted rail, crushed, and disengaged. Post nos. 7, 8, 9, and 10 rotated backward.
0.004	Vehicle's right mirror and hood contacted rail. Mirror disengaged, hood crushed and deformed toward left. Vehicle's left fender deformed.
0.033	Vehicle yawed away from system. Vehicle's right-front door contacted rail and was crushed and dented.
0.046	Vehicle's left headlight disengaged. Post no. 11 rotated backward.
0.054	Vehicle left-front tire contacted ground.
0.068	Vehicle left-rear tire airborne.
0.116	Vehicle left-rear tire contacted ground.
0.134	Vehicle became parallel to system at a speed of 47.3 mph.
0.152	Vehicle's right-rear door contacted rail and was scraped and dented.
0.171	Vehicle's right quarter-panel and rear bumper contacted rail and was scraped, dented, and deformed.
0.314	Vehicle exited system at a speed of 44.3 mph and an angle of 15.4 degrees.
4.688	Vehicle came to rest.


-0.380 sec


0.000 sec


0.200 sec


0.400 sec


0.600 sec


0.800 sec


0.000 sec


0.200 sec


0.400 sec


0.600 sec


0.800 sec


1.000 sec

Figure 233. Sequential Photographs, Test No. HBIB-4

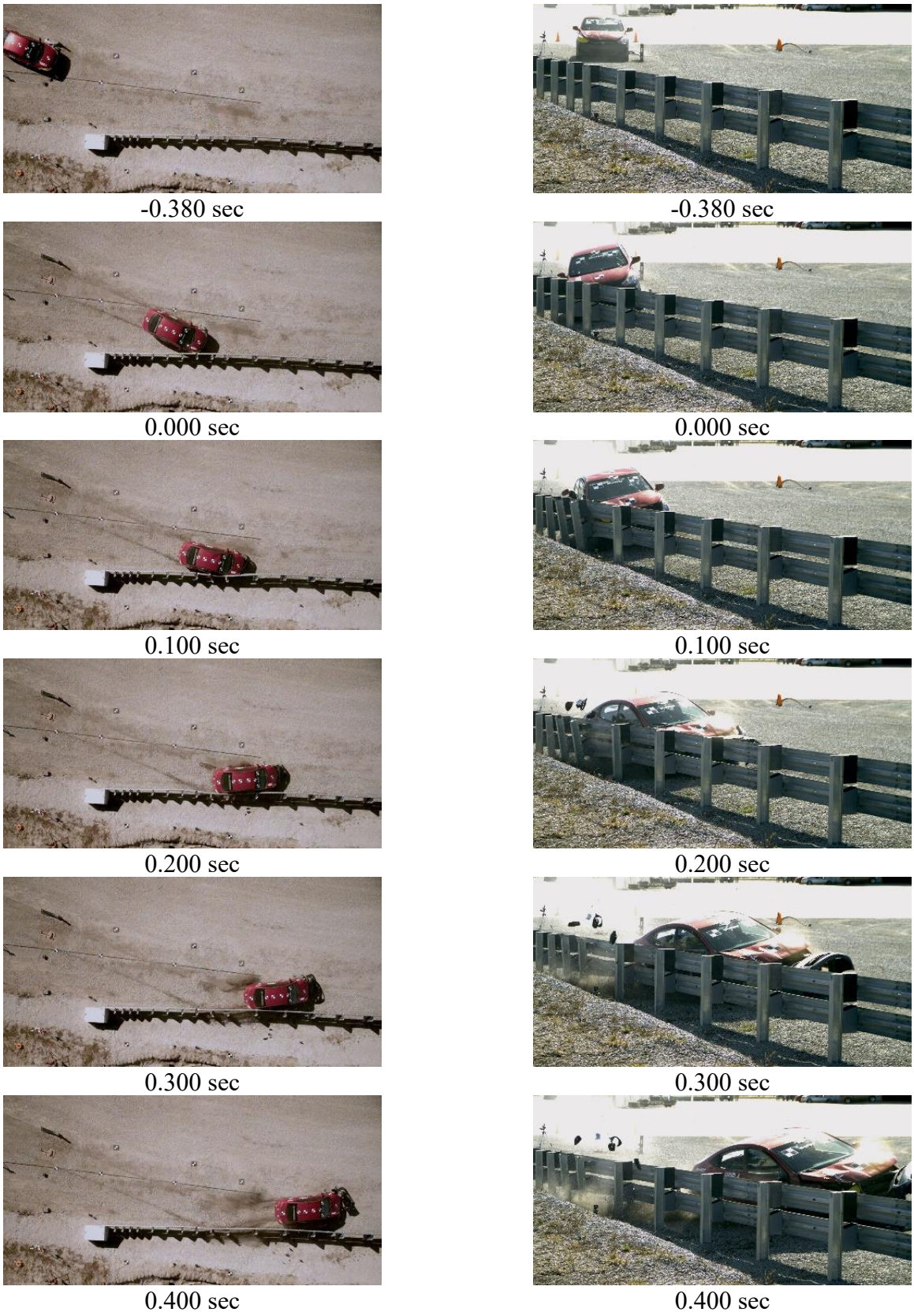


Figure 234. Sequential Photographs, Test No. HBIB-4

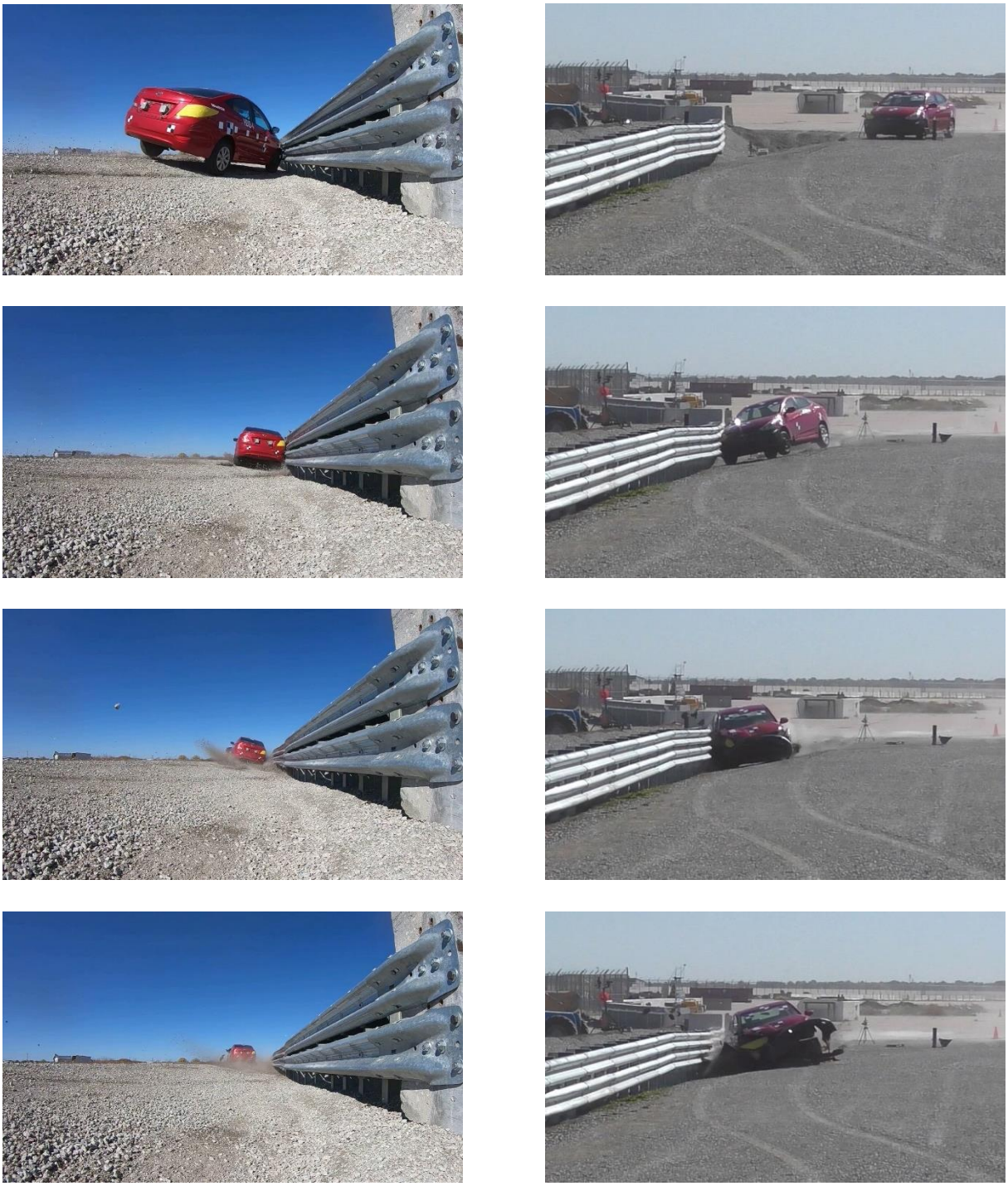


Figure 235. Documentary Photographs, Test No. HBIB-4





Figure 236. Vehicle Final Position and Trajectory Marks, Test No. HBIB-4

11.4 Barrier Damage

Damage to the barrier was minimal, as shown in Figures 237 through 239. The primary contact mark occurred 1 ft upstream from the centerline of post no. 8 and extended 19 ft – 10 in. downstream. Two contact marks were observed on the upper rail, one of which started 1 ft upstream from post no. 8 on the top corrugation of the upper rail and extended 12 ft – 9 in. downstream. The second contact mark on the upper rail began 1 ft upstream from post no. 8 and extended 15 ft – 6 in. downstream. A contact mark on the rubrail started 10 in. upstream from post no. 8 and extended 19 ft – 8 in. downstream on the top corrugation of the rail. Another contact mark on the rubrail began 7 in. upstream from post no. 8 and extended 11 ft – 5 in. downstream on the bottom corrugation.

No snagging was observed during the test. Gouging was observed on the center line of post no. 8 at the bottom corrugation of the upper rail and 28 in. downstream from post no. 8 on the bottom corrugation of the upper rail. Kinking occurred on the centerline of post no. 9, approximately 35 in. above the ground. Bending of the rail occurred 11 in. downstream from post no. 8 and extended 74 in. downstream on the bottom corrugation of the rail. A bend was also recorded at the centerline of post no. 9 that extended 10 in. downstream on the top corrugation of the rubrail. Kinking was observed 39 in. upstream from post no. 11 on the top corrugation of the rubrail, 26 in. from the ground line. Gouging measuring 3 in. was found at the centerline of post no. 7 located 27 in. from the ground line.

The upstream and downstream flanges of post no. 9 bent slightly. Post no. 8 deformed backward approximately 5 degrees. Post nos. 9 and 10 were deformed backward 10 degrees and downstream 10 and 5 degrees downstream, respectively. Post no. 11 deformed backward less than 5 degrees. Post no. 10 had a 5-degree clockwise rotation. Blockout nos. 9 and 10 rotated clockwise 30 and 150 degrees, respectively. Some contact marks were also observed on the top of the blockouts for post nos. 9 through 11.

The maximum lateral permanent set deflection of the system was 6.0 in., which occurred in post no. 9, as measured in the field. The maximum lateral dynamic system deflection was 11.9 in. at post no. 10, as determined from high-speed digital video analysis. The working width of the system was found to be 28.7 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 240.



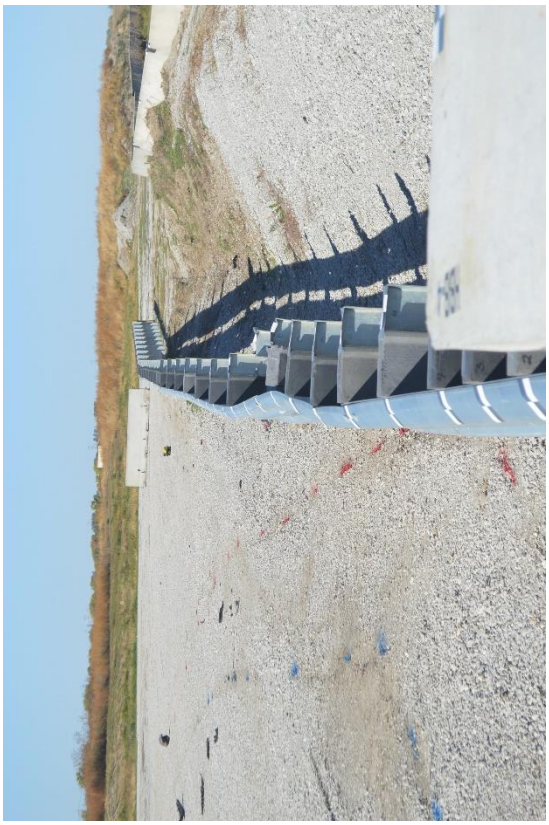






Figure 237. Overall System Damage, Test No. HBIB-4



Figure 238. Upper rail and Rubrail Damage, Test No. HBIB-4

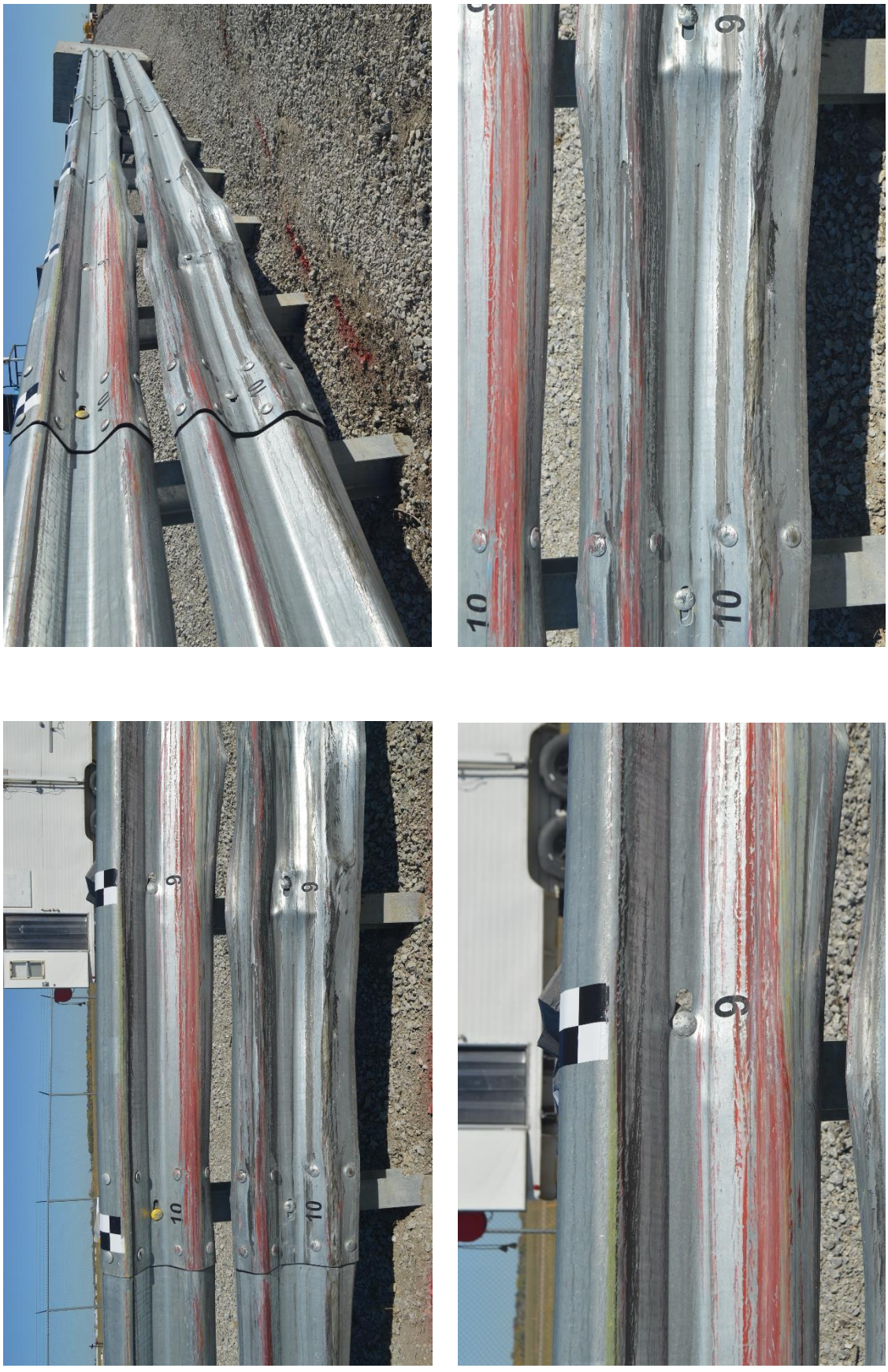


Figure 239. Upper Rail and Rubrail Damage, Test No. HBIB-4

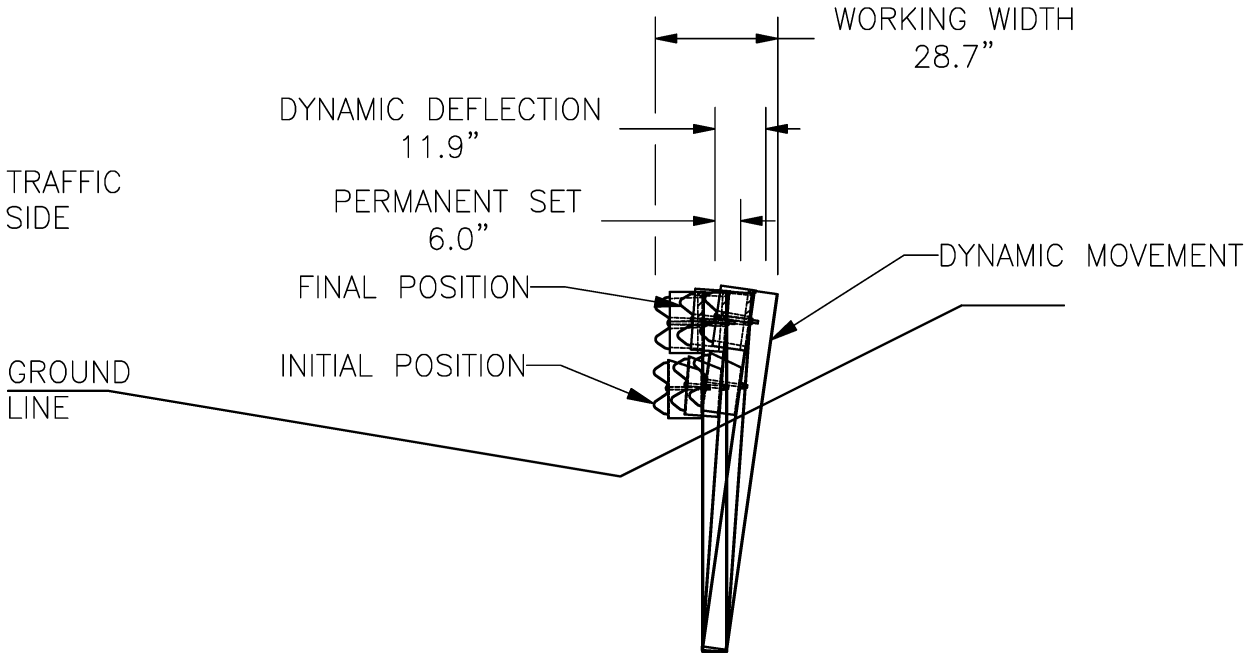


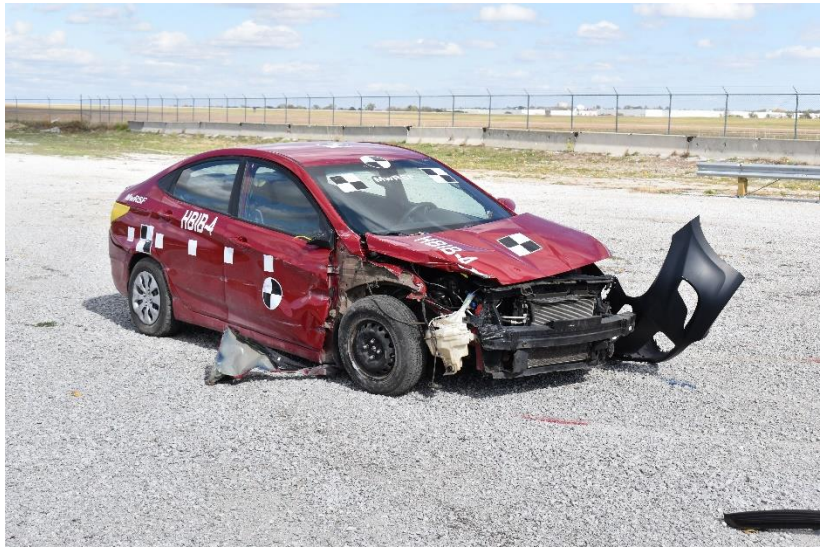
Figure 240. Permanent Set Deflection, Dynamic Deflection, and Working Width, Test No. HBIB-4

11.5 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 241 through 243. The majority of the damage was concentrated on the right-front corner and right side of the vehicle where the impact occurred. No cracks or contact marks were observed on the windshield or side windows of the vehicle. The right side of the vehicle hood was crushed inward, wrinkling the hood and shifting it to the left of the vehicle. The right-front fender of the vehicle was completely detached from the vehicle and crushed. The right side of the front bumper detached from the body due to impact to the rails and was crushed. Both headlights disengaged from the body. The right front and rear doors were scraped and dented, and the right-front door was crushed and shifted from its original position. The right-side mirror disengaged from the vehicle. Scratches and dents were recorded on the right-rear quarter panel that extended into the right side of the rear bumper.

Undercarriage damage was minimal. The right-side lower control arm was bent rearward. The right-front steering knuckle was broken at the connection to the shock, and the boot on the drive shaft at the right steering knuckle was torn. The frame in the right-front wheel well was bent inward. The bumper bracket on the left side of the vehicle was cracked away from the bumper.

The maximum occupant compartment intrusions are listed in Table 21, along with the intrusion limits established in MASH for various areas of the occupant compartment. Complete occupant compartment, vehicle intrusions, and the corresponding locations of the deformations are provided in Appendix F. MASH defines intrusion as the occupant compartment being deformed and reduced in size with no penetration. Outward deformations, which are denoted as negative numbers in Appendix F, are not considered as crush toward the occupant, and are not subject to evaluation by MASH criteria.



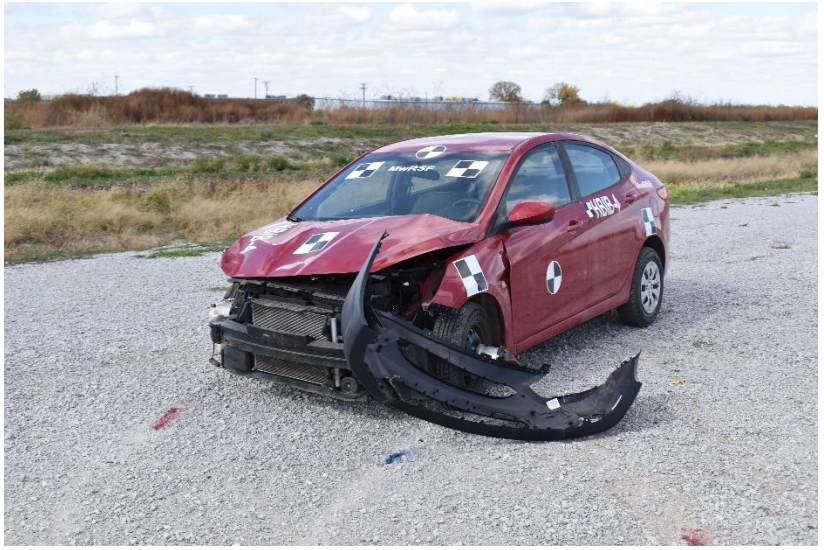






Figure 241. Vehicle Damage, Test No. HBIB-4



Figure 242. Vehicle Damage, Test No. HBIB-4



Figure 243. Interior and Undercarriage Damage, Test No. HBIB-4

Table 21. Maximum Occupant Compartment Intrusion by Location, HBIB-4

Location	Maximum Intrusion in.	MASH Allowable Intrusion in.
Wheel Well & Toe Pan	0.2	≤ 9
Floor Pan & Transmission Tunnel	0.1	≤ 12
A-Pillar	0.0	≤ 5
A-Pillar (Lateral)	0.0	≤ 3
B-Pillar	0.1	≤ 5
B-Pillar (Lateral)	0.0	≤ 3
Side Front Panel (in Front of A-Pillar)	0.0	≤ 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	Intact	No shattering resulting from contact with structural member of test article
Dash	0.3	N/A

N/A – Not applicable
*Negative value reported as 0.0. See Appendix F for further information.

11.6 Occupant Risk

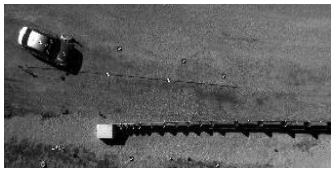
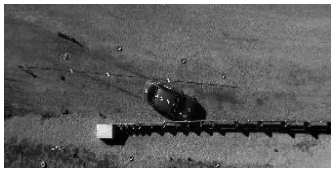
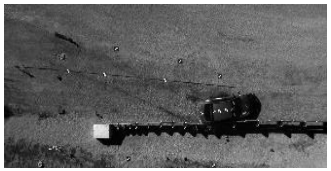
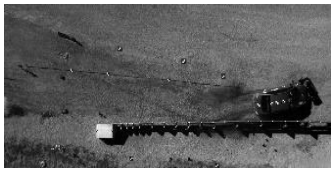
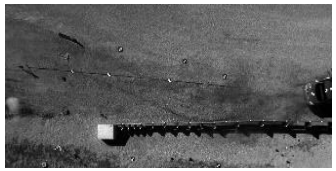
The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined by accelerometer data, are shown in Table 22. Note that the OIVs and ORAs were within suggested limits, as provided in MASH.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

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

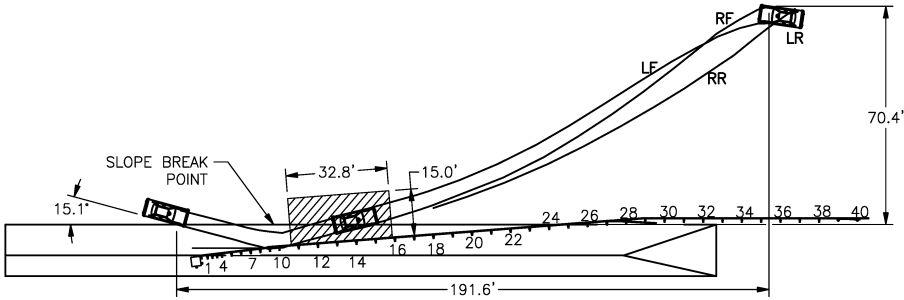
Evaluation Criteria		Transducer		MASH Limits
		SLICE-1 (primary)	SLICE-2 (backup)	
OIV ft/s	Longitudinal	-18.65	-19.64	±40
	Lateral	-25.77	-22.84	±40
ORA g's	Longitudinal	-4.71	-5.20	±20.49
	Lateral	-7.91	-8.14	±20.49
Maximum Angular Displacement deg.	Roll	18.5	16.0	±75
	Pitch	3.8	3.0	±75
	Yaw	-33.6	-34.3	not required
THIV ft/s		26.42	28.75	not required
PHD g's		6.72	7.68	not required
ASI		1.54	1.43	not required

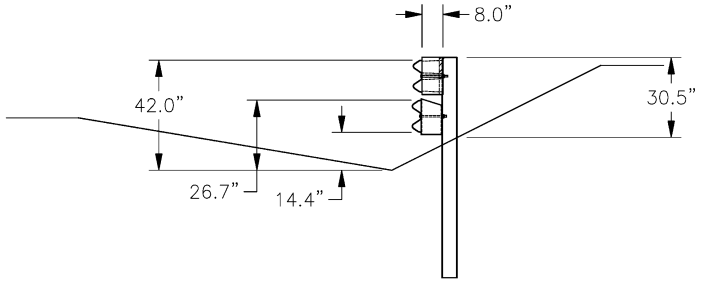
11.7 Discussion

The analysis of the test results for test no. HBIB-4 showed that the system adequately contained and redirected the 1100C vehicle with controlled lateral displacements of the system. A summary of the test results and sequential photographs are shown in Figure 244. 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 J, were deemed acceptable because they did not adversely influence occupant risk nor cause rollover. After impact, the vehicle exited the system at an angle of 15.4 degrees, and its trajectory did not violate the bounds of the exit box. Therefore, test no. HBIB-4 was determined to be acceptable according to the MASH safety performance criteria for test designation no. 3-34.

-0.380 sec 0.000 sec 0.200 sec 0.400 sec 0.600 sec





- Test Agency ..... MwRSF
- Test Number HBIB-4
- Date 10/20/23
- MASH Test Designation No. 3-34
- Test Article ..... Hawaii DOT Buried in Backslope
- Total Length ..... 219 ft – $3^{15}/_{16}$ in.
- Key Component – Steel W-beam Guardrail
  - Thickness ..... 12 gauge
  - Top Mounting Height ..... 32 in.
- Key Component – Steel Post
  - Shape W6x8.5
  - Length ..... 96 in.
  - Embedment Depth ..... 64 in.
  - Spacing ..... 75 in.
- Key Component – Composite Recycled Blockout (Post Nos. 1-38)
  - Shape ..... $14^{3}/_{16}$ x 8 x 5⅛ in.
- Soil Type ..... Coarse, Crushed Limestone (Well-Graded Gravel)
- Vehicle Make / Model ..... 2017 Hyundai Accent
  - Curb ..... 2,457 lb
  - Test Inertial ..... 2,418 lb (MASH Limit 2,420 ± 55 lb)
  - Gross Static ..... 2,580 lb (MASH Limit 2,585 ± 55 lb)
- Impact Conditions
  - Speed ..... 62.1 mph (MASH Limit 62 ± 2.5 mph)
  - Angle ..... 15.1 deg. (MASH Limit 15 ± 1.5 deg.)
  - Impact Location ..... 0.4 in. upstream from the centerline of post no. 8
- Impact Severity ..... 21.2 kip-ft ≥ 19 kip-ft minimum from MASH
- Exit Conditions
  - Speed ..... 44.3 mph
  - Angle ..... 15.4 deg.
- Vehicle Stability ..... Satisfactory
- Vehicle Stopping Distance ..... 191.6 ft downstream, 70.4 ft laterally in front
- Exit Box Criterion ..... Pass
- Vehicle Damage ..... Moderate
  - VDS [21] 1-RFQ-5
  - CDC [22] 01-FDEW-9
  - Maximum Interior Deformation ..... 0.3 in. at dash; No MASH Limit
- Test Article Damage ..... Minimal
- Maximum Test Article Deflections
  - Permanent Set ..... 6.0 in.
  - Dynamic ..... 11.9 in.
  - Working Width ..... 28.7 in.
- Transducer Data

Evaluation Criteria		Transducer		MASH Limit
		SLICE-1 (primary)	SLICE-2	
OIV ft/s	Longitudinal	-18.65	-19.64	±40
	Lateral	-25.77	-22.84	±40
ORA g's	Longitudinal	-4.71	-5.20	±20.49
	Lateral	-7.91	-8.14	±20.49
Maximum Angular Displacement deg.	Roll	18.5	16.0	±75
	Pitch	3.8	3.0	±75
	Yaw	-3.6	-34.3	not required
THIV – ft/s		26.42	28.75	not required
PHD – g's		6.72	7.68	not required
ASI		1.54	1.43	not required

Figure 244. Summary of Test Results and Sequential Photographs, Test No. HBIB-4

12 FULL-SCALE CRASH TEST NO. HBIB-5

12.1 Static Soil Test

Before full-scale crash test no. HBIB-5 was conducted, the strength of the foundation soil was evaluated with a static test, as described in MASH. The static test results, as shown in Appendix E, 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.

12.2 Weather Conditions

Test no. HBIB-5 was conducted on November 7, 2023, at approximately 1:15 p.m. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/KLNK) were reported and are shown in Table 23.

Table 23. Weather Conditions, Test No. HBIB-5

Temperature	68°F
Humidity	63%
Wind Speed	17 mph
Wind Direction	130° from True North
Sky Conditions	Partly Cloudy
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.00 in.
Previous 7-Day Precipitation	0.00 in.

12.3 Test Description

Initial vehicle impact was to occur at the centerline of post no. 8, as shown in Figure 245, which was selected using the recommended TL-3 test matrix tables 2-2D and 2-3 of MASH. The CIP plots found in MASH Section 2.3 were implemented to maximize the probability of pocketing and vehicle snagging on the concrete parapet. The 4,998-lb quad cab pickup truck impacted the slope of the HBIB system at a speed of 63.7 mph and at an angle of 25.0 degrees. The actual point of impact on the system was 4.1 in. upstream of the centerline post no. 8. The impact location of test no. HBIB-5 is shown in Figure 245. After brakes were applied, the vehicle came to rest at 164.7 ft downstream and 6.7 ft laterally in front of the system impact point.

A detailed description of the sequential impact events is reported in Tables 24 and 25. Sequential photographs are shown in Figures 246 and 247. Documentary photographs of the crash test are shown in Figure 248. The vehicle trajectory and final position are shown in Figure 249.



Figure 245. Impact Location, Test No. HBIB-5

Table 24. Sequential Description of Impact Events, Test No. HBIB-5

TIME (sec)	EVENT
-0.234	Vehicle's right-front tire crossed slope break point.
-0.096	Vehicle's right-front tire became airborne.
-0.036	Vehicle rolled toward system. Vehicle's left-front tire became airborne.
0.000	Vehicle's front bumper contacted rail 4.1 in. upstream from centerline of post no. 8. Vehicle's front bumper crushed inward and rearward and post no. 8 rotated backward.
0.008	Post no. 9 rotated backward.
0.022	Post nos. 7 and 10 rotated backward while Post no. 8 bent backward and twisted clockwise. Vehicle's right-front tire contacted rail.
0.033	Vehicle pitched upward. Vehicle's right fender was scraped and dented. Post no. 9 bent backward and twisted counterclockwise.
0.036	Post no. 10 bent downstream and twisted counterclockwise, while post no. 11 rotated backward. Rail disengaged from both blockouts at post no. 10. Vehicle yawed away from system.
0.040	Post no. 11 twisted, rotated backward, and bent downstream. Rail disengaged from both blockouts at post no. 11. Vehicle's left-front tire became airborne.
0.079	Post no. 12 bent downstream and twisted counterclockwise, while post no. 13 rotated backward. Rail disengaged from both blockouts at post no. 12.
0.093	Vehicle's right headlight and rear view mirror disengaged. Upstream concrete anchor block fractured.
0.104	Vehicle's right-rear tire became airborne.
0.122	Vehicle's right-front tire deflated.
0.138	Post no. 14 rotated backward.
0.148	Vehicle's right-rear door contacted rail and was dented and scraped.
0.216	Vehicle's right-rear tire contacted rail. Vehicle's right quarter panel contacted rail and was dented and scraped.
0.234	Vehicle pitched downward.
0.258	Vehicle became parallel to system at a speed of 38.1 mph.
0.276	Post no. 13 bent downstream and twisted counterclockwise. Rail disengaged from both blockouts at post no. 13.
0.324	Vehicle's bumper cover detached.
0.348	Vehicle's rear bumper contacted rail and deformed.
0.614	Vehicle's right-front tire became airborne.
0.634	Vehicle's right-rear tire became airborne.
0.770	Vehicle exited system at a speed of 29.5 mph and an angle of 21.1 degrees.
0.824	Vehicle's right-front tire contacted ground.
0.984	Vehicle rolled away from system.

Table 25. Sequential Description of Impact Events, Test No. HBIB-5, Cont.

TIME (sec)	EVENT
1.004	Vehicle yawed toward system.
1.054	Vehicle pitched upward.
1.164	Vehicle's right-rear tire contacted ground.
1.364	Vehicle's left-front tire contacted ground.
1.428	Vehicle's left-rear tire contacted ground.
2.494	Vehicle's left-rear tire became airborne.
4.783	Vehicle came to rest.


-0.234 sec


0.000 sec


0.000 sec


0.200 sec


0.200 sec


0.400 sec


0.400 sec


0.600 sec

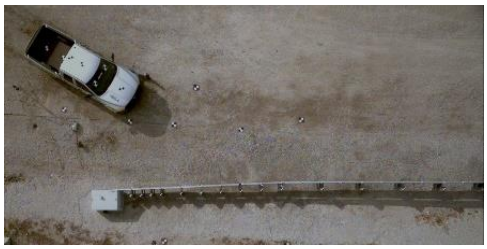

0.600 sec


0.800 sec


0.800 sec


1.000 sec

Figure 246. Sequential Photographs, Test No. HBIB-5


-0.234 sec


-0.234 sec


0.000 sec


0.000 sec


0.200 sec


0.200 sec


0.400 sec


0.400 sec


0.600 sec



0.600 sec


0.800 sec


0.800 sec

Figure 247. Sequential Photographs, Test No. HBIB-5



Figure 248. Documentary Photographs, Test No. HBIB-5





Figure 249. Vehicle Final Position and Trajectory Marks, Test No. HBIB-5

12.4 Barrier Damage

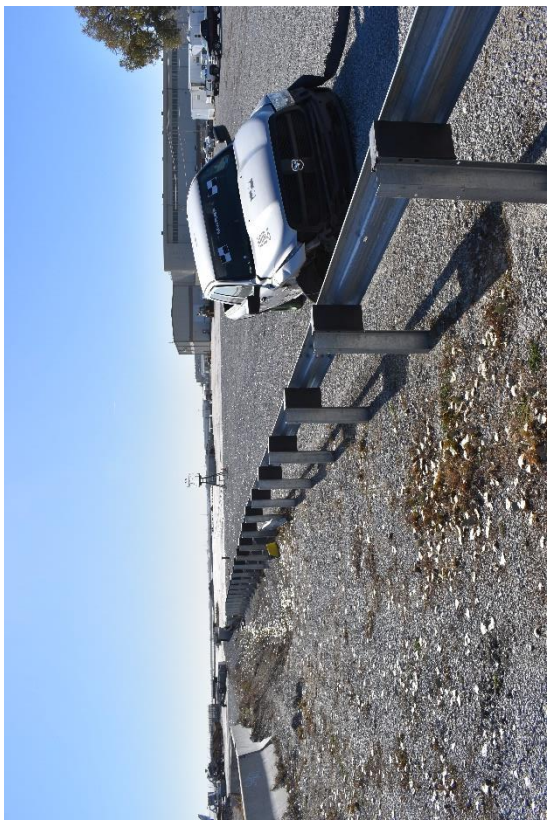
Damage to the system was moderate, as shown in Figures 250 through 252. Barrier damage consisted of rail kinks, flattening, bending, gouging, and bolt hole tearing and shearing, as well as post deflections and rotations and blockout detachment. The primary vehicle contact marks were observed on the upper rail and rubrail: the first began 32½ in. downstream from the centerline of post no. 7 on the rubrail and extended 113 in. downstream, while the other contact mark started 34 in. downstream from the center line of post no. 7 on the upper rail and extended 32 ft – 4 in. downstream.

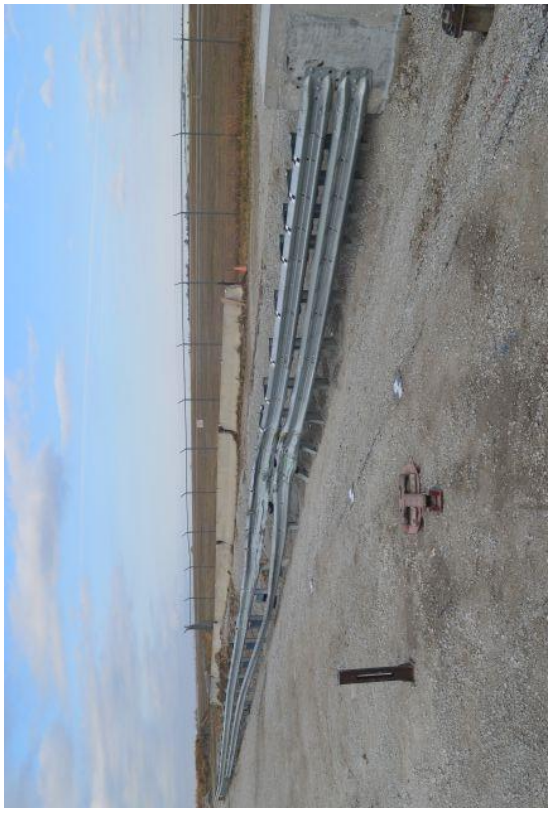
Rail damage consisted of kinks, flattening, bends, and bolt pullout. The top corrugation of the top rail was kinked $^{9}/_{16}$ in. downstream from post no. 7, and middle section of the top rail was kinked 2 in. upstream from post no. 7. The top corrugation of the rubrail was kinked 2 in. downstream from the centerline of post no. 11. The top rail was flattened on the top corrugation for a length of 31 ft - 9 in. downstream, beginning 1¾ in. upstream from post no. 8. The bottom corrugation of the top rail was also flattened for a length of 17 ft – 1 in. beginning 28 in. downstream from post no. 10. The rubrail was flattened 32½ in. downstream from post no. 7 for a length of 94¼ in. Located 46½ in. upstream from post no. 13, the top corrugation of the rubrail was bent, with a length of 22 in. Blockout bolts were pulled out from post nos. 9 through 12 on the top rail and post nos. 10 through 13 on the rubrail. The bolts holes for the top rail were torn at post no. 13 and for the rubrail at post nos. 11 through 13.

Flange bending was recorded on the front upstream faces of post nos. 8, 12, and 13 and on the back upstream face of post no. 10 . Flange buckling was observed on back upstream flange of post no. 9. The upstream anchor block rotated approximately 10 degrees clockwise. Post nos. 1, 9, and 12 rotated 5 degrees clockwise, post nos. 2 and 3 rotated 10 degrees clockwise, and post nos. 4 through 6 rotated 15 degrees clockwise. Post nos. 7 and 8, rotated 20 and 40 degrees clockwise, respectively. Post nos. 9, 10, 11, 12, and 13 deflected backwards, 30, 55, 30, 5, and 5 degrees, respectively. Damage to the entire system is shown in Figures 251 and 252.

The rail detached from the blockouts due to bolt pullout at post nos. 9 through 18, with the rail only detaching from the upper blockouts at post nos. 9 and 14 through 18. At post no. 11, the rail pulled out from the lower blockout, but the upper blockout sheared. At post nos. 11 through 13, the upper blockout detached from the post due to bolt shear. For the rest of the system, the blockouts remained intact.







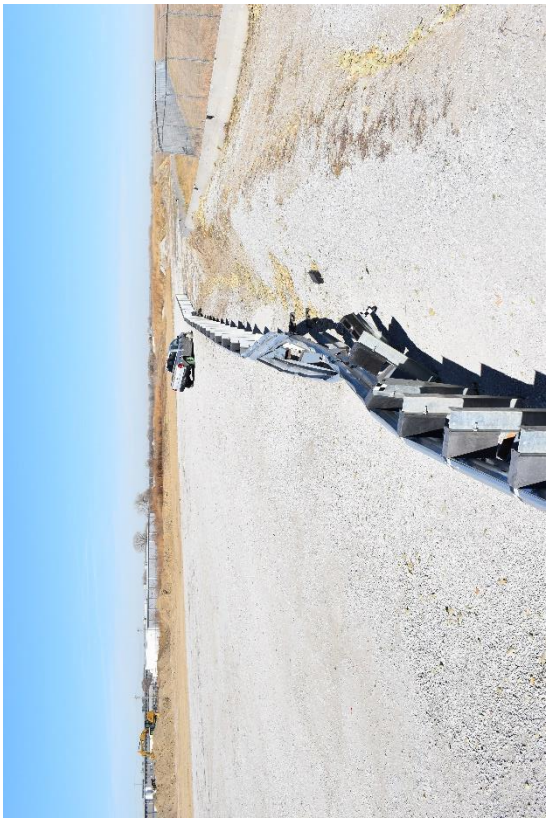


Figure 250. Overall System Damage, Test No. HBIB-5



Figure 251. Upper Rail and Rubrail Damage, Test No. HBIB-5









Figure 252. Upper Rail and Rubrail Damage, Test No. HBIB-5

The maximum lateral permanent set deflection of the system was 32.4 in., which occurred at post no. 10, as measured in the field. The maximum lateral dynamic system deflection was 35.7 in. on the rail between post nos. 10 and 11, as determined from high-speed digital video analysis. The working width of the system was found to be 56.8 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 253.

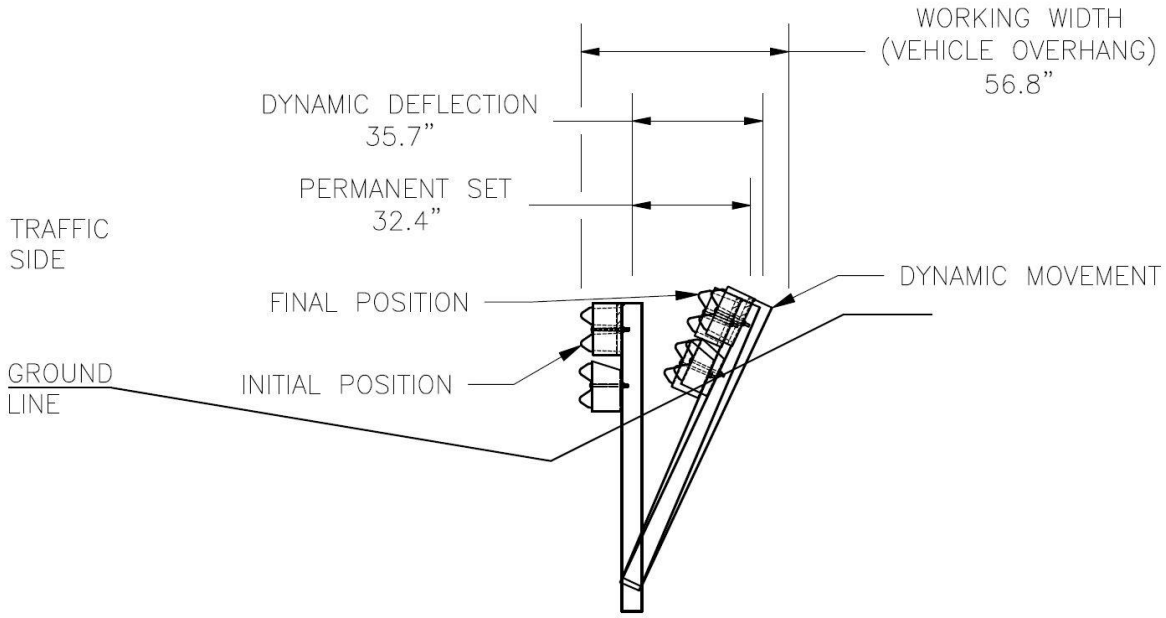


Figure 253. Permanent Set Deflection, Dynamic Deflection, and Working Width, Test No. HBIB-5

12.5 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 254 through 256. The majority of the damage was concentrated on the right-front corner and right side of the vehicle where the impact occurred. The front bumper cover was detached from the body and was crushed inward and rearward at its right end. The right-front fender was scraped and dented across its entire length and detached at its bottom end. The right headlight was disengaged from the body. The right-front door was dented and scraped along its entire length. The entire right side of the vehicle was scraped. The right side of the truck box was dented and scraped along its entire length, with the most severe damage being underneath the taillight. The right side of the rear bumper was crushed inward and scraped at the area of crush.

Undercarriage damage was moderate. The right-front shock was broken in half, and the right-front spring disengaged from the frame. The right-side lower control arm was disengaged from the vehicle. The right-side upper control arm was bent around the ball joint, and the lower control arm is disengaged from the vehicle. The right inner tie rod was detached from the steering rack.

The maximum occupant compartment intrusions are listed in Table 26, along with the intrusion limits established in MASH for various areas of the occupant compartment. Complete occupant compartment, vehicle intrusions, and the corresponding locations of the deformations are provided in Appendix F. MASH defines intrusion as the occupant compartment being deformed and reduced in size with no penetration. Outward deformations, which are denoted as negative numbers in Appendix F, are not considered as crush toward the occupant, and are not subject to evaluation by MASH criteria.



Figure 254. Vehicle Damage, Test No. HBIB-5



Figure 255. Vehicle Damage, Test No. HBIB-5






Figure 256. Interior and Undercarriage Damage, Test No. HBIB-5

Table 26. Maximum Occupant Compartment Intrusion by Location, Test No. HBIB-5

Location	Maximum Intrusion in.	MASH Allowable Intrusion in.
Wheel Well & Toe Pan	2.3	≤ 9
Floor Pan & Transmission Tunnel	0.0	≤ 12
A-Pillar	0.0	≤ 5
A-Pillar (Lateral)	0.0*	≤ 3
B-Pillar	0.1	≤ 5
B-Pillar (Lateral)	0.0*	≤ 3
Side Front Panel (in Front of A-Pillar)	0.3	≤ 12
Side Door (Above Seat)	0.0*	≤ 9
Side Door (Below Seat)	0.1	≤ 12
Roof	0.1	≤ 4
Windshield	0.0	≤ 3
Side Window	Intact	No shattering resulting from contact with structural member of test article
Dash	0.6	N/A

N/A – Not applicable
*Negative value reported as 0.0. See Appendix F for further information.

12.6 Occupant Risk

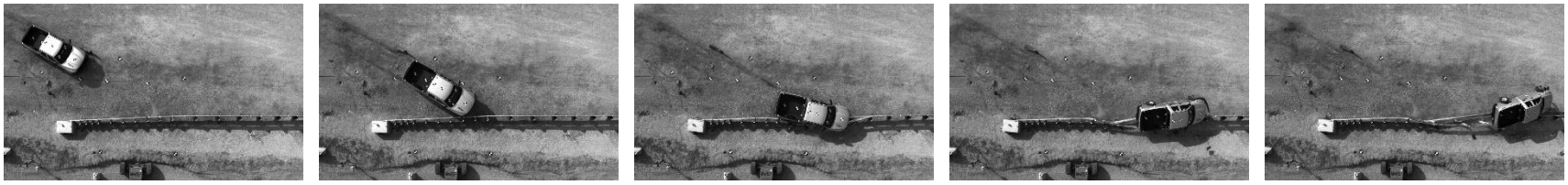
The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined by accelerometer data, are shown in Table 27. Note that the OIVs and ORAs were within suggested limits, as provided in MASH. The calculated THIV, PHD, and ASI values are also shown in Table 27. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix K.

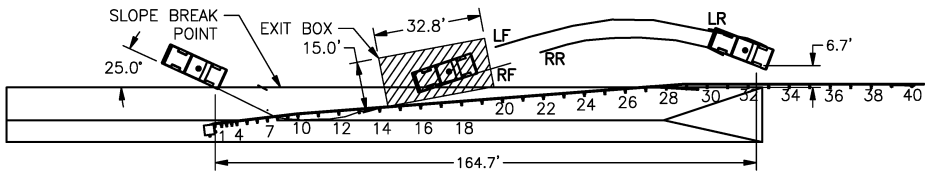
Table 27. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. HBIB-5

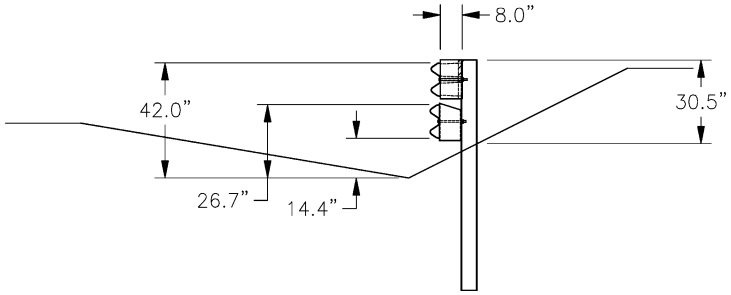
Evaluation Criteria		Transducer		MASH Limits
		SLICE-1 (backup)	SLICE-2 (primary)	
OIV ft/s	Longitudinal	-23.16	-21.95	±40
	Lateral	-15.50	-16.58	±40
ORA g's	Longitudinal	-10.14	-10.56	±20.49
	Lateral	-9.97	-9.20	±20.49
Maximum Angular Displacement deg.	Roll	53.0	47.3	±75
	Pitch	-5.3	-7.5	±75
	Yaw	-52.2	-52.8	not required
THIV ft/s		26.38	27.21	not required
PHD g's		12.00	12.05	not required
ASI		1.04	1.09	not required

12.7 Discussion

The analysis of the test results for test no. HBIB-5 showed that the system adequately contained and redirected the 2270P vehicle with controlled lateral displacements of the system. A summary of the test results and sequential photographs are shown in Figure 257. 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 system at a speed of 33.0 mph an angle of 21.1 degrees, and its trajectory did not violate the bounds of the exit box. Therefore, test no. HBIB-5 was determined to be acceptable according to the MASH safety performance criteria for test designation no. 3-35.







- Test Agency ..... MwRSF
- Test Number HBIB-5
- Date 11/7/23
- MASH Test Designation No. 3-35
- Test Article ..... Hawaii DOT Buried in Backslope
- Total Length ..... 219 ft – $3^{15}/_{16}$ in.
- Key Component – Steel W-beam Guardrail
  - Thickness ..... 12 gauge
  - Top Mounting Height ..... 32 in.
- Key Component – Steel Post
  - Shape W6x8.5
  - Length ..... 96 in.
  - Embedment Depth ..... 64 in.
  - Spacing ..... 75 in.
- Key Component – Composite Recycled Blockout (Post Nos. 1-38)
  - Shape ..... $14^{3}/_{16}$ x 8 x 5⅛
- Soil Type ..... Coarse, Crushed Limestone (Well-Graded Gravel)
- Vehicle Make / Model ..... 2018 Ram 1500
  - Curb ..... 5,013 lb
  - Test Inertial ..... 4,998 lb (MASH Limit 5,000 ± 110 lb)
  - Gross Static ..... 5,160 lb (MASH Limit 5,165 ± 110 lb)
- Impact Conditions
  - Speed ..... 63.7 mph (MASH Limit 62 ± 2.5 mph)
  - Angle ..... 25.0 deg. (MASH Limit 25 ± 1.5 deg.)
  - Impact Location ..... 4.1 in. upstream from centerline of post no. 8
- Impact Severity ..... 121.1 kip-ft ≥ 106 kip-ft minimum from MASH
- Exit Conditions
  - Speed ..... 29.5 mph
  - Angle ..... 21.1 deg.
- Vehicle Stability ..... Satisfactory
- Vehicle Stopping Distance ..... 164.7 ft downstream, 6.7 ft laterally in front
- Exit Box Criterion ..... Pass
- Vehicle Damage ..... Moderate
  - VDS [21] 1-RFQ-4
  - CDC [22] 01-FDEW-9
- Maximum Interior Deformation ..... 2.3 in. at Wheel Well & Toe Pan ≤ 9-in. MASH limit
- Test Article Damage ..... Minimal
- Maximum Test Article Deflections
  - Permanent Set ..... 32.4 in.
  - Dynamic ..... 35.7 in.
  - Working Width ..... 56.8 in.
- Transducer Data

Evaluation Criteria		Transducer		MASH Limit
		SLICE-1 (backup)	SLICE-2 (primary)	
OIV ft/s	Longitudinal	-23.16	-21.95	±40
	Lateral	-15.50	-16.58	±40
ORA g's	Longitudinal	-10.14	-10.56	±20.49
	Lateral	-9.97	-9.20	±20.49
Maximum Angular Displacement deg.	Roll	53.0	47.3	±75
	Pitch	-5.3	-7.5	±75
	Yaw	-52.2	-52.8	not required
THIV – ft/s		26.38	27.21	not required
PHD – g's		12.00	12.05	not required
ASI		1.04	1.09	not required

Figure 257. Summary of Test Results and Sequential Photographs, Test No. HBIB-5

13 CONCRETE ANCHOR BLOCK MODIFICATION

Full-scale crash test nos. HBIB-1 through HBIB-5 used the same concrete anchor block. Reinforcing posts were added to the downstream side and back sides of the block to simulate additional soil reinforcement that may be present due to in-use soil conditions. However, care should be taken to ensure that the anchor block is securely anchored into the soil. If the soil anchorage is insufficient, the anchor block may displace during an impact and allow an impacting vehicle to extend further into the ditch than desired. Increased deflection may increase the risk of wheel snagging or instability, potentially resulting in rollover. Therefore it is recommended that the anchor block be firmly engaged with the soil and additional subgrade reinforcement, such as a cored shaft or additional soil reinforcement like the posts used in this research effort, be used to decrease the soil displacement of the above-grade anchor. Photos documenting the anchor block displacement are shown in Figure 258.

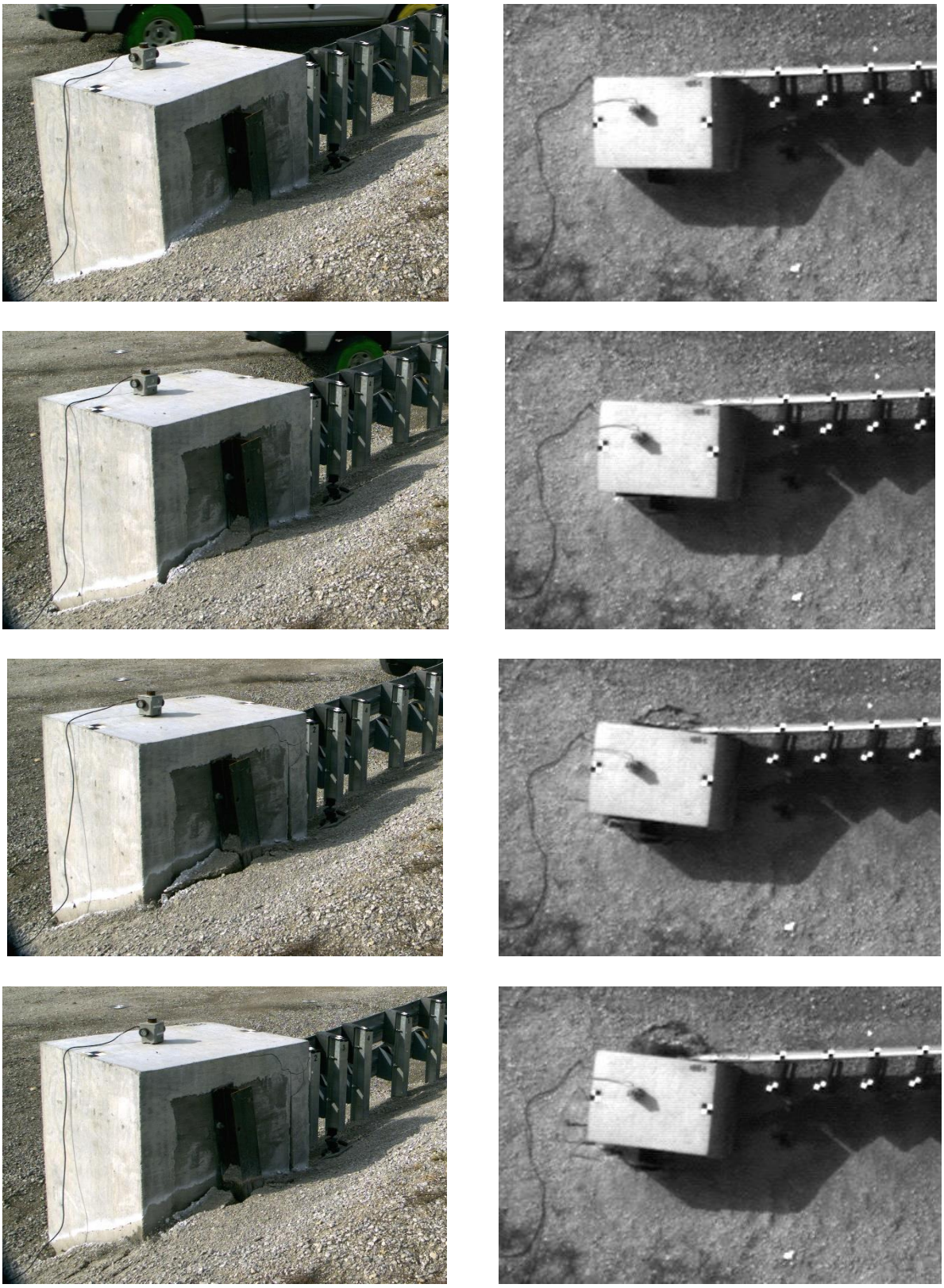


Figure 258. Anchor Block Displacement, Test No. HBIB-5

14 SUMMARY AND CONCLUSIONS

The Hawaii DOT Buried-in-Backslope terminal was successfully evaluated with MASH test designations 3-32, 3-33, 3-34, and 3-35. A summary of all test evaluations is shown in Table 28.

The initial system was constructed similarly to a system previously tested according to criteria presented in NCHRP Report No. 350 [4]. The system consisted of a roadside tangent MGS connected to a flared guardrail system with an upper W-beam rail and lower W-beam rubrail. Both rails were anchored to a 3-ft x 3-ft x 3-ft concrete anchor block at the upstream end using two W-beam end terminal connectors. Downstream from the anchor block was a stiffness transition using quarter- and half-post spacing, with nested upper W-beam and nested lower rubrail. Downstream from the stiffness transition, posts flared forward from the anchor block at a 13:1 rate until the system connected to the downstream tangent MGS. The W-beam rubrail was attached to the front face of the flanges of the posts through the ditch and was terminated by bending the W-beam backward and behind the back flange of post no. 29 and fastened to the post with a bolt and pipe collar. The rail height was 31 in. extending from the anchor block to the tangent MGS.

In test no. HBIB-1, the 2,411-lb small car impacted the system at a speed of 61.7 mph, an angle of 15.0 degrees at a location 12.3 in. downstream from the downstream end of the concrete anchor block, thus resulting in a kinetic energy of 305.4 kip-ft. After impacting the barrier system, the vehicle exited the system at a speed of 29.4 mph and an angle of 12.3 degrees. The vehicle was successfully contained; however, it was not redirected smoothly. Due to the severity of the impact to the top rail, the lateral deformation of the A-pillar measured 4.2 in., which exceeded the MASH safety limit of 3.0 in. The primary EDR recorded a longitudinal ORA of 27.56 g's, which exceeded the MASH limits of 20.49 g's. Therefore, test no. HBIB-1 was deemed unsuccessful according to the safety criteria of MASH test designation no. 3-32.

A review of system performance indicated that both A-pillar deformation and wheel snag for the small car impacting at a low angle would be improved by reducing the height of the system through the ditch and adding blockouts to the rubrail. An optimization study was conducted to identify the optimal system height as a function of offset from the ditch slope break point. Three system options were identified with the potential to capture the vehicle; the simplest of the three systems, which used W-beam that tapered down from the tangent guardrail to the anchor block, was preferred.

MASH test designation no. 3-32 was rerun after the failure of test no. HBIB-1 as test no. HBIB-2. In test no. HBIB-2, the 2,462-lb small car impacted the HBIB system at a speed of 61.7 mph and at an angle of 15.0 degrees at a location 9.9 in. downstream from the downstream end of the concrete anchor block, resulting in a kinetic energy of 313.3 kip-ft. After impacting the barrier system, the vehicle exited the system at a speed of 42.2 mph and an angle of 11.2 degrees. The vehicle was successfully contained and smoothly redirected with moderate damage to the vehicle and minimal damage to the barrier system. All vehicle decelerations, ORAs, and OIVs fell within the recommended safety limits established in MASH. Therefore, test no. HBIB-2 was successful according to the safety criteria of MASH test designation no. 3-32.

In test no. HBIB-3, the 5,068-lb quad cab pickup truck impacted the HBIB system at a speed of 62.5 mph and at an angle of 15.0 degrees at approximately 19.2 in. downstream from the

upstream end of the concrete anchor block, thus resulting in a kinetic energy of 661.8 kip-ft. After impacting the barrier system, the vehicle exited the system at a speed of 38.3 mph and an angle of 8.0 degrees. The vehicle was successfully contained and smoothly redirected with moderate damage to the vehicle and minimal damage to the barrier system. All vehicle decelerations, ORAs, and OIVs fell within the recommended safety limits established in MASH. Therefore, test no. HBIB-3 was successful according to the safety criteria of MASH test designation no. 3-33.

In test no. HBIB-4, the 2,418-lb small car impacted the HBIB system at a speed of 62.1 mph and at an angle of 15.1 degrees at a location 0.43 in. upstream of the centerline of post no. 8., thus resulting in an impact severity of 21.2 kip-ft. After impacting the barrier system, the vehicle exited the system at a speed of 44.3 mph and an angle of 15.4 degrees. The vehicle was successfully contained and smoothly redirected with moderate damage to the vehicle and minimal damage to the barrier system. All vehicle decelerations, ORAs, and OIVs fell within the recommended safety limits established in MASH. Therefore, test no. HBIB-4 was successful according to the safety criteria of MASH test designation no. 3-34.

In test no. HBIB-5, the 4,998-lb quad cab pickup truck impacted the HBIB system at a speed of 63.7 mph and at an angle of 25.0 degrees at the center line of post no. 8, thus resulting in an impact severity of 121.1 kip-ft. After impacting the barrier system, the vehicle exited the system at a speed of 29.5 mph and an angle of 21.1 degrees. The vehicle was successfully contained and smoothly redirected with moderate damage to both vehicle and barrier system. All vehicle decelerations, ORAs, and OIVs fell within the recommended safety limits established in MASH. Therefore, test no. HBIB-5 was successful according to the safety criteria of MASH test designation no. 3-35.

Table 28. Summary of Safety Performance Evaluation, Test Nos. HBIB-1 through HBIB-5

Evaluation Factors	Evaluation Criteria				HBIB-1	HBIB-2	HBIB-3	HBIB-4	HBIB-5
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	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	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.			U	S	S	S	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	S
	H.	Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 of MASH for calculation procedure) should satisfy the following limits:			S	S	S	S	S
		Occupant Impact Velocity Limits							
		Component	Preferred	Maximum					
		Longitudinal and Lateral	30 ft/s	40 ft/s					
	I.	The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH for calculation procedure) should satisfy the following limits:			U	S	S	S	S
		Occupant Ridedown Acceleration Limits							
		Component	Preferred	Maximum					
		Longitudinal and Lateral	15.0 g's	20.49 g's					
MASH Test Designation No.					3-32	3-32	3-33	3-34	3-35
Final Evaluation (Pass or Fail)					Fail	Pass	Pass	Pass	Pass

S – Satisfactory U – Unsatisfactory N/A – Not Applicable

15 MASH IMPLEMENTATION

The primary objective of this research study was to evaluate the crashworthiness of the Hawaii DOT Buried-in-Backslope system to MASH TL-3 impact conditions. According to MASH TL-3 evaluation criteria, end terminals may be subjected to eight full-scale crash tests. For this evaluation, MASH test designations 3-30 and 3-31 were unnecessary because the terminal is installed on a slope with limited end-on exposure. Additionally, HDOT indicated that when the anchor block is installed within the clear zone, additional soil grading or crashworthy end treatments may be used to shield the anchor block; however, the anchor block is typically installed outside of the clear zone. MASH test designations 3-32, 3-33, 3-34, and 3-35 were performed at the critical locations in the ditch and at the location of maximum potential for underride and override. Note that for the system to be used in reverse-direction configurations, it is necessary to evaluate the terminal according to MASH 3-37a and 3-37b impacts. Results of the reverse-direction evaluation are described in a separate report [23].

15.1 BiB Flare Rates

Two guardrail flare rates were evaluated in this study: a 13:1 flare rate adjacent to the roadway, and a 8.4:1 flare rate starting near the bottom of the V-ditch. Although historically flare rates higher than 8.4:1 were permitted upstream from the 8.4:1 flared system, it is not recommended that increased flare rates be used without additional testing. Guardrail flare rates, if in the clear zone, may increase the effective angle of impact and could lead to increased rail loading and potential for high vehicle accelerations, snag, or instability.

15.2 Alternative Ditch Configurations

The V-ditch selected for evaluation in this study had a maximum depth of 25 in. below the roadway surface. The as-tested configuration of the system is applicable in ditches with foreslopes of 6H:1V or flatter and which are wider and deeper than 25 in. Recommended configurations of the HBIB system for alternative ditch configurations are described in the following sections.

For V-ditches with foreslopes shallower than 6H:1V, it is recommended that a similar procedure be used as was applied for test no. HBIB-2. For posts up to 5 ft laterally from the slope break point, the rail should be installed at the same elevation as the tangent guardrail; and for posts farther than 5 ft from the slope break point, a constant elevation above the ditch surface should be used. Note that the 60-in. offset is measured between the ditch slope break point and the centerline of the back side of the post. Examples of potential installations in alternative ditch configurations are shown in Figures 259 through 263.

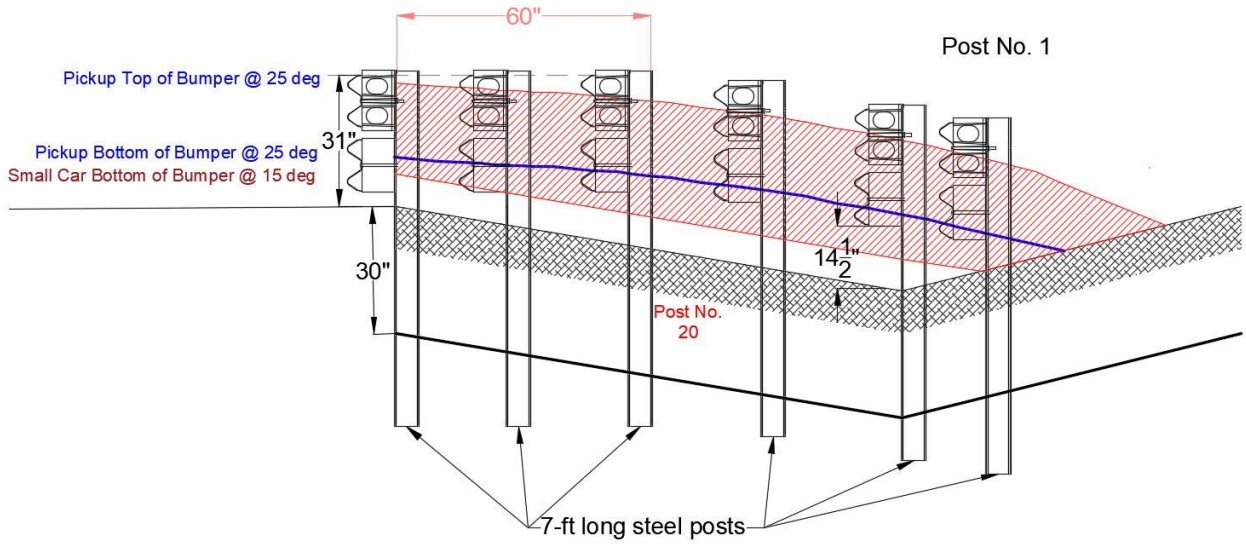


Figure 259. HBIB Configuration for V-ditch 6H:1V Front Slope, 4H:1V Backslope

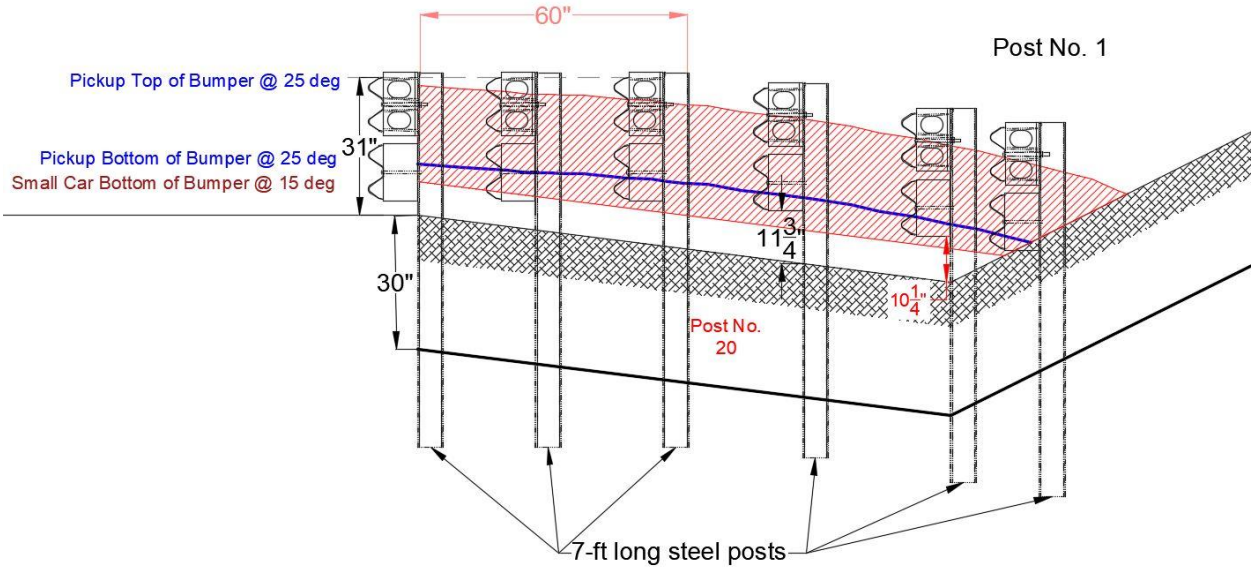


Figure 260. HBIB Configuration for 8H:1V Front Slope, 2H:1V Backslope

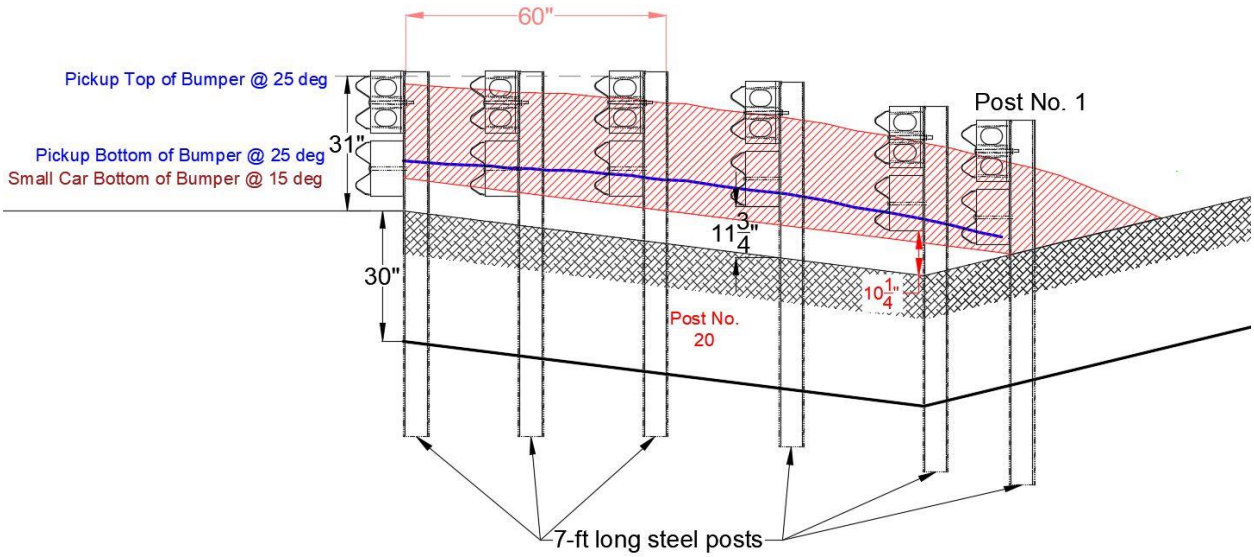


Figure 261. HBIB Configuration for 8H:1V Front Slope, 4H:1V Backslope

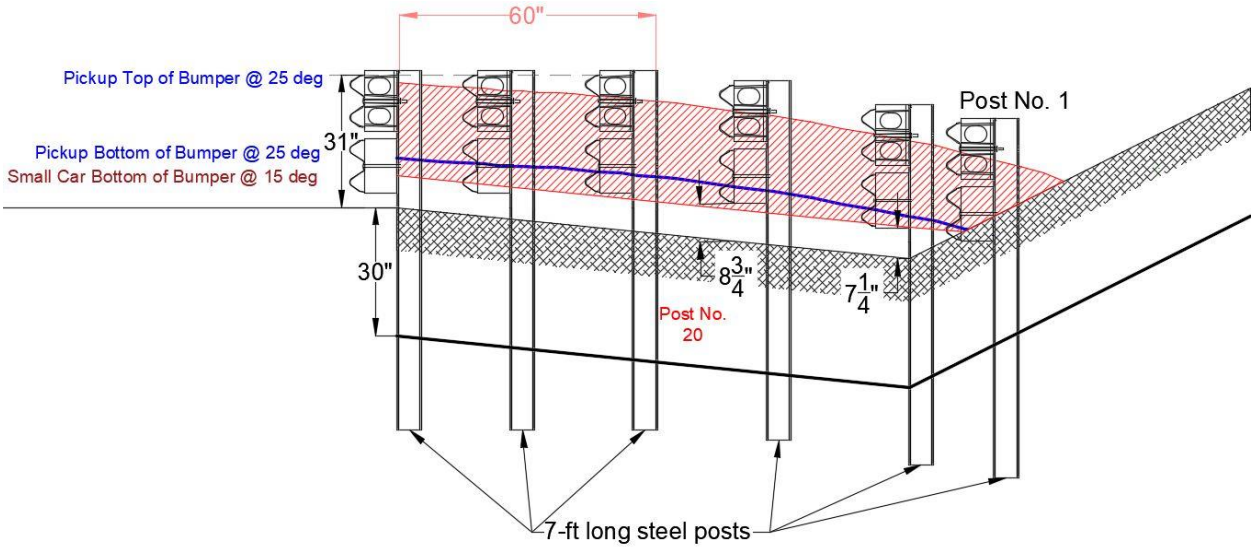


Figure 262. HBIB Configuration for 10H:1V Front Slope, 2H:1V Backslope

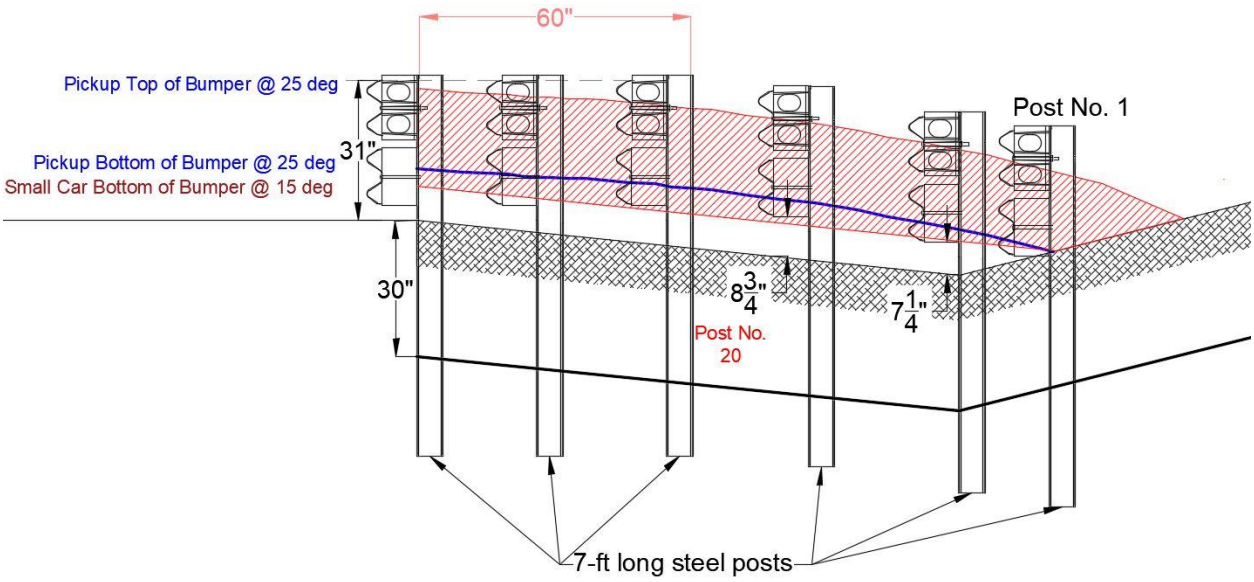


Figure 263. HBIB Configuration for 10H:1V Front Slope, 4H:1V Backslope

15.3 Limitations for Reverse-Direction and Trailing End Implementation

Not shown in this report, two CIPs were identified and full-scale crash tested in reverse-direction MASH test designations 3-37a and 3-37b. The two locations corresponded with the "knee" of the guardrail system located at post no. 27 and the anchor block at the upstream end of the system. Reverse-direction testing at the "knee" of the system was determined to be successful to MASH evaluation criteria, and reverse-direction impacts adjacent to the anchor block were successful with the two-flare configuration of the BIB system (i.e., Type B). Therefore, the two-flare configuration of the BIB system would be considered crashworthy for approach and departure-side applications, as well as in locations where the BIB system would be within the clear zone of opposing travel lanes. It is not recommended to install a single-flare configuration of the BIB system as a trailing-end termination.

16 REFERENCES

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17 APPENDICES

Appendix A. A2LA Accreditation Certificates



Accredited Laboratory

A2LA has accredited

MIDWEST ROADSIDE SAFETY FACILITY (MwRSF)

Lincoln, NE

for technical competence in the field of

Mechanical Testing

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2017 *General requirements for the competence of testing and calibration laboratories*. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (*refer to joint ISO-ILAC-IAF Communiqué dated April 2017*).

Presented this 1st day of December 2021.

Vice President, Accreditation Services
For the Accreditation Council
Certificate Number 2937.01
Valid to November 30, 2023

For the tests to which this accreditation applies, please refer to the laboratory's Mechanical Scope of Accreditation.

Figure A-1. Midwest Roadside Safety Facility A2LA Accreditation Certificate No. 2937.01

SCOPE OF ACCREDITATION TO ISO/IEC 17025:2017

MIDWEST ROADSIDE SAFETY FACILITY (MwRSF)[1]
University of Nebraska-Lincoln
4630 NW 36th Street
Lincoln, NE 68524
Ms. Karla Lechtenberg Phone: 402 472 9070

MECHANICAL

Valid To: November 30, 2023 Certificate Number: 2937.01

In recognition of the successful completion of the A2LA evaluation process, accreditation is granted to this laboratory to perform the following tests:

Tests	Test Methods[2]
Full-Scale Vehicle Crash Tests of Highway Safety Features	NCHRP Report 350; MASH; EN 1317
Full-Scale Vehicle Crash Tests of Perimeter Protection Systems and Access Control Devices	ASTM F2656; SD-STD-02.01 Revision A
Bogie Dynamic Tests of Highway Safety Features	Non-Standard Test Method: Dynamic Testing of Steel Post and Rigid Foundation; Non-Standard Test Method: Dynamic Testing of Post in Soil; Non-Standard Test Method: Dynamic Testing of Spacer Blocks
Crushable Nose Bogie Testing for Breakaway Supports	Non-Standard Test Method: Dynamic Testing of Breakaway Supports; AASHTO Breakaway Poles and Supports; NCHRP Report 350

On the following types of products, materials, and/or structures:
Metal, Wood, Concrete and Plastic Structures, Components of Structures, Fasteners, and Roadway Pavements.

[1] Administrative office located at: 2200 Vine Street, 130 Whittier Building, Lincoln, NE 68583-0853.

[2] This laboratory performs field testing activities for these tests.

(A2LA Cert. No. 2937.01) 12/01/2021 Page 1 of 1

5202 Presidents Court, Suite 220 | Frederick, MD 21703-8515 | Phone: 301 644 3248 | Fax: 240 454 9449 | www.A2LA.org

Figure A-2. Midwest Roadside Safety Facility Scope of Accreditation to ISO/IEC 17025

Appendix B. Material Specifications

Table B-1. Bill of Materials for Test Nos. HBIB-1 through HBIB-5

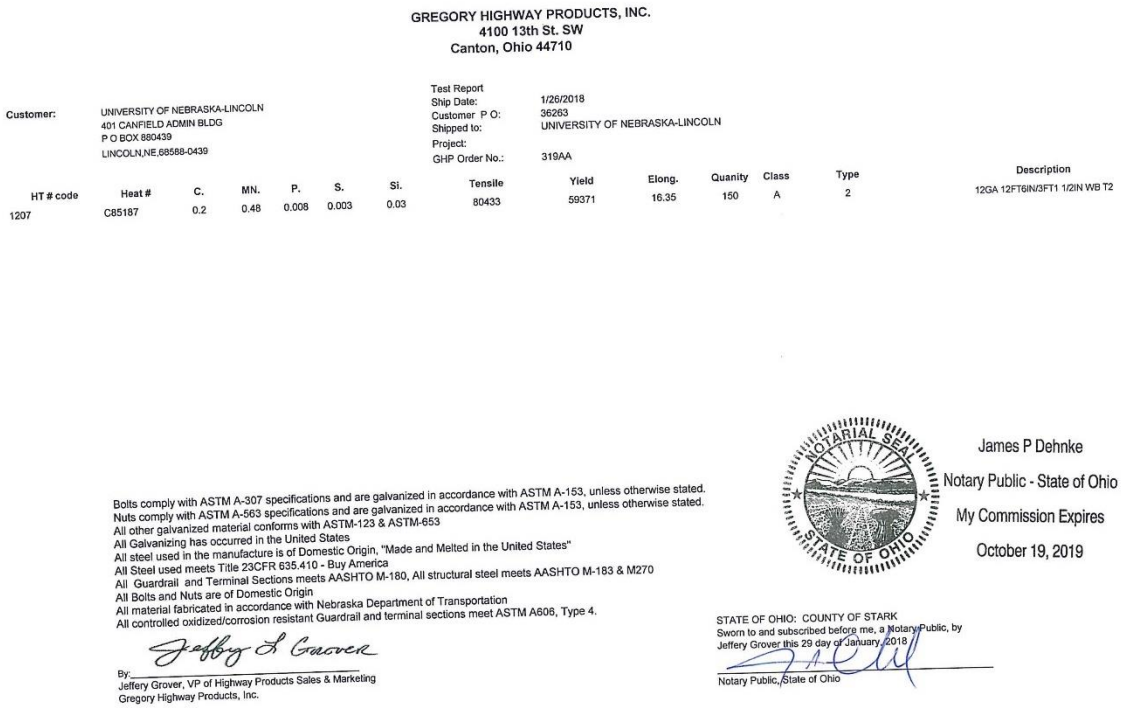
Item No.	Test No.	Description	Material Specification	Reference
a1	1-5	12'-6" 12-gauge W-Beam MGS Section	AASHTO M180	H#C85187
a2	1-5	12'-6" 12-gauge W-Beam MGS End Section	AASHTO M180	H#C85187
a3	1-5	6'-3" W-Beam Section	AASHTO M180	H#4114294
a4	1	12'-6" 12-gauge Bent W-Beam	AASHTO M180	H#L14222 H#L14422
	2-5	12'-6" 12-gauge Bent W-Beam [4.4 deg]		
a5	1	9'-4½" 12-gauge Bent W-Beam	AASHTO M180	H#L14222 H#L14422
	2-5	9'-4½" 12-gauge Bent W-Beam [2.4 deg]		
a6	1	12'-6" 12-gauge Bent W-Beam	AASHTO M180	H#L14222 H#L14422
	2-5	12'-6" 12-gauge Bent W-Beam [2.4 deg]		
a7	1	12'-6" W-Beam Section - 1/4 Post Spacing	AASHTO M180	H#4146161
	2-5			H#AA6765
a8	1	12'-6" 12-gauge Bent W-Beam	AASHTO M180	H#L14222 H#L14422
	2-5	W-Beam Terminal Connector		H#L13422
a9	1	12'-6" 12-gauge Bent W-Beam	AASHTO M180	H#L14222 H#L14422
	2-5	12'-6" 12-gauge Bent W-Beam [7.7 deg]		
a10	1	12'-6" 12-gauge Bent W-Beam	AASHTO M180	H#L14222 H#L14422
a11	1	W-Beam End Shoe Section	AASHTO M180	H#264531
a12	1	W-Beam Bent End Shoe Section	AASHTO M180	H#264531
b1	1-5	3' x 3' x 3' Concrete Block Anchor	Min. f'c = 4,000 psi	Ticket#2037468
c1	1-5	BCT Timber Post - MGS Height	SYP Grade No. 1 or better (No knots +/- 18" from ground on tension face)	Ch#6064
c2	1-5	72" Long Foundation Tube	ASTM A500 Gr. B	H#821T08220
c3	1-5	Ground Strut Assembly	ASTM A36	Strut H#C43126 Yoke H#574109
c4	1-5	BCT Cable Anchor Assembly	-	PO# 22-1010

Table B-2. Bill of Materials for Test Nos. HBIB-1 through HBIB-5, Cont.

Item No.	Test No.	Description	Material Specification	Reference
c5	1-5	Anchor Bracket Assembly	ASTM A36	H#JK16101488
c6	1-5	8" x 8" x ⅝" Anchor Bearing Plate	ASTM A36	H#1072318
c7	1-5	2⅜" O.D. x 6" Long BCT Post Sleeve	ASTM A53 Gr. B Schedule 40	H#B712810
d1	1-5	W6x8.5 or W6x9, 96" Long Steel Post	ASTM A992 Gr. 50	H#59105615
d2	1-5	W6x8.5 or W6x9, 72" Long Steel Post	ASTM A992 Gr. 50	H#55064803
d3	1-5	W6x15, 120" Long Steel Post	ASTM A992 Gr. 50	H#55071339 H#59105307
d4	1-5	$14^{3}/_{16}$" x 8" x 5⅛" Composite Recycled Blockout	Mondo Polymer GB14SH2 or Equivalent	L#1804-1000 P#GB14SH2
d5	1	6 x 12 x 14¼" Tapered Timber Blockout	SYP Grade No.1 or better	Ch#24883
	2-5	13⅝" [346] Long x 8" x 6" x ¼" [203 x 152 x 6] Steel Blockout	ASTM A500 Gr. B	H#A72851
d6	1	6 x 12 x 14¼" Tapered Timber Blockout	SYP Grade No.1 or better	Ch#24883
	2-5	16D Double Head Nail	-	PO E000357170
d7	1	6 x 12 x 14¼" Tapered Timber Blockout	SYP Grade No.1 or better	Ch#24883
d8	1			
d9	1	16D Double Head Nail	-	PO E000357170
e1	1-5	144½" Unbent Length #4 Rebar	ASTM A615 Gr. 60	H#6035977
e2	1-5	28" Long #4 Rebar	ASTM A615 Gr. 60	H#6035977
f1	1-5	⅝" Dia. UNC, 10" Long Guardrail Bolt	ASTM A307 Gr. A	H#10666100
	2-5			H#1000217087
f2	1-5	⅝" Dia, UNC, 5" Long Hex Head Bolt	ASTM A449 Gr. 5 or Equivalent	H#3093332 PB#157410
f3	1-5	⅝" Dia, UNC, 2" Long Hex Head Bolt	ASTM A307 Gr. A or Equivalent	P#1191921 C#200233148
f4	1-5	⅝" Dia. UNC, 1¼" Long Guardrail Bolt	ASTM A307 Gr. A	H#10710510
	2-5			H#20841080
f5	1-5	⅞" Dia. UNC, 8" Long Hex Head Bolt	ASTM A307 Gr. A or Equivalent	P#92005 C#llne35042

Table B-3. Bill of Materials for Test Nos. HBIB-1 through HBIB-5, Cont.

Item No.	Test No.	Description	Material Specification	Reference
f6	1-5	⅞" Dia. UNC, 2" Long Hex Head Bolt	ASTM A307 Gr. A or Equivalent	H#1000217614 C#210270562
f7	1-5	⅝" Dia. UNC, 10" Long Hex Head Bolt	ASTM A307 Gr. A or Equivalent	H#JK18104124
f8	1-5	⅝" Dia. UNC, 1½" Long Hex Head Bolt	ASTM A307 Gr. A or Equivalent	P#1191919 C#120383161
f9	1-5	¾" Dia., Unthreaded Spacer Sleeve	ASTM A53 Gr. B	H#4132970
f10	1	⅝" Dia., UNC, 8" Long Carriage Bolts	ASTM A307 Gr. A	P#28401
	2-5	¾" Dia. 10 UNC, 13" Long Fully Threaded Rod	ASTM A193 Gr. B7	H#6613040032
f11	1	¾" Dia. 10 UNC, 13" Long Fully Threaded Rod	ASTM A193 Gr. B7	H#6613040032
	2-5	⅞" Dia. 9 UNC, 10" Long Fully Threaded Rod	ASTM A307 Gr. A or Equivalent	H#18F03356
g1	1-5	⅞" Dia. Plain Round Washer	ASTM F844	P#33188 C#210151571
g2	1-5	⅝" Dia. Plain Round Washer	ASTM F844	L#20200515
g3	1	1" Dia. Plain Round Washer	ASTM F844	P#33188 C#210151571
h1	1	⅝" Dia. UNC Heavy Hex Nut	ASTM A563A or A563DH	H#10724400 H#B21110224
	2-5			H#10724400 H#8000021095
h2	1-5	⅝" Dia. Hex Nut	ASTM A563A	H#331608011 P#36713
h3	1-5	¾"-10 UNC Heavy Hex Nut	ASTM A563DH or Equivalent	H#HB01435 P#0123453M
h4	1-5	⅞" Dia. Hex Nut	ASTM A563A or equivalent	H#331704677
	2-5			P#36118
i1	1-5	¾" Dia. Wire Strut, 13⅜" Long Unbent	Min. Tensile Strength = 100,000 psi	H#1000215392 L#5716
i2	1-5	⅜" Dia. Wire Strut, 16⅜" Long Unbent		
i3	1-5	⅜" Dia. Wire Strut, 18" Long Unbent		
i4	1-5	⅞" Dia., Threaded Ferrule	-	L#696926 & L#695163
j1	1-5	Epoxy Adhesive	Min. Bond Strength = 1,450 psi	Hilti COC



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.

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

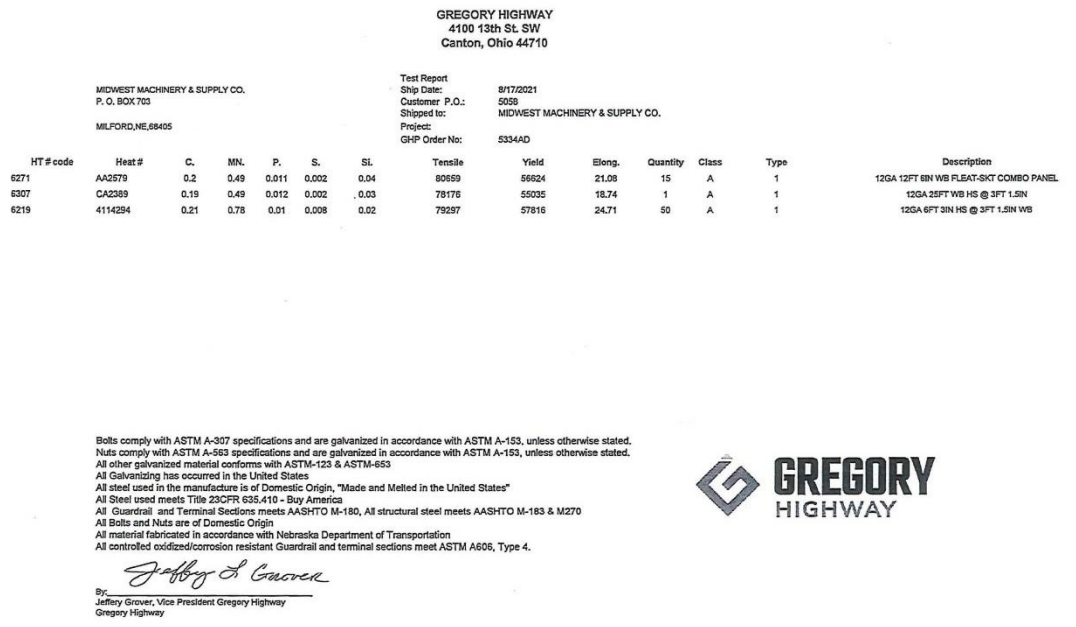
NOTARIAL SEAL STATE OF OHIO

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-1. 12-Gauge 12-ft 6-in. long W-Beam Guardrail, Test Nos. HBIB-1 through HBIB-5 (Item Nos. a1-a2)



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

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

MILFORD,NE,68405

Test Report
Ship Date: 8/17/2021
Customer P.O.: 5058
Shipped to: MIDWEST MACHINERY & SUPPLY CO.
Project:
GHP Order No: 5334AD

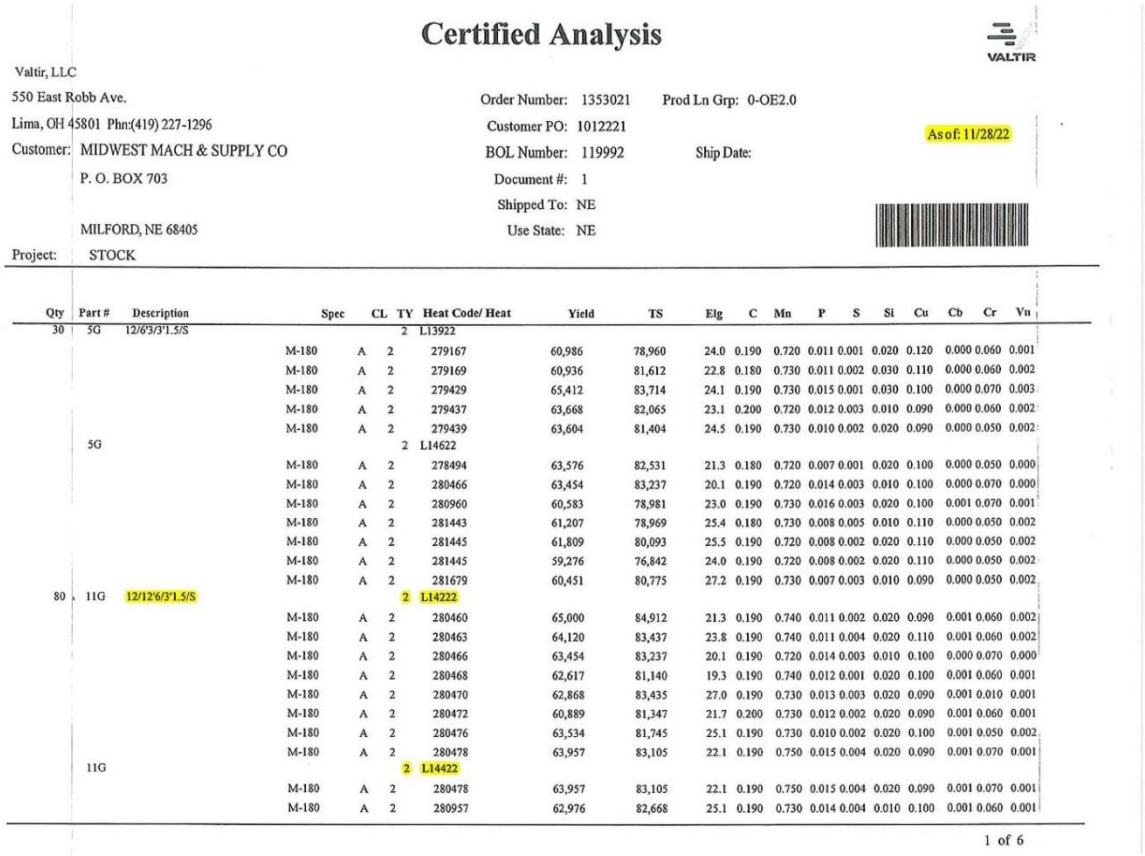
HT # code	Heat #	C.	MN.	P.	S.	Si.	Tensile	Yield	Elong.	Quantity	Class	Type	Description
6271	AA2579	0.2	0.49	0.011	0.002	0.04	80659	56624	21.08	15	A	1	12GA 12FT 6IN WB FLEAT-SKT COMBO PANEL
6307	CA2389	0.19	0.49	0.012	0.002	0.03	78176	55035	18.74	1	A	1	12GA 25FT WB HS @ 3FT 1.5IN
6219	4114294	0.21	0.78	0.01	0.008	0.02	79297	57816	24.71	50	A	1	12GA 6FT 3IN HS @ 3FT 1.5IN WB

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.

By: Jeffery Grover
Jeffery Grover, Vice President Gregory Highway
Gregory Highway

GREGORY HIGHWAY

Figure B-2. 12-Gauge 6-ft 3-in. long W-Beam Guardrail, Test Nos. HBIB-1 through HBIB-5 (Item No. a3)



Certified Analysis

VALTIR

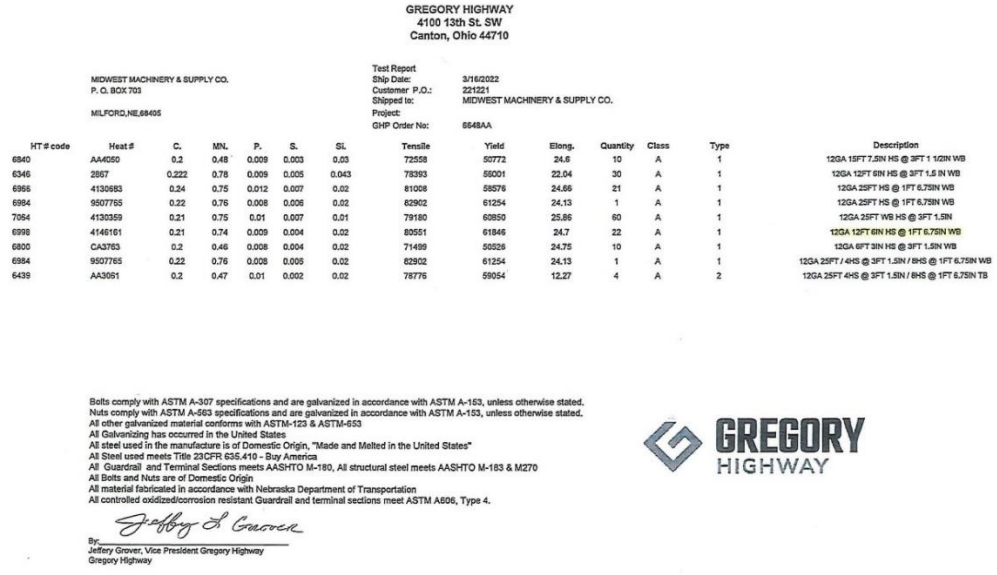
Valtir, LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296
Customer: MIDWEST MACH & SUPPLY CO
P. O. BOX 703
MILFORD, NE 68405
Project: STOCK

Order Number: 1353021 Prod Ln Grp: 0-OE2.0
Customer PO: 1012221
BOL Number: 119992 Ship Date:
As of: 11/28/22
Document #: 1
Shipped To: NE
Use State: NE

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn
30	5G	12/6'3/3'1.5/S			2	L13922												
			M-180	A	2	279167	60,986	78,960	24.0	0.190	0.720	0.011	0.001	0.020	0.120	0.000	0.060	0.001
			M-180	A	2	279169	60,936	81,612	22.8	0.180	0.730	0.011	0.002	0.030	0.110	0.000	0.060	0.002
			M-180	A	2	279429	65,412	83,714	24.1	0.190	0.730	0.015	0.001	0.030	0.100	0.000	0.070	0.003
			M-180	A	2	279437	63,668	82,065	23.1	0.200	0.720	0.012	0.003	0.010	0.090	0.000	0.060	0.002
			M-180	A	2	279439	63,604	81,404	24.5	0.190	0.730	0.010	0.002	0.020	0.090	0.000	0.050	0.002
	5G				2	L14622												
			M-180	A	2	278494	63,576	82,531	21.3	0.180	0.720	0.007	0.001	0.020	0.100	0.000	0.050	0.000
			M-180	A	2	280466	63,454	83,237	20.1	0.190	0.720	0.014	0.003	0.010	0.100	0.000	0.070	0.000
			M-180	A	2	280960	60,583	78,981	23.0	0.190	0.730	0.016	0.003	0.020	0.100	0.001	0.070	0.001
			M-180	A	2	281443	61,207	78,969	25.4	0.180	0.730	0.008	0.005	0.010	0.110	0.000	0.050	0.002
			M-180	A	2	281445	61,809	80,093	25.5	0.190	0.720	0.008	0.002	0.020	0.110	0.000	0.050	0.002
			M-180	A	2	281445	59,276	76,842	24.0	0.190	0.720	0.008	0.002	0.020	0.110	0.000	0.050	0.002
			M-180	A	2	281679	60,451	80,775	27.2	0.190	0.730	0.007	0.003	0.010	0.090	0.000	0.050	0.002
80	11G	12/12'6/3'1.5/S			2	L14222												
			M-180	A	2	280460	65,000	84,912	21.3	0.190	0.740	0.011	0.002	0.020	0.090	0.001	0.060	0.002
			M-180	A	2	280463	64,120	83,437	23.8	0.190	0.740	0.011	0.004	0.020	0.110	0.001	0.060	0.002
			M-180	A	2	280466	63,454	83,237	20.1	0.190	0.720	0.014	0.003	0.010	0.100	0.000	0.070	0.000
			M-180	A	2	280468	62,617	81,140	19.3	0.190	0.740	0.012	0.001	0.020	0.100	0.001	0.060	0.001
			M-180	A	2	280470	62,868	83,435	27.0	0.190	0.730	0.013	0.003	0.020	0.090	0.001	0.010	0.001
			M-180	A	2	280472	60,889	81,347	21.7	0.200	0.730	0.012	0.002	0.020	0.090	0.001	0.060	0.001
			M-180	A	2	280476	63,534	81,745	25.1	0.190	0.730	0.010	0.002	0.020	0.100	0.001	0.050	0.002
			M-180	A	2	280478	63,957	83,105	22.1	0.190	0.750	0.015	0.004	0.020	0.090	0.001	0.070	0.001
	11G				2	L14422												
			M-180	A	2	280478	63,957	83,105	22.1	0.190	0.750	0.015	0.004	0.020	0.090	0.001	0.070	0.001
			M-180	A	2	280957	62,976	82,668	25.1	0.190	0.730	0.014	0.004	0.010	0.100	0.001	0.060	0.001

1 of 6

Figure B-3. 12-Gauge 12-ft 6-in. long W-Beam Guardrail, Test Nos. HBIB-1 through HBIB-5 (Item Nos. a4-a6, a9), Part a5 cut from 12 ft – 6 in. Segment, Test No. HBIB-1 (Item Nos. a8, a10)



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

MIDWEST MACHINERY & SUPPLY CO.
P. O. BOX 703
MILFORD,NE,68405

Test Report
Ship Date: 3/16/2022
Customer P.O.: 221221
Shipped to: MIDWEST MACHINERY & SUPPLY CO.
Project:
GHP Order No: 6648AA

HT # code	Heat #	C.	MN.	P.	S.	SI.	Tensile	Yield	Elong.	Quantity	Class	Type	Description
6840	AA4050	0.2	0.48	0.009	0.003	0.03	72558	50772	24.6	10	A	1	12GA 15FT 7.5IN HS @ 3FT 1 1/2IN WB
6346	2867	0.222	0.78	0.009	0.005	0.043	78393	58001	22.04	30	A	1	12GA 12FT 6IN HS @ 3FT 1.5 IN WB
6966	4130693	0.24	0.75	0.012	0.007	0.02	81008	58576	24.66	21	A	1	12GA 25FT HS @ 1FT 6.75IN WB
6984	9507765	0.22	0.76	0.008	0.006	0.02	82902	61254	24.13	1	A	1	12GA 25FT HS @ 1FT 6.75IN WB
7054	4130359	0.21	0.75	0.01	0.007	0.01	79180	60850	25.86	60	A	1	12GA 25FT WB HS @ 3FT 1.5IN
6998	4146161	0.21	0.74	0.009	0.004	0.02	80551	61846	24.7	22	A	1	12GA 12FT 6IN HS @ 1FT 6.75IN WB
6800	CA3763	0.2	0.46	0.008	0.004	0.02	71499	50526	24.75	10	A	1	12GA 6FT 3IN HS @ 3FT 1.5IN WB
6984	9507765	0.22	0.76	0.008	0.006	0.02	82902	61254	24.13	1	A	1	12GA 25FT / 4HS @ 3FT 1.5IN / 8HS @ 1FT 6.75IN WB
6439	AA3051	0.2	0.47	0.01	0.002	0.02	78776	59054	12.27	4	A	2	12GA 25FT 4HS @ 3FT 1.5IN / 8HS @ 1FT 6.75IN TB

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.

By:
Jeffery Grover, Vice President Gregory Highway
Gregory Highway

GREGORY HIGHWAY

Figure B-4. 12-Gauge 12-ft 6-in. long ¼ Post Spacing W-Beam Guardrail, Test No. HBIB-1 (Item No. a7)

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

Test Report
Ship Date: 1/16/2023
Customer P.O.: 1216221
Shipped to: MIDWEST MACHINERY & SUPPLY CO.
Project:
GHP Order No: 8420AA

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

MILFORD,NE,68405

HT # Code	Heat #	C.	MN.	P.	S.	Si.	Tensile	Yield	Elong.	Quantity	Class	Type	Description
7869	CA6178	0.21	0.49	0.01	0.001	0.05	82981	62971	17.87	10	A	1	12GA 15FT 7.5IN HS @ 3FT 1 1/2IN WB
7931	4133100	0.22	0.75	0.012	0.005	0.02	84092	65036	23.43	20	A	1	12GA 12FT 6IN HS @ 3FT 1.5 IN WB
7931	4133100	0.22	0.75	0.012	0.005	0.02	84092	65036	23.43	2	A	1	12GA 12FT 6IN HS @ 3FT 1.5IN WB RX=12
7931	4133100	0.22	0.75	0.012	0.005	0.02	84092	65036	23.43	2	A	1	12GA 12FT 6IN HS @ 3FT 1.5IN WB RX=15
7931	4133100	0.22	0.75	0.012	0.005	0.02	84092	65036	23.43	2	A	1	12GA 12FT 6IN HS @ 3FT 1.5IN WB RX=20
7945	4133093	0.2	0.73	0.01	0.008	0.01	77029	60177	26.93	10	A	1	12GA 12FT 6IN WB FLEAT-SKT COMBO PANEL
8021	4149562	0.2	0.75	0.013	0.008	0.01	76555	56332	25.33	110	A	1	12GA 25FT WB HS @ 3FT 1.5IN
7903	AA6765	0.2	0.47	0.013	0.002	0.04	89945	70774	16.17	95	A	1	12GA 12FT 6IN HS @ 1FT 6.75IN WB
7866	EA3057	0.2	0.48	0.009	0.002	0.03	82614	60233	23.77	1	A	1	12GA 6FT 3IN HS @ 3FT 1.5IN WB RX=12

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.

By_____
Jeffery Grover, Vice President Gregory Highway
Gregory Highway

GREGORY HIGHWAY

Figure B-5. 12-Gauge 12-ft 6-in. long ¼ Post Spacing W-Beam Guardrail, Test Nos. HBIB-2 through HBIB-5 (Item No. a7)

Certified Analysis

VALTIR

Valtir, 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: 1353021 Prod Ln Grp: 0-OE2.0
Customer PO: 1012221
BOL Number: 119991 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 11/28/22

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn
20	929G	10/END SHOE/KS/2 EXT HOLE			2	L13422												
			M-180	B	2	276456	61,508	80,815	24.0	0.200	0.720	0.011	0.003	0.010	0.110	0.000	0.050	0.001
			M-180	A	2	278495	60,886	79,657	27.4	0.180	0.710	0.011	0.003	0.010	0.090	0.000	0.050	0.000
			M-180	A	2	278496	63,339	82,740	22.4	0.180	0.700	0.009	0.004	0.010	0.090	0.000	0.010	0.000
5	950A	T12/FLARE/12 HOLE ASS'Y	M-180	A	2	280460	65,000	84,912	21.3	0.190	0.740	0.011	0.002	0.020	0.090	0.001	0.060	0.002
70	980G	T10/END SHOE/SLANT 1"HO.	M-180	B	2	255069	48,862	59,562	35.6	0.050	0.490	0.012	0.003	0.020	0.110	0.000	0.050	0.000
	980G		M-180	B		279257	48,897	60,212	27.8	0.050	0.470	0.010	0.002	0.020	0.090	0.001	0.060	0.001
7	3177B	REF 18X18 YELLOW/BLACK	LABELS			221561												
30	3448G	1/4"X4"X4" SNOW LOAD WASH	HW			63445												
50	12124G	T12/18'9/12@1'6-3/4"/S			2	L34522												
			M-180	B	2	273780	61,609	82,355	23.3	0.190	0.730	0.010	0.002	0.020	0.110	0.000	0.070	0.002
			M-180	B	2	276349	60,441	80,006	25.8	0.190	0.730	0.009	0.003	0.010	0.110	0.000	0.080	0.001
			M-180	A	2	277537	63,316	82,406	24.2	0.200	0.720	0.010	0.002	0.020	0.070	0.001	0.030	0.001
			M-180	A	2	278493	63,087	81,390	243.9	0.180	0.720	0.011	0.003	0.010	0.090	0.000	0.050	0.001
			M-180	A	2	281431	64,066	82,604	23.5	0.180	0.730	0.014	0.003	0.010	0.110	0.000	0.060	0.003
32	15000G	6'0 SYT PST/8.5/31" GR HT	A-36			12703	53,000	74,000	23.8	0.160	0.740	0.026	0.027	0.200	0.290	0.001	0.170	0.011
	15000G		A-36			13070	51,000	75,000	22.0	0.160	0.810	0.017	0.024	0.200	0.300	0.000	0.180	0.006
175	54043G	7'0 PST/6X15/DB:3HI	A-572			1114127	57,700	69,300	31.5	0.070	0.860	0.010	0.024	0.230	0.140	0.028	0.040	0.002

2 of 6

Figure B-6. 10-Gauge W-Beam Bridge End Terminal, Test Nos. HBIB-2 through HBIB-5 (Item No. a8)

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

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

MILFORD,NE,68405

Test Report
Ship Date: 3/16/2022
Customer P.O.: 221221
Shipped to: MIDWEST MACHINERY & SUPPLY CO.
Project:
GHP Order No: 6648AA

HT # CODE	Lot #	C.	Mn.	P.	S.	Si.	Tensile	Yield	Elong.	Quantity	Class	Type	Description
264531		0.05	0.47	0.013	0.001	0.02	60088	48995	36.45	33	B	2	10GA BRIDGE SHOE
269797		0.06	0.46	0.011	0.003	0.02	60568	50023	35.4	124	B	2	10GA TB BRIDGE SHOE

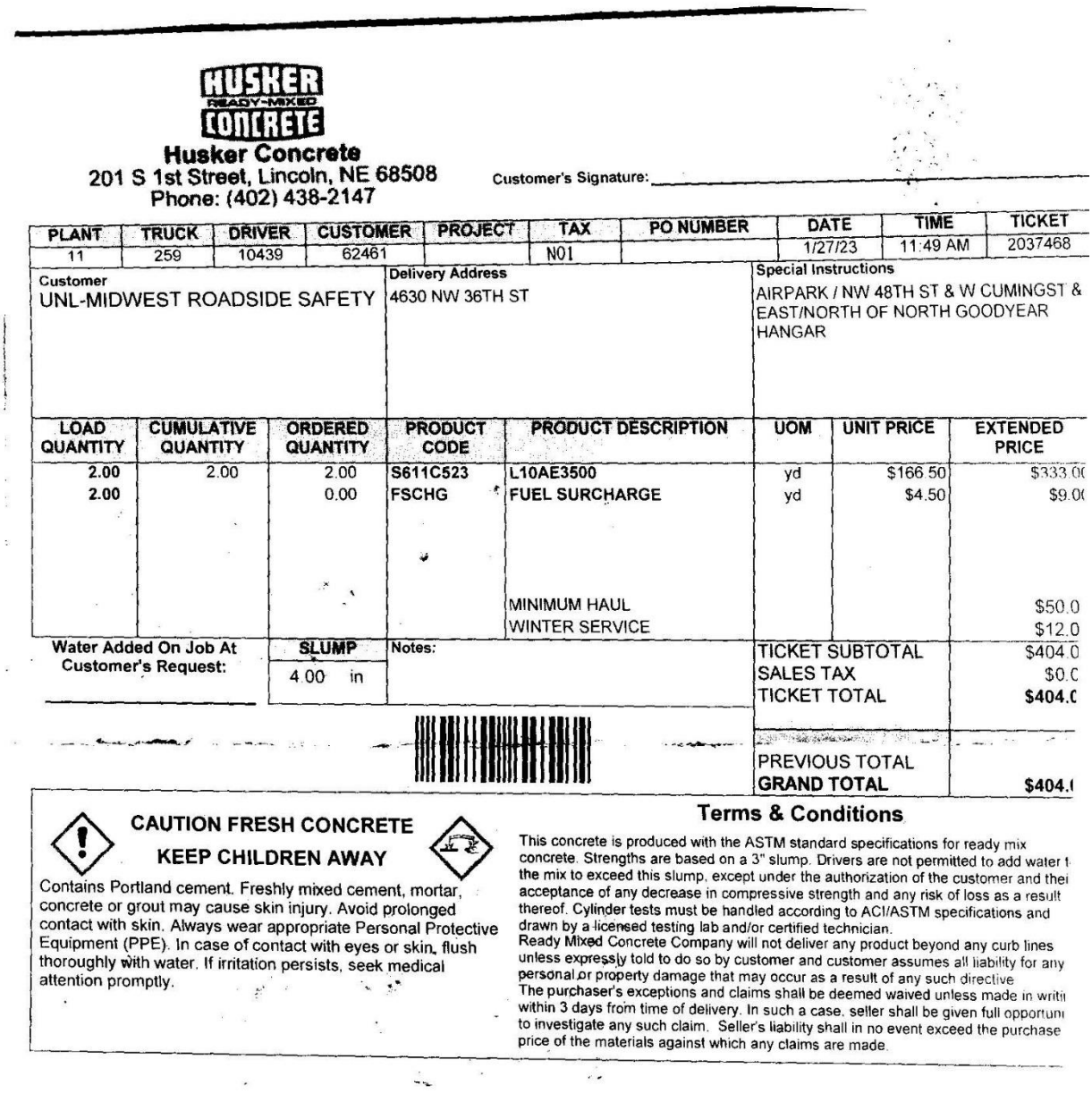
Bolts comply with ASTM A-307 specifications and are galvanized in accordance with ASTM A-153, unless otherwise stated.
Nuts comply with ASTM A-563 specifications and are galvanized in accordance with ASTM A-153, unless otherwise stated.
All other galvanized material conforms with ASTM-123 & ASTM-653
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 sheet, zinc-coated or zinc-iron alloy-coated by the hot dip process that meets ASTM Specifications A653

Jeffry L Grover

By:
Jeffery L Grover, Vice President Gregory Highway
Gregory Highway

GREGORY HIGHWAY

Figure B-7. 10-Gauge W-Beam Bridge End Terminal, Test No. HBIB-1 (Item Nos. a11-a12)



HUSKER READY-MIXED CONCRETE

Husker Concrete
201 S 1st Street, Lincoln, NE 68508
Phone: (402) 438-2147

Customer's Signature: _____

PLANT	TRUCK	DRIVER	CUSTOMER	PROJECT	TAX	PO NUMBER	DATE	TIME	TICKET
11	259	10439	62461		N01		1/27/23	11:49 AM	2037468

Customer
UNL-MIDWEST ROADSIDE SAFETY

Delivery Address
4630 NW 36TH ST

Special Instructions
AIRPARK / NW 48TH ST & W CUMINGST & EAST/NORTH OF NORTH GOODYEAR HANGAR

LOAD QUANTITY	CUMULATIVE QUANTITY	ORDERED QUANTITY	PRODUCT CODE	PRODUCT DESCRIPTION	UOM	UNIT PRICE	EXTENDED PRICE
2.00	2.00	2.00	S611C523	L10AE3500	yd	$166.50	$333.0(
2.00		0.00	FSCHG	FUEL SURCHARGE	yd	$4.50	$9.0(
				MINIMUM HAUL			$50.0
				WINTER SERVICE			$12.0

Water Added On Job At Customer's Request: _____

SLUMP	Notes:
4.00 in	

TICKET SUBTOTAL	$404.0
SALES TAX	$0.(
TICKET TOTAL	**$404.(**
PREVIOUS TOTAL	
GRAND TOTAL	**$404.(**

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 t the mix to exceed this slump, except under the authorization of the customer and thei 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 writi within 3 days from time of delivery. In such a case, seller shall be given full opportuni 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-8. Concrete Block Anchor, Test Nos. HBIB-1 through HBIB-5 (Item No. b1)

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# N54004
3Customer PO# 222221
Preservative: CCA – C 0.60D pcf AWPA UC

Part #	Physical Description	# Pieces	Charge #	Retention
105242b	6x12-19" RTD Block	168	6116	.667
GS6823 BLK	5.5x7.5-23" Rub Block	252	6088	.621
GS6814 BLK	5.5x7.5-14" CH Block	126	6088	.621
GS6846 PST	5.5x7.5-46" BCT	42	6064	.607
GR6819 BLK	6x8-19" Block OCD Thrie Block	252	6088	.621
GR61219 BLK	6x12-19" OCD Thrie Block	168	6088	.621

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

3/30/22
Date

Figure B-9. Concrete Block Anchor, Test Nos. HBIB-1 through HBIB-5 (Item No. b1)

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# N54004
3Customer PO# 222221
Preservative: CCA – C 0.60D pcf AWPA UC

Part #	Physical Description	# Pieces	Charge #	Retention
105242b	6x12-19" RTD Block	168	6116	.667
GS6823 BLK	5.5x7.5-23" Rub Block	252	6088	.621
GS6814 BLK	5.5x7.5-14" CH Block	126	6088	.621
GS6846 PST	5.5x7.5-46" BCT	42	6064	.607
GR6819 BLK	6x8-19" Block OCD Thrie Block	252	6088	.621
GR61219 BLK	6x12-19" OCD Thrie Block	168	6088	.621

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

3/30/22
Date

Figure B-10. BCT Timber Post – MGS Height, Test Nos. HBIB-1 through HBIB-5 (Item No. c1)

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: 10/26/2017
Customer P.O.: 3501
Shipped to: MIDWEST MACHINERY & SUPPLY CO.
PROJECT: STOCK
GHP Order No: 7044AA

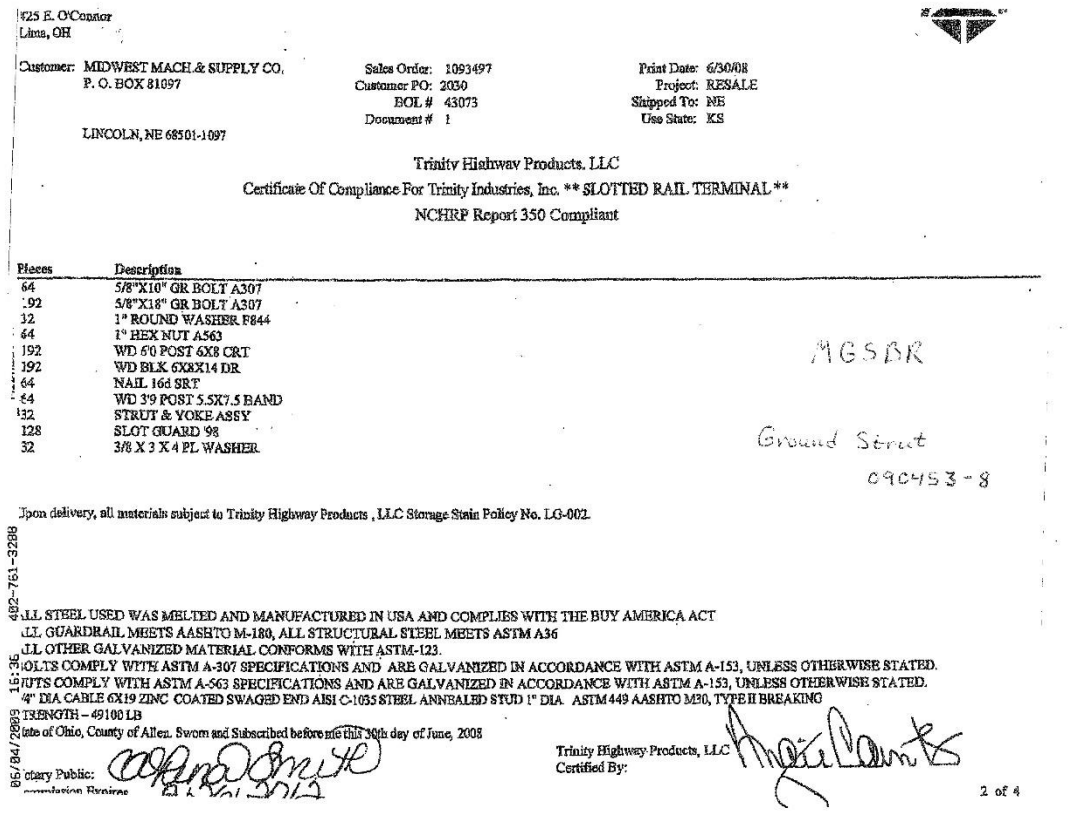
HT CODE	Lot #	C.	Mn.	P.	S.	Si.	Tensile	Yield	Elong.	Quantity	Class	Type	Description
616137		0.21	0.93	0.011	0.003	0.02	73148	58210	32	15		2	3/16 X 6IN X 8IN X 5FT0IN TUBE SLEEVE
821T08220		0.22	0.81	0.013	0.006	0.006	70934	57275	32	10		2	3/16IN X 6IN X 8IN X 6FT0IN TUBE SLEEVE
214482		0.04	0.83	0.014	0.005	0.02	75275	68023	28.6	25	B		10GA MGS TB TRAN APPROACH END-RIGHT
214143		0.04	0.81	0.015	0.006	0.02	75565	69618	29.7	18	B		10GA MGS TB TRAN DEPARTURE END-LEFT

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 sheet, zinc-coated or zinc-iron alloy-coated by the hot dip process that meets ASTM Specifications A653

Jeffry L Grover

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

Figure B-11. 72-in. Long Foundation Tube, Test Nos. HBIB-1 through HBIB-5 (Item No. c2)



525 E. O'Connor
Lima, OH

Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 81097

LINCOLN, NE 68501-1097

Sales Order: 1093497
Customer PO: 2030
BOL # 43073
Document # 1

Print Date: 6/30/08
Project: RESALE
Shipped To: NE
Use State: KS

Trinity Highway Products, LLC
Certificate Of Compliance For Trinity Industries, Inc. ** SLOTTED RAIL TERMINAL **
NCHRP Report 350 Compliant

Pieces	Description
64	5/8"X10" GR BOLT A307
92	5/8"X18" GR BOLT A307
32	1" ROUND WASHER F844
64	1" HEX NUT A563
192	WD 6'0 POST 6X8 CRT
192	WD BLK 6X8X14 DR
64	NAIL 16d SRT
64	WD 3'9 POST 5.5X7.5 BAND
32	STRUT & YOKE ASSY
128	SLOT GUARD '98
32	3/8 X 3 X 4 PL WASHER

MGSBR

Ground Strut

C90453-8

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 OTHER GALVANIZED MATERIAL CONFORMS WITH ASTM-123.
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.
1/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA. ASTM 449 AASHTO M30, TYPE II BREAKING
STRENGTH – 49100 LB
State of Ohio, County of Allen. Sworn and Subscribed before me this 30th day of June, 2008

Notary Public:
Commission Expires

Trinity Highway Products, LLC
Certified By:

2 of 4

Gallatin Steel Company
4831 U.S. Highway 42 West
Ghent, KY, 41045-9704
Phone: 1(800)581-3853 Fax: (859)567-3165

GALLATIN STEEL

METALLURGICAL TEST REPORT

InvoiceTo: Lawson Steel
3238 East 82nd Street
Cleveland, OH 44104

Ship To: Lawson Steel
Servisteel
4920 French Creek Road
Lorain, OH 44054

Customer No: 321
Mill Order No: 116211-1

Customer P.O. No: 020200
Customer Reference No: NA

Date: 09/20/07
Load No: 338238

This product was melted and manufactured in the USA to meet the requirements of:

HR Sheet Steel Bands
Ordered Size: Nom 0.132 (In.) X 43.42 (In.) X Coil
Coil Number(s): 790450

CHEMICAL ANALYSIS (Weight %)

Coil No	Heat	Mill Order No	Line Item	Net Wt	Ordered Width	Ordered Gauge	Cust. P.O.#	Cust Ref #
790450	C43128	116211	1	23,050	43.42	0.132 Nom	020200	

* This mechanical property has been tested at a subcontractor's laboratory.
All test performed according to ASTM standards E8 (yield strength determined using 0.2% offset method) or JIS Z2241, E18, E415, and E1019 and are correct as contained in the records of the company.
This report shall not be reproduced, except in full, without written approval of the Manager, Quality Assurance.

G5C Quality Assurance

Page 1 of 1

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Figure B-12. Ground Strut Assembly, Test Nos. HBIB-1 through HBIB-5 (Item No. c3)

AK Steel

CUSTOMER COPY

AK Steel Corporation
METALLURGICAL TEST REPORT
MIDDLETOWN WORKS
MIDDLETOWN, OH 45043

PAGE 1 OF 1
LOAD NO. 8601771
SRN NO. 8601771

CUSTOMER
LAWSON STEEL CO.
PUR DEPT
3238 E. 82ND STREET
CLEVELAND, OH 44104

SHIP TO
LAWSON STEEL INC.
C/O PRECISION STRIP
4400 OXFORD STATE RD
MIDDLETOWN, OH 45044

MILL ORDER NO.	PROCESSOR ORDER NO.	BUYERS ORDER NO.	PART NO.	SEQ NO.
97627426-6796	019885-3	019885-3		

ENGLISH UNITS
- PRODUCT SIZE:-
.1875 NOM 72.0000 X COIL

CHEMICAL ANALYSIS OF LADLE TEST

HEAT #	C	MN	P	S	SI	CU	AL	CB	V	NI	CR	TI	N	MO	B
574109	.045	.53	.011	.010	.008	.059	.052	.030	.002	.023	.058	.001	.0044	.012	.000

LIFT ID: 932932-1574A
PROC ID: 461799800
WGT: 35,660 LBS.
SHIPPING DATE: 08/31/2007

PRODUCT DESCRIPTION
HR SHT HSLAS DRY MILL EDGE TEST REPORTS ASTM A1011/A1011M-06B HSLAS GR50 CL1(AKS CODE B3D)

	LONGITUDINAL KSI
YIELD STRENGTH	61.7
TENSILE STRENGTH	68.9
% ELONG:	31.0

MELTED AND MANUFACTURED IN USA

THE CHEMICAL ANALYSIS AND PHYSICAL OR MECHANICAL TESTS REPORTED ABOVE ARE CORRECT AS CONTAINED IN THE RECORDS OF THE CORPORATION

ALL TESTING IS DONE IN ACCORDANCE WITH A.S.T.M. STANDARDS UNLESS OTHERWISE NOTED

AK Steel Corporation MWQC#0004 REV:2, 7/96

"THIS CERTIFIED TEST REPORT HAS BEEN DELIVERED TO A CONSIGNEE OF MATERIAL PURCHASED FROM AK Steel Corporation. TO AVOID THE POSSIBILITY OF ITS MISUSE ON REDELIVERY OF THE REPORT TO A THIRD PARTY MUST BE RECERTIFIED BY AND UNDER THE NAME OF SUCH CONSIGNEE"

SIGNED DATE 12/04/2007

Figure B-13. Ground Strut Assembly, Test Nos. HBIB-1 through HBIB-5 (Item No. c3), Cont.

COMMERCIAL GROUP LIFTING PRODUCTS
Commercial Group Lifting Products
12801 UNIVERSAL DR., TAYLOR, MI 48180 * PH# (734) 947-4000 FAX# (734) 947-4004

OCTOBER 24, 2022

SOLD TO:
COLORGUARD RAIL PRODUCTS
ACCTS PAYABLE
36225 DETROIT RD. #226
AVON, OH 44011

SHIP TO:
MIDWEST MACHINERY
974 238TH RD
MILFORD, NE 68405

CGLP ORDER# 400212
COLORGUARD PO# 22-1010
WIRECO ORDER# 301567

CERTIFICATION

THIS LETTER AND THE ENCLOSED ATTACHMENTS ARE TO CERTIFY THAT THE FOLLOWING ITEMS WERE 100% MANUFACTURED IN THE UNITED STATES OF AMERICA.

100PCS PART# CGDCG26078-2, LOT# S3028357, 3/4IN X 6FT 6IN DOUBLE SWAGE GUARD RAIL ASSEMBLYS NO HARDWARE. THEY SHOW THE DOMESTICITY OF ALL MATERIAL USED, 100% MELTED & MANUFACTURED IN THE USA. THE WIRE ROPE 3/4IN (6X19), TYPE II CONSTRUCTION, CLASS A, CONFORMS TO REQUIREMENTS DESIGNATION: AASHTO M30 / ASTM A741, MIN BREAKING STRENGTH: 46,000LBS PER AASHTO M30. THREAD RODS: 1IN-8 UNC, CLASS 2A PER ASME B1.1, THESE STUDS CONFORM TO REQUIREMENTS OF A.S.T.M. A576, AND SHALL BE GALVANIZED IN ACCORDANCE WITH A.S.T.M. A153. THREAD ROD SPECIFICATION TO ASTM A449. CERTIFICATION OF BREAKING STRENGTH PERFORMED, THE GALVANIZING PROCESS ALSO TOOK PLACE IN THE U.S.A.

ATTACHMENTS:
(WIRE ROPE) WIRECO WORLD GROUP REEL# 428-1029295-2
HEAT#S

20744340	WIRECO WORLDGROUP, MT JOY WIRE, HSM WIRE TECHNOLOGY, CHARTER STEEL
8000008669	WIRECO WORLDGROUP, MT JOY WIRE, HSM WIRE TECHNOLOGY, NUCOR STEEL
20752970	WIRECO WORLDGROUP, MT JOY WIRE, CHARTER STEEL
20721940	WIRECO WORLDGROUP, MT JOY WIRE, CHARTER STEEL
OT0023436	WIRECO WORLDGROUP, MT JOY WIRE, HSM WIRE TECHNOLOGY, OPTIMUS STEEL
20746670	WIRECO WORLDGROUP, MT JOY WIRE, LIBERTY WIRE, CHARTER STEEL
20734180	WIRECO WORLDGROUP, MT JOY WIRE, LIBERTY WIRE, CHARTER STEEL
10674470	WIRECO WORLDGROUP, MT JOY WIRE, CHARTER STEEL
OT0024724	WIRECO WORLDGROUP, MT JOY WIRE, HSM WIRE TECHNOLOGY, OPTIMUS STEEL

(END FITTINGS) SWEDGE COLLAR ASSEMBY

BODY HEAT#S 75083245, 79001521 COLORGUARD RAIL, REMLINGER MFG, NEW DIMENSIONS METALS, GERDAU NORTH AMERICA, INDIANA GALVANIZING

ROD HEAT# 75083057, COLORGUARD RAIL, REMLINGER MFG, L&H THREADED RODS, NEW DIMENSIONS METALS, GERDAU NORTH AMERICA, INDIANA GALVANIZING.

Regards, *Chris Swiderek*
Taylor, Shop Manager

HEADQUARTERS
12801 UNIVERSAL DR
TAYLOR, MI 48180

CLEVELAND
5213 GRANT AVE
CLEVELAND, OH 44105

CINCINNATI
11312 TAMARCO DR
CINCINNATI, OH 45242

GARY
1601 CLINE AVE
GARY, IN 46410

Figure B-14. BCT Anchor Cable Assembly, Test Nos. HBIB-1 through HBIB-5 (Item No. c4)

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 B-15. Anchor Bracket Assembly, Test Nos. HBIB-1 through HBIB-5 (Item No. c5)

CMC STEEL ALABAMA
101 S 50TH STREET
BIRMINGHAM AL 35212-3525

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

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

Marcus W. McCluney - CMC Steel AL
Quality Assurance Manager

1SERIES-BPS®

HEAT NO.:1072318 SECTION: FLAT 5/8x8 20'0" A36/52955 GRADE: ASTM A36-19/A529-14 Gr 55 ROLL DATE: 04/13/2021 MELT DATE: 04/13/2021 Cert. No.: 83529295 / 072318B780	SOLD TO	Interstate Steel Corporation 3616 Howard County Airport Rd Big Spring TX US 79720-0000 4322633725 4322674039	SHIP TO	Interstate Steel Corporation 3616 Howard County Airport Rd Big Spring TX US 79720-0000 4322633725 4322674039	Delivery#: 83529295 BOL#: 74263959 CUST PO#: 16500 CUST P/N: DLVRY LBS / HEAT: 9520.000 LB DLVRY PCS / HEAT: 28 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.15%	Elongation test 1	24%		
Mn	0.70%	Elongation Gage Lgth test 1	8IN		
P	0.017%	Yield to tensile ratio test1	0.74		
S	0.019%	Yield Strength test 2	56.6ksi		
Si	0.16%	Tensile Strength test 2	77.7ksi		
Cu	0.32%	Elongation test 2	24%		
Cr	0.17%	Elongation Gage Lgth test 2	8IN		
Ni	0.16%	Yield to tensile ratio test2	0.73		
Mo	0.017%				
V	0.004%				
Cb	0.017%				
Sn	0.010%				
B	0.0002%				
Ti	0.001%				
N	0.0101%				
Carbon Eq A6	0.35%				
Carbon Eq A529	0.38%				
Yield Strength test 1	57.2ksi				
Tensile Strength test 1	77.5ksi				

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 : ALSO MEETS ASTM GRADE A36, A529-50, A529-55, A572-50, A572-55, A709-36, A709-50, AASHTO M270-36, M270-50, CSA G40.21-04 44W,50W, 55W
ASME SA-36 2008A ADDEND A

Figure B-16. Anchor Bearing Plate, Test Nos. HBIB-1 through HBIB-5 (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

H#712810 R#18-773 2 3/8" O.D. x 6" Long BCT Post Sleeve

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.
Certified using the AWS D1.1 method.

Steel Tube Institute OF NORTH AMERICA

Page : 3 Of 4

Metals Service Center Institute

Figure B-17. BCT Post Sleeve, Test Nos. HBIB-1 through HBIB-5 (Item No. c7)

HIGHWAY SAFETY CORP

P.O. BOX 358
GLASTONBURY, CT 06033

CERTIFICATE OF COMPLIANCE/ANALYSIS REPORT

SOLD TO:
MIDWEST MACHINERY & SUPPLY
974-238th Road

Milford,NE,USA

SHIP TO:
MIDWEST MACHINERY & SUPPLY
974 238TH ROAD
MILFORD NE

INVOICE / S.O.: 0238729 / 0191285
CUSTOMER P.O.: 1025221

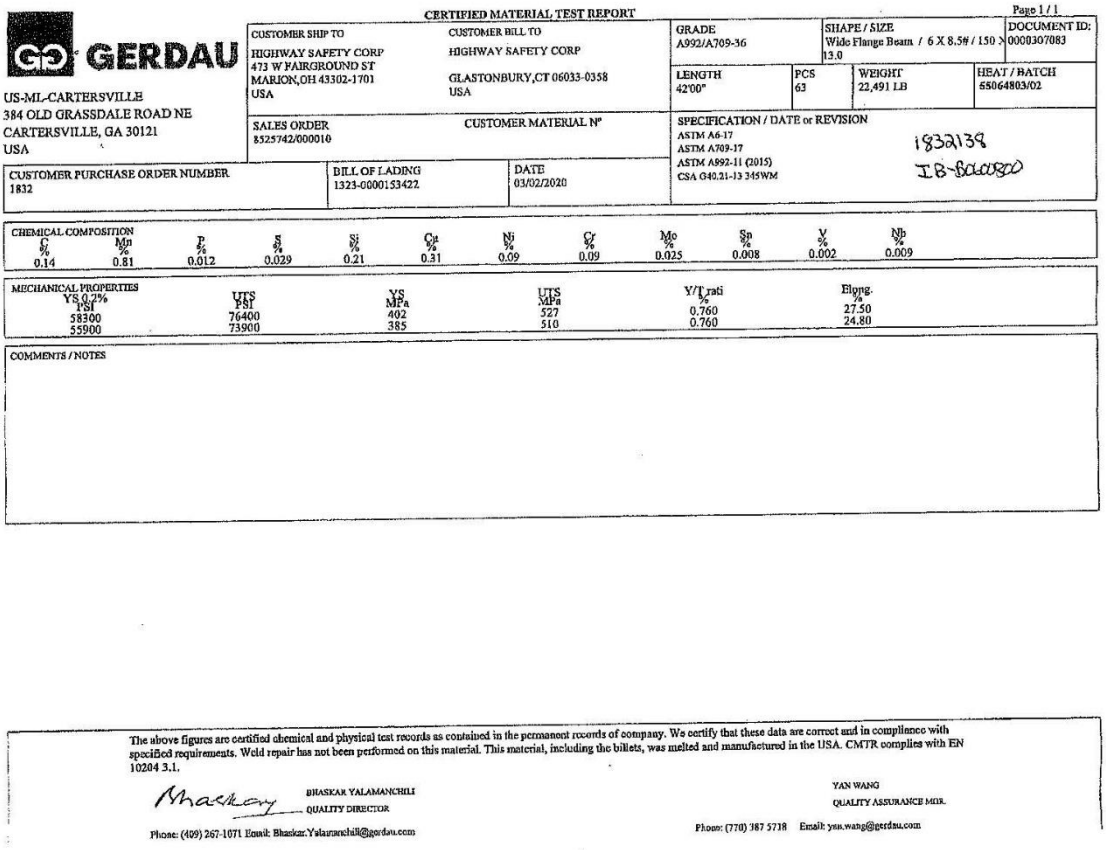
REFERENCE: STOCK
DATE SHIPPED: 10/31/2022

QTY:	HEAT/LOT NO:	ITEM NUMBER: YIELD:	CC: TENSILE: %ELONG:	DESCRIPTION: C: Mn: P: S: Si: Cl: Type ACW
700		T-POG060080600G	IB-B0600800	THRIE POST W06 x 008.5# x 06'00 OVERLAY NE HDG HOLES @
(350)	55082178			
(350)	55082177			
100	59105615	POG060080800-36	IB-B0600800	W06 x 008.5# x 08'00 CT 2HL 2 SD 7 GLV
1	GALVOH	GALV CERT OH	GALV CERT OH	GALVANIZING CERTIFICATION OH

ALL STEEL USED IN MANUFACTURING IS MADE AND MELTED IN THE USA, INCLUDING HARDWARE FASTENERS, AND COMPLIES WITH THE BUY AMERICA ACT. ALL COATINGS PROCESSES ARE PERFORMED IN THE USA AND COMPLY WITH THE BUY AMERICA ACT. BOLTS COMPLY WITH ASTMA-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTMA-153, UNLESS OTHERWISE STATED. NUTS COMPLY WITH ASTMA-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTMA-153, UNLESS OTHERWISE STATED. WASHERS COMPLY WITH ASTM F-436 AND/OR F-844 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTMA-153, UNLESS OTHERWISE STATED. ALL GUARDRAIL MEETS AASHTO M-180 AND ALL STRUCTURAL STEEL MEETS AASHTO M-270. ALL OTHER GALVANIZED MATERIAL CONFORMS WITH ASTMA-123. ALL OTHER ITEMS COMPLY WITH AASHTO M-111, M-165, M-133, M-265, ASTM A36, ASTMA-709, ASTMA-123, ASTM A505, AND ASTMA588 SPECIFICATIONS IF APPLICABLE. COMPLIANCE WITH ALL SPECIFICATIONS OF DEPARTMENT OF PUBLIC WORKS, DEPARTMENT OF HIGHWAYS AND TRANSPORTATION, DIVISION OF ROADS AND BRIDGES AND STATE HIGHWAY ADMINISTRATION IS MET IN ALL RESPECTS.

HIGHWAY SAFETY CORPORATION
R Light
QUALITY ASSURANCE MANAGER

Figure B-18. W6x8.5 or W6x9 84-in. Long Steel Post, Test Nos. HBIB-1 through HBIB-5 (Item No. d1)



CERTIFIED MATERIAL TEST REPORT

Page 1 / 1

GERDAU

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

CUSTOMER SHIP TO
HIGHWAY SAFETY CORP
473 W FAIRGROUND ST
MARION,OH 43302-1701
USA

CUSTOMER BILL TO
HIGHWAY SAFETY CORP
GLASTONBURY,CT 06033-0358
USA

GRADE: A992/A709-36

SHAPE / SIZE: Wide Flange Beam / 6 X 8.5# / 150 X 13.0

DOCUMENT ID: 0000307083

LENGTH: 42'00"

PCS: 63

WEIGHT: 22,491 LB

HEAT / BATCH: 55064803/02

SALES ORDER: 8525742/000010

CUSTOMER MATERIAL N°

SPECIFICATION / DATE or REVISION
ASTM A6-17
ASTM A709-17
ASTM A592-11 (2015)
CSA G40.21-13 345WM

1832139
IB-8044820

CUSTOMER PURCHASE ORDER NUMBER: 1832

BILL OF LADING: 1323-0000153422

DATE: 03/02/2020

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 rati %	Elong. %
58300	76400	402	527	0.760	27.50
55900	73900	385	510	0.760	24.80

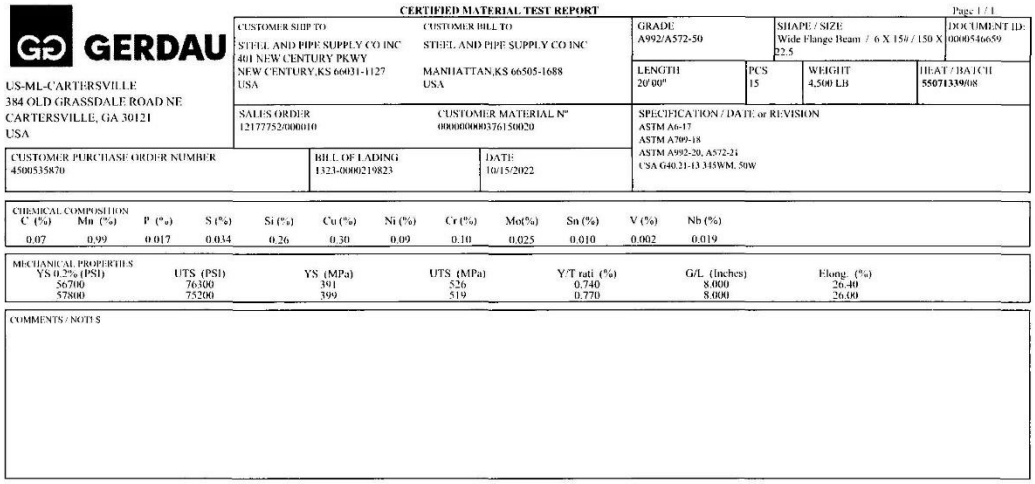
COMMENTS / NOTES

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

YAN WANG
QUALITY ASSURANCE MGR.
Phone: (770) 387 5738 Email: yan.wang@gerdau.com

Figure B-19. W6x8.5 or W6x9 72-in. Long Steel Post, Test Nos. HBIB-1 through HBIB-5 (Item No. d2)



CERTIFIED MATERIAL TEST REPORT Page 1 / 1

GERDAU

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

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
STEEL AND PIPE SUPPLY CO INC 401 NEW CENTURY PKWY NEW CENTURY,KS 66031-1127 USA	STEEL AND PIPE SUPPLY CO INC MANHATTAN,KS 66505-1688 USA	A992/A572-50	Wide Flange Beam / 6 X 15# / 150 X 22.5	0000546659

LENGTH	PCS	WEIGHT	HEAT / BATCH
20' 00"	15	4,500 LB	**55071339**/08

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
12177752/000010	000000000376150020	ASTM A6-17 ASTM A709-18 ASTM A992-20, A572-21 CSA G40.21-13 345WM, 50W

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
4500535870	1323-0000219823	10/15/2022

CHEMICAL COMPOSITION

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cu (%)	Ni (%)	Cr (%)	Mo(%)	Sn (%)	V (%)	Nb (%)
0.07	0.99	0.017	0.034	0.26	0.30	0.09	0.10	0.025	0.010	0.002	0.019

MECHANICAL PROPERTIES

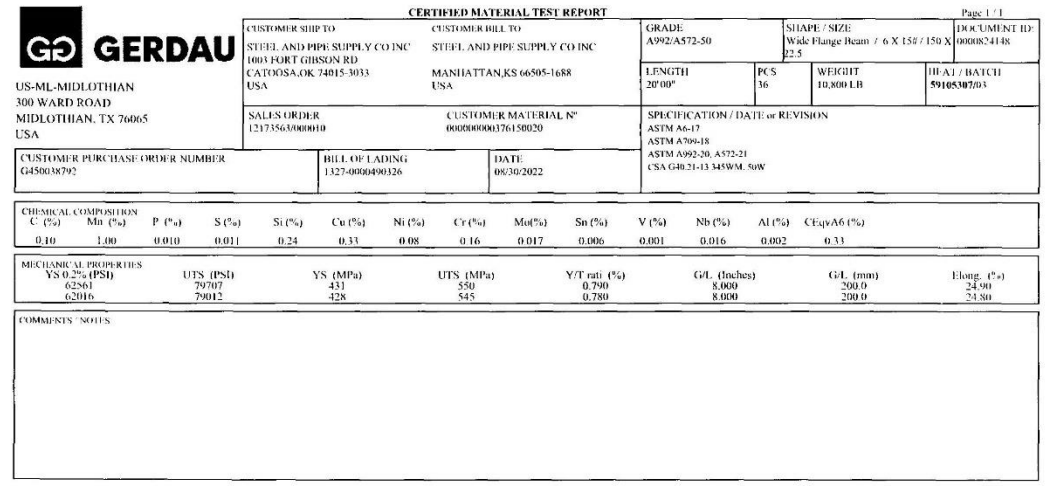
YS 0.2% (PSI)	UTS (PSI)	YS (MPa)	UTS (MPa)	Y/T rati (%)	G/L (Inches)	Elong. (%)
56700	76300	391	526	0.740	8.000	26.40
57800	75200	399	519	0.770	8.000	26.00

COMMENTS / NOTES

The above figures are certified chemical and physical test records as contained in the permanent records of the company. We certify that these data are correct and in compliance with specified requirements. No weld repair was performed on this material. The material has not been in contact with mercury while in Gerdau possession. For all products other than billets or beam blanks, this material was produced (Electric Arc Furnace, Melted, Continuously Cast, Hot Rolled and, if applicable, Cold-Drawn) in the USA. For billets or beam blanks, this material was produced (Electric Arc Furnace, Melted and Continuously Cast) in the USA. CMTR complies with EN 10204 3.1.

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



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 1003 FORT GIBSON RD CATOOSA,OK 74015-3033 USA	STEEL AND PIPE SUPPLY CO INC MANHATTAN,KS 66505-1688 USA	A992/A572-50	Wide Flange Beam / 6 X 15# / 150 X 22.5	0000824148

LENGTH	PCS	WEIGHT	HEAT / BATCH
20' 00"	36	10,800 LB	**59105307**/03

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
12173563/0000010	000000000376150020	ASTM A6-17 ASTM A709-18 ASTM A992-20, A572-21 CSA G40.21-13 345WM, 50W

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
G450038792	1327-0000490326	06/30/2022

CHEMICAL COMPOSITION

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cu (%)	Ni (%)	Cr (%)	Mo(%)	Sn (%)	V (%)	Nb (%)	Al (%)	CEqvA6 (%)
0.10	1.00	0.010	0.011	0.24	0.33	0.08	0.16	0.017	0.006	0.001	0.016	0.002	0.33

MECHANICAL PROPERTIES

YS 0.2% (PSI)	UTS (PSI)	YS (MPa)	UTS (MPa)	Y/T rati (%)	G/L (Inches)	G/L (mm)	Elong. (%)
62561	79707	431	550	0.790	8.000	200.0	24.90
62916	79012	428	545	0.780	8.000	200.0	24.80

COMMENTS / NOTES

The above figures are certified chemical and physical test records as contained in the permanent records of the company. We certify that these data are correct and in compliance with specified requirements. No weld repair was performed on this material. The material has not been in contact with mercury while in Gerdau possession. For all products other than billets or beam blanks, this material was produced (Electric Arc Furnace, Melted, Continuously Cast, Hot Rolled and, if applicable, Cold-Drawn) in the USA. For billets or beam blanks, this material was produced (Electric Arc Furnace, Melted and Continuously Cast) in the USA. CMTR complies with EN 10204 3.1.

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

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

Figure B-20. W6x15 120-in. Long Steel Post, Test Nos. HBIB-1 through HBIB-5 (Item No. d3)

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-21. Composite Recycled Blockout, Test Nos. HBIB-1 through HBIB-5 (Item No. d4)

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# N01210
Customer PO# 3560
Preservative: CCA – C 0.60D pcf AWPA UC4B

R#18-763 Painted Yellow
Purchased for Bullnose

Part #	Physical Description	# of Pieces	Charge #	Tested Retention
4075b	6x8-14" Block	126	24833	.604
GR6814 BLK	6x8-14" OCD Block	252	24883	.669
6120b	6x12-14" Block	84	24861	.661

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

Nick Sowl, General Counsel

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.

3/26/18
Date

Figure B-22. Tapered Timber Blockout, Test No. HBIB-1 (Item Nos. d5-d8)

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
E000357170

Order Placed By
Shaun M Tighe

McMaster-Carr Number
2098331-01

Line	Product	Ordered	Shipped
1	**97812A109** Steel Double-Headed Nail Size 16D, 3" Length, .16" Shank Diameter, 200 Pieces/Pack, 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-23. Double Head Nails, Test No. HBIB-1 (Item No. d9) and Test Nos. HBIB-2 through HBIB-5 (Item No. d6)

CMC

CMC STEEL OKLAHOMA
2353 E Main St
Durant OK 74701-4806

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

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

Robert Booth
Quality Assurance Manager

HEAT NO.:6035977 SECTION: SPOOL REBAR 13MM (#4) A615/A706-60 3.5T GRADE: ASTM A615 & A706 GR60 Dual Gr ROLL DATE: 10/05/2022 MELT DATE: 10/05/2022 Cert. No.: 85187560 / 035977J051	SOLD TO	Concrete Industries Inc 6300 Cornhusker Hwy Lincoln NE US 68529-0529 4024341899 4024341899	SHIP TO	Concrete Industries Inc 6300 Cornhusker Hwy Lincoln NE US 68529-0529 4024341899 4024341899	Delivery#: 85187560 BOL#: 75008230 CUST PO#: 155668 CUST P/N: DLVRY LBS / HEAT: 20993.000 LB DLVRY PCS / HEAT: 3 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.24%	Elongation Gage Lgth test 1	8IN		
Mn	1.28%	Tensile to Yield ratio test1	1.35		
P	0.014%	Bend Test 1	Passed		
S	0.033%	Rebar Deformation Avg. Spaci	0.315IN		
Si	0.23%	Rebar Deformation Avg. Heigh	0.028IN		
Cu	0.32%	Rebar Deformation Max. Gap	0.142IN		
Cr	0.16%	Bend Test Diameter	1.500IN		
Ni	0.14%	Strain at Peak Stress test 1	9.6%		
Mo	0.041%			The Following is true of the material represented by this MTR:	
V	0.007%			*Material is fully killed and is Hot Rolled Steel	
Sn	0.013%			*100% melted, rolled, and manufactured in the USA	
Al	0.001%			*EN10204:2004 3.1 compliant	
N	0.0000%			*Contains no weld repair	
Carbon Eq A706	0.48%			*Contains no Mercury contamination	
				*Manufactured in accordance with the latest version of the plant quality manual	
Yield Strength test 1	73.2ksi			*Meets the "Buy America" requirements of 23 CFR635.410, 49 CFR 661	
Yield Strength test 1 (metri	505MPa			*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	
Tensile Strength test 1	98.9ksi				
Tensile Strength 1 (metric)	682MPa				
Elongation test 1	16%				

REMARKS : ALSO MEETS AASHTO M31

Figure B-24. No. 4 Rebar, Test Nos. HBIB-1 through HBIB-5 (Item Nos. e1-e2)

AZZ GALVANIZING ROCKFORD

CERTIFICATE OF COMPLIANCE

FOR HOT DIP GALVANIZING

CUSTOMER: FASTENAL

DATE: SEPTEMBER 14, 2020

PO#: 040050891

ORDER#: 480015970

This is to certify that the hot dip galvanizing of the following material conforms to specification ASTM A-153. The following sizes and lot numbers comply with the coating, workmanship, finish, and appearance requirements of ASTM F2329 specifications. The hot dip galvanizing is ROHS compliant. The galvanizing process was conducted in a temperature range of 830F to 850F.

HEAT#	PART#	DESCRIPTION	ESTIMATED PIECES	LOT#	MIL
10666100	10406631	5/8-11 X 10 GUARD RAIL BOLT	2485	931491-7	5.6

This certification in no way implies anything other than the quality of our hot dip galvanizing as it pertains to your order.

This product was galvanized in Rockford, IL USA

AZZ Galvanizing Rockford, IL

Peggy Doering

Peggy Doering
Office Manager

PD:ac

Figure B-25. ⅝-in. Dia. UNC 10-in. Long Guardrail Bolt, Test Nos. HBIB-1 through HBIB-5 (Item No. f1)

CERTIFICATE OF COMPLIANCE

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

CUSTOMER NAME: BENNETT BOLT WORKS

CUSTOMER PO: 6022816

SHIPPER #: 074952
DATE SHIPPED: 12/5/2022

LOT#: 34899

SPECIFICATION: ASTM A307, GRADE A MILD CARBON STEEL BOLTS

TENSILE:	SPEC:	60,000 psi*min	RESULTS:	71,700 71,700
HARDNESS:		100 max		66.00 66.10

*Pounds Per Square Inch.

COATING: ASTM SPECIFICATION F-2329 HOT DIP GALVANIZE
UNIVERSAL GALVANIZING: 34899

CHEMICAL COMPOSITION

MILL	GRADE	HEAT#	C	Mn	P	S	Si
NUCOR	1010	1000217087	.11	.46	.007	.016	.17

QUANTITY AND DESCRIPTION:

4,950 PCS 5/8" X 10" GUARD RAIL BOLT

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

8th DAY OF December 2022

Brenda Mopland
APPROVED SIGNATORY

12-8-2022
DATE

Merry F Shane

Official Seal
Merry F Shane
Notary Public State of Illinois
My Commission Expires 10/3/2026

Figure B-26. ⅝-in. Dia. UNC 10-in. Long Guardrail Bolt, Test Nos. HBIB-2 through HBIB-5 (Item No. f1)

Portland Bolt & MANUFACTURING COMPANY
800-547-6758 | www.portlandbolt.com

FOR	MIDWEST ROADSIDE SAFETY FACIL
PB INVOICE	157410
CUSTOMER PO	Emailed
EST. SHIP DATE	11/4/2022

Certificate of Conformance

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.

5/8" X 5" DOM. GALV. F3125-A325 HEAVY HEX STRUCTURAL BOLT WITH 4" THD.

HEAT	3093332	BASE STEEL	4140AR	DIAMETER	5/8	SOURCE	COMMERCIAL METALS CO
lot#20511							

C	MN	P	S	SI	NI	CR	MO	CU	PB	V	CB	N
0.400	0.780	0.012	0.022	0.230	0.130	0.830	0.192	0.270	-	0.023	-	-

TN	HR	PROOF	YIELD	SLENG	RA	ELONG	CH1	CH2	CH3	CHV
30,380 LBF	285 HBN	19,200	-	-	-	-	-	-	-	-

Coatings

- ITEMS HOT-DIP GALVANIZED PER ASTM F2329

Other

- ALL ITEMS MELTED & MANUFACTURED IN THE USA

Certification Department Quality Assurance
Dane McKinnon

Figure B-27. ⅝-in. Dia. UNC 5-in. Long Hex Head Bolt, Test Nos. HBIB-1 through HBIB-5 (Item No. f2)

FASTENAL®

Fastenal Company
P.O Box 1286
WINONA, MN 55987-1286

The store serving you is
3201 N. 23rd Street STE 1

LINCOLN, NE 68521
Phone #: (402)476-7900
Fax #: 402/476-7958

Invoice

Date	Reference No.	Page
1/13/23	NELIN435542	1

Discount Due Date:2%10 1/22/2023
Final Due Date:NET30 2/11/2023
Contract No:
2018.000208

Cust. No. NELIN2067
Cust. P.O. HBIB
Job No.

Sold To
UNL TRANSPORTATION/Midwest Roadside Safe
1931 NORTH ANTELOPE VALLEY PKWY
LINCOLN, NE 68588
402-472-7937; 402-472-8660(Fax)

Ship To
UNL TRANSPORTATION/Midwest Roadside Safe
3201 N. 23rd Street STE 1
LINCOLN, NE 68521
4024729841; 402-472-0071(Fax)

This Order and Document are subject to the "Terms of Purchase" posted on www.fastenal.com.

Line No.	Quantity Ordered	Quantity Shipped	Quantity Backorder	Description	Control No.	Part No.	Price / Hundred	Amount
1	100	100	0	5/8-11x2 A307A Galv	200233148	1191921	187.4800	187.48 E
2	32	32	0	HCS 7/8-9 x 2 P5	210270562	12411	481.1700	153.97 E

Visa Account # XXXXXXXXXXX6926 Exp XX/XX

Cardmember acknowledges receipt of goods or services in the amount of the total shown hereon and agrees to perform the obligations set forth by the cardmember's agreement with the issuer.

X_____

Card Member Signature

Number of Parcels: _____

Received By

Comments
Contact: WEBORD CONTRACT:2018.000208

Tax Exemption
Exempt

NE

Subtotal	341.45
Shipping & Handling	0.00
State Tax	0.00
County Tax	0.00
City Tax	0.00
TOTAL USD	341.45

If you re-package or re-sell this product, you are required to maintain integrity of Country of Origin to the consumer of this product.

Reasonable collection and attorneys fees will be assessed to all accounts placed for collection
No materials accepted for return without our permission.

X indicates part is a hazardous material

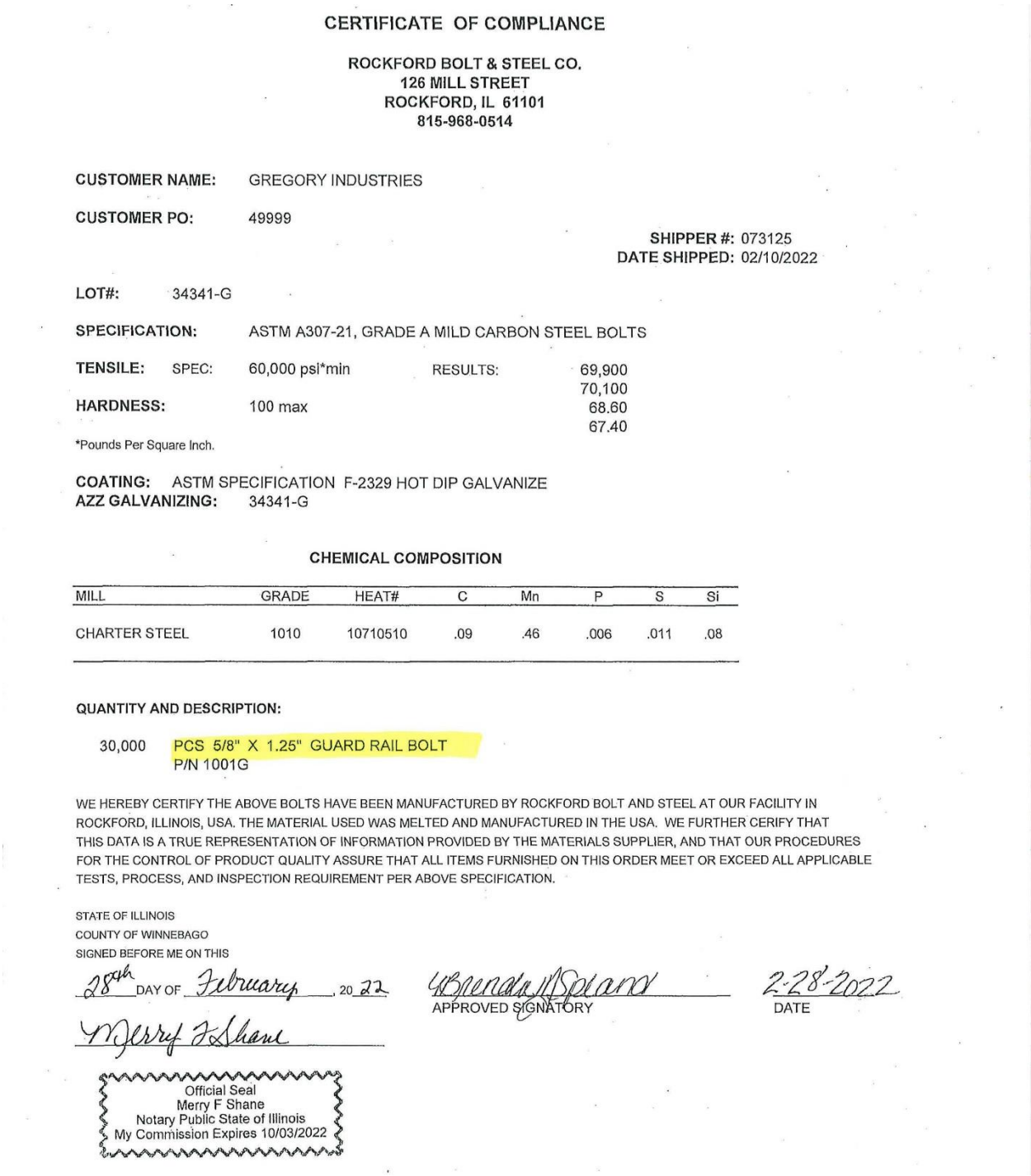
** indicates part was sold at a promotional or special discount price*

This is your invoice.
All discrepancies must be reported within 10 days. *0*

Thank You !

FORM - IN13

Figure B-28. ⅝-in. Dia. UNC 2-in. Long Hex Head Bolt, Test Nos. HBIB-1 through HBIB-5 (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: 49999

SHIPPER #: 073125
DATE SHIPPED: 02/10/2022

LOT#: 34341-G

SPECIFICATION: ASTM A307-21, GRADE A MILD CARBON STEEL BOLTS

TENSILE:	SPEC:	60,000 psi*min	RESULTS:	69,900 70,100
HARDNESS:		100 max		68.60 67.40

*Pounds Per Square Inch.

COATING: ASTM SPECIFICATION F-2329 HOT DIP GALVANIZE
AZZ GALVANIZING: 34341-G

CHEMICAL COMPOSITION

MILL	GRADE	HEAT#	C	Mn	P	S	Si
CHARTER STEEL	1010	10710510	.09	.46	.006	.011	.08

QUANTITY AND DESCRIPTION:

30,000 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
28th DAY OF February, 20 22

Brenda M Spiano
APPROVED SIGNATORY

2-28-2022
DATE

Merry F Shane

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

Figure B-29. ⅝-in. Dia. UNC 1¼-in. Long Guardrail Bolt, Test Nos. HBIB-1 through HBIB-5 (Item No. f4)

4740 Manufacturing Avenue
Cleveland, OH 44135 USA
Tel 216.881.3913 Fax 216.881.3918
www.autoboltusa.com

Certificate of Conformance

Issued to:

Bennett Bolt Works
12 Elbridge St
PO Box 922
Jordan, NY 13080

Customer PO#:	*6022666*
Report #:	*211269*
Date of Testing:	*2/8/2023*
Lot #:	*48766DL-1*
Lot Quantity:	*248,810*
Shipper #:	*12648*

Customer Part#:	*62C125BSP3H*	**Auto Bolt Part#:** *GARD7125*	
Description:	*GARD 5/8-11x1-1/4, ASTM 307A, Hot dip galvanized, Head -ABN/307A/USA/Release ID, Post Bolt*		
Mechanical & Material Requirements:	*per ASTM A307*		
Finish Specification:	*Hot Dip Galvanized per ASTM A 153/F2329 or ASTM A 123*		
Material Grade:	*1015-US*	**Heat Number:** *20841080*	***Cert Attached**

Test results using sampling plan ASME / ASTM B18.18.2M

***Core Hardness: 69-100 HRB**	*84.5*	*84.6*	*84.0*	*84.1*	*84.5*
Tensile Testing Spec: Method: Axial 60,000 PSI Min	*85,918*	*86,329*	*86,004*	*85,831*	*83,382*
Visual Inspection:	100pcs. were inspected for surface discontinuities and found within permissible limits per the above-mentioned specification.				

*** Denotes tests sub-contracted to an outside accredited laboratory or results provided by vendor.**

The Auto Bolt Company certifies the product listed above was produced in conformance with the contract requirements, drawing specifications, and any other applicable standards.

Certified by: Jacob Manning
Quality Manager:
Assigned Signatory: X

THE AUTO BOLT COMPANY IS AN ISO 9001:2015 & IATF 16949:2016 CERTIFIED COMPANY ISO CERT# 6122/ IATF# 0385461
THIS TEST REPORT RELATES ONLY TO SAMPLES TESTED AND IS THE CONFIDENTIAL PROPERTY OF OUR CUSTOMER. ANY REPRODUCTION OR DISTRIBUTION, IN WHOLE OR IN PART, WITHOUT OUR WRITTEN PERMISSION, IS STRICTLY PROHIBITED.
TO THE BEST OF OUR KNOWLEDGE, THE PARTS SUPPLIED ARE REACH, RoHS and CONFLICT MINERAL FREE COMPLIANT

THIS PRODUCT MANUFACTURED IN THE UNITED STATES OF AMERICA.

FORM# F 8.2.4-1
REV. DATE 3/18/22 **REV. L**

Figure B-30. ⅝-in. Dia. UNC 1¼-in. Long Guardrail Bolt, Test Nos. HBIB-2 through HBIB-5 (Item No. f4)

FASTENAL®

Fastenal Company
P.O Box 1286
WINONA, MN 55987-1286

Invoice

Date 3/27/18 | Reference No. NELIN314987 | Page 1

DUE DATE: 04/26/2018

Cust. No. NELIN2067
Cust. P.O.
Job No. TL-2 and Bullnose

The store serving you is
3201 N. 23rd Street STE 1
LINCOLN, NE 68521
Phone #: (402)476-7900
Fax #: 402/476-7958

Contract No:
1862 & 14284 OC

Sold To
UNL TRANSPORTATION
1931 NORTH ANTELOPE VALLEY PKWY
LINCOLN, NE 68588
402-472-7937; 402-472-8660(Fax)

Ship To
UNL TRANSPORTATION
4630 NW 36th Street
LINCOLN, NE 68524
402-580-8095; 402-472-0071(Fax)

Authorized Purchaser: Jim Holloway

This Order and Document are subject to the "Terms of Purchase" posted on www.fastenal.com.

Line No.	Quantity Ordered	Quantity Shipped	Quantity Backorder	Description	Control No.	Part No.	Price / Hundred	Amount
1	5	5 TS	0	7/8-9x8 A307A HDG	IIne35042	92005	509.5500	25.48 G
2	20	20 TS	0	7/8"-9 HX NUT GALV	110254885	36717	72.2400	14.45 G
3	5	5 TS	0	7/8-9x8 A307A HDG	IIne35042	92005	509.5500	25.48 G
4	5	5 TS	0	7/8-9x8 A307A HDG	IIne35042	92005	509.5500	25.48 G
5	5	5 TS	0	7/8-9x8 A307A HDG	IIne35042	92005	509.5500	25.48 G

Visa Account # XXXXXXXXXXX6926 Exp XX/XX

Cardmember acknowledges receipt of goods or services in the amount of the total shown hereon and agrees to perform the obligations set forth by the cardmember's agreement with the issuer.

X _____

Card Member Signature

Received By

Comments
Contact: WEBORD CONTRACT:1862 & 14284 OC

Tax Exemption
Government
NE

Subtotal	116.37
Shipping & Handling	0.00
State Tax	0.00
County Tax	0.00
City Tax	0.00
TOTAL USD	116.37

If you re-package or re-sell this product, you are required to maintain integrity of Country of Origin to the consumer of this product.

Reasonable collection and attorneys fees will be assessed to all accounts placed for collection
No materials accepted for return without our permission.

X indicates part is a hazardous material

** indicates part was sold at a promotional or special discount price*

This is your invoice.
All discrepancies must be reported within 10 days.

0

Thank You !

FORM - IN13

Figure B-31. ⅞-in. Dia. UNC 8-in. Long Hex Head Bolt, Test Nos. HBIB-1 through HBIB-5 (Item No. f5)

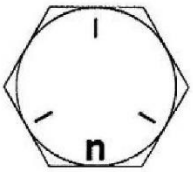
NUCOR® FASTENER

PRODUCT CERTIFICATION

LOT NUMBER W000010460

Nucor Fastener
6730 County Rd 60
Saint Joe, IN 46785
USA

Customer	Fastenal Company-Ks	**Quality Order**	IQO000000324
Nucor Sales Order	353403	**Quality Order Date**	10/31/2022
Nucor Item Number	1007063	**Name of Lab Sampler**	Carrie Mason
Customer Part Number	0137452	**Date Shipped**	11/8/2022
Nucor Purchase Order	210270562		



CERTIFIED MATERIAL TEST REPORT

Nucor Item Number	1007063	Manufacturer Date	10/31/2022
Lot Number	W000010460	Quantity	2700
Description	7/8-9 X 2 FT C GR 5 HX CAP SCREW PLAIN 1/8 KEG	Production Lot Size	10275

RAW MATERIAL

Material Item Number	1000552
Heat Number	1000217614
Material Grade	1037ML
Supplier name	n/a

CHEMISTRY

**Chemistry Composition (WT% Heat Analysis) By Material Supplier

C	Mn	P	S	Si
0.38	0.78	0.012	0.014	0.24

VISUAL

'--SURFACE QUALITY WITHIN LIMITS PRESCRIBED IN ASTM F788/F788M-20

Visual
Pass
LOT PASSED

HEAT TREATMENT

'--HEAT TREATMENT - AUSTENITIZED, OIL QUENCHED & TEMPERED (MIN 800 DEG F)

Heat Treatment
Pass

DIMENSIONS

'--DIMENSIONS PER ASME B18.2.1-2012

CHARACTERISTIC	#SAMPLES TESTED	SUMMARY (AVG)	MINIMUM	MAXIMUM
LengthIN	8	1.96	1.96	1.96
Major DiameterIN	8	0.8680	0.8667	0.8688
Width AcrCornersIN	8	1.4844	1.482	1.489

SAMPLING PLAN

'--SAMPLING PLAN PER ASTM F1470-19 UNLESS SPECIFIED BY CUSTOMER

Samples
Pass

Figure B-32. ⅞-in. Dia. UNC 2-in. Long Hex Head Bolt, Test Nos. HBIB-1 through HBIB-5 (Item No. f6)

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: _____ Date: 11/29/2018

Brian Hughes
Quality Assurance

Figure B-33. ⅝-in. Dia. UNC 10-in. Long Hex Head Bolt, Test Nos. HBIB-1 through HBIB-5 (Item No. f7)

FASTENAL®

Fastenal Company
P.O Box 1286
WINONA, MN 55987-1286

The store serving you is
3201 N. 23rd Street STE 1

LINCOLN, NE 68521
Phone #: (402)476-7900
Fax #: 402/476-7958

Invoice

Date	Reference No.	Page
1/13/23	NELIN435541	1

Discount Due Date:2%10 1/22/2023
Final Due Date:NET30 2/11/2023
Contract No:
2018.000208

Cust. No. NELIN2067
Cust. P.O. HBIB
Job No.

Sold To
UNL TRANSPORTATION/Midwest Roadside Safe
1931 NORTH ANTELOPE VALLEY PKWY
LINCOLN, NE 68588
402-472-7937; 402-472-8660(Fax)

Ship To
Picked up at Fastenal Store

This Order and Document are subject to the "Terms of Purchase" posted on www.fastenal.com.

Line No.	Quantity Ordered	Quantity Shipped	Quantity Backorder	Description	Control No.	Part No.	Price / Hundred	Amount
1	40	40	0	5/8-11xI-1/2 A307A G	120383161	1191919	101.4800	40.59 E
2	6	6	0	DH A563 GALV 5/8-11	210280003	36755	104.9200	6.30 E

Visa Account # XXXXXXXXXXX6926 Exp XX/XX

Cardmember acknowledges receipt of goods or services in the amount of the total shown hereon and agrees to perform the obligations set forth by the cardmember's agreement with the issuer.

X_____

Card Member Signature

Number of Parcels: _____

Received By

Comments
Contact: WEBORD CONTRACT:2018.000208

Tax Exemption
Exempt
NE

Subtotal	46.89
Shipping & Handling	0.00
State Tax	0.00
County Tax	0.00
City Tax	0.00
TOTAL USD	46.89

If you re-package or re-sell this product, you are required to maintain integrity of Country of Origin to the consumer of this product.

Reasonable collection and attorneys fees will be assessed to all accounts placed for collection
No materials accepted for return without our permission.

X indicates part is a hazardous material

** indicates part was sold at a promotional or special discount price*

This is your invoice.
All discrepancies must be reported within 10 days. *0*

Thank You !

FORM - IN13

Figure B-34. ⅝-in. Dia. UNC 1½-in. Long Hex Head Bolt, Test Nos. HBIB-1 through HBIB-5 (Item No. f8)

OnlineMetals
1138 West Ewing
Seattle, WA 98119
Phone: (206) 285-8603 Fax: (206) 285-7836
Website: http://www.onlinemetals.com

January [redacted], 2023 7:06:14PM
Page 1 of 1

Order Number: 2551238

Bill To UNL-MwRSF
4630 NW 36th St.
Lincoln, NE 68524

Ship To UNL-MwRSF
4630 NW 36TH ST.
LINCOLN, NE 68524
Attn: Alex Russell 402 309-0157

[redacted] P.O. #: HBIB
Contract:
Sales 1: Web Site
Terms: Visa

Sales Order No: 2551238
F.O.B.: Origin
Sales 2:

[redacted] **Due Date:** 1/19/23
Ship Via: UPS Ground

Ship Pcs	Order Pcs	Description	Length	Weight	Price UM	Extension Tax
1	1	1.5" OD x 0.375" Wall x 0.75" ID Carbon Steel Round Tube A513-Type 5 DOM A513 TYPE 5 **Heat Numbers:** 4132970	36"	13.52	$105.99 E	$105.99 E
		Tag Number: 13059948 - 1;				
1	1	Freight Charge				$8.99 E
		Heat Numbers:	**Tag Number:**			
		Total Weight	**13.5180**			
					Subtotal Non taxable	**$114.98**
					Subtotal taxable	
					Total	**$114.98**

Shipping Instructions:
Misc Instructions: Test Certificates Required;

Messages:
1010134548|

CERTIFICATE OF COMPLIANCE
We hereby certify that the material listed above was shipped as described. We hereby certify that mercury or any of its compounds are not used in the processing or distribution of our products. The products we distribute are not hazardous in their received state. For MSDS sheets go to www.onlinemetals.com

Jerry Bromley, Quality Manager

Jerry Bromley

Inspection prior to processing is recommended and any discrepancies should be reported within 30 days, and prior to on site machining. For information regarding the OnlineMetals return policy, visit http://www.onlinemetals.com/returns.cfm.

⚠ **WARNING:** Cancer and Reproductive Harm - www.P65Warnings.ca.gov

Figure B-35. ¾-in. Dia. Unthreaded Spacer Sleeve, Test Nos. HBIB-1 through HBIB-5 (Item No. f9)

FASTENAL®

Certificate of Compliance

Sold To:
UNL TRANSPORTATION/Midwest Roadside Safe

Purchase Order: EMAIL SHAUN WHEN IN
Job:
Invoice Date: 11/7/2022

THIS IS TO CERTIFY THAT WE HAVE SUPPLIED YOU WITH THE FOLLOWING PARTS.
THESE PARTS WERE PURCHASED TO THE FOLLOWING SPECIFICATIONS.

24 PCS 5/8"-11 x 8" Hot Dipped Galvanized Finish ASTM A307 Grade A Round Head Carriage Bolt SUPPLIED UNDER OUR TRACE NUMBER 200249810 AND UNDER PART NUMBER 28401

This is to certify that the above document is true and accurate to the best of my knowledge.

Tom Schall
Fastenal Account Representative Signature

Ross Schall
Printed Name

11/7/2022
Date

Please check current revision to avoid using obsolete copies.

This document was printed on 11/7/2022 and was current at that time.

Fastenal Store Location/Address:
3201 N. 23rd Street STE 1
LINCOLN, NE 68521 USA
Phone: (402)476-7900
Fax: 402/476-7958
Email: NELIN@stores.fastenal.com

Figure B-36. ⅝-in. Dia. UNC 8-in. Long Carriage Bolts, Test No. HBIB-1 (Item No. f10)

CERTIFICATE OF INSPECTION

Purchaser:	PFC	Date:	2013-11-3
P.O.NO:	PO 13062519	ISO NO:	15/11Q5220R11
INV NO:	98017RB133167B	Expire:	2014-03-22
Manufacturer:	ZHEJIANG GUORUI CO.,LTD.		
Address:	No.283 Chengxi North Road,Wuyuan Town,Haiyan Zhejiang,P.R.China		
Commodity:	ASTM A193 ALLOY GR.B7 FULL THREAD ROD，"B7"&MFG'S I.D. STAMPED ON END OF RODS(END TO END,NO CHAMFERED AT ENDS)	CUSTOMER PART NO.:	04170-3212-020
Size:	3/4-10 X 12FT	MANUFACTURING DATE:	2013.10.3
Lot NO.:	213B201-29		
Ship quantity:	0.125 MPCS	MATERIAL:	AISI 4140
Finish:	PLN		

DIMENSIONAL INSPECTION ACCORDING TO ASME B18.31.3-2009

TEST DATE: 2013-09-25 SAMPLED BY:WEIHAIJUN TITLE:QC MANAGER SAMPLING DATE: 2013-09-25

INSPECTION ITEM	SAMPLE SIZE	SPECIFICATION	ACTUAL RESULT	UNIT	ACCEPT	REJECT
Marking	46	B7&CF	OK		46	0
Major Diameter	14	0.7482-0.7353	0.738-0.741	INCH	14	0
Length	14	144.5-143.5	144.2-143.8	INCH	14	0
Straightness	8	1.152 MAX	OK	INCH	8	0
Go-Gage	14	UNC-2A	OK		14	0
No-Go Gage	14	UNC-2A	OK		14	0

CHEMICAL ANALYSIS: HEAT NO：6613040032

CHEMICAL ELEMENT (%)	C	Mn	P	S	Si	Cr	Mo	Ni	Al	Ti	V
SPECIFICATION ASTM A 193 GRADE B7	0.37-0.49	0.65-1.10	0.035 MAX	0.04 MAX	0.15-0.35	0.75-1.20	0.15-0.25				
TEST RESULT	0.39	0.76	0.010	0.005	0.17	0.9	0.18	0.09			

MACROETCH EXAMINATION	SUB-SURFACE CONDITIONS	RANDOM CONDITIONS	CENTER SEGREGATION
SPECIFICATION ASTM A 193 GRADE B7	S 1 / S 2	R 1 / R 2	C 1 / C 2 / C 3
TEST RESULT	S 1	R 1	C 1

MECHANICAL PROPERTIES: ACCORDING TO ASTM A 193/A 193M-2010a GR.B7

TEST DATE: 2013-09-25 SAMPLED BY:WEIHAIJUN TITLE:QC MANAGER SAMPLING DATE: 2013-09-25

TEST ITEM	SAMPLE SIZE	SPECIFICATION	ACTUAL RESULT	ACCEPT	REJECT
TENSILE STRENGTH(KSI)	1	125 MIN	140	1	0
YIELD STRENGTH(KSI)	1	105 MIN	126	1	0
ELONGATION (%)	1	16.00 MIN	17.5	1	0
REDUCTION OF AREA (%)	1	50.00 MIN	56	1	0
TEMPERING TEMPERATURE(°C)		593 MIN	700		
HARDNESS(HRC)	1	35 MAX	30	1	0

DECARBURIZATION:OPTICAL METHOD ACCORDING TO ASTM A 193/A 193M-2010a GR.B7

TEST DATE: 2013-09-25 SAMPLED BY:WEIHAIJUN TITLE:QC MANAGER SAMPLING DATE: 2013-09-25

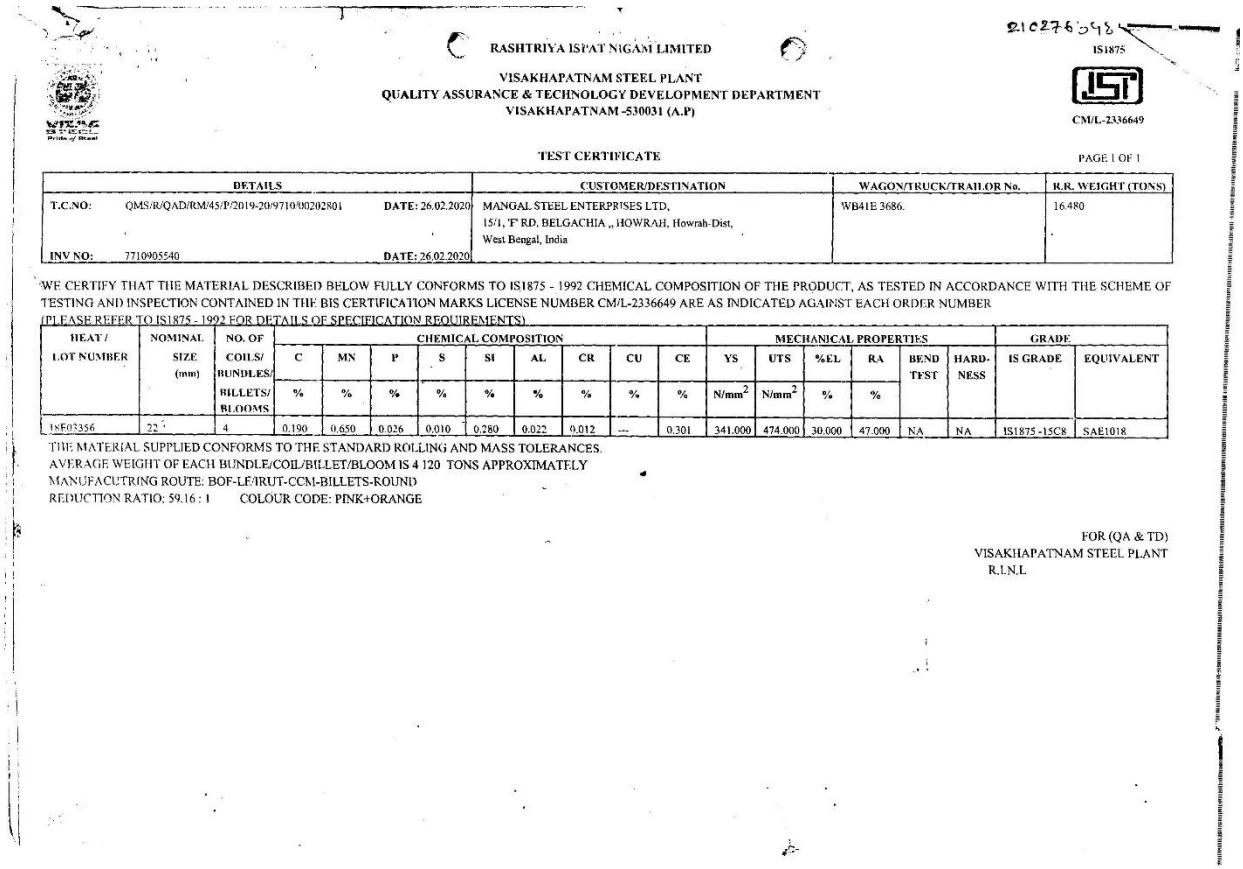
TEST ITEM	SAMPLE SIZE	SPECIFICATION	ACTUAL RESULT	UNIT	ACCEPT	REJECT
0.75hsFrom Root to Crest	1	0.046 MIN	0.055	INCH	1	0
0.1hs at Root	1	0.006 MAX	0.003	INCH	1	0

HEAT TREATMENT : INDUCTION-TYPE WITH POLYMER QUENCHING & TEMPERING

EN10204:2004.3.1 Certified SIGNATURE: WEIHAIJUN TITLE: QC MANAGER

Page 9

Figure B-37. ¾-in. Dia. UNC 13-in. Long Fully Threaded Rods, Test No. HBIB-1 (Item No. f11) and Test Nos. HBIB-2 through HBIB-5 (Item No. f10)



RASHTRIYA ISPAT NIGAM LIMITED

VISAKHAPATNAM STEEL PLANT
QUALITY ASSURANCE & TECHNOLOGY DEVELOPMENT DEPARTMENT
VISAKHAPATNAM -530031 (A.P)

IS1875

CM/L-2336649

TEST CERTIFICATE

PAGE 1 OF 1

DETAILS			CUSTOMER/DESTINATION	WAGON/TRUCK/TRAILOR No.	R.R. WEIGHT (TONS)
T.C.NO:	QMS/R/QAD/RM/45/P/2019-20/9710/80202801	DATE: 26.02.2020	MANGAL STEEL ENTERPRISES LTD, 15/1, 'F' RD, BELGACHIA ,, HOWRAH, Howrah-Dist, West Bengal, India	WB41E 3686.	16.480
INV NO:	7710905540	DATE: 26.02.2020			

WE CERTIFY THAT THE MATERIAL DESCRIBED BELOW FULLY CONFORMS TO IS1875 - 1992 CHEMICAL COMPOSITION OF THE PRODUCT, AS TESTED IN ACCORDANCE WITH THE SCHEME OF TESTING AND INSPECTION CONTAINED IN THE BIS CERTIFICATION MARKS LICENSE NUMBER CM/L-2336649 ARE AS INDICATED AGAINST EACH ORDER NUMBER
(PLEASE REFER TO IS1875 - 1992 FOR DETAILS OF SPECIFICATION REQUIREMENTS)

HEAT / LOT NUMBER	NOMINAL SIZE (mm)	NO. OF COILS/ BUNDLES/ BILLETS/ BLOOMS	CHEMICAL COMPOSITION									MECHANICAL PROPERTIES						GRADE	
			C	MN	P	S	SI	AL	CR	CU	CE	YS	UTS	%EL	RA	BEND TEST	HARD-NESS	IS GRADE	EQUIVALENT
			%	%	%	%	%	%	%	%	%	N/mm^2	N/mm^2	%	%				
18E03356	22	4	0.190	0.650	0.026	0.010	0.280	0.022	0.012	---	0.301	341.000	474.000	30.000	47.000	NA	NA	IS1875-15C8	SAE1018

THE MATERIAL SUPPLIED CONFORMS TO THE STANDARD ROLLING AND MASS TOLERANCES.
AVERAGE WEIGHT OF EACH BUNDLE/COIL/BILLET/BLOOM IS 4.120 TONS APPROXIMATELY
MANUFACUTRING ROUTE: BOF-LF/IRUT-CCM-BILLETS-ROUND
REDUCTION RATIO: 59.16 : 1 COLOUR CODE: PINK+ORANGE

FOR (QA & TD)
VISAKHAPATNAM STEEL PLANT
R.I.N.L

Figure B-38. ⅝-in. Dia. UNC 10-in. Long Fully Threaded Rods, Test Nos. HBIB-2 through HBIB-5 (Item No. f11)

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-39. ⅞-in. Dia. Plain Round Washer, Test Nos. HBIB-1 through HBIB-5 (Item No. g1)

SSF INDUSTRIAL CO., LIMITED

MILL TEST CERTIFICATION

Certification Conforms to EN1024 3.1B

Supplier: SSF INDUSTRIAL CO.,LIMITED
Buyer: FASTENAL COMPANY PURCHASING
Certificate No.: 000825
Invoice No.: FASTCO2020051501

Product Description: 5/8 USS F/W GALV
Product Size: 5/8
Quality Acceptance: ISO 3269
Shipped Q'ty: 12 MPCS
Lot No.: **20200515**

RAW MATERIAL scrap

Element	C	Si	Mn	S	P	Ni	Cr	Cu

SURFACE

Test Item	Spec.	Standard	Remark
Appearance	Flawless	/	OK

DIMENSION MEASUREMENT(L According to : USS

Test Item	Standard (mm)		Sampling	Remark	Test Result
	Min	Max			
INNER DIAMETER (d1)	17.3	18.23	80	OK	
OUTTER DIAMETER (d2)	44.28	45.21	80	OK	
THICKNESS (h)	2.75	4.06	80	OK	

MACHANICAL PROPERTIES According to : ISO 6507

Test Item	Spec.	Sampling	Remark	Test Result
HARDNESS (HRC/HV)	HV10 140 ~ HV10 250	10	OK	HV10 145 ~ HV10 150

COATING According to : ISO 4042

Test Item	Spec.	Sampling	Remark	Test Result
Plating thickness	min.3 μm	5	OK	4.573 μm - 5.328 μm
SST	2 hours no white corrosion and 12 hours no red rust	5	OK	OK

We hereby certify that all the above material were manufactured , sampled, tested, and inspected in accordance with the relevant specification and any supplementary requirements or other requirements designated in the purchase order and was found to meet those requirements.

Inspector: QC Chen **Inspc. Date:** 2020.11.16

For and on behalf of SSF INDUSTRIAL CO., LIMITED (Authorized Signature(s))

Figure B-40. ⅝-in. Dia. Plain Round Washer, Test Nos. HBIB-1 through HBIB-5 (Item No. g2)

DECKER
SINCE 1927 www.deckernut.com

DECKER MANUFACTURING CORPORATION
703 N. Clark Street
Albion, Michigan 49224
P: 517.629.3955 • F: 517.629.3535

Printed: 10/28/2021 10:46:51 AM
October 28, 2021

TRINITY INDUSTRIES INC 16
2548 N E 28TH STREET
FORT WORTH, TX 76111

PRODUCT MATERIAL CERTIFICATION

CUSTOMER PART NUMBER :	50CNFHG/D	INVOICE:	528371
CUSTOMER P.O. NUMBER :	215863 B3		

LOT NUMBER:	21-38-004	DESCRIPTION:	5/8 GRD RAIL NUT .031
DATE:	Jun 29, 2021	QUANTITY:	35,000
HEAT NUMBER:	10724400	MATERIAL SUPPLIER:	CHARTER STEEL
MATERIAL:	STEEL - C1010		

We certify the product above was manufactured at DECKER MANUFACTURING CORPORATION from the specified raw material and that said product is certified to be manufactured, randomly sampled, tested and/or inspected and conforms to applicable specifications. We additionally certify that said raw material was domestically manufactured in the United States of America and that said raw material was manufactured free of mercury contamination.

The items were processed under the Decker Quality Manual. The current revision is dated January 12, 2005
No welding was performed.

This document accurately represents values and statements provided by our suppliers accredited testing facility. The original metallurgical test report shall be retained on file by DECKER MANUFACTURING CORPORATION for a period of not less than (10) years.

CHEMICAL ANALYSIS BY MATERIAL SUPPLIER

CARBON :	0.09	PHOSPHOROUS :	0.008
MANGANESE :	0.45	SULFUR :	0.010

DECKER MANUFACTURING CORPORATION

Russel L. Wilson
Quality Assurance Manager

The above results pertain only to the items tested. This report shall not be reproduced except in full without the approval of this testing facility.

Figure B-41. ⅝-in. Dia. UNC Heavy Hex Nut, Test Nos. HBIB-1 through HBIB-5 (Item No. h1)

NINGBO DONGXIN HIGH-STRENGTH NUT CO.,LTD

TEST CERTIFICATE

(EN 10204.3.1)

Customer: FASTENAL COMPANY PURCHASING	Production Lot No.:	2205DX100-1970-8	Issue Date:	2022/10/15
	Add.of Customer:	4730 SERVICE DRIVEWINONA MN 55897 U.S.A	Inv. No.:	22745DX100-1063
	Description:	ASTM A563 GR.DH HEAVY HEX NUT	Manu. Date:	2022/6/15
		HDG With Blue Wax	Manu. Qty:	29664
	PO No.:	210280003	Shipped Qty:	28800
	Manufacturer:	Ningbo Dongxin High-strength Nut Co.,LTD	Marking:	DX,DH
	Address:	Xijingtang,Luotuo,Ningbo,China	LOT No.:	0629DX100-1970-8
	Tel./Fax:	0574-86533751/86531751	Sample Plan:	ASME B18.18-2017(Category.2)/ASTM F1470-2019
	Size:	5/8"-11	Part No.:	36755

Chemical Composition

Material type: 35K Φ24 Heat No.: B21110224

Chemical Analysis % (items)	C	Mn	P	S	Si	Cr	Ni	Mo	Others
	0.20-0.55	≥0.60	≤0.04	≤0.05	/	/	/	/	/
Result	0.34	0.66	0.020	0.005	0.14	0.073	0.018	/	/
Cert #:	0002596			Material supplier:			ZHEJIANG YUANLI		

Dimensions

DIM.SPEC: ASME B18.2.2-2022 INSPECTOR & SAMPER: Ms.Li DATE: 2022/10/15

Item	Specified	Result	Sampling	Rej.	Remark	Specification
Widthacrossflats(inch)	1.031 - 1.062	1.044 - 1.054	4	0	OK	------
Widthacrossangle(inch)	1.175 - 1.227	1.188 - 1.191	4	0	OK	------
Height(inch)	0.587 - 0.631	0.607 - 0.617	4	0	OK	------
Minor diameter(inch)	0.547 - 0.566	0.555 - 0.557	15	0	OK	ASME B1.1-03
Thread-2B	Thread GO gauge	HDG Bolt	15	0	OK	ASME B1.1-03
	Thread NO GO gauge	...	15	0	OK	
Appearance	OK	OK	29	0	OK	ASTM F812-17
FIM	MAX 0.021	0.008 - 0.010	4	0	OK	ASME B18.2.2-2022

Mechanical Properties

MEC,SPEC:ASTM A563/A563M-21a INSPECTOR & SAMPLER: Ms.Li DATE: 2022/10/15

ITEM	Test Method	SPECIFIED	Sampling	Result	JUG
Hardness HRC	ASTM F606/F606M-21	24 - 38	4	32 - 35.5	OK
Proof loading KSI	ASTM F606/F606M-21	150	3	156	OK

Plating

Plating Spec: ASTM F2329/F2329M-15 Inspector & Sampler : Ms Li Date: 2022/10/15

ITEM	Test Method	SPECIFIED	Sampling	Result	JUG
HDG With Blue Wax	ASTM B487 -2020	50 um Average	15	61 - 95 um	OK
Torque Tension K Value	SAE J174-2019	0.18 Max	4	0.12	OK

MACROETCH

Division	Surface Condition	Random Condition	Center Segregation	Test method
Spec.	S2	R2	C3	ASTM E381-2020
Results	S2	R2	C3	

REMARK:

***This inspection certificate is for responsibility under test sample only.**

***Quench at880℃ about 90 minutes,Tempering at550℃ about 120 minutes**

***This test report shall not be reproduced except in full without written approval of the LAB.**

***The samples tested CONFORM to the fastener specification & standards above.**

***Dimensional Testing is done at Ningbo Dongxin High-Strength Nut Co.,Ltd**

***The documentation for chemical analysis is provided by the suppliers.**

***Parts are manufactured and tested according to above specification and compliance with order, we certify that this is a true representation of information provided by manufacturer and laboratory.**

***The products supplied are in compliance with all the requirements of the order.**

***The MTR's are in compliance to DIN EN 10204 3.1.**

Yan Yingjun

QA: Yan Yingjun

Ningbo Dongxin High-Strength Nut Co.,Ltd

Figure B-42. ⅝-in. Dia. UNC Heavy Hex Nut, Test No. HBIB-1 (Item No. h1)

NUCOR® FASTENER

PRODUCT CERTIFICATION

LOT NUMBER W000037696

Nucor Fastener
6730 County Rd 60
Saint Joe, IN 46785
USA

Customer	Bennett Bolt Works Inc	**Quality Order**	IQO000023400
Nucor Sales Order	341788	**Quality Order Date**	3/9/2023
Nucor Item Number	1015073	**Name of Lab Sampler**	Jeffery J Zink
Customer Part Number		**Date Shipped**	3/14/2023
Nucor Purchase Order	6021296		

CERTIFIED MATERIAL TEST REPORT

Nucor Item Number	1015073	Manufacturer Date	3/10/2023
Lot Number	W000037696	Quantity	125000
Description	5/8-11 GR A GUARDRAIL HEX NUT .031 OS TAP HOT DIP GALV STRUCT CAN	Production Lot Size	192922

RAW MATERIAL

Material Item Number	1000666
Heat Number	8000021095
Material Grade	1045L
Supplier name	Nucor Steel South Carolina - Darlington

CHEMISTRY

**Chemistry Composition (WT% Heat Analysis) By Material Supplier

C	Mn	P	S	Si
0.4500	0.6700	0.0030	0.0150	0.2080

MECHANICAL

'--MECHANICAL PROPERTIES IN ACCORDANCE WITH ASTM A563/A563M-21ae1

Core HardnessHRBIN
1. 89.45 2. 89.95 3. 90.15 4. 88.45 5. 88.05
Average results from tests
89.21

Weight LoadLBS
1. 17000 2. 17000 3. 17000 4. 17000 5. 17000
Average results from tests
17000

SPECIAL TESTING

'--MECHANICAL PROPERTIES IN ACCORDANCE WITH ASTM A563/A563M-21ae1

Proof Load
Pass

VISUAL

'--SURFACE QUALITY WITHIN LIMITS PRESCRIBED IN ASTM F812-12 (2017)

Visual
Pass
LOT PASSED

Figure B-43. ⅝-in. Dia. UNC Heavy Hex Nut, Test Nos. HBIB-2 through HBIB-5 (Item No. h1)

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 :

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

MANUFACTURE DATE : 2016/08/26
COUNTRY OF ORIGIN : CHINA

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

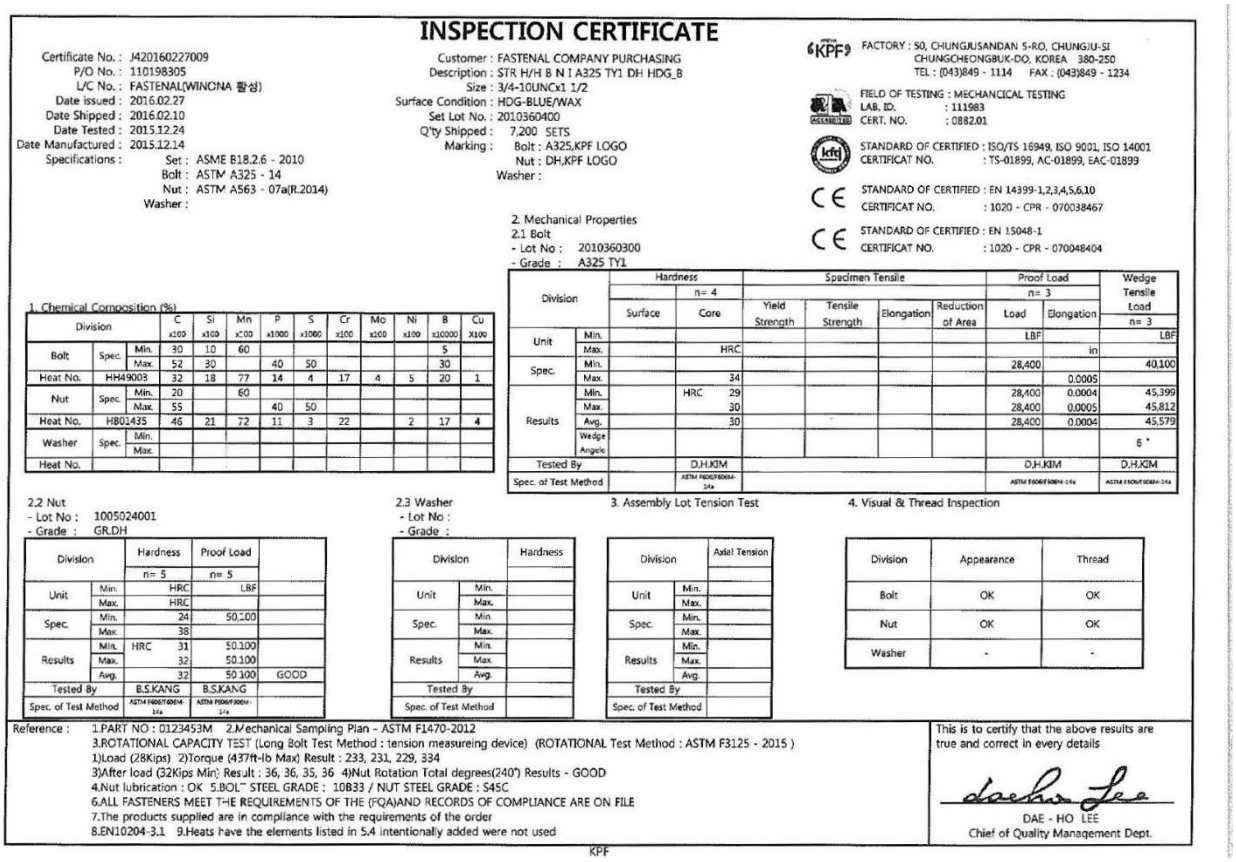
SAMPLED BY : GDAN LIAN

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:

Figure B-44. ⅝-in. Dia. UNC Hex Nut, Test Nos. HBIB-1 through HBIB-5 (Item No. h2)



INSPECTION CERTIFICATE

Certificate No. : J420160227009
P/O No. : 110198305
L/C No. : FASTENAL(WINONA 활성)
Date issued : 2016.02.27
Date Shipped : 2016.02.10
Date Tested : 2015.12.24
Date Manufactured : 2015.12.14
Specifications : Set : ASME B18.2.6 - 2010
Bolt : ASTM A325 - 14
Nut : ASTM A563 - 07a(R.2014)
Washer :

Customer : FASTENAL COMPANY PURCHASING
Description : STR H/H B N I A325 TY1 DH HDG_B
Size : 3/4-10UNCx1 1/2
Surface Condition : HDG-BLUE/WAX
Set Lot No. : 2010360400
Q'ty Shipped : 7,200 SETS
Marking : Bolt : A325,KPF LOGO
Nut : DH,KPF LOGO
Washer :

KPF FACTORY : 50, CHUNGJUSANDAN 5-RO, CHUNGJU-SI CHUNGCHEONGBUK-DO, KOREA 380-250
TEL : (043)849 - 1114 FAX : (043)849 - 1234

FIELD OF TESTING : MECHANICAL TESTING
LAB. ID. : 111983
CERT. NO. : 0882.01

STANDARD OF CERTIFIED : ISO/TS 16949, ISO 9001, ISO 14001
CERTIFICAT NO. : TS-01899, AC-01899, EAC-01899

STANDARD OF CERTIFIED : EN 14399-1,2,3,4,5,6,10
CERTIFICAT NO. : 1020 - CPR - 070038467

STANDARD OF CERTIFIED : EN 15048-1
CERTIFICAT NO. : 1020 - CPR - 070048404

1. Chemical Composition (%)

Division			C x100	Si x100	Mn x100	P x1000	S x1000	Cr x100	Mo x100	Ni x100	B x10000	Cu X100
Bolt	Spec.	Min.	30	10	60						5	
		Max.	52	30		40	50				30	
Heat No.		HH49003	32	18	77	14	4	17	4	5	20	1
Nut	Spec.	Min.	20		60							
		Max.	55			40	50					
Heat No.		HB01435	46	21	72	11	3	22		2	17	4
Washer	Spec.	Min.										
		Max.										
Heat No.												

2. Mechanical Properties
2.1 Bolt
- Lot No : 2010360300
- Grade : A325 TY1

Division		Hardness n= 4 Surface	Hardness n= 4 Core	Specimen Tensile Yield Strength	Specimen Tensile Tensile Strength	Specimen Tensile Elongation	Specimen Tensile Reduction of Area	Proof Load n= 3 Load	Proof Load n= 3 Elongation	Wedge Tensile Load n= 3
Unit	Min.							LBF		LBF
	Max.		HRC						in	
Spec.	Min.							28,400		40,100
	Max.		34						0.0005	
Results	Min.		HRC 29					28,400	0.0004	45,399
	Max.		30					28,400	0.0005	45,812
	Avg.		30					28,400	0.0004	45,579
	Wedge Angele									6 °
Tested By			D.H.KIM						D.H.KIM	
Spec. of Test Method			ASTM F606/F606M-14a						ASTM F606/F606M-14a	

2.2 Nut
- Lot No : 1005024001
- Grade : GR.DH

Division		Hardness n= 5	Proof Load n= 5	
Unit	Min.	HRC	LBF	
	Max.	HRC		
Spec.	Min.	24	50,200	
	Max.	38		
Results	Min.	HRC 31	50,100	
	Max.	32	50,100	
	Avg.	32	50,100	GOOD
Tested By		B.S.KANG	B.S.KANG	
Spec. of Test Method		ASTM F606/F606M-14a	ASTM F606/F606M-14a	

2.3 Washer
- Lot No :
- Grade :

Division		Hardness
Unit	Min.	
	Max.	
Spec.	Min.	
	Max.	
Results	Min.	
	Max.	
	Avg.	
Tested By		
Spec. of Test Method		

3. Assembly Lot Tension Test

Division		Axial Tension
Unit	Min.	
	Max.	
Spec.	Min.	
	Max.	
Results	Min.	
	Max.	
	Avg.	
Tested By		
Spec. of Test Method		

4. Visual & Thread Inspection

Division	Appearance	Thread
Bolt	OK	OK
Nut	OK	OK
Washer	-	-

Reference : 1.PART NO : 0123453M 2.Mechanical Sampling Plan - ASTM F1470-2012
3.ROTATIONAL CAPACITY TEST (Long Bolt Test Method : tension measureing device) (ROTATIONAL Test Method : ASTM F3125 - 2015)
1)Load (28Kips) 2)Torque (437ft-lb Max) Result : 233, 231, 229, 334
3)After load (32Kips Min) Result : 36, 36, 35, 36 4)Nut Rotation Total degrees(240°) Results - GOOD
4.Nut lubrication : OK 5.BOLT STEEL GRADE : 10B33 / NUT STEEL GRADE : S45C
6.ALL FASTENERS MEET THE REQUIREMENTS OF THE (FQA)AND RECORDS OF COMPLIANCE ARE ON FILE
7.The products supplied are in compliance with the requirements of the order
8.EN10204-3.1 9.Heats have the elements listed in 5.4 intentionally added were not used

This is to certify that the above results are true and correct in every details

DAE - HO LEE
Chief of Quality Management Dept.

KPF

Figure B-45. ¾-in. Dia. UNC Heavy Hex Nut, Test Nos. HBIB-1 through HBIB-5 (Item No. h3)

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 : 2018/03/28

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 110254885
COMMODITY : FINISHED HEX NUT GR-A
SIZE : 7/8-9 NC O/T 0.56MM
LOT NO : 1N1810005
SHIP QUANTITY : 9,000 PCS
LOT QUANTITY 55,748 PCS
HEADMARKS :

PACKING NO : GEM180115010
INVOICE NO : GEM/FNL-180201WI-1
PART NO : 36717
SAMPLING PLAN : ASME B18.18-2011(Category.2)/ASTM F1470-2012
HEAT NO : 331704677
MATERIAL : XGML08
FINISH : HOT DIP GALVANIZED PER ASTM A153-2009/ASTM F2329-2013

MANUFACTURE DATE : 2018/01/05
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	0.0360	0.0600	0.4500	0.0140	0.0030	0.0300

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.2-2015

SAMPLED BY : WDANDAN

INSPECTIONS ITEM	SAMPLE	SPECIFIED		ACTUAL RESULT	ACC.	REJ.
WIDTH ACROSS CORNERS	5 PCS		1.4470-1.5160 inch	1.4850-1.4930 inch	5	0
FIM	15 PCS	ASME B18.2.2-2015	Max. 0.0250 inch	0.0110-0.0200 inch	15	0
THICKNESS	5 PCS		0.7240-0.7760 inch	0.7460-0.7570 inch	5	0
WIDTH ACROSS FLATS	5 PCS		1.2690-1.3120 inch	1.2930-1.2980 inch	5	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 A563-2015

SAMPLED BY : TANGHAO

INSPECTIONS ITEM	SAMPLE	TEST METHOD	REF	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS	15 PCS	ASTM F606-2014		68-107 HRB	86-90 HRB	15	0
PROOF LOAD	5 PCS	ASTM F606-2014		Min. 31,416 LBF	OK	5	0
PLATING THICKNESS(μm)	29 PCS	ASTM B568-1998		>=53	62.38-62.57	29	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:

Figure B-46. ⅞-in. Dia. UNC Hex Nut, Test Nos. HBIB-1 through HBIB-5 (Item No. h4)

FASTENAL®

Fastenal Company
P.O Box 1286
WINONA, MN 55987-1286

Invoice

Date	Reference No.	Page
8/29/23	NELIN448334	1

The store serving you is
3201 N 23rd St
Unit 1
LINCOLN, NE 68521
Phone #: (402)476-7900
Fax #: 402/476-7958

Discount Due Date:2%10 9/7/2023
Final Due Date:NET30 9/27/2023
Contract No:
2018.000208

Cust. No. NELIN2067
Cust. P.O. HBIB-2
Job No. Pick up by

Sold To
UNL TRANSPORTATION/Midwest Roadside Safe
1931 NORTH ANTELOPE VALLEY PKWY
LINCOLN, NE 68588
402-472-7937; 402-472-8660(Fax)

Ship To
Picked up at Fastenal Store

This Order and Document are subject to the "Terms of Purchase" posted on www.fastenal.com.

Line No.	Quantity Ordered	Quantity Shipped	Quantity Backorder	Description	Control No.	Part No.	Price / Hundred	Amount
1	1	1	0	T ROD Z 7/8-9 X 6'	210285164	47173	5,242.5600	52.43 E
2	14	14	0	7/8"-9 Fin Hex Nut Z	110390270	36118	91.1600	12.76 E

Visa Account # XXXXXXXXXXXX6926 Exp XX/XX

Cardmember acknowledges receipt of goods or services in the amount of the total shown hereon and agrees to perform the obligations set forth by the cardmember's agreement with the issuer.

X_____

Card Member Signature

Number of Parcels: _____

Received By

Comments
Contact: Shaun Tighe

Tax Exemption
Exempt

NE

Subtotal	65.19
Shipping & Handling	0.00
State Tax	0.00
County Tax	0.00
City Tax	0.00
TOTAL USD	65.19

If you re-package or re-sell this product, you are required to maintain integrity of Country of Origin to the consumer of this product.

Reasonable collection and attorneys fees will be assessed to all accounts placed for collection
No materials accepted for return without our permission.

X indicates part is a hazardous material
** indicates part was sold at a promotional or special discount price*

This is your invoice.
All discrepancies must be reported within 10 days.

0

Thank You !

FORM - IN13

Figure B-47. ⅞-in. Dia. UNC Hex Nut, Test Nos. HBIB-2 through HBIB-5 (Item No. h4)

Dayton Superior Corp (1790908*1) Page 3 of 4 Total Pages

128258 - 083129

NUCOR

Mill Certification
04/19/2022

MTR#:1002639-3
Lot #:100021539241
2911 E NUCOR ROAD
PO BOX 309
NORFOLK, NE 68701 US
402 644-0200
Fax: 402 644-0329

Sold To: NORFOLK IRON & METAL CO
3001 N VICTORY RD
NORFOLK, NE 68702 US

Ship To: NORFOLK IRON & METAL CO
31181 WELD CR 39.5
GREELEY, CO 80631 US

Customer PO	03057825	Sales Order #	10042534 - 1.1
Product Group	Hot Roll - Merchant Bar Quality	Product #	3016386
Grade	Nucor Multigrade	Lot #	100021539241
Size	0.25" x 3"	Heat #	1000215392
BOL #	BOL-1105330	Load #	1002639
Description	Hot Roll - Merchant Bar Quality Flat 1/4" x 3" Nucor Multigrade 20' 0" [240"] 6001-8000 lbs	Customer Part #	00570
Production Date	03/16/2022	Qty Shipped LBS	19600
Product Country Of Origin	United States	Qty Shipped EA	384
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: 03/11/2022

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	Ti (%)	V (%)	Nb (%)
0.15	0.67	0.015	0.013	0.17	0.09	0.17	0.03	0.27	0.001	0.003	0.008

Sn (%)
0.010

ASTM A529 S78.2 CE (%) : 0.36

ASTM A992 5.4 CE (%) : 0.33

Tensile testing

	Yield (PSI)	Tensile (PSI)	Elongation in 8" (%)
(1)	51800	75900	31.0
(2)	52200	75100	30.0

Comments:
Nucor Multigrade Meets the Requirements of:
ASTM A36/A36M, A529/529M GR50(345), A572/572M GR50(345), A709/709M GR36(250) & GR50(345),
CSA G40.21 GR44W(300W) & GR50W(350W)
AASHTO M270/M270M GR36(270) & GR50(345),
ASME SA36/SA36M
Meets Reporting Requirements of EN10204 SEC 3.1
EN 10204 3.1
All manufacturing processes of the steel materials in this product, including melting, have been performed in the United States.
Finished product is hot rolled in the United States.
All products produced are weld free.
Mercury, in any form, has not been used in the production or testing of this material.
Test conform to ASTM A29-20, ASTM E415 and ASTM E1019-resulphurized grades or applicable customer requirements.
All material melted at Nucor Steel Nebraska is produced in an Electric Arc Furnace.
Strand Cast
Tests included in ISO 17025 scope: Chemistry, Tensile, Brinell Hardness, Rockwell Hardness, Inclusion, and Grain Size.
Exporting Country-USA
Sales@nucorne.com

NBMG-10 January 1, 2012

Jim Hill, Division Metallurgist

Page 1 of 1

CERT APPROVED
BY
DATE 6/3/22

Figure B-48. ¾-in. and ⅜-in. Dia. Wire Struts, Test Nos. HBIB-1 through HBIB-5 (Item Nos. i1-i3)

13 DEC 22 08:14AM Dayton Superior Corp (1790908*1) Page 2 of 4 Total Pages
SOPS5007.1 LYNNNL Avante 9.8.3e Dayton Superior LIVE.DATA

DAYTON SUPERIOR CORPORATION

Material Certification Document Cover Page

****

Order Number:	1790908	Release:	1
Order Line Nbr:	0001		
Ship Quantity:	3		
Sales UOM	EA	COO:	US
Part Number:	63500		
Description:	F41-4 BOLT-TYP 1-GUARD RAIL ANCHOR-7/8"X4"FERR		

Lot Numbers	Ship Qty	Documents	Issue Qty	UOM
PORCVR~696926		128258-1000215392_053122		LB
PORCVR~695163		88028-5716_052322		EA

Figure B-49. ⅞-in. Dia. Threaded Ferrule, Test Nos. HBIB-1 through HBIB-5 (Item No. i4)

HILTI

P.O. Box 21148
Tulsa, OK 74121
P: 800-879-8000
F: 800-879-7000

Date: 9/13/2023

Customer: NEBRASKA-LINCOLN * UNIV OF

Customer PO: HBIB

Subject: **Certificate of Conformance - HIT RE 500 V3 Adhesive**

Quantity: 20 PCS / 2123404 / Injectable mortar HIT-RE 500 V3/500/1

To Whom it May Concern:

This is to certify that the HIT-RE 500 V3 provided on the above referenced order is a high-strength, slow cure two-part epoxy adhesive contained in two cartridges separating the resin from the hardener.

Additionally, this certifies that the product has been seismically qualified per ICC-ES Acceptance Criteria AC308 and ACI 355.4 and meets the requirements of **ASTM** C881-90, **Type** I, II, IV and V, Grade 3, **Class** A, B and C.

The items are supplied under Hilti's **ISO 9001** quality program.

Sincerely,

B. Mitchell

B. Mitchell, Certification Specialist

HILTI, Inc.
RE500 V3

Figure B-50. Epoxy Adhesive, Test Nos. HBIB-1 through HBIB-5 (Item No. j1)

Appendix C. Critical Impact Point Determination

The criteria and considerations used in selecting MASH impact locations are noted in Section 4.3. Note that for test nos. HBIB-1 through HBIB-3, the beginning of the system should be evaluated at the nose of the system. Since the concrete anchor block was out of the clear zone, the impact point was selected 12 in. downstream from the downstream edge of the anchor block based on MASH recommendations. The CIP calculations therefore are for reference to any stiffness transition occurring after the anchor block. However, the system continuously decreases in stiffness starting at the anchor block through the standard, tangent MGS; there are no increases in stiffness traveling in the downstream direction. Thus, for MASH impact conditions 3-32 and 3-33, an impact point was selected close to the anchor block (12 in. downstream), which provided an impact tolerance to reduce the likelihood that the vehicle made direct contact with the anchor block, which could decrease system stiffness and provide a less conservative answer.

- **Section 1: Nested MGS plus Nested Rubrail at Quarter Post Spacing**

$$F_y = D\left(\frac{\sigma_y Z_p}{H_r}\right) = 1.5\left(\frac{36 * 5.73}{31.125}\right) = 9.94\ kips$$

$$F_p = \frac{F_y}{S} = \frac{9.94}{1.5625} = 6.36\frac{kip}{ft}$$

Where F_y is the force required to yield a post at the groundline, F_p is the average lateral force per unit length of rail, S is the post spacing.

$$M_p = M_h + \sum M_i \frac{H_i}{H_h} = \left[16.0 + 16.0\left(\frac{12.84}{30.12}\right)\right] * 2 = 45.64\ kip.ft$$

Where M_p is the effective rail bending moment considering multiple rails installed at different heights. In which the parameters are multiplied by a factor of two because of nested rails at this section. Also, the calculated value for F_s' shows that this value is greater than F_p, hence, F_p is used for the CIP determination.

$$M_p = 45.64 \text{ and } F_p = 6.36 \xrightarrow{Using\ MASH\ Figure\ 2-11} CIP = 7.35\ ft$$

- **Section 2: Nested MGS plus Nested Rubrail at Half Post Spacing**

$$F_y = D\left(\frac{\sigma_y Z_p}{H_r}\right) = 1.5\left(\frac{36 * 5.73}{35.6}\right) = 8.69\ kips$$

$$F_p = \frac{F_y}{S} = \frac{8.69}{3.125} = 2.78\frac{kip}{ft}$$

Where S is the distance between post nos. 6 and 5 (half post spacing)

$$M_p = M_h + \sum M_i \frac{H_i}{H_h} = \left[8.0 + 8.0\left(\frac{17.31}{34.6}\right)\right] * 2 = 24.00\ kip.ft$$

In which the parameters are multiplied by a factor of two because of nested rails at this section. Also, the calculated value for F_s' shows that this value is greater than F_p, hence, F_p is used for the CIP determination.

$$M_p = 24.00 \text{ and } F_p = 2.78 \xrightarrow{Using\ MASH\ Figure\ 2-11} CIP = 9.83\ ft$$

- **Section 3: MGS plus Rubrail at Half Post Spacing**

$$F_y = D\left(\frac{\sigma_y Z_p}{H_r}\right) = 1.5\left(\frac{36 * 5.73}{37.9}\right) = 8.16\ kips$$

$$F_p = \frac{F_y}{S} = \frac{8.16}{3.125} = 2.61\frac{kip}{ft}$$

Where S is the post spacing at post no. 6.

$$M_p = M_h + \sum M_i \frac{H_i}{H_h} = \left[8.0 + 8.0\left(\frac{19.61}{36.9}\right)\right] = 12.25\ kip.ft$$

The calculated value for F_s' shows that this value is greater than F_p, hence, F_p is used for the CIP determination.

$$M_p = 12.25 \text{ and } F_p = 2.61 \xrightarrow{Using\ MASH\ Figure\ 2-11} CIP = 10.8\ ft$$

- **Section 4: MGS plus Rubrail at Full Post Spacing**

$$F_y = D\left(\frac{\sigma_y Z_p}{H_r}\right) = 1.5\left(\frac{36 * 5.73}{43.84}\right) = 7.057\ kips$$

$$F_p = \frac{F_y}{S} = \frac{7.057}{6.25} = 1.13\frac{kip}{ft}$$

Where S is the distance between post nos. 5 and 6 (full post spacing).

$$M_p = M_h + \sum M_i \frac{H_i}{H_h} = \left[8.0 + 8.0\left(\frac{25.57}{42.84}\right)\right] = 12.77\ kip.ft$$

$$M_p = 16.59 \text{ and } F_p = 1.13 \xrightarrow{Using\ MASH\ Figure\ 2-11} CIP = 12\ ft$$

- **Section 5: Standard MGS**

$$F_y = D\left(\frac{\sigma_y Z_p}{H_r}\right) = 1.5\left(\frac{36 * 5.73}{31}\right) = 9.98\ kips$$

$$F_p = \frac{F_y}{S} = \frac{9.98}{6.25} = 1.6\frac{kip}{ft}$$

Where S is the distance between post (full post spacing).

$$M_p = M_h + \sum M_i \frac{H_i}{H_h} = [8.0 + 0] = 8.0\ kip.ft$$

The calculated value for F_s' shows that this value is greater than F_p, hence, F_p is used for the CIP determination.

$$M_p = 8.0 \text{ and } F_p = 1.6 \xrightarrow{Using\ MASH\ Figure\ 2-11} CIP = 12.75\ ft$$

Appendix D. Vehicle Center of Gravity Determination

		Test Name:	**HBIB-1**	**VIN:**	**KMHCT4AEXHU272805**
Model Year:	**2017**	**Make:**	**Hyundai**	**Model:**	**Accent**

Vehicle CG Determination

	Vehicle Equipment	Weight (lb)
+	Unballasted Car (Curb)	2459
+	Hub	19
+	Brake activation cylinder & frame	7
+	Pneumatic tank (Nitrogen)	20
+	Strobe/Brake Battery	5
+	Brake Receiver/Wires	5
+	CG Plate including DAQ	19
-	Battery	-31
-	Oil	-16
-	Interior	-62
-	Fuel	-20
-	Coolant	-8
-	Washer fluid	-4
+	Water Ballast (In Fuel Tank)	
+	Onboard Supplemental Battery	

Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle

Estimated Total Weight (lb): 2393

Vehicle Dimensions for C.G. Calculations

Wheel Base:	101.125	in.	Front Track Width:	59.375	in.
Roof Height:	56.5	in.	Rear Track Width:	59.625	in.

Center of Gravity	**1100C MASH Targets**	**Test Inertial**	**Difference**
Test Inertial Weight (lb)	2420 ± 55	2411	-9.0
Longitudinal CG (in.)	39 ± 4	38.001	-0.999
Lateral CG (in.)	NA	-0.999	NA
Vertical CG (in.)	NA	22.249	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	731	
Rear	445	470	
FRONT	1544		lb
REAR	915		lb
TOTAL	2459		lb

TEST INERTIAL WEIGHT (lb)

	Left	Right	
Front	796	709	
Rear	450	456	
FRONT	1505		lb
REAR	906		lb
TOTAL	2411		lb

Figure D-1. Vehicle Mass Distribution, Test No. HBIB-1

		Test Name:	**HBIB-2**	**VIN:**	**KNADM4A32H6015837**
Model Year:	**2017**	**Make:**	**Kia**	**Model:**	**Rio**

Vehicle CG Determination

	Vehicle Equipment	Weight (lb)
+	Unballasted Car (Curb)	2540
+	Hub	19
+	Brake activation cylinder & frame	7
+	Pneumatic tank (Nitrogen)	20
+	Strobe/Brake Battery	5
+	Brake Receiver/Wires	5
+	CG Plate including DAQ	20
-	Battery	-26
-	Oil	-12
-	Interior	-66
-	Fuel	-35
-	Coolant	-5
-	Washer fluid	-9
+	Water Ballast (In Fuel Tank)	
+	Onboard Supplemental Battery	

Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle

Estimated Total Weight (lb): 2463

Vehicle Dimensions for C.G. Calculations

Wheel Base:	101.25	in.	Front Track Width:	59.875	in.
Roof Height:	57.25	in.	Rear Track Width:	60.125	in.

Center of Gravity	**1100C MASH Targets**	**Test Inertial**	**Difference**
Test Inertial Weight (lb)	2420 ± 55	2462	42.0
Longitudinal CG (in.)	39 ± 4	38.287	-0.713
Lateral CG (in.)	NA	-0.829	NA
Vertical CG (in.)	NA	22.657	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	812	774	
Rear	491	463	
FRONT	1586		lb
REAR	954		lb
TOTAL	2540		lb

TEST INERTIAL WEIGHT (lb)

	Left	Right	
Front	799	732	
Rear	466	465	
FRONT	1531		lb
REAR	931		lb
TOTAL	2462		lb

Figure D-2. Vehicle Mass Distribution, Test No. HBIB-2

		Test Name:	**HBIB-3**	**VIN:**	**1C6RR6LT5HS722979**
Model Year:	**2017**	**Make:**	**Dodge**	**Model:**	**Ram 1500**

Vehicle CG Determination

	Vehicle Equipment	Weight (lb)	Vertical CG (in.)	Vertical M (lb-in.)
+	Unballasted Truck (Curb)	5384	29.283798	157663.97
+	Hub	19	15.625	296.875
+	Brake activation cylinder & frame	7	29	203
+	Pneumatic tank (Nitrogen)	20	27 1/2	550
+	Strobe/Brake Battery	5	27	135
+	Brake Receiver/Wires	5	55	275
+	CG Plate including DAQ	50	30	1500
-	Battery	-46	43	-1978
-	Oil	-13	20	-260
-	Interior	-131	36	-4716
-	Fuel	-165	18.5	-3052.5
-	Coolant	-14	33	-462
-	Washer fluid	-2	37	-74
+	Water Ballast (In Fuel Tank)			0
+	Onboard Supplemental Battery			0
-	Spare tire	-61	23	-1403
				0
				148678.34

Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle

Estimated Total Weight (lb)	5058
Vertical CG Location (in.)	29.39469

Vehicle Dimensions for C.G. Calculations

Wheel Base: 140.625 in. Front Track Width: 68.5625 in.
Rear Track Width: 68 in.

Center of Gravity	**2270P MASH Targets**	**Test Inertial**	**Difference**
Test Inertial Weight (lb)	5000 ± 110	5068	68.0
Longitudinal CG (in.)	63 ± 4	59.463176	-3.53682
Lateral CG (in.)	NA	-0.202095	NA
Vertical CG (in.)	28 or greater	29.39	1.39469

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	1579	1449	
Rear	1171	1185	
FRONT	3028		lb
REAR	2356		lb
TOTAL	5384		lb

TEST INERTIAL WEIGHT (lb)

	Left	Right	
Front	1485	1440	
Rear	1064	1079	
FRONT	2925		lb
REAR	2143		lb
TOTAL	5068		lb

Figure D-3. Vehicle Mass Distribution, Test No. HBIB-3

		Test Name:	**HBIB-4**	**VIN:**	**KMHCT4AE0HU266110**
Model Year:	**2017**	**Make:**	**Hyundai**	**Model:**	**Accent**

Vehicle CG Determination

	Vehicle Equipment	Weight (lb)
+	Unballasted Car (Curb)	2457
+	Hub	19
+	Brake activation cylinder & frame	7
+	Pneumatic tank (Nitrogen)	23
+	Strobe/Brake Battery	5
+	Brake Receiver/Wires	5
+	CG Plate including DAQ	19
-	Battery	-37
-	Oil	-14
-	Interior	-65
-	Fuel	-1
-	Coolant	-6
-	Washer fluid	0
+	Water Ballast (In Fuel Tank)	
+	Onboard Supplemental Battery	

Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle

Estimated Total Weight (lb): 2412

Vehicle Dimensions for C.G. Calculations

Wheel Base:	101.125	in.	Front Track Width:	59.375	in.
Roof Height:	56.75	in.	Rear Track Width:	59.375	in.

Center of Gravity	**1100C MASH Targets**	**Test Inertial**	**Difference**
Test Inertial Weight (lb)	2420 ± 55	2418	-2.0
Longitudinal CG (in.)	39 ± 4	38.1	-0.9
Lateral CG (in.)	NA	0	NA
Vertical CG (in.)	NA	22.213	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	817	735	
Rear	440	465	
FRONT	1552		lb
REAR	905		lb
TOTAL	2457		lb

TEST INERTIAL WEIGHT (lb)

	Left	Right	
Front	745	762	
Rear	464	447	
FRONT	1507		lb
REAR	911		lb
TOTAL	2418		lb

Figure D-4. Vehicle Mass Distribution, Test No. HBIB-4

		Test Name:	**HBIB-5**	**VIN:**	**1C6RR6FG2JS324827**
Model Year:	**2018**	**Make:**	**Dodge**	**Model:**	**Ram 1500**

Vehicle CG Determination

	Vehicle Equipment	Weight (lb)	Vertical CG (in.)	Vertical M (lb-in.)
+	Unballasted Truck (Curb)	5013	28.441203	142575.75
+	Hub	19	14.875	282.625
+	Brake activation cylinder & frame	7	27	189
+	Pneumatic tank (Nitrogen)	23	27	621
+	Strobe/Brake Battery	5	25	125
+	Brake Receiver/Wires	6	50	300
+	CG Plate including DAQ	30	29.5	885
-	Battery	-58	39.5	-2291
-	Oil	-9	14	-126
-	Interior	-103	28	-2884
-	Fuel	-155	17.5	-2712.5
-	Coolant	-10	36	-360
-	Washer fluid	0		0
+	Water Ballast (In Fuel Tank)	234	17.5	4095
+	Onboard Supplemental Battery			0
				0
				0
				140699.88

Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle

Estimated Total Weight (lb)	5002
Vertical CG Location (in.)	28.12872

Vehicle Dimensions for C.G. Calculations

Wheel Base: 140.5 in. Front Track Width: 68.125 in.
Rear Track Width: 67.625 in.

Center of Gravity	2270P MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb)	5000 ± 110	4998	-2.0
Longitudinal CG (in.)	63 ± 4	65.246198	2.24620
Lateral CG (in.)	NA	-0.774085	NA
Vertical CG (in.)	28 or greater	28.13	0.12872

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)

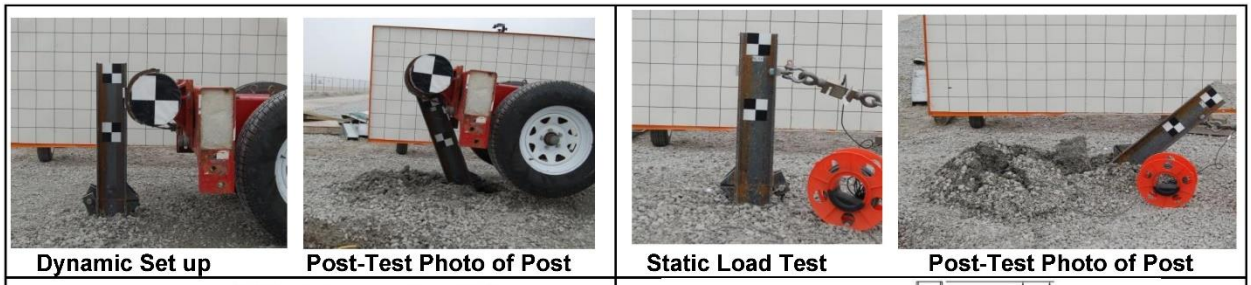
	Left	Right	
Front	1395	1355	
Rear	1161	1102	
FRONT	2750		lb
REAR	2263		lb
TOTAL	5013		lb

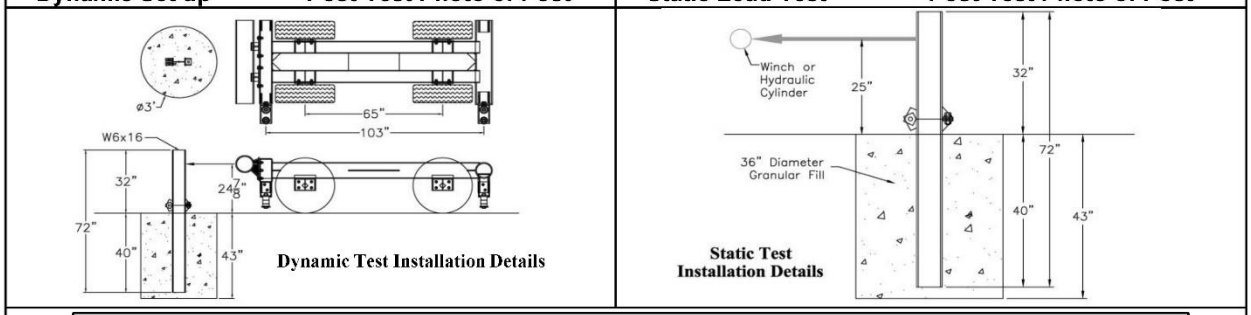
TEST INERTIAL WEIGHT (lb)

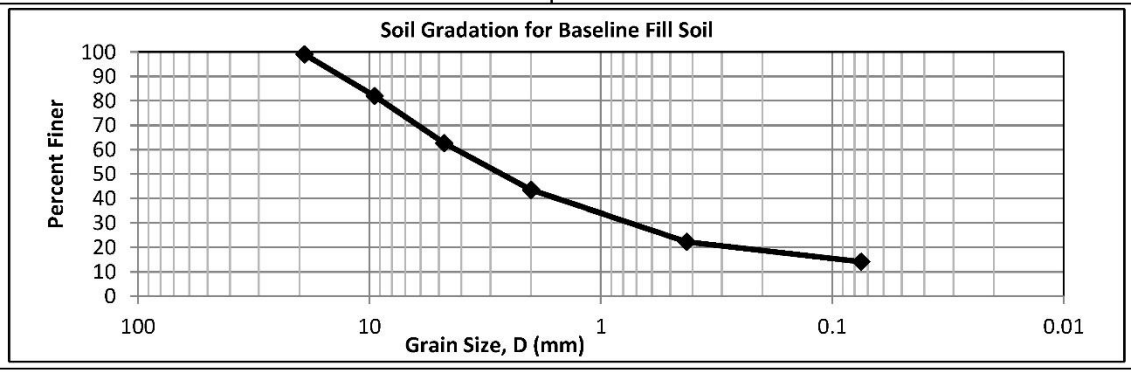
	Left	Right	
Front	1367	1310	
Rear	1189	1132	
FRONT	2677		lb
REAR	2321		lb
TOTAL	4998		lb

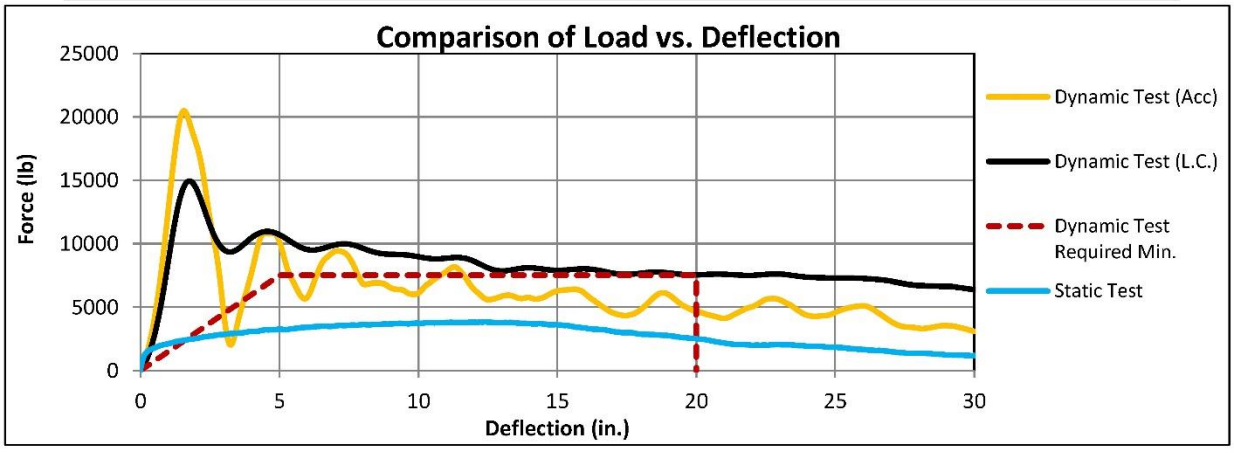
Figure D-5. Vehicle Mass Distribution, Test No. HBIB-5

Appendix E. Static Soil Tests



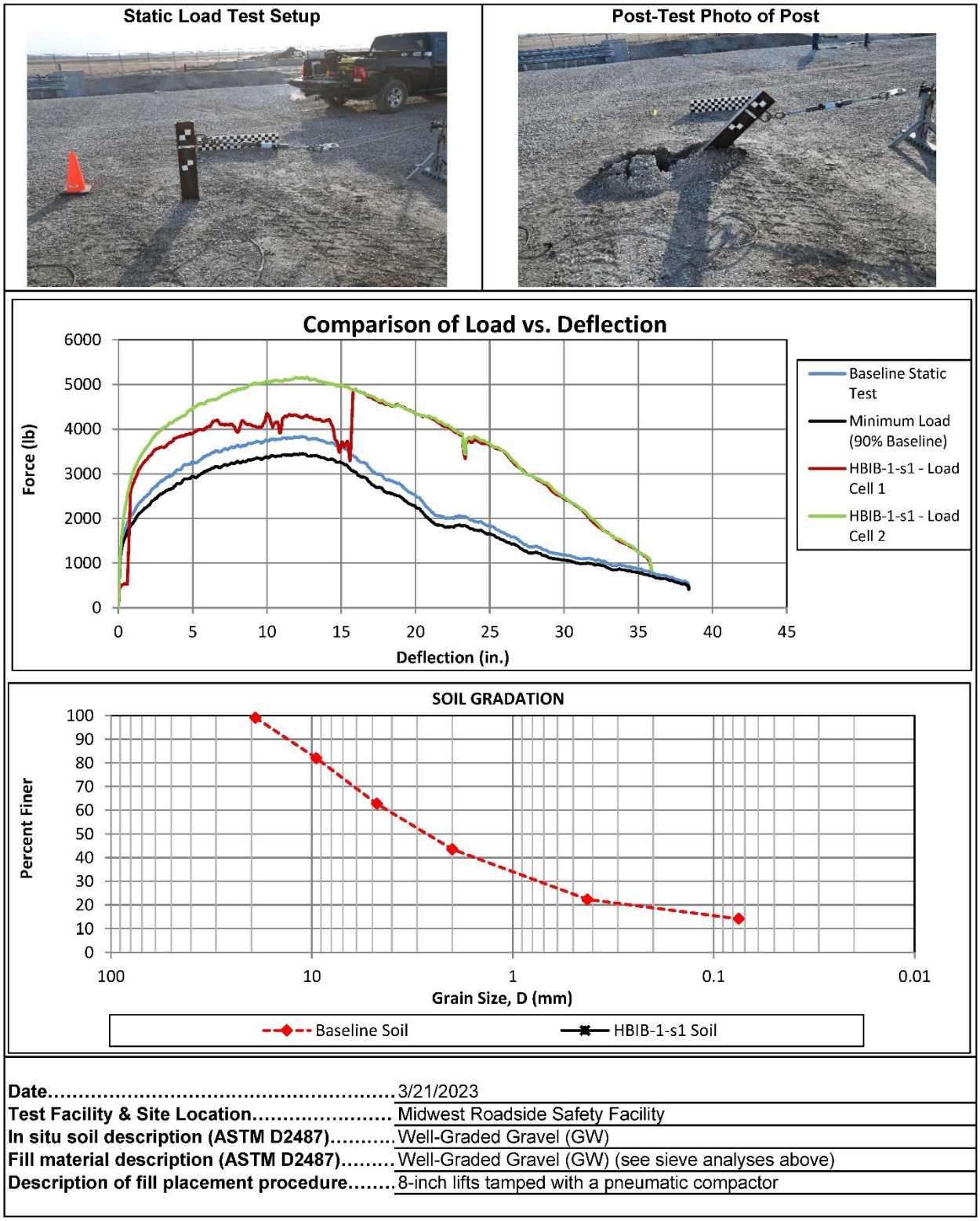






Date	5/18/2022		
Test Facility & Site Location	Midwest Roadside Safety Facility		
In situ soil description (ASTM D2487)	Well-Graded Gravel (GW)		
Fill material description (ASTM D2487)	Well-Graded Gravel (GW) (see sieve analyses above)		
Description of fill placement procedure	1/0/1900		
Bogie Weight	1858	lb	843 kg
Impact Velocity	20.3	mph	32.7 km/h

Figure E-1. Soil Strength, Initial Calibration Tests, Test Nos. HBIB-1 through HBIB-5



Date	3/21/2023
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 E-2. Static Soil Test, Test No. HBIB-1

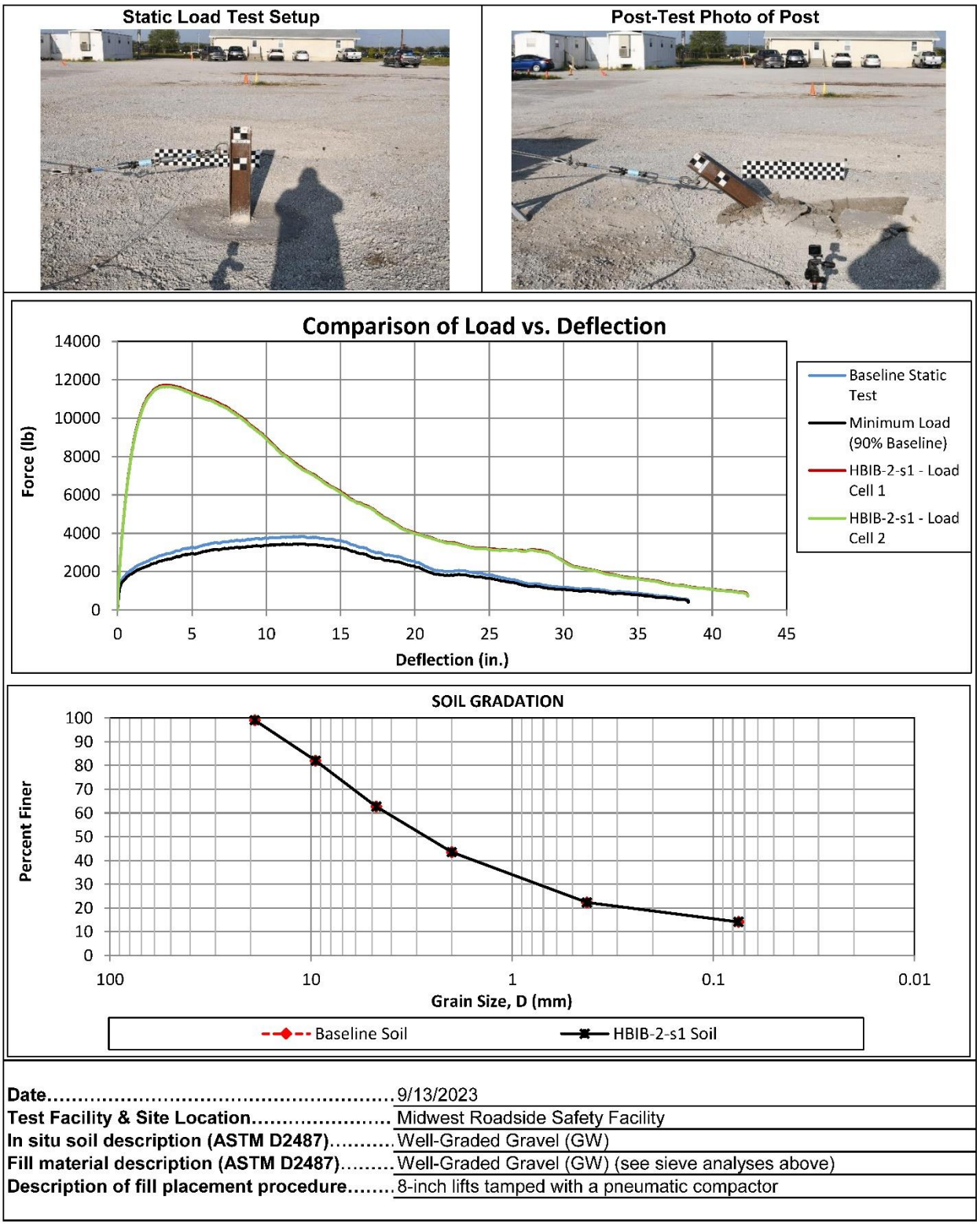
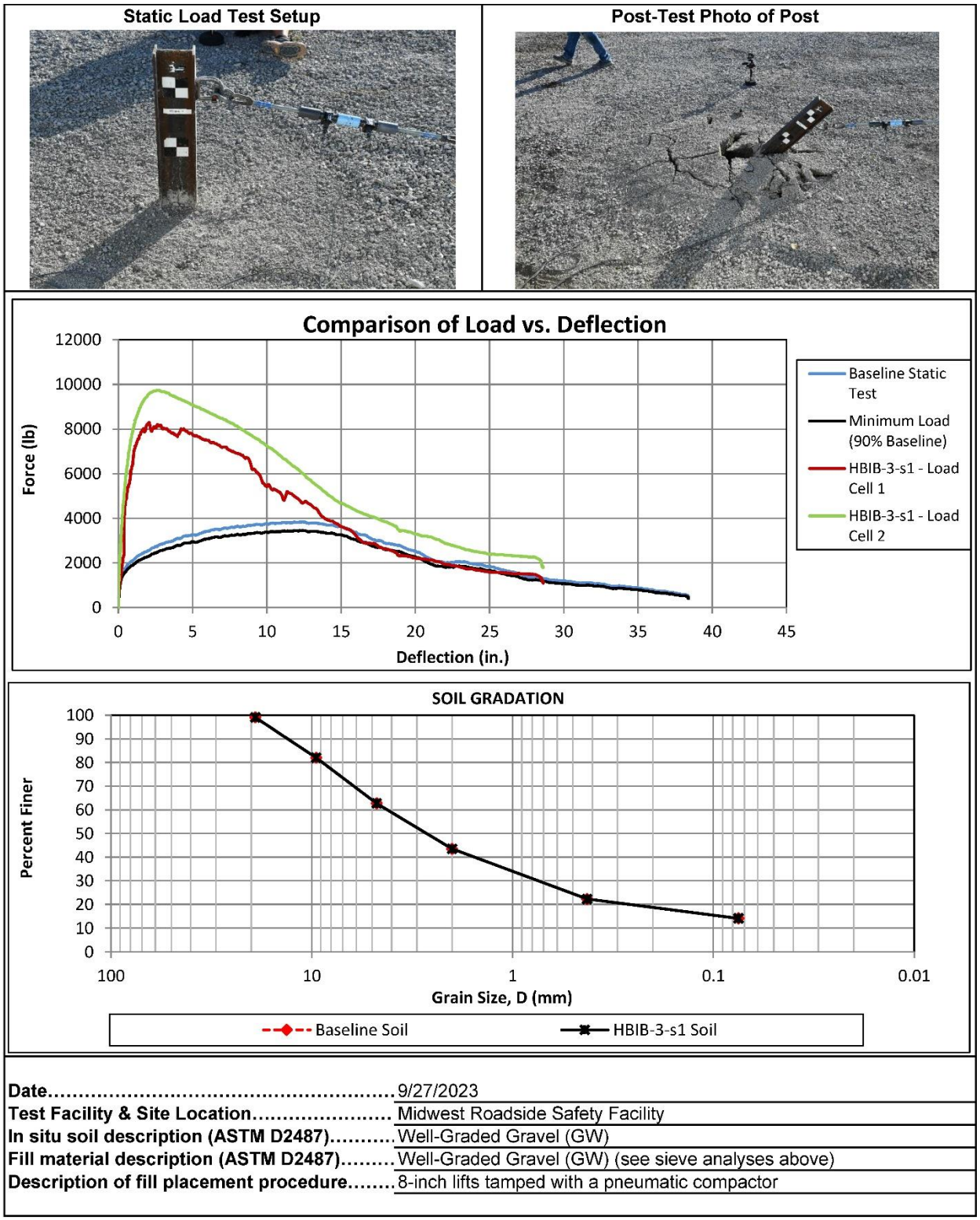
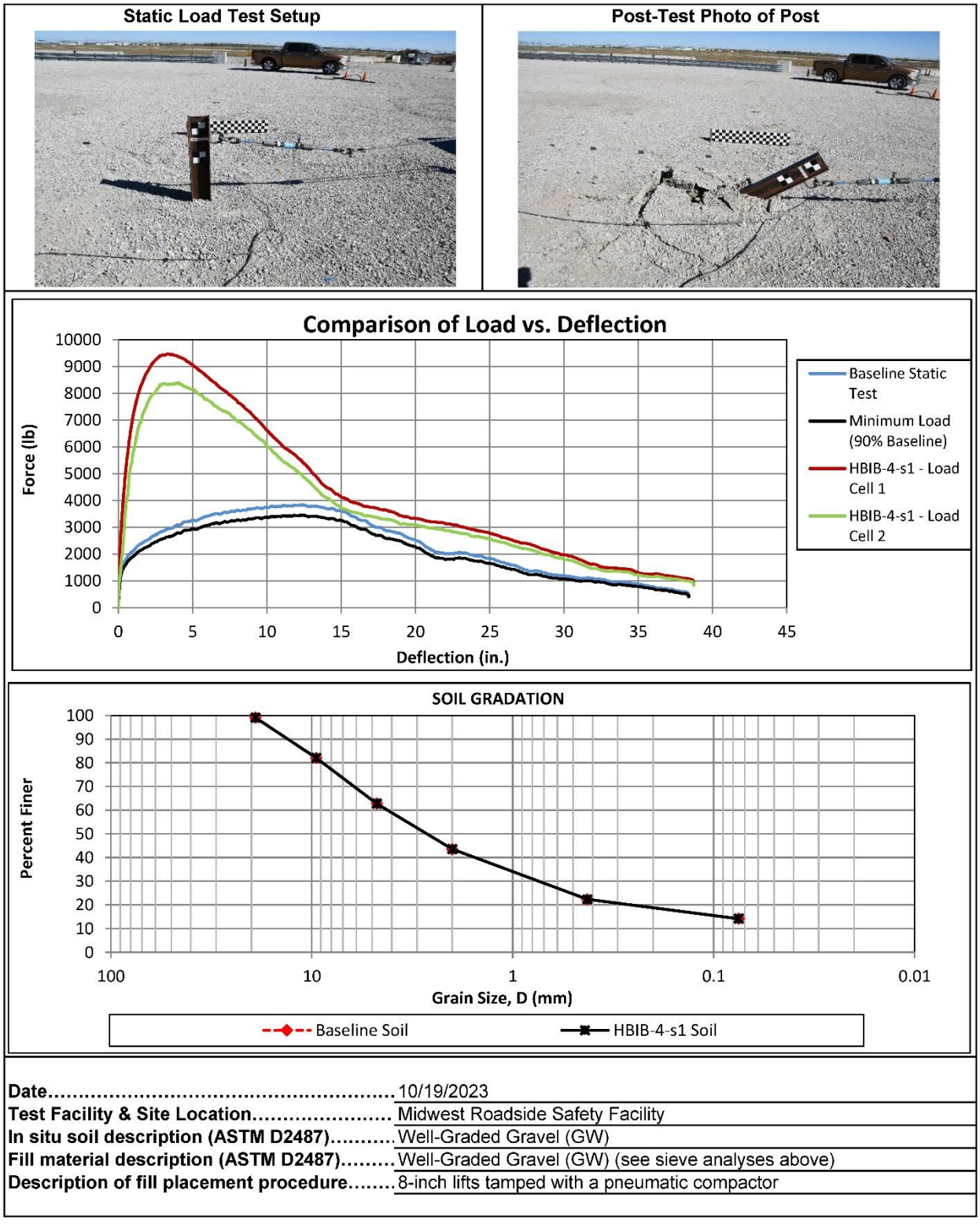


Figure E-3. Static Soil Test, Test No. HBIB-2



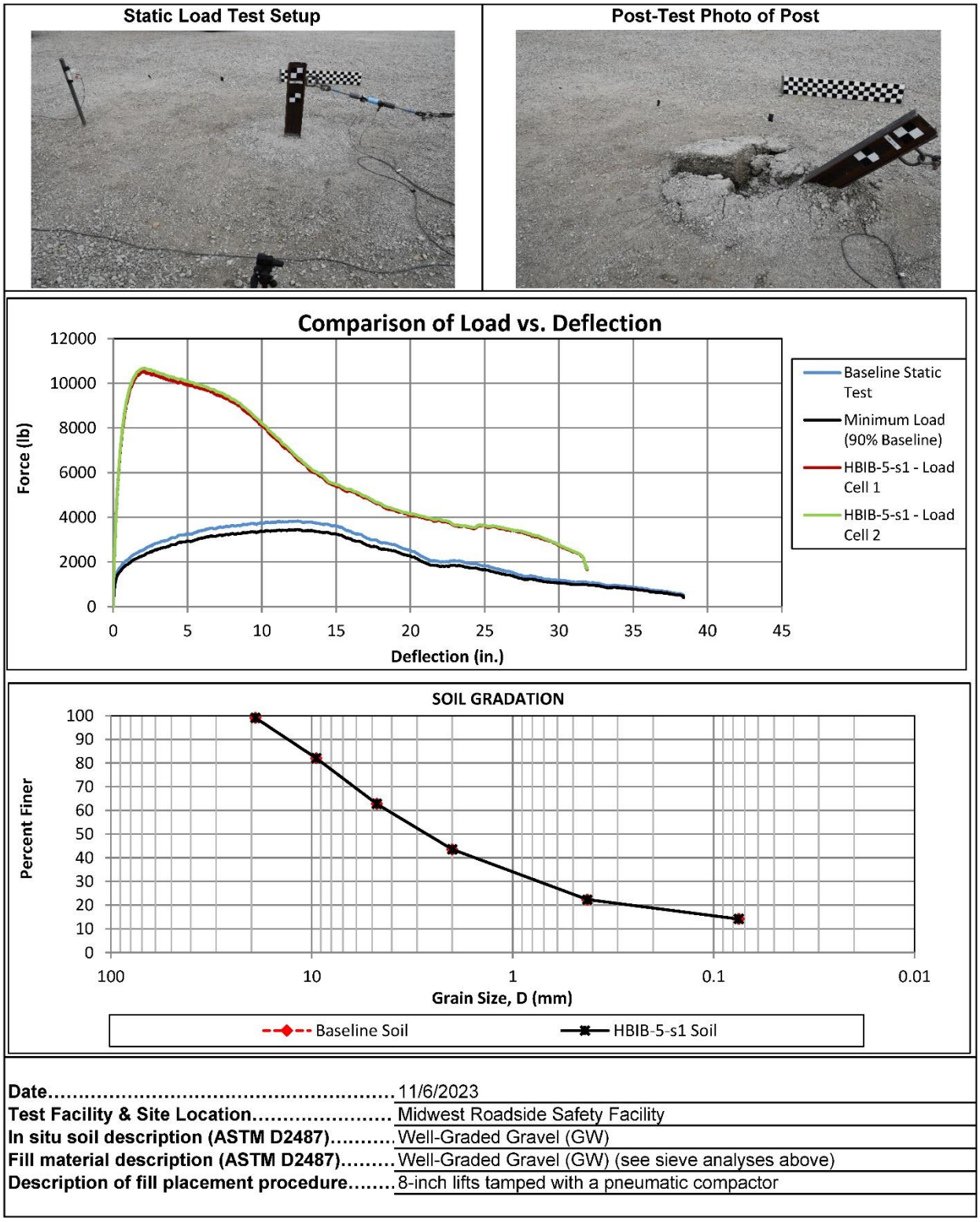
Date	9/27/2023
Test Facility & Site Location	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)	Well-Graded Gravel (GW)
Fill material description (ASTM D2487)	Well-Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure	8-inch lifts tamped with a pneumatic compactor

Figure E-4. Static Soil Test, Test No. HBIB-3



Date	10/19/2023
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 E-5. Static Soil Test, Test No. HBIB-4



Date	11/6/2023
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 E-6. Static Soil Test, Test No. HBIB-5

Appendix F. 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 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 criteria.

Model Year: 2017 Test Name: HBIB-1 Make: Hyundai VIN: KMHCT4AEXHU272805 Model: Accent

VEHICLE DEFORMATION
PASSENGER 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	86.6929	19.5704	5.1087	86.4739	19.9877	6.7871	0.2190	-0.4173	-1.6784	1.7433	0.2190	X
	2	86.9583	23.7985	5.6170	86.6122	24.1880	7.2679	0.3461	-0.3895	-1.6509	1.7312	0.3461	X
	3	87.2425	28.5997	5.6383	86.8989	28.9031	7.3622	0.3436	-0.3034	-1.7239	1.7838	0.3436	X
	4	87.0594	33.5111	5.8365	86.7442	33.7262	7.7730	0.3152	-0.2151	-1.9365	1.9737	0.3152	X
	5	85.4322	37.6905	4.3532	84.2108	37.0531	5.9006	1.2214	0.6374	-1.5474	2.0718	1.2214	X
	6	81.1608	18.8541	7.7063	80.8778	19.2040	9.1878	0.2830	-0.3499	-1.4815	1.5483	0.2830	X
	7	81.5313	23.7567	8.9314	81.1610	24.0292	10.4932	0.3703	-0.2725	-1.5618	1.6281	0.3703	X
	8	81.6571	28.2729	8.9811	81.3155	28.6359	10.6309	0.3416	-0.3630	-1.6498	1.7235	0.3416	X
	9	81.6219	32.9287	9.1298	81.1828	33.1689	10.8509	0.4391	-0.2402	-1.7211	1.7924	0.4391	X
	10	82.3011	38.7970	8.8620	81.9318	38.9293	10.5568	0.3693	-0.1323	-1.6948	1.7396	0.3693	X
FLOOR PAN (Z)	11	75.5940	19.0782	8.1232	75.2833	19.4020	9.5115	0.3107	-0.3238	-1.3883	1.4590	-1.3883	Z
	12	75.9762	25.2448	10.6287	75.6002	25.5370	12.1172	0.3760	-0.2922	-1.4885	1.5628	-1.4885	Z
	13	75.7434	29.9349	9.9055	75.3608	30.1854	11.4270	0.3826	-0.2505	-1.5215	1.5887	-1.5215	Z
	14	76.2686	34.2027	10.7936	75.7943	34.3598	12.4415	0.4743	-0.1571	-1.6479	1.7220	-1.6479	Z
	15	76.3883	38.5721	10.8408	75.8800	38.7690	12.2884	0.5083	-0.1969	-1.4476	1.5468	-1.4476	Z
	16	70.5608	18.9806	8.0950	70.2812	19.2664	9.3333	0.2796	-0.2858	-1.2383	1.3012	-1.2383	Z
	17	70.6952	25.2659	10.6326	70.2825	25.5224	12.0072	0.4127	-0.2565	-1.3746	1.4580	-1.3746	Z
	18	71.1340	30.1938	9.9305	70.7084	30.3924	11.3794	0.4256	-0.1986	-1.4489	1.5231	-1.4489	Z
	19	70.9538	35.0965	10.4898	70.5060	35.3421	12.0410	0.4478	-0.2456	-1.5512	1.6331	-1.5512	Z
	20	71.0169	38.2599	10.5375	70.4922	38.3411	12.3235	0.5247	-0.0812	-1.7860	1.8632	-1.7860	Z
	21	66.5209	18.9098	7.6203	66.2477	19.2073	8.8117	0.2732	-0.2975	-1.1914	1.2580	-1.1914	Z
	22	65.5777	25.7362	10.7657	65.2457	25.9707	12.0190	0.3320	-0.2345	-1.2533	1.3176	-1.2533	Z
	23	67.7367	30.5550	10.0483	67.3273	30.7395	11.4421	0.4094	-0.1845	-1.3938	1.4644	-1.3938	Z
	24	65.8281	35.2466	10.6421	65.4264	35.4460	12.0990	0.4017	-0.1994	-1.4569	1.5244	-1.4569	Z
	25	65.9102	38.3441	10.6927	65.4525	38.5967	12.2753	0.4577	-0.2526	-1.5826	1.6667	-1.5826	Z
	26	61.9912	19.2761	8.3572	61.7363	19.5139	9.4204	0.2549	-0.2378	-1.0632	1.1189	-1.0632	Z
	27	62.1644	24.6705	10.8560	61.7661	24.8816	12.0309	0.3983	-0.2111	-1.1749	1.2584	-1.1749	Z
	28	62.3493	29.1199	10.9442	61.8807	29.3038	12.2053	0.4686	-0.1839	-1.2611	1.3579	-1.2611	Z
	29	62.8422	33.8974	11.0248	62.4098	34.0874	12.3707	0.4324	-0.1900	-1.3459	1.4264	-1.3459	Z
	30	62.5706	38.2188	11.0604	62.0711	38.4179	12.4734	0.4995	-0.1991	-1.4130	1.5119	-1.4130	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 F-1. Floor Pan Deformation Data – Set 1, Test No. HBIB-1

Model Year: 2017 Test Name: HBIB-1 Make: Hyundai VIN: KMHCT4AEXHU272805 Model: Accent

VEHICLE DEFORMATION
PASSENGER 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	87.3667	-3.9476	6.2417	87.4897	-4.2030	5.0187	-0.1230	-0.2554	1.2230	1.2554	1.2230	Z
	2	87.5354	0.2888	6.7212	87.5856	0.0094	5.3919	-0.0502	0.2794	1.3293	1.3593	1.3293	Z
	3	87.7197	5.0949	6.7094	87.8183	4.7284	5.3636	-0.0986	0.3665	1.3458	1.3983	1.3458	Z
	4	87.4315	10.0028	6.8655	87.6129	9.5582	5.6556	-0.1814	0.4446	1.2099	1.3017	1.2099	Z
	5	85.7450	14.1361	5.3204	85.0136	12.8078	3.7381	0.7314	1.3283	1.5823	2.1916	1.7432	X, Z
	6	81.8050	-4.7594	8.7462	81.9386	-4.9894	7.5212	-0.1336	-0.2300	1.2250	1.2535	1.2250	Z
	7	82.0519	0.1590	9.9388	82.1842	-0.1299	8.7007	-0.1323	0.2889	1.2381	1.2782	1.2381	Z
	8	82.0833	4.6771	9.9549	82.2865	4.4804	8.7205	-0.2032	0.1967	1.2344	1.2664	1.2344	Z
	9	81.9490	9.3321	10.0661	82.1038	9.0156	8.8287	-0.1548	0.3165	1.2374	1.2866	1.2374	Z
	10	82.5113	15.2111	9.7639	82.7808	14.7749	8.3791	-0.2695	0.4362	1.3848	1.4767	1.3848	Z
FLOOR PAN (Z)	11	76.2282	-4.6482	9.0623	76.3475	-4.8469	7.9229	-0.1193	-0.1987	1.1394	1.1627	1.1394	Z
	12	76.4376	1.5438	11.5253	76.6303	1.3552	10.3688	-0.1927	0.1886	1.1565	1.1875	1.1565	Z
	13	76.1208	6.2224	10.7609	76.3263	5.9817	9.5659	-0.2055	0.2407	1.1950	1.2362	1.1950	Z
	14	76.5416	10.5068	11.6243	76.7255	10.1850	10.4688	-0.1839	0.3218	1.1555	1.2135	1.1555	Z
	15	76.5699	14.8780	11.6390	76.7572	14.5896	10.2039	-0.1873	0.2884	1.4351	1.4757	1.4351	Z
	16	71.1994	-4.8509	8.9454	71.3453	-5.0438	7.8224	-0.1459	-0.1929	1.1230	1.1487	1.1230	Z
	17	71.1581	1.4549	11.4351	71.3120	1.2773	10.3382	-0.1539	0.1776	1.0969	1.1218	1.0969	Z
	18	71.5073	6.3854	10.7020	71.6715	6.1344	9.5822	-0.1642	0.2510	1.1198	1.1593	1.1198	Z
	19	71.2157	11.2873	11.2191	71.4207	11.0966	10.1224	-0.2050	0.1907	1.0967	1.1319	1.0967	Z
	20	71.2125	14.4516	11.2428	71.3758	14.1015	10.3297	-0.1633	0.3501	0.9131	0.9915	0.9131	Z
	21	67.1709	-5.0095	8.3996	67.3055	-5.1620	7.3625	-0.1346	-0.1525	1.0371	1.0569	1.0371	Z
	22	66.0304	1.8194	11.4736	66.2710	1.6685	10.4136	-0.2406	0.1509	1.0600	1.0974	1.0600	Z
	23	68.1017	6.6766	10.7565	68.2879	6.4445	9.6864	-0.1862	0.2321	1.0701	1.1107	1.0701	Z
	24	66.0861	11.3317	11.2790	66.3416	11.1443	10.2532	-0.2555	0.1874	1.0258	1.0736	1.0258	Z
	25	66.1031	14.4305	11.3065	66.3334	14.2985	10.3500	-0.2303	0.1320	0.9565	0.9927	0.9565	Z
	26	62.6222	-4.7321	9.0529	62.8002	-4.8913	8.0301	-0.1780	-0.1592	1.0228	1.0503	1.0228	Z
	27	62.6388	0.6835	11.5117	62.8050	0.5405	10.5045	-0.1662	0.1430	1.0072	1.0308	1.0072	Z
	28	62.7300	5.1363	11.5678	62.8702	4.9667	10.5662	-0.1402	0.1696	1.0016	1.0255	1.0016	Z
	29	63.1223	9.9235	11.6193	63.3454	9.7587	10.6036	-0.2231	0.1648	1.0157	1.0529	1.0157	Z
	30	62.7607	14.2385	11.6158	62.9575	14.0863	10.6027	-0.1968	0.1522	1.0131	1.0432	1.0131	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 F-2. Floor Pan Deformation Data – Set 2, Test No. HBIB-1

Model Year: 2017 Test Name: HBIB-1 Make: Hyundai VIN: KMHCT4AEXHU272805 Model: Accent

VEHICLE DEFORMATION
PASSENGER 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	72.5540	16.5721	-18.7609	72.2400	15.6225	-17.5321	0.3140	0.9496	1.2288	1.5844	1.5844	X, Y, Z
	2	74.2859	29.0894	-16.8646	72.8641	28.1698	-15.6121	1.4218	0.9196	1.2525	2.1062	2.1062	X, Y, Z
	3	74.3146	39.8392	-17.0055	72.7761	38.4696	-15.9208	1.5385	1.3696	1.0847	2.3280	2.3280	X, Y, Z
	4	67.7431	17.0627	-12.0455	66.5882	15.8085	-11.1743	1.1549	1.2542	0.8712	1.9146	1.9146	X, Y, Z
	5	70.6145	29.5128	-10.7447	69.2517	28.3784	-9.2426	1.3628	1.1344	1.5021	2.3239	2.3239	X, Y, Z
	6	70.6632	38.5147	-10.8757	69.3961	37.4180	-9.2176	1.2671	1.0967	1.6581	2.3575	2.3575	X, Y, Z
SIDE PANEL (Y)	7	79.0176	41.1866	0.8097	78.1725	39.7663	2.4491	0.8451	1.4203	1.6394	2.3279	1.4203	Y
	8	78.5870	41.1556	3.8799	77.8342	40.1903	5.5110	0.7528	0.9653	1.6311	2.0394	0.9653	Y
	9	82.8974	41.0448	2.2611	81.9681	39.3470	3.7899	0.9293	1.6978	1.5288	2.4664	1.6978	Y
IMPACT SIDE DOOR (Y)	10	69.5443	42.7626	-15.1342	68.7238	40.5035	-13.6629	0.8205	2.2591	1.4713	2.8181	2.2591	Y
	11	56.3873	43.2200	-16.9558	55.7269	42.2896	-15.7341	0.6604	0.9304	1.2217	1.6716	0.9304	Y
	12	44.8984	43.8581	-17.3543	44.3682	44.2002	-16.4292	0.5302	-0.3421	0.9251	1.1198	-0.3421	Y
	13	71.9506	42.8850	3.3276	71.0823	42.5708	4.6171	0.8683	0.3142	1.2895	1.5860	0.3142	Y
	14	62.3789	43.7049	3.5209	61.6244	44.0569	4.7118	0.7545	-0.3520	1.1909	1.4531	-0.3520	Y
	15	48.7121	43.6593	1.4035	48.1157	44.7822	2.3003	0.5964	-1.1229	0.8968	1.5559	-1.1229	Y
ROOF - (Z)	16	61.1861	16.6323	-33.5016	61.7987	17.0192	-33.9475	-0.6126	-0.3869	-0.4459	0.8508	-0.4459	Z
	17	61.0459	26.2340	-33.3097	61.5914	26.5246	-33.6365	-0.5455	-0.2906	-0.3268	0.6992	-0.3268	Z
	18	59.5651	35.9422	-32.8289	59.8214	36.1862	-32.5064	-0.2563	-0.2440	0.3225	0.4788	0.3225	Z
	19	50.9776	17.6712	-36.5314	51.3014	18.0084	-36.4547	-0.3238	-0.3372	0.0767	0.4737	0.0767	Z
	20	51.2694	25.4429	-36.2147	51.6588	25.7349	-36.0952	-0.3894	-0.2920	0.1195	0.5012	0.1195	Z
	21	51.3714	34.0549	-35.5467	51.6773	34.3529	-35.2064	-0.3059	-0.2980	0.3403	0.5461	0.3403	Z
	22	38.1919	18.6777	-37.5707	38.5215	18.9310	-37.1957	-0.3296	-0.2533	0.3750	0.5598	0.3750	Z
	23	38.3843	26.2129	-37.2045	38.6470	26.5310	-36.8211	-0.2627	-0.3181	0.3834	0.5632	0.3834	Z
	24	38.9997	34.3017	-36.5414	39.2567	34.5903	-35.7931	-0.2570	-0.2886	0.7483	0.8422	0.7483	Z
	25	22.1313	19.0514	-37.0429	22.6247	19.2844	-35.3869	-0.4934	-0.2330	1.6560	1.7436	1.6560	Z
	26	22.3766	26.8839	-36.6861	22.8026	27.1287	-35.6480	-0.4260	-0.2448	1.0381	1.1485	1.0381	Z
	27	22.3171	35.2590	-35.9291	22.6289	35.4795	-35.3701	-0.3118	-0.2205	0.5590	0.6770	0.5590	Z
	28	7.3379	19.5710	-34.7423	7.6824	19.8193	-34.3553	-0.3445	-0.2483	0.3870	0.5745	0.3870	Z
	29	8.0824	26.6559	-34.5103	8.3923	26.8654	-33.9801	-0.3099	-0.2095	0.5302	0.6489	0.5302	Z
	30	10.5391	37.2202	-33.9154	10.7978	37.5044	-33.4577	-0.2587	-0.2842	0.4577	0.5976	0.4577	Z
A-PILLAR Maximum (X, Y, Z)	31	79.1174	40.6635	-20.7934	78.4249	36.4565	-18.9172	0.6925	4.2070	1.8762	4.6582	4.6582	X, Y, Z
	32	76.1112	40.2540	-22.9746	75.4517	36.0829	-21.2826	0.6595	4.1711	1.6920	4.5493	4.5493	X, Y, Z
	33	72.3100	39.6713	-25.0318	71.7388	36.4099	-23.7635	0.5712	3.2614	1.2683	3.5456	3.5456	X, Y, Z
	34	68.7653	39.1302	-26.8027	68.4273	36.7883	-25.9069	0.3380	2.3419	0.8958	2.5301	2.5301	X, Y, Z
	35	65.0506	38.5144	-28.6589	64.8799	37.1721	-28.0313	0.1707	1.3423	0.6276	1.4916	1.4916	X, Y, Z
	36	60.5810	37.8344	-30.7738	60.6764	37.5544	-30.5908	-0.0954	0.2800	0.1830	0.3478	0.3345	Y, Z
A-PILLAR Lateral (Y)	31	79.1174	40.6635	-20.7934	78.4249	36.4565	-18.9172	0.6925	4.2070	1.8762	4.6582	4.2070	Y
	32	76.1112	40.2540	-22.9746	75.4517	36.0829	-21.2826	0.6595	4.1711	1.6920	4.5493	4.1711	Y
	33	72.3100	39.6713	-25.0318	71.7388	36.4099	-23.7635	0.5712	3.2614	1.2683	3.5456	3.2614	Y
	34	68.7653	39.1302	-26.8027	68.4273	36.7883	-25.9069	0.3380	2.3419	0.8958	2.5301	2.3419	Y
	35	65.0506	38.5144	-28.6589	64.8799	37.1721	-28.0313	0.1707	1.3423	0.6276	1.4916	1.3423	Y
	36	60.5810	37.8344	-30.7738	60.6764	37.5544	-30.5908	-0.0954	0.2800	0.1830	0.3478	0.2800	Y
B-PILLAR Maximum (X, Y, Z)	37	38.0645	38.2533	-31.2811	38.2956	38.4583	-30.6147	-0.2311	-0.2050	0.6664	0.7345	0.6664	Z
	38	35.8647	39.9255	-27.2463	36.0465	40.0776	-26.5698	-0.1818	-0.1521	0.6765	0.7168	0.6765	Z
	39	39.7256	41.9603	-21.4986	39.8422	42.0607	-20.7634	-0.1166	-0.1004	0.7352	0.7511	0.7352	Z
	40	37.0559	42.4494	-17.1870	37.0390	42.5513	-16.4193	0.0169	-0.1019	0.7677	0.7746	0.7679	X, Z
B-PILLAR Lateral (Y)	37	38.0645	38.2533	-31.2811	38.2956	38.4583	-30.6147	-0.2311	-0.2050	0.6664	0.7345	-0.2050	Y
	38	35.8647	39.9255	-27.2463	36.0465	40.0776	-26.5698	-0.1818	-0.1521	0.6765	0.7168	-0.1521	Y
	39	39.7256	41.9603	-21.4986	39.8422	42.0607	-20.7634	-0.1166	-0.1004	0.7352	0.7511	-0.1004	Y
	40	37.0559	42.4494	-17.1870	37.0390	42.5513	-16.4193	0.0169	-0.1019	0.7677	0.7746	-0.1019	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 F-3. Occupant Compartment Deformation Data – Set 1, Test No. HBIB-1

Model Year: 2017 Test Name: HBIB-1 Make: Hyundai VIN: KMHCT4AEXHU272805 Model: Accent

VEHICLE DEFORMATION
PASSENGER 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	73.7238	-7.5209	-17.9527	72.9576	-9.2898	-18.9266	0.7662	-1.7689	-0.9739	2.1598	2.1598	X, Y, Z
	2	75.1778	5.0449	-16.1451	73.4549	3.3074	-17.3214	1.7229	1.7375	-1.1763	2.7150	2.7150	X, Y, Z
	3	74.9982	15.7914	-16.3861	73.2364	13.5948	-17.8792	1.7618	2.1966	-1.4931	3.1872	3.1872	X, Y, Z
	4	68.7914	-7.0648	-11.3237	67.3940	-9.0154	-12.4946	1.3974	-1.9506	-1.1709	2.6699	2.6699	X, Y, Z
	5	71.3958	5.4509	-10.0917	69.9303	3.6289	-10.9076	1.4655	1.8220	-0.8159	2.4765	2.4765	X, Y, Z
	6	71.2703	14.4505	-10.3062	69.9644	12.6675	-11.1046	1.3059	1.7830	-0.7984	2.3499	2.3499	X, Y, Z
SIDE PANEL (Y)	7	79.3720	17.3923	1.4919	78.8748	15.4051	0.3742	0.4972	1.9872	-1.1177	2.3335	1.9872	Y
	8	78.8902	17.3805	4.5546	78.5745	15.8999	3.4294	0.3157	1.4806	-1.1252	1.8862	1.4806	Y
	9	83.2287	17.3403	3.0092	82.6938	15.0639	1.6700	0.5349	2.2764	-1.3392	2.6947	2.2764	Y
IMPACT SIDE DOOR (Y)	10	70.1406	18.6368	-14.6224	69.1917	15.6350	-15.6134	0.9489	3.0018	-0.9910	3.3005	3.0018	Y
	11	57.0098	18.8177	-16.6680	56.1461	17.2150	-17.5403	0.8637	1.6027	-0.8723	2.0188	1.6027	Y
	12	45.5190	19.2252	-17.2645	44.7562	18.9727	-18.1182	0.7628	0.2525	-0.8537	1.1724	0.2525	Y
	13	72.2315	18.9735	3.8751	71.7820	18.1772	2.5751	0.4495	0.7963	-1.3000	1.5894	0.7963	Y
	14	62.6437	19.6058	3.9006	62.3089	19.5526	2.7696	0.3348	0.0532	-1.1310	1.1807	0.0532	Y
	15	49.0181	19.2712	1.5554	48.7598	20.0578	0.5358	0.2583	-0.7866	-1.0196	1.3134	-0.7866	Y
ROOF - (Z)	16	62.6077	-7.8183	-32.8815	62.2697	-8.4198	-35.2192	0.3380	-0.6015	-2.3377	2.4374	-2.3377	Z
	17	62.2762	1.7800	-32.7819	61.9504	1.0872	-35.1365	0.3258	0.6928	-2.3546	2.4759	-2.3546	Z
	18	60.5976	11.4611	-32.4169	60.0783	10.7519	-34.2163	0.5193	0.7092	-1.7994	2.0026	-1.7994	Z
	19	52.4336	-7.0087	-36.0912	51.7268	-7.6173	-37.5985	0.7068	-0.6086	-1.5073	1.7725	-1.5073	Z
	20	52.5676	0.7698	-35.8425	51.9946	0.1194	-37.4321	0.5730	0.6504	-1.5896	1.8106	-1.5896	Z
	21	52.4895	9.3878	-35.2536	51.9200	8.7562	-36.7536	0.5695	0.6316	-1.5000	1.7243	-1.5000	Z
	22	39.6501	-6.2643	-37.3537	38.9273	-6.8652	-38.1778	0.7228	-0.6009	-0.8241	1.2501	-0.8241	Z
	23	39.6885	1.2762	-37.0548	38.9651	0.7426	-37.9900	0.7234	0.5336	-0.9352	1.2972	-0.9352	Z
	24	40.1339	9.3812	-36.4574	39.4904	8.8314	-37.1671	0.6435	0.5498	-0.7097	1.1046	-0.7097	Z
	25	23.5786	-6.2032	-37.0981	23.0545	-6.6569	-36.1497	0.5241	-0.4537	0.9484	1.1747	0.9484	Z
	26	23.6643	1.6355	-36.8106	23.1326	1.1803	-36.6039	0.5317	0.4552	0.2067	0.7298	0.2067	Z
	27	23.4278	10.0143	-36.1332	22.8605	9.5326	-36.5267	0.5673	0.4817	-0.3935	0.8418	-0.3935	Z
	28	8.7410	-5.9551	-35.0502	8.1228	-6.2747	-34.9166	0.6182	-0.3196	0.1336	0.7086	0.1336	Z
	29	9.3425	1.1449	-34.8722	8.7516	0.7864	-34.7231	0.5909	0.3585	0.1491	0.7070	0.1491	Z
	30	11.5813	11.7606	-34.3353	11.0336	11.4629	-34.4942	0.5477	0.2977	-0.1589	0.6433	-0.1589	Z
A-PILLAR Maximum (X, Y, Z)	31	79.8473	16.6761	-20.1007	78.8667	11.5762	-20.9068	0.9806	5.0999	-0.8061	5.2555	5.1933	X, Y
	32	76.8870	16.1877	-22.3280	75.8652	11.1095	-23.2193	1.0218	5.0782	-0.8913	5.2561	5.1800	X, Y
	33	73.1333	15.5115	-24.4430	72.1140	11.3314	-25.6538	1.0193	4.1801	-1.2108	4.4697	4.3026	X, Y
	34	69.6303	14.8845	-26.2677	68.7683	11.6177	-27.7580	0.8620	3.2668	-1.4903	3.6927	3.3786	X, Y
	35	65.9603	14.1786	-28.1800	65.1869	11.9072	-29.8397	0.7734	2.2714	-1.6597	2.9175	2.3995	X, Y
	36	61.5412	13.3915	-30.3629	60.9434	12.1767	-32.3471	0.5978	1.2148	-1.9842	2.4021	1.3539	X, Y
A-PILLAR Lateral (Y)	31	79.8473	16.6761	-20.1007	78.8667	11.5762	-20.9068	0.9806	5.0999	-0.8061	5.2555	5.0999	Y
	32	76.8870	16.1877	-22.3280	75.8652	11.1095	-23.2193	1.0218	5.0782	-0.8913	5.2561	5.0782	Y
	33	73.1333	15.5115	-24.4430	72.1140	11.3314	-25.6538	1.0193	4.1801	-1.2108	4.4697	4.1801	Y
	34	69.6303	14.8845	-26.2677	68.7683	11.6177	-27.7580	0.8620	3.2668	-1.4903	3.6927	3.2668	Y
	35	65.9603	14.1786	-28.1800	65.1869	11.9072	-29.8397	0.7734	2.2714	-1.6597	2.9175	2.2714	Y
	36	61.5412	13.3915	-30.3629	60.9434	12.1767	-32.3471	0.5978	1.2148	-1.9842	2.4021	1.2148	Y
B-PILLAR Maximum (X, Y, Z)	37	39.0327	13.3609	-31.2507	38.5551	12.8133	-32.0710	0.4776	0.5476	-0.8203	1.0958	0.7266	X, Y
	38	36.7326	15.0257	-27.2691	36.3435	14.5043	-28.0348	0.3891	0.5214	-0.7657	1.0048	0.6506	X, Y
	39	40.4551	17.1883	-21.4769	40.1961	16.6740	-22.3336	0.2590	0.5143	-0.8567	1.0322	0.5758	X, Y
	40	37.7038	17.6635	-17.2154	37.4486	17.2374	-17.9628	0.2552	0.4261	-0.7474	0.8974	0.4967	X, Y
B-PILLAR Lateral (Y)	37	39.0327	13.3609	-31.2507	38.5551	12.8133	-32.0710	0.4776	0.5476	-0.8203	1.0958	0.5476	Y
	38	36.7326	15.0257	-27.2691	36.3435	14.5043	-28.0348	0.3891	0.5214	-0.7657	1.0048	0.5214	Y
	39	40.4551	17.1883	-21.4769	40.1961	16.6740	-22.3336	0.2590	0.5143	-0.8567	1.0322	0.5143	Y
	40	37.7038	17.6635	-17.2154	37.4486	17.2374	-17.9628	0.2552	0.4261	-0.7474	0.8974	0.4261	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 F-4. Occupant Compartment Deformation Data – Set 2, Test No. HBIB-1

Test Name: HBIB-1 VIN: KMHCT4AEXHU272805
Model Year: 2017 Make: Hyundai Model: Accent

Passenger 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	1.7	≤ 4	Z	Roof	0.9	≤ 4	Z
Windshield[D]	0.0	≤ 3	X, Z	Windshield[D]	NA	≤ 3	X, Z
A-Pillar Maximum	4.7	≤ 5	X, Y, Z	A-Pillar Maximum	5.2	≤ 5	X, Y
A-Pillar Lateral	4.2	≤ 3	Y	A-Pillar Lateral	5.1	≤ 3	Y
B-Pillar Maximum	0.8	≤ 5	X, Z	B-Pillar Maximum	0.7	≤ 5	X, Y
B-Pillar Lateral	-0.2	≤ 3	Y	B-Pillar Lateral	0.5	≤ 3	Y
Toe Pan - Wheel Well	1.2	≤ 9	X	Toe Pan - Wheel Well	1.7	≤ 9	X, Z
Side Front Panel	1.7	≤ 12	Y	Side Front Panel	2.3	≤ 12	Y
Side Door (above seat)	2.3	≤ 9	Y	Side Door (above seat)	3.0	≤ 9	Y
Side Door (below seat)	0.3	≤ 12	Y	Side Door (below seat)	0.8	≤ 12	Y
Floor Pan	-1.8	≤ 12	Z	Floor Pan	1.4	≤ 12	Z
Dash - no MASH requirement	2.4	NA	X, Y, Z	Dash - no MASH requirement	3.2	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.

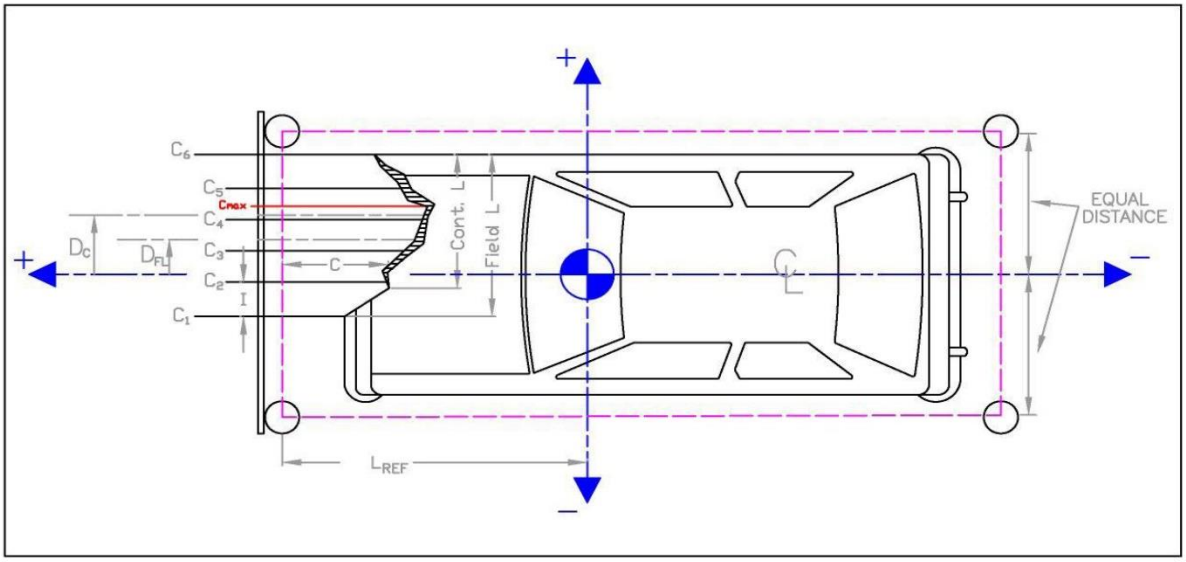
Notes on vehicle crush:

The secondary set of reference points (Set 2) has been compromised.

Figure F-5. Maximum Occupant Compartment Deformations by Location, Test No. HBIB-1

Test Name: HBIB-1 VIN: KMHCT4AEXHU272805

Model Year: 2017 Make: Hyundai Model: Accent



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	82	(2083)
Total Width of Vehicle:	66 1/2	(1689)
Width of contact and induced crush - Field L:	66 1/2	(1689)
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 1/2	(1689)
Distance from center of vehicle to center of contact damage - D_C:	0	()

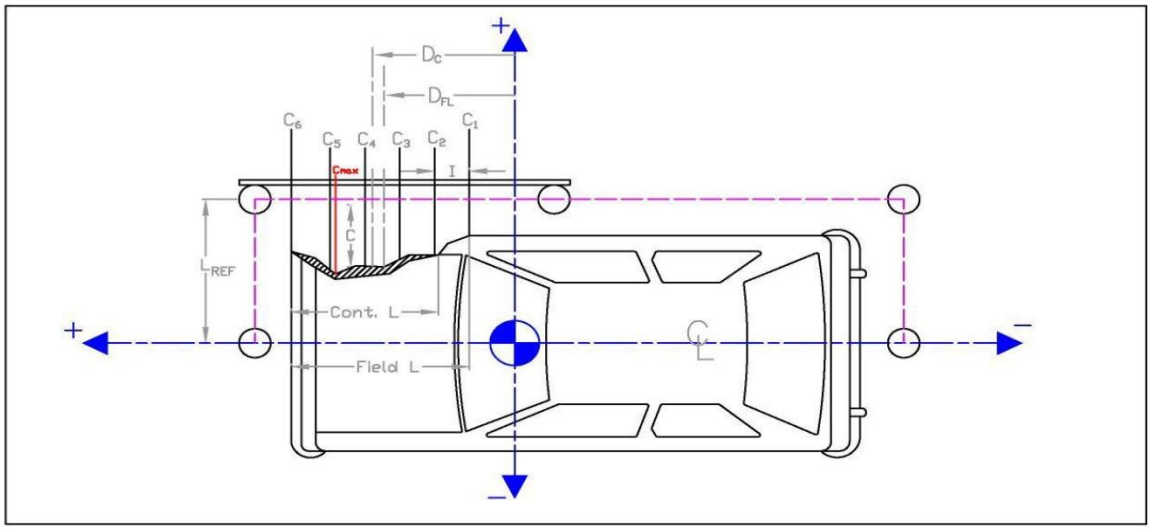
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

	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 1/4	-(845)	15 5/8	(397)	7 5/8	(194)	NA	NA
C_2	12	(305)	-20	-(508)	6 7/8	(175)			-2 1/2	-(64)
C_3	9 3/8	(238)	-6 3/4	-(171)	4 3/8	(111)			-2 5/8	-(67)
C_4	15 3/8	(391)	6 1/2	(165)	4 1/2	(114)			3 1/4	(83)
C_5	17 5/8	(448)	19 3/4	(502)	6 3/4	(171)			3 1/4	(83)
C_6	n/a	NA	33	(838)	15 5/8	(397)			NA	NA
C_{MAX}	17 5/8	(448)	19 3/4	(502)	6 3/4	(171)			3 1/4	(83)

Figure F-6. Exterior Vehicle Crush (NASS) - Front, Test No. HBIB-1

Test Name: HBIB-1 VIN: KMHCT4AEXHU272805

Model Year: 2017 Make: Hyundai Model: Accent



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	38 1/4	(972)
Total Vehicle Length:	171 1/4	(4350)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-13 3/4	-(349)
Width of contact and induced crush - Field L:	92 7/8	(2359)
Crush measurement spacing interval (L/5) - I:	18 5/8	(473)
Distance from vehicle c.g. to center of Field L - D_{FL}:	25 3/4	(654)
Width of Contact Damage:	92 7/8	(2359)
Distance from vehicle c.g. to center of contact damage - D_C:	25 3/4	(654)

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	6 7/8	(175)	-20 3/4	-(527)	8 1/8	(206)	-3	-(76)	1 3/4	(44)
C_2	7 3/4	(197)	-2 1/8	-(54)	8 1/4	(210)			2 1/2	(64)
C_3	10	(254)	16 1/2	(419)	8 1/4	(210)			4 3/4	(121)
C_4	n/a	NA	35 1/8	(892)	7	(178)			NA	NA
C_5	19 1/4	(489)	53 3/4	(1365)	7 7/8	(200)			14 3/8	(365)
C_6	n/a	NA	72 3/8	(1838)	27 1/2	(699)			NA	NA
C_{MAX}	19 1/4	(489)	53 3/4	(1365)	7 7/8	(200)			14 3/8	(365)

Figure F-7. Exterior Vehicle Crush (NASS) - Side, Test No. HBIB-1

Model Year: 2017 Test Name: HBIB-2 Make: Kia VIN: KNADM4A32H6015837 Model: Rio

VEHICLE DEFORMATION
PASSENGER 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	87.0065	22.9768	5.1466	87.0584	22.8954	5.7457	-0.0519	0.0814	-0.5991	0.6068	0.0000	NA
	2	87.0000	26.3427	6.1420	86.9596	26.2966	6.5197	0.0404	0.0461	-0.3777	0.3826	0.0404	X
	3	87.9529	29.4540	5.2967	87.7960	29.3506	5.6690	0.1569	0.1034	-0.3723	0.4170	0.1569	X
	4	87.7926	35.0436	4.3904	87.5016	34.5204	4.5512	0.2910	0.5232	-0.1608	0.6199	0.2910	X
	5	83.8699	40.4395	2.7564	83.5849	39.6821	2.7677	0.2850	0.7574	-0.0113	0.8093	0.2850	X
	6	81.2512	22.4181	9.1800	81.2472	22.3373	9.6311	0.0040	0.0808	-0.4511	0.4583	0.0040	X
	7	81.3560	26.5774	9.4134	81.2580	26.4440	9.7746	0.0980	0.1334	-0.3612	0.3973	0.0980	X
	8	80.6604	30.4657	9.1928	80.6412	30.3457	9.5343	0.0192	0.1200	-0.3415	0.3625	0.0192	X
	9	81.4858	36.5648	9.3054	81.4699	36.3424	9.5404	0.0159	0.2224	-0.2350	0.3239	0.0159	X
	10	81.6803	41.5689	8.9143	81.6021	41.3696	8.9590	0.0782	0.1993	-0.0447	0.2187	0.0782	X
FLOOR PAN (Z)	11	76.6155	21.5379	8.9551	76.6062	21.4648	9.3271	0.0093	0.0731	-0.3720	0.3792	-0.3720	Z
	12	76.8921	26.7576	11.4066	76.8866	26.6787	11.8037	0.0055	0.0789	-0.3971	0.4049	-0.3971	Z
	13	76.7397	30.1554	11.5244	76.6919	29.9961	11.8942	0.0478	0.1593	-0.3698	0.4055	-0.3698	Z
	14	76.2718	36.9751	11.5264	76.2272	36.7866	11.7406	0.0446	0.1885	-0.2142	0.2888	-0.2142	Z
	15	76.8890	41.6387	11.4083	76.8953	41.4579	11.4362	-0.0063	0.1808	-0.0279	0.1830	-0.0279	Z
	16	73.1752	21.4354	8.8171	73.1578	21.3682	9.1969	0.0174	0.0672	-0.3798	0.3861	-0.3798	Z
	17	72.4346	26.6390	11.6249	72.3587	26.6094	11.8601	0.0759	0.0296	-0.2352	0.2489	-0.2352	Z
	18	72.2864	30.1808	11.8010	72.2477	30.0400	12.0264	0.0387	0.1408	-0.2254	0.2686	-0.2254	Z
	19	72.1135	37.4358	11.8516	72.1458	37.3777	12.0847	-0.0323	0.0581	-0.2331	0.2424	-0.2331	Z
	20	72.6568	40.9546	11.8558	72.6732	40.7791	11.8976	-0.0164	0.1755	-0.0418	0.1812	-0.0418	Z
	21	67.1537	21.2001	8.7796	67.1399	21.1294	8.9673	0.0138	0.0707	-0.1877	0.2010	-0.1877	Z
	22	66.5467	26.2882	11.9478	66.5218	26.2308	12.1115	0.0249	0.0574	-0.1637	0.1752	-0.1637	Z
	23	66.5160	30.6886	11.7906	66.3955	30.6508	12.1058	0.1205	0.0378	-0.3152	0.3396	-0.3152	Z
	24	66.1039	37.5345	11.5877	66.0872	37.4143	11.7901	0.0167	0.1202	-0.2024	0.2360	-0.2024	Z
	25	65.6404	41.6062	11.8974	65.5274	41.6366	12.0321	0.1130	-0.0304	-0.1347	0.1784	-0.1347	Z
	26	60.4585	20.8844	8.5414	60.4959	20.8424	8.6894	-0.0374	0.0420	-0.1480	0.1583	-0.1480	Z
	27	60.2176	25.8809	11.9344	60.1955	25.8161	12.0495	0.0221	0.0648	-0.1151	0.1339	-0.1151	Z
	28	60.2751	30.6040	11.9891	60.2443	30.6122	12.0761	0.0308	-0.0082	-0.0870	0.0927	-0.0870	Z
	29	60.1245	36.1394	12.0561	60.0573	36.1171	12.1654	0.0672	0.0223	-0.1093	0.1302	-0.1093	Z
	30	59.8292	40.0697	12.0059	59.8010	40.0707	12.0482	0.0282	-0.0010	-0.0423	0.0508	-0.0423	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 F-8. Floor Pan Deformation Data – Set 1, Test No. HBIB-2

Model Year: 2017 Test Name: HBIB-2 Make: Kia VIN: KNADM4A32H6015837 Model: Rio

VEHICLE DEFORMATION
PASSENGER 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	86.5601	-5.9062	5.6985	86.6042	-5.9740	6.1398	-0.0441	-0.0678	-0.4413	0.4487	0.0000	NA
	2	86.6454	-2.5283	6.6488	86.6028	-2.5596	6.8598	0.0426	-0.0313	-0.2110	0.2175	0.0426	X
	3	87.6993	0.5413	5.7713	87.5365	0.4540	5.9677	0.1628	0.0873	-0.1964	0.2696	0.1628	X
	4	87.7154	6.1203	4.7891	87.4056	5.6121	4.7673	0.3098	0.5082	0.0218	0.5956	0.3106	X, Z
	5	83.9720	11.6083	3.0450	83.6585	10.8603	2.8755	0.3135	0.7480	0.1695	0.8286	0.3564	X, Z
	6	80.7532	-6.2374	9.6827	80.7528	-6.2958	9.9915	0.0004	-0.0584	-0.3088	0.3143	0.0004	X
	7	80.9807	-2.0803	9.8616	80.8864	-2.1895	10.0710	0.0943	-0.1092	-0.2094	0.2543	0.0943	X
	8	80.4044	1.8236	9.5823	80.3891	1.7246	9.7654	0.0153	0.0990	-0.1831	0.2087	0.0153	X
	9	81.4116	7.8963	9.6216	81.3982	7.6931	9.6840	0.0134	0.2032	-0.0624	0.2130	0.0134	X
	10	81.7600	12.8866	9.1656	81.6859	12.7042	9.0252	0.0741	0.1824	0.1404	0.2418	0.1588	X, Z
FLOOR PAN (Z)	11	76.0954	-6.9816	9.4244	76.0897	-7.0333	9.6676	0.0057	-0.0517	-0.2432	0.2487	-0.2432	Z
	12	76.5059	-1.7395	11.8086	76.5105	-1.7916	12.0646	-0.0046	-0.0521	-0.2560	0.2613	-0.2560	Z
	13	76.4545	1.6626	11.8795	76.4154	1.5312	12.1020	0.0391	0.1314	-0.2225	0.2613	-0.2225	Z
	14	76.1917	8.4926	11.7860	76.1567	8.3293	11.8392	0.0350	0.1633	-0.0532	0.1753	-0.0532	Z
	15	76.9498	13.1337	11.6117	76.9673	12.9730	11.4668	-0.0175	0.1607	0.1449	0.2171	0.1449	Z
	16	72.6551	-6.9830	9.2542	72.6410	-7.0283	9.5141	0.0141	-0.0453	-0.2599	0.2642	-0.2599	Z
	17	72.0450	-1.7217	11.9850	71.9824	-1.7239	12.0895	0.0626	-0.0022	-0.1045	0.1218	-0.1045	Z
	18	72.0016	1.8250	12.1124	71.9737	1.7106	12.2015	0.0279	0.1144	-0.0891	0.1477	-0.0891	Z
	19	72.0463	9.0819	12.0645	72.0926	9.0480	12.1447	-0.0463	0.0339	-0.0802	0.0986	-0.0802	Z
	20	72.6949	12.5826	12.0270	72.7236	12.4287	11.9084	-0.0287	0.1539	0.1186	0.1964	0.1186	Z
	21	66.6299	-7.0385	9.1612	66.6203	-7.0898	9.2450	0.0096	-0.0513	-0.0838	0.0987	-0.0838	Z
	22	66.1464	-1.8919	12.2551	66.1351	-1.9231	12.3048	0.0113	-0.0312	-0.0497	0.0598	-0.0497	Z
	23	66.2493	2.5050	12.0389	66.1422	2.4981	12.2293	0.1071	0.0069	-0.1904	0.2186	-0.1904	Z
	24	66.0450	9.3567	11.7407	66.0401	9.2619	11.8059	0.0049	0.0948	-0.0652	0.1152	-0.0652	Z
	25	65.7012	13.4444	11.9915	65.6062	13.5024	11.9780	0.0950	-0.0580	0.0135	0.1121	0.0135	Z
	26	59.9307	-7.1570	8.8620	59.9727	-7.1814	8.9238	-0.0420	-0.0244	-0.0618	0.0786	-0.0618	Z
	27	59.8083	-2.1098	12.1855	59.7997	-2.1485	12.2038	0.0086	-0.0387	-0.0183	0.0437	-0.0183	Z
	28	60.0072	2.6098	12.1777	59.9929	2.6438	12.1559	0.0143	-0.0340	0.0218	0.0428	0.0218	Z
	29	60.0223	8.1477	12.1694	59.9714	8.1526	12.1580	0.0509	-0.0049	0.0114	0.0524	0.0114	Z
	30	59.8457	12.0839	12.0638	59.8352	12.1098	11.9773	0.0105	-0.0259	0.0865	0.0909	0.0865	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 F-9. Floor Pan Deformation Data – Set 2, Test No. HBIB-2

Model Year: 2017 Test Name: HBIB-2 Make: Kia VIN: KNADM4A32H6015837 Model: Rio

VEHICLE DEFORMATION
PASSENGER 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	72.0140	19.1451	-18.6275	71.9618	18.9486	-18.6009	0.0522	0.1965	0.0266	0.2050	0.2050	X, Y, Z
	2	72.2551	29.4367	-18.3113	72.0828	29.2860	-18.3116	0.1723	0.1507	-0.0003	0.2289	0.2289	X, Y, Z
	3	72.2727	41.6215	-17.2694	71.9317	41.3356	-17.3476	0.3410	0.2859	-0.0782	0.4518	0.4518	X, Y, Z
	4	66.3722	18.6510	-11.2496	66.4728	18.3625	-11.0066	-0.1006	0.2885	0.2430	0.3904	0.3904	X, Y, Z
	5	67.6004	30.0650	-11.9274	67.5318	29.8335	-11.8775	0.0686	0.2315	0.0499	0.2466	0.2466	X, Y, Z
	6	68.3334	40.1514	-11.6646	68.0875	39.9117	-11.6847	0.2459	0.2397	-0.0201	0.3440	0.3440	X, Y, Z
SIDE PANEL (Y)	7	77.8457	44.2942	0.4719	77.6257	43.9383	0.4330	0.2200	0.3559	-0.0389	0.4202	0.3559	Y
	8	76.4922	44.2150	3.4952	76.3949	43.9012	3.4457	0.0973	0.3138	-0.0495	0.3322	0.3138	Y
	9	81.2696	44.1692	2.5857	81.1009	43.4726	2.7329	0.1687	0.6966	0.1472	0.7317	0.6966	Y
IMPACT SIDE DOOR (Y)	10	44.8403	45.2744	-14.4945	44.6928	45.8443	-14.6217	0.1475	-0.5699	-0.1272	0.6023	-0.5699	Y
	11	55.4158	45.5783	-13.3288	55.2996	45.9206	-13.3754	0.1162	-0.3423	-0.0466	0.3645	-0.3423	Y
	12	63.9427	45.0903	-11.9299	63.7881	45.3450	-11.8938	0.1546	-0.2547	0.0361	0.3001	-0.2547	Y
	13	46.6147	45.1769	1.6698	46.6782	46.4208	1.4446	-0.0635	-1.2439	-0.2252	1.2657	-1.2439	Y
	14	55.6597	45.5310	2.0402	55.5703	46.5370	1.8349	0.0894	-1.0060	-0.2053	1.0306	-1.0060	Y
	15	63.0186	46.0319	1.4139	62.9121	47.0599	1.2696	0.1065	-1.0280	-0.1443	1.0435	-1.0280	Y
ROOF - (Z)	16	62.7298	18.0097	-32.4692	62.8527	18.2287	-32.3883	-0.1229	-0.2190	0.0809	0.2638	0.0809	Z
	17	62.4368	26.6597	-32.1296	62.4983	26.8699	-32.2062	-0.0615	-0.2102	-0.0766	0.2320	-0.0766	Z
	18	61.3490	35.8929	-31.4304	61.3979	36.0351	-31.6591	-0.0489	-0.1422	-0.2287	0.2737	-0.2287	Z
	19	56.1896	18.6640	-35.0345	56.2229	18.7507	-34.9472	-0.0333	-0.0867	0.0873	0.1275	0.0873	Z
	20	55.8023	25.5007	-34.8238	55.7992	25.6365	-34.9604	0.0031	-0.1358	-0.1366	0.1926	-0.1366	Z
	21	54.6147	34.5147	-34.2032	54.5971	34.6526	-34.4850	0.0176	-0.1379	-0.2818	0.3142	-0.2818	Z
	22	45.4831	18.4234	-36.7459	45.4086	18.5369	-36.5745	0.0745	-0.1135	0.1714	0.2187	0.1714	Z
	23	45.0134	25.7808	-36.4608	45.0156	25.9442	-36.6761	-0.0022	-0.1634	-0.2153	0.2703	-0.2153	Z
	24	45.0438	32.5307	-35.8274	45.0462	32.6729	-36.0208	-0.0024	-0.1422	-0.1934	0.2401	-0.1934	Z
	25	28.4713	19.1024	-37.3458	28.4591	19.2561	-37.4308	0.0122	-0.1537	-0.0850	0.1761	-0.0850	Z
	26	27.9237	25.3903	-37.0692	27.8760	25.4537	-37.2094	0.0477	-0.0634	-0.1402	0.1611	-0.1402	Z
	27	27.2138	32.8944	-36.3696	27.1903	32.9666	-36.5370	0.0235	-0.0722	-0.1674	0.1838	-0.1674	Z
	28	9.8156	18.7208	-35.7056	9.8566	18.7769	-35.7805	-0.0410	-0.0561	-0.0749	0.1022	-0.0749	Z
	29	9.5950	23.7205	-35.5179	9.5872	23.7791	-35.6217	0.0078	-0.0586	-0.1038	0.1195	-0.1038	Z
	30	8.2890	31.9191	-34.7215	8.2884	31.9271	-34.8925	0.0006	-0.0080	-0.1710	0.1712	-0.1710	Z
A-PILLAR Maximum (X, Y, Z)	31	79.8247	43.4408	-20.6705	79.8338	42.3690	-20.9119	-0.0091	1.0718	-0.2414	1.0987	1.0718	Y
	32	74.4031	42.1435	-24.1854	74.4250	41.4383	-24.4230	-0.0219	0.7052	-0.2376	0.7445	0.7052	Y
	33	70.4559	41.4898	-26.6065	70.4052	41.0152	-26.8408	0.0507	0.4746	-0.2343	0.5317	0.4773	X, Y
	34	67.6136	41.2232	-26.5738	67.5538	40.8914	-26.8410	0.0598	0.3318	-0.2672	0.4302	0.3371	X, Y
	35	64.4325	40.6505	-28.1527	64.3695	40.4981	-28.4189	0.0630	0.1524	-0.2662	0.3131	0.1649	X, Y
	36	61.5707	40.2709	-29.2324	61.5116	40.2736	-29.5825	0.0591	-0.0027	-0.3501	0.3551	0.0591	X
A-PILLAR Lateral (Y)	31	79.8247	43.4408	-20.6705	79.8338	42.3690	-20.9119	-0.0091	1.0718	-0.2414	1.0987	1.0718	Y
	32	74.4031	42.1435	-24.1854	74.4250	41.4383	-24.4230	-0.0219	0.7052	-0.2376	0.7445	0.7052	Y
	33	70.4559	41.4898	-26.6065	70.4052	41.0152	-26.8408	0.0507	0.4746	-0.2343	0.5317	0.4746	Y
	34	67.6136	41.2232	-26.5738	67.5538	40.8914	-26.8410	0.0598	0.3318	-0.2672	0.4302	0.3318	Y
	35	64.4325	40.6505	-28.1527	64.3695	40.4981	-28.4189	0.0630	0.1524	-0.2662	0.3131	0.1524	Y
	36	61.5707	40.2709	-29.2324	61.5116	40.2736	-29.5825	0.0591	-0.0027	-0.3501	0.3551	-0.0027	Y
B-PILLAR Maximum (X, Y, Z)	37	36.5884	39.6169	-29.5812	36.5992	39.7370	-29.7910	-0.0108	-0.1201	-0.2098	0.2420	0.0000	NA
	38	34.0292	40.9780	-25.8380	33.9861	41.0759	-26.0036	0.0431	-0.0979	-0.1656	0.1971	0.0431	X
	39	37.3775	41.5695	-24.4069	37.3321	41.7034	-24.4827	0.0454	-0.1339	-0.0758	0.1604	0.0454	X
	40	34.4332	42.5953	-21.1704	34.3685	42.6749	-21.3292	0.0647	-0.0796	-0.1588	0.1890	0.0647	X
B-PILLAR Lateral (Y)	37	36.5884	39.6169	-29.5812	36.5992	39.7370	-29.7910	-0.0108	-0.1201	-0.2098	0.2420	-0.1201	Y
	38	34.0292	40.9780	-25.8380	33.9861	41.0759	-26.0036	0.0431	-0.0979	-0.1656	0.1971	-0.0979	Y
	39	37.3775	41.5695	-24.4069	37.3321	41.7034	-24.4827	0.0454	-0.1339	-0.0758	0.1604	-0.1339	Y
	40	34.4332	42.5953	-21.1704	34.3685	42.6749	-21.3292	0.0647	-0.0796	-0.1588	0.1890	-0.0796	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 F-10. Occupant Compartment Deformation Data – Set 1, Test No. HBIB-2

Model Year: 2017 Test Name: HBIB-2 Make: Kia VIN: KNADM4A32H6015837 Model: Rio

VEHICLE DEFORMATION
PASSENGER 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	71.6741	-9.6159	-18.1997	71.5661	-9.8270	-18.2944	0.1080	-0.2111	-0.0947	0.2553	0.2553	X, Y, Z
	2	72.2179	0.6676	-18.0340	71.9928	0.5054	-18.1639	0.2251	0.1622	-0.1299	0.3064	0.3064	X, Y, Z
	3	72.5879	12.8609	-17.1729	72.1942	12.5679	-17.3871	0.3937	0.2930	-0.2142	0.5355	0.5355	X, Y, Z
	4	65.9520	-9.8313	-10.8704	66.0125	-10.1312	-10.7305	-0.0605	-0.2999	0.1399	0.3364	0.3364	X, Y, Z
	5	67.5251	1.5298	-11.7055	67.4183	1.2883	-11.7710	0.1068	0.2415	-0.0655	0.2721	0.2721	X, Y, Z
	6	68.5550	11.5929	-11.5853	68.2724	11.3473	-11.7299	0.2826	0.2456	-0.1446	0.4014	0.4014	X, Y, Z
SIDE PANEL (Y)	7	78.0734	15.6357	0.5800	77.8470	15.2783	0.3905	0.2264	0.3574	-0.1895	0.4636	0.3574	Y
	8	76.6901	15.6423	3.5909	76.5959	15.3248	3.3948	0.0942	0.3175	-0.1961	0.3849	0.3175	Y
	9	81.4723	15.4415	2.7286	81.2916	14.7457	2.7217	0.1807	0.6958	-0.0069	0.7189	0.6958	Y
IMPACT SIDE DOOR (Y)	10	45.2516	17.3650	-14.7187	45.0844	17.9246	-14.9216	0.1672	-0.5596	-0.2029	0.6183	-0.5596	Y
	11	55.8203	17.3736	-13.4552	55.6804	17.7057	-13.6025	0.1399	-0.3321	-0.1473	0.3893	-0.3321	Y
	12	64.3156	16.6549	-11.9665	64.1381	16.9018	-12.0529	0.1775	-0.2469	-0.0864	0.3161	-0.2469	Y
	13	46.8726	17.4595	1.4617	46.9811	18.6932	1.1473	-0.1085	-1.2337	-0.3144	1.2777	-1.2337	Y
	14	55.9204	17.5515	1.9145	55.8700	18.5516	1.5980	0.0504	-1.0001	-0.3165	1.0502	-1.0001	Y
	15	63.2963	17.8251	1.3523	63.2276	18.8476	1.0760	0.0687	-1.0225	-0.2763	1.0614	-1.0225	Y
ROOF - (Z)	16	62.4888	-10.6854	-32.1124	62.5297	-10.4920	-32.1325	-0.0409	0.1934	-0.0201	0.1987	-0.0201	Z
	17	62.4498	-2.0264	-31.9042	62.4316	-1.8422	-32.0862	0.0182	0.1842	-0.1820	0.2596	-0.1820	Z
	18	61.6304	7.2444	-31.3526	61.6010	7.3590	-31.6884	0.0294	-0.1146	-0.3358	0.3560	-0.3358	Z
	19	55.9949	-9.8769	-34.7505	55.9353	-9.8135	-34.7454	0.0596	0.0634	0.0051	0.0872	0.0051	Z
	20	55.8090	-3.0294	-34.6451	55.7168	-2.9193	-34.8679	0.0922	0.1101	-0.2228	0.2651	-0.2228	Z
	21	54.8840	6.0242	-34.1699	54.7806	6.1348	-34.5401	0.1034	-0.1106	-0.3702	0.4000	-0.3702	Z
	22	45.3023	-9.8267	-36.5620	45.1303	-9.7319	-36.4448	0.1720	0.0948	0.1172	0.2287	0.1172	Z
	23	45.0488	-2.4552	-36.3906	44.9586	-2.3187	-36.6635	0.0902	0.1365	-0.2729	0.3182	-0.2729	Z
	24	45.2738	4.2997	-35.8572	45.1852	4.4155	-36.1118	0.0886	-0.1158	-0.2546	0.2934	-0.2546	Z
	25	28.3245	-8.6541	-37.3369	28.2156	-8.5237	-37.4305	0.1089	0.1304	-0.0936	0.1940	-0.0936	Z
	26	27.9614	-2.3493	-37.1590	27.8159	-2.3088	-37.3089	0.1455	0.0405	-0.1499	0.2128	-0.1499	Z
	27	27.4683	5.1822	-36.5777	27.3497	5.2307	-36.7574	0.1186	-0.0485	-0.1797	0.2207	-0.1797	Z
	28	9.6513	-8.4591	-35.8723	9.5967	-8.4250	-35.9031	0.0546	0.0341	-0.0308	0.0714	-0.0308	Z
	29	9.5776	-3.4528	-35.7609	9.4753	-3.4152	-35.8235	0.1023	0.0376	-0.0626	0.1257	-0.0626	Z
	30	8.5084	4.7919	-35.0990	8.4149	4.7782	-35.2292	0.0935	0.0137	-0.1302	0.1609	-0.1302	Z
A-PILLAR Maximum (X, Y, Z)	31	80.2217	14.4045	-20.5272	80.1467	13.3105	-20.9116	0.0750	1.0940	-0.3844	1.1620	1.0966	X, Y
	32	74.7968	13.2151	-24.0748	74.7355	12.4859	-24.4456	0.0613	0.7292	-0.3708	0.8204	0.7318	X, Y
	33	70.8545	12.6419	-26.5242	70.7209	12.1445	-26.8847	0.1336	0.4974	-0.3605	0.6287	0.5150	X, Y
	34	68.0053	12.4599	-26.5151	67.8671	12.1053	-26.9029	0.1382	0.3546	-0.3878	0.5434	0.3806	X, Y
	35	64.8233	11.9577	-28.1162	64.6829	11.7821	-28.4968	0.1404	0.1756	-0.3806	0.4420	0.2248	X, Y
	36	61.9617	11.6467	-29.2177	61.8272	11.6242	-29.6767	0.1345	0.0225	-0.4590	0.4788	0.1364	X, Y
A-PILLAR Lateral (Y)	31	80.2217	14.4045	-20.5272	80.1467	13.3105	-20.9116	0.0750	1.0940	-0.3844	1.1620	1.0940	Y
	32	74.7968	13.2151	-24.0748	74.7355	12.4859	-24.4456	0.0613	0.7292	-0.3708	0.8204	0.7292	Y
	33	70.8545	12.6419	-26.5242	70.7209	12.1445	-26.8847	0.1336	0.4974	-0.3605	0.6287	0.4974	Y
	34	68.0053	12.4599	-26.5151	67.8671	12.1053	-26.9029	0.1382	0.3546	-0.3878	0.5434	0.3546	Y
	35	64.8233	11.9577	-28.1162	64.6829	11.7821	-28.4968	0.1404	0.1756	-0.3806	0.4420	0.1756	Y
	36	61.9617	11.6467	-29.2177	61.8272	11.6242	-29.6767	0.1345	0.0225	-0.4590	0.4788	0.0225	Y
B-PILLAR Maximum (X, Y, Z)	37	36.9753	11.7265	-29.7991	36.9118	11.8237	-30.0511	0.0635	-0.0972	-0.2520	0.2775	0.0635	X
	38	34.4231	13.2191	-26.1016	34.3150	13.2985	-26.3032	0.1081	-0.0794	-0.2016	0.2421	0.1081	X
	39	37.7741	13.7329	-24.6470	37.6682	13.8503	-24.7687	0.1059	-0.1174	-0.1217	0.1995	0.1059	X
	40	34.8318	14.8941	-21.4548	34.7143	14.9584	-21.6514	0.1175	-0.0643	-0.1966	0.2379	0.1175	X
B-PILLAR Lateral (Y)	37	36.9753	11.7265	-29.7991	36.9118	11.8237	-30.0511	0.0635	-0.0972	-0.2520	0.2775	-0.0972	Y
	38	34.4231	13.2191	-26.1016	34.3150	13.2985	-26.3032	0.1081	-0.0794	-0.2016	0.2421	-0.0794	Y
	39	37.7741	13.7329	-24.6470	37.6682	13.8503	-24.7687	0.1059	-0.1174	-0.1217	0.1995	-0.1174	Y
	40	34.8318	14.8941	-21.4548	34.7143	14.9584	-21.6514	0.1175	-0.0643	-0.1966	0.2379	-0.0643	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 F-11. Occupant Compartment Deformation Data – Set 2, Test No. HBIB-2

Test Name: HBIB-2 VIN: KNADM4A32H6015837

Model Year: 2017 Make: Kia Model: Rio

Passenger 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	0.2	≤ 4	Z	Roof	0.1	≤ 4	Z
Windshield[D]	2.0	≤ 3	X, Z	Windshield[D]	NA	≤ 3	X, Z
A-Pillar Maximum	1.1	≤ 5	Y	A-Pillar Maximum	1.1	≤ 5	X, Y
A-Pillar Lateral	1.1	≤ 3	Y	A-Pillar Lateral	1.1	≤ 3	Y
B-Pillar Maximum	0.1	≤ 5	X	B-Pillar Maximum	0.1	≤ 5	X
B-Pillar Lateral	-0.1	≤ 3	Y	B-Pillar Lateral	-0.1	≤ 3	Y
Toe Pan - Wheel Well	0.3	≤ 9	X	Toe Pan - Wheel Well	0.4	≤ 9	X, Z
Side Front Panel	0.7	≤ 12	Y	Side Front Panel	0.7	≤ 12	Y
Side Door (above seat)	-0.6	≤ 9	Y	Side Door (above seat)	-0.6	≤ 9	Y
Side Door (below seat)	-1.2	≤ 12	Y	Side Door (below seat)	-1.2	≤ 12	Y
Floor Pan	-0.4	≤ 12	Z	Floor Pan	0.1	≤ 12	Z
Dash - no MASH requirement	0.5	NA	X, Y, Z	Dash - no MASH requirement	0.5	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.

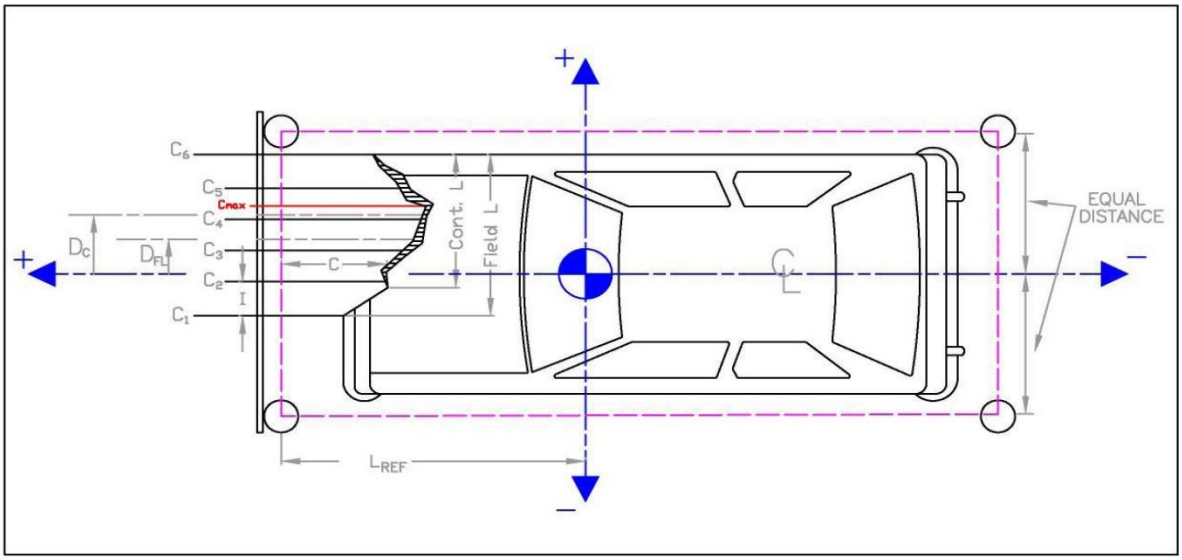
[D] If deformation is observered for the windshield then the windshield deformation is measured posttest with an examplar vehicle, therefore only one set of reference is measured and recorded.

Notes on vehicle crush:

Figure F-12. Maximum Occupant Compartment Deformations by Location, Test No. HBIB-2

Test Name: HBIB-2 VIN: KNADM4A32H6015837

Model Year: 2017 Make: Kia Model: Rio



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	85	(2159)
Total Width of Vehicle:	66 3/4	(1695)
Width of contact and induced crush - Field L:	66 3/4	(1695)
Crush measurement spacing interval (L/5) - I:	13 3/8	(340)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	66 3/4	(1695)
Distance from center of vehicle to center of contact damage - D_C:	0	()

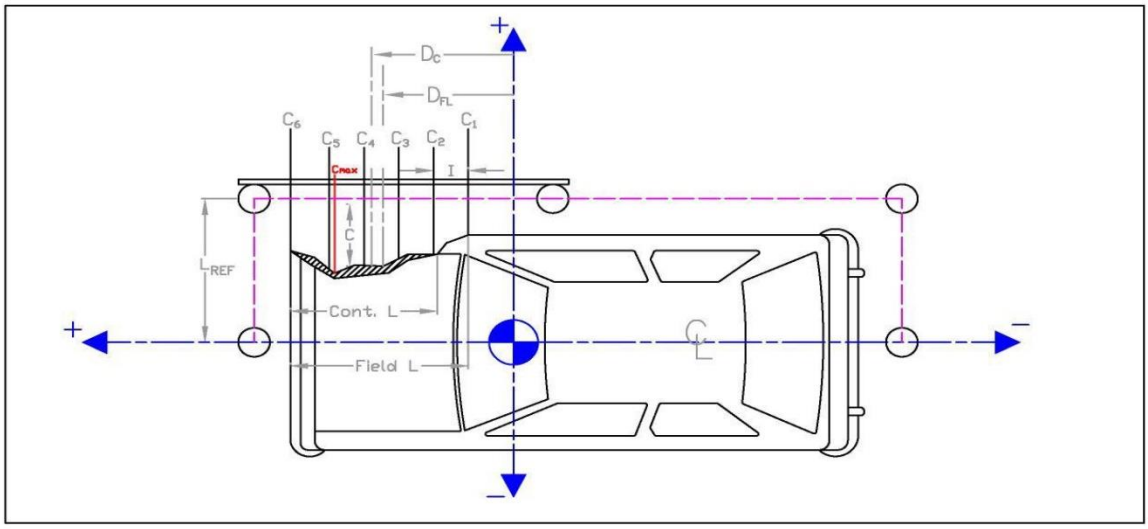
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

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 3/8	-(848)	24 1/8	(613)	5 1/3	(135)	NA	NA
C_2	18 3/4	(476)	-20	-(508)	11 5/8	(295)			1 4/5	(46)
C_3	16 1/4	(413)	-6 5/8	-(168)	8 7/8	(225)			2	(52)
C_4	16 3/4	(425)	6 3/4	(171)	8 7/8	(225)			2 4/7	(65)
C_5	22	(559)	20 1/8	(511)	11 5/8	(295)			5	(129)
C_6	N/a	NA	33 1/2	(851)	24 1/8	(613)			NA	NA
C_{MAX}	28	(711)	23	(584)	13 1/2	(343)			9 1/5	(233)

Figure F-13. Exterior Vehicle Crush (NASS) - Front, Test No. HBIB-2

Test Name: HBIB-2 VIN: KNADM4A32H6015837

Model Year: 2017 Make: Kia Model: Rio



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	43	(1092)
Total Vehicle Length:	172 1/8	(4372)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-14 7/8	-(378)
Width of contact and induced crush - Field L:	172 1/8	(4372)
Crush measurement spacing interval (L/5) - I:	34 3/8	(873)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-14 7/8	-(378)
Width of Contact Damage:	172 1/8	(4372)
Distance from vehicle c.g. to center of contact damage - D_C:	-14 7/8	-(378)

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	-101	-(2565)	33 1/4	(845)	3 1/2	(89)	NA	NA
C_2	n/a	NA	-66 5/8	-(1692)	7	(178)			NA	NA
C_3	9	(229)	-32 1/4	-(819)	6 1/4	(159)			- 3/4	-(19)
C_4	8 3/4	(222)	2 1/8	(54)	6 1/2	(165)			-1 1/4	-(32)
C_5	n/a	NA	36 1/2	(927)	7	(178)			NA	NA
C_6	n/a	NA	70 7/8	(1800)	18 1/8	(460)			NA	NA
C_{MAX}	22 1/4	(565)	61	(1549)	9 5/8	(244)			9 1/8	(232)

Figure F-14. Exterior Vehicle Crush (NASS) - Side, Test No. HBIB-2

Model Year: 2017 Test Name: HBIB-3 Make: Dodge VIN: 1C6RR6LT5HS722979 Model: Ram 1500

VEHICLE DEFORMATION
PASSENGER 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	59.3035	35.9482	-6.5769	58.3603	36.1021	-7.1347	0.9432	-0.1539	0.5578	1.1065	1.0958	X, Z
	2	59.9947	37.8794	-3.9702	57.8823	38.1830	-5.3712	2.1124	-0.3036	1.4010	2.5529	2.5348	X, Z
	3	59.8293	41.9228	-2.6125	54.3369	40.9341	-5.0896	5.4924	0.9887	2.4771	6.1057	6.0252	X, Z
	4	59.8785	46.8902	-2.8600	54.0079	45.6050	-5.6205	5.8706	1.2852	2.7605	6.6133	6.4872	X, Z
	5	60.2125	50.2792	-5.1734	56.3484	48.8361	-7.0647	3.8641	1.4431	1.8913	4.5377	4.3021	X, Z
	6	55.7173	33.8262	-5.8400	54.9089	33.7808	-6.4438	0.8084	0.0454	0.6038	1.0100	1.0090	X, Z
	7	56.7193	37.1293	-3.4356	55.7695	37.0824	-3.9554	0.9498	0.0469	0.5198	1.0837	1.0827	X, Z
	8	57.1562	41.7800	-1.1265	54.3729	41.2567	-2.2356	2.7833	0.5233	1.1091	3.0415	2.9961	X, Z
	9	57.0718	47.5418	-1.0365	53.2970	46.2707	-2.3676	3.7748	1.2711	1.3311	4.1996	4.0026	X, Z
	10	57.3131	50.3795	-1.3907	54.8545	48.6960	-2.3922	2.4586	1.6835	1.0015	3.1435	2.6548	X, Z
FLOOR PAN (Z)	11	52.3950	33.1134	-3.9261	51.5475	33.0026	-4.6865	0.8475	0.1108	0.7604	1.1440	0.7604	Z
	12	53.3510	36.6615	-1.3018	52.2922	36.5844	-2.0602	1.0588	0.0771	0.7584	1.3047	0.7584	Z
	13	53.8590	41.6349	0.7040	53.0534	41.4081	0.8567	0.8056	0.2268	-0.1527	0.8507	-0.1527	Z
	14	53.9553	46.4882	0.6796	52.4870	46.0637	0.7480	1.4683	0.4245	-0.0684	1.5300	-0.0684	Z
	15	53.6098	50.2381	0.8897	52.6729	49.0670	1.1822	0.9369	1.1711	-0.2925	1.5280	-0.2925	Z
	16	48.7398	31.6161	-1.7705	47.9345	31.4002	-2.5457	0.8053	0.2159	0.7752	1.1384	0.7752	Z
	17	48.1248	35.5256	1.2476	47.3757	35.5254	0.7437	0.7491	0.0002	0.5039	0.9028	0.5039	Z
	18	48.2018	40.8680	1.2580	47.5653	40.7593	2.0057	0.6365	0.1087	-0.7477	0.9879	-0.7477	Z
	19	48.0179	45.8986	1.2498	47.5106	45.7045	3.0131	0.5073	0.1941	-1.7633	1.8451	-1.7633	Z
	20	48.1351	49.6624	1.3130	47.6337	49.1645	2.7384	0.5014	0.4979	-1.4254	1.5909	-1.4254	Z
	21	43.0737	29.9341	-1.7463	42.7100	29.9011	-2.1196	0.3637	0.0330	0.3733	0.5222	0.3733	Z
	22	42.1232	35.2765	1.2231	41.7860	35.1592	1.2194	0.3372	0.1173	0.0037	0.3570	0.0037	Z
	23	42.0158	39.9761	1.2317	41.6327	39.7880	1.6249	0.3831	0.1881	-0.3932	0.5803	-0.3932	Z
	24	41.8393	45.0475	1.2631	41.4165	44.8600	2.2035	0.4228	0.1875	-0.9404	1.0480	-0.9404	Z
	25	42.2140	49.9261	1.3020	41.8997	49.6477	2.1024	0.3143	0.2784	-0.8004	0.9038	-0.8004	Z
	26	36.9013	29.9429	-1.7694	36.5301	30.0292	-2.2050	0.3712	-0.0863	0.4356	0.5788	0.4356	Z
	27	37.1270	35.5434	0.3466	36.7917	35.3809	0.0672	0.3353	0.1625	0.2794	0.4657	0.2794	Z
	28	36.9879	39.9723	0.2962	36.6861	39.8279	0.0783	0.3018	0.1444	0.2179	0.3993	0.2179	Z
	29	36.8321	44.4602	0.2590	36.5746	44.3073	0.1464	0.2575	0.1529	0.1126	0.3199	0.1126	Z
	30	36.8766	49.4662	0.2820	36.6747	49.3528	0.3075	0.2019	0.1134	-0.0255	0.2330	-0.0255	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 F-15. Floor Pan Deformation Data – Set 1, Test No. HBIB-3

Model Year: 2017 Test Name: HBIB-3 Make: Dodge VIN: 1C6RR6LT5HS722979 Model: Ram 1500

VEHICLE DEFORMATION
PASSENGER 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	55.6995	16.7940	-2.8435	55.2591	17.0405	-3.1811	0.4404	-0.2465	0.3376	0.6072	0.5549	X, Z
	2	56.3887	18.7344	-0.2431	54.7741	19.1046	-1.3999	1.6146	-0.3702	1.1568	2.0204	1.9862	X, Z
	3	56.1932	22.7775	1.1116	51.2042	21.8188	-1.0731	4.9890	0.9587	2.1847	5.5301	5.4464	X, Z
	4	56.1933	27.7449	0.8588	50.8256	26.4897	-1.5696	5.3677	1.2552	2.4284	6.0237	5.8915	X, Z
	5	56.4803	31.1344	-1.4601	53.1234	29.7533	-3.0093	3.3569	1.3811	1.5492	3.9467	3.6971	X, Z
	6	52.1384	14.6386	-2.0817	51.8359	14.6807	-2.4802	0.3025	-0.0421	0.3985	0.5021	0.5003	X, Z
	7	53.1240	17.9536	0.3130	52.6830	17.9738	0.0242	0.4410	-0.0202	0.2888	0.5275	0.5271	X, Z
	8	53.5310	22.6108	2.6147	51.2587	22.1225	1.7827	2.2723	0.4883	0.8320	2.4686	2.4198	X, Z
	9	53.3920	28.3716	2.6993	50.1328	27.1264	1.6930	3.2592	1.2452	1.0063	3.6312	3.4110	X, Z
	10	53.6040	31.2111	2.3408	51.6663	29.5671	1.6732	1.9377	1.6440	0.6676	2.6274	2.0495	X, Z
FLOOR PAN (Z)	11	48.8352	13.8961	-0.1461	48.4956	13.8577	-0.7030	0.3396	0.0384	0.5569	0.6534	0.5569	Z
	12	49.7739	17.4560	2.4685	49.2251	17.4289	1.9419	0.5488	0.0271	0.5266	0.7611	0.5266	Z
	13	50.2469	22.4361	4.4660	49.9612	22.2401	4.8859	0.2857	0.1960	-0.4199	0.5444	-0.4199	Z
	14	50.2967	27.2900	4.4362	49.3485	26.8905	4.8131	0.9482	0.3995	-0.3769	1.0958	-0.3769	Z
	15	49.9167	31.0367	4.6447	49.5083	29.8926	5.2663	0.4084	1.1441	-0.6216	1.3646	-0.6216	Z
	16	45.2082	12.3662	2.0340	44.9147	12.2055	1.4539	0.2935	0.1607	0.5801	0.6697	0.5801	Z
	17	44.5749	16.2729	5.0521	44.3405	16.3028	4.7753	0.2344	-0.0299	0.2768	0.3639	0.2768	Z
	18	44.6010	21.6158	5.0567	44.4886	21.5297	6.0715	0.1124	0.0861	-1.0148	1.0246	-1.0148	Z
	19	44.3689	26.6444	5.0446	44.3931	26.4673	7.1129	-0.0242	0.1771	-2.0683	2.0760	-2.0683	Z
	20	44.4505	30.4092	5.1032	44.4803	29.9300	6.8609	-0.0298	0.4792	-1.7577	1.8221	-1.7577	Z
	21	39.5587	10.6302	2.0958	39.7085	10.6524	1.9089	-0.1498	-0.0222	0.1869	0.2406	0.1869	Z
	22	38.5759	15.9664	5.0658	38.7584	15.8785	5.2905	-0.1825	0.0879	-0.2247	0.3025	-0.2247	Z
	23	38.4237	20.6648	5.0704	38.5630	20.5027	5.7286	-0.1393	0.1621	-0.6582	0.6920	-0.6582	Z
	24	38.1989	25.7343	5.0978	38.3016	25.5683	6.3433	-0.1027	0.1660	-1.2455	1.2607	-1.2455	Z
	25	38.5272	30.6163	5.1295	38.7372	30.3612	6.2711	-0.2100	0.2551	-1.1416	1.1885	-1.1416	Z
	26	33.3865	10.5800	2.1118	33.5272	10.7203	1.8707	-0.1407	-0.1403	0.2411	0.3124	0.2411	Z
	27	33.5720	16.1846	4.2206	33.7536	16.0589	4.1772	-0.1816	0.1257	0.0434	0.2251	0.0434	Z
	28	33.3902	20.6120	4.1668	33.6047	20.5044	4.2193	-0.2145	0.1076	-0.0525	0.2457	-0.0525	Z
	29	33.1914	25.0981	4.1260	33.4499	24.9820	4.3188	-0.2585	0.1161	-0.1928	0.3427	-0.1928	Z
	30	33.1882	30.1044	4.1437	33.5019	30.0270	4.5135	-0.3137	0.0774	-0.3698	0.4911	-0.3698	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 F-16. Floor Pan Deformation Data – Set 2, Test No. HBIB-3

Model Year: 2017 Test Name: HBIB-3 Make: Dodge VIN: 1C6RR6LT5HS722979 Model: Ram 1500

VEHICLE DEFORMATION
PASSENGER 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	44.3828	22.4710	-30.8011	44.6467	21.4604	-31.5121	-0.2639	1.0106	-0.7110	1.2635	1.2635	X, Y, Z
	2	47.4701	36.8985	-30.1443	47.5513	35.9643	-31.1077	-0.0812	0.9342	-0.9634	1.3444	1.3444	X, Y, Z
	3	47.5018	50.1162	-29.4538	47.3587	49.1836	-30.3502	0.1431	0.9326	-0.8964	1.3014	1.3014	X, Y, Z
	4	41.5336	24.0014	-20.2046	41.4057	23.1644	-21.0472	0.1279	0.8370	-0.8426	1.1945	1.1945	X, Y, Z
	5	43.6836	38.3895	-20.3527	43.3924	37.3806	-21.4320	0.2912	1.0089	-1.0793	1.5058	1.5058	X, Y, Z
	6	44.6737	50.8402	-20.0348	44.0035	49.8849	-21.0828	0.6702	0.9553	-1.0480	1.5684	1.5684	X, Y, Z
SIDE PANEL (Y)	7	53.5009	52.6838	-9.7730	52.5301	49.8715	-10.1662	0.9708	2.8123	-0.3932	3.0010	2.8123	Y
	8	53.2250	52.6732	-4.5669	52.4612	50.2904	-4.9159	0.7638	2.3828	-0.3490	2.5265	2.3828	Y
	9	57.4758	52.5692	-6.4199	56.5662	49.4589	-6.9633	0.9096	3.1103	-0.5434	3.2858	3.1103	Y
IMPACT SIDE DOOR (Y)	10	44.6874	54.0476	-26.5762	43.6042	52.7225	-27.0741	1.0832	1.3251	-0.4979	1.7824	1.3251	Y
	11	32.4487	54.2075	-26.7749	31.5338	54.8008	-27.1750	0.9149	-0.5933	-0.4001	1.1615	-0.5933	Y
	12	18.6865	54.3828	-27.1383	18.1138	56.3508	-27.4014	0.5727	-1.9680	-0.2631	2.0664	-1.9680	Y
	13	40.8880	55.1567	-7.2577	40.2157	54.8523	-7.5610	0.6723	0.3044	-0.3033	0.7979	0.3044	Y
	14	30.6641	55.4719	-6.1114	30.0185	56.1541	-6.4188	0.6456	-0.6822	-0.3074	0.9883	-0.6822	Y
	15	19.5290	54.9460	-7.8817	18.9905	56.2835	-8.1792	0.5385	-1.3375	-0.2975	1.4722	-1.3375	Y
ROOF - (Z)	16	40.3138	25.1966	-46.8071	40.5268	24.9129	-47.0230	-0.2130	0.2837	-0.2159	0.4153	-0.2159	Z
	17	38.9321	34.8140	-46.6562	39.1211	34.5525	-47.0565	-0.1890	0.2615	-0.4003	0.5142	-0.4003	Z
	18	36.0356	45.3439	-46.0519	36.3250	45.1349	-46.6262	-0.2894	0.2090	-0.5743	0.6762	-0.5743	Z
	19	32.9978	23.6913	-49.7984	33.2742	23.3705	-50.0178	-0.2764	0.3208	-0.2194	0.4769	-0.2194	Z
	20	31.9666	32.6844	-49.6664	32.2419	32.3849	-50.0064	-0.2753	0.2995	-0.3400	0.5302	-0.3400	Z
	21	30.1639	43.0859	-49.0977	30.4491	42.7908	-49.5712	-0.2852	0.2951	-0.4735	0.6267	-0.4735	Z
	22	14.5336	22.1213	-51.4238	14.8400	21.8029	-51.6350	-0.3064	0.3184	-0.2112	0.4897	-0.2112	Z
	23	14.2056	30.8362	-51.2518	14.4436	30.4649	-51.5624	-0.2380	0.3713	-0.3106	0.5394	-0.3106	Z
	24	14.1364	41.6472	-50.6056	14.4698	41.3182	-51.0040	-0.3334	0.3290	-0.3984	0.6149	-0.3984	Z
	25	-4.7740	22.0948	-51.7171	-4.4836	21.7363	-51.9883	-0.2904	0.3585	-0.2712	0.5352	-0.2712	Z
	26	-4.7195	30.8800	-51.5674	-4.4156	30.5432	-51.9135	-0.3039	0.3368	-0.3461	0.5706	-0.3461	Z
	27	-4.4204	42.2500	-50.9495	-4.1064	41.9512	-51.3753	-0.3140	0.2988	-0.4258	0.6076	-0.4258	Z
	28	-22.9186	22.4682	-51.1275	-22.6226	22.1070	-51.4828	-0.2960	0.3612	-0.3553	0.5868	-0.3553	Z
	29	-23.1156	31.6446	-51.0107	-22.7778	31.3144	-51.4279	-0.3378	0.3302	-0.4172	0.6303	-0.4172	Z
	30	-22.9847	42.2447	-50.5918	-22.6160	41.8921	-51.0993	-0.3687	0.3527	-0.5075	0.7196	-0.5075	Z
A-PILLAR Maximum (X, Y, Z)	31	50.9087	50.9415	-33.4250	51.1516	50.3271	-34.0276	-0.2429	0.6144	-0.6026	0.8942	0.6144	Y
	32	49.0812	50.6006	-34.7349	49.4161	50.0508	-35.3856	-0.3349	0.5498	-0.6507	0.9153	0.5498	Y
	33	46.0943	48.9559	-36.2719	46.4143	48.5849	-36.9496	-0.3200	0.3710	-0.6777	0.8363	0.3710	Y
	34	42.5285	48.4398	-39.3368	42.8789	48.1840	-39.9908	-0.3504	0.2558	-0.6540	0.7848	0.2558	Y
	35	39.3896	47.3240	-40.9213	39.6992	47.0616	-41.6805	-0.3096	0.2624	-0.7592	0.8609	0.2624	Y
	36	36.6122	47.5283	-44.0828	36.8820	47.3737	-44.7482	-0.2698	0.1546	-0.6654	0.7345	0.1546	Y
A-PILLAR Lateral (Y)	31	50.9087	50.9415	-33.4250	51.1516	50.3271	-34.0276	-0.2429	0.6144	-0.6026	0.8942	0.6144	Y
	32	49.0812	50.6006	-34.7349	49.4161	50.0508	-35.3856	-0.3349	0.5498	-0.6507	0.9153	0.5498	Y
	33	46.0943	48.9559	-36.2719	46.4143	48.5849	-36.9496	-0.3200	0.3710	-0.6777	0.8363	0.3710	Y
	34	42.5285	48.4398	-39.3368	42.8789	48.1840	-39.9908	-0.3504	0.2558	-0.6540	0.7848	0.2558	Y
	35	39.3896	47.3240	-40.9213	39.6992	47.0616	-41.6805	-0.3096	0.2624	-0.7592	0.8609	0.2624	Y
	36	36.6122	47.5283	-44.0828	36.8820	47.3737	-44.7482	-0.2698	0.1546	-0.6654	0.7345	0.1546	Y
B-PILLAR Maximum (X, Y, Z)	37	12.4166	47.4225	-45.9576	12.7230	47.1791	-46.3527	-0.3064	0.2434	-0.3951	0.5561	0.2434	Y
	38	9.5881	49.1522	-41.1971	9.8835	48.9499	-41.6343	-0.2954	0.2023	-0.4372	0.5652	0.2023	Y
	39	12.9003	51.1668	-35.4516	13.0917	51.0115	-35.8977	-0.1914	0.1553	-0.4461	0.5096	0.1553	Y
	40	9.7072	52.2035	-29.7455	9.9229	52.0789	-30.1813	-0.2157	0.1246	-0.4358	0.5020	0.1246	Y
B-PILLAR Lateral (Y)	37	12.4166	47.4225	-45.9576	12.7230	47.1791	-46.3527	-0.3064	0.2434	-0.3951	0.5561	0.2434	Y
	38	9.5881	49.1522	-41.1971	9.8835	48.9499	-41.6343	-0.2954	0.2023	-0.4372	0.5652	0.2023	Y
	39	12.9003	51.1668	-35.4516	13.0917	51.0115	-35.8977	-0.1914	0.1553	-0.4461	0.5096	0.1553	Y
	40	9.7072	52.2035	-29.7455	9.9229	52.0789	-30.1813	-0.2157	0.1246	-0.4358	0.5020	0.1246	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 F-17. Occupant Compartment Deformation Data – Set 1, Test No. HBIB-3

Model Year: 2017 Test Name: HBIB-3 Make: Dodge VIN: 1C6RR6LT5HS722979 Model: Ram 1500

VEHICLE DEFORMATION
PASSENGER 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	40.7659	3.1615	-26.9412	41.2027	2.4488	-27.5504	-0.4368	0.7127	-0.6092	1.0343	1.0343	X, Y, Z
	2	43.7144	17.6194	-26.3171	43.9592	16.9675	-27.0609	-0.2448	0.6519	-0.7438	1.0189	1.0189	X, Y, Z
	3	43.6196	30.8375	-25.6400	43.6373	30.1682	-26.2039	-0.0177	0.6693	-0.5639	0.8754	0.8754	X, Y, Z
	4	37.9645	4.6749	-16.3295	38.0300	4.0407	-17.0558	-0.0655	0.6342	-0.7263	0.9664	0.9664	X, Y, Z
	5	39.9714	19.0834	-16.5047	39.8661	18.2684	-17.3499	0.1053	0.8150	-0.8452	1.1788	1.1788	X, Y, Z
	6	40.8403	31.5435	-16.2052	40.3513	30.7659	-16.9125	0.4890	0.7776	-0.7073	1.1593	1.1593	X, Y, Z
SIDE PANEL (Y)	7	49.7094	33.4850	-5.9978	48.9574	30.7599	-6.0719	0.7520	2.7251	-0.0741	2.8279	2.7251	Y
	8	49.4645	33.4773	-0.7901	48.9259	31.1389	-0.8223	0.5386	2.3384	-0.0322	2.3998	2.3384	Y
	9	53.7051	33.4132	-2.6682	53.0198	30.3657	-2.9065	0.6853	3.0475	-0.2383	3.1327	3.0475	Y
IMPACT SIDE DOOR (Y)	10	40.7836	34.7439	-22.7498	39.8756	33.6412	-22.8747	0.9080	1.1027	-0.1249	1.4339	1.1027	Y
	11	28.5430	34.7829	-22.8760	27.7933	35.5939	-22.8651	0.7497	-0.8110	0.0109	1.1045	-0.8110	Y
	12	14.7778	34.8219	-23.1581	14.3669	37.0058	-22.9743	0.4109	-2.1839	0.1838	2.2298	-2.1839	Y
	13	37.0878	35.8360	-3.4102	36.6230	35.5902	-3.3350	0.4648	0.2458	0.0752	0.5311	0.2458	Y
	14	26.8683	36.0514	-2.2036	26.4300	36.7773	-2.1038	0.4383	-0.7259	0.0998	0.8538	-0.7259	Y
	15	15.7286	35.4138	-3.9073	15.3961	36.8058	-3.7751	0.3325	-1.3920	0.1322	1.4373	-1.3920	Y
ROOF - (Z)	16	36.5756	5.8297	-42.9254	36.9278	5.9704	-42.9904	-0.3522	-0.1407	-0.0650	0.3848	-0.0650	Z
	17	35.0998	15.4332	-42.7760	35.4241	15.5877	-42.9410	-0.3243	-0.1545	-0.1650	0.3953	-0.1650	Z
	18	32.1031	25.9346	-42.1651	32.5252	26.1291	-42.4101	-0.4221	-0.1945	-0.2450	0.5254	-0.2450	Z
	19	29.2572	4.2492	-45.8718	29.6734	4.3766	-45.9373	-0.4162	-0.1274	-0.0655	0.4402	-0.0655	Z
	20	28.1380	13.2318	-45.7427	28.5495	13.3727	-45.8506	-0.4115	-0.1409	-0.1079	0.4481	-0.1079	Z
	21	26.2360	23.6155	-45.1738	26.6550	23.7481	-45.3240	-0.4190	-0.1326	-0.1502	0.4644	-0.1502	Z
	22	10.8001	2.4953	-47.3862	11.2580	2.6321	-47.4200	-0.4579	-0.1368	-0.0338	0.4791	-0.0338	Z
	23	10.3871	11.2067	-47.2210	10.7736	11.2822	-47.2798	-0.3865	-0.0755	-0.0588	0.3982	-0.0588	Z
	24	10.2149	22.0172	-46.5852	10.6928	22.1225	-46.6410	-0.4779	-0.1053	-0.0558	0.4925	-0.0558	Z
	25	-8.5077	2.2779	-47.5650	-8.0515	2.3688	-47.6217	-0.4562	-0.0909	-0.0567	0.4686	-0.0567	Z
	26	-8.5391	11.0633	-47.4243	-8.0733	11.1684	-47.4817	-0.4658	-0.1051	-0.0574	0.4809	-0.0574	Z
	27	-8.3486	22.4364	-46.8196	-7.8772	22.5661	-46.8613	-0.4714	-0.1297	-0.0417	0.4907	-0.0417	Z
	28	-26.6513	2.4727	-46.8681	-26.1749	2.5482	-46.9712	-0.4764	-0.0755	-0.1031	0.4932	-0.1031	Z
	29	-26.9383	11.6469	-46.7594	-26.4241	11.7459	-46.8465	-0.5142	-0.0990	-0.0871	0.5308	-0.0871	Z
	30	-26.9096	22.2482	-46.3519	-26.3683	22.3139	-46.4405	-0.5413	-0.0657	-0.0886	0.5524	-0.0886	Z
A-PILLAR Maximum (X, Y, Z)	31	46.9946	31.6922	-29.6323	47.3860	31.3769	-29.8996	-0.3914	0.3153	-0.2673	0.5693	0.3153	Y
	32	45.1629	31.3319	-30.9309	45.6440	31.0931	-31.2449	-0.4811	0.2388	-0.3140	0.6222	0.2388	Y
	33	42.1833	29.6562	-32.4485	42.6474	29.6089	-32.7950	-0.4641	0.0473	-0.3465	0.5811	0.0473	Y
	34	38.6047	29.1016	-35.4918	39.0950	29.1943	-35.8088	-0.4903	-0.0927	-0.3170	0.5912	0.0000	NA
	35	35.4676	27.9532	-37.0564	35.9161	28.0526	-37.4806	-0.4485	-0.0994	-0.4242	0.6253	0.0000	NA
	36	32.6697	28.1267	-40.2017	33.0737	28.3579	-40.5213	-0.4040	-0.2312	-0.3196	0.5646	0.0000	NA
A-PILLAR Lateral (Y)	31	46.9946	31.6922	-29.6323	47.3860	31.3769	-29.8996	-0.3914	0.3153	-0.2673	0.5693	0.3153	Y
	32	45.1629	31.3319	-30.9309	45.6440	31.0931	-31.2449	-0.4811	0.2388	-0.3140	0.6222	0.2388	Y
	33	42.1833	29.6562	-32.4485	42.6474	29.6089	-32.7950	-0.4641	0.0473	-0.3465	0.5811	0.0473	Y
	34	38.6047	29.1016	-35.4918	39.0950	29.1943	-35.8088	-0.4903	-0.0927	-0.3170	0.5912	-0.0927	Y
	35	35.4676	27.9532	-37.0564	35.9161	28.0526	-37.4806	-0.4485	-0.0994	-0.4242	0.6253	-0.0994	Y
	36	32.6697	28.1267	-40.2017	33.0737	28.3579	-40.5213	-0.4040	-0.2312	-0.3196	0.5646	-0.2312	Y
B-PILLAR Maximum (X, Y, Z)	37	8.4657	27.7801	-41.9328	8.9244	27.9261	-41.9361	-0.4587	-0.1460	-0.0033	0.4814	0.0000	NA
	38	5.6485	29.4868	-37.1574	6.1065	29.6313	-37.1860	-0.4580	-0.1445	-0.0286	0.4811	0.0000	NA
	39	8.9745	31.5401	-31.4336	9.3363	31.6820	-31.4639	-0.3618	-0.1419	-0.0303	0.3898	0.0000	NA
	40	5.8052	32.5513	-25.7097	6.2047	32.6736	-25.7193	-0.3995	-0.1223	-0.0096	0.4179	0.0000	NA
B-PILLAR Lateral (Y)	37	8.4657	27.7801	-41.9328	8.9244	27.9261	-41.9361	-0.4587	-0.1460	-0.0033	0.4814	-0.1460	Y
	38	5.6485	29.4868	-37.1574	6.1065	29.6313	-37.1860	-0.4580	-0.1445	-0.0286	0.4811	-0.1445	Y
	39	8.9745	31.5401	-31.4336	9.3363	31.6820	-31.4639	-0.3618	-0.1419	-0.0303	0.3898	-0.1419	Y
	40	5.8052	32.5513	-25.7097	6.2047	32.6736	-25.7193	-0.3995	-0.1223	-0.0096	0.4179	-0.1223	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 F-18. Occupant Compartment Deformation Data – Set 2, Test No. HBIB-3

Test Name: HBIB-3 VIN: 1C6RR6LT5HS722979

Model Year: 2017 Make: Dodge Model: Ram 1500

Passenger 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	-0.2	≤ 4	Z
Windshield[D]	0.0	≤ 3	X, Z	Windshield[D]	NA	≤ 3	X, Z
A-Pillar Maximum	0.6	≤ 5	Y	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	B-Pillar Maximum	0.0	≤ 5	NA
B-Pillar Lateral	0.2	≤ 3	Y	B-Pillar Lateral	-0.1	≤ 3	Y
Toe Pan - Wheel Well	6.5	≤ 9	X, Z	Toe Pan - Wheel Well	5.9	≤ 9	X, Z
Side Front Panel	3.1	≤ 12	Y	Side Front Panel	3.0	≤ 12	Y
Side Door (above seat)	1.3	≤ 9	Y	Side Door (above seat)	1.1	≤ 9	Y
Side Door (below seat)	0.3	≤ 12	Y	Side Door (below seat)	0.2	≤ 12	Y
Floor Pan	0.8	≤ 12	Z	Floor Pan	0.6	≤ 12	Z
Dash - no MASH requirement	1.6	NA	X, Y, Z	Dash - no MASH requirement	1.2	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.

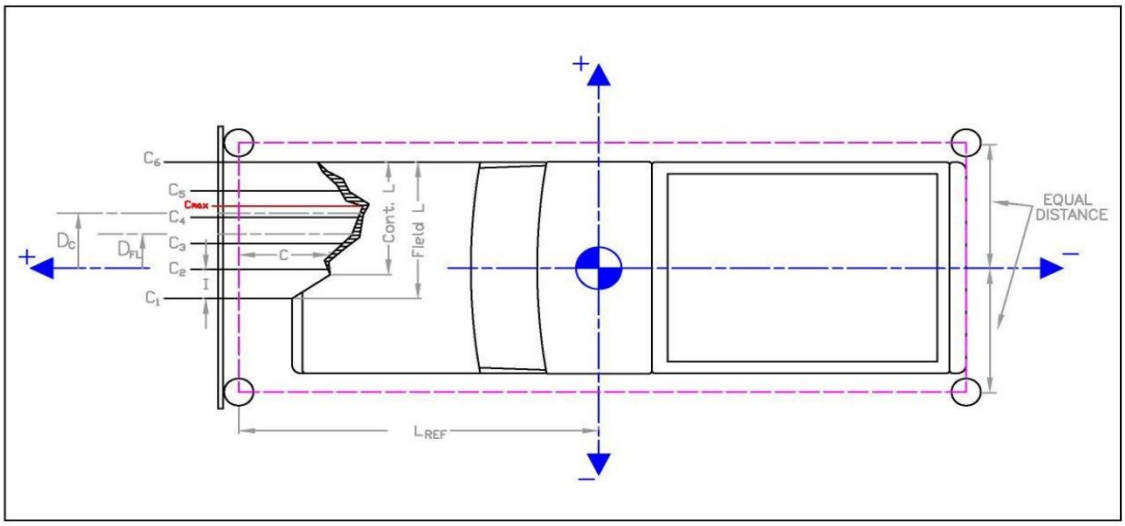
[D] If deformation is observered for the windshield then the windshield deformation is measured posttest with an examplar vehicle, therefore only one set of reference is measured and recorded.

Notes on vehicle interior crush:

Figure F-19. Maximum Occupant Compartment Deformations by Location, Test No. HBIB-3

Test Name: HBIB-3 VIN: 1C6RR6LT5HS722979

Model Year: 2017 Make: Dodge Model: Ram 1500



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	111 1/2	(2832)
Total Vehicle Width:	76 5/8	(1946)
Width of contact and induced crush - Field L:	76 5/8	(1946)
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:	23	(586)
Distance from center of vehicle to center of contact damage - D_C:	27 2/7	(693)

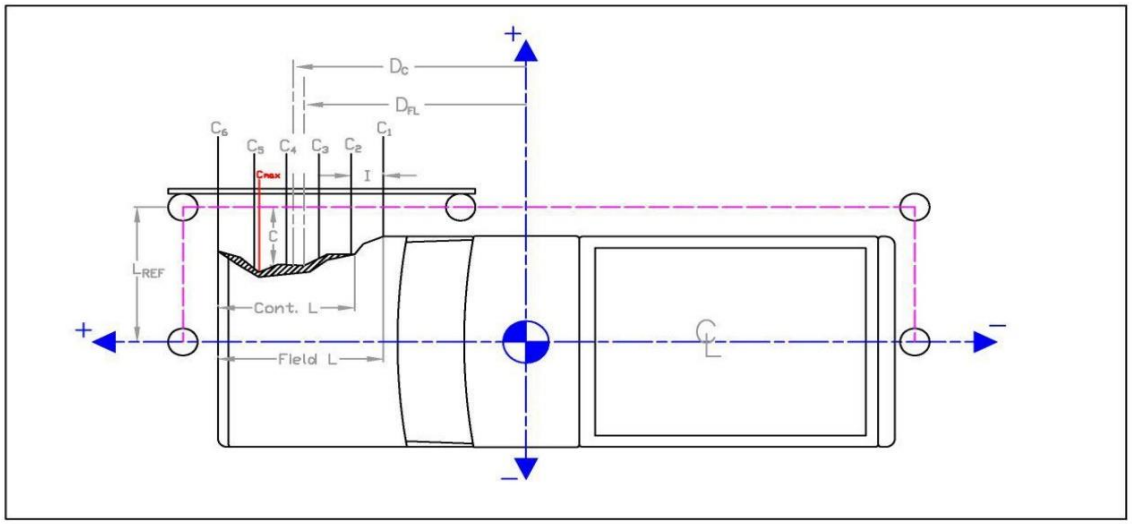
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

	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 3/8	-(975)	22 1/2	(572)	8 1/5	(208)	N/A	N/A
C_2	14 1/2	(368)	-23	-(584)	6 1/2	(165)			- 1/5	-(5)
C_3	9 1/4	(235)	-7 5/8	-(194)	4 1/4	(108)			-3 1/5	-(81)
C_4	11	(279)	7 3/4	(197)	4 1/4	(108)			-1 4/9	-(37)
C_5	24 3/4	(629)	23 1/8	(587)	6 1/8	(156)			10 4/9	(265)
C_6	N/A	N/A	38 1/2	(978)	20 1/2	(521)			N/A	N/A
C_{MAX}	24 3/4	(629)	23 1/8	(587)	6 1/8	(156)			10 4/9	(265)

Figure F-20. Exterior Vehicle Crush (NASS) - Front, Test No. HBIB-3

Test Name: HBIB-3 VIN: 1C6RR6LT5HS722979

Model Year: 2017 Make: Dodge Model: Ram 1500



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	50 1/2	(1283)
Total Vehicle Length:	229 1/4	(5823)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-6 4/7	-(167)
Width of contact and induced crush - Field L:	229 1/4	(5823)
Crush measurement spacing interval (L/5) - I:	45 7/8	(1165)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-6 5/8	-(168)
Width of Contact Damage:	229 1/4	(5823)
Distance from vehicle c.g. to center of contact damage - D_C:	-6 5/8	-(168)

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	-121 1/4	-(3080)	44	(1118)	6 1/2	(165)	N/A	N/A
C_2	N/A	N/A	-75 3/8	-(1915)	5 1/4	(133)			N/A	N/A
C_3	10 3/4	(273)	-29 1/2	-(749)	5 1/4	(133)			-1	-(25)
C_4	10 1/4	(260)	16 3/8	(416)	5 1/8	(130)			-1 3/8	-(35)
C_5	N/A	N/A	62 1/4	(1581)	5 1/4	(133)			N/A	N/A
C_6	N/A	N/A	108 1/8	(2746)	33 1/2	(851)			N/A	N/A
C_{MAX}	30	(762)	88	(2235)	6 1/8	(156)			17 3/8	(441)

Figure F-21. Exterior Vehicle Crush (NASS) - Side, Test No. HBIB-3

Model Year: 2017 Test Name: HBIB-4 Make: Hyundai VIN: KMHCT4AE0HU266110 Model: Accent

VEHICLE DEFORMATION
PASSENGER 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	86.0877	-4.6318	5.6178	86.1191	-4.5661	5.6293	-0.0314	0.0657	-0.0115	0.0737	0.0000	NA
	2	86.1453	-0.7403	6.1000	86.1145	-0.6597	6.0636	0.0308	0.0806	0.0364	0.0936	0.0477	X, Z
	3	86.2239	3.6852	6.1200	86.1826	3.7021	6.0417	0.0413	-0.0169	0.0783	0.0901	0.0885	X, Z
	4	86.1384	9.1479	6.1745	86.0787	9.1561	6.0989	0.0597	-0.0082	0.0756	0.0967	0.0963	X, Z
	5	84.9337	12.7928	4.0278	84.8302	12.8287	3.8907	0.1035	-0.0359	0.1371	0.1755	0.1718	X, Z
	6	82.7404	-4.8127	7.9672	82.7133	-4.7738	7.9749	0.0271	0.0389	-0.0077	0.0480	0.0271	X
	7	82.7291	-0.0483	7.8031	82.6964	0.0220	7.7017	0.0327	0.0703	0.1014	0.1276	0.1065	X, Z
	8	83.1947	3.8755	7.9363	83.1182	3.9012	7.8969	0.0765	-0.0257	0.0394	0.0898	0.0861	X, Z
	9	82.8265	9.0957	8.1439	82.7503	9.1078	8.0878	0.0762	-0.0121	0.0561	0.0954	0.0946	X, Z
	10	81.7528	13.6573	8.7850	81.7803	13.7422	8.7140	-0.0275	-0.0849	0.0710	0.1140	0.0710	Z
FLOOR PAN (Z)	11	78.4171	-5.2993	8.6408	78.4366	-5.3070	8.5810	-0.0195	-0.0077	0.0598	0.0634	0.0598	Z
	12	78.4901	-0.7490	10.3124	78.4556	-0.7696	10.3022	0.0345	-0.0206	0.0102	0.0415	0.0102	Z
	13	78.6020	3.5869	10.2442	78.6149	3.5863	10.1595	-0.0129	0.0006	0.0847	0.0857	0.0847	Z
	14	79.0120	9.0945	10.1109	79.0044	9.1047	10.0469	0.0076	-0.0102	0.0640	0.0653	0.0640	Z
	15	77.9794	14.4823	10.3446	77.9762	14.4803	10.2695	0.0032	0.0020	0.0751	0.0752	0.0751	Z
	16	72.9173	-5.1344	8.8895	72.9146	-5.1422	8.8145	0.0027	-0.0078	0.0750	0.0755	0.0750	Z
	17	72.9051	0.6112	10.8292	72.9112	0.6546	10.7538	-0.0061	-0.0434	0.0754	0.0872	0.0754	Z
	18	73.2079	5.7904	10.0726	73.2465	5.8010	10.0073	-0.0386	-0.0106	0.0653	0.0766	0.0653	Z
	19	72.7646	10.3505	10.5383	72.7963	10.3452	10.4626	-0.0317	0.0053	0.0757	0.0822	0.0757	Z
	20	72.5654	14.1124	10.5529	72.1374	14.3302	10.5096	0.4280	-0.2178	0.0433	0.4822	0.0433	Z
	21	68.0753	-5.1162	8.9065	68.0806	-5.1280	8.7997	-0.0053	-0.0118	0.1068	0.1076	0.1068	Z
	22	67.7585	0.7281	10.7969	67.7422	0.7210	10.7103	0.0163	0.0071	0.0866	0.0884	0.0866	Z
	23	68.2568	5.9828	10.1316	68.2723	6.0153	10.0779	-0.0155	-0.0325	0.0537	0.0647	0.0537	Z
	24	68.0161	10.4983	10.5495	67.9877	10.4789	10.4812	0.0284	0.0194	0.0683	0.0765	0.0683	Z
	25	68.1040	13.6792	10.5973	68.1021	13.6653	10.5211	0.0019	0.0139	0.0762	0.0775	0.0762	Z
	26	62.5195	-5.1452	8.8456	62.5102	-5.1444	8.7252	0.0093	0.0008	0.1204	0.1208	0.1204	Z
	27	61.8820	1.3165	11.0087	61.9242	1.3749	10.9308	-0.0422	-0.0584	0.0779	0.1061	0.0779	Z
	28	62.2667	7.5571	10.2658	62.2730	7.5976	10.2146	-0.0063	-0.0405	0.0512	0.0656	0.0512	Z
	29	62.6254	11.0288	10.7584	62.5633	11.0543	10.7089	0.0621	-0.0255	0.0495	0.0834	0.0495	Z
	30	62.7319	13.6319	10.7749	62.7004	13.6709	10.7190	0.0315	-0.0390	0.0559	0.0751	0.0559	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 F-22. Floor Pan Deformation Data – Set 1, Test No. HBIB-4

Model Year: 2017 Test Name: HBIB-4 Make: Hyundai VIN: KMHCT4AE0HU266110 Model: Accent

VEHICLE DEFORMATION
PASSENGER 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	86.0068	13.1217	5.1574	86.0214	13.0814	5.6095	-0.0146	0.0403	-0.4521	0.4541	0.0000	NA
	2	86.1140	17.0080	5.6716	86.0675	16.9822	6.0891	0.0465	0.0258	-0.4175	0.4209	0.0465	X
	3	86.2450	21.4319	5.7279	86.1911	21.3428	6.1177	0.0539	0.0891	-0.3898	0.4035	0.0539	X
	4	86.2246	26.8947	5.8286	86.1568	26.7966	6.2385	0.0678	0.0981	-0.4099	0.4269	0.0678	X
	5	85.0474	30.5714	3.7214	84.9501	30.5102	4.0761	0.0973	0.0612	-0.3547	0.3729	0.0973	X
	6	82.6749	12.9603	7.5300	82.6185	12.8896	7.9607	0.0564	0.0707	-0.4307	0.4401	0.0564	X
	7	82.7188	17.7258	7.4057	82.6621	17.6881	7.7433	0.0567	0.0377	-0.3376	0.3444	0.0567	X
	8	83.2318	21.6426	7.5682	83.1337	21.5591	7.9825	0.0981	0.0835	-0.4143	0.4339	0.0981	X
	9	82.9269	26.8648	7.8220	82.8325	26.7675	8.2347	0.0944	0.0973	-0.4127	0.4344	0.0944	X
	10	81.9119	31.4331	8.5092	81.9230	31.4061	8.9171	-0.0111	0.0270	-0.4079	0.4089	0.0000	NA
FLOOR PAN (Z)	11	78.3512	12.5190	8.2316	78.3368	12.4038	8.5709	0.0144	0.1152	-0.3393	0.3586	-0.3393	Z
	12	78.4903	17.0539	9.9406	78.4175	16.9203	10.3446	0.0728	0.1336	-0.4040	0.4317	-0.4040	Z
	13	78.6530	21.3886	9.9076	78.6319	21.2752	10.2521	0.0211	0.1134	-0.3445	0.3633	-0.3445	Z
	14	79.1272	26.8919	9.8173	79.0913	26.7891	10.2027	0.0359	0.1028	-0.3854	0.4005	-0.3854	Z
	15	78.1601	32.2894	10.1036	78.1322	32.1744	10.4902	0.0279	0.1150	-0.3866	0.4043	-0.3866	Z
	16	72.8558	12.7465	8.5225	72.8179	12.6360	8.8196	0.0379	0.1105	-0.2971	0.3192	-0.2971	Z
	17	72.9257	18.4753	10.5102	72.8927	18.4095	10.8262	0.0330	0.0658	-0.3160	0.3245	-0.3160	Z
	18	73.2842	23.6568	9.7946	73.2918	23.5595	10.1386	-0.0076	0.0973	-0.3440	0.3576	-0.3440	Z
	19	72.8984	28.2177	10.3016	72.9005	28.1035	10.6478	-0.0021	0.1142	-0.3462	0.3646	-0.3462	Z
	20	72.7438	31.9814	10.3490	72.2925	32.0956	10.7426	0.4513	-0.1142	-0.3936	0.6096	-0.3936	Z
	21	68.0146	12.8215	8.5757	67.9844	12.7118	8.8167	0.0302	0.1097	-0.2410	0.2665	-0.2410	Z
	22	67.7808	18.6530	10.5171	67.7249	18.5420	10.7959	0.0559	0.1110	-0.2788	0.3052	-0.2788	Z
	23	68.3363	23.9070	9.8920	68.3209	23.8362	10.2237	0.0154	0.0708	-0.3317	0.3395	-0.3317	Z
	24	68.1521	28.4213	10.3492	68.0940	28.2980	10.6796	0.0581	0.1233	-0.3304	0.3574	-0.3304	Z
	25	68.2779	31.6004	10.4229	68.2491	31.4820	10.7562	0.0288	0.1184	-0.3333	0.3549	-0.3333	Z
	26	62.4585	12.8585	8.5559	62.4141	12.7670	8.7555	0.0444	0.0915	-0.1996	0.2240	-0.1996	Z
	27	61.9134	19.3087	10.7775	61.9162	19.2671	11.0380	-0.0028	0.0416	-0.2605	0.2638	-0.2605	Z
	28	62.3664	25.5504	10.0838	62.3425	25.4928	10.3933	0.0239	0.0576	-0.3095	0.3157	-0.3095	Z
	29	62.7697	29.0133	10.6026	62.6779	28.9396	10.9271	0.0918	0.0737	-0.3245	0.3452	-0.3245	Z
	30	62.9071	31.6148	10.6401	62.8484	31.5539	10.9672	0.0587	0.0609	-0.3271	0.3379	-0.3271	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 F-23. Floor Pan Deformation Data – Set 2, Test No. HBIB-4

Model Year: 2017 Test Name: HBIB-4 Make: Hyundai VIN: KMHCT4AE0HU266110 Model: Accent

VEHICLE DEFORMATION
PASSENGER 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	72.2516	-7.8408	-18.4807	72.3152	-7.8140	-18.5105	-0.0636	0.0268	-0.0298	0.0752	0.0752	X, Y, Z
	2	73.7590	4.9800	-16.7277	73.8512	4.9973	-16.8022	-0.0922	-0.0173	-0.0745	0.1198	0.1198	X, Y, Z
	3	73.9550	14.9450	-17.1840	73.9833	14.9644	-17.2489	-0.0283	-0.0194	-0.0649	0.0734	0.0734	X, Y, Z
	4	67.3304	-7.5715	-11.7399	67.4365	-7.5549	-11.8330	-0.1061	0.0166	-0.0931	0.1421	0.1421	X, Y, Z
	5	70.2150	5.4908	-10.9478	70.3415	5.4551	-11.1624	-0.1265	0.0357	-0.2146	0.2517	0.2517	X, Y, Z
	6	70.1645	13.4756	-11.2265	70.1952	13.4604	-11.3431	-0.0307	0.0152	-0.1166	0.1215	0.1215	X, Y, Z
SIDE PANEL (Y)	7	81.3429	16.5554	4.8501	81.2875	16.5388	4.8448	0.0554	0.0166	-0.0053	0.0581	0.0166	Y
	8	77.8055	16.6475	3.3474	77.7571	16.6048	3.3066	0.0484	0.0427	-0.0408	0.0764	0.0427	Y
	9	80.4003	16.5869	-0.2485	80.3505	16.5655	-0.1954	0.0498	0.0214	0.0531	0.0759	0.0214	Y
IMPACT SIDE DOOR (Y)	10	69.7998	17.8785	-15.6888	69.5699	17.8616	-15.6577	0.2299	0.0169	0.0311	0.2326	0.0169	Y
	11	56.4870	18.2296	-17.1464	56.2991	18.5565	-17.2102	0.1879	-0.3269	-0.0638	0.3824	-0.3269	Y
	12	44.4533	18.8299	-17.3977	44.2773	19.3480	-17.4343	0.1760	-0.5181	-0.0366	0.5484	-0.5181	Y
	13	73.4803	18.2193	3.4235	73.2048	18.5245	3.5096	0.2755	-0.3052	0.0861	0.4201	-0.3052	Y
	14	58.8500	19.3884	2.4058	58.7249	20.1416	2.4131	0.1251	-0.7532	0.0073	0.7636	-0.7532	Y
	15	47.5813	18.9164	1.9766	47.5345	19.1541	1.7961	0.0468	-0.2377	-0.1805	0.3021	-0.2377	Y
ROOF - (Z)	16	60.8508	-7.0873	-33.2598	60.8638	-7.1074	-33.3285	-0.0130	-0.0201	-0.0687	0.0728	-0.0687	Z
	17	60.8250	0.8206	-33.2232	60.8319	0.8142	-33.3047	-0.0069	0.0064	-0.0815	0.0820	-0.0815	Z
	18	59.1434	10.4666	-32.9822	59.2034	10.4985	-33.0529	-0.0600	-0.0319	-0.0707	0.0981	-0.0707	Z
	19	50.9712	-7.7765	-36.4021	50.9474	-7.7375	-36.4523	0.0238	0.0390	-0.0502	0.0679	-0.0502	Z
	20	51.1122	-1.0645	-36.2638	51.0966	-1.0309	-36.3199	0.0156	0.0336	-0.0561	0.0672	-0.0561	Z
	21	51.4649	8.2279	-35.6947	51.4389	8.2117	-35.7838	0.0260	0.0162	-0.0891	0.0942	-0.0891	Z
	22	38.1463	-7.1167	-37.6093	38.0963	-7.1183	-37.6371	0.0500	-0.0016	-0.0278	0.0572	-0.0278	Z
	23	38.4023	1.0657	-37.3557	38.3334	1.0720	-37.3948	0.0689	-0.0063	-0.0391	0.0795	-0.0391	Z
	24	38.7917	7.7898	-36.9194	38.7289	7.7685	-36.9855	0.0628	0.0213	-0.0661	0.0936	-0.0661	Z
	25	22.0617	-6.5771	-37.2394	22.0536	-6.5252	-37.2470	0.0081	0.0519	-0.0076	0.0531	-0.0076	Z
	26	22.2634	0.3366	-37.0582	22.2697	0.3656	-37.0774	-0.0063	-0.0290	-0.0192	0.0353	-0.0192	Z
	27	22.5290	8.2693	-36.5697	22.4974	8.2881	-36.5867	0.0316	-0.0188	-0.0170	0.0405	-0.0170	Z
	28	7.1523	-6.6768	-35.0904	7.1952	-6.6140	-35.0894	-0.0429	0.0628	0.0010	0.0761	0.0010	Z
	29	7.9329	1.4332	-34.9503	7.9239	1.4877	-34.9432	0.0090	-0.0545	0.0071	0.0557	0.0071	Z
	30	10.2201	10.4554	-34.6568	10.2181	10.4902	-34.6559	0.0020	-0.0348	0.0009	0.0349	0.0009	Z
A-PILLAR Maximum (X, Y, Z)	31	77.9640	15.7764	-20.8298	77.9849	15.7318	-20.9156	-0.0209	0.0446	-0.0858	0.0989	0.0446	Y
	32	74.4610	15.1533	-23.4938	74.4863	15.1293	-23.5550	-0.0253	0.0240	-0.0612	0.0704	0.0240	Y
	33	69.5841	14.2539	-26.4959	69.5771	14.2389	-26.5938	0.0070	0.0150	-0.0979	0.0993	0.0166	X, Y
	34	64.9953	13.2932	-29.0265	64.9960	13.2626	-29.1484	-0.0007	0.0306	-0.1219	0.1257	0.0306	Y
	35	61.9739	12.7543	-30.5882	61.9796	12.7354	-30.6935	-0.0057	0.0189	-0.1053	0.1071	0.0189	Y
	36	59.1212	12.4738	-31.4006	59.1150	12.4791	-31.4543	0.0062	-0.0053	-0.0537	0.0543	0.0062	X
A-PILLAR Lateral (Y)	31	77.9640	15.7764	-20.8298	77.9849	15.7318	-20.9156	-0.0209	0.0446	-0.0858	0.0989	0.0446	Y
	32	74.4610	15.1533	-23.4938	74.4863	15.1293	-23.5550	-0.0253	0.0240	-0.0612	0.0704	0.0240	Y
	33	69.5841	14.2539	-26.4959	69.5771	14.2389	-26.5938	0.0070	0.0150	-0.0979	0.0993	0.0150	Y
	34	64.9953	13.2932	-29.0265	64.9960	13.2626	-29.1484	-0.0007	0.0306	-0.1219	0.1257	0.0306	Y
	35	61.9739	12.7543	-30.5882	61.9796	12.7354	-30.6935	-0.0057	0.0189	-0.1053	0.1071	0.0189	Y
	36	59.1212	12.4738	-31.4006	59.1150	12.4791	-31.4543	0.0062	-0.0053	-0.0537	0.0543	-0.0053	Y
B-PILLAR Maximum (X, Y, Z)	37	37.7013	12.8121	-31.8772	37.6070	12.8281	-31.9693	0.0943	-0.0160	-0.0921	0.1328	0.0943	X
	38	35.4103	14.4121	-28.2109	35.4089	14.4366	-28.2749	0.0014	-0.0245	-0.0640	0.0685	0.0014	X
	39	39.2372	16.5384	-22.3986	39.2620	16.5638	-22.4885	-0.0248	-0.0254	-0.0899	0.0967	0.0000	NA
	40	36.5389	17.3156	-17.5096	36.4990	17.3399	-17.5526	0.0399	-0.0243	-0.0430	0.0635	0.0399	X
B-PILLAR Lateral (Y)	37	37.7013	12.8121	-31.8772	37.6070	12.8281	-31.9693	0.0943	-0.0160	-0.0921	0.1328	-0.0160	Y
	38	35.4103	14.4121	-28.2109	35.4089	14.4366	-28.2749	0.0014	-0.0245	-0.0640	0.0685	-0.0245	Y
	39	39.2372	16.5384	-22.3986	39.2620	16.5638	-22.4885	-0.0248	-0.0254	-0.0899	0.0967	-0.0254	Y
	40	36.5389	17.3156	-17.5096	36.4990	17.3399	-17.5526	0.0399	-0.0243	-0.0430	0.0635	-0.0243	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 F-24. Occupant Compartment Deformation Data – Set 1, Test No. HBIB-4

Model Year: 2017 Test Name: HBIB-4 Make: Hyundai VIN: KMHCT4AE0HU266110 Model: Accent

VEHICLE DEFORMATION
PASSENGER 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	71.9589	10.2985	-18.8707	72.1152	10.2916	-18.5502	-0.1563	0.0069	0.3205	0.3566	0.3566	X, Y, Z
	2	73.6281	23.0851	-17.0172	73.8179	23.0621	-16.6998	-0.1898	0.0230	0.3174	0.3705	0.3705	X, Y, Z
	3	73.9364	33.0508	-17.3880	74.0752	33.0312	-17.0330	-0.1388	0.0196	0.3550	0.3817	0.3817	X, Y, Z
	4	67.0910	10.5652	-12.0911	67.2572	10.5358	-11.8571	-0.1662	0.0294	0.2340	0.2885	0.2885	X, Y, Z
	5	70.1329	23.5859	-11.2068	70.3287	23.4995	-11.0457	-0.1958	0.0864	0.1611	0.2679	0.2679	X, Y, Z
	6	70.1731	31.5729	-11.4154	70.2834	31.5076	-11.1346	-0.1103	0.0653	0.2808	0.3087	0.3087	X, Y, Z
SIDE PANEL (Y)	7	81.5049	34.3816	4.6034	81.4551	34.2597	5.0575	0.0498	0.1219	0.4541	0.4728	0.1219	Y
	8	77.9578	34.5278	3.1280	77.9219	34.3880	3.5296	0.0359	0.1398	0.4016	0.4267	0.1398	Y
	9	80.5251	34.4689	-0.4876	80.5056	34.3561	0.0205	0.0195	0.1128	0.5081	0.5208	0.1128	Y
IMPACT SIDE DOOR (Y)	10	69.8267	36.0188	-15.8363	69.7030	35.9655	-15.3969	0.1237	0.0533	0.4394	0.4596	0.0533	Y
	11	56.5085	36.5365	-17.1911	56.4382	36.8459	-16.9055	0.0703	-0.3094	0.2856	0.4269	-0.3094	Y
	12	44.4810	37.2779	-17.3472	44.4268	37.7920	-17.0882	0.0542	-0.5141	0.2590	0.5782	-0.5141	Y
	13	73.6518	36.1488	3.2502	73.3949	36.3627	3.7669	0.2569	-0.2139	0.5167	0.6154	-0.2139	Y
	14	59.0290	37.4957	2.3522	58.9339	38.1753	2.7279	0.0951	-0.6796	0.3757	0.7823	-0.6796	Y
	15	47.7527	37.1577	2.0032	47.7303	37.3366	2.1299	0.0224	-0.1789	0.1267	0.2204	-0.1789	Y
ROOF - (Z)	16	60.4589	11.3138	-33.5570	60.6359	11.3128	-33.3282	-0.1770	0.0010	0.2288	0.2893	0.2288	Z
	17	60.5252	19.2208	-33.4511	60.7046	19.2334	-33.2138	-0.1794	-0.0126	0.2373	0.2977	0.2373	Z
	18	58.9576	28.8831	-33.1135	59.1995	28.9340	-32.8471	-0.2419	-0.0509	0.2664	0.3634	0.2664	Z
	19	50.5491	10.7665	-36.6311	50.7043	10.8440	-36.4324	-0.1552	-0.0775	0.1987	0.2638	0.1987	Z
	20	50.7690	17.4749	-36.4354	50.9389	17.5463	-36.2237	-0.1699	-0.0714	0.2117	0.2807	0.2117	Z
	21	51.2338	26.7573	-35.7879	51.3998	26.7771	-35.5829	-0.1660	-0.0198	0.2050	0.2645	0.2050	Z
	22	37.7242	11.5850	-37.7366	37.8592	11.6393	-37.5753	-0.1350	-0.0543	0.1613	0.2172	0.1613	Z
	23	38.0770	19.7613	-37.4136	38.2008	19.8226	-37.2400	-0.1238	-0.0613	0.1736	0.2219	0.1736	Z
	24	38.5478	26.4764	-36.9215	38.6821	26.5084	-36.7554	-0.1343	-0.0320	0.1661	0.2160	0.1661	Z
	25	21.6501	12.3071	-37.2418	21.8264	12.4308	-37.1352	-0.1763	-0.1237	0.1066	0.2403	0.1066	Z
	26	21.9334	19.2161	-37.0018	22.1302	19.3159	-36.8874	-0.1968	-0.0998	0.1144	0.2486	0.1144	Z
	27	22.2947	27.1406	-36.4461	22.4596	27.2287	-36.3069	-0.1649	-0.0881	0.1392	0.2331	0.1392	Z
	28	6.7568	12.3607	-34.9822	6.9735	12.5052	-34.9387	-0.2167	-0.1445	0.0435	0.2641	0.0435	Z
	29	7.6326	20.4596	-34.7773	7.8053	20.5949	-34.7019	-0.1727	-0.1353	0.0754	0.2320	0.0754	Z
	30	10.0265	29.4518	-34.4221	10.2142	29.5637	-34.3180	-0.1877	-0.1119	0.1041	0.2421	0.1041	Z
A-PILLAR Maximum (X, Y, Z)	31	77.9277	33.8680	-21.0564	78.0769	33.7898	-20.7014	-0.1492	0.0782	0.3550	0.3929	0.3635	Y, Z
	32	74.3982	33.3088	-23.6994	74.5642	33.2619	-23.3381	-0.1660	0.0469	0.3613	0.4004	0.3643	Y, Z
	33	69.4892	32.4923	-26.6727	69.6363	32.4686	-26.3736	-0.1471	0.0237	0.2991	0.3342	0.3000	Y, Z
	34	64.8710	31.6070	-29.1771	65.0367	31.5796	-28.9269	-0.1657	0.0274	0.2502	0.3013	0.2517	Y, Z
	35	61.8322	31.1168	-30.7208	62.0100	31.1084	-30.4698	-0.1778	0.0084	0.2510	0.3077	0.2511	Y, Z
	36	58.9704	30.8764	-31.5143	59.1404	30.8970	-31.2257	-0.1700	-0.0206	0.2886	0.3356	0.2886	Z
A-PILLAR Lateral (Y)	31	77.9277	33.8680	-21.0564	78.0769	33.7898	-20.7014	-0.1492	0.0782	0.3550	0.3929	0.0782	Y
	32	74.3982	33.3088	-23.6994	74.5642	33.2619	-23.3381	-0.1660	0.0469	0.3613	0.4004	0.0469	Y
	33	69.4892	32.4923	-26.6727	69.6363	32.4686	-26.3736	-0.1471	0.0237	0.2991	0.3342	0.0237	Y
	34	64.8710	31.6070	-29.1771	65.0367	31.5796	-28.9269	-0.1657	0.0274	0.2502	0.3013	0.0274	Y
	35	61.8322	31.1168	-30.7208	62.0100	31.1084	-30.4698	-0.1778	0.0084	0.2510	0.3077	0.0084	Y
	36	58.9704	30.8764	-31.5143	59.1404	30.8970	-31.2257	-0.1700	-0.0206	0.2886	0.3356	-0.0206	Y
B-PILLAR Maximum (X, Y, Z)	37	37.5529	31.4664	-31.8278	37.6373	31.5240	-31.6787	-0.0844	-0.0576	0.1491	0.1808	0.1491	Z
	38	35.3078	33.0603	-28.1306	35.4692	33.1178	-27.9602	-0.1614	-0.0575	0.1704	0.2416	0.1704	Z
	39	39.2019	35.0911	-22.3288	39.3638	35.1296	-22.1603	-0.1619	-0.0385	0.1685	0.2368	0.1685	Z
	40	36.5490	35.8563	-17.4131	36.6234	35.8839	-17.2084	-0.0744	-0.0276	0.2047	0.2195	0.2047	Z
B-PILLAR Lateral (Y)	37	37.5529	31.4664	-31.8278	37.6373	31.5240	-31.6787	-0.0844	-0.0576	0.1491	0.1808	-0.0576	Y
	38	35.3078	33.0603	-28.1306	35.4692	33.1178	-27.9602	-0.1614	-0.0575	0.1704	0.2416	-0.0575	Y
	39	39.2019	35.0911	-22.3288	39.3638	35.1296	-22.1603	-0.1619	-0.0385	0.1685	0.2368	-0.0385	Y
	40	36.5490	35.8563	-17.4131	36.6234	35.8839	-17.2084	-0.0744	-0.0276	0.2047	0.2195	-0.0276	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 F-25. Occupant Compartment Deformation Data – Set 2, Test No. HBIB-4

Test Name: HBIB-4 VIN: KMHCT4AE0HU266110

Model Year: 2017 Make: Hyundai Model: Accent

Passenger 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	0.3	≤ 4	Z
Windshield[D]	0.0	≤ 3	X, Z	Windshield[D]	NA	≤ 3	X, Z
A-Pillar Maximum	0.0	≤ 5	Y	A-Pillar Maximum	0.4	≤ 5	Y, Z
A-Pillar Lateral	0.0	≤ 3	Y	A-Pillar Lateral	0.1	≤ 3	Y
B-Pillar Maximum	0.1	≤ 5	X	B-Pillar Maximum	0.2	≤ 5	Z
B-Pillar Lateral	0.0	≤ 3	Y	B-Pillar Lateral	-0.1	≤ 3	Y
Toe Pan - Wheel Well	0.2	≤ 9	X, Z	Toe Pan - Wheel Well	0.1	≤ 9	X
Side Front Panel	0.0	≤ 12	Y	Side Front Panel	0.1	≤ 12	Y
Side Door (above seat)	0.0	≤ 9	Y	Side Door (above seat)	0.1	≤ 9	Y
Side Door (below seat)	-0.8	≤ 12	Y	Side Door (below seat)	-0.7	≤ 12	Y
Floor Pan	0.1	≤ 12	Z	Floor Pan	-0.4	≤ 12	Z
Dash - no MASH requirement	0.3	NA	X, Y, Z	Dash - no MASH requirement	0.4	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.

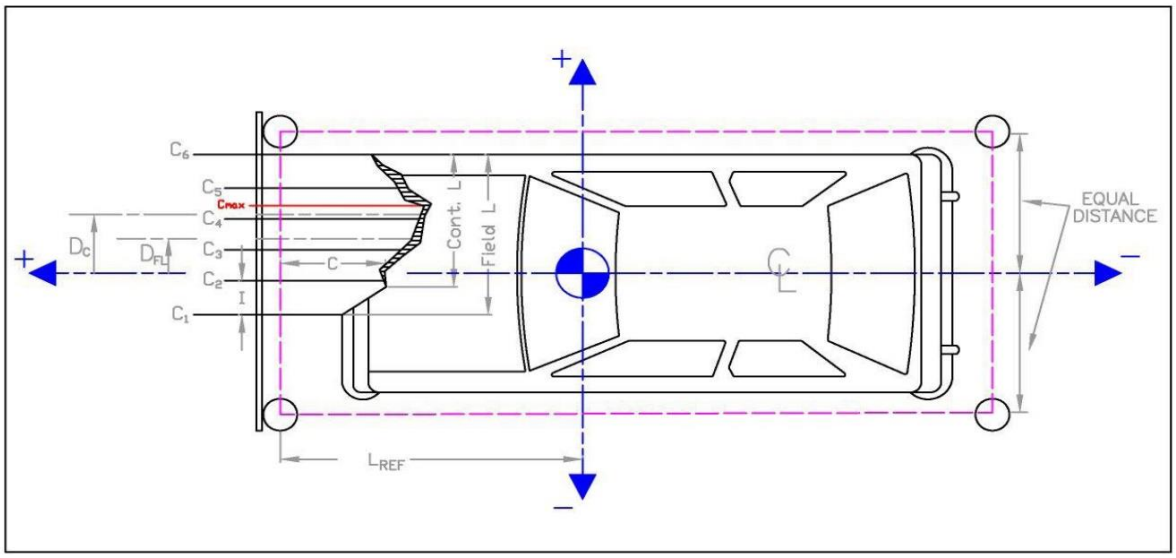
[D] If deformation is observered for the windshield then the windshield deformation is measured posttest with an examplar vehicle, therefore only one set of reference is measured and recorded.

Notes on vehicle crush:

Figure F-26. Maximum Occupant Compartment Deformations by Location, Test No. HBIB-4

Test Name: HBIB-4 VIN: KMHCT4AE0HU266110

Model Year: 2017 Make: Hyundai Model: Accent



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	73 7/8	(1876)
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	()

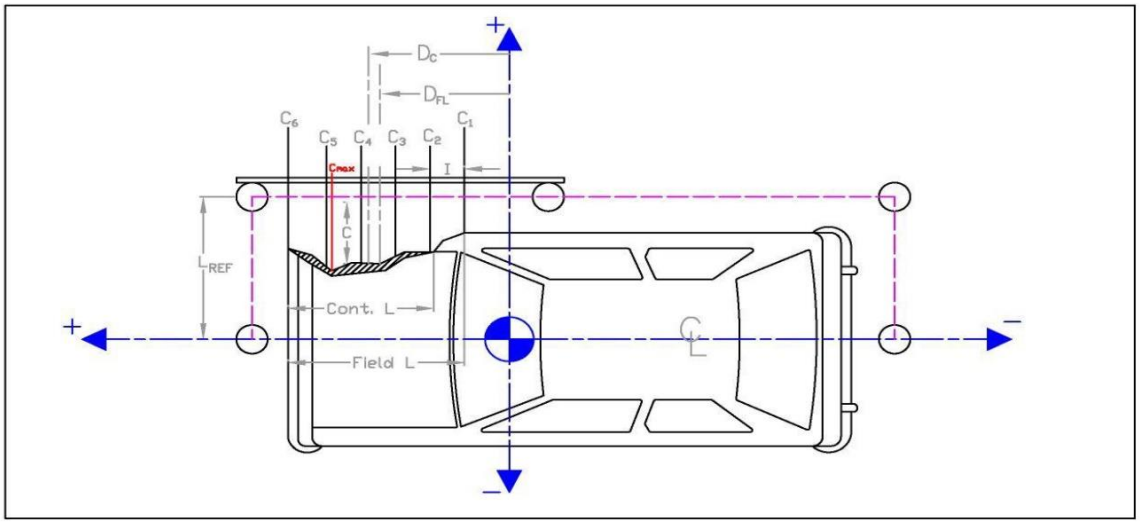
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

	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)	- 5/8	-(16)	NA	NA
C_2	7 1/8	(181)	-19 7/8	-(505)	6 7/8	(175)			7/8	(22)
C_3	6 1/4	(159)	-6 5/8	-(168)	4 3/8	(111)			2 1/2	(64)
C_4	7 1/2	(191)	6 5/8	(168)	4 1/2	(114)			3 5/8	(92)
C_5	11 1/4	(286)	19 7/8	(505)	6 3/4	(171)			5 1/8	(130)
C_6	N/a	NA	33 1/8	(841)	15 5/8	(397)			NA	NA
C_{MAX}	15 1/2	(394)	24	(610)	8 3/4	(222)			7 3/8	(187)

Figure F-27. Exterior Vehicle Crush (NASS) - Front, Test No. HBIB-4

Test Name: HBIB-4 VIN: KMHCT4AE0HU266110

Model Year: 2017 Make: Hyundai Model: Accent



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	44	(1118)
Total Vehicle Length:	172	(4369)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-15	-(381)
Width of contact and induced crush - Field L:	172	(4369)
Crush measurement spacing interval (L/5) - I:	34 3/8	(873)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-15	-(381)
Width of Contact Damage:	172	(4369)
Distance from vehicle c.g. to center of contact damage - D_C:	-15	-(381)

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	-101	-(2565)	41 1/4	(1048)	2 3/4	(70)	NA	NA
C_2	N/a	NA	-66 5/8	-(1692)	7	(178)			NA	NA
C_3	11 1/4	(286)	-32 1/4	-(819)	8 1/8	(206)			3/8	(10)
C_4	10 5/8	(270)	2 1/8	(54)	8 1/4	(210)			- 3/8	-(10)
C_5	N/a	NA	36 1/2	(927)	7	(178)			NA	NA
C_6	N/a	NA	70 7/8	(1800)	25 5/8	(651)			NA	NA
C_{MAX}	20 1/4	(514)	57 1/2	(1461)	9	(229)			8 1/2	(216)

Figure F-28. Exterior Vehicle Crush (NASS) - Side, Test No. HBIB-4

Model Year: 2018 Test Name: HBIB-5 Make: Dodge VIN: 1C6RR6FG2JS324827 Model: Ram 1500

VEHICLE DEFORMATION
PASSENGER 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	56.3983	35.3593	-8.0766	56.2891	35.5021	-7.9140	0.1092	-0.1428	-0.1626	0.2424	0.1092	X
	2	57.1825	38.2228	-6.8013	57.0587	38.3567	-6.5559	0.1238	-0.1339	-0.2454	0.3057	0.1238	X
	3	58.8200	41.2471	-3.9599	58.9497	41.3299	-3.7042	-0.1297	-0.0828	-0.2557	0.2984	0.0000	NA
	4	59.9967	45.8065	-3.3652	59.3170	45.8604	-3.5372	0.6797	-0.0539	0.1720	0.7032	0.7011	X, Z
	5	58.7994	52.6743	-5.0683	57.0534	51.9593	-6.5074	1.7460	0.7150	1.4391	2.3729	2.2626	X, Z
	6	53.3412	33.0925	-7.3804	53.2911	33.2287	-7.2879	0.0501	-0.1362	-0.0925	0.1721	0.0501	X
	7	54.2951	37.8347	-5.1760	54.2185	37.8684	-4.8776	0.0766	-0.0337	-0.2984	0.3099	0.0766	X
	8	55.8521	41.4355	-1.9793	55.8880	41.2456	-1.4576	-0.0359	0.1899	-0.5217	0.5563	0.0000	NA
	9	56.0756	46.3427	-1.2154	55.5823	46.0769	-1.3806	0.4933	0.2658	0.1652	0.5842	0.5202	X, Z
	10	56.3089	52.6819	-1.3014	54.8157	52.1745	-2.4907	1.4932	0.5074	1.1893	1.9752	1.9089	X, Z
FLOOR PAN (Z)	11	49.4458	32.6254	-5.3901	49.3875	32.8177	-5.3226	0.0583	-0.1923	-0.0675	0.2120	-0.0675	Z
	12	50.4581	37.5691	-2.4601	50.4321	37.6071	-2.1053	0.0260	-0.0380	-0.3548	0.3578	-0.3548	Z
	13	51.6953	41.5964	0.9835	51.6365	41.4011	1.4532	0.0588	0.1953	-0.4697	0.5121	-0.4697	Z
	14	51.8626	46.8828	1.0510	51.8110	46.6460	1.4575	0.0516	0.2368	-0.4065	0.4733	-0.4065	Z
	15	52.0614	53.2067	0.9290	51.7642	52.8366	0.8799	0.2972	0.3701	0.0491	0.4772	0.0491	Z
	16	44.3185	32.5144	-3.5933	44.1599	32.5207	-3.4839	0.1586	-0.0063	-0.1094	0.1928	-0.1094	Z
	17	46.1141	36.8342	1.4053	46.1368	36.7446	1.6732	-0.0227	0.0896	-0.2679	0.2834	-0.2679	Z
	18	46.3708	41.5347	1.5313	46.3435	41.4095	1.8853	0.0273	0.1252	-0.3540	0.3765	-0.3540	Z
	19	46.4614	47.3752	1.4714	46.4437	47.2092	1.9007	0.0177	0.1660	-0.4293	0.4606	-0.4293	Z
	20	46.2784	52.8985	1.4353	46.3289	52.7337	1.7342	-0.0505	0.1648	-0.2989	0.3450	-0.2989	Z
	21	38.9237	32.8405	-2.6301	38.8207	32.8373	-2.5494	0.1030	0.0032	-0.0807	0.1309	-0.0807	Z
	22	40.3566	36.4365	1.5381	40.2940	36.3107	1.7681	0.0626	0.1258	-0.2300	0.2695	-0.2300	Z
	23	40.3813	41.2723	1.4646	40.3023	41.0697	1.7604	0.0790	0.2026	-0.2958	0.3671	-0.2958	Z
	24	40.3836	47.8820	1.3834	40.3782	47.7199	1.7819	0.0054	0.1621	-0.3985	0.4302	-0.3985	Z
	25	40.4204	52.7913	1.3282	40.4148	52.6247	1.6236	0.0056	0.1666	-0.2954	0.3392	-0.2954	Z
	26	34.9714	32.9046	-2.5007	34.8945	32.9650	-2.3944	0.0769	-0.0604	-0.1063	0.1444	-0.1063	Z
	27	34.6616	35.4579	0.6938	34.5505	35.3313	0.9281	0.1111	0.1266	-0.2343	0.2886	-0.2343	Z
	28	34.7666	42.0727	0.5923	34.7598	41.8683	0.8184	0.0068	0.2044	-0.2261	0.3049	-0.2261	Z
	29	34.5057	46.4885	0.5223	34.5190	46.3826	0.7103	-0.0133	0.1059	-0.1880	0.2162	-0.1880	Z
	30	34.7239	51.3918	0.4628	34.7702	51.1831	0.5980	-0.0463	0.2087	-0.1352	0.2529	-0.1352	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 F-29. Floor Pan Deformation Data – Set 1, Test No. HBIB-5

Model Year: 2018 Test Name: HBIB-5 Make: Dodge VIN: 1C6RR6FG2JS324827 Model: Ram 1500

VEHICLE DEFORMATION
PASSENGER 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	54.0711	16.0419	-4.8094	54.0265	16.1682	-4.2765	0.0446	-0.1263	-0.5329	0.5495	0.0446	X
	2	54.8666	18.8953	-3.5185	54.7979	19.0164	-2.9059	0.0687	-0.1211	-0.6126	0.6282	0.0687	X
	3	56.5437	21.8968	-0.6761	56.7061	21.9773	-0.0530	-0.1624	-0.0805	-0.6231	0.6489	0.0000	NA
	4	57.7116	26.4551	-0.0550	57.0551	26.5082	0.1432	0.6565	-0.0531	-0.1982	0.6878	0.6565	X
	5	56.4529	33.3349	-1.6624	54.7325	32.6180	-2.7580	1.7204	0.7169	1.0956	2.1620	2.0396	X, Z
	6	51.0374	13.7540	-4.0805	51.0455	13.8768	-3.6349	-0.0081	-0.1228	-0.4456	0.4623	0.0000	NA
	7	52.0118	18.4771	-1.8439	51.9781	18.5030	-1.2009	0.0337	-0.0259	-0.6430	0.6444	0.0337	X
	8	53.6125	22.0509	1.3614	53.6692	21.8629	2.2256	-0.0567	0.1880	-0.8642	0.8862	0.0000	NA
	9	53.8290	26.9507	2.1731	53.3429	26.6921	2.3411	0.4861	0.2586	-0.1680	0.5757	0.4861	X
	10	54.0332	33.2915	2.1502	52.5372	32.7940	1.2839	1.4960	0.4975	0.8663	1.7989	1.7287	X, Z
FLOOR PAN (Z)	11	47.1820	13.2483	-2.0230	47.1651	13.4339	-1.6309	0.0169	-0.1856	-0.3921	0.4341	-0.3921	Z
	12	48.2274	18.1653	0.9400	48.2230	18.2045	1.6099	0.0044	-0.0392	-0.6699	0.6711	-0.6699	Z
	13	49.5112	22.1617	4.4026	49.4487	21.9780	5.1829	0.0625	0.1837	-0.7803	0.8041	-0.7803	Z
	14	49.6568	27.4477	4.5232	49.5998	27.2234	5.2237	0.0570	0.2243	-0.7005	0.7377	-0.7005	Z
	15	49.8258	33.7734	4.4647	49.5192	33.4178	4.6918	0.3066	0.3556	-0.2271	0.5216	-0.2271	Z
	16	42.0897	13.0951	-0.1322	41.9590	13.0998	0.2615	0.1307	-0.0047	-0.3937	0.4149	-0.3937	Z
	17	43.9596	17.3700	4.8777	43.9724	17.2951	5.4278	-0.0128	0.0749	-0.5501	0.5553	-0.5501	Z
	18	44.1982	22.0701	5.0488	44.1606	21.9592	5.6718	0.0376	0.1109	-0.6230	0.6339	-0.6230	Z
	19	44.2623	27.9112	5.0494	44.2351	27.7590	5.7284	0.0272	0.1522	-0.6790	0.6964	-0.6790	Z
	20	44.0547	33.4337	5.0754	44.0939	33.2840	5.6035	-0.0392	0.1497	-0.5281	0.5503	-0.5281	Z
	21	36.7124	13.3865	0.9348	36.6288	13.3854	1.2556	0.0836	0.0011	-0.3208	0.3315	-0.3208	Z
	22	38.2073	16.9448	5.1135	38.1329	16.8340	5.5823	0.0744	0.1108	-0.4688	0.4874	-0.4688	Z
	23	38.2097	21.7812	5.0910	38.1200	21.5929	5.6092	0.0897	0.1883	-0.5182	0.5586	-0.5182	Z
	24	38.1818	28.3913	5.0801	38.1665	28.2431	5.6784	0.0153	0.1482	-0.5983	0.6166	-0.5983	Z
	25	38.1962	33.3011	5.0764	38.1795	33.1490	5.5556	0.0167	0.1521	-0.4792	0.5030	-0.4792	Z
	26	32.7630	13.4313	1.1386	32.7039	13.4942	1.4535	0.0591	-0.0629	-0.3149	0.3265	-0.3149	Z
	27	32.5018	15.9494	4.3652	32.3852	15.8347	4.7967	0.1166	0.1147	-0.4315	0.4615	-0.4315	Z
	28	32.5762	22.5653	4.3321	32.5642	22.3733	4.7325	0.0120	0.1920	-0.4004	0.4442	-0.4004	Z
	29	32.2949	26.9804	4.3139	32.3021	26.8871	4.6600	-0.0072	0.0933	-0.3461	0.3585	-0.3461	Z
	30	32.4907	31.8849	4.3025	32.5307	31.6893	4.5801	-0.0400	0.1956	-0.2776	0.3419	-0.2776	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 F-30. Floor Pan Deformation Data – Set 2, Test No. HBIB-5

Model Year: 2018 Test Name: HBIB-5 Make: Dodge VIN: 1C6RR6FG2JS324827 Model: Ram 1500

VEHICLE DEFORMATION
PASSENGER 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	42.9337	23.6349	-30.3521	43.0412	23.9878	-30.3830	-0.1075	-0.3529	-0.0309	0.3702	0.3702	X, Y, Z
	2	46.0419	40.1252	-29.8890	46.0900	40.4103	-30.0238	-0.0481	-0.2851	-0.1348	0.3190	0.3190	X, Y, Z
	3	47.7462	51.3498	-30.6190	47.7912	51.6923	-30.9386	-0.0450	-0.3425	-0.3196	0.4706	0.4706	X, Y, Z
	4	40.1449	23.3343	-23.8597	40.2548	23.5946	-23.8571	-0.1099	-0.2603	0.0026	0.2826	0.2826	X, Y, Z
	5	42.0416	39.8401	-20.6223	42.1092	40.1233	-20.7706	-0.0676	-0.2832	-0.1483	0.3267	0.3267	X, Y, Z
	6	43.0039	53.1362	-20.0696	42.9563	53.5179	-20.5119	0.0476	-0.3817	-0.4423	0.5862	0.5862	X, Y, Z
SIDE PANEL (Y)	7	51.8739	55.7979	-8.6250	51.7181	55.6738	-8.9518	0.1558	0.1241	-0.3268	0.3827	0.1241	Y
	8	51.6585	55.8455	-3.4470	51.5102	55.6069	-3.7758	0.1483	0.2386	-0.3288	0.4325	0.2386	Y
	9	54.6801	55.7954	-6.4579	54.3542	55.5050	-6.8549	0.3259	0.2904	-0.3970	0.5900	0.2904	Y
IMPACT SIDE DOOR (Y)	10	20.6329	58.4252	-18.9412	20.4006	58.9595	-18.8456	0.2323	-0.5343	0.0956	0.5904	-0.5343	Y
	11	29.1066	58.3141	-18.5158	28.9119	58.6940	-18.4894	0.1947	-0.3799	0.0264	0.4277	-0.3799	Y
	12	37.3567	58.0662	-18.0922	37.1312	58.2931	-18.2061	0.2255	-0.2269	-0.1139	0.3396	-0.2269	Y
	13	20.8803	58.9932	-6.7751	20.7899	59.1391	-6.7129	0.0904	-0.1459	0.0622	0.1826	-0.1459	Y
	14	29.0973	58.6909	-6.1774	28.9498	58.6848	-6.1860	0.1475	0.0061	-0.0086	0.1479	0.0061	Y
	15	37.1987	59.4332	-6.4394	37.1195	59.3114	-6.5147	0.0792	0.1218	-0.0753	0.1636	0.1218	Y
ROOF - (Z)	16	39.2375	22.9451	-46.4183	39.2907	23.1270	-46.5030	-0.0532	-0.1819	-0.0847	0.2076	-0.0847	Z
	17	38.6244	33.6254	-46.3541	38.7585	33.8778	-46.4347	-0.1341	-0.2524	-0.0806	0.2970	-0.0806	Z
	18	36.1756	44.6878	-46.1644	36.2321	44.9393	-46.3193	-0.0565	-0.2515	-0.1549	0.3007	-0.1549	Z
	19	33.2650	22.9559	-49.1559	33.2745	23.2604	-49.2258	-0.0095	-0.3045	-0.0699	0.3126	-0.0699	Z
	20	32.4814	33.0641	-49.2063	32.5404	33.3125	-49.3060	-0.0590	-0.2484	-0.0997	0.2741	-0.0997	Z
	21	30.3015	44.0690	-48.9859	30.3227	44.3125	-49.1042	-0.0212	-0.2435	-0.1183	0.2715	-0.1183	Z
	22	12.6594	21.4488	-51.2346	12.7044	21.5669	-51.2497	-0.0450	-0.1181	-0.0151	0.1273	-0.0151	Z
	23	12.7428	30.0777	-51.2663	12.8150	30.2723	-51.2806	-0.0722	-0.1946	-0.0143	0.2081	-0.0143	Z
	24	12.6517	42.5734	-50.8598	12.6159	42.8302	-50.8723	0.0358	-0.2568	-0.0125	0.2596	-0.0125	Z
	25	-0.4426	22.9622	-51.6223	-0.3968	23.0598	-51.6012	-0.0458	-0.0976	0.0211	0.1099	0.0211	Z
	26	-0.5510	32.0368	-51.6403	-0.4652	32.1105	-51.5971	-0.0858	-0.0737	0.0432	0.1211	0.0432	Z
	27	-0.5695	42.8756	-51.3217	-0.5051	43.0258	-51.2502	-0.0644	-0.1502	0.0715	0.1784	0.0715	Z
	28	-17.4932	22.6308	-51.6278	-17.4844	22.6765	-51.5504	-0.0088	-0.0457	0.0774	0.0903	0.0774	Z
	29	-17.8147	31.1765	-51.6576	-17.7578	31.2457	-51.5590	-0.0569	-0.0692	0.0986	0.1332	0.0986	Z
	30	-17.3096	42.1234	-51.4520	-17.3130	42.2235	-51.3142	0.0034	-0.1001	0.1378	0.1704	0.1378	Z
A-PILLAR Maximum (X, Y, Z)	31	50.7624	53.8195	-33.1331	50.9447	54.1637	-33.4940	-0.1823	-0.3442	-0.3609	0.5310	0.0000	NA
	32	47.8653	53.3258	-35.3344	48.1231	53.5552	-35.6830	-0.2578	-0.2294	-0.3486	0.4905	0.0000	NA
	33	44.4779	52.3610	-37.8717	44.7563	52.6035	-38.1496	-0.2784	-0.2425	-0.2779	0.4621	0.0000	NA
	34	41.9312	51.5586	-39.8161	42.1483	51.7927	-40.0530	-0.2171	-0.2341	-0.2369	0.3976	0.0000	NA
	35	39.1105	51.4406	-42.3507	39.2231	51.6746	-42.5985	-0.1126	-0.2340	-0.2478	0.3589	0.0000	NA
	36	35.7539	50.5158	-44.0124	35.8857	50.7600	-44.2755	-0.1318	-0.2442	-0.2631	0.3824	0.0000	NA
A-PILLAR Lateral (Y)	31	50.7624	53.8195	-33.1331	50.9447	54.1637	-33.4940	-0.1823	-0.3442	-0.3609	0.5310	-0.3442	Y
	32	47.8653	53.3258	-35.3344	48.1231	53.5552	-35.6830	-0.2578	-0.2294	-0.3486	0.4905	-0.2294	Y
	33	44.4779	52.3610	-37.8717	44.7563	52.6035	-38.1496	-0.2784	-0.2425	-0.2779	0.4621	-0.2425	Y
	34	41.9312	51.5586	-39.8161	42.1483	51.7927	-40.0530	-0.2171	-0.2341	-0.2369	0.3976	-0.2341	Y
	35	39.1105	51.4406	-42.3507	39.2231	51.6746	-42.5985	-0.1126	-0.2340	-0.2478	0.3589	-0.2340	Y
	36	35.7539	50.5158	-44.0124	35.8857	50.7600	-44.2755	-0.1318	-0.2442	-0.2631	0.3824	-0.2442	Y
B-PILLAR Maximum (X, Y, Z)	37	11.3997	50.1708	-46.2072	11.4798	50.3835	-46.1947	-0.0801	-0.2127	0.0125	0.2276	0.0125	Z
	38	8.3235	52.0835	-41.2104	8.4073	52.2866	-41.1535	-0.0838	-0.2031	0.0569	0.2270	0.0569	Z
	39	11.3417	53.1109	-38.4961	11.4238	53.3374	-38.4433	-0.0821	-0.2265	0.0528	0.2466	0.0528	Z
	40	8.7873	54.6856	-33.3399	8.8922	54.8739	-33.2286	-0.1049	-0.1883	0.1113	0.2426	0.1113	Z
B-PILLAR Lateral (Y)	37	11.3997	50.1708	-46.2072	11.4798	50.3835	-46.1947	-0.0801	-0.2127	0.0125	0.2276	-0.2127	Y
	38	8.3235	52.0835	-41.2104	8.4073	52.2866	-41.1535	-0.0838	-0.2031	0.0569	0.2270	-0.2031	Y
	39	11.3417	53.1109	-38.4961	11.4238	53.3374	-38.4433	-0.0821	-0.2265	0.0528	0.2466	-0.2265	Y
	40	8.7873	54.6856	-33.3399	8.8922	54.8739	-33.2286	-0.1049	-0.1883	0.1113	0.2426	-0.1883	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 F-31. Occupant Compartment Deformation Data – Set 1, Test No. HBIB-5

Model Year: 2018 Test Name: HBIB-5 Make: Dodge VIN: 1C6RR6FG2JS324827 Model: Ram 1500

VEHICLE DEFORMATION
PASSENGER 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	40.2631	4.6057	-26.9636	40.5695	4.7617	-26.7113	-0.3064	-0.1560	0.2523	0.4265	0.4265	X, Y, Z
	2	43.2505	21.1144	-26.3783	43.5397	21.1967	-26.2739	-0.2892	-0.0823	0.1044	0.3183	0.3183	X, Y, Z
	3	44.8524	32.3596	-27.0168	45.1741	32.4931	-27.1307	-0.3217	-0.1335	-0.1139	0.3665	0.3665	X, Y, Z
	4	37.6027	4.2120	-20.4225	37.8568	4.3104	-20.1582	-0.2541	-0.0984	0.2643	0.3796	0.3796	X, Y, Z
	5	39.4323	20.6962	-17.0400	39.6621	20.8272	-16.9799	-0.2298	-0.1310	0.0601	0.2713	0.2713	X, Y, Z
	6	40.3010	33.9928	-16.3591	40.4449	34.2238	-16.6395	-0.1439	-0.2310	-0.2804	0.3908	0.3908	X, Y, Z
SIDE PANEL (Y)	7	49.3693	36.6009	-5.0585	49.3220	36.3464	-5.1617	0.0473	0.2545	-0.1032	0.2787	0.2545	Y
	8	49.2536	36.5904	0.1228	49.1713	36.2436	0.0157	0.0823	0.3468	-0.1071	0.3722	0.3468	Y
	9	52.2168	36.5974	-2.9460	51.9818	36.1769	-3.0949	0.2350	0.4205	-0.1489	0.5042	0.4205	Y
IMPACT SIDE DOOR (Y)	10	17.9152	39.0892	-14.7422	17.8818	39.5393	-14.6898	0.0334	-0.4501	0.0524	0.4544	-0.4501	Y
	11	26.3961	39.0415	-14.4812	26.3977	39.3147	-14.4285	-0.0016	-0.2732	0.0527	0.2782	-0.2732	Y
	12	34.6546	38.8554	-14.2191	34.6215	38.9537	-14.2378	0.0331	-0.0983	-0.0187	0.1054	-0.0983	Y
	13	18.3932	39.5265	-2.5776	18.4033	39.6392	-2.5610	-0.0101	-0.1127	0.0166	0.1144	-0.1127	Y
	14	26.6224	39.2838	-2.1415	26.5707	39.2229	-2.1266	0.0517	0.0609	0.0149	0.0813	0.0609	Y
	15	34.7111	40.0941	-2.5510	34.7330	39.8932	-2.5404	-0.0219	0.2009	0.0106	0.2024	0.2009	Y
ROOF - (Z)	16	36.2627	4.0613	-42.9624	36.6467	3.9904	-42.7948	-0.3840	0.0709	0.1676	0.4249	0.1676	Z
	17	35.5673	14.7350	-42.7684	36.0614	14.7377	-42.6477	-0.4941	-0.0027	0.1207	0.5086	0.1207	Z
	18	33.0361	25.7745	-42.4095	33.4809	25.7851	-42.4296	-0.4448	-0.0106	-0.0201	0.4454	-0.0201	Z
	19	30.2385	4.0539	-45.5843	30.6004	4.1115	-45.4507	-0.3619	-0.0576	0.1336	0.3900	0.1336	Z
	20	29.3750	14.1554	-45.5080	29.8150	14.1601	-45.4545	-0.4400	-0.0047	0.0535	0.4433	0.0535	Z
	21	27.1137	25.1393	-45.1241	27.5446	25.1471	-45.1538	-0.4309	-0.0078	-0.0297	0.4320	-0.0297	Z
	22	9.6090	2.4038	-47.2828	10.0180	2.3271	-47.2609	-0.4090	0.0767	0.0219	0.4167	0.0219	Z
	23	9.6243	11.0329	-47.2208	10.0846	11.0329	-47.2339	-0.4603	0.0000	-0.0131	0.4605	-0.0131	Z
	24	9.4431	23.5223	-46.6746	9.8270	23.5867	-46.7382	-0.3839	-0.0644	-0.0636	0.3944	-0.0636	Z
	25	-3.5095	3.8159	-47.4017	-3.0936	3.7556	-47.4589	-0.4159	0.0603	-0.0572	0.4241	-0.0572	Z
	26	-3.6893	12.8890	-47.3173	-3.2072	12.8057	-47.3926	-0.4821	0.0833	-0.0753	0.4950	-0.0753	Z
	27	-3.7865	23.7232	-46.8787	-3.2981	23.7180	-46.9712	-0.4884	0.0052	-0.0925	0.4971	-0.0925	Z
	28	-20.5539	3.3475	-47.0829	-20.1774	3.2851	-47.2238	-0.3765	0.0624	-0.1409	0.4068	-0.1409	Z
	29	-20.9428	11.8901	-47.0121	-20.4938	11.8527	-47.1712	-0.4490	0.0374	-0.1591	0.4778	-0.1591	Z
	30	-20.5196	22.8379	-46.6953	-20.1015	22.8307	-46.8568	-0.4181	0.0072	-0.1615	0.4483	-0.1615	Z
A-PILLAR Maximum (X, Y, Z)	31	47.8000	34.8807	-29.5611	48.2870	34.9978	-29.7036	-0.4870	-0.1171	-0.1425	0.5208	0.0000	NA
	32	44.8649	34.3878	-31.7115	45.4446	34.3896	-31.8657	-0.5797	-0.0018	-0.1542	0.5999	0.0000	NA
	33	41.4367	33.4234	-34.1938	42.0558	33.4374	-34.3017	-0.6191	-0.0140	-0.1079	0.6286	0.0000	NA
	34	38.8594	32.6219	-36.0976	39.4311	32.6262	-36.1820	-0.5717	-0.0043	-0.0844	0.5779	0.0000	NA
	35	35.9912	32.5088	-38.5785	36.4788	32.5103	-38.6960	-0.4876	-0.0015	-0.1175	0.5016	0.0000	NA
	36	32.6105	31.5752	-40.1855	33.1278	31.5902	-40.3426	-0.5173	-0.0150	-0.1571	0.5408	0.0000	NA
A-PILLAR Lateral (Y)	31	47.8000	34.8807	-29.5611	48.2870	34.9978	-29.7036	-0.4870	-0.1171	-0.1425	0.5208	-0.1171	Y
	32	44.8649	34.3878	-31.7115	45.4446	34.3896	-31.8657	-0.5797	-0.0018	-0.1542	0.5999	-0.0018	Y
	33	41.4367	33.4234	-34.1938	42.0558	33.4374	-34.3017	-0.6191	-0.0140	-0.1079	0.6286	-0.0140	Y
	34	38.8594	32.6219	-36.0976	39.4311	32.6262	-36.1820	-0.5717	-0.0043	-0.0844	0.5779	-0.0043	Y
	35	35.9912	32.5088	-38.5785	36.4788	32.5103	-38.6960	-0.4876	-0.0015	-0.1175	0.5016	-0.0015	Y
	36	32.6105	31.5752	-40.1855	33.1278	31.5902	-40.3426	-0.5173	-0.0150	-0.1571	0.5408	-0.0150	Y
B-PILLAR Maximum (X, Y, Z)	37	8.2218	31.0583	-41.9151	8.7045	31.1024	-41.9972	-0.4827	-0.0441	-0.0821	0.4916	0.0000	NA
	38	5.2279	32.8916	-36.8393	5.6780	32.9558	-36.9099	-0.4501	-0.0642	-0.0706	0.4601	0.0000	NA
	39	8.2898	33.9137	-34.1723	8.7188	34.0037	-34.2258	-0.4290	-0.0900	-0.0535	0.4416	0.0000	NA
	40	5.8233	35.4115	-28.9509	6.2368	35.4922	-28.9734	-0.4135	-0.0807	-0.0225	0.4219	0.0000	NA
B-PILLAR Lateral (Y)	37	8.2218	31.0583	-41.9151	8.7045	31.1024	-41.9972	-0.4827	-0.0441	-0.0821	0.4916	-0.0441	Y
	38	5.2279	32.8916	-36.8393	5.6780	32.9558	-36.9099	-0.4501	-0.0642	-0.0706	0.4601	-0.0642	Y
	39	8.2898	33.9137	-34.1723	8.7188	34.0037	-34.2258	-0.4290	-0.0900	-0.0535	0.4416	-0.0900	Y
	40	5.8233	35.4115	-28.9509	6.2368	35.4922	-28.9734	-0.4135	-0.0807	-0.0225	0.4219	-0.0807	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 F-32. Occupant Compartment Deformation Data – Set 2, Test No. HBIB-5

Test Name: HBIB-5 VIN: 1C6RR6FG2JS324827

Model Year: 2018 Make: Dodge Model: Ram 1500

Passenger 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	0.1	≤ 4	Z	Roof	0.2	≤ 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	-0.3	≤ 3	Y	A-Pillar Lateral	-0.1	≤ 3	Y
B-Pillar Maximum	0.1	≤ 5	Z	B-Pillar Maximum	0.0	≤ 5	NA
B-Pillar Lateral	-0.2	≤ 3	Y	B-Pillar Lateral	-0.1	≤ 3	Y
Toe Pan - Wheel Well	2.3	≤ 9	X, Z	Toe Pan - Wheel Well	2.0	≤ 9	X, Z
Side Front Panel	0.3	≤ 12	Y	Side Front Panel	0.4	≤ 12	Y
Side Door (above seat)	-0.5	≤ 9	Y	Side Door (above seat)	-0.5	≤ 9	Y
Side Door (below seat)	0.1	≤ 12	Y	Side Door (below seat)	0.2	≤ 12	Y
Floor Pan	0.0	≤ 12	Z	Floor Pan	-0.8	≤ 12	Z
Dash - no MASH requirement	0.6	NA	X, Y, Z	Dash - no MASH requirement	0.4	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.

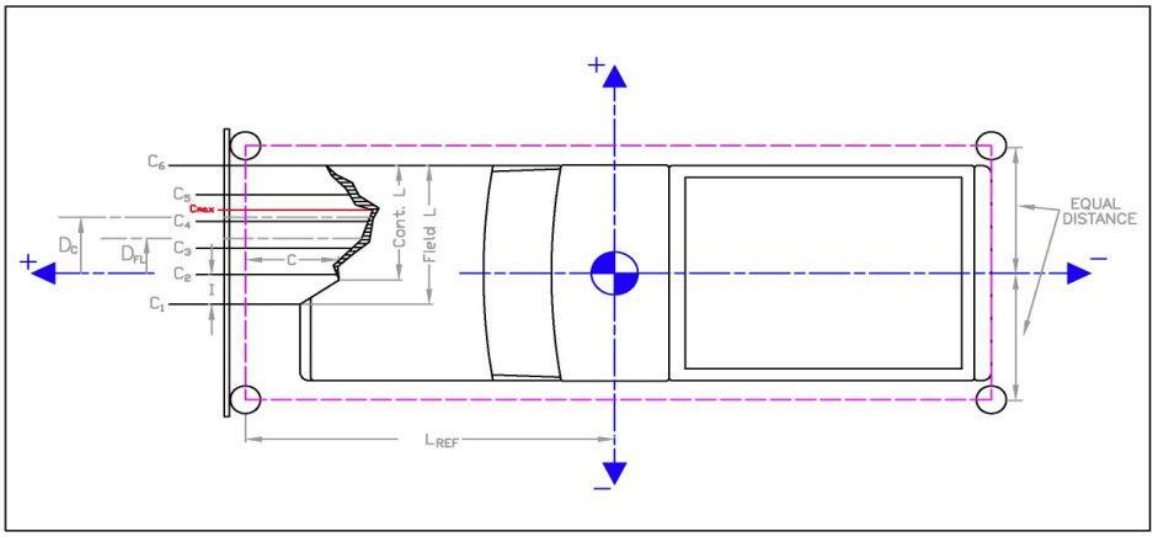
[D] If deformation is observered for the windshield then the windshield deformation is measured posttest with an examplar vehicle, therefore only one set of reference is measured and recorded.

Notes on vehicle interior crush:

Figure F-33. Maximum Occupant Compartment Deformations by Location, Test No. HBIB-5

Test Name: HBIB-5 VIN: 1C6RR6FG2JS324827

Model Year: 2018 Make: Dodge Model: Ram 1500



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	118	(2997)
Total Vehicle Width:	76 3/4	(1949)
Width of contact and induced crush - Field L:	38 3/8	(975)
Crush measurement spacing interval (L/5) - I:	7 5/8	(194)
Distance from center of vehicle to center of Field L - D_{FL}:	19 1/5	(487)
Width of Contact Damage:	25 3/8	(645)
Distance from center of vehicle to center of contact damage - D_C:	26 2/3	(678)

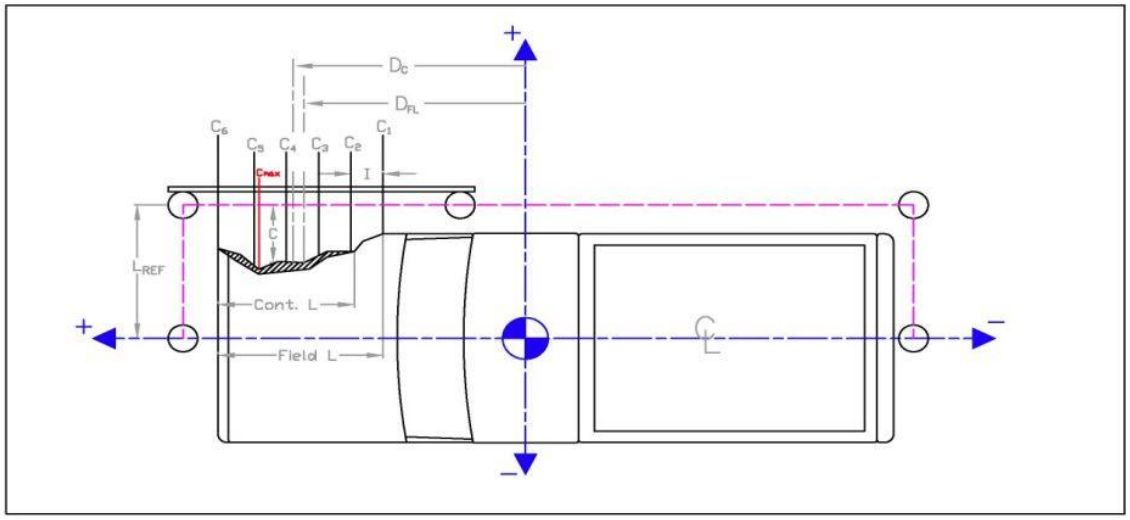
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

	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	11	(279)	0	()	4	(102)	8 3/4	(222)	-1 3/4	-(44)
C_2	11 7/8	(302)	7 5/8	(194)	4 1/4	(108)			-1 1/8	-(29)
C_3	16 5/8	(422)	15 1/4	(387)	4 7/8	(124)			3	(76)
C_4	27 3/4	(705)	22 7/8	(581)	6 1/8	(156)			12 7/8	(327)
C_5	N/A	N/A	30 1/2	(775)	9 5/8	(244)			N/A	N/A
C_6	N/A	N/A	38 1/8	(968)	20 1/2	(521)			N/A	N/A
C_{MAX}	27 3/4	(705)	22 7/8	(581)	6 1/8	(156)			12 7/8	(327)

Figure F-34. Exterior Vehicle Crush (NASS) - Front, Test No. HBIB-5

Test Name: HBIB-5 VIN: 1C6RR6FG2JS324827

Model Year: 2018 Make: Dodge Model: Ram 1500



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	48	(1219)
Total Vehicle Length:	229 1/4	(5823)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-9 1/2	-(241)
Width of contact and induced crush - Field L:	229 1/4	(5823)
Crush measurement spacing interval (L/5) - I:	45 7/8	(1165)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-9 1/2	-(241)
Width of Contact Damage:	228 1/4	(5798)
Distance from vehicle c.g. to center of contact damage - D_C:	-9 1/2	-(241)

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	-124 1/8	-(3153)	33 1/2	(851)	4	(102)	N/A	N/A
C_2	N/a	N/A	-78 1/4	-(1988)	5 1/2	(140)			N/A	N/A
C_3	9 1/2	(241)	-32 3/8	-(822)	5 3/4	(146)			- 1/4	-(6)
C_4	9 3/4	(248)	13 1/2	(343)	5	(127)			3/4	(19)
C_5	N/a	N/A	59 3/8	(1508)	5 5/8	(143)			N/A	N/A
C_6	N/a	N/A	105 1/4	(2673)	9 1/4	(235)			N/A	N/A
C_{MAX}	26 1/2	(673)	86	(2184)	5 3/8	(137)			17 1/8	(435)

Figure F-35. Exterior Vehicle Crush (NASS) - Side, Test No. HBIB-5

Appendix G. Accelerometer and Rate Transducer Data Plots, Test No. HBIB-1

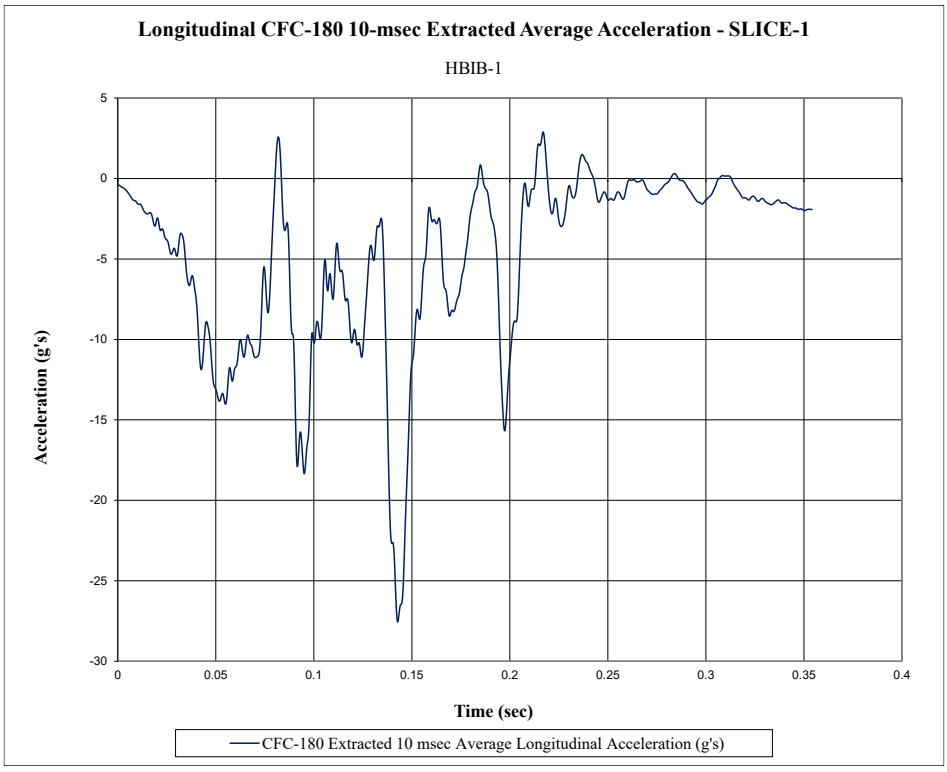


Figure G-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. HBIB-1

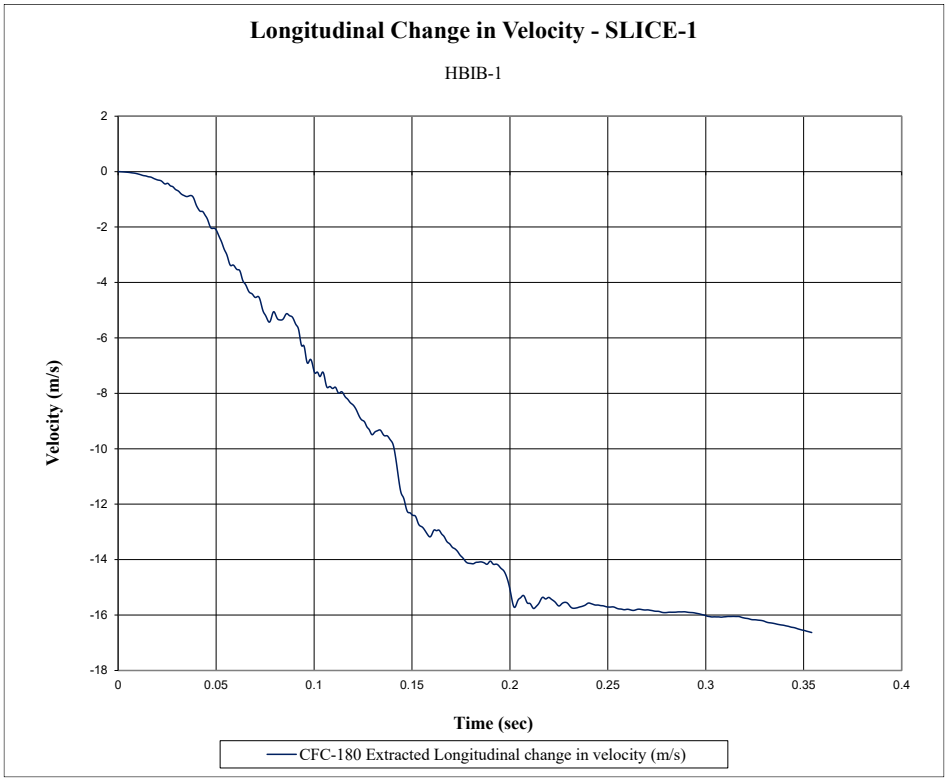


Figure G-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. HBIB-1

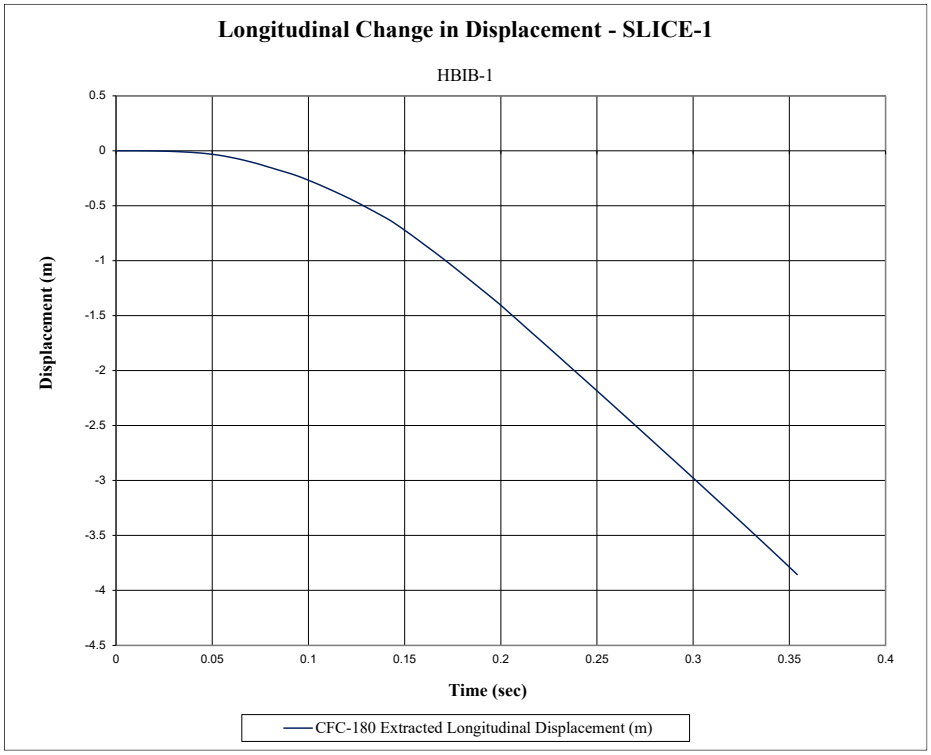


Figure G-3. Longitudinal Occupant Displacement (SLICE-1), Test No. HBIB-1

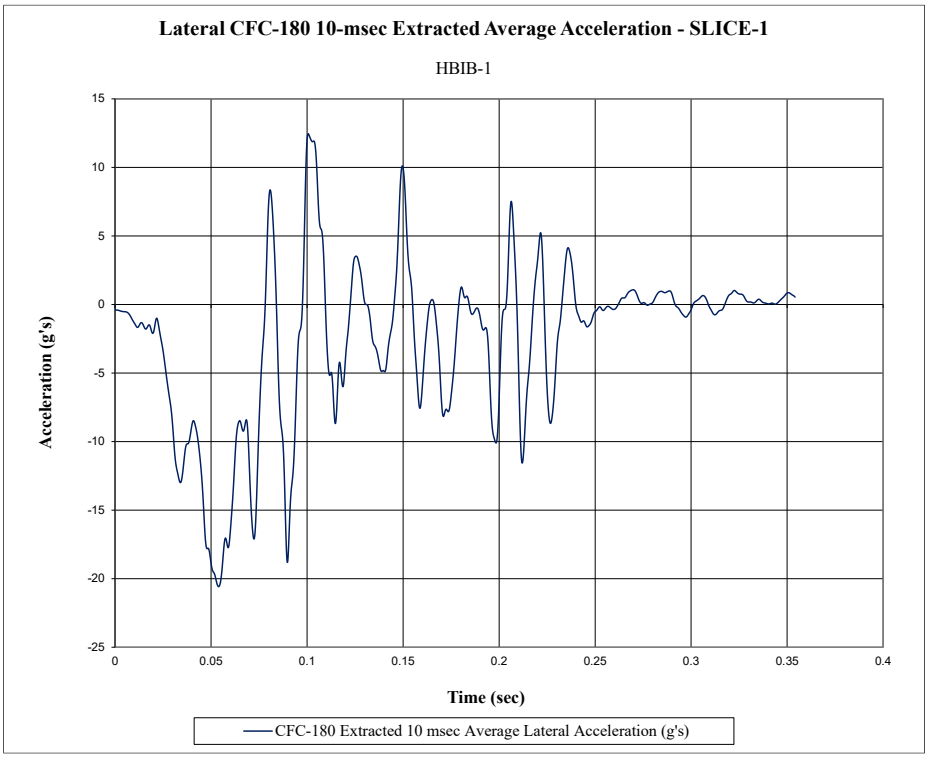


Figure G-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. HBIB-1

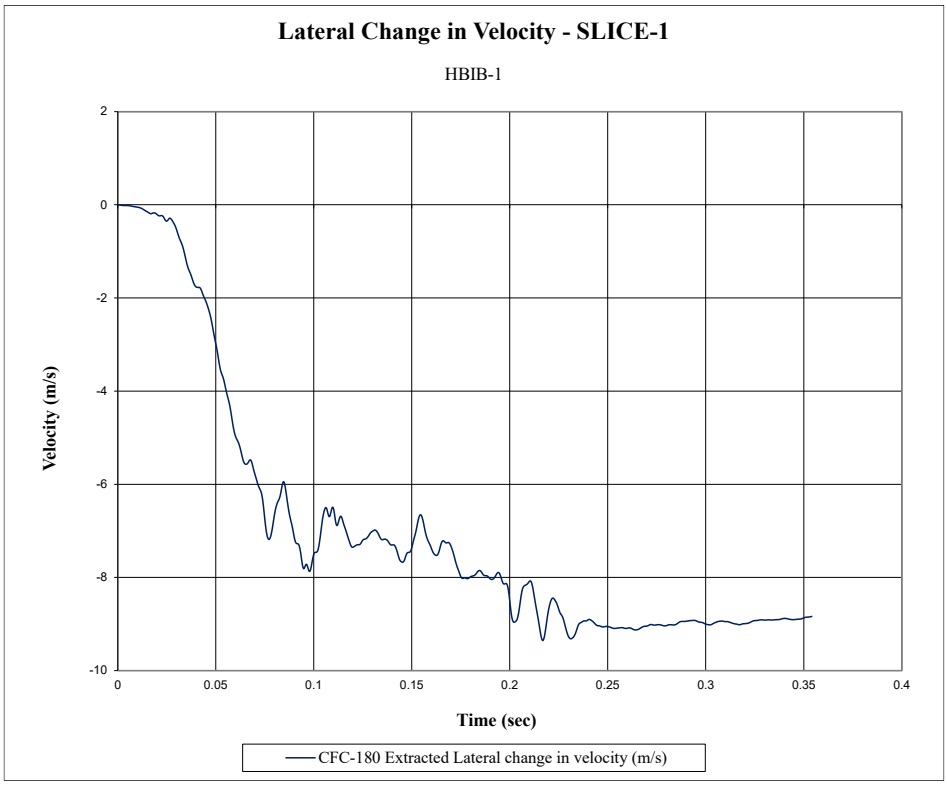


Figure G-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. HBIB-1

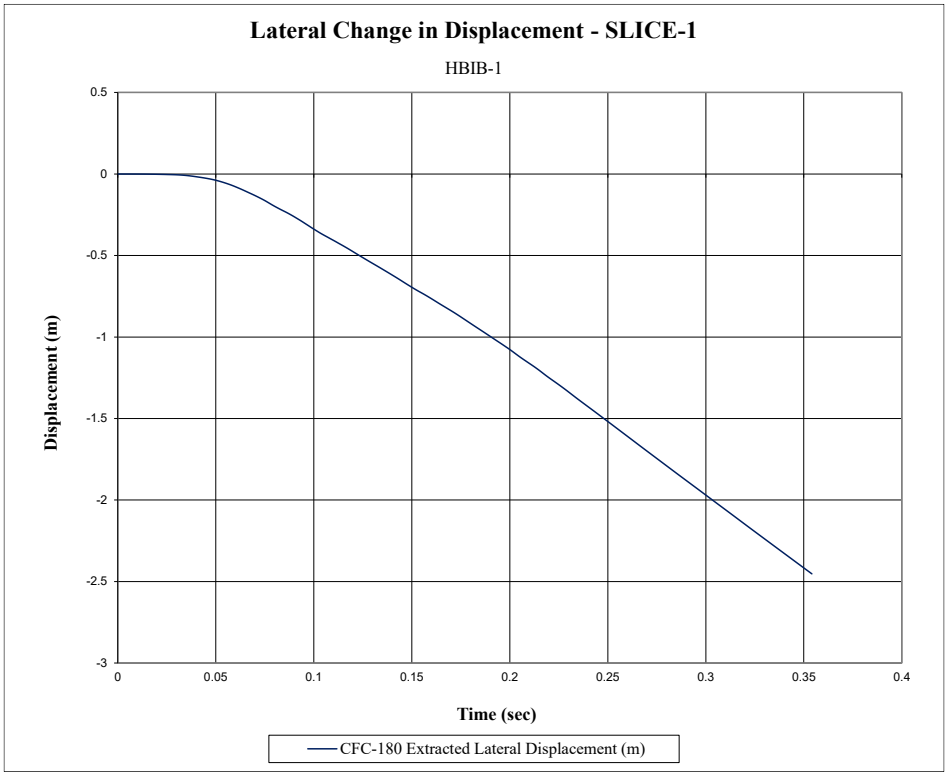


Figure G-6. Lateral Occupant Displacement (SLICE-1), Test No. HBIB-1

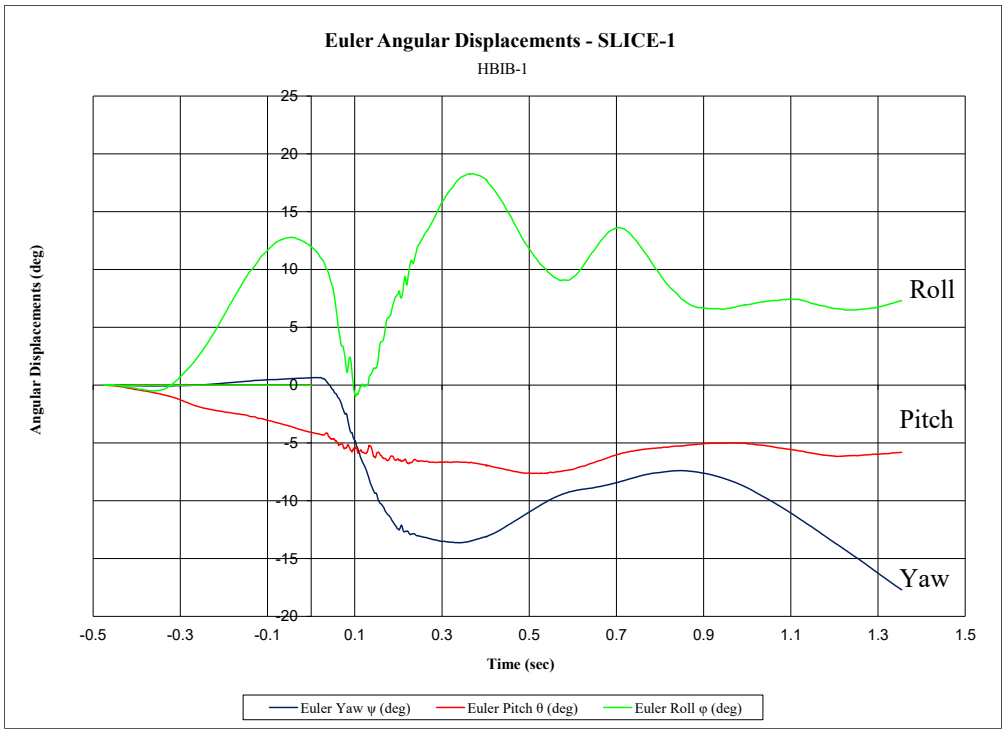


Figure G-7. Vehicle Angular Displacements (SLICE-1), Test No. HBIB-1

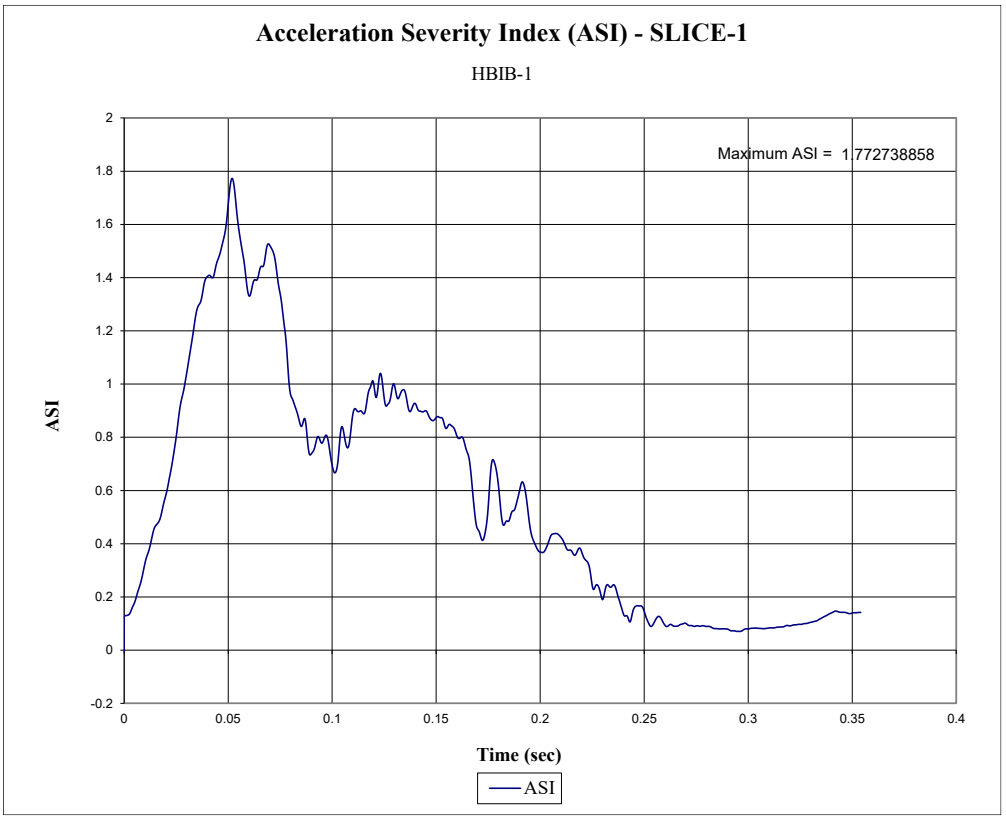


Figure G-8. Acceleration Severity Index (SLICE-1), Test No. HBIB-1

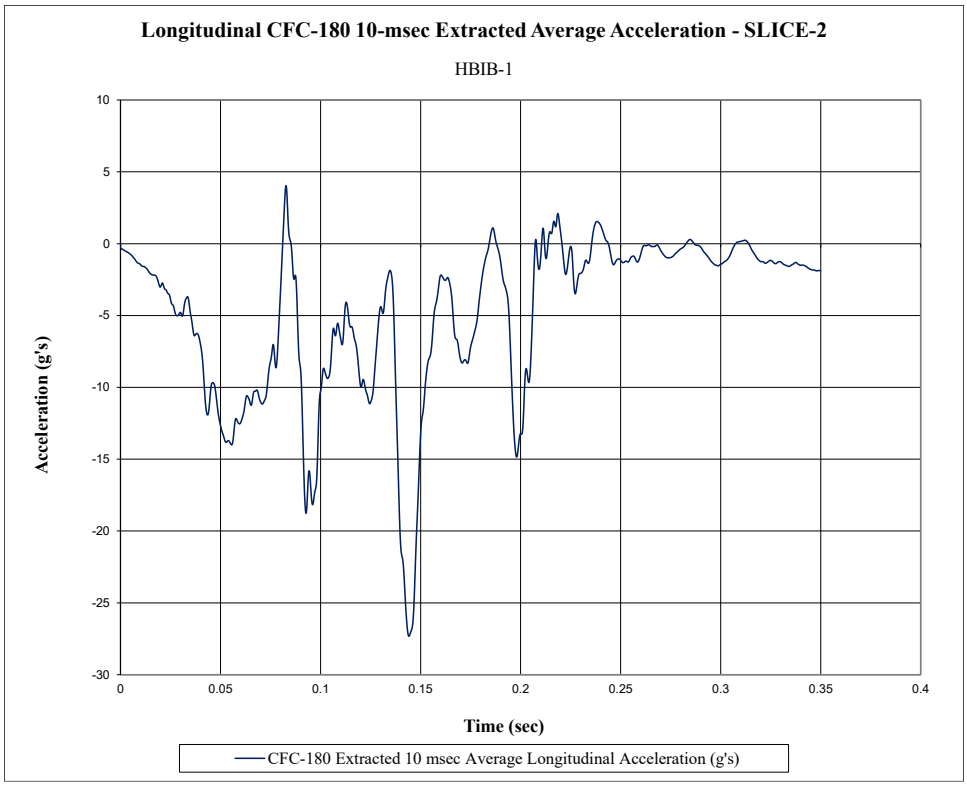


Figure G-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. HBIB-1

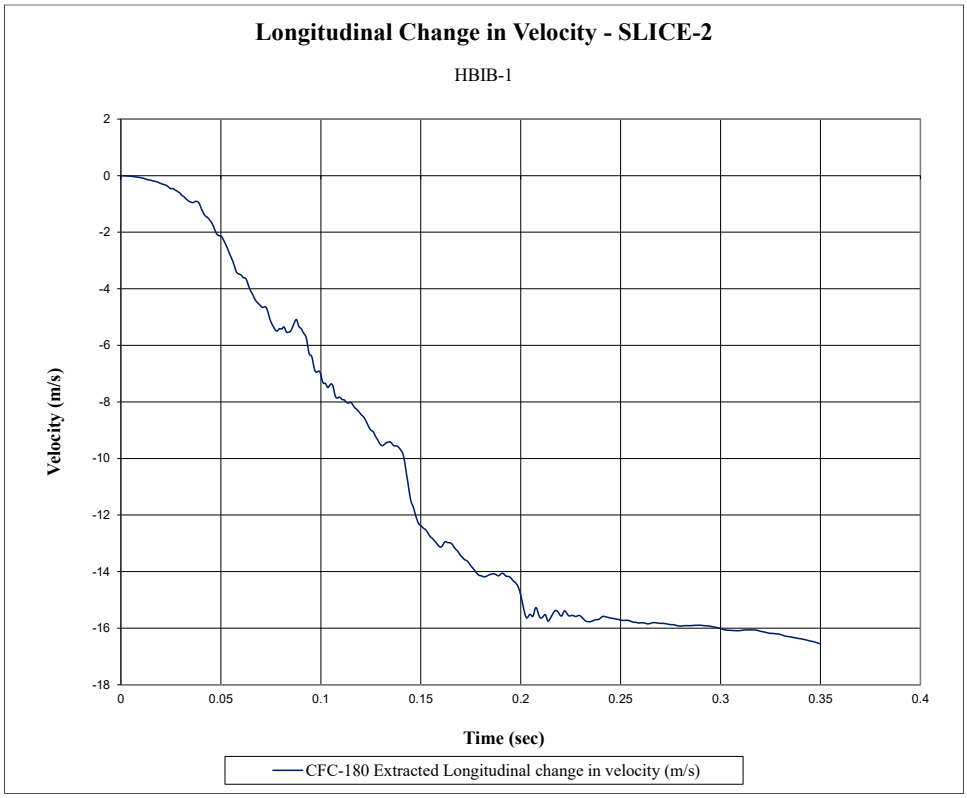


Figure G-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. HBIB-1

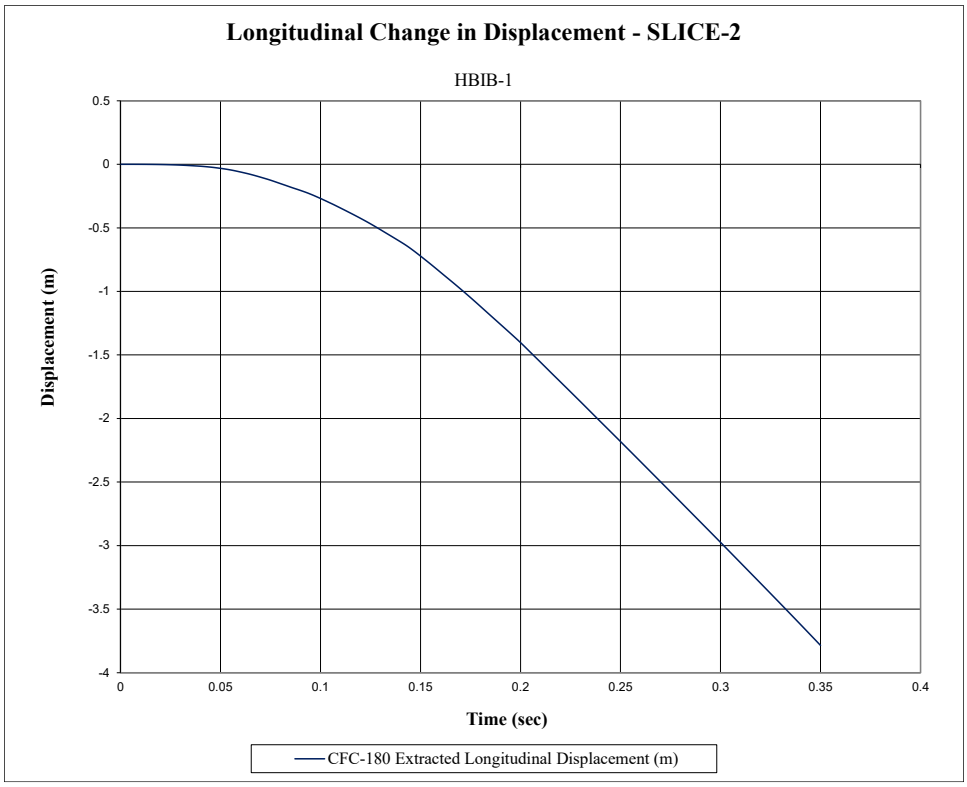


Figure G-11. Longitudinal Occupant Displacement (SLICE-2), Test No. HBIB-1

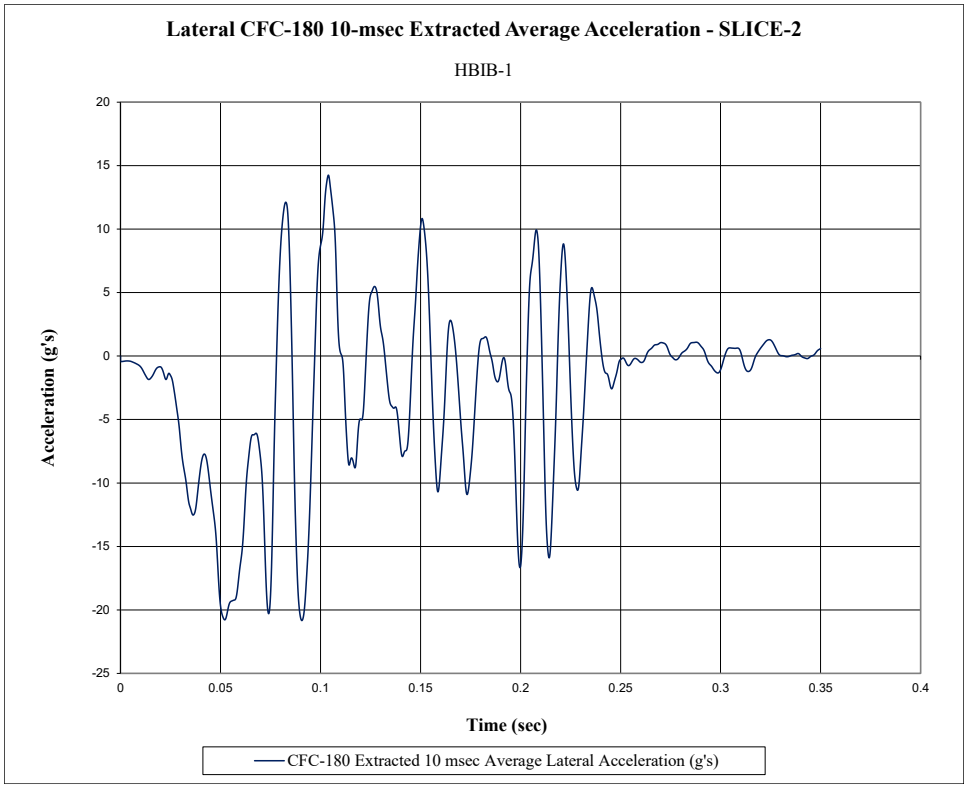


Figure G-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. HBIB-1

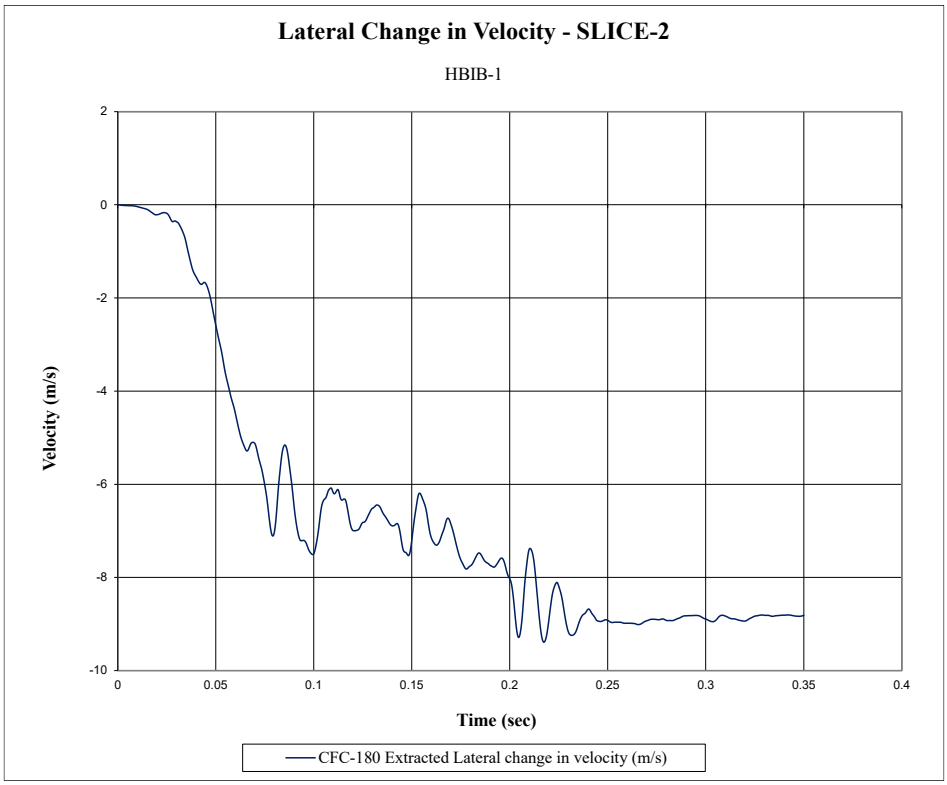


Figure G-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. HBIB-1

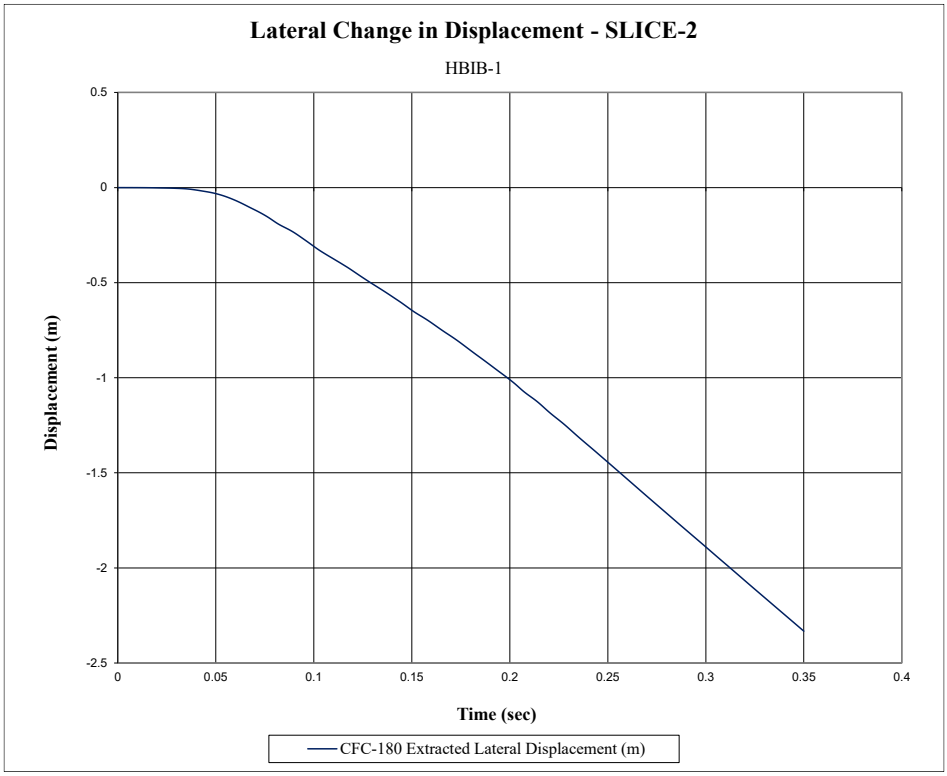


Figure G-14. Lateral Occupant Displacement (SLICE-2), Test No. HBIB-1

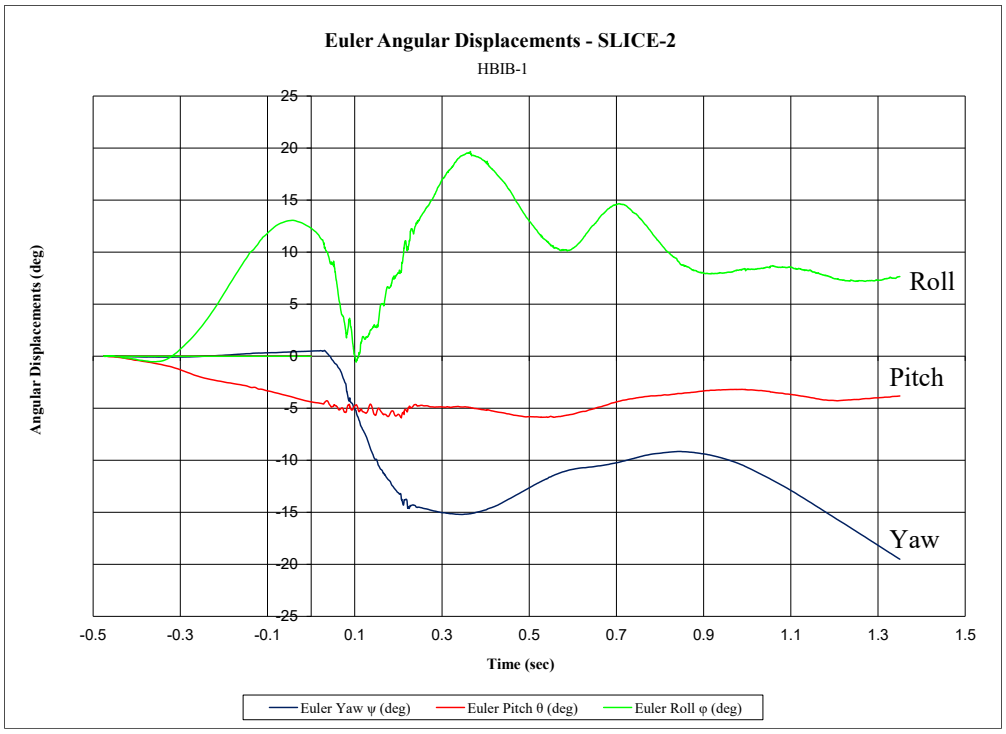


Figure G-15. Vehicle Angular Displacements (SLICE-2), Test No. HBIB-1

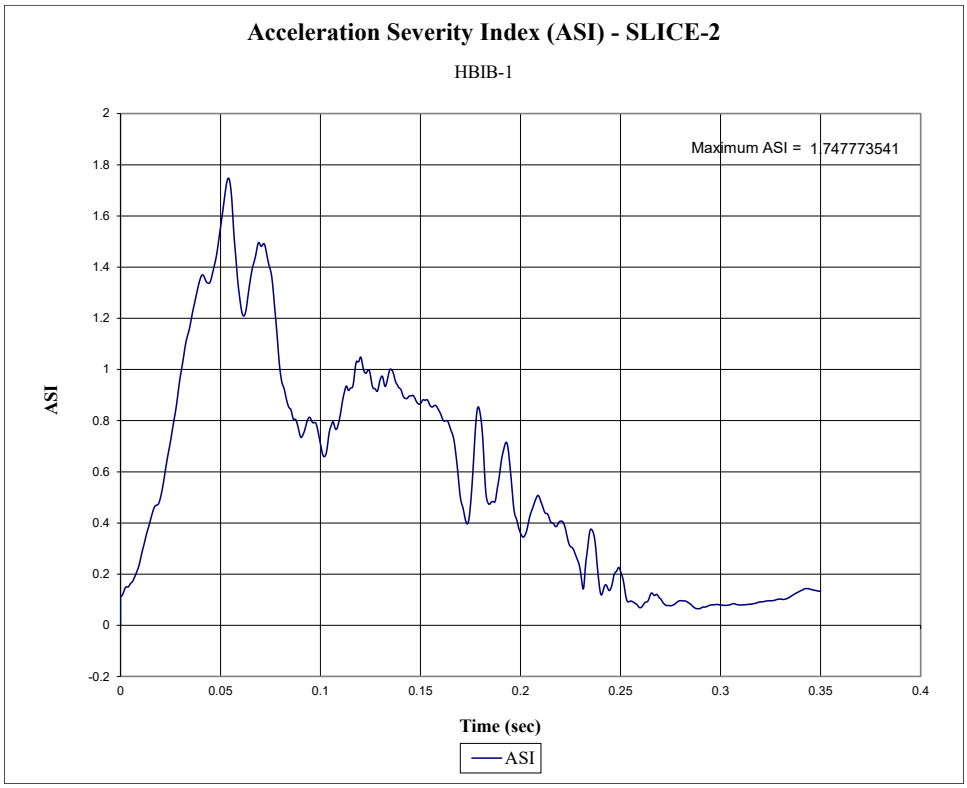


Figure G-16. Acceleration Severity Index (SLICE-2), Test No. HBIB-1

Appendix H. Accelerometer and Rate Transducer Data Plots, Test No. HBIB-2

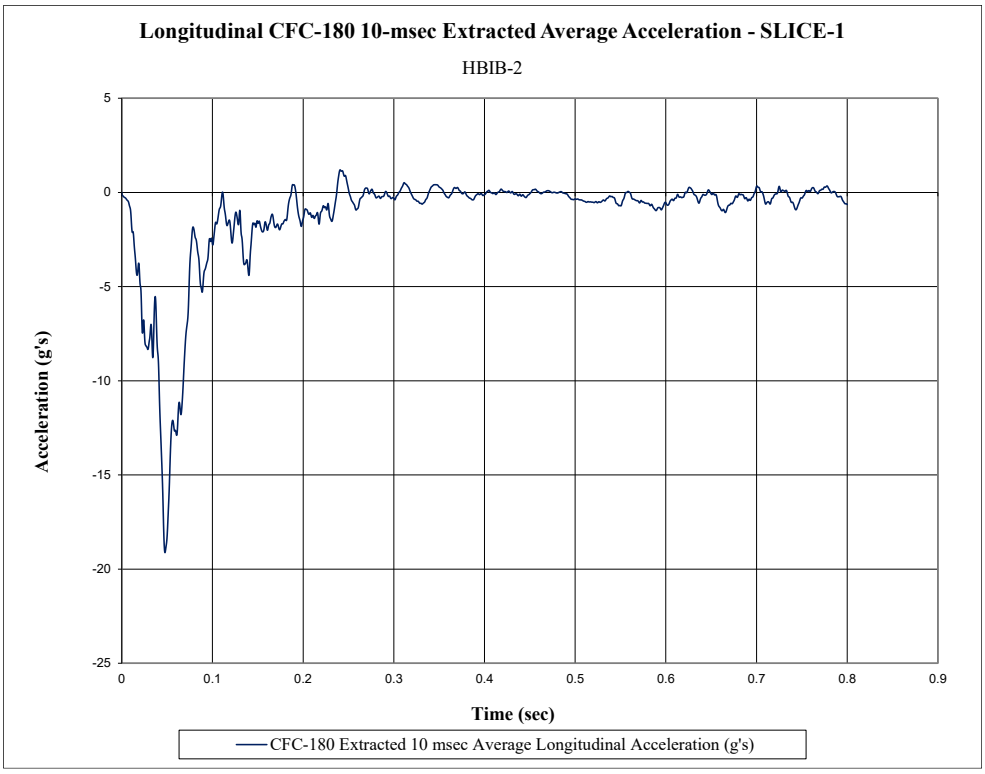


Figure H-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. HBIB-2

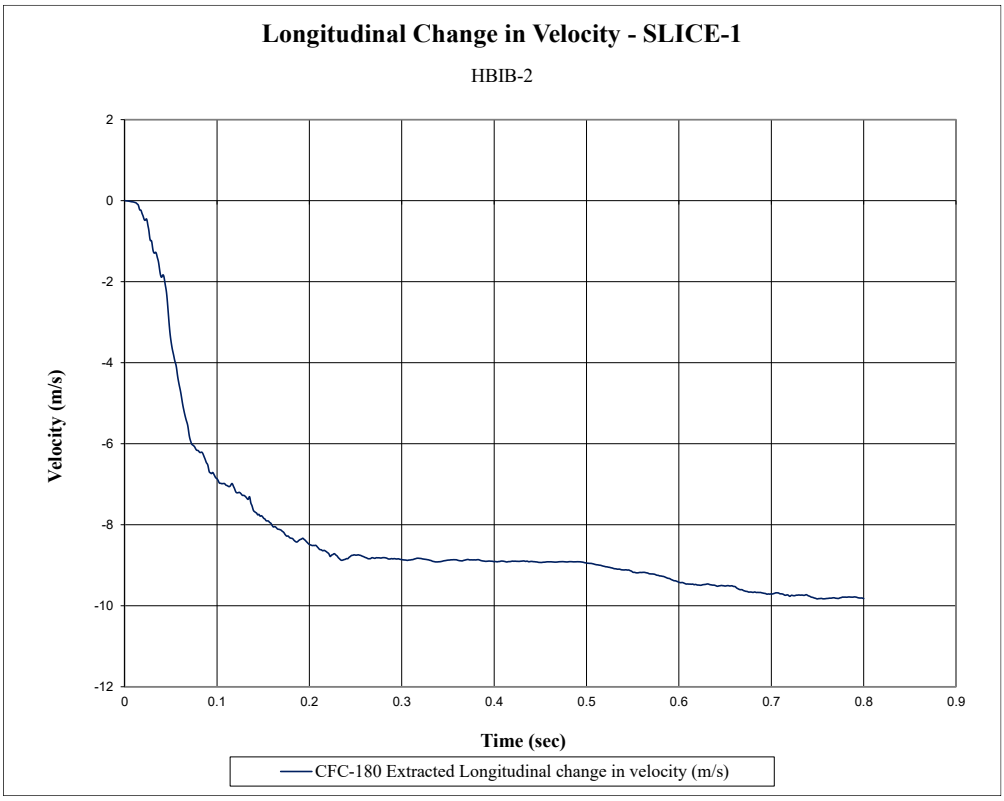


Figure H-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. HBIB-2

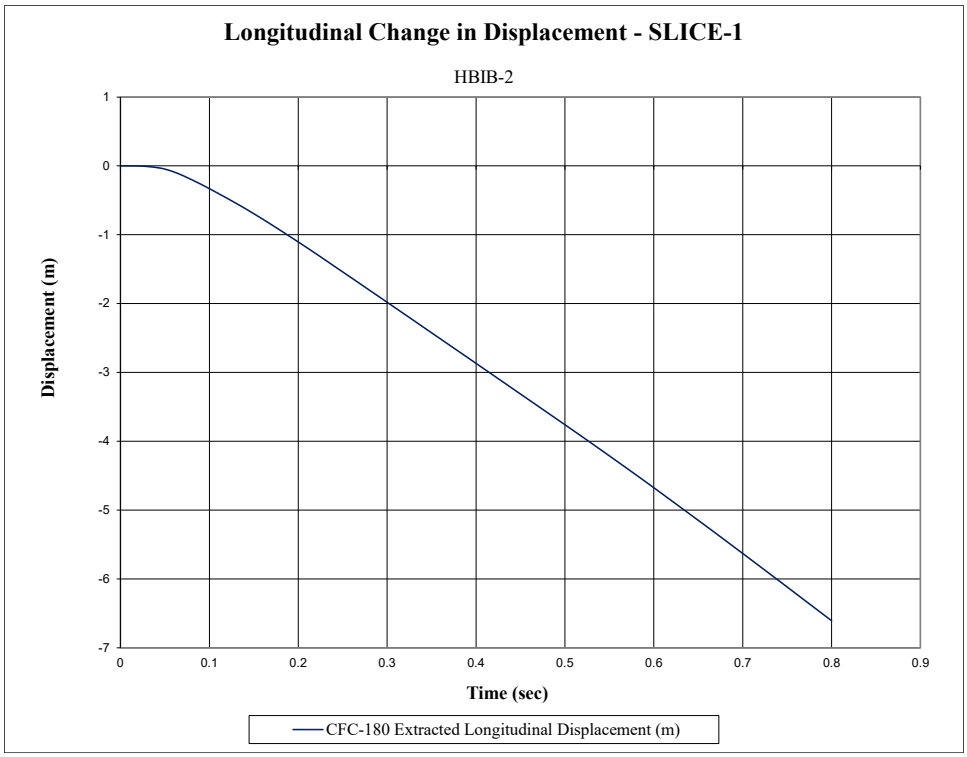


Figure H-3. Longitudinal Occupant Displacement (SLICE-1), Test No. HBIB-2

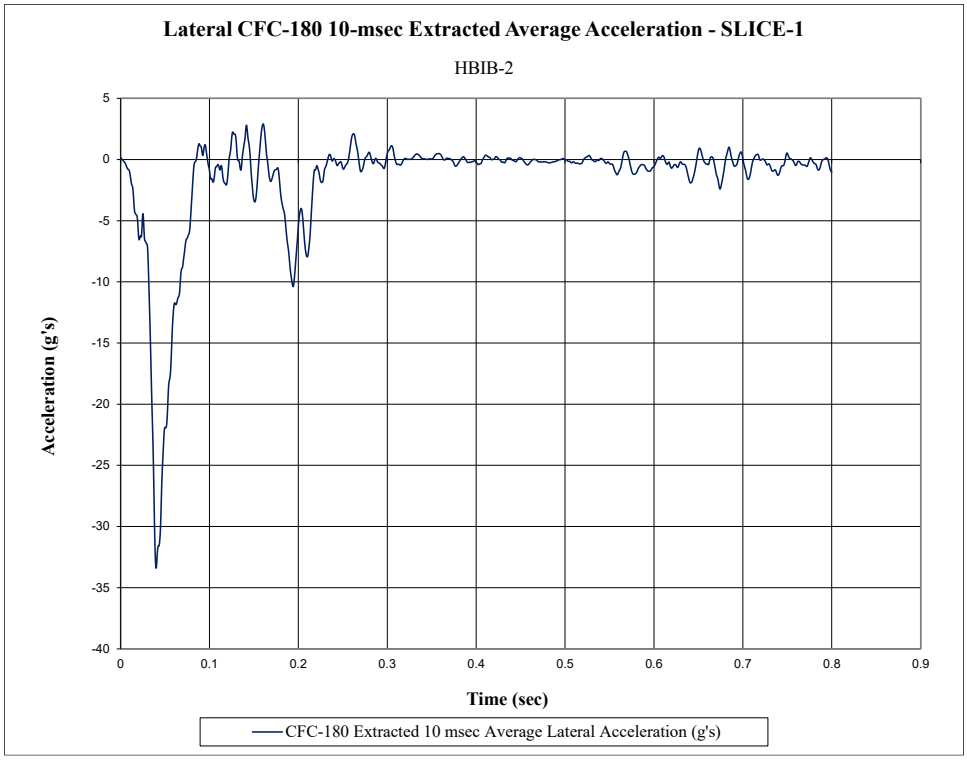


Figure H-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. HBIB-2

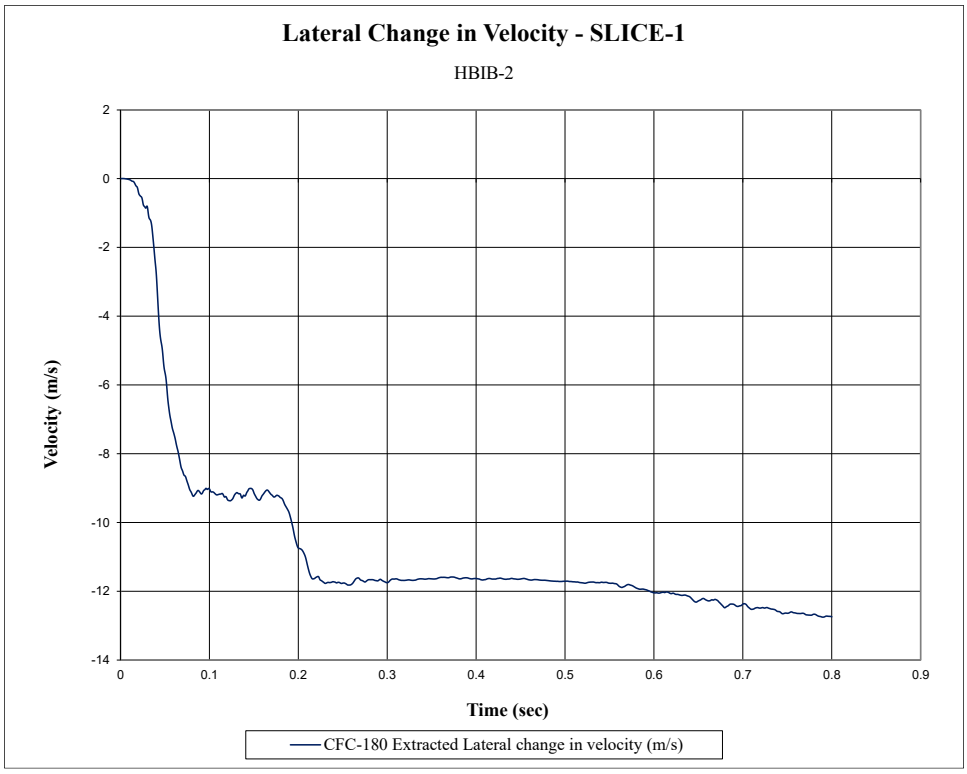


Figure H-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. HBIB-2

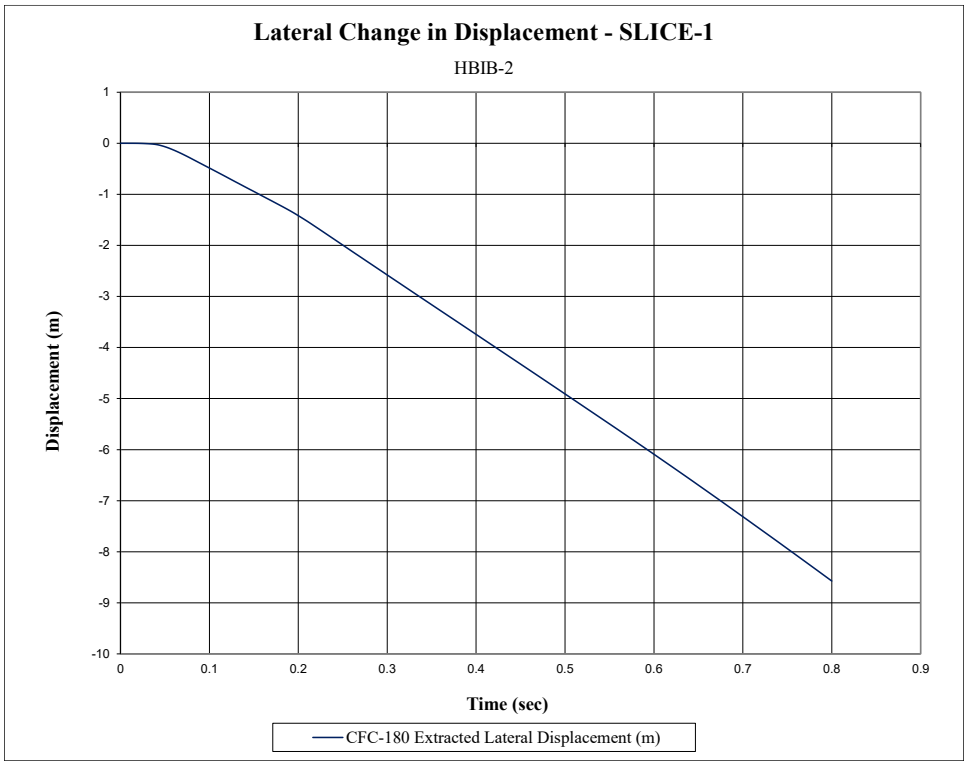


Figure H-6. Lateral Occupant Displacement (SLICE-1), Test No. HBIB-2

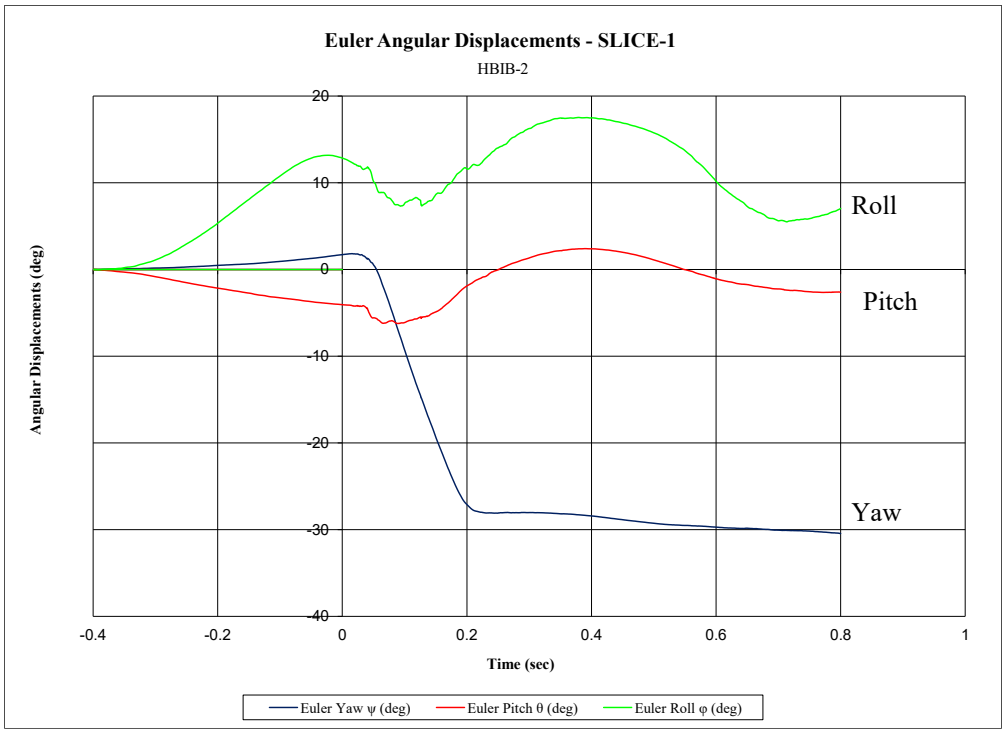


Figure H-7. Vehicle Angular Displacements (SLICE-1), Test No. HBIB-2

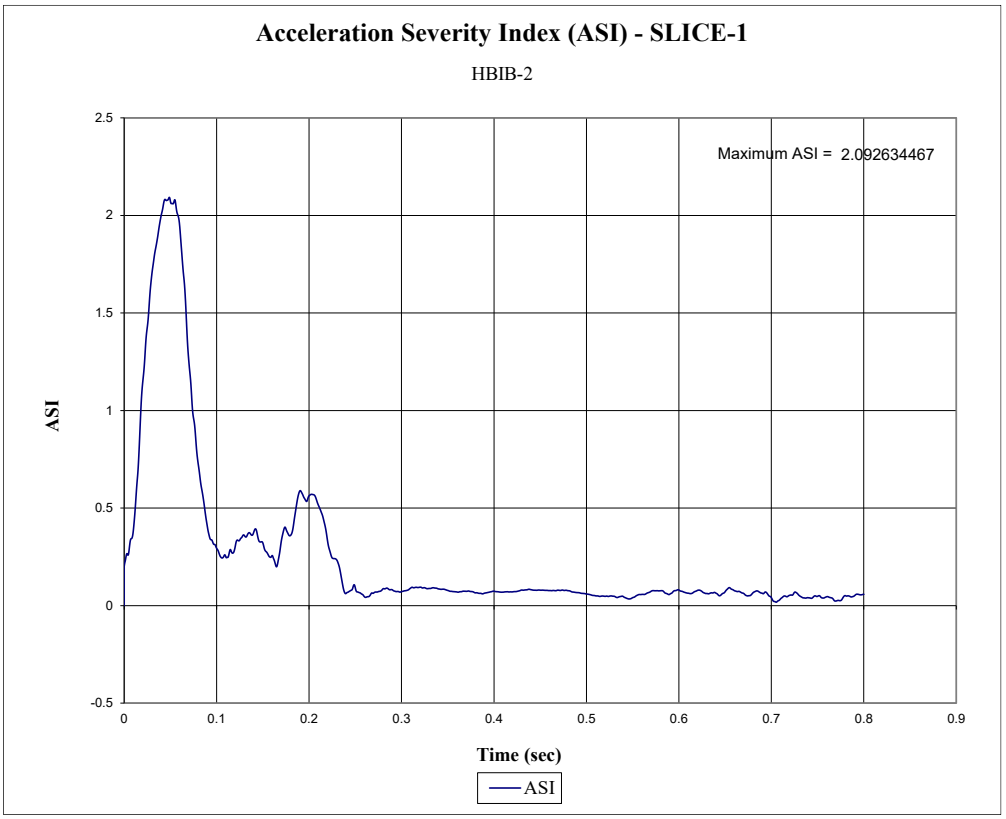


Figure H-8. Acceleration Severity Index (SLICE-1), Test No. HBIB-2

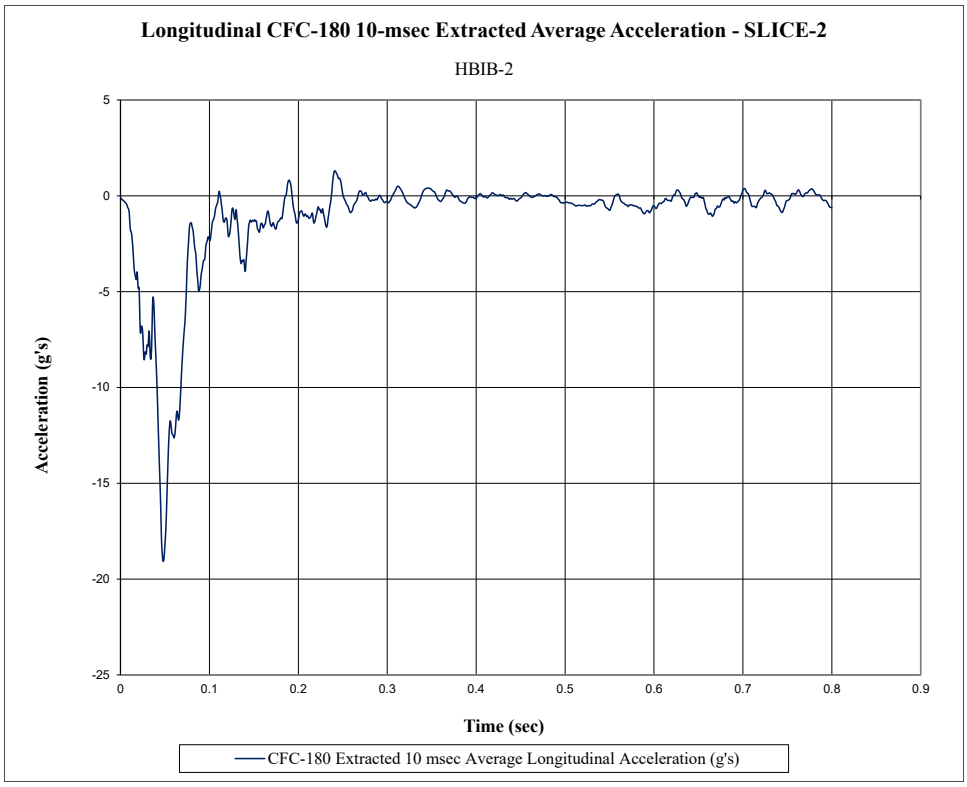


Figure H-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. HBIB-2

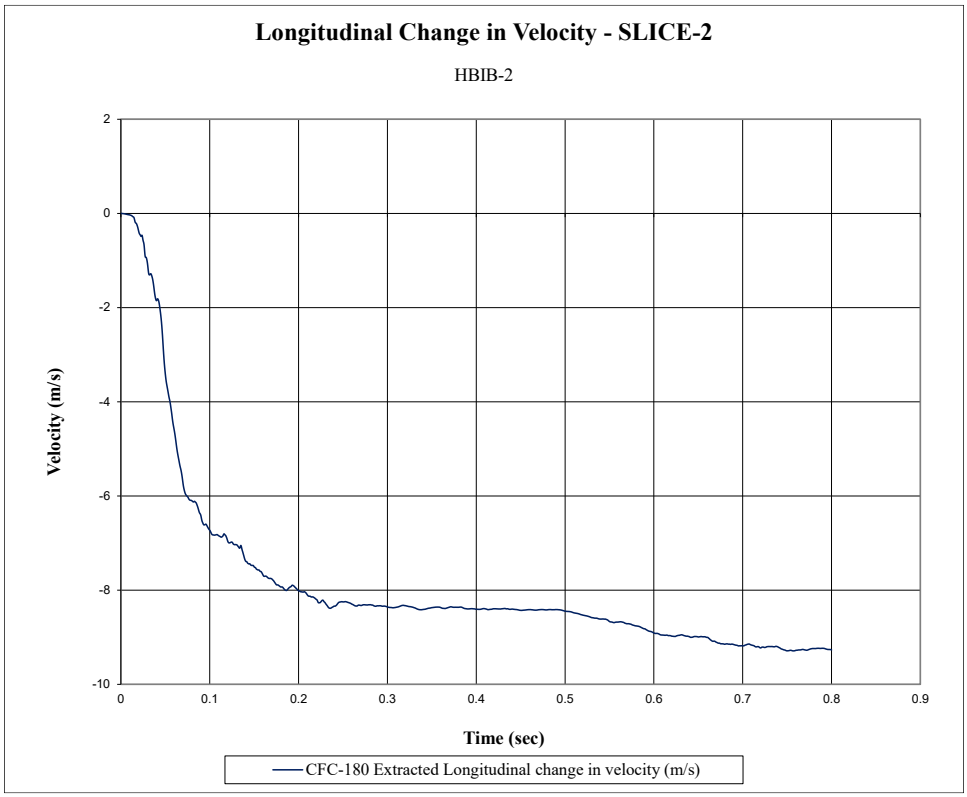


Figure H-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. HBIB-2

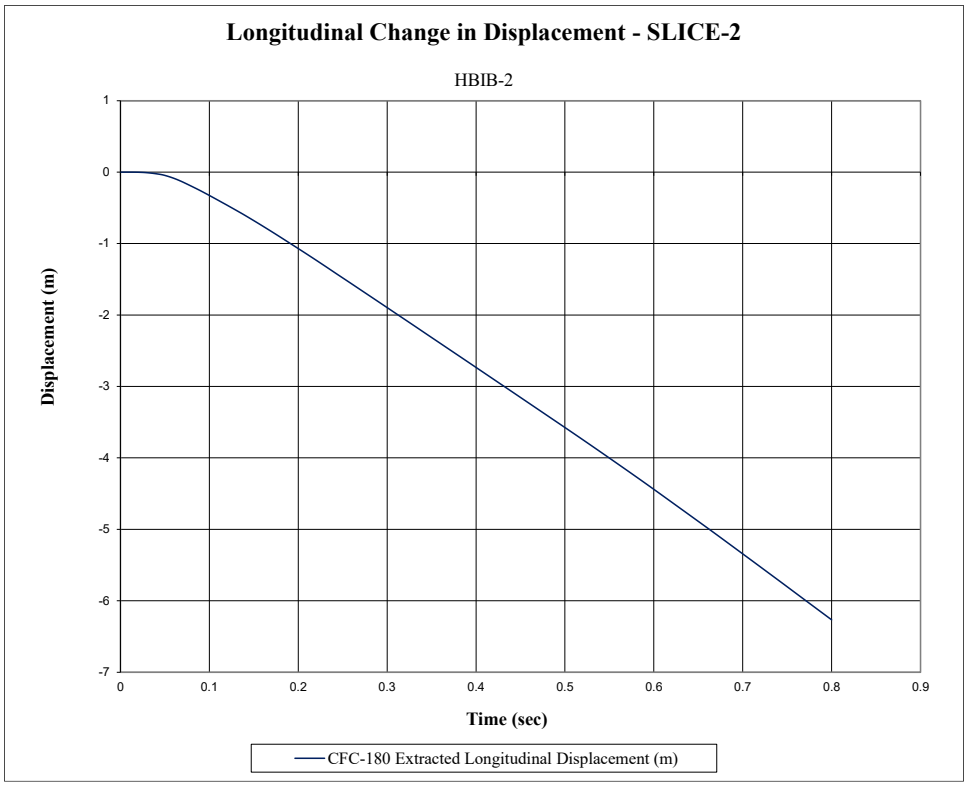


Figure H-11. Longitudinal Occupant Displacement (SLICE-2), Test No. HBIB-2

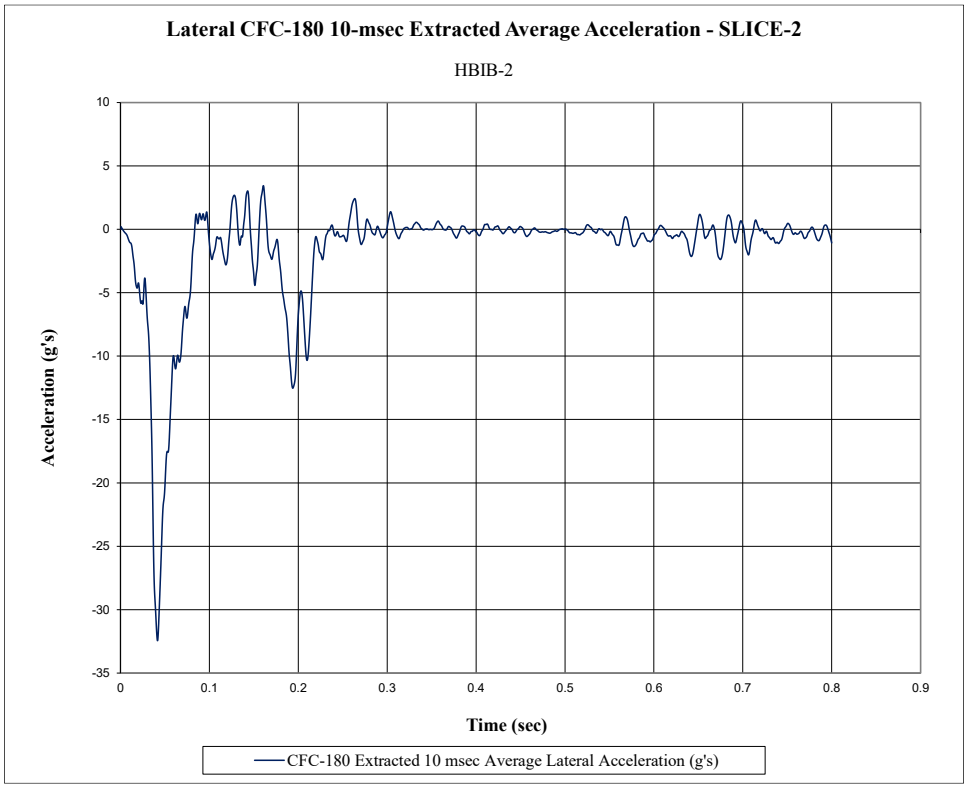


Figure H-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. HBIB-2

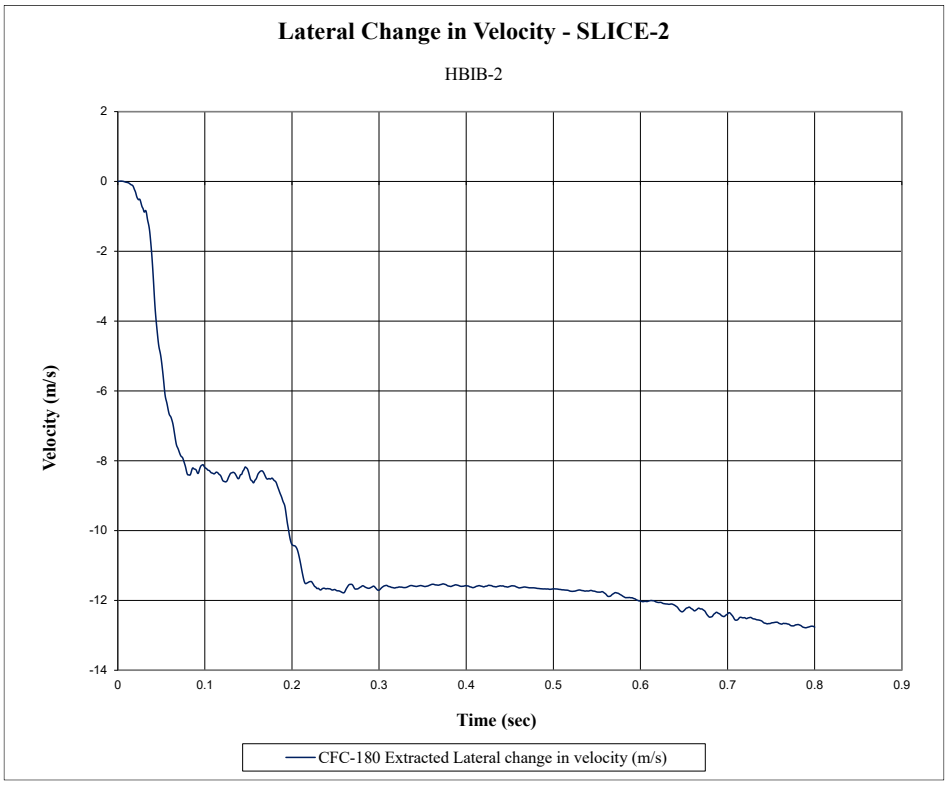


Figure H-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. HBIB-2

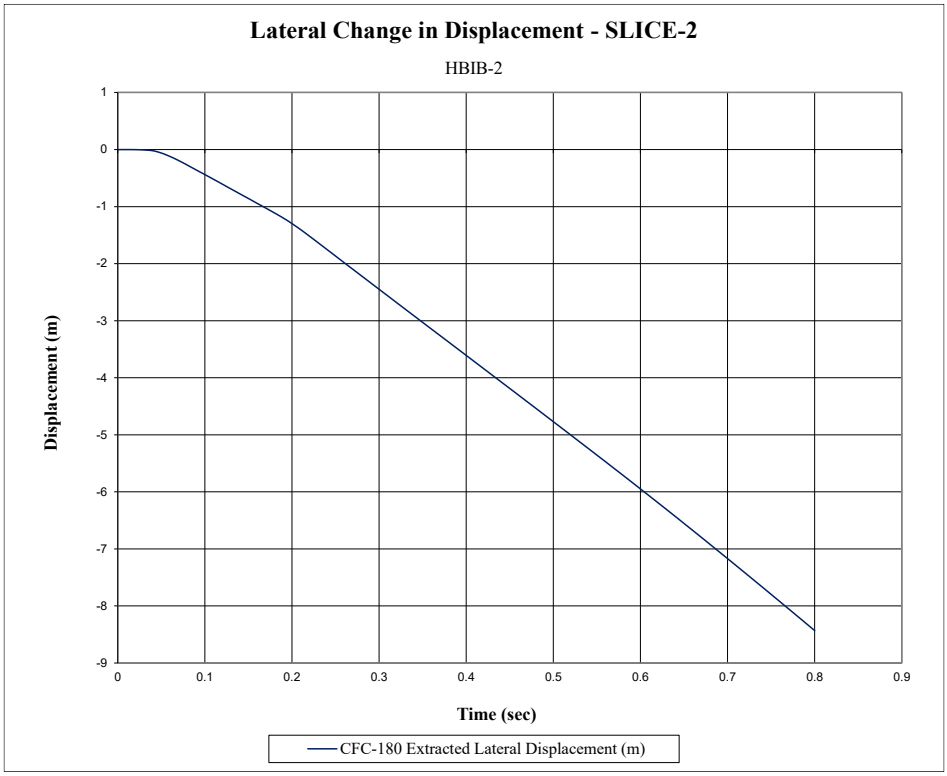


Figure H-14. Lateral Occupant Displacement (SLICE-2), Test No. HBIB-2

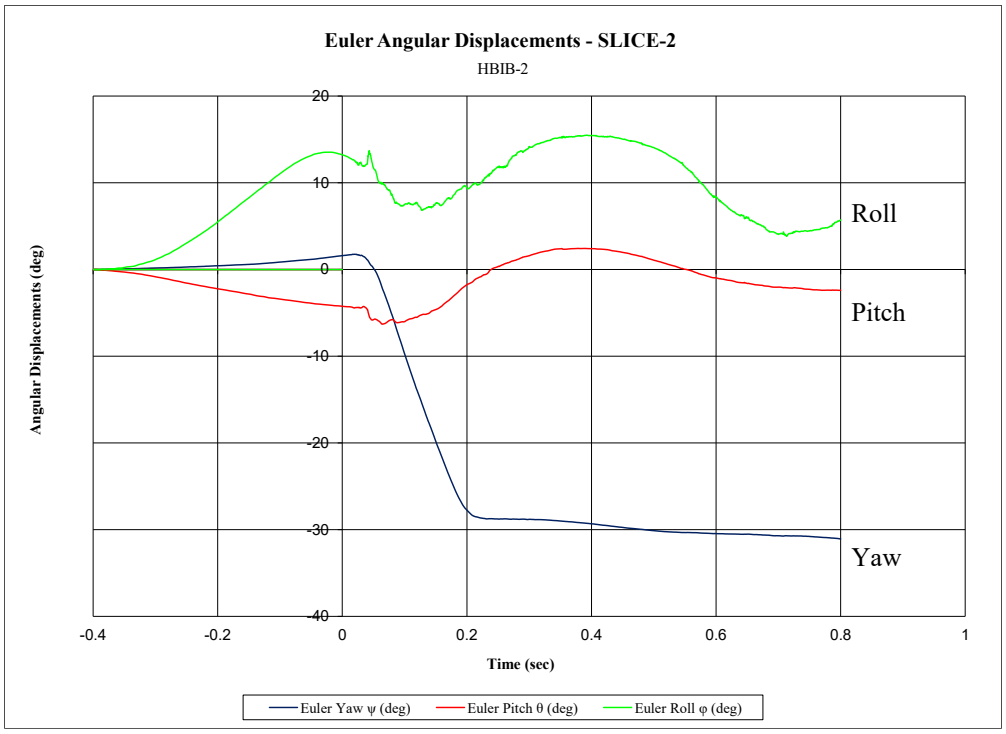


Figure H-15. Vehicle Angular Displacements (SLICE-2), Test No. HBIB-2

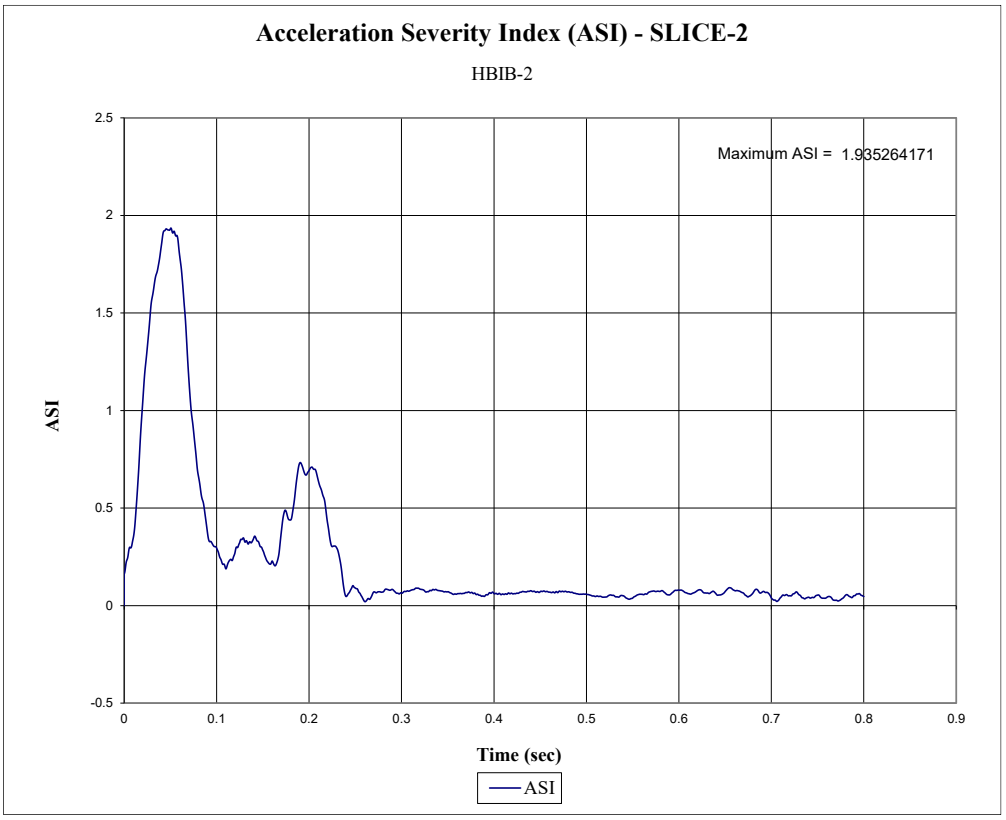


Figure H-16. Acceleration Severity Index (SLICE-2), Test No. HBIB-2

Appendix I. Accelerometer and Rate Transducer Data Plots, Test No. HBIB-3

The Vehicle Angular Displacement graph for SLICE-2 was excluded due to issues with data collection.

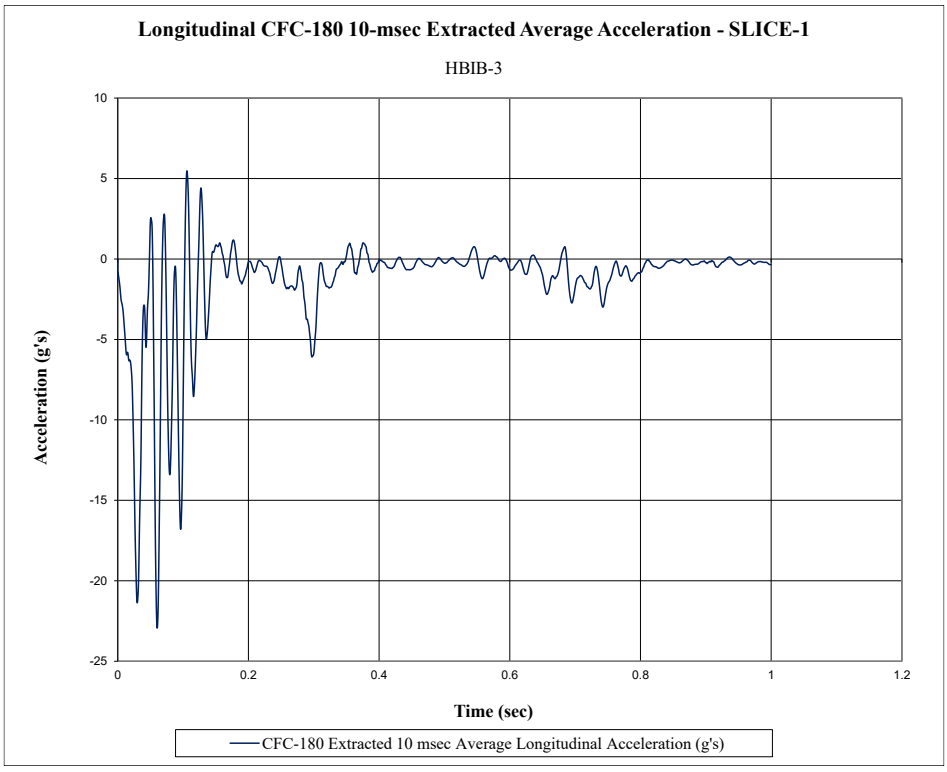


Figure I-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. HBIB-3

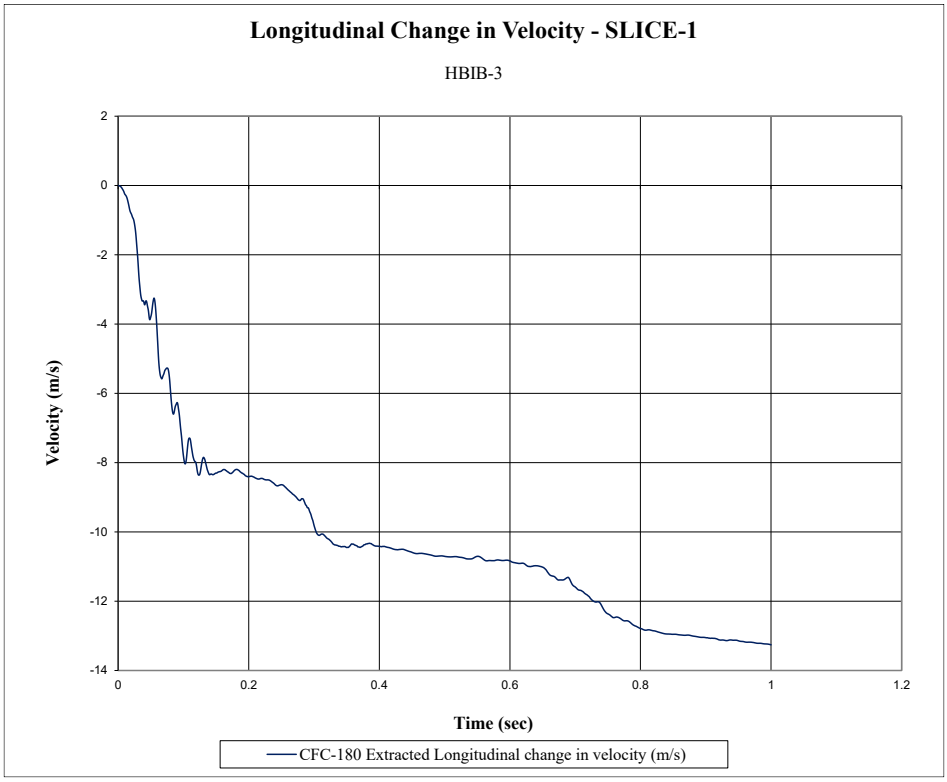


Figure I-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. HBIB-3

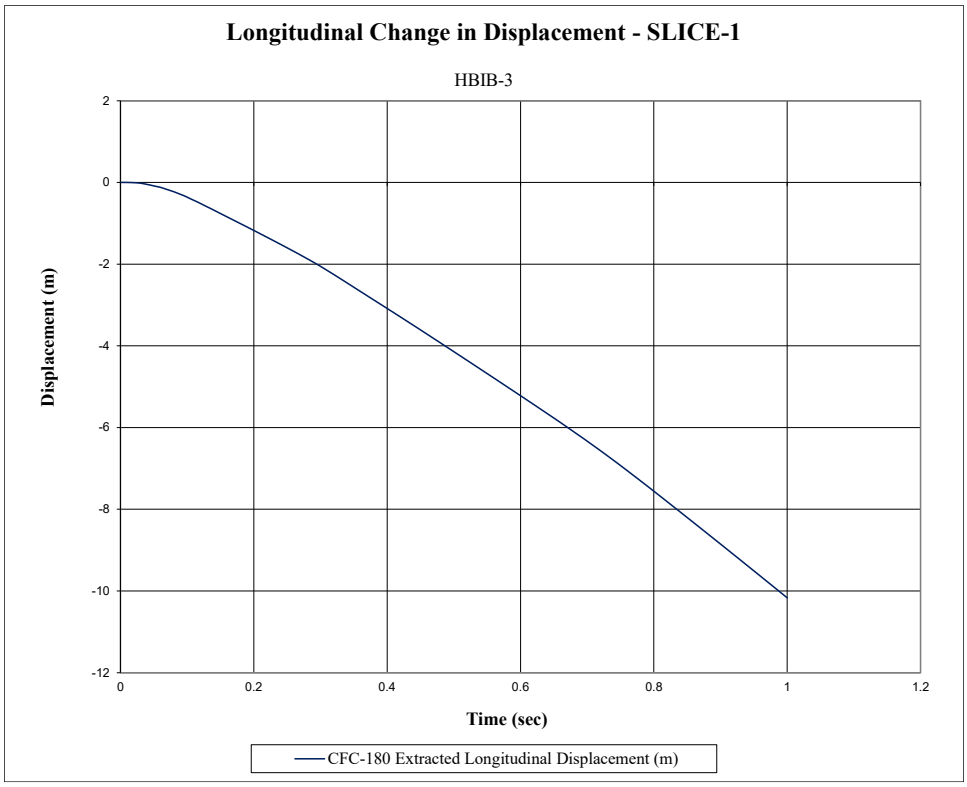


Figure I-3. Longitudinal Occupant Displacement (SLICE-1), Test No. HBIB-3

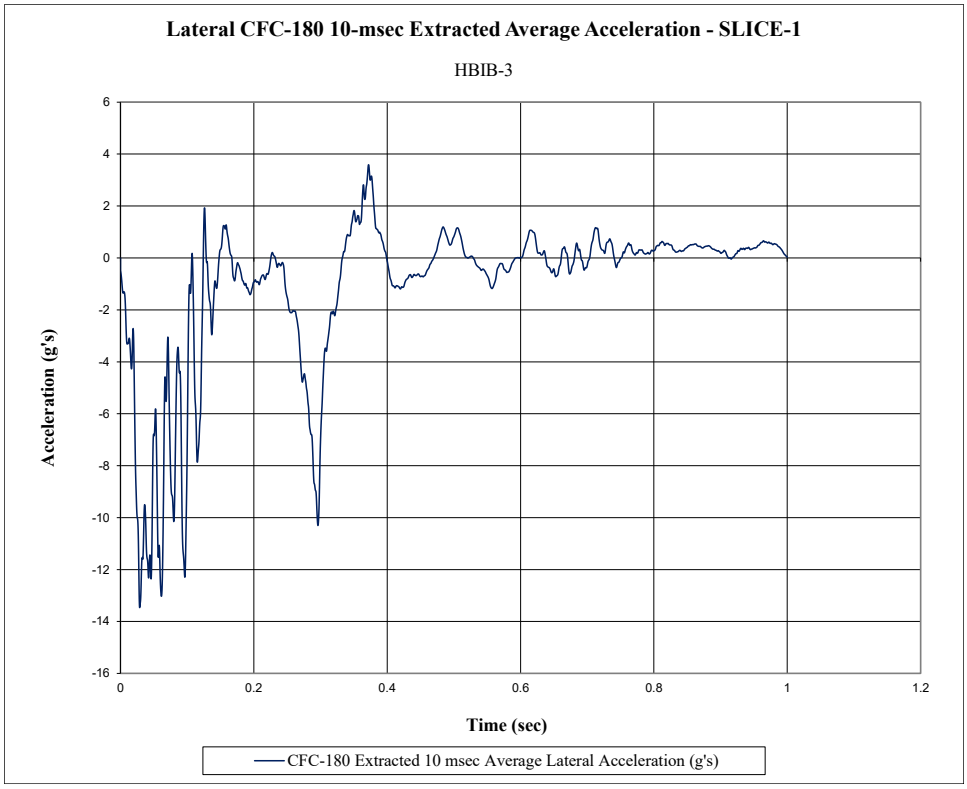


Figure I-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. HBIB-3

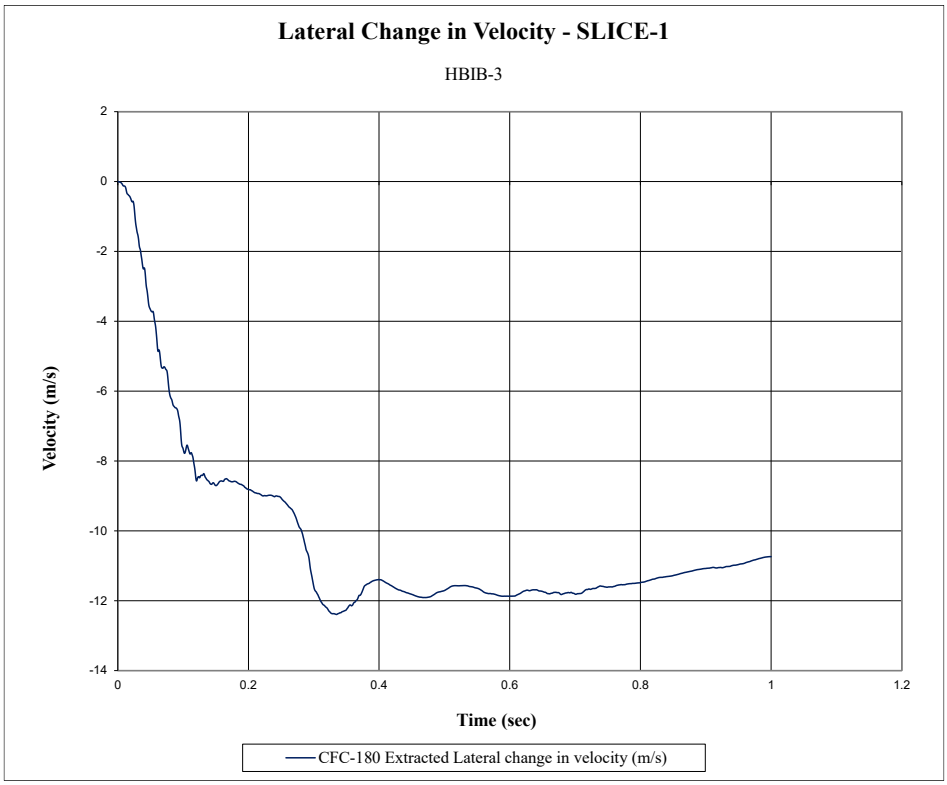


Figure I-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. HBIB-3



Figure I-6. Lateral Occupant Displacement (SLICE-1), Test No. HBIB-3

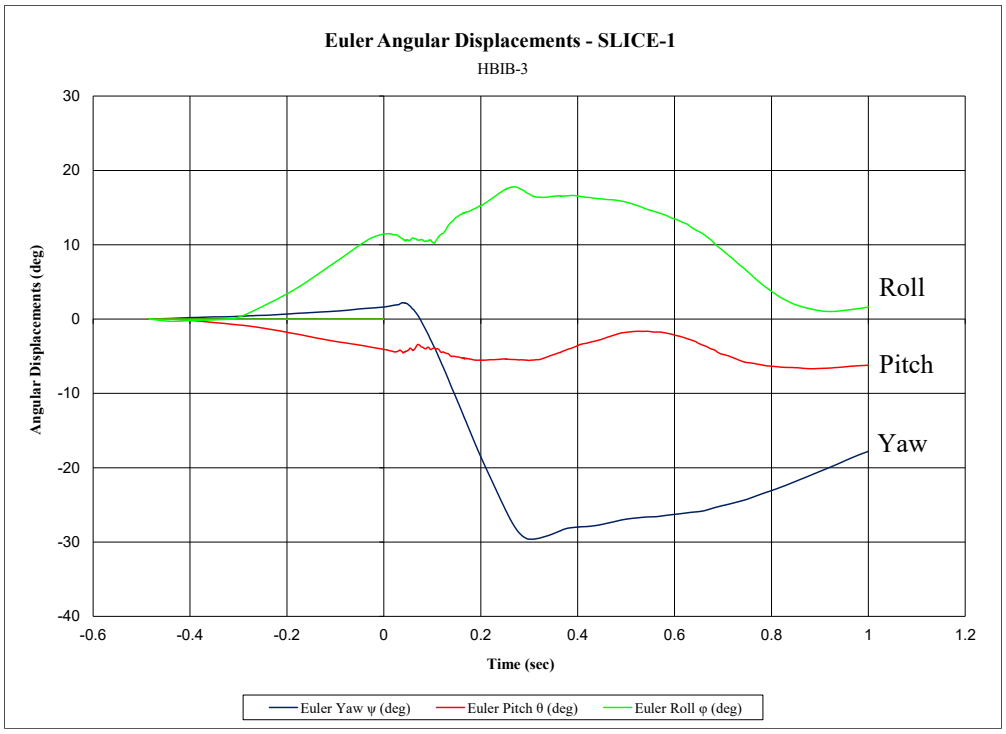


Figure I-7. Vehicle Angular Displacements (SLICE-1), Test No. HBIB-3

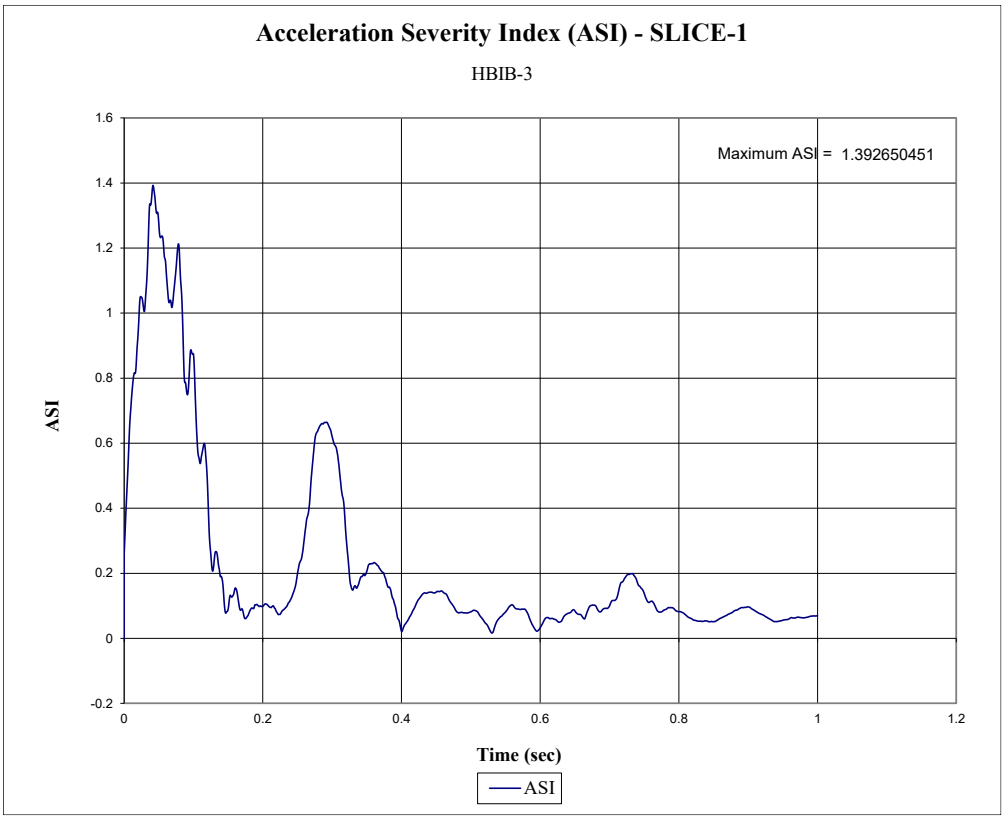


Figure I-8. Acceleration Severity Index (SLICE-1), Test No. HBIB-3

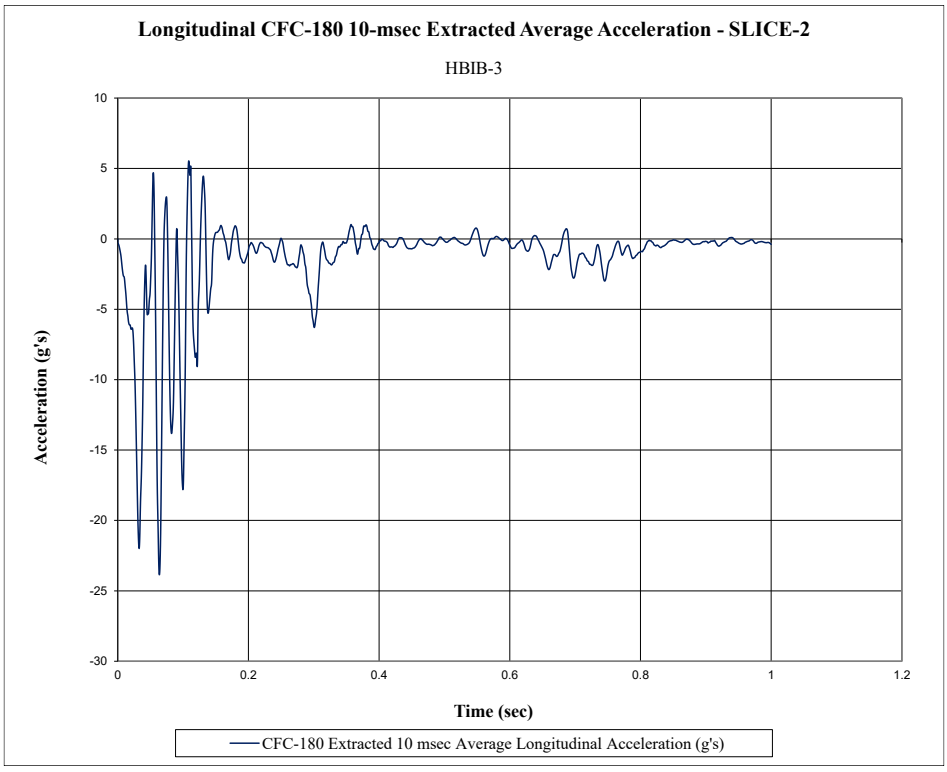


Figure I-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. HBIB-3

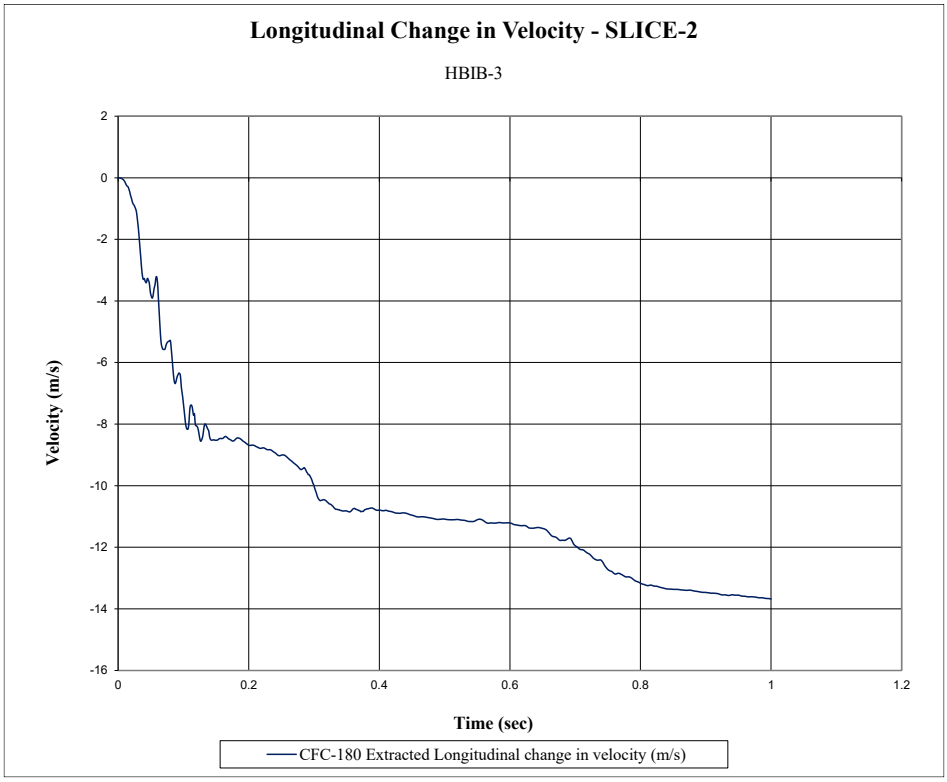


Figure I-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. HBIB-3

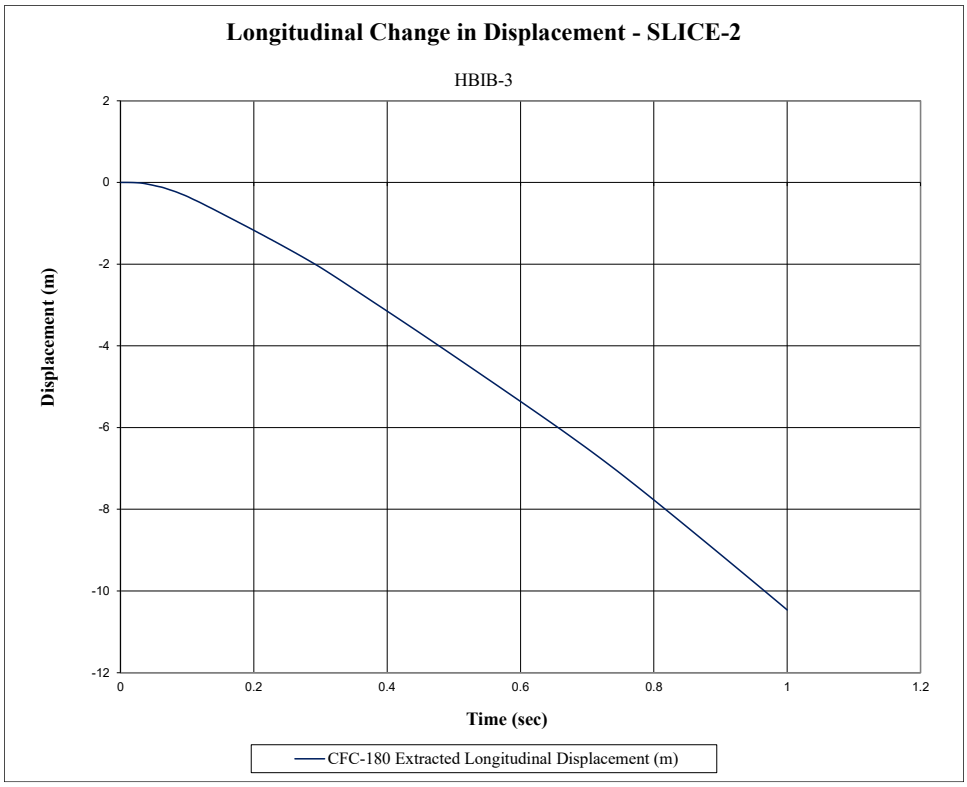


Figure I-11. Longitudinal Occupant Displacement (SLICE-2), Test No. HBIB-3

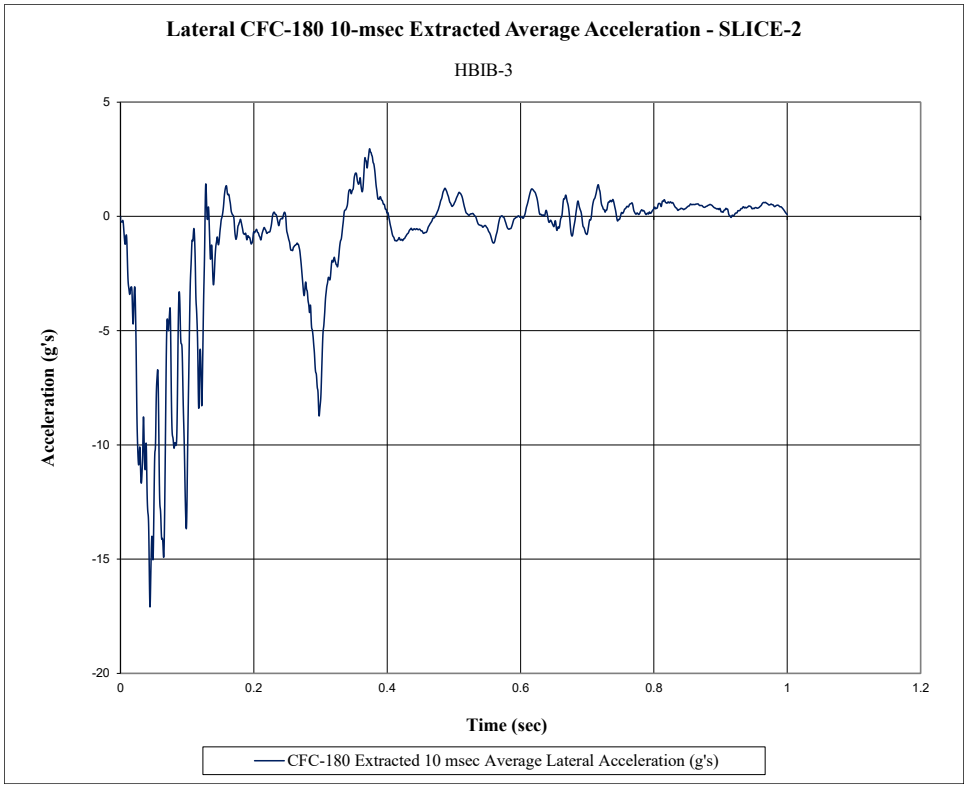


Figure I-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. HBIB-3

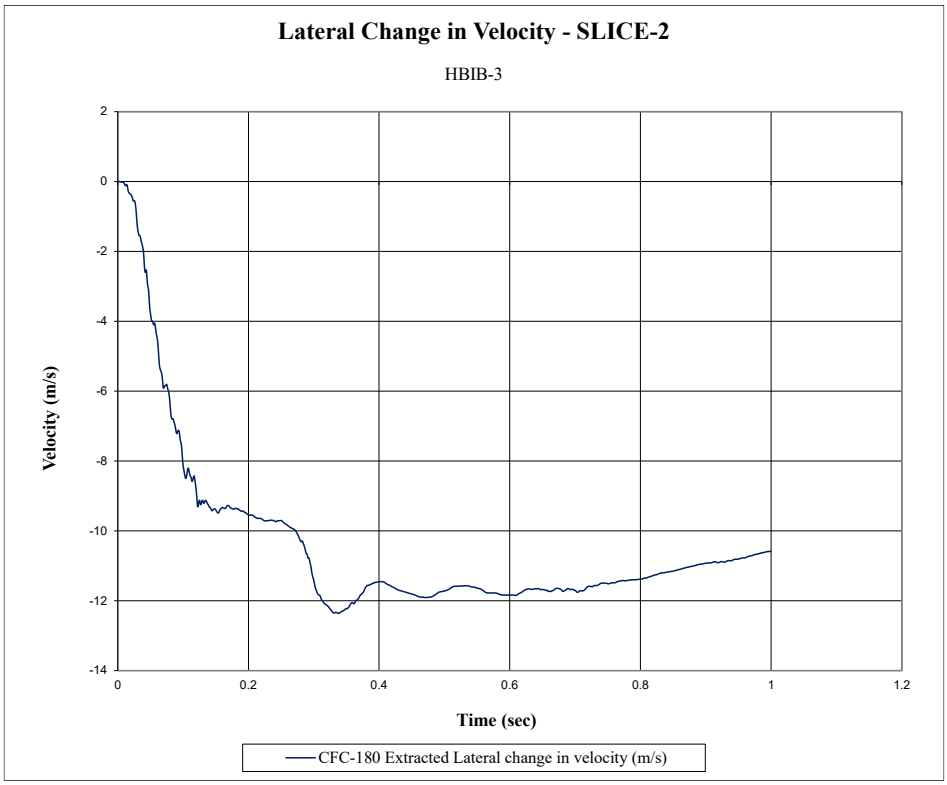


Figure I-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. HBIB-3



Figure I-14. Lateral Occupant Displacement (SLICE-2), Test No. HBIB-3

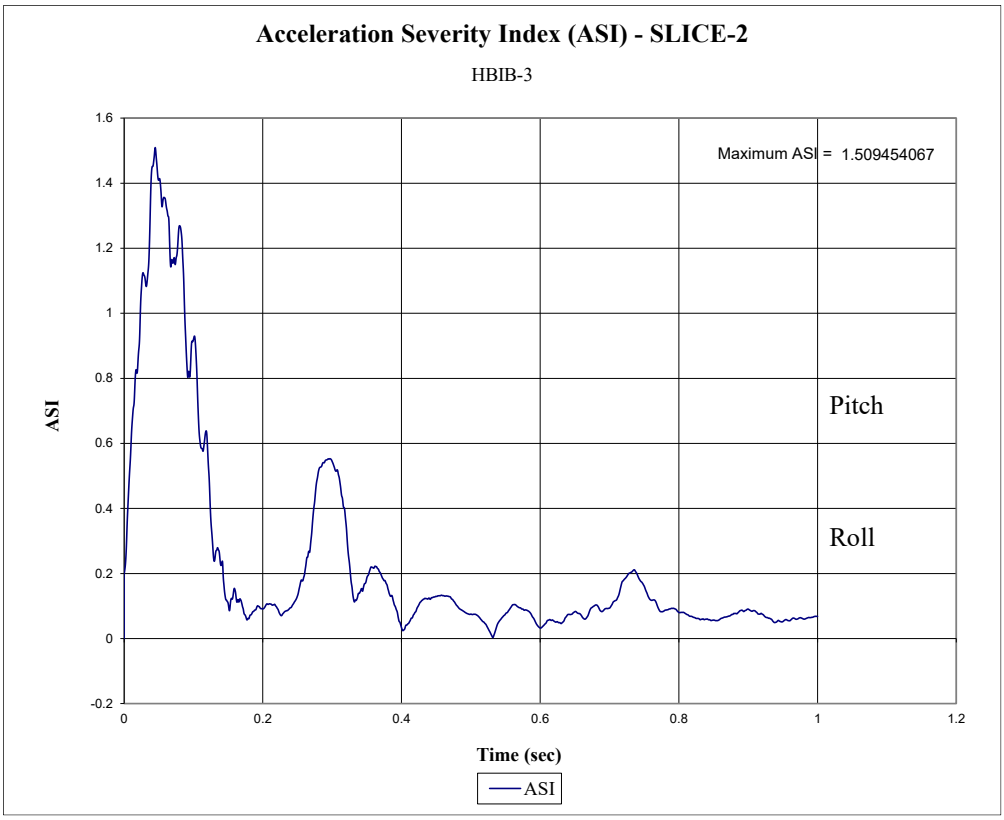


Figure I-15. Acceleration Severity Index (SLICE-2), Test No. HBIB-3

Appendix J. Accelerometer and Rate Transducer Data Plots, Test No. HBIB-4

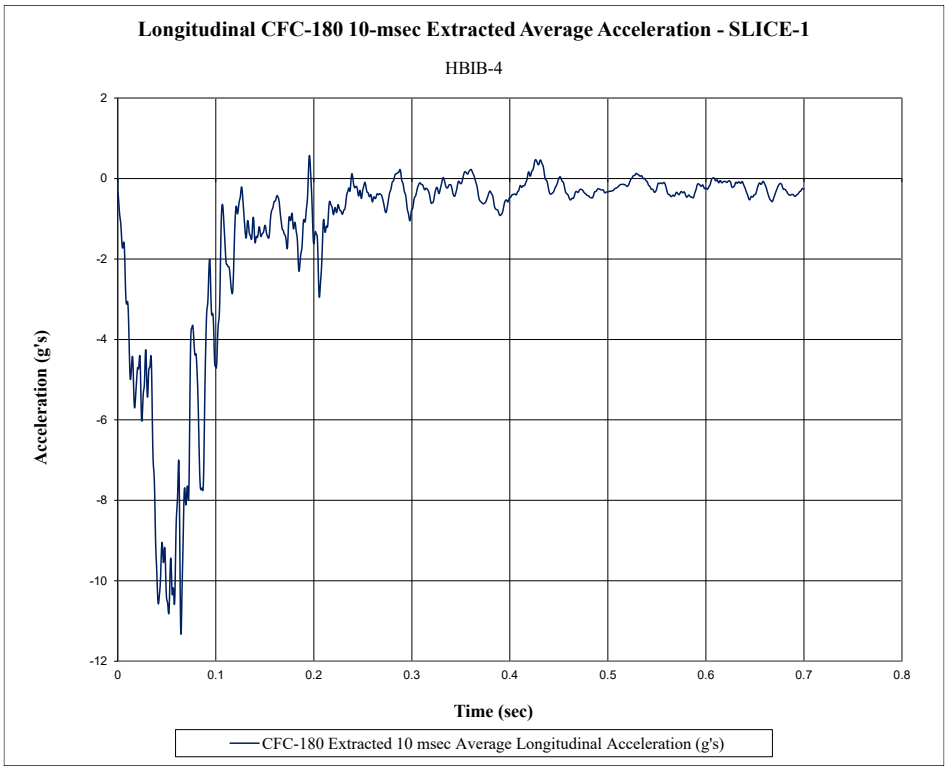


Figure J-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. HBIB-4

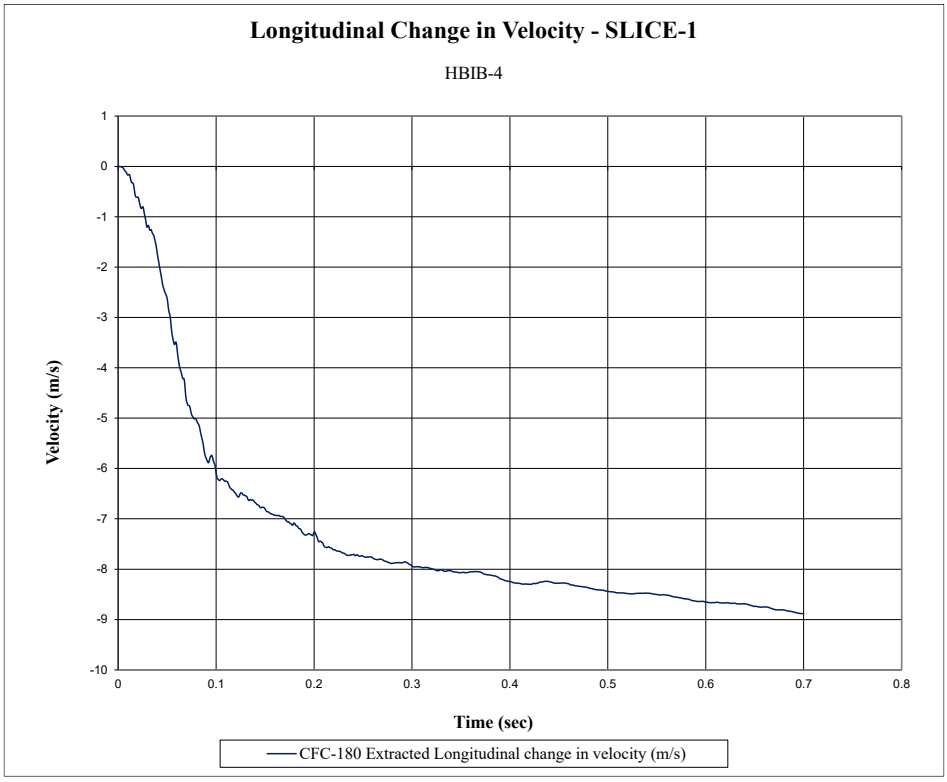


Figure J-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. HBIB-4

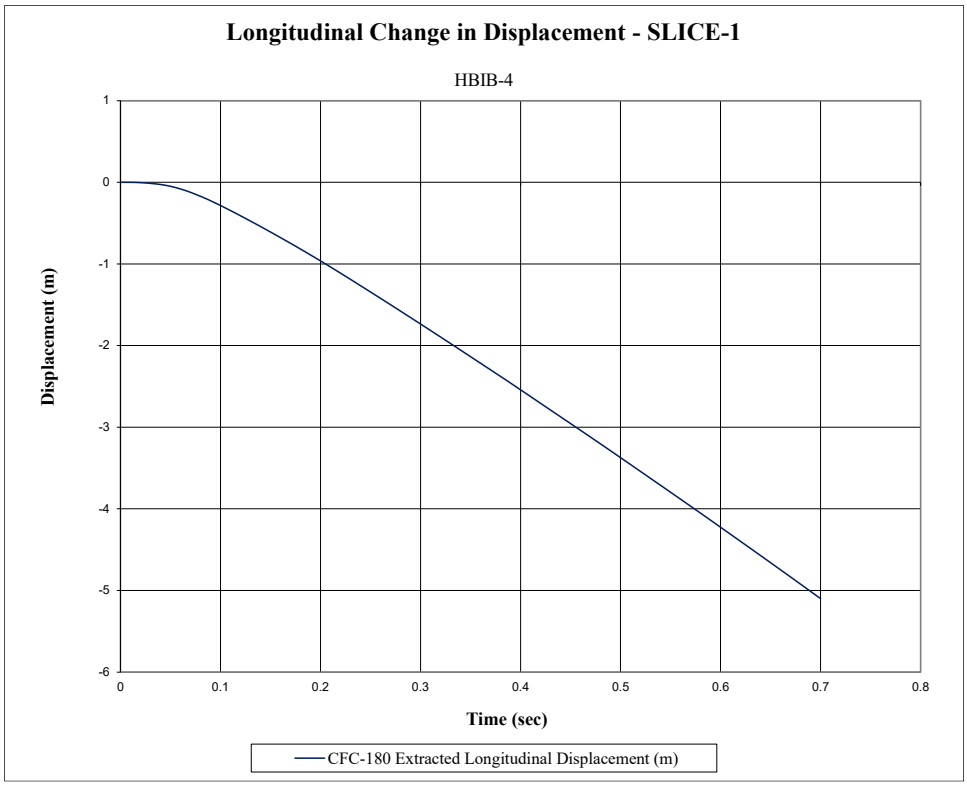


Figure J-3. Longitudinal Occupant Displacement (SLICE-1), Test No. HBIB-4

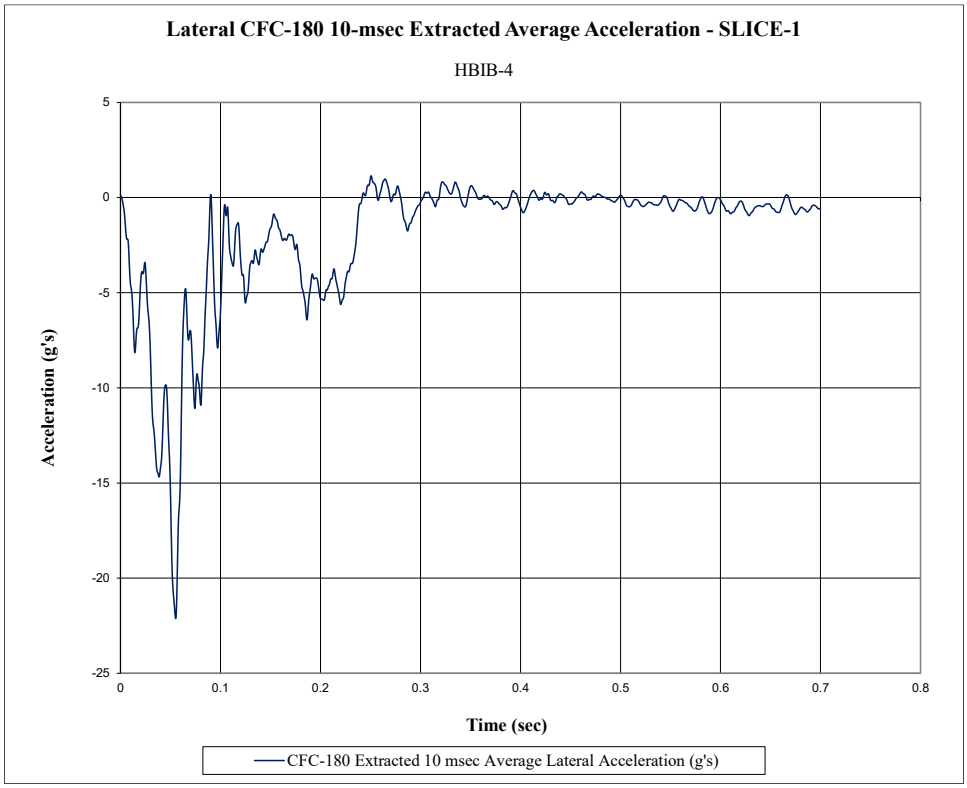


Figure J-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. HBIB-4

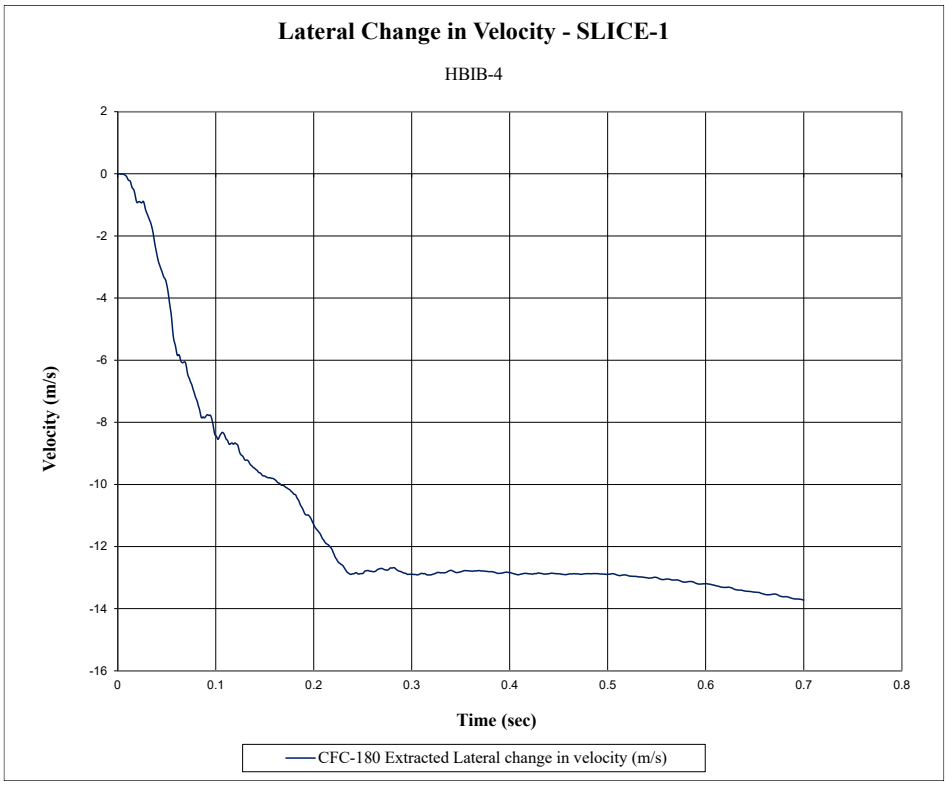


Figure J-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. HBIB-4

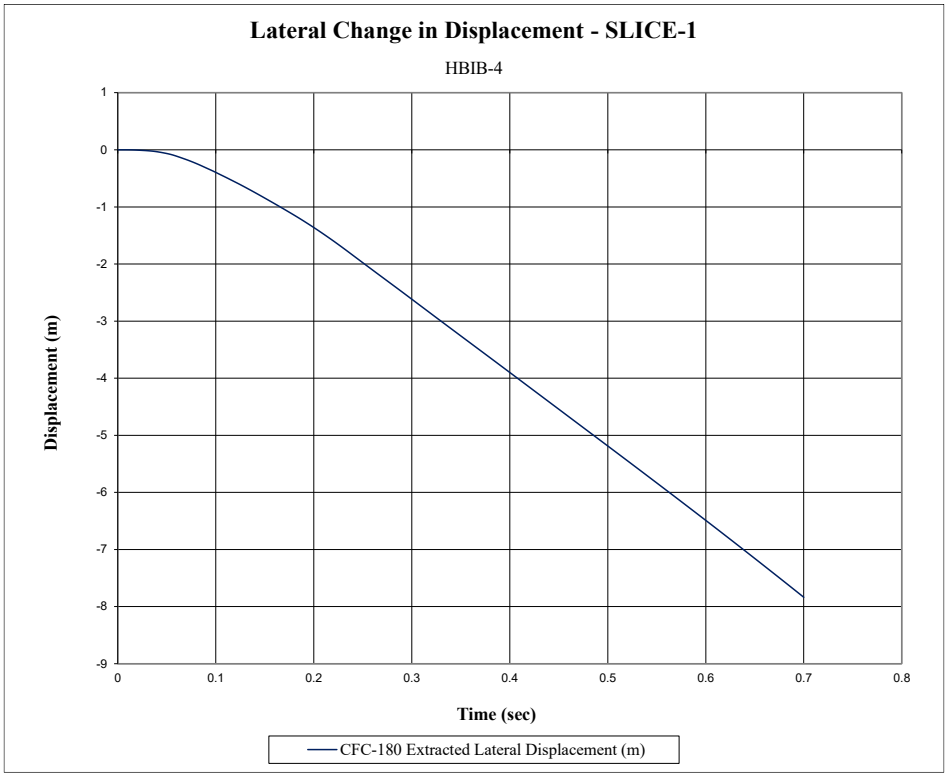


Figure J-6. Lateral Occupant Displacement (SLICE-1), Test No. HBIB-4

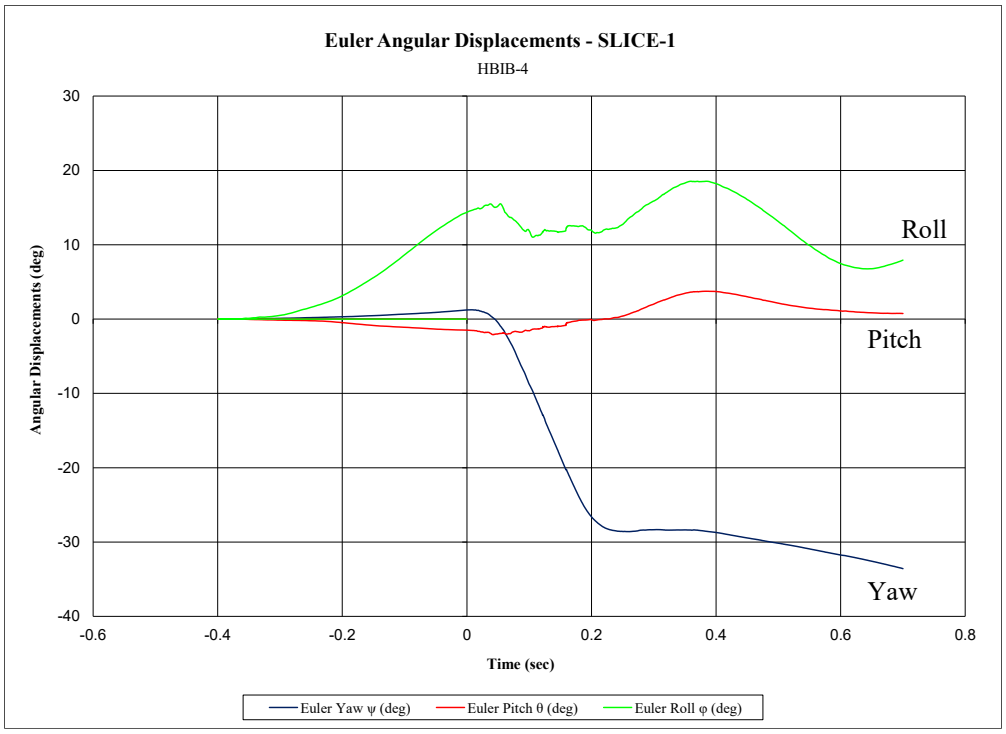


Figure J-7. Vehicle Angular Displacements (SLICE-1), Test No. HBIB-4

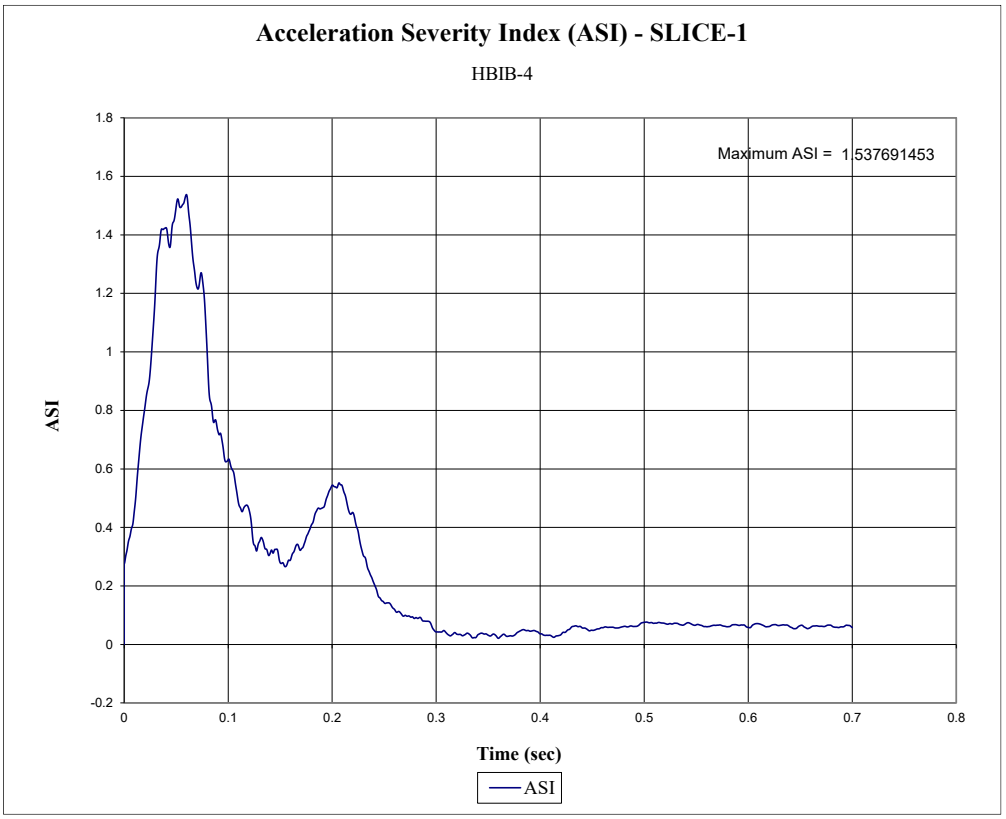


Figure J-8. Acceleration Severity Index (SLICE-1), Test No. HBIB-4

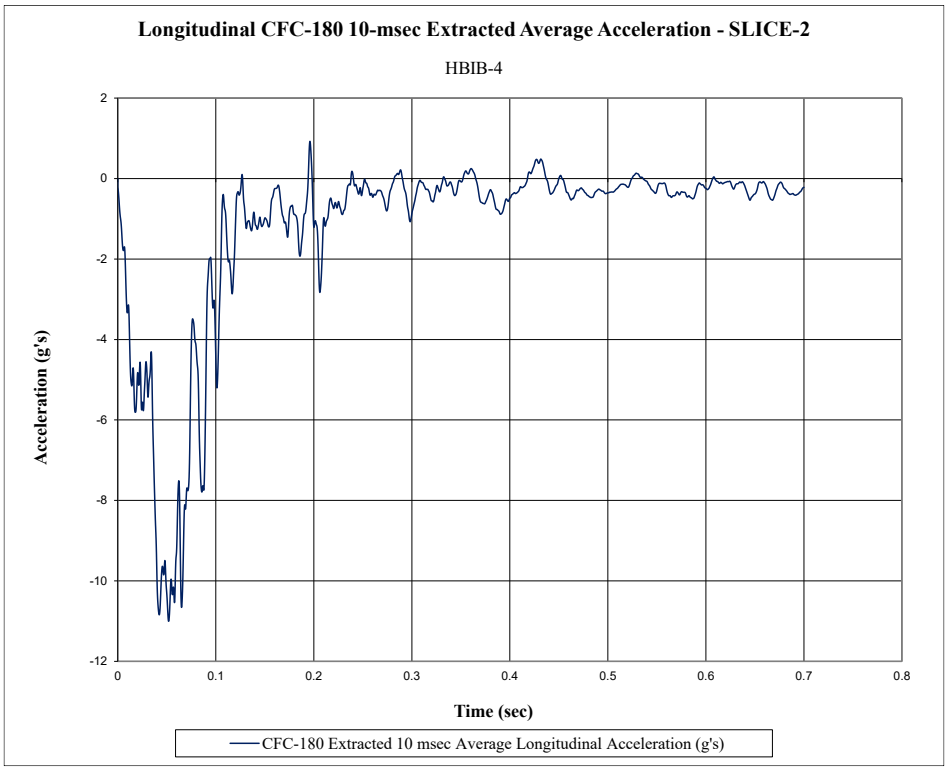


Figure J-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. HBIB-4

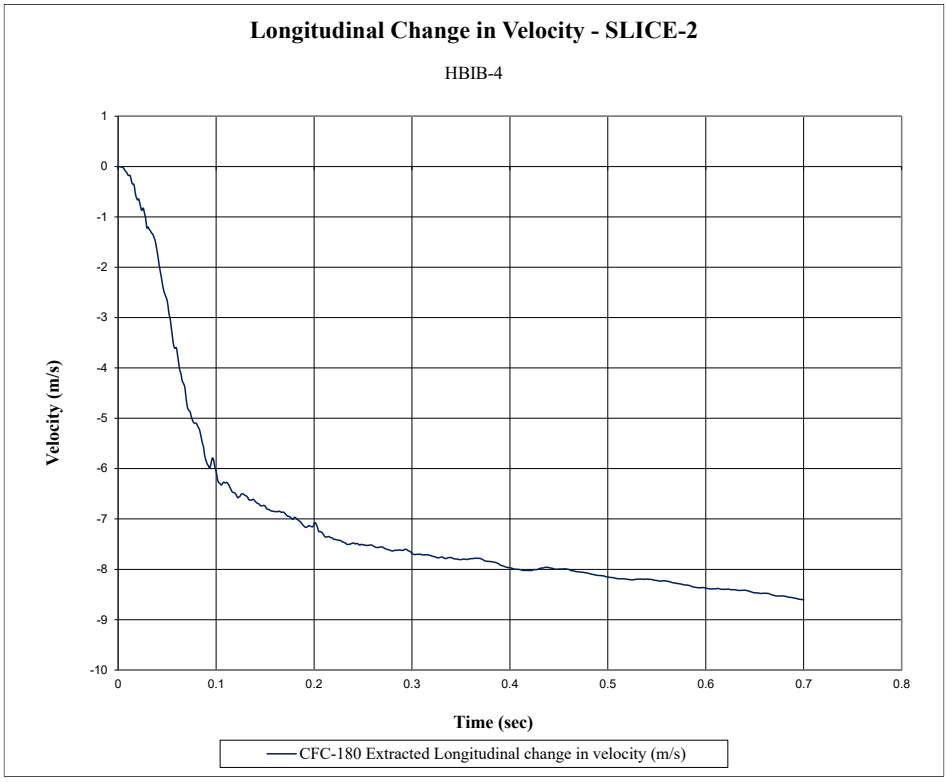


Figure J-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. HBIB-4

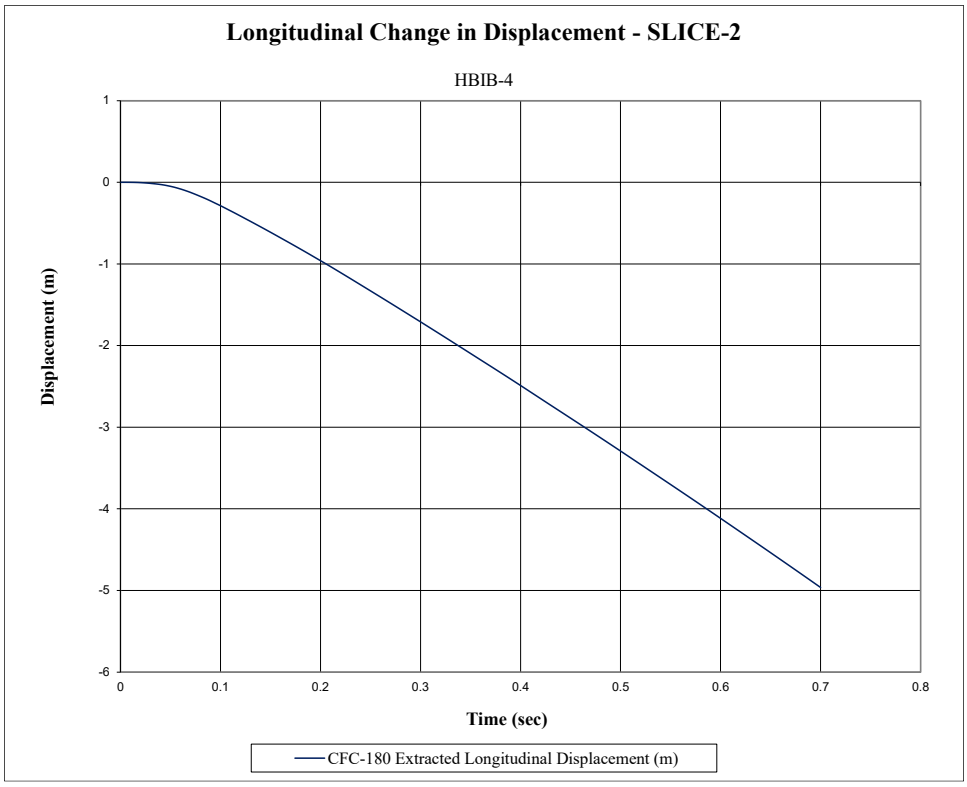


Figure J-11. Longitudinal Occupant Displacement (SLICE-2), Test No. HBIB-4

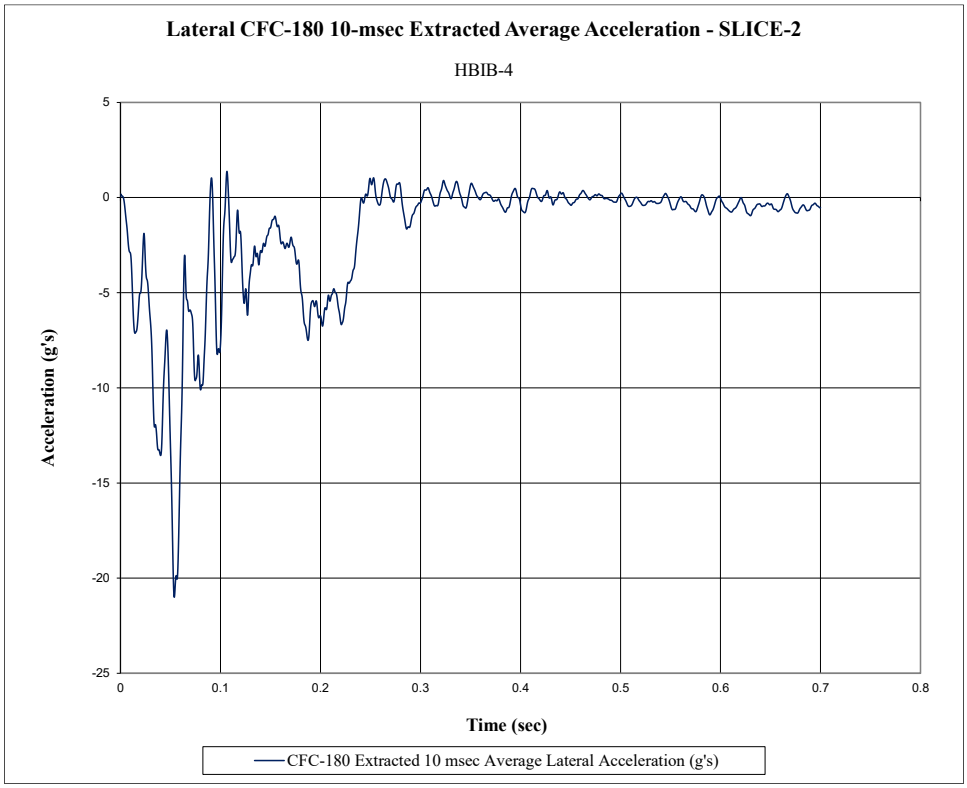


Figure J-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. HBIB-4

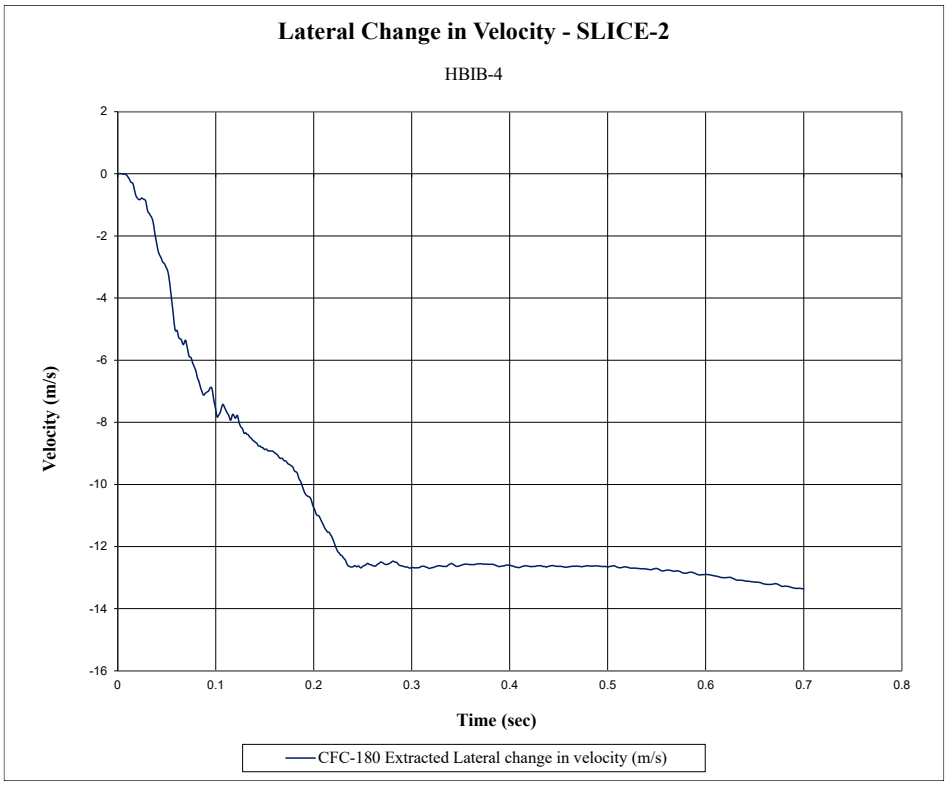


Figure J-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. HBIB-4



Figure J-14. Lateral Occupant Displacement (SLICE-2), Test No. HBIB-4

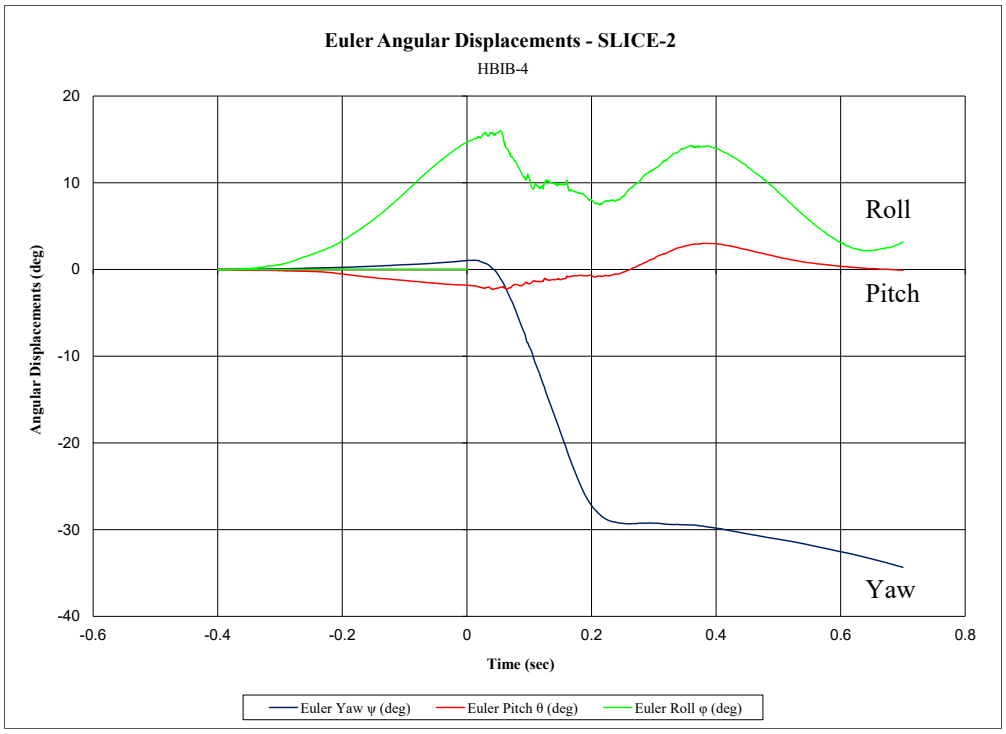


Figure J-15. Vehicle Angular Displacements (SLICE-2), Test No. HBIB-4

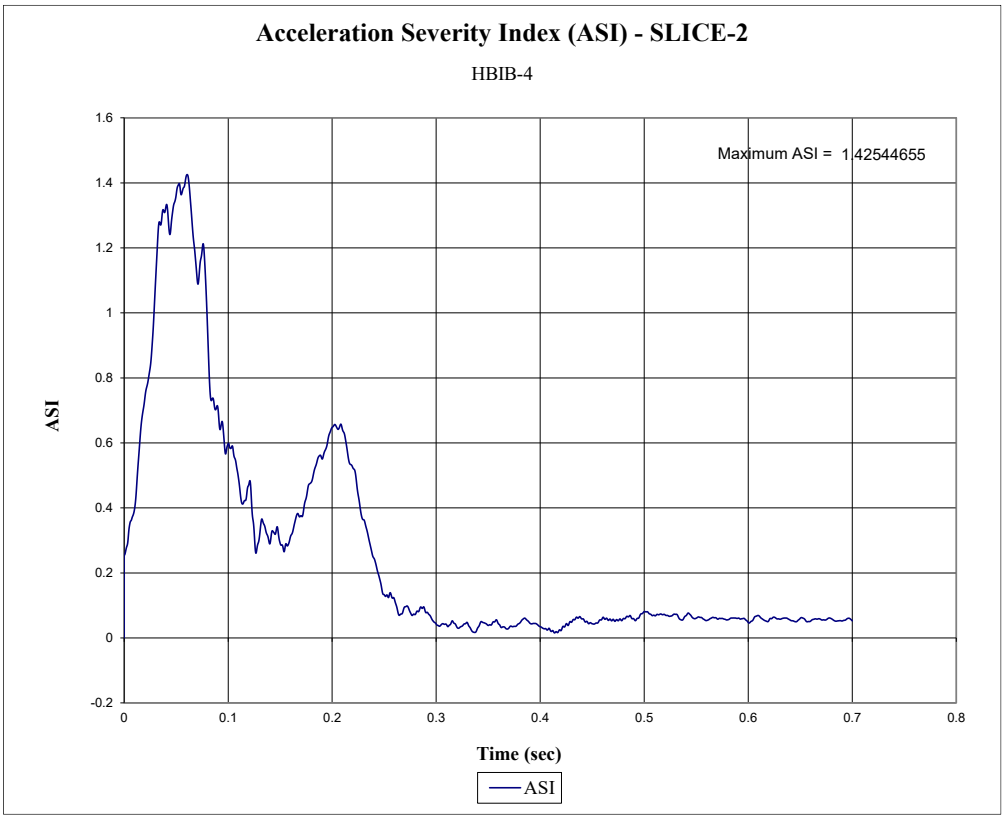


Figure J-16. Acceleration Severity Index (SLICE-2), Test No. HBIB-4

Appendix K. Accelerometer and Rate Transducer Data Plots, Test No. HBIB-5

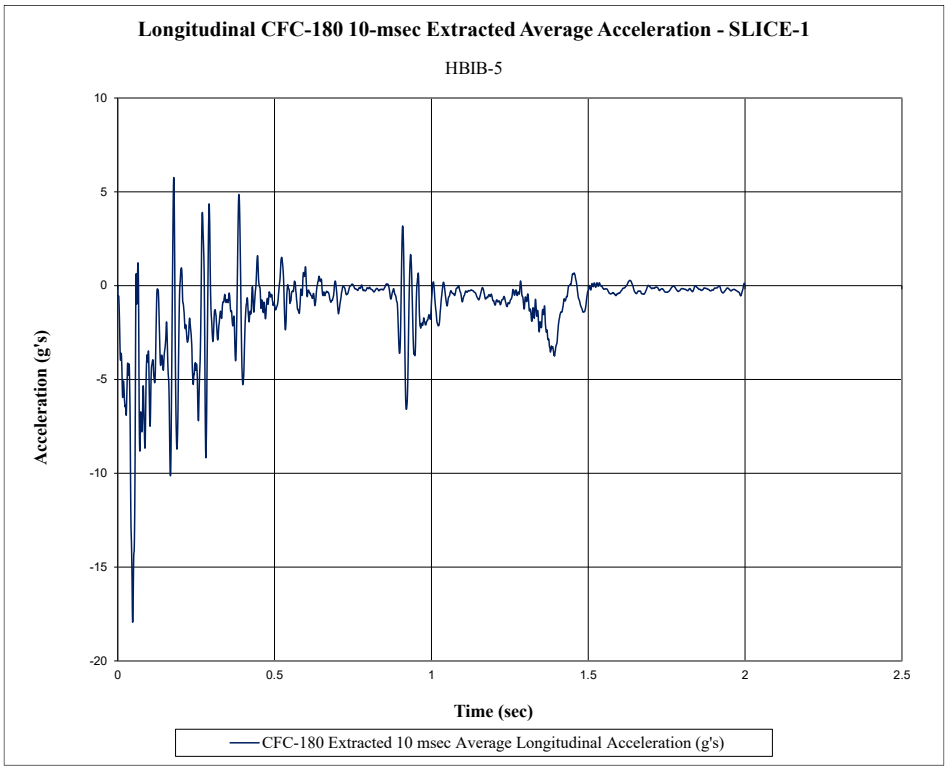


Figure K-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. HBIB-5

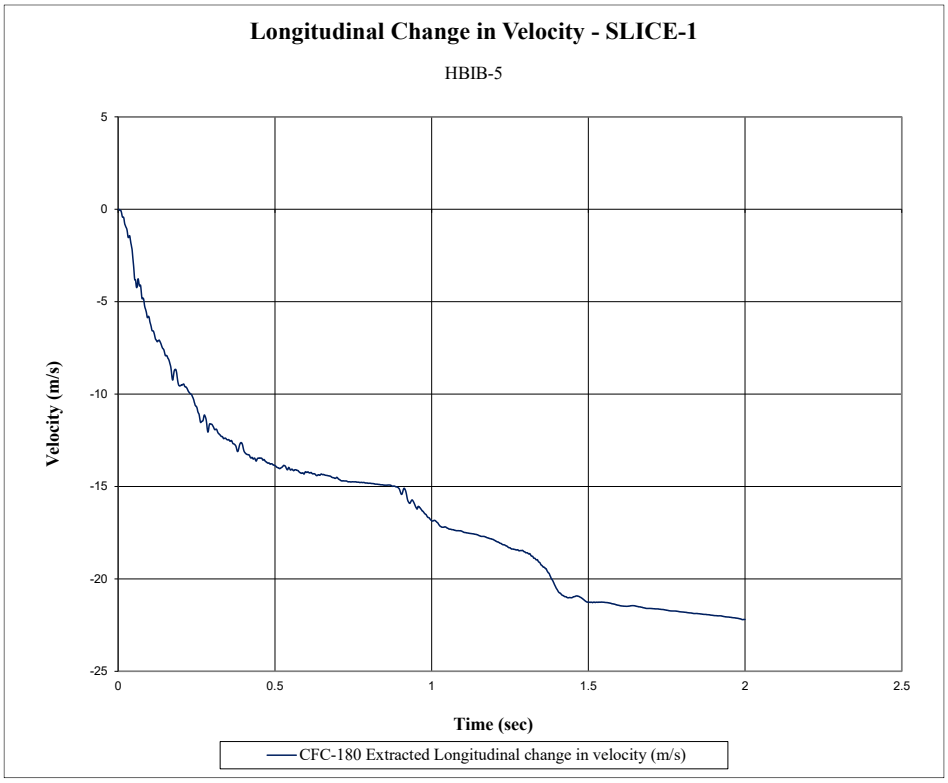


Figure K-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. HBIB-5

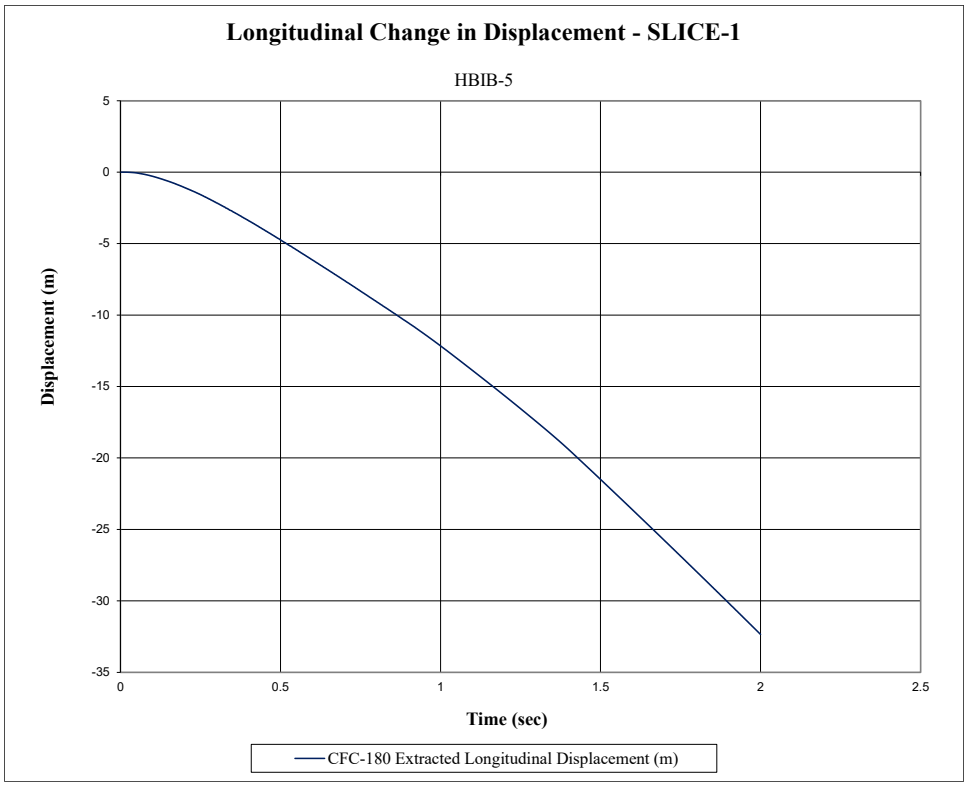


Figure K-3. Longitudinal Occupant Displacement (SLICE-1), Test No. HBIB-5

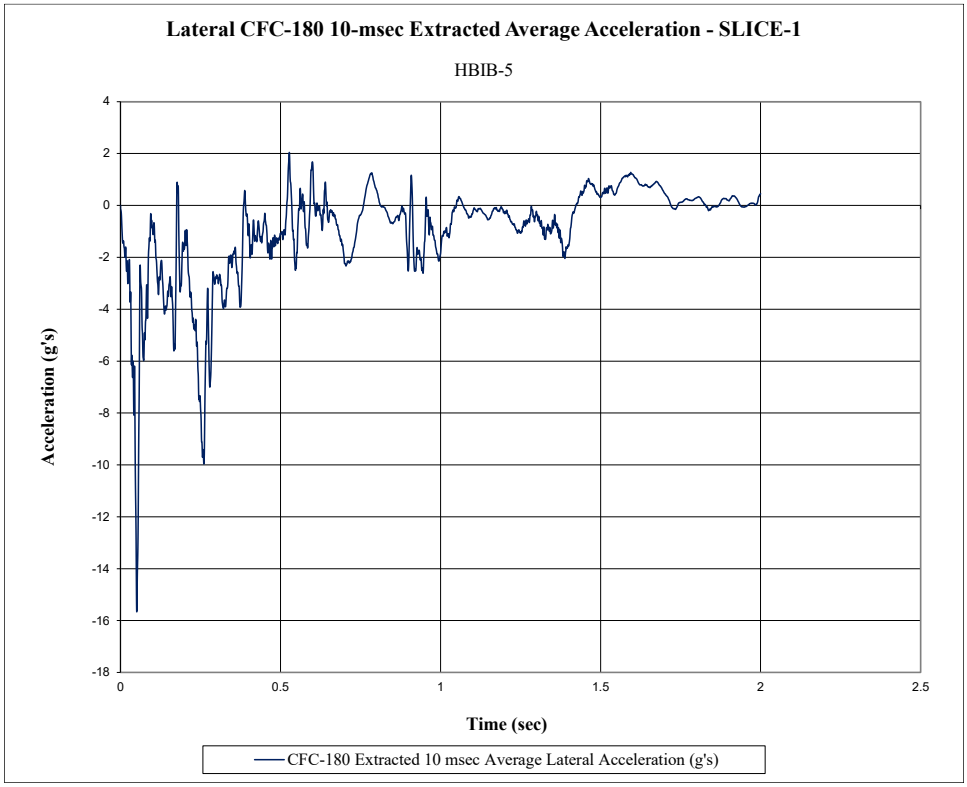


Figure K-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. HBIB-5

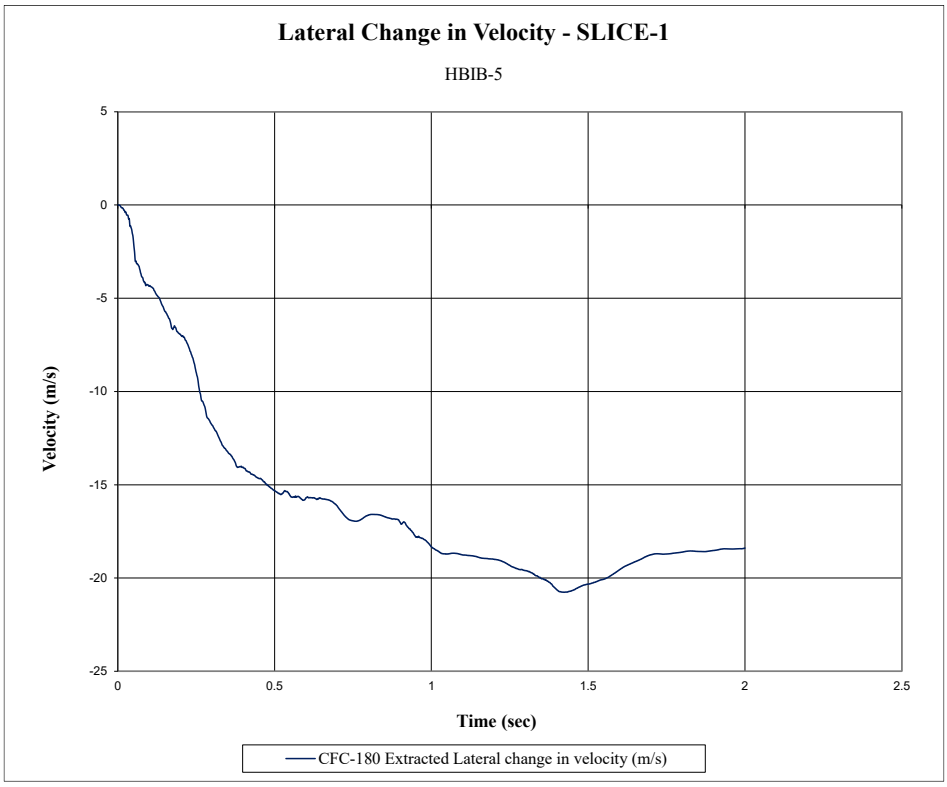


Figure K-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. HBIB-5

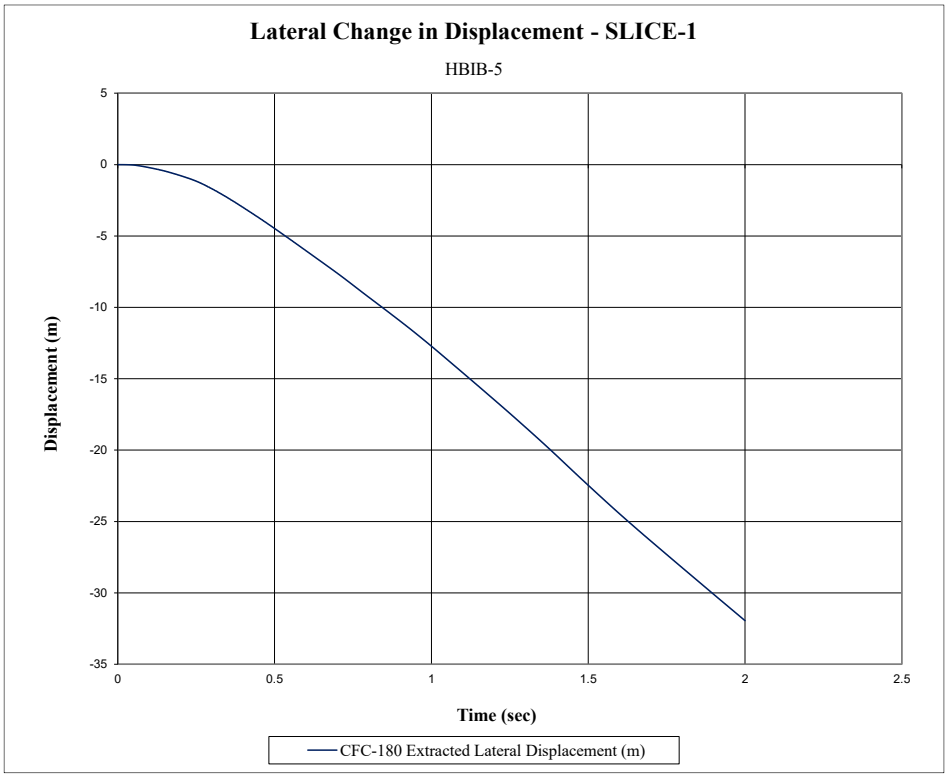


Figure K-6. Lateral Occupant Displacement (SLICE-1), Test No. HBIB-5

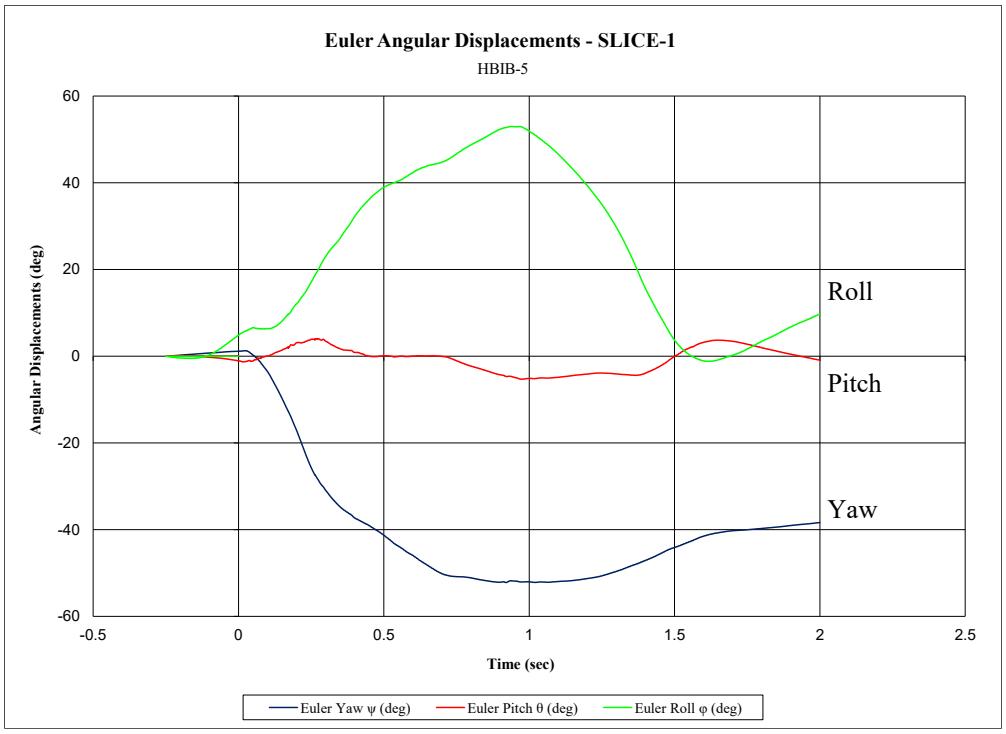


Figure K-7. Vehicle Angular Displacements (SLICE-1), Test No. HBIB-5

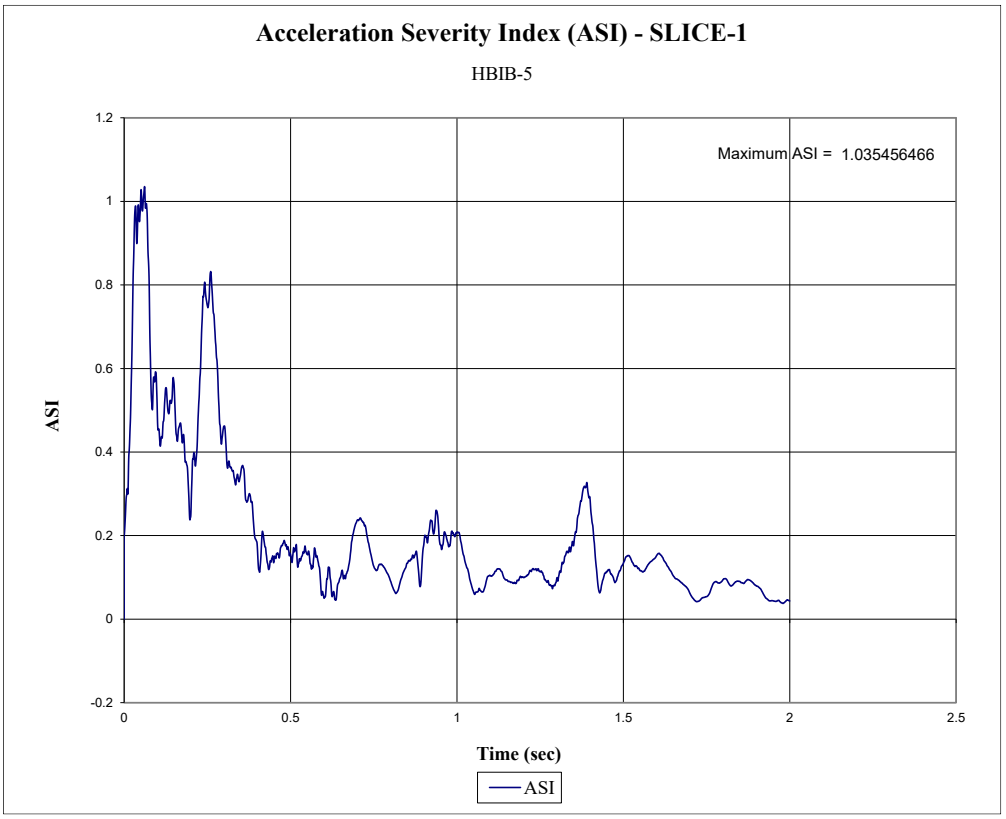


Figure K-8. Acceleration Severity Index (SLICE-1), Test No. HBIB-5

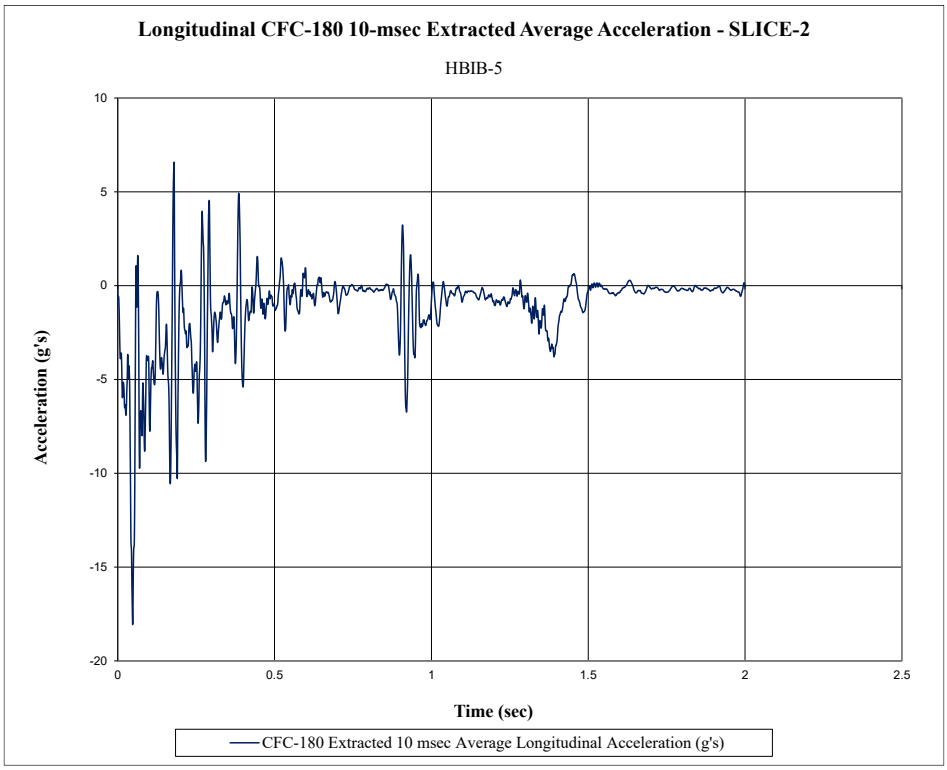


Figure K-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. HBIB-5

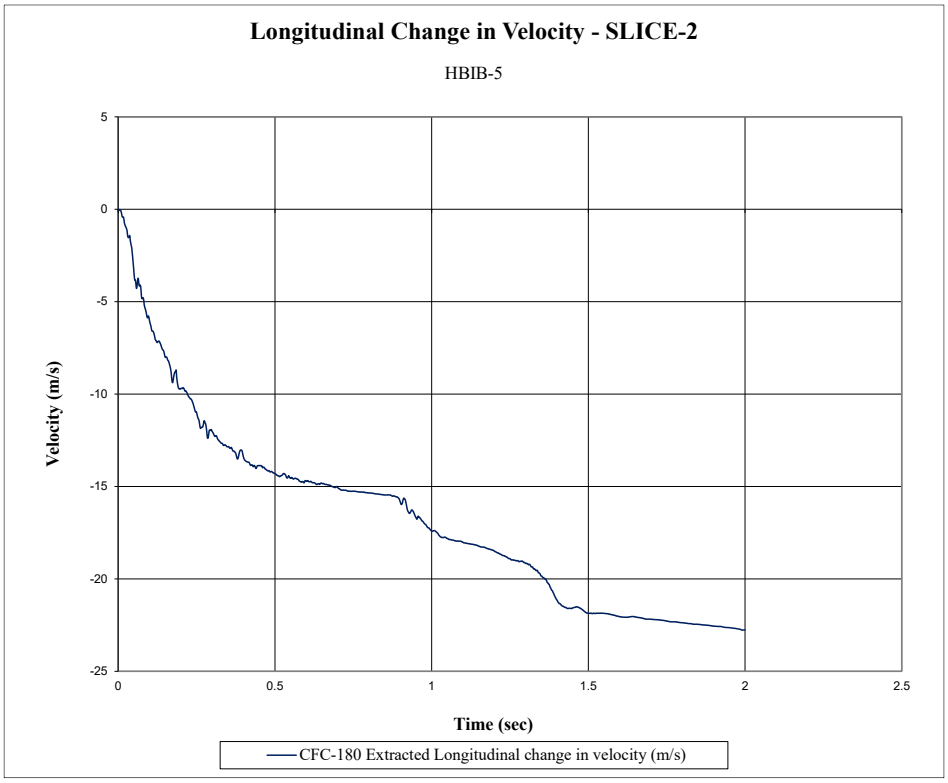


Figure K-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. HBIB-5

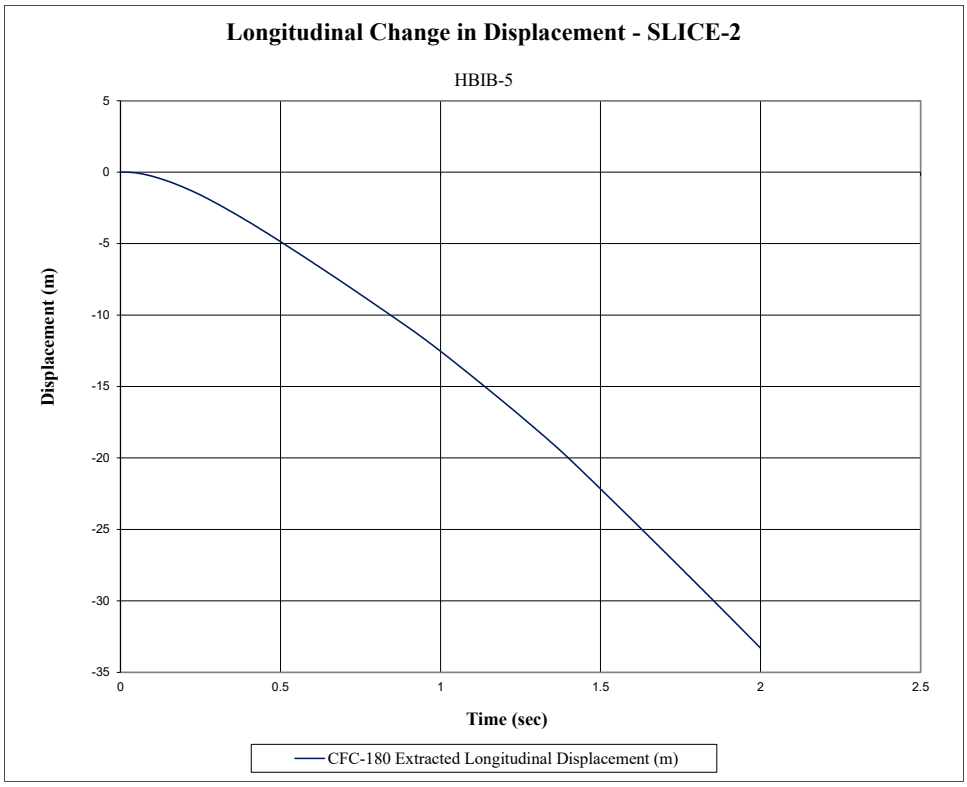


Figure K-11. Longitudinal Occupant Displacement (SLICE-2), Test No. HBIB-5

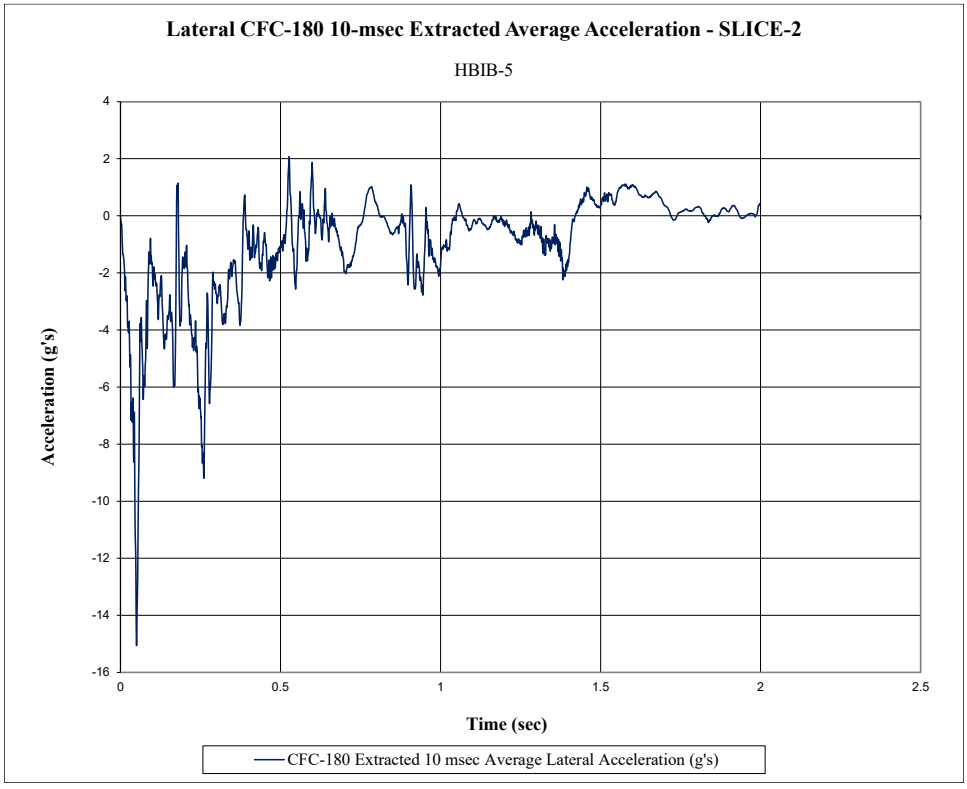


Figure K-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. HBIB-5

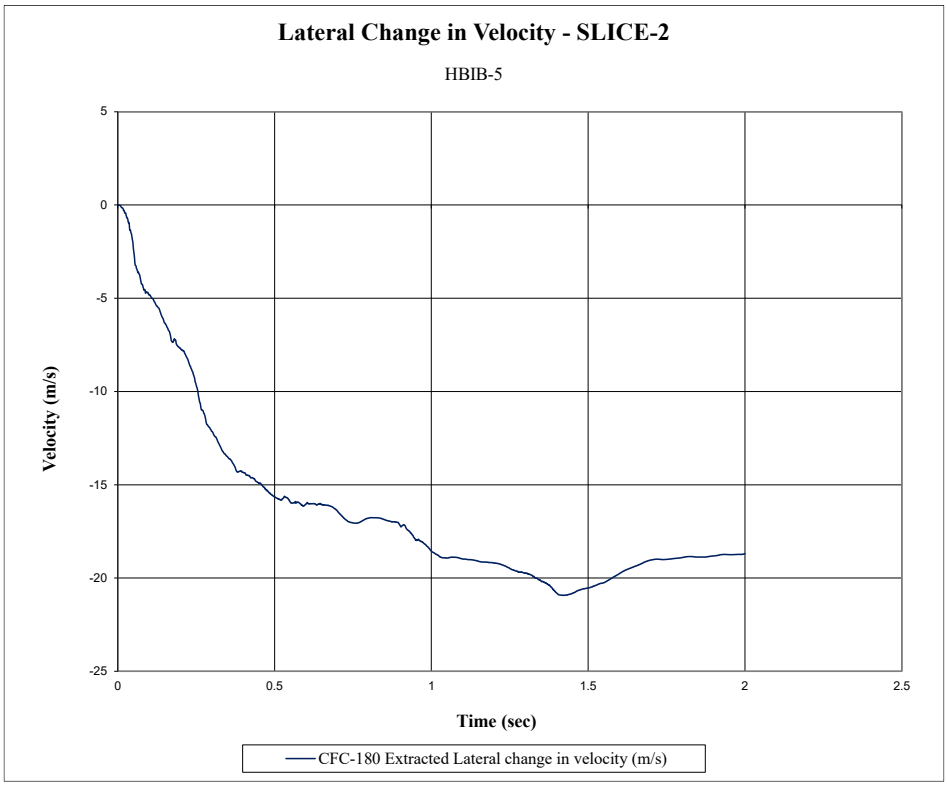


Figure K-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. HBIB-5

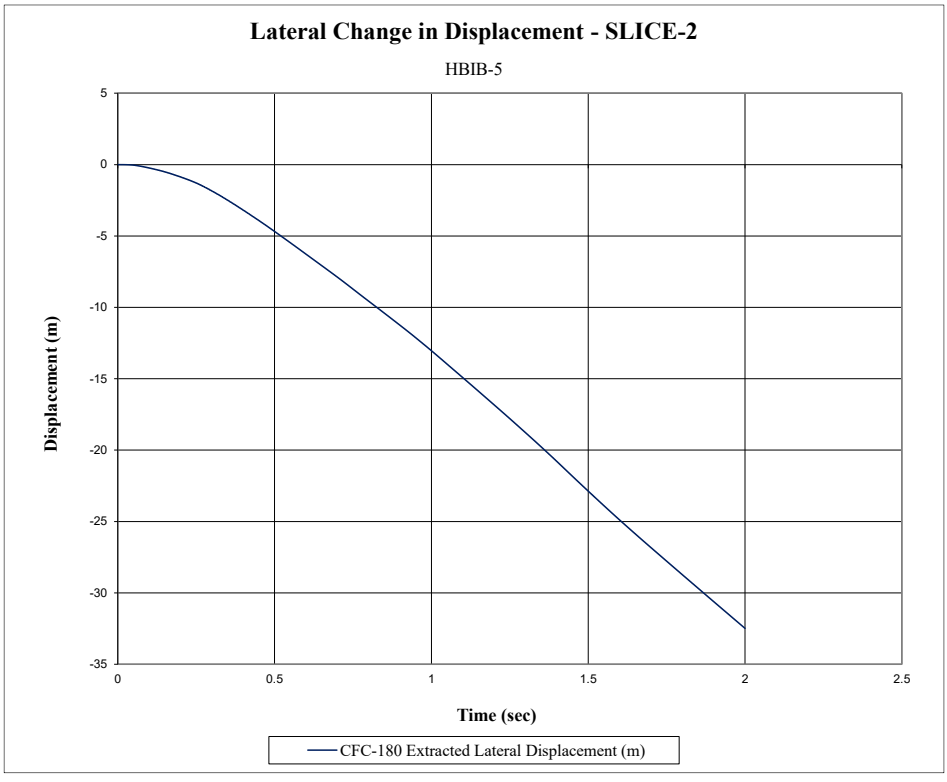


Figure K-14. Lateral Occupant Displacement (SLICE-2), Test No. HBIB-5

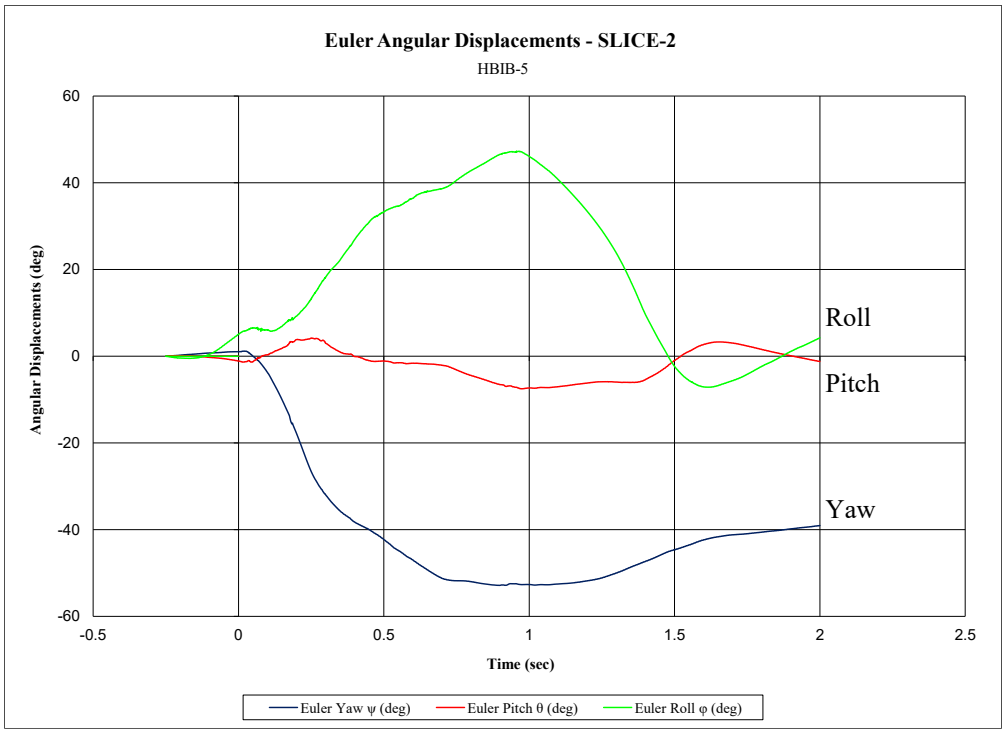


Figure K-15. Vehicle Angular Displacements (SLICE-2), Test No. HBIB-5

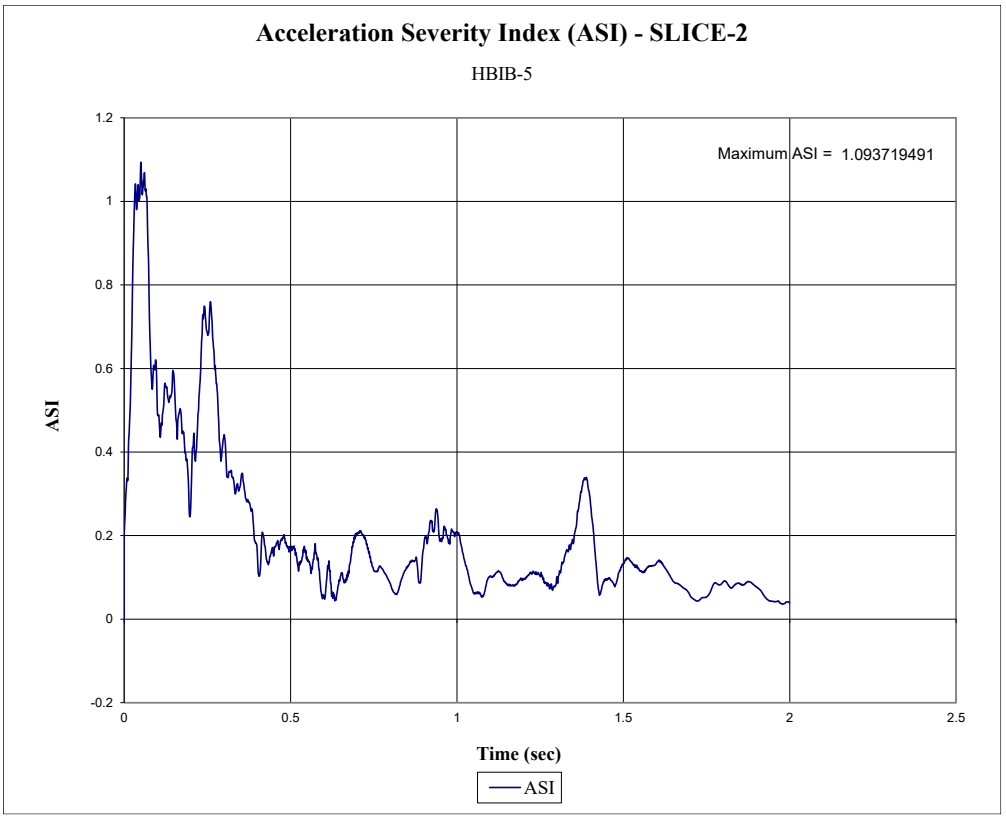


Figure K-16. Vehicle Angular Displacements (SLICE-2), Test No. HBIB-5

Appendix L. System Redesign Details, Options 1a, 1b, and 2

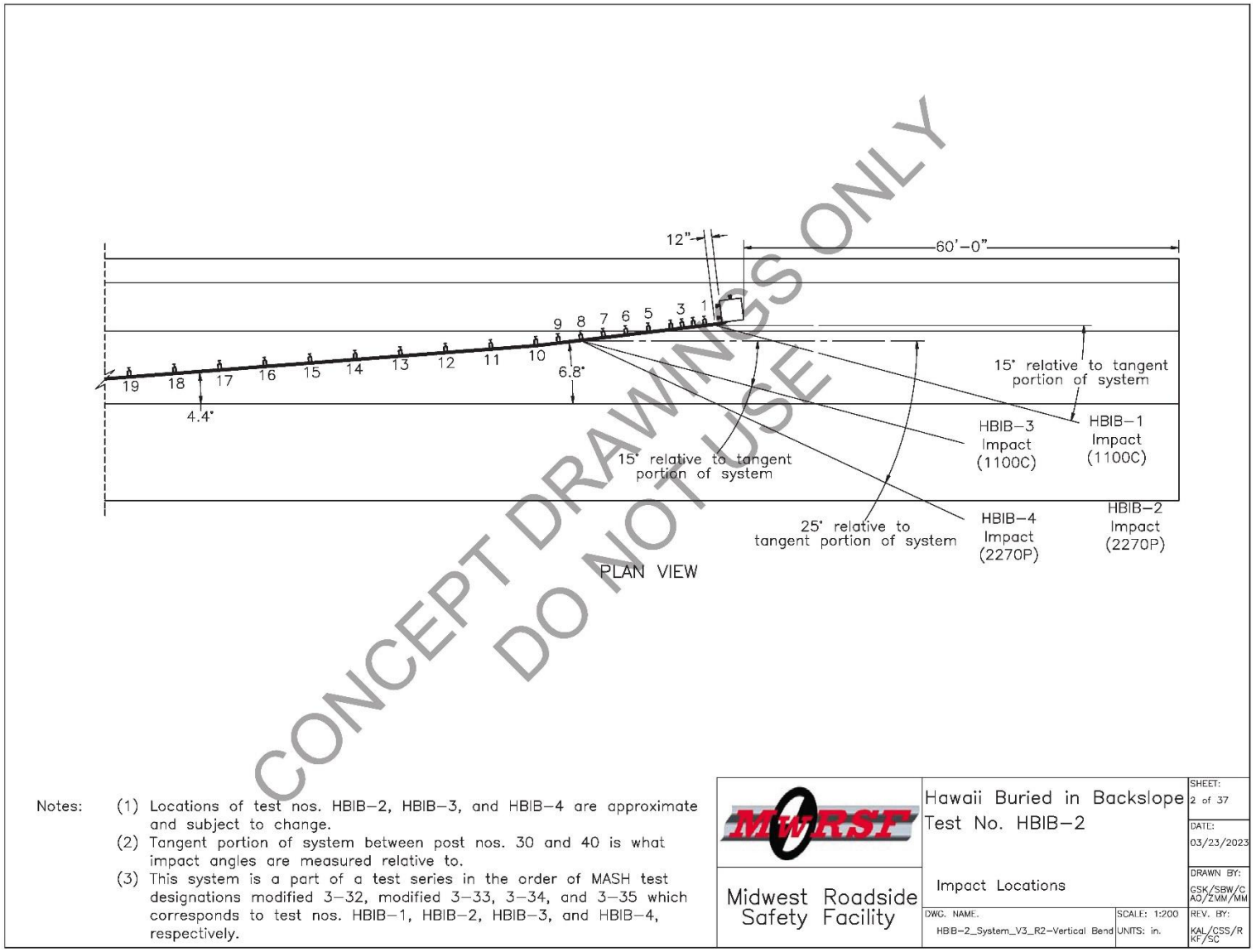


Figure L-1. Impact Location, Test No. HBIB-2, Options 1a, 1b, and 2

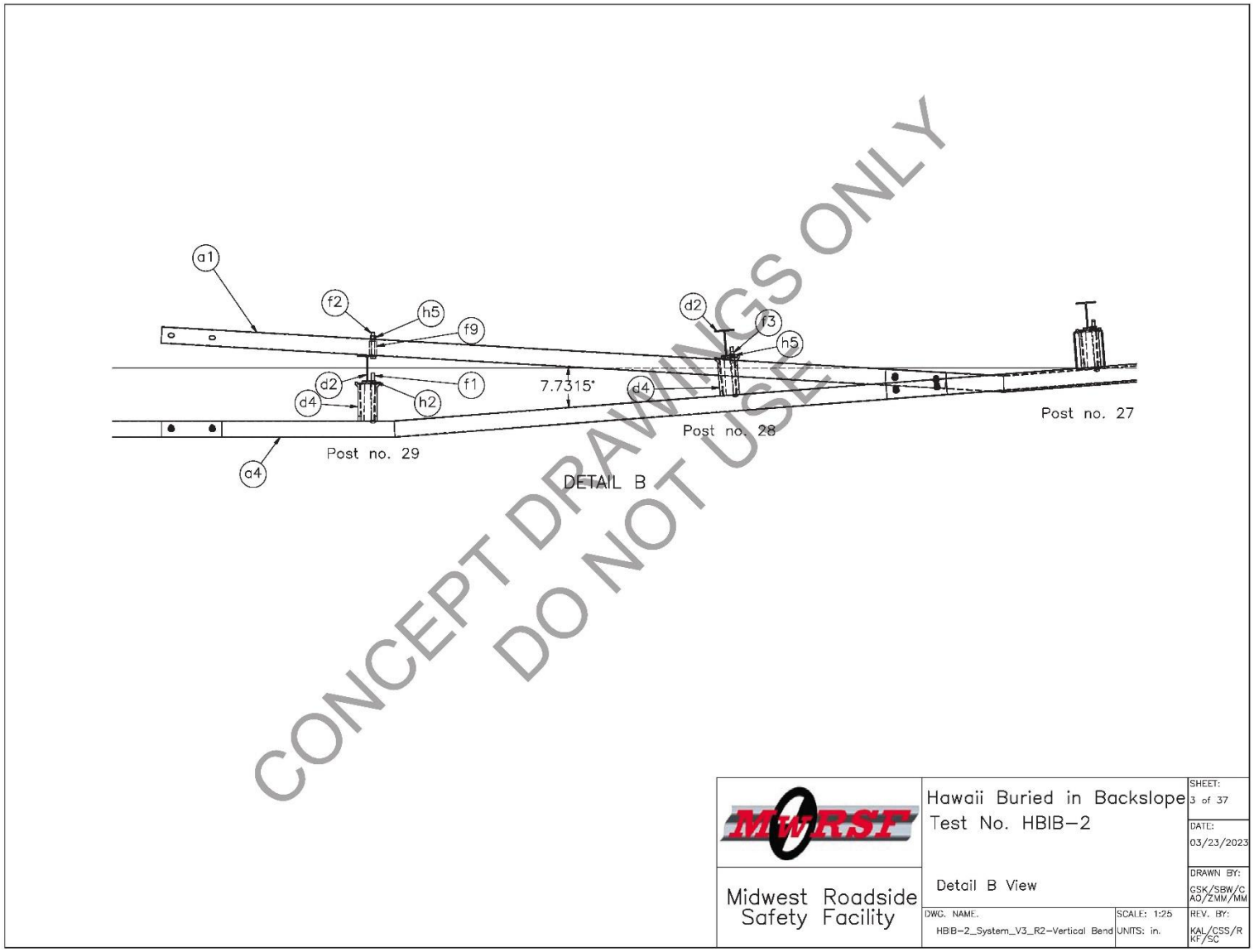


Figure L-2. Rubrail Termination Details, First Deviations Point, Test No. HBIB-2, Options 1a, 1b, and 2

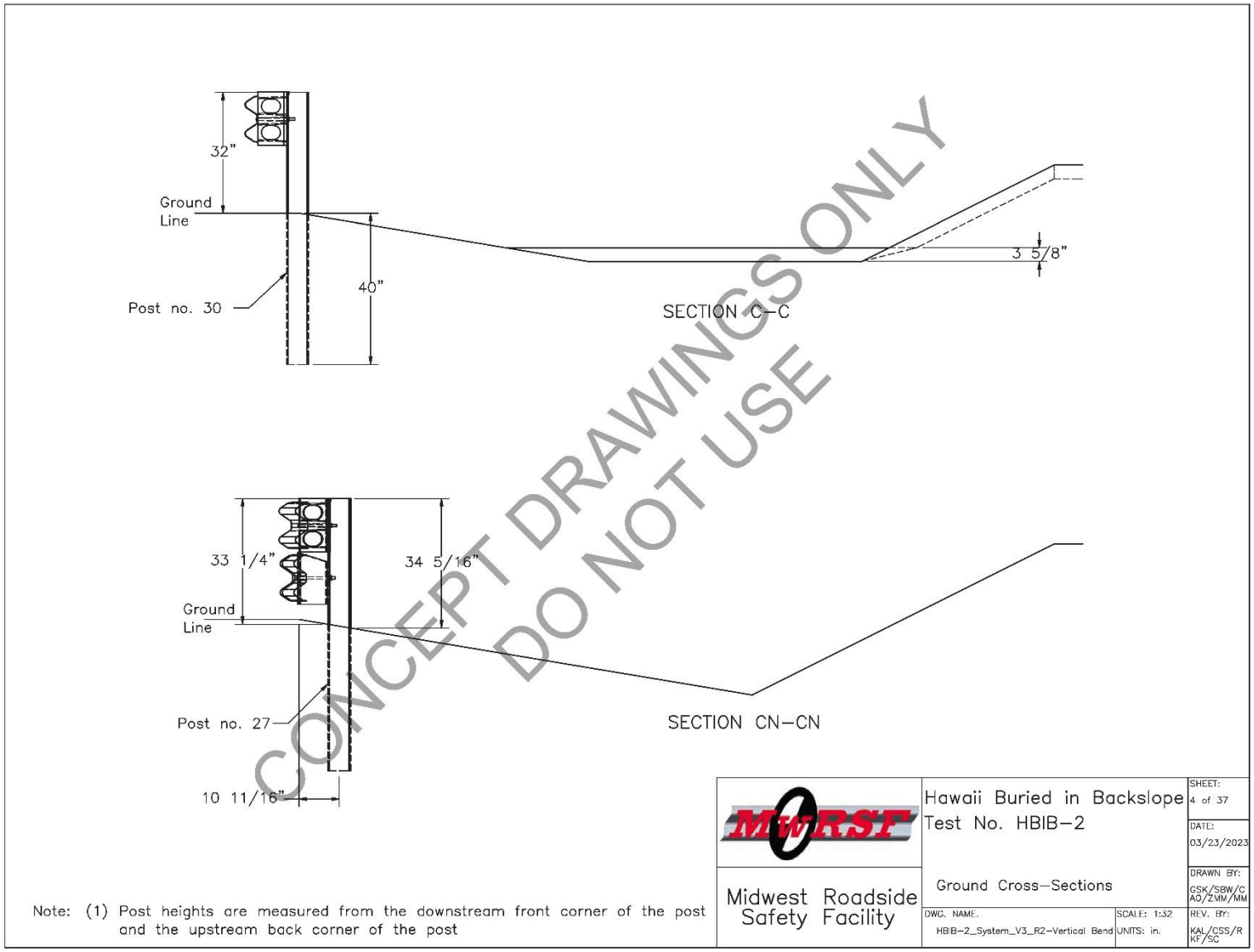


Figure L-3. Ground Cross Sections, Test No. HBIB-2, Options 1a, 1b, and 2

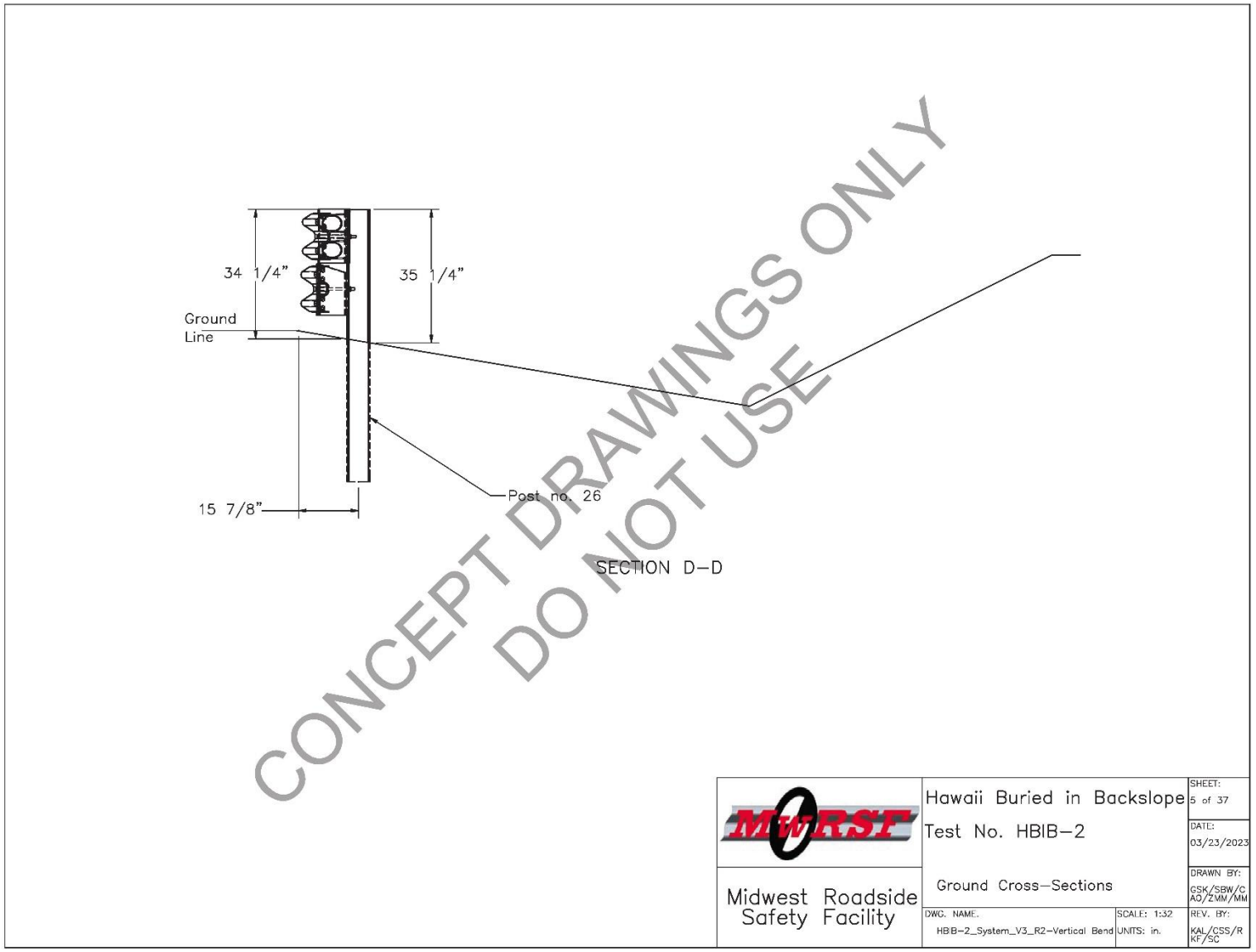


Figure L-4. Ground Cross Sections, Test No. HBIB-2, Options 1a, 1b, and 2

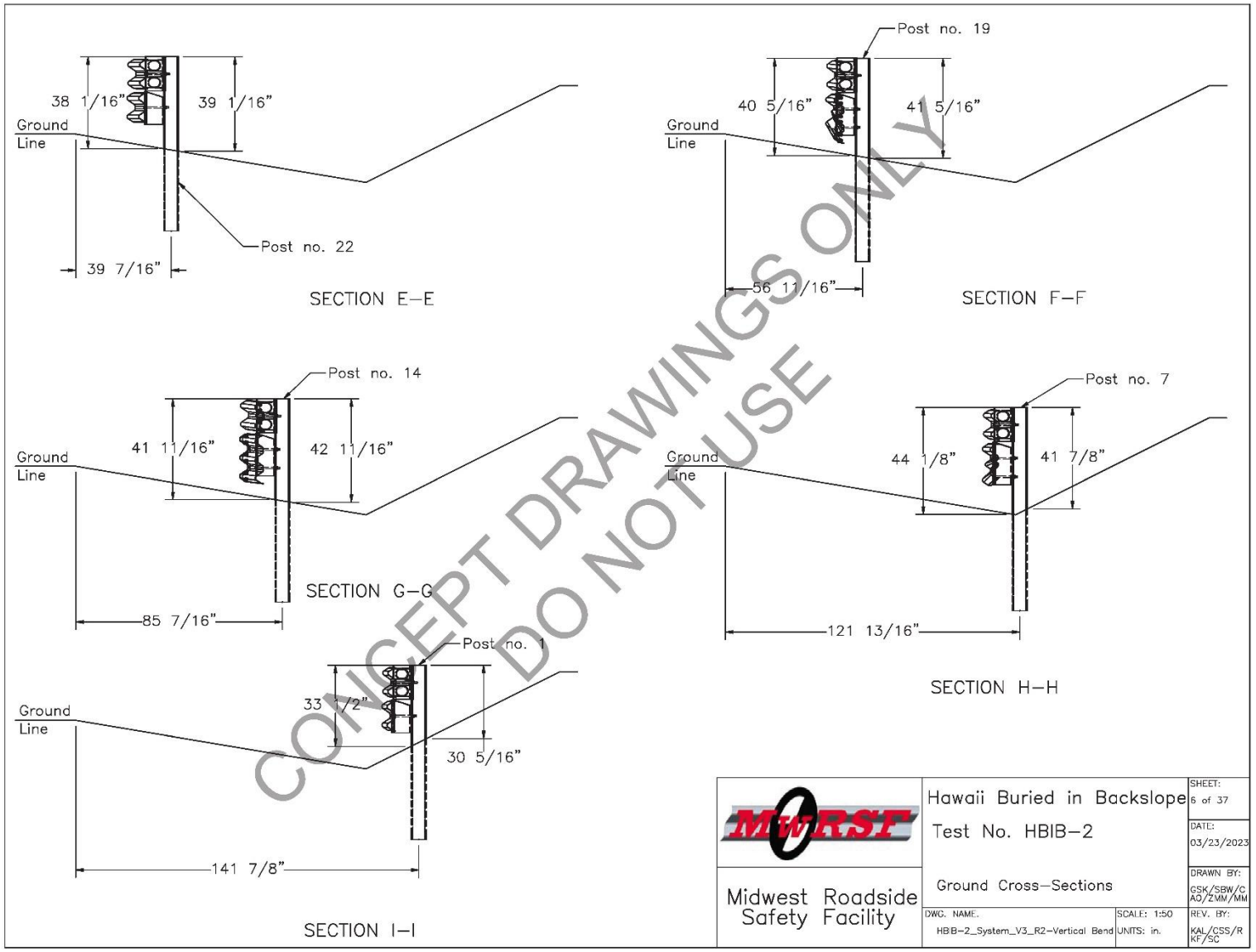


Figure L-5. Ground Cross Sections, Test No. HBIB-2, Options 1a and 1b

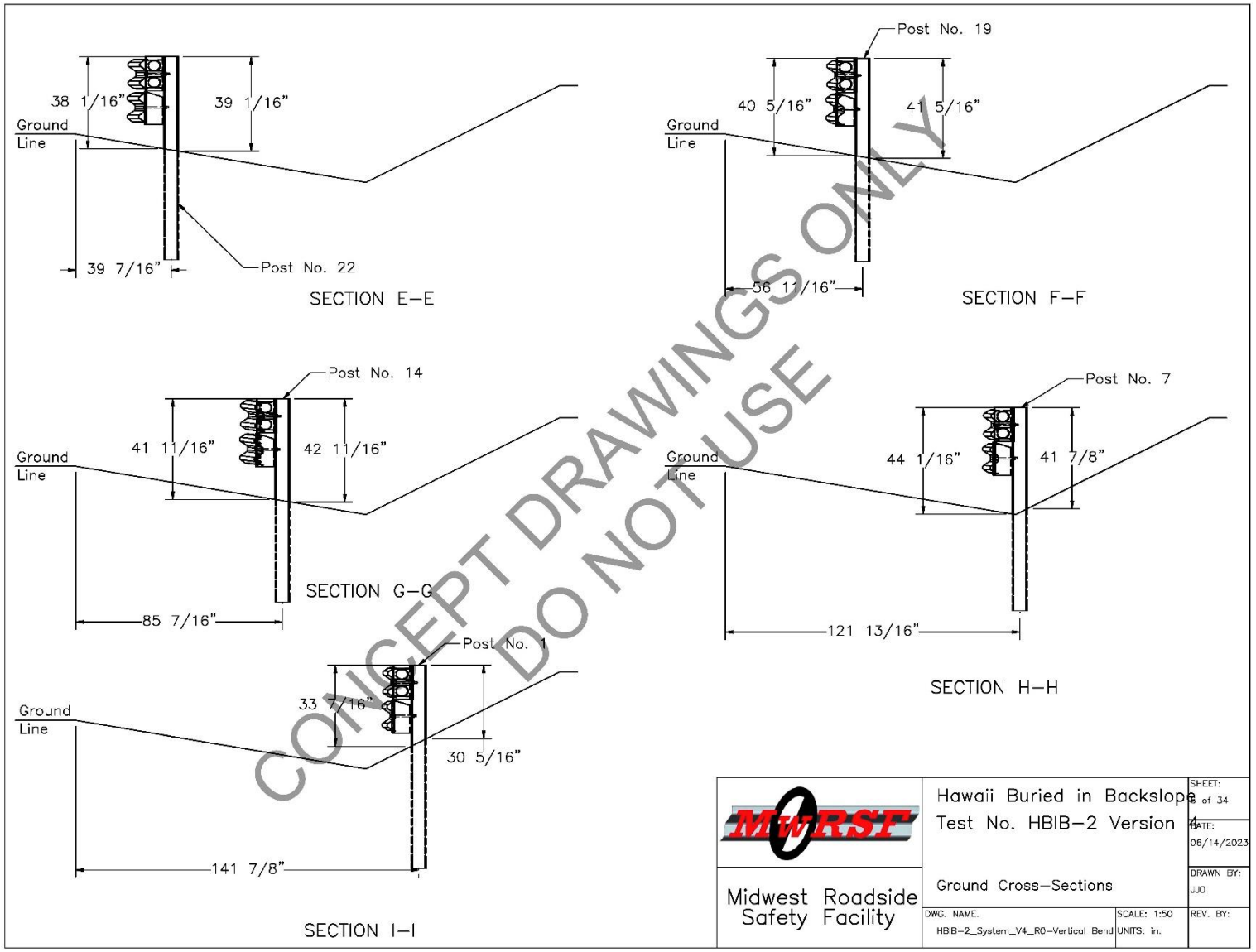
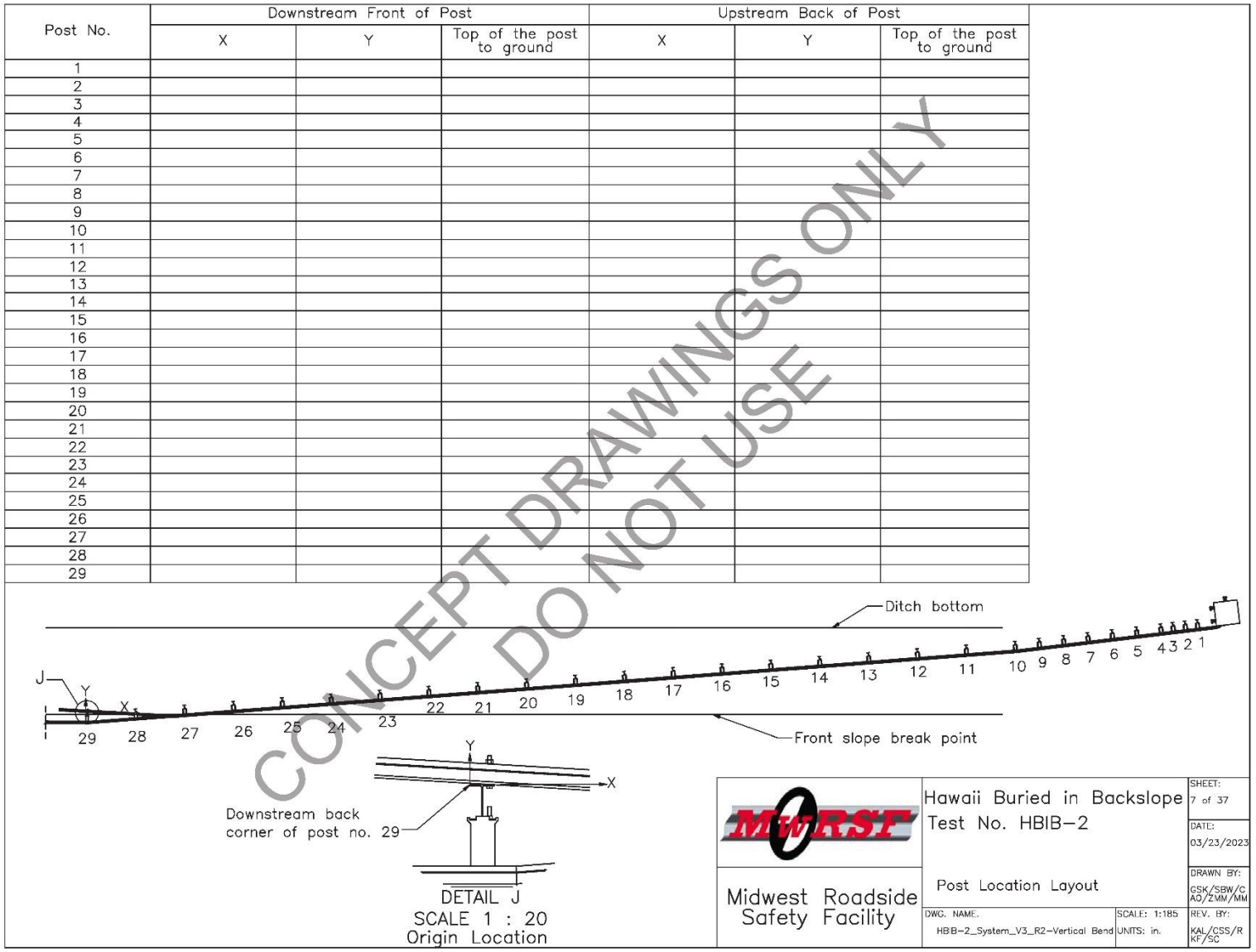


Figure L-6. Ground Cross Sections, Test No. HBIB-2, Options 2



Post No.	Downstream Front of Post			Upstream Back of Post		
	X	Y	Top of the post to ground	X	Y	Top of the post to ground
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						

Figure L-7. Post Location Layout, Test No. HBIB-2, Options 1a and 1b

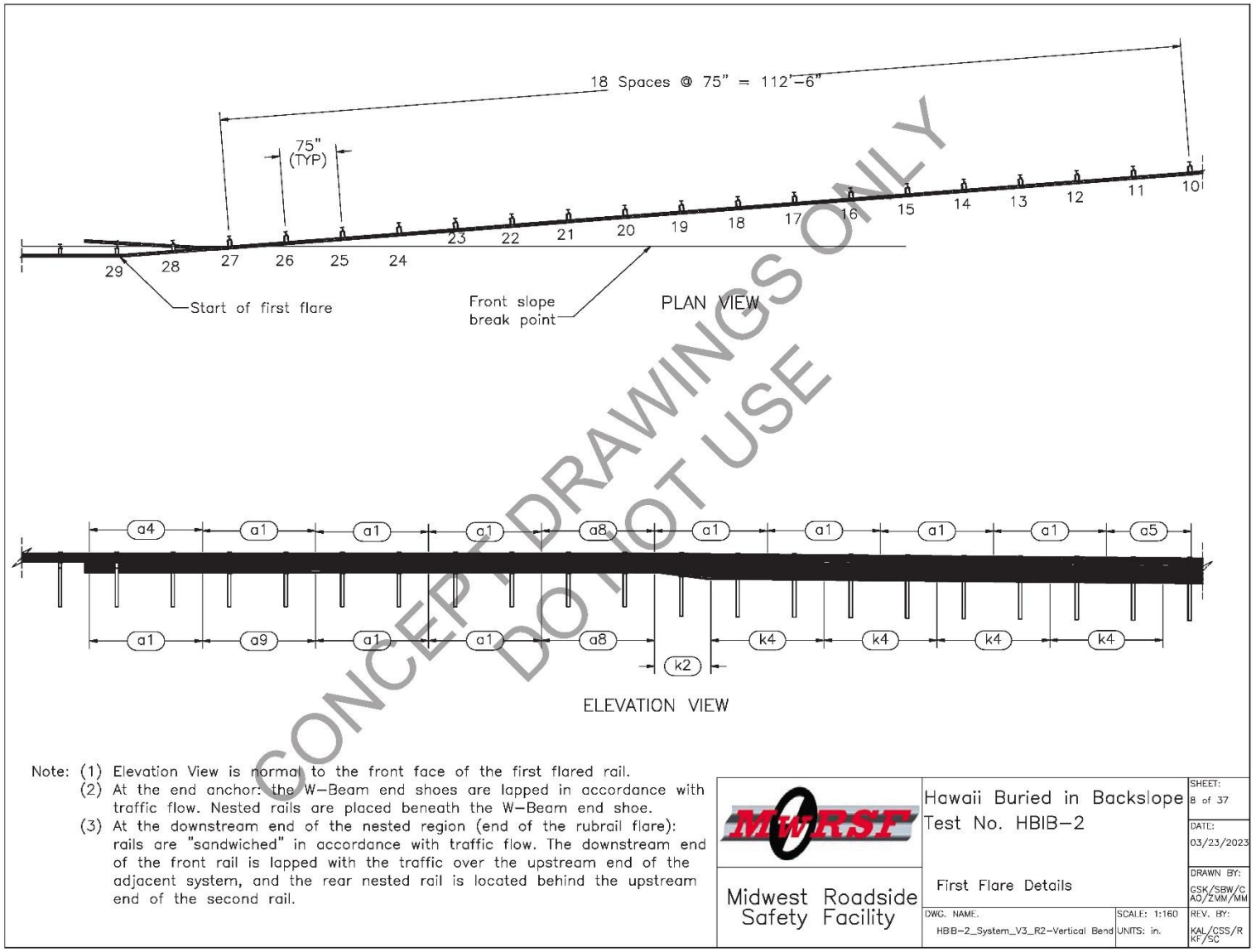


Figure L-8. First Flare Details, Test No. HBIB-2, Options 1a and 1b

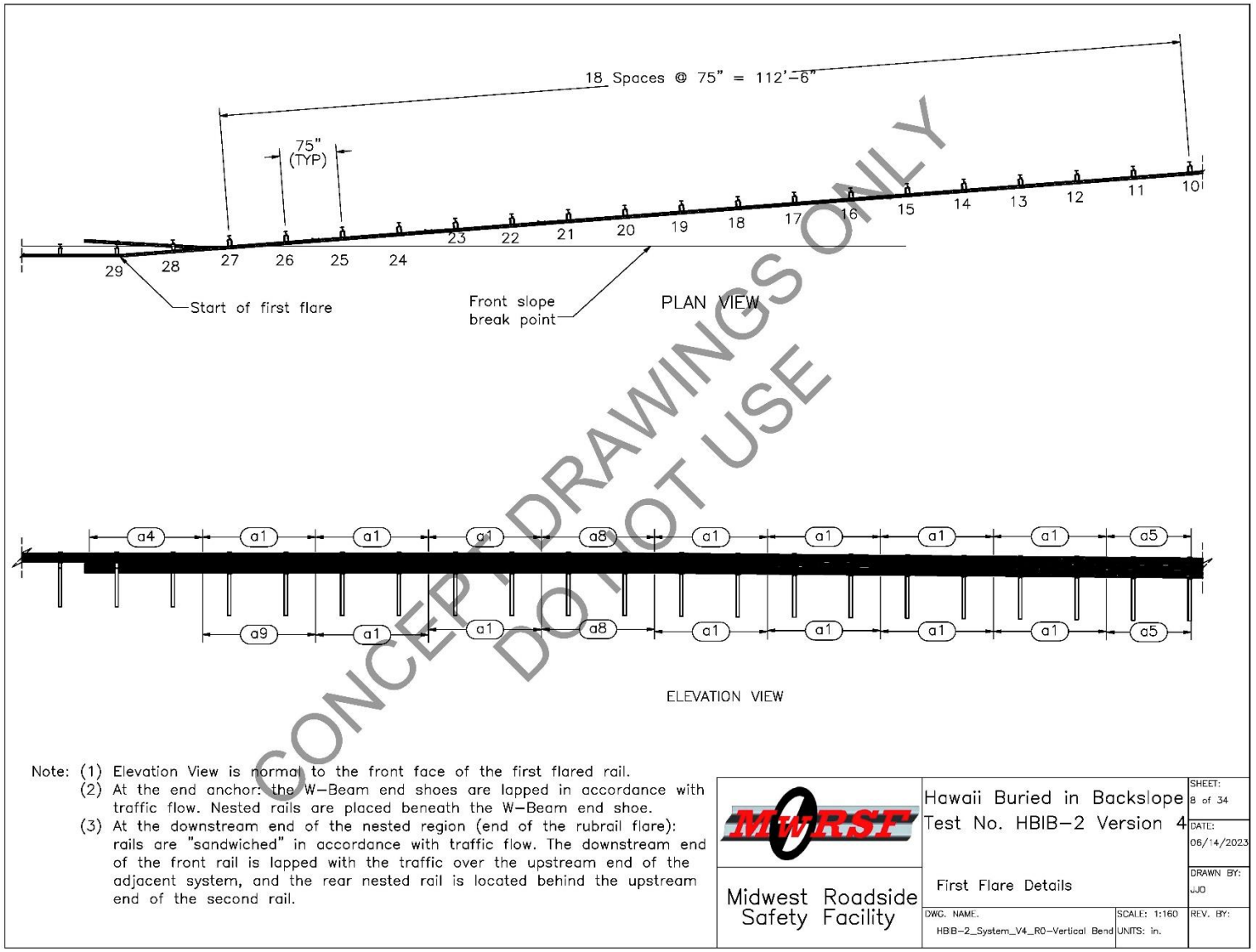
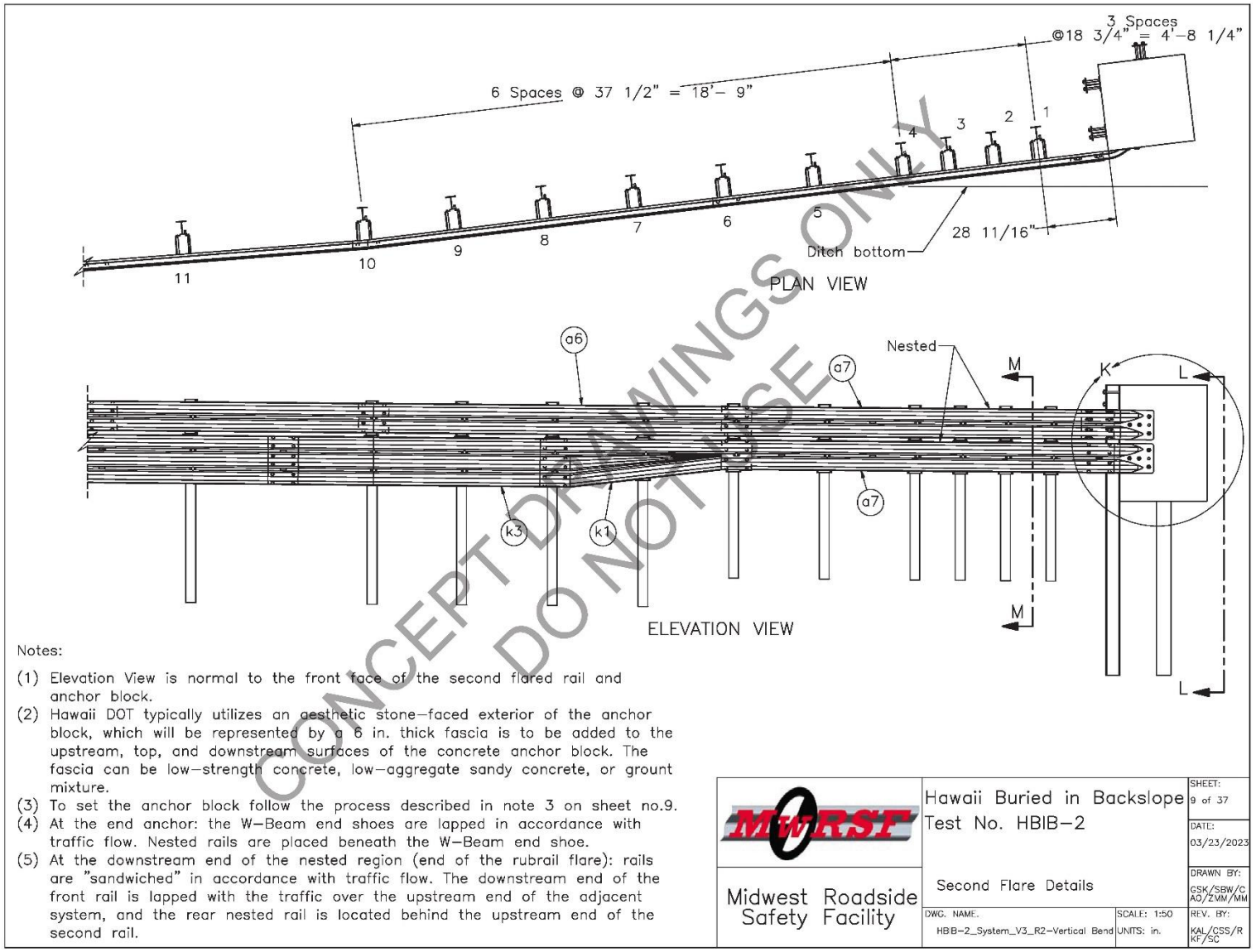


Figure L-9. First Flare Details, Test No. HBIB-2, Option 2



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Figure L-10. Second Flare Details, Test No. HBIB-2, Option 1a

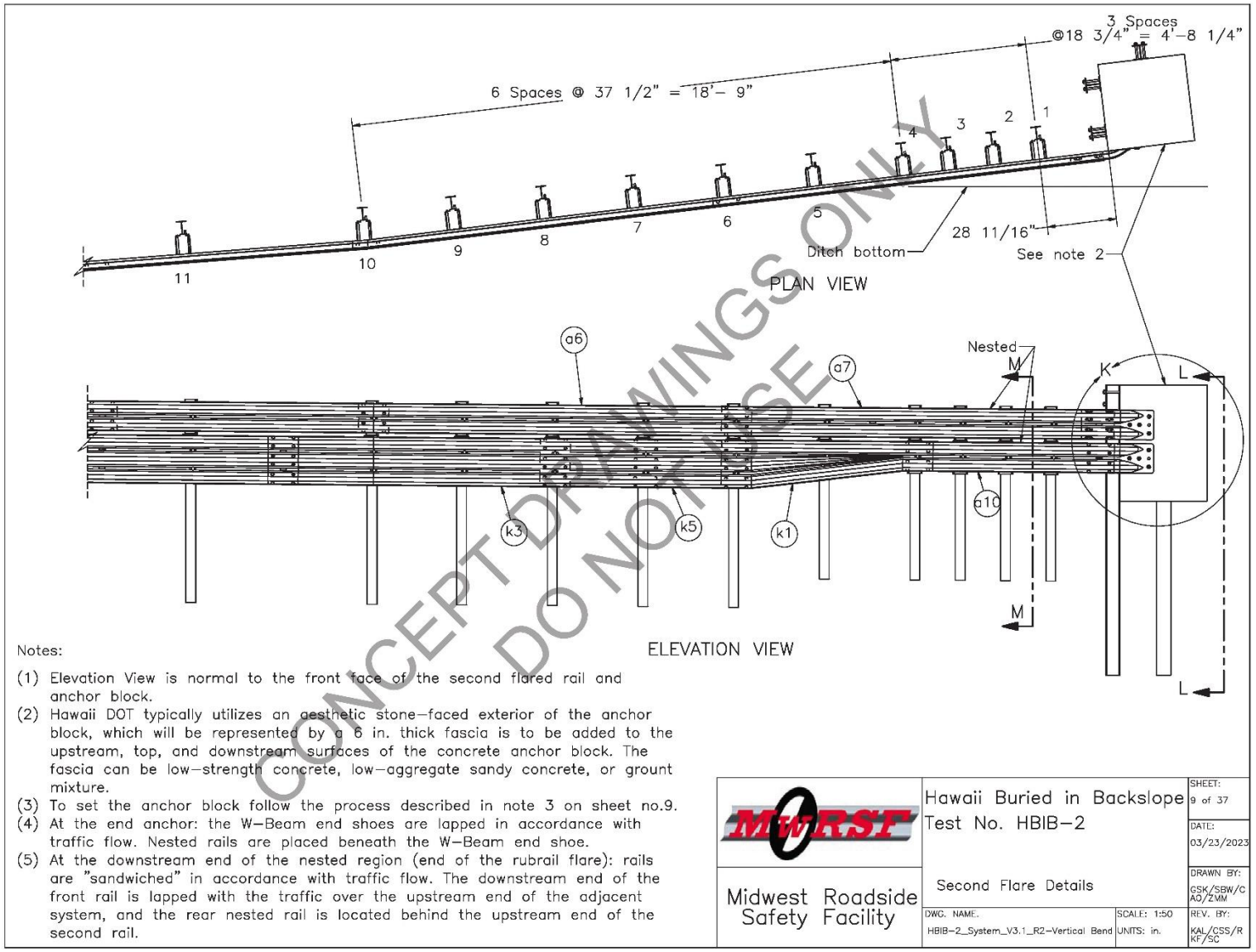


Figure L-11. Second Flare Details, Test No. HBIB-2, Option 1b

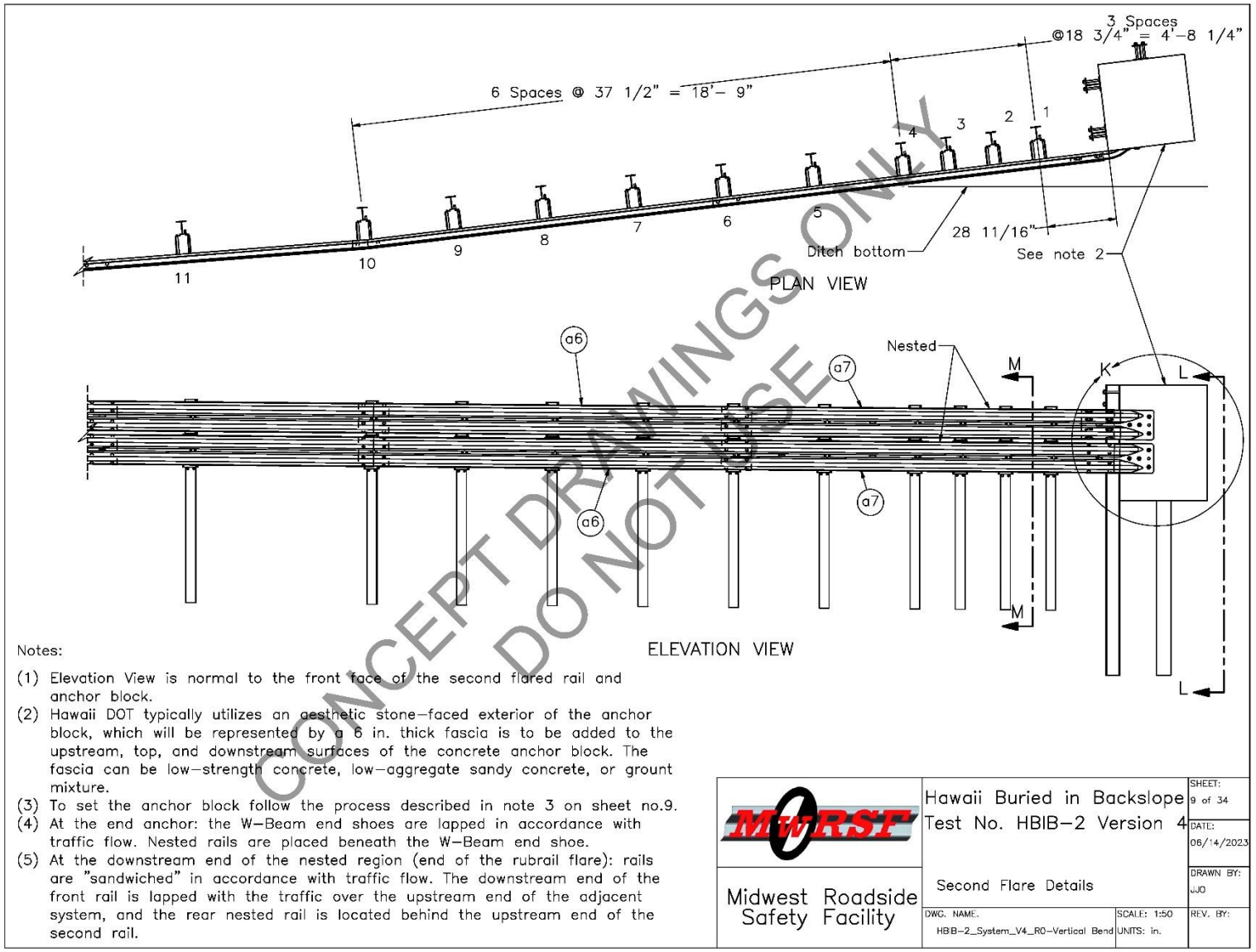


Figure L-12. Second Flare Details, Test No. HBIB-2, Option 2

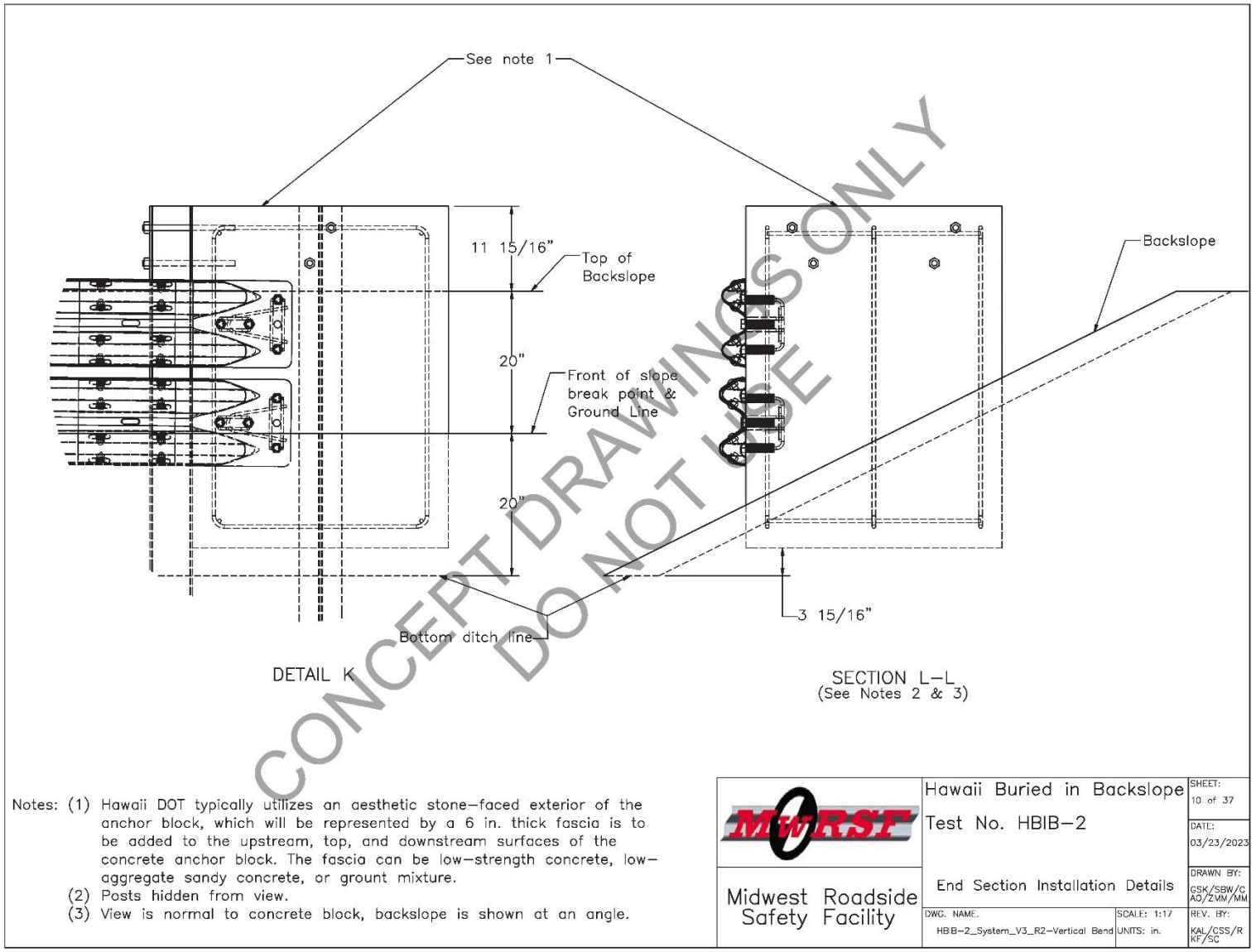


Figure L-13. End Section Installation Details, Test No. HBIB-2, Options 1a, 1b, and 2

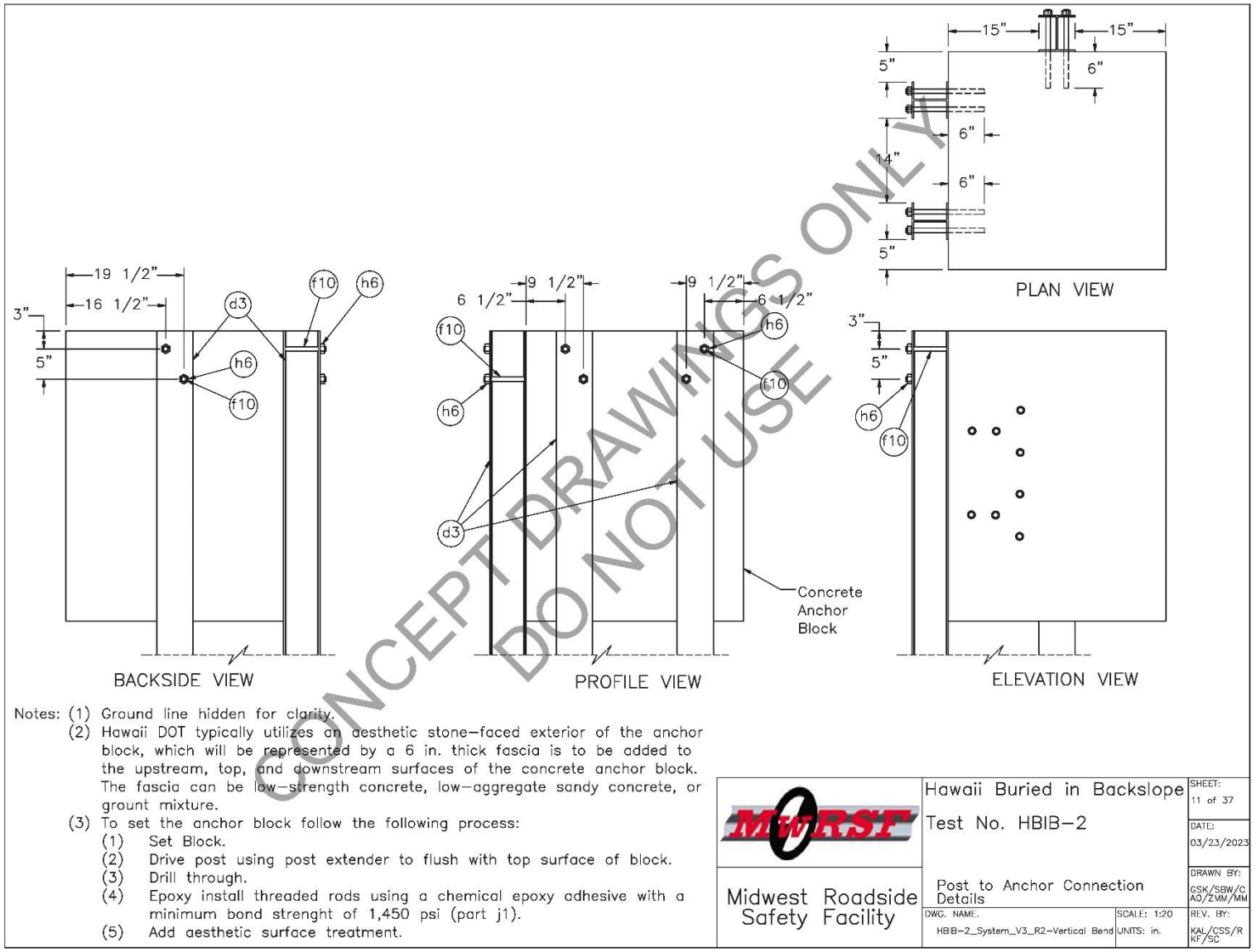


Figure L-14. Post to Anchor Connection, Test No. HBIB-2, Options 1a, 1b, and 2

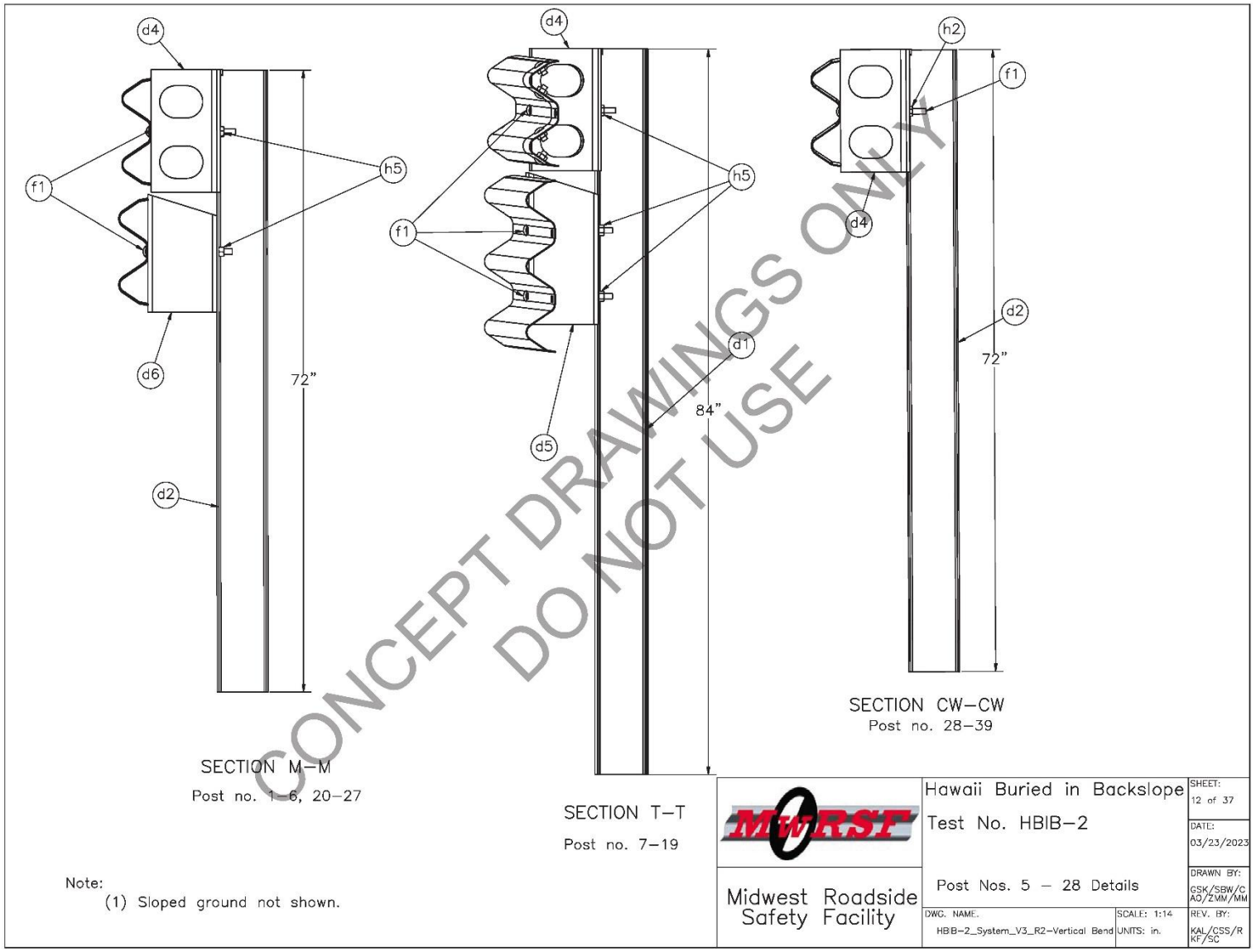


Figure L-15. Post Details, Test No. HBIB-2, Option 1a

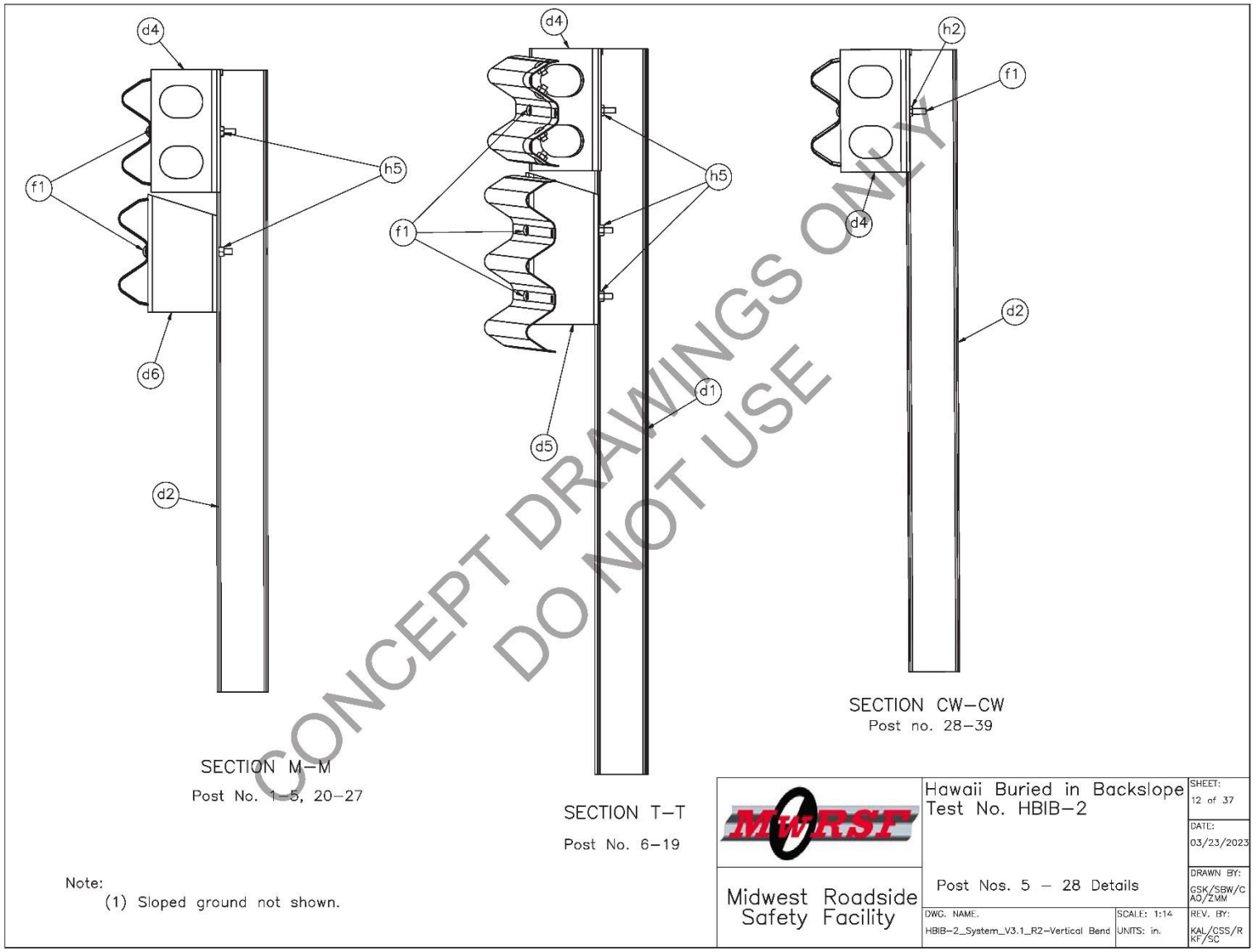


Figure L-16. Post Details, Test No. HBIB-2, Option 1b

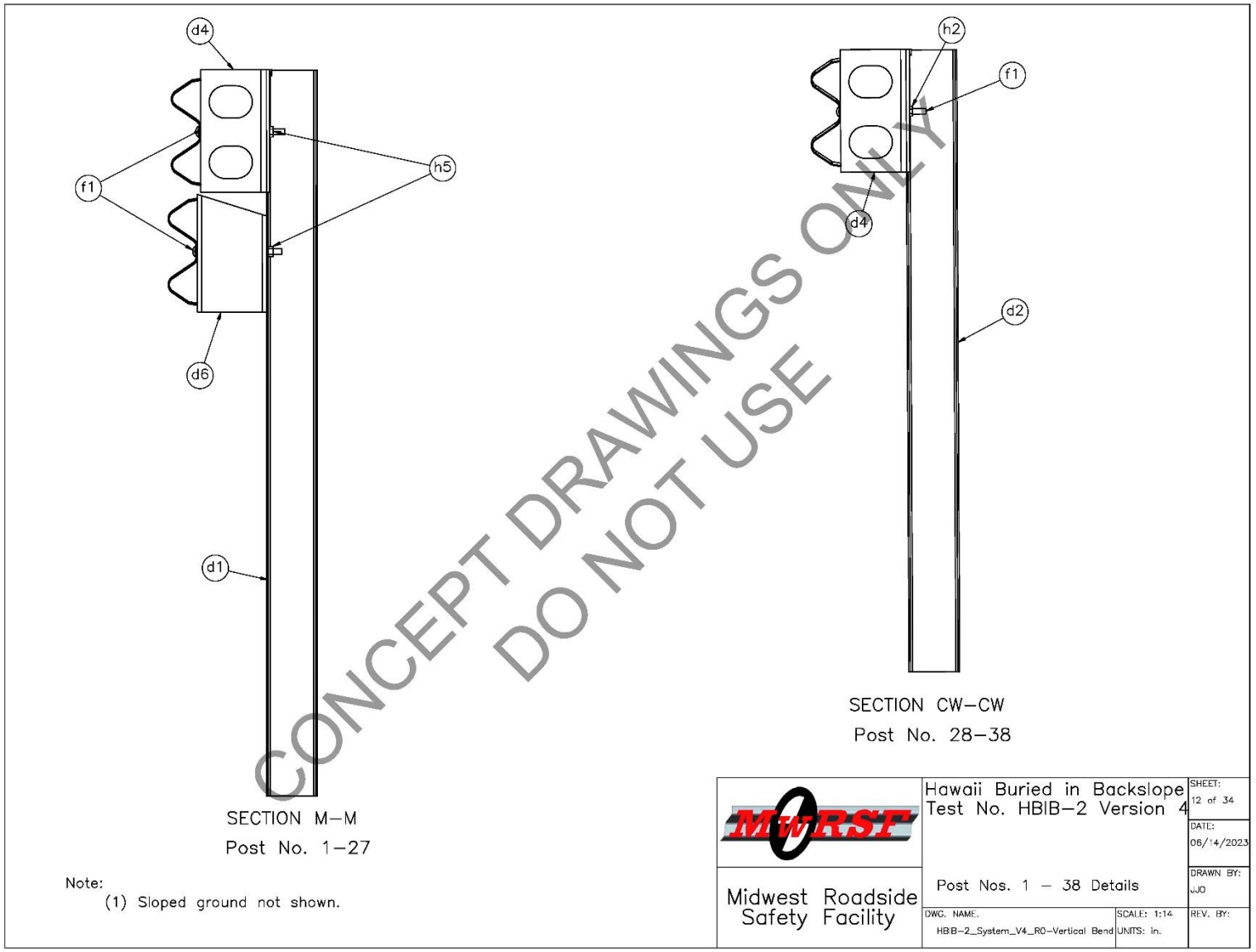


Figure L-17. Post Details, Test No. HBIB-2, Option 2

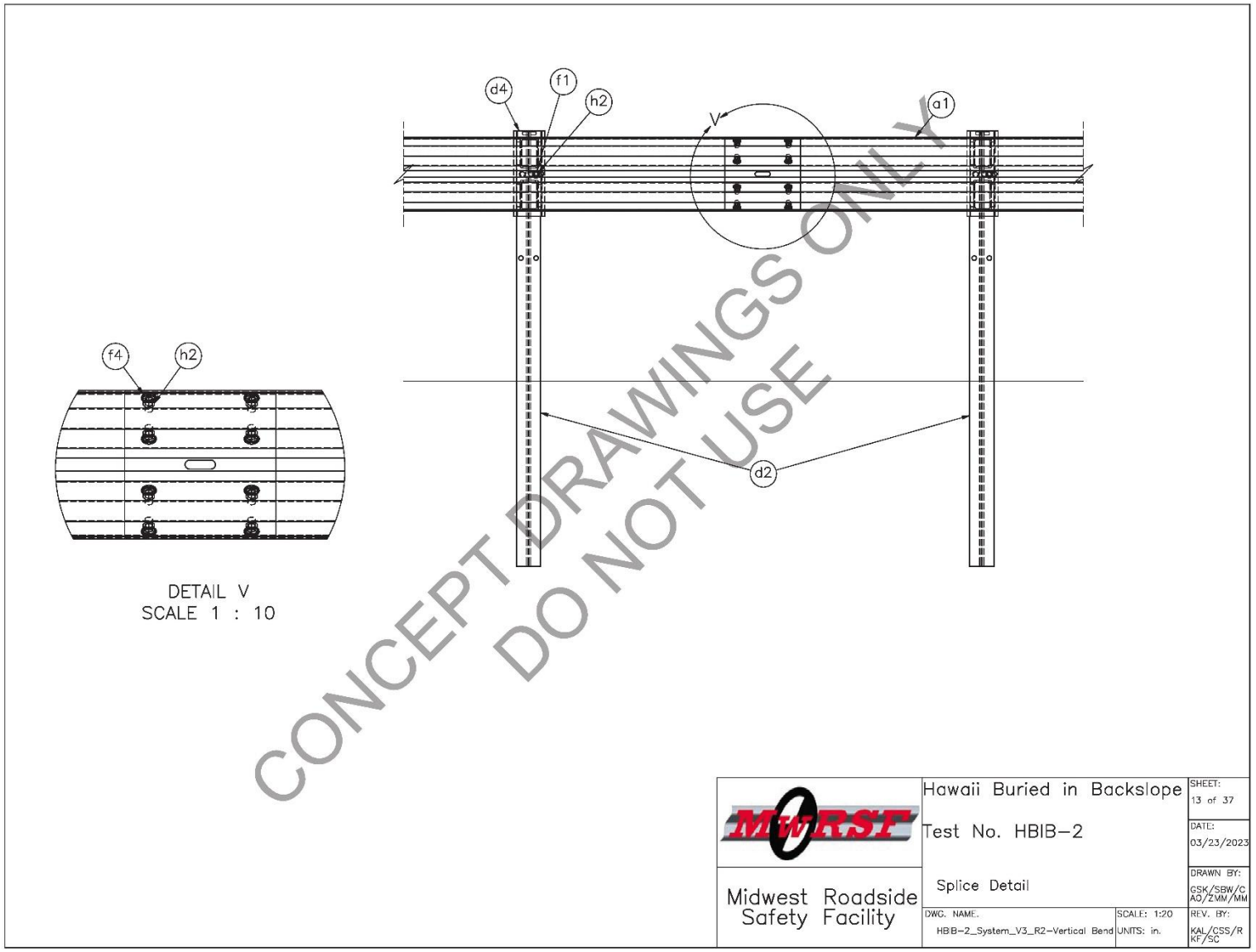


Figure L-18. Splice Details, Test No. HBIB-2, Options 1a, 1b, and 2

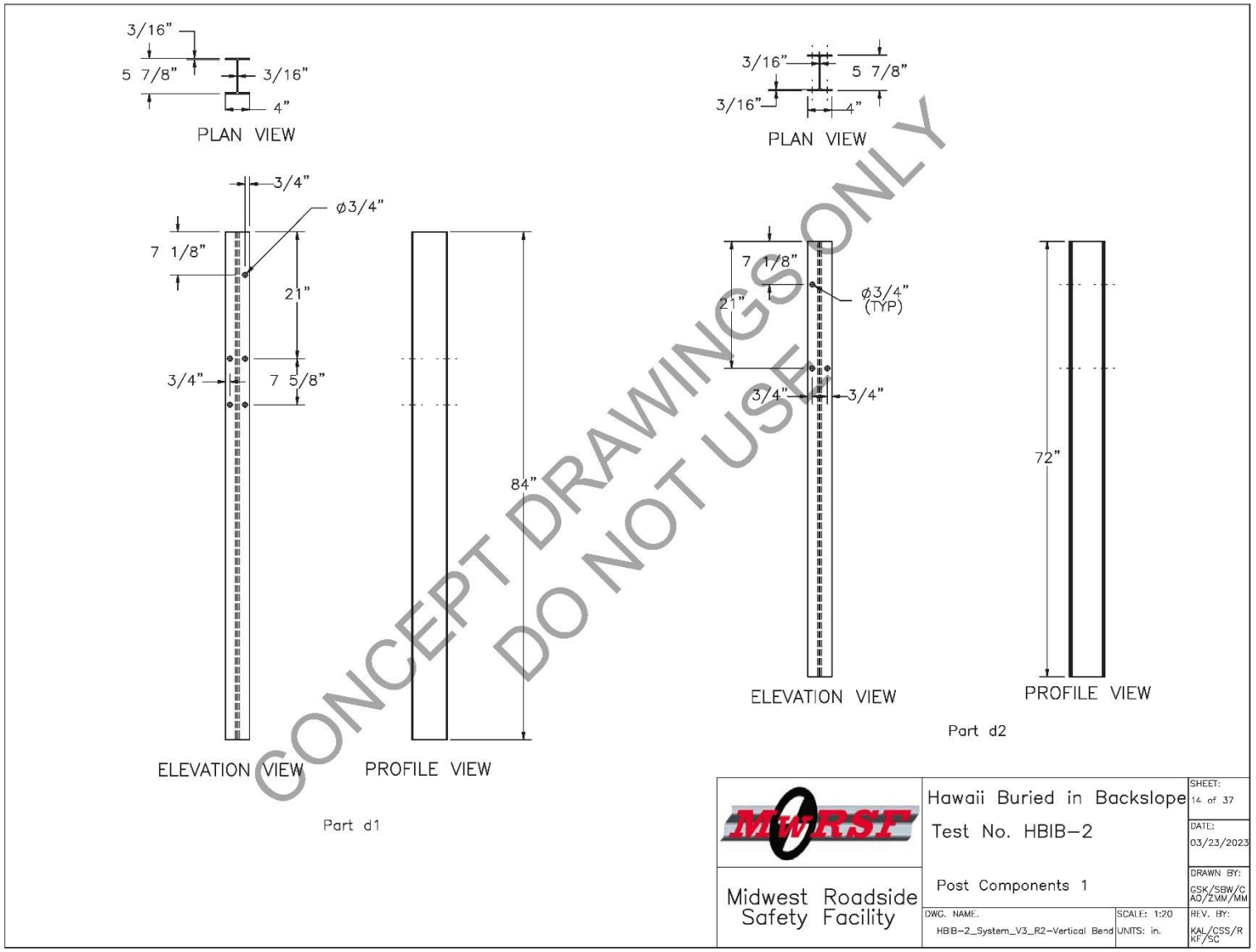


Figure L-19. Post Components Details, Test No. HBIB-2, Options 1a, 1b, and 2

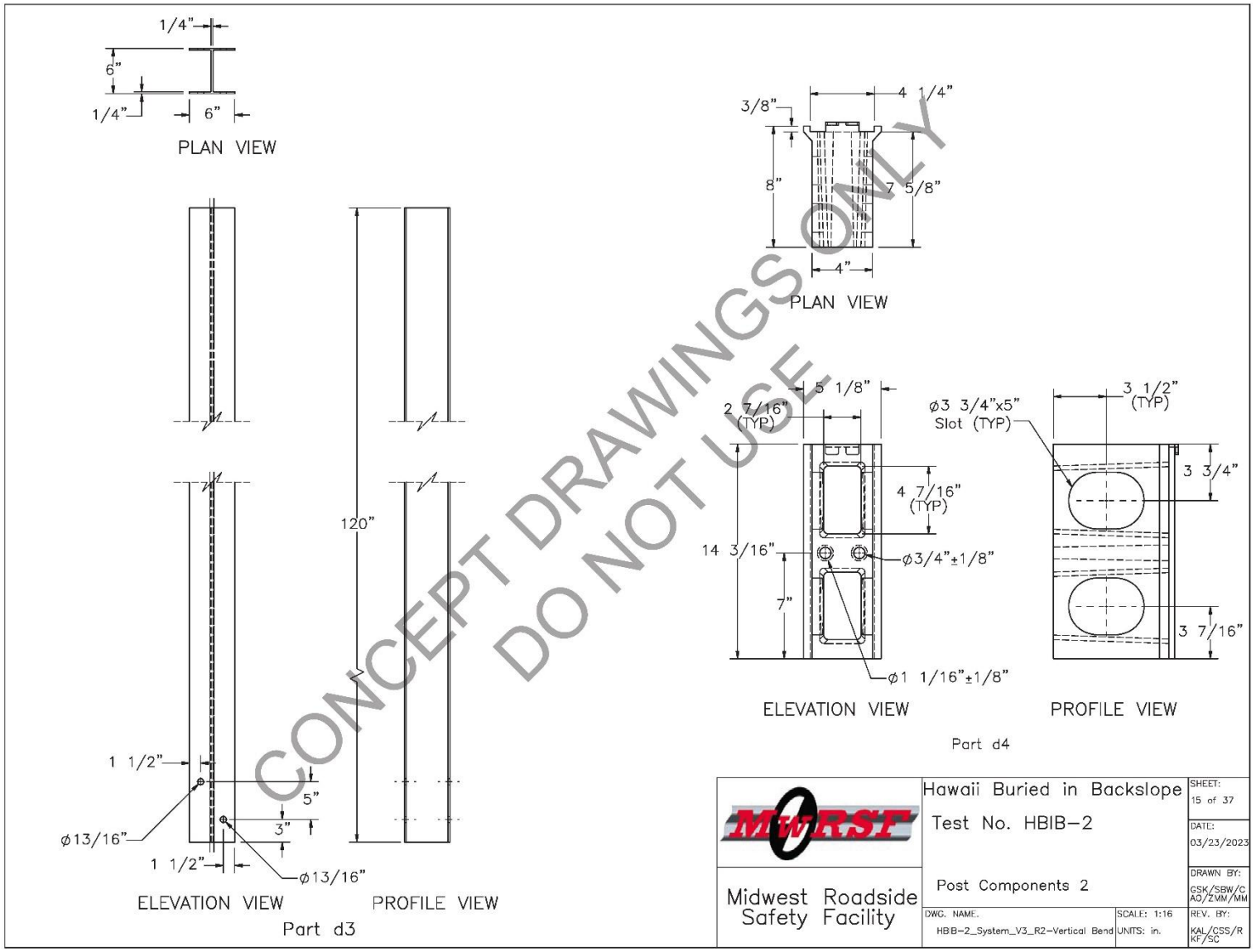


Figure L-20. Post Components Details, Test No. HBIB-2, Options 1a, 1b, and 2

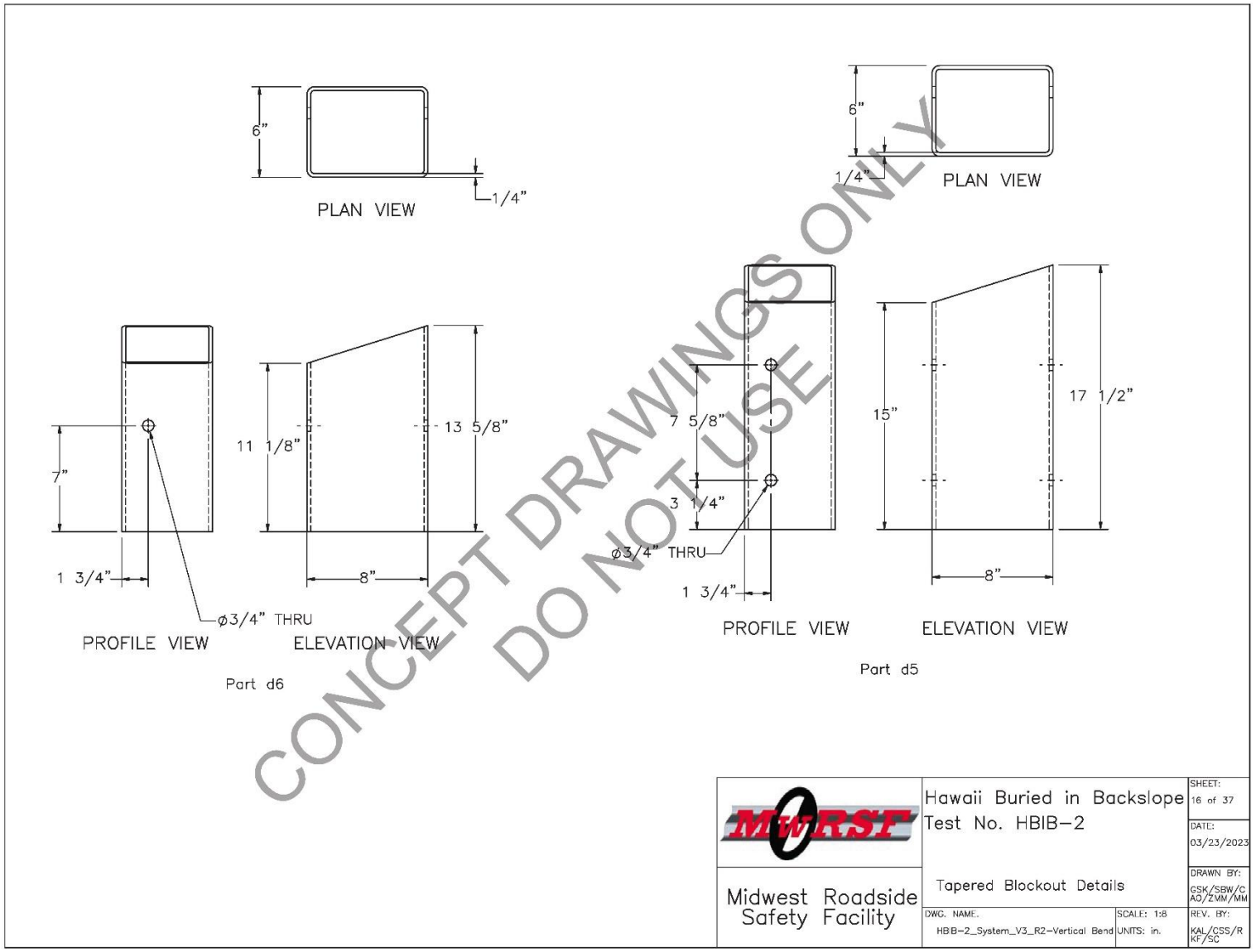


Figure L-21. Steel Blockout Details, Test No. HBIB-2, Options 1a and 1b

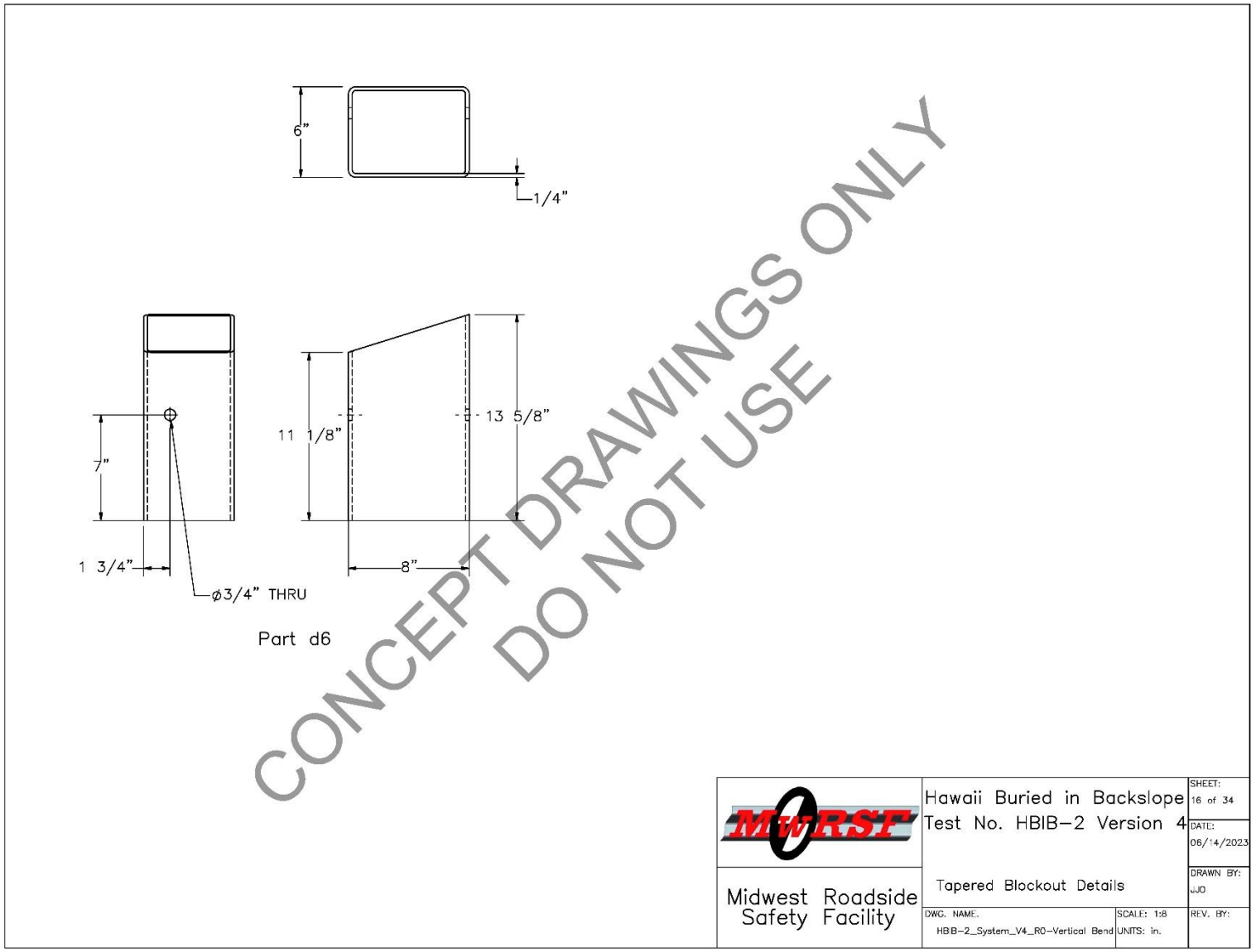


Figure L-22. Steel Blockout Details, Test No. HBIB-2, Option 2

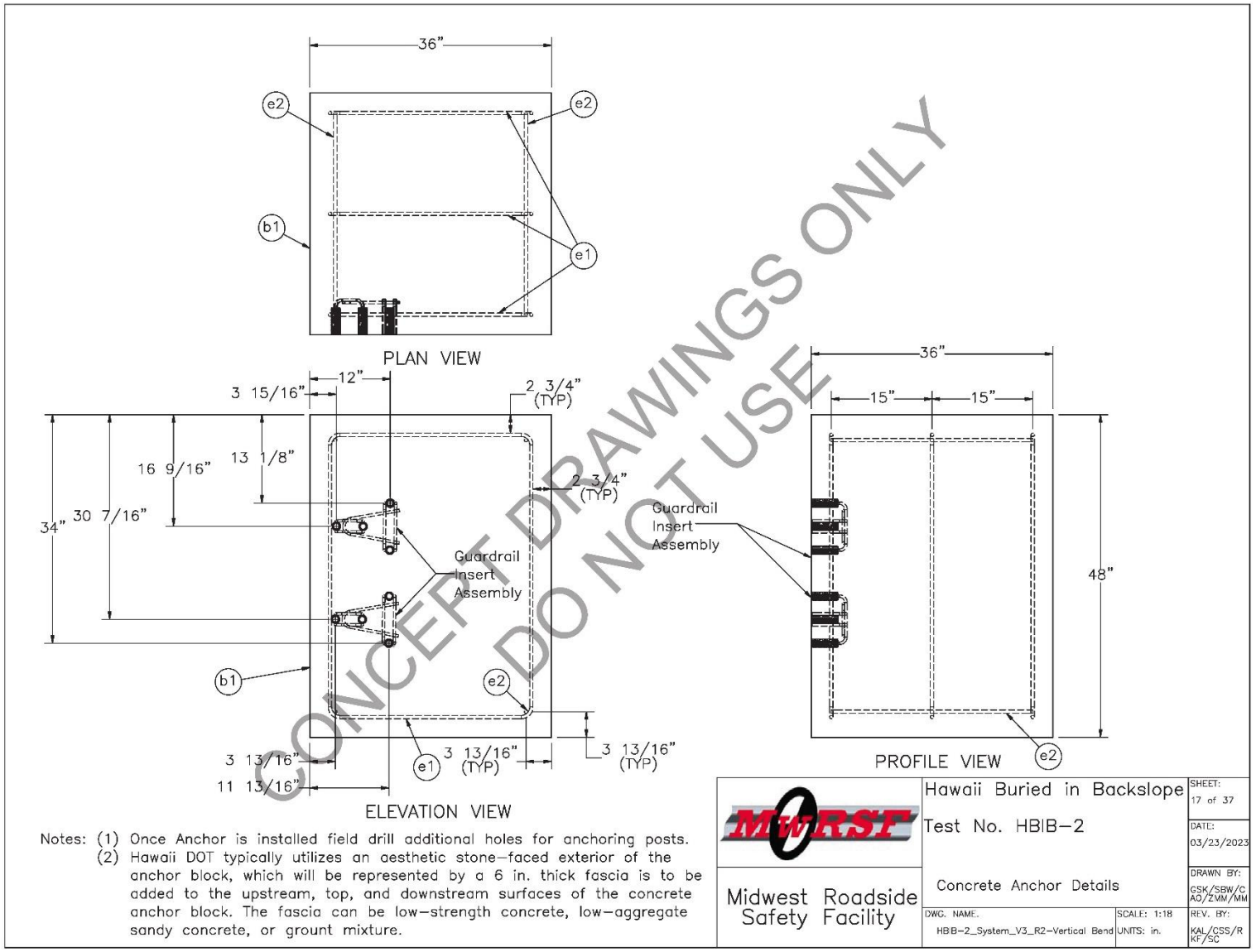
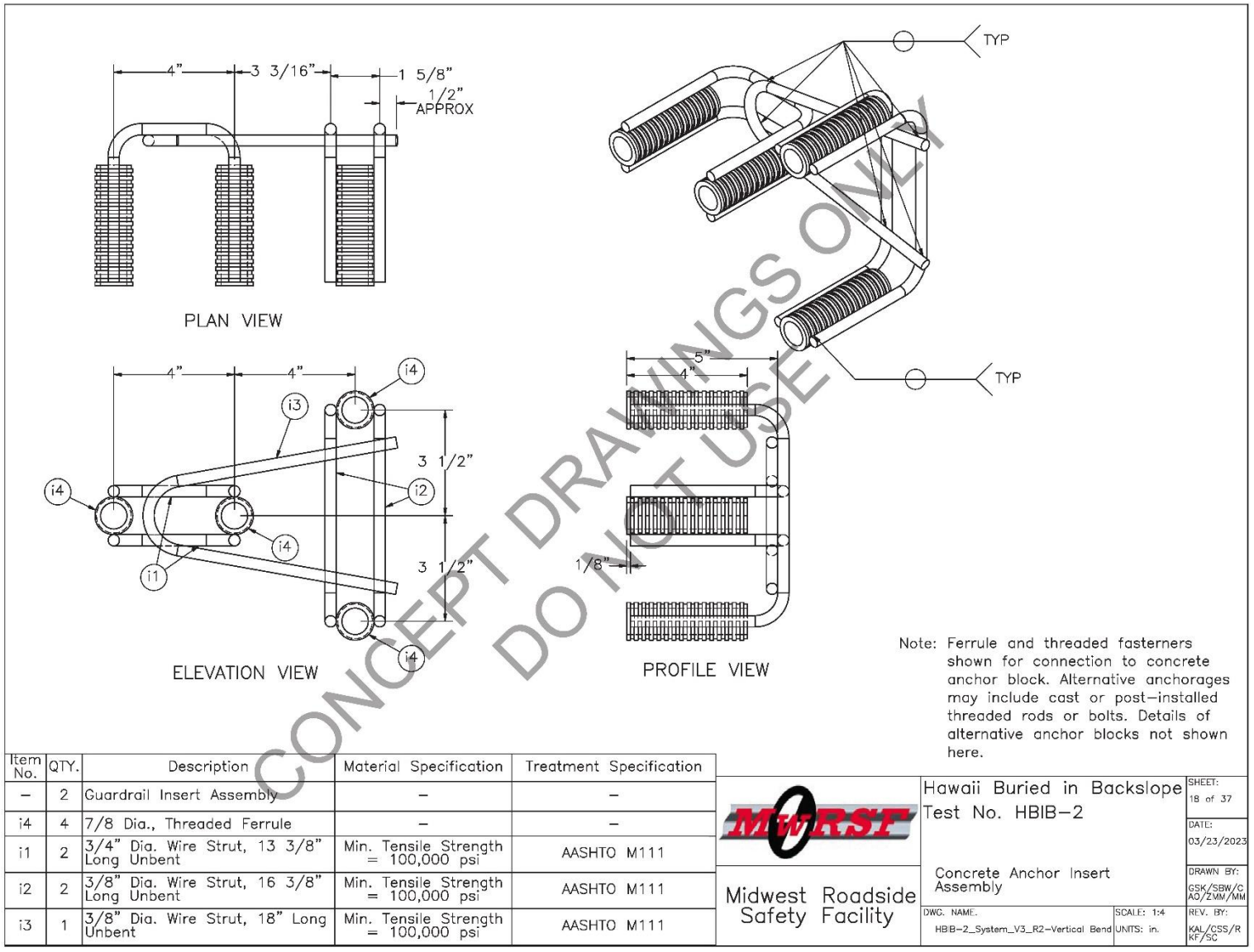


Figure L-23. Concrete Anchor Details, Test No. HBIB-2, Options 1a, 1b, and 2



Note: Ferrule and threaded fasterners shown for connection to concrete anchor block. Alternative anchorages may include cast or post-installed threaded rods or bolts. Details of alternative anchor blocks not shown here.

Item No.	QTY.	Description	Material Specification	Treatment Specification
–	2	Guardrail Insert Assembly	–	–
i4	4	7/8 Dia., Threaded Ferrule	–	–
i1	2	3/4" Dia. Wire Strut, 13 3/8" Long Unbent	Min. Tensile Strength = 100,000 psi	AASHTO M111
i2	2	3/8" Dia. Wire Strut, 16 3/8" Long Unbent	Min. Tensile Strength = 100,000 psi	AASHTO M111
i3	1	3/8" Dia. Wire Strut, 18" Long Unbent	Min. Tensile Strength = 100,000 psi	AASHTO M111

MwRSF

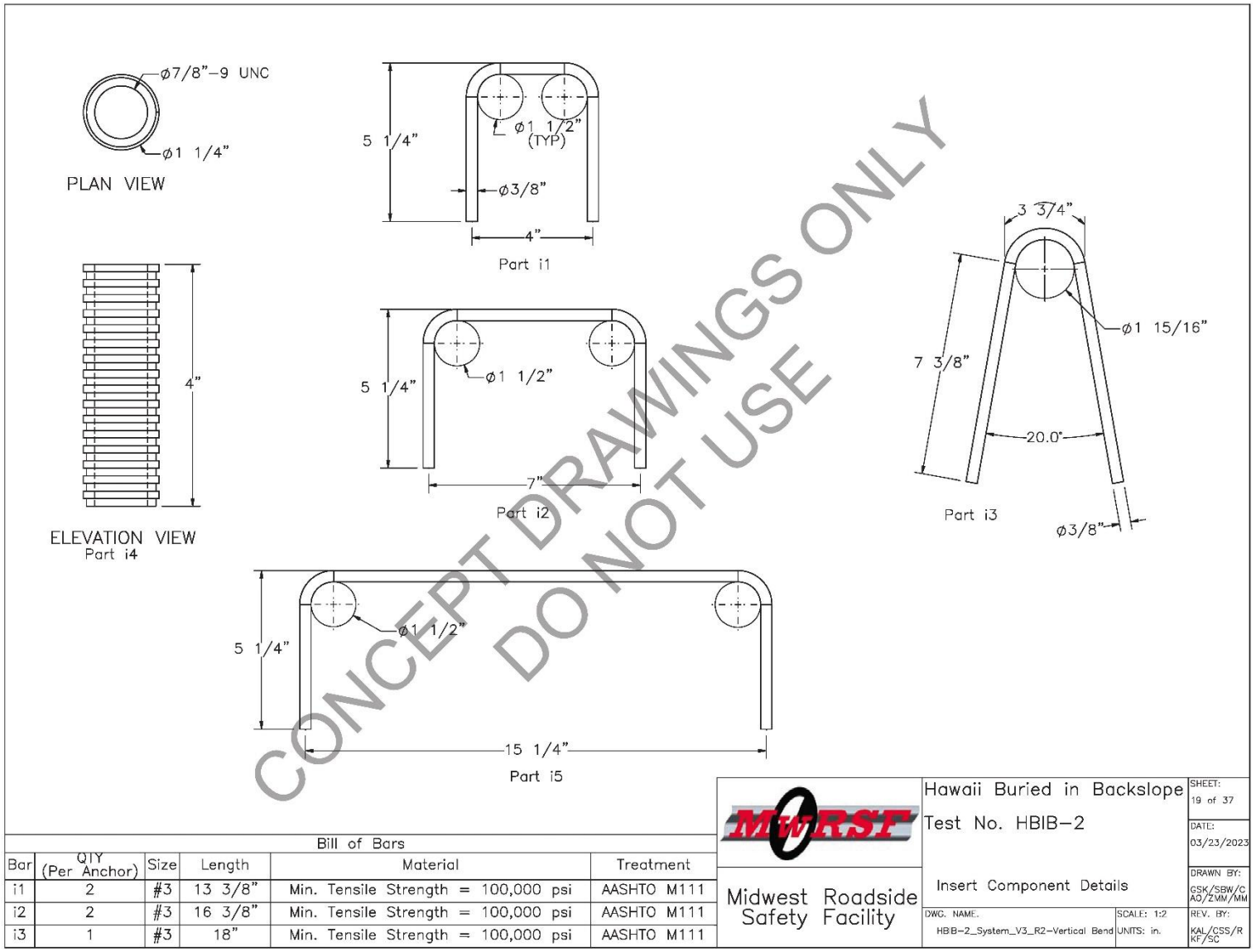
Midwest Roadside Safety Facility

Hawaii Buried in Backslope
Test No. HBIB-2

Concrete Anchor Insert Assembly

SHEET: 18 of 37
DATE: 03/23/2023
DRAWN BY: GSK/SBW/CAO/ZMM/MM
DWG. NAME: HBIB-2_System_V3_R2-Vertical Bend
SCALE: 1:4
UNITS: in.
REV. BY: KAL/CSS/RKF/SC

Figure L-24. Concrete Anchor Insert Details, Test No. HBIB-2, Options 1a, 1b, and 2



Bill of Bars

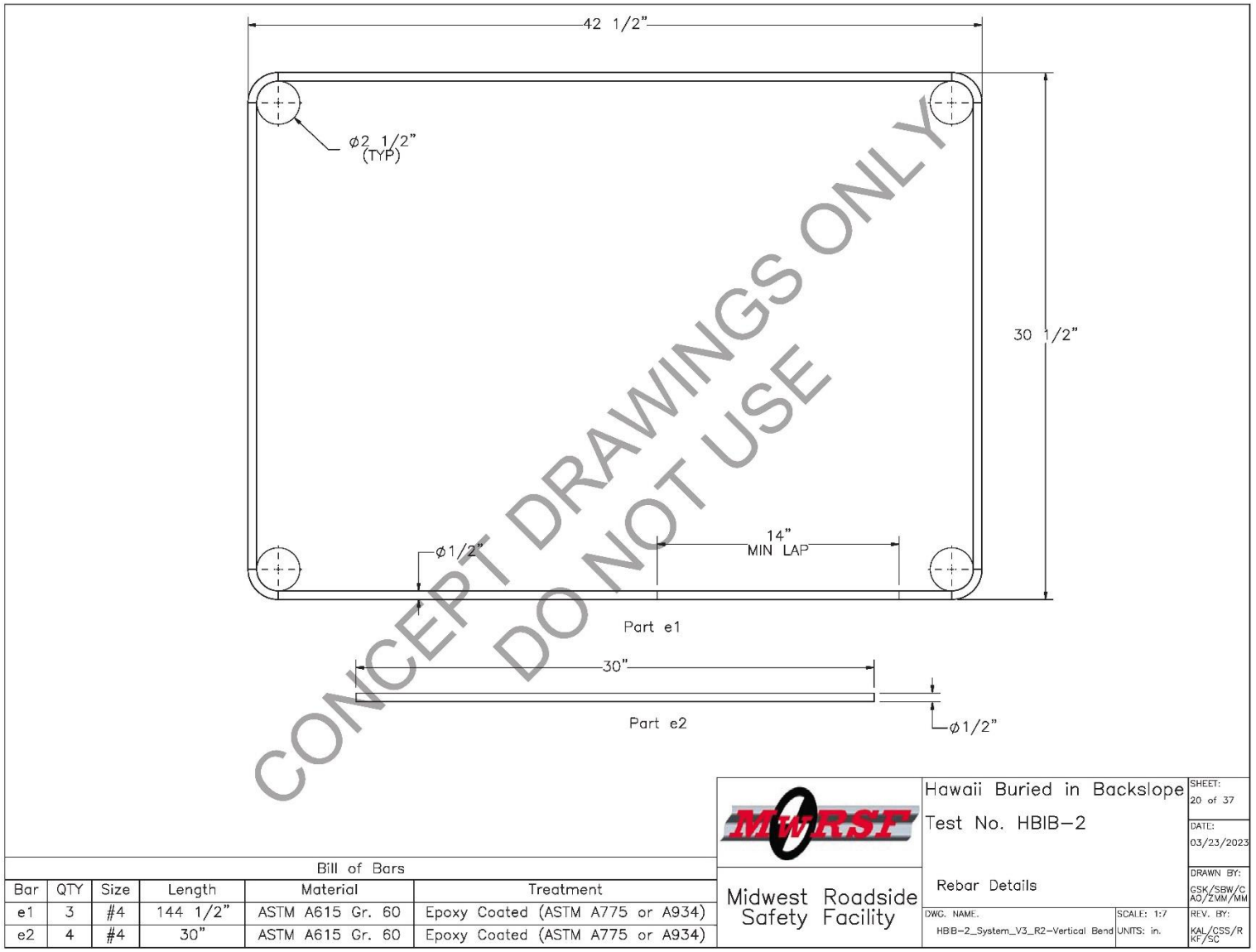
Bar	QTY (Per Anchor)	Size	Length	Material	Treatment
i1	2	#3	13 3/8"	Min. Tensile Strength = 100,000 psi	AASHTO M111
i2	2	#3	16 3/8"	Min. Tensile Strength = 100,000 psi	AASHTO M111
i3	1	#3	18"	Min. Tensile Strength = 100,000 psi	AASHTO M111

Midwest Roadside Safety Facility

Hawaii Buried in Backslope
Test No. HBIB–2
Insert Component Details

SHEET: 19 of 37
DATE: 03/23/2023
DRAWN BY: GSK/SBW/CAO/ZMM/MM
REV. BY: KAL/CSS/RKF/SC
DWG. NAME: HBIB–2_System_V3_R2–Vertical Bend
SCALE: 1:2
UNITS: in.

Figure L-25. Insert Component Details, Test No. HBIB-2, Options 1a, 1b, and 2



Bill of Bars

Bar	QTY	Size	Length	Material	Treatment
e1	3	#4	144 1/2"	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)
e2	4	#4	30"	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)

Figure L-26. Rebar Details, Test No. HBIB-2, Options 1a, 1b, and 2

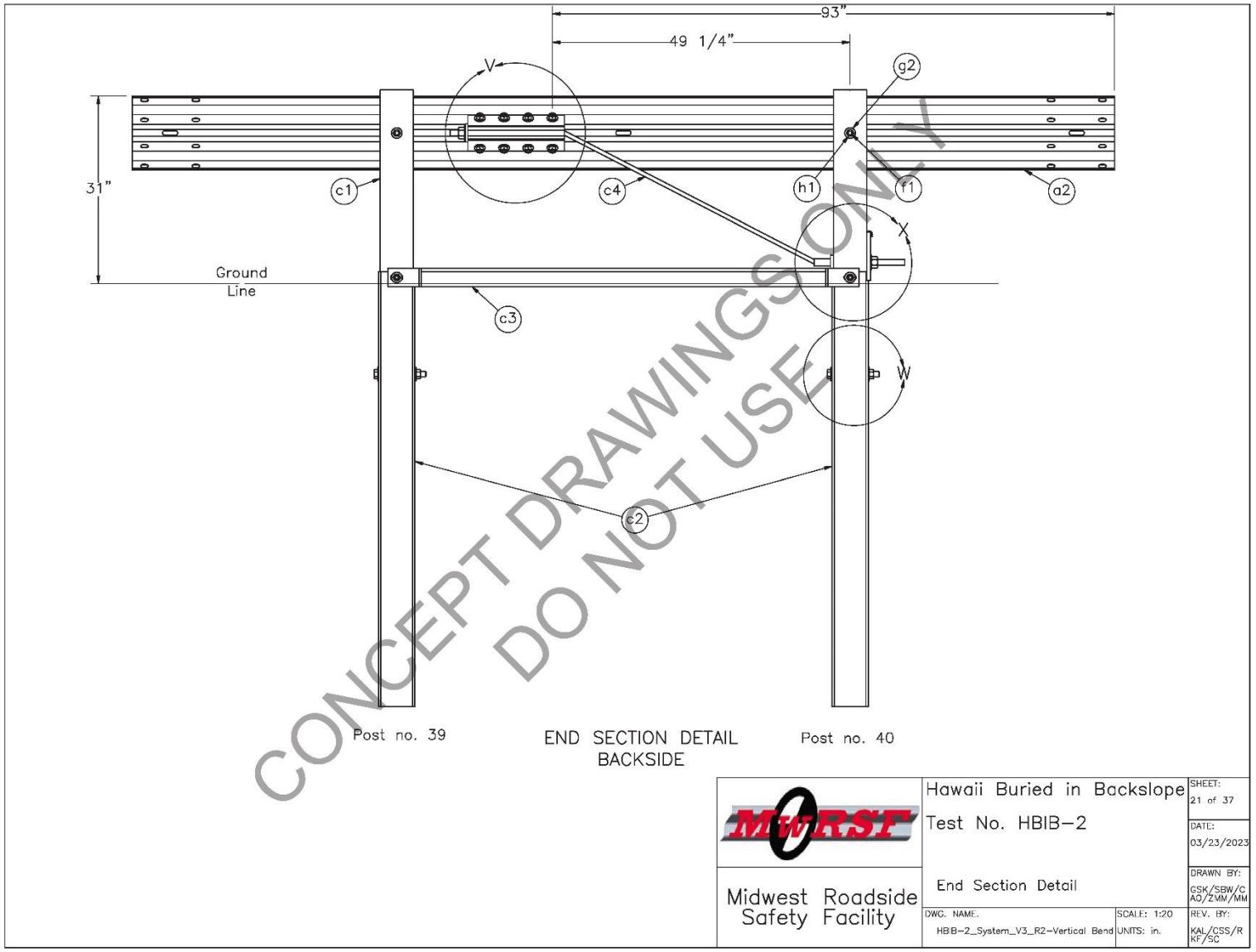


Figure L-27. End Section Details, Test No. HBIB-2, Options 1a, 1b, and 2

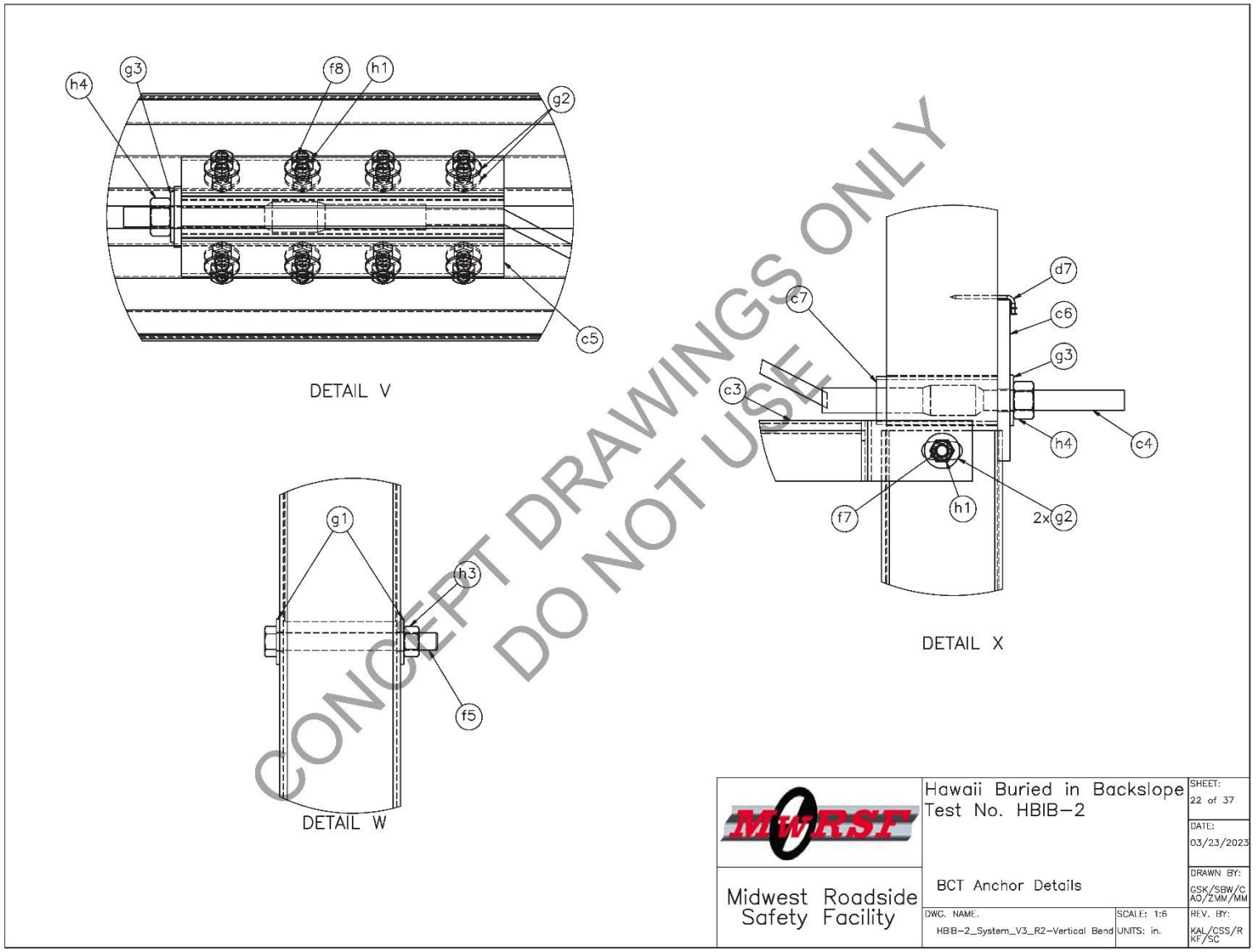


Figure L-28. BCT Anchor Details, Test No. HBIB-2, Options 1a, 1b and 2

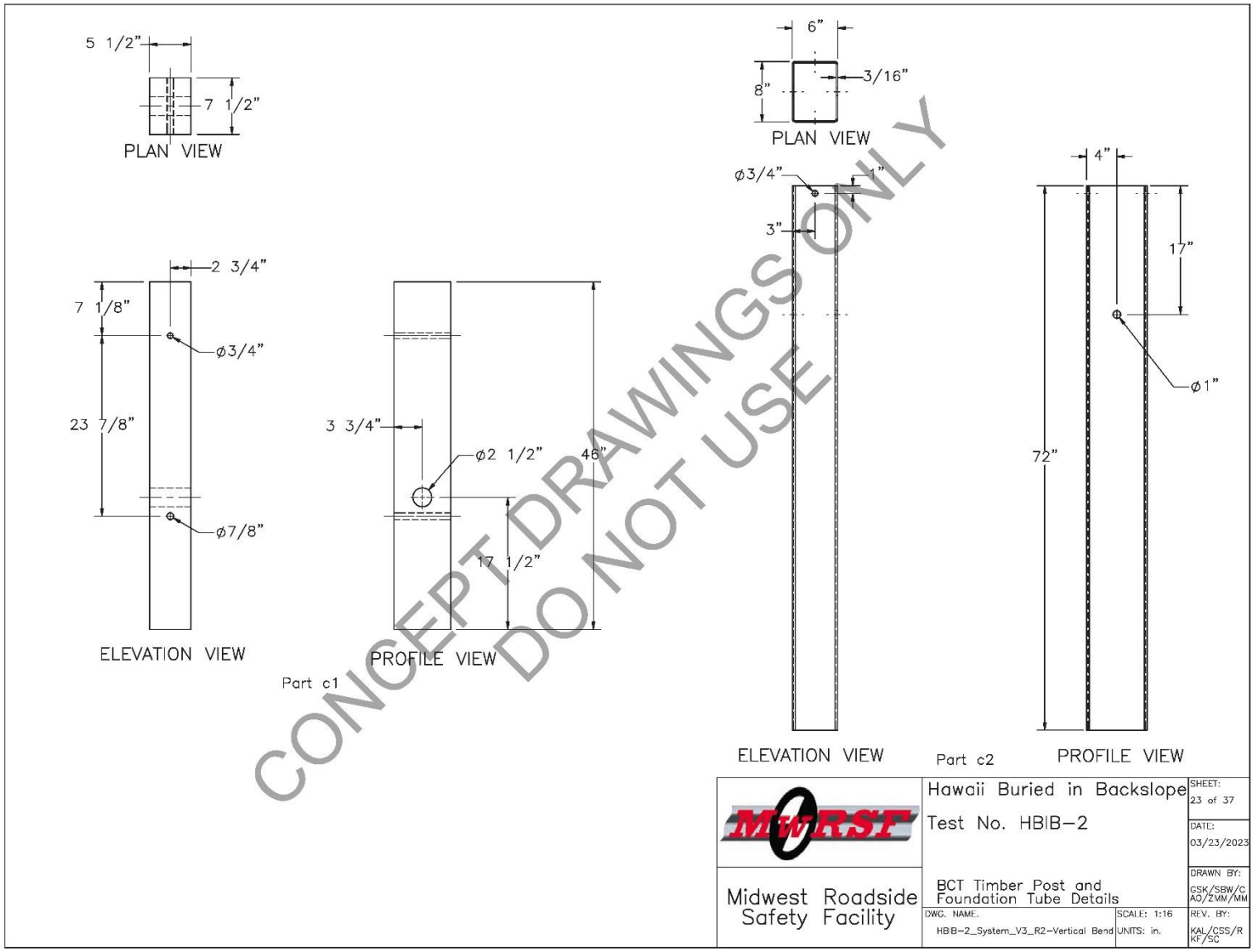
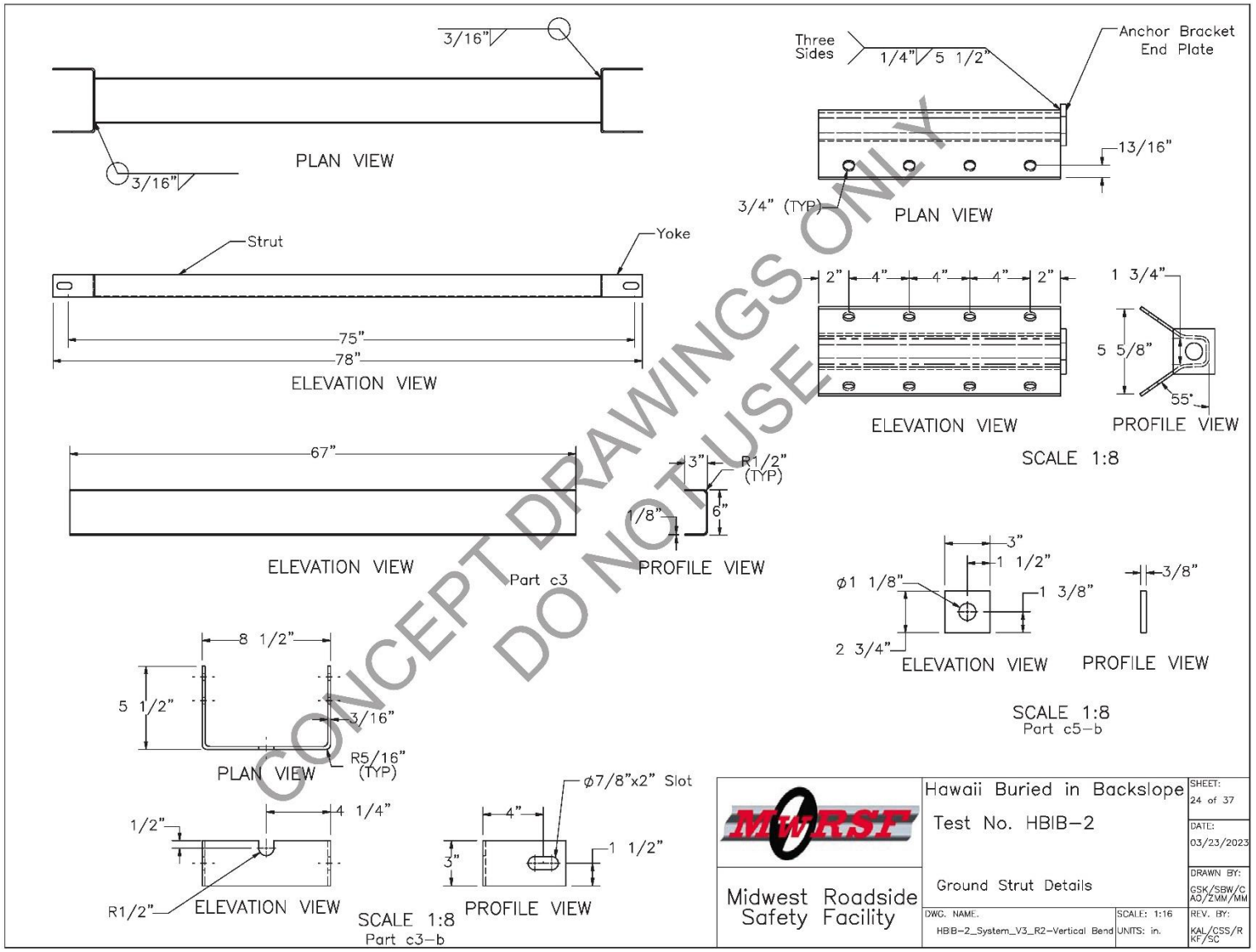


Figure L-29. BCT Timber Post and Foundation Tube Details, Test No. HBIB-2, Options 1a, 1b, and 2



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Figure L-30. Ground Strut Details, Test No. HBIB-2, Options 1a, 1b, and 2

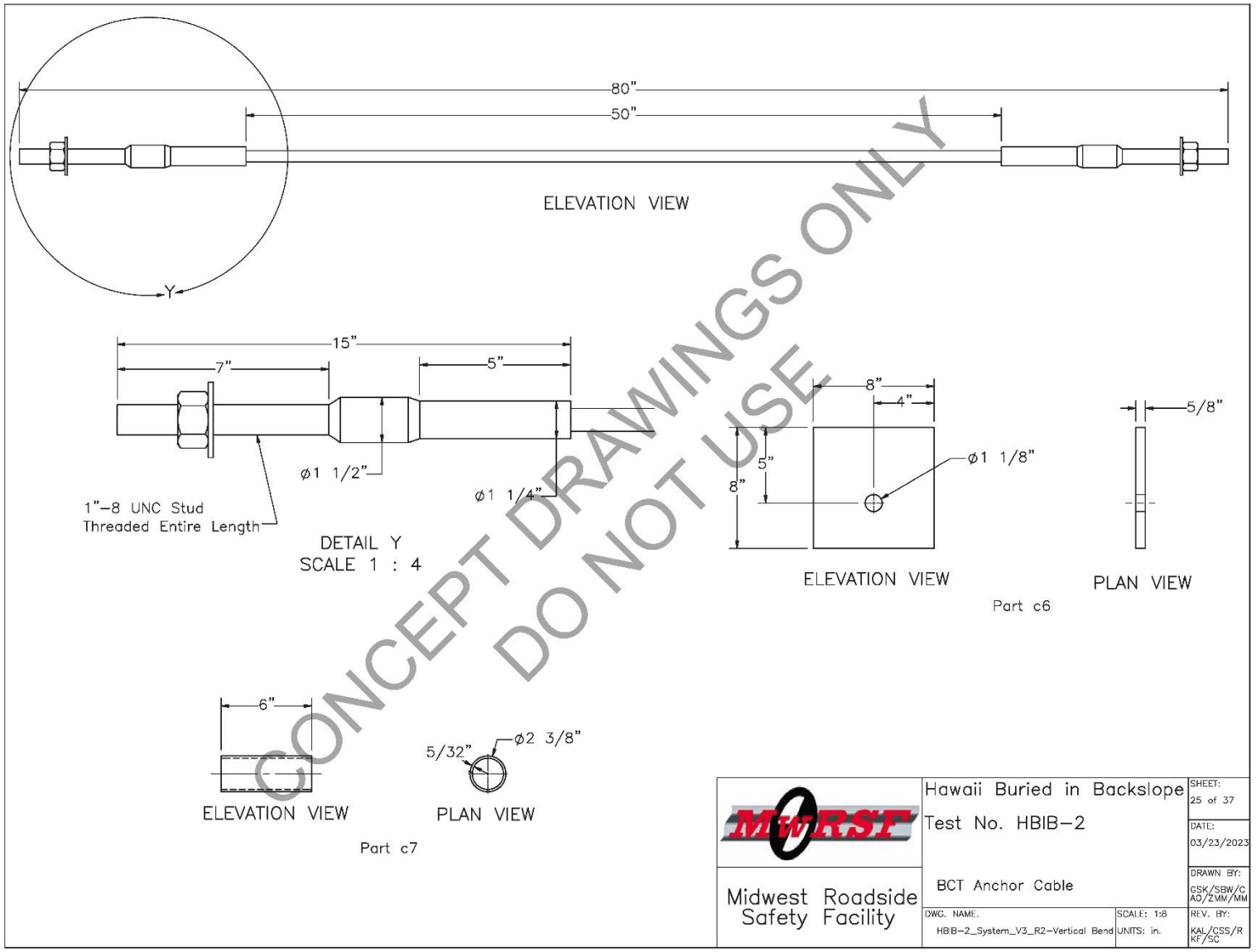


Figure L-31. BCT Anchor Cable Details, Test No. HBIB-2, Options 1a, 1b, and 2

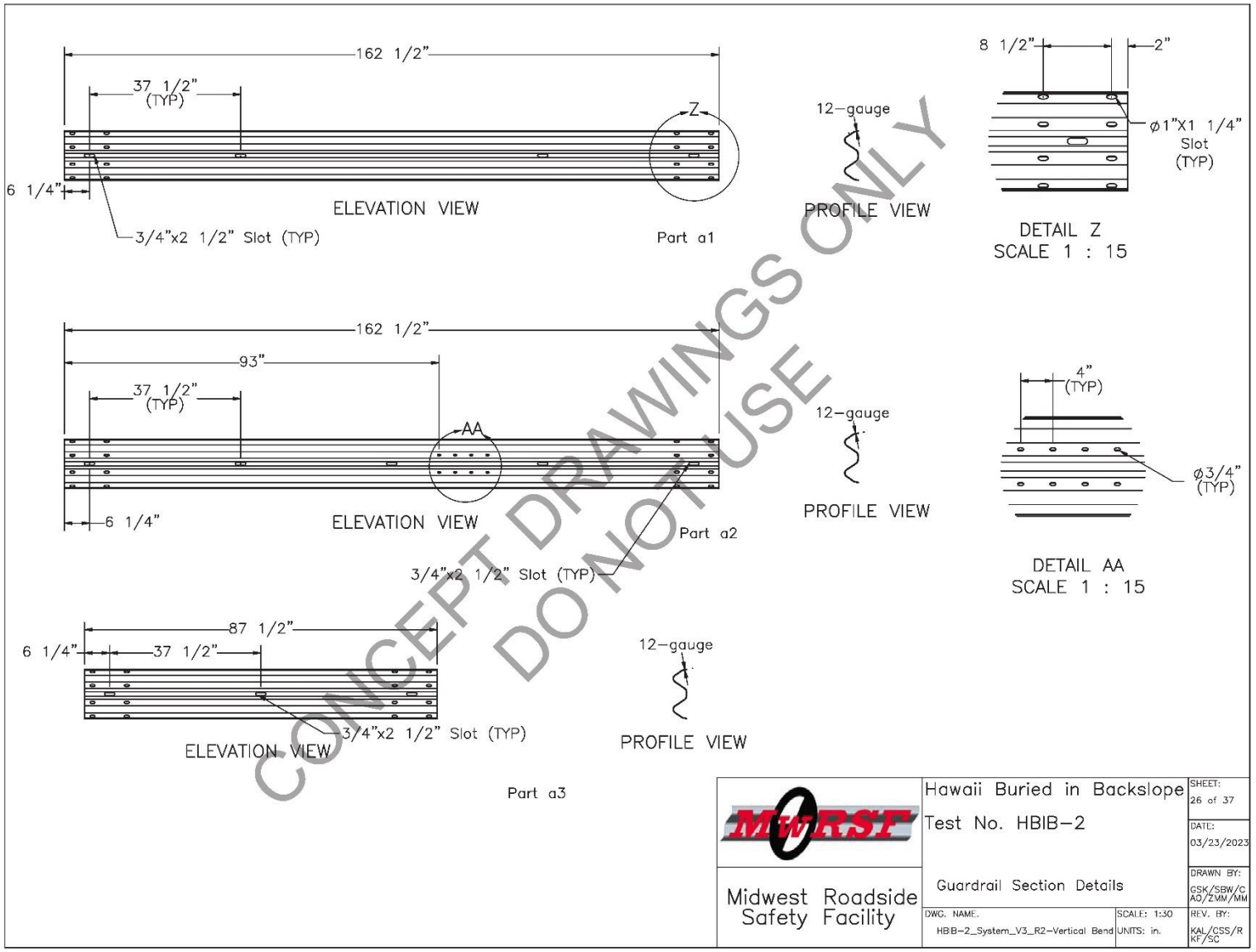


Figure L-32. Guardrail Section Details, Test No. HBIB-2, Options 1a and 1b

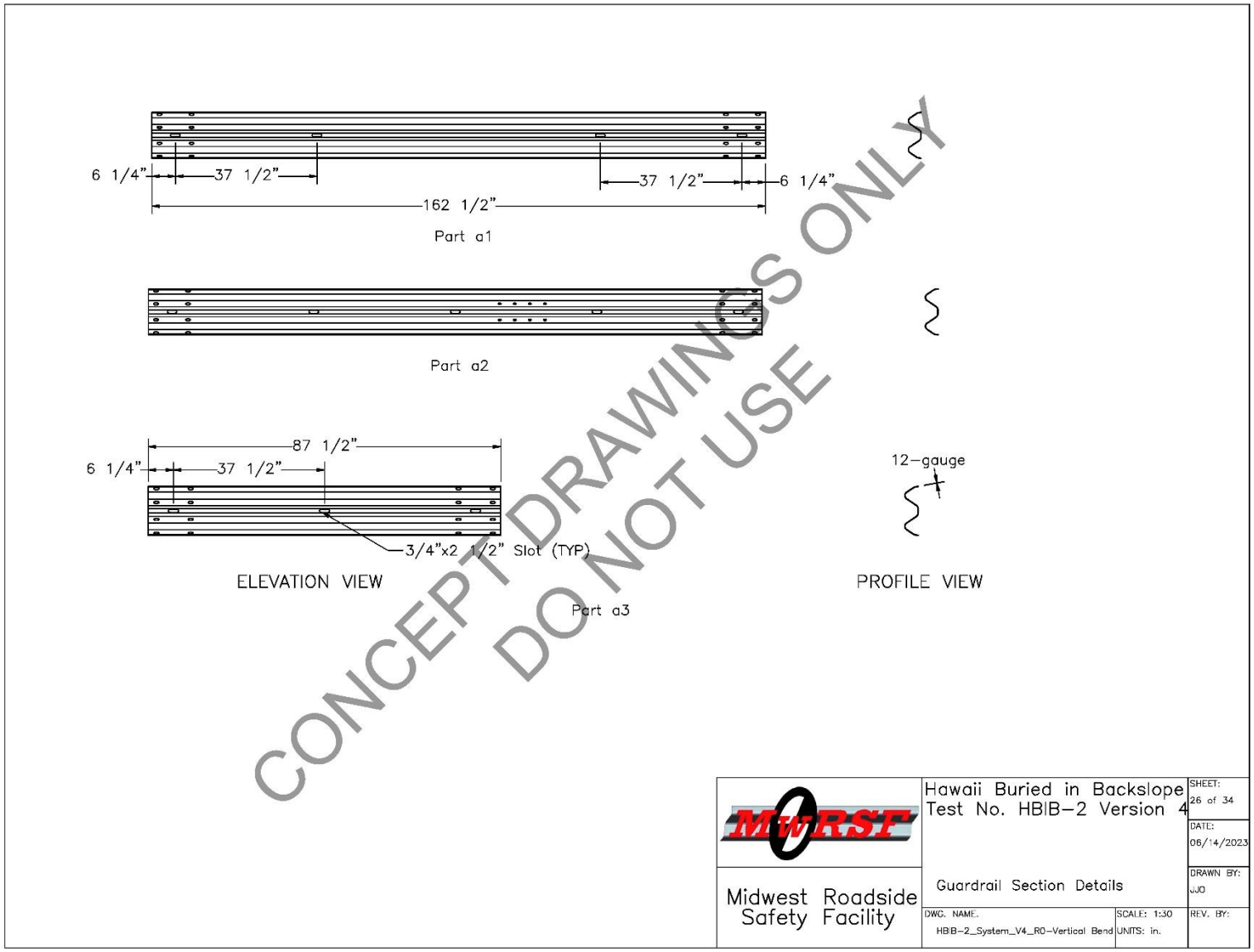


Figure L-33. Guardrail Section Details, Test No. HBIB-2, Option 2

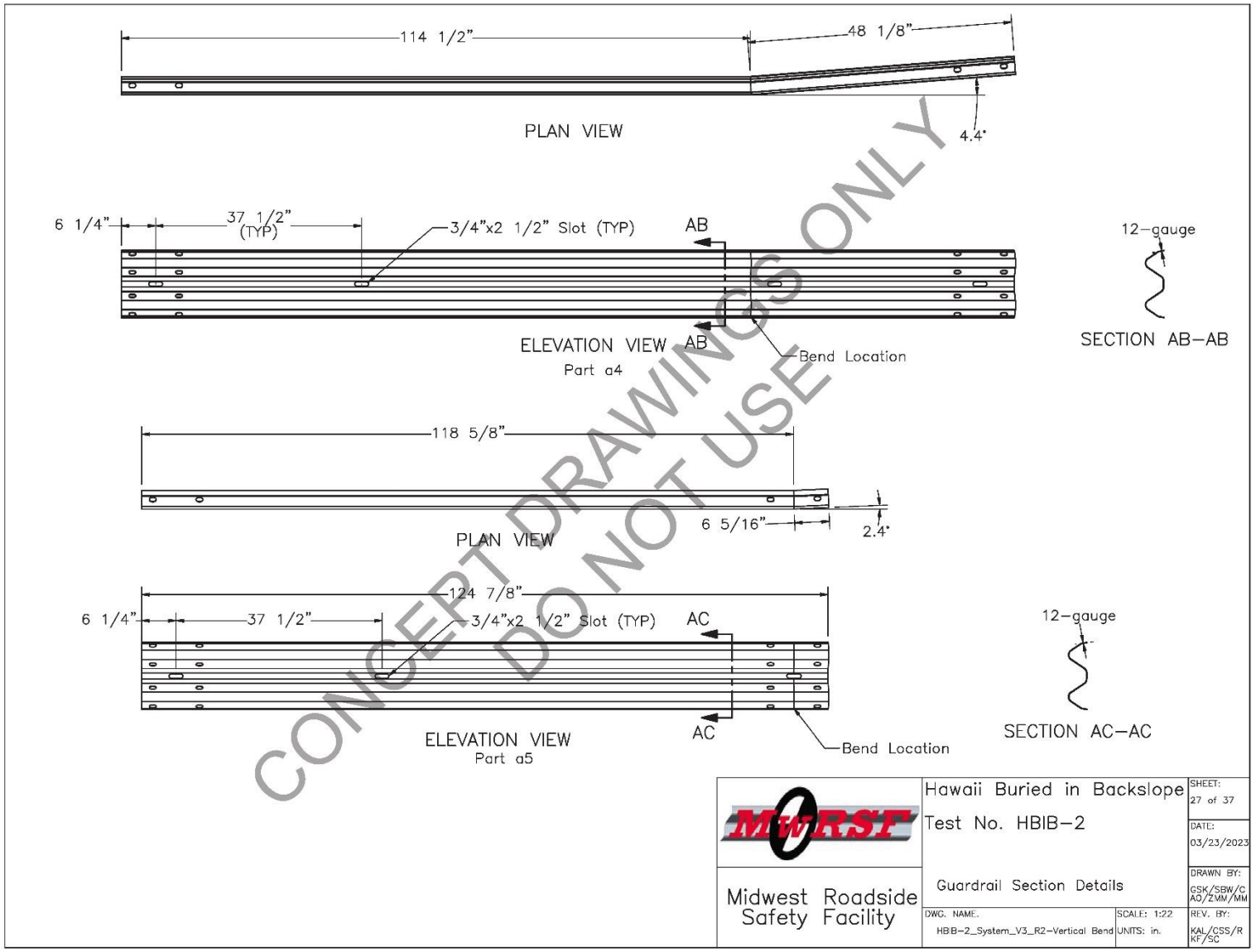


Figure L-34. Guardrail Section Details, Test No. HBIB-2, Options 1a and 1b

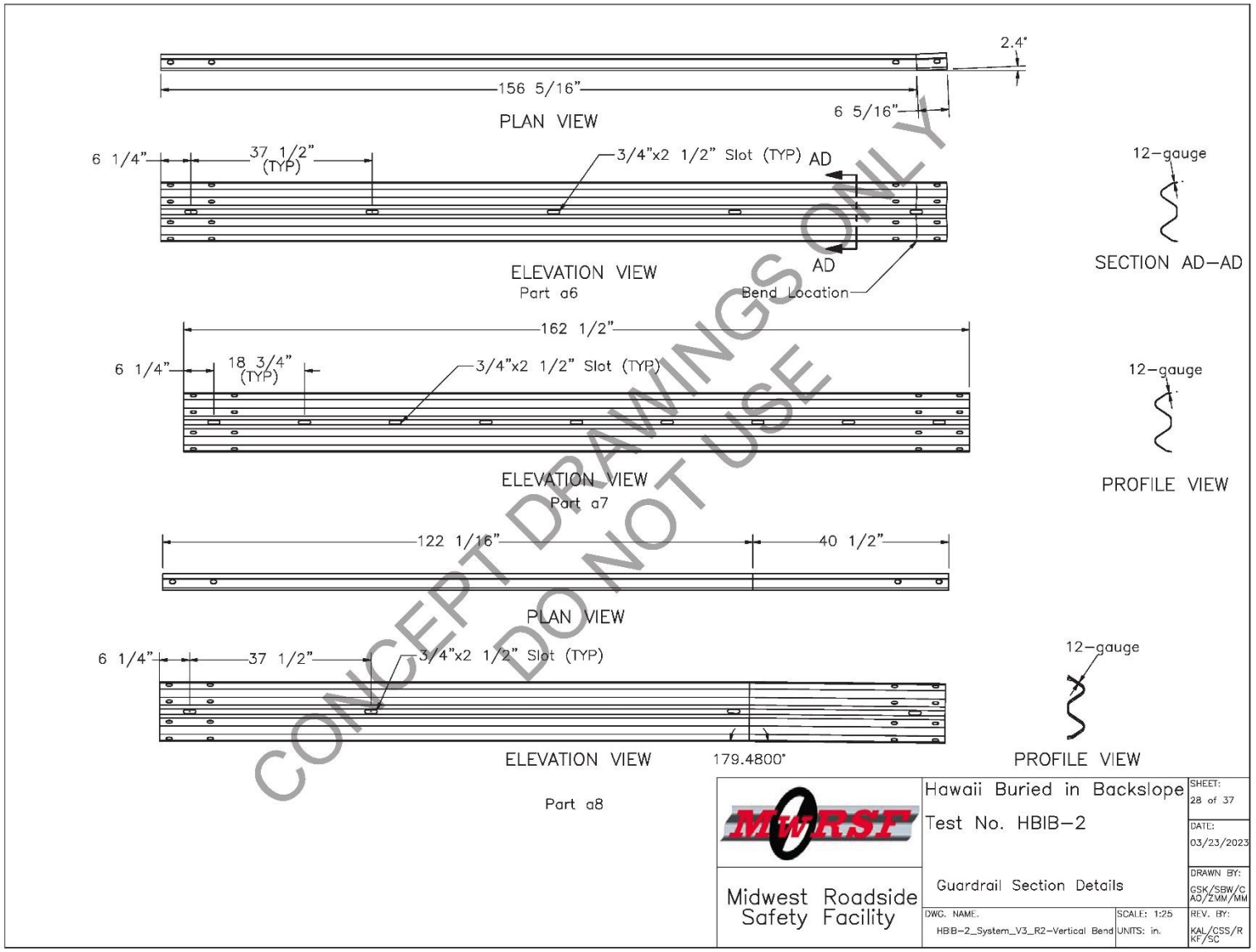


Figure L-35. Guardrail Section Details, Test No. HBIB-2, Options 1a and 1b

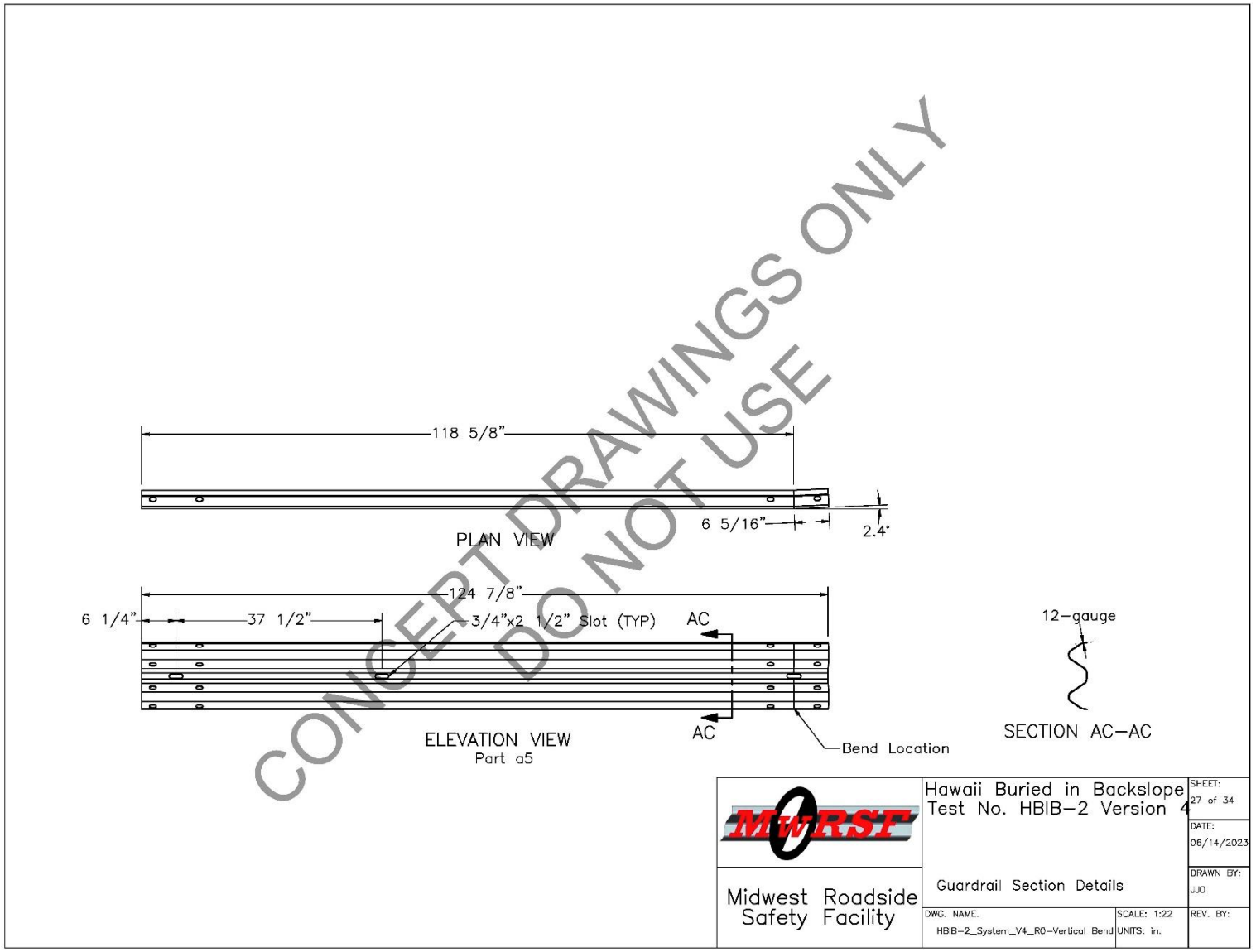


Figure L-36. Guardrail Section Details, Test No. HBIB-2, Option 2

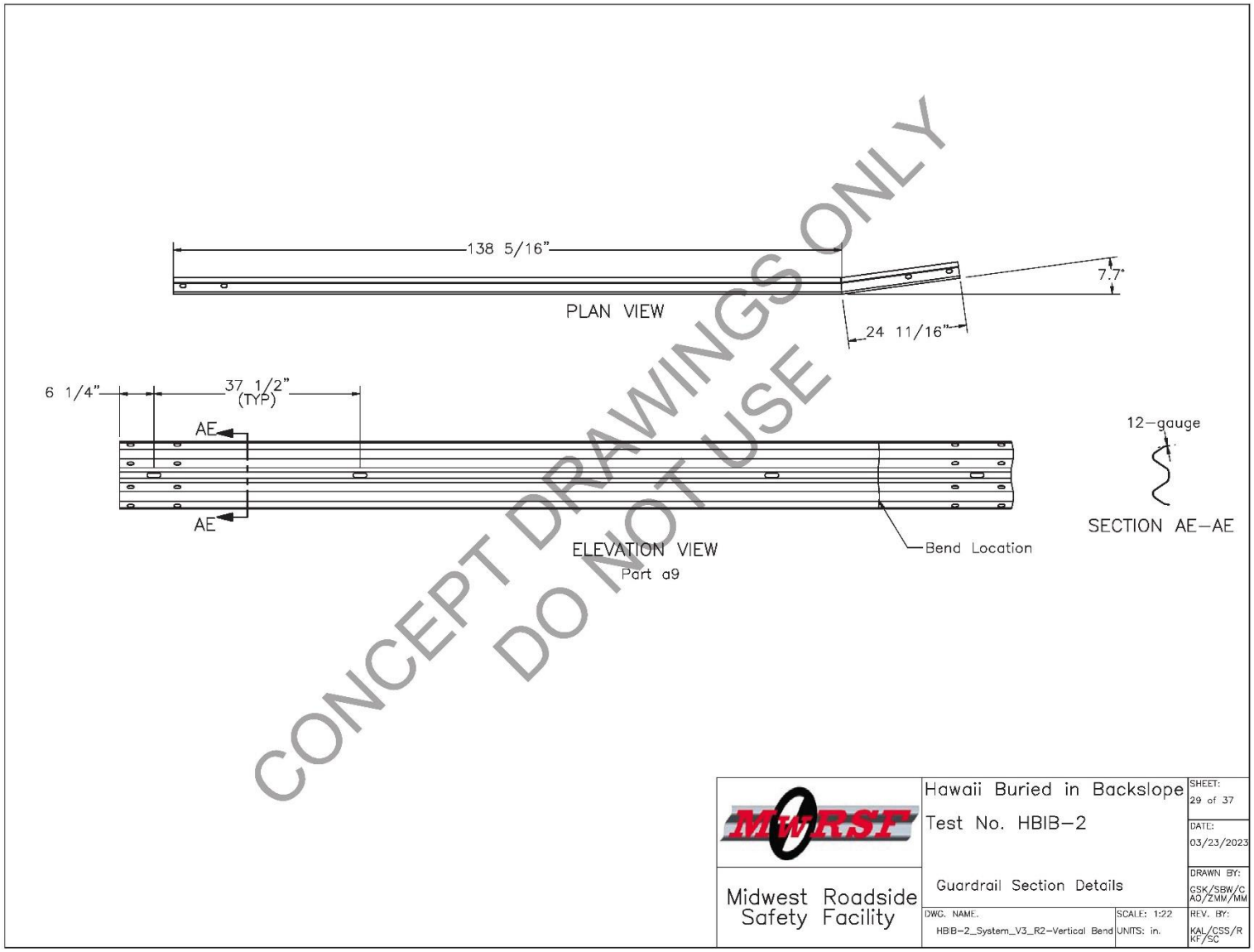


Figure L-37. Guardrail Section Details, Test No. HBIB-2, Options 1a and 1b

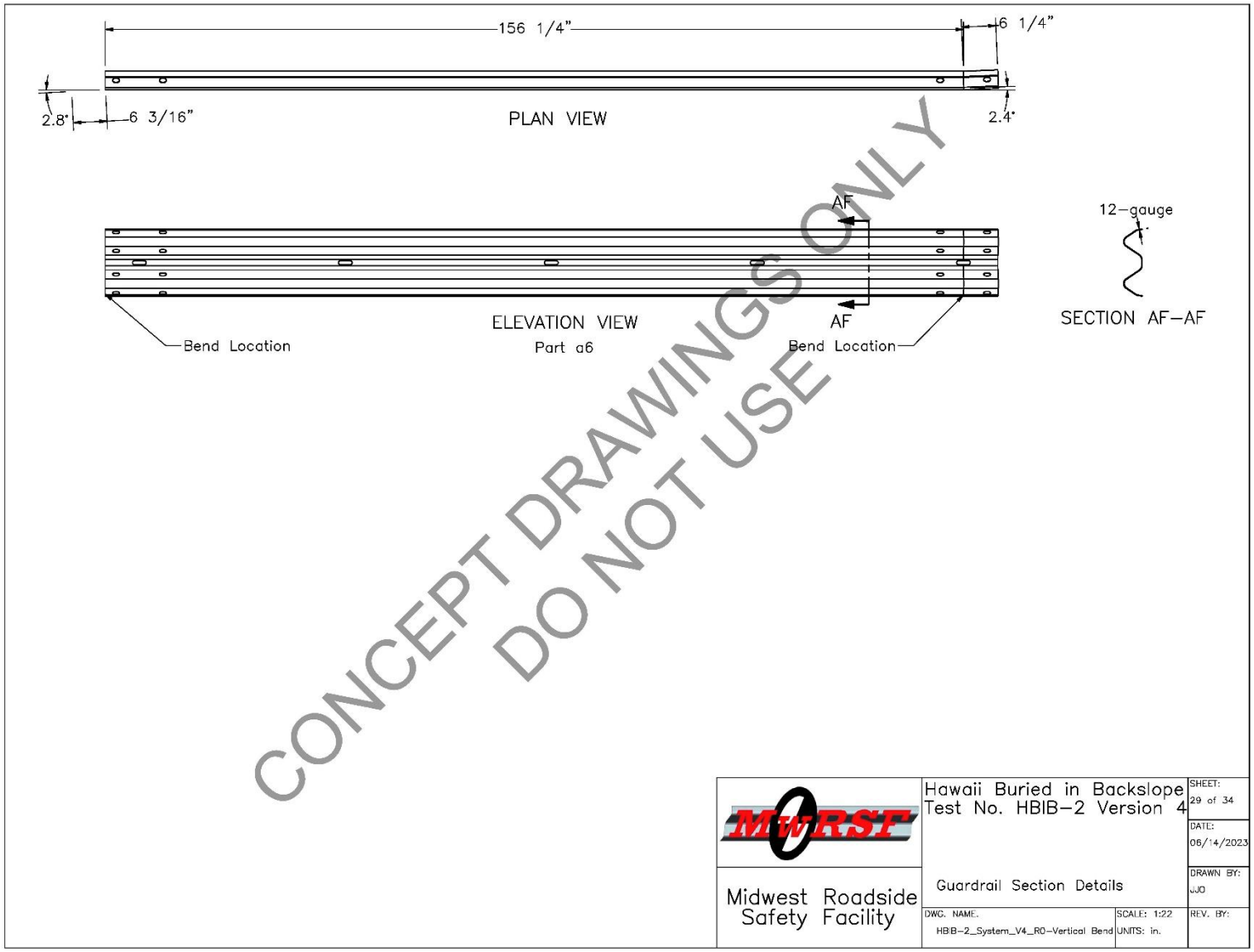


Figure L-38. Guardrail Section Details, Test No. HBIB-2, Option 2

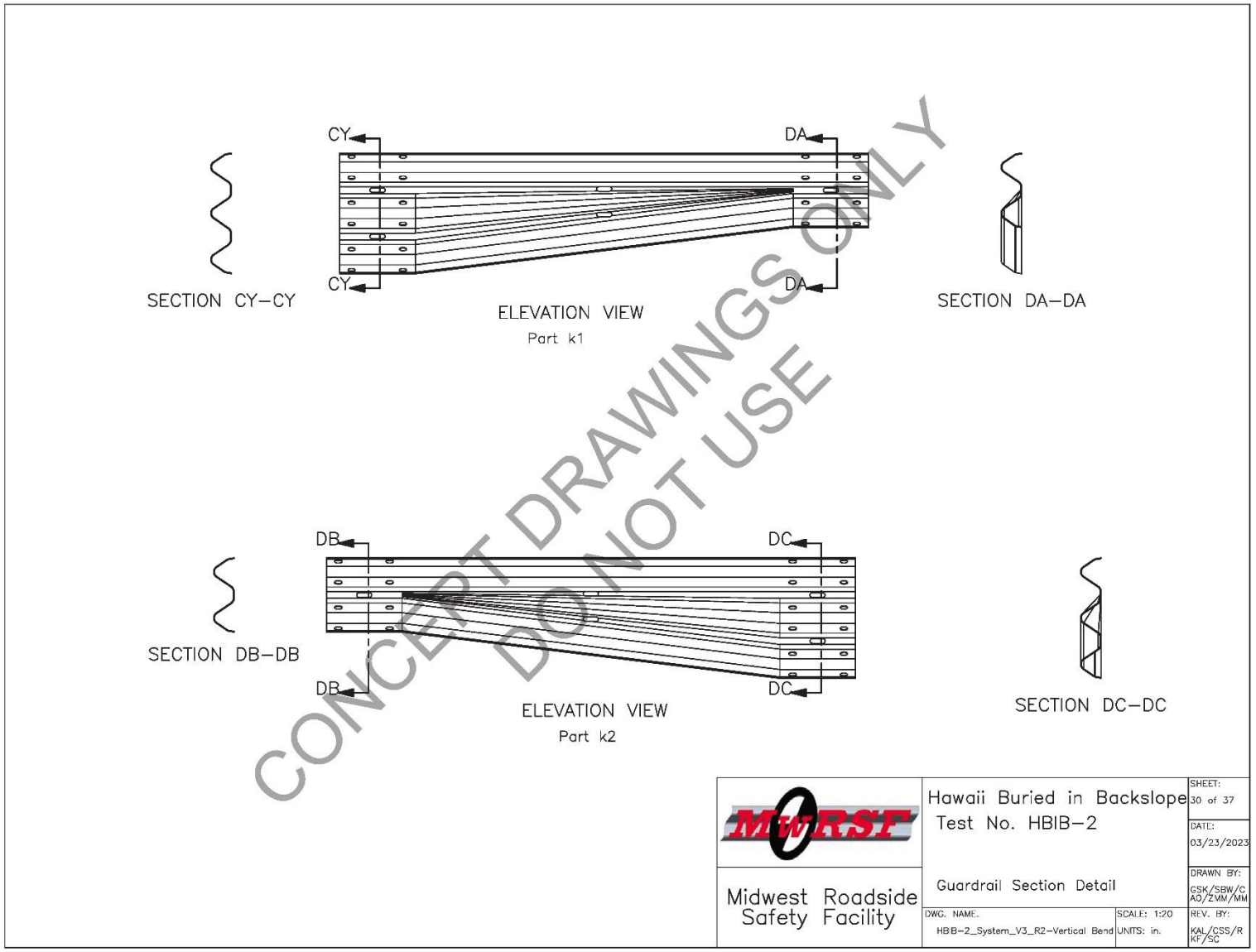


Figure L-39. Asymmetric Transition Sections, Test No. HBIB-2, Options 1a and 1b

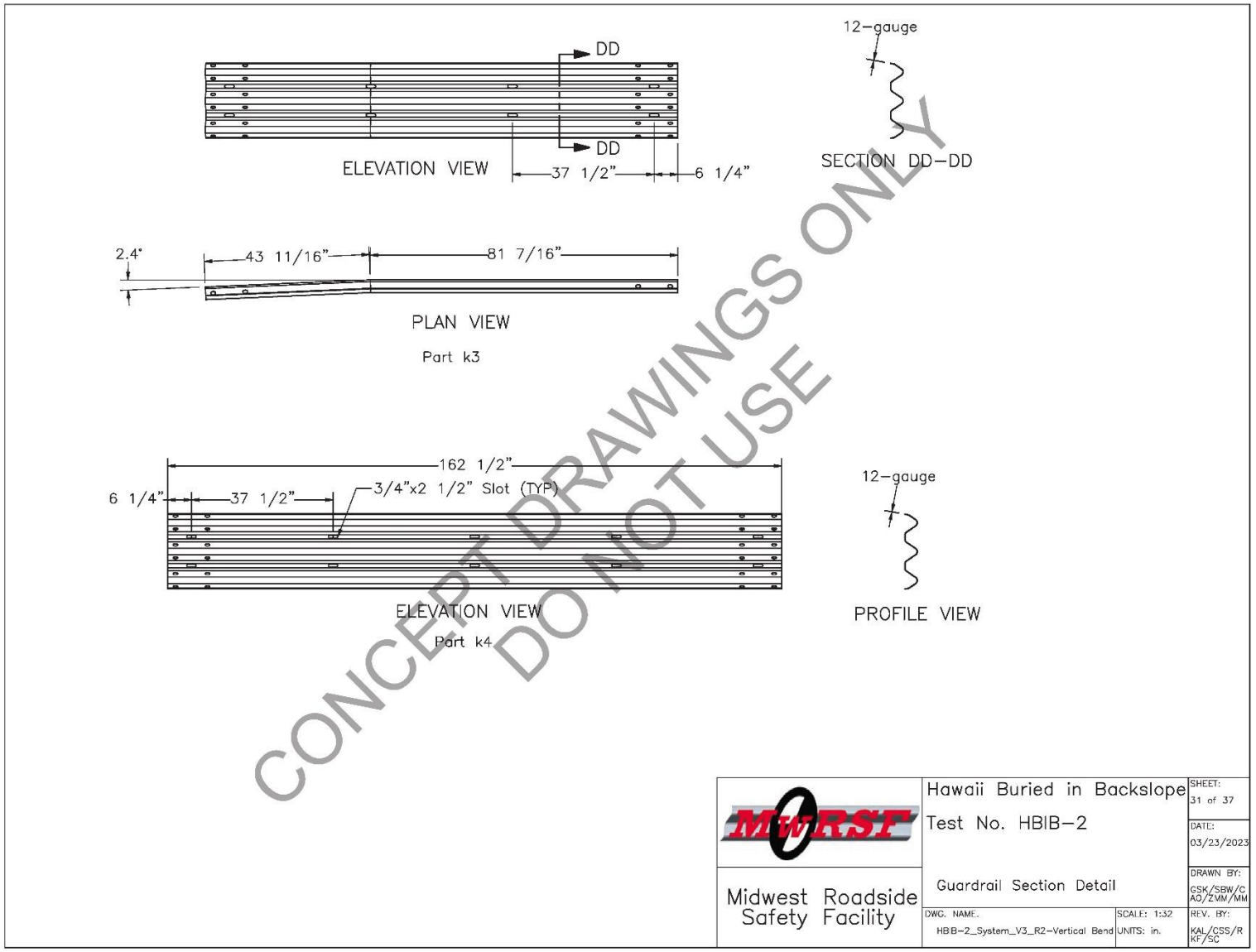


Figure L-40. Guardrail Section Details, Test No. HBIB-2, Options 1a and 1b

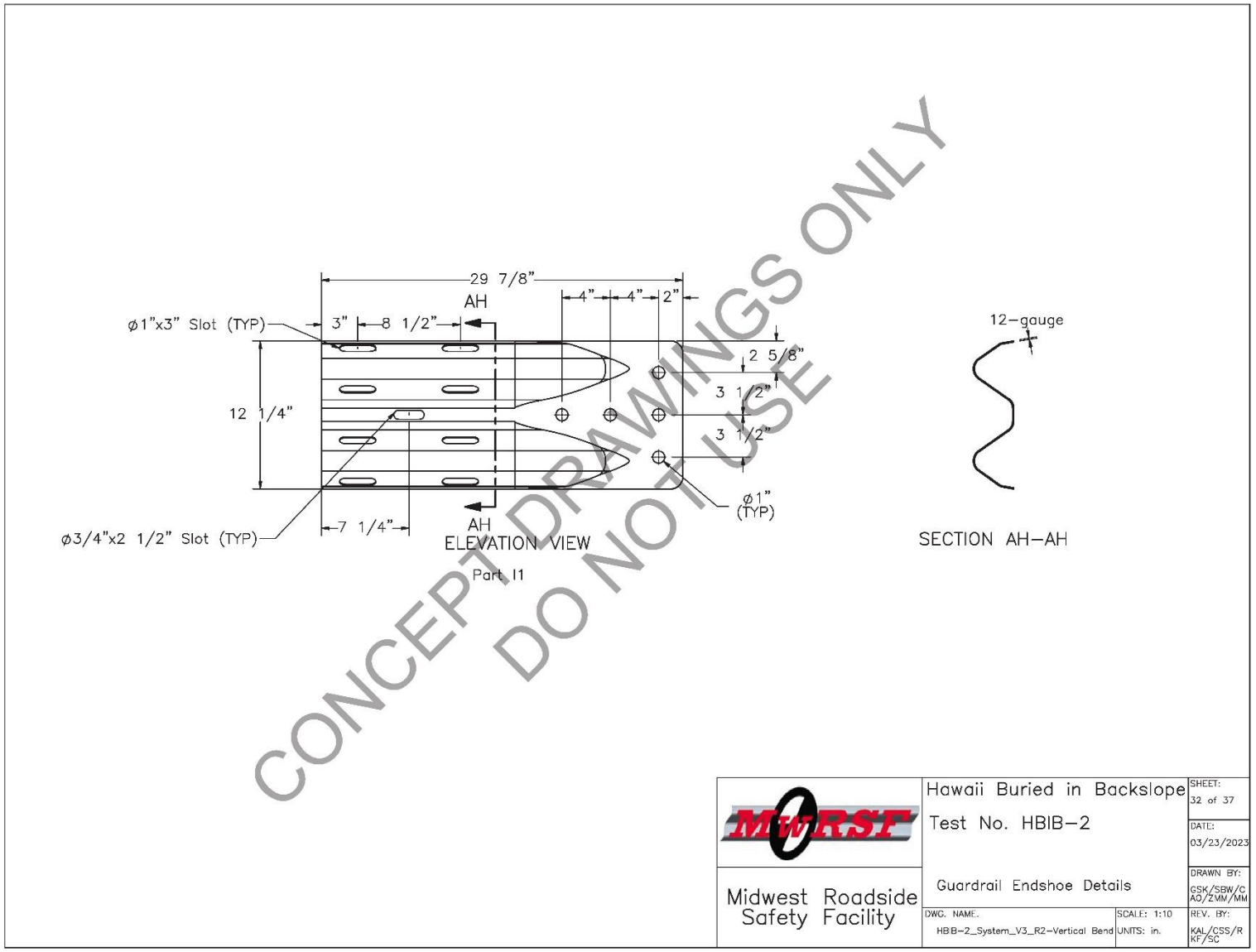


Figure L-41. Guardrail End Connector Details, Test No. HBIB-2, Options 1a, 1b, and 2

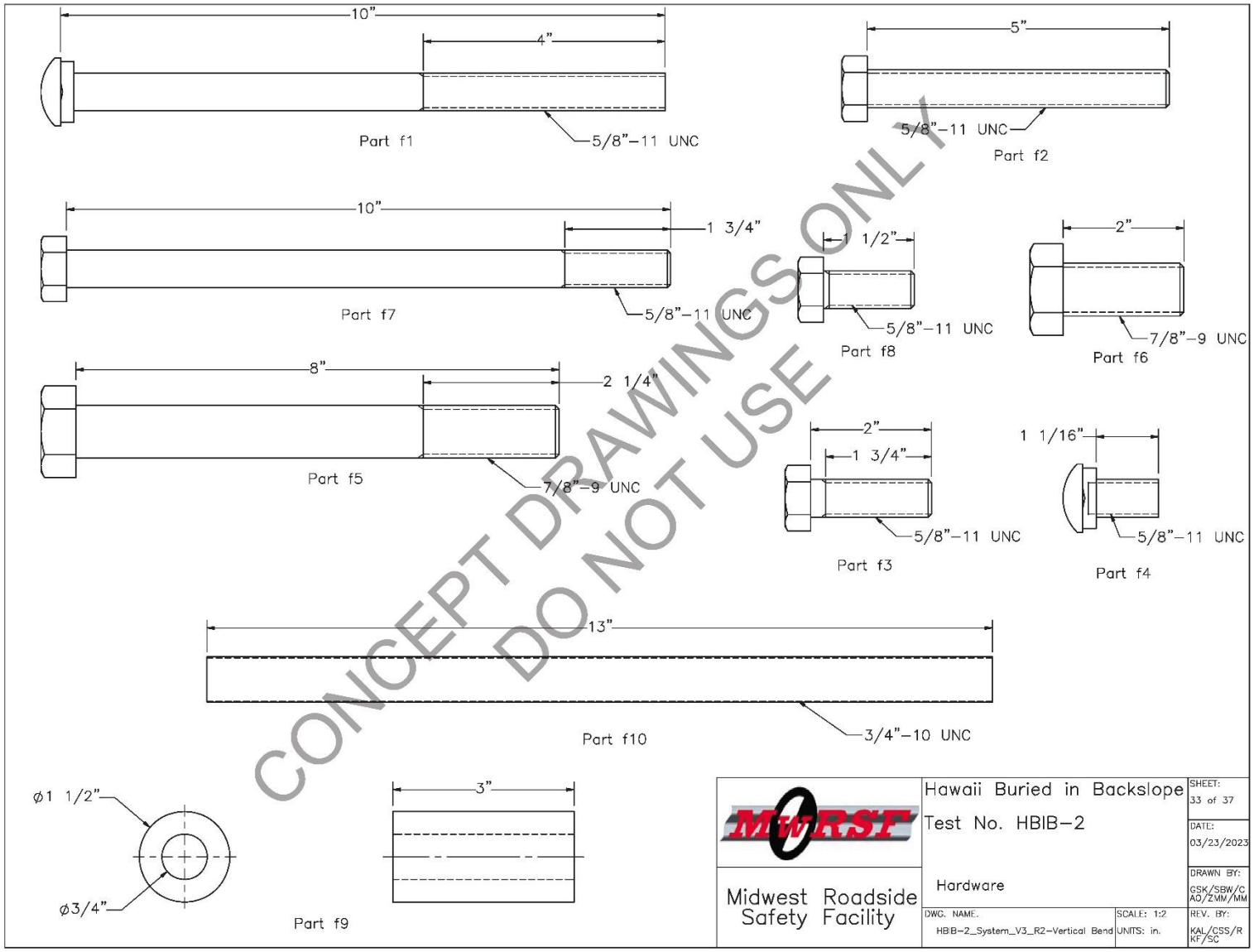


Figure L-42. Hardware Details, Test No. HBIB-2, Options 1a and 1b

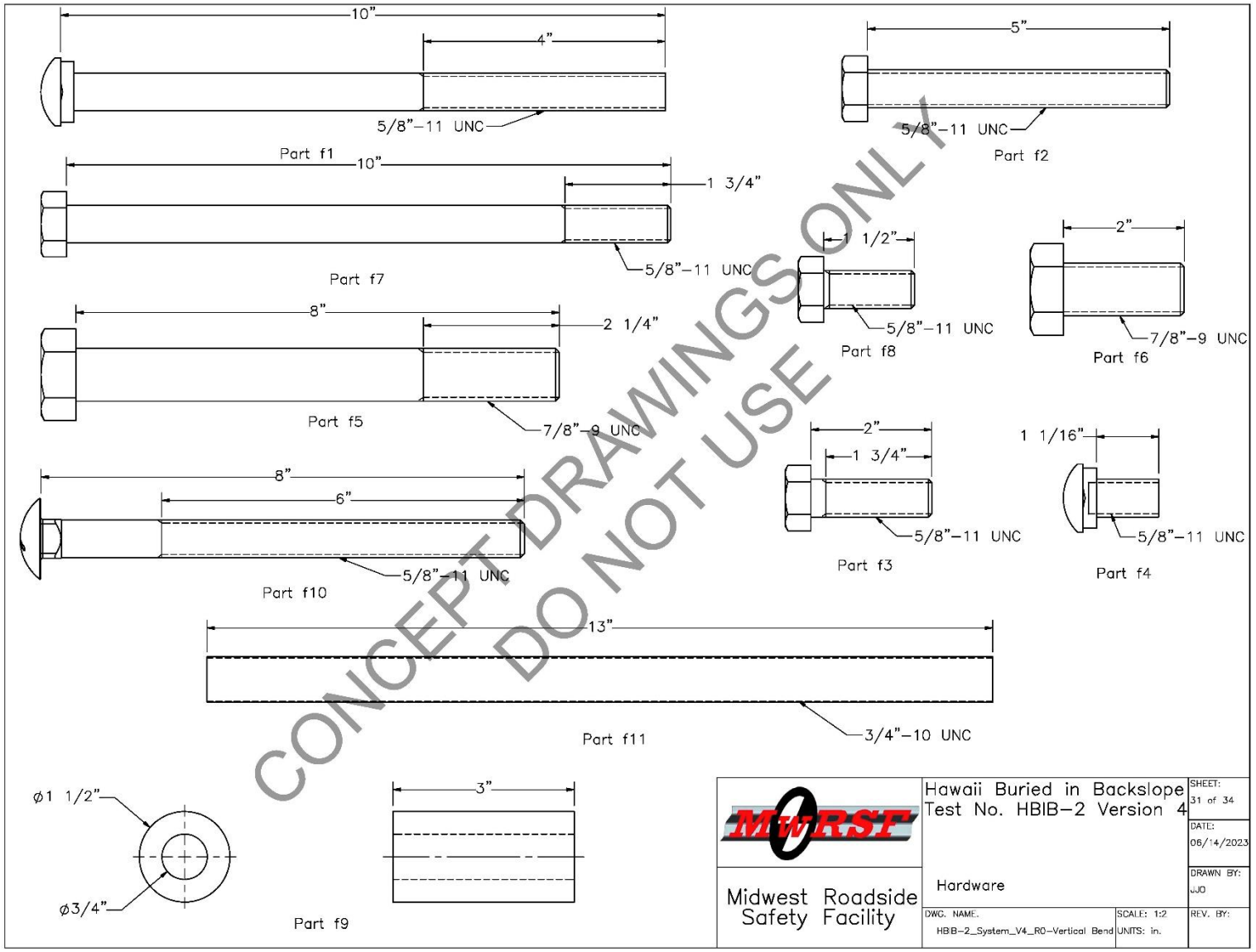


Figure L-43. Hardware Details, Test No. HBIB-2, Option 2

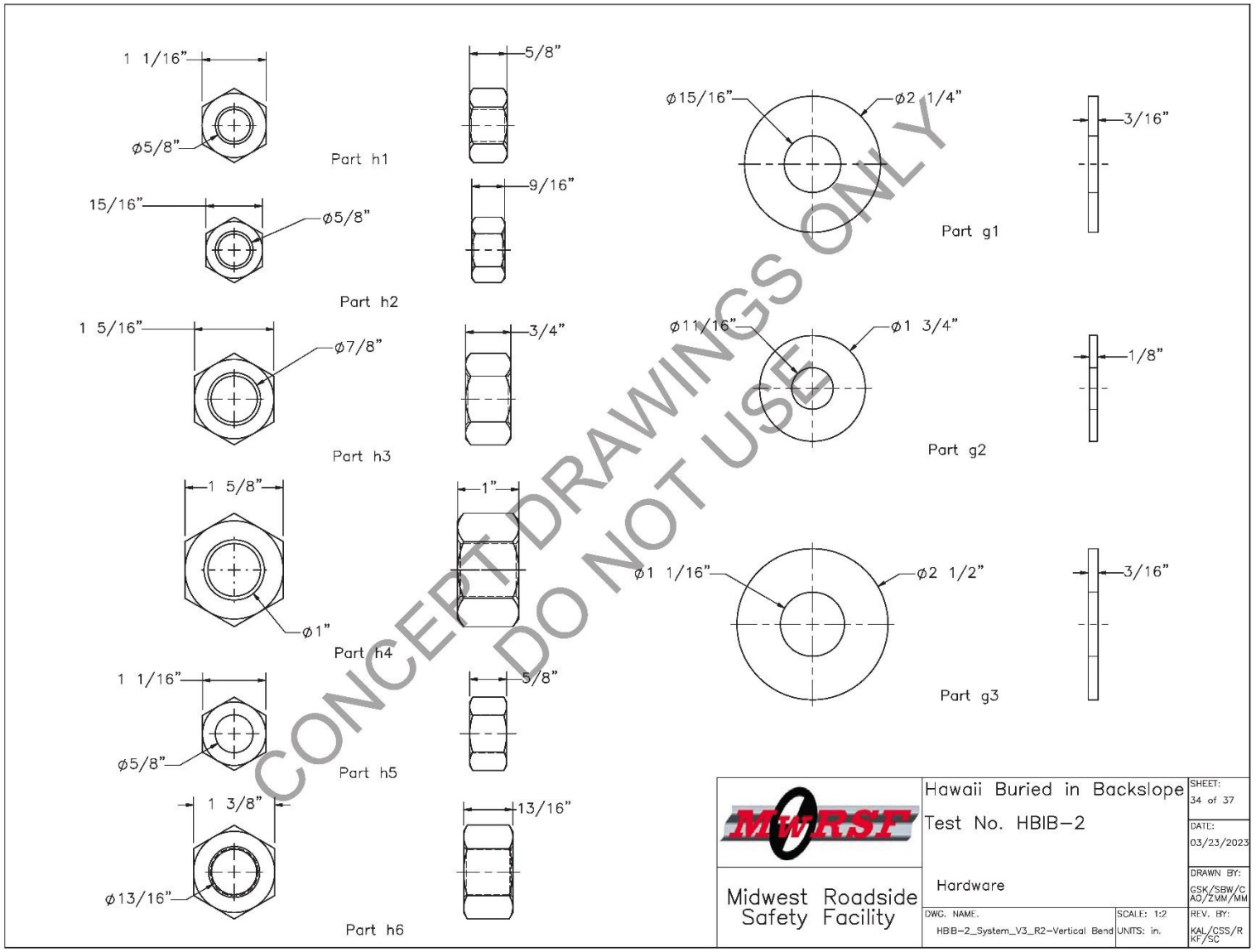


Figure L-44. Hardware Details, Test No. HBIB-2, Options 1a, 1b, and 2

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
a1	14	12'–6" 12–gauge W–Beam MGS Section	AASHTO M180	ASTM A123 or A653	RWM04a
a2	1	12'–6" 12–gauge W–Beam MGS End Section	AASHTO M180	ASTM A123 or A653	RWM14a
a3	1	7'–3.5" W–Beam Section	12 gauge AASHTO M180	ASTM A123 or A653	RWM01b
a4	1	12'–6" 12–gauge Bent W–Beam [4.4 deg]	AASHTO M180	ASTM A123 or A653	–
a5	1	10.4' 12–gauge Bent W–Beam [2.4 deg]	AASHTO M180	ASTM A123 or A653	–
a6	1	12'–6" 12–gauge Bent W–Beam [2.4 deg]	AASHTO M180	ASTM A123 or A653	–
a7	4	12'–6" W–Beam Section – 1/4 Post Spacing	12 gauge AASHTO M180	ASTM A123 or A653	RWM04a
a8	2	12' – 6" 12 guage W beam Vert bend [0.52 deg]	AASHTO M180	ASTM A123 or A653	–
a9	1	12'–6" 12–gauge Bent W–Beam [7.7 deg]	AASHTO M180	ASTM A123 or A653	–
b1	1	3"x3"x3" Concrete Block Anchor	Min. f'c = 4,000 psi	–	–
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	1	BCT Cable Anchor Assembly	–	–	FCA01
c5	1	Anchor Bracket Assembly	ASTM A36	ASTM A123	FPA01
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
d1	13	W6x8.5 or W6x9, 96" Long Steel Post	ASTM A992 Gr. 50	ASTM A123	PWE06
d2	25	W6x8.5 or W6x9, 72" Long Steel Post	ASTM A992 Gr. 50	ASTM A123	PWE06
d3	3	W6x15, 120" Long Steel Post	ASTM A992 Gr. 50	ASTM A123	–
d4	38	14 3/16"x8"x5 1/8" Composite Recycled Blockout	Mondo Polymer GB14SH2 or Equivalent	–	–
d5	13	17 1/2" [445] Long, 8"x6"x1/4" [203x152x6] Steel Blockout	ASTM A500 Gr. B	*ASTM A123	–
d6	14	13 5/8" [346] Long, 8"x6"x1/4" [203x152x6] Steel Blockout	ASTM A500 Gr. B	*ASTM A123	–
d7	2	16D Double Head Nail	–	–	–
e1	3	144 1/2" Unbent Length #4 Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
e2	4	28" Long #4 Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–

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Hawaii Buried in Backslope
Test No. HBIB–2
Bill of Materials

SHEET: 35 of 37
DATE: 03/23/2023
DRAWN BY: GSK/SBW/CAO/ZMM/MM
REV. BY: KAL/CSS/RKF/SC
DWG. NAME: HBIB–2_System_V3_R2–Vertical Bend
SCALE: 1:768
UNITS: in.

Figure L-45. Bill of Materials, Test No. HBIB-2, Option 1a

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
f1	80	5/8" Dia. UNC, 10" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBB03
f2	1	5/8 Dia, UNC, 5" Long Hex Head Bolt	ASTM A459 Gr. 5 or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f3	1	5/8" Dia, UNC, 2" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f4	280	5/8" Dia. UNC, 1 1/4" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBB01
f5	2	7/8" Dia. UNC, 8" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX22a
f6	11	7/8" Dia. UNC, 2" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX22a
f7	2	5/8" Dia. UNC, 10" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f8	8	5/8" Dia. UNC, 1 1/2" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f9	1	3/4 Dia, Unthreaded Spacer Sleeve	ASTM A53 Gr. B	ASTM A123	FMM03-04
f10	6	3/4" Dia. 9 UNC, 13" Long Fully Threaded Rod	ASTM A307 Gr. A of Equivalent	ASTM A153 of B695 Class 55 or F2329	–
g1	4	7/8" Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC20a
g2	22	5/8" Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC16a
g3	2	1" Dia. Plain Round Washer	ASTM F844	ASTM A153 (AASHTO M232) for Class D or ASTM B695 (AASHTO M298) for Class 50	FWC24a
h1	13	5/8" Dia. Heavy Hex Nut	ASTM A563A	ASTM A153 (AASHTO M232) for Class C or ASTM B695 (AASHTO M298) for Class 50	FNX16b
h2	58	5/8" Dia. Hex Nut	ASTM A563A	ASTM A153 (AASHTO M232) for Class C or ASTM B695 (AASHTO M298) for Class 50	FNX16a
h3	2	7/8" Dia. Hex Nut	ASTM A307A or equivalent	ASTM A153 (AASHTO M232) for Class C or ASTM B695 (AASHTO M298) for Class 50	–
h4	2	1"-8 UNC Heavy Hex Nut	ASTM A563DH or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX24b
h5	301	5/8" Dia. Heavy Hex Nut	ASTM A563DH or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX16b
h6	6	3/4"-9 UNC Heavy Hex Nut	ASTM A563DH or Equivalent	ASMT A153 or B695 Class 55 or F2329	FNX20b
i1	4	3/4" Dia. Wire Strut, 13 3/8" Long Unbent	Min. Tensile Strength = 100,000 psi	AASHTO M111	
i2	4	3/8" Dia. Wire Strut, 16 3/8" Long Unbent	Min. Tensile Strength = 100,000 psi	AASHTO M111	–
i3	2	3/8" Dia. Wire Strut, 18" Long Unbent	Min. Tensile Strength = 100,000 psi	AASHTO M111	–
i4	8	7/8 Dia., Threaded Ferrule	–	–	–
j1	–	Epoxy Adhesive	Min. Bond Strength = 1,450 psi	–	–

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Hawaii Buried in Backslope
Test No. HBIB-2

Bill of Materials

DWG. NAME: HBIB-2_System_V3_R2-Vertical Bend
SCALE: 1:14
UNITS: in.

SHEET: 36 of 37
DATE: 03/23/2023
DRAWN BY: GSK/SBW/CAO/ZMM/MM
REV. BY: KAL/CSS/RKF/SC

Figure L-46. Bill of Materials, Test No. HBIB-2, Option 1a

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
k1	1	7'–3.5" 10–gauge W–Beam to Thrie–Beam Asymmetric Transition Section	AASHTO M180	ASTM A123 or A653	RWT02
k2	1	7'–3.5" 10–gauge W–Beam to Thrie–Beam Asymmetric Transition Section	AASHTO M180	ASTM A653	RWT02
k3	1	10.4' 12 gauge Threbeam bent [2.4 deg]	AASHTO M180	ASTM A123 or A653	–
k4	4	12'–6" 12–gauge Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM08a
l1	2	W–Beam End Shoe Section	12 gauge AASHTO M180	ASTM A123 or A653	–

CONCEPT DRAWINGS ONLY
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Midwest Roadside Safety Facility

Hawaii Buried in Backslope
Test No. HBIB–2
Bill of Materials

DWG. NAME: HBIB–2_System_V3_R2–Vertical Bend
SCALE: 1:14
UNITS: in.

SHEET: 37 of 37
DATE: 03/23/2023
DRAWN BY: GSK/SBW/CAO/ZMM/MM
REV. BY: KAL/CSS/RKF/SC

Figure L-47. Bill of Materials, Test No. HBIB-2, Option 1a

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
a1	14	12'–6" 12–gauge W–Beam MGS Section	AASHTO M180	ASTM A123 or A653	RWM04a
a2	1	12'–6" 12–gauge W–Beam MGS End Section	AASHTO M180	ASTM A123 or A653	RWM14a
a3	1	7'–3.5" W–Beam Section	12 gauge AASHTO M180	ASTM A123 or A653	RWM01b
a4	1	12'–6" 12–gauge Bent W–Beam [4.4 deg]	AASHTO M180	ASTM A123 or A653	–
a5	1	10.4' 12–gauge Bent W–Beam [2.4 deg]	AASHTO M180	ASTM A123 or A653	–
a6	1	12'–6" 12–gauge Bent W–Beam [2.4 deg]	AASHTO M180	ASTM A123 or A653	–
a7	2	12'–6" W–Beam Section – 1/4 Post Spacing	12 gauge AASHTO M180	ASTM A123 or A653	RWM04a
a8	2	12' – 6" 12 guage W beam Vert bend [0.52 deg]	AASHTO M180	ASTM A123 or A653	–
a9	1	12'–6" 12–gauge Bent W–Beam [7.7 deg]	AASHTO M180	ASTM A123 or A653	–
a10	2	6'–3" W–Beam Section	12 gauge AASHTO M180	ASTM A123 or A653	RWM01b
b1	1	3"x3"x3" Concrete Block Anchor	Min. f'c = 4,000 psi	–	–
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	1	BCT Cable Anchor Assembly	–	–	FCA01
c5	1	Anchor Bracket Assembly	ASTM A36	ASTM A123	FPA01
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
d1	14	W6x8.5 or W6x9, 96" Long Steel Post	ASTM A992 Gr. 50	ASTM A123	PWE06
d2	24	W6x8.5 or W6x9, 72" Long Steel Post	ASTM A992 Gr. 50	ASTM A123	PWE06
d3	3	W6x15, 120" Long Steel Post	ASTM A992 Gr. 50	ASTM A123	–
d4	38	14 3/16"x8"x5 1/8" Composite Recycled Blockout	Mondo Polymer GB14SH2 or Equivalent	–	–
d5	14	17 1/2" [445] Long, 8"x6"x1/4" [203x152x6] Steel Blockout	ASTM A500 Gr. B	*ASTM A123	–
d6	13	13 5/8" [346] Long, 8"x6"x1/4" [203x152x6] Steel Blockout	ASTM A500 Gr. B	*ASTM A123	–
d7	2	16D Double Head Nail	–	–	–
e1	3	144 1/2" Unbent Length #4 Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–

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Hawaii Buried in Backslope
Test No. HBIB–2
Bill of Materials

SHEET: 35 of 37
DATE: 03/23/2023
DRAWN BY: GSK/SBW/CAO/ZMM
REV. BY: KAL/CSS/RKF/SC
DWG. NAME: HBIB–2_System_V3.1_R2–Vertical Bend
SCALE: 1:768
UNITS: in.

Figure L-48. Bill of Materials, Test No. HBIB-2, Option 1b

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
e2	4	28" Long #4 Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
f1	81	5/8" Dia. UNC, 10" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBB03
f2	1	5/8 Dia, UNC, 5" Long Hex Head Bolt	ASTM A459 Gr. 5 or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f3	1	5/8" Dia, UNC, 2" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f4	304	5/8" Dia. UNC, 1 1/4" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBB01
f5	2	7/8" Dia. UNC, 8" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX22a
f6	11	7/8" Dia. UNC, 2" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX22a
f7	2	5/8" Dia. UNC, 10" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f8	8	5/8" Dia. UNC, 1 1/2" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f9	1	3/4 Dia, Unthreaded Spacer Sleeve	ASTM A53 Gr. B	ASTM A123	FMM03-04
f10	6	3/4" Dia. 9 UNC, 13" Long Fully Threaded Rod	ASTM A307 Gr. A of Equivalent	ASTM A153 of B695 Class 55 or F2329	–
g1	4	7/8" Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC20a
g2	22	5/8" Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC16a
g3	2	1" Dia. Plain Round Washer	ASTM F844	ASTM A153 (AASHTO M232) for Class D or ASTM B695 (AASHTO M298) for Class 50	FWC24a
h1	13	5/8" Dia. Heavy Hex Nut	ASTM A563A	ASTM A153 (AASHTO M232) for Class C or ASTM B695 (AASHTO M298) for Class 50	FNX16b
h2	58	5/8" Dia. Hex Nut	ASTM A563A	ASTM A153 (AASHTO M232) for Class C or ASTM B695 (AASHTO M298) for Class 50	FNX16a
h3	2	7/8" Dia. Hex Nut	ASTM A307A or equivalent	ASTM A153 (AASHTO M232) for Class C or ASTM B695 (AASHTO M298) for Class 50	–
h4	2	1"-8 UNC Heavy Hex Nut	ASTM A563DH or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX24b
h5	326	5/8" Dia. Heavy Hex Nut	ASTM A563DH or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX16b
h6	6	3/4"-9 UNC Heavy Hex Nut	ASTM A563DH or Equivalent	ASMT A153 or B695 Class 55 or F2329	FNX20b
i1	4	3/4" Dia. Wire Strut, 13 3/8" Long Unbent	Min. Tensile Strength = 100,000 psi	AASHTO M111	
i2	4	3/8" Dia. Wire Strut, 16 3/8" Long Unbent	Min. Tensile Strength = 100,000 psi	AASHTO M111	–
i3	2	3/8" Dia. Wire Strut, 18" Long Unbent	Min. Tensile Strength = 100,000 psi	AASHTO M111	–
i4	8	7/8 Dia., Threaded Ferrule	–	–	–

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Hawaii Buried in Backslope
Test No. HBIB-2

Bill of Materials

SHEET: 36 of 37
DATE: 03/23/2023
DRAWN BY: GSK/SBW/CAO/ZMM
REV. BY: KAL/CSS/RKF/SC
DWG. NAME: HBIB-2_System_V3.1_R2-Vertical Bend
SCALE: 1:14
UNITS: in.

Figure L-49. Bill of Materials, Test No. HBIB-2, Option 1b

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
j1	–	Epoxy Adhesive	Min. Bond Strength = 1,450 psi	–	–
k1	1	7'–3.5" 10–gauge W–Beam to Thrie–Beam Asymmetric Transition Section	AASHTO M180	ASTM A123 or A653	RWT02
k2	1	7'–3.5" 10–gauge W–Beam to Thrie–Beam Asymmetric Transition Section	AASHTO M180	ASTM A653	RWT02
k3	1	10.4' 12 gauge Threbeam bent [2.4 deg]	AASHTO M180	ASTM A123 or A653	–
k4	4	12'–6" 12–gauge Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM08a
k5	1	12'–6" 12–gauge Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM08a
l1	2	W–Beam End Shoe Section	12 gauge AASHTO M180	ASTM A123 or A653	–

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Hawaii Buried in Backslope
Test No. HBIB–2

Bill of Materials

SHEET: 37 of 37
DATE: 03/23/2023
DRAWN BY: GSK/SBW/CAO/ZMM
REV. BY: KAL/CSS/RKF/SC
DWG. NAME: HBIB–2_System_V3.1_R2–Vertical Bend
SCALE: 1:14
UNITS: in.

Figure L-50. Bill of Materials, Test No. HBIB-2, Option 1b

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
a1	18	12'–6" 12–gauge W–Beam MGS Section	AASHTO M180	ASTM A123 or A653	RWM04a
a2	1	12'–6" 12–gauge W–Beam MGS End Section	AASHTO M180	ASTM A123 or A653	RWM14a
a3	1	7'–3.5" W–Beam Section	12 gauge AASHTO M180	ASTM A123 or A653	RWM01b
a4	1	12'–6" 12–gauge Bent W–Beam [4.4 deg]	AASHTO M180	ASTM A123 or A653	–
a5	2	10.4' 12–gauge Bent W–Beam [2.4 deg]	AASHTO M180	ASTM A123 or A653	–
a6	2	12'–6" 12–gauge Bent W–Beam [2.4 deg]	AASHTO M180	ASTM A123 or A653	–
a7	4	12'–6" W–Beam Section – 1/4 Post Spacing	12 gauge AASHTO M180	ASTM A123 or A653	RWM04a
a8	2	12'–6" 12 guage W beam Vert bend [0.52 deg]	AASHTO M180	ASTM A123 or A653	–
a9	1	12'–6" 12–gauge Bent W–Beam [7.7 deg]	AASHTO M180	ASTM A123 or A653	–
b1	1	3"x3"x3" Concrete Block Anchor	Min. f'c = 4,000 psi	–	–
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	1	BCT Cable Anchor Assembly	–	–	FCA01
c5	1	Anchor Bracket Assembly	ASTM A36	ASTM A123	FPA01
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
d1	27	W6x8.5 or W6x9, 84" Long Steel Post	ASTM A992 Gr. 50	ASTM A123	PWE06
d2	11	W6x8.5 or W6x9, 72" Long Steel Post	ASTM A992 Gr. 50	ASTM A123	PWE06
d3	3	W6x15, 120" Long Steel Post	ASTM A992 Gr. 50	ASTM A123	–
d4	38	14 3/16"x8"x5 1/8" Composite Recycled Blockout	Mondo Polymer GB14SH2 or Equivalent	–	–
d6	27	13 5/8" [346] Long, 8"x6"x1/4" [203x152x6] Steel Blockout	ASTM A500 Gr. B	*ASTM A123	–
d9	2	16D Double Head Nail	–	–	–
e1	3	144 1/2" Unbent Length #4 Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
e2	4	28" Long #4 Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
f1	67	5/8" Dia. UNC, 10" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBB03
f11	6	3/4" Dia. 9 UNC, 13" Long Fully Threaded Rod	ASTM A307 Gr. A of Equivalent	ASTM A153 of B695 Class 55 or F2329	–
f2	1	5/8 Dia, UNC, 5" Long Hex Head Bolt	ASTM A459 Gr. 5 or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f3	1	5/8" Dia, UNC, 2" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a

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Hawaii Buried in Backslope
Test No. HBIB–2 Version 4
Bill of Materials

SHEET: 33 of 34
DATE: 06/14/2023
DRAWN BY: JJO
REV. BY:
DWG. NAME: HBIB–2_System_V4_R0–Vertical Bend
SCALE: 1:768
UNITS: in.

Figure L-51. Bill of Materials, Test No. HBIB-2, Option 2

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
f4	232	5/8" Dia. UNC, 1 1/4" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBB01
f5	2	7/8" Dia. UNC, 8" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX22a
f6	11	7/8" Dia. UNC, 2" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX22a
f7	2	5/8" Dia. UNC, 10" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f8	8	5/8" Dia. UNC, 1 1/2" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f9	1	3/4 Dia, Unthreaded Spacer Sleeve	ASTM A53 Gr. B	ASTM A123	FMM03-04
g1	4	7/8" Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC20a
g2	22	5/8" Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC16a
g3	2	1" Dia. Plain Round Washer	ASTM F844	ASTM A153 (AASHTO M232) for Class D or ASTM B695 (AASHTO M298) for Class 50	FWC24a
h1	12	5/8" Dia. Heavy Hex Nut	ASTM A563A	ASTM A153 (AASHTO M232) for Class C or ASTM B695 (AASHTO M298) for Class 50	FNX16b
h2	58	5/8" Dia. Hex Nut	ASTM A563A	ASTM A153 (AASHTO M232) for Class C or ASTM B695 (AASHTO M298) for Class 50	FNX16a
h3	2	7/8" Dia. Hex Nut	ASTM A307A or equivalent	ASTM A153 (AASHTO M232) for Class C or ASTM B695 (AASHTO M298) for Class 50	-
h4	2	1"-8 UNC Heavy Hex Nut	ASTM A563DH or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX24b
h5	241	5/8" Dia. Heavy Hex Nut	ASTM A563DH or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX16b
h6	6	3/4"-9 UNC Heavy Hex Nut	ASTM A563DH or Equivalent	ASMT A153 or B695 Class 55 or F2329	FNX20b
i1	4	3/4" Dia. Wire Strut, 13 3/8" Long Unbent	Min. Tensile Strength = 100,000 psi	AASHTO M111	
i2	4	3/8" Dia. Wire Strut, 16 3/8" Long Unbent	Min. Tensile Strength = 100,000 psi	AASHTO M111	-
i3	2	3/8" Dia. Wire Strut, 18" Long Unbent	Min. Tensile Strength = 100,000 psi	AASHTO M111	-
i4	8	7/8 Dia., Threaded Ferrule	-	-	-
j1	-	Epoxy Adhesive	Min. Bond Strength = 1,450 psi	-	-
l1	2	W-Beam End Shoe Section	12 gauge AASHTO M180	ASTM A123 or A653	-

CONCEPT DRAWINGS ONLY
DO NOT USE

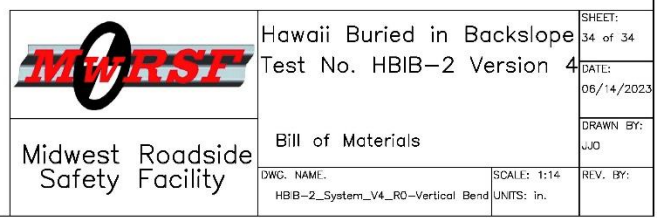


Figure L-52. Bill of Materials, Test No. HBIB-2, Option 2

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