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HAWAII DOT FLARED BURIED-IN-BACKSLOPE GUARDRAIL END TERMINAL PART 2 – REVERSE DIRECTION TESTS

Submitted and Approved by

Mojtaba Atash Bahar, M.S.C.E
Graduate Research Assistant

Cody S. Stolle, Ph.D.
Research Associate Professor

Ronald K. Faller, Ph.D., P.E.
Research Professor & MwRSF Director

Joshua Steelman, Ph.D., P.E.
Associate Professor, Civil Engineering

Karla A. Lechtenberg, M.S.M.E.
Research Engineer

J.C. Holloway, M.S.C.E.,
Research Engineer & Assistant Director – Physical Testing Division

Erin L. Urbank, B.A.
Research Communication Specialist

James B. Wills, Jr., B.S.C.E.
Graduate Research Assistant

MIDWEST ROADSIDE SAFETY FACILITY
Nebraska Transportation Center
University of Nebraska-Lincoln

Main Office
Prem S. Paul Research Center at Whittier School
Room 130, 2200 Vine Street
Lincoln, Nebraska 68583-0853
(402) 472-0965

Outdoor Test Site
4630 N.W. 36th Street
Lincoln, Nebraska 68524

Submitted to
HAWAII DEPARTMENT OF TRANSPORTATION
Aliiaimoku Building
869 Punchbowl Street
Honolulu, Hawaii 96813

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16. Abstract

The Hawaii Department of Transportation's (HDOT's) Buried-in-Backslope system was evaluated to Manual for Assessing Safety Hardware (MASH) Test Level 3 (TL-3) impact conditions in the reverse direction. The system consisted of Midwest Guardrail System (MGS) W-beam railing supported by W6x8.5 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.

The dual-flare system was evaluated in the reverse-direction configuration in test nos. HBIB-6 through HBIB-8 and HBIB-10. During test no. HBIB-6, conducted according to MASH test designation 3-37a, a 2270P pickup truck impacted the system 197.6 in. upstream from the centerline splice between post nos. 29 and 30, and the barrier system effectively contained and redirected the vehicle. In test no. HBIB-7, conducted according to MASH test designation 3-37b, an 1100C passenger car impacted the system 82½ in. upstream from the centerline splice between post nos. 29 and 30, and the barrier system effectively contained and redirected the vehicle. During test no. HBIB-8, conducted according to MASH test designation 3-37a, a 2270P pickup truck impacted the barrier 67.0 in. upstream from the upstream end of the concrete anchor block, and the barrier system effectively contained and redirected the vehicle and test no. HBIB-8. During test no. HBIB-10, conducted according to MASH test designation 3-37b, a 1100C passenger car impacted the barrier 41.5 in. upstream from the upstream end of the anchor block, and the barrier system effectively contained and redirected the 1100C vehicle. Test nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10 were deemed acceptable according to the MASH safety performance criteria for test designation nos. 3-37a and 3-37b, therefore, the HDOT Buried-in-Backslope system was deemed acceptable according to MASH evaluation criteria.

HDOT desired to have an option for both dual-flare and single-flare embodiments of the HBIB design. Single-flare systems may be used in locations where the backslope is located close to the roadway or in some reverse-direction applications. The single-flare configuration was evaluated in the reverse-direction configuration in test no. HBIB-9, conducted according to MASH test designation 3-37a, in which a 2270P pickup truck impacted the barrier 68.5 in. upstream from the upstream end of the concrete anchor. After exiting the system, the vehicle rolled over, coming to rest on its roof, and occupant compartment deformation values exceeded MASH limits at the A-pillar, B-pillar, and roof. Therefore, test no. HBIB-9 was determined to be unsuccessful according to MASH safety performance criteria for test designation no. 3-37a.

In conclusion, only the dual-flare HBIB system was determined to be crashworthy according to MASH TL-3 impact conditions.

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UNCERTAINTY OF MEASUREMENT STATEMENT

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

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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R.W. Bielenberg, M.S.M.E., Research Engineer
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M. Asadollahi Pajouh, Ph.D., P.E., former Research Assistant Professor
B.J. Perry, M.E.M.E., Research Engineer
A.E. Loken, Ph.D., Research Assistant Professor
T.Y. Yosef, Ph.D., Research Assistant Professor
Q.A. Alomari, Ph.D., Research Assistant Professor
A.T. Russell, B.S.B.A., Testing and Maintenance Technician II
E.W. Krier, B.S., Former Engineering Testing Technician II
D.S. Charroin, Engineering Testing Technician II
R.M. Novak, Engineering Testing Technician II
T.C. Donahoo, Engineering Testing Technician I
J.T. Jones, Engineering Testing Technician II
E.L. Urbank, Research Communication Specialist
Z.Z. Jabr, Engineering Technician
J.J. Oliver, Solidworks Drafting Coordinator
Undergraduate and Graduate Research Assistants

Hawaii Department of Transportation
Brent Ching, Structural Engineer
Keith Kalani, Structural Engineer
Kimberly Okamura, Engineer

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

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

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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 fully demonstrated. A previous report examining the crashworthiness of the system found the initial system design insufficient, and modifications were made, which were sufficient for MASH TL-3 impact standards upon further testing [1]. In this report, the modified system from the prior report was further investigated under MASH TL-3 impact conditions. This report documents the full-scale crash testing conducted to evaluate the safety performance of the modified Type A-1 flare system with the American Association of State Highway and Transportation (AASHTO) *Manual for Assessing Safety Hardware* (MASH) [2].

Initially, HDOT provided four system configurations that varied the location of the end anchorage block. The four configurations were built-up options. 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 may be more severe, they may not be used in practice. Thus, the most severe configuration that is used in practice was Option 2. The system plans provided by HDOT are shown in Figures 1 through 3.

Although the Option 1 configuration was more common and was likely less severe for impacting vehicles in standard travel directions, the single-flare configuration was likely more severe for reverse-direction configurations. Dual-flare systems utilize a larger secondary flare, and the effective impact angle when departing the roadway decreases as the secondary flare rate increases. The single-flare configuration had a larger effective impact angle. Reverse-direction impacts may occur if the HBIB system is used in a trailing-end configuration or when the upstream end of the guardrail may be exposed to impacts from vehicles traveling in the opposite travel direction.

This system was crash-tested in test no. HBIB-1, which resulted in the system failing to meet Test Level 3 (TL-3) impact standards. The system failed the crash test due to excessive Occupant Ridedown Accelerations (ORA) and excessive deformation of vehicle components. The high ORA values were likely the result of snagging/pocketing from when the vehicle underrode the rubrail and snagged on the post flanges. The excessive deformation of the vehicle's A-pillar resulted from contact with the guardrail. Both issues could be resolved by lowering the height of the guardrail.

1.2 Objective

The objective of this research was to conduct full-scale crash testing of the HDOT buried-in-backslope system in the reverse direction according to TL-3 of MASH impact safety standards.

1.3 Scope

The research objective was performed through the completion of several tasks. An earlier report [1] discussed initial tasks, which involved a comprehensive literature review of the existing BIB roadside safety features, a crash test which did not meet MASH TL-3 requirements, design revisions to improve constructability and standardization, and four subsequently successful crash tests. System plans were developed using CAD, and a ditch with a 6:1 foreslope and 2:1 backslope was constructed to model a HDOT roadside ditch. The system was constructed and subjected to three full-scale crash tests in accordance with MASH test designation no. 3-37 with the small car and pickup truck in the reverse direction. The full-scale vehicle crash test results were analyzed, evaluated, and documented. Conclusions and recommendations were then made pertaining to the safety performance of the HBIB guardrail, rubrail, and end anchorage.

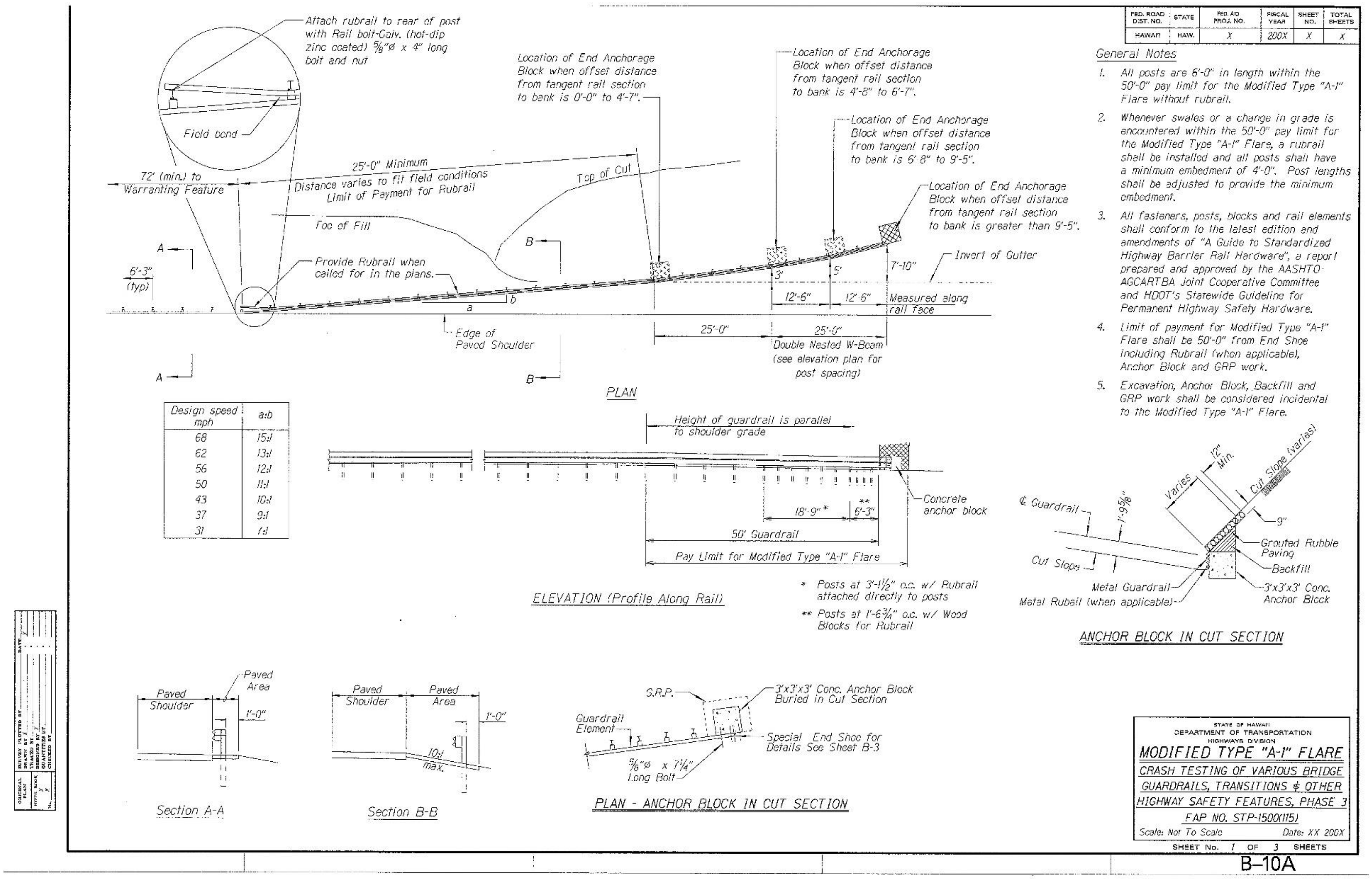


Figure 1. HDOT Standard Plans - HBIB Modified Type A-1 Flare, Sheet 1

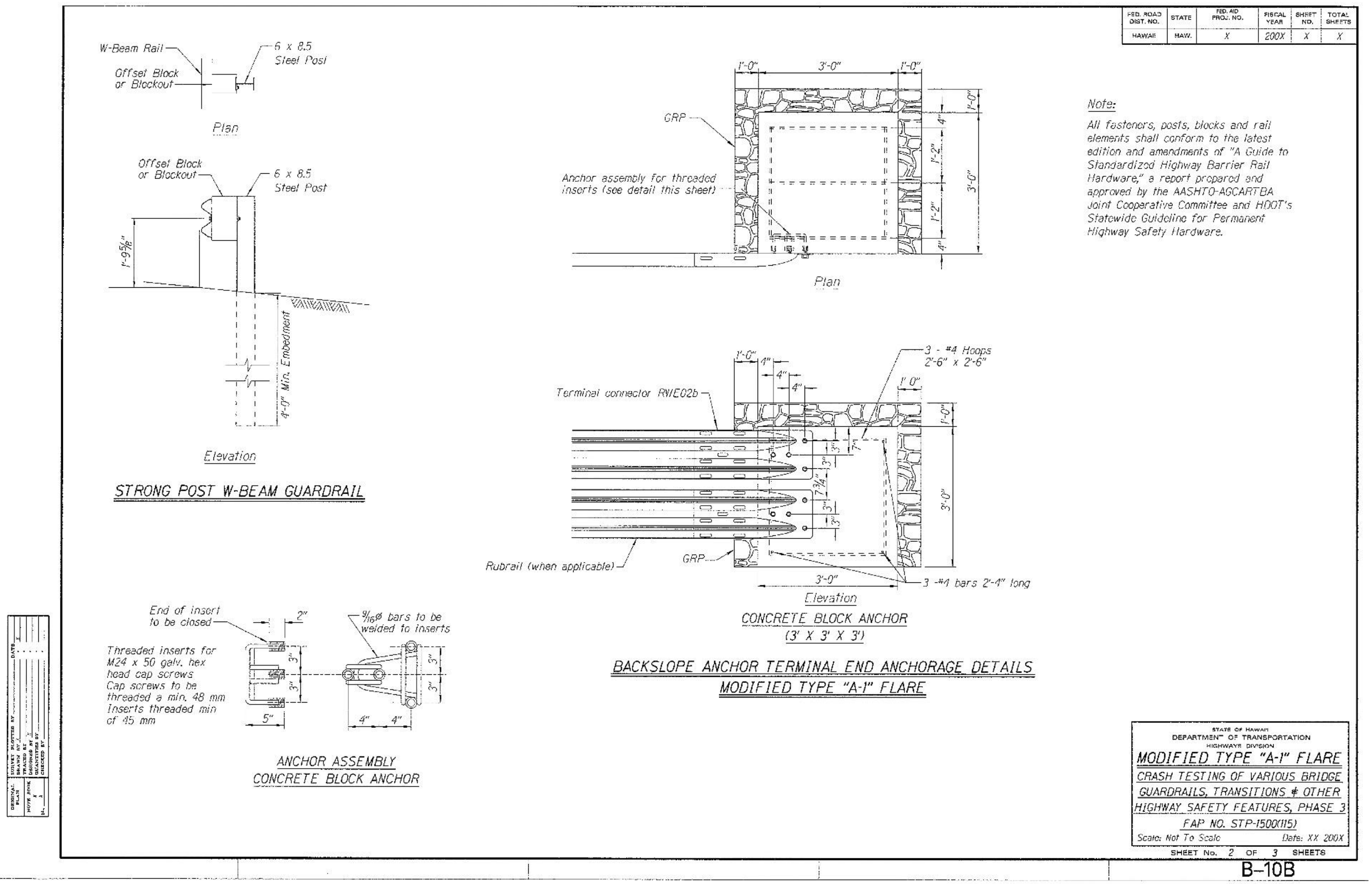


Figure 2. HDOT Standard Plans - HBIB Modified Type A-1 Flare, Sheet 2

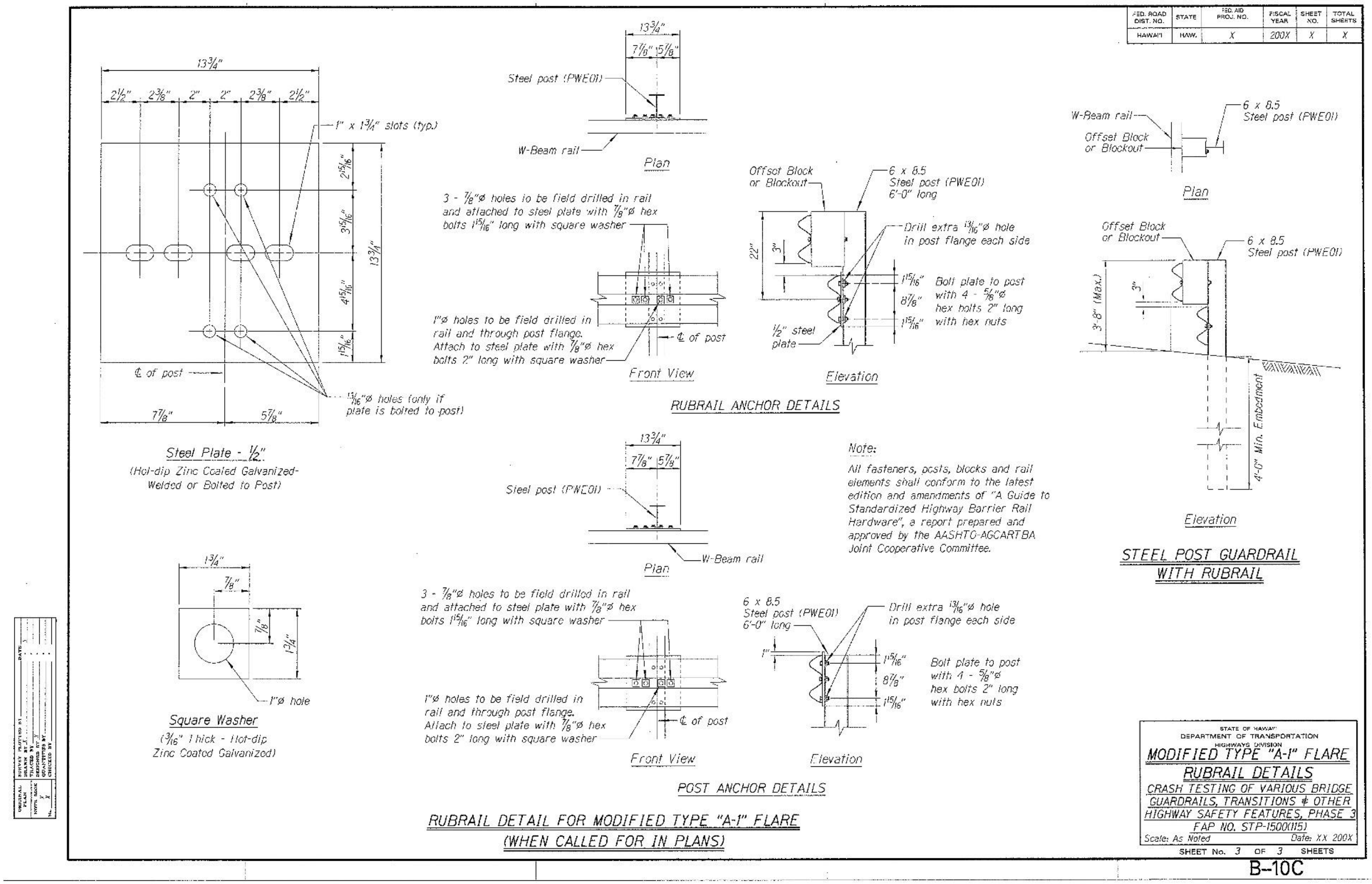


Figure 3. HDOT Standard Plans - HBIB Modified Type A-1 Flare, Sheet 3

2 TEST REQUIREMENTS AND EVALUATION CRITERIA

2.1 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 are 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

Ten full-scale crash tests are required 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 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 nos. 3-36 is recommended for terminals directly 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.

2.2 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="3">Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.</td></tr>
<tr><td rowspan="12">Occupant Risk</td><td>D.</td><td colspan="3">Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH.</td></tr>
<tr><td>F.</td><td colspan="3">The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 deg.</td></tr>
<tr><td rowspan="5">H.</td><td colspan="3">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="3">Occupant Impact Velocity Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>30 ft/s</td><td>40 ft/s</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td rowspan="4">I.</td><td colspan="3">The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH for calculation procedure) should satisfy the following limits:</td></tr>
<tr><td colspan="3">Occupant Ridedown Acceleration Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>15.0 g’s</td><td>20.49 g’s</td></tr>
</table>

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.

2.3 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.

3 CRITICAL IMPACT POINT

3.1 Impact Conditions

Based on the most reliable data obtained from the reconstruction of passenger vehicle crashes on high-speed roadways [3-4], 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. Additionally, recognizing that larger trucks have reduced cornering characteristics, the impact angle was 25 degrees. 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, have been identified as essential to evaluate the crashworthiness of HDOT's BIB system.

The process of choosing the impact location in most full-scale crash tests is a key point to replicating critical conditions that are most likely to result in test failure. For end terminals and longitudinal barriers, the CIPs are 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.

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. Basically, ISF is a suitable indicator of the magnitude of loading on the barrier systems, which is defined as:

$$ISF = \frac{1}{2}\, M(V sin(\theta))^2 \qquad (3\text{-}1)$$

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:

$$KE = \frac{1}{2}\, MV^2 \qquad (3\text{-}2)$$

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. 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.

3.2 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.

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:

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

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:

$$F_s' = F_s \left(\frac{D_e'}{D_e}\right)^2 \tag{3-4}$$

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:

$$M_p = M_h + \sum M_i \frac{H_i}{H_h} \tag{3-5}$$

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 Figures 4 and a summary of recommended CIP offsets from critical barrier features provided in MASH is shown in Figures 5 through 8.

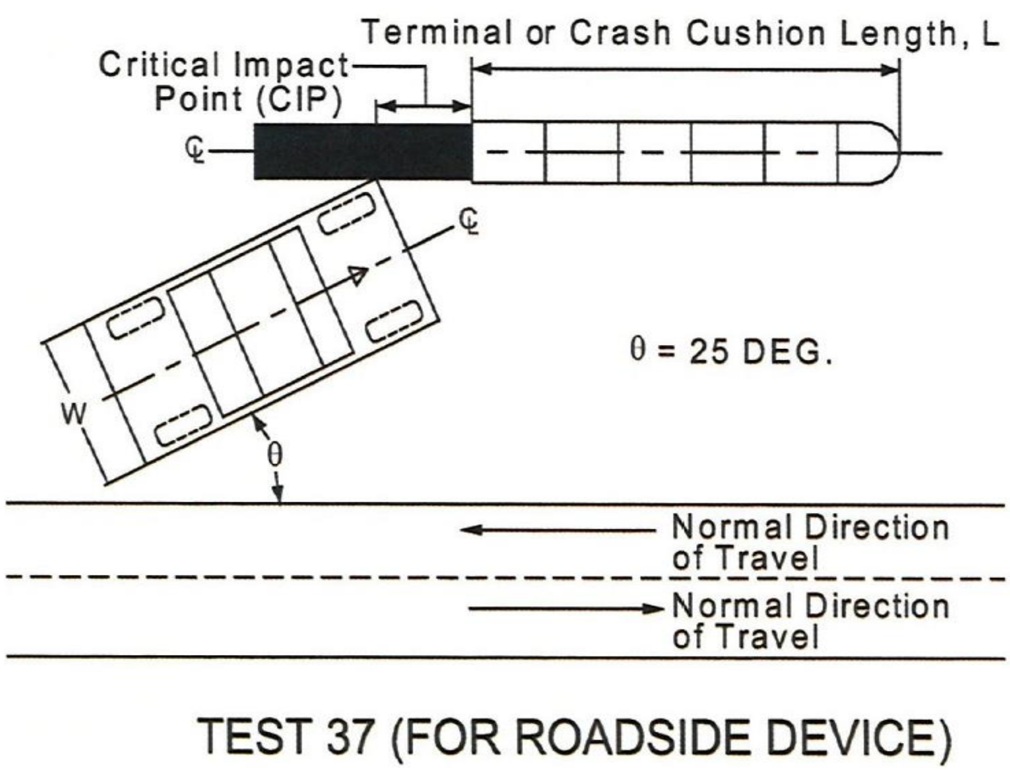


Figure 4. CIP Distance and Test Conditions, Test Level 3, Test Designation Nos. 3-37

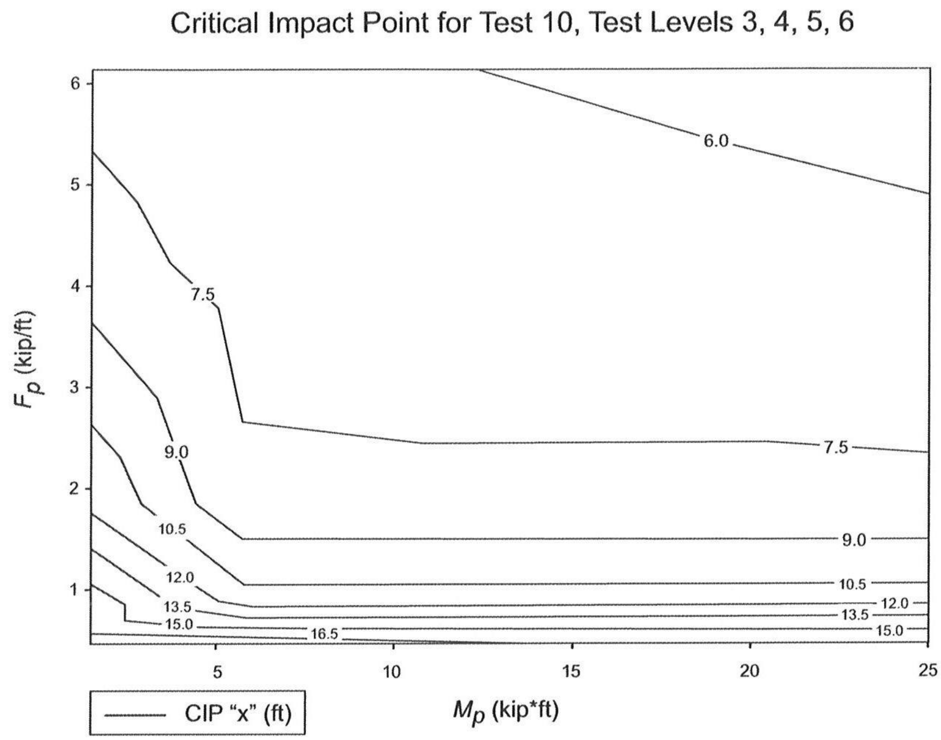


Figure 5. Critical Impact Point Selection for MASH Test Designation 3-37 low M_P [2]

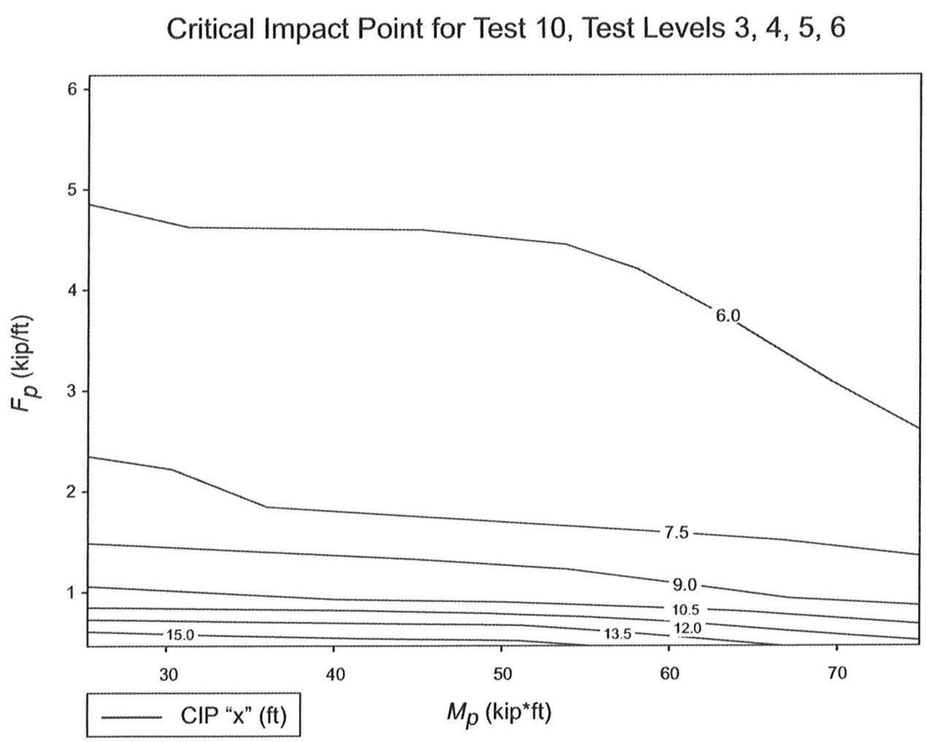


Figure 6. Critical Impact Point Selection for MASH Test Designation 3-37 high M_P [2]

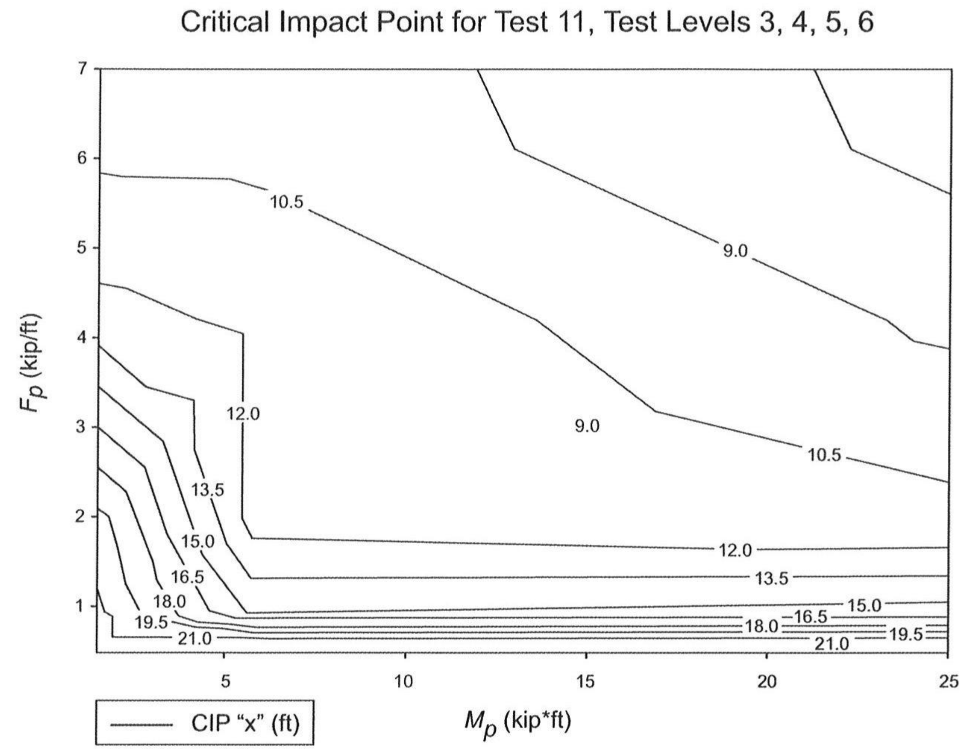


Figure 7. Critical Impact Point Selection for MASH Test Designation 3-37 low M_P [2]

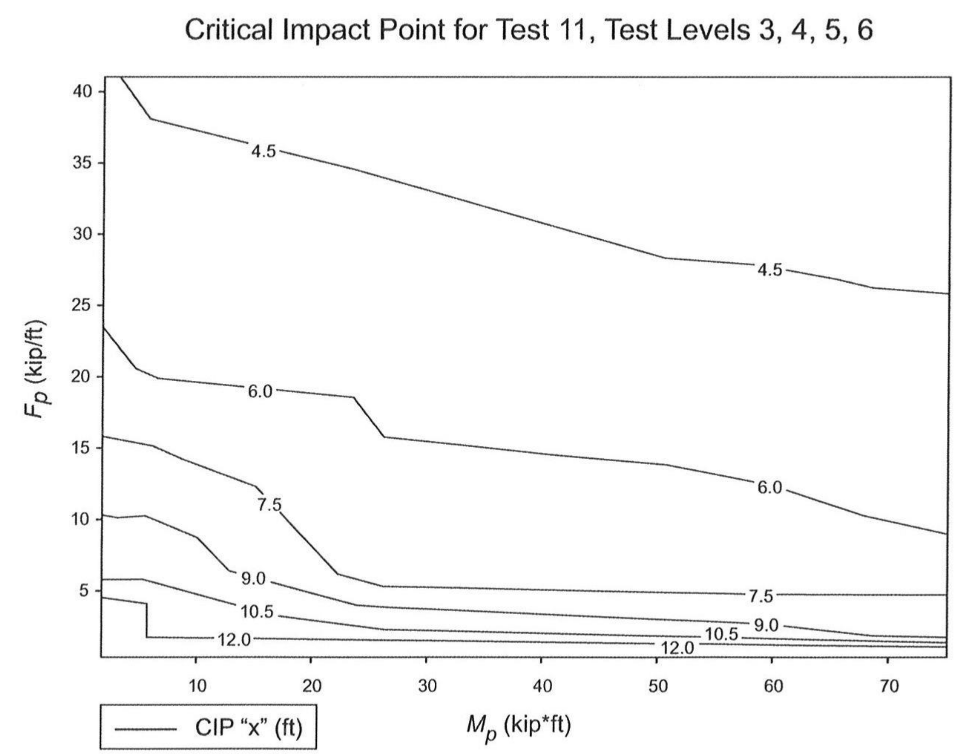


Figure 8. Critical Impact Point Selection for MASH Test Designation 3-37 high M_P [2]

3.3 CIP Selection for HBIB System

A detailed calculation of different CIPs identified for the HBIB system are reported in Appendix B. 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 Figures 35 through 38 (Chapter 5).

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 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 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 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**	**Section 6**
Fp (kips)	9.34	3.99	3.99	2.00	1.98	1.98
Fs' (kips)	14.88	12.48	12.48	12.48	12.40	12.40
Mp (kip.ft)	25.30	26.40	13.20	13.20	12.10	8.00
X (ft) 3-10	4.20	6.64	8.29	8.29	8.27	8.18
X (ft) 3-11	7.00	8.91	10.69	11.81	11.89	11.89

*All the sections are shown in Figure 9. See the following description for each section:
Section 1: post nos. 1 through 4 - system has nested rails and rubrails and quarter post spacing (18.8 in.)
Section 2: post nos. 4 through 6 - system has nested rails and rubrails and half post spacing (37½ in.)
Section 3: from post nos. 6 through 10 - system has both upper rail and rubrail at half post spacing (37 ½ in.)
Section 4: from post nos. 10 through 23 - system has upper rail and rubrail using full post spacing at Highest Height over Ditch (75 in.)
Section 5: from post nos. 23 through 29 - system has upper rail and rubrail using full post spacing (75 in.)
Section 6: from post nos. 29 through 40 - system is consistent with standard, tangent MGS with full post spacing (75 in.)

The following concerns and parameters were considered during the detection of the CIPs to evaluate downstream performance of the system using MASH Figures 2-8 and 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 [5];
- 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.

This report addresses the reverse-direction testing of the HBIB system. Using the guidelines provided above, two primary reference points were selected for reverse-direction impact. The first was the downstream end of the rubrail which was attached to the back side of post no. 29. The reverse-direction impacts toward the rubrail used a modified, reduced-strength CIP estimate for standard MGS spacing to accommodate the bend in the W-beam and loss of moment capacity across the “knee”.

The second reverse-direction impact reference point was selected as the reinforced concrete anchor block in the system. During evaluation of the standard-direction impacts, the anchor block was weakly reinforced with respect to the ditch soil using W-section steel posts on the upstream and back faces. Despite these post reinforcements, the anchor block experienced significant longitudinal movement during test nos. HBIB-3 and HBIB-5. For reverse-direction tests, a more robust ground anchorage system was developed by placing a reinforced concrete shaft below the anchor block to a depth of 10 ft. This condition was believed to simulate a completely rigid anchor and would be the most severe for reverse-direction impacts.

Nonetheless, the anchor block was installed on a flare. To account for the reduced impact angle, the research team used a ratio of the effective impact angle in the reverse direction divided by the nominal MASH impact angle of 25 degrees, and multiplied that factor by the calculated value for “X” for both the 2270P and 1100C using Table 3 and MASH Figures 2-8 and 2-11.

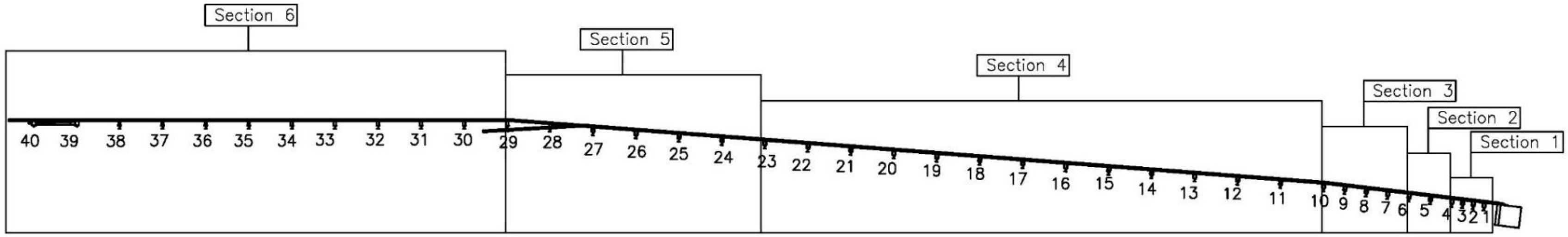


Figure 9. System Sections Based on System Stiffness and Post Spacing

4 TEST CONDITIONS

4.1 Test Facility

The Outdoor Test Site is located at the Lincoln Air Park on the northwest side of the Lincoln Municipal Airport and is approximately 5 miles northwest of the University of Nebraska-Lincoln.

4.2 Vehicle Tow and Guidance System

A reverse-cable, tow system with a 1:2 mechanical advantage was used to propel 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 [6] 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.

4.3 Test Vehicles

For test no. HBIB-6, a 2018 Ram 1500 crew cab pickup truck was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 5,304 lb, 5,061 lb, and 5,222 lb, respectively. The test vehicle is shown in Figures 10 and 11, and vehicle dimensions are shown in Figure 12. Note, the impact side of the vehicle, or the passenger's side, is referred to as the vehicle's right side throughout this report. The non-impact side, or driver's side, is referred to as the vehicle's left side.

For test no. HBIB-7, a 2018 Kia Rio was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 2,467 lb, 2,419 lb, and 2,577 lb, respectively. The test vehicle is shown in Figures 13 and 14, and vehicle dimensions are shown in Figure 15.

For test no. HBIB-8, a 2018 Ram 1500 crew cab pickup truck was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 5,126 lb, 5,000 lb, and 5,162 lb, respectively. The test vehicle is shown in Figures 16 and 17, and vehicle dimensions are shown in Figure 18.

For test no. HBIB-10, a 2019 Hyundai Accent was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 2,517 lb, 2,421 lb, and 2,585 lb, respectively. The test vehicle is shown in Figures 19 and 20, and vehicle dimensions are shown in Figure 21.

For test no. HBIB-9, a 2018 Ram 1500 crew cab pickup truck was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 4,983 lb, 5,000 lb, and 4,997 lb, respectively. The test vehicle is shown in Figures 22 and 23, and vehicle dimensions are shown in Figure 24.

Figure 10. Test Vehicle Photographs, Test No. HBIB-6

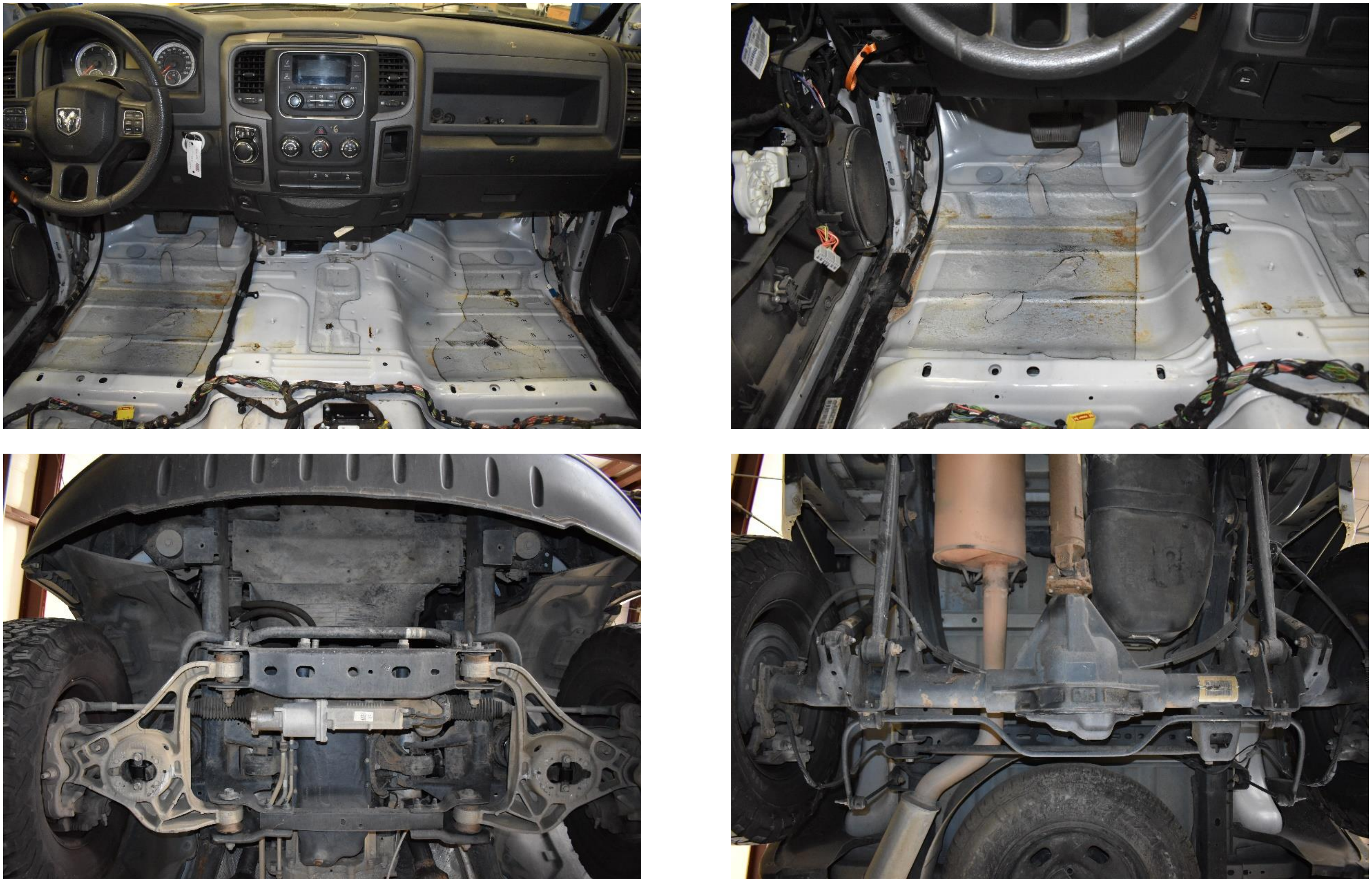
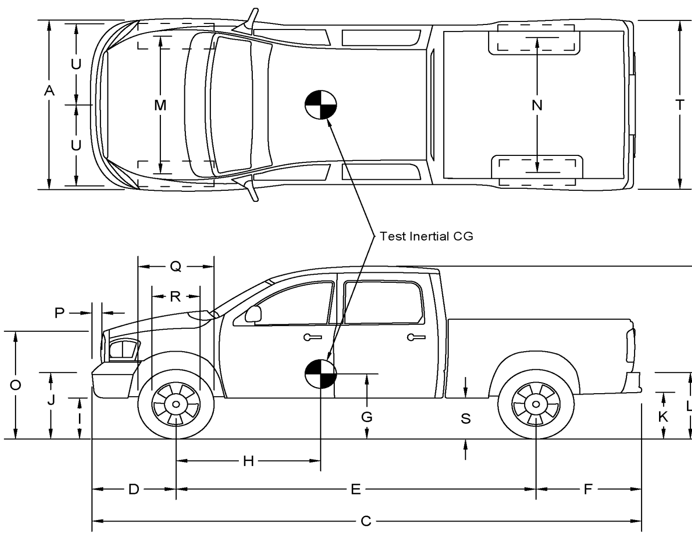


Figure 11. Test Vehicle Interior Floorboards and Undercarriage, Test No. HBIB-6

Test Name: HBIB-6 **VIN No:** 3C6RR6KT6JG186123

Model Year: 2018 **Make:** RAM **Model:** 1500

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



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

A:	78 5/16 1989 11/80 78±2 (1950±50)	B:	74 9/16 1893 71/80
C:	229 3/8 5826 1/8 237±13 (6020±325)	D:	42 3/4 1085 17/20 39±3 (1000±75)
E:	140 5/8 3571 7/8 148±12 (3760±300)	F:	46 1168 2/5
G:	28 7/16 722 5/16 min: 28 (710)	H:	60 1/8 1527 7/40 63±4 (1575±100)
I:	13 330 1/5	J:	25 635
K:	20 3/4 527 1/20	L:	29 7/16 747 57/80
M:	67 1/4 1708 3/20 67±1.5 (1700±38)	N:	67 5/8 1717 27/40 67±1.5 (1700±38)
O:	44 1/4 1123 19/20 43±4 (1100±75)	P:	4 1/4 107 19/20
Q:	30 7/8 784 9/40	R:	18 3/8 466 29/40
S:	14 7/8 377 33/40	T:	79 3/16 2011 29/80

U (impact width):	36 1/4 920 3/4
Wheel Center Height (Front):	15 1/4 387 7/20
Wheel Center Height (Rear):	15 3/8 390 21/40
Wheel Well Clearance (Front):	34 11/16 881 1/16
Wheel Well Clearance (Rear):	37 15/16 963 49/80
Bottom Frame Height (Front):	18 1/4 463 11/20
Bottom Frame Height (Rear):	25 7/8 657 9/40
Engine Type:	Gasoline
Engine Size:	5.7L V8
Transmission Type:	Automatic
Drive Type:	RWD
Cab Style:	Crew Cab
Bed Length:	67"

Mass Distribution - lb (kg)

Gross Static				
	LF	1463 (664)	RF	1532 (695)
	LR	1118 (507)	RR	1109 (503)

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	2950 (1338)	2898 (1315)	2995 (1359)
W-rear	2354 (1068)	2163 (981)	2227 (1010)
W-total	5304 (2406)	5061 (2296) 5000±110 (2270±50)	5222 (2369) 5165±110 (2343±50)

GVWR Ratings - lb	
Front	3700
Rear	3900
Total	6800

Surrogate Occupant Data

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

Note any damage prior to test: Minor Hail damage prevelent on hood and roof of vehicle. Numerous dents on upper portion of tailgate near handle. Dent along upper part of bed on passenger side, along with deep scratch above rear passenger side wheel-well. Dent above rear passenger side door handle.

Figure 12. Vehicle Dimensions, Test No. HBIB-6

Figure 13. Test Vehicle Photographs, Test No. HBIB-7

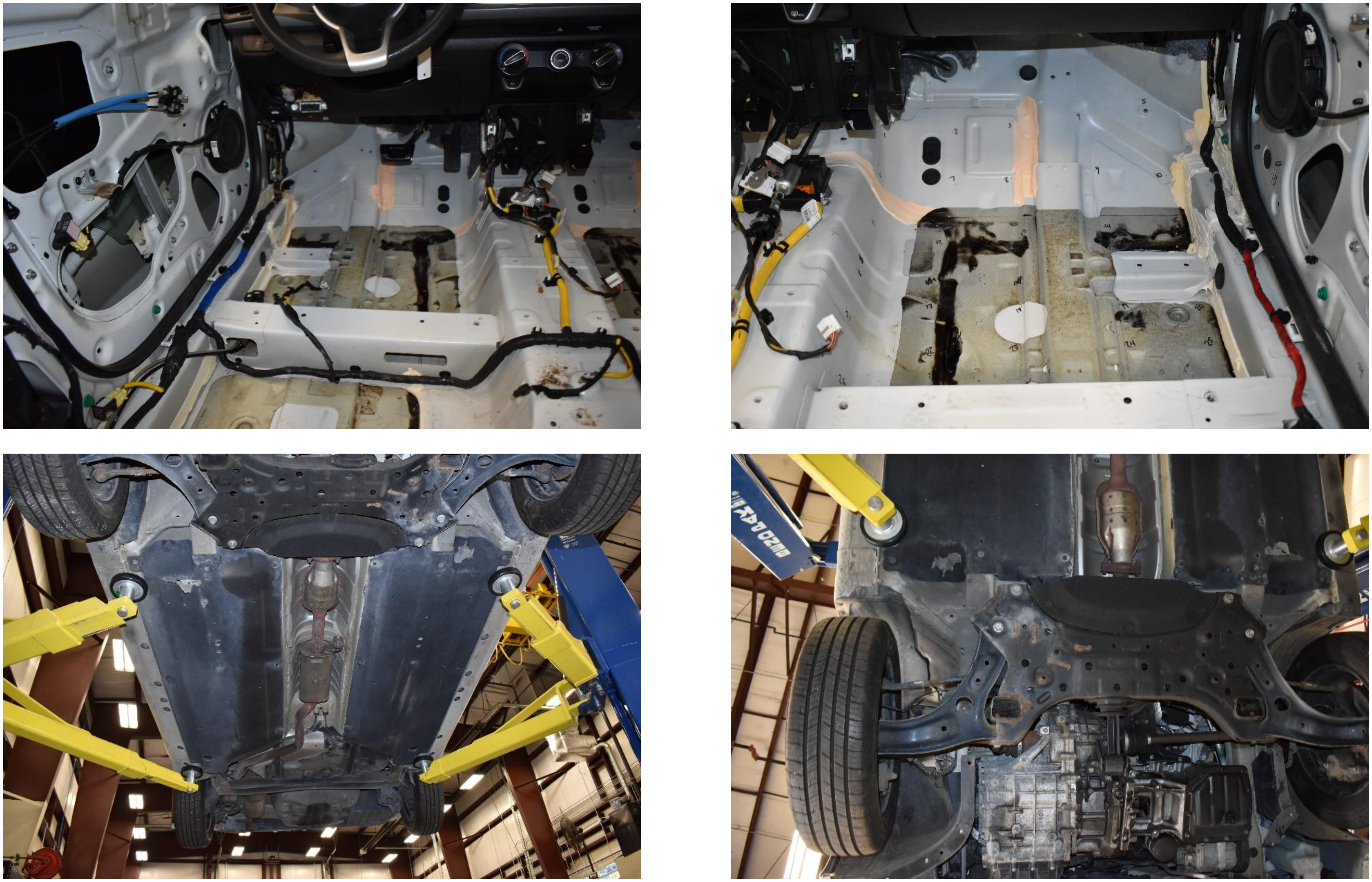
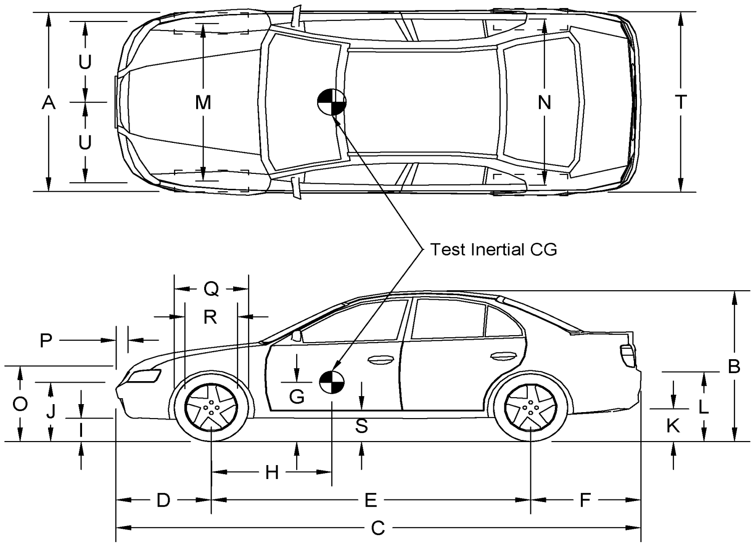


Figure 14. Test Vehicle Interior Floorboards and Undercarriage, Test No. HBIB-7

		Test Name:	HBIB-7	**VIN No:**	3KPA24AB2JE079301
Model Year:	2018	**Make:**	Kia	**Model:**	Rio
Tire Size:	185/65/R15	**Tire Inflation Pressure:**	33 psi	**Odometer:**	141243



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

A:	67 11/16	(1719)	B:	57 1/8	(1451)
	65±3 (1650±75)				
C:	172 3/8	(4378)	D:	32 7/16	(824)
	169±8 (4300±200)			35±4 (900±100)	
E:	101 11/16	(2583)	F:	38 1/4	(972)
	98±5 (2500±125)				
G:	21 15/16	(557)	H:	38 3/8	(975)
				39±4 (990±100)	
I:	8	(203)	J:	25 1/4	(641)
K:	12 1/4	(311)	L:	26 3/16	(665)
M:	59 13/16	(1519)	N:	60 1/8	(1527)
	59±2 (1498±50)			59±2 (1425±50)	
O:	31 5/16	(795)	P:	5 3/8	(137)
	28±4 (711±100)				
Q:	23 3/4	(603)	R:	16 5/16	(414)
S:	8 1/8	(206)	T:	67 7/8	(1724)

U (impact width):	33 1/8	(841)
Top of radiator core support:	29 1/8	(740)
Wheel Center Height (Front):	11 7/16	(291)
Wheel Center Height (Rear):	11 5/8	(295)
Wheel Well Clearance (Front):	26 1/16	(662)
Wheel Well Clearance (Rear):	26 1/8	(664)
Bottom Frame Height (Front):	16 1/2	(419)
Bottom Frame Height (Rear):	15 3/4	(400)
Engine Type:	Gasoline	
Engine Size:	1.6L 4 cyl	
Transmission Type:	Automatic	
Drive Type:	FWD	

Mass Distribution - lb (kg)

Gross Static	LF	804	(365)	RF	779	(353)
	LR	483	(219)	RR	511	(232)

Weights lb (kg)	Curb		Test Inertial		Gross Static	
W-front	1558	(707)	1506	(683)	1583	(718)
W-rear	909	(412)	913	(414)	994	(451)
W-total	2467	(1119)	2419	(1097)	2577	(1169)
			2420±55 (1100±25)		2585±55 (1175±50)	

GVWR Ratings lb	
Front	1940
Rear	1852
Total	3616

Surrogate Occupant Data

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

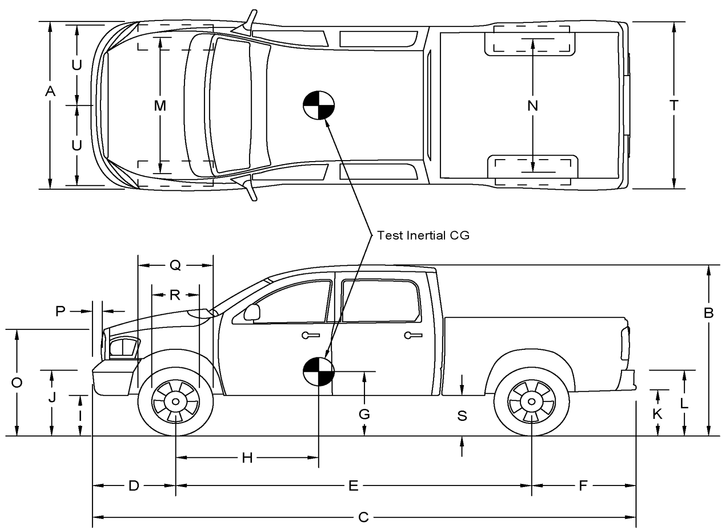
Note any damage prior to test: Small dent in lower rear section of the right front door. Scrape in RR rocker panel.

Figure 15. Vehicle Dimensions, Test No. HBIB-7

Figure 16. Test Vehicle Photographs, Test No. HBIB-8

Figure 17. Test Vehicle Interior Floorboards and Undercarriage, Test No. HBIB-8

		Test Name:	HBIB-8
VIN No:	1C6RR6GT7JS173589		
Model Year:	2018	**Make:**	Ram
Model:	1500 Hemi		
Tire Size:	265/70 R17	**Tire Inflation Pressure:**	40 psi
Odometer:	171503		



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

	in.	(mm)	Target		in.	(mm)	Target
A:	77	1955 4/5	78±2 (1950±50)	B:	74 5/8	1895 19/40	
C:	229 1/8	5819 31/40	237±13 (6020±325)	D:	40 5/8	1031 7/8	39±3 (1000±75)
E:	140 3/8	3565 21/40	148±12 (3760±300)	F:	48 1/8	1222 3/8	
G:	28 1/8	714 3/8	min: 28 (710)	H:	59 9/16	1512 71/80	63±4 (1575±100)
I:	13	330 1/5		J:	24 1/4	615 19/20	
K:	20 1/2	520 7/10		L:	29 1/2	749 3/10	
M:	67 3/4	1720 17/20	67±1.5 (1700±38)	N:	67 7/8	1724 1/40	67±1.5 (1700±38)
O:	44 1/4	1123 19/20	43±4 (1100±75)	P:	3	76 1/5	
Q:	31	787 2/5		R:	18 1/2	469 9/10	
S:	14	355 3/5		T:	77	1955 4/5	
				U (impact width):	36 3/4	933 9/20	

	in.	(mm)
Wheel Center Height (Front):	15	381
Wheel Center Height (Rear):	15	381
Wheel Well Clearance (Front):	34 3/8	873 1/8
Wheel Well Clearance (Rear):	37 3/4	958 17/20
Bottom Frame Height (Front):	17 7/8	454 1/40
Bottom Frame Height (Rear):	25 7/8	657 9/40

Mass Distribution - lb (kg)

Gross Static				
LF	1467 (665)	RF	1508 (684)
LR	1101 (499)	RR	1086 (493)

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	2957 (1341)	2879 (1306)	2975 (1349)
W-rear	2169 (984)	2121 (962)	2187 (992)
W-total	5126 (2325)	5000 (2268) 5000±110 (2270±50)	5162 (2341) 5165±110 (2343±50)

Engine Type:	Gasoline
Engine Size:	5.7L
Transmission Type:	Automatic
Drive Type:	RWD
Cab Style:	Quad Cab
Bed Length:	76"

GVWR Ratings - lb	
Front	3700
Rear	3900
Total	6900

Surrogate Occupant Data	
Type:	Hybrid II
Mass:	162 lb
Seat Position:	Right front

Note any damage prior to test: Right side box dent around rear wheel opening

Figure 18. Vehicle Dimensions, Test No. HBIB-8

Figure 19. Test Vehicle Photographs, Test No. HBIB-10

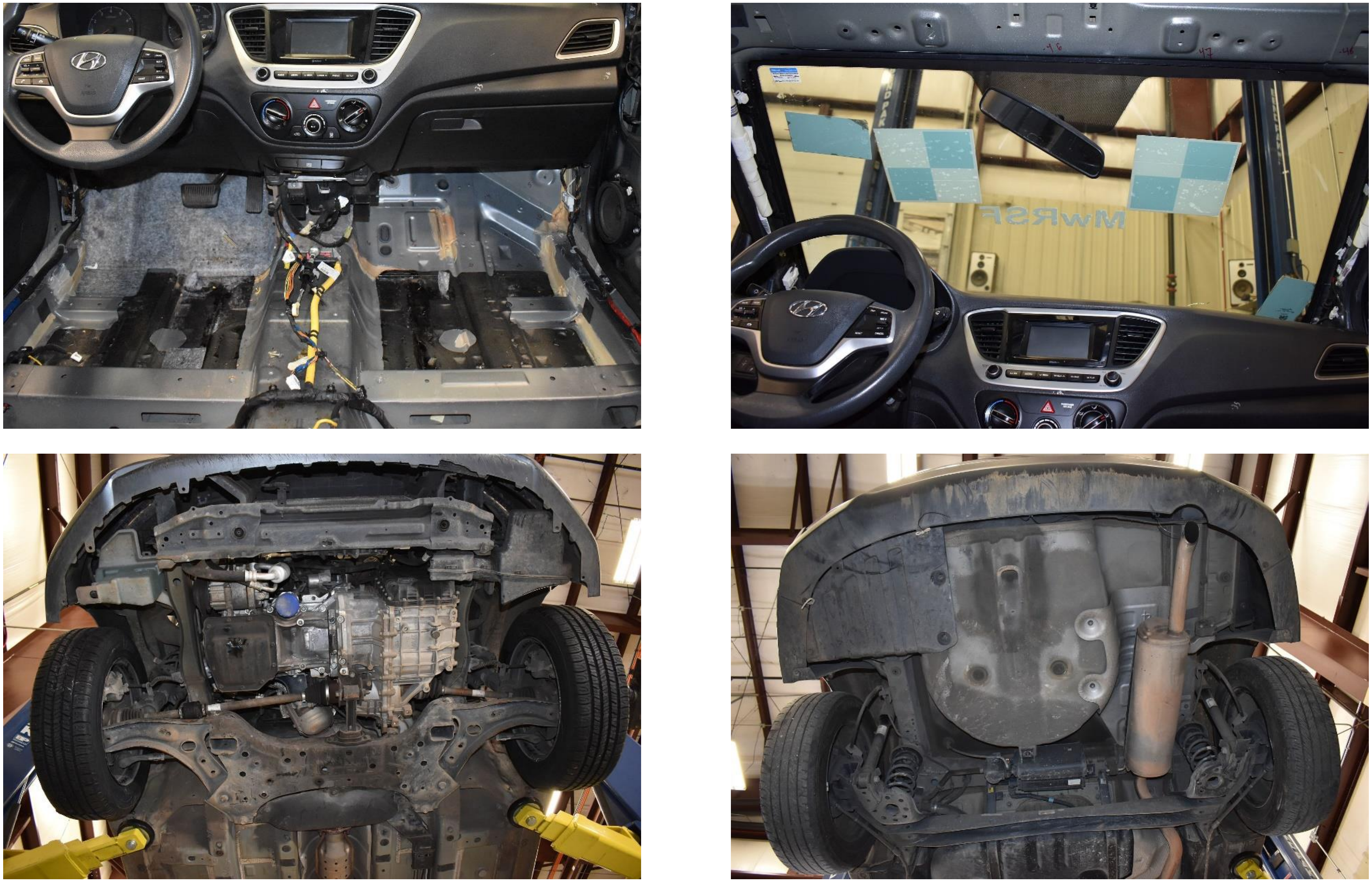
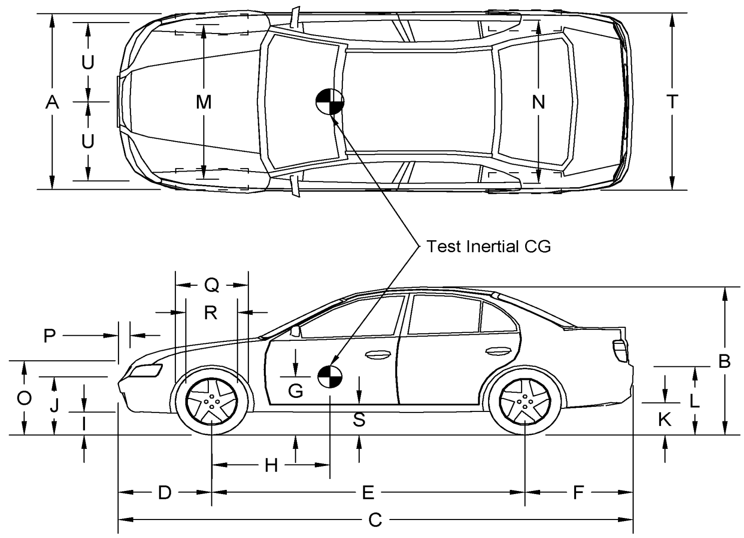


Figure 20. Test Vehicle Interior Floorboards and Undercarriage, Test No. HBIB-10

Test Name: HBIB-10 | **VIN No:** 3KPC24A34KE056878

Model Year: 2019 | **Make:** Hyundai | **Model:** Accent Sedan

Tire Size: 185/65 R15 | **Tire Inflation Pressure:** 33 psi | **Odometer:** 150536



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

A:	67 1/4 (1708) 65±3 (1650±75)	B:	56 5/8 (1438)
C:	172 3/8 (4378) 169±8 (4300±200)	D:	32 7/8 (835) 35±4 (900±100)
E:	101 1/2 (2578) 98±5 (2500±125)	F:	38 (965)
G:	21 7/8 (556)	H:	38 3/8 (975) 39±4 (990±100)
I:	8 (203)	J:	24 1/2 (622)
K:	11 1/2 (292)	L:	25 1/4 (641)
M:	59 7/8 (1521) 59±2 (1498±50)	N:	60 (1524) 59±2 (1425±50)
O:	29 1/2 (749) 28±4 (711±100) Top of Rad. Core	P:	1 1/4 (32)
Q:	24 1/4 (616)	R:	16 1/4 (413)
S:	10 5/8 (270)	T:	66 3/4 (1695)

U (impact width): 31 13/16 (808)

Mass Distribution - lb (kg)

Gross Static				
	LF	795 (361)	RF	788 (357)
	LR	496 (225)	RR	506 (230)

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	1550 (703)	1506 (683)	1583 (718)
W-rear	967 (439)	915 (415)	1002 (454)
W-total	2517 (1142)	2421 (1098) 2420±55 (1100±25)	2585 (1173) 2585±55 (1175±50)

Wheel Center Height (Front):	11 3/8 (289)
Wheel Center Height (Rear):	11 1/2 (292)
Wheel Well Clearance (Front):	25 5/8 (651)
Wheel Well Clearance (Rear):	25 1/2 (648)
Bottom Frame Height (Front):	16 1/4 (413)
Bottom Frame Height (Rear):	15 3/4 (400)
Engine Type:	Gasoline
Engine Size:	41.6L
Transmission Type:	Automatic
Drive Type:	FWD

GVWR Ratings lb

Front	1940
Rear	1852
Total	357

Surrogate Occupant Data

Type:	Hybrid II
Mass:	161 lb
Seat Position:	164

Note any damage prior to test:

Figure 21. Vehicle Dimensions, Test No. HBIB-10

Figure 22. Test Vehicle Photographs, Test No. HBIB-9

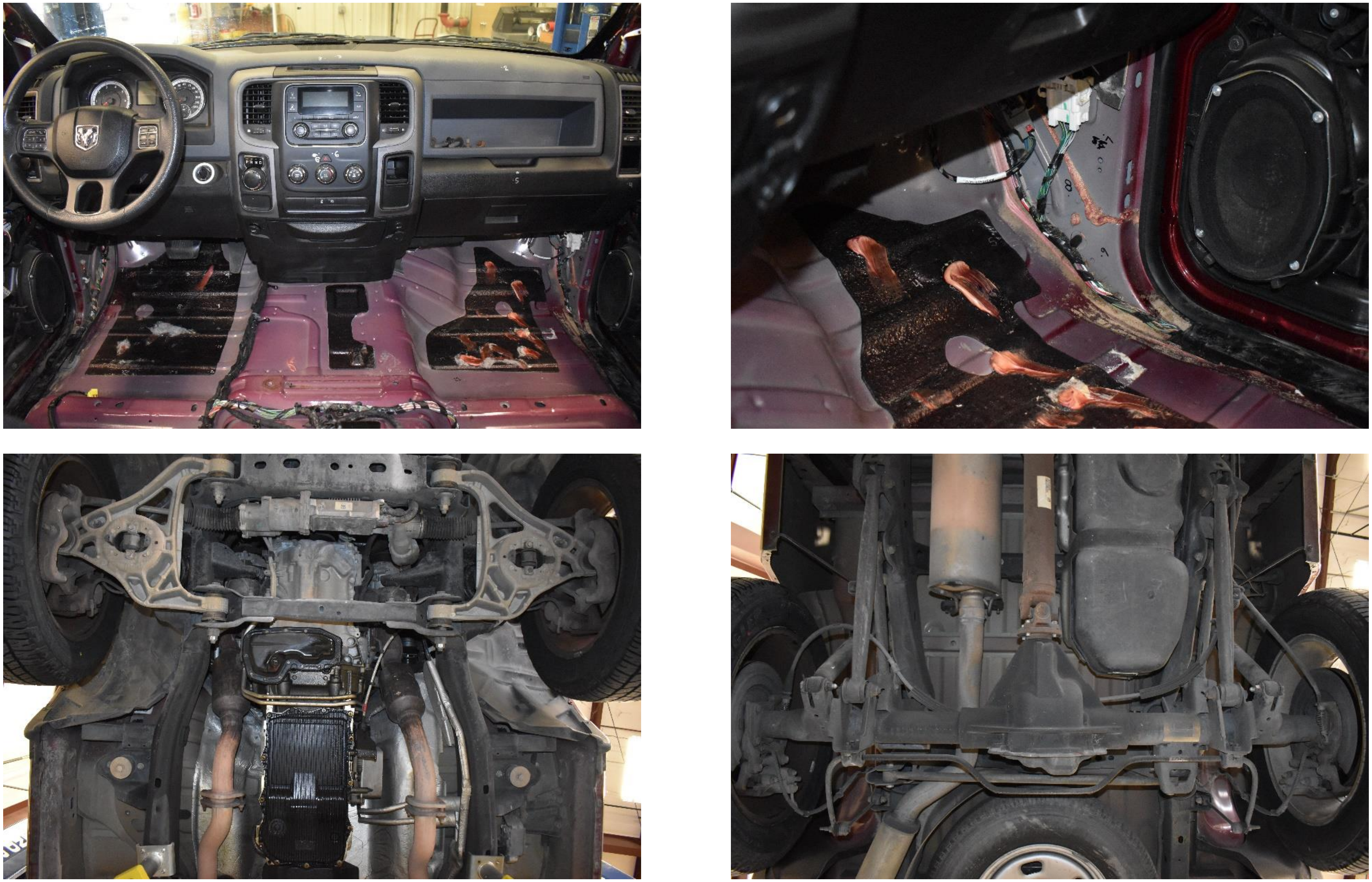
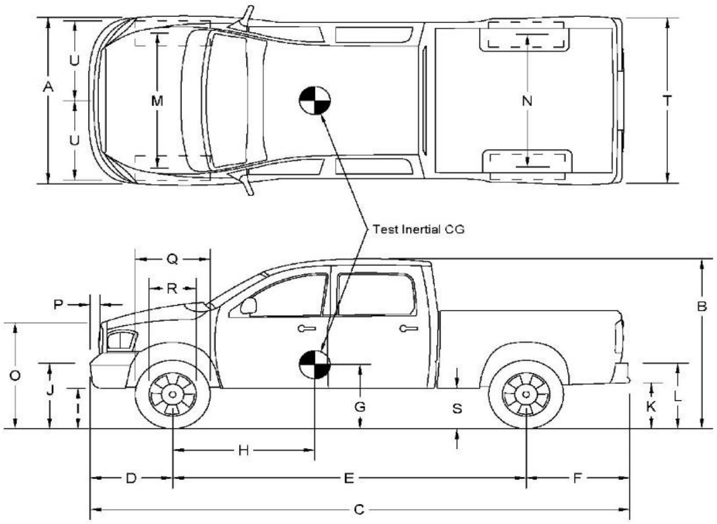


Figure 23. Test Vehicle Interior Floorboards and Undercarriage, Test No. HBIB-9

Test Name: HBIB-9 VIN No: 1C6RR6FG0KS526339

Model Year: 2019 Make: Ram Model: 1500

Tire Size: 275/55/R20 Tire Inflation Pressure: 40 psi Odometer: 135,717



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

A:	77 1/8 1958 39/40 (78±2 (1950±50))	B:	74 3/4 1898 13/20
C:	229 3/8 5826 1/8 (237±13 (6020±325))	D:	40 5/8 1031 7/8 (39±3 (1000±75))
E:	140 5/8 3571 7/8 (148±12 (3760±300))	F:	48 1/8 1222 3/8
G:	28 1/4 717 11/20 (min: 28 (710))	H:	65 1651 (63±4 (1575±100))
I:	13 3/8 339 29/40	J:	25 3/8 644 21/40
K:	20 5/16 515 15/16	L:	29 7/8 758 33/40
M:	68 9/16 1741 39/80 (67±1.5 (1700±38))	N:	67 11/16 1719 21/80 (67±1.5 (1700±38))
O:	45 1/4 1149 7/20 (43±4 (1100±75))	P:	4 3/16 106 29/80
Q:	30 3/4 781 1/20	R:	21 1/2 546 1/10
S:	15 1/4 387 7/20	T:	78 7/16 1992 5/16

U (impact width): 35 7/8 911 9/40

Mass Distribution - lb (kg)

Gross Static	LF	1380 (626)	RF	1405 (637)
	LR	1200 (544)	RR	1174 (533)

Wheel Center Height (Front):	14 15/16 379 33/80
Wheel Center Height (Rear):	15 3/16 385 61/80
Wheel Well Clearance (Front):	35 5/16 896 15/16
Wheel Well Clearance (Rear):	38 1/16 966 63/80
Bottom Frame Height (Front):	18 5/8 473 3/40
Bottom Frame Height (Rear):	26 11/16 677 69/80

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	2722 (1235)	2689 (1220)	2785 (1263)
W-rear	2261 (1026)	2311 (1048)	2374 (1077)
W-total	4983 (2260)	5000 (2268) 5000±110 (2270±50)	5159 (2340) 5165±110 (2343±50)

Engine Type: Gasoline

Engine Size: 3.6L V6

GVWR Ratings - lb		Surrogate Occupant Data			
Front	3700	Type:	Hybrid II	Transmission Type:	Automatic
Rear	3900	Mass:	159 lb	Drive Type:	RWD
Total	6800	Seat Position:	ıssenger Side/ Front Rig	Cab Style:	Quad Cab
				Bed Length:	76"

Note any damage prior to test: er's side front door at about center height of the door. Dent in rear bumper near Left rear corner of veh

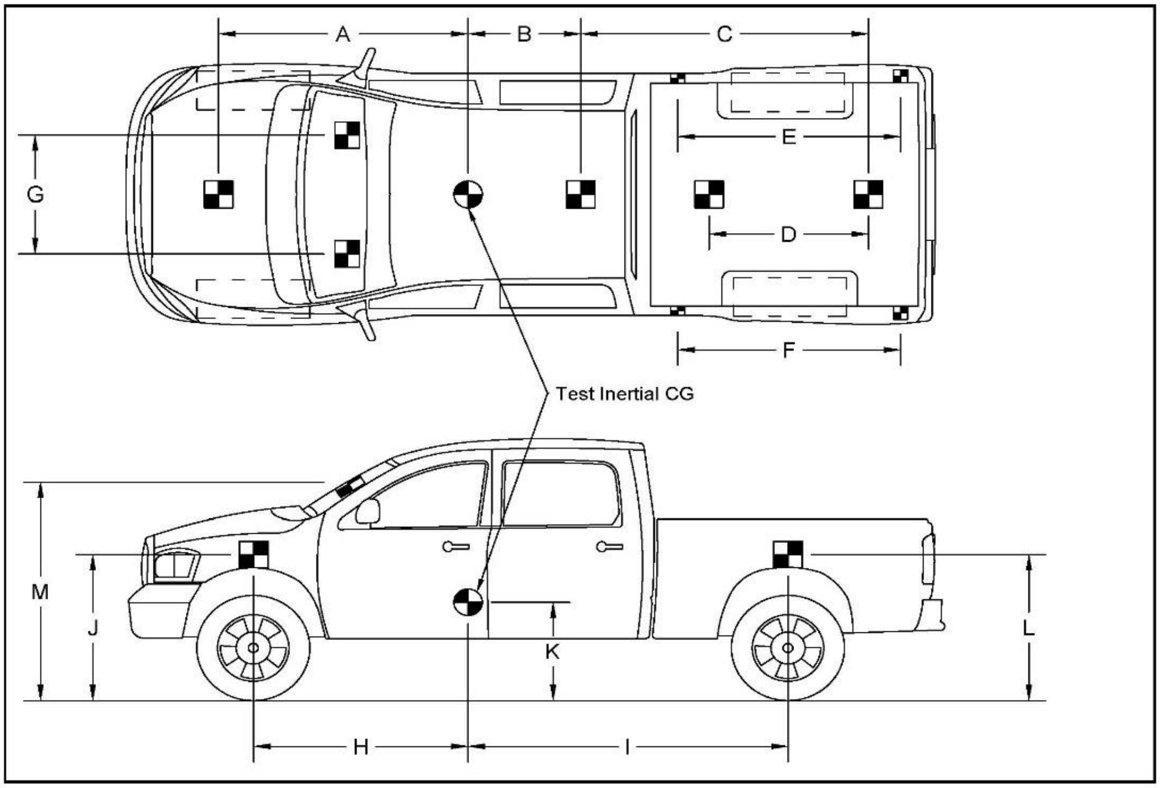
Figure 24. Vehicle Dimensions, Test No. HBIB-9

The longitudinal component of the center of gravity (c.g.) was determined using the measured axle weights. The Suspension Method [7] 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 [8]. The location of the final c.g. for the test vehicles for test nos. HBIB-6 through HBIB-10 are shown in Figures 25 through 29. Data used to calculate the locations of the vehicles' c.g. and ballast information for the 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 25 through 29. Round, checkered targets were placed at the c.g. on the left-side door, the right-side door, and the roof of the vehicles.

The front wheels of the test vehicles were aligned to vehicle standards except the toe-in value was adjusted to zero such that the vehicles would track properly along the guide cable. A 5B flash bulb was mounted under each vehicle's windshield wiper. 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 vehicle could be brought safely to a stop after the test.

		Test Name:	HBIB-6	VIN:	3C6RR6KT6JG186123
Model Year:	2018	Make:	RAM	Model:	1500



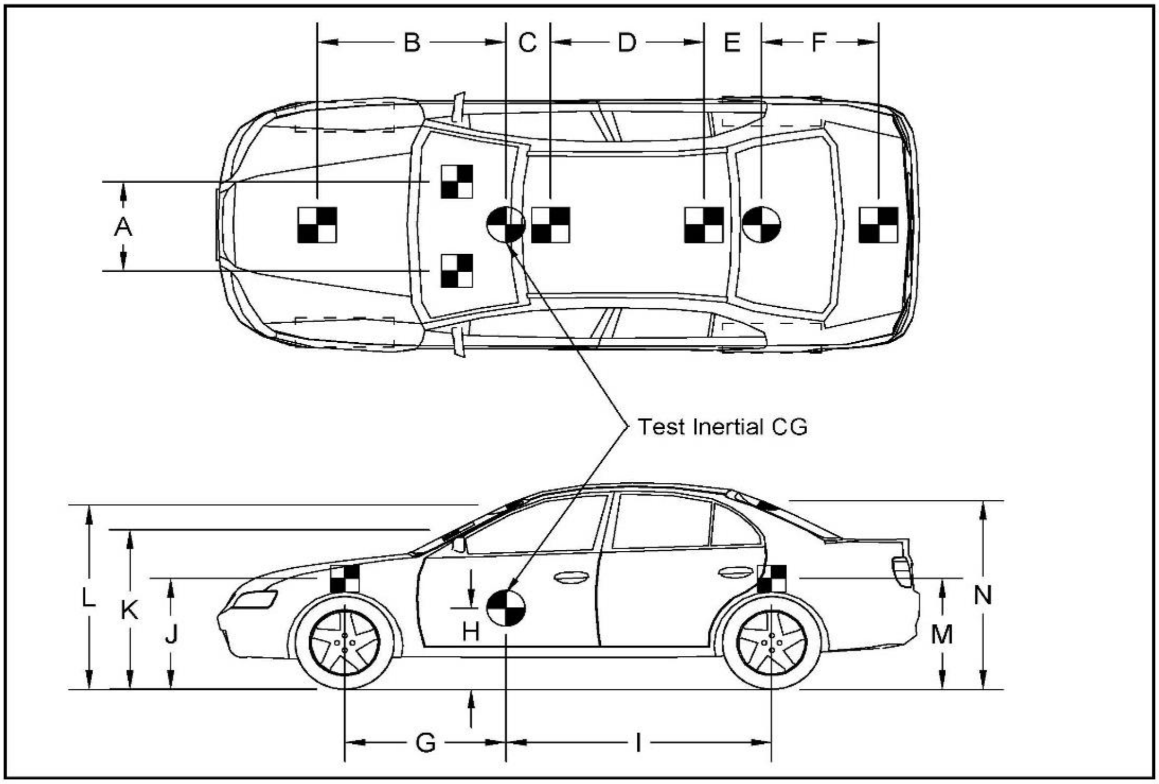
TARGET GEOMETRY-- in. (mm)

A:	79 1/16 (2008)	E:	54 5/8 (1387)	J:	38 5/8 (981)
B:	31 3/8 (797)	F:	54 11/16 (1389)	K:	28 7/16 (722)
C:	68 1/2 (1740)	G:	28 1/16 (713)	L:	42 (1067)
D:	32 9/16 (827)	H:	60 1/8 (1527)	M:	62 15/16 (1599)
		I:	80 1/2 (2045)		

Figure 25. Target Geometry, Test No. HBIB-6

Test Name: HBIB-7 **VIN:** 3KPA24AB2JE079301

Model Year: 2018 **Make:** Kia **Model:** Rio

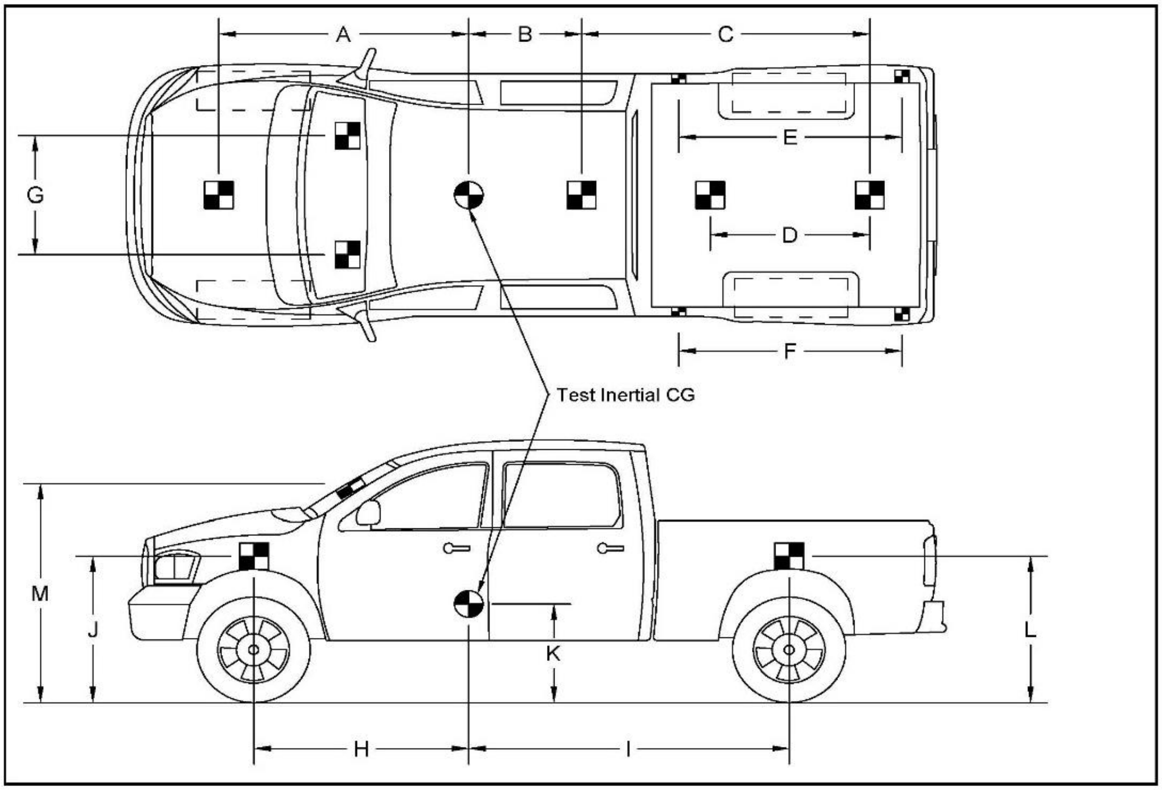


TARGET GEOMETRY-- in. (mm)

A:	25 1/4	(641)	F:	32 1/4	(819)	K: Windshield Target	50	(1270)
B:	51 1/4	(1302)	G:	38 3/8	(975)	L: Front round CG target	53 7/8	(1368)
C:	9	(229)	H:	21 15/16	(557)	M:	30 1/8	(765)
D:	39 1/8	(994)	I:	63 3/	#VALUE!	N: Rear Round target	53 7/8	(1368)
E:	8 7/8	(225)	J:	30	(762)			

Figure 26. Target Geometry, Test No. HBIB-7

Model Year:	2018	Test Name:	HBIB-8	VIN:	1C6RR6GT7JS173589
		Make:	Ram	Model:	1500 Hemi



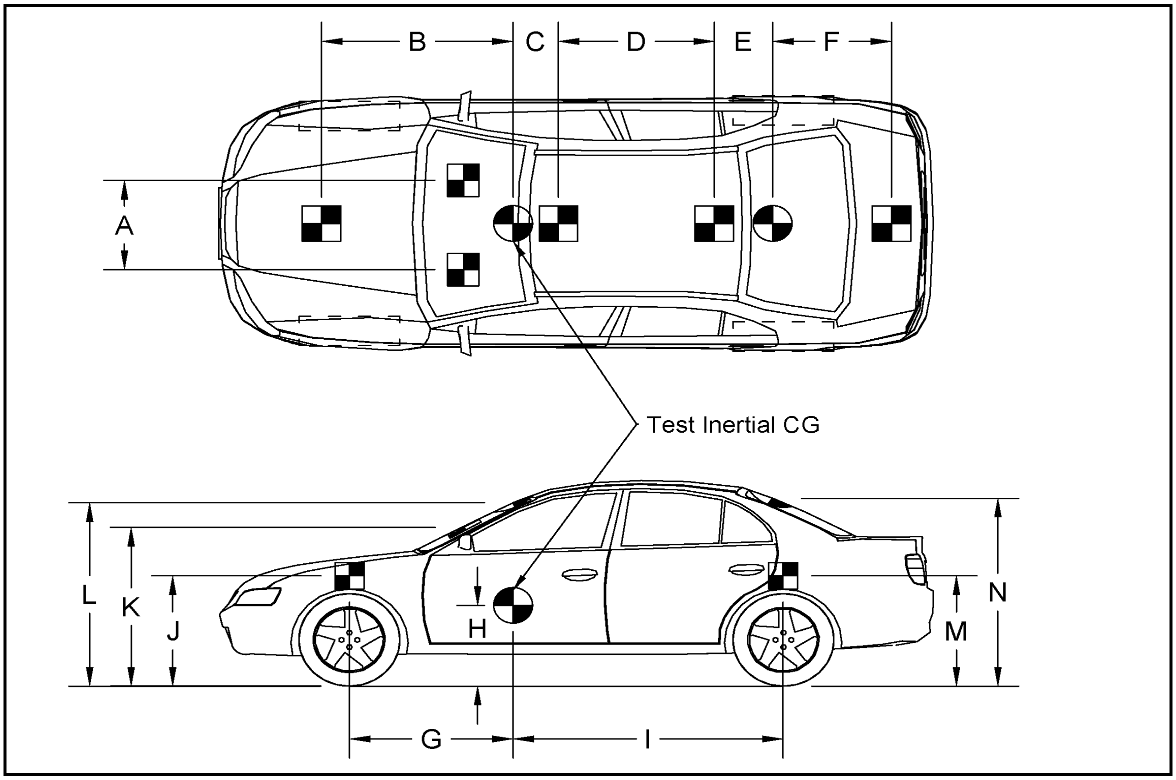
TARGET GEOMETRY-- in. (mm)

A:	71 9/16 (1818)	E:	61 3/4 (1568)	J:	38 1/4 (972)
B:	31 1/2 (800)	F:	61 3/4 (1568)	K:	28 1/8 (714)
C:	70 1/2 (1791)	G:	28 (711)	L:	41 3/4 (1060)
D:	36 1/2 (927)	H:	59 9/16 (1513)	M:	62 3/4 (1594)
		I:	81 (2057)		

Figure 27. Target Geometry, Test No. HBIB-8

Test Name: HBIB-10 **VIN:** 3KPC24A34KE056878

Model Year: 2019 **Make:** Hyundai **Model:** Accent Sedan

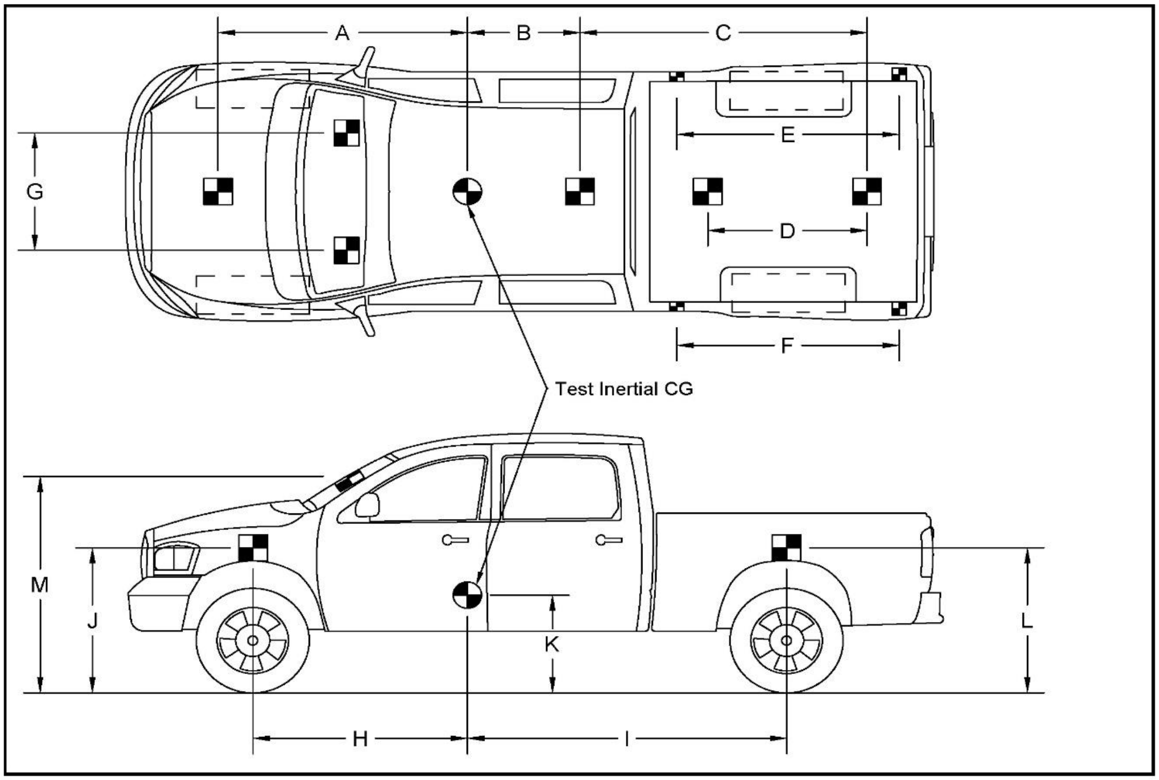


TARGET GEOMETRY-- in. (mm)

A:	20 11/16 (525)	F:	35 (889)	K:	48 3/8 (1229) Windshield Target
B:	50 3/8 (1280)	G:	38 3/8 (975)	L:	53 1/2 (1359) Front round CG target
C:	9 1/4 (235)	H:	21 7/8 (556)	M:	29 9/16 (751)
D:	37 1/2 (953)	I:	63 9/16 (1614)	N:	53 1/2 (1359) Rear Round target
E:	9 (229)	J:	29 (737)		

Figure 28. Target Geometry, Test No. HBIB-10

Test Name: HBIB-9 VIN: 1C6RR6FG0KS526339
Model Year: 2019 Make: Ram Model: 1500



TARGET GEOMETRY-- in. (mm)

A:	86 5/16 (2192)	E:	63 3/8 (1610)	J:	39 5/16 (999)
B:	16 1/16 (408)	F:	63 1/2 (1613)	K:	28 1/4 (718)
C:	86 11/16 (2202)	G:	34 3/4 (883)	L:	42 3/8 (1076)
D:	48 1/2 (1232)	H:	65 (1651)	M:	65 3/8 (1661)
		I:	75 1/16 (1907)		

Figure 29. Target Geometry, Test No. HBIB-9

4.4 Surrogate Occupant

For test nos. HBIB-6 through HBIB-10, 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 occupants' 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-6 through HBIB-10

Test No.	Weight lb
HBIB-6	160
HBIB-7	161
HBIB-8	162
HBIB-10	161
HBIB-9	159

4.5 Data Acquisition

4.5.1 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-7 and HBIB-10. The SLICE-2 unit was designated as primary for test nos. HBIB-6, HBIB-8, and HBIB-9. 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 [9].

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.

4.5.2 Rate Transducers

Two identical angular rate sensor systems mounted inside the bodies of the SLICE-1 and SLICE-2 event data recorders were used to measure the rates of rotation of the test 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.

4.5.3 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.

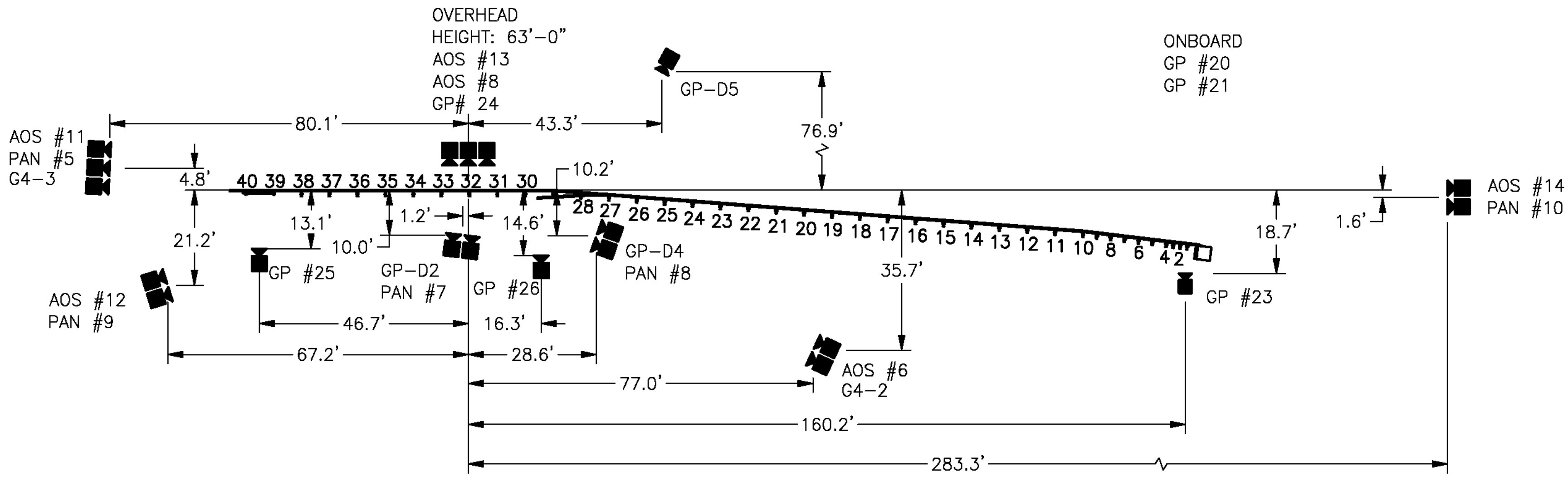
4.5.4 Digital Photography

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-6 through HBIB-10, 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 30 through 34.

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.

Table 5. Digital Video Camera Usage for Test Nos. HBIB-6 through HBIB-10

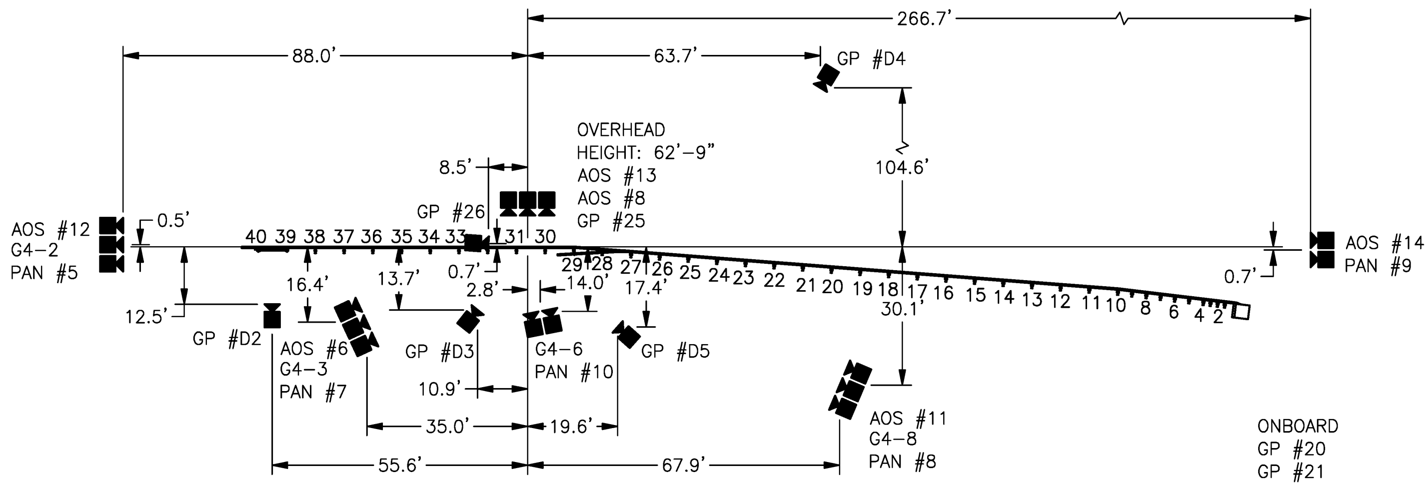
Test No.	Detailed Information	Number of Cameras			
		AOS	GoPro	Panasonic	Ubiquiti
HBIB-6	Figure 30	6	9	4	2
HBIB-7	Figure 31	6	8	5	4
HBIB-8	Figure 32	5	8	3	4
HBIB-10	Figure 33	6	7	4	1
HBIB-9	Figure 34	5	7	5	2



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-6	AOS J-PRI	500	Kowa 25 mm Fixed	-
AOS-8	AOS S-VIT 1531	500	Kowa 12 mm Fixed	-
AOS-11	AOS J-PRI	500	Sigma 24-135	35
AOS-12	AOS J-PRI	500	Sigma 17-50	21
AOS-13	AOS J-PRI	500	Canon EF 14 mm Fixed	-
AOS-14	AOS J-PRI	500	Canon 24-70	70
GP-20	GoPro Hero 6	240		
GP-21	GoPro Hero 6	240		
GP-23*	GoPro Hero 7	240		
GP-24	GoPro Hero 7	240		
GP-25	GoPro Hero 10	240		
GP-26	GoPro Hero 10	240		
GP-D2	GoPro Hero 10	240		
GP-D4	GoPro Hero 10	240		
GP-D5	GoPro Hero 10	240		
PAN-7*	Panasonic HC-VX981	120		
PAN-8	Panasonic HC-VX981	120		
PAN-9	Panasonic HC-VX981	120		
PAN-10	Panasonic HC-VX981	120		
G4-2	Ubiquiti G4 Plus	24		
G4-3	Ubiquiti G4 Plus	24		

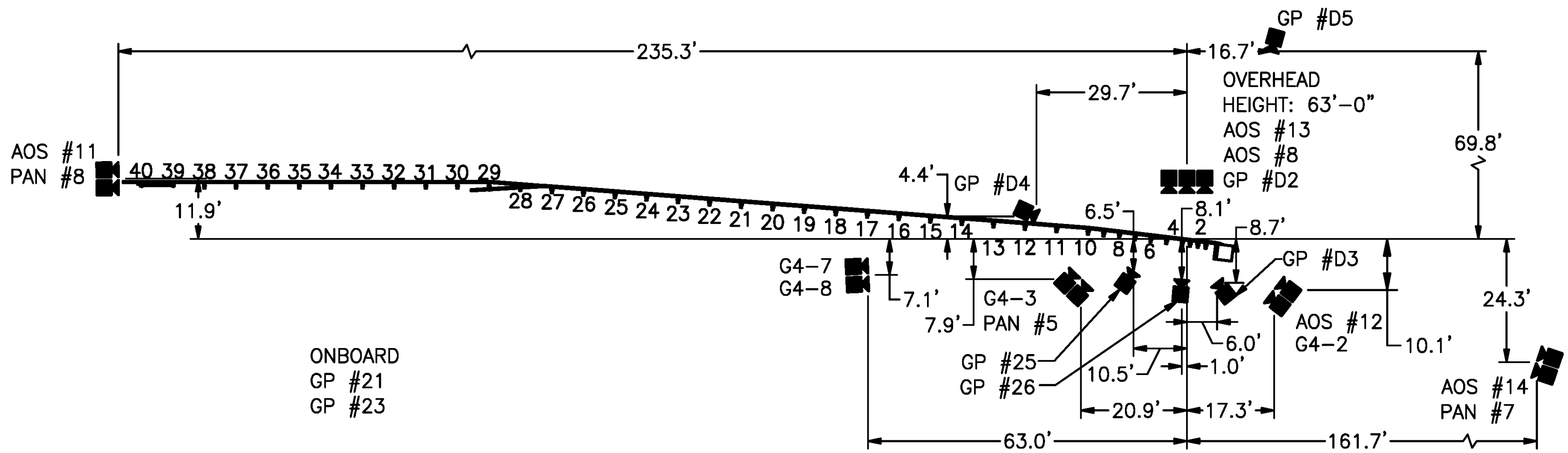
*Camera did not record impact event due to technical difficulties.

Figure 30. Camera Locations, Speeds, and Lens Settings, Test No. HBIB-6



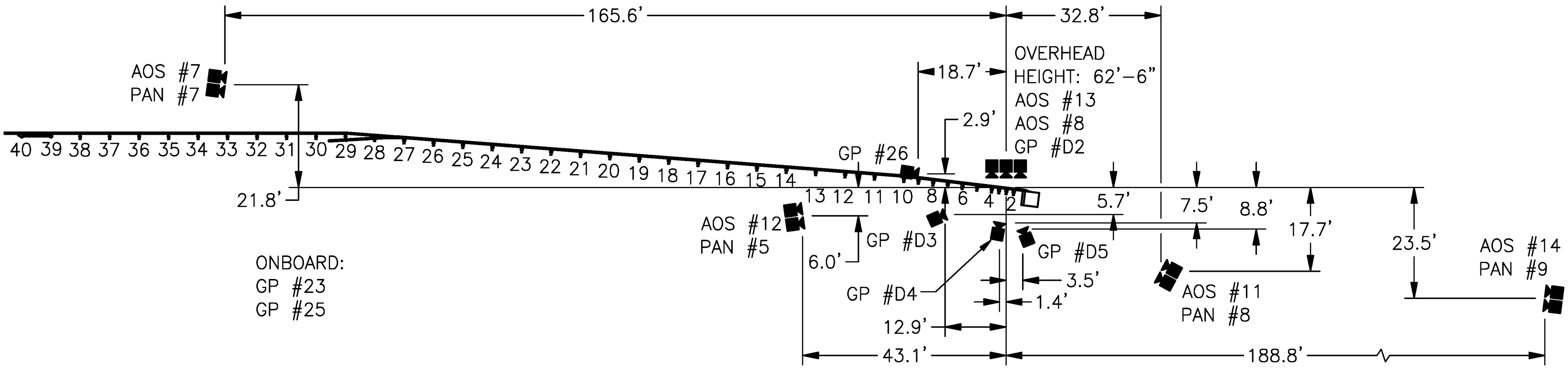
No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-6	AOS J-PRI	500	Fujinon 35 mm Fixed	-
AOS-8	AOS S-VIT 1531	500	Kowa 12 mm Fixed	-
AOS-11	AOS J-PRI	500	Sigma 24-135	50
AOS-12	AOS J-PRI	500	Sigma 17-50	35
AOS-13	AOS J-PRI	500	Canon EF 14 mm Fixed	-
AOS-14	AOS J-PRI	500	Canon 24-70	70
GP-20	GoPro Hero 6	240		
GP-21	GoPro Hero 6	240		
GP-25	GoPro Hero 10	240		
GP-26	GoPro Hero 10	240		
GP-D2	GoPro Hero 10	240		
GP-D3	GoPro Hero 10	240		
GP-D4	GoPro Hero 10	240		
GP-D5	GoPro Hero 10	240		
PAN-5	Panasonic HC-VX981	120		
PAN-7	Panasonic HC-VX981	120		
PAN-8	Panasonic HC-VX981	120		
PAN-9	Panasonic HC-VX981	120		
PAN-10	Panasonic HC-VX981	120		
G4-2	Ubiquiti G4 Plus	24		
G4-3	Ubiquiti G4 Plus	24		
G4-7	Ubiquiti G4 Plus	24		
G4-8	Ubiquiti G4 Plus	24		

Figure 31. Camera Locations, Speeds, and Lens Settings, Test No. HBIB-7



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-8	AOS S-VIT 1531	500	Kowa 12 mm Fixed	-
AOS-11	AOS J-PRI	500	Sigma 24-135	35
AOS-12	AOS J-PRI	500	Sigma 17-50	17
AOS-13	AOS J-PRI	500	Canon EF 14 mm Fixed	-
AOS-14	AOS J-PRI	500	Canon 24-70	70
GP-21	GoPro Hero 6	240		
GP-23	GoPro Hero 7	240		
GP-25	GoPro Hero 10	240		
GP-26	GoPro Hero 10	240		
GP-D2	GoPro Hero 10	240		
GP-D3	GoPro Hero 7	240		
GP-D4	GoPro Hero 7	240		
GP-D5	GoPro Hero 7	240		
PAN-5	Panasonic HC-VX981	120		
PAN-7	Panasonic HC-VX981	120		
PAN-8	Panasonic HC-VX981	120		
G4-2	Ubiquiti G4 Plus	24		
G4-3	Ubiquiti G4 Plus	24		
G4-7	Ubiquiti G4 Plus	24		
G4-8	Ubiquiti G4 Plus	24		

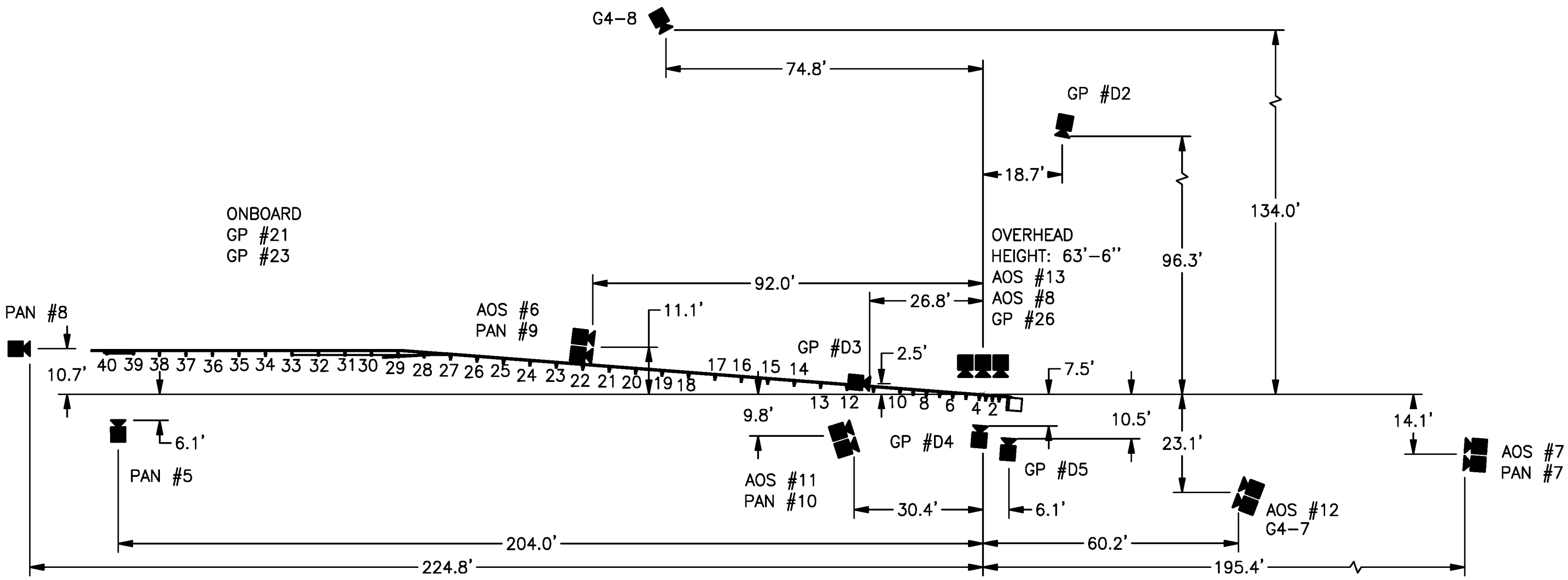
Figure 32. Camera Locations, Speeds, and Lens Settings, Test No. HBIB-8



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-7	AOS X-PRI	500	Sigma 28-70	70
AOS-8	AOS S-VIT 1531	500	Kowa 12 mm Fixed	-
AOS-11	AOS J-PRI	500	Sigma 24-135	24
AOS-12	AOS J-PRI	500	Sigma 17-50	50
AOS-13	AOS J-PRI	500	Canon EF 14 mm Fixed	-
AOS-14	AOS J-PRI	500	Canon EF 24-70	70
GP-23	GoPro Hero 7	240		
GP-25*	GoPro Hero 10	60		
GP-26	GoPro Hero 10	240		
GP-D2	GoPro Hero 10	240		
GP- D3	GoPro Hero 10	240		
GP- D4	GoPro Hero 10	240		
GP- D5	GoPro Hero 10	240		
PAN-5	Panasonic HC-VX981	120		
PAN-7	Panasonic HC-VX981	120		
PAN-8	Panasonic HC-VX981	120		
PAN-9	Panasonic HC-VX981	120		
PAN-10	Panasonic HC-VX981	120		

*Camera did not record impact event due to technical difficulties.

Figure 33. Camera Locations, Speeds, and Lens Settings, Test No. HBIB-10



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-6	AOS J-PRI	500	Nikon #1 28-70	35
AOS-8	AOS S-VIT 1531	500	Kowa 12 mm Fixed	-
AOS-11	AOS J-PRI	500	Nikon #1 28-70	50
AOS-12	AOS J-PRI	500	Sigma 17-50	21
AOS-13	AOS J-PRI	500	Canon EF 14 mm Fixed	-
GP-21	GoPro Hero 6	240		
GP-23	GoPro Hero 7	240		
GP-26	GoPro Hero 10	240		
GP-D2	GoPro Hero 10	240		
GP- D3	GoPro Hero 10	240		
GP- D4	GoPro Hero 10	240		
GP- D5	GoPro Hero 10	240		
PAN-5	Panasonic HC-VX981	120		
PAN-7	Panasonic HC-VX981	120		
PAN-8	Panasonic HC-VX981	120		
PAN-9	Panasonic HC-VX981	120		
PAN-10	Panasonic HC-VX981	120		
G4-7	Ubiquiti G4 Plus	24		
G4-8	Ubiquiti G4 Plus	24		

Figure 34. Camera Locations, Speeds, and Lens Settings, Test No. HBIB-9

5 DESIGN DETAILS: TWO-FLARE DESIGN

5.1 HDOT Design Modifications and Revisions

The HDOT BIB system was very similar to the as-tested configuration from full-scale testing in the literature conducted in the previous report [1]. 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. The original modification to the HDOT system for MGS involved increasing the post length from 6 ft to 7 ft throughout the ditch region where the post embedment of a 6-ft long post would be less than 30 in. This design was insufficient for TL-3 impact conditions with a small car and required further modification. An excessively tall system with respect to the impacting small car was identified as the primary issue, and so the height of the top of the rail was maintained at a constant height above the ditch, such that the top of the back side of the post along the centerline was approximately 43⅞ in. between post nos. 8 and 17. Lastly, the rail was horizontal and at a constant height of 1 ft – 11⅜ in. from post nos. 1 to 6. The modified system was evaluated according to MASH TL-3 safety criteria test designation no. 3-37 in full-scale crash test nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10.

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 stiffer than native soil or MASH strong soil conditions. Thus, additional soil reinforcement was added to the anchor block to simulate conditions in use. The additional reinforcement consisted of a vertical concrete shaft with a 3-ft diameter extending 10 ft deep. Vertical rebar and hoops were used to reinforce the concrete shaft. The additional size and strength of the soil foundation were used to evaluate a practical worst-case anchor block rigidity for testing. The increased reinforcement and foundation strength are not required for typical construction cases.

5.2 Upper and Lower Rails

The total length of the system installation was 219 ft – 4 in. A 12-ft 6-in. W-beam MGS section was used for the anchorage from post nos. 40 to 39. A 6-ft 3-in. W-beam MGS section was used from post nos. 38 to 37, followed by a 50-ft section of 12-ft 6-in. MGS 12-gauge W-beam. The first deviation point occurred at post no. 29, with a 12-ft 6-in. W-beam section bent at 4.4 degrees. For post nos. 29 through 1, a lower rubrail was added to the system, which was attached at the back side of post no. 29, the front side (with no blockout) at post no. 28, and was blocked away from the face of post nos. 27 through 1. The following section, from post nos. 27 through 10, included eight 12-ft 6-in. 12-gauge W-beam sections for a total of 100 ft in both the upper and lower rails. The second deviation point occurred at post no. 10, where a 12-ft 6-in. 12-gauge W-beam section was bent by 2.4 degrees to increase the total deviation to 6.8 degrees. A W-beam section followed from post nos. 9 through 6, with a 9-ft 4½-in. 12-gauge W-beam segment, and then a nested 12-ft 6-in. 12-gauge W-beam segment extended from post no. 6 to the concrete anchor block. The guardrail was connected to an anchor block with two W-beam terminal connectors.

The upstream and downstream ends of the guardrail installation were configured with a trailing-end anchorage system. The guardrail anchorage system was utilized 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, which closely resembled the hardware used in the Modified Breakaway Cable Terminal (BCT) system and is now part of a crashworthy, downstream trailing end terminal [10-14].

The details of the installation system for test nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10 are identical; Figures 35 through 75 show the system installation. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix D.

5.3 Posts and Blockouts

For test nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10, post nos. 1 through 27 were 84-in. long W6x8.5 steel posts and post nos. 28 through 38 were 72-in. long W6x8.5 steel posts. At the end of the installation where the system was anchored to the terrain, two MGS-height 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:

- **Section 1:** post nos. 1 through 4 - nested rails and rubrails and quarter post spacing (18.8 in.)
- **Section 2:** post nos. 4 through 6 - nested rails and rubrails and half post spacing (37 ½ in.)
- **Section 3:** from post nos. 6 through 10 - upper rail and rubrail at half post spacing (37 ½ in.)
- **Section 4:** from post nos. 10 through 23 - upper rail and rubrail using full post spacing at highest height over ditch (75 in.)
- **Section 5:** from post nos. 23 through 29 - upper rail and rubrail using full post spacing (75 in.)
- **Section 6:** from post nos. 29 through 40 - system is consistent with standard, tangent MGS with full post spacing (75 in.)

More detailed information about the post layouts is shown in Figure 42. Due to Hawaii's environmental conditions and HDOT's preference, tapered Hollow Structural Section (HSS) steel and recycled plastic blockouts were used in the BIB system. Posts nos. 1 through 38 used 14¼-in. tall x 8-in. deep x 5¼-in. wide composite recycled blockouts. For the rubrail, post nos. 1 through 27 used 13⅝-in. tall and 8-in. deep x 6-in. wide x ¼-in. thick tapered HSS steel blockouts. More details about the recycled blockouts and the tapered HSS blockouts are provided in Figures 41 and 54.

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 Anchor Block

HDOT typically utilizes an aesthetic stone-faced exterior for the anchor block. To represent this aesthetic exterior, a 6-in. 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-6 through HBIB-8 and HBIB-10, the fascia was simulated using a small-aggregate concrete mix with a nominal compressive strength of 4,000 psi. More information on the installation of the fascia can be found in Figure 58.

The anchor block originally designed 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, a 3-ft diameter drilled shaft going 10 ft into the ground was cast with the anchor block. The bottom of the anchor block also extended an extra 1½ ft below ground for a total height of 4½ ft to connect to the drilled shaft. The drilled shaft was reinforced with #4 spirals and #8 longitudinal rebar, and the longitudinal rebar continued into the anchor block for at least 20 in. to provide a secure connection. Information on the anchor block and drilled shaft can be found in Figures 45 through 48. More information on the reinforcement can be found in Figure 57.

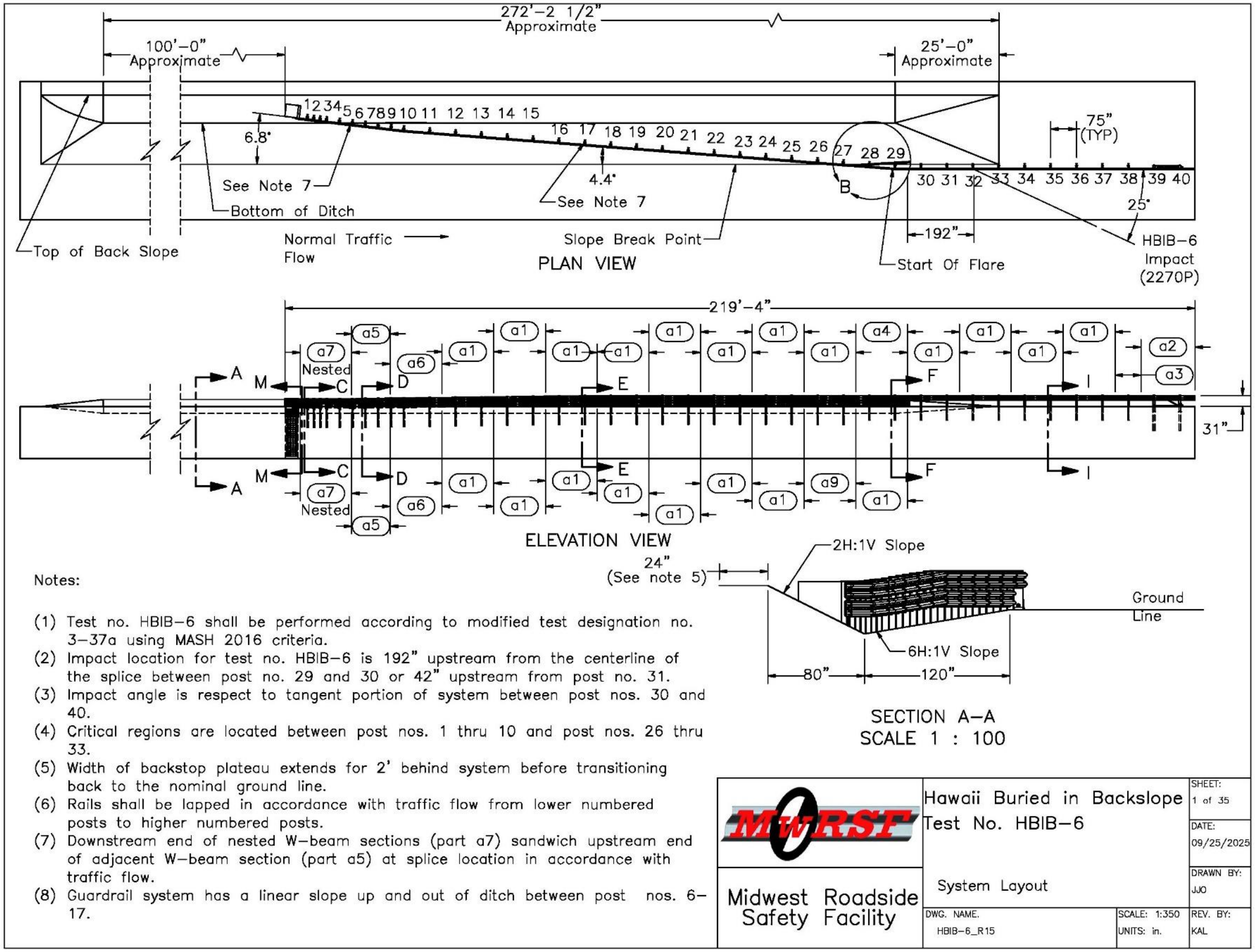


Figure 35. System Layout, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10, and Impact Location, Test No. HBIB-6

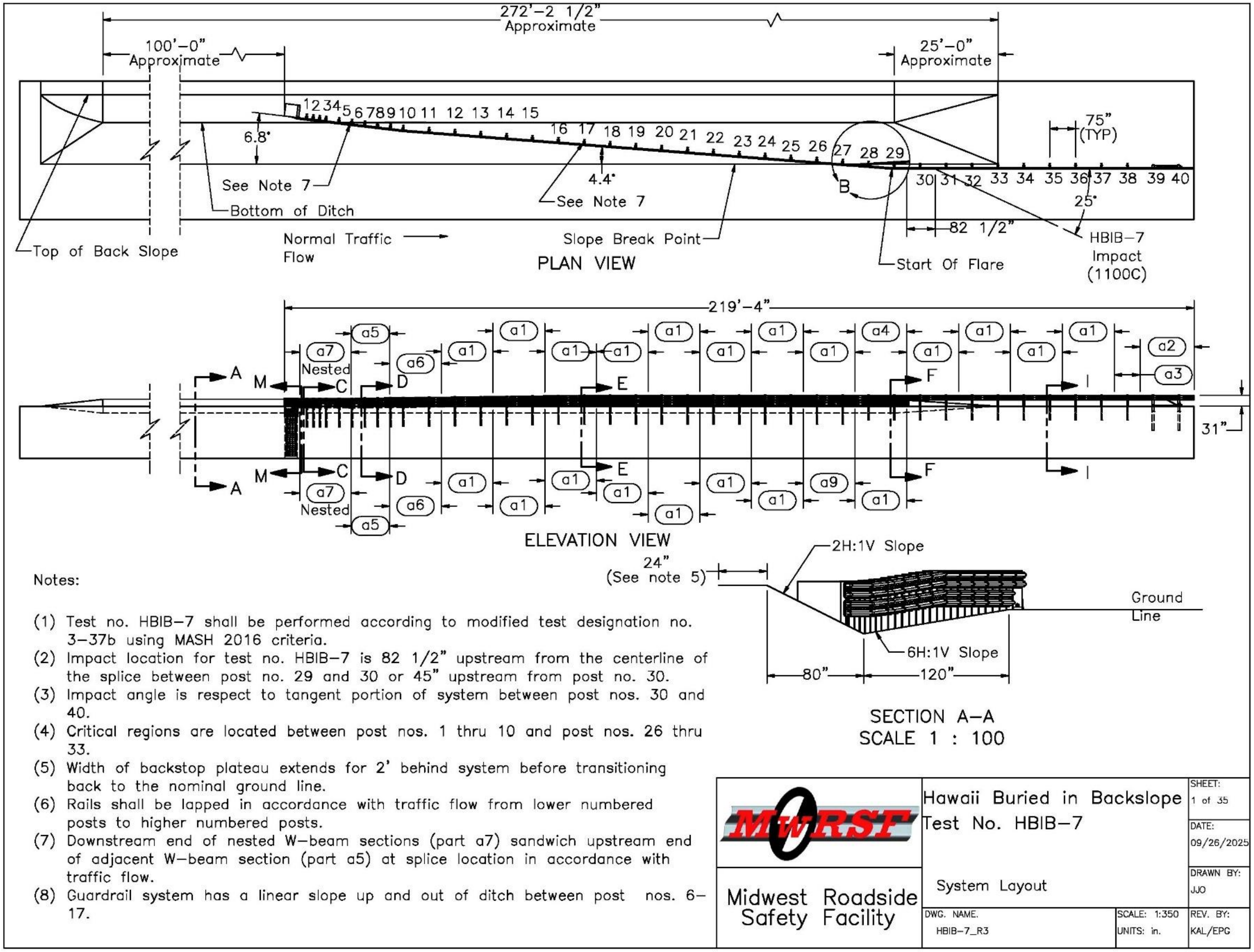


Figure 36. System Layout, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10, and Impact Location, Test No. HBIB-7

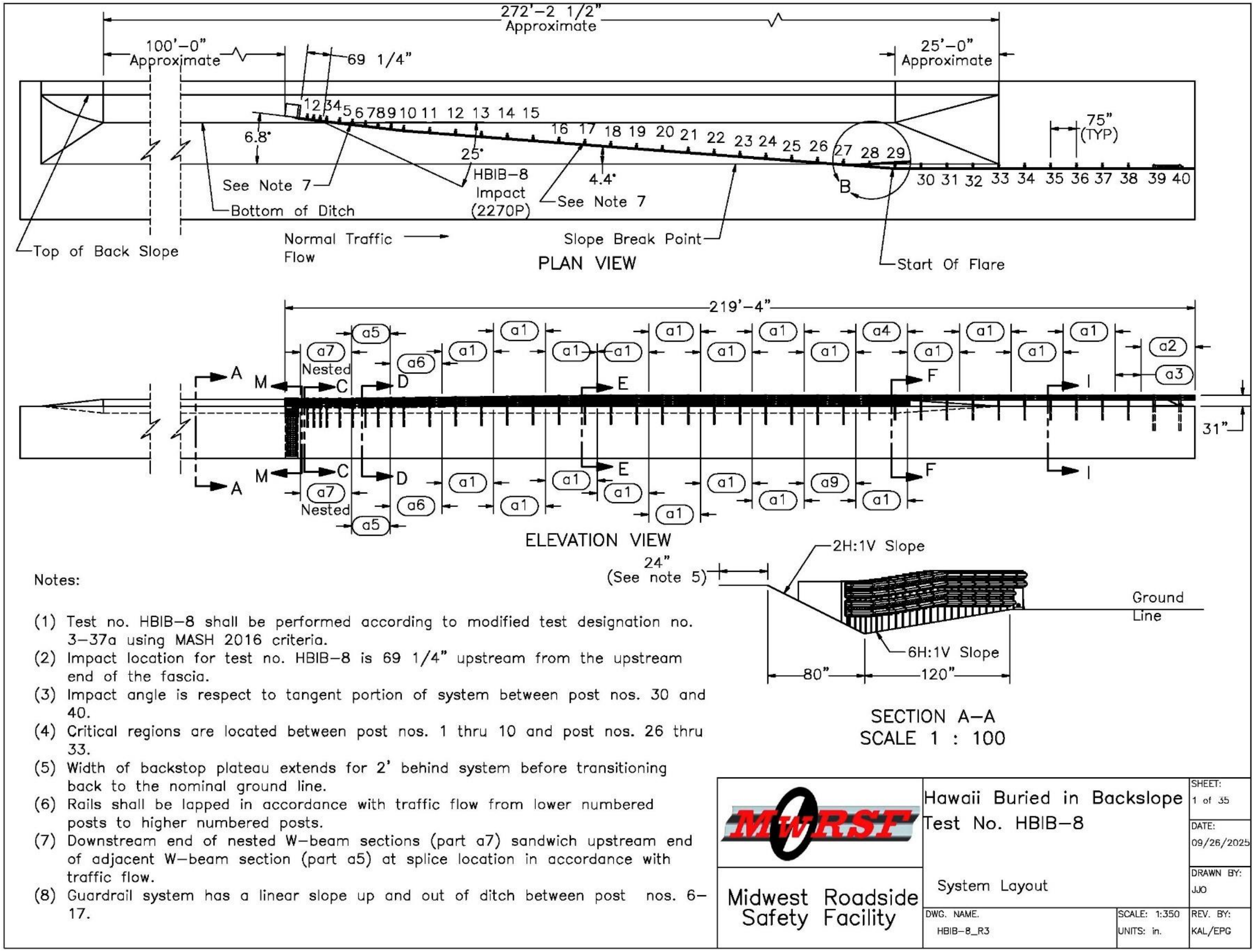


Figure 37. System Layout, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10, and Impact Location, Test No. HBIB-8

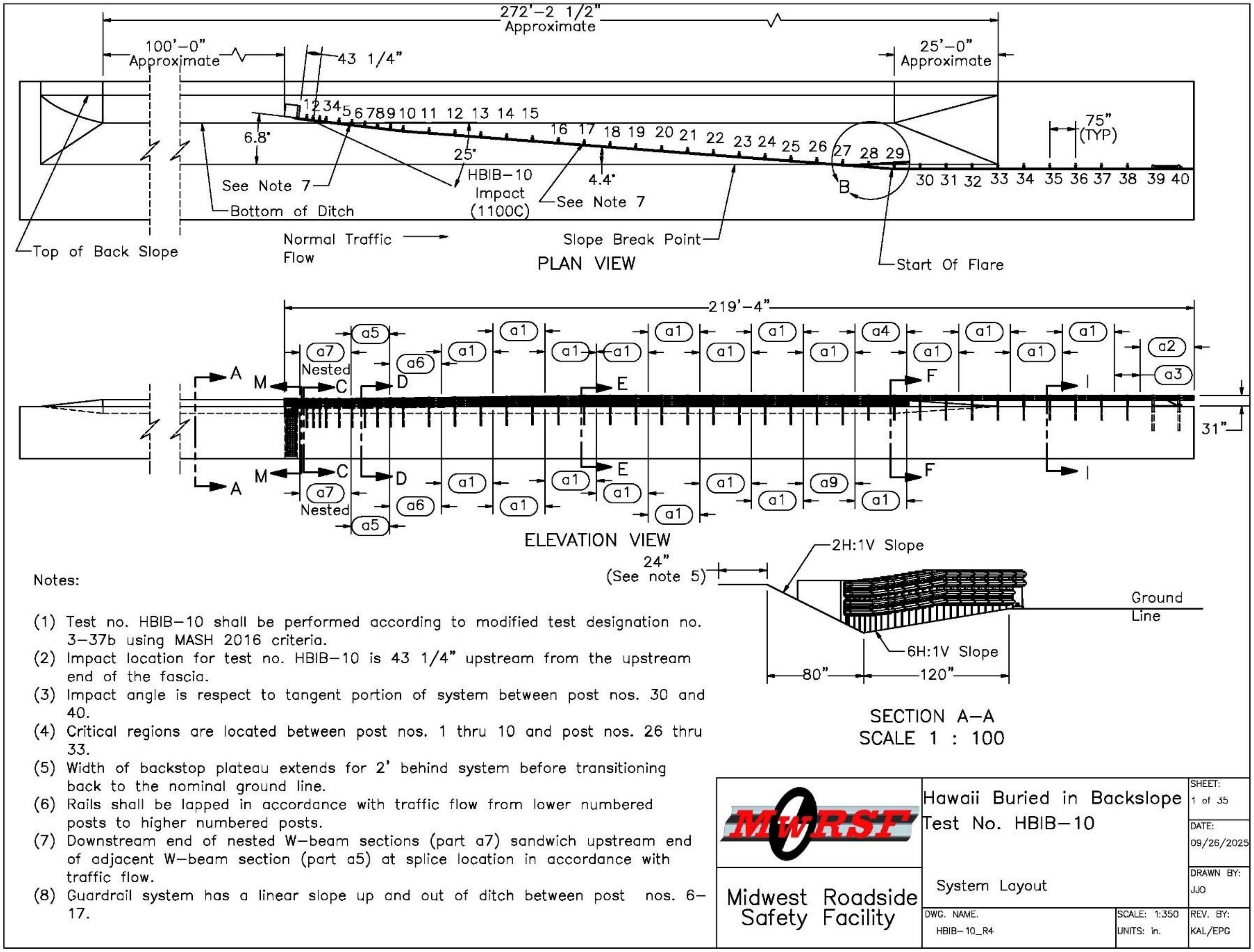


Figure 38. System Layout, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10, and Impact Location, Test No. HBIB-10

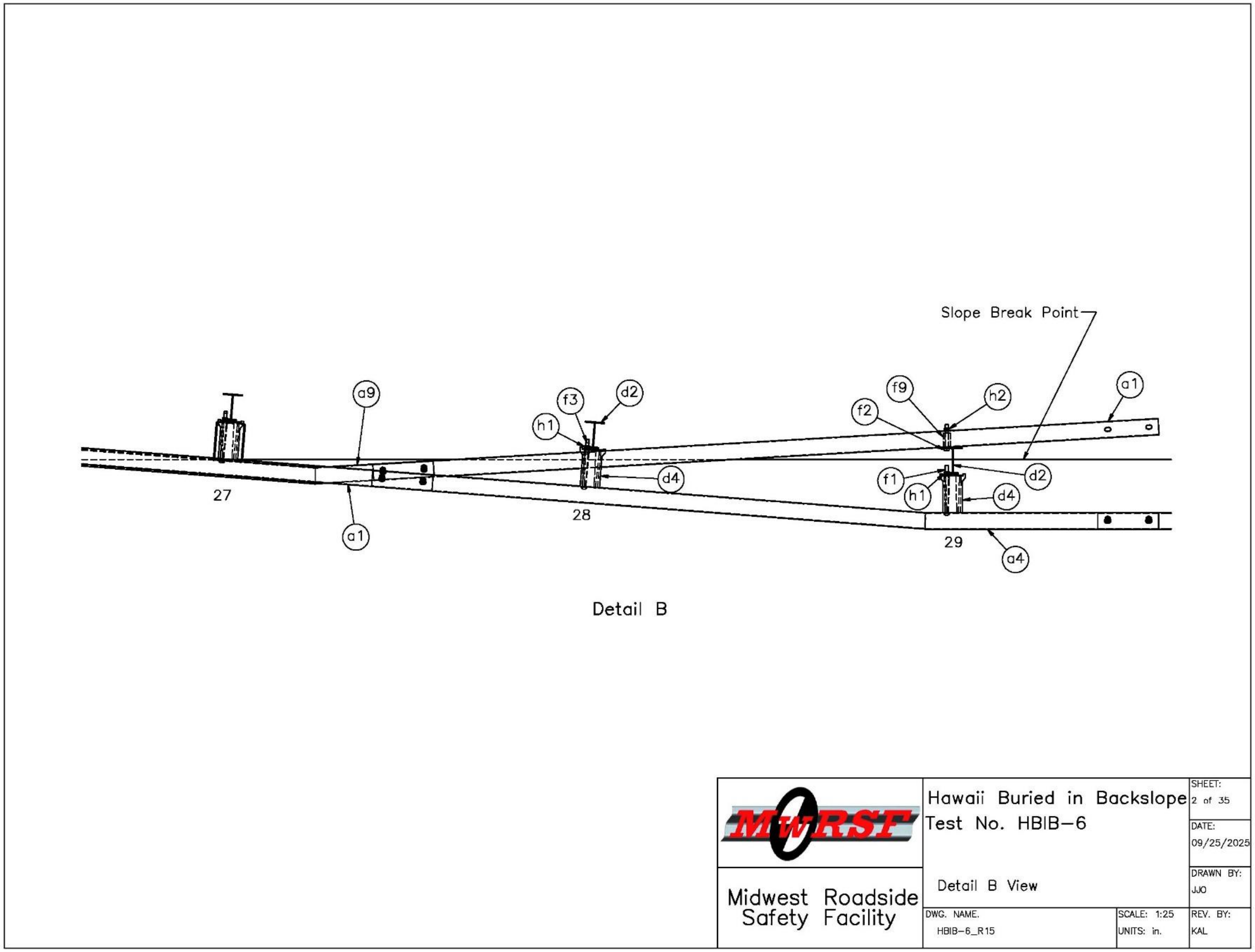


Figure 39. Rubrail Termination Details, First Deviation Point, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

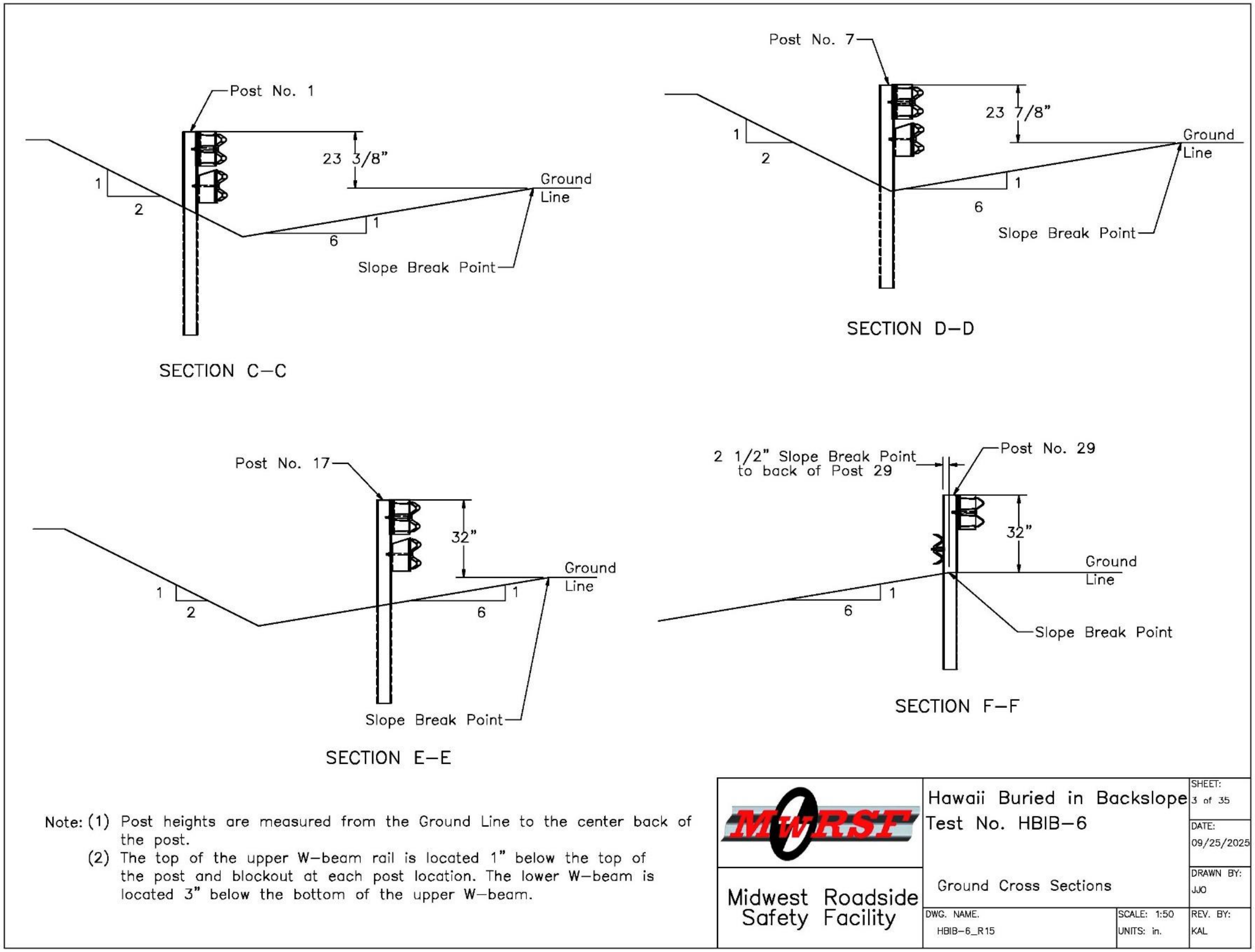


Figure 40. Ground Cross Sections, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

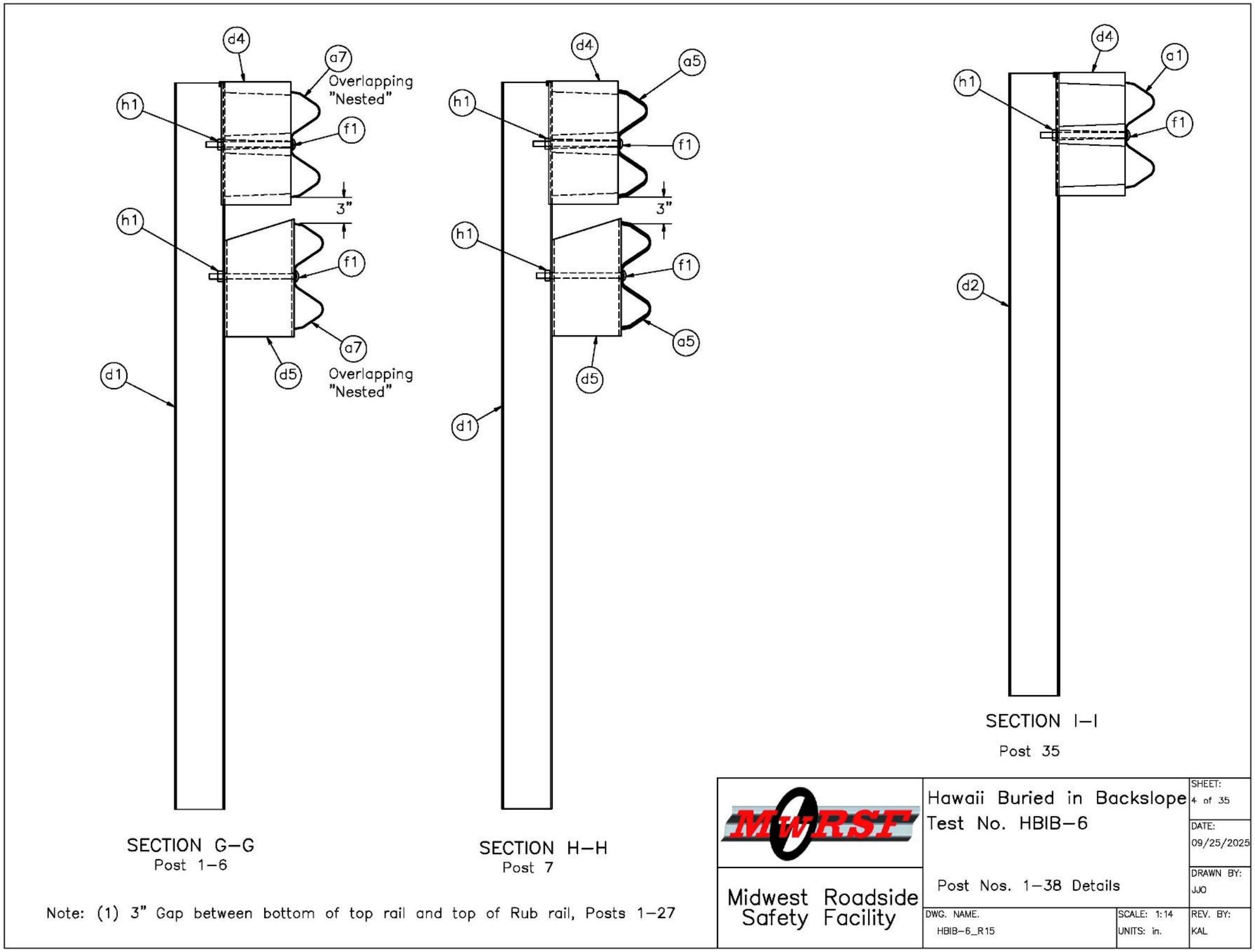
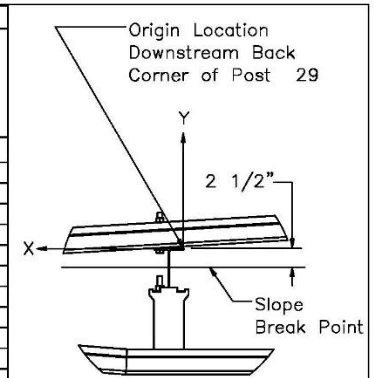
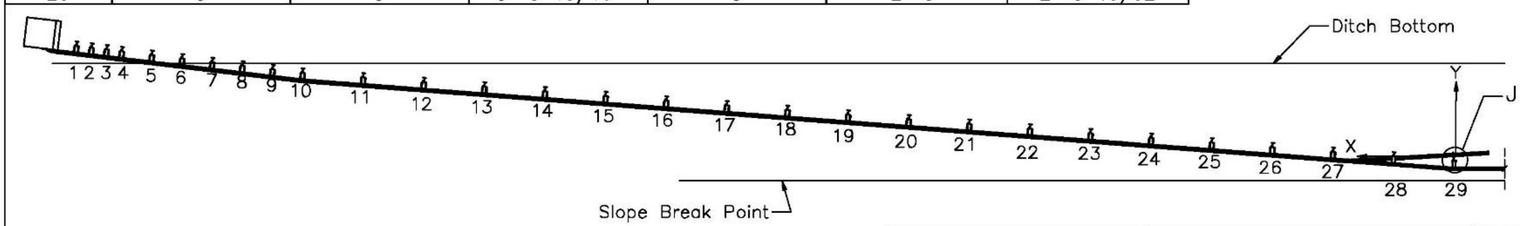


Figure 41. Post Nos. 1 through 38 Details, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

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 11/16"	11'–9 55/64"	141'–10 19/32"	11'–10 21/64"	1'–11 3/8"	2'–7 3/32"
2	140'–0 1/16"	11'–7 41/64"	140'–3 63/64"	11'–8 7/64"	1'–11 3/8"	2'–8 13/64"
3	138'–3 29/64"	11'–5 27/64"	138'–9 23/64"	11'–5 7/8"	1'–11 3/8"	2'–9 5/16"
4	136'–10 53/64"	11'–3 13/64"	137'–2 3/4"	11'–3 43/64"	1'–11 3/8"	2'–10 27/64"
5	133'–9 19/32"	10'–10 49/64	134'–1 1/2"	10'–11 15/64"	1'–11 3/8"	3'–0 41/64"
6	130'–8 23/64"	10'–6 5/16"	131'–0 17/64"	10'–6 51/64"	1'–11 3/8"	3'–2 7/8"
7	127'–7 1/8"	10'–1 7/8"	127'–11 1/32"	10'–2 11/32"	1'–11 27/32"	3'–5 9/16"
8	124'–5 7/8"	9'–9 7/16"	125'–2 7/16"	9'–9 29/32"	2'–0 21/64"	3'–7 27/32"
9	121'–4 21/32"	9'–5"	121'–8 9/16	9'–5 15/32"	2'–0 13/16"	3'–7 27/32"
10	118'–3 31/32"	9'–0 11/16"	118'–7 57/64"	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



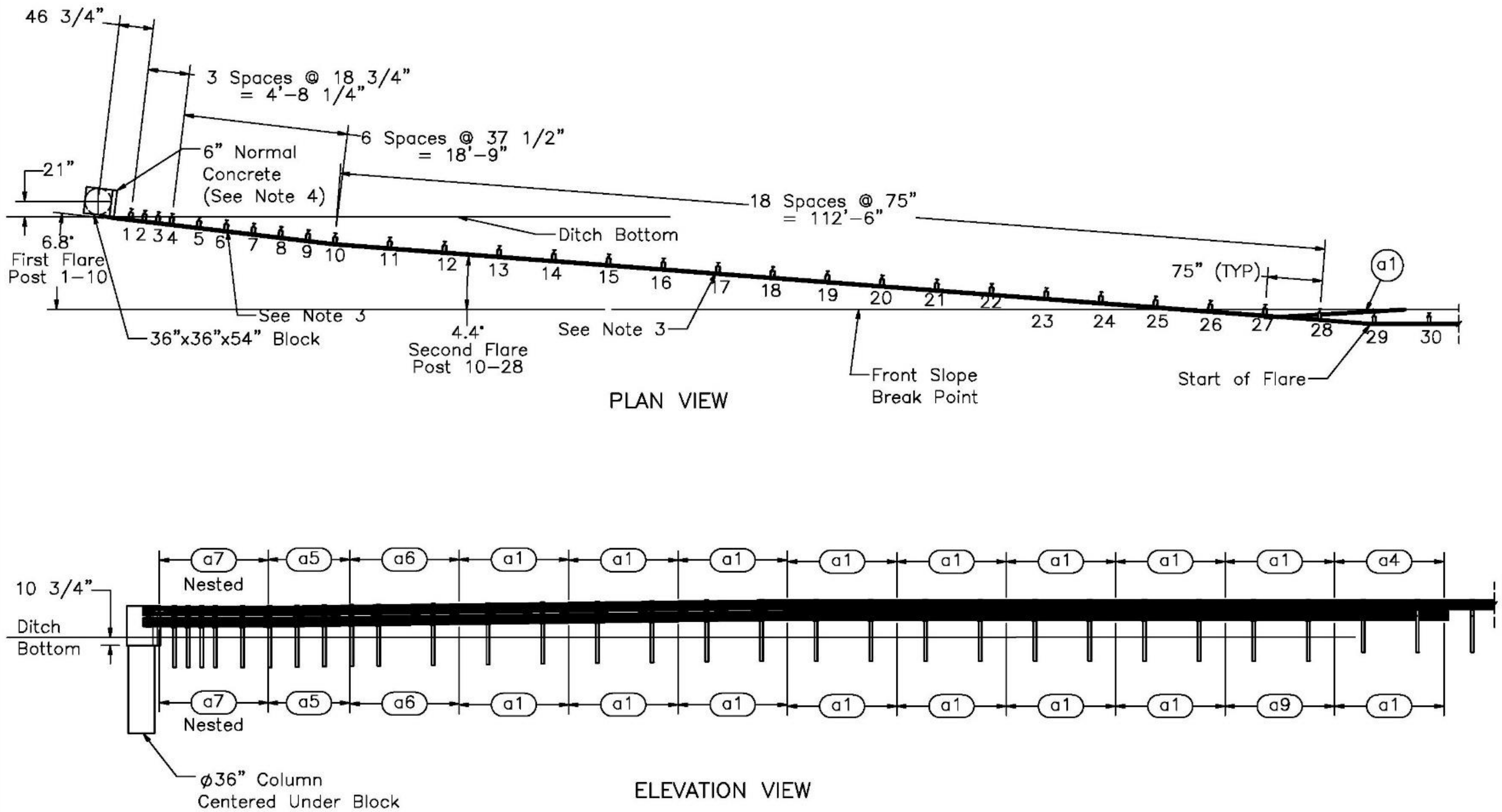
DETAIL J
SCALE 1 : 20



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.

Midwest Roadside Safety Facility	Hawaii Buried in Backslope Test No. HBIB–6	SHEET: 5 of 35
		DATE: 09/25/2025
	Post Location Layout	DRAWN BY: JJO
	DWG. NAME. HBIB–6_R15 / SCALE: 1:185 UNITS: in.	REV. BY: KAL

Figure 42. Post Location Layout, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10



Notes: (1) Elevation view is normal to the front face of the first flared rail.
(2) Downstream end of nested W-beam sections (part a7) sandwich upstream end of adjacent W-beam section (part a5) at splice location in accordance with traffic flow.
(3) System slopes with ditch between post nos. 6–17. Vertical slope will be accomplished by offsetting the vertical angles of the W-beam rails at splice locations.
(4) Compact crushed limestone under add-on 6" wall cast on rock or formwork.

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		DATE: 09/25/2025
	Flare Details	DRAWN BY: JJO
	DWG. NAME. HBIB-6_R15 — SCALE: 1:200 UNITS: in.	REV. BY: KAL

Figure 43. Flare Details, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

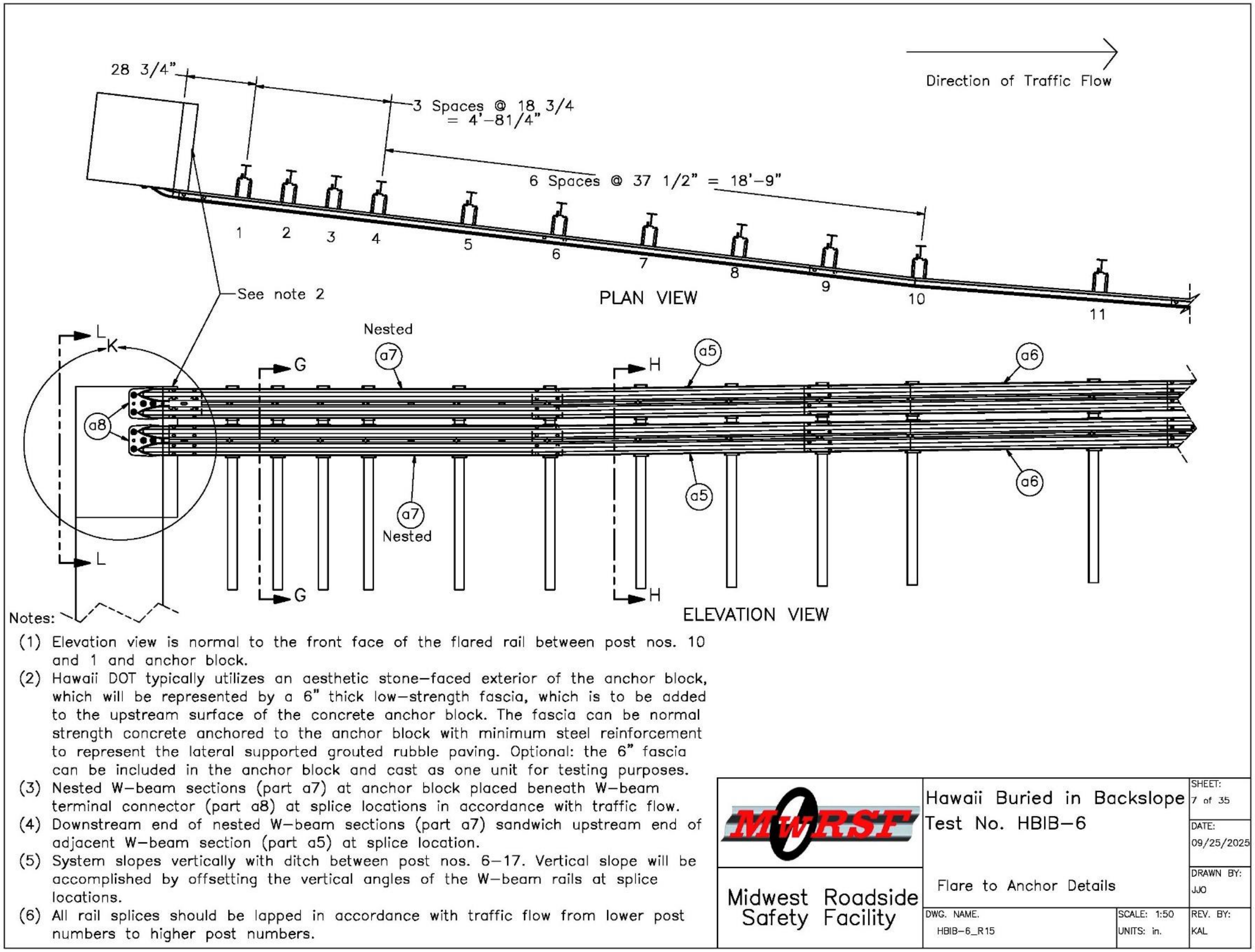


Figure 44. Flare to Anchor Details, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

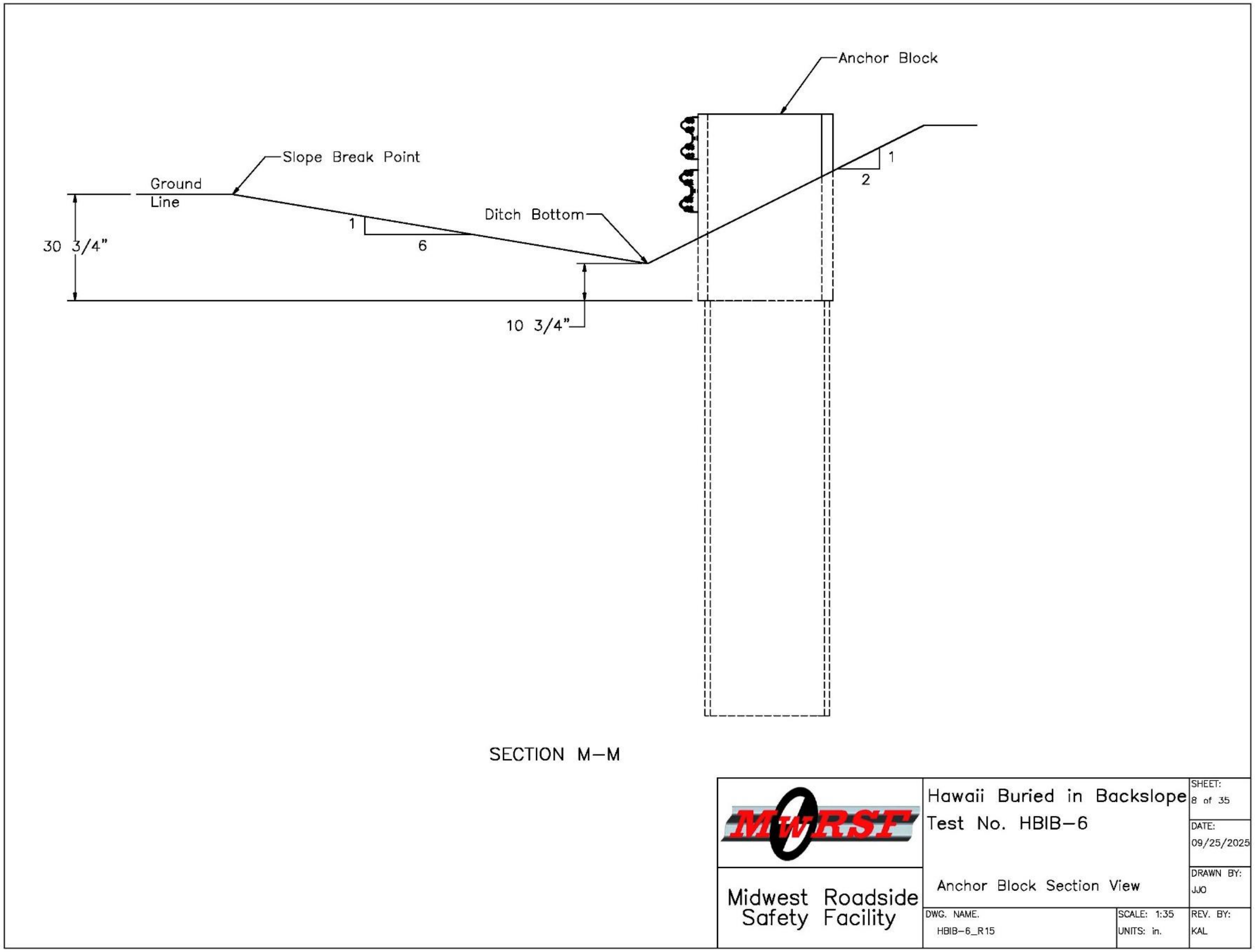
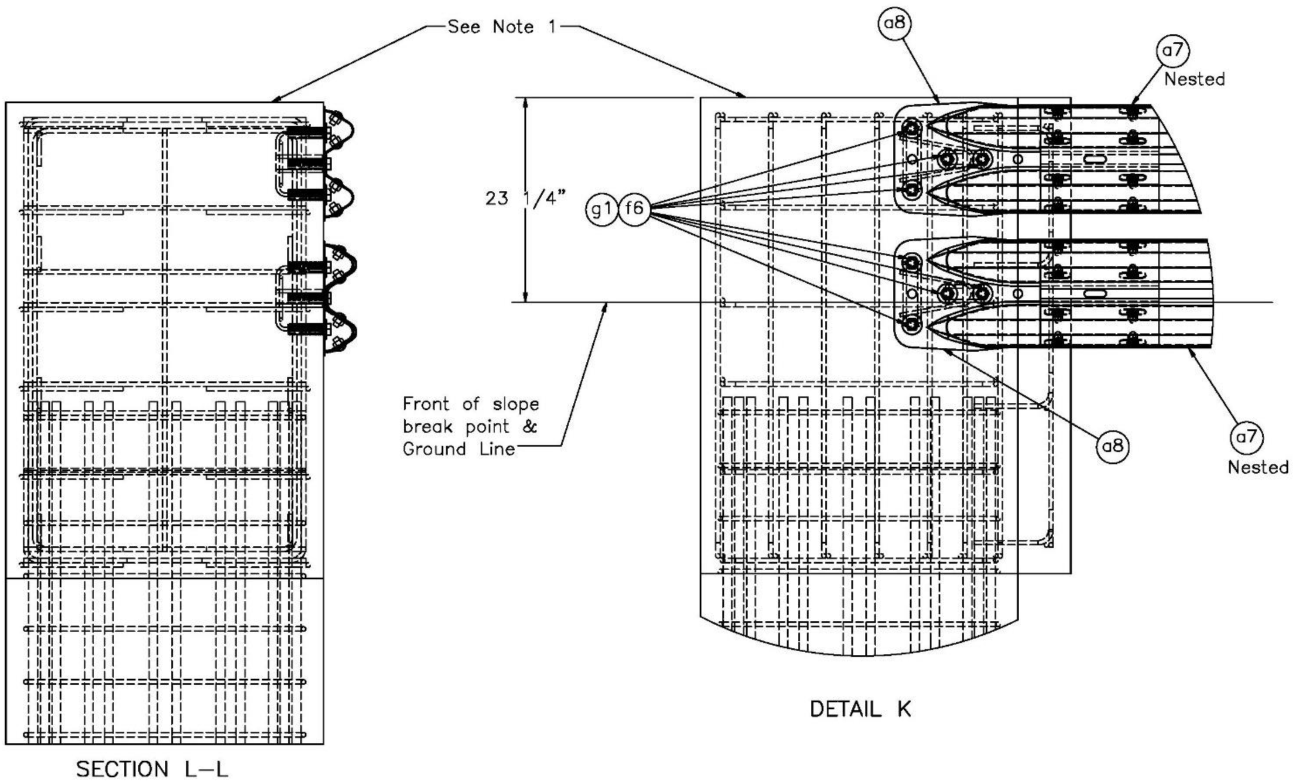


Figure 45. Anchor Block Section View, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10



Notes: (1) Hawaii DOT typically utilizes an aesthetic stone–faced exterior of the anchor block, which will be represented by a 6" thick low–strength fascia, which is to be added to the upstream surface of the concrete anchor block. The fascia can be normal strength concrete anchored to the anchor block with minimum steel reinforcement to represent the lateral supported grouted rubble paving.Optional: the 6" fascia can be included in the anchor block and cast as one unit for testing purposes.

(2) View is normal to concrete block, back slope is shown at an angle.

(3) See sheet 12 for optional end section installation details.

MwRSF	Hawaii Buried in Backslope Test No. HBIB–6		SHEET: 9 of 35
			DATE: 09/25/2025
Midwest Roadside Safety Facility	End Section Installation Details		DRAWN BY: JJO
	DWG. NAME. HBIB–6_R15	SCALE: 1:17 UNITS: in.	REV. BY: KAL

Figure 46. End Section Installation Details, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

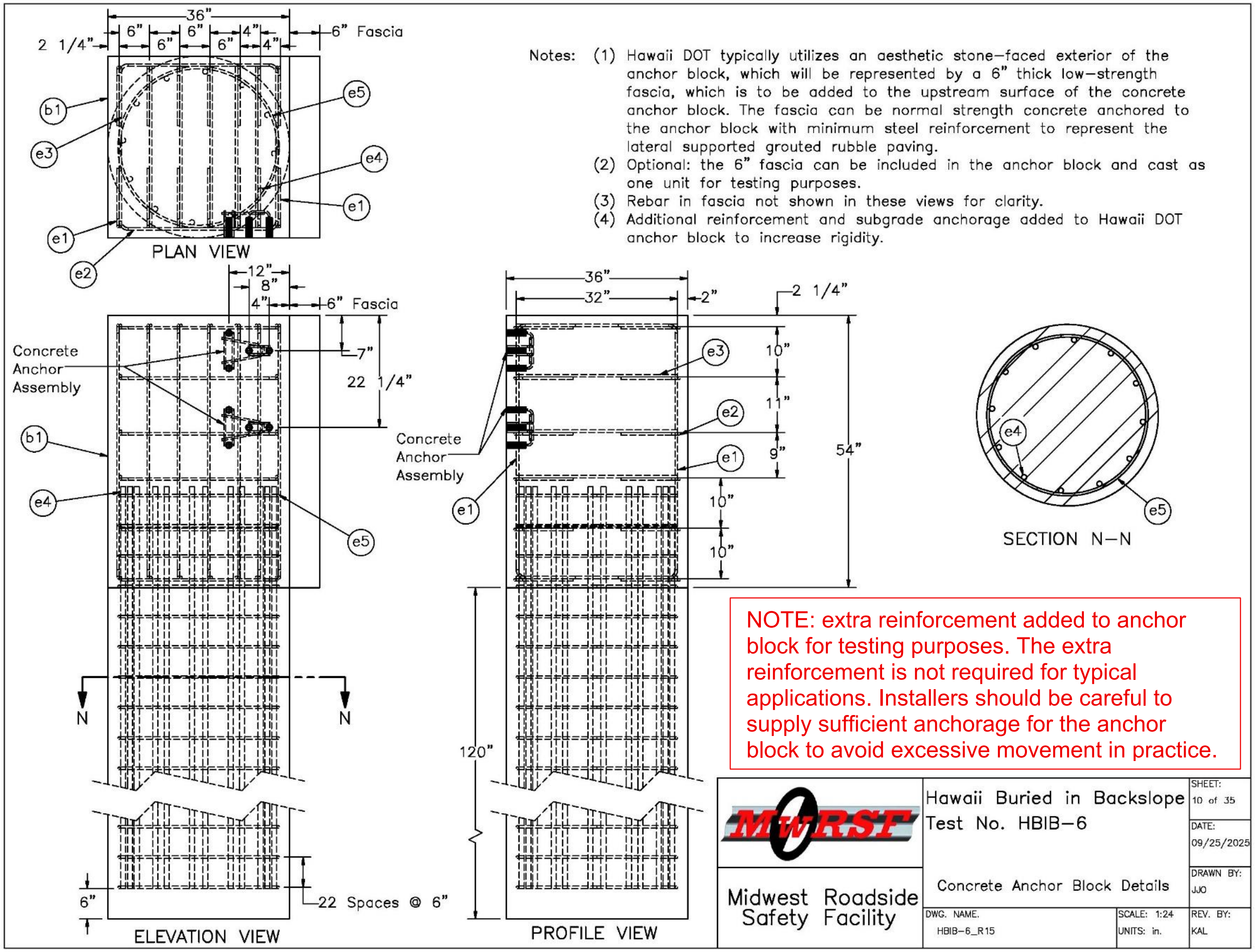
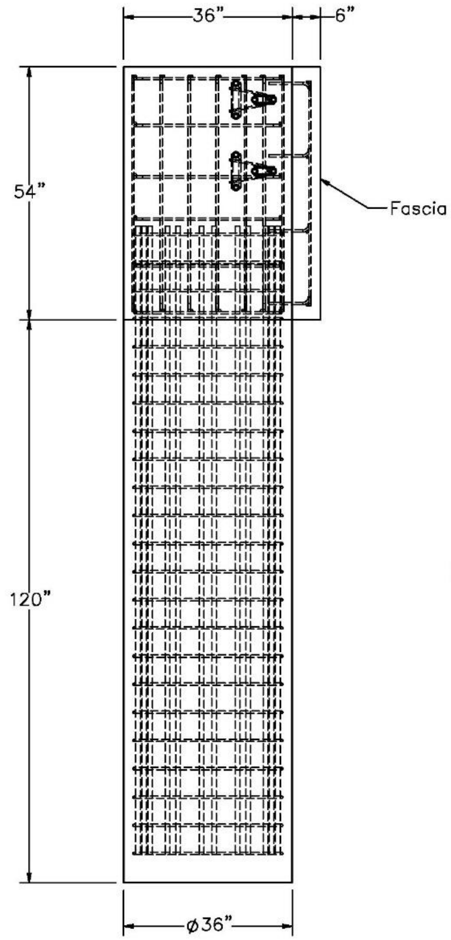


Figure 47. Concrete Anchor Block Details, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10



NOTE: extra reinforcement added to anchor block for testing purposes. The extra reinforcement is not required for typical applications. Installers should be careful to supply sufficient anchorage for the anchor block to avoid excessive movement in practice.

Notes:

(1) Hawaii DOT typically utilizes an aesthetic stone–faced exterior of the anchor block, which will be represented by a 6" thick low–strength fascia, which is to be added to the upstream surface of the concrete anchor block. The fascia can be normal strength concrete anchored to the anchor block with minimum steel reinforcement to represent the lateral supported grouted rubble paving.

(2) Optional: the 6" fascia can be included in the anchor block and cast as one unit for testing purposes.

MwRSF Midwest Roadside Safety Facility	Hawaii Buried in Backslope Test No. HBIB–6	SHEET: 11 of 35
		DATE: 09/25/2025
	Anchor Block Assembly	DRAWN BY: JJO
	DWG. NAME. HBIB–6_R15	SCALE: 1:32 UNITS: in.
		REV. BY: KAL

Figure 48. Anchor Block Assembly, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

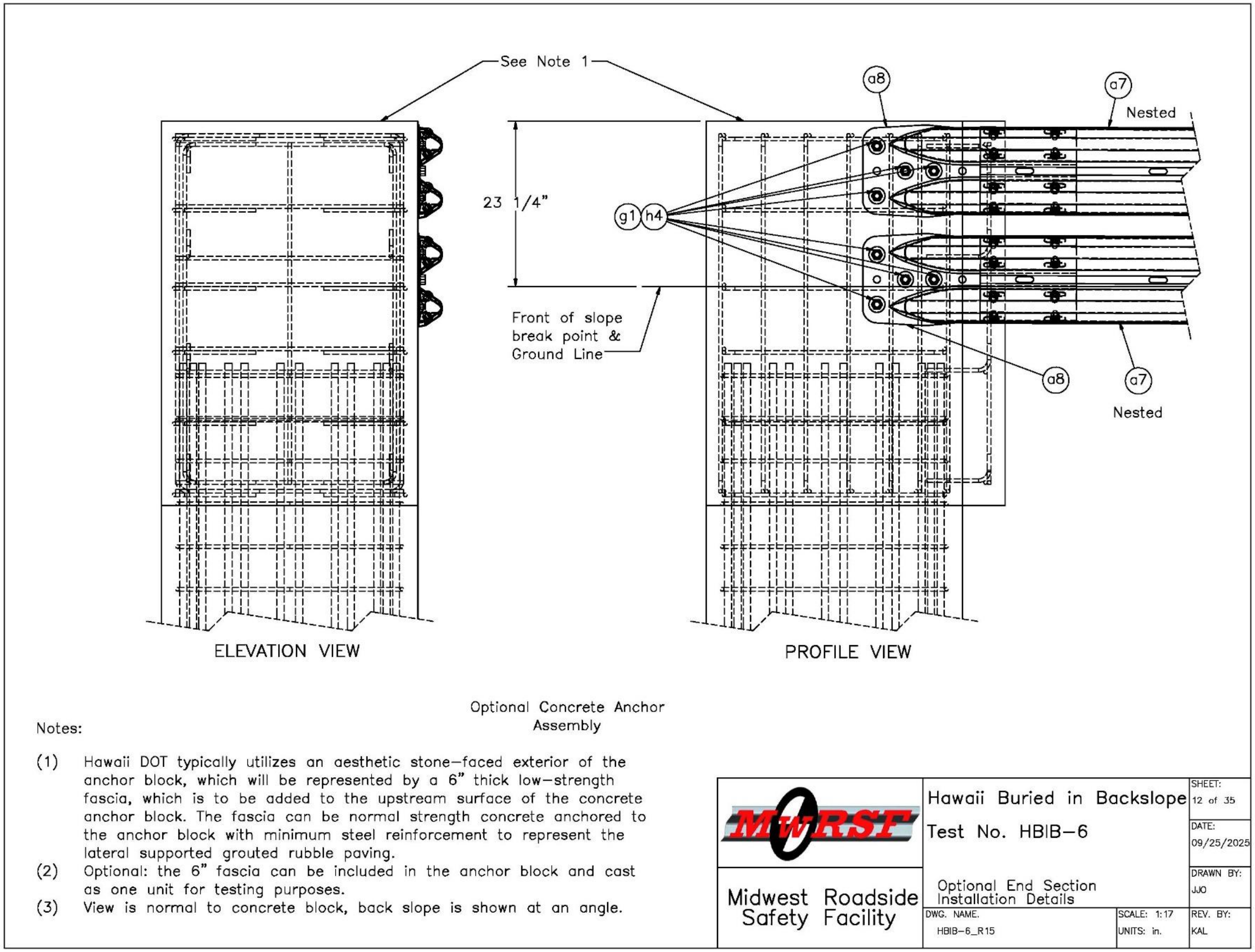


Figure 49. Optional End Section Installation Details, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

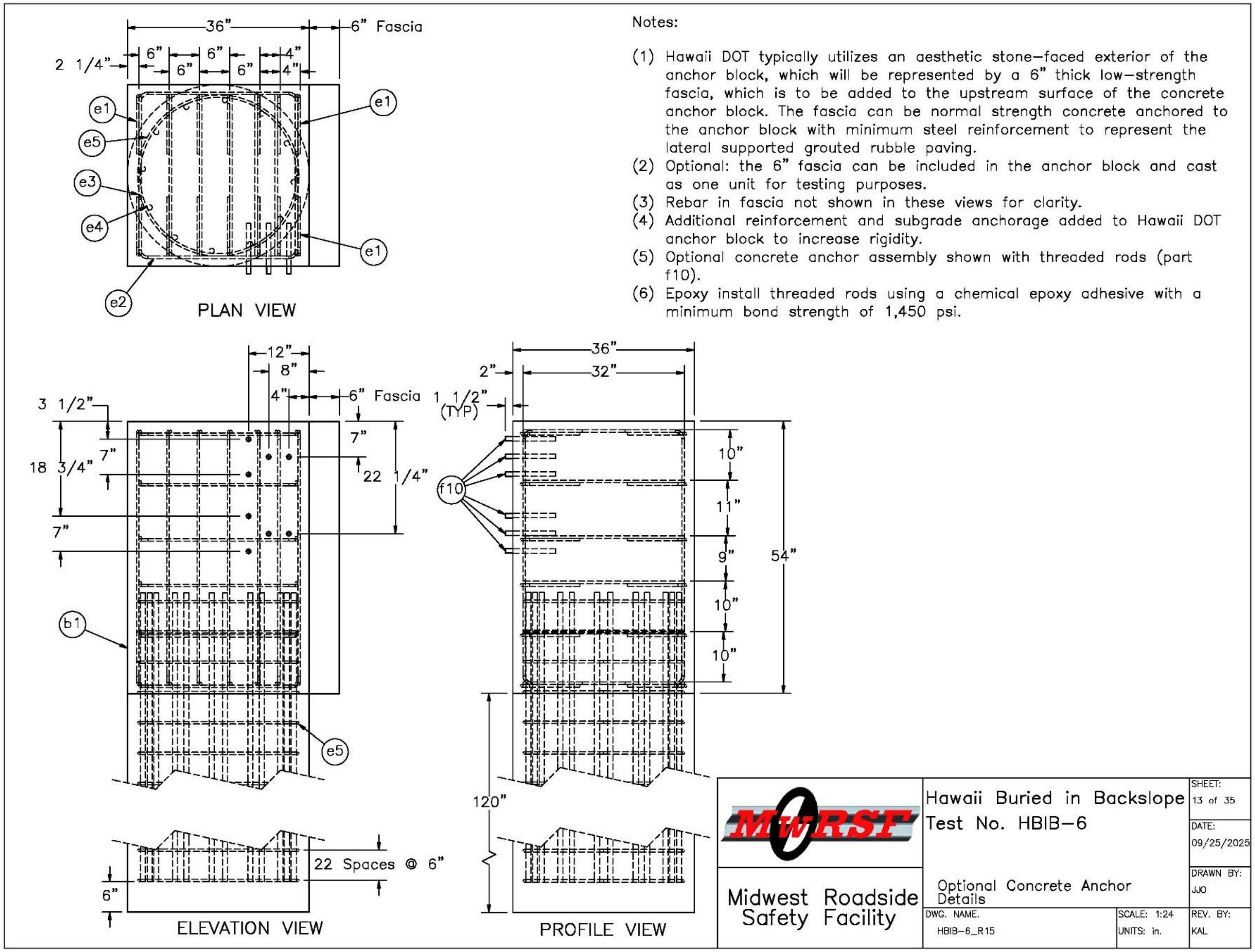
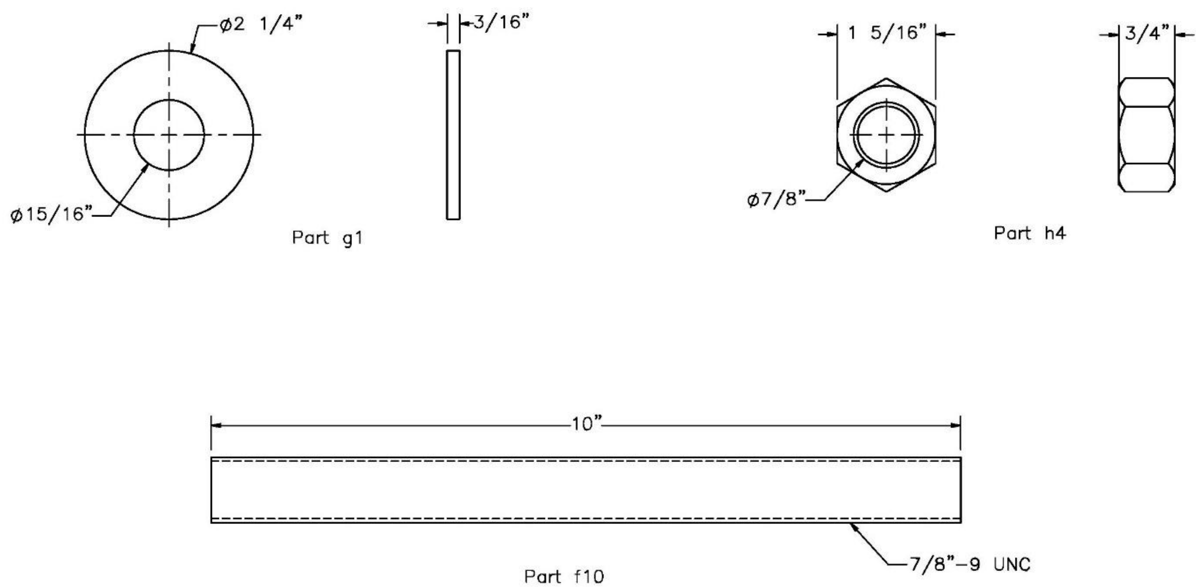


Figure 50. Optional Concrete Anchor Details, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

*Optional Hardware					
Item No.	QTY.	Description	Material Specification	Treatment Specification	
f10	8	7/8" Dia. 9 UNC, 10" Long Fully Threaded Rod	ASTM A307 Gr. A or Equivalent	ASTM A153 or B695 Class 55 or F2329	–
g1	8	7/8" Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC20a
h4	8	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	–



Notes: (1) Additional hardware required for optional anchor.

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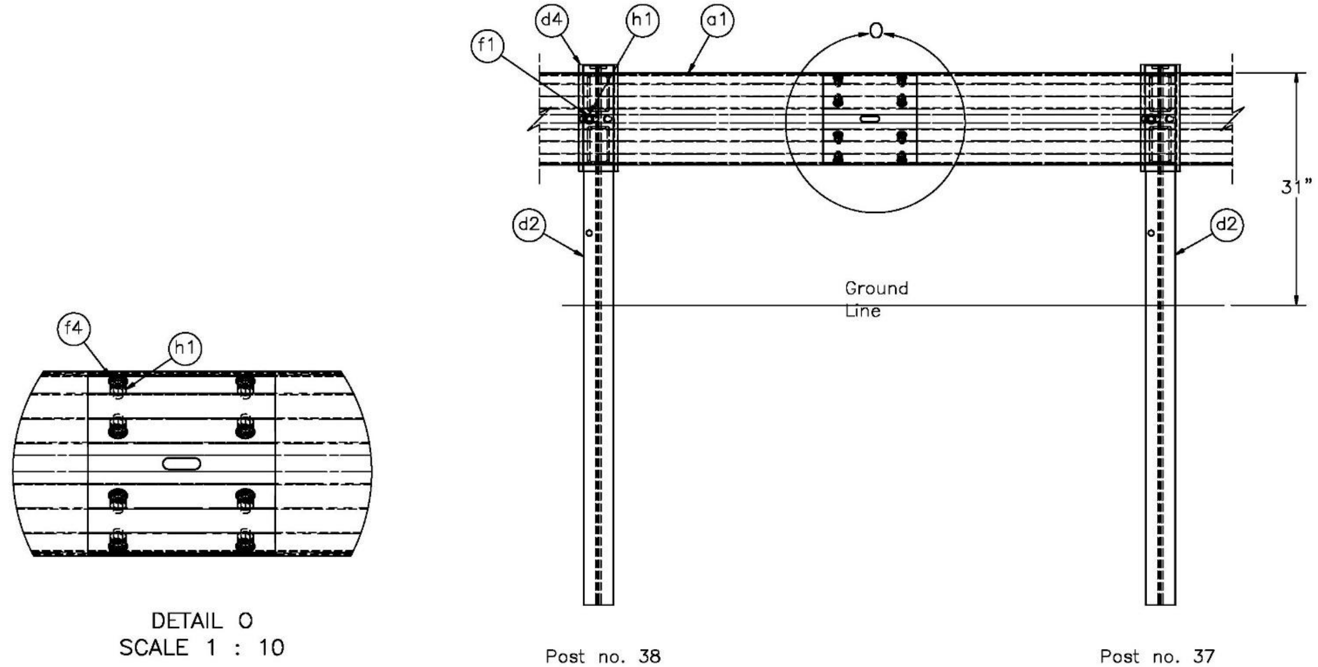
Hawaii Buried in Backslope Test No. HBIB-6

Optional Concrete Anchor Block Hardware

SHEET: 14 of 35
DATE: 09/25/2025
DRAWN BY: JJO
REV. BY: KAL
DWG. NAME. HBIB-6_R15
SCALE: 1:2
UNITS: in.

Figure 51. Optional Concrete Anchor Block Hardware, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10



Note:

(1) Guardrail bolts (part f1) on the upstream side of the web.
(2) Guardrail bolts (part f4) may be used in place of guardrail bolts (part f3) in nested W-beam splices if the nut can be fully threaded (dependent on thickness of stacked guardrail layers).
(3) All rail splices should be lapped in accordance with traffic flow from lower post numbers to higher post numbers.

Midwest Roadside Safety Facility	Hawaii Buried in Backslope Test No. HBIB-6	SHEET: 15 of 35
		DATE: 09/25/2025
	Splice Detail	DRAWN BY: JJO
	DWG. NAME. HBIB-6_R15 / SCALE: 1:20 UNITS: in.	REV. BY: KAL

Figure 52. Splice Detail, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

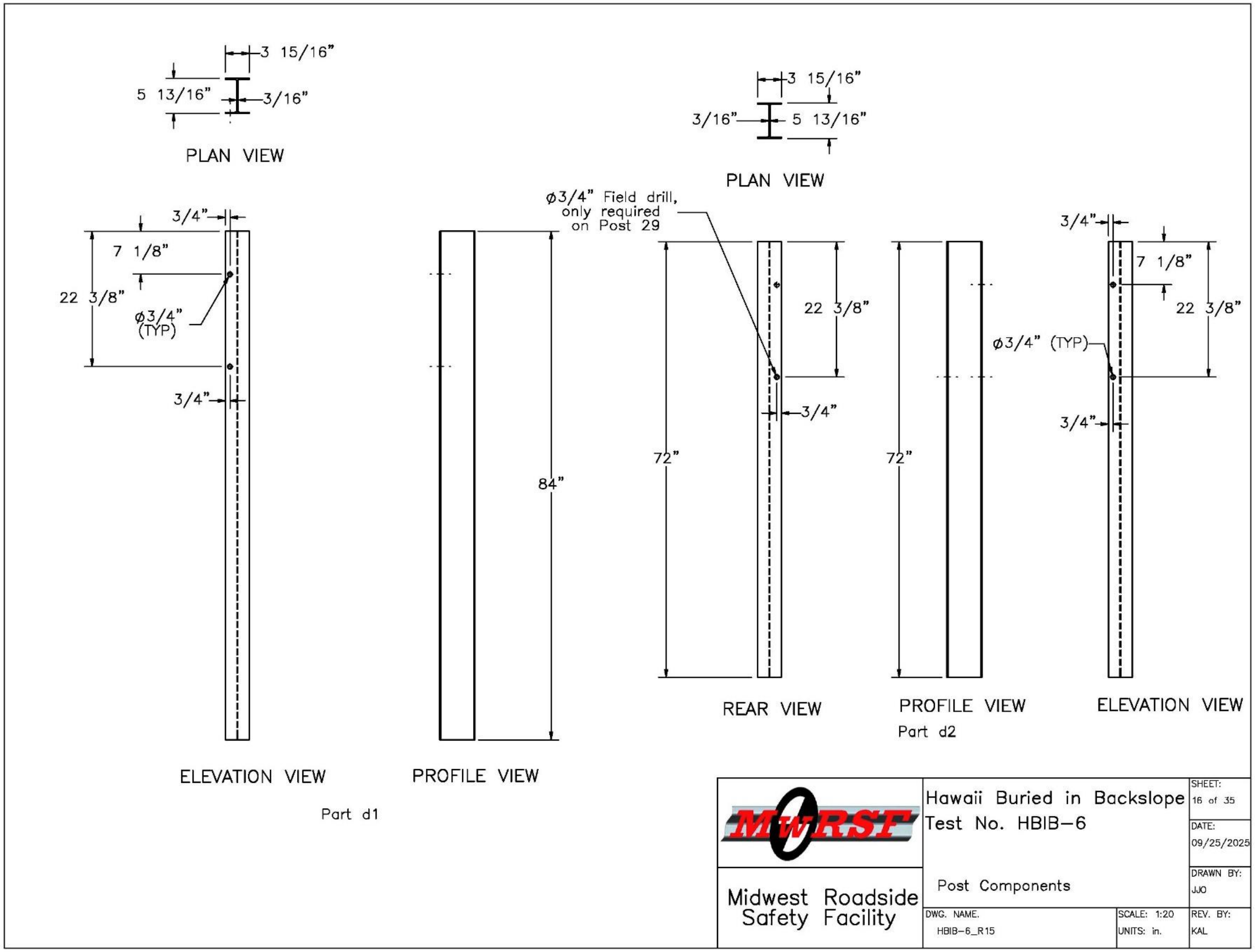


Figure 53. Post Components, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

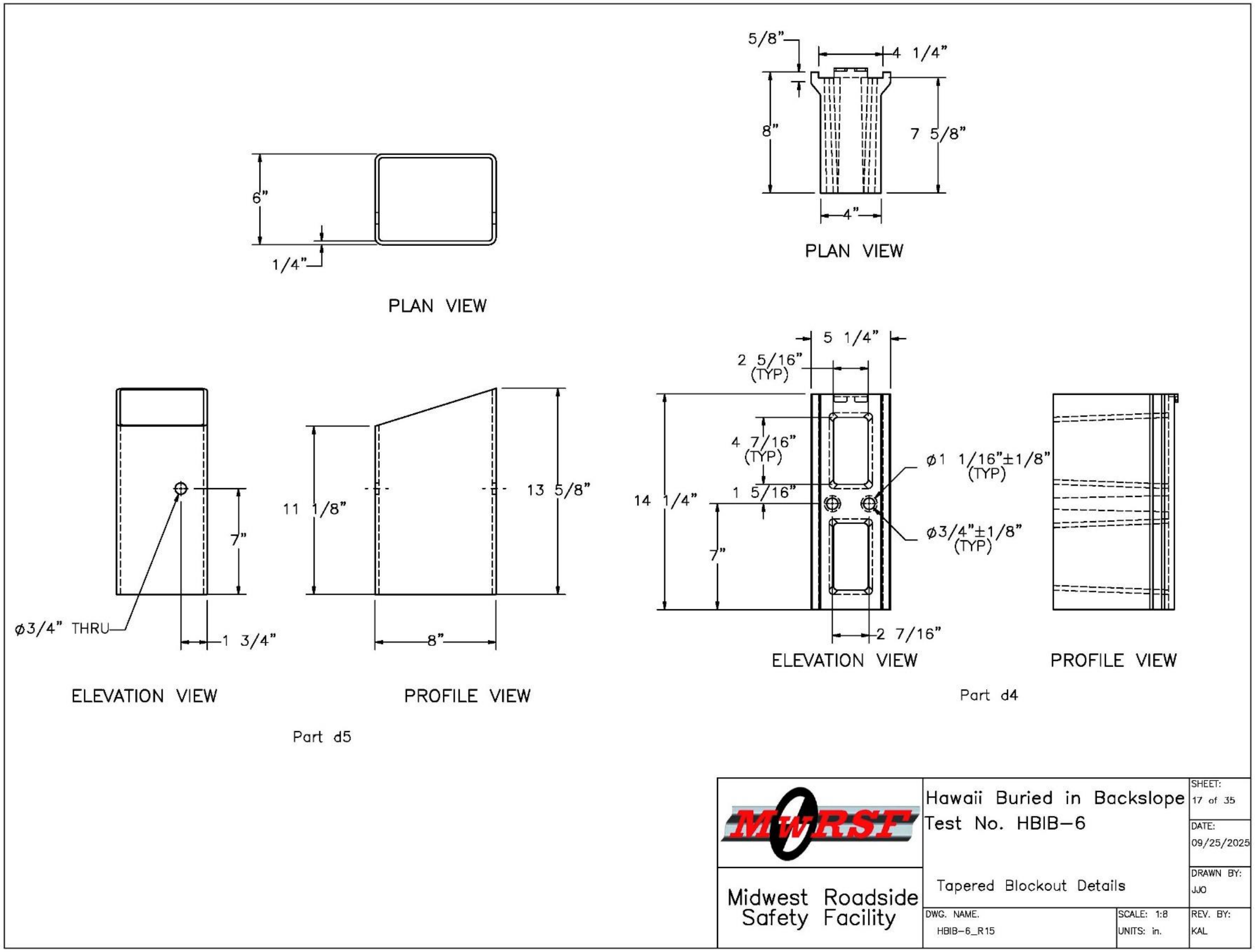
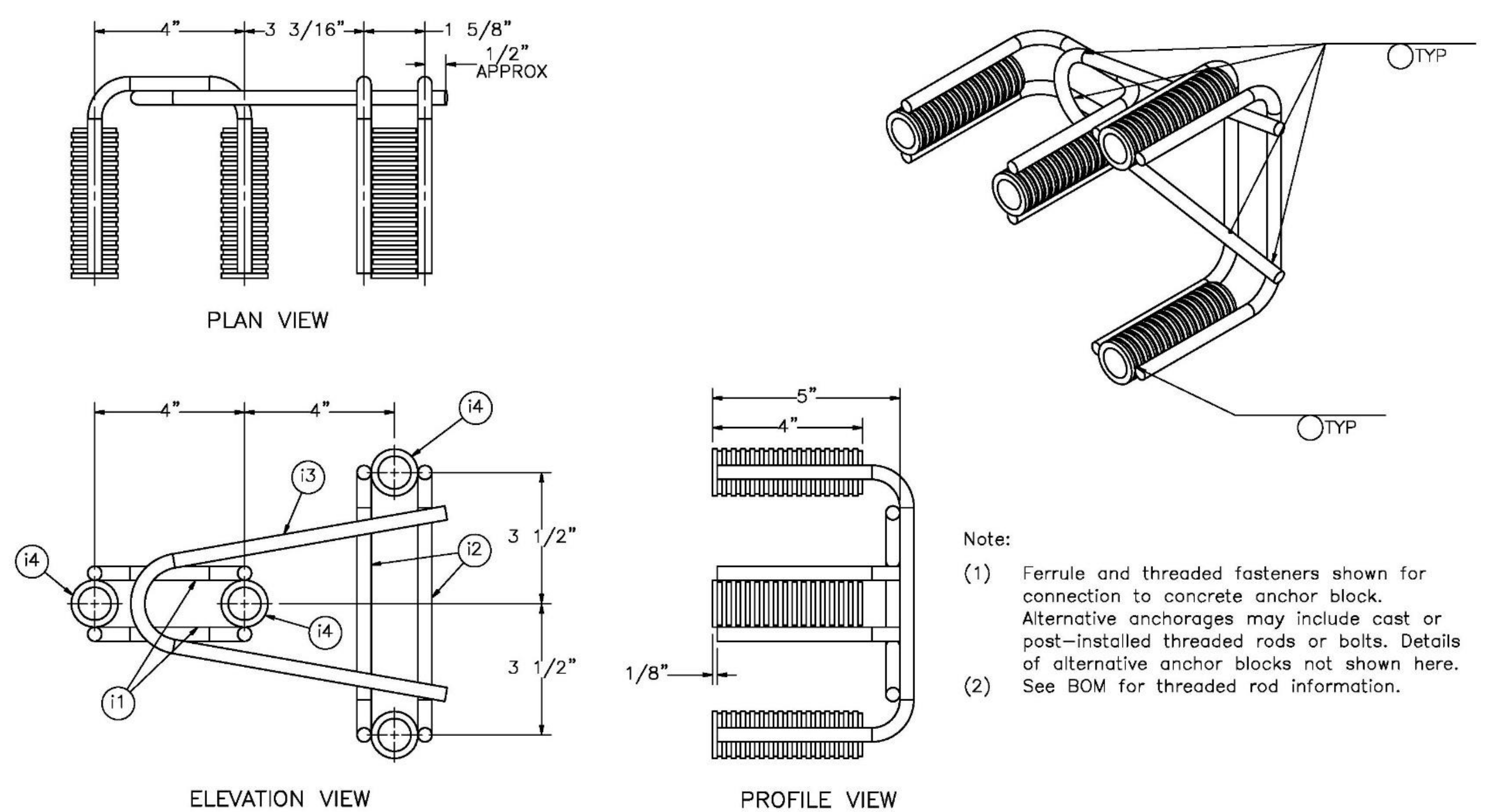


Figure 54. Tapered Blockout Details, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10



Item No.	QTY.	Description	Material Specification	Treatment Specification
–	2	Concrete Anchor	–	–
i1	2	3/8" 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
i4	4	7/8 Dia. Threaded Ferrule	–	–

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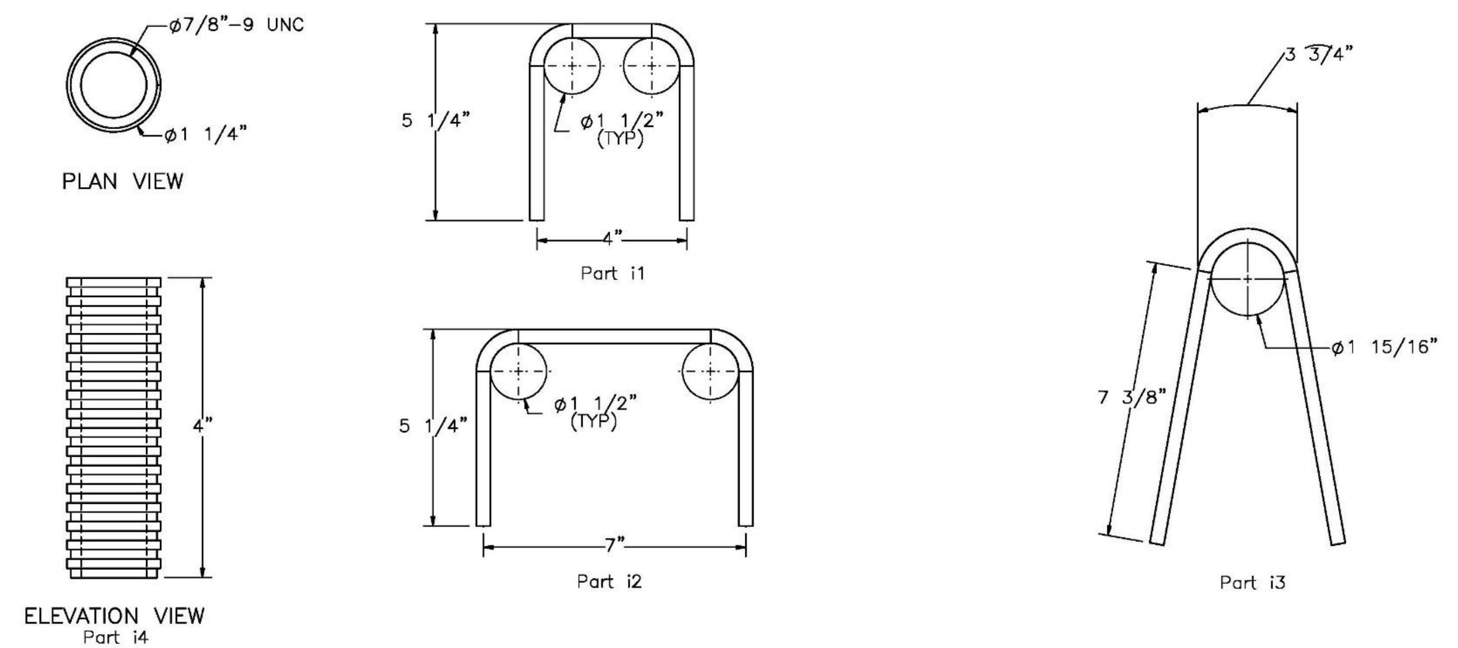
Hawaii Buried in Backslope Test No. HBIB-6

Concrete Anchor Block Insert Assembly

SHEET: 18 of 35
DATE: 09/25/2025
DRAWN BY: JJO
DWG. NAME. HBIB-6_R15
SCALE: 1:4
UNITS: in.
REV. BY: KAL

Figure 55. Concrete Anchor Block Insert Assembly, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10



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

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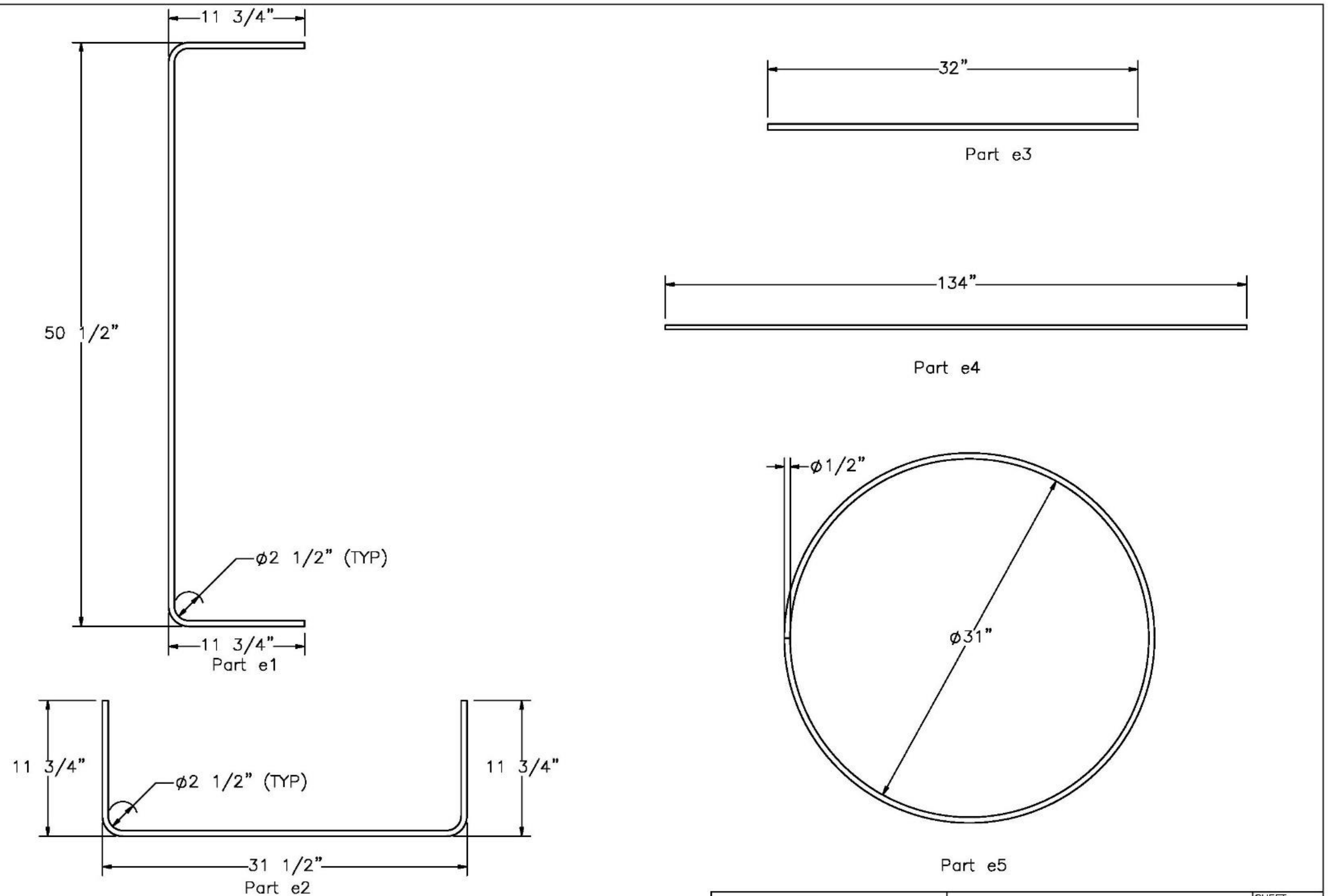
Hawaii Buried in Backslope
Test No. HBIB-6

Insert Component Details

SHEET: 19 of 35
DATE: 09/25/2025
DRAWN BY: JJO
DWG. NAME. HBIB-6_R15
SCALE: 1:2
UNITS: in.
REV. BY: KAL

Figure 56. Insert Component Details, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10



Bill of Bars					
Bar	QTY	Size	Length	Material	Treatment
e1	14	#4	72"	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)
e2	10	#4	53"	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)
e3	20	#4	32"	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)
e4	16	#8	134"	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)
e5	23	#4	99"	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)

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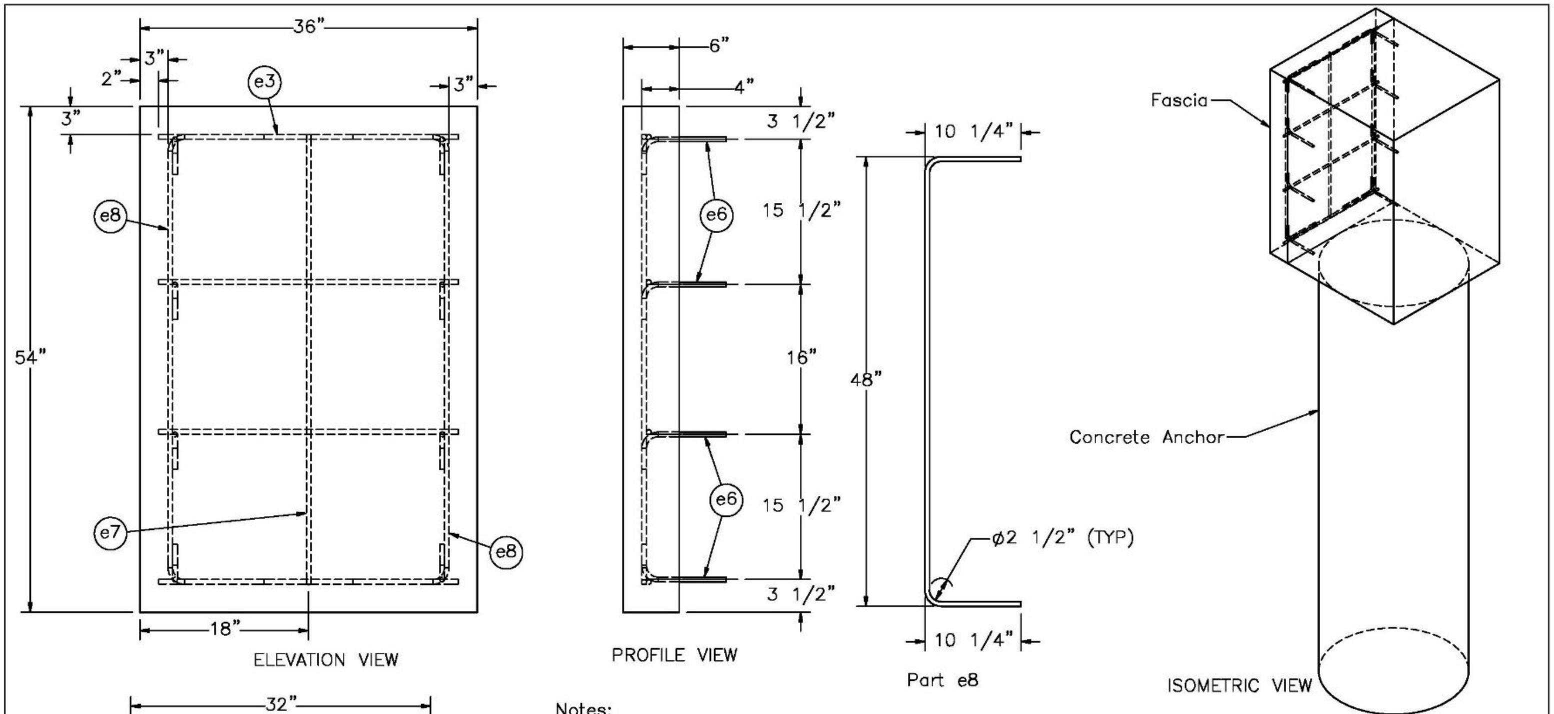
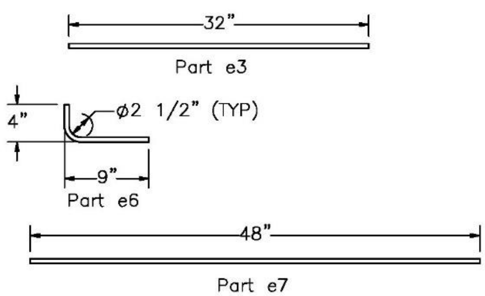
Hawaii Buried in Backslope Test No. HBIB-6

Anchor Block Rebar Details

SHEET: 20 of 35
DATE: 09/25/2025
DRAWN BY: JJO
DWG. NAME. HBIB-6_R15
SCALE: 1:12
UNITS: in.
REV. BY: KAL

Figure 57. Anchor Block Rebar Details, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10





Notes:

(1) Hawaii DOT typically utilizes an aesthetic stone-faced exterior of the anchor block, which will be represented by a 6" thick fascia, which is to be added to the upstream surface of the concrete anchor block. The fascia can be normal strength concrete anchored to the anchor block with minimum steel reinforcement to represent the lateral supported grouted rubble paving. The installation procedure should be followed. Remove forms from the concrete anchor and drill holes in the anchor block. Install epoxied rebar as shown. Apply Fascia then backfill and compact soil.

(2) Optional: the 6" fascia can be included in the anchor block and cast as one unit for testing purposes.

Bill of Bars

Bar	QTY	Size	Length	Material	Treatment
e3	4	#4	32"	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)
e6	8	#4	12"	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)
e7	1	#4	48"	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)
e8	2	#4	67"	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)

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Hawaii Buried in Backslope Test No. HBIB-6

Fascia Installation

SHEET: 21 of 35
DATE: 09/25/2025
DRAWN BY: JJO
DWG. NAME. HBIB-6_R15
SCALE: 1:16
UNITS: in.
REV. BY: KAL

Figure 58. Fascia Installation, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

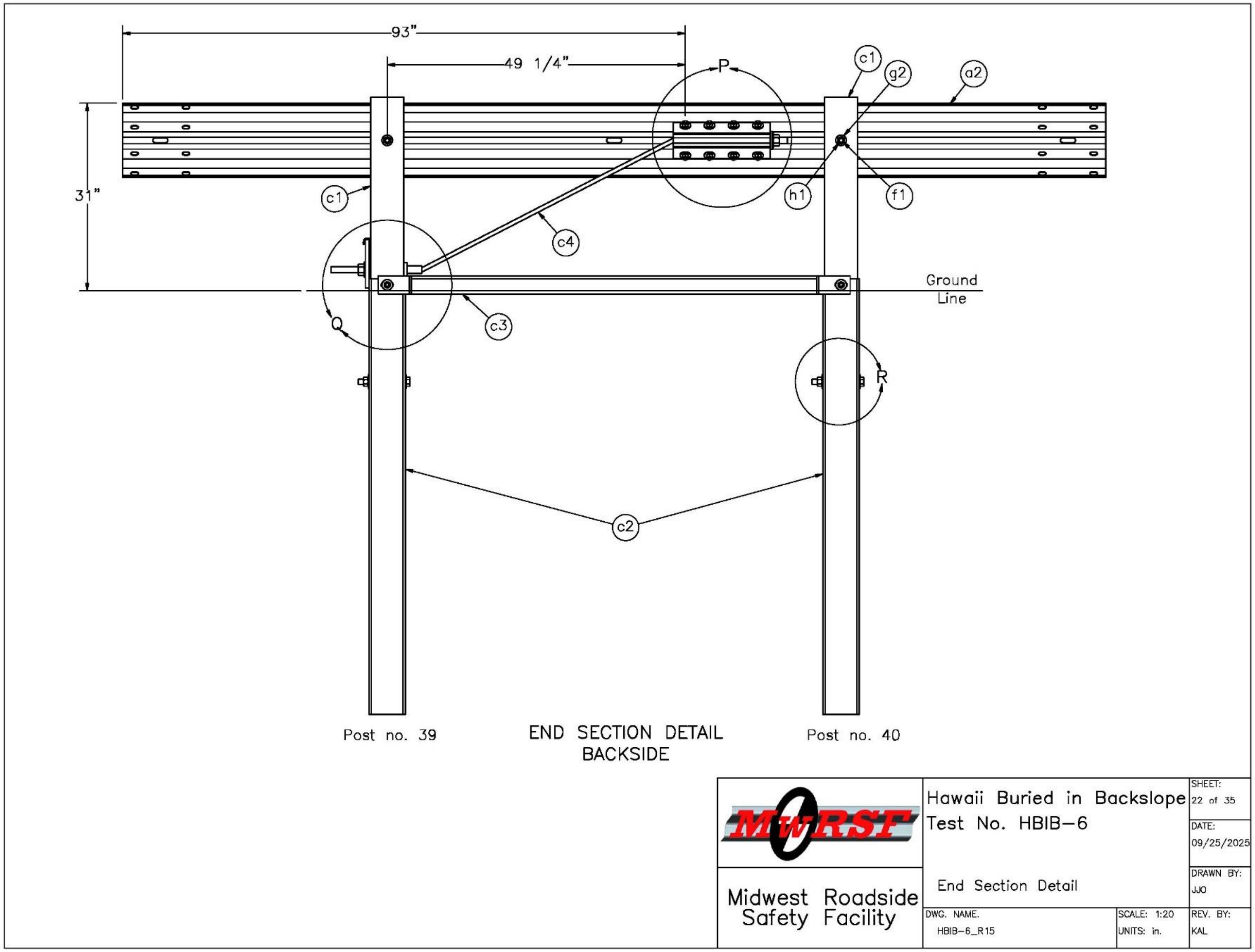


Figure 59. End Section Detail, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

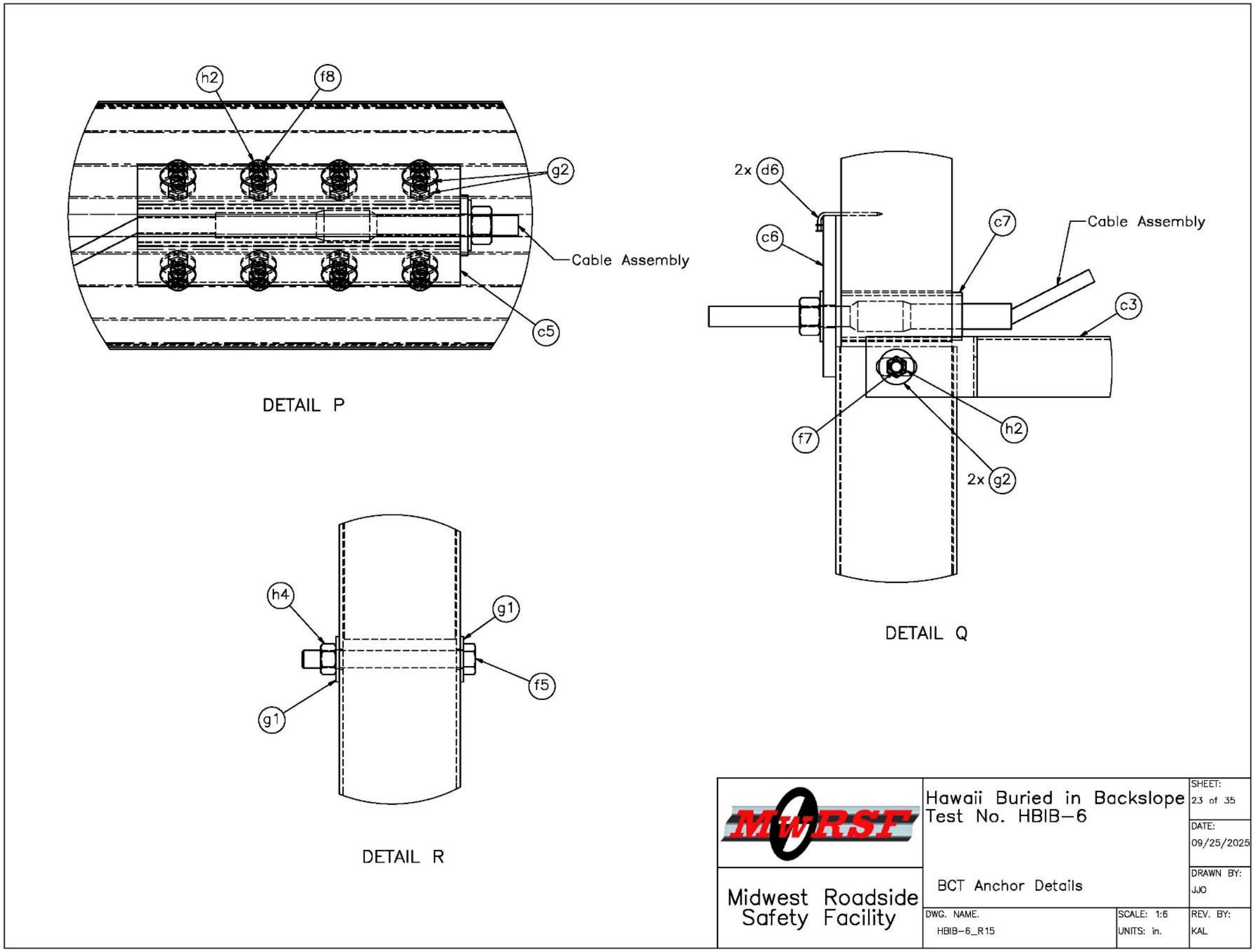


Figure 60. BCT Anchor Details, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

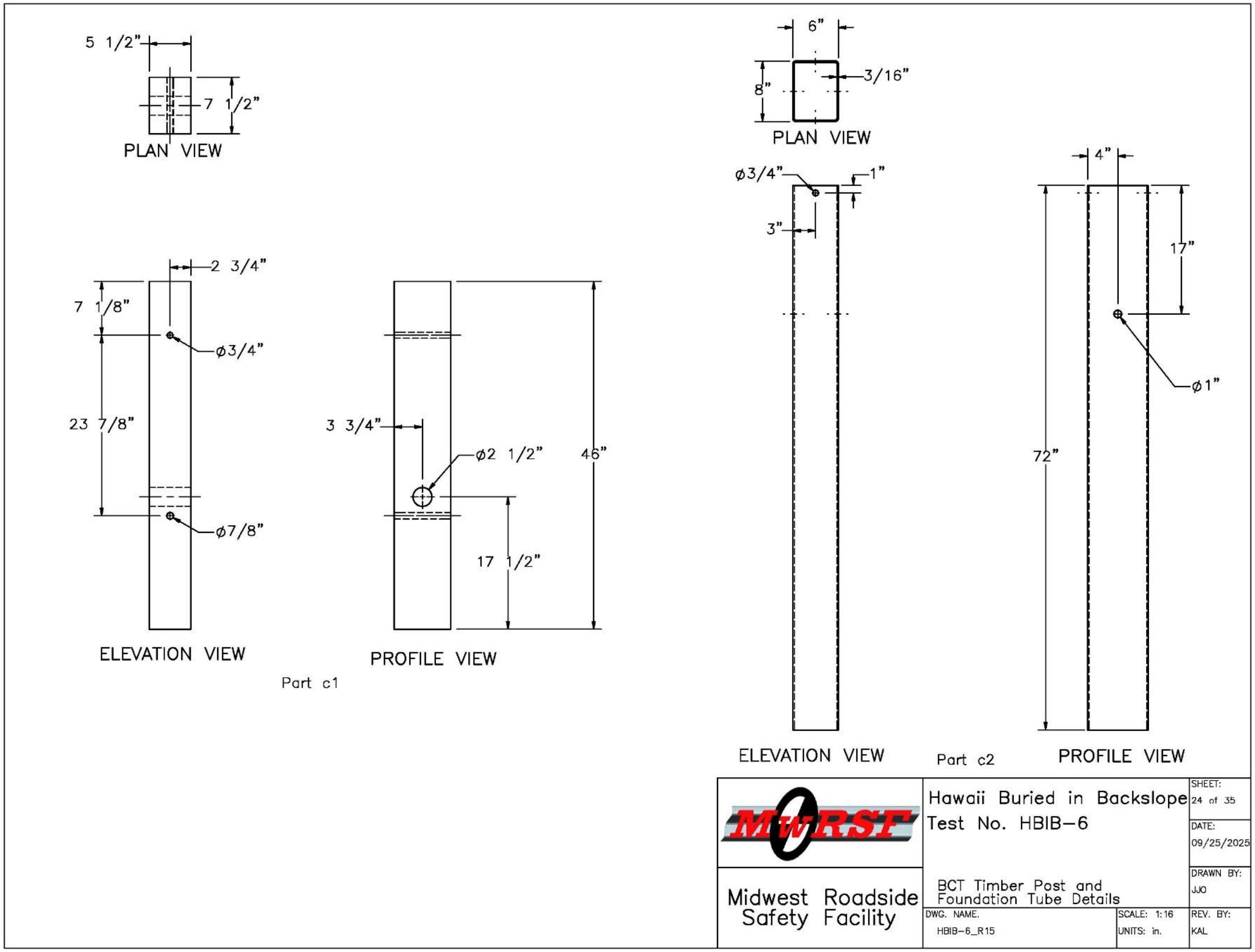


Figure 61. BCT Timber Post and Foundation Tube Details, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

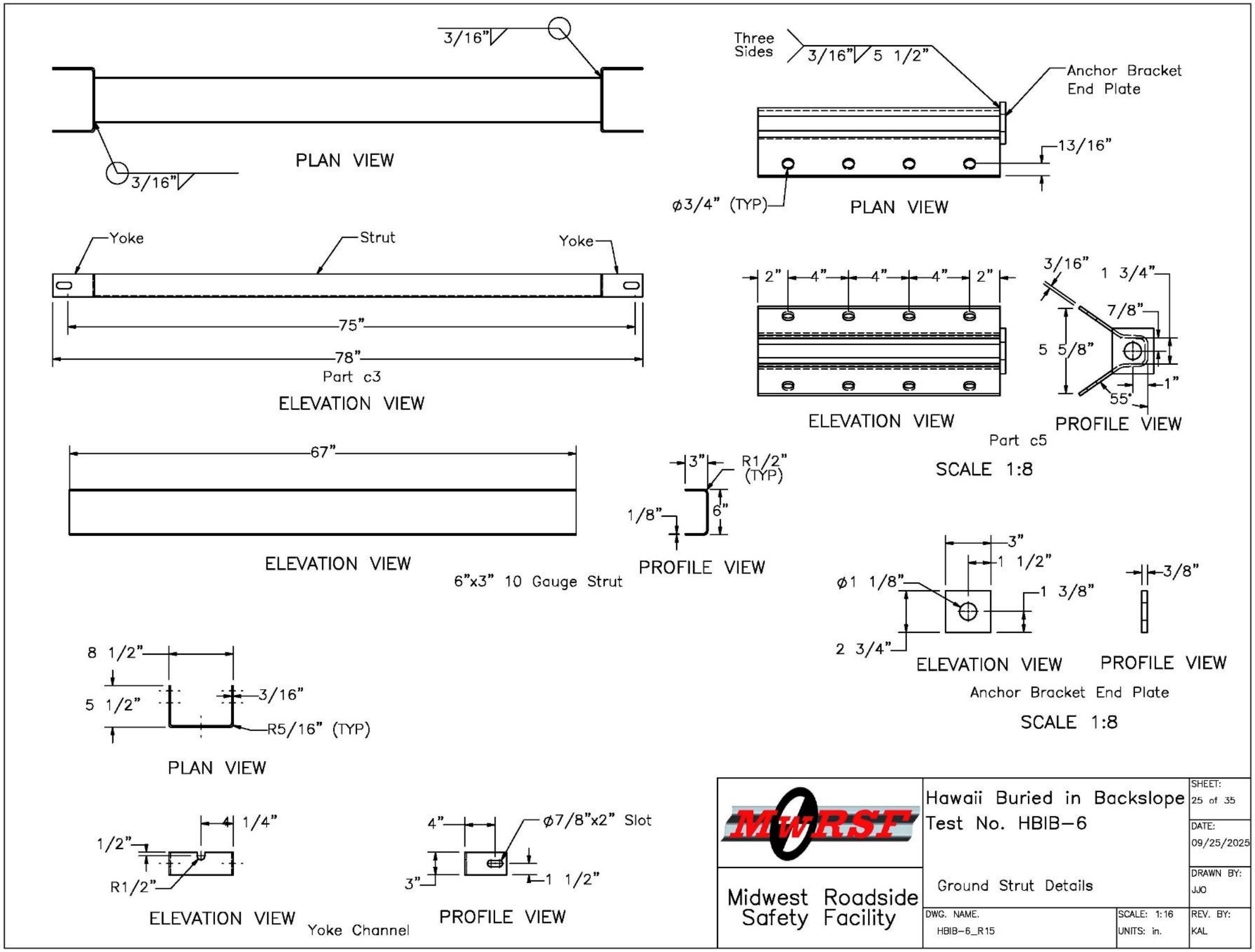


Figure 62. Ground Strut Details, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

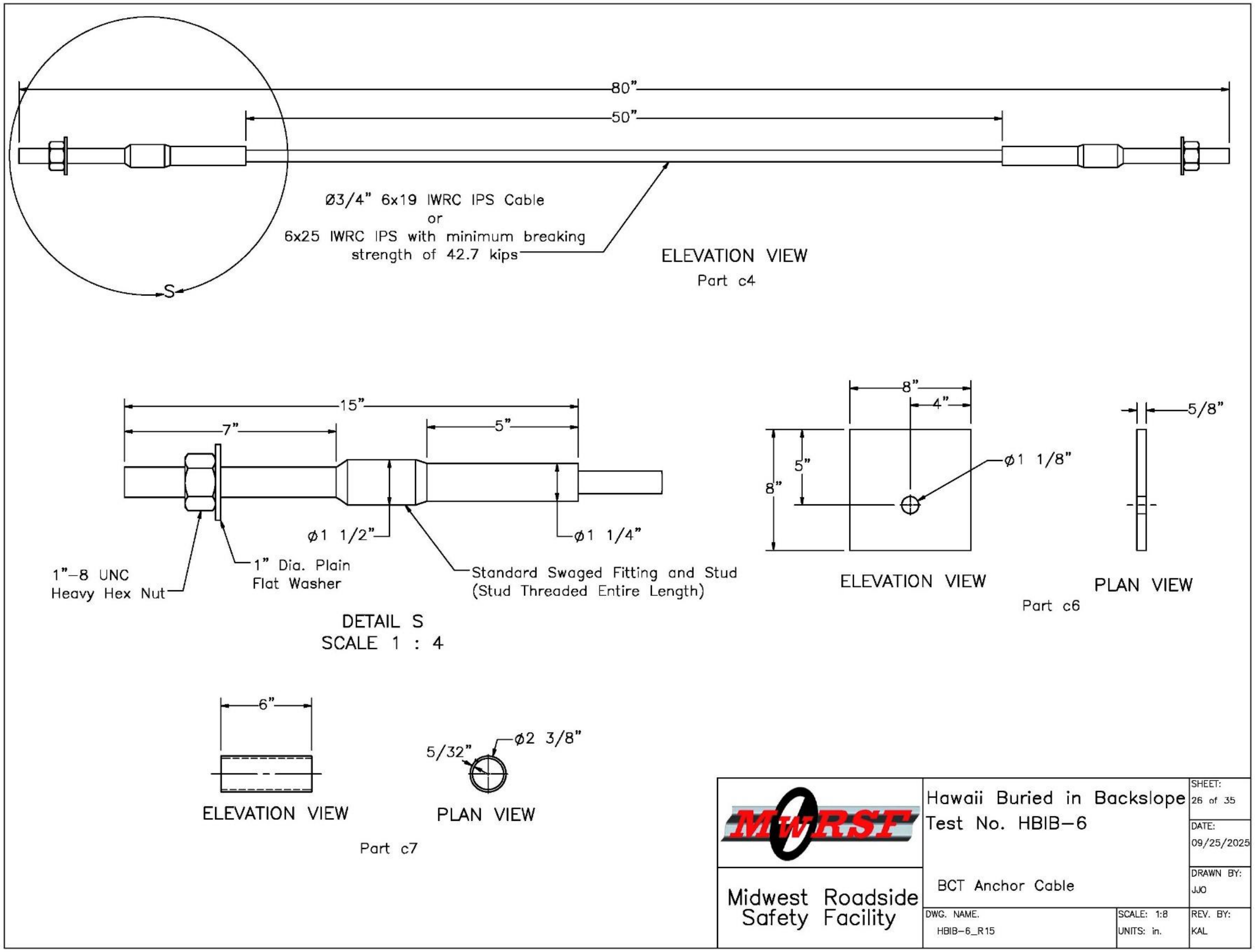


Figure 63. BCT Anchor Cable, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

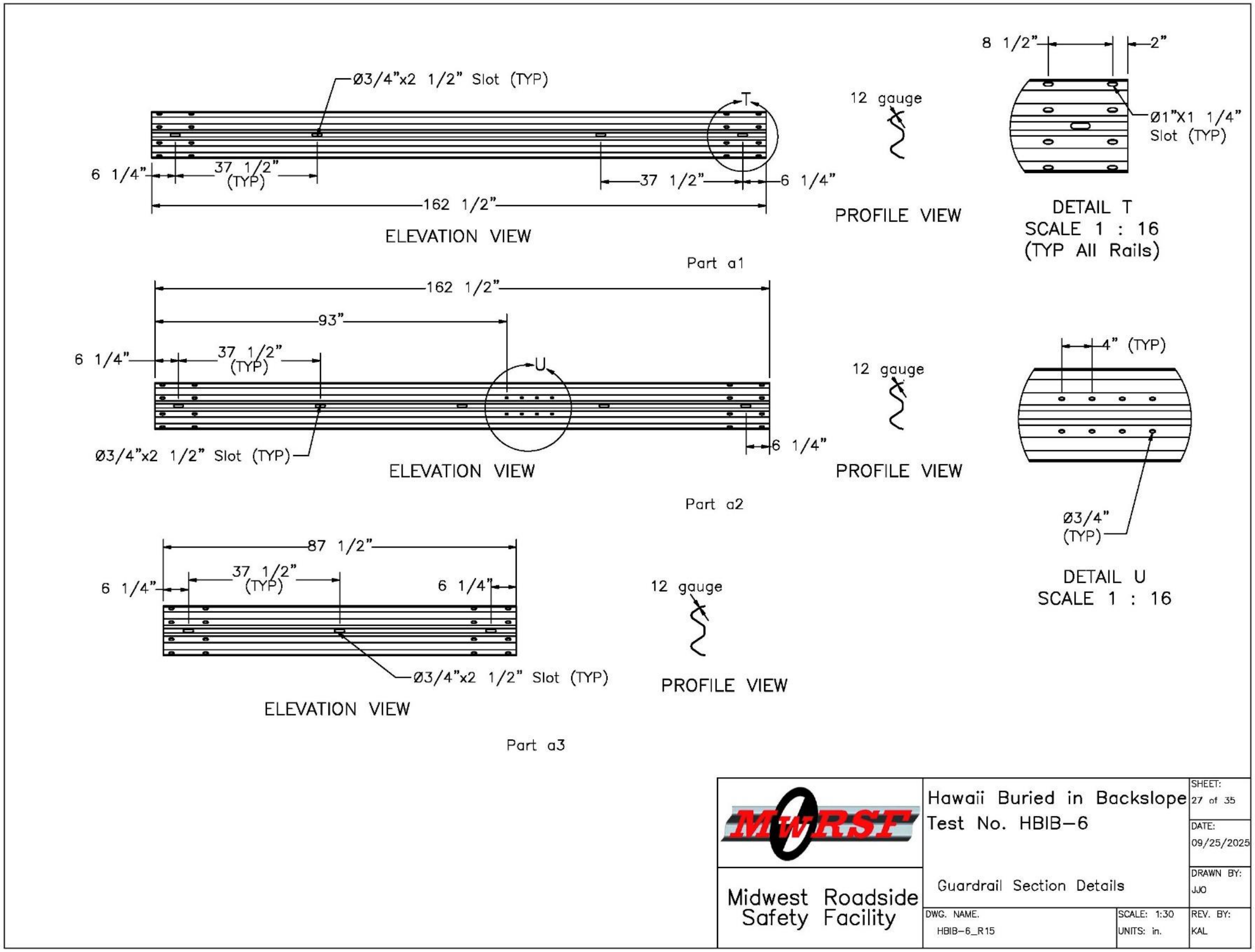


Figure 64. Guardrail Section Details, Page 1, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

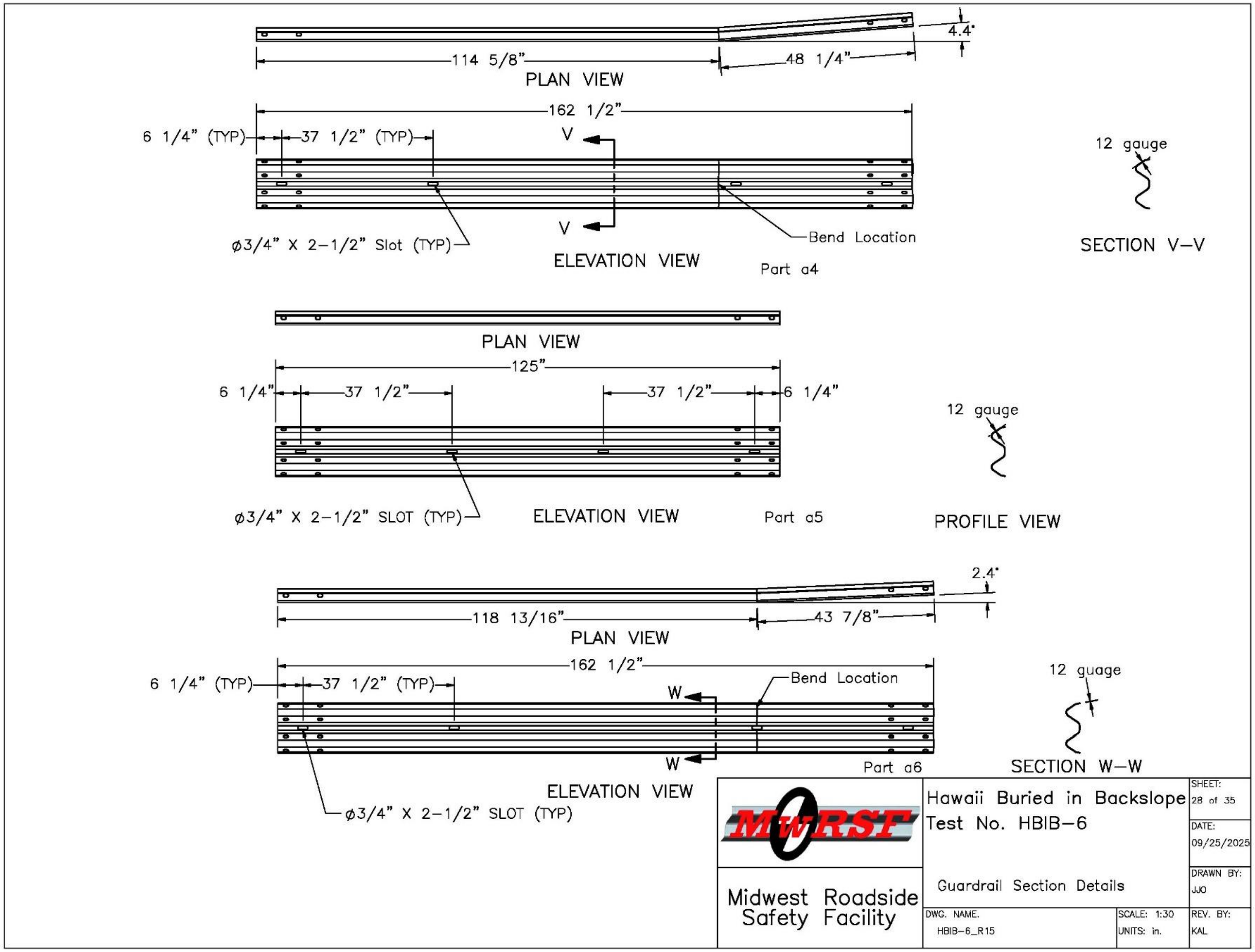


Figure 65. Guardrail Section Details, Page 2, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

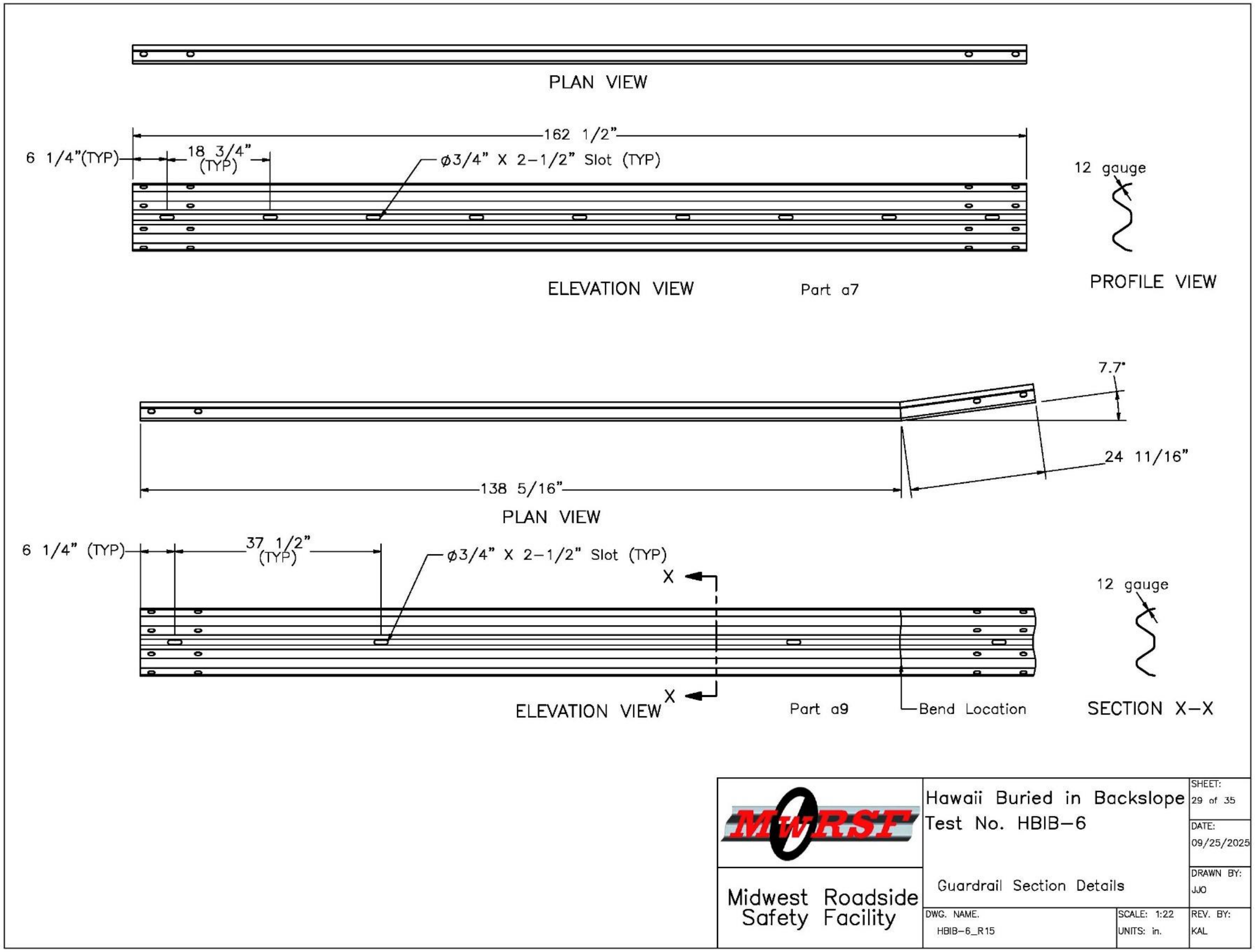


Figure 66. Guardrail Section Details, Page 3, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

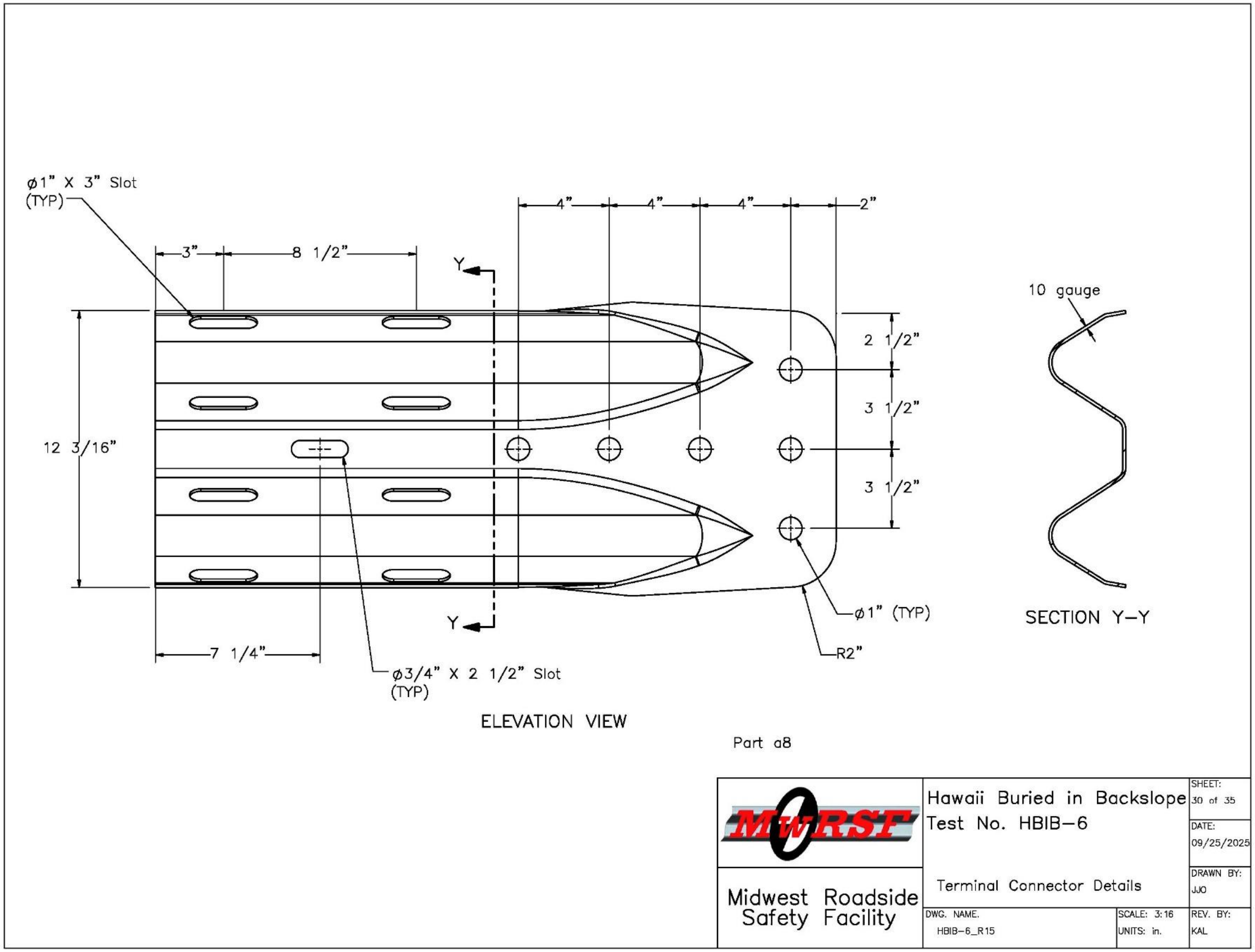


Figure 67. Terminal Connector Details, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

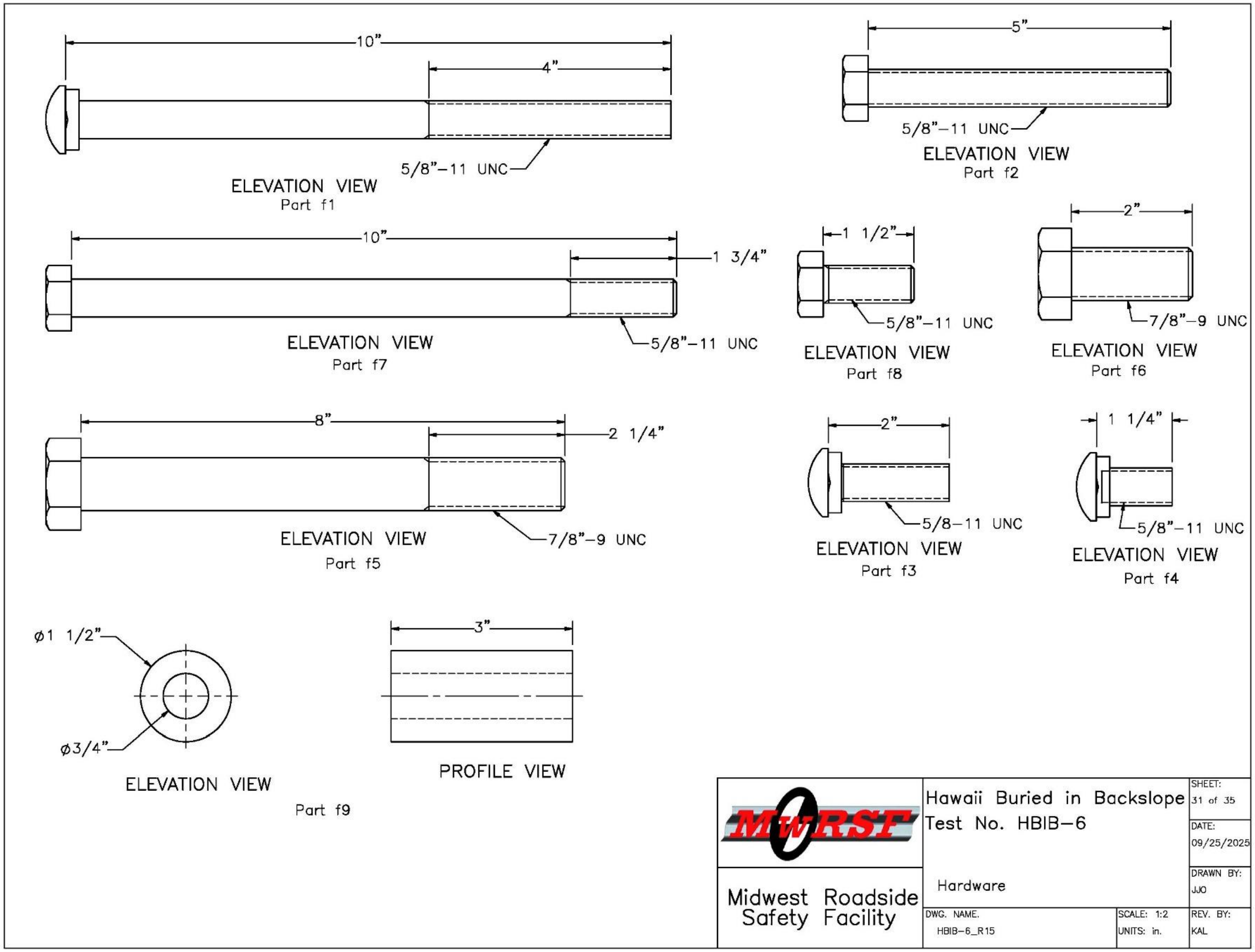


Figure 68. Hardware Details, Page 1, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

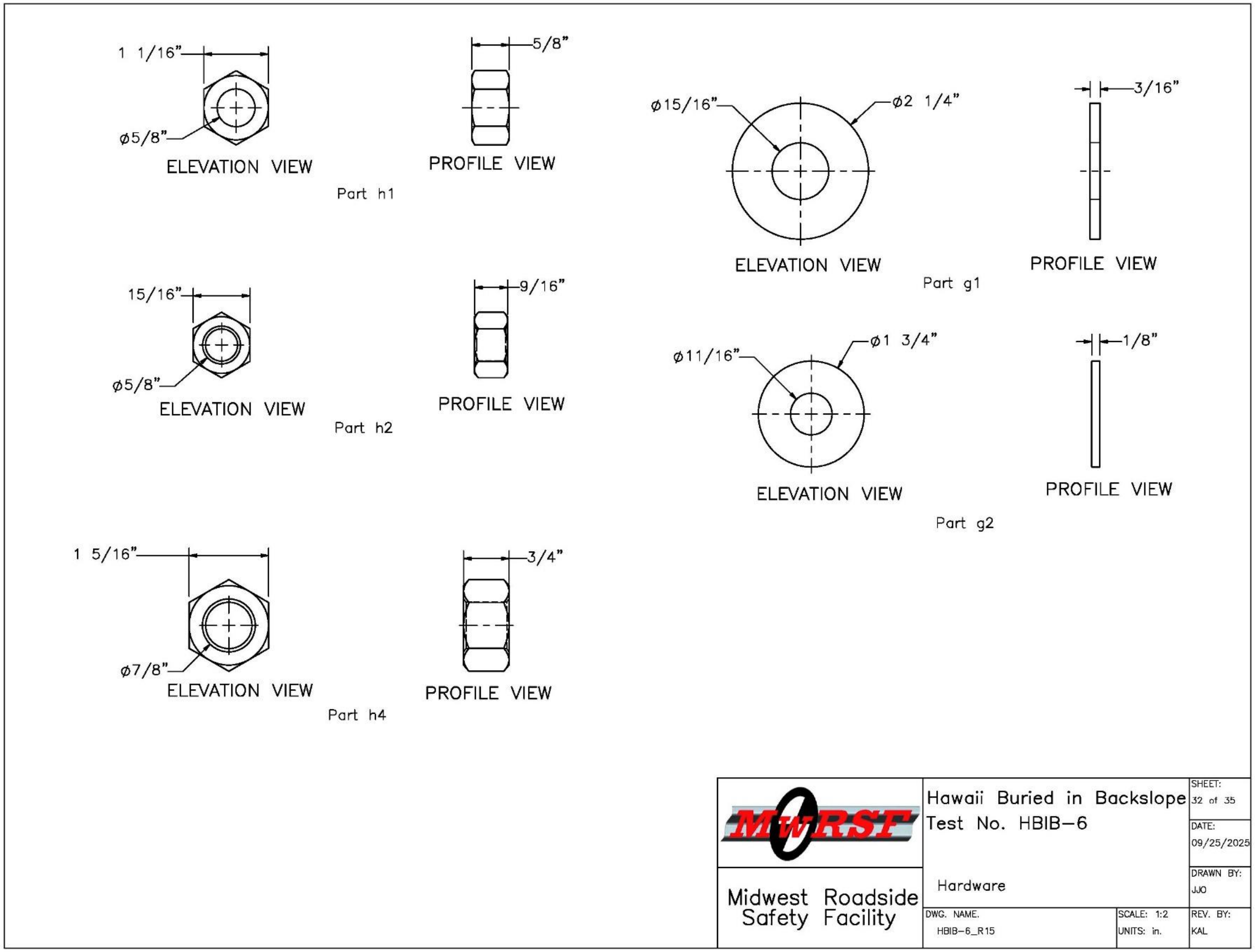


Figure 69. Hardware Details, Page 2, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

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 W–Beam	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' Concrete Anchor Block	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	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
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
d4	38	Composite Recycled Blockout	Mondo Polymer GB14SH2 or Equivalent	–	–
d5	27	13 5/8" Long, 8"x6"x1/4" Steel Blockout	ASTM A500 Gr. B	*ASTM A123	–
d6	2	16D Double Head Nail	–	–	–

Midwest Roadside Safety Facility

Hawaii Buried in Backslope Test No. HBIB–6

Bill of Materials

SHEET: 33 of 35
DATE: 09/25/2025
DRAWN BY: JJO
DWG. NAME. HBIB–6_R15
SCALE: None
UNITS: in.
REV. BY: KAL

Figure 70. Bill of Materials, Page 1, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
e1	14	61" Unbent Length #4 Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
e2	12	51" Unbent Length #4 Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
e3	27	32" Long #4 Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
e4	12	138 1/2" Long #8 Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
e5	23	103" Unbent Length #4 Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
e6	8	12" Long Unbent #4 Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
e7	1	48" Long #4 Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
e8	2	67" Unbent Length #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 A459 Gr. 5 or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f3	1	5/8" Dia. UNC, 2" Long Guardrail Bolt	ASTM A307 Gr. A	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	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
f9	1	3/4 Dia, Unthreaded Spacer Sleeve	ASTM A53 Gr. B	ASTM A123	FMM03-04

Midwest Roadside Safety Facility

Hawaii Buried in Backslope Test No. HBIB-6

Bill of Materials

SHEET: 34 of 35

DATE: 09/25/2025

DRAWN BY: JJO

DWG. NAME. HBIB-6_R15

SCALE: None UNITS: in.

REV. BY: KAL

Figure 71. Bill of Materials, Page 2, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
g1	12	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	308	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	11	5/8" Dia. Hex Nut	ASTM A563A	ASTM A153 (AASHTO M232) for Class C or ASTM B695 (AASHTO M298) for Class 50	FNX16a
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	3/8" 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	–	–	–
k1	–	Soil	–	–	–
k2	1	Fascia	Min. f'c = 4,000 psi	–	–

* Components not required if optional anchor is used.

MwRSF
Midwest Roadside Safety Facility

Hawaii Buried in Backslope
Test No. HBIB–6

Bill of Material

SHEET: 35 of 35
DATE: 09/25/2025
DRAWN BY: JJO
DWG. NAME. HBIB–6_R15
SCALE: 1:768
UNITS: in.
REV. BY: KAL

Figure 72. Bill of Materials, Page 3, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

Figure 73. Test Installation Photographs, Test No. HBIB-6

Figure 74. Test Installation Photographs, Test No. HBIB-6

Figure 75. Test Installation Photographs, System Anchorage, Test No. HBIB-6

6 FULL-SCALE CRASH TEST NO. HBIB-6

6.1 Static Soil Test

Before full-scale crash test no. HBIB-6 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-6 was conducted on August 27, 2024, at approximately 2:30 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-6

Temperature	93°F
Humidity	46%
Wind Speed	7 mph
Wind Direction	350° from True North
Sky Conditions	Partly Cloudy
Visibility	8 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.00 in.
Previous 7-Day Precipitation	0.09 in.

6.3 Test Description

Initial vehicle impact was to occur 192 in. upstream from the centerline splice between post nos. 29 and 30 (42 in. upstream from post no. 31), as shown in Figure 76. The CIP for test no. HBIB-6 was selected using the recommended TL-3 test matrix Table 2-3 of MASH in the reverse-direction to maximize the risk of snagging on the W-beam rubrail termination. The 5,061-lb crew cab pickup truck impacted the HBIB system in the reverse direction at a speed of 62.7 mph and at an angle of 24.9 degrees. The actual point of impact was 197.6 in. upstream from the centerline splice between post nos. 29 and 30. During the impact event, the vehicle's right-front wheel snagged between the upper and lower rails at post no. 26 and detached. At 0.990 sec the vehicle exited the system at a speed of 22.3 mph and an angle of 17.4 degrees. The vehicle re-entered the system at 2.984 sec and came to rest 98.1 ft downstream from impact and 0.1 ft laterally in front of the slope break point.

A detailed description of the sequential impact events is reported in Tables 7 and 8. Sequential photographs are shown in Figures 77 and 78. Documentary photographs of the crash test are shown in Figure 79. The vehicle trajectory and final position are shown in Figure 80.

Figure 76. Target Impact Location, Test No. HBIB-6

Table 7. Sequential Description of Impact Events, Test No. HBIB-6

Time sec	Event
0.000	Vehicle's right-front bumper contacted barrier 5.6 in. upstream from targeted impact point and crushed. Vehicle's right-front fender contacted barrier and deformed.
0.018	Post nos. 31 and 32 rotated backward.
0.028	Post no. 32 twisted clockwise. Vehicle's hood became ajar.
0.050	Post no. 33 twisted clockwise.
0.060	Post no. 31 bent downstream and twisted counterclockwise. Post no. 30 rotated backward.
0.078	Vehicle yawed away from barrier.
0.100	Post no. 30 bent downstream and twisted counterclockwise.
0.128	Post no. 29 rotated backward.
0.133	Occupant's head contacted right-front side window and vehicle's right-front side door became ajar at top.
0.138	Vehicle's right-front door contacted barrier and encountered dents and tears.
0.162	Vehicle rolled toward barrier.
0.194	Post no. 29 bent downstream and twisted counterclockwise.
0.218	Post no. 28 rotated backward.
0.246	Vehicle's right-rear bumper contacted rail and deformed outward.
0.264	Post no. 28 bent downstream and twisted counterclockwise.
0.288	Vehicle's right-rear door was scraped from contact barrier.
0.318	Post no. 27 rotated backward.
0.326	Vehicle's right headlight contacted post no. 28 and detached. Vehicle became parallel to system at a speed of 40.3 mph.
0.346	Vehicle's left-rear tire became airborne.
0.406	Post no. 27 bent downstream and twisted counterclockwise.
0.440	Vehicle's left-front tire became airborne.
0.556	Vehicle rolled away from barrier.
0.613	Vehicle's left-rear tire became airborne.
0.630	Vehicle's right-front tire snagged on post no. 26 and detached.
0.672	Post no. 26 rotated backward, bent downstream, and twisted counterclockwise.
0.846	Vehicle's left-rear tire contacted ground.
0.858	Vehicle's left-front tire contacted ground.
0.904	Vehicle yawed toward barrier.
0.992	Vehicle exited the system at a speed of 22.3 mph and an angle of 17.4 degrees.
1.062	Vehicle rolled toward barrier.

Table 8. Sequential Description of Impact Events, Test No. HBIB-6, Cont.

Time (sec)	Event
1.125	Vehicle's grill detached.
1.312	Vehicle's left-rear tire contacted ground.
1.338	Vehicle's left-front tire became airborne.
1.396	Vehicle's left-front tire contacted ground.
2.984	Vehicle's right-front bumper contacted barrier again.
3.033	Post no. 18 rotated backward and twisted counterclockwise.
3.467	Vehicle's right side mirror contacted barrier and bent backward.
4.238	Vehicle and system both came to rest.

0.000 sec

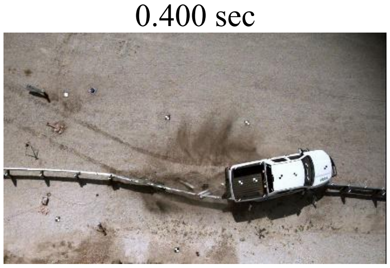
0.000 sec

0.200 sec

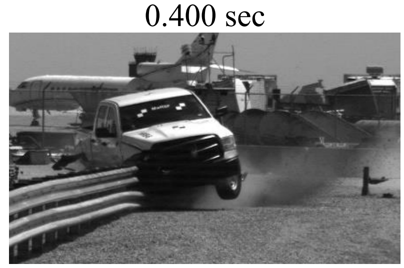
0.200 sec

0.400 sec

0.400 sec

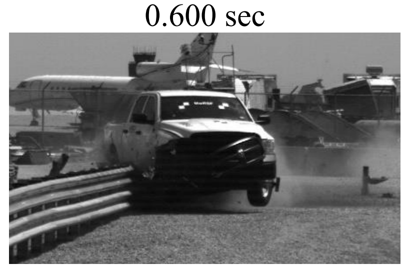


0.600 sec

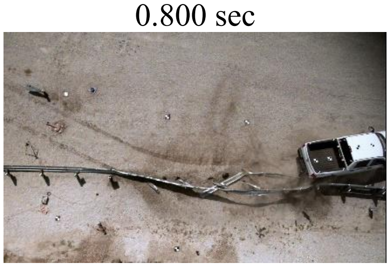


0.600 sec

0.800 sec



0.800 sec



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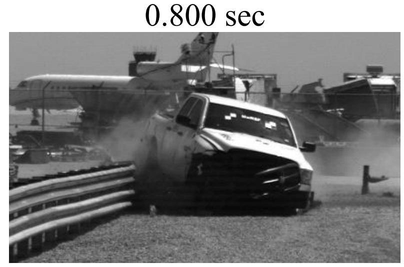


1.000 sec

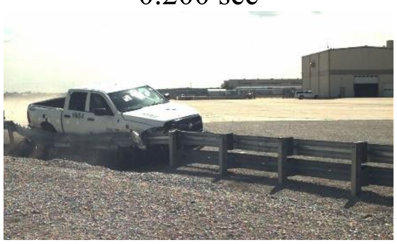
Figure 77. Sequential Photographs, Test No. HBIB-6


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


1.000 sec

Figure 78. Sequential Photographs, Test No. HBIB-6

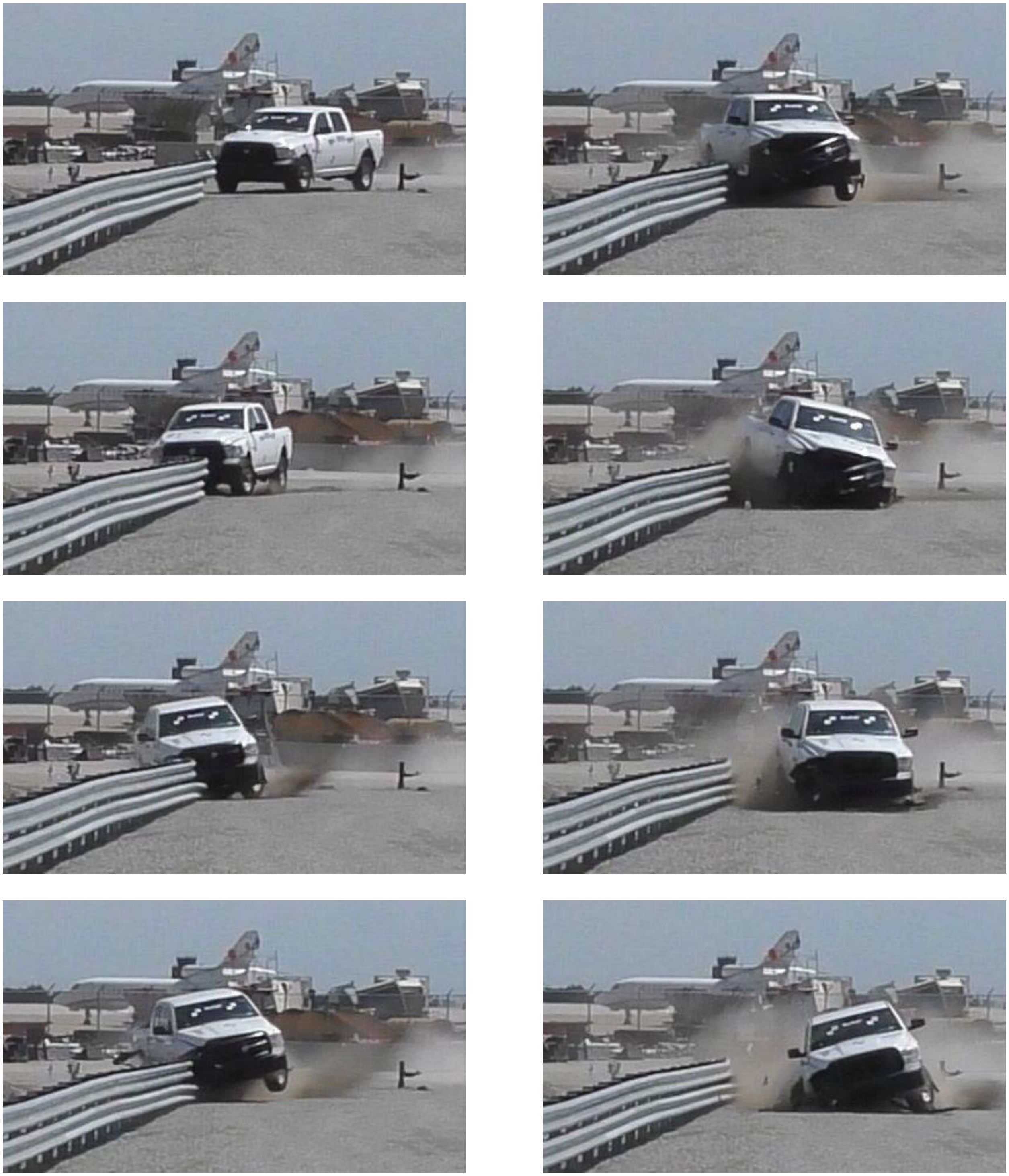


Figure 79. Documentary Photographs, Test No. HBIB-6

Figure 80. Vehicle Final Position and Trajectory Marks, Test No. HBIB-6

6.4 Barrier Damage

Damage to the barrier was severe, as shown in Figures 81 through 86. Barrier damage consisted of kinks, rail flattening, bending, gouging, and bolt hole tearing. The length of vehicle contact along the barrier was approximately 31 ft which spanned from the centerline of post no. 32 to the vehicle's final position near post no. 27. Secondary contact occurred 23 in. upstream from the centerline of post no. 17 and extended 65 in. downstream.

Damage to the rail was primarily located along both the top and bottom rails. The top rail showed significant contact marks, with the primary mark located at the centerline of post no. 32, extending 31 in. downstream along the top rail. Another contact mark appeared 23 in. upstream from the centerline of post no. 17 and extended 65 in. downstream. On the bottom rail, a contact mark began at the downstream centerline of post no. 28 and extended for 104 in. with a consistent width of 3 in. Flattening of the top rail was observed 51 in. downstream from post no. 32, continuing 22 in. along the entire vertical face of the rail. Additional damage included a bend in the rail beginning at the centerline of post no. 32 measuring 30 in. long, 16 in. wide, and 4½ in. deep. Kinks were noted along the top rail, specifically at the centerline of post no. 32, extending 15 in. Bolt hole pullouts occurred along the top rail between post nos. 27 and 38. The bottom rail also exhibited bolt hole pullouts between post nos. 27 and 29. Additional damage to the top rail included tearing near bolt holes at post nos. 26, 27, 24, and 31. Tears were observed on the top rail 5 in. downstream from post no. 30 and 10 in. downstream from post no. 28, both measuring 5 in. wide.

Several posts showed substantial deformation. Post no. 26 exhibited a kink on the front flange starting 22½ in. from the ground and measuring 1½ in. in both length and width. This post also experienced lower rail pullout, and the blockout disengaged. The front flange of post no. 27 was bent beginning 37 in. from the ground and extending 10 in. Both upper and lower rail pullouts were observed here, with the top blockout disengaged. Additionally, a 4-in. long by 1-in. wide kink was found on the upstream side of the flange of post no. 27 beginning 20 in. from the ground. Post no. 28 had a 4-in. long by 1-in. wide kink on the downstream side of the front flange. Both the upper and lower rails pulled out, and the blockout disengaged. Further deformation was recorded on post no. 29, including flange flattening, upper and lower rail pullouts, bolt hole tearout, and blockout disengagement. The lower bolt of post no. 29 remained intact, but the post was visibly bent. At post no. 30, a kink was observed on the downstream side of the front flange, starting 7½ in. from the ground and extending 8 in. with a width of 1½ in. This post also had upper rail pullout and bottom rail bolt hole tearout, with the top blockout disengaged. Post no. 31 experienced bending in both the front and rear flanges as well as the web, with the blockout disengaged. Post nos. 27 and 28 deflected 15 degrees backward and rotated 30 degrees counterclockwise, while post no. 29 deflected 20 degrees backward with a slight counterclockwise rotation.

The impact resulted in bolt deformation across various posts. At post no. 27, the upper and lower bolts exhibited bending, with the top bolt showing a pronounced bend while the bottom bolt had only minor bending. At post no. 28, the lower bolt fractured, and the upper bolt bent. Additionally, bending of the upper bolts was observed on post nos. 29 through 33. Blockouts at post nos. 32 and 33 rotated downstream, which caused the bolts at these posts to bend in the same direction. Between post nos. 34 and 38, the guardrail elongated and disengaged from the bolts, resulting in rail disengagement.

Figure 81. System Damage, Test No. HBIB-6

Figure 82. System Damage, Test No. HBIB-6

Figure 83. Upper Rail and Rubrail Damage Test No. HBIB-6

Figure 84. Post Damage Test No. HBIB-6

Figure 85. Post Damage, Post Nos. 26 (top left), 27 (bottom left), 28 (top right), and 29 (bottom right), Test No. HBIB-6

Figure 86. Post Damage, Post Nos. 30 through 33, Test No. HBIB-6

The maximum lateral permanent set of the barrier system was 46.4 in. at the rail near post no. 29, as measured in the field. The maximum lateral dynamic deflection of the rail was 54.4 in. at the rail at post no. 29. The maximum lateral dynamic deflection of the post was 29.7 in. at post no. 31, as determined from high-speed digital video analysis. The working width of the system was found to be 70.1 in., including vehicle overhang at the vehicle's rear bumper, also determined from high-speed digital video analysis. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 87.

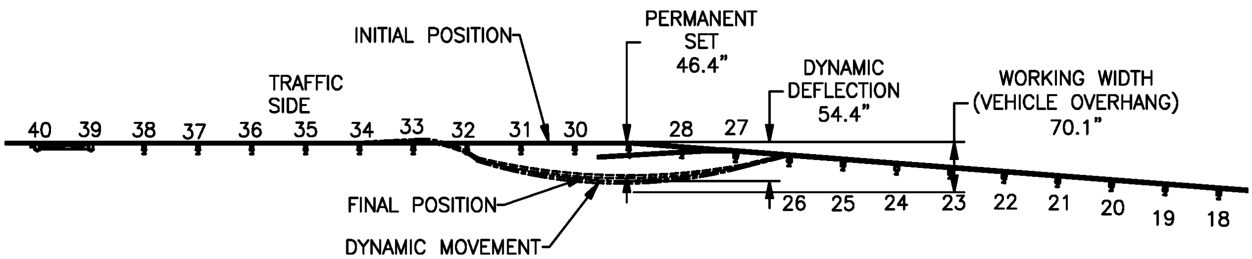


Figure 87. Permanent Set, Dynamic Deflection, and Working Width, Test No. HBIB-6

6.5 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 88 through 90. Note, the impact side of the vehicle, or the passenger's side, is referred to as the vehicle's right side throughout this report. 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 front end of the vehicle showed considerable deformation. The front bumper was crushed inward and twisted along the right side, with buckling in the center. The right-front fender was also damaged and it was pushed rearward and inward along its length. The grille and right headlight were detached, with the headlight itself broken. The hood was crushed inward and deformed along its right edge and the windshield displayed a crack on the right side. The damage continued along the right side of the vehicle. The right-front door had multiple dents, especially along the leading edge, with a tear measuring approximately 4 in. by 1½ in. The right rear door showed light scraping but no structural damage. The right side of the truck bed exhibited large dents from the wheel well to the rear bumper, causing the bed to fold inward. Although still attached, the right taillight was crushed. At the rear, the right side of the bumper buckled outward. The side windows remained intact.

The undercarriage and suspension components were also affected. The right-front suspension had damage, with the lower control arm and spring detached and the tie rod bent. The frame horn on the right side was bent inward, and the right front body mount was twisted.

The maximum occupant compartment intrusions are listed in Table 9, 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 88. Vehicle Damage, Test No. HBIB-6

Figure 89. Vehicle Damage, Test No. HBIB-6

Figure 90. Test Vehicle's Interior Floorboards and Undercarriage Damage, Test No. HBIB-6

Table 9. Maximum Occupant Compartment Intrusion by Location, Test No. HBIB-6

Location	Maximum Intrusion in.	MASH Allowable Intrusion in.
Wheel Well & Toe Pan	0.1	≤ 9
Floor Pan & Transmission Tunnel	0.0*	≤ 12
A-Pillar	0.2	≤ 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)	0.2	≤ 12
Side Door (Above Seat)	0.1	≤ 9
Side Door (Below Seat)	0.2	≤ 12
Roof	0.1	≤ 4
Windshield	0.0	≤ 3
Side Window	Intact	No shattering resulting from contact with structural member of test article
Dash	0.2	N/A

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

6.6 Occupant Risk

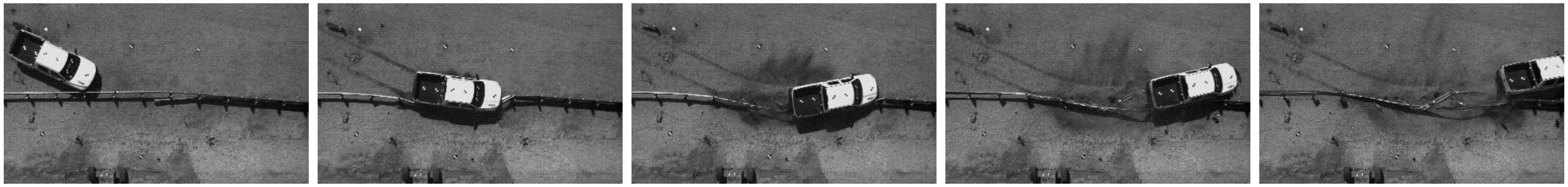
The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined by accelerometer data, are shown in Table 10. Note that the OIVs and ORAs were within suggested limits, as provided in MASH.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

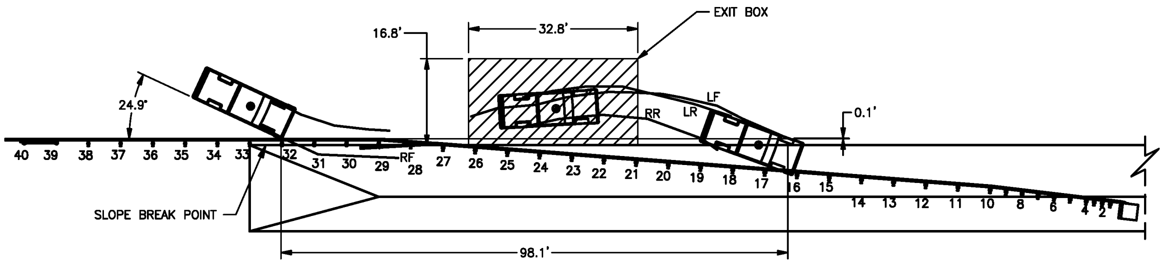
Table 10. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. HBIB-6

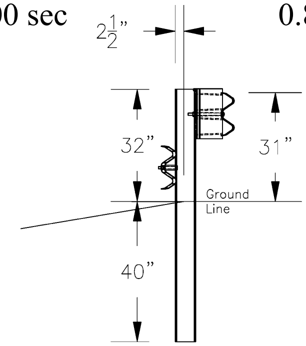
Evaluation Criteria		Transducer		MASH Limits
		SLICE-1 (backup)	SLICE-2 (primary)	
OIV ft/s	Longitudinal	-18.08	-17.63	±40
	Lateral	-12.11	-13.37	±40
ORA g's	Longitudinal	-13.40	-13.93	±20.49
	Lateral	-5.78	-5.92	±20.49
Maximum Angular Displacement deg.	Roll	14.6	-14.8	±75
	Pitch	-3.7	-3.7	±75
	Yaw	-37.7	-38.3	not required
THIV – ft/s		21.12	21.53	not required
PHD – g's		14.26	14.61	not required
ASI		0.55	0.59	not required

6.7 Discussion

The analysis of the test results for test no. HBIB-6 showed that the barrier system effectively contained and redirected the 2270P vehicle with controlled lateral displacements of the barrier. A summary of the test results and sequential photographs are shown Figure 91. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment, nor did they present an undue hazard to other traffic, pedestrians, or work-zone personnel. There were no deformations or intrusions into the occupant compartment that could have caused serious injury to an occupant. 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 G, were deemed acceptable because they did not adversely influence occupant risk nor cause rollover. After impact, the vehicle exited the barrier at an angle of 17.4 degrees with respect to the slope break point, and its trajectory did not violate the bounds of the exit box. Therefore, test no. HBIB-6 was deemed acceptable according to the MASH safety performance criteria for test designation 3-37a.







- Test Agency .... MwRSF
- Test Number HBIB-6
- Date 8/27/2024
- MASH Test Designation No. .... Modified 3-37a
- Test Article .... Hawaii DOT Buried in Backslope
- Total Length .... 219 ft – 4 in.
- Key Component – Steel W-beam Guardrail
  - Thickness .... 12 gauge
  - Top Mounting Height .... 31 in.
- Key Component – Steel Post
  - Shape W6x8.5
  - Length .... 96 in.
  - Embedment Depth .... Varies
  - Spacing .... 75 in.
- Key Component – Composite Recycled Blockout (Post Nos. 1-38)
  - Shape .... 14¼ x 8 x 5¼ in.
- Soil Type .... Coarse, Crushed Limestone (Well-Graded Gravel)
- Vehicle Make / Model .... 2018 Ram 1500
  - Curb .... 5,034 lb
  - Test Inertial .... 5,061 lb (MASH Limit 2,420 ± 55 lb)
  - Gross Static .... 5,222 lb (MASH Limit 2,585 ± 55 lb)
- Impact Conditions
  - Speed .... 62.7 mph (MASH Limit 62 ± 2.5 mph)
  - Angle .... 24.9 deg. (MASH Limit 15 ± 1.5 deg.)
  - Impact Location .... 197.6 in. US from centerline splice between post nos. 29 & 30
- Impact Severity .... 117.9 kip-ft > 106 kip-ft MASH minimum
- Exit Conditions
  - Speed .... 22.3 mph
  - Angle .... 17.4 deg
- Exit Box Criterion .... Pass
- Vehicle Stability .... Pass
- Vehicle Stopping Distance ...... 98.1 ft downstream, 0.1 ft laterally in front of slope break
- Vehicle Damage .... Moderate
  - VDS [15] 1-RFQ-4
  - CDC [16] 01-RFEE-9
  - Maximum Interior Deformation .... 0.2 in. at A-Pillar ≤ 5 in. MASH limit
- Test Article Damage .... Moderate
- Maximum Test Article Deflections
  - Permanent Set .... 46.4 in.
  - Dynamic .... 54.4 in.
  - Working Width .... 70.1 in.
- Transducer Data

Evaluation Criteria		Transducer		MASH Limits
		SLICE-1 (backup)	SLICE-2 (primary)	
OIV ft/s	Longitudinal	-18.08	-17.63	±40
	Lateral	-12.11	-13.37	±40
ORA g's	Longitudinal	-13.40	-13.93	±20.49
	Lateral	-5.78	-5.92	±20.49
Maximum Angular Displacement deg.	Roll	14.6	-14.8	±75
	Pitch	-3.7	-3.7	±75
	Yaw	-37.7	-38.3	not required
THIV – ft/s		21.12	21.53	not required
PHD – g's		14.26	14.61	not required
ASI		0.55	0.59	not required

Figure 91. Summary of Test Results and Sequential Photographs, Test No. HBIB-6

7 FULL-SCALE CRASH TEST NO. HBIB-7

7.1 Static Soil Test

Before full-scale crash test no. HBIB-7 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.

7.2 Weather Conditions

Test no. HBIB-7 was conducted on October 8, 2024, at approximately 1:30 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-7

Temperature	81°F
Humidity	20%
Wind Speed	9 mph
Wind Direction	210° from True North
Sky Conditions	Clear, Sunny
Visibility	7 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.00 in.
Previous 7-Day Precipitation	0.00 in.

7.3 Test Description

Initial vehicle impact was to occur 82½ in. upstream from centerline splice between post nos. 29 and 30 (45 in. upstream from post no. 30) as shown in Figure 92. The CIP for test no. HBIB-7 was selected using the recommended TL-3 test matrix Table 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 W-beam rubrail termination. The 2,419-lb small car impacted the HBIB system in the reverse direction at a speed of 63.8 mph and at an angle of 25.0 degrees between post nos. 29 and 30. The actual point of impact was 82.8 in. upstream from the centerline splice between post nos. 29 and 30. The vehicle came to rest 46.4 ft downstream from impact and 5.0 ft laterally in front of the system with no brakes applied.

A detailed description of the sequential impact events is reported in Table 12. Sequential photographs are shown in Figures 93 and 94. Documentary photographs of the crash test are shown in Figure 95. The vehicle trajectory and final position are shown in Figure 96 .

Figure 92. Target Impact Location, Test No. HBIB-7

Table 12. Sequential Description of Impact Events, Test No. HBIB-7.

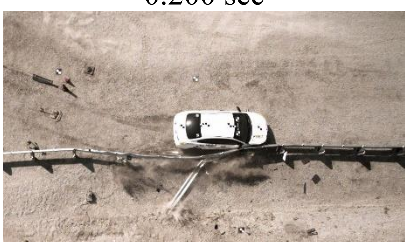
Time sec	Event
0.000	Vehicle's front bumper contacted rail 82.8 in. upstream from centerline splice between post nos. 29 and 30 and disengaged.
0.008	Vehicle's right headlight contacted barrier and disengaged.
0.014	Post nos. 30 and 31 rotated backward.
0.034	Vehicle yawed away from barrier.
0.042	Vehicle's right-front fender contacted barrier and was dented, crushed and scraped. Vehicle's right-front wheel contacted post no. 30 and was dented and scraped, tire disengaged from wheel.
0.054	Post no. 29 rotated backward. Post no. 30 bent downstream, twisted clockwise, and its blockout fractured and disengaged.
0.068	Vehicle rolled away from barrier.
0.076	Vehicle's hood contacted barrier and was bent inward and upward.
0.083	Vehicle's right-front door contacted barrier and was torn, dented and scraped.
0.092	Post no. 29 bent downstream and twisted clockwise and its blockout fractured and disengaged.
0.108	Post no. 28 rotated backward.
0.120	Post no. 27 rotated backward. Occupant head contacted right-front window.
0.166	Post no. 28 bent downstream and twisted clockwise, and its blockout disengaged.
0.288	Post no. 27 bent downstream and twisted clockwise. and both blockouts disengaged from rail.
0.406	Vehicle yawed toward barrier.
0.438	Vehicle's right-rear tire became airborne.
0.458	Vehicle's left-rear tire became airborne.
0.476	Lower rail post bolt pulled through the rail at post no. 26.
0.576	Vehicle's grille detached from vehicle.
0.722	Vehicle's left-rear tire contacted ground.
0.830	Vehicle rolled toward barrier.
0.894	Vehicle's right-rear tire contacted ground.
1.740	Vehicle exited system at a speed of 10.9 mph and an angle of 0.4 degrees.
2.336	System came to rest.
2.704	Vehicle came to rest.


0.000 sec


0.000 sec


0.200 sec


0.200 sec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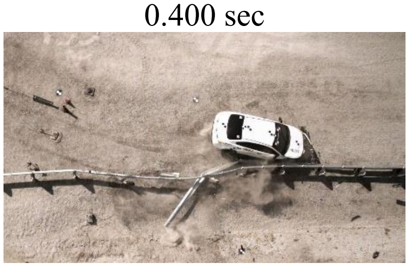
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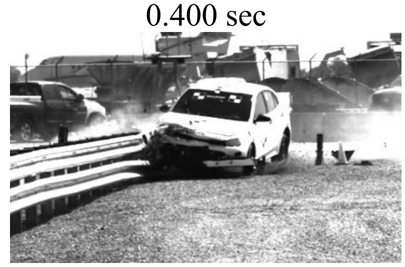
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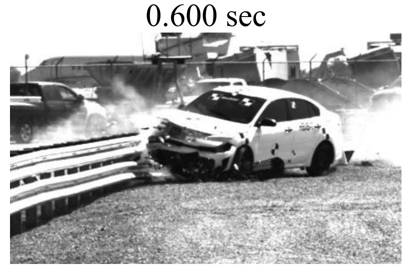
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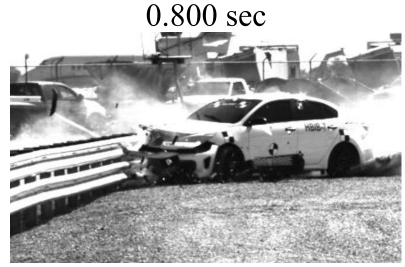
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Figure 93. Sequential Photographs, Test No. HBIB-7

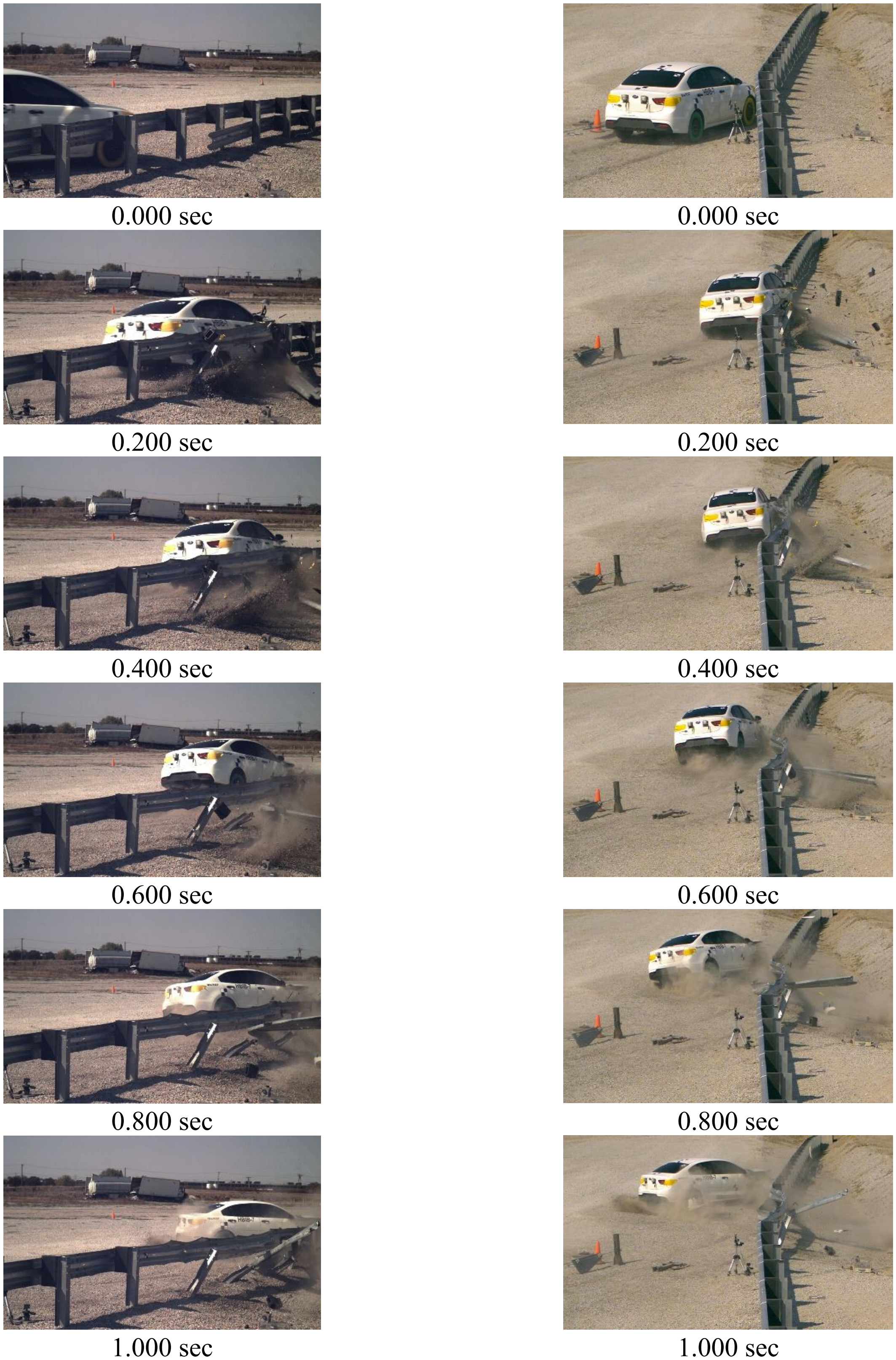

Figure 94. Sequential Photographs, Test No. HBIB-7

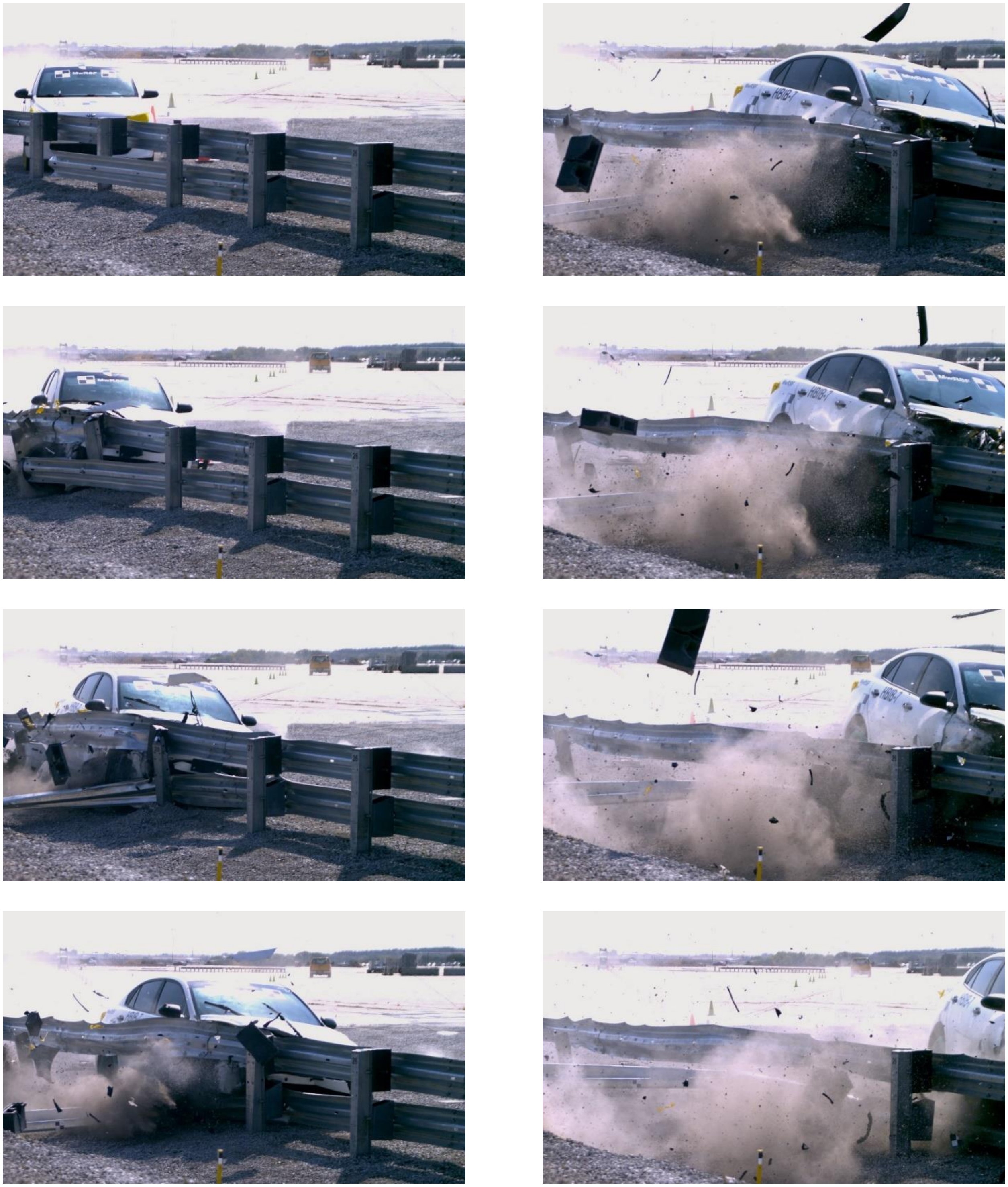

Figure 95. Documentary Photographs, Test No. HBIB-7

Figure 96. Vehicle Final Position and Trajectory Marks, Test No. HBIB-7

7.4 Barrier Damage

The damage to the barrier was moderate, as shown in Figures 97 through 100. Barrier damage consisted of kinks, rail flattening, bending, gouging, and bolt hole tearing. The length of vehicle contact along the barrier was approximately 24 ft – 11 in., which spanned 21 in. downstream from the centerline of post no. 31 to 20.4 in. downstream from post no. 27. Secondary contact occurred 196 in. upstream from the centerline of post no. 29 and ended between posts no. 26 and 27.

Damage to the rail was primarily located along both the top and bottom rails. The top rail showed significant contact marks, with the primary mark beginning at the centerline of post no. 31 and extending 21 in., with a consistent width of 15 in. downstream along the top rail. Additional damage included bends on the bottom rail located at the centerline of post no. 27, measuring 9 in. long by 3 in. wide by 5 in. deep at a height of 11 in. above ground, and at the centerline of post no. 28, measuring 5 in. long by 5 in. wide by 7 in. deep. Kinks were noted along the top rail from posts nos. 27 through 31, specifically 78 in. downstream from the centerline of post no. 31, and at the bottom rail 33 in. upstream from post no. 26. Additional damage included flattening 42¼ in. upstream from the centerline of post no. 29 measuring 151 in. long and 8 in. wide. Furthermore, a bolt hole tear occurred at the top rail at post no. 30 and at the bottom rail at post no. 28. The top rail bolt hole elongated between posts nos. 26 through 29 and at the bottom rail at posts nos. 26 and 27.

Post no. 27 exhibited a kink on the front flange starting 14½ in. from the ground, measuring 6 in. long and 1 in. wide. This post also experienced a bent flange in the front flange, measuring 21 in. long and ½ in. wide. At post no. 28, a kink on the front flange began 17 in. from the ground, measuring 2 in. long and ½ in. wide. The front flange of post no. 28 had a bend that measured 16 in. long and 1½ in. wide, and the blockout at this post disengaged. Post no. 29 had a 20-in. long and 2-in. wide bend on the front flange, a kink on the front flange starting 10 in. from the ground and measuring 2 in. long by ½ in. wide, a kink on the back flange starting 20 in. from the ground and measuring 5 in. long and ½ in. wide, and a disengaged blockout. The bottom downstream bolt hole on the front flange of post no. 30 was torn. Post no. 30 also exhibited two kinks on the front flange, one starting 20 in. from the ground and measuring 2 in. long and ½ in. wide and another starting 6 in. from the ground and measuring 3 in. long and ½ in. wide, and the blockout was disengaged. The bottom rail pulled out from the bolts on posts no. 25 through 29. The top rail pulled out from the bolts on posts no. 27 through 30, and the bolts on posts no. 27 through 30 were bent.

Several posts showed substantial deformation. The top of post no. 27 deflected 9 in. backward and 28 in. downstream, and the post rotated 40 degrees clockwise. Post no. 28 deflected 17 in. backward and 35 in. downstream with a 70-degree clockwise rotation. Post no. 29 deflected 6 in. backward and 39 in. downstream with an 80-degree clockwise rotation and bent 39 in. from the top of the post. Post no. 30 deflected 5 in. backward and 13 in. downstream and rotated 30 degrees clockwise.

Figure 97. Overall System Damage Test No. HBIB-7

Figure 98. System Damage Test No. HBIB-7

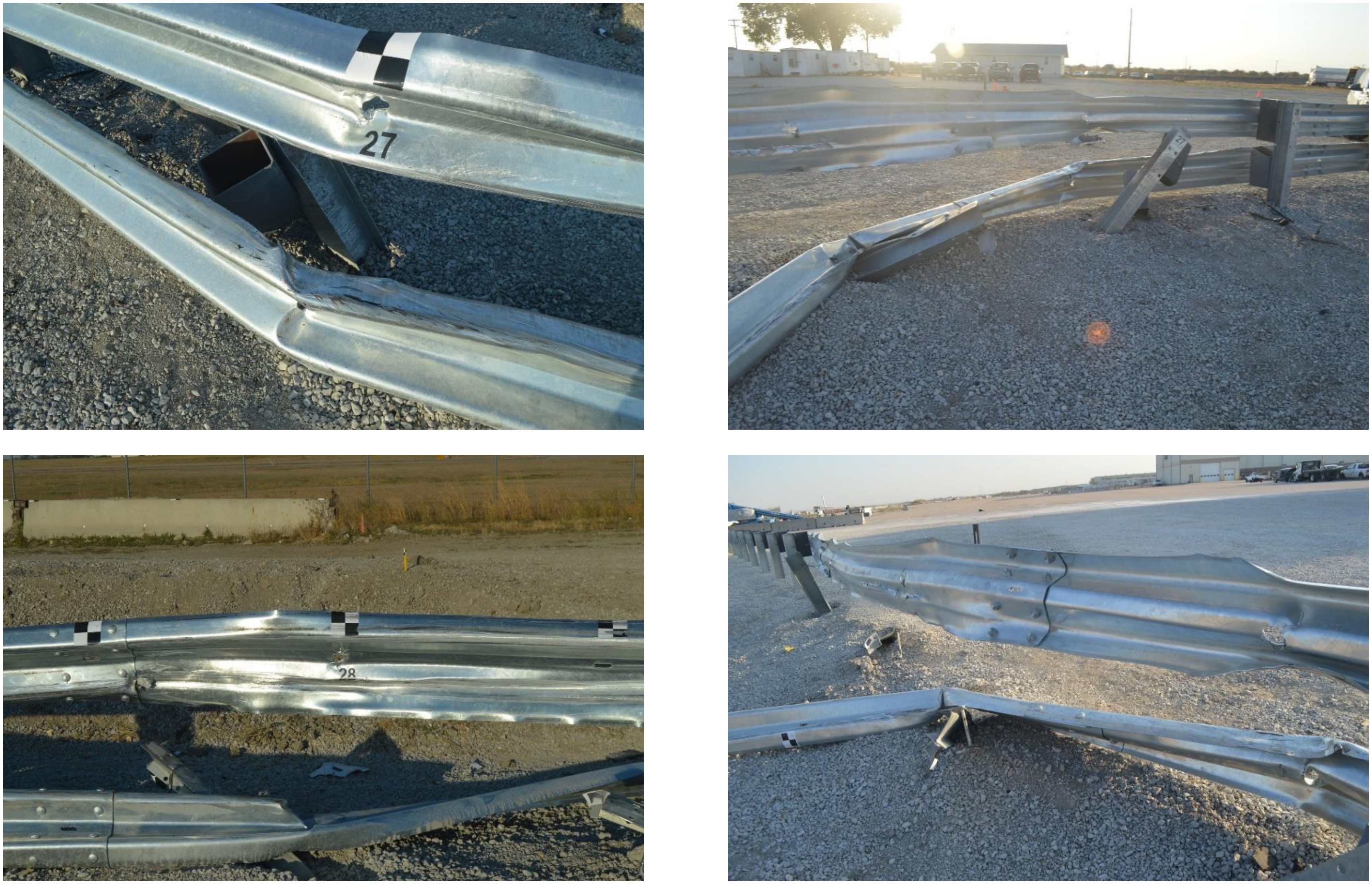

Figure 99. Upper Rail and Rubrail Damage Test No. HBIB-7

Figure 100. Post Damage, Post Nos. 27 through 30, Test No. HBIB-7

The maximum lateral permanent set of the barrier system was 88.9 in. at the rail in post no. 29, as measured in the field. The maximum lateral dynamic deflection of the upper rail was 30.0 in. at post no. 29. The maximum lateral dynamic deflection of the lower rail was 108.5 in. at post no. 29. The maximum lateral dynamic deflection of the post was 21.3 in. at post no. 28. All dynamic deflections were determined from high-speed digital video analysis. The working width of the system was found to be 130.0 in. at the free end of the rub rail, also determined from high-speed digital video analysis. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 101.

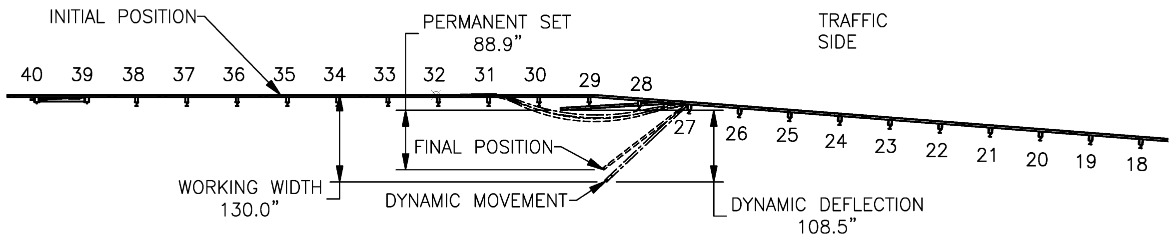

Figure 101. Permanent Set, Dynamic Deflection, and Working Width, Test No. HBIB-7

7.5 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 102 and 103. 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 disengaged from the vehicle. The bumper bar was dented and crushed slightly rearward. The right headlight disengaged. The hood was bent in and upward at the right leading end. The fender was crushed, dented, and scraped throughout, with the majority of the damage located just above the wheel opening and behind the headlight area. Damage from the fender extended to the door panel, which had a 5-in. high and 5-in. long tear with some of the sheet metal folded back. The door panel was dented and had a 13-in. long scrape just behind the tear. The right-front wheel was dented and scraped in several places around the outer perimeter with the tire detached but still present. The tire was pinched between the wheel and the firewall. The side windows and windshield remained undamaged.

The undercarriage and suspension components were also affected. The right front strut was bent at both the lower mount and at the upper spring location. The front sway bar shifted toward the right side of the vehicle, with the right end of the sway bar—near its connection to the tie-rod end link—bent inward toward the motor. The right-front lower control arm was bent downward in the center and bent upward from its attachment point on the front subframe, forming a peak at the midpoint. The arm was torn from the front pivot. The left-front side lower control arm was tilted upward slightly from its attachment points on the front subframe. The right inner tie rod was bent slightly.

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

Figure 102. Vehicle Damage, Test No. HBIB-7

Figure 103. Test Vehicle's Interior Floorboards and Undercarriage Damage, Test No. HBIB-7

Table 13. Maximum Occupant Compartment Intrusion by Location, Test No. HBIB-7

Location	Maximum Intrusion in.	MASH Allowable Intrusion in.
Wheel Well & Toe Pan	0.2	≤ 9
Floor Pan & Transmission Tunnel	0.2	≤ 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)	0.1	≤ 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	0.2	N/A

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

7.6 Occupant Risk

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined 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-7

Evaluation Criteria		Transducer		MASH Limits
		SLICE-1 (primary)	SLICE-2 (backup)	
OIV ft/s	Longitudinal	-22.06	-22.18	±40
	Lateral	-15.50	-15.50	±40
ORA g's	Longitudinal	-12.45	-12.20	±20.49
	Lateral	-8.54	-9.25	±20.49
Maximum Angular Displacement deg.	Roll	-10.2	-9.2	±75
	Pitch	-5.2	-4.4	±75
	Yaw	-31.4	-30.1	not required
THIV – ft/s		27.33	27.08	not required
PHD – g's		13.61	13.39	not required
ASI		0.90	0.90	not required

7.7 Discussion

The analysis of the test results for test no. HBIB-7 showed that the barrier system effectively contained and redirected the 1100C vehicle with controlled lateral displacements of the barrier. A summary of the test results and sequential photographs are shown in Figure 104. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment, nor did they present an undue hazard to other traffic, pedestrians, or work-zone personnel. There were no deformations or intrusions into the occupant compartment that could have caused serious injury to an occupant. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix H, were deemed acceptable because they did not adversely influence occupant risk nor cause rollover. After impact, the vehicle exited the barrier at an angle of 20.3 degrees with respect to the slope break point, and its trajectory did not violate the bounds of the exit box. Therefore, test no. HBIB-7 was deemed acceptable according to the MASH safety performance criteria for test designation 3-37b.

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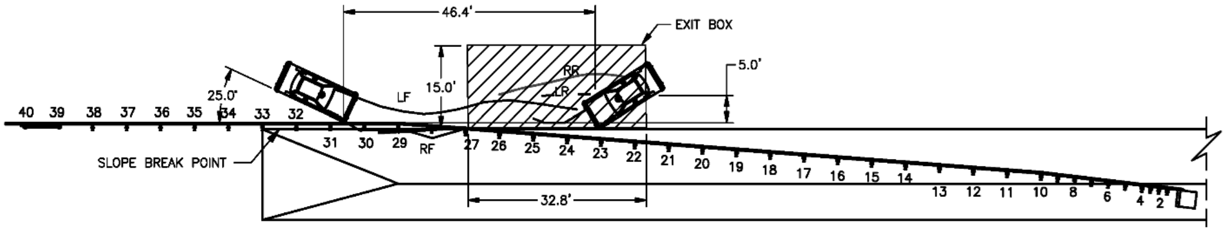
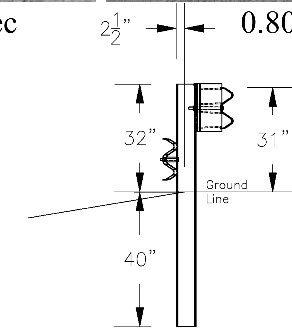




- Test Agency .... MwRSF
- Test Number HBIB-7
- Date 10/8/2024
- MASH Test Designation No. .... Modified 3-37b
- Test Article .... Hawaii DOT Buried in Backslope
- Total Length .... 219 ft – 4 in.
- Key Component – Steel W-beam Guardrail
  - Thickness .... 12 gauge
  - Top Mounting Height .... 31 in.
- Key Component – Steel Post
  - Shape W6x8.5
  - Length .... 96 in.
  - Embedment Depth .... Varies
  - Spacing .... 75 in.
- Key Component – Composite Recycled Blockout (Post Nos. 1-38)
  - Shape .... 14¼ x 8 x 5¼ in.
- Soil Type .... Coarse, Crushed Limestone (Well-Graded Gravel)
- Vehicle Make / Model .... 2018 Kia Rio
  - Curb .... 2,467 lb
  - Test Inertial .... 2,419 lb (MASH Limit 2,420 ± 55 lb)
  - Gross Static .... 2,577 lb (MASH Limit 2,585 ± 55 lb)
- Impact Conditions
  - Speed .... 63.8 mph (MASH Limit 62 ± 2.5 mph)
  - Angle .... 25.0 deg. (MASH Limit 15 ± 1.5 deg.)
  - Impact Location .... 82.8 in. US from centerline splice between post nos. 29 & 30
- Impact Severity .... 58.8 kip-ft ≥ 51 kip-ft MASH minimum
- Exit Conditions
  - Speed .... 10.9 mph
  - Angle .... 0.4 deg
- Exit Box Criterion .... Pass
- Vehicle Stability .... Pass
- Vehicle Stopping Distance. 46.4 ft downstream, 5.0 ft. laterally in front of slope break
- Vehicle Damage .... Moderate
  - VDS [15] 1-RFQ-5
  - CDC [16] 01-RFEE-9
- Maximum Interior Deformation ... 0.2 in. at wheel well & toe pan ≤ 9-in. MASH limit
- Test Article Damage .... Moderate
- Maximum Test Article Deflections
  - Permanent Set .... 88.9 in.
  - Dynamic .... 108.5 in.
  - Working Width .... 130.0 in.
- Transducer Data

Evaluation Criteria		Transducer SLICE-1 (primary)	Transducer SLICE-2 (backup)	MASH Limits
OIV ft/s	Longitudinal	-22.06	-22.18	±40
	Lateral	-15.50	-15.50	±40
ORA g's	Longitudinal	-12.45	-12.20	±20.49
	Lateral	-8.54	-9.25	±20.49
Maximum Angular Displacement deg.	Roll	-10.2	-9.2	±75
	Pitch	-5.2	-4.4	±75
	Yaw	-31.4	-30.1	not required
THIV – ft/s		27.33	27.08	not required
PHD – g's		13.61	13.39	not required
ASI		0.90	0.90	not required

Figure 104. Summary of Test Results and Sequential Photographs, Test No. HBIB-7

8 FULL-SCALE CRASH TEST NO. HBIB-8

8.1 Static Soil Test

Before full-scale crash test no. HBIB-8 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.

8.2 Weather Conditions

Test no. HBIB-8 was conducted on December 6, 2024, at approximately 2:30 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-8

Temperature	52°F
Humidity	30%
Wind Speed	9 mph
Wind Direction	230° from True North
Sky Conditions	Clear, Sunny
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.97 in.
Previous 7-Day Precipitation	0.97 in.

8.3 Test Description

The targeted vehicle impact was to occur 69¼ in. upstream from the upstream end of the concrete anchor block as shown in Figure 105. The CIP for test no. HBIB-8 was selected using the recommended TL-3 test matrix Table 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, but the calculated value for "X" was multiplied by the ratio of the effective nominal impact angle affected by the flare divided by the MASH test designation impact angle. The first flare rate was used for the calculation, which had an effective flare angle of 4.4 degrees. Thus, "X" was multiplied by 20.6/25 = 0.824. The 5,000-lb quad cab pickup truck impacted the slope break point of the system in the reverse direction at a speed of 61.5 mph and at an angle of 24.9 degrees and impacted the barrier at a speed of 61.5 mph and at an angle of 27.5 degrees. The actual point of impact was 67.0 in. upstream from the upstream end of the concrete anchor block. The vehicle came to rest 147.2 ft downstream and 34.0 ft laterally behind the slope break point without brakes applied.

A detailed description of the sequential impact events is reported in Table 16. Sequential photographs are shown in Figures 106 and Figure 107. Documentary photographs of the crash test are shown in Figure 108. The vehicle trajectory and final position are shown in Figure 109.

Figure 105. Target Impact Location, Test No. HBIB-8

Table 16. Sequential Description of Impact Events, Test No. HBIB-8

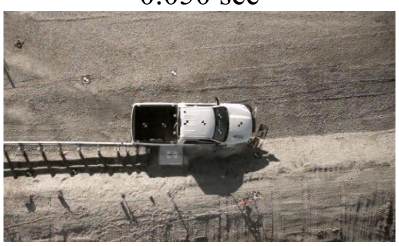
Time sec	Event
-0.236	Vehicle rolled toward barrier and traversed slope break point.
-0.158	Vehicle's right-front tire became airborne.
-0.088	Vehicle's right-rear tire became airborne.
-0.036	Vehicle's left-front tire became airborne.
0.000	Vehicle's front bumper contacted rail 67.0 in. upstream from upstream end of concrete anchor and was dented and crushed inward. Vehicle's right headlight contacted rail and shattered. Vehicle's right fender contacted rail and was crushed and torn.
0.012	Post nos. 1 through 4 rotated backward. Vehicle's right-front tire contacted ground.
0.018	Post no. 5 rotated backward. Vehicle's left headlight disengaged.
0.028	Vehicle yawed away from the barrier. Vehicle's right-front door contacted rail and was buckled and torn.
0.050	Vehicle's left-rear tire became airborne. Vehicle's roof deformed.
0.068	Vehicle rolled away from the barrier.
0.076	Vehicle's right-rear tire contacted ground.
0.086	Vehicle's grille contacted rail and was disengaged.
0.096	Vehicle's right-front window shattered.
0.104	Occupant's head contacted B-pillar.
0.130	Vehicle's right-rear door contacted rail and was buckled and torn.
0.160	Vehicle's C-pillar contacted rail and was torn.
0.172	Vehicle's right quarter panel contacted rail and was dented inward, scraped, and torn.
0.188	Vehicle's right taillight contacted rail and cracked.
0.196	Vehicle's rear bumper contacted rail and was dented and bent backward.
0.232	Vehicle yawed toward the barrier.
0.267	System came to a rest.
0.296	Vehicle's left-rear tire contacted ground.
0.306	Vehicle exited system at a speed of 48.0 mph speed and an angle of -8.3 degrees with respect to the barrier.
0.434	Vehicle's left-front tire contacted ground.
3.808	Vehicle came to rest.


0.000 sec


0.000 sec


0.050 sec


0.050 sec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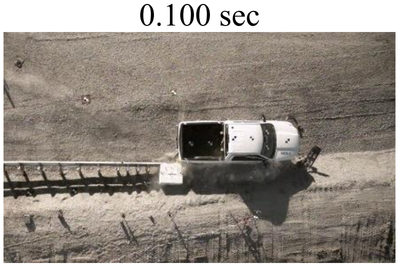
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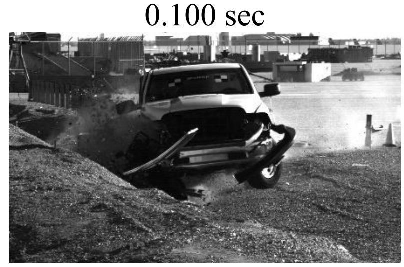
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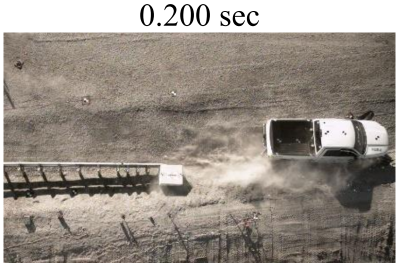
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Figure 106. Sequential Photographs, Test No. HBIB-8

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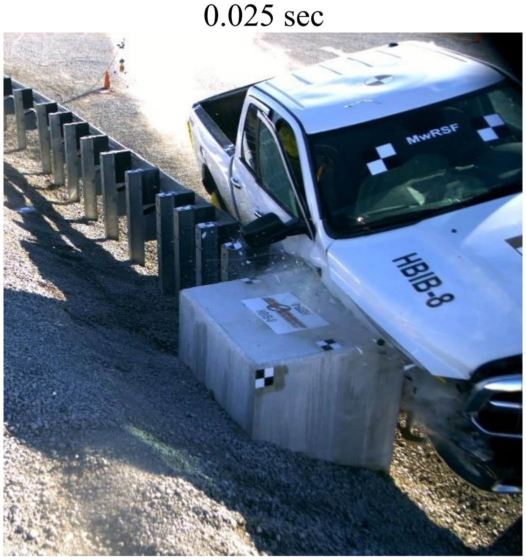

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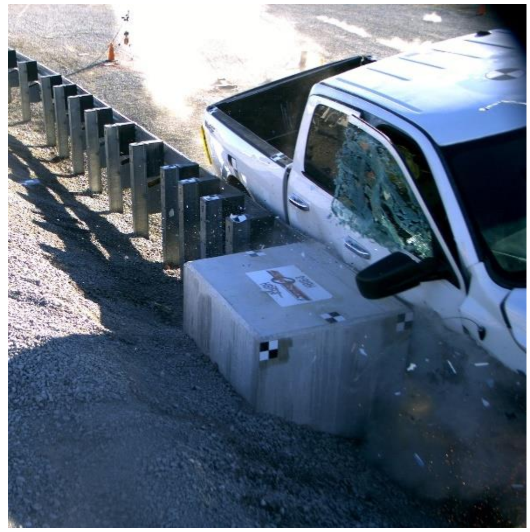

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Figure 107. Sequential Photographs, Test No. HBIB-8

Figure 108. Documentary Photographs, Test No. HBIB-8

Figure 109. Vehicle Final Position and Trajectory Marks, Test No. HBIB-8

8.4 Barrier Damage

The damage to the barrier was minimal, as shown in Figures 110 and 111. Barrier damage consisted of kinks and rail flattening. The length of vehicle contact along the barrier was approximately 108½ in. which spanned from 6¼ in. upstream from the centerline of post no. 3 through to the end of the concrete anchor. The primary contact mark spanned the bottom corrugation of the top rail and both corrugations of the bottom rail, beginning at the centerline of post no. 3 and extending downstream to the end of the concrete anchor.

A series of kinks on the top rail was observed 25 in. downstream from post no. 1 measuring 19½ in. long, 2 in. wide, ½ in. deep, and 24 in. downstream from post no. 1 measuring 17 in. long, 2 in. wide, ½ in. deep. The bottom flange of the top rail and the top flange of the bottom rail had a series of kinks 24 in. downstream from post no. 1 measuring 17 in. long, 2 in. wide, ½ in. deep. The bottom rail had a series of kinks 24 in. downstream from post no. 1 measuring 20 in. long, 2 in. wide, ½ in. deep.

Additional damage included flattening of the bottom rail 5 in. upstream from the centerline of post no. 1 measuring 17 in. long, 2 in. wide, and 1 in. deep. A kink was found on the top flange of the top rail 6 in. downstream from the centerline of post no. 3 measuring 18 in. long and 2 in. wide. The blockout at post no. 1 had two tears: a 5-in. long vertical tear at the top on the upstream side, and a 6-in. long vertical tear at the bottom on the downstream side.

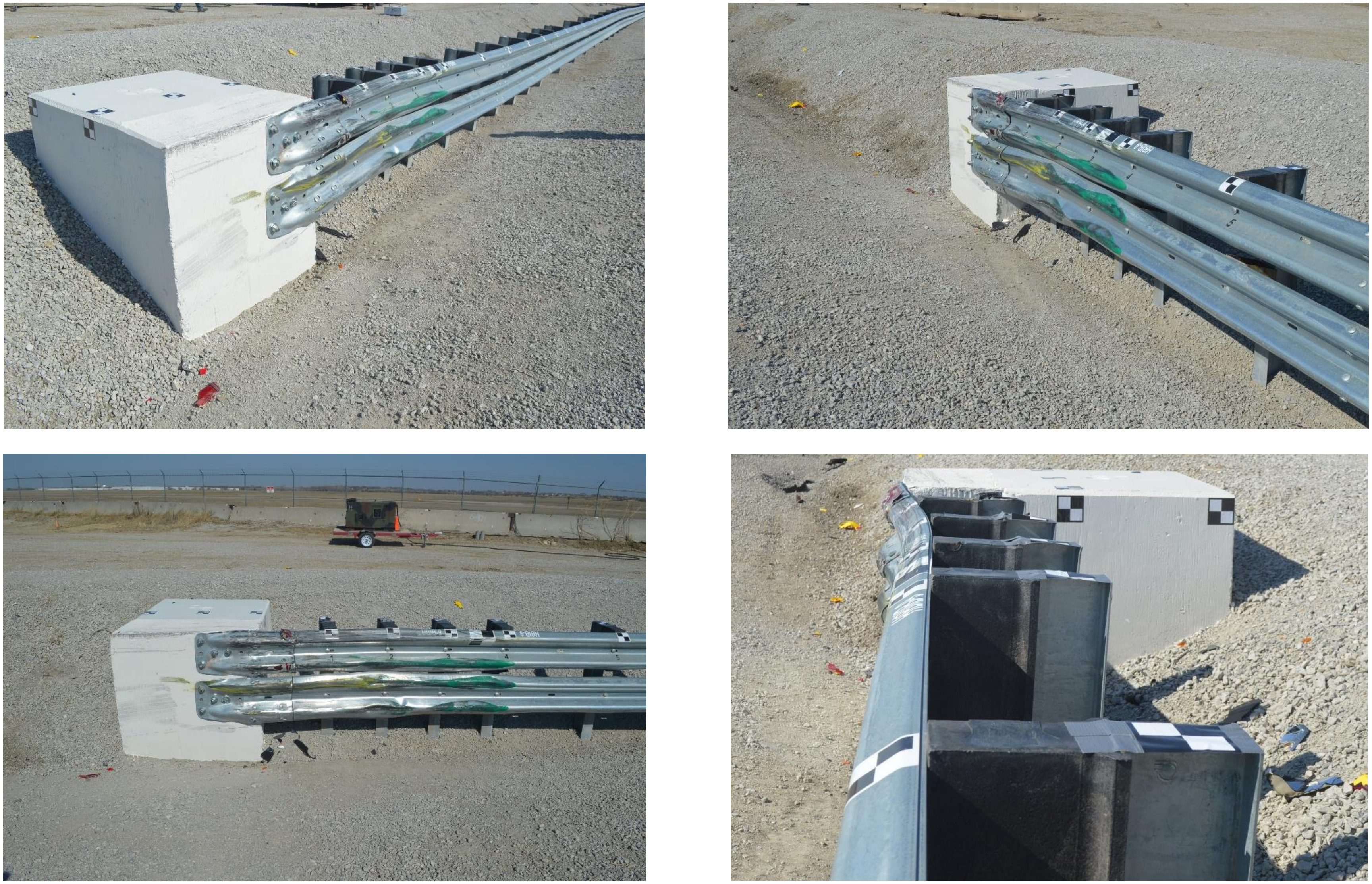


Figure 110. System Damage, Test No. HBIB-8

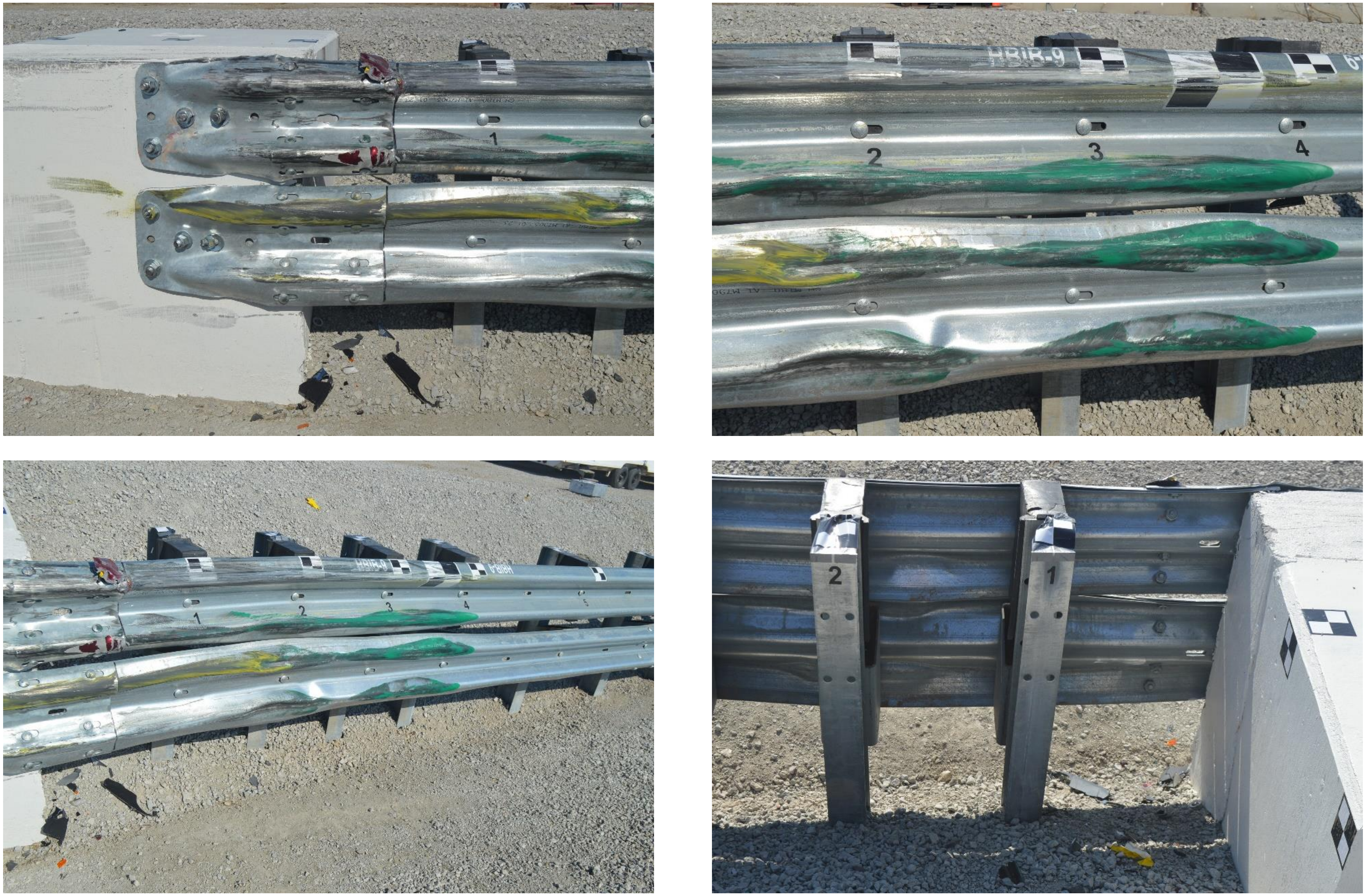


Figure 111. Upper Rail and Rub rail Damage, Test No. HBIB-8

The maximum lateral permanent set of the barrier system was 0.7 in. at post no. 2, as measured in the field. The maximum lateral dynamic deflection of the rail was 2.9 in. at the rail at post no. 2. The maximum lateral dynamic deflection of the post was 3.1 in. at post no. 2. The maximum lateral dynamic deflection of the anchorage was 2.8 in. at the upstream concrete anchor, as determined from high-speed digital video analysis. The working width of the system was found to be 20.3 in. at post no. 2, also determined from high-speed digital video analysis. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 112.

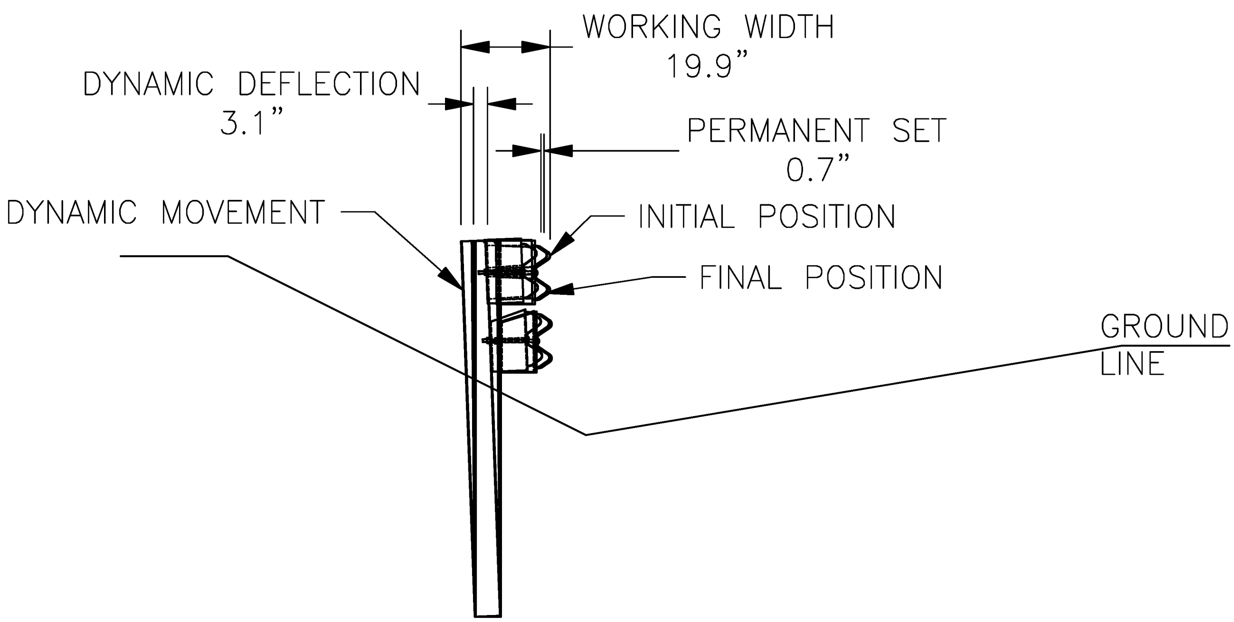


Figure 112. Permanent Set, Dynamic Deflection, and Working Width, Test No. HBIB-8

8.5 Vehicle Damage

The damage to the vehicle was severe, as shown in the Figures 113 through 116. The majority of the damage was concentrated on the right-front corner and right side of the vehicle where the impact had occurred. A large dent was found on the right-front corner of the front bumper. Both headlights and the grille were disengaged from the vehicle. The right one-third of the rear bumper was bent backward at roughly a 45-degree angle, leading to protrusion of the bumper's corner and an inward buckle at the point of bending. Denting and buckling were found along the entire length of the right side of the truck bed with a width of approximately 10 to 16 in. midway up the bed and along the top of the wheel opening. A gouge approximately 3 in. in length was found on the leading edge of the box.

The middle section of the right-rear door was dented and buckled. A 2-in. gouge was found on the trailing edge of the right-rear door, and a 10-in. gouge was found on the door's leading edge. The right-front door panel buckled along the middle of the door. There was a gap at the top of the right-front door where it no longer sat flush with the vehicle's frame. The leading edge of the door panel was buckled and torn approximately 4 in. rearward. Severe crushing and denting were located at the top of the wheel opening with scrapes and gouges throughout the right-front side of the vehicle.

The undercarriage and suspension components were also affected, as shown in the Figure 116. The right-front shock and spring were bent rearward and inward toward the vehicle. The left shock remained intact. The end link was disengaged from the sway bar and the vehicle on the right side. The right steering knuckle was also disengaged from the vehicle. The left-side steering knuckle sustained two minor scrapes where it contacted the lower control arm. The front right lower control arm was detached from the vehicle, and the front right upper control arm was slightly twisted at the point where the rubber bushing met the frame. No damage was observed on the front left upper control arm, though small scrapes were present on the leading and trailing edges of the front left lower control arm.

Additionally, the front right steering arm was detached from both the steering gearbox and the vehicle. The front left steering arm was bent in a manner that caused the entire steering assembly, comprising the steering gearbox and left steering arm, to deform at an angle of approximately 120 degrees. The outer encasement of the steering box was sheared and split into three nearly equal parts. The section located at the left-front side of the vehicle included bent steering shaft linkages. The left-front tie rod remained undamaged, while the right-front tie rod was disengaged from the vehicle.

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 113. Vehicle Damage, Test No. HBIB-8

Figure 114. Vehicle Damage, Test No. HBIB-8

Figure 115. Vehicle Damage, Test No. HBIB-8

Figure 116. Test Vehicle’s Interior Floorboards and Undercarriage Damage, Test No. HBIB-8

Table 17. Maximum Occupant Compartment Intrusion by Location, Test No. HBIB-8

Location	Maximum Intrusion in.	MASH Allowable Intrusion in.
Wheel Well & Toe Pan	0.3	≤ 9
Floor Pan & Transmission Tunnel	0.1	≤ 12
A-Pillar	0.2	≤ 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)	2.8	≤ 12
Side Door (Above Seat)	1.1	≤ 9
Side Door (Below Seat)	0.9	≤ 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	0.6	N/A

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

8.6 Occupant Risk

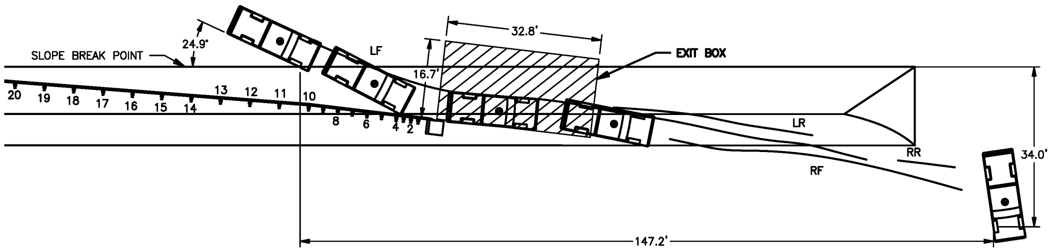
The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined by accelerometer data, are shown in Table 18. Note that the OIVs and ORAs were within suggested limits, as provided in MASH. 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.

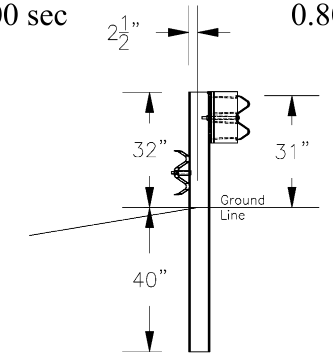
Table 18. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. HBIB-8

Evaluation Criteria		Transducer		MASH Limits
		SLICE-1 (backup)	SLICE-2 (primary)	
OIV ft/s	Longitudinal	-13.90	-14.91	±40
	Lateral	-18.12	-22.01	±40
ORA g's	Longitudinal	-4.45	-4.94	±20.49
	Lateral	-12.12	-9.63	±20.49
Maximum Angular Displacement deg.	Roll	13.3	12.1	±75
	Pitch	3.2	2.8	±75
	Yaw	-19.5	-19.8	not required
THIV – ft/s		22.32	24.77	not required
PHD – g's		12.13	9.63	not required
ASI		1.36	1.45	not required

8.7 Discussion

The analysis of the test results for test no. HBIB-8 showed that the barrier system effectively contained and redirected the 2270P vehicle with controlled lateral displacements of the barrier. A summary of the test results and sequential photographs are shown in Figure 117. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment, nor did they present an undue hazard to other traffic, pedestrians, or work-zone personnel. There were no deformations or intrusions into the occupant compartment that could have caused serious injury to an occupant. The test vehicle did not penetrate or ride over the barrier and remained upright throughout 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 -8.3 degrees with respect to the barrier, and its trajectory did not violate the bounds of the exit box. Therefore, test no. HBIB-8 was deemed acceptable according to the MASH safety performance criteria for test designation 3-37a.





- Test Agency .... MwRSF
- Test Number HBIB-8
- Date 12/6/2024
- MASH Test Designation No. .... Modified 3-37a
- Test Article .... Hawaii Buried in Backslope
- Total Length .... 219 ft – 4 in.
- Key Component – Steel W-beam Guardrail
  - Thickness .... 12 Gauge
  - Top Mounting Height .... 32 in.
- Key Component – Steel Post
  - Shape W6x8.5
  - Length .... 84 in./72 in.
  - Embedment Depth .... Varies
  - Spacing .... 75 in.
- Key Component – Composite Recycled Blockout (Post Nos. 1-38)
  - Shape .... 14¼ x 8 x 5¼ in.
- Soil Type .... Coarse, Crushed Limestone (Well-Graded Gravel)
- Vehicle Make /Model .... 2018 RAM 1500
  - Curb .... 5,126 lb
  - Test Inertial .... 5,000 lb (MASH Limit 5,000 ± 110 lb)
  - Gross Static .... 4,991 lb (MASH Limit 5,165 ± 110 lb)
- Impact Conditions – Slope Break Point
  - Speed .... 61.5 mph (MASH Limit 62 ± 2.5 mph)
  - Angle .... 24.9 deg. (MASH Limit 25 ± 1.5 deg.)
- Impact Conditions – Barrier
  - Speed 61.5
  - Angle .... 27.5 deg.
  - Impact Location .... 67.0 in. upstream from upstream end of concrete anchor
- Impact Severity – Slope Break Point .... 112.1 kip-ft > 106 kip-ft MASH minimum
- Impact Severity – Barrier .... 134.8 kip-ft
- Exit Conditions
  - Speed .... 48.0 mph
  - Angle .... -8.3 deg.
- Exit Box Criterion .... Pass
- Vehicle Stability .... Pass
- Vehicle Stopping Distance .... 147.2 ft downstream, 34.0 ft laterally behind slope break point
- Vehicle Damage .... Severe
  - VDS [15] 1-RFQ-5
  - CDC [16] 01-RFEE-9
  - Maximum Interior Deformation .... 2.8 in. at side front panel ≤ 12-in. MASH limit
- Test Article Damage .... Minimal
- Maximum Test Article Deflections
  - Permanent Set .... 0.7 in.
  - Dynamic .... 3.1 in.
  - Working Width .... 19.9 in.
- Transducer Data

Evaluation Criteria		Transducer		MASH Limits
		SLICE-1 (primary)	SLICE-2 (primary)	
OIV ft/s	Longitudinal	-13.90	-14.91	±40
	Lateral	-18.12	-22.01	±40
ORA g's	Longitudinal	-4.45	-4.94	±20.49
	Lateral	-12.12	-9.63	±20.49
Maximum Angular Displacement deg.	Roll	13.3	12.1	±75
	Pitch	3.2	2.8	±75
	Yaw	-19.5	-19.8	not required
THIV – ft/s		22.32	24.77	not required
PHD – g's		12.13	9.63	not required
ASI		1.36	1.45	not required

Figure 117. Summary of Test Results and Sequential Photographs, Test No. HBIB-8

9 FULL-SCALE CRASH TEST NO. HBIB-10

9.1 Static Soil Test

Before full-scale crash test no. HBIB-10 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-10 was conducted on June 20, 2025, at approximately 2:30 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-10

Temperature	101°F
Humidity	30%
Wind Speed	25 mph
Wind Direction	200° from True North
Sky Conditions	Clear
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.25 in.
Previous 7-Day Precipitation	0.58 in.

9.3 Test Description

Initial vehicle impact was to occur 43¼ in. upstream from the upstream end of the concrete anchor block, as shown in Figure 118, which was selected using the CIP plots found in Section 2.3 of MASH to maximize pocketing and the probability of wheel snag and pocketing adjacent to the rigid concrete parapet. The same multiplication factor was applied to the calculated value for “X” for the small car of 0.824. The 2,421-lb small car impacted the slope break point of the system in the reverse direction at a speed of 62.7 mph and an angle of 25.1 degrees and impacted the barrier at a speed of 62.4 mph and at an angle of 29.4 degrees. The actual point of impact was 41.5 in. upstream from the upstream end of the concrete anchor block, or 1.7 in. downstream from the target impact point. After brakes were applied, the vehicle came to rest 165.4 ft downstream from impact and 1.7 ft laterally behind the slope break point.

A detailed description of the sequential impact events is contained in Table 20. Sequential photographs are shown in Figures 119 and 120 . Documentary photographs of the crash test are shown in Figures 121 through 123. The vehicle trajectory and final position are shown in Figure 124.

Figure 118. Target Impact Location, Test No. HBIB-10

Table 20. Sequential Description of Impact Events, Test No. HBIB-10

Time (sec)	Event
-0.246	Vehicle rolled toward the system and traversed slope break point.
-0.210	Vehicle's right-front tire became airborne.
-0.064	Vehicle's left-front tire became airborne.
-0.056	Vehicle's right-rear tire became airborne.
-0.032	Vehicle's left-rear tire became airborne.
-0.004	Vehicle's right-rear tire contacted ground.
0.000	Vehicle's front bumper contacted rail 41.5 in. upstream from the upstream end of concrete anchor, crushed inward, and tore. Vehicle's right headlight contacted rail and was shattered.
0.006	Vehicle's right-front tire contacted ground. Vehicle's right fender contacted rail, crushed inward, was scraped, and tore.
0.012	Vehicle's hood contacted rail and crushed inward. Post nos. 1 through 4 rotated backward. Vehicle's right-front tire contacted rail.
0.020	Vehicle's right mirror contacted rail and disengaged. Vehicle yawed away from system. Vehicle's right A-pillar contacted barrier and bent inward.
0.032	Vehicle rolled away from the system.
0.038	Vehicle's roof was dented and buckled. Vehicle's windshield encountered significant cracking.
0.042	Vehicle's right-front door contacted rail, crushed inward, was scraped, and tore.
0.072	Vehicle's right-front window shattered.
0.094	Vehicle's right-front tire contacted concrete anchor and deflated.
0.133	Vehicle's left-rear tire contacted ground.
0.152	Vehicle exited system at a speed of 44.5 mph and an angle of -1.5 degrees.
0.166	Vehicle's left-front tire contacted ground. System came to rest.
0.233	Vehicle's right-rear tire became airborne.
0.282	Vehicle's left-front tire became airborne.
0.558	Vehicle rolled toward the system.
0.668	Vehicle's right-rear tire contacted ground.
0.692	Vehicle was parallel to system at a speed of 40.2 mph.
0.708	Vehicle's left-front tire contacted ground.
0.780	Vehicle rolled away from the system.
0.968	Vehicle rolled toward the system.
1.317	Vehicle's left-rear tire became airborne.
1.842	Vehicle's left-rear tire contacted ground.
3.883	Vehicle came to rest.

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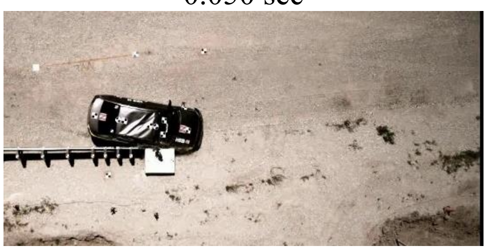

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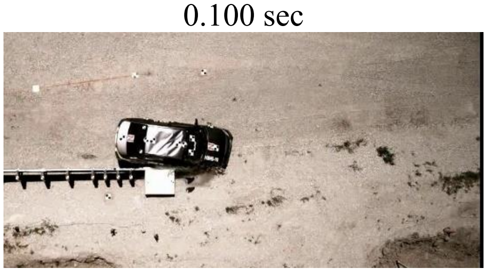

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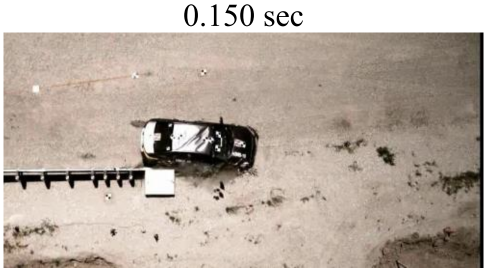

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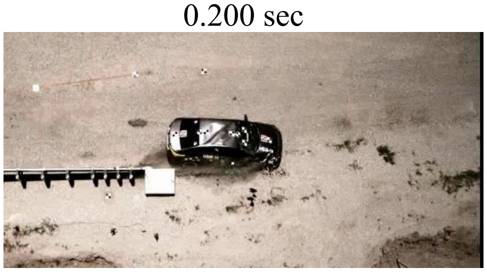

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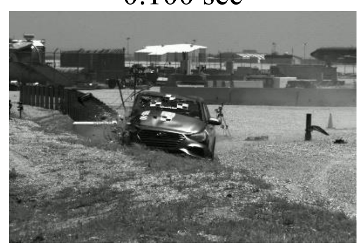

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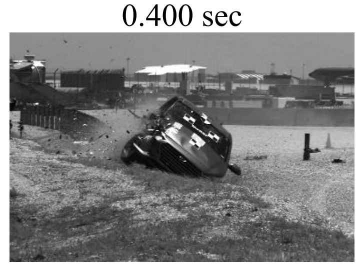

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Figure 119. Sequential Photographs, Test No. HBIB-10

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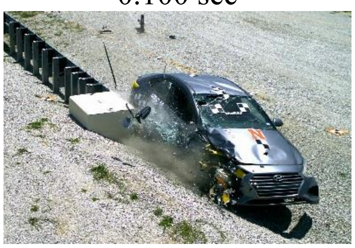

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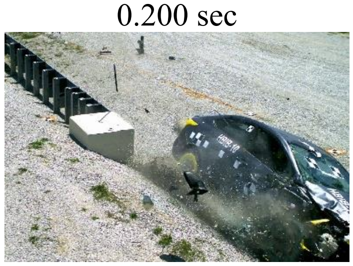

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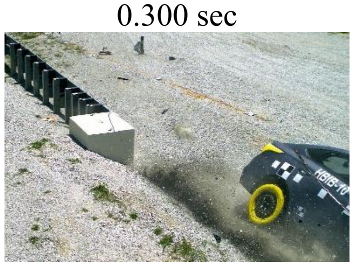

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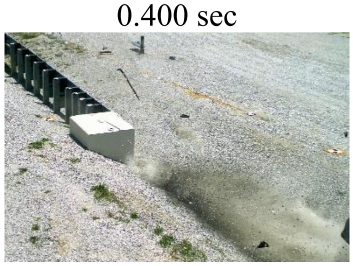

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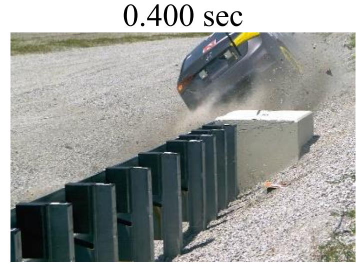

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Figure 120. Sequential Photographs, Test No. HBIB-10

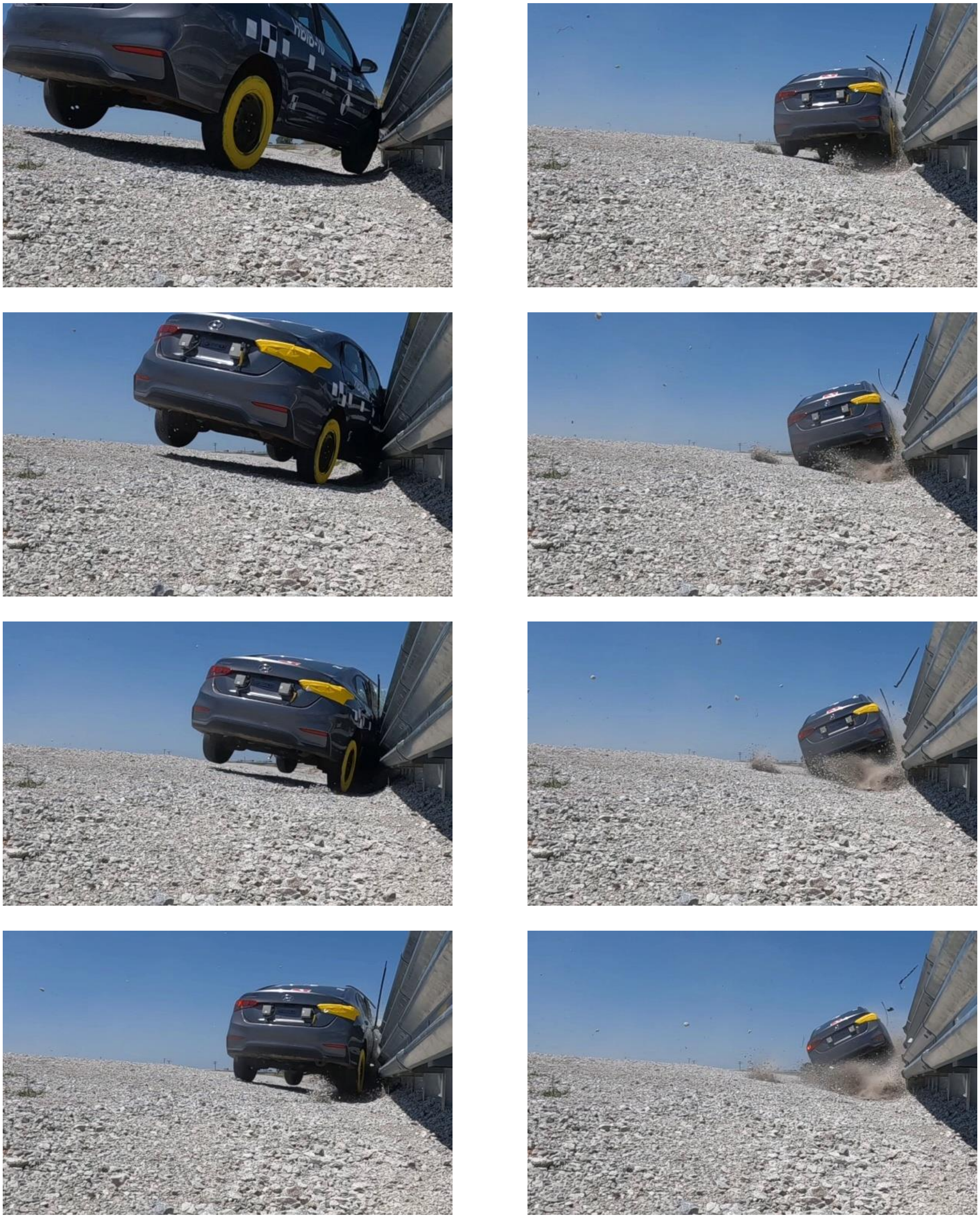


Figure 121. Documentary Photographs, Test No. HBIB-10

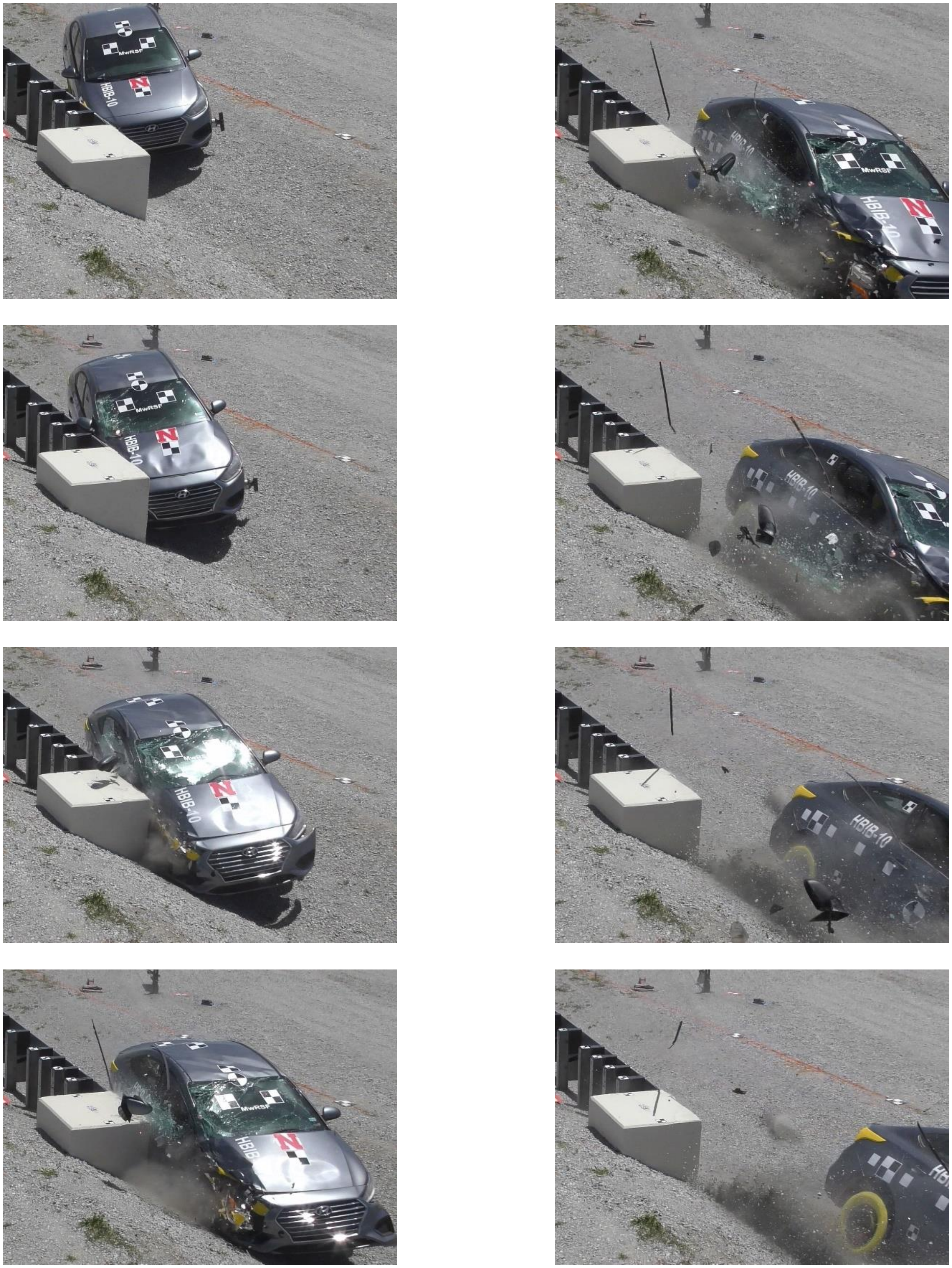


Figure 122. Documentary Photographs, Test No. HBIB-10

Figure 123. Documentary Photographs, Test No. HBIB-10

Figure 124. Vehicle Final Position and Trajectory Marks, Test No. HBIB-10

9.4 Barrier Damage

Damage to the barrier was minimal, as shown in Figures 125 and 126. Barrier damage consisted of contact marks, tears, flattening, kinks, translation of the rails at splices, post deformation, and concrete cracking. The length of vehicle contact along the barrier was approximately 7 ft – 4 in. which spanned from 8 in. downstream from post no. 3 to the downstream end of the concrete fascia.

Rail damage consisted of contact marks, tears, flattening, kinks, and splice slipping. There was a total of four major contact marks. The first contact mark was located on the top rail on the top flange, beginning 8 in. downstream from post no. 3 and was 66 in. in length and 5 in. in width. The second contact mark was located on the top rail on the top flange, ½ in. upstream from post no. 3, and was 5 in. long and ¼ in. wide. The third contact mark, located on the top rail on the bottom flange 9½ in. downstream from post no. 3, was 65 in. long and 5 in. wide. The fourth contact mark, located on the bottom rail and continuing onto the concrete, began 18 in. downstream from post no. 3 and was 81 in. long and 12 in. wide.

A 25-in. long and 1½-in. wide tear was found on the rail 11½ in. downstream from post no. 1 and 37½ in. from the ground. The bottom rail was flattened on its bottom flange 14 in. downstream from post no. 2 and 14 in. from the ground, measured 4 in. long and 2 in. wide. A series of kinks was observed on the top flange of the top rail located 22 in. downstream from post no. 1, measuring 15 in. long and ½ in. wide. A 17-in. long and ½-in. deep series of kinks was also present on the top flange of the bottom rail located 22 in. downstream from post no. 1. A 20-in. in long and ½-in. deep kink was found on the bottom flange of the top rail located 22 in. downstream from post no. 1. Finally, a series of kinks was found on the bottom flange of the bottom rail located 19 in. downstream from post no. 1 and measured 20 in. in length and ½ in. in depth.

An ⅛-in. splice slip occurred at the splice located downstream from post no. 1 and between post nos. 13 and 14. A ¼ in. splice slip occurred at the splice located between post nos. 17 and 18. Two posts had slight deformation after the crash. Post nos. 2 and 3 both deflected backward ¼ in.

Several cracks were observed on the concrete anchor. The first crack was found on the upstream front corner of the concrete block measuring 11 in. long, along with spalling that measured 11 in. long and 3½ in. wide. A 6-in. long crack was located 10 in. upstream from the front downstream corner of the concrete block. A crack was located 14 in. upstream from the front, downstream corner of the concrete that measured 4 in. long. Finally, a 4-in. long crack was located 11 in. upstream from the front, downstream corner of the concrete block.

Figure 125. System Damage, Test No. HBIB-10

Figure 126. Upper Rail and Rub Rail Damage, Test No. HBIB-10

The maximum lateral permanent set of the barrier system was 0.7 in. at post no. 11, as measured in the field. The maximum lateral dynamic deflection of the rail was 2.6 in. at post no. 1, as determined from high-speed digital video analysis. The maximum lateral dynamic deflection of the post was 2.8 in. at post no. 2, as determined from high-speed digital video analysis. The working width of the system was found to be 19.7 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 127.

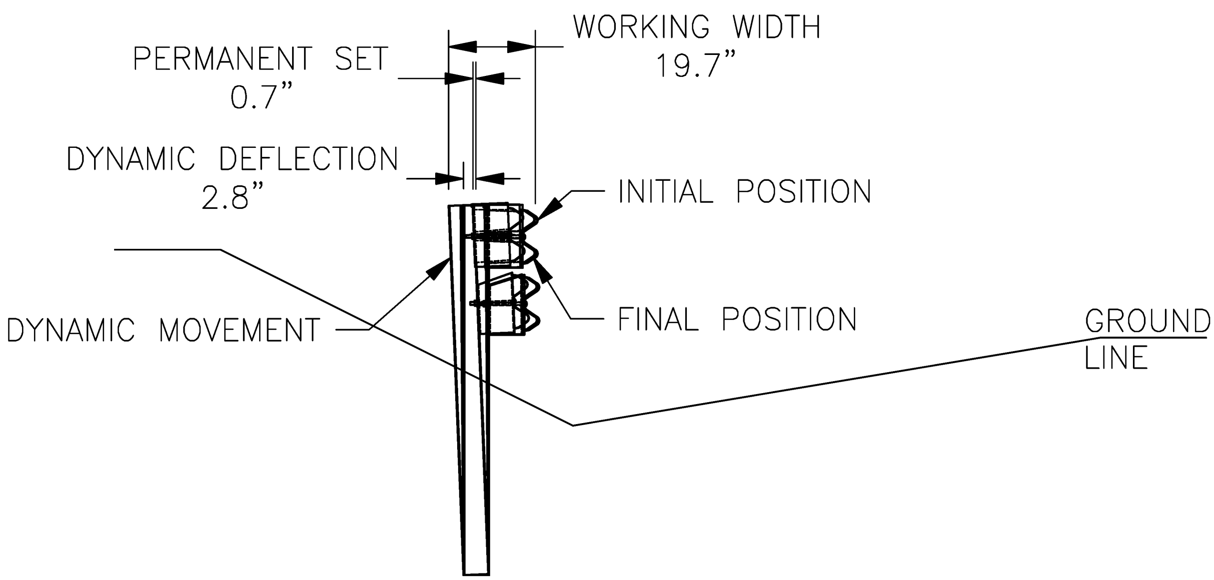


Figure 127. Permanent Set, Dynamic Deflection, and Working Width, Test No. HBIB-10

9.5 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 128 through 130. 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 detached and the right headlight was damaged, but remained attached. The right-front fender panel was crashed rearward and inward throughout its length, and the leading edge of the panel was detached and bent rearward. The right side of the hood was dented and scraped and the hood panel buckled and deformed, causing the center of the hood to heave upward. The right-front door panel was dented, deformed, with scrapes extending from the fender panel. The leading edge of the right-front door panel was torn rearward at the area just under the side mirror. The upper tear was 8 in. long and 6 in. high, while the lower tear was 12 in. long. The tears in the right-side doors did not penetrate into the interior of the occupant compartment. The window on the passenger door was shattered. The right side of the front windshield was crushed inward and the glass liner was torn due to deformation of the right-side door frame and the roof panel. The roof panel was deformed across the entire panel but showed no evidence of damage from direct contact.

Damage to the vehicle’s undercarriage was minimal. The right-front shock, end of the sway bar, and right-side outer tie rod were bent. The right-side lower control arm was bent downward and inward.

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 and vehicle deformations and the corresponding locations are provided in Appendix F. MASH defines intrusion or deformation as the occupant compartment being deformed and reduced in size with no observed penetration. There were no penetrations into the occupant compartment and none of the established MASH deformation limits were violated. Outward deformations, which are denoted as negative numbers in Appendix F, are not considered crush toward the occupant, and are not evaluated by MASH criteria. The windshield was torn at the top edge and along the right-side edge, but the tearing was associated with deformation to the right-side door frame and roof and did not result from direct contact with the test article or a component of the vehicle. Thus, while total windshield deflection resulting from the tear exceeded MASH limits, the deformation values were not applicable.

Figure 128. Vehicle Damage, Test No. HBIB-10

Figure 129. Vehicle Damage, Test No. HBIB-10

Figure 130. Test Vehicle’s Interior Floorboards and Undercarriage Damage, Test No. HBIB-10

Table 21. Maximum Occupant Compartment Intrusion by Location, Test No. HBIB-10

Location	Maximum Intrusion in.	MASH Allowable Intrusion in.
Wheel Well & Toe Pan	2.8	≤ 9
Floor Pan & Transmission Tunnel	2.6	≤ 12
A-Pillar	1.6	≤ 5
A-Pillar (Lateral)	1.1	≤ 3
B-Pillar	1.3	≤ 5
B-Pillar (Lateral)	0.0*	≤ 3
Side Front Panel (in Front of A-Pillar)	0.4	≤ 12
Side Door (Above Seat)	0.4	≤ 9
Side Door (Below Seat)	0.0*	≤ 12
Roof	1.2	≤ 4
Windshield	**	≤ 3
Side Window	Shattered due to contact with simulated occupant's head	No shattering resulting from contact with structural member of test article
Dash	2.7	N/A

N/A – No MASH criteria exist for this location.
*Negative value reported as 0.0. See Appendix F for further information.
**The windshield damage occurred due to translation of the base of the vehicle's A-pillar. The windshield experienced lateral flexure, which resulted in shattering, but this deformation was unrelated to windshield impact with the test article and does not violate MASH evaluation criteria.

9.6 Occupant Risk

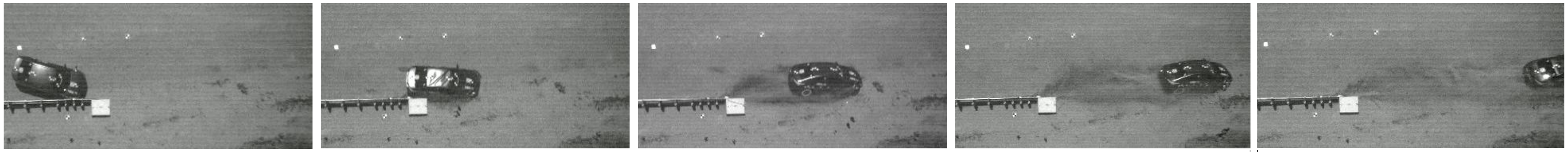
The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined from the accelerometer data, are shown in Table 22. Note that the OIVs and ORAs were within suggested limits, as provided 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 is shown graphically in Appendix J.

Table 22. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. HBIB-10

Evaluation Criteria		Transducer		MASH Limits
		SLICE-1 (primary)	SLICE-2 (backup)	
OIV ft/s	Longitudinal	-21.14	-21.19	±40
	Lateral	-23.43	-22.34	±40
ORA g's	Longitudinal	-4.08	-4.30	±20.49
	Lateral	-4.14	-3.90	±20.49
Maximum Angular Displacement deg.	Roll	-36.8	-38.0	±75
	Pitch	-3.7	-3.3	±75
	Yaw	-32.8	-33.5	not required
THIV – ft/s		29.23	28.54	not required
PHD – g's		5.75	5.67	not required
ASI		1.85	1.80	not required

9.7 Discussion

The analysis of the test results for test no. HBIB-10 showed that the system adequately contained and redirected the 1100C vehicle with controlled lateral displacements of the barrier. A summary of the test results and sequential photographs are shown in Figure 131. 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. Note that the windshield damage occurred due to translation of the base of the vehicle's A-pillar. The windshield experienced lateral flexure, which resulted in shattering, but this deformation was unrelated to windshield impact with the test article and does not violate MASH evaluation criteria. 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 barrier at an angle of -1.5 degrees with respect to the barrier, and its trajectory did not violate the bounds of the exit box. Therefore, test no. HBIB-10 was determined to be acceptable according to the MASH safety performance criteria for test designation no. 3-37b.



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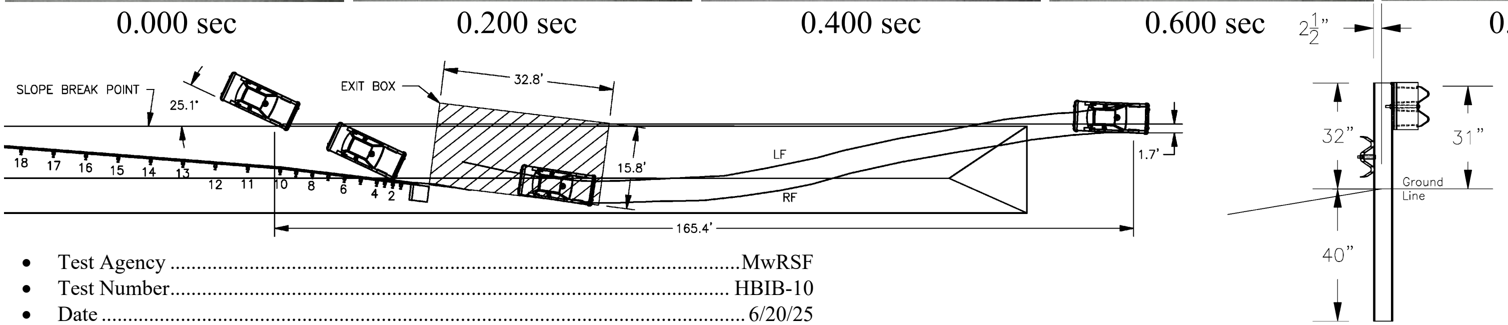


- Test Agency .... MwRSF
- Test Number HBIB-10
- Date 6/20/25
- MASH Test Designation No. 3-37b
- Test Article .... Hawaii Buried in Backslope
- Total Length .... 219 ft – 4 in.
- Key Component – Steel W-beam Guardrail
  - Thickness .... 12 Gauge
  - Top Mounting Height .... 31 in.
- Key Component – Steel Post
  - Shape W6x8.5
  - Length .... 84 in. (post nos. 1-27), 72 in. (post nos. 28-38)
  - Embedment Depth .... Varies
  - Spacing .... 75 in.
- Key Component – Composite Recycled Blockout (Post Nos. 1-38)
  - Shape .... 14¼ x 8 x 5¼ in.
- Soil Type .... Coarse, Crushed Limestone (Well-Graded Gravel)
- Vehicle Make /Model .... 2019 Hyundai Accent
  - Curb .... 2,517 lb
  - Test Inertial .... 2,421 lb (MASH Limit 5,000 ± 110 lb)
  - Gross Static .... 2,585 lb (MASH Limit 5,165 ± 110 lb)
- Impact Conditions – Slope Break Point
  - Speed .... 62.7 mph (MASH Limit 62 ± 2.5 mph)
  - Angle .... 25.1 deg. (MASH Limit 25 ± 1.5 deg.)
- Impact Conditions – Barrier
  - Speed .... 62.4 mph
  - Angle .... 29.4 deg.
  - Impact Location .... 41.5 in. upstream from the upstream end of concrete anchor
- Impact Severity – Slope Break Point .... 57.3 kip-ft ≥ 51 kip-ft MASH minimum
- Impact Severity – Barrier .... 75.9 kip-ft
- Exit Conditions
  - Speed .... 44.5 mph
  - Angle .... -1.5 deg.
- Exit Box Criterion .... Pass
- Vehicle Stability .... Pass
- Vehicle Stopping Distance .... 165.4 ft downstream, 1.7 ft laterally behind slope break
- Vehicle Damage .... Moderate
  - VDS [15] 2-RFQ-5
  - CDC [16] 02RFEW6
  - Maximum Interior Deformation .... 2.8 in. at Wheel Well ≤ 9-in. MASH limit
- Test Article Damage .... Minimal
- Maximum Test Article Deflections
  - Permanent Set .... 0.7 in.
  - Dynamic .... 2.8 in.
  - Working Width .... 19.7 in.
- Transducer Data

Evaluation Criteria		Transducer		MASH Limits
		SLICE-1 (primary)	SLICE-2 (backup)	
OIV ft/s	Longitudinal	-21.14	-21.19	±40
	Lateral	-23.43	-22.34	±40
ORA g's	Longitudinal	-4.08	-4.30	±20.49
	Lateral	-4.14	-3.90	±20.49
Maximum Angular Displacement deg.	Roll	-36.8	-38.0	±75
	Pitch	-3.7	-3.3	±75
	Yaw	-32.8	-33.5	not required
THIV – ft/s		29.23	28.54	not required
PHD – g's		5.75	5.67	not required
ASI		1.85	1.80	not required

Figure 131. Summary of Test Results and Sequential Photographs, Test No. HBIB-10

10 DESIGN DETAILS: SINGLE-FLARE DESIGN

Hawaii DOT typically uses two configurations of a flared buried-in-backslope system design. The first configuration consists of a single flare extending from the tangent guardrail system, terminating at a rigid anchor block. The second configuration utilizes a secondary flare at adjacent to the end anchorage. The primary flare of the rail has flare rates selected based on the design speed of the barrier system and roadway, whereas the secondary flare is fixed at 7.4:1 with respect to the tangent roadway.

A full evaluation was performed with MASH test designation nos. 3-32, 3-33, 3-34, 3-35, and 3-37a and 3-37b on the HBIB system with dual-flare configuration. The dual flare was most severe for standard traffic direction crashes, but would be less severe when used in trailing-end or reverse-direction crashes. This was because the secondary flare of the dual-flare system had a larger flare rate away from the roadway. For standard-direction impacts, the secondary flare rate contributes to a higher effective impact angle; for reverse-direction impacts, the secondary flare decreases the effective impact angle. Thus, the single-flare configuration was believed to be more severe in reverse-direction configurations.

The system was modified to represent the single-flare configuration. This was accomplished by extending the transition post nos. 1 through 8 with the single-flare configuration (4.4-degrees or 13:1), and placing the anchor block adjacent to the bottom toe of the V-ditch. The resulting system had a 13:1 flare rate between the anchor block and post no. 29.

The same reinforced concrete block was used for the single-flare configuration as was used for the dual-flare configuration. To accommodate the difference in anchor positions, a built-up "cap" was added to the front face of the concrete anchor block so that the rail would be terminated at the block and in line with the single flare. The cap consisted of a trapezoidal shape, as shown in Figure 145 measuring 12¾ in. on the downstream side and 14½ in. thick on the upstream side. Note that for purposes of this discussion, downstream refers to nominal travel direction, not the direction of reverse-direction impact. The trapezoidal cap was doweled into the face of the existing concrete anchor block with bent no. 4 bars and epoxied to a depth of at least 6 in. Additionally, researchers selected post-installed attachments to secure the W-beam end shoe to the reinforced cap instead of cast-in ferrule assemblies.

All other system details were the same for the single-flare configuration evaluated during test no. HBIB-9. The system installation for test no. HBIB-9 is shown in Figures 132 through 169, and material specifications, mill certifications, and certificates of conformity for the system materials are provided in Appendix D.

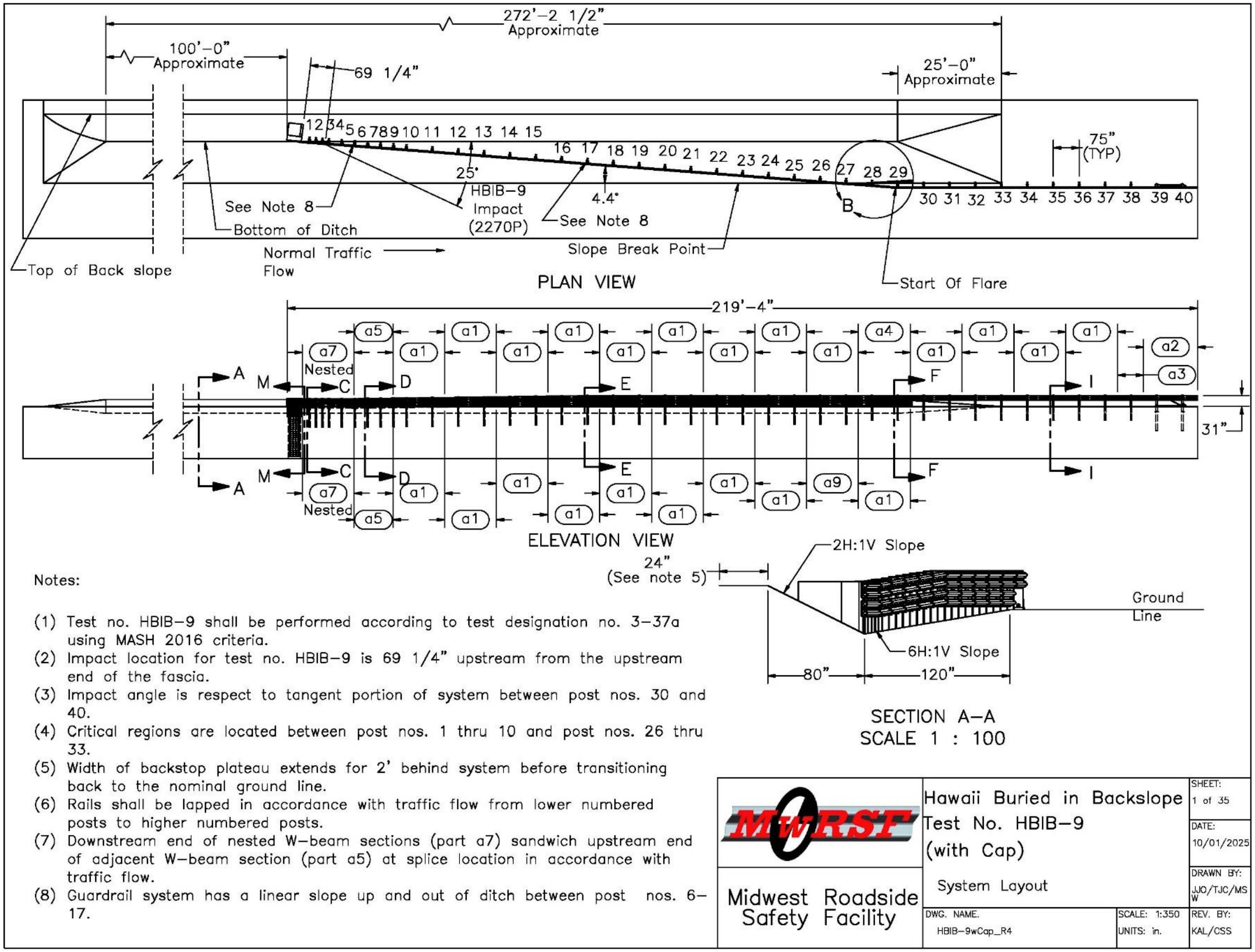


Figure 132. System Overview and Impact Location, Test No. HBIB-9

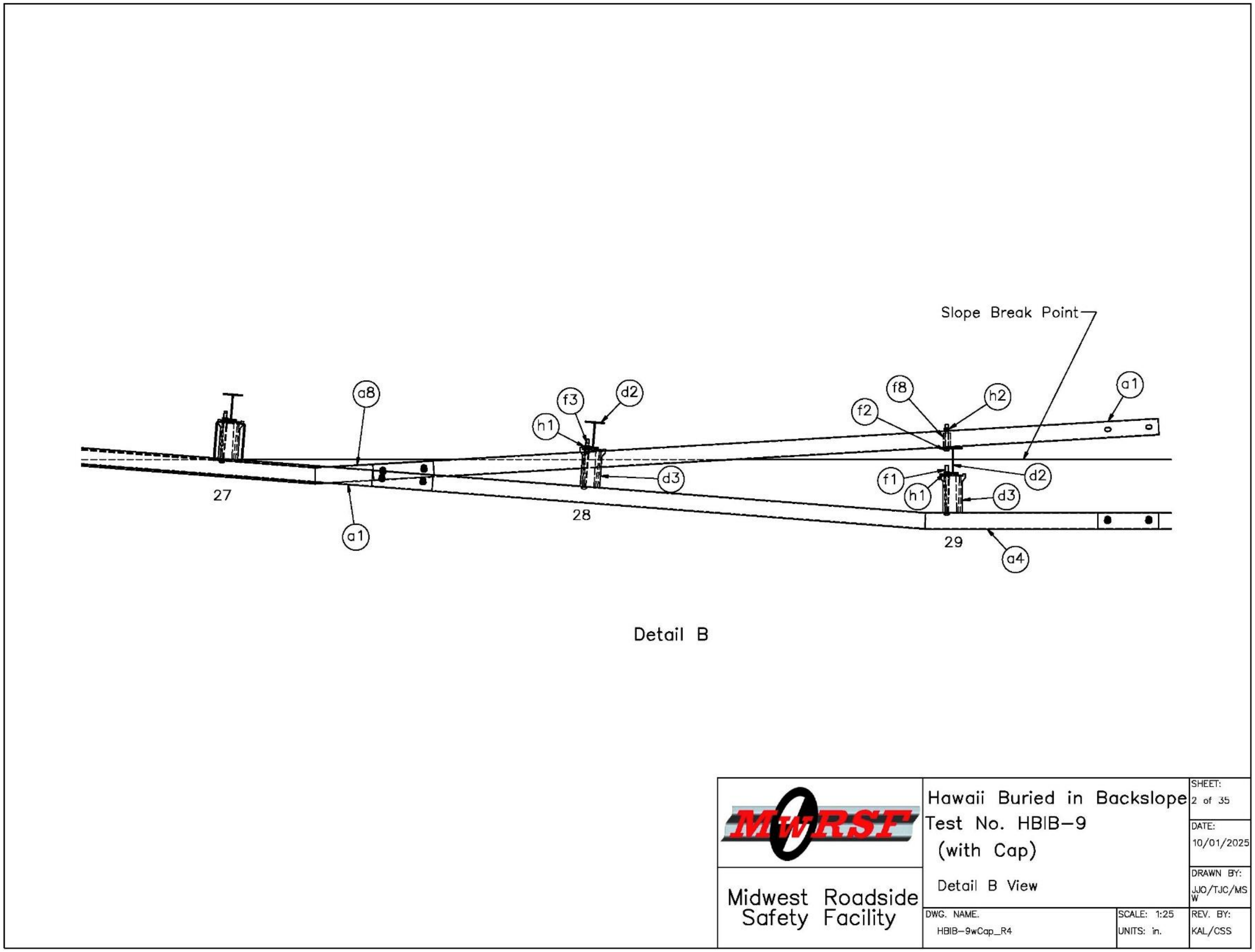


Figure 133. Rubrail Termination Details, Deviation Point, Test No. HBIB-9

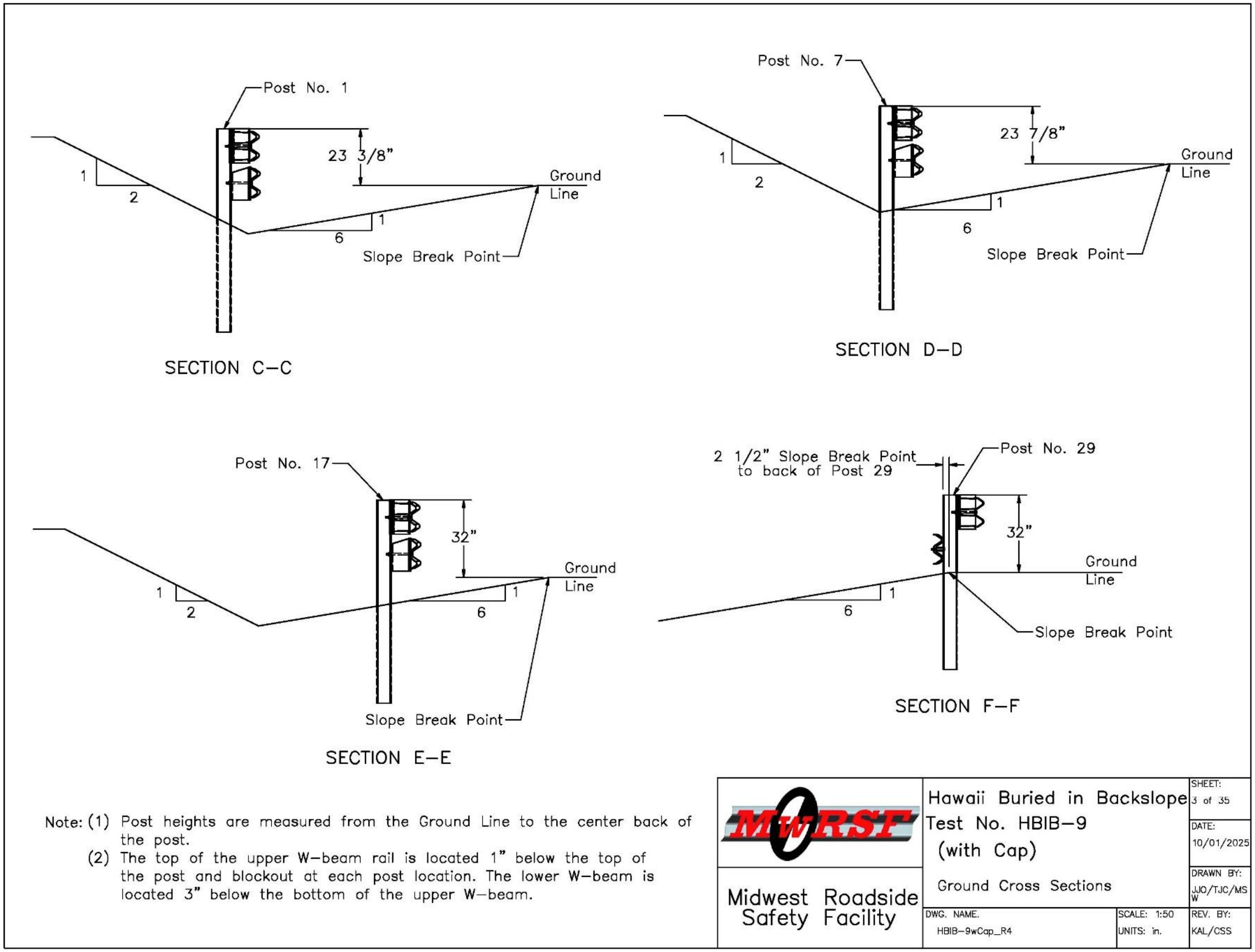


Figure 134. Ground Cross Sections, Test No. HBIB-9

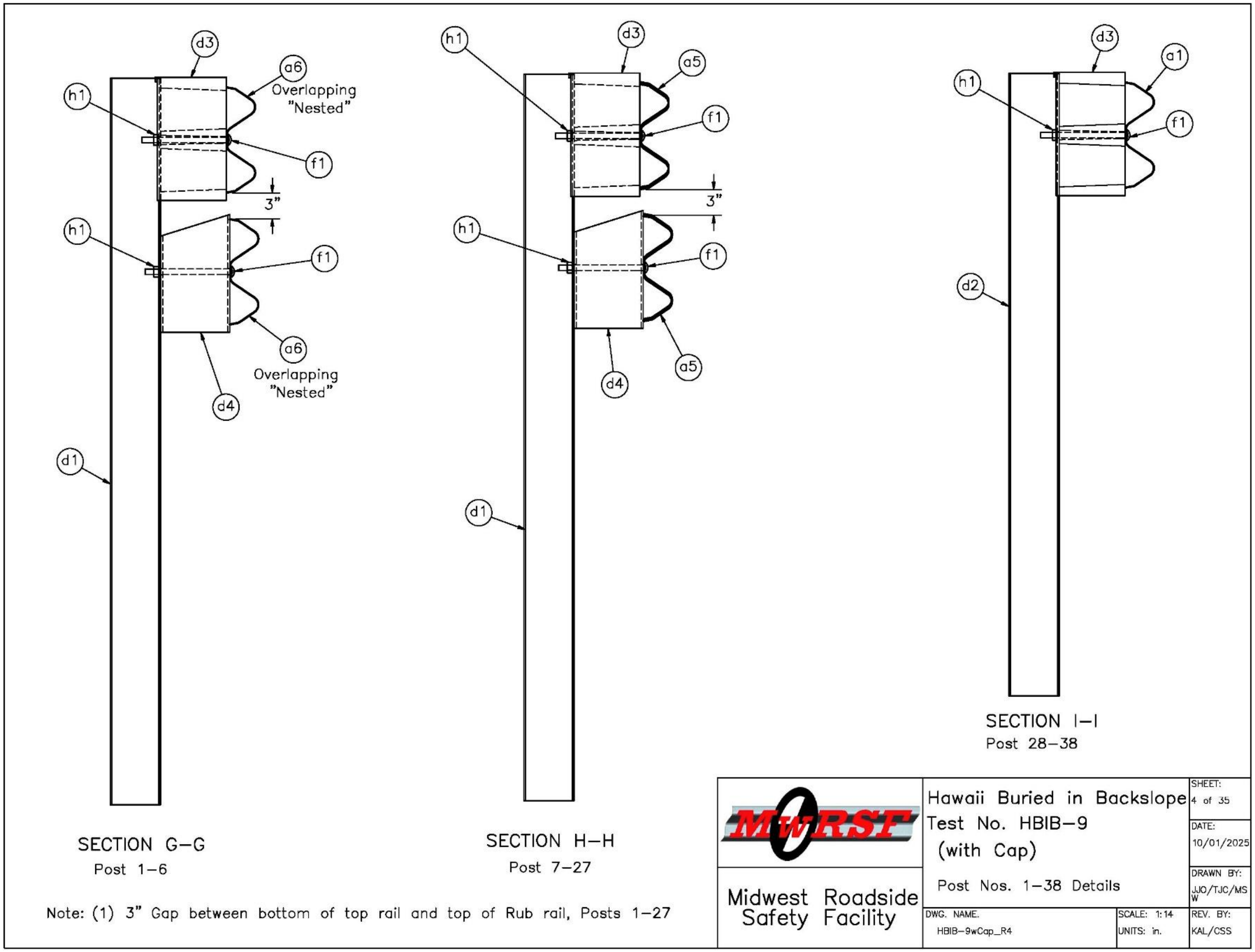
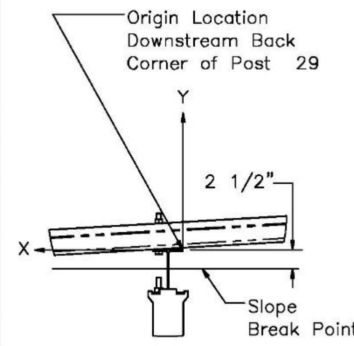
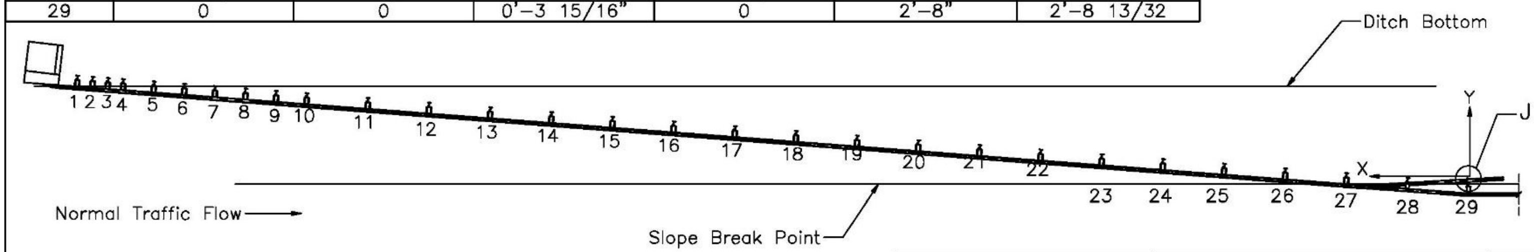


Figure 135. Post Nos. 1 through 38 Details, Test No. HBIB-9

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'-8 35/64"	10'-10 1/4"	142'-0 31/64"	10'-10 35/64"	1'-11 3/8"	3'-0 15/16"
2	140'-1 55/64"	10'-8 13/16"	140'-5 25/32"	10'-9 7/64"	1'-11 3/8"	3'-1 21/32"
3	138'-7 5/32"	10'-7 3/8"	138'-11 3/32"	10'-7 43/64"	1'-11 3/8"	3'-2 3/8"
4	137'-0 15/32"	10'-5 15/16"	137'-4 25/64"	10'-6 15/64"	1'-11 3/8"	3'-3 3/32"
5	133'-11 5/64"	10'-3 1/16"	134'-3"	10'-3 23/64	1'-11 3/8"	3'-4 17/32
6	130'-9 11/16"	10'-0 3/16"	131'-1 39/64"	10'-0 31/64"	1'-11 3/8"	3'-5 61/64
7	127'-8 19/64"	9'-9 19/64"	128'-0 15/64"	9'-9 39/64"	1'-11 27/32"	3'-7 27/32
8	124'-6 29/32"	9'-6 7/16"	124'-10 27/32"	9'-6 47/64	2'-0 21/64"	3'-7 27/32
9	121'-5 17/32"	9'-3 35/64"	121'-9 29/64"	9'-3 27/32"	2'-0 13/16"	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



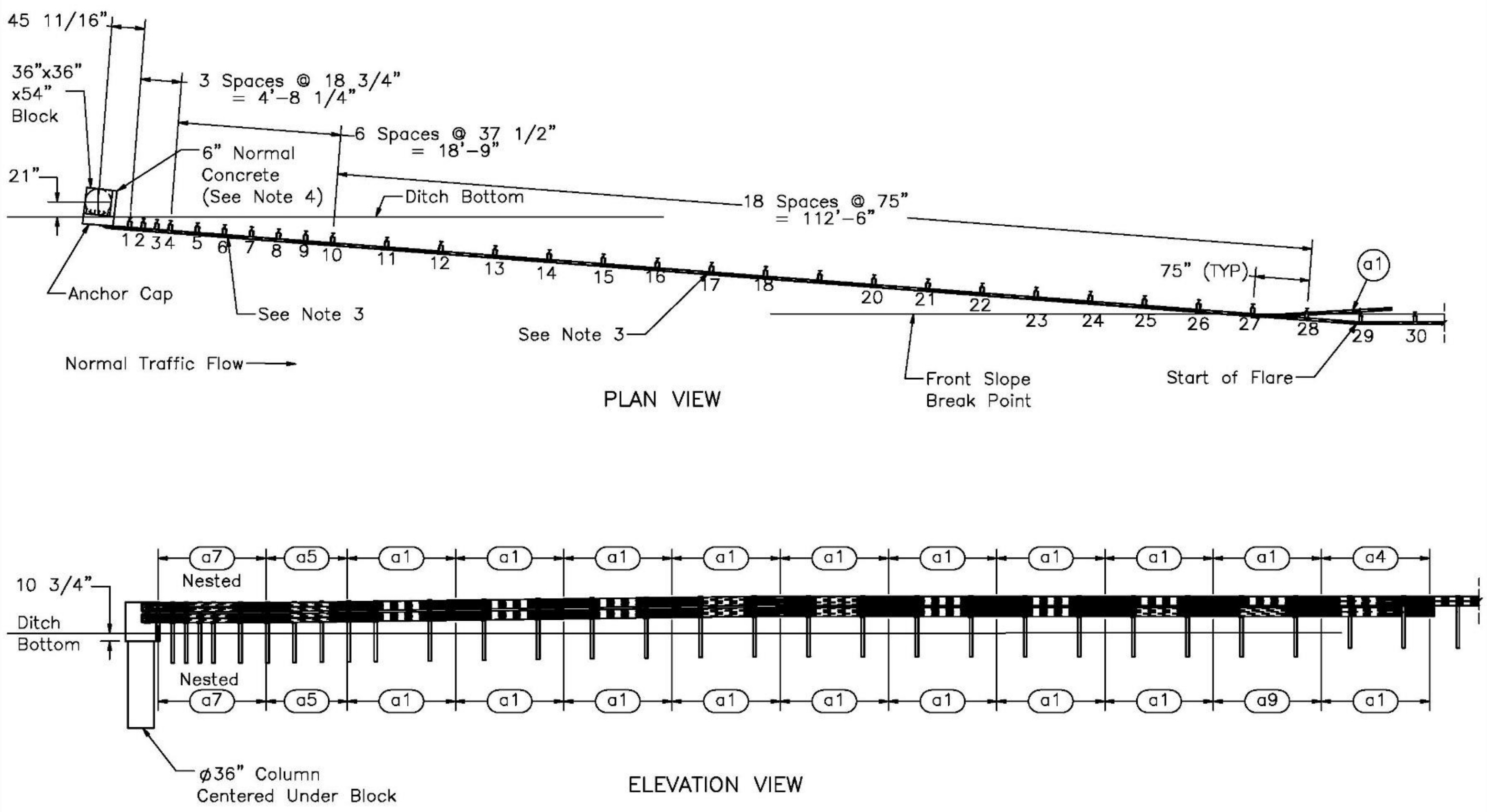
DETAIL J
SCALE 1 : 20



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 Midwest Roadside Safety Facility	Hawaii Buried in Backslope Test No. HBIB-9 (with Cap)	SHEET: 5 of 35
		DATE: 10/01/2025
	Post Location Layout	DRAWN BY: JJO/TJC/MSW
	DWG. NAME. HBIB-9wCap_R4	SCALE: 1:185 UNITS: in.	REV. BY: KAL/CSS

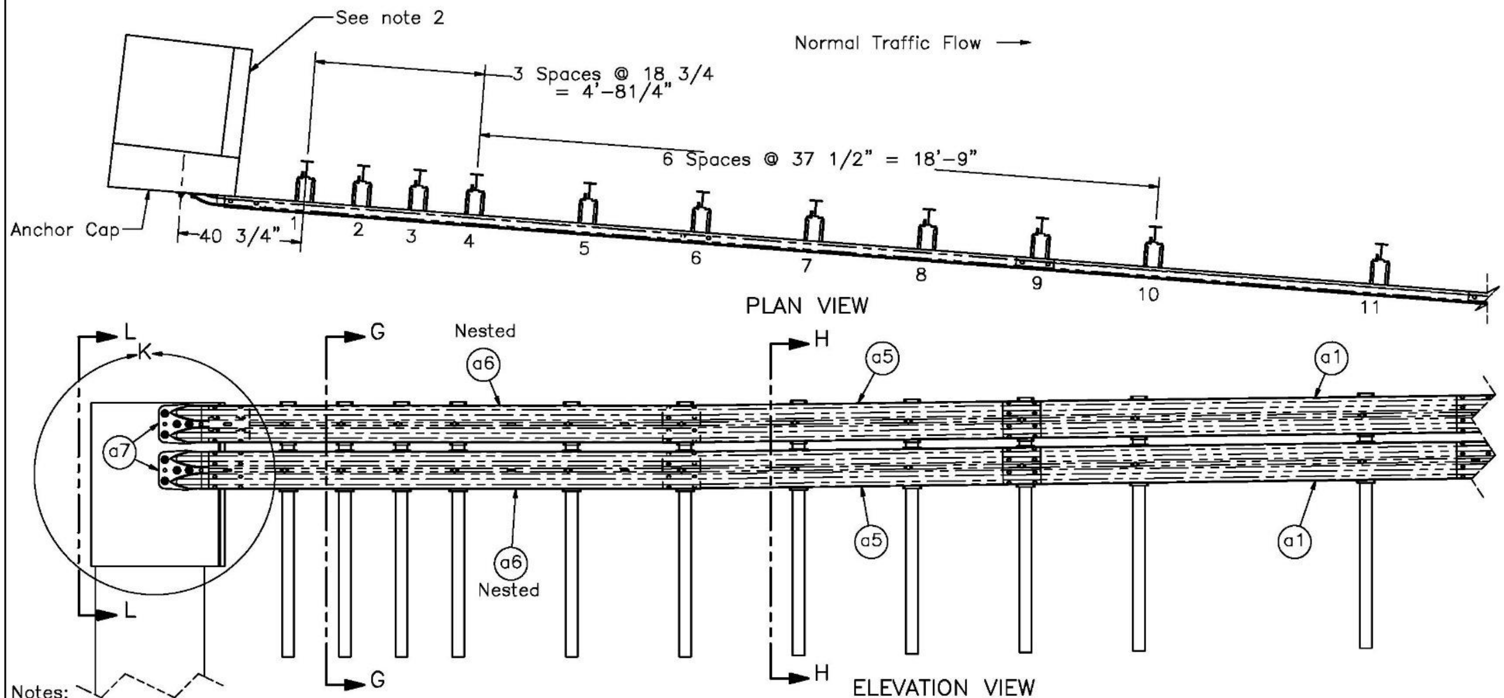
Figure 136. Post Location Layout, Test No. HBIB-9



Notes: (1) Elevation view is normal to the front face of the first flared rail.
(2) Downstream ends of nested W-beam sections (part a7) sandwich upstream end of adjacent W-beam section (part a5) at splice location in accordance with traffic flow.
(3) System slopes with ditch between post nos. 6-17. Vertical slope will be accomplished by offsetting the vertical angles of the W-beam rails at splice locations.
(4) Compact crushed limestone under add-on 6" wall cast on rock or formwork.

Midwest Roadside Safety Facility	Hawaii Buried in Backslope Test No. HBIB-9 (with Cap)		SHEET: 6 of 35
			DATE: 10/01/2025
	Flare Details		DRAWN BY: JJO/TJC/MSW
	DWG. NAME. HBIB-9wCap_R4	SCALE: 1:200 UNITS: in.	REV. BY: KAL/CSS

Figure 137. Flare Details, Test No. HBIB-9



Notes:

(1) Elevation view is normal to the front face of the flared rail between post nos. 10 and 1 and anchor block.

(2) Hawaii DOT typically utilizes an aesthetic stone-faced exterior of the anchor block, which will be represented by a 6" thick low-strength fascia, which is to be added to the upstream surface of the concrete anchor block. The fascia can be normal strength concrete anchored to the anchor block with minimum steel reinforcement to represent the lateral supported grouted rubble paving. Optional: the 6" fascia can be included in the anchor block and cast as one unit for testing purposes.

(3) Nested W-beam sections (part a7) at anchor block placed beneath W-beam terminal connector (part a8) at splice locations in accordance with traffic flow.

(4) Downstream end of nested W-beam sections (part a7) sandwich upstream end of adjacent W-beam section (part a5) at splice location.

(5) System slopes vertically with ditch between post nos. 6-17. Vertical slope will be accomplished by offsetting the vertical angles of the W-beam rails at splice locations.

(6) All rail splices should be lapped in accordance with traffic flow from lower post numbers to higher post numbers.

Midwest Roadside Safety Facility	Hawaii Buried in Backslope Test No. HBIB-9 (with Cap)	SHEET: 7 of 35
		DATE: 10/01/2025
	Flare to Anchor Details	DRAWN BY: JJO/TJC/MSW
	DWG. NAME. HBIB-9wCap_R4 / SCALE: 1:50 / UNITS: in.	REV. BY: KAL/CSS

Figure 138. Flare to Anchor Details, Test No. HBIB-9

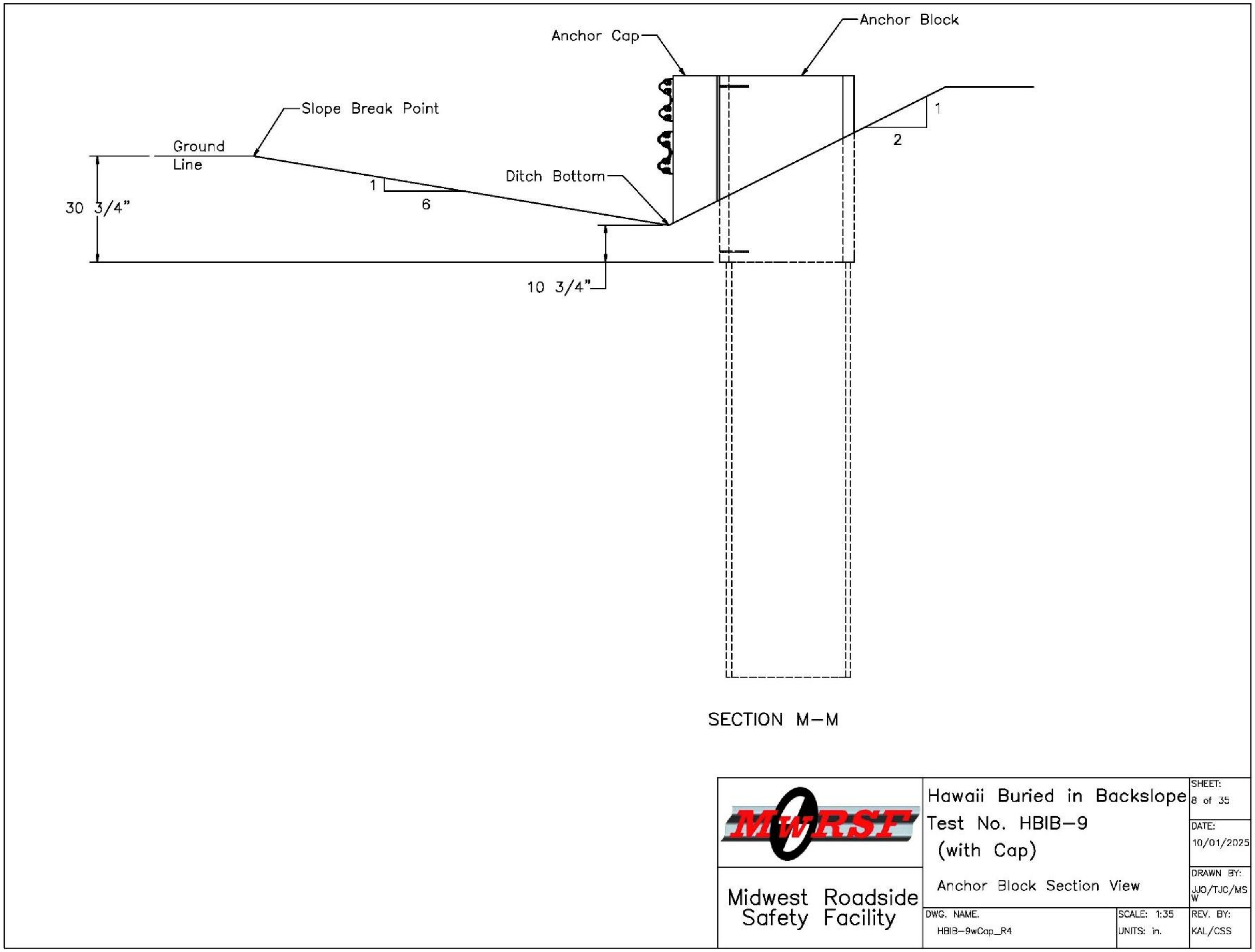
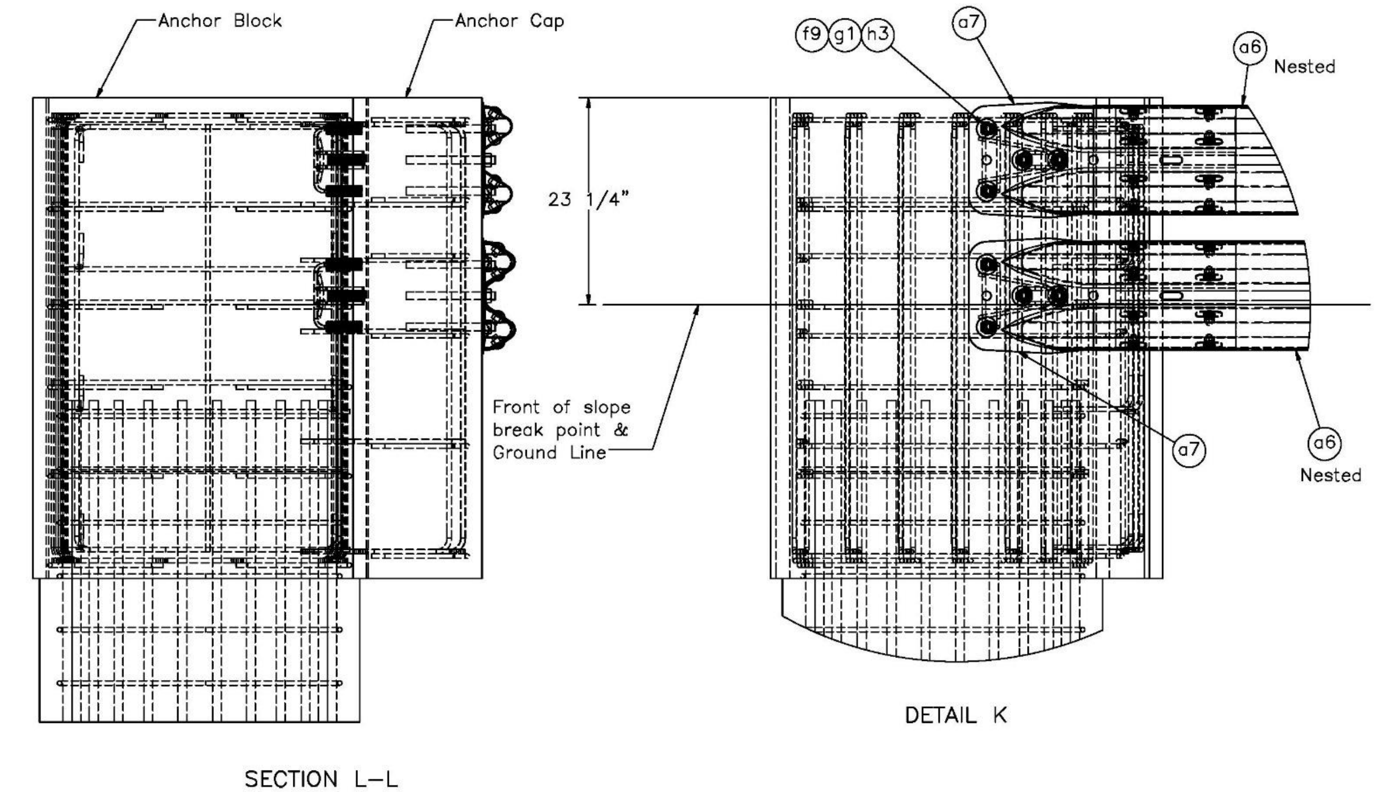


Figure 139. Anchor Block Section View, Test No. HBIB-9



Notes: (1) Hawaii DOT typically utilizes an aesthetic stone–faced exterior of the anchor block, which will be represented by a 6" thick low–strength fascia, which is to be added to the upstream surface of the concrete anchor block. The fascia can be normal strength concrete anchored to the anchor block with minimum steel reinforcement to represent the lateral supported grouted rubble paving.

(2) Optional: the 6" fascia can be included in the anchor block and cast as one unit for testing purposes.

(3) View is normal to concrete block, back slope is shown at an angle.

(4) See sheet 12 for optional end section installation details.

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		DATE: 10/01/2025
	End Section Installation Details	DRAWN BY: JJO/TJC/MSW
	DWG. NAME. HBIB–9wCap_R4 / SCALE: 1:17 / UNITS: in.	REV. BY: KAL/CSS

Figure 140. End Section Installation Details, Test No. HBIB-9

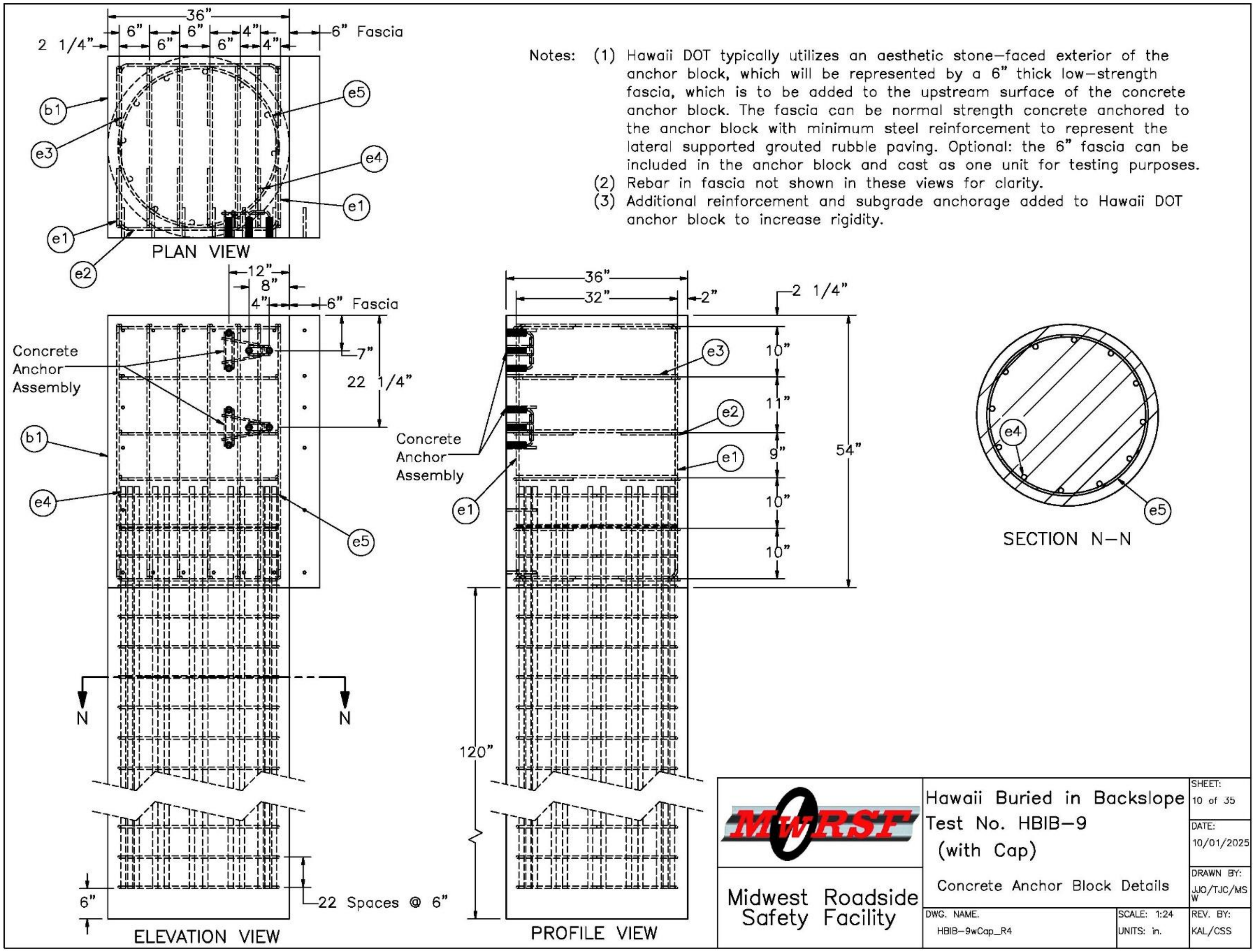
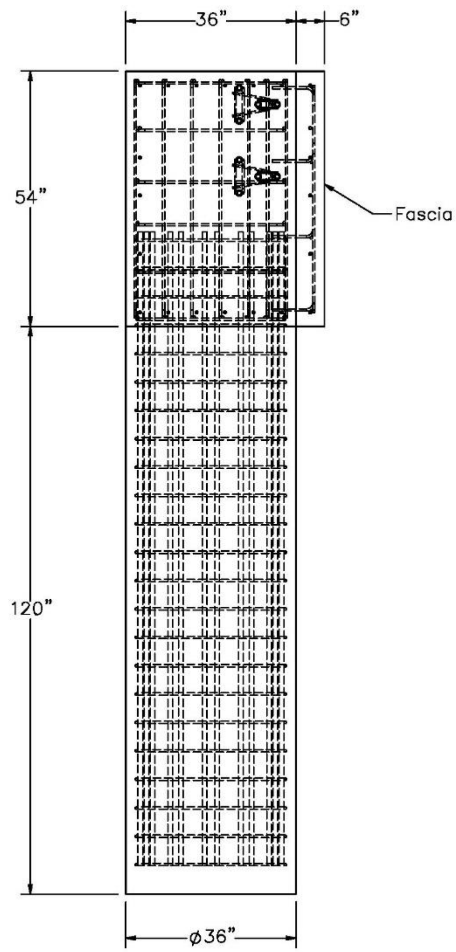


Figure 141. Concrete Anchor Block Details, Test No. HBIB-9



Note: (1) Hawaii DOT typically utilizes an aesthetic stone–faced exterior of the anchor block, which will be represented by a 6" thick low–strength fascia, which is to be added to the upstream surface of the concrete anchor block. The fascia can be normal strength concrete anchored to the anchor block with minimum steel reinforcement to represent the lateral supported grouted rubble paving.

(2) Optional: the 6" fascia can be included in the anchor block and cast as one unit for testing purposes.

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		DATE: 10/01/2025
Midwest Roadside Safety Facility	Anchor Block Assembly	DRAWN BY: JJO/TJC/MSW
	DWG. NAME. HBIB–9wCap_R4	SCALE: 1:32 UNITS: in.	REV. BY: KAL/CSS

Figure 142. Anchor Block Assembly, Test No. HBIB-9

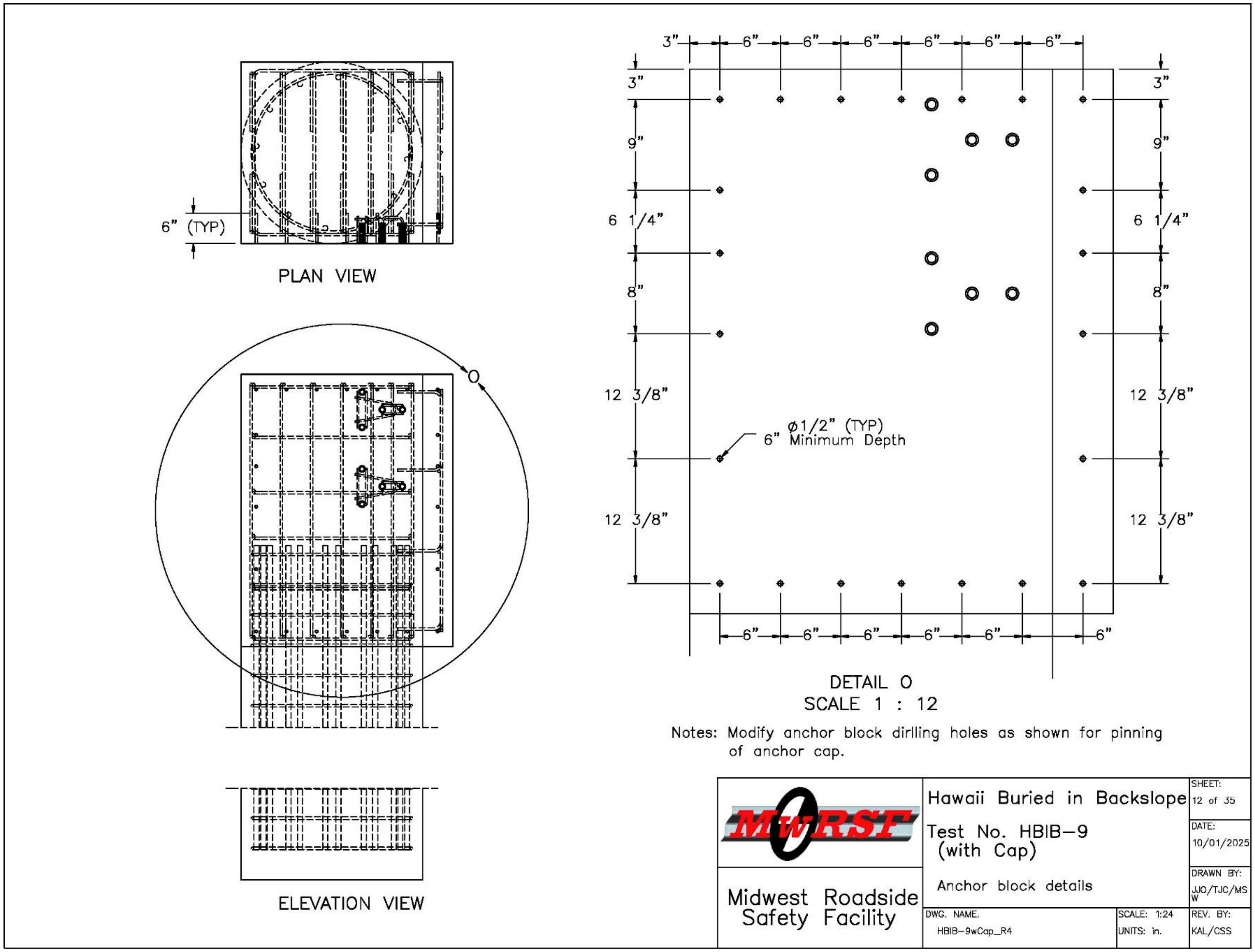
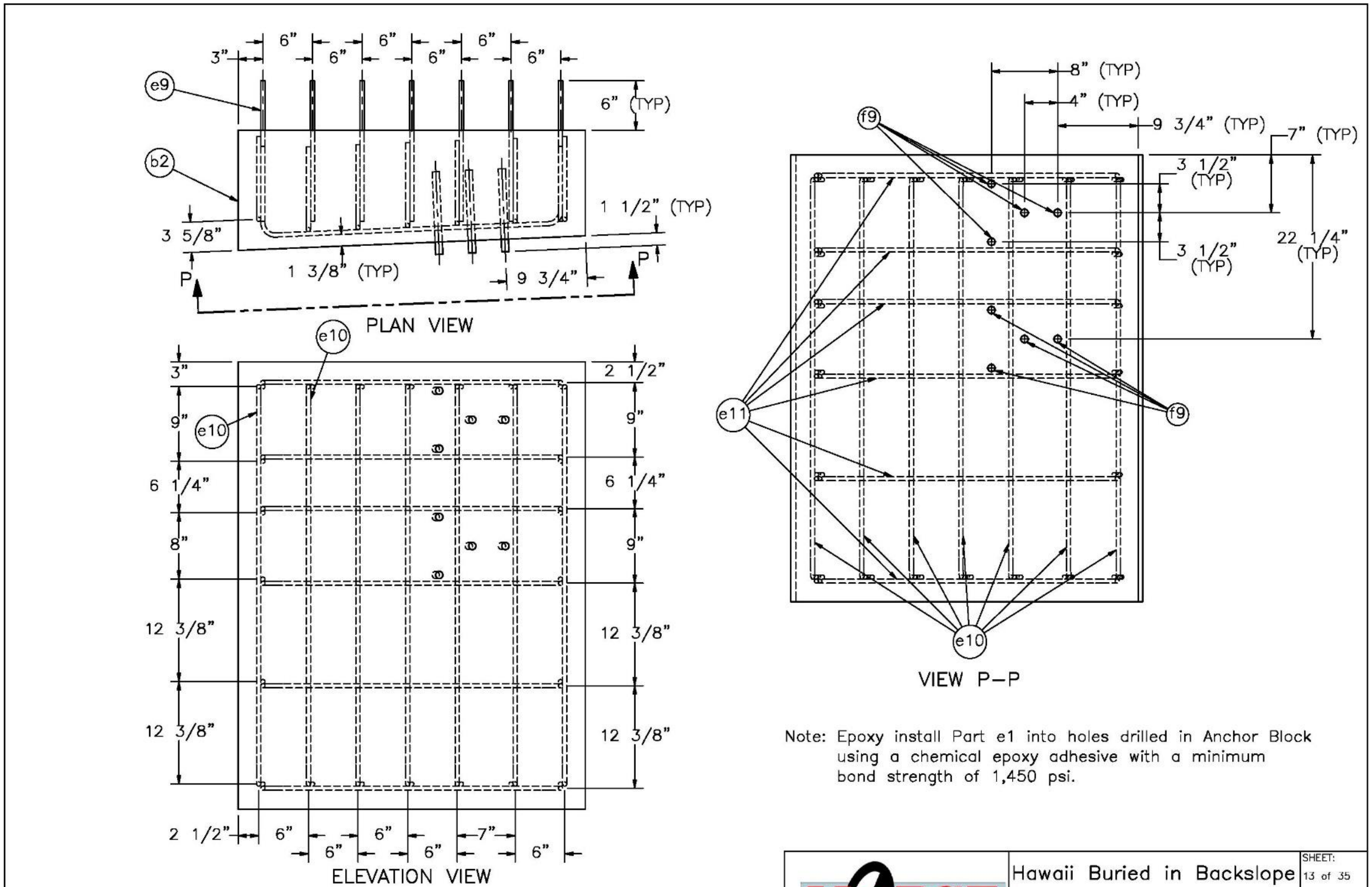


Figure 143. Anchor Block Details, Test No. HBIB-9



Bill of Bars

Bar	QTY	Size	Length	Material	Treatment
e9	22	#4	17"	ASTM A615 Gr. 60	Eposy Coated (ASTM A775 or A934)
e10	7	#4	67"	ASTM A615 Gr. 60	Eposy Coated (ASTM A775 or A934)
e11	6	#4	54 3/4"	ASTM A615 Gr. 60	Eposy Coated (ASTM A775 or A934)

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Hawaii Buried in Backslope Test No. HBIB–9 (with Cap)

Anchor Cap with Rebar

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DATE: 10/01/2025
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DWG. NAME. HBIB–9wCap_R4
SCALE: 1:16
UNITS: in.
REV. BY: KAL/CSS

Figure 144. Anchor Cap with Rebar Details, Test No. HBIB-9

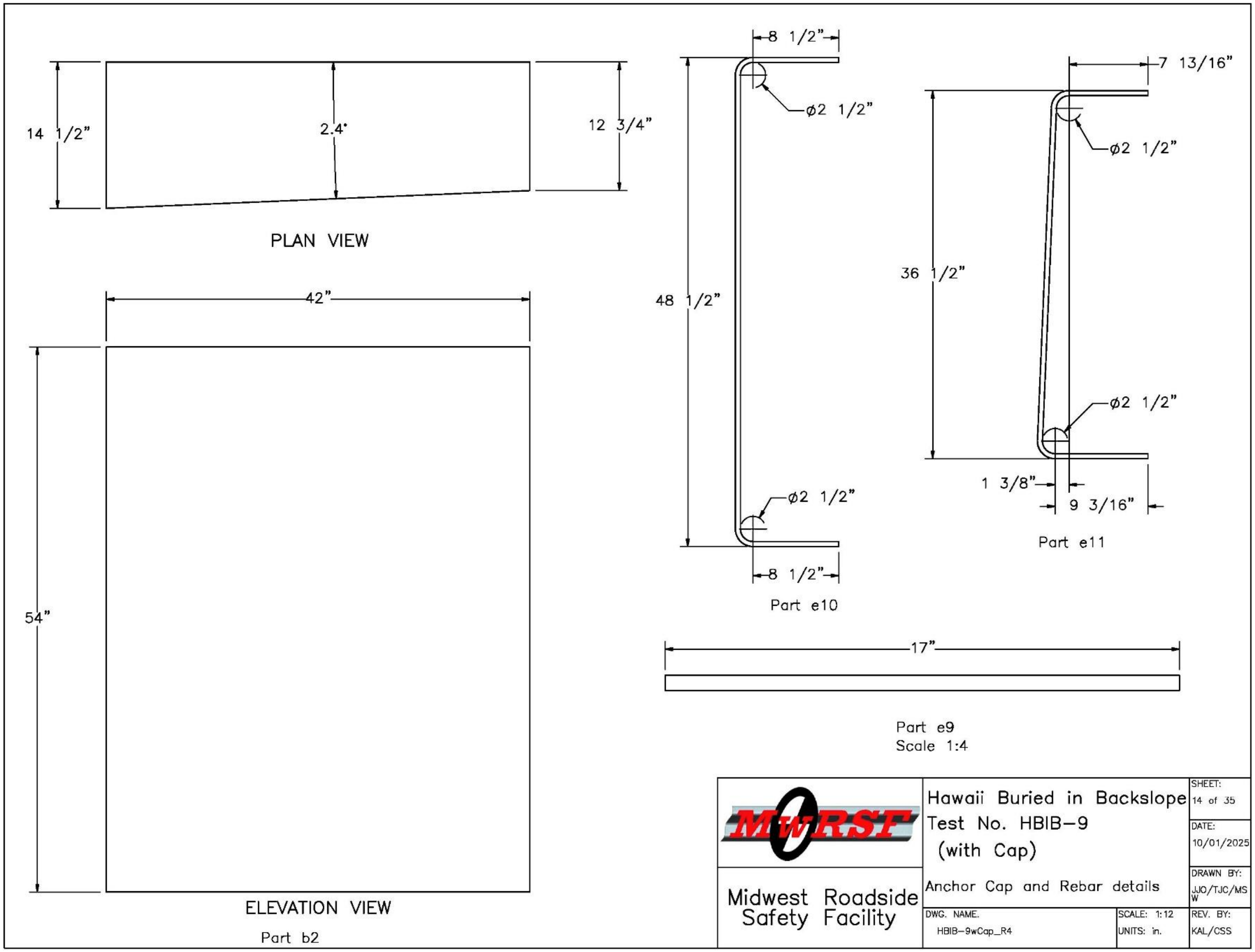


Figure 145. Anchor Cap and Rebar Details, Test No. HBIB-9

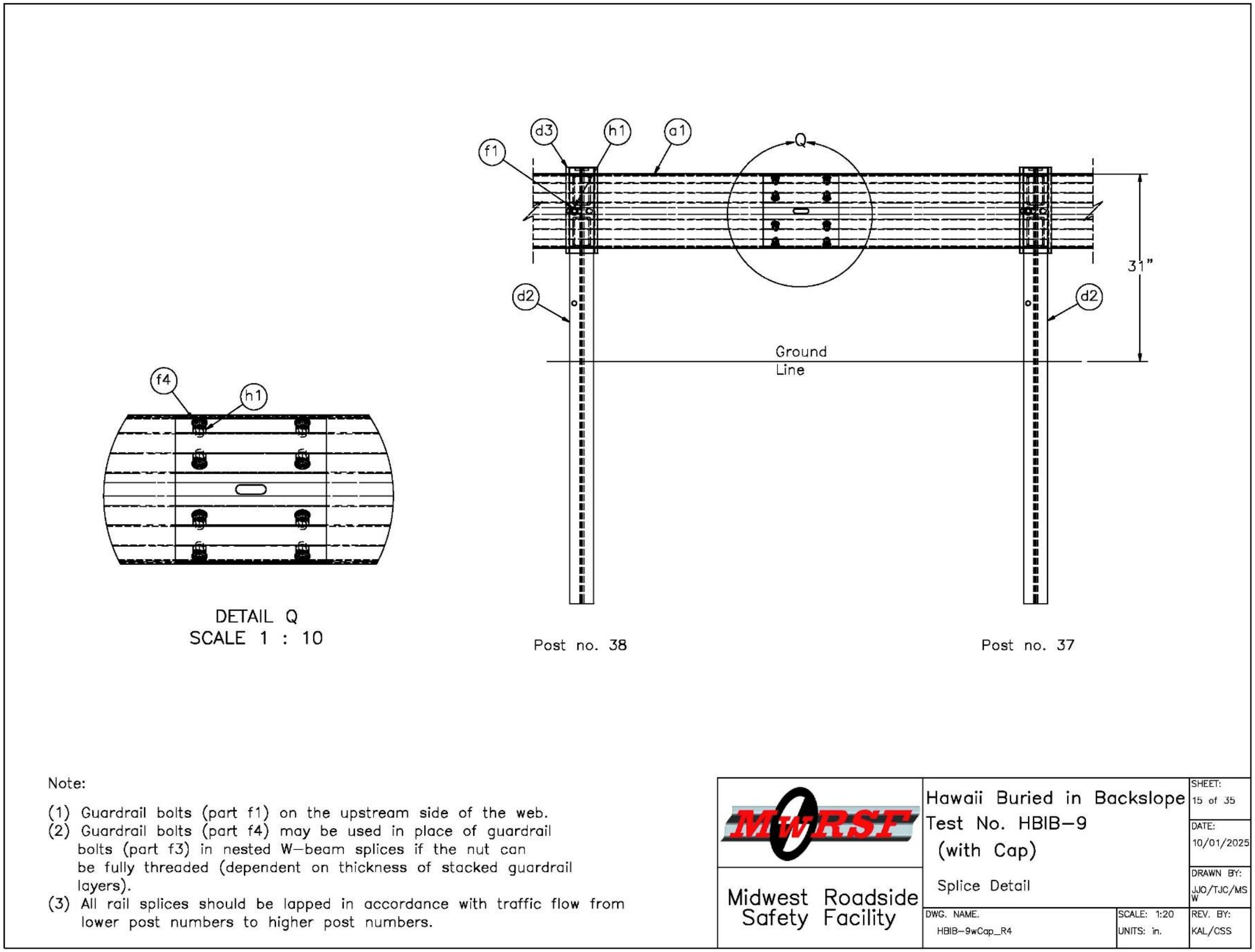


Figure 146. Splice Detail, Test No. HBIB-9

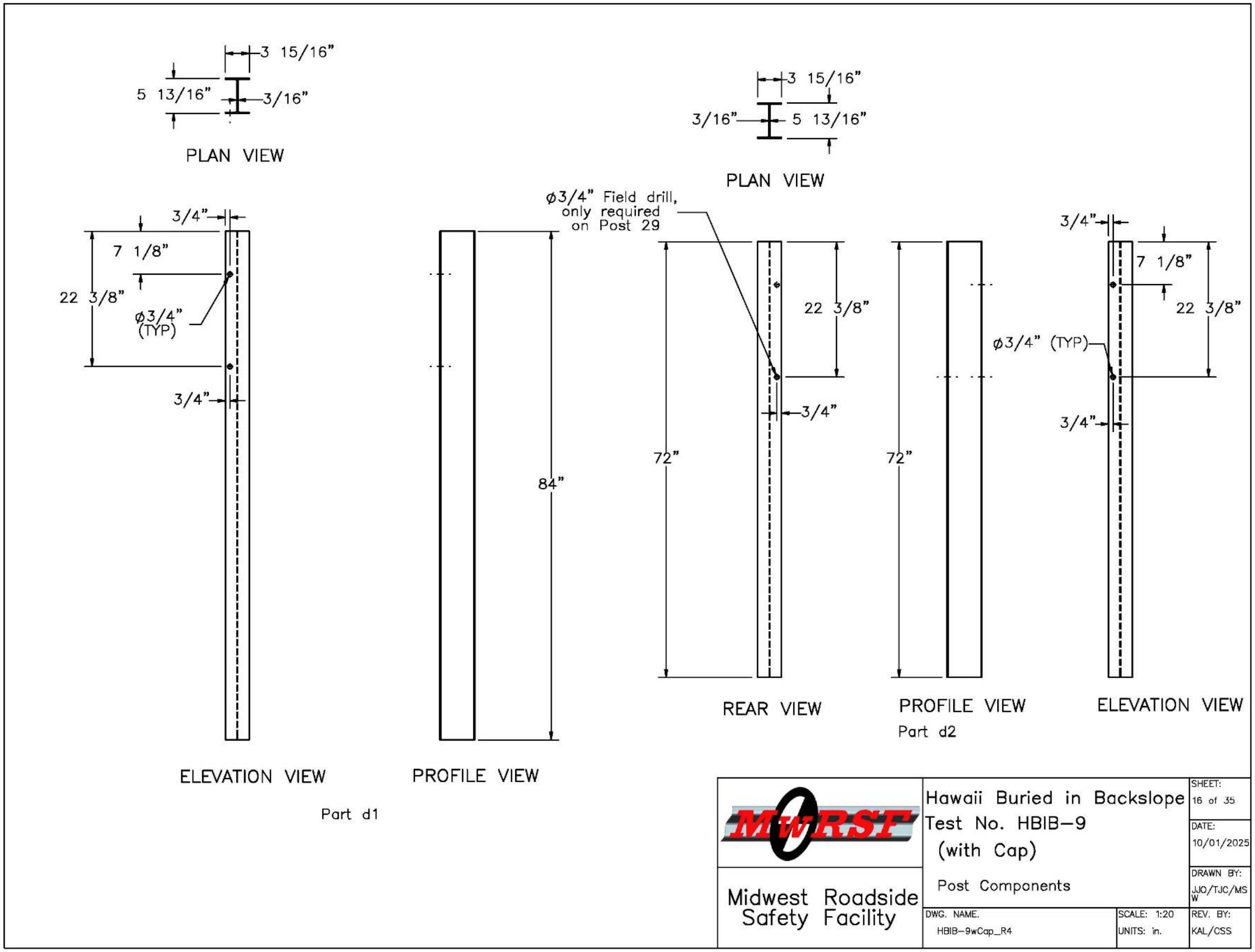


Figure 147. Post Components, Test No. HBIB-9

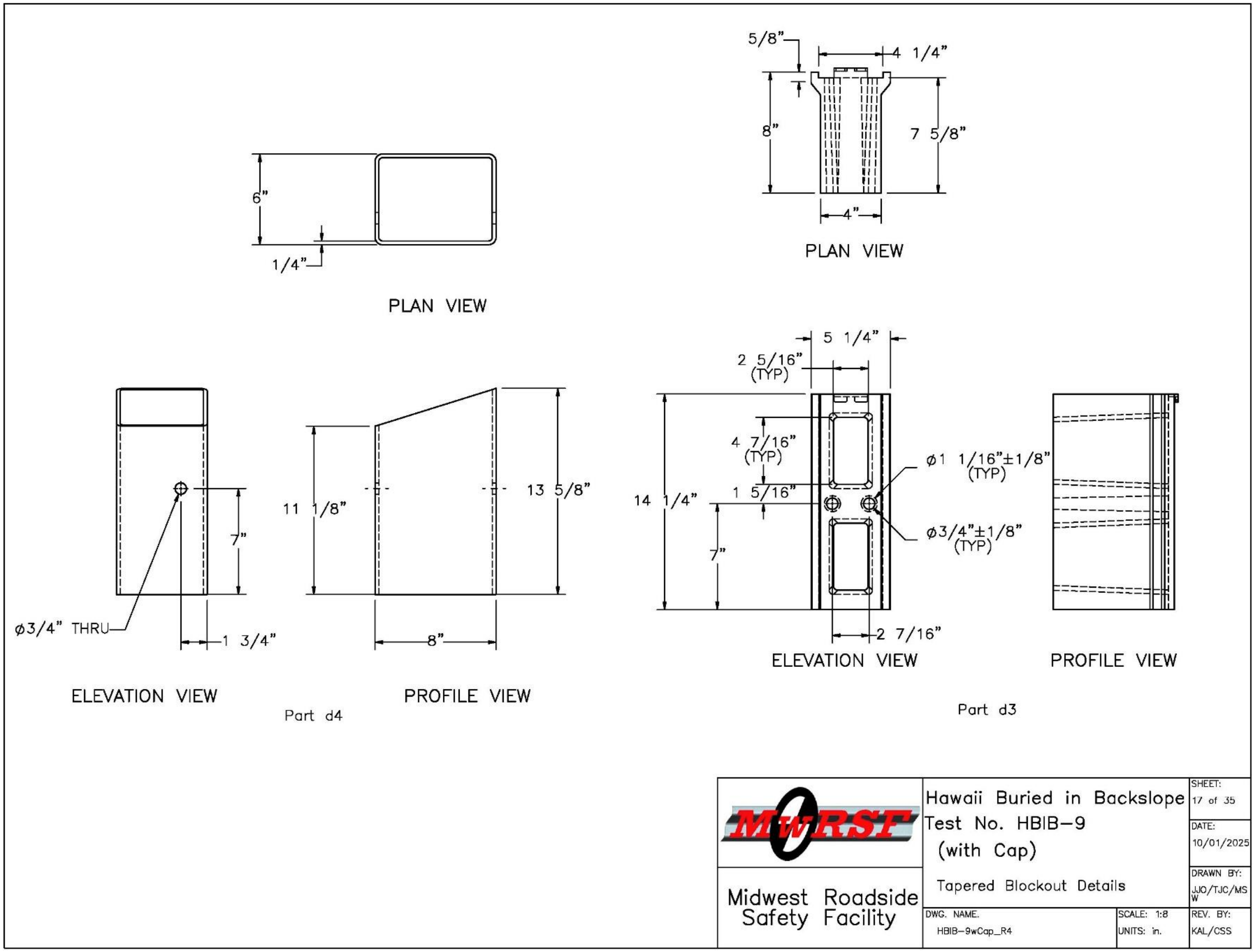
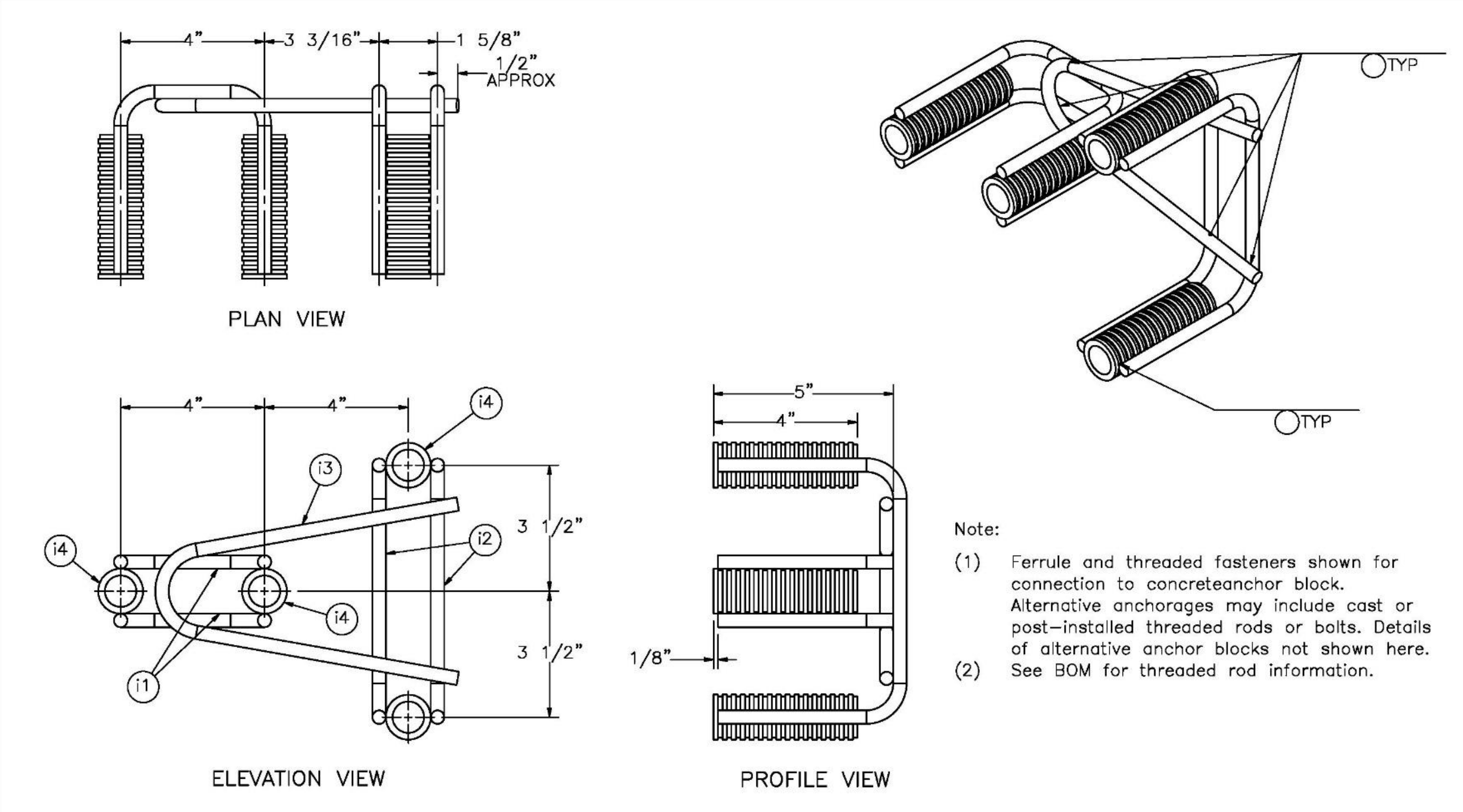


Figure 148. Tapered Blockout Details, Test No. HBIB-9



Item No.	QTY.	Description	Material Specification	Treatment Specification
–	2	Concrete Anchor	–	–
i1	2	3/8" 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
i4	4	7/8 Dia. Threaded Ferrule	–	–

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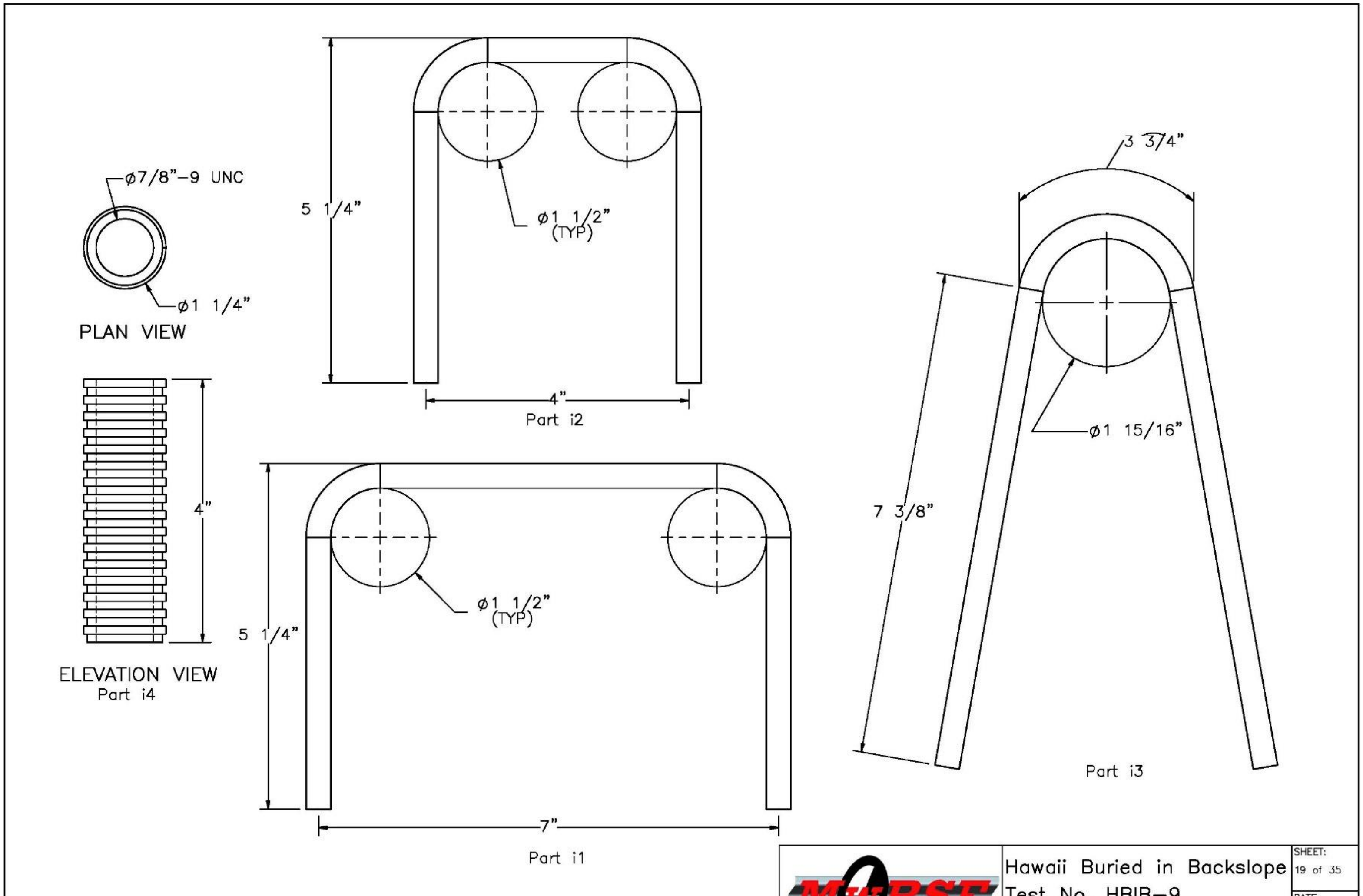
	Concrete Anchor Block Insert Assembly		DRAWN BY: JJO/TJC/MSW
	DWG. NAME. HBIB-9wCap_R4	SCALE: 1:4 UNITS: in.	REV. BY: KAL/CSS

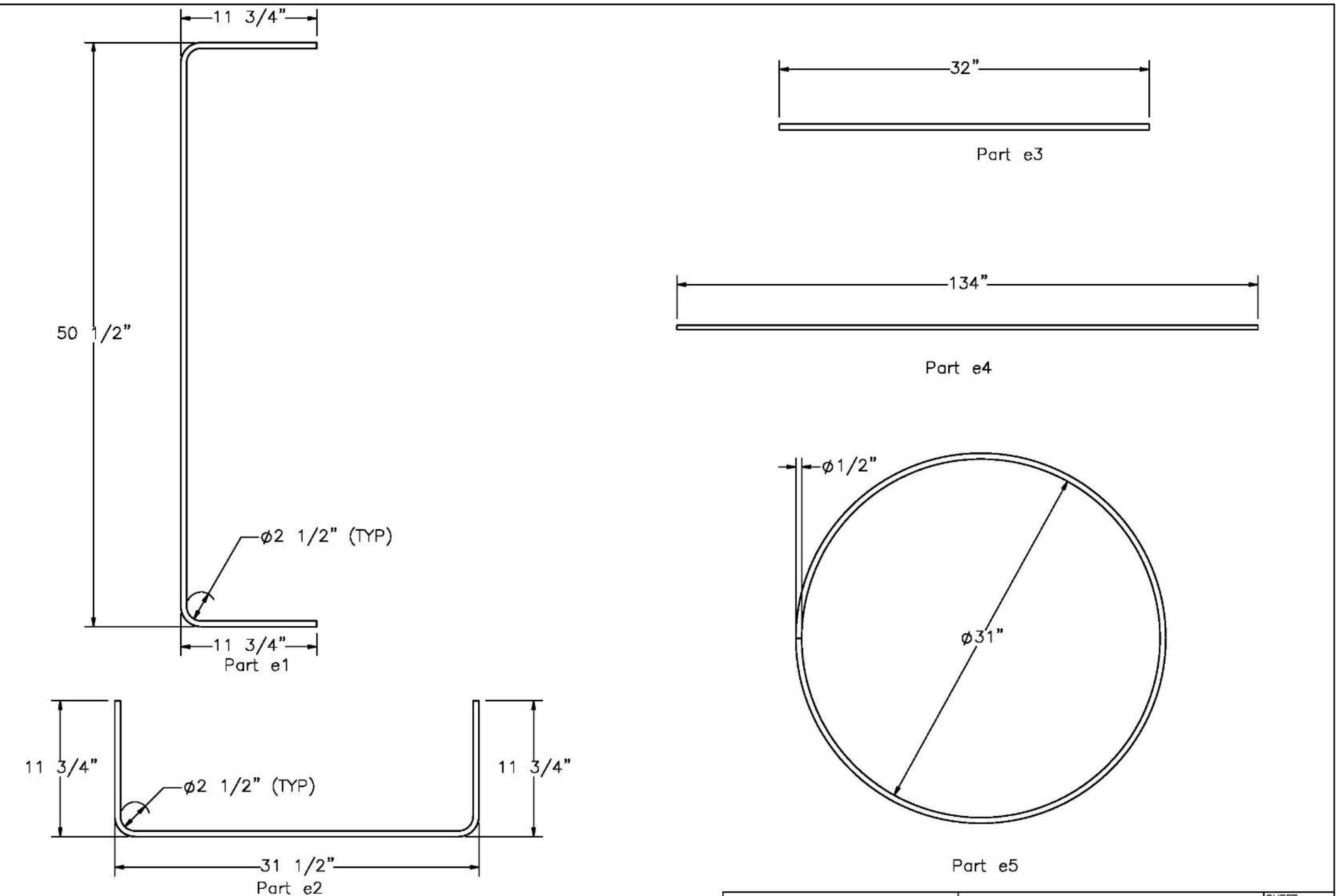
Figure 149. Concrete Anchor Block Insert Assembly, Test No. HBIB-9



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

Figure 150. Insert Component Details, Test No. HBIB-9



Bill of Bars

Bar	QTY	Size	Length	Material	Treatment
e1	14	#4	72"	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)
e2	12	#4	53"	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)
e3	23	#4	32"	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)
e4	12	#8	134"	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)
e5	23	#4	99"	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)

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Hawaii Buried in Backslope Test No. HBIB-9 (with Cap)

Anchor Block Rebar Details

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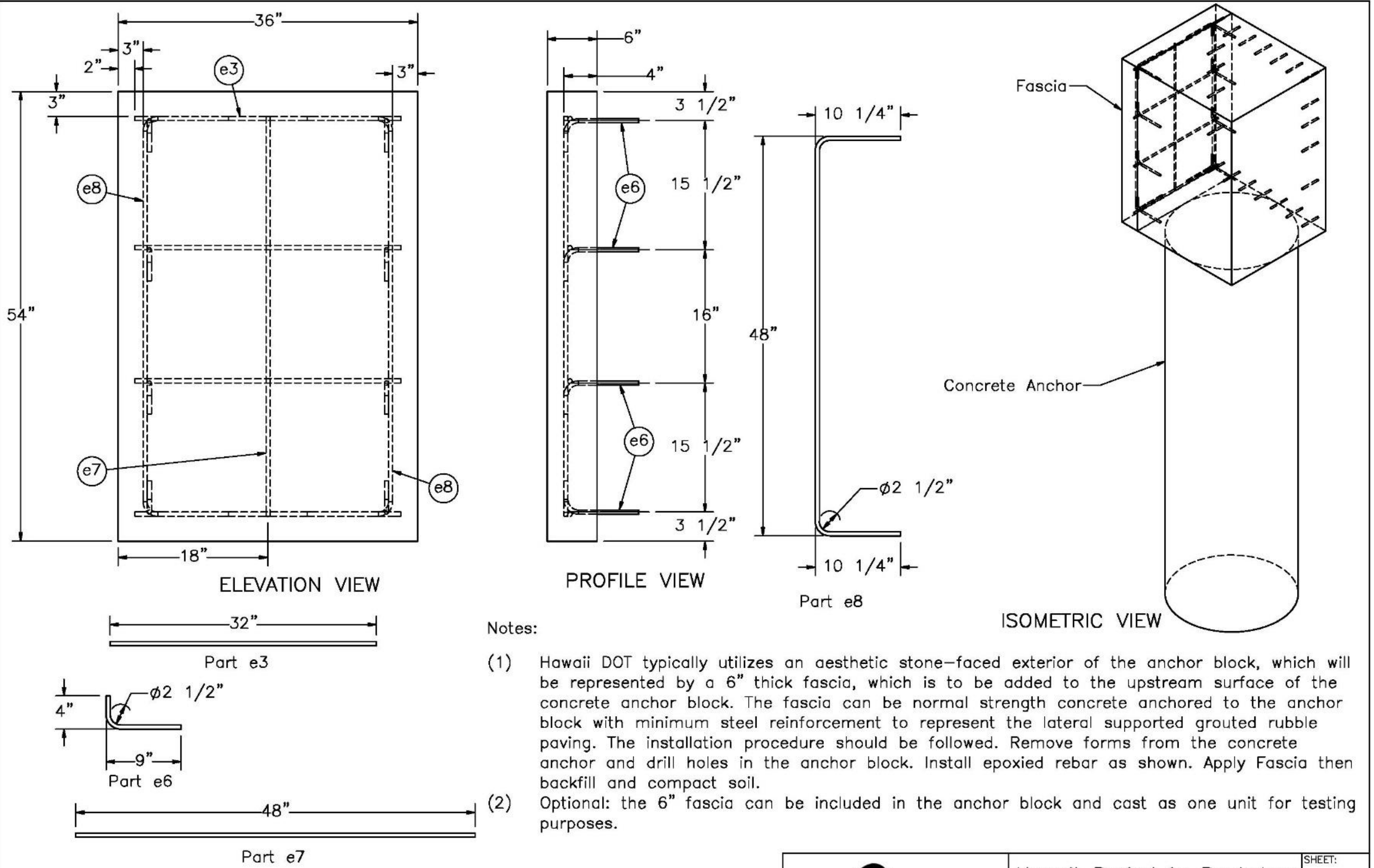
DWG. NAME. HBIB-9wCap_R4
SCALE: 1:12
UNITS: in.
REV. BY: KAL/CSS

Figure 151. Anchor Block Rebar Details, Test No. HBIB-9



Notes:

(1) Hawaii DOT typically utilizes an aesthetic stone-faced exterior of the anchor block, which will be represented by a 6" thick fascia, which is to be added to the upstream surface of the concrete anchor block. The fascia can be normal strength concrete anchored to the anchor block with minimum steel reinforcement to represent the lateral supported grouted rubble paving. The installation procedure should be followed. Remove forms from the concrete anchor and drill holes in the anchor block. Install epoxied rebar as shown. Apply Fascia then backfill and compact soil.

(2) Optional: the 6" fascia can be included in the anchor block and cast as one unit for testing purposes.

Bill of Bars

Bar	QTY	Size	Length	Material	Treatment
e3	4	#4	32"	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)
e6	8	#4	12"	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)
e7	1	#4	48"	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)
e8	2	#4	67"	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)

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Hawaii Buried in Backslope Test No. HBIB-9 (with Cap)

Fascia Installation

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DATE: 10/01/2025
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SCALE: 1:16
UNITS: in.
REV. BY: KAL/CSS

Figure 152. Fascia Installation, Test No. HBIB-9

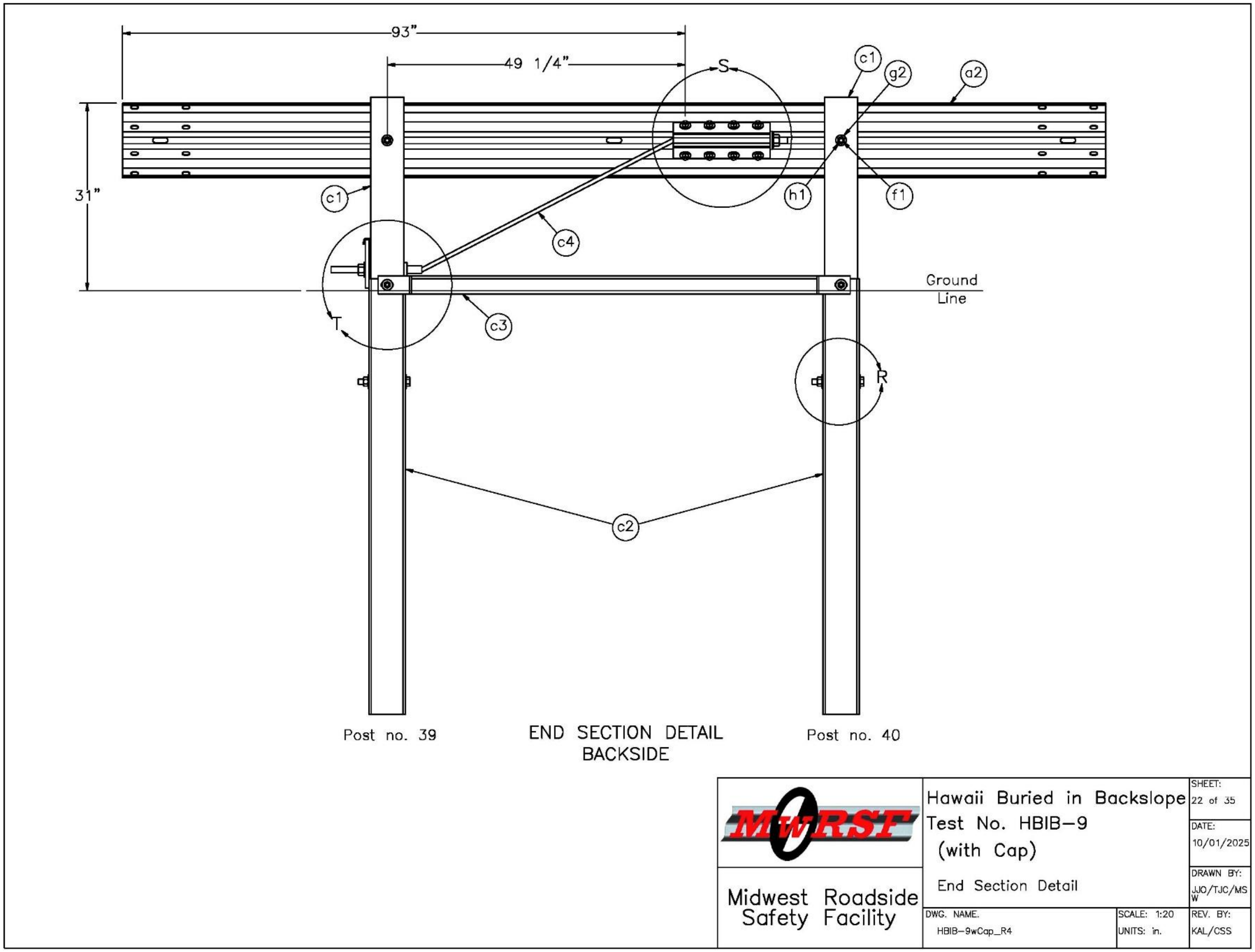

Figure 153. End Section Detail, Test No. HBIB-9

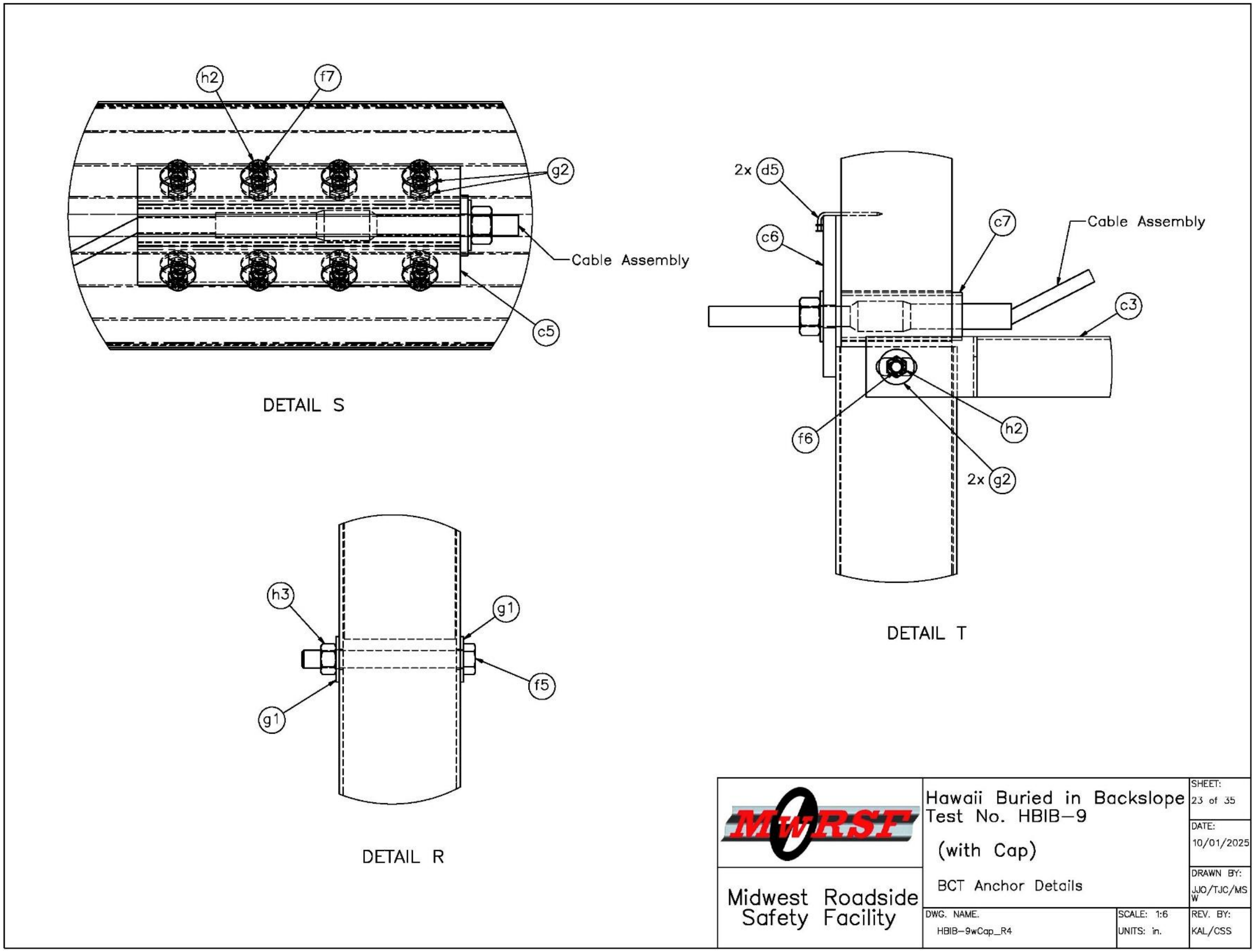

Figure 154. BCT Anchor Details, Test No. HBIB-9

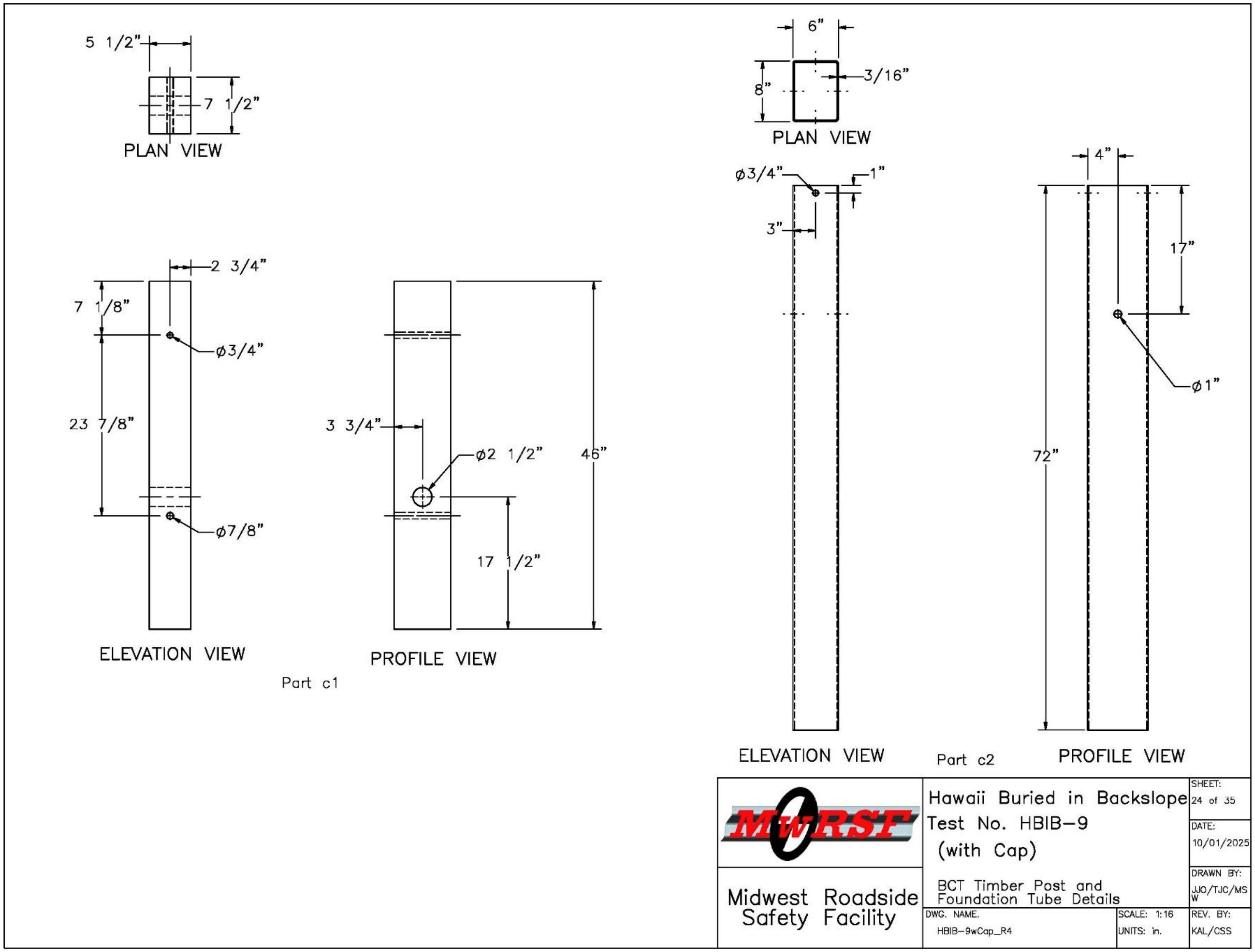

Figure 155. BCT Timber Post and Foundation Tube Details, Test No. HBIB-9

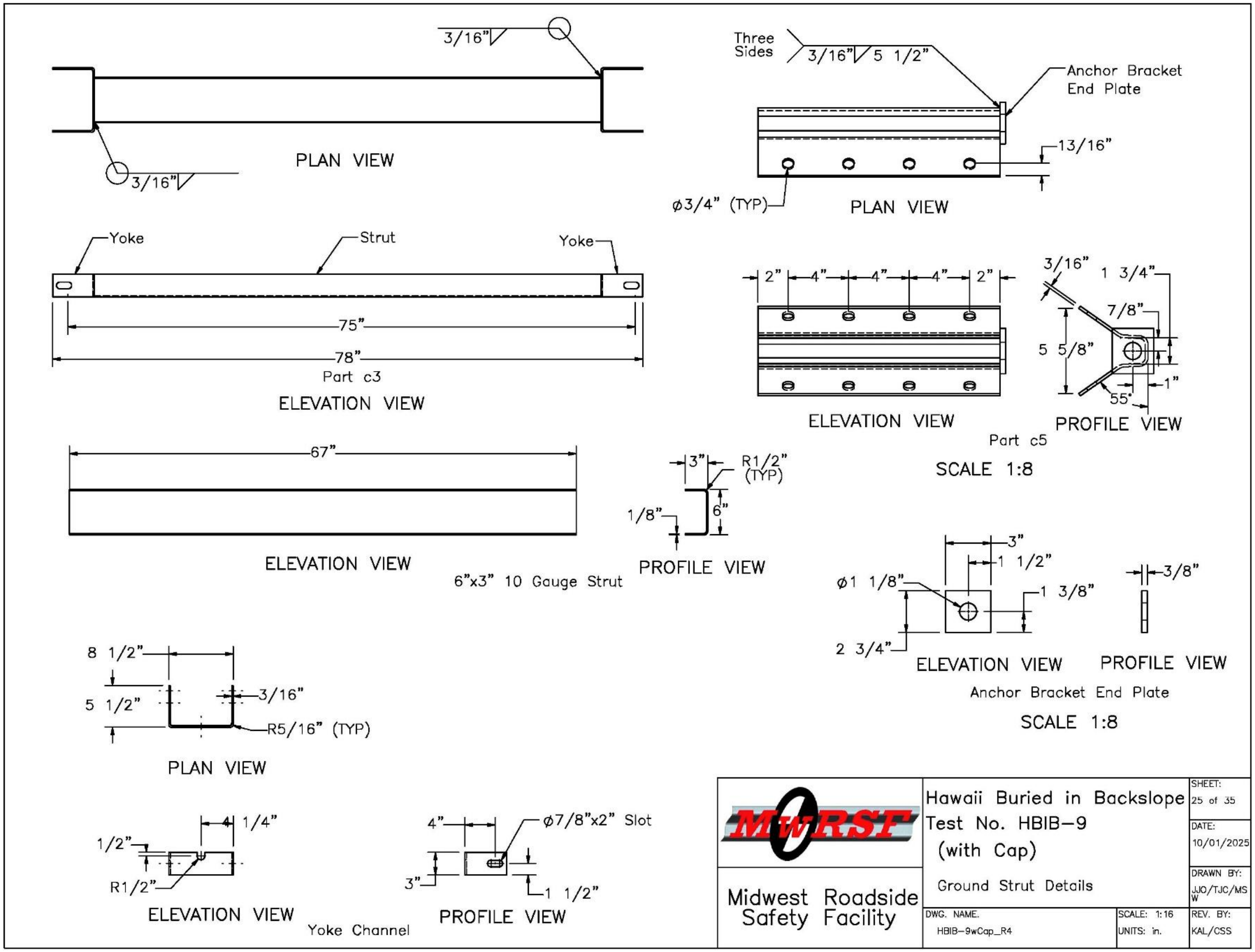

Figure 156. Ground Strut Details, Test No. HBIB-9

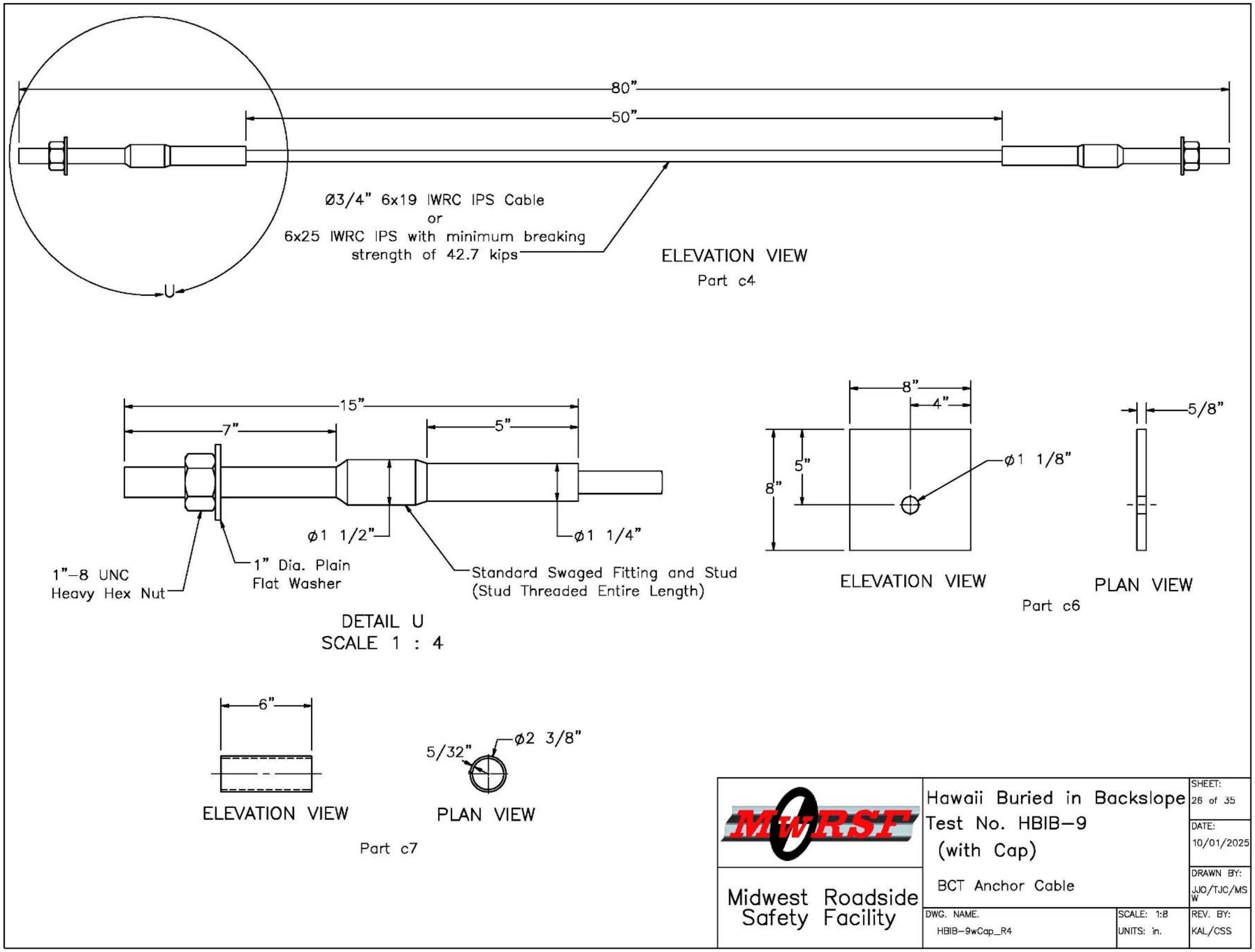

Figure 157. BCT Anchor Cable, Test No. HBIB-9

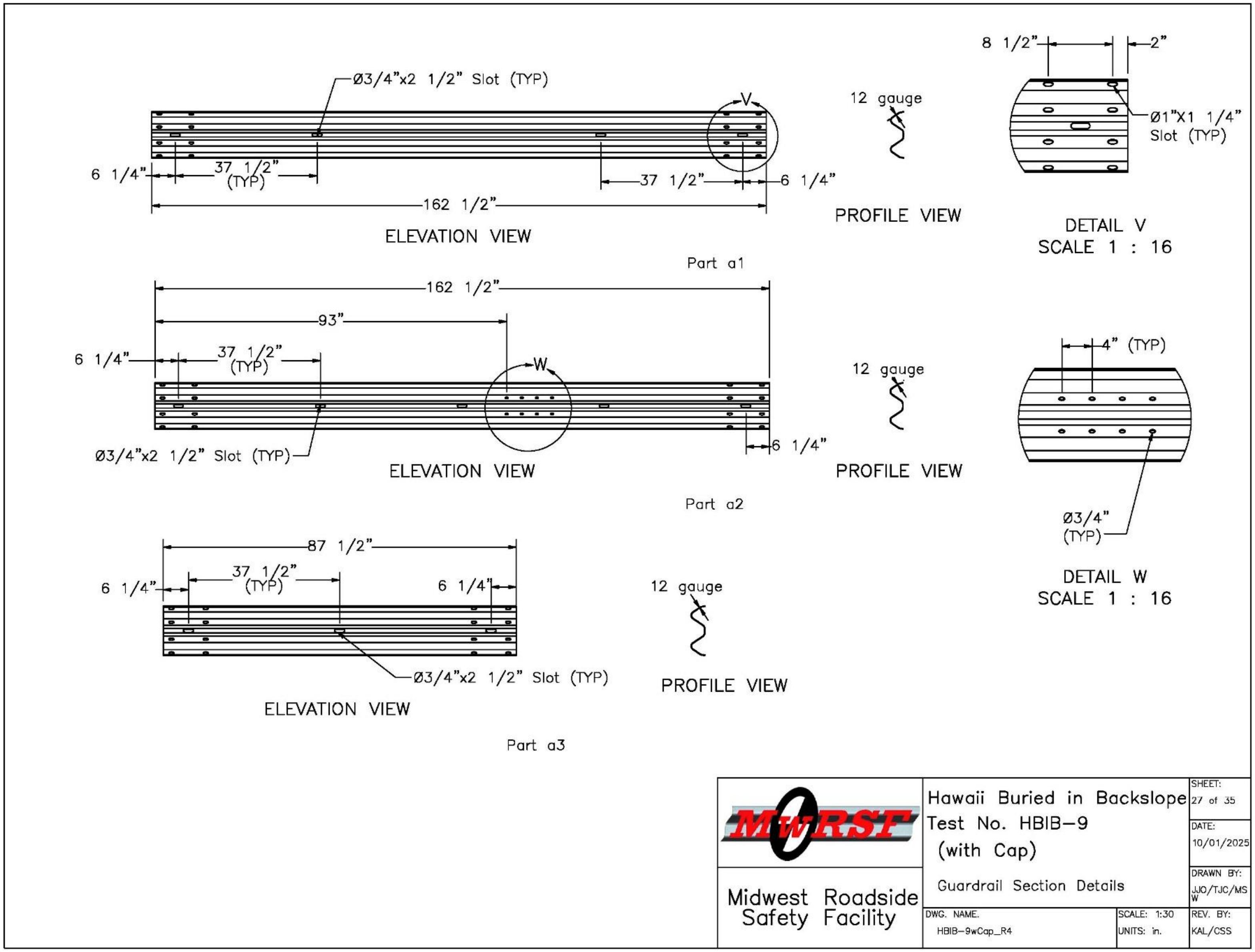

Figure 158. Guardrail Section Details, Test No. HBIB-9

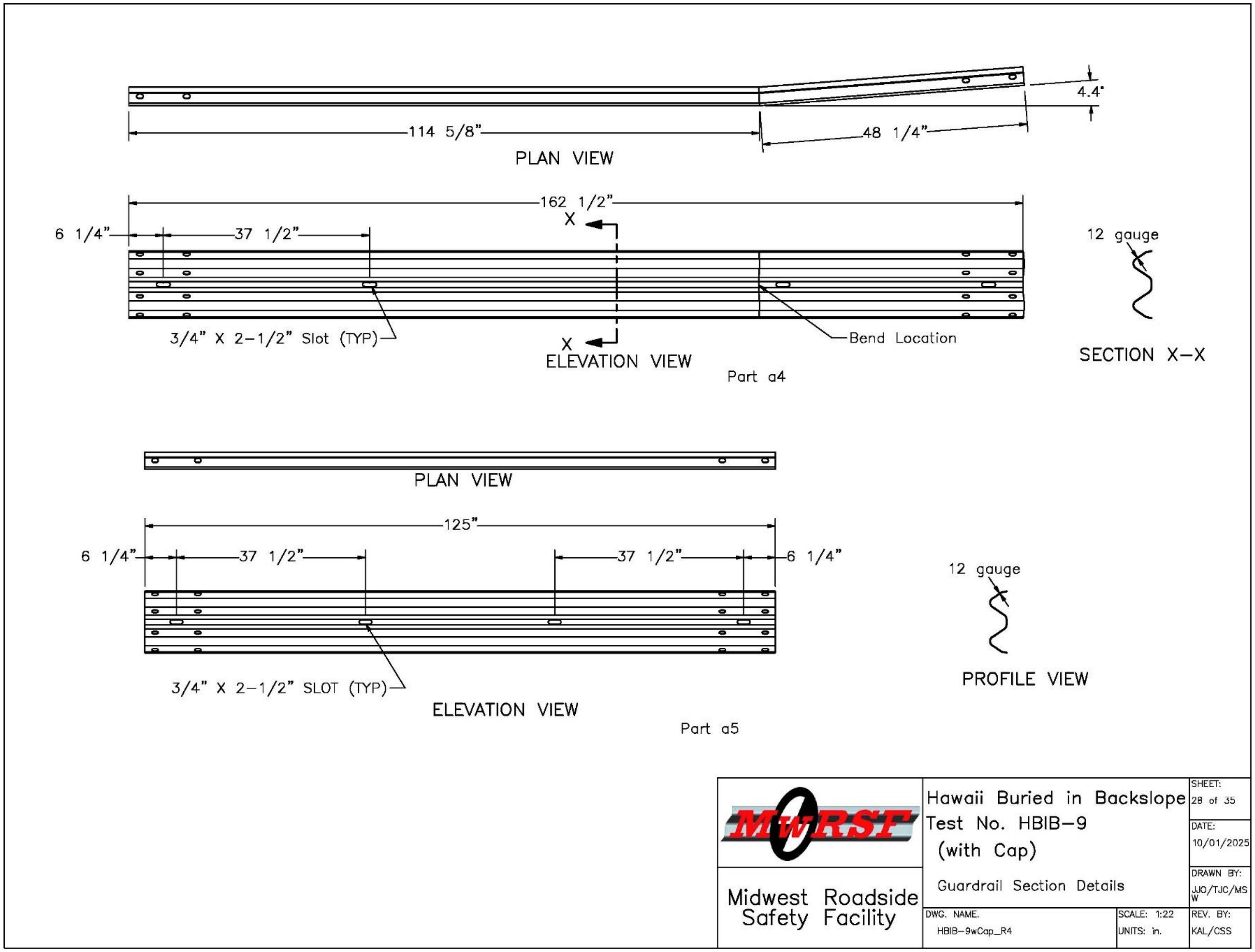

Figure 159. Guardrail Section Details, Cont., Test No. HBIB-9

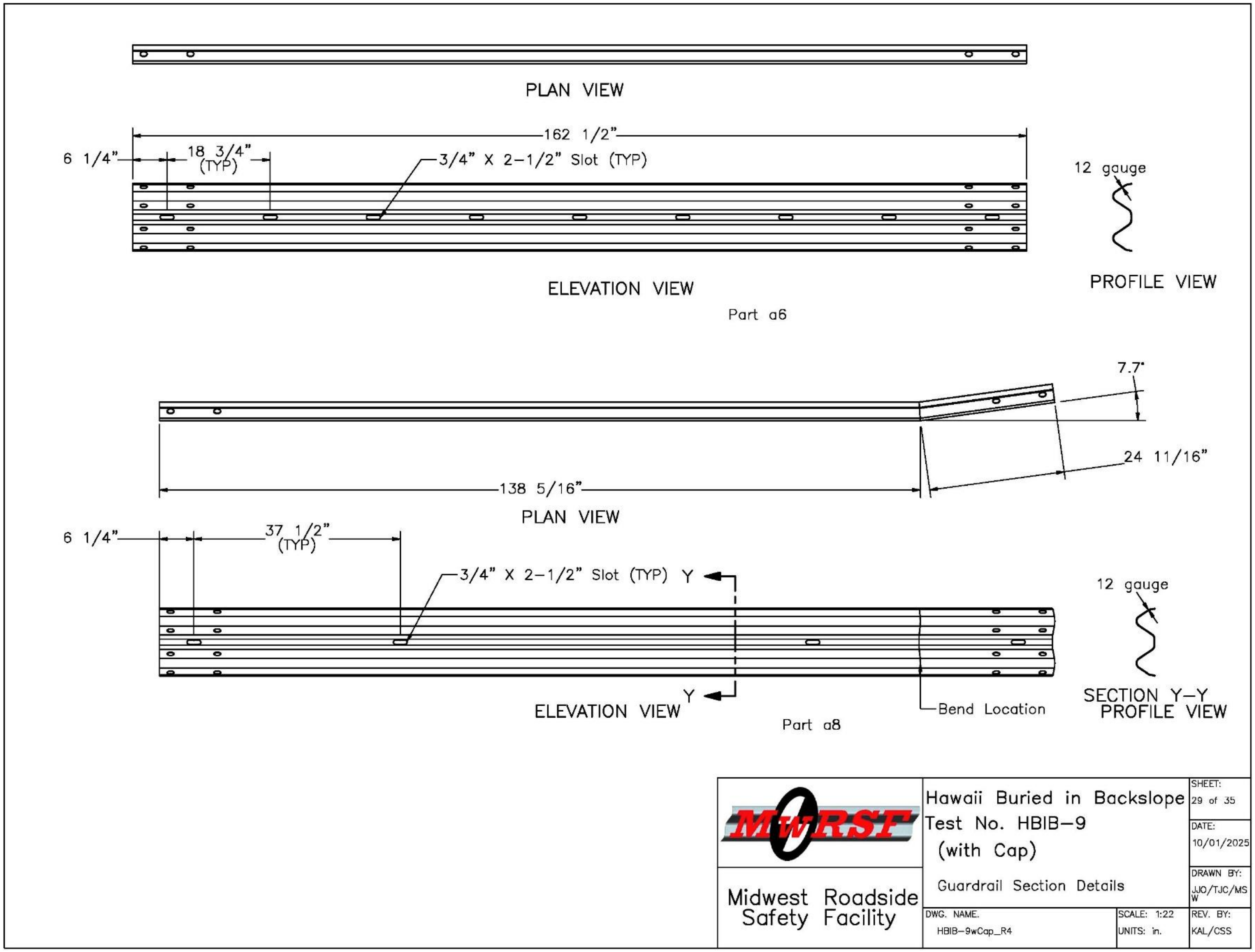

Figure 160. Guardrail Section Details, Cont., Test No. HBIB-9

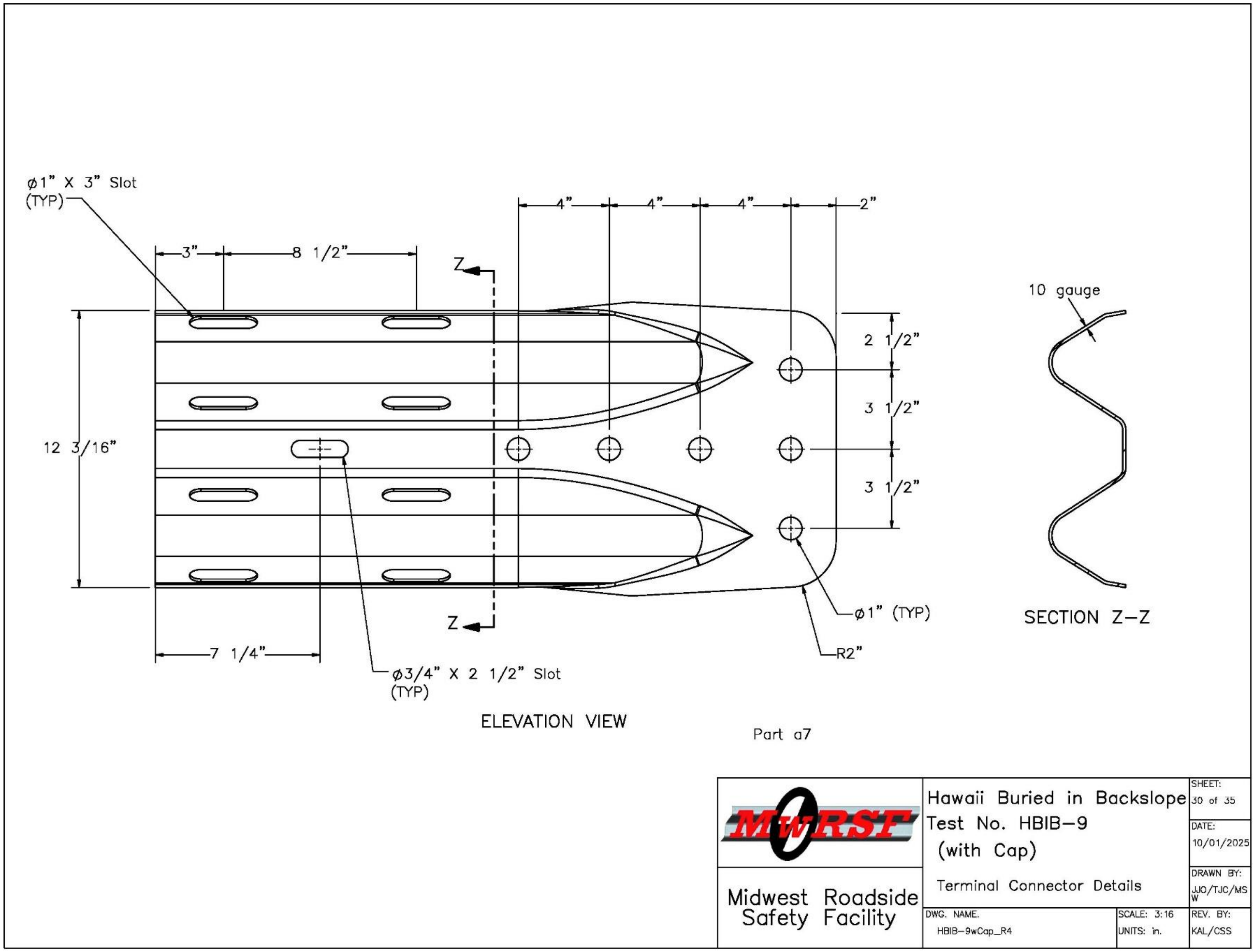

Figure 161. Terminal Connector Details, Test No. HBIB-9

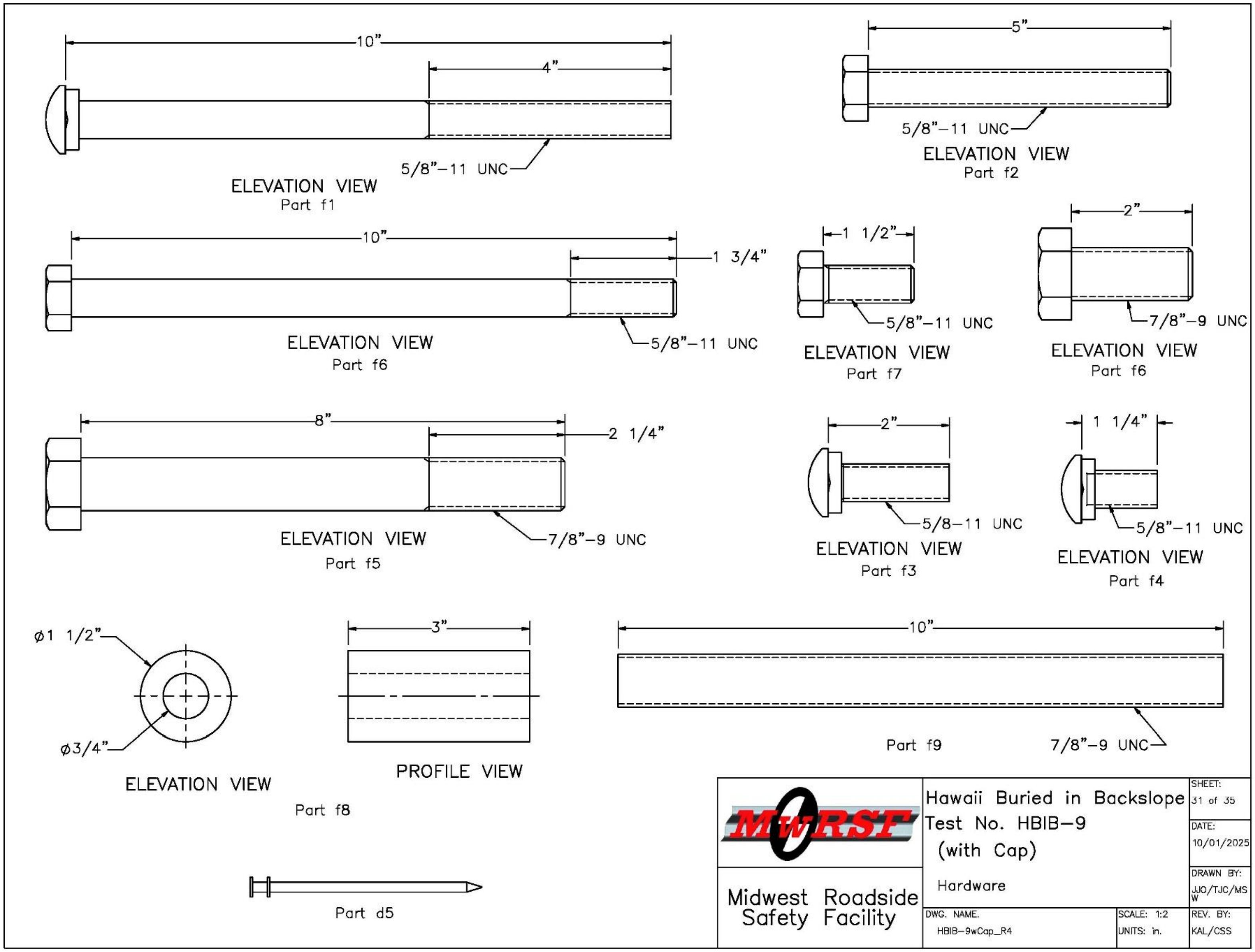

Figure 162. Hardware Details, Test No. HBIB-9

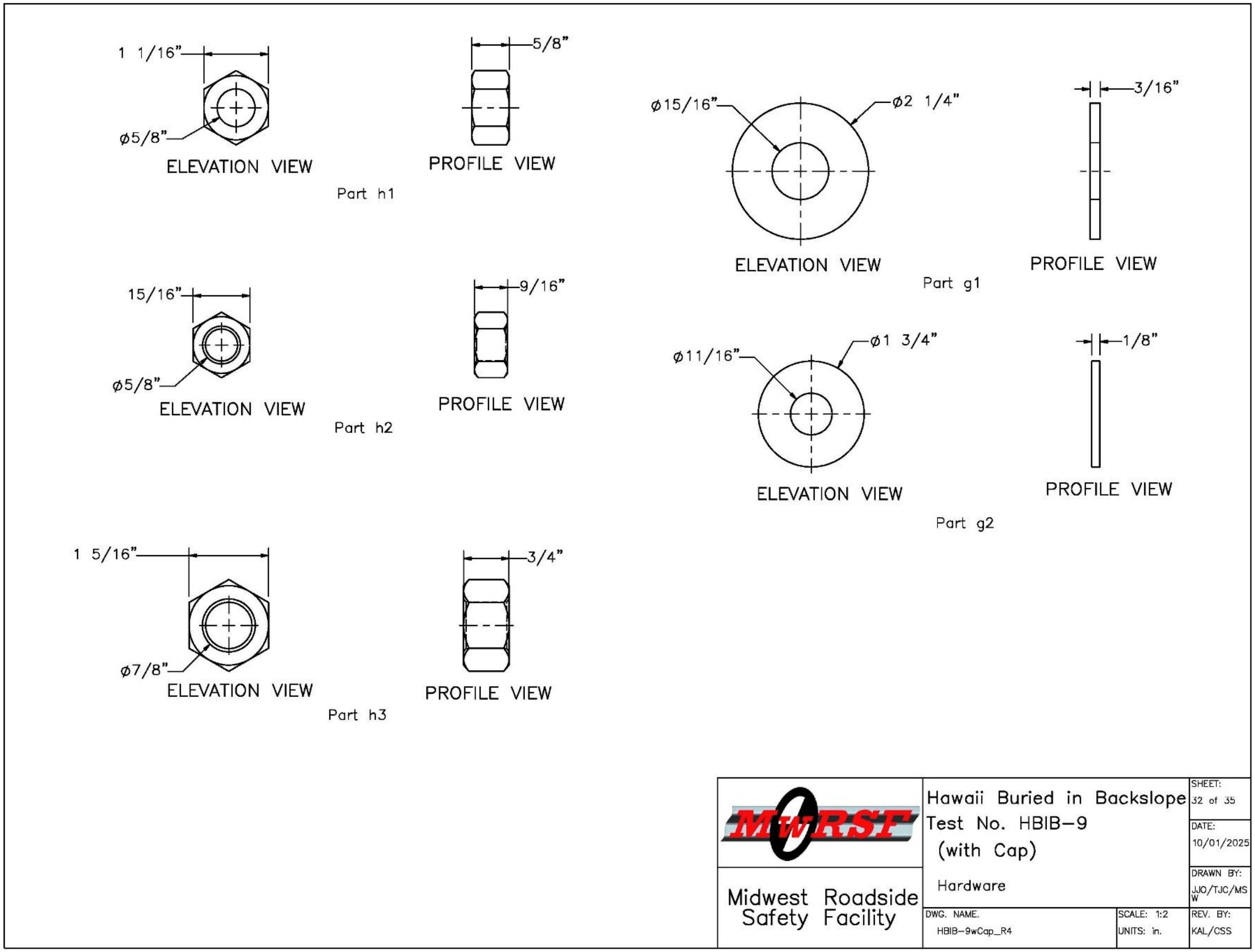

Figure 163. Hardware Details, Cont., Test No. HBIB-9

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
a1	22	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 W–Beam	AASHTO M180	ASTM A123 or A653	–
a6	4	12'–6" 12–gauge W–Beam Section – 1/4 Post Spacing	AASHTO M180	ASTM A123 or A653	RWM04a
a7	2	W–Beam Terminal Connector	AASHTO M180	ASTM A123 or A653	RWE02b
a8	1	12'–6" 12–gauge Bent W–Beam [7.7 deg]	AASHTO M180	ASTM A123 or A653	–
b1	1	3'x3' Concrete Anchor Block	Min. f'c = 4,000 psi	–	–
b2	1	Anchor Cap	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	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
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	38	Composite Recycled Blockout	Mondo Polymer GB14SH2 or Equivalent	–	–
d4	27	13 5/8" Long, 8"x6"x1/4" Steel Blockout	ASTM A500 Gr. B	*ASTM A123	–
d5	2	16D Double Head Nail	–	–	–

Midwest Roadside Safety Facility

Hawaii Buried in Backslope Test No. HBIB–9 (with Cap)

Bill of Materials

SHEET: 33 of 35
DATE: 10/01/2025
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DWG. NAME. HBIB–9wCap_R4
SCALE: None
UNITS: in.
REV. BY: KAL/CSS

Figure 164. Bill of Materials, Test No. HBIB-9

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
e1	14	72" Unbent Length #4 Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
e2	12	53" Unbent Length #4 Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
e3	27	32" Long #4 Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
e4	12	134" Long #8 Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
e5	23	99" Unbent Length #4 Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
e6	8	12" Long Unbent #4 Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
e7	1	48" Long #4 Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
e8	2	67" Unbent Length #4 Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
e9	22	17" Long #4 Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
e10	7	67" Unbent Length #4 Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
e11	6	54 3/4" Unbent Length #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 A459 Gr. 5 or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f3	1	5/8" Dia. UNC, 2" Long Guardrail Bolt	ASTM A307 Gr. A	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	5/8" Dia. UNC, 10" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f7	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
f8	1	3/4 Dia, Unthreaded Spacer Sleeve	ASTM A53 Gr. B	ASTM A123	FMM03–04
f9	8	7/8" Dia. 9 UNC, 10" Long Fully Threaded Rod	ASTM A307 Gr. A or Equivalent	ASTM A153 or B695 Class 55 or F2329	–

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			DATE: 10/01/2025
	Bill of Materials		DRAWN BY: JJO/TJC/MSW
	DWG. NAME. HBIB-9wCap_R4	SCALE: None UNITS: in.	REV. BY: KAL/CSS

Figure 165. Bill of Materials, Cont., Test No. HBIB-9

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
g1	12	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	308	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	11	5/8" Dia. Hex Nut	ASTM A563A	ASTM A153 (AASHTO M232) for Class C or ASTM B695 (AASHTO M298) for Class 50	FNX16a
h3	10	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	3/8" 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	–	–	–
k2	1	Fascia	Min. f'c = 4,000 psi	–	–
–	–	Soil	–	–	–

* Components not required if optional anchor is used.

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		DATE: 10/01/2025
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	DWG. NAME. HBIB-9wCap_R4 — SCALE: 1:768 UNITS: in.	REV. BY: KAL/CSS

Figure 166. Bill of Materials, Cont., Test No. HBIB-9

Figure 167. Test Installation Photographs, Test No. HBIB-9

Figure 168. Test Installation Photographs, Test No. HBIB-9

Figure 169. Test Installation Photographs, Rubrail Termination and System Anchorage, Test No. HBIB-9

11 FULL-SCALE CRASH TEST NO. HBIB-9

11.1 Static Soil Test

Before full-scale crash test no. HBIB-9 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-9 was conducted on March 27, 2025, 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 23.

Table 23. Weather Conditions, Test No. HBIB-9

Temperature	80°F
Humidity	44%
Wind Speed	9 mph
Wind Direction	130° from True North
Sky Conditions	Clear, Sunny
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.00 in.
Previous 7-Day Precipitation	0.00 in.

11.3 Test Description

The targeted vehicle impact was to occur 69¼ in. upstream from the upstream end of the concrete anchor block, as shown in Figure 170. The CIP for test no. HBIB-9 was selected using the recommended TL-3 test matrix Table 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 5,000-lb quad cab pickup truck impacted the slope break point of the system in the reverse direction at a speed of 62.0 mph and at an angle of 25.4 degrees and impacted the barrier at a speed of 62.1 mph and at an angle of 28.8 degrees. The actual point of impact was 68.5 in. upstream from the upstream end of the concrete anchor. At 0.330 sec, the vehicle exited the system and at 0.508 sec the vehicle began to roll away from the system, subsequently rolling over. At 6.838 sec, the vehicle came to rest on its roof.

A detailed description of the sequential impact events is reported in Table 24. Sequential photographs are shown in Figures 171 and 172. Documentary photographs of the crash test are shown in Figures 173 through 175. The vehicle trajectory and final position are shown in Figure 176.

Figure 170. Target Impact Location, Test No. HBIB-9

Table 24. Sequential Description of Impact Events, Test No. HBIB-9

Time sec	Event
-0.163	Vehicle's right-front tire became airborne as vehicle traversed slope.
-0.142	Vehicle rolled toward the system.
0.000	Vehicle's front bumper contacted rail 68.5 in. upstream from the upstream end of the concrete anchor and crushed rearward. Post nos. 1, 3, and 4 rotated backward.
0.012	Vehicle's right headlight contacted rail and shattered. Vehicle's left-front tire became airborne. Vehicle's right-front tire contacted rail.
0.018	Post nos. 2 and 5 rotated backward. Vehicle's right fender contacted rail and crushed inward.
0.028	Vehicle's grille contacted rail and disengaged.
0.052	Vehicle's right-front tire deflated.
0.076	Vehicle's right-front door contacted rail, crushed inward, was scraped, and tore.
0.104	Vehicle's right-front window shattered and front windshield cracked. Vehicle's left-rear tire became airborne.
0.117	Occupant's head extended out vehicle's right-front window.
0.142	Vehicle's right-rear door contacted rail, crushed inward, was scraped, and tore.
0.178	Vehicle's right quarter panel contacted rail, crushed and dented inward, and was scraped. Vehicle's right taillight contacted rail and shattered. Vehicle pitched downward.
0.190	Vehicle was parallel to system at a speed of 48.4 mph.
0.225	Vehicle's right-front wheel disengaged.
0.276	Vehicle yawed toward the system.
0.330	Vehicle exited system at a speed of 46.3 mph and an angle of -3.7 degrees.
0.508	Vehicle rolled away from the system.
0.571	Vehicle occupant's head extended out the vehicle's right-front window.
0.640	Vehicle's left-front tire contacted ground.
0.658	Vehicle's right-rear tire became airborne.
0.825	Vehicle pitched upward. Vehicle's left-rear tire contacted ground.
1.442	Vehicle pitched downward.
1.750	Vehicle pitched upward.
1.908	Vehicle's roof contacted ground for the first time and crushed inward.
1.963	Vehicle occupant's head extended out of vehicle's right-front window.
2.021	Vehicle's right C-Pillar bent. Vehicle's right A-Pillar and B-Pillar crushed inward.
2.058	Vehicle's right-rear window shattered. Vehicle's roof deformed onto occupant's head.
2.392	Vehicle's right-rear tire contacted ground.
2.690	Vehicle's right-rear tire became airborne.

Table 25. Sequential Description of Impact Events, Test No. HBIB-9, Cont.

Time sec	Event
2.733	Vehicle's left-rear tire contacted ground.
2.767	Vehicle's left-front tire contacted ground.
3.583	Vehicle's left-front tire became airborne.
3.750	Vehicle's roof contacted ground.
3.796	Vehicle's left-rear tire became airborne.
6.838	Vehicle came to rest on its roof.

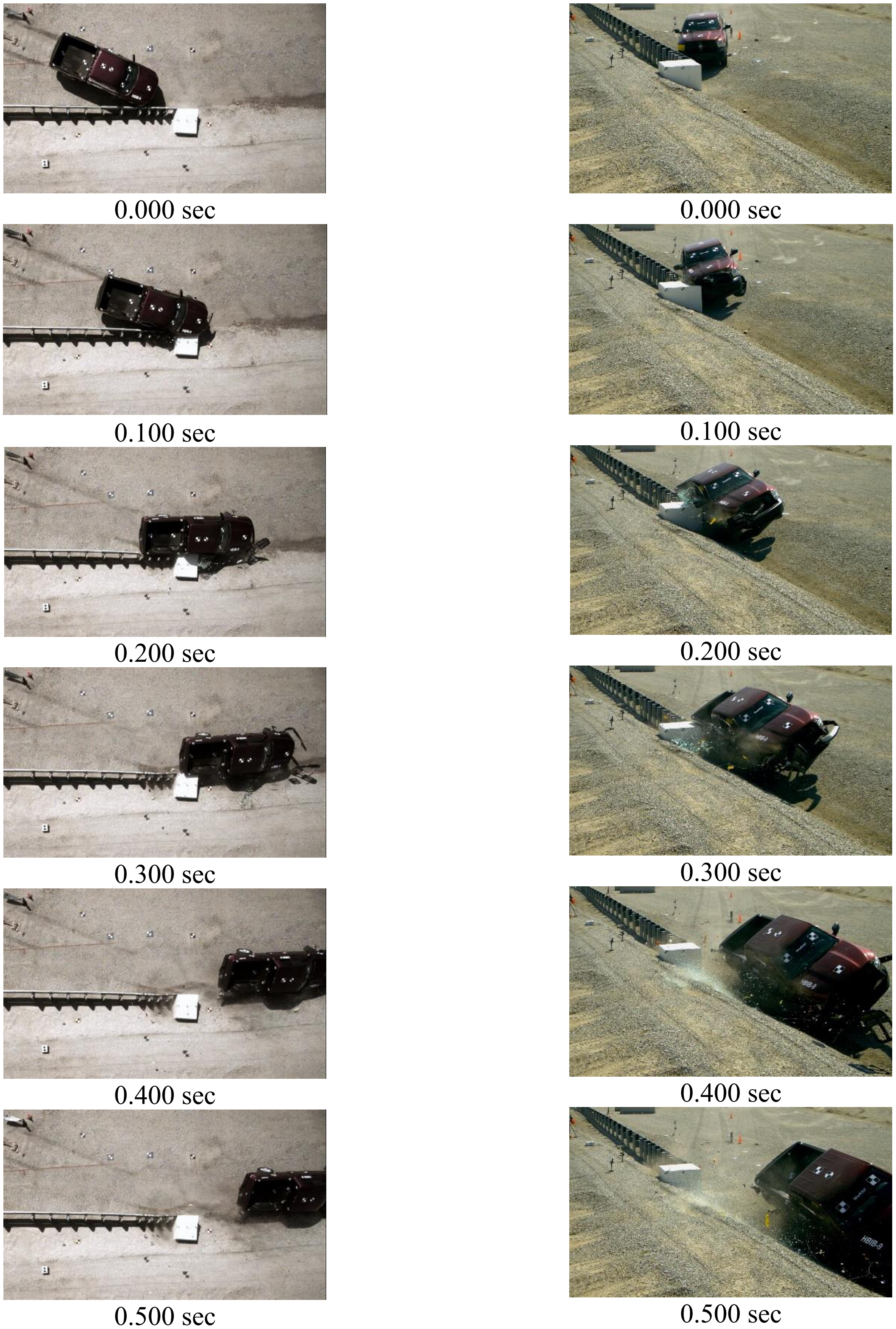
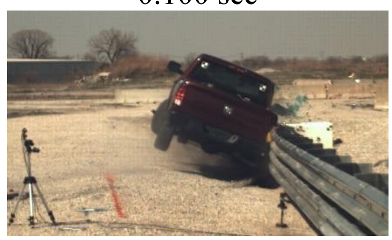


Figure 171. Sequential Photographs, Test No. HBIB-9

0.000 sec

0.100 sec



0.200 sec

0.300 sec

0.400 sec

0.500 sec

Figure 172. Sequential Photographs, Test No. HBIB-9

Figure 173. Documentary Photographs, Test No. HBIB-9

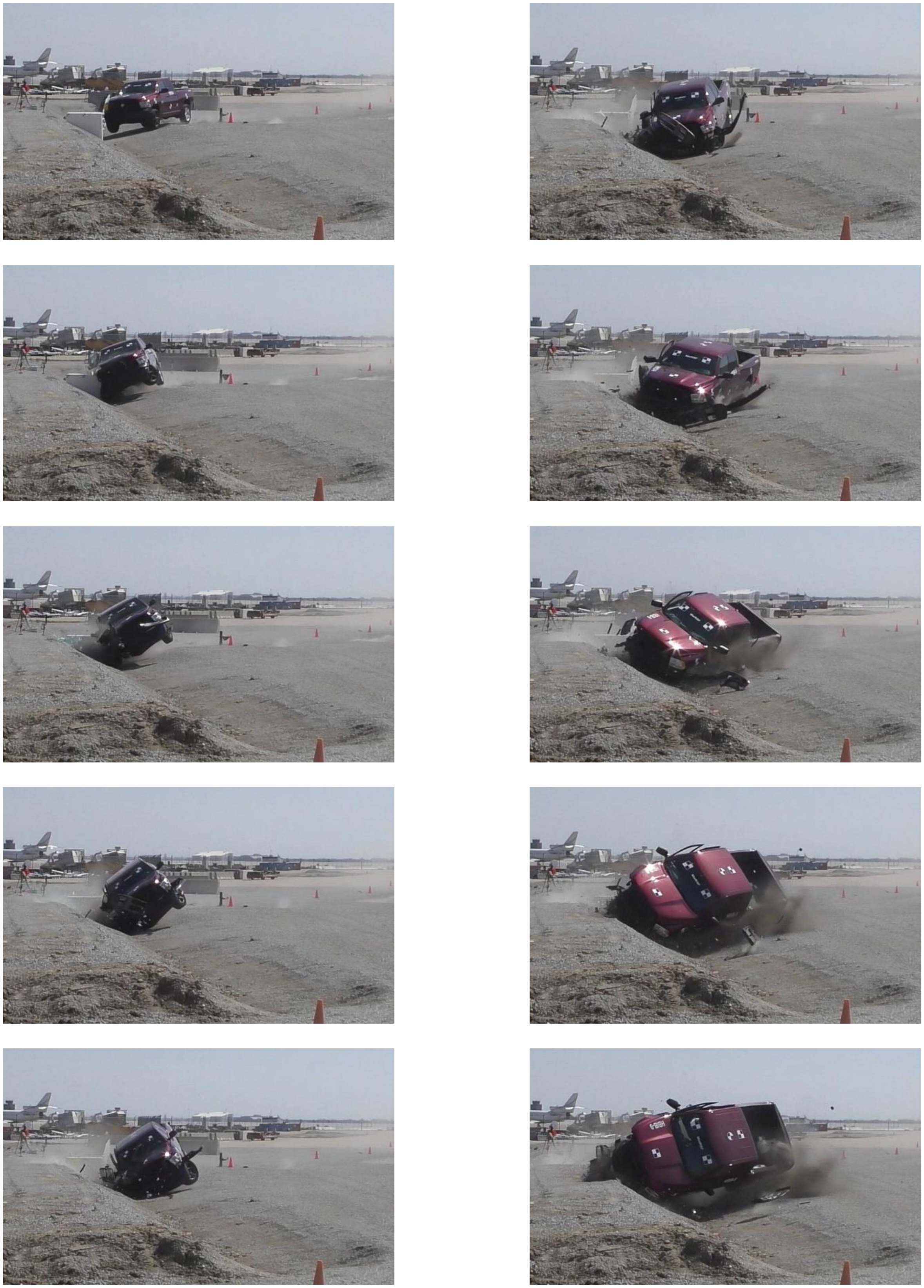


Figure 174. Documentary Photographs, Test No. HBIB-9

Figure 175. Documentary Photographs, Test No. HBIB-9

Figure 176. Vehicle Final Position and Trajectory Marks, Test No. HBIB-9

11.4 Barrier Damage

The damage to the barrier was minimal, as shown in Figures 177 and 178. Barrier damage consisted of contact marks, rail bending and flattening, and chipping of the concrete anchor. The length of vehicle contact along the barrier was approximately 136 in., which spanned from 12 in. upstream from the centerline of post no. 4 to the end of the concrete anchor. Additional contact marks spanned the bottom corrugation of the top rail and both corrugations of the bottom rail, beginning in the top rail 12 in. upstream from the centerline of post no. 4 and in the bottom rail 4 in. upstream from the centerline of post no. 4, with both marks extending downstream to the end of the concrete anchor.

A bend was observed in the top rail near the upstream edge of the concrete anchor that spanned 29½ in. downstream. A bend measuring 10½ in. long and 13 in. wide was found 9½ in. downstream from the upstream edge of the concrete anchor. Bending was also observed 5 in. upstream from post no. 2. Additional damage included flattening of the top rail 1 in. downstream from the centerline of post no. 4 measuring 46 in. long and 4 in. wide, as well as 3 in. downstream from the centerline of post no. 2 measuring 10 in. long and 4 in. wide. Flattening was observed at the bottom rail 7 in. upstream from the centerline of post no. 2 that measured 21 in. long and 5 in. wide.

The concrete anchor was chipped in several places: 5 in. from the top of the anchor measuring 3 in. long and 1½ in. wide; 13 in. from the top of the anchor measuring 2 in. long and 1 in. wide; and 28 in. from the top of the anchor measuring 2 in. long and 1 in. wide.

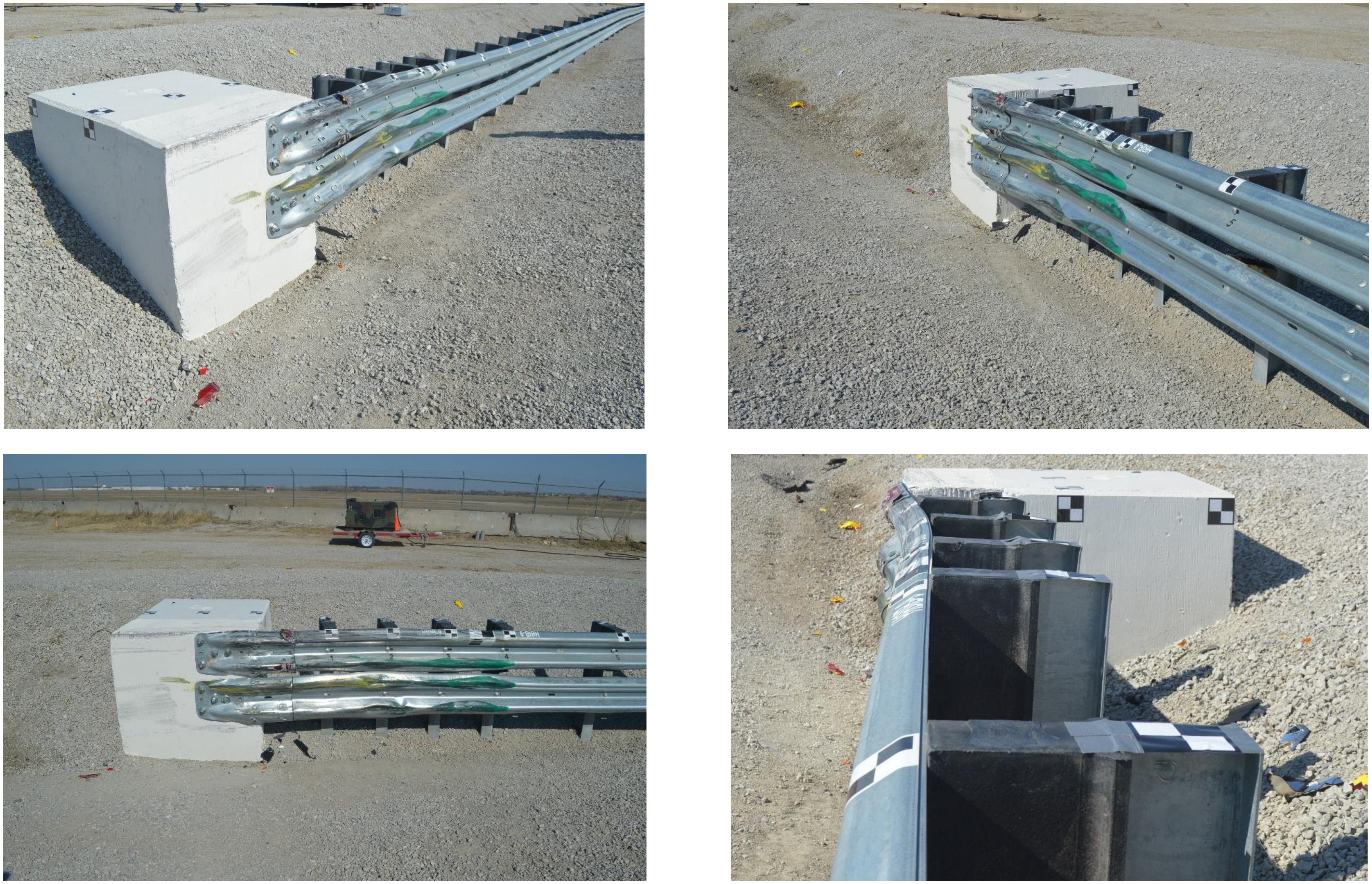


Figure 177. System Damage, Test No. HBIB-9

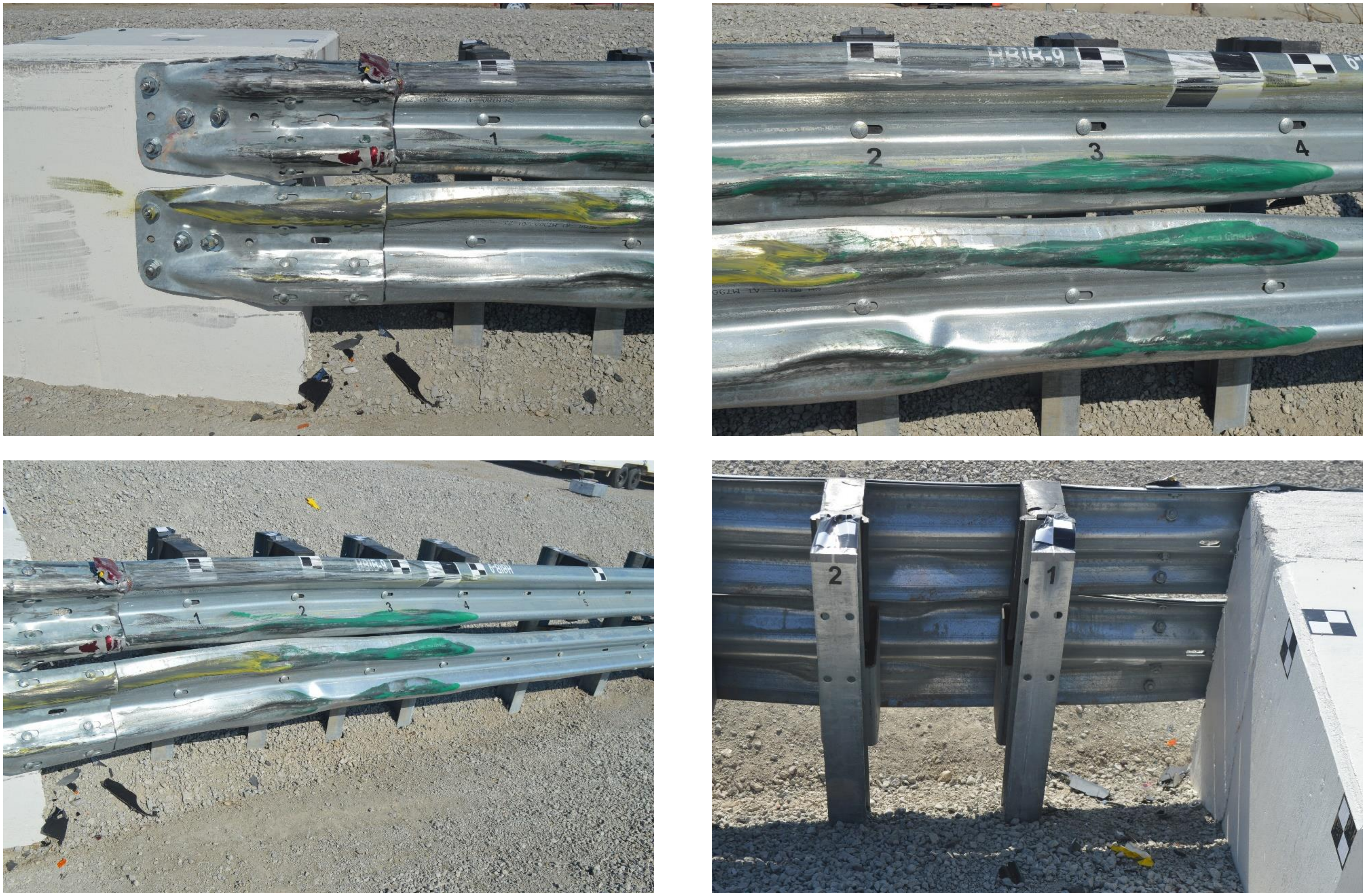


Figure 178. Upper Rail and Rub Rail Damage, Test No. HBIB-9

The maximum lateral permanent set of the barrier system was 3.2 at post no. 2, as measured in the field. The maximum lateral dynamic deflection of the rail was 5.5 in. at the rail at post no. 3, as determined from high-speed digital video analysis. The maximum lateral dynamic deflection of the post was 4.5 in. at post no. 2, as determined from high-speed digital video analysis. The working width of the system was found to be 22.3 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 179.

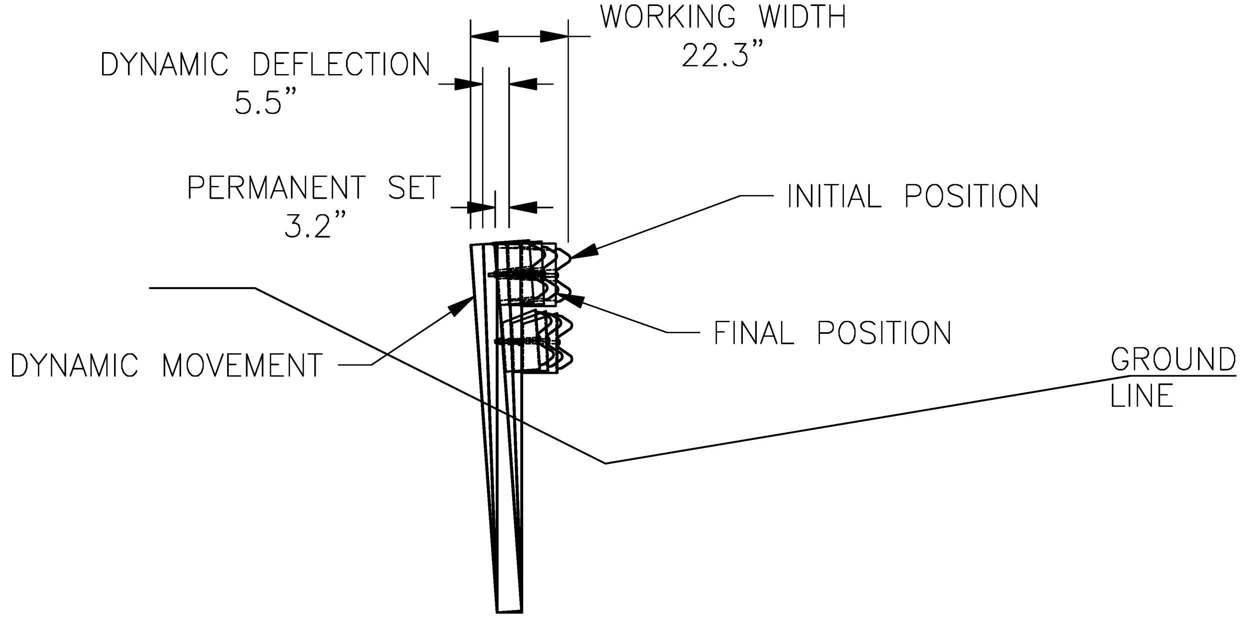


Figure 179. Permanent Set, Dynamic Deflection, and Working Width, Test No. HBIB-9

11.5 Vehicle Damage

The damage to the vehicle was severe, as shown in Figures 180 through 182. Majority of the damage was concentrated on the right-front corner and right side of the vehicle where the impact had occurred. The grille and right headlight were disengaged from the vehicle. The bumper was crushed rearward at its rightmost end. The hood was dented and scraped along both the right and left leading edges of the panel, and two dents appeared just behind the scraped areas. The right fender was severely crushed inward immediately above and behind the wheel opening. This damage extended into the right-front door panel, which was crushed inward and scraped at its vertical center, and the deformation continued onto the rear door. The upper portion of the door’s window frame was bent and buckled and the side window shattered; the upper half of the panel protruded noticeably from the vehicle and a 2-in. tear appeared at the rear of the crushed section.

The right-rear door panel was similarly crushed inward and scraped at its vertical center, extending into the box side; a 6-in. tear formed at its leading edge. The upper half of that panel, including its window frame, was bent inward, and the roof above collapsed. The right side of the truck bed was severely crushed, scraped, and dented along its vertical center from the rear door to the tail of the bed, with significant tearing and gouging at the leading edge just behind the cab. At the rear, the extreme right end of the bumper was dented and scraped.

On the left side, the box was dented and scraped along its entire length, and the fuel door folded forward from its rear to its front edge. The left-rear door was dented and scraped along its trailing edge and around the window opening, while the left-front door bore a slight dent at its upper center. The left front fender was dented inward and downward at the leading edge just behind the headlight. The roof was dented and scraped downward at the rear of its panel, with additional damage at the roof-to-door transition. Finally, the windshield cracked throughout, with the most extensive fracture concentrated in the upper right section of the pane.

The undercarriage and suspension components were also affected. The end link on the right side detached at its lower mounting. The right lower control arm separated from the cross members, and the upper control arm was bent rearward. The inner tie rod was bent, and the steering rack and gearbox were split in half. The middle cross member exhibited a slight twist, and the right frame horn buckled slightly. The right-front tire disengaged, and the right-front brake line was severed at the steering knuckle.

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 180. Vehicle Damage, Test No. HBIB-9

Figure 181. Vehicle Damage, Test No. HBIB-9

Figure 182. Test Vehicle’s Interior Floorboards and Undercarriage Damage, Test No. HBIB-9

Table 26. Maximum Occupant Compartment Intrusion by Location, Test No. HBIB-9

Location	Maximum Intrusion in.	MASH Allowable Intrusion in.
Wheel Well & Toe Pan	1.8	≤ 9
Floor Pan & Transmission Tunnel	0.0*	≤ 12
A-Pillar	6.4	≤ 5
A-Pillar (Lateral)	6.2	≤ 3
B-Pillar	17.5	≤ 5
B-Pillar (Lateral)	0.0*	≤ 3
Side Front Panel (in Front of A-Pillar)	1.9	≤ 12
Side Door (Above Seat)	0.0*	≤ 9
Side Door (Below Seat)	0.0*	≤ 12
Roof	7.6	≤ 4
Windshield	0.0	≤ 3
Side Window	Shattered due to contact with simulated occupant's head	No shattering resulting from contact with structural member of test article
Dash	0.2	N/A

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

11.6 Occupant Risk

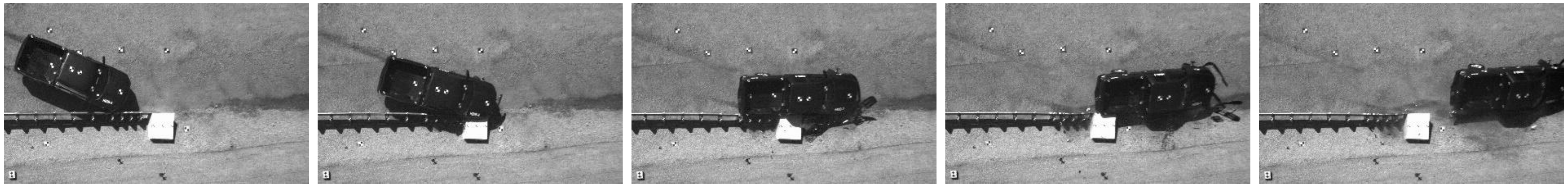
The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined by accelerometer data, are shown in Table 27. Note that the OIVs and ORAs were within suggested limits, as provided in MASH. 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-9

Evaluation Criteria		Transducer		MASH Limits
		SLICE-1 (backup)	SLICE-2 (primary)	
OIV ft/s	Longitudinal	-17.46	-17.51	±40
	Lateral	-23.80	-24.83	±40
ORA g's	Longitudinal	-6.28	-6.55	±20.49
	Lateral	-7.99	-7.37	±20.49
Maximum Angular Displacement deg.	Roll	-540.8	-543.9	±75
	Pitch	-12.5	-13.2	±75
	Yaw	121.9	120.2	not required
THIV – ft/s		29.63	29.99	not required
PHD – g's		8.45	7.77	not required
ASI		1.40	1.47	not required

11.7 Discussion

Analysis of the test results for test no. HBIB-9 showed that the 2270P vehicle impact with the system resulted in test failure. A summary of the test results and sequential photographs are shown in Figure 183. The barrier system effectively contained and redirected the 1100C vehicle with controlled lateral displacements of the barrier. 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. However, due to the severity of the impact to the top rail, the deformation of the vehicle's A-pillar measured 6.4 in., exceeding the MASH safety limits of 5 in.; the deformation of the B-pillar measured 17.5 in., exceeding the MASH safety limits of 5 in.; and the lateral deformation of the A-pillar measured 6.2 in., exceeding the MASH safety limits of 3 in. The test vehicle did not penetrate or override the barrier. Pitch and yaw angular displacements, shown in Appendix K, were deemed acceptable, however, the vehicle's maximum roll of -543.9 degrees exceeded the MASH safety limit of 75 degrees and the vehicle rolled over. Deformation of the roof measured 7.6 in., exceeding the MASH safety limit of 4 in. After impact, the vehicle exited the barrier at an angle of -3.7 degrees with respect to the barrier, and its trajectory did not violate the bounds of the exit box. Therefore, test no. HBIB-9 was determined to be unsuccessful according to MASH safety performance criteria for test designation no. 3-37a.



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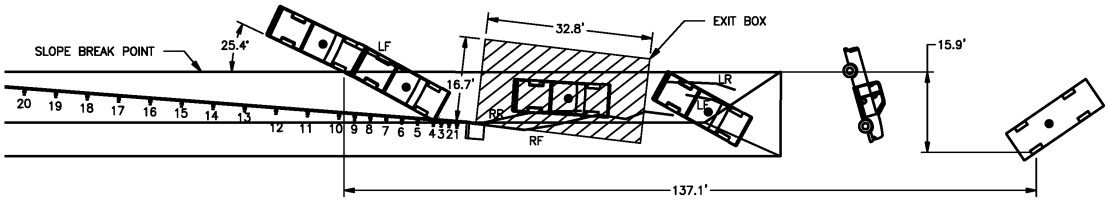

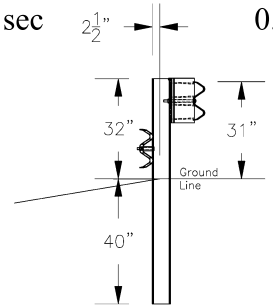

- Test Agency .... MwRSF
- Test Number HBIB-9
- Date 3/27/2024
- MASH Test Designation No. .... Modified 3-37a
- Test Article .... Hawaii DOT Buried in Backslope
- Total Length .... 219 ft – 4 in.
- Key Component – Steel W-beam Guardrail
  - Thickness .... 12 gauge
  - Top Mounting Height .... 31 in.
- Key Component – Steel Post
  - Shape W6x8.5
  - Length .... 96 in.
  - Embedment Depth .... Varies
  - Spacing .... 75 in.
- Key Component – Composite Recycled Blockout (Post Nos. 1-38)
  - Shape .... 14¼ x 8 x 5¼ in.
- Soil Type .... Coarse, Crushed Limestone (Well-Graded Gravel)
- Vehicle Make / Model .... 2018 Ram 1500
  - Curb .... 4,983 lb
  - Test Inertial .... 5,000 lb (MASH Limit 2,420 ± 55 lb)
  - Gross Static .... 4,997 lb (MASH Limit 2,585 ± 55 lb)
- Impact Conditions – Slope Break Point
  - Speed .... 62.0 mph (MASH Limit 62 ± 2.5 mph)
  - Angle .... 25.4 deg. (MASH Limit 25 ± 1.5 deg.)
- Impact Conditions – Barrier
  - Speed .... 62.1 mph
  - Angle .... 28.8 deg.
  - Impact Location ...... 68.5 in. upstream from the upstream end of the concrete anchor
- Impact Severity – Slope Break Point ....118.2 kip-ft > 106 kip-ft MASH minimum
- Impact Severity – Barrier .... 149.6 kip-ft
- Exit Conditions
  - Speed .... 46.3 mph
  - Angle .... -3.7 deg
- Exit Box Criterion .... Pass
- Vehicle Stability .... Fail
- Vehicle Stopping Distance .... 137.1 ft downstream, 15.9 ft laterally behind slope break
- Vehicle Damage .... Severe
  - VDS [15] 1-RFQ-7
  - CDC [16] 01-RFEE-9
  - Maximum Interior Deformation ....17.5 in. at B-Pillar ≥ 5-in. MASH limit
- Test Article Damage .... Moderate
- Maximum Test Article Deflections
  - Permanent Set .... 3.2 in.
  - Dynamic .... 5.5 in.
  - Working Width .... 22.3 in.
- Transducer Data

Evaluation Criteria		Transducer		MASH Limits
		SLICE-1 (backup)	SLICE-2 (primary)	
OIV ft/s	Longitudinal	-17.46	-17.51	±40
	Lateral	-23.80	-24.83	±40
ORA g's	Longitudinal	-6.28	-6.55	±20.49
	Lateral	-7.99	-7.37	±20.49
Maximum Angular Displacement deg.	Roll	-540.8	-543.9	±75
	Pitch	-12.5	-13.2	±75
	Yaw	121.9	120.2	not required
THIV – ft/s		29.63	29.99	not required
PHD – g's		8.45	7.77	not required
ASI		1.40	1.47	not required

Figure 183. Summary of Test Results and Sequential Photographs, Test No. HBIB-9

12 SUMMARY AND CONCLUSIONS

The Hawaii DOT Buried-in-Backslope (HBIB), reverse direction system terminal was successfully evaluated with MASH test designations 3-37a and 3-37b. A summary the test evaluations for test nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10 is shown in Table 28, and a summary of the test evaluation for test no. HBIB-9 is shown in Table 29.

For test nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10, the 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 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 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 elevation of the rail was maintained at a constant height extending from the anchor block to the tangent MGS, and was nominally 31 in. above the roadway surface.

In test no. HBIB-6, the 5,061-lb quad cab pickup truck impacted the HBIB system at a speed of 62.7 mph and at an angle of 24.9 degrees, and at a location 197.6 in. upstream from the centerline splice between post nos. 29 and 30, thus resulting in an actual impact severity of 117.9 kip-ft. After impacting the barrier system, the vehicle exited the system at a speed of 22.3 mph and an angle of 17.4 degrees with respect to the slope break point. 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-6 was successful according to the safety criteria of MASH test designation no. 3-37a.

In test no. HBIB-7, the 2,419-lb passenger car impacted the HBIB system at a speed of 63.8 mph and at an angle of 25.0 degrees, and at a location 82.8 in. upstream from the centerline splice between post nos. 29 and 30, thus resulting in an actual impact severity of 58.8 kip-ft. After impacting the barrier, the vehicle exited the system at a speed of 10.9 mph and an angle of 0.4 degrees with respect to the slope break point. 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-7 was successful according to the safety criteria of MASH test designation no. 3-37b.

In test no. HBIB-8, the 5,000-lb quad cab pickup truck impacted the HBIB system at a speed of 61.5 mph and at an angle of 24.9 degrees with respect to the slope break point of the system and at a speed of 61.5 mph and at an angle of 27.5 degrees with respect to the barrier. The actual point of impact was 67.0 in. upstream from the upstream end of the concrete fascia, thus resulting in an actual impact severity of 112.1 kip-ft with respect to the slope break point and 134.8 kip-ft with respect to the barrier. After impacting the barrier system, the vehicle exited the system at a speed of 48.0 mph and an angle of -8.3 degrees with respect to the slope break point. 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-8 was successful according to the safety criteria of MASH test designation no. 3-37a.

In test no. HBIB-10, the 2,421-lb passenger car impacted the HBIB system at a speed of 62.7 mph and at an angle of 25.1 degrees. The actual point of impact was 41.5 in. upstream from the upstream end of the concrete anchor, thus resulting in an actual impact severity of 57.3 kip-ft. After impacting the barrier system, the vehicle exited the system at a speed of 44.5 mph and an angle of -1.5 degrees with respect to the slope break point. 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-10 was successful according to the safety criteria of MASH test designation no. 3-37b.

HDOT desired to have an option for both dual-flare and single-flare embodiments of the HBIB design. Single-flare systems may be used in locations where the backslope is located close to the roadway or in some reverse-direction applications. A single flare system was evaluated in test no. HBIB-9, where the 5,000-lb quad cab pickup truck impacted the single-flare HBIB system in the reverse direction at a speed of 62.0 mph and at an angle of 25.4 degrees. The actual point of impact was 68.5 in. upstream from the upstream end of the concrete anchor, thus resulting in an actual impact severity of 118.2 kip-ft. At 0.330 sec, the vehicle exited the system and at 0.508 sec the vehicle began to roll away from the system, subsequently rolling over. At 6.838 sec, the vehicle came to rest on its roof.

Due to the severity of the impact to the top rail, the deformation of the vehicle's A-pillar measured 6.4 in., exceeding the MASH safety limits of 5 in.; the deformation of the B-pillar measured 17.5 in., exceeding the MASH safety limits of 5 in.; and the lateral deformation of the A-pillar measured 6.2 in., exceeding the MASH safety limits of 3 in. While the pitch and yaw angular displacements were deemed acceptable, the vehicle's maximum roll of -543.9 degrees exceeded the MASH safety limit of 75 degrees and the vehicle rolled over. Deformation of the roof measured 7.6 in., exceeding the MASH safety limit of 4 in. Therefore, test no. HBIB-9 was determined to be unsuccessful according to the safety criteria of MASH test designation no. 3-37a.

Table 28. Summary of Safety Performance Evaluation, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

Evaluation Factors		Evaluation Criteria	Test No. HBIB-6	Test No. HBIB-7	Test No. HBIB-8	Test No. HBIB-10
Structural Adequacy	A.	Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.	S	S	S	S
Occupant Risk	D.	1. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.	S	S	S	S
		2. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH.	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
	H.	Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 of MASH for calculation procedure) should satisfy the following limits: Occupant Impact Velocity Limits Component: Longitudinal and Lateral; Preferred: 30 ft/s; Maximum: 40 ft/s	S	S	S	S
	I.	The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH for calculation procedure) should satisfy the following limits: Occupant Ridedown Acceleration Limits Component: Longitudinal and Lateral; Preferred: 15.0 g's; Maximum: 20.49 g's	S	S	S	S
MASH Test Designation No.			3-37a	3-37b	3-37a	3-37b
Final Evaluation (Pass or Fail)			Pass	Pass	Pass	Pass

S – Satisfactory U – Unsatisfactory

Table 29. Summary of Safety Performance Evaluation, Test No. HBIB-9

<table>
<tr><th>Evaluation Factors</th><th colspan="4">Evaluation Criteria</th><th>Test No. HBIB-9</th></tr>
<tr><td>Structural Adequacy</td><td>A.</td><td colspan="3">Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.</td><td>U</td></tr>
<tr><td rowspan="10">Occupant Risk</td><td>D.</td><td colspan="3">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.
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.</td><td>S
U</td></tr>
<tr><td>F.</td><td colspan="3">The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</td><td>U</td></tr>
<tr><td rowspan="4">H.</td><td colspan="3">Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 of MASH for calculation procedure) should satisfy the following limits:</td><td rowspan="4">S</td></tr>
<tr><td colspan="3">Occupant Impact Velocity Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>30 ft/s</td><td>40 ft/s</td></tr>
<tr><td rowspan="4">I.</td><td colspan="3">The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH for calculation procedure) should satisfy the following limits:</td><td rowspan="4">S</td></tr>
<tr><td colspan="3">Occupant Ridedown Acceleration Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>15.0 g’s</td><td>20.49 g’s</td></tr>
<tr><td colspan="5">MASH Test Designation No.</td><td>3-37a</td></tr>
<tr><td colspan="5">Final Evaluation (Pass or Fail)</td><td>Fail</td></tr>
</table>

S – Satisfactory U – Unsatisfactory

13 MASH IMPLEMENTATION

Full-scale crash testing was performed on the Hawaii Buried-in-Backslope (HBIB) terminal system according to MASH Test Level 3 impact conditions. Test results were provided in two test reports: (1) a previously published report that details the standard-direction testing according to MASH test designations 3-32, 3-33, 3-34, and 3-35, evaluated in test nos. HBIB-1 through 5 [17], and (2) this report, which details reverse-direction testing according to MASH test designations 3-37a and 3-37b, evaluated in test nos. HBIB-6 through 10.

It was determined that the dual-flare HBIB configuration was satisfactory to MASH evaluation criteria based on the results of test nos. HBIB-1 through 8 and 10. The system would be eligible for installation on ditches with approach slopes as steep as 4H:1V and with back slopes as steep as 2H:1V. Additionally, the system was eligible for use in approach and trailing end conditions, and when exposed to reverse-direction traffic conditions. It was noted that because the concrete anchor block was not considered within the clear zone for the purposes of this evaluation, it was not treated; thus care must be taken to ensure the anchor block does not itself become a potential hazard to adjacent drivers.

Based on results of test no. HBIB-9, it was determined that the single-flare configuration of the HBIB system would likely be acceptable to MASH for standard-direction impacts, but was not acceptable according to MASH evaluation criteria for reverse-direction impacts. During test no. HBIB-9, the test vehicle yawed after impacting the system, and a combination of the front bumper of the pickup truck and the rear wheel dug into the approach slope and back slopes of the V-ditch, tripping the vehicle and resulting in rollover. Thus, the single-flare configuration of the HBIB could be used on the upstream end of a guardrail system when the upstream end is not exposed to reverse-direction travel or is out of the clear zone for opposite-direction impacts. However, the system would not be recommended for use in trailing end configurations or when reverse-direction impacts could occur at the end anchorage.

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APPENDICES

Appendix A. A2LA Accreditation Documents

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*).

American Association for Laboratory Accreditation
CORPORATE SEAL 1978
DISTRICT OF COLUMBIA
A2LA

Presented this 27th day of June 2024.

Mr. Trace McInturff, Vice President, Accreditation Services
For the Accreditation Council
Certificate Number 2937.01
Valid to November 30, 2025

For the tests to which this accreditation applies, please refer to the laboratory's Mechanical Scope of Accreditation.

Figure A-1. MwRSF 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, 2025 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**
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.

(A2LA Cert. No. 2937.01) 06/27/2024 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. Critical Impact Point Determination

- **Section 1: Nested MGS plus Nested Rubrail at Quarter Post Spacing**

$$F_{y-post} = 14.6\ kips$$

$F_{soil} = 12.4\ kips$ at 40 in. embedment

For embedment = 48.0 in → $F_S' = 14.88\ kips$

$$F_y = \min(F_{y-post}, F_S') = 14.6\ kips$$

$$F_p = \frac{F_y}{S} = \frac{14.6}{1.5625} = 9.34\frac{kip}{ft}$$

Where S is a quarter post spacing and the embedment of post no. 4 is considered.

$$M_p = M_h + \sum M_i \frac{H_i}{H_h} = \left[16.0 + 16.0\left(\frac{21.00}{36.00}\right)\right] = 25.3\ kip.ft$$

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.

$$M_p = 25.3 \text{ and } F_p = 9.34 \xrightarrow{Using\ MASH\ Figure\ 2-8} CIP = 4.2\ ft\ (Test\ Designation\ 10)$$

$$M_p = 25.3 \text{ and } F_p = 9.34 \xrightarrow{Using\ MASH\ Figure\ 2-11} CIP = 7.0\ ft\ (Test\ Designation\ 11)$$

- **Section 2: Nested MGS plus Nested Rubrail at Half Post Spacing**

$$F_{y-post} = 14.6\ kips$$

$$F_{soil} = 12.4\ kips\text{, Embed=40.3 in } \rightarrow F_S' = 12.5\ kips$$

$$F_y = \min(F_{y-post}, F_S') = 12.5\ kips$$

$$F_p = \frac{F_y}{S} = \frac{12.5}{3.125} = 4.00\frac{kip}{ft}$$

Where S is the distance between post nos. 6 and 5 (half post spacing)

$$M_p = M_h + \sum M_i \frac{H_i}{H_h} = \left[16.0 + 16.0\left(\frac{27.8}{42.8}\right)\right] = 26.4\ kip.ft$$

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.

$$M_p = 26.40 \text{ and } F_p = 3.99 \xrightarrow{Using\ MASH\ Figure\ 2-8} CIP = 6.64\ ft$$

$$M_p = 26.40 \text{ and } F_p = 3.99 \xrightarrow{Using\ MASH\ Figure\ 2-11} CIP = 8.91\ ft$$

- **Section 3: MGS plus Rubrail at Half Post Spacing**

$$F_{y-post} = 14.6\ kips$$

$$F_{soil} = 12.4\ kips, \text{Embed=40.3 in} \ \rightarrow \ F_S' = 12.5\ kips$$

$$F_y = \min\left(F_{y-post}, F_S'\right) = 12.5\ kips$$

$$F_p = \frac{F_y}{S} = \frac{12.5}{3.125} = 3.99\frac{kip}{ft}$$

Where S is the distance between post nos. 6 and 5 (half post spacing).

$$M_p = M_h + \sum M_i \frac{H_i}{H_h} = \left[8.0 + 8.0\left(\frac{27.8}{42.8}\right)\right] = 13.2\ kip.ft$$

The calculated value for F_s' shows that this value is greater than F_p, hence, F_p is used for the CIP determination.

$$M_p = 13.20 \text{ and } F_p = 3.99 \xrightarrow{Using\ MASH\ Figure\ 2-8} CIP = 8.29\ ft$$

$$M_p = 13.20 \text{ and } F_p = 3.99 \xrightarrow{Using\ MASH\ Figure\ 2-11} CIP = 10.69\ ft$$

- **Section 4: MGS with Rubrail at Highest Height over Ditch**

$$F_{y-post} = 14.6\ kips$$

$$F_{soil} = 12.4\ kips, \text{Embed=40.3 in} \ \rightarrow \ F_S' = 12.5\ kips$$

$$F_y = \min\left(F_{y-post}, F_S'\right) = 12.5\ kips$$

$$F_p = \frac{F_y}{S} = \frac{12.5}{6.25} = 2.00\frac{kip}{ft}$$

Where S is the distance between post nos. 11 and 10.

$$M_p = M_h + \sum M_i \frac{H_i}{H_h} = \left[8.0 + 8.0\left(\frac{27.80}{42.80}\right)\right] = 13.20\ kip.ft$$

The calculated value for F_s' shows that this value is greater than F_p, hence, F_p is used for the CIP determination.

$$M_p = 13.20 \text{ and } F_p = 2.00 \xrightarrow{Using\ MASH\ Figure\ 2-8} CIP = 8.29\ ft$$

$$M_p = 13.20 \text{ and } F_p = 2.00 \xrightarrow{Using\ MASH\ Figure\ 2-11} CIP = 11.81\ ft$$

- **Section 5: MGS with Rubrail**

$$F_{y-post} = 14.6\ kips$$

$$F_{soil} = 12.4\ kips, \text{Embed=40.0 in} \ \rightarrow \ F_S' = 12.4\ kips$$

$$F_y = \min\left(F_{y-post}, F_S'\right) = 12.4\ kips$$

$$F_p = \frac{F_y}{S} = \frac{12.4}{6.25} = 1.98\frac{kip}{ft}$$

Where S is the distance between post nos. 24 and 23.

$$M_p = M_h + \sum M_i \frac{H_i}{H_h} = \left[8.0 + 8.0\left(\frac{16.0}{31.0}\right)\right] = 12.1\ kip.ft$$

The calculated value for F_S' shows that this value is greater than F_p, hence, F_p is used for the CIP determination.

$$M_p = 12.10 \text{ and } F_p = 1.98 \xrightarrow{Using\ MASH\ Figure\ 2-8} CIP = 8.27\ ft$$

$$M_p = 12.10 \text{ and } F_p = 1.98 \xrightarrow{Using\ MASH\ Figure\ 2-11} CIP = 11.89\ ft$$

- **Section 6: Standard MGS**

$$F_{y-post} = 14.6\ kips$$

$$F_{soil} = 12.4\ kips, \text{Embed=40.0 in} \ \rightarrow \ F_S' = 12.4\ kips$$

$$F_y = \min\left(F_{y-post}, F_S'\right) = 12.4\ kips$$

$$F_p = \frac{F_y}{S} = \frac{12.4}{6.25} = 1.98\frac{kip}{ft}$$

Where S is the distance between post nos. 30 and 29.

$$M_p = M_h + \sum M_i \frac{H_i}{H_h} = [8.0 + 0] = 8.0\ kip.ft$$

The calculated value for F_S' shows that this value is greater than F_p, hence, F_p is used for the CIP determination.

$$M_p = 8.0 \text{ and } F_p = 1.98 \xrightarrow{Using\ MASH\ Figure\ 2-8} CIP = 8.18\ ft$$

$$M_p = 8.0 \text{ and } F_p = 1.98 \xrightarrow{Using\ MASH\ Figure\ 2-11} CIP = 11.89\ ft$$

Appendix C. Vehicle Center of Gravity Determination

	Test Name: HBIB-6	VIN:	3C6RR6KT6JG186123
Model Year: 2018	Make: RAM	Model:	1500

Vehicle CG Determination

	Vehicle Equipment	Weight (lb)	Vertical CG (in.)	Vertical M (lb-in.)
+	Unballasted Truck (Curb)	5304	28.297653	150090.75
+	Hub	19	15.25	289.75
+	Brake activation cylinder & frame	7	28.5	199.5
+	Pneumatic tank (Nitrogen)	20	26.75	535
+	Strobe/Brake Battery	5	26.5	132.5
+	Brake Receiver/Wires	5	52.25	261.25
+	CG Plate including DAQ	50	30 5/16	1515.625
-	Battery	0	40.5	0
-	Oil	-6	25	-150
-	Interior	-142	30	-4260
-	Fuel	-119	21.5	-2558.5
-	Coolant	-13	37	-481
-	Washer fluid	-4	33	-132
+	Water Ballast (In Fuel Tank)			0
+	Onboard Supplemental Battery			0
-	Spare Tire	-63	23	-1449
				0
				143993.88

Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle

Estimated Total Weight (lb)	5063
Vertical CG Location (in.)	28.44043

Vehicle Dimensions for C.G. Calculations

Wheel Base: 140.625 in. | Front Track Width: 67.25 in. | Rear Track Width: 67.625 in.

Center of Gravity	2270P MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb)	5000 ± 110	5061	61.0
Longitudinal CG (in.)	63 ± 4	60.101141	-2.89886
Lateral CG (in.)	NA	-0.233186	NA
Vertical CG (in.)	28 or greater	28.44	0.44043

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	1477	1473
Rear	1202	1152

FRONT	2950	lb
REAR	2354	lb
TOTAL	5304	lb

TEST INERTIAL WEIGHT (lb)

	Left	Right
Front	1452	1446
Rear	1096	1067

FRONT	2898	lb
REAR	2163	lb
TOTAL	5061	lb

Figure C-1. Vehicle Mass Distribution, Test No. HBIB-6

		Test Name:	**HBIB-7**
VIN:	**3KPA24AB2JE079301**		
Model Year:	**2018**	**Make:**	**Kia**
Model:	**Rio**		

Vehicle CG Determination

	Vehicle Equipment	Weight (lb)
+	Unballasted Car (Curb)	2467
+	Hub	19
+	Brake activation cylinder & frame	7
+	Pneumatic tank (Nitrogen)	20
+	Strobe/Brake Battery	5
+	Brake Receiver/Wires	5
+	CG Plate including DAQ	21
-	Battery	-38
-	Oil	-10
-	Interior	-76
-	Fuel	-20
-	Coolant	-7
-	Washer fluid	-9
+	Water Ballast (In Fuel Tank)	34
+	Onboard Supplemental Battery	

Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle

Estimated Total Weight (lb) 2418

Vehicle Dimensions for C.G. Calculations

Wheel Base:	101.688	in.	Front Track Width:	59.813	in.
Roof Height:	57.125	in.	Rear Track Width:	60.125	in.

Center of Gravity	**1100C MASH Targets**	**Test Inertial**	**Difference**
Test Inertial Weight (lb)	2420 ± 55	2419	-1.0
Longitudinal CG (in.)	39 ± 4	38.38	-0.62
Lateral CG (in.)	NA	-0.905	NA
Vertical CG (in.)	NA	21.961	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	801	757
Rear	456	453

FRONT	1558	lb
REAR	909	lb
TOTAL	2467	lb

TEST INERTIAL WEIGHT (lb)

	Left	Right
Front	791	715
Rear	455	458

FRONT	1506	lb
REAR	913	lb
TOTAL	2419	lb

Figure C-2. Vehicle Mass Distribution, Test No. HBIB-7

	Test Name: HBIB-8	**VIN:** 1C6RR6GT7JS173589	
Model Year: 2018	**Make:** Ram	**Model:** 1500 Hemi	

Vehicle CG Determination

	Vehicle Equipment	Weight (lb)	Vertical CG (in.)	Vertical M (lb-in.)
+	Unballasted Truck (Curb)	5126	28.245976	144788.88
+	Hub	19	15	285
+	Brake activation cylinder & frame	7	28	196
+	Pneumatic tank (Nitrogen)	20	28	560
+	Strobe/Brake Battery	5	31	155
+	Brake Receiver/Wires	5	52.5	262.5
+	CG Plate including DAQ	30	29.375	881.25
-	Battery	-42	41	-1722
-	Oil	-12	19.5	-234
-	Interior	-85	35	-2975
-	Fuel	-173	17.5	-3027.5
-	Coolant	-12	32	-384
-	Washer fluid	-3	37	-111
+	Water Ballast (In Fuel Tank)	106	15	1590
+	Onboard Supplemental Battery			0
				0
				0
				140265.13

Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle

Estimated Total Weight (lb)	4991
Vertical CG Location (in.)	28.10361

Vehicle Dimensions for C.G. Calculations

Wheel Base: 140.375 in.

Front Track Width: 67.75 in.

Rear Track Width: 67.875 in.

Center of Gravity	**2270P MASH Targets**	**Test Inertial**	**Difference**
Test Inertial Weight (lb)	5000 ± 110	5000	0.0
Longitudinal CG (in.)	63 ± 4	59.547075	-3.45293
Lateral CG (in.)	NA	-0.461125	NA
Vertical CG (in.)	28 or greater	28.10	0.10361

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	1512	1445
Rear	1104	1065

FRONT	2957	lb
REAR	2169	lb
TOTAL	5126	lb

TEST INERTIAL WEIGHT (lb)

	Left	Right
Front	1455	1424
Rear	1079	1042

FRONT	2879	lb
REAR	2121	lb
TOTAL	5000	lb

Figure C-3. Vehicle Mass Distribution, Test No. HBIB-8

		Test Name:	**HBIB-10**	**VIN:**	**3KPC24A34KE056878**
Model Year:	**2019**	**Make:**	**Hyundai**	**Model:**	**Accent Sedan**

Vehicle CG Determination

	Vehicle Equipment	Weight (lb)
+	Unballasted Car (Curb)	2517
+	Hub	19
+	Brake activation cylinder & frame	7
+	Pneumatic tank (Nitrogen)	23
+	Strobe/Brake Battery	5
+	Brake Receiver/Wires	5
+	CG Plate including DAQ	21
-	Battery	-40
-	Oil	-9
-	Interior	-68
-	Fuel	-19
-	Coolant	-7
-	Washer fluid	-3
+	Water Ballast (In Fuel Tank)	
+	Onboard Supplemental Battery	
-	Trunk contents	-33

Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle

Estimated Total Weight (lb) 2418

Vehicle Dimensions for C.G. Calculations

Wheel Base:	101.5	in.	Front Track Width:	59.875	in.
Roof Height:	56.625	in.	Rear Track Width:	60.0	in.

Center of Gravity	**1100C MASH Targets**	**Test Inertial**	**Difference**
Test Inertial Weight (lb)	2420 ± 55	2421	1.0
Longitudinal CG (in.)	39 ± 4	38.361	-0.639
Lateral CG (in.)	NA	-0.928	NA
Vertical CG (in.)	NA	21.904	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	790	760
Rear	495	472

FRONT	1550	lb
REAR	967	lb
TOTAL	2517	lb

TEST INERTIAL WEIGHT (lb)

	Left	Right
Front	780	726
Rear	468	447

FRONT	1506	lb
REAR	915	lb
TOTAL	2421	lb

Figure C-4. Vehicle Mass Distribution, Test No. HBIB-10

		Test Name: HBIB-9	**VIN:** 1C6RR6FG0KS526339
Model Year: 2019		**Make:** Ram	**Model:** 1500

Vehicle CG Determination

	Vehicle Equipment	Weight (lb)	Vertical CG (in.)	Vertical M (lb-in.)
+	Unballasted Truck (Curb)	4983	28.71621	143092.88
+	Hub	19	14.9375	283.8125
+	Brake activation cylinder & frame	7	27.5	192.5
+	Pneumatic tank (Nitrogen)	23	26.5	609.5
+	Strobe/Brake Battery	5	27.5	137.5
+	Brake Receiver/Wires	5	52.25	261.25
+	CG Plate including DAQ	42	30.25	1270.5
-	Battery	-37	43	-1591
-	Oil	-8	21.5	-172
-	Interior	-85	38.5	-3272.5
-	Fuel	-172	18.5	-3182
-	Coolant	-9	34.5	-310.5
-	Washer fluid	-3	38	-114
+	Water Ballast (In Fuel Tank)	227	18	4086
+	Onboard Supplemental Battery			0
				0
				0
				141291.94

Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle

Estimated Total Weight (lb)	4997
Vertical CG Location (in.)	28.27535

Vehicle Dimensions for C.G. Calculations

Wheel Base: 140.625 in. Front Track Width: 68.5625 in.
Rear Track Width: 67.6875 in.

Center of Gravity	2270P MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb)	5000 ± 110	5000	0.0
Longitudinal CG (in.)	63 ± 4	64.996875	1.99688
Lateral CG (in.)	NA	-0.19075	NA
Vertical CG (in.)	28 or greater	28.28	0.27535

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	1378	1344
Rear	1158	1103
FRONT	2722	lb
REAR	2261	lb
TOTAL	4983	lb

TEST INERTIAL WEIGHT (lb)

	Left	Right
Front	1337	1352
Rear	1177	1134
FRONT	2689	lb
REAR	2311	lb
TOTAL	5000	lb

Figure C-5. Vehicle Mass Distribution, Test No. HBIB-9

Appendix D. Material Specifications

Table D-1. Bill of Materials, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10

Item No.	Description	Material Specification	Reference
a1	12'-6" 12-gauge W-Beam MGS Section	AASHTO M180	H#2L14222 H#2L14422
a2	12'-6" 12-gauge W-Beam MGS End Section	AASHTO M180	H#C85187
a3	6'-3" 12-gauge W-Beam Section	AASHTO M180	H#4114294
a4	12'-6" 12-gauge Bent W-Beam [4.4 deg]	AASHTO M180	H#2L14222 H#2L14422
a5	9'-4 1/2" 12-gauge W-Beam	AASHTO M180	H#2L14222 H#2L14422
a6	12'-6" 12-gauge Bent W-Beam [2.4 deg]	AASHTO M180	H#2L14222 H#2L14422
a7	12'-6" 12-gauge W-Beam Section - 1/4 Post Spacing	AASHTO M180	H#AA6765
a8	W-Beam Terminal Connector	AASHTO M180	H#290820
a9	12'-6" 12-gauge Bent W-Beam [7.7 deg]	AASHTO M180	H#C85187
b1	3'x3' Concrete Anchor Block	Min. f'c = 4,000 psi	Ticket#2050257
c1	BCT Timber Post - MGS Height	SYP Grade No. 1 or better (No knots +/- 18" from ground on tension face)	P#GS6846PST
c2	72" Long Foundation Tube	ASTM A500 Gr. B	H#821T08220
c3	Ground Strut Assembly	ASTM A36	H#C43126
c4	BCT Anchor Cable Assembly with Heavy Hex Nuts and Washers	Fitting-ASTM A576 Gr. 1035 Stud-ASTM F568 Class C	H#20744340
c4	3/4" Dia. X 54" Long IWRC Wire Rope	ASTM A741 Type II	H#20744340
c5	Ground Anchor Bracket Assembly	ASTM A36	H#JK16101488
c6	8"x8"x5/8" Anchor Bearing Plate	ASTM A36	H#1072318
c7	2 3/8" O.D. 6" Long BCT Post Sleeve	ASTM A53 Gr. B Schedule 40	H#712810
c8	Yoke	ASTM A36	missing
c10	Anchor Bracket End Plate	A36 Steel	missing
d1	W6x8.5 or W6x9, 84" Long Steel Post	ASTM A992 Gr. 50	H#2909166

Table D-2. Bill of Materials, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10, Cont.

Item No.	Description	Material Specification	Reference
d2	W6x8.5 or W6x9, 72" Long Steel Post	ASTM A992 Gr. 50	H#55073781
d4	14 3/16"x8"x5 1/8" Composite Recycled Blockout	Mondo Polymer GB14SH2 or Equivalent	PO#HWTT L#1804/1000 L#1904/1000 P# MGS14SH P#GB14SH2
d5	13 5/8" Long, 8"x6"x1/4" Steel Blockout	ASTM A500 Gr. B	H#A70164 H#B62340 H#B63642 H#B64993
d6	16D Double Head Nail	-	P#97812A109
e1	61" Unbent Length #4 Rebar	ASTM A615 Gr. 60	PO#161834 H#7034726 H#9700023976 H#9700027794
e2	51" Unbent Length #4 Rebar	ASTM A615 Gr. 60	PO#161834 H#7034726 H#9700023976 H#9700027794
e3	32" Long #4 Rebar	ASTM A615 Gr. 60	PO#161834 H#7034726 H#9700023976 H#9700027794
e4	138 1/2" Long #8 Rebar	ASTM A615 Gr. 60	PO#161834 H#7034726 H#9700023976 H#9700027794
e5	103" Unbent Length #4 Rebar	ASTM A615 Gr. 60	PO#161834 H#7034726 H#9700023976 H#9700027794
e6	12" Long Unbent #4 Rebar	ASTM A615 Gr. 60	PO#161834 H#7034726 H#9700023976 H#9700027794
e7	48" Long #4 Rebar	ASTM A615 Gr. 60	PO#161834 H#7034726 H#9700023976 H#9700027794
e8	67" Unbent Length #4 Rebar	ASTM A615 Gr. 60	PO#161834 H#7034726 H#9700023976 H#9700027794
f1	5/8" Dia. UNC, 10" Long Guardrail Bolt	ASTM A307 Gr. A	H#1000217087
f2	5/8 Dia, UNC, 5" Long Hex Head Bolt	ASTM A459 Gr. 5 or equivalent	H#3093332
f3	5/8" Dia. UNC, 2" Long Guardrail Bolt	ASTM A307 Gr. A	P#1191921 P#12411
f4	5/8" Dia. UNC, 1 1/4" Long Guardrail Bolt	ASTM A307 Gr. A	H#20841080
f5	7/8" Dia. UNC, 8" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	P#92005

Table D-3. Bill of Materials, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10, Cont.

Item No.	Description	Material Specification	Reference
f6	7/8" Dia. UNC, 2" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	H#1000217614
f7	5/8" Dia. UNC, 10" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	H#JK18104124
f8	5/8" Dia. UNC, 1 1/2" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	H#20841080 P#1015-625-US
f9	3/4 Dia, Unthreaded Spacer Sleeve	ASTM A53 Gr. B	H#4132970
g1	7/8" Dia. Plain Round Washer	ASTM F844	P#33187
g2	5/8" Dia. Plain Round Washer	ASTM F844	P#33185 P#0838687
g3	1" Dia. Plain Round Washer	ASTM F844	H#18108472-3
h1	5/8" Dia. UNC Heavy Hex Nut	ASTM A563A or equivalent	P#1191919 P#36755
h2	5/8" Dia. Hex Nut	ASTM A563A	H#8000021095
h4	7/8" Dia. UNC Hex Nut	ASTM A307A or equivalent	P#92005 P#36717
h5	1"-8 UNC Heavy Hex Nut	ASTM A563DH or equivalent	N/A
i1	3/8" Dia. Wire Strut, 13 3/8" Long Unbent	Min. Tensile Strength = 100,000 psi	
i2	3/8" Dia. Wire Strut, 16 3/8" Long Unbent	Min. Tensile Strength = 100,000 psi	
i3	3/8" Dia. Wire Strut, 18" Long Unbent	Min. Tensile Strength = 100,000 psi	
i4	7/8 Dia. Threaded Ferrule	-	
k1	Soil	-	
k2	Fascia	Min. f'c = 4,000 psi	Ticket#2050257

*Components not required if optional anchor is used.

Table D-4. Bill of Materials, Test No. HBIB-9

Item No.	Description	Material Specification	Reference
a1	12'-6" 12-gauge W-Beam MGS Section	AASHTO M180	H#2L14222 H#2L14422
a2	12'-6" 12-gauge W-Beam MGS End Section	AASHTO M180	H#C85187
a3	6'-3" 12-gauge W-Beam Section	AASHTO M180	H#4114294
a4	12'-6" 12-gauge Bent W-Beam [4.4 deg]	AASHTO M180	H#2L14222 H#2L14422
a5	9'-4 1/2" 12-gauge W-Beam	AASHTO M180	H#2L14222 H#2L14422
a7	12'-6" 12-gauge W-Beam Section - 1/4 Post Spacing	AASHTO M180	H#AA6765
a8	W-Beam Terminal Connector	AASHTO M180	H#290820
a9	12'-6" 12-gauge Bent W-Beam [7.7 deg]	AASHTO M180	H#C85187
b1	3'x3' Concrete Anchor Block	Min. f'c = 4,000 psi	Ticket#2050257
c1	BCT Timber Post - MGS Height	SYP Grade No. 1 or better (No knots +/- 18" from ground on tension face)	P#GS6846PST
c2	72" Long Foundation Tube	ASTM A500 Gr. B	H#821T08220
c3	Ground Strut Assembly	ASTM A36	H#C43126
c4	BCT Anchor Cable Assembly with Heavy Hex Nuts and Washers	Fitting-ASTM A576 Gr. 1035 Stud-ASTM F568 Class C	H#20744340
c4	3/4" Dia. x 54" Long IWRC Wire Rope	ASTM A741 Type II	H#20744340
c5	Ground Anchor Bracket Assembly	ASTM A36	H#JK16101488
c6	8"x8"x5/8" Anchor Bearing Plate	ASTM A36	H#1072318
c7	2 3/8" O.D. 6" Long BCT Post Sleeve	ASTM A53 Gr. B Schedule 40	H#712810
d1	W6x8.5 or W6x9, 84" Long Steel Post	ASTM A992 Gr. 50	H#2909166
d2	W6x8.5 or W6x9, 72" Long Steel Post	ASTM A992 Gr. 50	H#55073781
d4	14 3/16"x8"x5 1/8" Composite Recycled Blockout	Mondo Polymer GB14SH2 or Equivalent	PO#HWTT L#1804/1000 L#1904/1000 P# MGS14SH P#GB14SH2
d5	13 5/8" Long, 8"x6"x1/4" Steel Blockout	ASTM A500 Gr. B	H#A70164 H#B62340 H#B63642 H#B649933
d6	16D Double Head Nail	-	P#97812A109

Table D-5. Bill of Materials, Test No. HBIB-9, Cont.

Item No.	Description	Material Specification	Reference
e1	72" Unbent Length #4 Rebar	ASTM A615 Gr. 60	PO#161834 H#7034726 H#9700023976 H#9700027794
e2	53" Unbent Length #4 Rebar	ASTM A615 Gr. 60	PO#161834 H#7034726 H#9700023976 H#9700027794
e3	32" Long #4 Rebar	ASTM A615 Gr. 60	PO#161834 H#7034726 H#9700023976 H#9700027794
e4	134" Long #8 Rebar	ASTM A615 Gr. 60	PO#161834 H#7034726 H#9700023976 H#9700027794
e5	99" Unbent Length #4 Rebar	ASTM A615 Gr. 60	PO#161834 H#7034726 H#9700023976 H#9700027794
e6	12" Long Unbent #4 Rebar	ASTM A615 Gr. 60	PO#161834 H#7034726 H#9700023976 H#9700027794
e7	48" Long #4 Rebar	ASTM A615 Gr. 60	PO#161834 H#7034726 H#9700023976 H#9700027794
e8	67" Unbent Length #4 Rebar	ASTM A615 Gr. 60	PO#161834 H#7034726 H#9700023976 H#9700027794
f1	5/8" Dia. UNC, 10" Long Guardrail Bolt	ASTM A307 Gr. A	H#1000217087
f2	5/8 Dia, UNC, 5" Long Hex Head Bolt	ASTM A459 Gr. 5 or equivalent	H#3093332
f3	5/8" Dia. UNC, 2" Long Guardrail Bolt	ASTM A307 Gr. A	Not used in system
f4	5/8" Dia. UNC, 1 1/4" Long Guardrail Bolt	ASTM A307 Gr. A	H#20841080
f5	7/8" Dia. UNC, 8" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	P#92005
f6	7/8" Dia. UNC, 2" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	not used in this system, used alternate method of epoxy and threaded rod (f10) to attach W-Beam end shoes to anchor block
f7	5/8" Dia. UNC, 10" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	H#JK18104124
f8	5/8" Dia. UNC, 1 1/2" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	H#20841080 P#1015-625-US
f9	¾" Dia., Unthreaded Spacer Sleeve	ASTM A53 Gr. B	H#4132970
g1	7/8" Dia. Plain Round Washer	ASTM F844	P#33187
g2	5/8" Dia. Plain Round Washer	ASTM F844	P#33185 P#0838687

Table D-6. Bill of Materials, Test No. HBIB-9, Cont.

Item No.	Description	Material Specification	Reference
h1	5/8" Dia. UNC Heavy Hex Nut	ASTM A563A or equivalent	P#1191919 P#36755
h2	5/8" Dia. Hex Nut	ASTM A563A	H#8000021095
h4	7/8" Dia. UNC Hex Nut	ASTM A307A or equivalent	P#92005 P#36717
*i1	3/8" Dia. Wire Strut, 13 3/8" Long Unbent	Min. Tensile Strength = 100,000 psi	N/A
*i2	3/8" Dia. Wire Strut, 16 3/8" Long Unbent	Min. Tensile Strength = 100,000 psi	N/A
*i3	3/8" Dia. Wire Strut, 18" Long Unbent	Min. Tensile Strength = 100,000 psi	N/A
*i4	7/8 Dia. Threaded Ferrule	-	N/A
k1	Soil	-	N/A
k2	Fascia	Min. f'c = 4,000 psi	Ticket#2050257

*Components not required if optional anchor is used.

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

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

MILFORD,NE,68405

Test Report
Ship Date: 1/16/2023
Customer P.O.: 1216221
Shipped to: MIDWEST MACHINERY & SUPPLY CO.
Project:
GHP Order No: 8420AA

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	AA5765	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	EA3067	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 L Grover
Jeffery Grover, Vice President Gregory Highway
Gregory Highway

Figure D-1. 12-gauge W-Beam Section, Test Nos. HBIB-6 through HBIB-9 (Item Nos. a1, a4, a5, a7)

Certified Analysis

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:
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
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 D-2. 12-gauge W-Beam Section, Test Nos. HBIB-6 through HBIB-10 (Item Nos. a1, a4, a5, 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
40	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
			M-180	A	2	280958	62,598	81,453	23.0	0.190	0.720	0.015	0.001	0.020	0.090	0.001	0.070	0.002
			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
	11G				2	L14522												
			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	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	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
			M-180	A	2	280958	62,598	81,453	23.0	0.190	0.720	0.015	0.001	0.020	0.090	0.001	0.070	0.002
			M-180	A	2	281442	61,762	80,996	25.6	0.190	0.730	0.012	0.004	0.010	0.110	0.000	0.060	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	281447	61,327	79,717	24.5	0.190	0.720	0.010	0.003	0.010	0.110	0.000	0.050	0.002
50	850G	12/BUFFER/ROLLED	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
7	923G	BRONSTAD 98" W/O GUSSET	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

1 of 6

Figure D-3. 12-gauge W-Beam Section, Test Nos. HBIB-6 through HBIB-10 (Item Nos. a1, a4, a5, a7)

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 L 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 D-4. 12-gauge W-Beam Section, Test Nos. HBIB-6 through HBIB-10 (Item No. a2)

NUCOR
NUCOR STEEL GALLATIN

Nucor Steel Gallatin
4831 U.S. Highway 42 West
Ghent, KY 41045-9704
Phone: 1(800)581-3853 Fax: (859)567-3165

METALLURGICAL TEST REPORT

Invoice To: Gregory Industries
4100 13th Street SW
Canton, OH 44710

Ship To: Gregory Industries
4100 13th Street SW
Canton, OH 44710

Date: 1/21/2018
Customer No: 10019
Customer P.O.: 39620

Mill Order No: 214078-1 **Customer Reference No:** 39620 **Load No:** 736148

This product was melted and manufactured in the USA to meet the requirements of: 1020 steel for SS 50 grade for Guard Rails - 50 ksi min yield, 70 ksi min tensile, 0.10% max Si, and 0.06% Cr max
HR Sheet Steel Bands

Ordered Size: Min 0.095 (In.) X 56.88 (In.) X Coil
Min 2.413 (mm) X 1445 (mm) X Coil

Coil Number(s): 1465177

CHEMICAL ANALYSIS (Weight %)

Heat No	C	Mn	P	S	Si	Cu	Ni	Cr	Mo
C85187	0.20	0.48	0.008	0.003	0.03	0.06	0.02	0.05	0.01
	Al	Ca	Nb	V	B	Ti	N	Sn	
	0.029	0.0017	0.000	0.001	0.0001	0.001	0.0080	0.003	

MECHANICAL PROPERTIES

Coil Tested								
Yield Strength(ksi)								
Yield Strength(mpa)								
Tensile Strength(ksi)								
Tensile Strength(mpa)								
% Elongation								
N-Value								
N-Value Range								
Hardness(HRBW)								
Test Section								
Orientation								
Test Method								

BEND TEST RESULTS

Coil ID #	Orientation	Diameter/radius of mandrel	No. of cracks	Size of cracks	Pass/ Fail

Ht code
1207

Hot rolled coils manufactured through Nucor Steel Gallatin do not contain welds or weld repairs at the time of shipment (fca mill).
Mercury was not added during production of this material. The material was produced using a fully killed fine grain practice with a grain size of 6 or finer according to ASTM E112.

This product is in compliance with DFARS 252.225, the Buy American Act.

Above tests performed in accordance to ASTM standards E8 (yield strength determined using 0.2% offset method and elongation determined using at fracture method) or JIS Z2241, E18, E415, and E1019 and are correct as contained in the records of the company.

The elongation original gauge length is 2 inches for ASTM test method and 1.97 inches for JIS test method.
Above test results were performed in accordance to EN 10204 3.1

Bend tests were conducted in accordance with ISO 7438, ASTM E290, or JIS Z2248 using the press, guided, two support and a mandrel bend method at a 180 degree bend. Bend test specimen is longer than 6" and wider than 0.8"

This report shall not be reproduced, except in full, without written approval of the undersigned laboratory managers.
* This mechanical property has been tested at a subcontractor's laboratory.

Stephen S. Sipple
Stephen S. Sipple
Chemical Laboratory
Mechanical Laboratory
steve.sipple@nucor.com

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Figure D-5. 12-gauge W-Beam Section, Test Nos. HBIB-6 through HBIB-10 (Item No. 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.

GREGORY HIGHWAY

By: Jeffery L. Grover
Jeffery Grover, Vice President Gregory Highway
Gregory Highway

Figure D-6. 12-gauge W-Beam Section, Test Nos. HBIB-6 through HBIB-10 (Item No. a3)

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

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

MILFORD,NE,68405

Test Report
Ship Date: 1/16/2023
Customer P.O.: 1216221
Shipped to: MIDWEST MACHINERY & SUPPLY CO.
Project:
GHP Order No: 8420AA

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	EA3067	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.

GREGORY HIGHWAY

By: Jeffery L. Grover
Jeffery Grover, Vice President Gregory Highway
Gregory Highway

Figure D-7. 12-gauge W-Beam Section, Test Nos. HBIB-6 through HBIB-10 (Item No. a7)

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

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

MILFORD,NE,68405

Test Report
Ship Date: 6/25/2024
Customer P.O.: 613242
Shipped to: MIDWEST MACHINERY & SUPPLY CO.
Project:
GHP Order No: A259AA

Heat # Code	Lot #	C.	Mn.	P.	S.	SI.	Tensile	Yield	Elong.	Quantity	Class	Type	Description
290820		0.05	0.49	0.012	0.002	0.02	60107	48493	37.8	20	B	2	10GA BRIDGE SHOE
4160407		0.22	0.74	0.01	0.003	0.02	78000	57500	26	4	A	2	12GA TB TRANS.
B3K572		0.17	0.96	0.008	0.003	0.18	74000	53000	38	11		2	5/8IN X 8IN X 8IN BRG. PL.
291140		0.19	0.53	0.017	0.002	0.02	73709	53003	28.81	20		2	CABLE AB
23002641		0.2	0.36	0.015	0.004	0.02	76000	53000	37	14		2	MASH BEARING PLATE ME750 5/8" X 8" X 8" GALVANIZED A123
55089687		0.13	0.84	0.013	0.021	0.22	75400	57100	27.3	8		2	MASH HINGE POST #2 MHP2A GALVANIZED A123
27369		0.12	0.61	0.023	0.025	0.18	64000	45000	26.2	21		2	UNIVERSAL HINGE POST #2 UPPER SKT/FLEAT RSI# UHP2A
15380		0.2	1.01	0.011	0.026	0.25	79000	55000	17.1			2	UNIVERSAL HINGE POST #2 UPPER SKT/FLEAT RSI# UHP2A
59114746		0.09	0.84	0.012	0.023	0.17	67514	55529	25.8	15		2	SKT/FLEAT BOTTOM POST #2/3 77IN OAL GALV. A-123 RSI# HP2B
9534742		0.07	0.75	0.008	0.002	0.01	77000	63600	33			2	SKT/FLEAT BOTTOM POST #2/3 77IN OAL GALV. A-123 RSI# HP2B
27350		0.13	0.71	0.013	0.324	0.21	89000	51000	18.4	24		2	BOTTOM POST ASSEMBLY #2
15598		0.14	0.87	0.01	0.022	0.23	86000	58000	16.5			2	BOTTOM POST ASSEMBLY #2
27364		0.12	0.58	0.018	0.02	0.18	66000	44000	24.3			2	BOTTOM POST ASSEMBLY #2
294388		0.04	0.56	0.011	0.002	0.02	68026	57102	32.21	11	A		MASH STRUT & YOKE GALV. A-123 RSI DWG. NO. MS785
294753		0.2	0.53	0.012	0.004	0.02	70102	48125	34.2		A		MASH STRUT & YOKE GALV. A-123 RSI DWG. NO. MS785
335407		0.083	0.479	0.007	0.004	0.01					A		MASH STRUT & YOKE GALV. A-123 RSI DWG. NO. MS785

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-costed or zinc-iron alloy-coated by the hot dip process that meets ASTM Specifications A653

GREGORY HIGHWAY

By: Jeffery L Grover
Jeffery L Grover, Vice President Gregory Highway
Gregory Highway

Figure D-8. W-Beam Terminal Connector, Test Nos. HBIB-6 through HBIB-10 (Item No. a8)

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 L 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 D-9. 12-gauge Bent W-Beam, Test Nos. HBIB-6 through HBIB-10 (Item No. a9)

NUCOR
NUCOR STEEL GALLATIN

Nucor Steel Gallatin
4831 U.S. Highway 42 West
Ghent, KY 41045-9704
Phone: 1(800)581-3853 Fax: (859)567-3165

METALLURGICAL TEST REPORT

Invoice To: Gregory Industries
4100 13th Street SW
Canton, OH 44710

Ship To: Gregory Industries
4100 13th Street SW
Canton, OH 44710

Date: 1/21/2018
Customer No: 10019
Customer P.O.: 39620

Mill Order No: 214078-1 **Customer Reference No:** 39620 **Load No:** 736148

This product was melted and manufactured in the USA to meet the requirements of: 1020 steel for SS 50 grade for Guard Rails - 50 ksi min yield, 70 ksi min tensile, 0.10% max Si, and 0.06% Cr max
HR Sheet Steel Bands

Ordered Size: Min 0.095 (In.) X 56.88 (In.) X Coil
Min 2.413 (mm) X 1445 (mm) X Coil

Coil Number(s): 1465177

CHEMICAL ANALYSIS (Weight %)

Heat No	C	Mn	P	S	Si	Cu	Ni	Cr	Mo
C85187	0.20	0.48	0.008	0.003	0.03	0.06	0.02	0.05	0.01
	Al	**Ca**	**Nb**	**V**	**B**	**Ti**	**N**	**Sn**	
	0.029	0.0017	0.000	0.001	0.0001	0.001	0.0080	0.003	

MECHANICAL PROPERTIES

Coil Tested								
Yield Strength(ksi)								
Yield Strength(mpa)								
Tensile Strength(ksi)								
Tensile Strength(mpa)								
% Elongation								
N-Value								
N-Value Range								
Hardness(HRBW)								
Test Section								
Orientation								
Test Method								

BEND TEST RESULTS

Coil ID #	Orientation	Diameter/radius of mandrel	No. of cracks	Size of cracks	Pass/ Fail

Ht code
1207

Hot rolled coils manufactured through Nucor Steel Gallatin do not contain welds or weld repairs at the time of shipment (fca mill).
Mercury was not added during production of this material. The material was produced using a fully killed fine grain practice with a grain size of 6 or finer according to ASTM E112.

This product is in compliance with DFARS 252.225, the Buy American Act.

Above tests performed in accordance to ASTM standards E8 (yield strength determined using 0.2% offset method and elongation determined using at fracture method) or JIS Z2241, E18, E415, and E1019 and are correct as contained in the records of the company.

The elongation original gauge length is 2 inches for ASTM test method and 1.97 inches for JIS test method.
Above test results were performed in accordance to EN 10204 3.1

Bend tests were conducted in accordance with ISO 7438, ASTM E290, or JIS Z2248 using the press, guided, two support and a mandrel bend method at a 180 degree bend. Bend test specimen is longer than 6" and wider than 0.8"

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* This mechanical property has been tested at a subcontractor's laboratory.

Stephen S. Sipple
Stephen S. Sipple
Chemical Laboratory
Mechanical Laboratory
steve.sipple@nucor.com

Page 1 of 1

Figure D-10. 12-gauge Bent W-Beam, Test Nos. HBIB-6 through HBIB-10 (Item No. a9)

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	299	11024	62461		NTE		8/2/24	7:26 AM	2050257

Customer	Delivery Address	Special Instructions
UNL-MIDWEST ROADSIDE SAFETY	4630 NW 36TH ST	AIRPORT / NORTH OF THE NORTH GOODYEAR HANGER

LOAD QUANTITY	CUMULATIVE QUANTITY	ORDERED QUANTITY	PRODUCT CODE	PRODUCT DESCRIPTION	UOM	UNIT PRICE	EXTENDED PRICE
7.00	7.00	7.00	QL3S4504	LNK47B1S384000H	yd	$184.50	$1,291.50
7.00		0.00	FSCHG	FUEL SURCHARGE	yd	$2.70	$18.90

Water Added On Job At Customer's Request:	SLUMP	Notes:		
	4.00 in		TICKET SUBTOTAL	$1,310.40
			SALES TAX	$0.00
			TICKET TOTAL	**$1,310.40**
			PREVIOUS TOTAL	
			GRAND TOTAL	**$1,310.40**

CAUTION FRESH CONCRETE
KEEP CHILDREN AWAY

Contains Portland cement. Freshly mixed cement, mortar, concrete or grout may cause skin injury. Avoid prolonged contact with skin. Always wear appropriate Personal Protective Equipment (PPE). In case of contact with eyes or skin, flush thoroughly with water. If irritation persists, seek medical attention promptly.

Terms & Conditions

This concrete is produced with the ASTM standard specifications for ready mix concrete. Strengths are based on a 3" slump. Drivers are not permitted to add water to the mix to exceed this slump, except under the authorization of the customer and their acceptance of any decrease in compressive strength and any risk of loss as a result thereof. Cylinder tests must be handled according to ACI/ASTM specifications and drawn by a licensed testing lab and/or certified technician.
Ready Mixed Concrete Company will not deliver any product beyond any curb lines unless expressly told to do so by customer and customer assumes all liability for any personal or property damage that may occur as a result of any such directive.
The purchaser's exceptions and claims shall be deemed waived unless made in writing within 3 days from time of delivery. In such a case, seller shall be given full opportunity to investigate any such claim. Seller's liability shall in no event exceed the purchase price of the materials against which any claims are made.

ruck	Driver	User	Disp Ticket Num	Ticket ID	Time	Date
99	11024	user	2050257	145770	7:26	8/2/24

oad Size	Mix Code	Returned	Qty	Mix Age	Seq	Load ID
.00 CYDS	QL3S4504				D	147495

terial	Description	Design Qty	Required	Batched	% Var	% Moisture	Actual Wat
M1S38	TYPE 1S38	611.0 lb	4277.0 lb	4260.0 lb	-0.40%		
7B	GRAVEL	1993 lb	14240 lb	14220 lb	-0.14%	2.07% M	289 lb
'B	47-B ROCK	867 lb	6125 lb	6080 lb	-0.74%	0.93% A	56 lb
WR	POZZ 322 N LOW	3.00 /C	128.31 oz	126.00 oz	-1.80%		
:	MB-AE 200	6.00 oz #	42.00 oz	42.00 oz	0.00%		
TER	WATER 1	33.0 gl	189.6 gl	190.8 gl *	0.59%		1592.0 lb

ual   Num Batches: 1   Manual 7:26:37
id 26163 lb   Design W/C: 0.451   Water/Cement: 0.455 A   Design 1927.7 lb   Actual 1936.3 lb   To Add: 0.0 lb
mp: 4.00 in   Water in Truck: 0.0 gl   Adjust Water: 0.0 gl / Load   Trim Water: 0.0 gl / CYDS
ual W/C Ratio: 0.455   Actual Water: 1936 lb   Batched Cement: 4260 lb   Allowable Water: 0 lb

Figure D-11. Concrete Anchor Block, Test Nos. HBIB-6 through HBIB-10 (Item No. b1, k2)

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# N77508
Customer PO# 903231
Preservative: CCA – C 0.40 PCF Highway Construction Use

Part #	Physical Description	# Pieces	Charge #	Retention
GS6846PST	5.5x7.5-46" BCT	42	8872	.704
621134b	6x12-14" OCD Block	84	9554	.652
621135b	6x12-19" OCD Block	112	9554	.652
4075b	6x8-14" Block	126	8797	.682

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

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

Nick Sowl, General Counsel

10/20/2023
Date

Figure D-12. BCT Timber Post, Test Nos. HBIB-6 through HBIB-10 (Item No. c1)

3046HD6

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

Atlas Tube
A DIVISION OF ZEKELMAN INDUSTRIES

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

MATERIAL TEST REPORT

Sold to

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

Shipped to

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

H#821T08220 R#18-642 Black Paint 72" Long Foundation Tube

Material: 8.0x6.0x188x27'0"0(2x2)SILDOMUS — Material No: 80060188 — Made in: USA — Melted in: USA
Sales order: 1105121 — Purchase Order: 35569 — Cust Material #: TRB3/16-8-6-27

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

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

Material Note:
Sales Or.Note:

Material: 8.0x6.0x188x30'0"0(2x3)SILDOMUS — Material No: 80060188 — Made in: USA — Melted in: USA
Sales order: 1105121 — Purchase Order: 35569 — Cust Material #: TRB3/16-8-6-30

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

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

Material Note:
Sales Or.Note:

Material: 8.0x6.0x188x30'0"0(2x3)SILDOMUS — Material No: 80060188 — Made in: USA — Melted in: USA
Sales order: 1105121 — Purchase Order: 35569 — Cust Material #: TRB3/16-8-6-30

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

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

Material Note:
Sales Or.Note:

Jason Richard

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

Steel Tube Institute OF NORTH AMERICA

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Metals Service Center Institute

Figure D-13. 72-in. Long Foundation Tube, Test Nos. HBIB-6 through HBIB-10 (Item No. c2)

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

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

Figure D-14. 72-in. Long Foundation Tube, Test Nos. HBIB-6 through HBIB-10 (Item No. c2)

GALLATIN STEEL

Gallatin Steel Company
4831 U.S. Highway 42 West
Ghent, KY, 41045-9704
Phone: 1(800)581-3853 Fax: (859)567-3165

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	C43126	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.

L K Chung
GSC Quality Assurance

P 1e 1 of 1

The information contained in this report may be confidential information intended only for the use of the individual or entity named above. If the reader of this message is not the intended recipient, you are hereby notified that any dissemination, distribution, or copying of this communication is strictly prohibited. If you have received this communication in error, please notify us immediately by telephone and destroy the original message. Thank You.

Figure D-15. Ground Strut Assembly, Test Nos. HBIB-6 through HBIB-10 (Item No. c3)

WireCo® WorldGroup
24150 Oak Grove Lane
Sedalia MO. 65302-0844
660-829-6721(P)
660-829-6780(F)

Date: 10/12/22
Sold to: Commercial group Lifting Prod - Detroit
12801 Universal Drive
Taylor MI 48180-6844
Order: 301567

Certificate of Compliance

Report of Chemical Analysis and Physical Tests

Order No. 301567 **Reel number** 428-1029295-2 **Rope Description** 3/4 6x19W-WSC CLA SZ (RR) L030 DEV A741 US 100

Item No.	Description	Tensile Strength Lbs.	Lbs. per sq. in.		Wt. Coat	Torsion Test 8"	Heat No.	C	Mn	P	S	Si
001	**.0400" Galvanized Wire**											
	0.040	329	262,000		.477	99	20744340	.74	.70	.005	.008	.26
	0.040	336	267,000		.502	89	8000008669	.75	.66	.004	.009	.24
	0.040	347	276,000		.406	78	20752970	.72	.67	.008	.012	.22
002	**.0460" Galvanized Wire**											
	0.046	422	254,000		.407	63	20721940	.75	.64	.005	.010	.20
003	**.0540" Galvanized Wire**											
	0.054	631	276,000		.497	53	OT0023436	.82	.66	.011	.011	.26
	0.054	620	271,000		.405	48	20746670	.82	.51	.005	.005	.23
	0.054	668	292,000		.483	51	20734180	.81	.53	.006	.008	.23
004	**.0610" Galvanized Wire**											
	0.061	772	264,000		.462	42	10674470	.79	.82	.007	.010	.25
	0.061	804	275,000		.450	52	OT0024724	.81	.54	.006	.008	.23

Page 2 of 2

The material covered by this certification was manufactured and tested in accordance with specifications as listed above. We certify that representative samples of the material have been tested and the results conform to the requirements outlined in these specifications.

The chemical, physical, or mechanical tests reported above are correct as contained in the records of the corporation.

Signed: Michele Johnson

KESHA JOY LAGOY LAURENT
Notary Public, Notary Seal
State of Missouri
Pettis County
Commission # 20814032
My Commission Expires 09-01-2024

10/13/2022

Figure D-16. BCT Anchor Cable Assembly/IWRC Wire Rope, Test Nos. HBIB-6 through HBIB-10 (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													

3 of 5

Figure D-17. Ground Anchor Bracket Assembly, Test Nos. HBIB-6 through HBIB-10 (Item No. c5)

ONEAL THE METALS COMPANY

O'NEAL STEEL, INC.
Shipping Papers
www.onealsteel.com
Page 1 of 4

Copies Printed 1
Sales Order No. 20124825 SO
Shipment No. 74099134
Ship Date 10/20/2016

O'Neal Branch BIRMINGHAM
Salesperson CHASSITY LAYTON
Phone 205-599-8000

Load No. 174433
Origin 101
Order Date 10/13/2016

Carrier WATKINS TRUCKING CO INC
Mode Of Transport

Ship Weight 40622.20
Trailer No. 420

Sold To 252646
TRINITY HIGHWAY PRODUCTS, LLC
P.O. BOX 566028 MAILSTOP 7115
DALLAS, TX75356-6
205 - 884-1532

Ship To 54243243
TRINITY HWY PRODUCTS
550 EAST ROBB AVE.
LIMA, OH 45801
205 - 884-1532

Delivery Instructions:
LD PLT FOR SHTLIFTER UNLD-5000
NO FRIDAY DELIVERIES!

Special Instructions:
PASSED & CERTIFIED
OCT 24 2016
Trinity Highway Products, LLC
Dallas, Texas Plant 92

Line	Qty	UM	Description	Color	Customer PO	MTR	Weight	Billed Units	UM
1.000	1 ✓	PC	SQTB HREW A500 B 3 X5/16W X40		180009	SM	423.20	423.20	LB
2.000	15 ✓	PC	FLAT A36/A529G50 1/2 X3 X20		180009	SM	1530.00	1530.00	LB
3.000	102	PC	ANGLE A36/A529G50 3 X3 X1/4 X40		180009	SM	19992.00	19992.00	LB

Line 1.000:
Customer Part Number 101992B
Heat Numbers U1271 ✓
O'Neal Item # 873717
SHIP HEAT# U1271

Line 2.000:
Customer Part Number 100379B
Heat Numbers JK16101488 ✓
O'Neal Item # 777557
PULL HEAT# JK16101488

Line 3.000:
Customer Part Number 101929B

Signature ____________________ Authorized Agent ______ Date

By signing above, Buyer acknowledges receipt of the goods and services described in these shipping papers in good condition. The sale and delivery of such goods and services is subject to and governed by our standard terms and conditions in effect on the order date.

Our terms and conditions can be found on our website at www.onealsteel.com and are incorporated by reference into these shipping papers. By purchasing goods or services from us, you agree to these terms and conditions. If you are unable to access our website, you may obtain a copy of the terms and conditions by calling us at 1-800-292-4090.

Invoice, Test Report, and Signed Delivery Ticket documents are now available for download in our Customer Gateway at www.onealsteel.com

"We appreciate your order"

Figure D-18. Ground Anchor Bracket Assembly, Test Nos. HBIB-6 through HBIB-10 (Item No. c5)

NUCOR
NUCOR STEEL JACKSON, INC.

Mill Certification
7/27/2016

MTR #: M1-150903
NUCOR STEEL JACKSON, INC.
3630 Fourth Street
Flowood, MS 39232
(601) 939-1623
Fax: (601) 936-6202

Sold To: O'NEAL STEEL INC
ATTN ACCOUNTS PAYABLE
PO BOX 98
BIRMINGHAM, AL 35202-0098
(205) 599-8000
Fax: (205) 599-8052

Ship To: O'NEAL STEEL INC
4530 MESSER-AIRPORT HWY
BIRMINGHAM, AL 35222
(205) 599-8000
Fax: (205) 599-8052

Customer P.O.	00771356	Sales Order	343125.6
Product Group	Merchant Bar Quality	Part Number	5350030024010W0
Grade	NUCOR MULTIGRADE	Lot #	JK1610148801
Size	1/2x3" Flat	Heat #	JK16101488
Product	1/2x3" Flat 20' NUCOR MULTIGRADE	B.L. Number	M1-429898
Description	NUCOR MULTIGRADE	Load Number	M1-150903
Customer Spec		Customer Part #	00777557

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.

Roll Date: 4/5/2016 Melt Date: 3/30/2016 Qty Shipped LBS: 4,900 Qty Shipped Pcs: 48

Melt Date: 3/30/2016

C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Cb	Sn
0.16%	0.78%	0.017%	0.028%	0.20%	0.28%	0.09%	0.14%	0.020%	0.0280%	0.001%	0.010%
CE4020	CEA529										
0.35%	0.39%										

CE4020: C. E. CSA G4020, AASHTO M270
CEA529: A529 CARBON EQUIVALENT

Roll Date: 4/5/2016

Yield 1: 56,172psi	Tensile 1: 75,460psi	Elongation: 25% in 8"(% in 203.3mm)
Yield 2: 56,126psi	Tensile 2: 76,500psi	Elongation 25% in 8"(% in 203.3mm)

Specification Comments: NUCOR MULTIGRADE MEETS THE REQUIREMENTS OF: ASTM A36/36M, ASTM A529/529M GR50 ASTM A572/572M GR50 ASTM709/709M GR36/GR50 CSA G40.21 GR44W(300W)/GR50W(350W) AASHTO M270/M270M GR36/GR50 ASME SA36/SA36M MEETS EN10204 SEC 3.1 REPORTING REQUIREMENTS

ALL MANUFACTURING PROCESSES OF THE STEEL MATERIALS IN THIS PRODUCT, INCLUDING MELTING, HAVE OCCURRED WITHIN 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.

QA Approved
SI# 777557

Christopher Smith
Christopher Smith
Division Metallurgist

NBMG-10 January 1, 2012

Page 1 of 1

Figure D-19. Ground Anchor Bracket Assembly, Test Nos. HBIB-6 through HBIB-10 (Item No. c5)

CMC STEEL ALABAMA
101 S 50TH STREET
BIRMINGHAM AL 35212-3525

1SERIES-BPS ®

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

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

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Figure D-20. Anchor Bearing Plate, Test Nos. HBIB-6 through HBIB-10 (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: *[signature]*
The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements.
Calculated using the AWS D1.1 method.

Steel Tube Institute

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Metals Service Center Institute

Figure D-21. 6-in. Long BCT Post Sleeve, Test Nos. HBIB-6 through HBIB-10 (Item No. c7)

R. G. STEEL CORP.
www.rgsteel.com
P. O. Box 356, Rt. 551 • Pulaski, PA 16143 • Phone: 724-656-1722 • Fax: 724-656-1725

Material Test Report

Customer: GUARDRAIL SYSTEMS **Ship Date:** 9/18/2019
Bill of Lading Number: 23509 UNIVERSAL
Project Number: **County:** **State:** NE

HEAT NUMBER	CHEMICAL ANALYSIS C	MN	PHOS	S	SI	PHYSICAL ANALYSIS YIELD STRENGTH	TENSILE STRENGTH	% ELONG	GALV. COATING WT.	QTY. SHIPPED	ITEM NUMBER	DESCRIPTION
2909166	0.070	0.860	0.010	0.014	0.230	55,700	68,600	25	3.3 MILS	750	RG-196	7'-0", 6"WF x 8.5# POST GALV.

Bolts comply with ASTM A-307 Specifications are galvanized in accordance with ASTM A-153, unless otherwise stated.
Nuts comply with ASTM A-563 Specifications are galvanized in accordance with ASTM A-153, unless otherwise stated.
All other galvanized material conforms with ASTM A123.
All steel used in the manufacture is of domestic origin.
All guardrail meets AASHTO M-180, all structural steel meets AASHTO M-270.
All bolts and nuts are of domestic origin.
All material fabricated in accordance with D.O.T. Specifications.

State of Pennsylvania County of Lawrence
Sworn and subscribed before me:
This 18th Day Of Sept 2019
Dawn L Kliem
Notary Public
My commission Expires March 26, 2021

COMMONWEALTH OF PENNSYLVANIA
NOTARIAL SEAL
Dawn L. Kliem, Notary Public
Pulaski Twp., Lawrence County
My Commission Expires March 26, 2021
MEMBER, PENNSYLVANIA ASSOCIATION OF NOTARIES

Name of Producer: R.G. STEEL CORP.
Certified By: [signature]
Approved By:

Figure D-22. 84-in. Long Steel Post, Test Nos. HBIB-6 through HBIB-10 (Item No. d1)

JCOR STEEL – BERKELEY
155 Hagan Avenue
iger, SC 29450
ione: (843) 336-6000

CERTIFIED MILL TEST REPORT

8/05/19 7:11:19
100% EAF MELTED AND MANUFACTURED IN THE USA
Structural sections produced by Nucor-Berkeley are cast
and hot rolled to a fully killed and fine grain practice.
Mercury has not been used in the direct manufacturing of this material.

Sold To: RG STEEL CORP
PO BOX 356
PULASKI, PA 16143

Ship To: R.G. STEEL
ROUTE 551
PULASKI, PA 16143

Customer #.: 711 - 1
Customer PO: 11894
B.o.L. #...: 1425833
MOS: T

PECIFICATIONS: Tested in accordance with ASTM specification A6/A6M-17a and A370. Quality Manual Rev #10 (3-14-19).
AASHTO : m270-345M270-50-15
ASME : SA-36 13
ASTM : A992-11(15:/A36-19/A529-19-50/A5725018T1/A7093618/A7095018
CSA : G40.21-44w/G40.2150WM

RG-196

escription art #	Heat# Grade(s) Test/Heat JW	Yield/ Tensile Ratio	Yield (PSI) (MPa)	Tensile (PSI) (MPa)	Elong %	C Cr XXXXXX	Mn Mo Ti	P Sn XXXXXX	S B XXXXXX	Si V N	Cu Nb XXXXXX	Ni XXXXXX CI	CE1 CE2 Pcm
5X8.5	2909166	.81	55700	68600	25.20	.07	.86	.010	.014	.23	.12	.04	.23
042' 00.00"	A992-11(15		384	473		.04	.01	.0060	.0001	.004	.016		.2762
150X12.6		.82	55800	68400	29.10		.001			.0053		3.26	.1290
012.8016m	ANSW		385	472	84 Pc(s)	29,988 lbs		Customer PO: 11894				InvH:	0
5X8.5	2909165	.81	55500	68800	28.50	.07	.84	.007	.021	.22	.11	.04	.23
042' 00.00"	A992-11(15		383	474		.03	.01	.0058	.0002	.004	.015		.2701
150X12.6		.80	54700	68200	30.00		.001			.0049		3.00	.1293
012.8016m	ANSW		377	470	42 Pc(s)	14,994 lbs		Customer PO: 11894				InvH:	0

2 Heat(s) for this MTR.

.ongation based on 8" (20.32cm) gauge length. 'No Weld Repair' was peformed.
: = 26.01Cu+3.88Ni+1.20Cr+1.49Si+17.28P-(7.29Cu*Ni)-(9.10Ni*P)-33.39(Cu*Cu)
:m = C+(Si/30)+(Mn/20)+(Cu/20)+(Ni/60)+(Cr/20)+(Mo/15)+(V/10)+5B
:1 = C+(Mn/6)+((Cr+Mo+V)/5)+((Ni+Cu)/15)

'All mechanical testing is performed by the Quality testing lab, which is independent of the production departments'
CE2 = C+((Mn+Si)/6)+((Cr+Mo+V+Cb)/5)+((Ni+Cu)/15)

hereby certify that the contents of this report are accurate and
orrect. All test results and operations performed by the material
anufacturer are in compliance with material specifications, and
hen designated by the Purchaser, meet applicable specifications.

Bruce A. Work
Metallurgist
Quality Control

Figure D-23. 84-in. Long Steel Post, Test Nos. HBIB-6 through HBIB-10 (Item No. d1)

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.: 0231526 / 0181901
CUSTOMER P.O.: 5092

REFERENCE: STOCK
DATE SHIPPED: 9/28/2021

QTY:	HEAT/LOT NO:	ITEM NUMBER: YIELD:	CC: TENSILE: %ELONG:	DESCRIPTION: C: Mn: P: S: Si: Cl: Type ACW
200		T-POG060080606B	IB-B0600800	THRIE POST W06 x 008.5# x 06'06 F/ RTD WOOD THRIE BLOC
	55073776			
250		T-POG060080600G	IB-B0600800	THRIE POST W06 x 008.5# x 06'00 OVERLAY NE HDG HOLES @
(50)	55073783			
(150)	55073780			
(50)	55073781			
400		PSG030050503-20	IBSB03005000	POST S03@05.7 x 05'03.0 3 HL 2 SD W/PLT 3.5-3-3 SPGLV
	58046969		PL-B025-080240	
	D21569			
50		T-POG060080900	IB-B0600800	THRIE POST W06 x 008.5# x 09'00 2-SD 7 / 7.625 GLV
	55069390			
1		GALV CERT OH	GALV CERT OH	GALVANIZING CERTIFICATION OH
	GALVOH			

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 D-24. 72-in. Long Steel Post, Test Nos. HBIB-6 through HBIB-10 (Item No. d2)

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**

PACKING LIST

PAGE: 1
FOB RENO
TERMS NET30
SHIP METHOD FEDEXF

SOLD TO

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

SHIP TO

Midwest Roadside Safety

4630 NW 36th Street
Lincoln, NE 68524

ORDER NUMBER	ORDER DATE	CUSTOMER ID	PURCHASE ORDER	SHIP DATE
34545	04/04/19	MIDWEST	HWTT	4/4/2019

LINE	ORDERED	SHIPPED	UOM	ITEM NUMBER	DESCRIPTION
1	10.0000	10.0000	EACH	GB14SH2	Composite Guardrial Block 14" for Steel Post w/hanger CO *1804/1000*
2	4.0000	4.0000	EACH	MGS14SH	Midwest Composite Block 14" h x 12" d for Steel Post *1904/1000*
3	1.0000	1.0000	EACH	FREIGHT-GUARDRAIL	FREIGHT-GUARDRAIL BLOCK

THANK YOU FOR YOUR BUSINESS

AUTHORIZED SIGNATURE

Figure D-25. Composite Recycled Blockout, Test Nos. HBIB-6 through HBIB-10 (Item No. d4)

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

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

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

MATERIAL CERTIFICATE

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

PAGE: 2

CONSIGNED TO

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

SHIP TO

Midwest Roadside Safety

4630 NW 36th Street
Lincoln, NE 68524

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

MADE IN USA

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

All materials meet required specifications.

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

Print Name: Maggie Ellis **Position:** General Manager

Figure D-26. Composite Recycled Blockout, Test Nos. HBIB-6 through HBIB-10 (Item No. d4)

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 D-27. Composite Recycled Blockout, Test Nos. HBIB-6 through HBIB-10 (Item No. d4)

MARUICHI LEAVITT PIPE AND TUBE

MATERIAL TEST REPORT

ORIGINAL

M/C No. MC0000075568
Date 04/04/2022

BL No. SH0000087697
Destination STEEL & PIPE SUPPLY-JONESBURG
Supplier STEEL & PIPE SUPPLY CO., INC. - BILL TO

MARUICHI LEAVITT PIPE & TUBE, LLC
1717 W. 115TH ST.
CHICAGO, IL. 60643
TEL:773-239-7700 FAX:773-239-1023

	SPEC / SIZE / Customer PO No. / Customer Item No.	No of PCS / Calculated Wt(LBS)	Heat No	C (%) X 100	Si (%) X 100	Mn (%) X 100	P (%) X 1000	S (%) X 1000	Cu (%) X 1000	Ni (%) X 1000	Cr (%) X 1000	Mo (%) X 1000	V (%) X 1000	Yield Strength (PSI)	Tensile Strength (PSI)	Elongation (%)	Hydrostatic Test Pressure (PSI) Result	Bending Test Flattening Test	Remarks
1	ASTM A500/A500M-21A GRADE B ERW TUBING 6IN x 6IN x 0.313IN x 40FT HRB 4500526173 / 6560031340	12 11,204	A70164	20	4	68	10	2	30	10	50	7	5	60,173	77,067	27			SA0000226166 A500 Grade B/C
2	ASTM A500/A500M-21A GRADE B ERW TUBING 4IN x 4IN x 0.375IN x 40FT HRB 4500527208 / 6540037540	18 12,436	B62340	6	4	113	6	2	30	20	50	11	6	57,894	71,473	27			SA0000227459 A500 Grade B/C
3	ASTM A500/A500M-21A GRADE B ERW TUBING 4IN x 4IN x 0.375IN x 40FT HRB 4500527208 / 6540037540	9 6,218	B63642	6	25	131	12	2	20	10	70	17	4	71,480	81,129	25			SA0000227459 A500 Grade B/C
4	ASTM A500/A500M-21A GRADE B ERW TUBING 4IN x 4IN x 0.375IN x 40FT HRB 4500527208 / 6540037540	6 4,144	B63642	6	25	131	12	2	20	10	70	17	4	71,480	81,129	25			SA0000227459 A500 Grade B/C
5	ASTM A500/A500M-21A GRADE B ERW TUBING 8IN x 6IN x 0.250IN x 40FT HRB 4500527208 / 6680060025040	9 8,072	B64993	19	4	69	6	2	20	10	60	12	6	53,580	65,284	30			SA0000227459 A500 Grade B/C

Melted and Manufactured in the USA
This material has not come in direct contact with mercury during the manufacturing or testing processes. No Weld Repair. EN10204:2004 TYPE 3.1 Cert
Remarks:

We hereby certify that the material described herein conforms fully to the said specification.

Maruichi Leavitt Pipe & Tube, LLC

F-824-101 - Rev. 0

Figure D-28. Steel Blockout, Test Nos. HBIB-6 through HBIB-10 (Item No. d5)

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

Page 1 of 1

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 D-29. 16D Double Head Nail, Test Nos. HBIB-6 through HBIB-10 (Item No. d6)

SIMCOTE, INC.

We certify that the reinforcing steel is represented by the attached mill certification analysis of laboratory numbers listed.

SIZE	POUNDS	HEAT OR LAB
11		
10		
9		
8		
7		
6	10,832	7034726
5	25,827	9700023976
4	10,963	9700027794
3		
TOTAL	47,622	

1645 Red Rock Road, St. Paul, MN 55119
Phone: (651) 735-9660 Fax: (651) 735-9664

250 N. Greenwood St., Marion, OH 43302
Phone: (740) 382-5000 Fax: (740) 383-1167

Figure D-30. Rebar, Test Nos. HBIB-6 through HBIB-10 (Item No. e1, e2, e3, e4, e5, e6, e7, e8)

SUMMARY SHEET 11/27/2023

JOB/ORDER NUMBER	53527
CUSTOMER NAME	CONCRETE INDUSTRIES. INC.
CONTRACTOR	
TICKET/RELEASE # (S)	19

SIZE	HEAT	LOT	DATE
4	9700027794	230388	11-15-23C
5	9700023976	230632	06-19-23A
6	7034726	230632	07-10-23C

Figure D-31. Rebar, Test Nos. HBIB-6 through HBIB-10 (Item No. e1, e2, e3, e4, e5, e6, e7, e8)

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 A. Aspland — 12-8-2022
APPROVED SIGNATORY — DATE

Merry F Shane

Official Seal
Merry F Shane
Notary Public State of Illinois
My Commission Expires 10/3/2026

Figure D-32. 10-in. Long Guardrail Bolt, Test Nos. HBIB-6 through HBIB-10 (Item No. f1)

NUCOR

Mill Certification

07/29/2022

MTR#:1080502-2
Lot #:100021708720
2911 E NUCOR ROAD
PO BOX 309
NORFOLK, NE 68701 US
402 644-0200
Fax: 402 644-0329

Sold To: KING STEEL CORP
5225 E COOK RD
GRAND BLANC, MI 48439 US

Ship To: KING STEEL - CUSTOMER PICK UP
REFER TO DISPATCH
NORFOLK, NE 68701 US

Customer PO	041552-MS-T/25 N1	Sales Order #	10043412 - 3.1
Product Group	Wire Rod - Industrial Quality	Product #	1045333
Grade	1010M1	Lot #	100021708720
Size	0.5938"	Heat #	1000217087
BOL #	BOL-1195416	Load #	1080502
Description	Wire Rod - Industrial Quality Round 0.5938" (19/32") 1010M1 COIL 4300 lbs	Customer Part #	0.593 1010 IQ HR RD ROD
Production Date	07/07/2022	Qty Shipped LBS	29310
Product Country Of Origin	United States	Qty Shipped EA	7
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: 06/30/2022

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	Ti (%)	V (%)	B (%)
0.11	0.46	0.007	0.016	0.17	0.09	0.12	0.04	0.24	0.000	0.002	0.0001

Nb (%)	Sn (%)	Al (%)	Pb (%)	Ca (%)
0.001	0.009	0.002	0.000	0.0010

Reduction Ratio 158.19 : 1

Tensile testing

	Yield (PSI)	Tensile (PSI)	Elongation in 8" (%)
(1)	42500	62200	23.0

Comments:
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

Figure D-33. 10-in. Long Guardrail Bolt, Test Nos. HBIB-6 through HBIB-10 (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	BASE STEEL	DIAMETER	SOURCE
3093332	4140AR	5/8	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 D-34. 5-in. Long Hex Head Bolt, Test Nos. HBIB-6 through HBIB-10 (Item No. f2)

CMC

CMC STEEL TEXAS
1 STEEL MILL DRIVE
SEGUIN TX 78155-7510

CERTIFIED MILL TEST REPORT
For additional copies call
830-372-8771

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

Rolando A Davila
Quality Assurance Manager

HEAT NO.:3093332 SECTION: ROUND 5/8 x 20'0" 4140 GRADE: AISI 4140 ROLL DATE: 12/22/2019 MELT DATE: 12/12/2019 Cert. No.: 83107020 / 093332A018	SOLD TO: Portland Bolt & Mfg 3441 NW Guam St Portland OR US 97210-1613 5032275488 5032274634	SHIP TO: CPU Seguin 1 Steel Mill Dr Seguin TX US 78155-7510 9999999999	Delivery#: 83107020 BOL#: 1934806 CUST PO#: 46177 CUST P/N: DLVRY LBS / HEAT: 3671.000 LB DLVRY PCS / HEAT: 176 EA Prod LBS/HEAT: 85168 LB

Characteristic	Value	Characteristic	Value
C	0.40%	Macro Core Rating	1
Mn	0.78%	Reduction Ratio	127
P	0.012%		
S	0.022%		
Si	0.23%		
Cu	0.27%		
Cr	0.83%		
Ni	0.13%		
Mo	0.192%		
V	0.023%		
Cb	0.001%		
Sn	0.008%		
Al	0.001%		
Ideal Diameter	4.7IN		
BHN @ Surface test 1	302BHN		
Grain Size	6		
Macro Etch Method	ASTM E381		
Macro Surface Rating	1		
Macro Random Rating	2		

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

GRADE 4140 PER ASTM SPECIFICATION A29

REMARKS : ROUND STEEL BAR ALLOYED GRADE HOT ROLLED

Figure D-35. 5-in. Long Hex Head Bolt, Test Nos. HBIB-6 through HBIB-10 (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 D-36. 2-in. Long Guardrail Bolt, Test Nos. HBIB-6 through HBIB-8 (Item No. f3)

FASTENAL®

Certificate of Compliance

Sold To:
UNL TRANSPORTATION/Midwest Roadside Safe

Purchase Order: HBIB
Job:
Invoice Date: 01/13/2023

THIS IS TO CERTIFY THAT WE HAVE SUPPLIED YOU WITH THE FOLLOWING PARTS.
THESE PARTS WERE PURCHASED TO THE FOLLOWING SPECIFICATIONS.

100 PCS 5/8"-11 x 2" ASTM A307 Grade A Hot Dipped Galvanized Hex Bolt SUPPLIED UNDER OUR TRACE NUMBER 200233148 AND UNDER PART NUMBER 1191921

32 PCS 7/8"-9 x 2" Grade 5 Plain Finish Hex Cap Screw SUPPLIED UNDER OUR TRACE NUMBER 210270562 AND UNDER PART NUMBER 12411

This is to certify that the above document is true and accurate to the best of my knowledge.

Please check current revision to avoid using obsolete copies.

Ross Schall
Fastenal Account Representative Signature

This document was printed on 01/13/2023 and was current at that time.

Ross Schall
Printed Name

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

1/13/2023
Date

Figure D-37. 2-in. Long Guardrail Bolt, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10 (Item No. f3)

AUTO BOLT
QUALITY BOLT-MAKING

4740 Manufacturing Avenue
Cleveland, OH 44135 USA
Tel 216.881.3913 Fax 216.881.3918
www.autoboltusa.com

Certificate of Conformance

Issued to:

Customer PO#:	6022666
Report #:	211269
Date of Testing:	2/8/2023
Lot #:	48766DL-1
Lot Quantity:	248,810
Shipper #:	12648

Bennett Bolt Works
12 Elbridge St
PO Box 922
Jordan, NY 13080

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

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.

CERTIFIED IATF 16949:2016

FORM# F 8.2.4-1
REV. DATE 3/18/22 **REV. L**

Figure D-38. 1¼-in. Long Guardrail Bolt, Test Nos. HBIB-6 through HBIB-10 (Item No. f4)

FASTENAL®

Fastenal Company
P.O Box 1286
WINONA, MN 55987-1286

Invoice

Date	Reference No.	Page
3/27/18	NELIN314987	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	llne35042	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	llne35042	92005	509.5500	25.48 G
4	5	5 TS	0	7/8-9x8 A307A HDG	llne35042	92005	509.5500	25.48 G
5	5	5 TS	0	7/8-9x8 A307A HDG	llne35042	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 [signature]
Card Member Signature

Received By

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

Comments
Contact: WEBORD CONTRACT:1862 & 14284 OC

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 D-39. 8-in. Long Hex Head Bolt, Test Nos. HBIB-6 through HBIB-10 (Item No. f5)

NUCOR

Mill Certification

08/08/2022

MTR#:1107231-1
Lot #:100021761420
2911 E NUCOR ROAD
PO BOX 309
NORFOLK, NE 68701 US
402 644-0200
Fax: 402 644-0329

RM036299

Sold To: NUCOR FASTENER INDIANA
PO BOX 6100
SAINT JOE, IN 46785 US

Ship To: NUCOR FASTENER INDIANA
6730 CR 60
SAINT JOE, IN 46785 US

Customer PO	222720	Sales Order #	10044331 - 8.2
Product Group	Hot Roll - Engineered Bar	Product #	3099676
Grade	1037ML	Lot #	100021761420
Size	0.8906"	Heat #	1000217614
BOL #	BOL-1202266	Load #	1107231
Description	Hot Roll - Engineered Bar Round 0.8906" (57/64") 1037ML COIL 5200 lbs	Customer Part #	005014
Production Date	08/06/2022	Qty Shipped LBS	202385
Product Country Of Origin	United States	Qty Shipped EA	39
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: 08/01/2022

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	Ti (%)	V (%)	B (%)
0.38	0.78	0.012	0.014	0.24	0.08	0.33	0.04	0.10	0.001	0.003	0.0002

Nb (%)	Sn (%)	Al (%)	Pb (%)	Ca (%)
0.003	0.007	0.002	0.000	0.0000

Cu + Ni + Mo (%) : 0.23

Reduction Ratio 70.14 : 1

Comments:
Coarse Grain Practice
Sellenium,Tellurium,Lead,Bismuth or Boron were not intentionally added to this heat.
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

chem check SNP 8/9/22

Figure D-40. 2-in. Long Hex Head Bolt, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10 (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: [signature] **Date:** 11/29/2018

Brian Hughes
Quality Assurance

Figure D-41. 10-in. Long Hex Head Bolt, Test Nos. HBIB-6 through HBIB-10 (Item No. f7)

CHARTER STEEL
A Division of Charter Manufacturing Company, Inc.

LOAD

1658 Cold Springs Road
Saukville, Wisconsin 53080
(262) 268-2400
1-800-437-8789
Fax (262) 268-2570

CHARTER STEEL TEST REPORT

Melted in USA Manufactured in USA

Kreher Steel Co - Romulus
1550 N. 25th Ave.
Melrose Park,IL-60160

Cust P.O.	66978
Customer Part #	351470
Charter Sales Order	70116651
Heat #	20841080
Ship Lot #	2236544
Grade	1015 X AK FG RHQ 5/8 RNDCOIL
Process	HR
Finish Size	5/8
Ship date	21-NOV-22

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed below and that it satisfies these requirements. The recording of false, fictitious and fraudulent statements or entries on this document may be punishable as a felony under federal statute.

Test results of Heat Lot # 20841080

Lab Code: 125544

CHEM	C	MN	P	S	SI	NI	CR	MO	CU	SN	V
%Wt	.15	.32	.008	.004	.070	.03	.03	.01	.05	.003	.001
	AL	N	B	TI	CA	NB					
	.047	.0070	.0001	.001	.0008	.001					

CAT DI (in)=.20

Test results of Rolling Lot # 2236544

REDUCTION RATIO=160:1

Specifications: Manufactured per Charter Steel Quality Manual Rev Date 05/12/17
Charter Steel certifies this product is indistinguishable from background radiation levels by having process radiation detectors in place to measure for the presence of radiation within our process & products.
Meets customer specifications with any applicable Charter Steel exceptions for the following customer documents:
Customer Document = MATERIAL SPECIFICATION - CHQ PRODUCTS Revision = 4 Dated = 06-MAR-20

Additional Comments: Steel is Vacuum Degassed

Melt Source:

Charter Steel

Cuyahoga Heights, OH, USA

This MTR supersedes all previously dated MTRs for this order

Douglas Jones Division Mgr. of Quality Assurance

jonesdo@chartersteel.com

Trip: R4305284

Printed Date : 11/21/2022

Figure D-42. 1½-in. Long Hex Head Bolt, Test Nos. HBIB-6 through HBIB-10 (Item No. f8)

Customer Name	Customer PO#	Shipper No	Heat Number
UNL-MwRSF	HBIB	2551238	4132970

Customer:ONLINE METALS | Ord #:T638832 | Part #:15536 | Cust PO #:186102

Sharon Tube
A DIVISION OF ZEKELMAN INDUSTRIES
100 Martin Luther King Jr. Blvd., Farrell, 16121

R488890

PRODUCT CERTIFICATION
HEAT NUMBER
4132970
SALES ORDER
0005801707

SOLD TO
EARLE M. JORGENSEN
CORPORATE OFFICE
1900 MITCHELL BLVD.
SCHAUMBURG, IL 60193
USA

SHIP TO
EARLE M. JORGENSEN
BAY 7
1900 MITCHELL BLVD
SCHAUMBURG, IL 60193-4539
USA

CUSTOMER P.O.	P.O. LINE #	CUSTOMER PART	QUANTITY	BNDLS	LADING NO	SHIPMENT DATE
P237396-423	010	120511	1,386 FT	1	0085110605	12/20/2022

SPECIFICATION EDTRN15000.3750-9000
Grade 1026AK
O.D. 1.5000 +0.0050 - 0.0000
I.D. 0.7500 +0.0000 -0.0000 *Reference Dimension
Wall .3750 +0.0100 -0.0100
Len 20' 0.000"/24' 0.000" Random
Temp Stress Relieved
ASTM A-513 Type 5 Drawn Over Mandrel (DOM)
Cold Drawn Electric Weld Carbon Steel Round Mechanical Tubing
WT/FT: 4.50563
SPC Required: None
Finish Type: Normal
End Use: None

***** STENCIL REQUIRED *****
Stencil Must Include:
STANDARD STENCIL FIELDS

PHYSICAL TESTS REQUIRED

Weight: 6303 LBS

CERTIFICATION REQUIREMENTS

Chemical, Ladle Analysis, %

C	Mn	P	S	Si	Al	Cu	Ni	Cr	Mo	V
.25	.65	.01	.002	.02	.039	.03	.02	.04	.	.001

Ca
.0027

Physical Tests

Anthony Yurcho, Manager, Technical Services, deposes and says that the figures set forth above are correct, as contained in the figures of Sharon Tube Company.

(C) Sharon Tube Company - qtc302 (v6.0) Page 1 of 2

Customer:ONLINE METALS | Ord #:T638832 | Part #:15536 | Cust PO #:186102

Figure D-43. ¾-in. Diameter, Unthreaded Spacer Sleeve, Test Nos. HBIB-6 through HBIB-10 (Item No. f9)

Customer Name	Customer PO#	Shipper No	Heat Number
UNL-MwRSF	HBIB	2551238	4132970

Customer:ONLINE METALS | Ord #:T638832 | Part #:15536 | Cust PO #:186102

Sharon *Tube*
A DIVISION OF ZEKELMAN INDUSTRIES
300 Martin Luther King Jr. Blvd., Farrell, 16121

PRODUCT CERTIFICATION

HEAT NUMBER
4132970
SALES ORDER
0005801707

SOLD TO
EARLE M. JORGENSEN
CORPORATE OFFICE
1900 MITCHELL BLVD.
SCHAUMBURG, IL 60193
USA

SHIP TO
EARLE M. JORGENSEN
BAY 7
1900 MITCHELL BLVD
SCHAUMBURG, IL 60193-4539
USA

CUSTOMER P.O.	P.O. LINE #	CUSTOMER PART	QUANTITY	BNDLS	LADING NO	SHIPMENT DATE
P237396-423	010	120511	1,385 FT	1	0085110805	12/20/2022

Melt Mill	Melt Country	Melt Practice	Cast
Clev. Cliffs - Cleveland	United States	Basic Oxygen	Strand

Reduction Ratio	DFARS Compliant
>6:1	Yes

Tubing Mechanical Test Results

TEST	UNITS	HIGH	LOW	AVERAGE
Yield,PSI	PSI	80171	80171	80171
Tensile,PSI	PSI	96620	96620	96620
Elongation,%-2"	%-2"	21.27	21.27	21.27
Yield/Tensile Ratio		.830	.830	0.830
Rockwell B Hardness	HRb	92	92	92

Certified Test Report Type 3.1B in accordance with EN 10204/ISO 10474/DIN 50049. Material has not come in direct contact with mercury, any of its compounds or any mercury bearing devices during the manufactured process, tests or inspections. Material does not contain any polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE).

Cold Drawn Electric Weld Carbon Steel Mechanical Tubing Meeting the Requirements of ASTM A513-20a Type 5. Eddy Current Tested per S8.2.1 or Flux Leakage Tested per S8.4 or Ultrasonic Tested per S8.3. No weld repairs have been performed. Hardness and tensile testing conducted per most current editions of ASTMA513 S5 and ASTM A370. Yield Strength determined @ 0.2% offset. Grain size #5 or finer. All steel fully killed. Manufactured in the U.S.A.

End of Certification

Anthony Yurcho, Manager, Technical Services, deposes and says that the figures set forth above are correct, as contained in the figures of Sharon Tube Company.

(C) Sharon Tube Company - qtc302 (v6.0)

Page 2 of 2

Customer:ONLINE METALS | Ord #:T638832 | Part #:15536 | Cust PO #:186102

Figure D-44. ¾-in. Diameter, Unthreaded Spacer Sleeve, Test Nos. HBIB-6 through HBIB-10 (Item No. f9)

FASTENAL®

Fastenal Company
P.O Box 1286
WINONA, MN 55987-1286

Invoice

Date	Reference No.	Page
3/27/18	NELIN314984	1

DUE DATE: 04/26/2018

The store serving you is
3201 N. 23rd Street STE 1

LINCOLN, NE 68521
Phone #: (402)476-7900
Fax #: 402/476-7958

Cust. No. NELIN2067
Cust. P.O.
Job No. TL-2 and Bullnose

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	40	40 TS	0	USS GALV FLAT 7/8	170077928	33187	62.3500	24.94 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	24.94
Shipping & Handling	0.00
State Tax	0.00
County Tax	0.00
City Tax	0.00
TOTAL USD	24.94

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 D-45. ⅞-in. Dia. Plain Round Washer, Test Nos. HBIB-6 through HBIB-10 (Item No. g1)

FASTENAL®

Certificate of Compliance

Sold To:
UNL TRANSPORTATION/Midwest Roadside Safe

Purchase Order:	70Acct.
Job:	Pick up
Invoice Date:	05/24/2024

THIS IS TO CERTIFY THAT WE HAVE SUPPLIED YOU WITH THE FOLLOWING PARTS.
THESE PARTS WERE PURCHASED TO THE FOLLOWING SPECIFICATIONS.

250 PCS 5/8" x 1.750" OD Low Carbon Hot Dipped Galvanized Finish Steel USS General Purpose Flat Washer SUPPLIED UNDER OUR TRACE NUMBER 210307244 AND UNDER PART NUMBER 33185

1 PCS 3/4" Blackstone[REG] Nylon Tube Brush SUPPLIED UNDER OUR TRACE NUMBER 130852 AND UNDER PART NUMBER 0838687

This is to certify that the above document is true and accurate to the best of my knowledge.

Please check current revision to avoid using obsolete copies.

Sam Rice
Fastenal Account Representative Signature

This document was printed on 05/24/2024 and was current at that time.

Sam Rice
Printed Name

5/24/24
Date

Fastenal Store Location/Address:
3201 N 23rd St
Unit 1
LINCOLN, NE 68521 USA
Phone: (402)476-7900
Fax: 402/476-7958
Email: NELIN@stores.fastenal.com

Page 1 of 1

Figure D-46. ⅝-in. Dia. Plain Round Washer, Test Nos. HBIB-6 through HBIB-10 (Item No. g2)

GEM-YEAR TESTING LABORATORY
CERTIFICATE OF INSPECTION

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

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

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 210167591
COMMODITY : FINISHED HEX NUT GR-A
SIZE : 7/8-9 NC O/T 0.56MM
LOT NO : 1N18BC001
SHIP QUANTITY : 2,250 PCS
LOT QUANTITY 3,910 PCS
HEADMARKS :

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

MANUFACTURE DATE : 2018/11/05
COUNTRY OF ORIGIN : CHINA

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A563-2015

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

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.2-2015

SAMPLED BY : YUQIAN

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

MECHANICAL PROPERTIES : ACCORDING TO ASTM A563-2015

SAMPLED BY : GDAN LIAN

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

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

Quality Supervisor:

Figure D-47. 1-in. Dia. Plain Round Washer, Test Nos. HBIB-6, HBIB-7, HBIB-8, and HBIB-10 (Item No. g3)

FASTENAL®

Certificate of Compliance

Sold To:
UNL TRANSPORTATION/Midwest Roadside Safe

Purchase Order: HBIB
Job:
Invoice Date: 01/13/2023

THIS IS TO CERTIFY THAT WE HAVE SUPPLIED YOU WITH THE FOLLOWING PARTS.
THESE PARTS WERE PURCHASED TO THE FOLLOWING SPECIFICATIONS.

40 PCS 5/8"-11 x 1-1/2" ASTM A307 Grade A Hot Dipped Galvanized Hex Bolt SUPPLIED UNDER OUR TRACE NUMBER 120383161 AND UNDER PART NUMBER 1191919

6 PCS 5/8"-11 A-563 Grade DH Hot Dip Galvanized Heavy Hex Nut SUPPLIED UNDER OUR TRACE NUMBER 210280003 AND UNDER PART NUMBER 36755

This is to certify that the above document is true and accurate to the best of my knowledge.

Please check current revision to avoid using obsolete copies.

Ross Schall
Fastenal Account Representative Signature

This document was printed on 01/13/2023 and was current at that time.

Ross Schall
Printed Name

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

1/13/2023
Date

Page 1 of 1

Figure D-48. ⅝-in. Dia. UNC Heavy Hex Nut, Test Nos. HBIB-6 through HBIB-10 (Item No. h1)

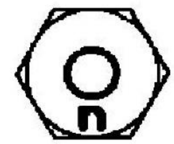
NUCOR FASTENER

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

Page 1 of 2

Figure D-49. ⅝-in. Dia. Hex Nut, Test Nos. HBIB-6 through HBIB-10 (Item No. h2)

Apr. 12. 2018 4:32PM Fastenal-NELIN No. 4682 P. 3

FASTENAL®

Certificate of Compliance

Sold To:

UNL TRANSPORTATION

Purchase Order:

Job: TL-2 and Bullnose

Invoice Date: 03/27/2018

THIS IS TO CERTIFY THAT WE HAVE SUPPLIED YOU WITH THE FOLLOWING PARTS.
THESE PARTS WERE PURCHASED TO THE FOLLOWING SPECIFICATIONS.

5 PCS 7/8"-9 x 8" ASTM A307 Grade A Hot Dipped Galvanized Hex Bolt SUPPLIED UNDER OUR TRACE NUMBER lIne35042 AND UNDER PART NUMBER 92005

20 PCS 7/8"-9 Hot Dip Galvanized Finish Grade A Finished Hex Nut SUPPLIED UNDER OUR TRACE NUMBER 110254885 AND UNDER PART NUMBER 36717

5 PCS 7/8"-9 x 8" ASTM A307 Grade A Hot Dipped Galvanized Hex Bolt SUPPLIED UNDER OUR TRACE NUMBER lIne35042 AND UNDER PART NUMBER 92005

5 PCS 7/8"-9 x 8" ASTM A307 Grade A Hot Dipped Galvanized Hex Bolt SUPPLIED UNDER OUR TRACE NUMBER lIne35042 AND UNDER PART NUMBER 92005

5 PCS 7/8"-9 x 8" ASTM A307 Grade A Hot Dipped Galvanized Hex Bolt SUPPLIED UNDER OUR TRACE NUMBER lIne35042 AND UNDER PART NUMBER 92005

This is to certify that the above document is true and accurate to the best of my knowledge.

Fastenal Account Representative Signature

Jeremiah Moorland

Printed Name

4/12/18

Date

Please check current revision to avoid using obsolete copies.

This document was printed on 04/12/2018 and was current at that time.

Fastenal Store Location/Address

3201 N. 23rd Street STE 1
LINCOLN, NE 68521
Phone #: (402)476-7900
Fax #: 402/476-7958

Page 1 of 1

Figure D-50. ⅞-in. Dia. UNC Hex Nut, Test Nos. HBIB-6 through HBIB-10 (Item No. h4)

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	llne35042	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	llne35042	92005	509.5500	25.48 G
4	5	5 TS	0	7/8-9x8 A307A HDG	llne35042	92005	509.5500	25.48 G
5	5	5 TS	0	7/8-9x8 A307A HDG	llne35042	92005	509.5500	25.48 G

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

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.

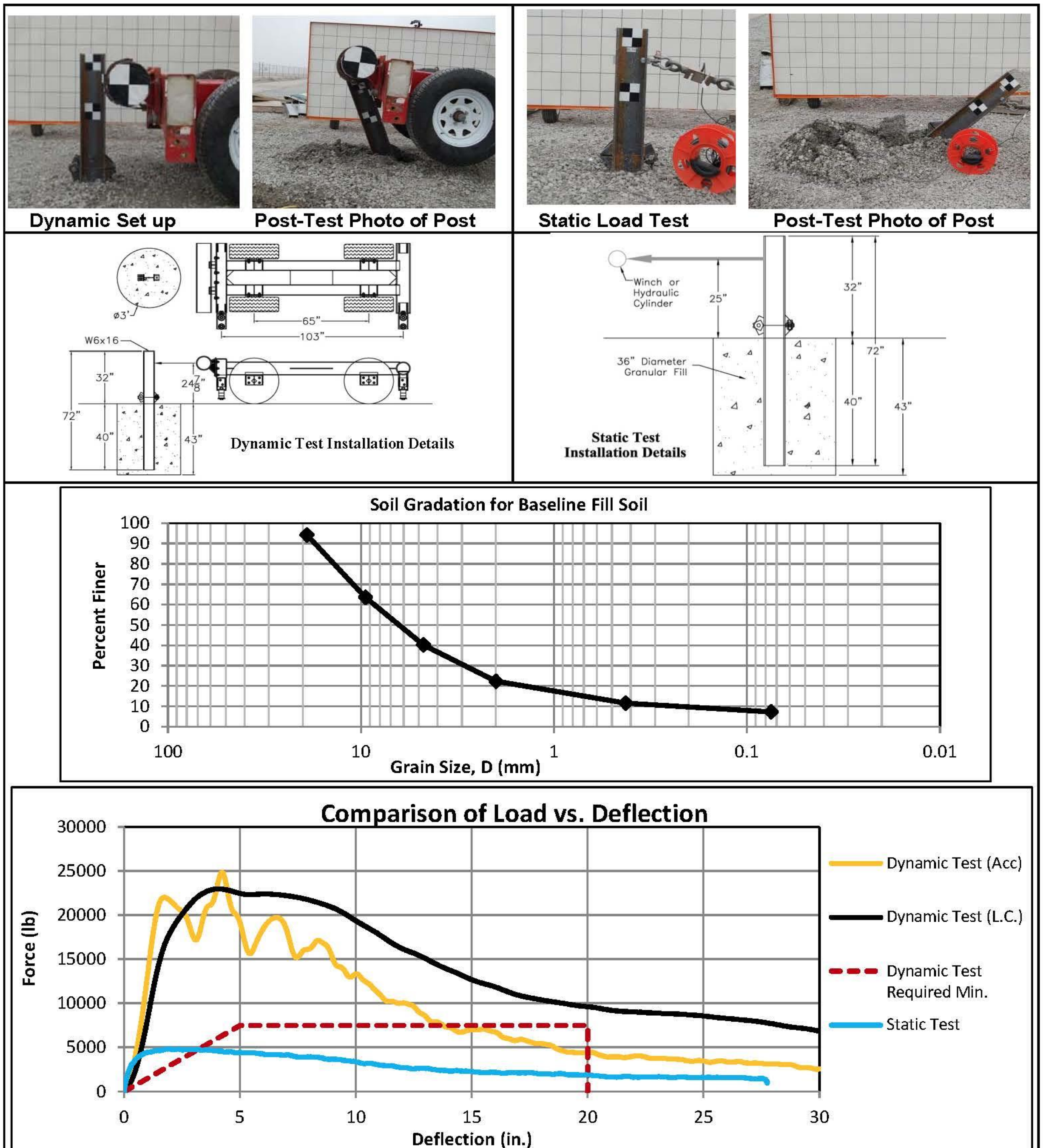
0

Thank You !

FORM - IN13

Figure D-51. ⅞-in. Dia. UNC Hex Nut, Test Nos. HBIB-6 through HBIB-10 (Item No. h4)

Appendix E. Static Soil Tests

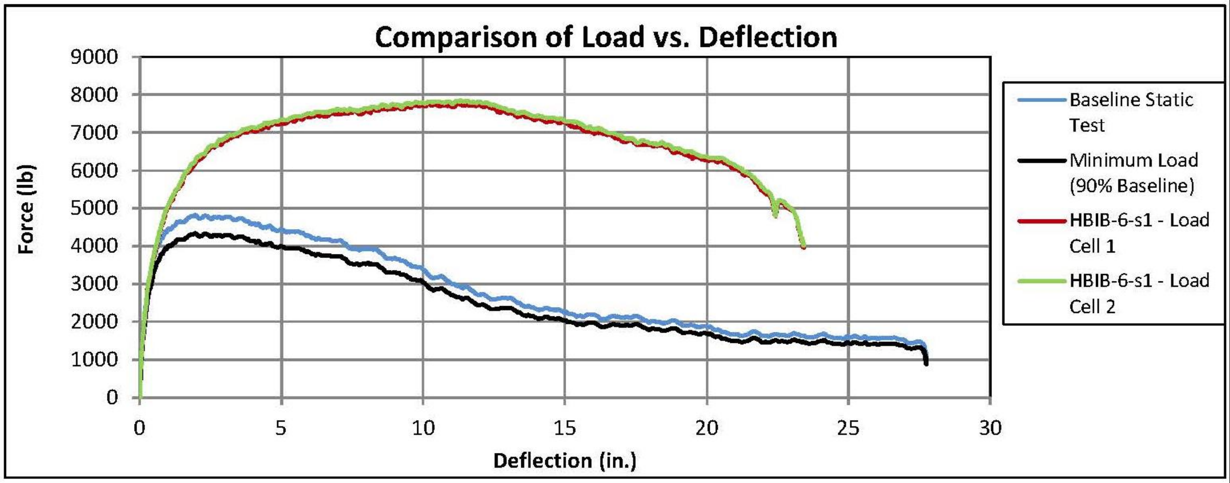


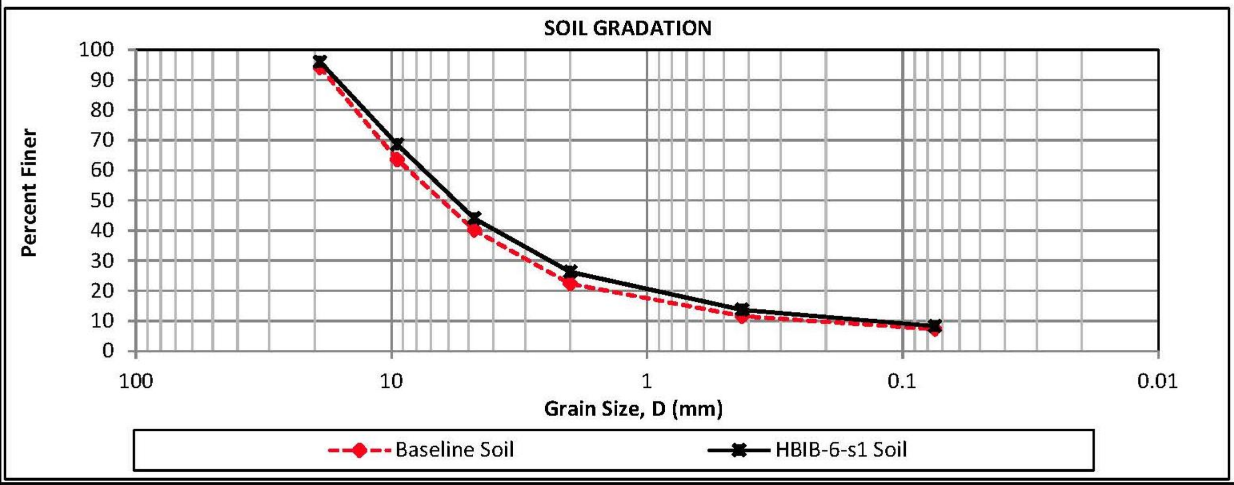
Date..	2/16/2018			
Test Facility & Site Location......................	Midwest Roadside Safety Facility			
In situ soil description (ASTM D2487)..........	Well-Graded Gravel (GW)			
Fill material description (ASTM D2487).........	Well-Graded Gravel (GW) (see sieve analyses above)			
Description of fill placement procedure........	H.E.-8			
Bogie Weight..	1786	lb	810	kg
Impact Velocity...	20.9	mph	33.7	km/h

Figure E-1. Soil Strength, Initial Calibration Tests, Test Nos. HBIB-6 through HBIB-10

Static Load Test Setup

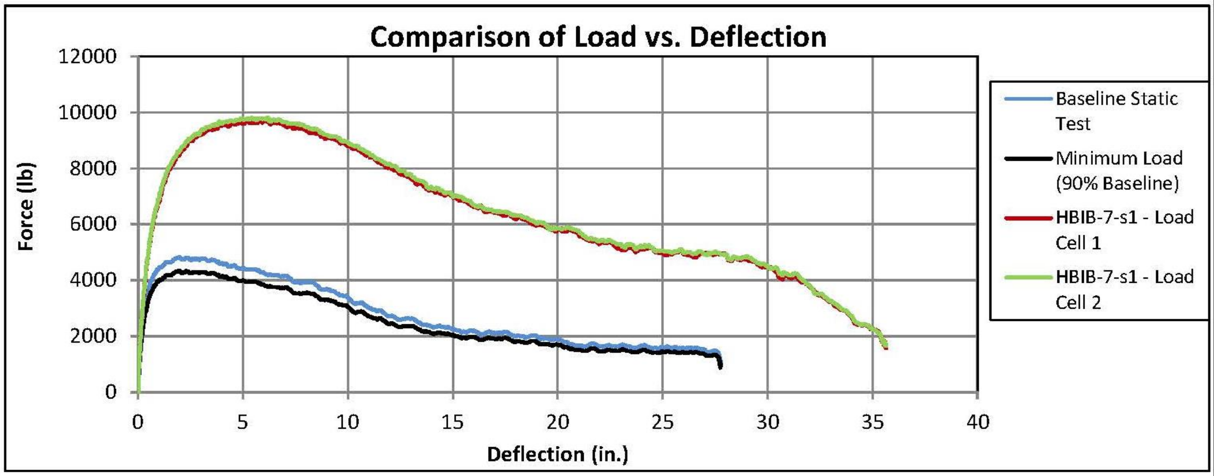
Post-Test Photo of Post

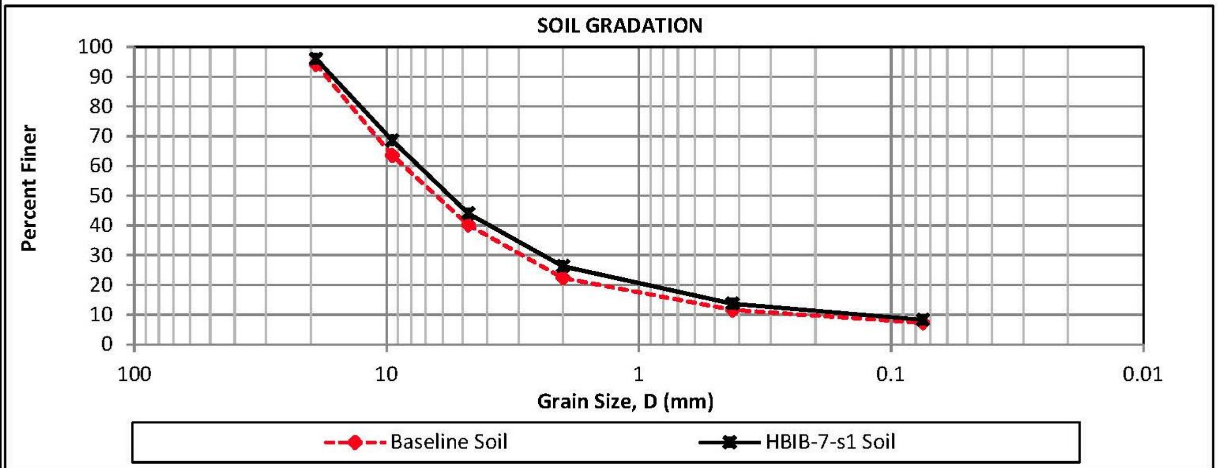




Date	8/27/2024
Test Facility & Site Location	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)	Well-Graded Gravel (GW)
Fill material description (ASTM D2487)	Well-Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure	8-inch lifts tamped with a pneumatic compactor

Figure E-2. Static Soil Test, Test No. HBIB-6

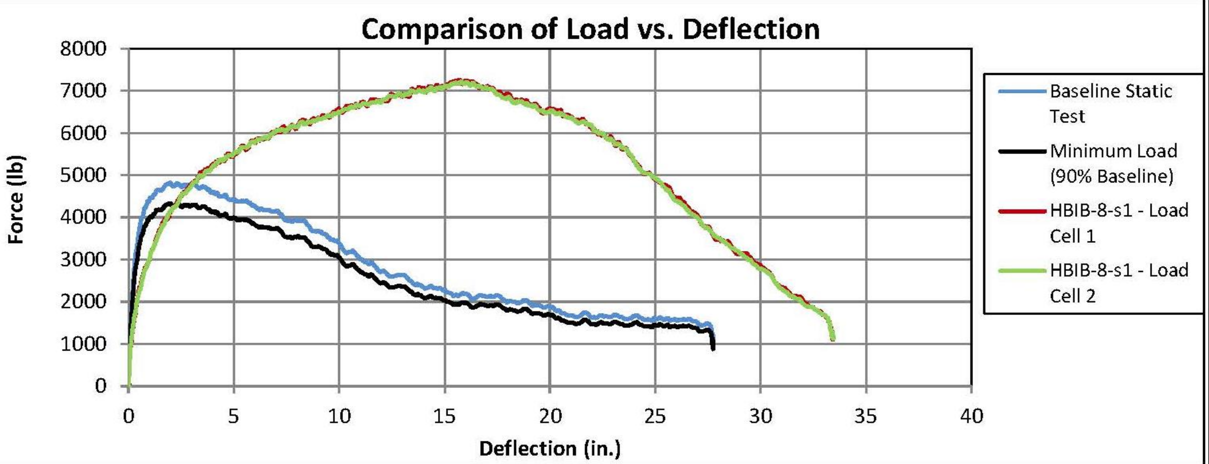


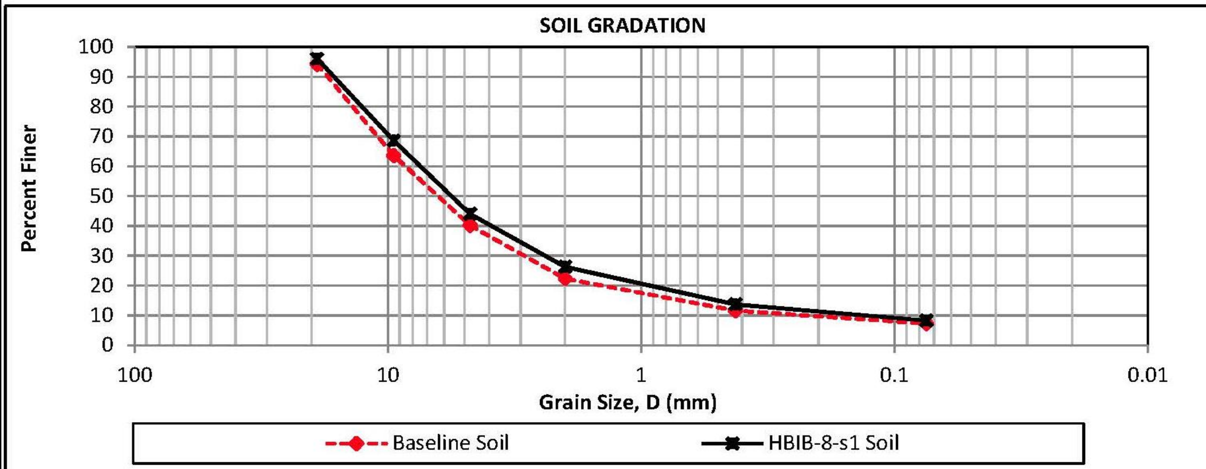


Date	10/7/2024
Test Facility & Site Location	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)	Well-Graded Gravel (GW)
Fill material description (ASTM D2487)	Well-Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure	8-inch lifts tamped with a pneumatic compactor

Figure E-3. Static Soil Test, Test No. HBIB-7

Static Load Test Setup	Post-Test Photo of Post

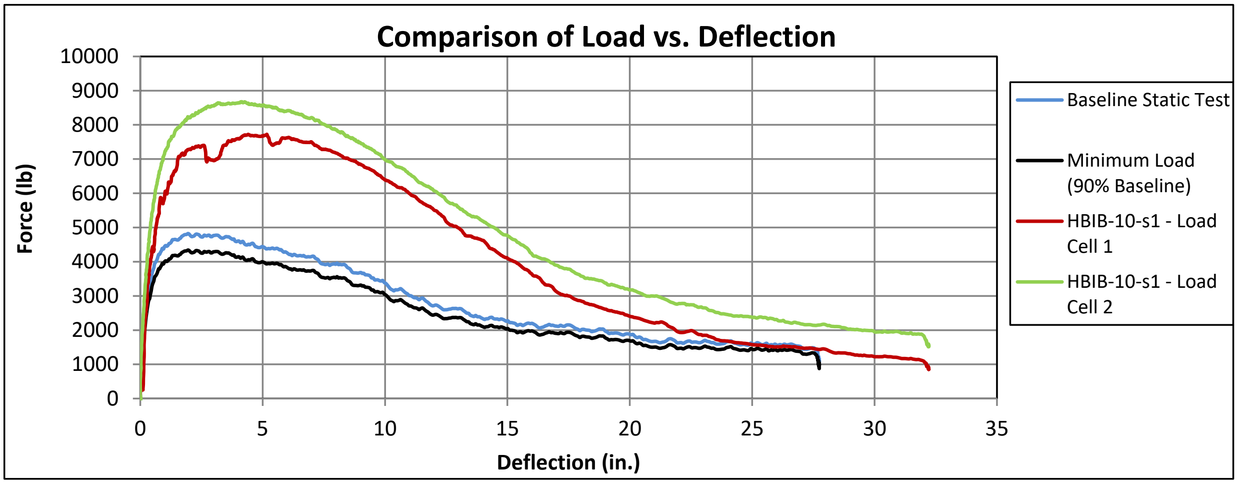


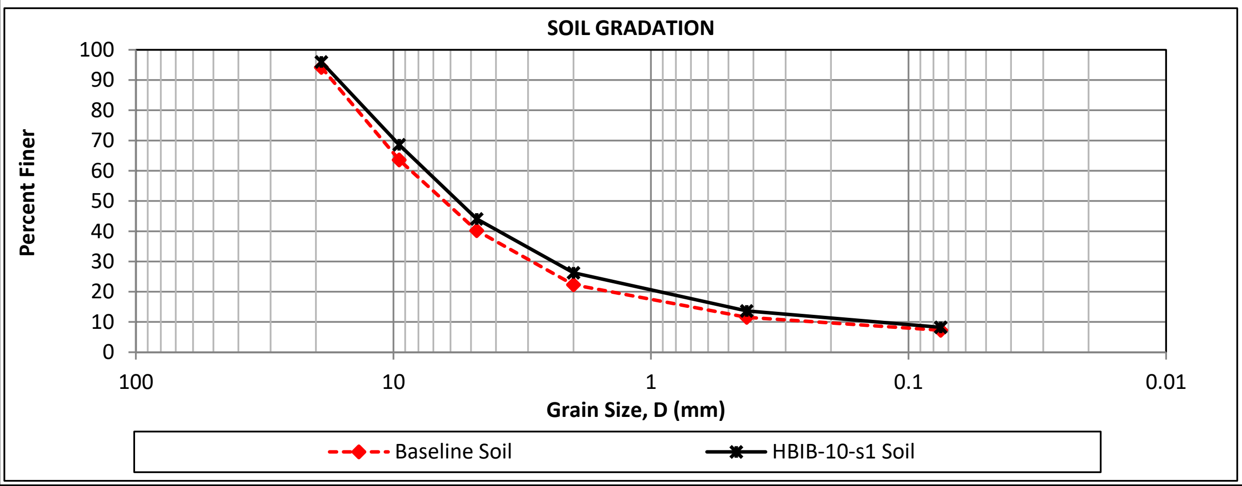


Date…………………………………………………	12/6/2024
Test Facility & Site Location……………………	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)……….	Well-Graded Gravel (GW)
Fill material description (ASTM D2487)………	Well-Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure……..	8-inch lifts tamped with a pneumatic compactor

Figure E-4. Static Soil Test, Test No. HBIB-8

Static Load Test Setup	Post-Test Photo of Post
	

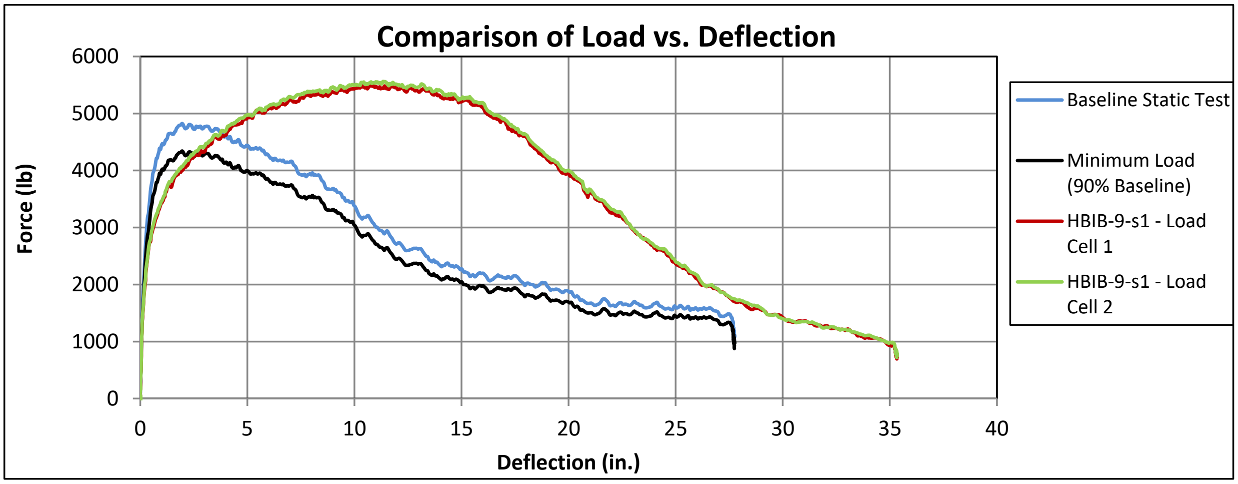


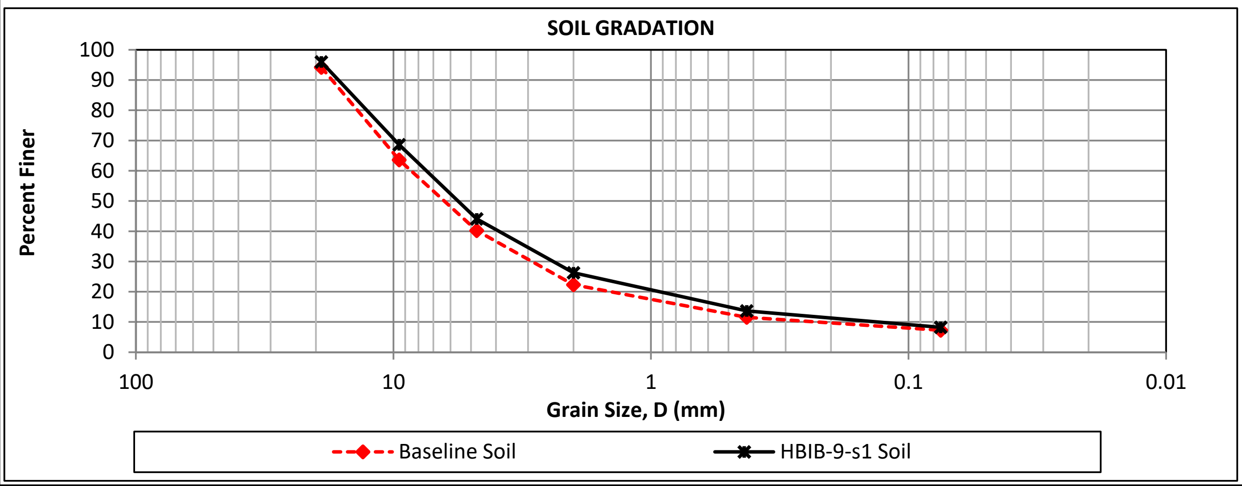


Date...	6/19/2025
Test Facility & Site Location........................	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)...........	Well-Graded Gravel (GW)
Fill material description (ASTM D2487).........	Well-Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure........	8-inch lifts tamped with a pneumatic compactor

Figure E-5. Static Soil Test, Test No. HBIB-10

Static Load Test Setup	Post-Test Photo of Post
	





Date...	3/26/2025
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-9

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: 2018 | Test Name: HBIB-6 | Make: RAM | VIN: 3C6RR6KT6JG186123 | Model: 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	54.3564	13.1478	-2.3664	54.3266	13.1541	-2.2485	0.0298	-0.0063	-0.1179	0.1218	0.0298	X
	2	55.3645	17.4393	-0.0382	55.3434	17.4605	0.1309	0.0211	-0.0212	-0.1691	0.1717	0.0211	X
	3	56.8173	21.2250	3.3470	56.7949	21.1782	3.5086	0.0224	0.0468	-0.1616	0.1697	0.0224	X
	4	56.8908	27.6152	3.5554	56.8667	27.4988	3.7069	0.0241	0.1164	-0.1515	0.1926	0.0241	X
	5	56.9703	32.2352	3.5894	56.9669	32.2054	3.7272	0.0034	0.0298	-0.1378	0.1410	0.0034	X
	6	50.7212	12.7268	-0.4296	50.6802	12.7050	-0.3147	0.0410	0.0218	-0.1149	0.1239	0.0410	X
	7	51.8988	16.6894	3.0131	51.8799	16.6549	3.1035	0.0189	0.0345	-0.0904	0.0986	0.0189	X
	8	52.5602	21.5267	5.0094	52.5177	21.5087	5.1714	0.0425	0.0180	-0.1620	0.1684	0.0425	X
	9	52.8060	27.8249	4.8404	52.7816	27.8684	5.0127	0.0244	-0.0435	-0.1723	0.1794	0.0244	X
	10	52.6258	32.2374	4.9683	52.5550	32.2331	5.1132	0.0708	0.0043	-0.1449	0.1613	0.0708	X
FLOOR PAN (Z)	11	47.3157	12.7272	1.3266	47.2980	12.7363	1.4272	0.0177	-0.0091	-0.1006	0.1025	-0.1006	Z
	12	48.5749	16.0986	5.0106	48.5301	16.1056	5.1497	0.0448	-0.0070	-0.1391	0.1463	-0.1391	Z
	13	49.0344	21.8690	4.9307	48.9693	21.8697	5.0670	0.0651	-0.0007	-0.1363	0.1511	-0.1363	Z
	14	49.1449	28.0144	4.8874	49.0980	28.0166	5.0220	0.0469	-0.0022	-0.1346	0.1426	-0.1346	Z
	15	49.2799	32.6231	4.9898	49.2439	32.5921	5.1067	0.0360	0.0310	-0.1169	0.1262	-0.1169	Z
	16	44.9276	12.8833	2.1216	44.8794	12.8866	2.2094	0.0482	-0.0033	-0.0878	0.1002	-0.0878	Z
	17	45.7306	16.7527	5.0542	45.6665	16.7677	5.1756	0.0641	-0.0150	-0.1214	0.1381	-0.1214	Z
	18	45.9467	22.7311	4.8841	45.8975	22.7317	5.0138	0.0492	-0.0006	-0.1297	0.1387	-0.1297	Z
	19	46.4375	28.0853	4.8872	46.3548	28.1646	5.0105	0.0827	-0.0793	-0.1233	0.1683	-0.1233	Z
	20	46.0481	32.7998	5.0060	46.0109	32.8027	5.1143	0.0372	-0.0029	-0.1083	0.1145	-0.1083	Z
	21	42.0809	13.1288	2.7952	42.0011	13.1365	2.8991	0.0798	-0.0077	-0.1039	0.1312	-0.1039	Z
	22	42.6758	17.0217	4.9624	42.6715	17.1181	5.0860	0.0043	-0.0964	-0.1236	0.1568	-0.1236	Z
	23	43.3630	22.7039	4.9045	43.2674	22.7748	5.0189	0.0956	-0.0709	-0.1144	0.1651	-0.1144	Z
	24	43.7605	28.6060	4.9089	43.7343	28.6473	5.0268	0.0262	-0.0413	-0.1179	0.1276	-0.1179	Z
	25	43.3115	33.0094	5.0219	43.2628	33.0185	5.1241	0.0487	-0.0091	-0.1022	0.1136	-0.1022	Z
	26	38.4196	13.4096	3.5044	38.3753	13.4077	3.5804	0.0443	0.0019	-0.0760	0.0880	-0.0760	Z
	27	38.0944	17.1340	4.2848	38.0621	17.1541	4.3851	0.0323	-0.0201	-0.1003	0.1073	-0.1003	Z
	28	38.3275	22.8716	4.0229	38.2669	22.8151	4.1254	0.0606	0.0565	-0.1025	0.1318	-0.1025	Z
	29	38.4305	28.4357	4.2416	38.4217	28.4029	4.3467	0.0088	0.0328	-0.1051	0.1105	-0.1051	Z
	30	38.4532	32.7814	4.0345	38.4181	32.7812	4.1348	0.0351	0.0002	-0.1003	0.1063	-0.1003	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-6

Model Year: 2018 | Test Name: HBIB-6 | Make: RAM | VIN: 3C6RR6KT6JG186123 | Model: 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	53.4800	28.9283	-6.2709	53.4838	28.8566	-6.2544	-0.0038	0.0717	-0.0165	0.0737	0.0000	NA
	2	54.4447	33.2285	-3.9402	54.4677	33.1717	-3.8771	-0.0230	0.0568	-0.0631	0.0880	0.0000	NA
	3	55.8545	37.0266	-0.5509	55.8885	36.9021	-0.5003	-0.0340	0.1245	-0.0506	0.1386	0.0000	NA
	4	55.8751	43.4173	-0.3439	55.9179	43.2232	-0.3076	-0.0428	0.1941	-0.0363	0.2021	0.0000	NA
	5	55.9167	48.0378	-0.3109	55.9867	47.9304	-0.2914	-0.0700	0.1074	-0.0195	0.1297	0.0000	NA
	6	49.8414	28.4781	-4.3469	49.8371	28.3849	-4.3265	0.0043	0.0932	-0.0204	0.0955	0.0043	X
	7	50.9745	32.4510	-0.9010	51.0045	32.3458	-0.9098	-0.0300	0.1052	0.0088	0.1097	0.0088	Z
	8	51.5892	37.2940	1.0963	51.6063	37.2055	1.1548	-0.0171	0.0885	-0.0585	0.1075	0.0000	NA
	9	51.7842	43.5939	0.9265	51.8281	43.5668	0.9908	-0.0439	0.0271	-0.0643	0.0824	0.0000	NA
	10	51.5675	48.0049	1.0526	51.5723	47.9299	1.0869	-0.0048	0.0750	-0.0343	0.0826	0.0000	NA
FLOOR PAN (Z)	11	46.4299	28.4511	-2.6028	46.4518	28.3952	-2.5904	-0.0219	0.0559	-0.0124	0.0613	-0.0124	Z
	12	47.6483	31.8335	1.0847	47.6549	31.7760	1.1311	-0.0066	0.0575	-0.0464	0.0742	-0.0464	Z
	13	48.0610	37.6074	1.0050	48.0558	37.5428	1.0439	0.0052	0.0646	-0.0389	0.0756	-0.0389	Z
	14	48.1215	43.7535	0.9604	48.1436	43.6904	0.9936	-0.0221	0.0631	-0.0332	0.0746	-0.0332	Z
	15	48.2185	48.3633	1.0621	48.2589	48.2668	1.0743	-0.0404	0.0965	-0.0122	0.1053	-0.0122	Z
	16	44.0377	28.5878	-1.8164	44.0308	28.5300	-1.8126	0.0069	0.0578	-0.0038	0.0583	-0.0038	Z
	17	44.7986	32.4644	1.1181	44.7869	32.4190	1.1514	0.0117	0.0454	-0.0333	0.0575	-0.0333	Z
	18	44.9666	38.4443	0.9472	44.9785	38.3843	0.9846	-0.0119	0.0600	-0.0374	0.0717	-0.0374	Z
	19	45.4136	43.8023	0.9506	45.3995	43.8201	0.9772	0.0141	-0.0178	-0.0266	0.0350	-0.0266	Z
	20	44.9853	48.5135	1.0667	45.0245	48.4558	1.0762	-0.0392	0.0577	-0.0095	0.0704	-0.0095	Z
	21	41.1868	28.8103	-1.1529	41.1498	28.7614	-1.1281	0.0370	0.0489	-0.0248	0.0661	-0.0248	Z
	22	41.7421	32.7084	1.0154	41.7898	32.7493	1.0563	-0.0477	-0.0409	-0.0409	0.0750	-0.0409	Z
	23	42.3831	38.3960	0.9584	42.3481	38.4098	0.9851	0.0350	-0.0138	-0.0267	0.0461	-0.0267	Z
	24	42.7323	44.3011	0.9626	42.7758	44.2853	0.9885	-0.0435	0.0158	-0.0259	0.0530	-0.0259	Z
	25	42.2471	48.7008	1.0729	42.2750	48.6533	1.0810	-0.0279	0.0475	-0.0081	0.0557	-0.0081	Z
	26	37.5208	29.0614	-0.4569	37.5211	29.0090	-0.4534	-0.0003	0.0524	-0.0035	0.0525	-0.0035	Z
	27	37.1624	32.7831	0.3214	37.1815	32.7540	0.3474	-0.0191	0.0291	-0.0260	0.0434	-0.0260	Z
	28	37.3495	38.5224	0.0589	37.3490	38.4160	0.0830	0.0005	0.1064	-0.0241	0.1091	-0.0241	Z
	29	37.4063	44.0872	0.2764	37.4662	44.0049	0.2994	-0.0599	0.0823	-0.0230	0.1044	-0.0230	Z
	30	37.3944	48.4329	0.0683	37.4337	48.3828	0.0836	-0.0393	0.0501	-0.0153	0.0655	-0.0153	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-6

Model Year: 2018 | Test Name: HBIB-6 | VIN: 3C6RR6KT6JG186123
Make: RAM | Model: 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)	31	51.5174	32.9811	-27.0716	51.6557	33.0772	-26.9291	-0.1383	-0.0961	0.1425	0.2206	0.2206	X, Y, Z
	32	49.5206	20.5887	-26.9172	49.6375	20.7139	-26.7730	-0.1169	-0.1252	0.1442	0.2239	0.2239	X, Y, Z
	33	49.7768	4.2592	-28.1419	49.8783	4.3564	-28.0030	-0.1015	-0.0972	0.1389	0.1976	0.1976	X, Y, Z
	34	46.6843	33.9117	-15.0854	46.6737	33.9875	-15.0268	0.0106	-0.0758	0.0586	0.0964	0.0964	X, Y, Z
	35	45.3112	20.8773	-16.8431	45.3908	20.9251	-16.7203	-0.0796	-0.0478	0.1228	0.1540	0.1540	X, Y, Z
	36	43.2588	4.2700	-20.2555	43.3470	4.3879	-20.1166	-0.0882	-0.1179	0.1389	0.2024	0.2024	X, Y, Z
SIDE PANEL (Y)	37	55.5768	35.7029	-2.9652	55.5231	35.4995	-2.7875	0.0537	0.2034	0.1777	0.2754	0.2034	Y
	38	57.2478	35.5872	-0.0782	57.2179	35.5069	0.0847	0.0299	0.0803	0.1629	0.1841	0.0803	Y
	39	54.8095	35.5956	2.5642	54.7655	35.4333	2.7604	0.0440	0.1623	0.1962	0.2584	0.1623	Y
IMPACT SIDE DOOR (Y)	40	23.2706	38.4277	-17.7157	23.0199	38.5504	-17.6462	0.2507	-0.1227	0.0695	0.2876	-0.1227	Y
	41	30.8308	38.2746	-18.1811	30.5762	38.2721	-18.0937	0.2546	0.0025	0.0874	0.2692	0.0025	Y
	42	42.6283	38.0858	-16.1687	42.3746	38.0348	-16.0240	0.2537	0.0510	0.1447	0.2965	0.0510	Y
	43	26.0286	38.6280	-2.4521	25.7724	38.5370	-2.3211	0.2562	0.0910	0.1310	0.3018	0.0910	Y
	44	32.4133	38.4147	-1.3612	32.0949	38.2718	-1.2305	0.3184	0.1429	0.1307	0.3727	0.1429	Y
	45	41.2599	39.1944	-1.9073	41.0406	39.0400	-1.6746	0.2193	0.1544	0.2327	0.3551	0.1544	Y
ROOF - (Z)	46	41.9443	5.2817	-43.1179	42.0661	5.4262	-43.0405	-0.1218	-0.1445	0.0774	0.2042	0.0774	Z
	47	40.8760	16.5053	-42.9348	40.9823	16.6185	-42.8527	-0.1063	-0.1132	0.0821	0.1757	0.0821	Z
	48	38.4936	26.3283	-42.4002	38.5803	26.4469	-42.3121	-0.0867	-0.1186	0.0881	0.1713	0.0881	Z
	49	34.0915	5.2441	-46.1241	34.2028	5.3463	-46.0539	-0.1113	-0.1022	0.0702	0.1666	0.0702	Z
	50	32.1330	14.3766	-46.1795	32.1909	14.5091	-46.1079	-0.0579	-0.1325	0.0716	0.1614	0.0716	Z
	51	31.0209	25.8742	-45.4437	31.0753	25.9654	-45.3713	-0.0544	-0.0912	0.0724	0.1285	0.0724	Z
	52	17.2899	5.2512	-47.4291	17.4099	5.3350	-47.3863	-0.1200	-0.0838	0.0428	0.1525	0.0428	Z
	53	16.6726	13.4258	-47.2613	16.7911	13.4883	-47.2101	-0.1185	-0.0625	0.0512	0.1434	0.0512	Z
	54	16.0772	24.4396	-46.6690	16.1413	24.4659	-46.6101	-0.0641	-0.0263	0.0589	0.0909	0.0589	Z
	55	-4.4440	5.2911	-47.5577	-4.3569	5.4054	-47.5577	-0.0871	-0.1143	0.0000	0.1437	0.0000	Z
	56	-4.4872	13.2141	-47.4262	-4.4300	13.3021	-47.4157	-0.0572	-0.0880	0.0105	0.1055	0.0105	Z
	57	-4.9375	23.2786	-46.9780	-4.8952	23.3364	-46.9554	-0.0423	-0.0578	0.0226	0.0751	0.0226	Z
	58	-21.3234	4.7150	-46.9171	-21.1480	4.7298	-46.9546	-0.1754	-0.0148	-0.0375	0.1800	-0.0375	Z
	59	-21.3027	12.1151	-46.8422	-21.1399	12.1452	-46.8727	-0.1628	-0.0301	-0.0305	0.1683	-0.0305	Z
	60	-20.7428	23.8658	-46.4485	-20.6722	23.8836	-46.4669	-0.0706	-0.0178	-0.0184	0.0751	-0.0184	Z
A-PILLAR Maximum (X, Y, Z)	61	38.1325	30.8647	-40.7024	38.1503	30.9917	-40.6426	-0.0178	-0.1270	0.0598	0.1415	0.0598	Z
	62	41.1960	30.6576	-37.8148	41.2410	30.7781	-37.7351	-0.0450	-0.1205	0.0797	0.1513	0.0797	Z
	63	43.9673	32.3193	-37.4502	44.0499	32.4753	-37.4135	-0.0826	-0.1560	0.0367	0.1803	0.0367	Z
	64	46.7996	32.6483	-34.5606	46.8651	32.7697	-34.4605	-0.0655	-0.1214	0.1001	0.1704	0.1001	Z
	65	51.5442	33.8507	-31.4998	51.6675	33.9824	-31.3416	-0.1233	-0.1317	0.1582	0.2399	0.1582	Z
	66	54.4281	34.6808	-27.4417	54.4496	34.7414	-27.3225	-0.0215	-0.0606	0.1192	0.1354	0.1192	Z
A-PILLAR Lateral (Y)	61	38.1325	30.8647	-40.7024	38.1503	30.9917	-40.6426	-0.0178	-0.1270	0.0598	0.1415	-0.1270	Y
	62	41.1960	30.6576	-37.8148	41.2410	30.7781	-37.7351	-0.0450	-0.1205	0.0797	0.1513	-0.1205	Y
	63	43.9673	32.3193	-37.4502	44.0499	32.4753	-37.4135	-0.0826	-0.1560	0.0367	0.1803	-0.1560	Y
	64	46.7996	32.6483	-34.5606	46.8651	32.7697	-34.4605	-0.0655	-0.1214	0.1001	0.1704	-0.1214	Y
	65	51.5442	33.8507	-31.4998	51.6675	33.9824	-31.3416	-0.1233	-0.1317	0.1582	0.2399	-0.1317	Y
	66	54.4281	34.6808	-27.4417	54.4496	34.7414	-27.3225	-0.0215	-0.0606	0.1192	0.1354	-0.0606	Y
B-PILLAR Maximum (X, Y, Z)	67	10.8773	30.7423	-41.6663	10.9421	30.7970	-41.6689	-0.0648	-0.0547	-0.0026	0.0848	0.0000	NA
	68	14.8121	34.5259	-30.5434	14.8820	34.5993	-30.4784	-0.0699	-0.0734	0.0650	0.1204	0.0650	Z
	69	12.0088	35.3945	-24.5054	11.9702	35.4454	-24.4518	0.0386	-0.0509	0.0536	0.0834	0.0661	X, Z
	70	15.9384	35.5987	-20.1613	15.9109	35.6567	-20.0778	0.0275	-0.0580	0.0835	0.1053	0.0879	X, Z
B-PILLAR Lateral (Y)	67	10.8773	30.7423	-41.6663	10.9421	30.7970	-41.6689	-0.0648	-0.0547	-0.0026	0.0848	-0.0547	Y
	68	14.8121	34.5259	-30.5434	14.8820	34.5993	-30.4784	-0.0699	-0.0734	0.0650	0.1204	-0.0734	Y
	69	12.0088	35.3945	-24.5054	11.9702	35.4454	-24.4518	0.0386	-0.0509	0.0536	0.0834	-0.0509	Y
	70	15.9384	35.5987	-20.1613	15.9109	35.6567	-20.0778	0.0275	-0.0580	0.0835	0.1053	-0.0580	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-6

Test Name: HBIB-6 VIN: 3C6RR6KT6JG186123
Model Year: 2018 Make: RAM Model: 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)	31	50.5671	48.7319	-30.9912	50.7230	48.7394	-30.9576	-0.1559	-0.0075	0.0336	0.1597	0.1597	X, Y, Z
	32	48.6710	36.3237	-30.8407	48.7870	36.3629	-30.7938	-0.1160	-0.0392	0.0469	0.1311	0.1311	X, Y, Z
	33	49.0648	19.9965	-32.0601	49.1390	20.0063	-32.0085	-0.0742	-0.0098	0.0516	0.0909	0.0909	X, Y, Z
	34	45.6840	49.6258	-19.0225	45.7144	49.6270	-19.0648	-0.0304	-0.0012	-0.0423	0.0521	0.0521	X, Y, Z
	35	44.4236	36.5803	-20.7817	44.5216	36.5549	-20.7487	-0.0980	0.0254	0.0330	0.1065	0.1065	X, Y, Z
	36	42.5190	19.9559	-24.1970	42.5940	20.0013	-24.1335	-0.0750	-0.0454	0.0635	0.1083	0.1083	X, Y, Z
SIDE PANEL (Y)	37	54.5183	51.4924	-6.8712	54.5322	51.2090	-6.8116	-0.0139	0.2834	0.0596	0.2899	0.2834	Y
	38	56.1799	51.3911	-3.9783	56.2220	51.2302	-3.9364	-0.0421	0.1609	0.0419	0.1715	0.1609	Y
	39	53.7323	51.3802	-1.3446	53.7655	51.1426	-1.2650	-0.0332	0.2376	0.0796	0.2528	0.2376	Y
IMPACT SIDE DOOR (Y)	40	22.2437	53.9499	-21.7373	22.0353	54.0297	-21.7292	0.2084	-0.0798	0.0081	0.2233	-0.0798	Y
	41	29.8065	53.8585	-22.1758	29.5941	53.8015	-22.1634	0.2124	0.0570	0.0124	0.2203	0.0570	Y
	42	41.5978	53.7664	-20.1214	41.3901	53.6447	-20.0731	0.2077	0.1217	0.0483	0.2455	0.1217	Y
	43	24.9456	54.1763	-6.4641	24.7612	54.0484	-6.3994	0.1844	0.1279	0.0647	0.2336	0.1279	Y
	44	31.3279	54.0154	-5.3504	31.0834	53.8263	-5.2977	0.2445	0.1891	0.0527	0.3136	0.1891	Y
	45	40.1697	54.8672	-5.8653	40.0245	54.6538	-5.7269	0.1452	0.2134	0.1384	0.2929	0.2134	Y
ROOF - (Z)	46	41.2776	20.9515	-47.0642	41.3460	21.0106	-47.0605	-0.0684	-0.0591	0.0037	0.0905	0.0037	Z
	47	40.1171	32.1660	-46.8879	40.1873	32.1955	-46.8847	-0.0702	-0.0295	0.0032	0.0762	0.0032	Z
	48	37.6527	41.9694	-46.3643	37.7189	42.0082	-46.3572	-0.0662	-0.0388	0.0071	0.0771	0.0071	Z
	49	33.4361	20.8490	-50.0983	33.4886	20.8755	-50.0874	-0.0525	-0.0265	0.0109	0.0598	0.0109	Z
	50	31.4033	29.9652	-50.1630	31.4159	30.0247	-50.1532	-0.0126	-0.0595	0.0098	0.0616	0.0098	Z
	51	30.1948	41.4536	-49.4342	30.2226	41.4739	-49.4290	-0.0278	-0.0203	0.0052	0.0348	0.0052	Z
	52	16.6398	20.7187	-51.4630	16.6985	20.7510	-51.4490	-0.0587	-0.0323	0.0140	0.0684	0.0140	Z
	53	15.9552	28.8880	-51.2996	16.0251	28.9002	-51.2811	-0.0699	-0.0122	0.0185	0.0733	0.0185	Z
	54	15.2678	39.8967	-50.7123	15.3011	39.8738	-50.6923	-0.0333	0.0229	0.0200	0.0451	0.0200	Z
	55	-5.0931	20.5810	-51.6689	-5.0679	20.6762	-51.6581	-0.0252	-0.0952	0.0108	0.0991	0.0108	Z
	56	-5.2014	28.5035	-51.5396	-5.1939	28.5724	-51.5234	-0.0075	-0.0689	0.0162	0.0712	0.0162	Z
	57	-5.7355	38.5640	-51.0958	-5.7268	38.6038	-51.0730	-0.0087	-0.0398	0.0228	0.0467	0.0228	Z
	58	-21.9694	19.8673	-51.0882	-21.8552	19.8892	-51.0834	-0.1142	-0.0219	0.0048	0.1164	0.0048	Z
	59	-22.0095	27.2674	-51.0152	-21.8966	27.3045	-51.0083	-0.1129	-0.0371	0.0069	0.1190	0.0069	Z
	60	-21.5469	39.0223	-50.6226	-21.5079	39.0461	-50.6123	-0.0390	-0.0238	0.0103	0.0468	0.0103	Z
A-PILLAR Maximum (X, Y, Z)	61	37.2485	46.5031	-44.6690	37.2557	46.5515	-44.6926	-0.0072	-0.0484	-0.0236	0.0543	0.0000	NA
	62	40.3033	46.3217	-41.7705	40.3427	46.3612	-41.7795	-0.0394	-0.0395	-0.0090	0.0565	0.0000	NA
	63	43.0596	48.0060	-41.3964	43.1397	48.0773	-41.4546	-0.0801	-0.0713	-0.0582	0.1220	0.0000	NA
	64	45.8788	48.3589	-38.4969	45.9477	48.3931	-38.4970	-0.0689	-0.0342	-0.0001	0.0769	0.0000	NA
	65	50.6026	49.6006	-35.4195	50.7365	49.6406	-35.3709	-0.1339	-0.0400	0.0486	0.1480	0.0486	Z
	66	53.4651	50.4552	-31.3514	53.5065	50.4217	-31.3477	-0.0414	0.0335	0.0037	0.0534	0.0337	Y, Z
A-PILLAR Lateral (Y)	61	37.2485	46.5031	-44.6690	37.2557	46.5515	-44.6926	-0.0072	-0.0484	-0.0236	0.0543	-0.0484	Y
	62	40.3033	46.3217	-41.7705	40.3427	46.3612	-41.7795	-0.0394	-0.0395	-0.0090	0.0565	-0.0395	Y
	63	43.0596	48.0060	-41.3964	43.1397	48.0773	-41.4546	-0.0801	-0.0713	-0.0582	0.1220	-0.0713	Y
	64	45.8788	48.3589	-38.4969	45.9477	48.3931	-38.4970	-0.0689	-0.0342	-0.0001	0.0769	-0.0342	Y
	65	50.6026	49.6006	-35.4195	50.7365	49.6406	-35.3709	-0.1339	-0.0400	0.0486	0.1480	-0.0400	Y
	66	53.4651	50.4552	-31.3514	53.5065	50.4217	-31.3477	-0.0414	0.0335	0.0037	0.0534	0.0335	Y
B-PILLAR Maximum (X, Y, Z)	67	9.9988	46.1579	-45.7298	10.0512	46.1745	-45.7658	-0.0524	-0.0166	-0.0360	0.0657	0.0000	NA
	68	13.8630	49.9761	-34.5939	13.9463	50.0130	-34.5720	-0.0833	-0.0369	0.0219	0.0937	0.0219	Z
	69	11.0312	50.8232	-28.5662	11.0184	50.8450	-28.5512	0.0128	-0.0218	0.0150	0.0294	0.0197	X, Z
	70	14.9435	51.0605	-24.2082	14.9499	51.0865	-24.1705	-0.0064	-0.0260	0.0377	0.0462	0.0377	Z
B-PILLAR Lateral (Y)	67	9.9988	46.1579	-45.7298	10.0512	46.1745	-45.7658	-0.0524	-0.0166	-0.0360	0.0657	-0.0166	Y
	68	13.8630	49.9761	-34.5939	13.9463	50.0130	-34.5720	-0.0833	-0.0369	0.0219	0.0937	-0.0369	Y
	69	11.0312	50.8232	-28.5662	11.0184	50.8450	-28.5512	0.0128	-0.0218	0.0150	0.0294	-0.0218	Y
	70	14.9435	51.0605	-24.2082	14.9499	51.0865	-24.1705	-0.0064	-0.0260	0.0377	0.0462	-0.0260	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-6

Model Year: 2018	Test Name: HBIB-6	VIN: 3C6RR6KT6JG186123	
	Make: RAM	Model: 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	0.0	≤ 4	Z
Windshield[D]	0.0	≤ 3	X, Z	Windshield[D]	NA	≤ 3	X, Z
A-Pillar Maximum	0.2	≤ 5	Z	A-Pillar Maximum	0.0	≤ 5	Z
A-Pillar Lateral	-0.2	≤ 3	Y	A-Pillar Lateral	0.0	≤ 3	Y
B-Pillar Maximum	0.1	≤ 5	X, Z	B-Pillar Maximum	0.0	≤ 5	Z
B-Pillar Lateral	-0.1	≤ 3	Y	B-Pillar Lateral	0.0	≤ 3	Y
Toe Pan - Wheel Well	0.1	≤ 9	X	Toe Pan - Wheel Well	0.0	≤ 9	Z
Side Front Panel	0.2	≤ 12	Y	Side Front Panel	0.3	≤ 12	Y
Side Door (above seat)	0.1	≤ 9	Y	Side Door (above seat)	0.1	≤ 9	Y
Side Door (below seat)	0.2	≤ 12	Y	Side Door (below seat)	0.2	≤ 12	Y
Floor Pan	-0.1	≤ 12	Z	Floor Pan	0.0	≤ 12	Z
Dash - no MASH requirement	0.2	NA	X, Y, Z	Dash - no MASH requirement	0.2	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.

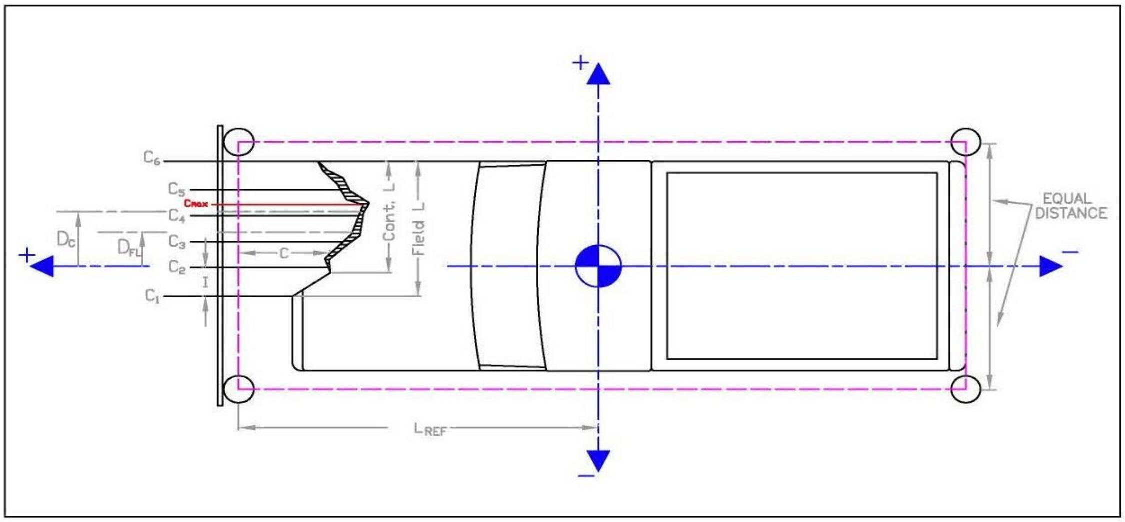
[C] For Toe Pan - Wheel Well the direction of defromation may include X and Z direction. For A-Pillar Maximum and B-Pillar Maximum the direction of deformation may include X, Y, and Z directions. The direction of deformation for Toe Pan -Wheel Well, A-Pillar Maximum, and B-Pillar Maximum only include 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-5. Maximum Occupant Compartment Deformations by Location, Test No. HBIB-6

		Test Name:	HBIB-6	**VIN:**	3C6RR6KT6JG186123
Model Year:	2018	**Make:**	RAM	**Model:**	1500



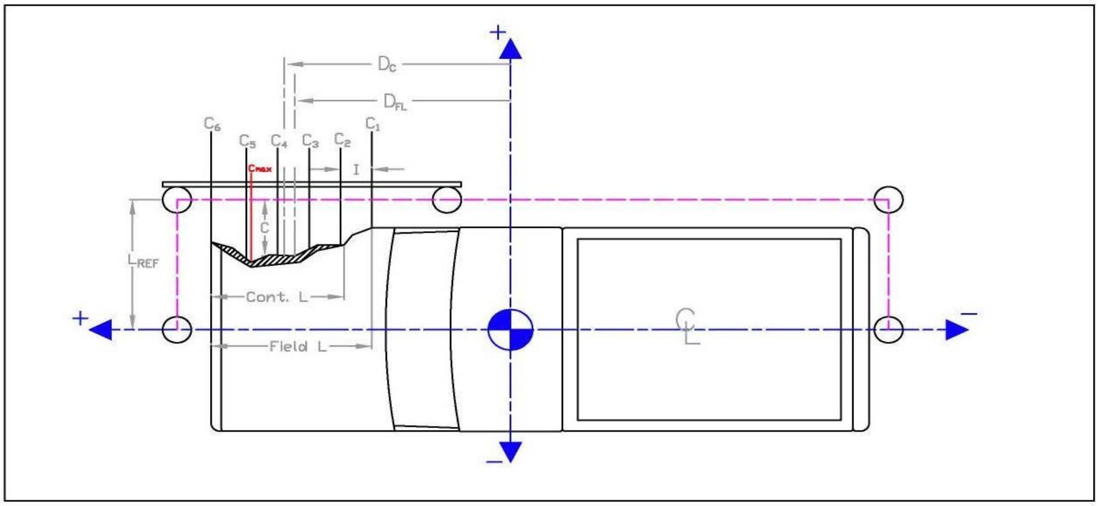
	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	118	(2997)
Total Vehicle Width:	78 1/3	(1989)
Width of contact and induced crush - Field L:	78 1/3	(1990)
Crush measurement spacing interval (L/5) - I:	15 5/8	(397)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	78 1/3	(1990)
Distance from center of vehicle to center of contact damage - D_C:	0	()

NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Lateral Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	n/a	N/A	-39 1/8	-(994)	22 1/2	(572)	14	(356)	N/A	N/A
C_2	20	(508)	-23 1/2	-(597)	6 5/8	(168)			- 5/8	-(16)
C_3	19 3/4	(502)	-7 7/8	-(200)	4 1/4	(108)			1 1/2	(38)
C_4	20	(508)	7 3/4	(197)	4 1/4	(108)			1 3/4	(44)
C_5	25 1/2	(648)	23 3/8	(594)	6 1/4	(159)			5 1/4	(133)
C_6	n/a	N/A	39	(991)	20 1/2	(521)			N/A	N/A
C_{MAX}	35 1/2	(902)	25	(635)	6 3/4	(171)			14 3/4	(375)

Figure F-6. Exterior Vehicle Crush (NASS) - Front, Test No. HBIB-6

		Test Name:	HBIB-6	VIN:	3C6RR6KT6JG186123
Model Year:	2018	Make:	RAM	Model:	1500



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	46	(1168)
Total Vehicle Length:	229 3/8	(5826)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-11 4/5	-(300)
Width of contact and induced crush - Field L:	229 3/8	(5826)
Crush measurement spacing interval (L/5) - I:	45 7/8	(1165)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-11 4/5	-(300)
Width of Contact Damage:	229 3/8	(5826)
Distance from vehicle c.g. to center of contact damage - D_C:	-11 4/5	-(300)

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	24	(610)	-126 1/2	-(3213)	33 1/2	(851)	2	(51)	-11 1/2	-(292)
C_2	N/A	N/A	-80 5/8	-(2048)	5 1/2	(140)			N/A	N/A
C_3	8 7/8	(225)	-34 3/4	-(883)	5 7/8	(149)			1	(25)
C_4	9 1/8	(232)	11 1/8	(283)	5	(127)			2 1/8	(54)
C_5	N/A	N/A	57	(1448)	5 3/8	(137)			N/A	N/A
C_6	N/A	N/A	102 7/8	(2613)	16 3/8	(416)			N/A	N/A
C_{MAX}	24	(610)	90	(2286)	6 3/8	(162)			15 5/8	(397)

Figure F-7. Exterior Vehicle Crush (NASS) - Side, Test No. HBIB-6

Model Year: 2018

Test Name: HBIB-7

Make: Kia

VIN: 3KPA24AB2JE079301

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	85.7201	18.6459	5.6237	85.7192	18.6930	5.5603	0.0009	-0.0471	0.0634	0.0790	0.0634	X, Z
	2	87.2313	23.3515	6.1823	87.1864	23.3933	6.0488	0.0449	-0.0418	0.1335	0.1469	0.1408	X, Z
	3	87.8401	27.5841	5.6404	87.8836	27.7007	5.4644	-0.0435	-0.1166	0.1760	0.2156	0.1760	Z
	4	88.0764	32.1687	5.0891	88.0831	32.2205	4.9006	-0.0067	-0.0518	0.1885	0.1956	0.1885	Z
	5	88.7675	36.9695	4.2547	88.6675	36.9994	4.1141	0.1000	-0.0299	0.1406	0.1751	0.1725	X, Z
	6	82.3332	18.8404	6.8014	82.3281	18.8642	6.7080	0.0051	-0.0238	0.0934	0.0965	0.0935	X, Z
	7	84.0160	23.2327	8.2073	84.0057	23.2964	8.0776	0.0103	-0.0637	0.1297	0.1449	0.1301	X, Z
	8	84.2148	27.6896	8.2613	84.1923	27.7152	8.1129	0.0225	-0.0256	0.1484	0.1523	0.1501	X, Z
	9	84.8346	33.5912	8.0479	84.8537	33.6597	7.8639	-0.0191	-0.0685	0.1840	0.1973	0.1840	Z
	10	84.6565	38.7011	8.3123	84.6693	38.7844	8.1001	-0.0128	-0.0833	0.2122	0.2283	0.2122	Z
FLOOR PAN (Z)	11	77.7822	19.0888	7.5009	77.7806	19.1162	7.4241	0.0016	-0.0274	0.0768	0.0816	0.0768	Z
	12	78.5789	23.3046	9.9013	78.5593	23.3249	9.7953	0.0196	-0.0203	0.1060	0.1097	0.1060	Z
	13	79.4882	28.3170	9.9837	79.5003	28.3263	9.8703	-0.0121	-0.0093	0.1134	0.1144	0.1134	Z
	14	80.6068	34.0270	9.8698	80.5927	34.1124	9.7242	0.0141	-0.0854	0.1456	0.1694	0.1456	Z
	15	81.2408	39.2493	9.8517	81.2198	39.2841	9.6768	0.0210	-0.0348	0.1749	0.1796	0.1749	Z
	16	72.5928	19.2286	7.3526	72.5450	19.2561	7.2682	0.0478	-0.0275	0.0844	0.1008	0.0844	Z
	17	72.7325	22.8952	9.9393	72.7855	22.9349	9.8398	-0.0530	-0.0397	0.0995	0.1195	0.0995	Z
	18	72.7787	28.5466	10.2255	72.7429	28.6156	10.1223	0.0358	-0.0690	0.1032	0.1292	0.1032	Z
	19	72.9938	34.4880	10.2651	72.9379	34.5501	10.1409	0.0559	-0.0621	0.1242	0.1497	0.1242	Z
	20	73.0062	39.1272	10.3123	72.9606	39.1881	10.1527	0.0456	-0.0609	0.1596	0.1768	0.1596	Z
	21	69.1521	19.3480	7.3683	69.1436	19.3882	7.3248	0.0085	-0.0402	0.0435	0.0598	0.0435	Z
	22	68.3313	23.3677	10.1541	68.3503	23.4257	10.0650	-0.0190	-0.0580	0.0891	0.1080	0.0891	Z
	23	69.1702	28.6294	10.3149	69.2165	28.6628	10.2169	-0.0463	-0.0334	0.0980	0.1134	0.0980	Z
	24	69.6353	34.4485	10.3869	69.5844	34.5405	10.2674	0.0509	-0.0920	0.1195	0.1592	0.1195	Z
	25	69.8524	39.6912	10.4282	69.8019	39.7409	10.2739	0.0505	-0.0497	0.1543	0.1698	0.1543	Z
	26	64.7411	19.7251	8.0676	64.7296	19.7515	7.9862	0.0115	-0.0264	0.0814	0.0863	0.0814	Z
	27	65.2706	23.3863	10.2766	65.2978	23.4533	10.1940	-0.0272	-0.0670	0.0826	0.1098	0.0826	Z
	28	66.1886	28.3352	10.5042	66.2418	28.4546	10.4115	-0.0532	-0.1194	0.0927	0.1602	0.0927	Z
	29	66.3497	34.7946	10.5248	66.4046	34.8783	10.4051	-0.0549	-0.0837	0.1197	0.1560	0.1197	Z
	30	66.8835	39.7399	10.5383	66.8399	39.8396	10.3782	0.0436	-0.0997	0.1601	0.1936	0.1601	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-7

Model Year: 2018 | Test Name: HBIB-7 | VIN: 3KPA24AB2JE079301
Make: Kia | 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	82.6362	-2.7535	4.9097	82.6334	-2.7767	4.8071	0.0028	-0.0232	0.1026	0.1052	0.1026	X, Z
	2	84.0198	1.9962	5.4237	83.9749	1.9647	5.2579	0.0449	0.0315	0.1658	0.1746	0.1718	X, Z
	3	84.5102	6.2393	4.8446	84.5525	6.2854	4.6420	-0.0423	-0.0461	0.2026	0.2120	0.2026	Z
	4	84.6186	10.8239	4.2548	84.6269	10.8051	4.0479	-0.0083	0.0188	0.2069	0.2079	0.2069	Z
	5	85.1745	15.6347	3.3782	85.0778	15.5928	3.2274	0.0967	0.0419	0.1508	0.1840	0.1791	X, Z
	6	79.2497	-2.6422	6.0994	79.2443	-2.6897	5.9702	0.0054	-0.0475	0.1292	0.1378	0.1293	X, Z
	7	80.8166	1.8061	7.4625	80.8076	1.7952	7.3027	0.0090	0.0109	0.1598	0.1604	0.1601	X, Z
	8	80.8932	6.2672	7.4790	80.8745	6.2176	7.3083	0.0187	0.0496	0.1707	0.1787	0.1717	X, Z
	9	81.3500	12.1816	7.2147	81.3735	12.1761	7.0173	-0.0235	0.0055	0.1974	0.1989	0.1974	Z
	10	81.0329	17.2866	7.4379	81.0515	17.2954	7.2211	-0.0186	-0.0088	0.2168	0.2178	0.2168	Z
FLOOR PAN (Z)	11	74.6963	-2.5128	6.8150	74.6950	-2.5562	6.7067	0.0013	-0.0434	0.1083	0.1167	0.1083	Z
	12	75.3860	1.7431	9.1775	75.3705	1.6877	9.0466	0.0155	0.0554	0.1309	0.1430	0.1309	Z
	13	76.1577	6.7791	9.2151	76.1760	6.7132	9.0844	-0.0183	0.0659	0.1307	0.1475	0.1307	Z
	14	77.1188	12.5165	9.0498	77.1105	12.5257	8.8953	0.0083	-0.0092	0.1545	0.1550	0.1545	Z
	15	77.6092	17.7539	8.9864	77.5971	17.7120	8.8112	0.0121	0.0419	0.1752	0.1805	0.1752	Z
	16	69.5045	-2.5164	6.6863	69.4569	-2.5589	6.5753	0.0476	-0.0425	0.1110	0.1280	0.1110	Z
	17	69.5532	1.1740	9.2423	69.6096	1.1420	9.1217	-0.0564	0.0320	0.1206	0.1369	0.1206	Z
	18	69.4454	6.8267	9.4818	69.4145	6.8212	9.3673	0.0309	0.0055	0.1145	0.1187	0.1145	Z
	19	69.4976	12.7719	9.4719	69.4487	12.7588	9.3463	0.0489	0.0131	0.1256	0.1354	0.1256	Z
	20	69.3828	17.4099	9.4809	69.3458	17.3957	9.3278	0.0370	0.0142	0.1531	0.1581	0.1531	Z
	21	66.0619	-2.4913	6.7148	66.0535	-2.5186	6.6475	0.0084	-0.0273	0.0673	0.0731	0.0673	Z
	22	65.1416	1.5275	9.4708	65.1639	1.5141	9.3652	-0.0223	0.0134	0.1056	0.1088	0.1056	Z
	23	65.8364	6.8113	9.5850	65.8886	6.7736	9.4787	-0.0522	0.0377	0.1063	0.1243	0.1063	Z
	24	66.1419	12.6413	9.6073	66.0973	12.6593	9.4892	0.0446	-0.0180	0.1181	0.1275	0.1181	Z
	25	66.2152	17.8882	9.6048	66.1739	17.8636	9.4607	0.0413	0.0246	0.1441	0.1519	0.1441	Z
	26	61.6448	-2.2295	7.4286	61.6343	-2.2705	7.3279	0.0105	-0.0410	0.1007	0.1092	0.1007	Z
	27	62.0820	1.4632	9.6053	62.1124	1.4599	9.5088	-0.0304	0.0033	0.0965	0.1012	0.0965	Z
	28	62.8647	6.4371	9.7886	62.9216	6.4863	9.6892	-0.0569	-0.0492	0.0994	0.1247	0.0994	Z
	29	62.8486	12.8984	9.7555	62.9103	12.9118	9.6401	-0.0617	-0.0134	0.1154	0.1315	0.1154	Z
	30	63.2466	17.8564	9.7263	63.2109	17.8828	9.5788	0.0357	-0.0264	0.1475	0.1540	0.1475	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-7

Model Year: 2018 | Test Name: HBIB-7 | Make: Kia | VIN: 3KPA24AB2JE079301 | 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)	31	76.6323	38.5464	-18.6328	76.5992	38.4919	-18.8277	0.0331	0.0545	-0.1949	0.2051	0.2051	X, Y, Z
	32	75.2513	27.1514	-19.4792	75.1925	27.1356	-19.6265	0.0588	0.0158	-0.1473	0.1594	0.1594	X, Y, Z
	33	75.1433	17.6584	-19.8335	75.2053	17.6116	-19.9955	-0.0620	0.0468	-0.1620	0.1797	0.1797	X, Y, Z
	34	73.6088	38.0923	-12.2670	73.5590	38.0865	-12.4513	0.0498	0.0058	-0.1843	0.1910	0.1910	X, Y, Z
	35	72.2394	26.9590	-11.9599	72.1902	26.9260	-12.1085	0.0492	0.0330	-0.1486	0.1600	0.1600	X, Y, Z
	36	71.2437	16.8726	-10.4150	71.1973	16.8346	-10.4985	0.0464	0.0380	-0.0835	0.1028	0.1028	X, Y, Z
SIDE PANEL (Y)	37	82.2975	41.3551	-1.0378	82.2281	41.3463	-1.2008	0.0694	0.0088	-0.1630	0.1774	0.0088	Y
	38	84.7628	41.5924	0.4317	84.7369	41.4510	0.2506	0.0259	0.1414	-0.1811	0.2312	0.1414	Y
	39	81.5720	41.8417	2.5245	81.5523	41.8483	2.4018	0.0197	-0.0066	-0.1227	0.1244	-0.0066	Y
IMPACT SIDE DOOR (Y)	40	48.6473	44.1130	-14.6263	48.6049	44.1665	-14.7369	0.0424	-0.0535	-0.1106	0.1300	-0.0535	Y
	41	61.9271	43.9169	-15.2338	61.9596	43.9329	-15.3708	-0.0325	-0.0160	-0.1370	0.1417	-0.0160	Y
	42	70.5446	44.0355	-12.6519	70.5828	44.0521	-12.7939	-0.0382	-0.0166	-0.1420	0.1480	-0.0166	Y
	43	51.4093	43.9557	1.1912	51.3745	43.9769	1.1270	0.0348	-0.0212	-0.0642	0.0760	-0.0212	Y
	44	61.7139	43.6438	4.2940	61.7528	43.7073	4.2477	-0.0389	-0.0635	-0.0463	0.0877	-0.0635	Y
	45	76.1937	43.1509	3.1748	76.1588	43.1859	3.0262	0.0349	-0.0350	-0.1486	0.1566	-0.0350	Y
ROOF - (Z)	46	64.0844	14.8442	-34.2095	64.1317	14.7922	-34.2499	-0.0473	0.0520	-0.0404	0.0811	-0.0404	Z
	47	64.1868	24.4358	-33.9368	64.2126	24.3679	-34.0059	-0.0258	0.0679	-0.0691	0.1003	-0.0691	Z
	48	63.2230	35.3802	-33.0978	63.2652	35.3519	-33.1865	-0.0422	0.0283	-0.0887	0.1022	-0.0887	Z
	49	57.9471	14.2398	-36.4147	57.9827	14.1263	-36.4689	-0.0356	0.1135	-0.0542	0.1307	-0.0542	Z
	50	58.0916	24.0068	-36.1600	58.0961	23.9541	-36.2371	-0.0045	0.0527	-0.0771	0.0935	-0.0771	Z
	51	57.5536	32.8599	-35.4709	57.5969	32.8299	-35.5565	-0.0433	0.0300	-0.0856	0.1005	-0.0856	Z
	52	40.8519	15.4509	-37.8336	40.8262	15.4737	-37.8753	0.0257	-0.0228	-0.0417	0.0540	-0.0417	Z
	53	40.8733	20.9248	-37.7282	40.8786	20.9156	-37.7755	-0.0053	0.0092	-0.0473	0.0485	-0.0473	Z
	54	42.3172	33.5615	-36.6494	42.3567	33.5223	-36.7161	-0.0395	0.0392	-0.0667	0.0869	-0.0667	Z
	55	25.4256	16.5004	-37.3644	25.4227	16.4500	-37.4023	0.0029	0.0504	-0.0379	0.0631	-0.0379	Z
	56	25.3196	23.6434	-37.1413	25.3451	23.6375	-37.1848	-0.0255	0.0059	-0.0435	0.0508	-0.0435	Z
	57	25.7837	32.9493	-36.3607	25.7902	32.9042	-36.4137	-0.0065	0.0451	-0.0530	0.0699	-0.0530	Z
	58	10.3770	14.3781	-35.2663	10.2451	14.2946	-35.2447	0.1319	0.0835	0.0216	0.1576	0.0216	Z
	59	11.0446	23.4487	-35.1737	10.9614	23.3294	-35.1806	0.0832	0.1193	-0.0069	0.1456	-0.0069	Z
	60	11.7855	33.6896	-34.3321	11.7040	33.6521	-34.3534	0.0815	0.0375	-0.0213	0.0922	-0.0213	Z
A-PILLAR Maximum (X, Y, Z)	61	63.5878	38.2855	-31.1503	63.5654	38.2877	-31.2243	0.0224	-0.0022	-0.0740	0.0773	0.0224	X
	62	67.8530	38.7935	-29.9051	67.8143	38.7881	-29.9664	0.0387	0.0054	-0.0613	0.0727	0.0391	X, Y
	63	71.0144	39.2071	-27.9072	71.0143	39.2067	-27.9824	0.0001	0.0004	-0.0752	0.0752	0.0004	X, Y
	64	73.9764	39.6549	-25.7249	73.9398	39.6484	-25.8686	0.0366	0.0065	-0.1437	0.1484	0.0372	X, Y
	65	78.5338	40.2125	-23.8995	78.5227	40.1972	-24.0176	0.0111	0.0153	-0.1181	0.1196	0.0189	X, Y
	66	81.8081	40.8297	-19.9792	81.7745	40.8190	-20.1427	0.0336	0.0107	-0.1635	0.1673	0.0353	X, Y
A-PILLAR Lateral (Y)	61	63.5878	38.2855	-31.1503	63.5654	38.2877	-31.2243	0.0224	-0.0022	-0.0740	0.0773	-0.0022	Y
	62	67.8530	38.7935	-29.9051	67.8143	38.7881	-29.9664	0.0387	0.0054	-0.0613	0.0727	0.0054	Y
	63	71.0144	39.2071	-27.9072	71.0143	39.2067	-27.9824	0.0001	0.0004	-0.0752	0.0752	0.0004	Y
	64	73.9764	39.6549	-25.7249	73.9398	39.6484	-25.8686	0.0366	0.0065	-0.1437	0.1484	0.0065	Y
	65	78.5338	40.2125	-23.8995	78.5227	40.1972	-24.0176	0.0111	0.0153	-0.1181	0.1196	0.0153	Y
	66	81.8081	40.8297	-19.9792	81.7745	40.8190	-20.1427	0.0336	0.0107	-0.1635	0.1673	0.0107	Y
B-PILLAR Maximum (X, Y, Z)	67	40.8902	38.5631	-30.7618	40.8598	38.5439	-30.8296	0.0304	0.0192	-0.0678	0.0767	0.0360	X, Y
	68	39.2633	41.8568	-22.6236	39.2478	41.8323	-22.6990	0.0155	0.0245	-0.0754	0.0808	0.0290	X, Y
	69	44.7577	42.7051	-15.1041	44.7346	42.6899	-15.2158	0.0231	0.0152	-0.1117	0.1151	0.0277	X, Y
	70	40.4338	42.8339	-9.8929	40.3645	42.8173	-9.9744	0.0693	0.0166	-0.0815	0.1083	0.0713	X, Y
B-PILLAR Lateral (Y)	67	40.8902	38.5631	-30.7618	40.8598	38.5439	-30.8296	0.0304	0.0192	-0.0678	0.0767	0.0192	Y
	68	39.2633	41.8568	-22.6236	39.2478	41.8323	-22.6990	0.0155	0.0245	-0.0754	0.0808	0.0245	Y
	69	44.7577	42.7051	-15.1041	44.7346	42.6899	-15.2158	0.0231	0.0152	-0.1117	0.1151	0.0152	Y
	70	40.4338	42.8339	-9.8929	40.3645	42.8173	-9.9744	0.0693	0.0166	-0.0815	0.1083	0.0166	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-7

Model Year: 2018 | Test Name: HBIB-7 | VIN: 3KPA24AB2JE079301
Make: Kia | 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)	31	72.9143	16.6880	-19.4727	72.8664	16.6056	-19.6648	0.0479	0.0824	-0.1921	0.2144	0.2144	X, Y, Z
	32	71.8434	5.2529	-20.2201	71.7642	5.2104	-20.3828	0.0792	0.0425	-0.1627	0.1859	0.1859	X, Y, Z
	33	71.9946	-4.2422	-20.4960	72.0333	-4.3120	-20.6897	-0.0387	-0.0698	-0.1937	0.2095	0.2095	X, Y, Z
	34	69.9285	16.2042	-13.0913	69.8682	16.1606	-13.2712	0.0603	0.0436	-0.1799	0.1947	0.1947	X, Y, Z
	35	68.8663	5.0405	-12.6875	68.8039	4.9696	-12.8491	0.0624	0.0709	-0.1616	0.1872	0.1872	X, Y, Z
	36	68.1535	-5.0562	-11.0558	68.0922	-5.1340	-11.1685	0.0613	-0.0778	-0.1127	0.1500	0.1500	X, Y, Z
SIDE PANEL (Y)	37	78.5667	19.7972	-1.9242	78.4982	19.7284	-2.0844	0.0685	0.0688	-0.1602	0.1873	0.0688	Y
	38	81.0300	20.1141	-0.4665	81.0101	19.9106	-0.6459	0.0199	0.2035	-0.1794	0.2720	0.2035	Y
	39	77.8415	20.2933	1.6369	77.8259	20.2358	1.5181	0.0156	0.0575	-0.1188	0.1329	0.0575	Y
IMPACT SIDE DOOR (Y)	40	44.8025	21.5187	-15.4002	44.7480	21.5477	-15.4752	0.0545	-0.0290	-0.0750	0.0971	-0.0290	Y
	41	58.0803	21.6816	-16.0591	58.1011	21.6714	-16.1724	-0.0208	0.0102	-0.1133	0.1156	0.0102	Y
	42	66.7009	22.0578	-13.5128	66.7298	22.0410	-13.6381	-0.0289	0.0168	-0.1253	0.1297	0.0168	Y
	43	47.6273	21.5687	0.4069	47.5960	21.5385	0.3760	0.0313	0.0302	-0.0309	0.0534	0.0302	Y
	44	57.9482	21.5651	3.4709	57.9923	21.5707	3.4479	-0.0441	-0.0056	-0.0230	0.0501	-0.0056	Y
	45	72.4318	21.4600	2.2979	72.4012	21.4312	2.1600	0.0306	0.0288	-0.1379	0.1442	0.0288	Y
ROOF - (Z)	46	60.9629	-7.4778	-34.8041	60.9735	-7.5247	-34.8715	-0.0106	-0.0469	-0.0674	0.0828	-0.0674	Z
	47	60.8031	2.1150	-34.6105	60.7961	2.0511	-34.6903	0.0070	0.0639	-0.0798	0.1025	-0.0798	Z
	48	59.5425	13.0354	-33.8575	59.5553	13.0107	-33.9380	-0.0128	0.0247	-0.0805	0.0852	-0.0805	Z
	49	54.8362	-8.2685	-36.9797	54.8345	-8.3715	-37.0562	0.0017	-0.1030	-0.0765	0.1283	-0.0765	Z
	50	54.7136	1.5006	-36.8058	54.6827	1.4572	-36.8891	0.0309	0.0434	-0.0833	0.0989	-0.0833	Z
	51	53.9355	10.3410	-36.1872	53.9464	10.3205	-36.2639	-0.0109	0.0205	-0.0767	0.0801	-0.0767	Z
	52	37.7090	-7.5382	-38.3401	37.6414	-7.4982	-38.3881	0.0676	0.0400	-0.0480	0.0921	-0.0480	Z
	53	37.5806	-2.0651	-38.2797	37.5469	-2.0563	-38.3240	0.0337	0.0088	-0.0443	0.0564	-0.0443	Z
	54	38.6813	10.6150	-37.3104	38.6878	10.5925	-37.3540	-0.0065	0.0225	-0.0436	0.0495	-0.0436	Z
	55	22.2615	-6.9081	-37.8179	22.2195	-6.9359	-37.8467	0.0420	-0.0278	-0.0288	0.0580	-0.0288	Z
	56	21.9604	0.2310	-37.6530	21.9483	0.2481	-37.6757	0.0121	-0.0171	-0.0227	0.0309	-0.0227	Z
	57	22.1720	9.5523	-36.9507	22.1457	9.5283	-36.9671	0.0263	0.0240	-0.0164	0.0392	-0.0164	Z
	58	7.2849	-9.4245	-35.6423	7.1162	-9.4869	-35.6015	0.1687	-0.0624	0.0408	0.1844	0.0408	Z
	59	7.7037	-0.3385	-35.6268	7.5877	-0.4358	-35.5997	0.1160	-0.0973	0.0271	0.1538	0.0271	Z
	60	8.1665	9.9255	-34.8722	8.0543	9.9085	-34.8434	0.1122	0.0170	0.0288	0.1171	0.0288	Z
A-PILLAR Maximum (X, Y, Z)	61	59.8348	15.9657	-31.9354	59.7851	15.9664	-31.9964	0.0497	-0.0007	-0.0610	0.0787	0.0497	X
	62	64.0891	16.6007	-30.7115	64.0247	16.5900	-30.7624	0.0644	0.0107	-0.0509	0.0828	0.0653	X, Y
	63	67.2455	17.1174	-28.7297	67.2214	17.1082	-28.7968	0.0241	0.0092	-0.0671	0.0719	0.0258	X, Y
	64	70.2023	17.6644	-26.5630	70.1437	17.6430	-26.7001	0.0586	0.0214	-0.1371	0.1506	0.0624	X, Y
	65	74.7495	18.3619	-24.7604	74.7187	18.3279	-24.8749	0.0308	0.0340	-0.1145	0.1233	0.0459	X, Y
	66	78.0204	19.1011	-20.8585	77.9705	19.0632	-21.0200	0.0499	0.0379	-0.1615	0.1732	0.0627	X, Y
A-PILLAR Lateral (Y)	61	59.8348	15.9657	-31.9354	59.7851	15.9664	-31.9964	0.0497	-0.0007	-0.0610	0.0787	-0.0007	Y
	62	64.0891	16.6007	-30.7115	64.0247	16.5900	-30.7624	0.0644	0.0107	-0.0509	0.0828	0.0107	Y
	63	67.2455	17.1174	-28.7297	67.2214	17.1082	-28.7968	0.0241	0.0092	-0.0671	0.0719	0.0092	Y
	64	70.2023	17.6644	-26.5630	70.1437	17.6430	-26.7001	0.0586	0.0214	-0.1371	0.1506	0.0214	Y
	65	74.7495	18.3619	-24.7604	74.7187	18.3279	-24.8749	0.0308	0.0340	-0.1145	0.1233	0.0340	Y
	66	78.0204	19.1011	-20.8585	77.9705	19.0632	-21.0200	0.0499	0.0379	-0.1615	0.1732	0.0379	Y
B-PILLAR Maximum (X, Y, Z)	67	37.1397	15.6243	-31.4585	37.0829	15.6107	-31.4931	0.0568	0.0136	-0.0346	0.0679	0.0584	X, Y
	68	35.4538	18.9398	-23.3412	35.4205	18.9083	-23.3764	0.0333	0.0315	-0.0352	0.0578	0.0458	X, Y
	69	40.9512	20.0008	-15.8509	40.9170	19.9638	-15.9257	0.0342	0.0370	-0.0748	0.0902	0.0504	X, Y
	70	36.6451	20.0544	-10.6236	36.5696	20.0076	-10.6640	0.0755	0.0468	-0.0404	0.0976	0.0888	X, Y
B-PILLAR Lateral (Y)	67	37.1397	15.6243	-31.4585	37.0829	15.6107	-31.4931	0.0568	0.0136	-0.0346	0.0679	0.0136	Y
	68	35.4538	18.9398	-23.3412	35.4205	18.9083	-23.3764	0.0333	0.0315	-0.0352	0.0578	0.0315	Y
	69	40.9512	20.0008	-15.8509	40.9170	19.9638	-15.9257	0.0342	0.0370	-0.0748	0.0902	0.0370	Y
	70	36.6451	20.0544	-10.6236	36.5696	20.0076	-10.6640	0.0755	0.0468	-0.0404	0.0976	0.0468	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-7

Model Year: 2018

Test Name: HBIB-7

Make: Kia

VIN: 3KPA24AB2JE079301

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	0.0	≤ 4	Z	Roof	0.0	≤ 4	Z
Windshield[D]	0.0	≤ 3	X, Z	Windshield[D]	NA	≤ 3	X, Z
A-Pillar Maximum	0.0	≤ 5	X, Y	A-Pillar Maximum	0.1	≤ 5	X, Y
A-Pillar Lateral	0.0	≤ 3	Y	A-Pillar Lateral	0.0	≤ 3	Y
B-Pillar Maximum	0.1	≤ 5	X, Y	B-Pillar Maximum	0.1	≤ 5	X, Y
B-Pillar Lateral	0.0	≤ 3	Y	B-Pillar Lateral	0.0	≤ 3	Y
Toe Pan - Wheel Well	0.2	≤ 9	Z	Toe Pan - Wheel Well	0.2	≤ 9	Z
Side Front Panel	0.1	≤ 12	Y	Side Front Panel	0.2	≤ 12	Y
Side Door (above seat)	-0.1	≤ 9	Y	Side Door (above seat)	0.0	≤ 9	Y
Side Door (below seat)	-0.1	≤ 12	Y	Side Door (below seat)	0.0	≤ 12	Y
Floor Pan	0.2	≤ 12	Z	Floor Pan	0.2	≤ 12	Z
Dash - no MASH requirement	0.2	NA	X, Y, Z	Dash - no MASH requirement	0.2	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.

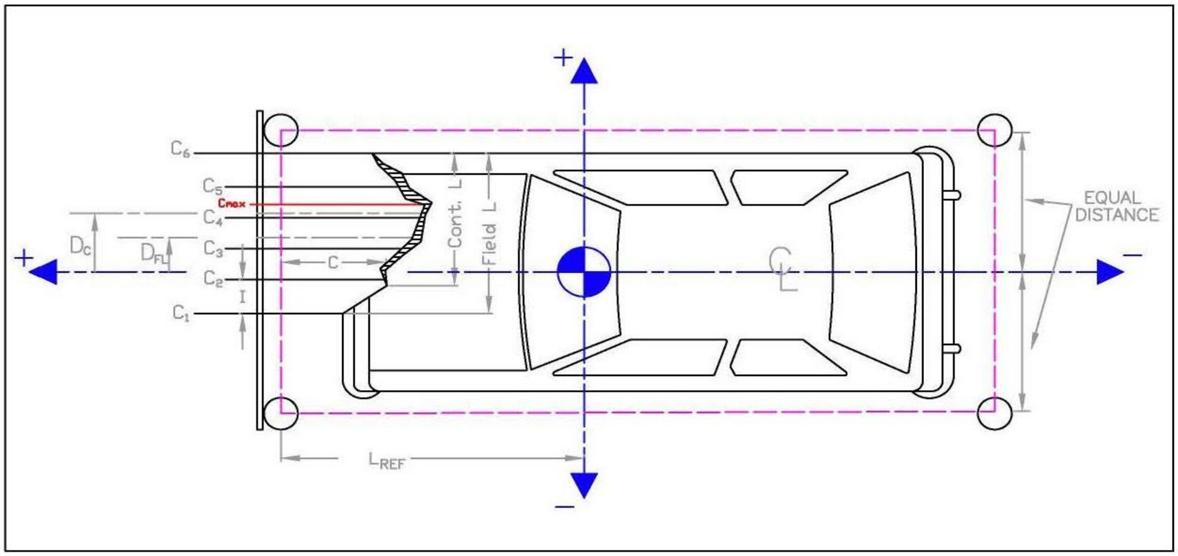
[C] For Toe Pan - Wheel Well the direction of defromation may include X and Z direction. For A-Pillar Maximum and B-Pillar Maximum the direction of deformation may include X, Y, and Z directions. The direction of deformation for Toe Pan -Wheel Well, A-Pillar Maximum, and B-Pillar Maximum only include 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:

Figure F-12. Maximum Occupant Compartment Deformations by Location, Test No. HBIB-7

Test Name:	HBIB-7	VIN:	3KPA24AB2JE079301
Model Year:	2018	Make: Kia	Model: Rio



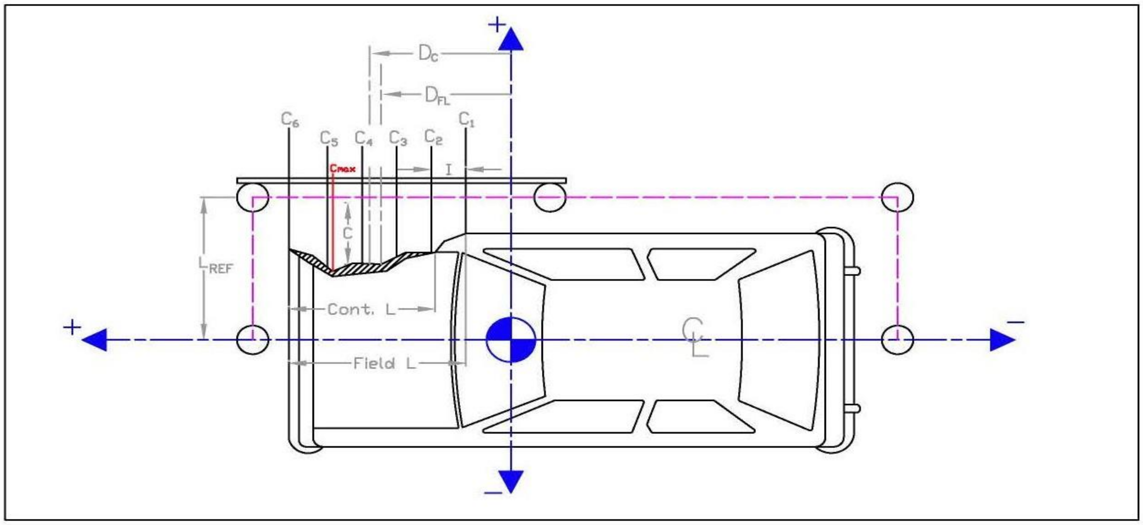
	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	78	(1981)
Total Width of Vehicle:	67 2/3	(1719)
Width of contact and induced crush - Field L:	67 2/3	(1719)
Crush measurement spacing interval (L/5) - I:	13 1/2	(343)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	67 2/3	(1719)
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	NA	NA	-33 7/8	-(860)	24 7/8	(632)	-3 1/5	-(81)	NA	NA
C_2	18	(457)	-20 3/8	-(518)	12 1/2	(318)			8 2/3	(221)
C_3	12	(305)	-6 7/8	-(175)	10 3/8	(264)			4 4/5	(122)
C_4	14	(356)	6 5/8	(168)	10 1/4	(260)			7	(176)
C_5	12	(305)	20 1/8	(511)	12 1/8	(308)			3	(78)
C_6	NA	NA	33 5/8	(854)	24 7/8	(632)			NA	NA
C_{MAX}	18	(457)	-20 3/8	-(518)	12 1/2	(318)			8 2/3	(221)

Figure F-13. Exterior Vehicle Crush (NASS) - Front, Test No. HBIB-7

Test Name:	HBIB-7	VIN:	3KPA24AB2JE079301
Model Year: 2018	Make: Kia	Model: Rio	



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	39 1/2	(1003)
Total Vehicle Length:	172 3/8	(4378)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-15 3/8	-(391)
Width of contact and induced crush - Field L:	70 4/5	(1799)
Crush measurement spacing interval (L/5) - I:	14 1/8	(359)
Distance from vehicle c.g. to center of Field L - D_{FL}:	35 2/5	(899)
Width of Contact Damage:	70 4/5	(1799)
Distance from vehicle c.g. to center of contact damage - D_C:	35 2/5	(899)

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	7	(178)	0	()	10 1/4	(260)	-3 3/4	-(95)	1/2	(13)
C_2	7 1/8	(181)	14 1/8	(359)	10 1/2	(267)			3/8	(10)
C_3	NA	NA	28 1/4	(718)	10 1/2	(267)			NA	NA
C_4	NA	NA	42 3/8	(1076)	10 1/2	(267)			NA	NA
C_5	11 1/2	(292)	56 1/2	(1435)	11 3/4	(298)			3 1/2	(89)
C_6	NA	NA	70 5/8	(1794)	37 1/2	(953)			NA	NA
C_{MAX}	11 1/2	(292)	56 1/2	(1435)	11 3/4	(298)			3 1/2	(89)

Figure F-14. Exterior Vehicle Crush (NASS) - Side, Test No. HBIB-7

Model Year: 2018   Test Name: HBIB-8   VIN: 1C6RR6GT7JS173589
Make: Ram   Model: 1500 Hemi

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	52.8436	36.3912	-8.1140	52.5945	36.4144	-7.8223	0.2491	-0.0232	-0.2917	0.3843	0.2491	X
	2	53.9022	40.5399	-6.3042	53.7555	40.4053	-5.9766	0.1467	0.1346	-0.3276	0.3834	0.1467	X
	3	55.2826	44.0977	-3.1928	55.2479	43.8346	-2.8554	0.0347	0.2631	-0.3374	0.4293	0.0347	X
	4	55.7477	49.4071	-2.6492	55.6691	49.1686	-2.3955	0.0786	0.2385	-0.2537	0.3570	0.0786	X
	5	55.9403	55.1128	-2.7295	55.6858	54.6752	-2.7023	0.2545	0.4376	-0.0272	0.5070	0.2545	X
	6	49.3863	35.8829	-6.2613	49.3468	35.7259	-5.9775	0.0395	0.1570	-0.2838	0.3267	0.0395	X
	7	50.3328	39.7912	-4.1401	50.3129	39.5413	-3.7593	0.0199	0.2499	-0.3808	0.4559	0.0199	X
	8	51.5223	43.5155	-0.9464	51.4975	43.2651	-0.5783	0.0248	0.2504	-0.3681	0.4459	0.0248	X
	9	51.8358	49.2998	-0.4778	51.8142	49.1110	-0.2632	0.0216	0.1888	-0.2146	0.2866	0.0216	X
	10	51.9463	55.1504	-0.5540	51.9305	54.8405	-0.5929	0.0158	0.3099	0.0389	0.3127	0.0420	X, Z
FLOOR PAN (Z)	11	46.2840	35.6407	-4.7684	46.3249	35.3790	-4.3929	-0.0409	0.2617	-0.3755	0.4595	-0.3755	Z
	12	47.4879	39.0197	-1.4132	47.5188	38.8521	-1.0511	-0.0309	0.1676	-0.3621	0.4002	-0.3621	Z
	13	48.2593	43.0511	0.1942	48.2467	42.8937	0.5076	0.0126	0.1574	-0.3134	0.3509	-0.3134	Z
	14	48.8423	49.2041	0.0972	48.8214	49.0757	0.3832	0.0209	0.1284	-0.2860	0.3142	-0.2860	Z
	15	48.4887	54.8250	0.0910	48.4538	54.5710	0.2797	0.0349	0.2540	-0.1887	0.3183	-0.1887	Z
	16	43.7849	35.5506	-3.7808	43.8214	35.3930	-3.5280	-0.0365	0.1576	-0.2528	0.3001	-0.2528	Z
	17	44.7198	38.4138	0.1690	44.8801	38.7386	0.4943	-0.1603	-0.3248	-0.3253	0.4868	-0.3253	Z
	18	45.0311	42.7557	0.2403	45.0251	42.6332	0.4984	0.0060	0.1225	-0.2581	0.2858	-0.2581	Z
	19	45.7389	49.2485	0.0884	45.4078	49.3349	0.3474	0.3311	-0.0864	-0.2590	0.4292	-0.2590	Z
	20	45.7403	54.6785	0.0880	45.7327	54.5183	0.2471	0.0076	0.1602	-0.1591	0.2259	-0.1591	Z
	21	39.1274	35.7318	-2.9483	39.0455	35.5871	-2.7840	0.0819	0.1447	-0.1643	0.2338	-0.1643	Z
	22	39.6825	38.2042	0.3526	39.6452	38.0593	0.5824	0.0373	0.1449	-0.2298	0.2742	-0.2298	Z
	23	39.8767	42.9137	0.2109	39.8719	42.7810	0.3889	0.0048	0.1327	-0.1780	0.2221	-0.1780	Z
	24	39.8927	48.6945	0.0870	39.9033	48.6118	0.2927	-0.0106	0.0827	-0.2057	0.2220	-0.2057	Z
	25	39.9010	54.5619	0.0702	40.0016	54.3621	0.2185	-0.1006	0.1998	-0.1483	0.2684	-0.1483	Z
	26	34.8524	36.0299	-2.1249	34.8170	35.9265	-1.9746	0.0354	0.1034	-0.1503	0.1858	-0.1503	Z
	27	34.8543	38.7995	-0.3904	34.8621	38.7443	-0.2354	-0.0078	0.0552	-0.1550	0.1647	-0.1550	Z
	28	34.8383	43.4958	-0.5140	34.8740	43.4009	-0.4146	-0.0357	0.0949	-0.0994	0.1420	-0.0994	Z
	29	34.7405	48.5351	-0.6293	34.7682	48.5033	-0.6039	-0.0277	0.0318	-0.0254	0.0492	-0.0254	Z
	30	35.1054	54.8859	-0.7740	35.2110	54.8097	-0.8260	-0.1056	0.0762	0.0520	0.1402	0.0520	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-8

Model Year: 2018 | Test Name: HBIB-8 | VIN: 1C6RR6GT7JS173589
Make: Ram | Model: 1500 Hemi

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	44.4207	11.8357	-3.4289	44.1518	11.9496	-3.2364	0.2689	-0.1139	-0.1925	0.3498	0.2689	X
	2	45.5676	15.9255	-1.5404	45.3976	15.8769	-1.3112	0.1700	0.0486	-0.2292	0.2895	0.1700	X
	3	47.0191	19.3934	1.6394	46.9637	19.2098	1.8775	0.0554	0.1836	-0.2381	0.3057	0.0554	X
	4	47.6029	24.6800	2.2816	47.4973	24.5234	2.4452	0.1056	0.1566	-0.1636	0.2499	0.1056	X
	5	47.9251	30.3803	2.3067	47.6296	30.0336	2.2503	0.2955	0.3467	0.0564	0.4590	0.3008	X, Z
	6	40.9472	11.3723	-1.5947	40.8914	11.2922	-1.4028	0.0558	0.0801	-0.1919	0.2153	0.0558	X
	7	41.9759	15.2185	0.6004	41.9389	15.0405	0.8915	0.0370	0.1780	-0.2911	0.3432	0.0370	X
	8	43.2400	18.8557	3.8651	43.2035	18.6732	4.1463	0.0365	0.1825	-0.2812	0.3372	0.0365	X
	9	43.6831	24.6218	4.4407	43.6432	24.5036	4.5798	0.0399	0.1182	-0.1391	0.1868	0.0399	X
	10	43.9265	30.4688	4.4724	43.8798	30.2348	4.3664	0.0467	0.2340	0.1060	0.2611	0.1158	X, Z
FLOOR PAN (Z)	11	37.8358	11.1733	-0.1143	37.8638	10.9768	0.1775	-0.0280	0.1965	-0.2918	0.3529	-0.2918	Z
	12	39.1061	14.4621	3.3055	39.1325	14.3553	3.5880	-0.0264	0.1068	-0.2825	0.3032	-0.2825	Z
	13	39.9640	18.4448	4.9886	39.9461	18.3482	5.2277	0.0179	0.0966	-0.2391	0.2585	-0.2391	Z
	14	40.6866	24.5837	5.0062	40.6508	24.5180	5.2283	0.0358	0.0657	-0.2221	0.2344	-0.2221	Z
	15	40.4605	30.2103	5.1025	40.3988	30.0208	5.2368	0.0617	0.1895	-0.1343	0.2403	-0.1343	Z
	16	35.3325	11.1219	0.8650	35.3617	11.0258	1.0451	-0.0292	0.0961	-0.1801	0.2062	-0.1801	Z
	17	36.3203	13.8903	4.8691	36.4928	14.2659	5.1334	-0.1725	-0.3756	-0.2643	0.4906	-0.2643	Z
	18	36.7298	18.2220	5.0210	36.7198	18.1557	5.2165	0.0100	0.0663	-0.1955	0.2067	-0.1955	Z
	19	37.5850	24.6987	4.9903	37.2433	24.8496	5.2013	0.3417	-0.1509	-0.2110	0.4290	-0.2110	Z
	20	37.7095	30.1264	5.0898	37.6771	30.0260	5.2059	0.0324	0.1004	-0.1161	0.1569	-0.1161	Z
	21	30.6777	11.3936	1.6888	30.5913	11.3051	1.7976	0.0864	0.0885	-0.1088	0.1647	-0.1088	Z
	22	31.2790	13.7919	5.0361	31.2449	13.6952	5.2130	0.0341	0.0967	-0.1769	0.2045	-0.1769	Z
	23	31.5803	18.4976	4.9814	31.5707	18.4141	5.1152	0.0096	0.0835	-0.1338	0.1580	-0.1338	Z
	24	31.7277	24.2778	4.9639	31.7248	24.2437	5.1374	0.0029	0.0341	-0.1735	0.1768	-0.1735	Z
	25	31.8691	30.1428	5.0550	31.9440	29.9910	5.1799	-0.0749	0.1518	-0.1249	0.2104	-0.1249	Z
	26	26.4082	11.7737	2.5067	26.3714	11.7168	2.6180	0.0368	0.0569	-0.1113	0.1303	-0.1113	Z
	27	26.4678	14.5103	4.2918	26.4768	14.4971	4.4140	-0.0090	0.0132	-0.1222	0.1232	-0.1222	Z
	28	26.5586	19.2072	4.2545	26.5865	19.1551	4.3295	-0.0279	0.0521	-0.0750	0.0955	-0.0750	Z
	29	26.5754	24.2487	4.2316	26.5881	24.2614	4.2439	-0.0127	-0.0127	-0.0123	0.0218	-0.0123	Z
	30	27.0847	30.5911	4.2046	27.1632	30.5603	4.1496	-0.0785	0.0308	0.0550	0.1007	0.0550	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-8

Model Year:	2018	Test Name:	HBIB-8	VIN:	1C6RR6GT7JS173589
		Make:	Ram	Model:	1500 Hemi

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)	31	48.1916	54.2202	-32.0643	47.9315	53.9252	-32.1396	0.2601	0.2950	-0.0753	0.4004	0.4004	X, Y, Z
	32	46.5330	43.5345	-32.0864	46.4172	43.3809	-32.2058	0.1158	0.1536	-0.1194	0.2264	0.2264	X, Y, Z
	33	46.5515	27.2198	-32.5009	46.3971	27.1119	-32.6146	0.1544	0.1079	-0.1137	0.2200	0.2200	X, Y, Z
	34	42.4284	55.9678	-21.1121	42.0789	55.5088	-21.1137	0.3495	0.4590	-0.0016	0.5769	0.5769	X, Y, Z
	35	41.6879	43.7828	-20.9267	41.6038	43.3223	-21.1062	0.0841	0.4605	-0.1795	0.5014	0.5014	X, Y, Z
	36	39.8467	26.7698	-24.6837	39.8033	26.5755	-24.7626	0.0434	0.1943	-0.0789	0.2142	0.2142	X, Y, Z
SIDE PANEL (Y)	37	51.5566	58.5952	-9.1057	51.3594	55.8167	-9.2130	0.1972	2.7785	-0.1073	2.7876	2.7785	Y
	38	53.1402	58.6616	-4.0262	53.0276	57.1648	-4.3505	0.1126	1.4968	-0.3243	1.5357	1.4968	Y
	39	51.0200	58.6595	-2.3578	50.9813	57.2837	-2.6069	0.0387	1.3758	-0.2491	1.3987	1.3758	Y
IMPACT SIDE DOOR (Y)	40	19.6514	60.6994	-23.4906	19.0308	61.1007	-23.8357	0.6206	-0.4013	-0.3451	0.8156	-0.4013	Y
	41	28.2320	60.6241	-23.2556	27.5700	60.5392	-23.5815	0.6620	0.0849	-0.3259	0.7427	0.0849	Y
	42	38.8924	60.5922	-20.7489	38.1263	59.4733	-21.0476	0.7661	1.1189	-0.2987	1.3885	1.1189	Y
	43	21.7811	61.3254	-7.9810	21.1371	61.4553	-8.3343	0.6440	-0.1299	-0.3533	0.7459	-0.1299	Y
	44	28.6477	61.1711	-6.6854	27.9067	60.5233	-6.9695	0.7410	0.6478	-0.2841	1.0244	0.6478	Y
	45	37.0890	62.0215	-7.3229	36.3072	61.1532	-7.7864	0.7818	0.8683	-0.4635	1.2570	0.8683	Y
ROOF - (Z)	46	38.7036	26.1611	-47.3758	38.4595	26.1833	-47.5366	0.2441	-0.0222	-0.1608	0.2931	-0.1608	Z
	47	37.7694	37.5064	-47.3617	37.5714	37.5016	-47.5753	0.1980	0.0048	-0.2136	0.2913	-0.2136	Z
	48	34.0585	50.0644	-47.1839	33.9700	50.0859	-47.4330	0.0885	-0.0215	-0.2491	0.2652	-0.2491	Z
	49	31.5784	25.6611	-50.2908	31.5777	25.6689	-50.3410	0.0007	-0.0078	-0.0502	0.0508	-0.0502	Z
	50	30.8881	35.5924	-50.3847	30.8881	35.5800	-50.4929	0.0000	0.0124	-0.1082	0.1089	-0.1082	Z
	51	28.1254	46.5879	-50.2919	28.0472	46.5720	-50.4908	0.0782	0.0159	-0.1989	0.2143	-0.1989	Z
	52	17.4010	25.0188	-51.7293	17.4322	24.9822	-51.7799	-0.0312	0.0366	-0.0506	0.0698	-0.0506	Z
	53	15.8460	33.9553	-51.8718	15.9172	33.8952	-51.9636	-0.0712	0.0601	-0.0918	0.1308	-0.0918	Z
	54	13.2275	44.8057	-51.6854	13.1975	44.7505	-51.8351	0.0300	0.0552	-0.1497	0.1623	-0.1497	Z
	55	-1.6742	24.8556	-52.2077	-1.6521	24.7427	-52.2722	-0.0221	0.1129	-0.0645	0.1319	-0.0645	Z
	56	-2.1929	33.1332	-52.3084	-2.1804	33.0410	-52.4044	-0.0125	0.0922	-0.0960	0.1337	-0.0960	Z
	57	-2.1648	44.4503	-52.1056	-2.2050	44.4953	-52.2357	0.0402	-0.0450	-0.1301	0.1434	-0.1301	Z
	58	-17.7431	26.2317	-51.9846	-17.7689	26.3196	-52.1175	0.0258	-0.0879	-0.1329	0.1614	-0.1329	Z
	59	-17.9020	33.9240	-52.1080	-17.8940	33.9954	-52.2471	-0.0080	-0.0714	-0.1391	0.1566	-0.1391	Z
	60	-17.5962	46.8203	-51.9157	-17.5762	46.8328	-52.0860	-0.0200	-0.0125	-0.1703	0.1719	-0.1703	Z
A-PILLAR Maximum (X, Y, Z)	61	34.9642	52.6057	-45.1051	34.9205	52.6561	-45.3027	0.0437	-0.0504	-0.1976	0.2086	0.0437	X
	62	39.0889	53.8355	-43.4894	39.0325	53.8938	-43.6953	0.0564	-0.0583	-0.2059	0.2213	0.0564	X
	63	42.9693	54.5067	-39.7118	42.8337	54.4999	-39.8883	0.1356	0.0068	-0.1765	0.2227	0.1358	X, Y
	64	46.3149	55.6220	-38.4086	46.2010	55.6685	-38.5957	0.1139	-0.0465	-0.1871	0.2239	0.1139	X
	65	48.9965	56.1845	-34.7518	48.8382	56.2066	-34.9114	0.1583	-0.0221	-0.1596	0.2259	0.1583	X
	66	52.1350	56.9498	-32.9832	51.9408	57.0307	-33.1365	0.1942	-0.0809	-0.1533	0.2603	0.1942	X
A-PILLAR Lateral (Y)	61	34.9642	52.6057	-45.1051	34.9205	52.6561	-45.3027	0.0437	-0.0504	-0.1976	0.2086	-0.0504	Y
	62	39.0889	53.8355	-43.4894	39.0325	53.8938	-43.6953	0.0564	-0.0583	-0.2059	0.2213	-0.0583	Y
	63	42.9693	54.5067	-39.7118	42.8337	54.4999	-39.8883	0.1356	0.0068	-0.1765	0.2227	0.0068	Y
	64	46.3149	55.6220	-38.4086	46.2010	55.6685	-38.5957	0.1139	-0.0465	-0.1871	0.2239	-0.0465	Y
	65	48.9965	56.1845	-34.7518	48.8382	56.2066	-34.9114	0.1583	-0.0221	-0.1596	0.2259	-0.0221	Y
	66	52.1350	56.9498	-32.9832	51.9408	57.0307	-33.1365	0.1942	-0.0809	-0.1533	0.2603	-0.0809	Y
B-PILLAR Maximum (X, Y, Z)	67	10.5722	52.1066	-47.0316	10.5482	52.1572	-47.2790	0.0240	-0.0506	-0.2474	0.2537	0.0240	X
	68	7.5784	53.7271	-42.7796	7.4906	53.7600	-42.9870	0.0878	-0.0329	-0.2074	0.2276	0.0878	X
	69	11.3221	56.8017	-33.6244	11.2371	56.8667	-33.9252	0.0850	-0.0650	-0.3008	0.3193	0.0850	X
	70	8.5806	57.9072	-21.2142	8.5895	57.8740	-21.4541	-0.0089	0.0332	-0.2399	0.2423	0.0332	Y
B-PILLAR Lateral (Y)	67	10.5722	52.1066	-47.0316	10.5482	52.1572	-47.2790	0.0240	-0.0506	-0.2474	0.2537	-0.0506	Y
	68	7.5784	53.7271	-42.7796	7.4906	53.7600	-42.9870	0.0878	-0.0329	-0.2074	0.2276	-0.0329	Y
	69	11.3221	56.8017	-33.6244	11.2371	56.8667	-33.9252	0.0850	-0.0650	-0.3008	0.3193	-0.0650	Y
	70	8.5806	57.9072	-21.2142	8.5895	57.8740	-21.4541	-0.0089	0.0332	-0.2399	0.2423	0.0332	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-8

Model Year: 2018 | Test Name: HBIB-8 | Make: Ram | VIN: 1C6RR6GT7JS173589 | Model: 1500 Hemi

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)	31	40.2451	30.2016	-27.0591	39.8442	30.0453	-27.1884	0.4009	0.1563	-0.1293	0.4493	0.4493	X, Y, Z
	32	38.3447	19.5585	-27.2819	38.1083	19.5387	-27.4671	0.2364	0.0198	-0.1852	0.3010	0.3010	X, Y, Z
	33	37.9946	3.2580	-27.9962	37.7457	3.2853	-28.2063	0.2489	-0.0273	-0.2101	0.3269	0.3269	X, Y, Z
	34	34.4906	31.8788	-16.0914	34.0326	31.5271	-16.1267	0.4580	0.3517	-0.0353	0.5785	0.5785	X, Y, Z
	35	33.4734	19.7124	-16.1319	33.3012	19.3556	-16.3662	0.1722	0.3568	-0.2343	0.4603	0.4603	X, Y, Z
	36	31.2582	2.8173	-20.2058	31.1466	2.7282	-20.3602	0.1116	0.0891	-0.1544	0.2103	0.2103	X, Y, Z
SIDE PANEL (Y)	37	43.6403	34.0777	-4.0155	43.3244	31.3979	-4.2315	0.3159	2.6798	-0.2160	2.7070	2.6798	Y
	38	45.2100	34.0150	1.0684	45.0235	32.6115	0.6557	0.1865	1.4035	-0.4127	1.4748	1.4035	Y
	39	43.0853	34.0305	2.7311	42.9811	32.7379	2.4034	0.1042	1.2926	-0.3277	1.3376	1.2926	Y
IMPACT SIDE DOOR (Y)	40	11.8338	37.1695	-18.4405	11.1057	37.6565	-18.7113	0.7281	-0.4870	-0.2708	0.9169	-0.4870	Y
	41	20.4098	36.8949	-18.1851	19.6313	36.9106	-18.4772	0.7785	-0.0157	-0.2921	0.8316	-0.0157	Y
	42	31.0593	36.5749	-15.6522	30.1644	35.5716	-15.9761	0.8949	1.0033	-0.3239	1.3829	1.0033	Y
	43	13.9312	37.4627	-2.9166	13.2280	37.6516	-3.2080	0.7032	-0.1889	-0.2914	0.7843	-0.1889	Y
	44	20.7886	37.1287	-1.6066	19.9773	36.5499	-1.8692	0.8113	0.5788	-0.2626	1.0306	0.5788	Y
	45	29.2489	37.7986	-2.2069	28.3886	37.0196	-2.6816	0.8603	0.7790	-0.4747	1.2539	0.7790	Y
ROOF - (Z)	46	30.1688	2.6507	-42.9080	29.7817	2.8274	-43.1361	0.3871	-0.1767	-0.2281	0.4828	-0.2281	Z
	47	29.4920	14.0120	-42.6877	29.1318	14.1603	-42.9440	0.3602	-0.1483	-0.2563	0.4663	-0.2563	Z
	48	26.0663	26.6457	-42.2885	25.7961	26.8120	-42.5425	0.2702	-0.1663	-0.2540	0.4064	-0.2540	Z
	49	23.0428	2.3662	-45.8499	22.8890	2.5149	-45.9435	0.1538	-0.1487	-0.0936	0.2335	-0.0936	Z
	50	22.5781	12.3106	-45.7629	22.4079	12.4394	-45.8933	0.1702	-0.1288	-0.1304	0.2501	-0.1304	Z
	51	20.0651	23.3625	-45.4750	19.7989	23.4863	-45.6651	0.2662	-0.1238	-0.1901	0.3498	-0.1901	Z
	52	8.8587	2.0726	-47.3360	8.7313	2.1552	-47.3817	0.1274	-0.0826	-0.0457	0.1586	-0.0457	Z
	53	7.5072	11.0433	-47.3182	7.4041	11.1000	-47.3828	0.1031	-0.0567	-0.0646	0.1342	-0.0646	Z
	54	5.1348	21.9452	-46.9390	4.9134	22.0051	-47.0311	0.2214	-0.0599	-0.0921	0.2472	-0.0921	Z
	55	-10.2137	2.3517	-47.8659	-10.3542	2.3270	-47.8595	0.1405	0.0247	0.0064	0.1428	0.0064	Z
	56	-10.5443	10.6394	-47.8158	-10.7078	10.6355	-47.8227	0.1635	0.0039	-0.0069	0.1637	-0.0069	Z
	57	-10.2602	21.9473	-47.4049	-10.4913	22.0820	-47.4213	0.2311	-0.1347	-0.0164	0.2680	-0.0164	Z
	58	-26.2479	4.0882	-47.6585	-26.4340	4.2389	-47.6566	0.1861	-0.1507	0.0019	0.2395	0.0019	Z
	59	-26.2320	11.7831	-47.6409	-26.3977	11.9167	-47.6301	0.1657	-0.1336	0.0108	0.2131	0.0108	Z
	60	-25.6345	24.6635	-47.2107	-25.8098	24.7386	-47.2086	0.1753	-0.0751	0.0021	0.1907	0.0021	Z
A-PILLAR Maximum (X, Y, Z)	61	27.0232	29.1274	-40.1611	26.8017	29.3178	-40.3614	0.2215	-0.1904	-0.2003	0.3542	0.2215	X
	62	31.1699	30.2333	-38.5125	30.9398	30.4359	-38.7333	0.2301	-0.2026	-0.2208	0.3778	0.2301	X
	63	35.0533	30.7468	-34.7133	34.7551	30.8845	-34.9186	0.2982	-0.1377	-0.2053	0.3873	0.2982	X
	64	38.4194	31.7617	-33.3813	38.1470	31.9555	-33.6059	0.2724	-0.1938	-0.2246	0.4027	0.2724	X
	65	41.1023	32.1960	-29.7081	40.7971	32.3630	-29.9141	0.3052	-0.1670	-0.2060	0.4043	0.3052	X
	66	44.2520	32.8573	-27.9177	43.9174	33.0855	-28.1260	0.3346	-0.2282	-0.2083	0.4554	0.3346	X
A-PILLAR Lateral (Y)	61	27.0232	29.1274	-40.1611	26.8017	29.3178	-40.3614	0.2215	-0.1904	-0.2003	0.3542	-0.1904	Y
	62	31.1699	30.2333	-38.5125	30.9398	30.4359	-38.7333	0.2301	-0.2026	-0.2208	0.3778	-0.2026	Y
	63	35.0533	30.7468	-34.7133	34.7551	30.8845	-34.9186	0.2982	-0.1377	-0.2053	0.3873	-0.1377	Y
	64	38.4194	31.7617	-33.3813	38.1470	31.9555	-33.6059	0.2724	-0.1938	-0.2246	0.4027	-0.1938	Y
	65	41.1023	32.1960	-29.7081	40.7971	32.3630	-29.9141	0.3052	-0.1670	-0.2060	0.4043	-0.1670	Y
	66	44.2520	32.8573	-27.9177	43.9174	33.0855	-28.1260	0.3346	-0.2282	-0.2083	0.4554	-0.2282	Y
B-PILLAR Maximum (X, Y, Z)	67	2.6320	29.2180	-42.1585	2.4232	29.3717	-42.3228	0.2088	-0.1537	-0.1643	0.3069	0.2088	X
	68	-0.3369	30.8279	-37.8851	-0.5976	30.9509	-37.9961	0.2607	-0.1230	-0.1110	0.3089	0.2607	X
	69	3.4484	33.6484	-28.6654	3.2187	33.7933	-28.8768	0.2297	-0.1449	-0.2114	0.3442	0.2297	X
	70	0.6959	34.5884	-16.2441	0.6002	34.6023	-16.3852	0.0957	-0.0139	-0.1411	0.1711	0.0957	X
B-PILLAR Lateral (Y)	67	2.6320	29.2180	-42.1585	2.4232	29.3717	-42.3228	0.2088	-0.1537	-0.1643	0.3069	-0.1537	Y
	68	-0.3369	30.8279	-37.8851	-0.5976	30.9509	-37.9961	0.2607	-0.1230	-0.1110	0.3089	-0.1230	Y
	69	3.4484	33.6484	-28.6654	3.2187	33.7933	-28.8768	0.2297	-0.1449	-0.2114	0.3442	-0.1449	Y
	70	0.6959	34.5884	-16.2441	0.6002	34.6023	-16.3852	0.0957	-0.0139	-0.1411	0.1711	-0.0139	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-8

Test Name: HBIB-8 | VIN: 1C6RR6GT7JS173589

Model Year: 2018 | Make: Ram | Model: 1500 Hemi

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	-0.2	≤ 4	Z	Roof	0.0	≤ 4	Z
Windshield[D]	0.0	≤ 3	X, Z	Windshield[D]	NA	≤ 3	X, Z
A-Pillar Maximum	0.2	≤ 5	X	A-Pillar Maximum	0.3	≤ 5	X
A-Pillar Lateral	0.0	≤ 3	Y	A-Pillar Lateral	-0.2	≤ 3	Y
B-Pillar Maximum	0.1	≤ 5	X	B-Pillar Maximum	0.3	≤ 5	X
B-Pillar Lateral	0.0	≤ 3	Y	B-Pillar Lateral	-0.2	≤ 3	Y
Toe Pan - Wheel Well	0.3	≤ 9	X	Toe Pan - Wheel Well	0.3	≤ 9	X, Z
Side Front Panel	2.8	≤ 12	Y	Side Front Panel	2.7	≤ 12	Y
Side Door (above seat)	1.1	≤ 9	Y	Side Door (above seat)	1.0	≤ 9	Y
Side Door (below seat)	0.9	≤ 12	Y	Side Door (below seat)	0.8	≤ 12	Y
Floor Pan	0.1	≤ 12	Z	Floor Pan	0.1	≤ 12	Z
Dash - no MASH requirement	0.6	NA	X, Y, Z	Dash - no MASH requirement	0.6	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.

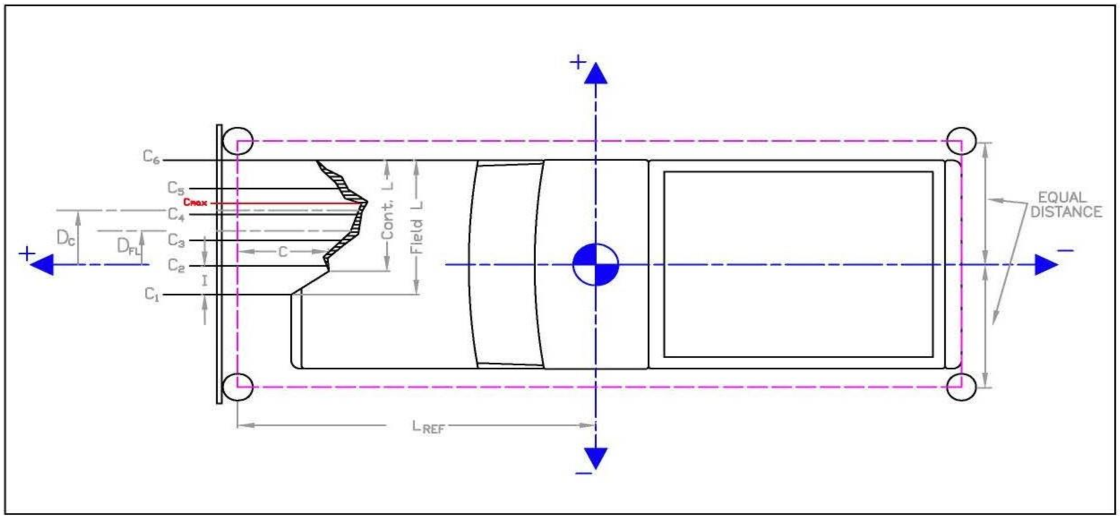
[C] For Toe Pan - Wheel Well the direction of defromation may include X and Z direction. For A-Pillar Maximum and B-Pillar Maximum the direction of deformation may include X, Y, and Z directions. The direction of deformation for Toe Pan -Wheel Well, A-Pillar Maximum, and B-Pillar Maximum only include 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-8

		Test Name:	HBIB-8	VIN:	1C6RR6GT7JS173589
Model Year:	2018	Make:	Ram	Model:	1500 Hemi



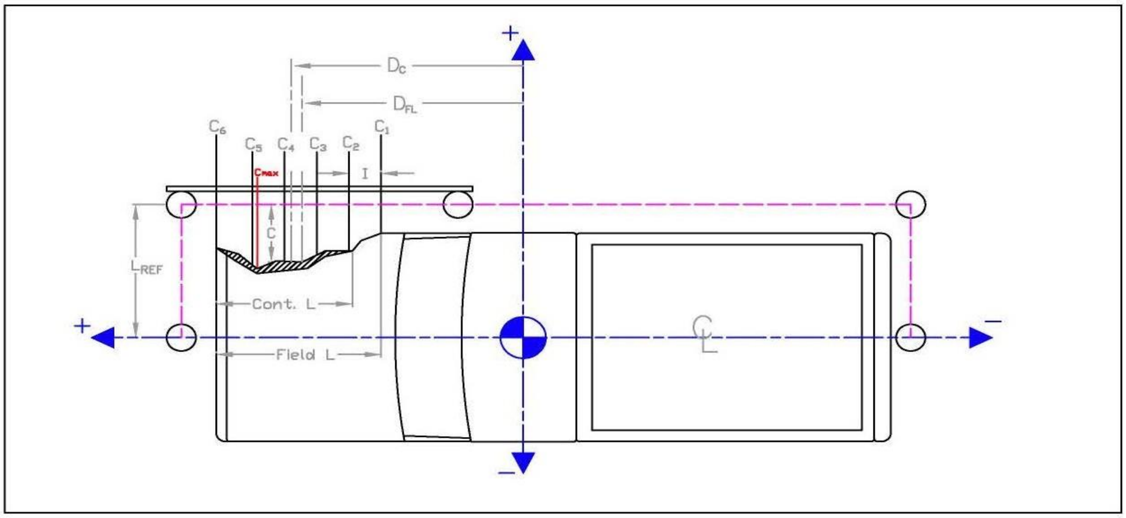
	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	109	(2769)
Total Vehicle Width:	77	(1956)
Width of contact and induced crush - Field L:	77	(1956)
Crush measurement spacing interval (L/5) - I:	15 3/8	(391)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	17	(432)
Distance from center of vehicle to center of contact damage - D_C:	30	(762)

NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Lateral Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	N/a	N/A	-38 1/2	-(978)	22 1/2	(572)	5 1/3	(135)	N/A	N/A
C_2	10 3/4	(273)	-23 1/8	-(587)	6 1/2	(165)			-1	-(27)
C_3	10 1/4	(260)	-7 3/4	-(197)	4 1/4	(108)			2/3	(17)
C_4	10 3/4	(273)	7 5/8	(194)	4 1/4	(108)			1 1/5	(30)
C_5	17 3/4	(451)	23	(584)	6 1/8	(156)			6 1/3	(160)
C_6	N/a	N/A	38 3/8	(975)	20 1/2	(521)			N/A	N/A
C_{MAX}	17 3/4	(451)	23	(584)	6 1/8	(156)			6 1/3	(160)

Figure F-20. Exterior Vehicle Crush (NASS) - Front, Test No. HBIB-8

Test Name:	HBIB-8	VIN:	1C6RR6GT7JS173589
Model Year: 2018	Make: Ram	Model:	1500 Hemi



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	46	(1168)
Total Vehicle Length:	229 1/8	(5820)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-14 3/8	-(365)
Width of contact and induced crush - Field L:	229 1/8	(5820)
Crush measurement spacing interval (L/5) - I:	45 7/8	(1165)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-14 3/8	-(365)
Width of Contact Damage:	229 1/8	(5820)
Distance from vehicle c.g. to center of contact damage - D_C:	-14 3/8	-(365)

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	-129	-(3277)	33 1/2	(851)	2	(51)	N/A	N/A
C_2	N/a	N/A	-83 1/8	-(2111)	5 1/2	(140)			N/A	N/A
C_3	8 1/2	(216)	-37 1/4	-(946)	5 7/8	(149)			5/8	(16)
C_4	8 3/8	(213)	8 5/8	(219)	5	(127)			1 3/8	(35)
C_5	N/a	N/A	54 1/2	(1384)	5 3/4	(146)			N/A	N/A
C_6	N/a	N/A	100 3/8	(2550)	10 3/4	(273)			N/A	N/A
C_{MAX}	21	(533)	84	(2134)	5 3/4	(146)			13 1/4	(337)

Figure F-21. Exterior Vehicle Crush (NASS) - Side, Test No. HBIB-8

Model Year: 2019 | Test Name: HBIB-10 | VIN: 3KPC24A34KE056878
Make: Hyundai | Model: Accent Sedan

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	87.5718	13.7789	6.1769	87.6088	13.8296	4.0682	-0.0370	-0.0507	2.1087	2.1096	2.1087	Z
	2	88.0256	17.6857	6.1560	88.0162	17.7059	3.8642	0.0094	-0.0202	2.2918	2.2919	2.2918	X, Z
	3	88.4724	22.5487	5.9233	88.4595	22.4828	3.4857	0.0129	0.0659	2.4376	2.4385	2.4376	X, Z
	4	88.7466	27.4109	5.0038	88.6028	27.4278	2.4815	0.1438	-0.0169	2.5223	2.5265	2.5264	X, Z
	5	88.2997	31.6835	3.6195	88.0778	31.5425	0.8952	0.2219	0.1410	2.7243	2.7370	2.7333	X, Z
	6	83.3584	13.8977	8.4949	83.4494	13.9984	6.4108	-0.0910	-0.1007	2.0841	2.0885	2.0841	Z
	7	83.5150	18.7281	8.6132	83.5449	18.8180	6.3890	-0.0299	-0.0899	2.2242	2.2262	2.2242	Z
	8	84.4209	24.0539	7.8264	84.4224	24.1635	5.4194	-0.0015	-0.1096	2.4070	2.4095	2.4070	Z
	9	85.3021	29.2086	8.2815	85.1976	29.3130	5.7814	0.1045	-0.1044	2.5001	2.5045	2.5023	X, Z
	10	85.8198	32.9187	6.6490	85.8296	32.8814	3.8763	-0.0098	0.0373	2.7727	2.7730	2.7727	Z
FLOOR PAN (Z)	11	78.5116	13.4334	8.8637	78.5530	13.5191	6.8155	-0.0414	-0.0857	2.0482	2.0504	2.0482	Z
	12	79.6640	20.3682	10.6147	79.7956	20.4961	8.4353	-0.1316	-0.1279	2.1794	2.1871	2.1794	Z
	13	80.6487	24.8401	9.5145	80.6893	24.9237	7.2028	-0.0406	-0.0836	2.3117	2.3136	2.3117	Z
	14	81.9311	30.1027	10.1525	81.9182	30.2974	7.6819	0.0129	-0.1947	2.4706	2.4783	2.4706	Z
	15	82.7109	32.7629	9.8845	82.6966	32.9386	7.3090	0.0143	-0.1757	2.5755	2.5815	2.5755	Z
	16	74.0342	13.6511	8.5340	74.0528	13.7418	6.5838	-0.0186	-0.0907	1.9502	1.9524	1.9502	Z
	17	73.0868	17.5014	10.7781	73.2598	17.5429	8.8001	-0.1730	-0.0415	1.9780	1.9860	1.9780	Z
	18	72.7652	21.2562	10.9061	72.8597	21.4279	8.8701	-0.0945	-0.1717	2.0360	2.0454	2.0360	Z
	19	73.1207	25.2210	9.9304	73.1843	25.2979	7.7998	-0.0636	-0.0769	2.1306	2.1329	2.1306	Z
	20	73.0429	32.5234	10.9016	73.0111	32.6743	8.6094	0.0318	-0.1509	2.2922	2.2974	2.2922	Z
	21	67.9789	13.9977	8.2743	68.0115	13.9991	6.2805	-0.0326	-0.0014	1.9938	1.9941	1.9938	Z
	22	67.9166	16.8331	11.0544	68.0765	16.9959	9.1669	-0.1599	-0.1628	1.8875	1.9012	1.8875	Z
	23	68.2905	21.7824	10.9673	68.4146	21.8610	9.0816	-0.1241	-0.0786	1.8857	1.8914	1.8857	Z
	24	68.4640	25.8589	10.0348	68.5107	26.0057	7.9978	-0.0467	-0.1468	2.0370	2.0428	2.0370	Z
	25	68.9153	33.5437	10.9312	68.8821	33.6907	8.7664	0.0332	-0.1470	2.1648	2.1700	2.1648	Z
	26	63.2210	14.3604	8.4603	63.2520	14.4029	6.6733	-0.0310	-0.0425	1.7870	1.7878	1.7870	Z
	27	63.6586	17.6172	10.9271	63.8101	17.6650	9.0988	-0.1515	-0.0478	1.8283	1.8352	1.8283	Z
	28	64.2866	22.0952	11.1234	64.4241	22.2165	9.2401	-0.1375	-0.1213	1.8833	1.8922	1.8833	Z
	29	64.5832	25.6400	10.1233	64.6270	25.7068	8.1899	-0.0438	-0.0668	1.9334	1.9350	1.9334	Z
	30	65.0766	33.5846	11.0130	65.0829	33.7138	8.9623	-0.0063	-0.1292	2.0507	2.0548	2.0507	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-10

Model Year: 2019	Test Name: HBIB-10	VIN: 3KPC24A34KE056878	
	Make: Hyundai	Model: Accent Sedan	

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	89.3286	1.6049	5.5237	89.4593	1.1729	5.8957	-0.1307	0.4320	-0.3720	0.5849	0.0000	NA
	2	89.2192	5.5357	5.4491	89.3478	5.0688	5.6879	-0.1286	0.4669	-0.2388	0.5400	0.0000	NA
	3	88.9637	10.4089	5.1510	89.1540	9.8618	5.3038	-0.1903	0.5471	-0.1528	0.5991	0.0000	NA
	4	88.5290	15.2471	4.1689	88.6500	14.7810	4.2891	-0.1210	0.4661	-0.1202	0.4963	0.0000	NA
	5	87.4594	19.3924	2.7392	87.6036	18.7876	2.6846	-0.1442	0.6048	0.0546	0.6241	0.0546	Z
	6	85.1700	1.1536	7.8993	85.2797	0.7852	8.1756	-0.1097	0.3684	-0.2763	0.4734	0.0000	NA
	7	84.6363	5.9581	7.9568	84.7302	5.5743	8.1428	-0.0939	0.3838	-0.1860	0.4367	0.0000	NA
	8	84.7622	11.3471	7.0926	84.8997	10.9885	7.1728	-0.1375	0.3586	-0.0802	0.3923	0.0000	NA
	9	84.9034	16.5807	7.4727	84.9738	16.1956	7.5331	-0.0704	0.3851	-0.0604	0.3961	0.0000	NA
	10	84.8656	20.3035	5.7881	85.1517	19.8154	5.6285	-0.2861	0.4881	0.1596	0.5878	0.1596	Z
FLOOR PAN (Z)	11	80.4442	0.0076	8.3420	80.4858	-0.3445	8.5084	-0.0416	0.3521	-0.1664	0.3917	-0.1664	Z
	12	80.6152	7.0598	9.9922	80.7598	6.7369	10.1288	-0.1446	0.3229	-0.1366	0.3793	-0.1366	Z
	13	80.9373	11.6106	8.8241	81.0719	11.2436	8.8983	-0.1346	0.3670	-0.0742	0.3979	-0.0742	Z
	14	81.4623	17.0107	9.3800	81.5639	16.7336	9.3819	-0.1016	0.2771	-0.0019	0.2951	-0.0019	Z
	15	81.8506	19.7509	9.0688	81.9877	19.4550	9.0139	-0.1371	0.2959	0.0549	0.3307	0.0549	Z
	16	75.9779	-0.4206	8.0727	76.0003	-0.7257	8.2091	-0.0224	-0.3051	-0.1364	0.3350	-0.1364	Z
	17	74.5176	3.2862	10.2831	74.6727	2.9364	10.4036	-0.1551	0.3498	-0.1205	0.4012	-0.1205	Z
	18	73.6643	6.9581	10.3700	73.7558	6.7330	10.4576	-0.0915	0.2251	-0.0876	0.2583	-0.0876	Z
	19	73.4377	10.9189	9.3414	73.5761	10.6111	9.3823	-0.1384	0.3078	-0.0409	0.3400	-0.0409	Z
	20	72.3292	18.1484	10.2248	72.4060	17.8985	10.1703	-0.0768	0.2499	0.0545	0.2671	0.0545	Z
	21	69.9325	-0.9453	7.8942	69.9841	-1.2788	7.8151	-0.0516	-0.3335	0.0791	0.3466	0.0791	Z
	22	69.4997	1.8908	10.6404	69.6042	1.7013	10.6944	-0.1045	0.1895	-0.0540	0.2230	-0.0540	Z
	23	69.1615	6.8411	10.4879	69.2900	6.5679	10.6017	-0.1285	0.2732	-0.1138	0.3226	-0.1138	Z
	24	68.7393	10.8872	9.5036	68.8474	10.6876	9.5088	-0.1081	0.1996	-0.0052	0.2271	-0.0052	Z
	25	68.0989	18.5695	10.3002	68.1762	18.3536	10.2632	-0.0773	0.2159	0.0370	0.2323	0.0370	Z
	26	65.1743	-1.2628	8.1428	65.2080	-1.5150	8.1358	-0.0337	-0.2522	0.0070	0.2545	0.0070	Z
	27	65.1721	2.0573	10.5635	65.2881	1.7938	10.5610	-0.1160	0.2635	0.0025	0.2879	0.0025	Z
	28	65.1561	6.5815	10.6966	65.2858	6.3866	10.6998	-0.1297	0.1949	-0.0032	0.2341	-0.0032	Z
	29	64.9310	10.1179	9.6494	65.0361	9.8721	9.6437	-0.1051	0.2458	0.0057	0.2674	0.0057	Z
	30	64.2949	18.0633	10.4356	64.4055	17.8686	10.4023	-0.1106	0.1947	0.0333	0.2264	0.0333	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-10

Test Name: HBIB-10 VIN: 3KPC24A34KE056878

Model Year: 2019 Make: Hyundai Model: Accent Sedan

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)	31	72.9933	11.2643	-18.9035	72.4977	10.6510	-20.8509	0.4956	0.6133	-1.9474	2.1010	2.1010	X, Y, Z
	32	73.9613	21.3984	-18.7340	73.3066	20.8014	-20.8187	0.6547	0.5970	-2.0847	2.2652	2.2652	X, Y, Z
	33	76.8372	32.0253	-18.0403	75.8201	31.2588	-20.3721	1.0171	0.7665	-2.3318	2.6569	2.6569	X, Y, Z
	34	68.8121	10.4090	-12.1100	68.7793	9.6497	-13.8713	0.0328	0.7593	-1.7613	1.9183	1.9183	X, Y, Z
	35	71.4771	22.4371	-11.7750	71.1369	21.6917	-13.7582	0.3402	0.7454	-1.9832	2.1458	2.1458	X, Y, Z
	36	73.8140	33.1063	-12.3933	73.0089	32.4193	-14.7028	0.8051	0.6870	-2.3095	2.5405	2.5405	X, Y, Z
SIDE PANEL (Y)	37	83.6704	35.8507	1.7983	83.3815	35.6312	-0.8210	0.2889	0.2195	-2.6193	2.6443	0.2195	Y
	38	80.9882	36.0210	3.8201	80.7301	35.8070	1.2366	0.2581	0.2140	-2.5835	2.6052	0.2140	Y
	39	81.9255	35.6718	-0.3925	81.4648	35.2983	-2.8964	0.4607	0.3735	-2.5039	2.5732	0.3735	Y
IMPACT SIDE DOOR (Y)	40	47.3498	39.0889	-13.4146	46.5788	39.8696	-15.2074	0.7710	-0.7807	-1.7928	2.1019	-0.7807	Y
	41	61.2528	38.8671	-12.6870	60.3657	39.2006	-14.8158	0.8871	-0.3335	-2.1288	2.3302	-0.3335	Y
	42	69.7449	37.6614	-12.4920	68.7846	37.3047	-14.7636	0.9603	0.3567	-2.2716	2.4919	0.3567	Y
	43	49.6268	39.0614	-0.4661	49.3396	39.9670	-2.3654	0.2872	-0.9056	-1.8993	2.1237	-0.9056	Y
	44	64.1524	38.7725	2.9675	63.5827	39.0963	0.7633	0.5697	-0.3238	-2.2042	2.2995	-0.3238	Y
	45	69.7268	38.6773	2.8133	69.2010	38.9809	0.3376	0.5258	-0.3036	-2.4757	2.5491	-0.3036	Y
ROOF - (Z)	46	61.8857	9.0830	-33.0468	60.8585	9.3264	-34.4165	1.0272	-0.2434	-1.3697	1.7293	-1.3697	Z
	47	62.2582	18.8553	-33.0168	61.1017	19.1280	-34.7514	1.1565	-0.2727	-1.7346	2.1025	-1.7346	Z
	48	61.7270	27.6217	-32.8849	60.5765	27.9074	-34.9653	1.1505	-0.2857	-2.0804	2.3944	-2.0804	Z
	49	50.8416	10.5797	-36.6503	49.7817	10.6871	-37.1470	1.0599	-0.1074	-0.4967	1.1754	-0.4967	Z
	50	51.2967	17.6121	-36.5741	50.0670	17.6065	-37.8223	1.2297	0.0056	-1.2482	1.7522	-1.2482	Z
	51	51.7518	26.1149	-36.1809	50.3762	26.0522	-37.8789	1.3756	0.0627	-1.6980	2.1862	-1.6980	Z
	52	40.2599	11.5662	-37.4227	39.3258	11.3775	-37.7951	0.9341	0.1887	-0.3724	1.0231	-0.3724	Z
	53	40.6865	18.0988	-37.3446	39.3826	18.0589	-38.0715	1.3039	0.0399	-0.7269	1.4934	-0.7269	Z
	54	41.3146	26.1037	-36.9813	40.0237	25.9699	-38.2494	1.2909	0.1338	-1.2681	1.8145	-1.2681	Z
	55	25.1543	13.0659	-37.1914	24.6367	13.0633	-35.9688	0.5176	0.0026	1.2226	1.3277	1.2226	Z
	56	25.5736	19.0002	-37.1136	24.9959	18.9581	-36.1384	0.5777	0.0421	0.9752	1.1343	0.9752	Z
	57	26.0064	27.0533	-36.7135	25.1127	26.8972	-37.0968	0.8937	0.1561	-0.3833	0.9849	-0.3833	Z
	58	12.0635	12.0439	-35.5381	11.4037	12.1121	-35.5969	0.6598	-0.0682	-0.0588	0.6659	-0.0588	Z
	59	12.3038	18.8210	-35.4409	11.5749	18.8824	-35.5211	0.7289	-0.0614	-0.0802	0.7359	-0.0802	Z
	60	13.4057	28.5085	-35.0149	12.6726	28.3841	-35.1495	0.7331	0.1244	-0.1346	0.7557	-0.1346	Z
A-PILLAR Maximum (X, Y, Z)	61	82.9615	34.3890	-22.1040	81.7402	33.3056	-24.8707	1.2213	1.0834	-2.7667	3.2125	1.6326	X, Y
	62	78.7868	33.9757	-24.2760	77.5394	33.3406	-26.7686	1.2474	0.6351	-2.4926	2.8587	1.3998	X, Y
	63	74.3300	33.4984	-26.5834	73.0871	33.2265	-28.9708	1.2429	0.2719	-2.3874	2.7053	1.2723	X, Y
	64	70.8079	33.1002	-28.2466	69.5062	33.1921	-30.6418	1.3017	-0.0919	-2.3952	2.7276	1.3017	X
	65	66.7833	32.7162	-29.4806	65.4670	33.3893	-31.8665	1.3163	-0.6731	-2.3859	2.8068	1.3163	X
	66	63.4331	32.2190	-31.5188	62.1748	32.6472	-33.7548	1.2583	-0.4282	-2.2360	2.6012	1.2583	X
A-PILLAR Lateral (Y)	61	82.9615	34.3890	-22.1040	81.7402	33.3056	-24.8707	1.2213	1.0834	-2.7667	3.2125	1.0834	Y
	62	78.7868	33.9757	-24.2760	77.5394	33.3406	-26.7686	1.2474	0.6351	-2.4926	2.8587	0.6351	Y
	63	74.3300	33.4984	-26.5834	73.0871	33.2265	-28.9708	1.2429	0.2719	-2.3874	2.7053	0.2719	Y
	64	70.8079	33.1002	-28.2466	69.5062	33.1921	-30.6418	1.3017	-0.0919	-2.3952	2.7276	-0.0919	Y
	65	66.7833	32.7162	-29.4806	65.4670	33.3893	-31.8665	1.3163	-0.6731	-2.3859	2.8068	-0.6731	Y
	66	63.4331	32.2190	-31.5188	62.1748	32.6472	-33.7548	1.2583	-0.4282	-2.2360	2.6012	-0.4282	Y
B-PILLAR Maximum (X, Y, Z)	67	40.6752	33.6298	-30.6597	39.4049	33.7491	-32.0632	1.2703	-0.1193	-1.4035	1.8968	1.2703	X
	68	38.5598	35.5975	-26.5153	37.4306	35.6485	-27.8748	1.1292	-0.0510	-1.3595	1.7680	1.1292	X
	69	42.8225	37.0902	-21.5250	42.1689	37.1923	-22.9124	0.6536	-0.1021	-1.3874	1.5370	0.6536	X
	70	39.9623	38.0759	-14.4620	39.2378	38.0821	-15.8457	0.7245	-0.0062	-1.3837	1.5619	0.7245	X
B-PILLAR Lateral (Y)	67	40.6752	33.6298	-30.6597	39.4049	33.7491	-32.0632	1.2703	-0.1193	-1.4035	1.8968	-0.1193	Y
	68	38.5598	35.5975	-26.5153	37.4306	35.6485	-27.8748	1.1292	-0.0510	-1.3595	1.7680	-0.0510	Y
	69	42.8225	37.0902	-21.5250	42.1689	37.1923	-22.9124	0.6536	-0.1021	-1.3874	1.5370	-0.1021	Y
	70	39.9623	38.0759	-14.4620	39.2378	38.0821	-15.8457	0.7245	-0.0062	-1.3837	1.5619	-0.0062	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-10

Test Name: HBIB-10 VIN: 3KPC24A34KE056878
Model Year: 2019 Make: Hyundai Model: Accent Sedan

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)	31	74.9537	-3.3161	-19.3163	75.2875	-4.0118	-19.2377	-0.3338	-0.6957	0.0786	0.7756	0.7756	X, Y, Z
	32	74.4657	6.8537	-19.2835	74.7313	6.1556	-19.2195	-0.2656	0.6981	0.0640	0.7497	0.7497	X, Y, Z
	33	75.8019	17.7909	-18.7595	75.8170	16.8555	-18.7623	-0.0151	0.9354	-0.0028	0.9355	0.9355	X, Y, Z
	34	71.0209	-4.6641	-12.4547	71.6312	-5.4975	-12.3118	-0.6103	-0.8334	0.1429	1.0428	1.0428	X, Y, Z
	35	71.9438	7.6248	-12.3033	72.3555	6.7517	-12.1944	-0.4117	0.8731	0.1089	0.9714	0.9714	X, Y, Z
	36	72.7244	18.5086	-13.0840	72.7904	17.6328	-13.1386	-0.0660	0.8758	-0.0546	0.8800	0.8800	X, Y, Z
SIDE PANEL (Y)	37	82.2602	22.8304	0.9329	82.4292	22.2106	0.8881	-0.1690	0.6198	-0.0448	0.6440	0.6198	Y
	38	79.6061	22.6444	2.9902	79.7474	22.0313	2.9055	-0.1413	0.6131	-0.0847	0.6348	0.6131	Y
	39	80.5321	22.3735	-1.2307	80.6059	21.6232	-1.2148	-0.0738	0.7503	0.0159	0.7541	0.7503	Y
IMPACT SIDE DOOR (Y)	40	45.6665	20.6382	-13.8047	45.6121	21.4812	-14.0563	0.0544	-0.8430	-0.2516	0.8814	-0.8430	Y
	41	59.4664	22.4131	-13.2706	59.3571	22.6622	-13.4575	0.1093	-0.2491	-0.1869	0.3300	-0.2491	Y
	42	68.0453	22.4345	-13.1806	67.9522	21.9093	-13.2748	0.0931	0.5252	-0.0942	0.5416	0.5252	Y
	43	48.0821	21.1176	-0.8902	48.1406	21.9540	-1.1749	-0.0585	-0.8364	-0.2847	0.8855	-0.8364	Y
	44	62.5408	22.9528	2.3415	62.3232	22.9977	2.1681	0.2176	-0.0449	-0.1734	0.2818	-0.0449	Y
	45	68.0692	23.6520	2.1100	67.9123	23.6344	1.8265	0.1569	0.0176	-0.2835	0.3245	0.0176	Y
ROOF - (Z)	46	64.0998	-7.2586	-33.2742	64.1364	-6.8885	-32.9719	-0.0366	0.3701	0.3023	0.4793	0.3023	Z
	47	63.0725	2.4664	-33.3680	63.0719	2.8574	-33.3283	0.0006	-0.3910	0.0397	0.3930	0.0397	Z
	48	61.2958	11.0682	-33.3351	61.3808	11.4876	-33.5725	-0.0850	-0.4194	-0.2374	0.4894	-0.2374	Z
	49	52.9120	-7.4040	-36.7395	53.0197	-7.0228	-35.8708	-0.1077	0.3812	0.8687	0.9548	0.8687	Z
	50	52.3585	-0.3782	-36.7552	52.3875	-0.1278	-36.5595	-0.0290	0.2504	0.1957	0.3191	0.1957	Z
	51	51.5988	8.1071	-36.4717	51.5654	8.2834	-36.6332	0.0334	-0.1763	-0.1615	0.2414	-0.1615	Z
	52	42.2893	-7.9486	-37.3747	42.5764	-7.7373	-36.6765	-0.2871	0.2113	0.6982	0.7839	0.6982	Z
	53	41.7790	-1.4216	-37.3819	41.7435	-1.1085	-36.9692	0.0355	0.3131	0.4127	0.5192	0.4127	Z
	54	41.2613	6.5953	-37.1248	41.3236	6.8171	-37.1579	-0.0623	-0.2218	-0.0331	0.2327	-0.0331	Z
	55	27.1284	-8.6170	-36.9488	27.7679	-8.0301	-35.0738	-0.6395	0.5869	1.8750	2.0662	1.8750	Z
	56	26.6963	-2.6831	-36.9490	27.3382	-2.1403	-35.2532	-0.6419	0.5428	1.6958	1.8927	1.6958	Z
	57	25.9789	5.3541	-36.6528	26.4068	5.7425	-36.2301	-0.4279	-0.3884	0.4227	0.7160	0.4227	Z
	58	14.3391	-11.4735	-35.0988	14.7768	-10.7424	-34.8969	-0.4377	0.7311	0.2019	0.8757	0.2019	Z
	59	13.6097	-4.7308	-35.0873	14.0400	-4.0099	-34.8359	-0.4303	0.7209	0.2514	0.8764	0.2514	Z
	60	13.3212	5.0198	-34.7946	13.8516	5.5535	-34.4724	-0.5304	-0.5337	0.3222	0.8185	0.3222	Z
A-PILLAR Maximum (X, Y, Z)	61	81.4755	20.9473	-22.9375	81.4775	19.6732	-23.1773	-0.0020	1.2741	-0.2398	1.2965	1.2741	Y
	62	77.3765	19.9119	-25.0453	77.3389	19.1450	-25.1377	0.0376	0.7669	-0.0924	0.7734	0.7678	X, Y
	63	73.0058	18.7712	-27.2836	72.9757	18.4353	-27.4058	0.0301	0.3359	-0.1222	0.3587	0.3372	X, Y
	64	69.5567	17.8511	-28.8921	69.4573	17.9214	-29.1299	0.0994	-0.0703	-0.2378	0.2672	0.0994	X
	65	65.6135	16.8794	-30.0645	65.4470	17.5759	-30.4153	0.1665	-0.6965	-0.3508	0.7974	0.1665	X
	66	62.3441	15.8807	-32.0491	62.3125	16.3993	-32.3505	0.0316	-0.5186	-0.3014	0.6007	0.0316	X
A-PILLAR Lateral (Y)	61	81.4755	20.9473	-22.9375	81.4775	19.6732	-23.1773	-0.0020	1.2741	-0.2398	1.2965	1.2741	Y
	62	77.3765	19.9119	-25.0453	77.3389	19.1450	-25.1377	0.0376	0.7669	-0.0924	0.7734	0.7669	Y
	63	73.0058	18.7712	-27.2836	72.9757	18.4353	-27.4058	0.0301	0.3359	-0.1222	0.3587	0.3359	Y
	64	69.5567	17.8511	-28.8921	69.4573	17.9214	-29.1299	0.0994	-0.0703	-0.2378	0.2672	-0.0703	Y
	65	65.6135	16.8794	-30.0645	65.4470	17.5759	-30.4153	0.1665	-0.6965	-0.3508	0.7974	-0.6965	Y
	66	62.3441	15.8807	-32.0491	62.3125	16.3993	-32.3505	0.0316	-0.5186	-0.3014	0.6007	-0.5186	Y
B-PILLAR Maximum (X, Y, Z)	67	39.6303	14.0410	-30.8866	39.5767	14.4470	-31.0015	0.0536	-0.4060	-0.1149	0.4253	0.0536	X
	68	37.3062	15.7446	-26.7370	37.3031	16.0676	-26.8479	0.0031	-0.3230	-0.1109	0.3415	0.0031	X
	69	41.3725	17.9002	-21.8257	41.7168	18.2339	-21.8194	-0.3443	-0.3337	0.0063	0.4795	0.0063	Z
	70	38.4873	18.5667	-14.7356	38.5865	18.7277	-14.7994	-0.0992	-0.1610	-0.0638	0.1996	0.0000	NA
B-PILLAR Lateral (Y)	67	39.6303	14.0410	-30.8866	39.5767	14.4470	-31.0015	0.0536	-0.4060	-0.1149	0.4253	-0.4060	Y
	68	37.3062	15.7446	-26.7370	37.3031	16.0676	-26.8479	0.0031	-0.3230	-0.1109	0.3415	-0.3230	Y
	69	41.3725	17.9002	-21.8257	41.7168	18.2339	-21.8194	-0.3443	-0.3337	0.0063	0.4795	-0.3337	Y
	70	38.4873	18.5667	-14.7356	38.5865	18.7277	-14.7994	-0.0992	-0.1610	-0.0638	0.1996	-0.1610	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-10

Model Year:	2019	Test Name:	HBIB-10
		Make:	Hyundai
VIN:	3KPC24A34KE056878	Model:	Accent Sedan

Passenger Side Maximum Deformations

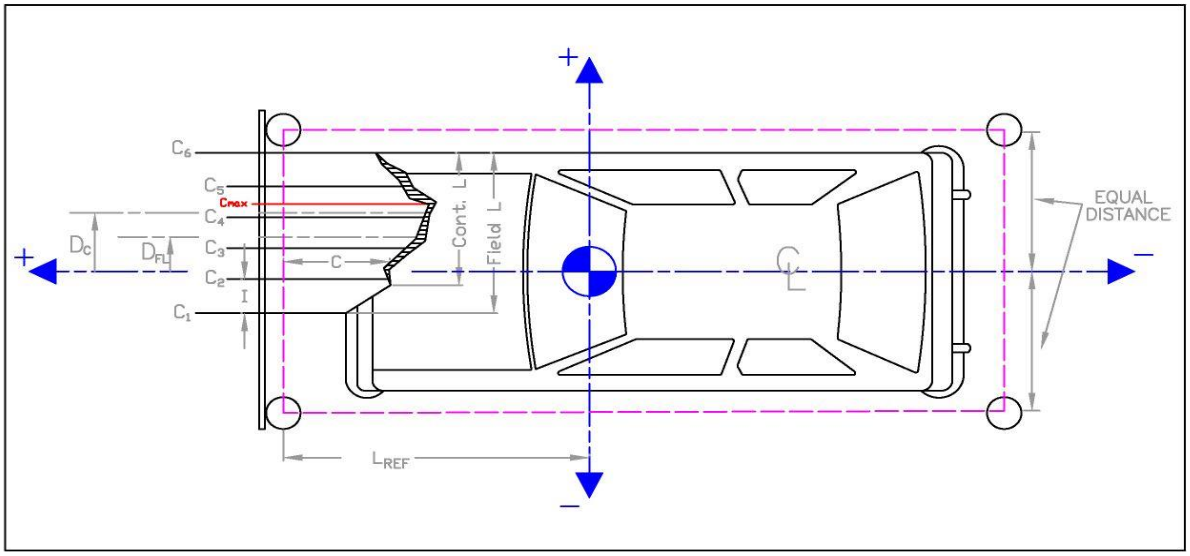
Primary Reference Set				Secondary Reference Set			
Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]	Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]
Roof	1.2	≤ 4	Z	Roof	1.9	≤ 4	Z
Windshield[D]	N/A	≤ 3	X, Z	Windshield[D]	N/A	≤ 3	X, Z
A-Pillar Maximum	1.6	≤ 5	X, Y	A-Pillar Maximum	1.3	≤ 5	Y
A-Pillar Lateral	1.1	≤ 3	Y	A-Pillar Lateral	1.3	≤ 3	Y
B-Pillar Maximum	1.3	≤ 5	X	B-Pillar Maximum	0.1	≤ 5	X
B-Pillar Lateral	-0.1	≤ 3	Y	B-Pillar Lateral	-0.4	≤ 3	Y
Toe Pan - Wheel Well	2.8	≤ 9	Z	Toe Pan - Wheel Well	0.2	≤ 9	Z
Side Front Panel	0.4	≤ 12	Y	Side Front Panel	0.8	≤ 12	Y
Side Door (above seat)	0.4	≤ 9	Y	Side Door (above seat)	0.5	≤ 9	Y
Side Door (below seat)	-0.9	≤ 12	Y	Side Door (below seat)	0.0	≤ 12	Y
Floor Pan	2.6	≤ 12	Z	Floor Pan	0.1	≤ 12	Z
Dash - no MASH requirement	2.7	NA	X, Y, Z	Dash - no MASH requirement	1.0	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:
Windshield shattering was due to loading on the A-pillar. See scan for deformation value.

Figure F-26. Maximum Occupant Compartment Deformations by Location, Test No. HBIB-10

		Test Name:	HBIB-10	VIN:	3KPC24A34KE056878
Model Year:	2019	Make:	Hyundai	Model:	Accent Sedan



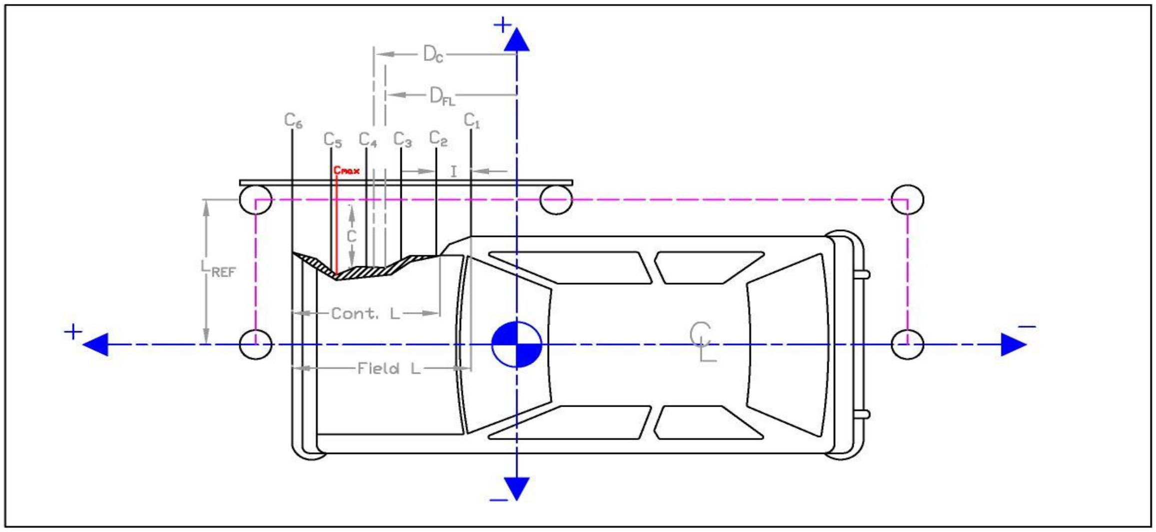
	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	80	(2032)
Total Width of Vehicle:	67 1/4	(1708)
Width of contact and induced crush - Field L:	14 3/4	(375)
Crush measurement spacing interval (L/5) - I:	3	(76)
Distance from center of vehicle to center of Field L - D_{FL}:	24 1/5	(614)
Width of Contact Damage:	14 3/4	(375)
Distance from center of vehicle to center of contact damage - D_C:	24 1/5	(614)

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	9 1/2	(241)	16 7/8	(429)	5 3/4	(146)	4 4/9	(113)	- 2/3	-(17)
C_2	10 5/8	(270)	19 7/8	(505)	6 7/8	(175)			- 2/3	-(17)
C_3	19 4/5	(503)	22 7/8	(581)	8 3/4	(222)			6 5/8	(168)
C_4	20 1/2	(521)	25 7/8	(657)	10 1/2	(267)			5 4/7	(141)
C_5	N/A	NA	28 7/8	(733)	12 5/8	(321)			NA	NA
C_6	N/A	NA	31 7/8	(810)	16 5/8	(422)			NA	NA
C_{MAX}	19 4/5	(503)	22 7/8	(581)	8 3/4	(222)			6 5/8	(168)

Figure F-27. Exterior Vehicle Crush (NASS) - Front, Test No. HBIB-10

		Test Name:	HBIB-10	VIN:	3KPC24A34KE056878
Model Year:	2019	Make:	Hyundai	Model:	Accent Sedan



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	42 1/4	(1073)
Total Vehicle Length:	172 3/8	(4378)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-15	-(379)
Width of contact and induced crush - Field L:	93 1/4	(2369)
Crush measurement spacing interval (L/5) - I:	18 5/8	(473)
Distance from vehicle c.g. to center of Field L - D_{FL}:	24 5/8	(625)
Width of Contact Damage:	91	(2311)
Distance from vehicle c.g. to center of contact damage - D_C:	24 5/8	(625)

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	10 1/2	(267)	-22	-(559)	4 1/4	(108)	5 1/4	(133)	1	(25)
C_2	9 1/2	(241)	-3 3/8	-(86)	4 1/4	(108)			0	()
C_3	12	(305)	15 1/4	(387)	3 3/4	(95)			3	(76)
C_4	NA	NA	33 7/8	(860)	3 1/2	(89)			NA	NA
C_5	15 1/2	(394)	52 1/2	(1334)	4 1/4	(108)			6	(152)
C_6	N/A	NA	71 1/8	(1807)	32	(813)			NA	NA
C_{MAX}	23 1/2	(597)	65 1/2	(1664)	7 1/2	(191)			10 3/4	(273)

Figure F-28. Exterior Vehicle Crush (NASS) - Side, Test No. HBIB-10

Model Year: 2019 | Test Name: HBIB-9 | VIN: 1C6RR6FG0KS526339
Make: Ram | Model: 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)	71	49.4297	17.5022	-3.3959	49.1991	17.6777	-2.5848	0.2306	-0.1755	-0.8111	0.8613	0.2306	X
	72	50.3919	21.5721	-1.3243	50.0745	21.7072	-0.4130	0.3174	-0.1351	-0.9113	0.9744	0.3174	X
	73	51.8486	24.9540	1.7693	51.6383	24.9671	2.7478	0.2103	-0.0131	-0.9785	1.0009	0.2103	X
	74	51.8746	30.2474	2.0487	51.5555	30.2393	2.9262	0.3191	0.0081	-0.8775	0.9338	0.3191	X
	75	52.1498	36.1214	1.8939	50.3317	35.9868	2.7723	1.8181	0.1346	-0.8784	2.0237	1.8181	X
	76	46.2362	16.1232	-2.1065	46.0562	16.1634	-1.4204	0.1800	-0.0402	-0.6861	0.7105	0.1800	X
	77	47.1524	21.0440	0.9365	47.0345	21.0405	1.8421	0.1179	0.0035	-0.9056	0.9132	0.1179	X
	78	48.5259	24.3740	3.7345	48.2732	24.3305	4.7030	0.2527	0.0435	-0.9685	1.0019	0.2527	X
	79	48.5907	29.9108	4.0054	48.2737	29.8510	4.9620	0.3170	0.0598	-0.9566	1.0095	0.3170	X
	80	48.8219	36.4048	3.8384	48.5591	36.1213	4.7758	0.2628	0.2835	-0.9374	1.0140	0.2628	X
FLOOR PAN (Z)	81	41.9599	15.3083	-1.1907	41.9410	15.2954	-0.3221	0.0189	0.0129	-0.8686	0.8689	-0.8686	Z
	82	43.7013	20.7230	4.1475	43.4731	20.6931	5.0137	0.2282	0.0299	-0.8662	0.8963	-0.8662	Z
	83	43.8314	24.6432	4.3785	43.6145	24.6289	5.2736	0.2169	0.0143	-0.8951	0.9211	-0.8951	Z
	84	43.8301	29.5876	4.3524	43.5595	29.6196	5.3685	0.2706	-0.0320	-1.0161	1.0520	-1.0161	Z
	85	43.6981	36.6202	4.6219	43.4468	36.5393	5.4984	0.2513	0.0809	-0.8765	0.9154	-0.8765	Z
	86	37.6216	15.3657	-0.0913	37.5149	15.4487	0.4902	0.1067	-0.0830	-0.5815	0.5970	-0.5815	Z
	87	39.0328	19.3082	4.7031	38.8145	19.2753	5.4656	0.2183	0.0329	-0.7625	0.7938	-0.7625	Z
	88	39.3130	25.2260	4.6146	39.0900	25.1960	5.4774	0.2230	0.0300	-0.8628	0.8917	-0.8628	Z
	89	38.8133	29.4981	4.6097	38.5178	29.4205	5.6075	0.2955	0.0776	-0.9978	1.0435	-0.9978	Z
	90	39.2664	35.9369	4.6796	38.9764	35.8811	5.6647	0.2900	0.0558	-0.9851	1.0284	-0.9851	Z
	91	34.6062	15.4123	0.2126	34.5215	15.5481	0.8086	0.0847	-0.1358	-0.5960	0.6171	-0.5960	Z
	92	35.6221	20.0623	4.8032	35.4355	20.1063	5.4985	0.1866	-0.0440	-0.6953	0.7212	-0.6953	Z
	93	35.9937	26.0037	4.7337	35.7782	25.9742	5.5511	0.2155	0.0295	-0.8174	0.8458	-0.8174	Z
	94	35.7331	30.1488	4.7091	35.4577	30.1009	5.6560	0.2754	0.0479	-0.9469	0.9873	-0.9469	Z
	95	35.5591	35.9144	4.6801	35.2787	35.8369	5.6112	0.2804	0.0775	-0.9311	0.9755	-0.9311	Z
	96	31.8017	15.5097	0.6095	31.6841	15.6132	1.1082	0.1176	-0.1035	-0.4987	0.5227	-0.4987	Z
	97	32.1533	20.2101	4.1587	31.9305	20.2221	4.7383	0.2228	-0.0120	-0.5796	0.6211	-0.5796	Z
	98	32.3184	26.1004	4.2492	32.0926	26.1537	4.8859	0.2258	-0.0533	-0.6367	0.6777	-0.6367	Z
	99	32.1201	30.4049	4.1202	31.8830	30.4205	4.7780	0.2371	-0.0156	-0.6578	0.6994	-0.6578	Z
	100	31.8055	35.6107	3.9120	31.5499	35.5276	4.5944	0.2556	0.0831	-0.6824	0.7334	-0.6824	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-9

Model Year: 2019 | Test Name: HBIB-9 | VIN: 1C6RR6FG0KS526339
Make: Ram | Model: 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)	71	50.6748	28.9666	-7.1432	50.4019	28.8346	-6.9063	0.2729	0.1320	-0.2369	0.3847	0.2729	X
	72	51.6993	33.0201	-5.0694	51.3790	32.8648	-4.7797	0.3203	0.1553	-0.2897	0.4590	0.3203	X
	73	53.1968	36.3777	-1.9689	53.0250	36.1195	-1.6554	0.1718	0.2582	-0.3135	0.4410	0.1718	X
	74	53.3228	41.6700	-1.6960	53.0752	41.3938	-1.5362	0.2476	0.2762	-0.1598	0.4039	0.2476	X
	75	53.7126	47.5374	-1.8561	51.9969	47.1682	-1.7548	1.7157	0.3692	-0.1013	1.7579	1.7157	X
	76	47.4454	27.6513	-5.8772	47.2220	27.4133	-5.7255	0.2234	0.2380	-0.1517	0.3600	0.2234	X
	77	48.4326	32.5579	-2.8334	48.3234	32.3004	-2.5177	0.1092	0.2575	-0.3157	0.4218	0.1092	X
	78	49.8483	35.8647	-0.0290	49.6451	35.5900	0.3063	0.2032	0.2747	-0.3353	0.4787	0.2032	X
	79	50.0179	41.3996	0.2353	49.7849	41.1113	0.5033	0.2330	0.2883	-0.2680	0.4574	0.2330	X
	80	50.3756	47.8878	0.0619	50.2284	47.3699	0.2468	0.1472	0.5179	-0.1849	0.5693	0.1472	X
FLOOR PAN (Z)	81	43.1471	26.9204	-4.9938	43.0863	26.6618	-4.6181	0.0608	0.2586	-0.3757	0.4601	-0.3757	Z
	82	44.9510	32.3082	0.3509	44.7548	32.0786	0.6570	0.1962	0.2296	-0.3061	0.4300	-0.3061	Z
	83	45.1549	36.2255	0.5779	44.9955	36.0122	0.8728	0.1594	0.2133	-0.2949	0.3973	-0.2949	Z
	84	45.2494	41.1689	0.5454	45.0665	41.0035	0.9117	0.1829	0.1654	-0.3663	0.4416	-0.3663	Z
	85	45.2510	48.2031	0.8050	45.1284	47.9249	0.9639	0.1226	0.2782	-0.1589	0.3430	-0.1589	Z
	86	38.8023	27.0631	-3.9285	38.6656	26.9357	-3.8083	0.1367	0.1274	-0.1202	0.2222	-0.1202	Z
	87	40.2518	30.9845	0.8718	40.0620	30.7840	1.1241	0.1898	0.2005	-0.2523	0.3740	-0.2523	Z
	88	40.6469	36.8957	0.7779	40.4867	36.6955	1.0695	0.1602	0.2002	-0.2916	0.3883	-0.2916	Z
	89	40.2299	41.1766	0.7636	40.0214	40.9344	1.1521	0.2085	0.2422	-0.3885	0.5031	-0.3885	Z
	90	40.8066	47.6056	0.8288	40.6429	47.3816	1.1369	0.1637	0.2240	-0.3081	0.4146	-0.3081	Z
	91	35.7860	27.1684	-3.6483	35.6757	27.1142	-3.4914	0.1103	0.0542	-0.1569	0.1993	-0.1569	Z
	92	36.8557	31.8045	0.9441	36.7051	31.7002	1.1472	0.1506	0.1043	-0.2031	0.2735	-0.2031	Z
	93	37.3424	37.7375	0.8700	37.1957	37.5579	1.1340	0.1467	0.1796	-0.2640	0.3514	-0.2640	Z
	94	37.1622	41.8867	0.8380	36.9794	41.6922	1.1925	0.1828	0.1945	-0.3545	0.4438	-0.3545	Z
	95	37.0997	47.6545	0.8003	36.9452	47.4301	1.0833	0.1545	0.2244	-0.2830	0.3928	-0.2830	Z
	96	32.9809	27.3204	-3.2735	32.8409	27.2543	-3.1930	0.1400	0.0661	-0.0805	0.1745	-0.0805	Z
	97	33.3955	32.0182	0.2724	33.2040	31.8959	0.3852	0.1915	0.1223	-0.1128	0.2537	-0.1128	Z
	98	33.6736	37.9044	0.3566	33.5157	37.8229	0.4663	0.1579	0.0815	-0.1097	0.2088	-0.1097	Z
	99	33.5595	42.2117	0.2205	33.4138	42.0921	0.3104	0.1457	0.1196	-0.0899	0.2088	-0.0899	Z
	100	33.3470	47.4223	0.0032	33.2096	47.2036	0.0694	0.1374	0.2187	-0.0662	0.2666	-0.0662	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-9

Test Name: HBIB-9 VIN: 1C6RR6FG0KS526339

Model Year: 2019 Make: Ram Model: 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)	101	43.6732	35.0576	-27.4464	42.9787	35.0739	-27.0846	0.6945	-0.0163	0.3618	0.7833	0.7833	X, Y, Z
	102	42.3687	23.3315	-27.3468	41.9225	23.3340	-26.8933	0.4462	-0.0025	0.4535	0.6362	0.6362	X, Y, Z
	103	42.8457	7.3090	-28.2569	42.6939	7.3104	-27.7472	0.1518	-0.0014	0.5097	0.5318	0.5318	X, Y, Z
	104	38.8816	36.6128	-16.6271	38.1486	36.3953	-16.3506	0.7330	0.2175	0.2765	0.8130	0.8130	X, Y, Z
	105	38.1589	24.2944	-17.2257	37.7227	24.1497	-16.8299	0.4362	0.1447	0.3958	0.6065	0.6065	X, Y, Z
	106	36.4510	6.8752	-20.4263	36.3356	6.8519	-19.9250	0.1154	0.0233	0.5013	0.5149	0.5149	X, Y, Z
SIDE PANEL (Y)	107	48.1121	38.9586	-3.4234	47.3612	37.0350	-2.9203	0.7509	1.9236	0.5031	2.1254	1.9236	Y
	108	49.8655	38.9316	0.1220	49.1861	37.6996	0.5395	0.6794	1.2320	0.4175	1.4676	1.2320	Y
	109	47.6321	38.8791	2.6275	47.3261	38.1579	3.2548	0.3060	0.7212	0.6273	1.0036	0.7212	Y
IMPACT SIDE DOOR (Y)	110	16.4809	41.0155	-18.4143	15.3088	47.3808	-17.6230	1.1721	-6.3653	0.7913	6.5205	-6.3653	Y
	111	27.7838	40.4258	-19.5395	26.3255	45.2525	-19.1085	1.4583	-4.8267	0.4310	5.0606	-4.8267	Y
	112	35.6629	41.0150	-15.8910	33.8148	42.7228	-15.7618	1.8481	-1.7078	0.1292	2.5197	-1.7078	Y
	113	17.6033	41.2673	-1.5390	16.3357	44.8050	-0.9057	1.2676	-3.5377	0.6333	3.8109	-3.5377	Y
	114	24.9269	41.3655	-1.8936	23.3891	42.8867	-1.5092	1.5378	-1.5212	0.3844	2.1970	-1.5212	Y
	115	34.0273	42.2339	-1.9738	32.5190	42.4843	-2.0213	1.5083	-0.2504	-0.0475	1.5297	-0.2504	Y
ROOF - (Z)	116	34.9355	7.3042	-43.2575	34.5155	6.8774	-42.4741	0.4200	0.4268	0.7834	0.9860	0.7834	Z
	117	33.2976	20.6758	-43.1050	32.2666	20.1377	-41.5975	1.0310	0.5381	1.5075	1.9040	1.5075	Z
	118	30.3037	30.6525	-42.6747	28.7894	29.8997	-40.5462	1.5143	0.7528	2.1285	2.7185	2.1285	Z
	119	28.2814	7.5658	-45.9669	27.6414	6.9378	-44.8084	0.6400	0.6280	1.1585	1.4650	1.1585	Z
	120	26.9996	18.8793	-45.9034	25.7349	18.0883	-43.6710	1.2647	0.7910	2.2324	2.6849	2.2324	Z
	121	23.4614	28.6185	-45.7395	21.9108	27.4897	-42.8145	1.5506	1.1288	2.9250	3.4977	2.9250	Z
	122	13.2426	6.9864	-47.3787	12.5928	5.6416	-46.2512	0.6498	1.3448	1.1275	1.8714	1.1275	Z
	123	11.8862	16.7608	-47.2962	10.8105	15.2755	-45.0708	1.0757	1.4853	2.2254	2.8837	2.2254	Z
	124	11.2542	28.6042	-46.5646	9.7000	26.5555	-41.5354	1.5542	2.0487	5.0292	5.6485	5.0292	Z
	125	-5.8750	6.9053	-47.6064	-6.3578	4.4128	-45.3927	0.4828	2.4925	2.2137	3.3684	2.2137	Z
	126	-5.6507	15.6245	-47.5666	-6.3564	12.7500	-42.7990	0.7057	2.8745	4.7676	5.6117	4.7676	Z
	127	-5.1735	27.6793	-47.0835	-6.3741	24.4404	-39.8052	1.2006	3.2389	7.2783	8.0564	7.2783	Z
	128	-20.5846	6.4619	-47.2857	-20.3243	3.4117	-41.8635	-0.2603	3.0502	5.4222	6.2267	5.4222	Z
	129	-21.1862	15.5101	-47.2724	-21.8473	12.2276	-42.5861	0.6611	3.2825	4.6863	5.7596	4.6863	Z
	130	-21.3612	26.7381	-46.9132	-22.4564	22.8538	-39.3355	1.0952	3.8843	7.5777	8.5854	7.5777	Z
A-PILLAR Maximum (X, Y, Z)	131	30.7972	33.3547	-41.2525	29.2590	32.6435	-39.1458	1.5382	0.7112	2.1067	2.7037	2.7037	X, Y, Z
	132	35.6955	34.4729	-37.6315	34.5184	34.0207	-36.1270	1.1771	0.4522	1.5045	1.9631	1.9631	X, Y, Z
	133	41.0059	36.0334	-34.9967	40.0129	35.8899	-34.0522	0.9930	0.1435	0.9445	1.3779	1.3779	X, Y, Z
	134	43.5555	36.4855	-32.1205	42.7507	36.3686	-31.4869	0.8048	0.1169	0.6336	1.0309	1.0309	X, Y, Z
	135	45.9184	37.1540	-30.8824	45.2293	37.2756	-30.3987	0.6891	-0.1216	0.4837	0.8507	0.8419	X, Z
	136	47.2019	37.6507	-27.9292	45.4002	31.4922	-37.0232	1.8017	6.1585	-9.0940	11.1299	6.4166	X, Y
A-PILLAR Lateral (Y)	131	30.7972	33.3547	-41.2525	29.2590	32.6435	-39.1458	1.5382	0.7112	2.1067	2.7037	0.7112	Y
	132	35.6955	34.4729	-37.6315	34.5184	34.0207	-36.1270	1.1771	0.4522	1.5045	1.9631	0.4522	Y
	133	41.0059	36.0334	-34.9967	40.0129	35.8899	-34.0522	0.9930	0.1435	0.9445	1.3779	0.1435	Y
	134	43.5555	36.4855	-32.1205	42.7507	36.3686	-31.4869	0.8048	0.1169	0.6336	1.0309	0.1169	Y
	135	45.9184	37.1540	-30.8824	45.2293	37.2756	-30.3987	0.6891	-0.1216	0.4837	0.8507	-0.1216	Y
	136	47.2019	37.6507	-27.9292	45.4002	31.4922	-37.0232	1.8017	6.1585	-9.0940	11.1299	6.1585	Y
B-PILLAR Maximum (X, Y, Z)	137	6.7214	32.9566	-41.6369	3.4855	40.9437	-24.4178	3.2359	-7.9871	17.2191	19.2552	17.5205	X, Z
	138	4.2228	37.6739	-25.1009	7.8023	40.2243	-19.8882	-3.5795	-2.5504	5.2127	6.8183	5.2127	Z
	139	8.4842	38.0347	-20.5129	7.7702	40.2285	-19.8823	0.7140	-2.1938	0.6306	2.3917	0.9526	X, Z
	140	4.6087	38.1739	-14.1028	4.0296	39.6409	-13.5513	0.5791	-1.4670	0.5515	1.6708	0.7997	X, Z
B-PILLAR Lateral (Y)	137	6.7214	32.9566	-41.6369	3.4855	40.9437	-24.4178	3.2359	-7.9871	17.2191	19.2552	-7.9871	Y
	138	4.2228	37.6739	-25.1009	7.8023	40.2243	-19.8882	-3.5795	-2.5504	5.2127	6.8183	-2.5504	Y
	139	8.4842	38.0347	-20.5129	7.7702	40.2285	-19.8823	0.7140	-2.1938	0.6306	2.3917	-2.1938	Y
	140	4.6087	38.1739	-14.1028	4.0296	39.6409	-13.5513	0.5791	-1.4670	0.5515	1.6708	-1.4670	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-9

Model Year: 2019 | Test Name: HBIB-9 | Make: Ram | VIN: 1C6RR6FG0KS526339 | Model: 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)	101	45.4463	46.5954	-31.2606	44.6193	46.1061	-31.6007	0.8270	0.4893	-0.3401	1.0193	1.0193	X, Y, Z
	102	43.9149	34.8968	-31.1562	43.2672	34.3995	-31.2778	0.6477	0.4973	-0.1216	0.8256	0.8256	X, Y, Z
	103	44.0894	18.8668	-32.0420	43.6339	18.3530	-31.9518	0.4555	0.5138	0.0902	0.6925	0.6925	X, Y, Z
	104	40.6012	48.2583	-20.4811	39.8255	47.6694	-20.8830	0.7757	0.5889	-0.4019	1.0536	1.0536	X, Y, Z
	105	39.6455	35.9553	-21.0696	39.0906	35.4339	-21.2249	0.5549	0.5214	-0.1553	0.7771	0.7771	X, Y, Z
	106	37.6267	18.5677	-24.2611	37.2671	18.1429	-24.1259	0.3596	0.4248	0.1352	0.5728	0.5728	X, Y, Z
SIDE PANEL (Y)	107	49.7720	50.4444	-7.2085	49.0530	48.2271	-7.4593	0.7190	2.2173	-0.2508	2.3444	2.2173	Y
	108	51.4968	50.3887	-3.6495	50.8946	48.8843	-4.0068	0.6022	1.5044	-0.3573	1.6594	1.5044	Y
	109	49.2434	50.3828	-1.1615	49.0470	49.4198	-1.2971	0.1964	0.9630	-0.1356	0.9921	0.9630	Y
IMPACT SIDE DOOR (Y)	110	18.3044	53.0899	-22.4493	17.2699	59.2127	-22.2821	1.0345	-6.1228	0.1672	6.2118	-6.1228	Y
	111	29.6022	52.2805	-23.4852	28.2292	56.7906	-23.7419	1.3730	-4.5101	-0.2567	4.7214	-4.5101	Y
	112	37.4626	52.7228	-19.7758	35.6527	54.1105	-20.3659	1.8099	-1.3877	-0.5901	2.3558	-1.3877	Y
	113	19.2997	53.3441	-5.5660	18.2337	56.7997	-5.5367	1.0660	-3.4556	0.0293	3.6164	-3.4556	Y
	114	26.6264	53.3005	-5.8634	25.2364	54.6973	-6.1176	1.3900	-1.3968	-0.2542	1.9869	-1.3968	Y
	115	35.7422	53.9930	-5.8735	34.3532	54.0589	-6.6237	1.3890	-0.0659	-0.7502	1.5800	-0.0659	Y
ROOF - (Z)	116	36.2980	18.9932	-47.1040	35.4453	17.9613	-46.6741	0.8527	1.0319	0.4299	1.4060	0.4299	Z
	117	34.9174	32.3941	-46.9815	33.5319	31.2831	-45.9467	1.3855	1.1110	1.0348	2.0554	1.0348	Z
	118	32.1134	42.4273	-46.5875	30.3022	41.1408	-45.0055	1.8112	1.2865	1.5820	2.7273	1.5820	Z
	119	29.6715	19.3793	-49.8657	28.5747	18.1688	-49.0100	1.0968	1.2105	0.8557	1.8440	0.8557	Z
	120	28.6079	30.7154	-49.8268	26.9502	29.3760	-47.9981	1.6577	1.3394	1.8287	2.8082	1.8287	Z
	121	25.2572	40.5213	-49.7031	23.3647	38.8799	-47.2477	1.8925	1.6414	2.4554	3.5078	2.4554	Z
	122	14.6357	19.0881	-51.3946	13.4980	17.2367	-50.4405	1.1377	1.8514	0.9541	2.3733	0.9541	Z
	123	13.4678	28.8870	-51.3352	11.9595	26.9251	-49.3686	1.5083	1.9619	1.9666	3.1609	1.9666	Z
	124	13.0589	40.7415	-50.6238	11.1344	38.2685	-45.9602	1.9245	2.4730	4.6636	5.6186	4.6636	Z
	125	-4.4774	19.3757	-51.7719	-5.4775	16.4961	-49.5712	1.0001	2.8796	2.2007	3.7597	2.2007	Z
	126	-4.0851	28.0890	-51.7414	-5.2654	24.8593	-47.0712	1.1803	3.2297	4.6702	5.7996	4.6702	Z
	127	-3.3791	40.1330	-51.2701	-4.9877	36.5793	-44.2088	1.6086	3.5537	7.0613	8.0671	7.0613	Z
	128	-19.1949	19.2167	-51.5658	-19.4644	15.8874	-46.0331	0.2695	3.3293	5.5327	6.4628	5.5327	Z
	129	-19.6218	28.2748	-51.5687	-20.7646	24.7303	-46.8549	1.1428	3.5445	4.7138	6.0074	4.7138	Z
	130	-19.5827	39.5046	-51.2253	-21.1049	35.4043	-43.7238	1.5222	4.1003	7.5015	8.6834	7.5015	Z
A-PILLAR Maximum (X, Y, Z)	131	32.6479	45.1215	-45.1649	30.8411	43.8875	-43.6359	1.8068	1.2340	1.5290	2.6693	2.6693	X, Y, Z
	132	37.5385	46.1501	-41.5071	36.1339	45.1653	-40.6320	1.4046	0.9848	0.8751	1.9258	1.9258	X, Y, Z
	133	42.8573	47.6117	-38.8327	41.6741	46.9185	-38.5775	1.1832	0.6932	0.2552	1.3949	1.3949	X, Y, Z
	134	45.3926	48.0186	-35.9372	44.4234	47.3567	-36.0173	0.9692	0.6619	-0.0801	1.1764	1.1737	X, Y
	135	47.7583	48.6432	-34.6815	46.9243	48.2131	-34.9390	0.8340	0.4301	-0.2575	0.9731	0.9384	X, Y
	136	49.0280	49.1192	-31.7190	46.9611	43.3624	-41.5043	2.0669	5.7568	-9.7853	11.5397	6.1166	X, Y
A-PILLAR Lateral (Y)	131	32.6479	45.1215	-45.1649	30.8411	43.8875	-43.6359	1.8068	1.2340	1.5290	2.6693	1.2340	Y
	132	37.5385	46.1501	-41.5071	36.1339	45.1653	-40.6320	1.4046	0.9848	0.8751	1.9258	0.9848	Y
	133	42.8573	47.6117	-38.8327	41.6741	46.9185	-38.5775	1.1832	0.6932	0.2552	1.3949	0.6932	Y
	134	45.3926	48.0186	-35.9372	44.4234	47.3567	-36.0173	0.9692	0.6619	-0.0801	1.1764	0.6619	Y
	135	47.7583	48.6432	-34.6815	46.9243	48.2131	-34.9390	0.8340	0.4301	-0.2575	0.9731	0.4301	Y
	136	49.0280	49.1192	-31.7190	46.9611	43.3624	-41.5043	2.0669	5.7568	-9.7853	11.5397	5.7568	Y
B-PILLAR Maximum (X, Y, Z)	137	8.5727	45.1876	-45.7372	5.2871	53.0002	-29.0061	3.2856	-7.8126	16.7311	18.7553	17.0507	X, Z
	138	6.0366	49.9759	-29.2273	9.5849	52.2229	-24.4680	-3.5483	-2.2470	4.7593	6.3475	4.7593	Z
	139	10.2682	50.2610	-24.6066	9.5530	52.2280	-24.4621	0.7152	-1.9670	0.1445	2.0980	0.7297	X, Z
	140	6.3462	50.4841	-18.2272	5.7996	51.8060	-18.1255	0.5466	-1.3219	0.1017	1.4341	0.5560	X, Z
B-PILLAR Lateral (Y)	137	8.5727	45.1876	-45.7372	5.2871	53.0002	-29.0061	3.2856	-7.8126	16.7311	18.7553	-7.8126	Y
	138	6.0366	49.9759	-29.2273	9.5849	52.2229	-24.4680	-3.5483	-2.2470	4.7593	6.3475	-2.2470	Y
	139	10.2682	50.2610	-24.6066	9.5530	52.2280	-24.4621	0.7152	-1.9670	0.1445	2.0980	-1.9670	Y
	140	6.3462	50.4841	-18.2272	5.7996	51.8060	-18.1255	0.5466	-1.3219	0.1017	1.4341	-1.3219	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-9

Test Name: HBIB-9 VIN: 1C6RR6FG0KS526339

Model Year: 2019 Make: Ram Model: 1500

Driver Side Maximum Deformation							
Reference Set 1				Reference Set 2			
Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]	Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]
Roof	0.0	≤ 4	Z	Roof	0.0	≤ 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	0.0	≤ 3	Y	A-Pillar Lateral	0.0	≤ 3	Y
B-Pillar Maximum	0.0	≤ 5	NA	B-Pillar Maximum	0.0	≤ 5	NA
B-Pillar Lateral	0.0	≤ 3	Y	B-Pillar Lateral	0.0	≤ 3	Y
Toe Pan - Wheel Well	0.0	≤ 9	NA	Toe Pan - Wheel Well	0.0	≤ 9	NA
Side Front Panel	0.0	≤ 12	Y	Side Front Panel	0.0	≤ 12	Y
Side Door (above seat)	0.0	≤ 9	Y	Side Door (above seat)	0.0	≤ 9	Y
Side Door (below seat)	0.0	≤ 12	Y	Side Door (below seat)	0.0	≤ 12	Y
Floor Pan	0.0	≤ 12	Z	Floor Pan	0.0	≤ 12	Z
Dash - no MASH requirement	0.0	NA	X, Y, Z	Dash - no MASH requirement	0.0	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.

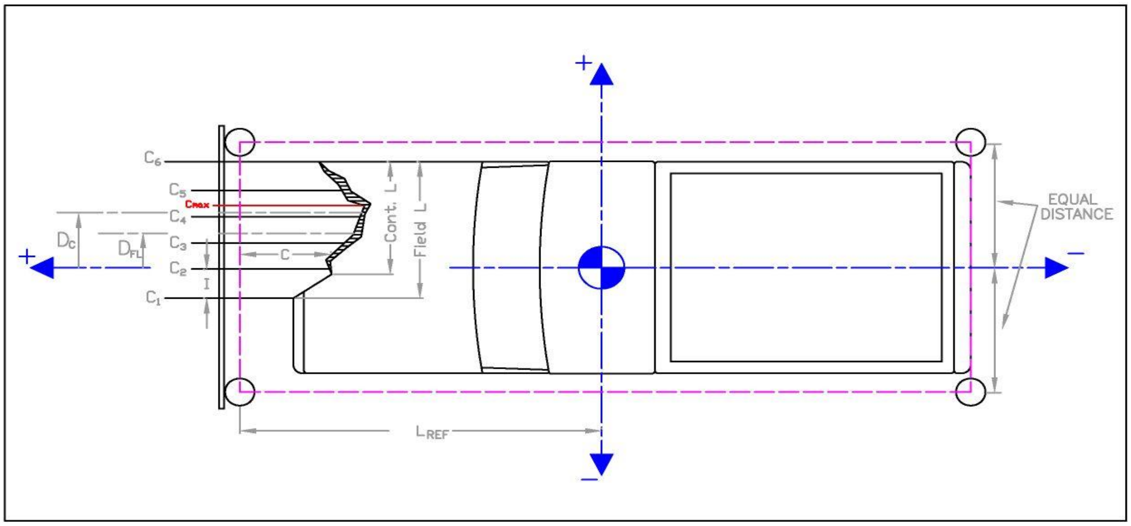
[D] If deformation is observered for the windshield then the windshield deformation is measured posttest with an examplar vehicle, therefore only one set of reference is measured and recorded.

Notes on vehicle interior crush:

Figure F-33. Maximum Occupant Compartment Deformations by Location, Test No. HBIB-9

Test Name: HBIB-9 **VIN:** 1C6RR6FG0KS526339

Model Year: 2019 **Make:** Ram **Model:** 1500



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	114 1/2	(2908)
Total Vehicle Width:	77 1/8	(1959)
Width of contact and induced crush - Field L:	77 1/8	(1959)
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	(686)

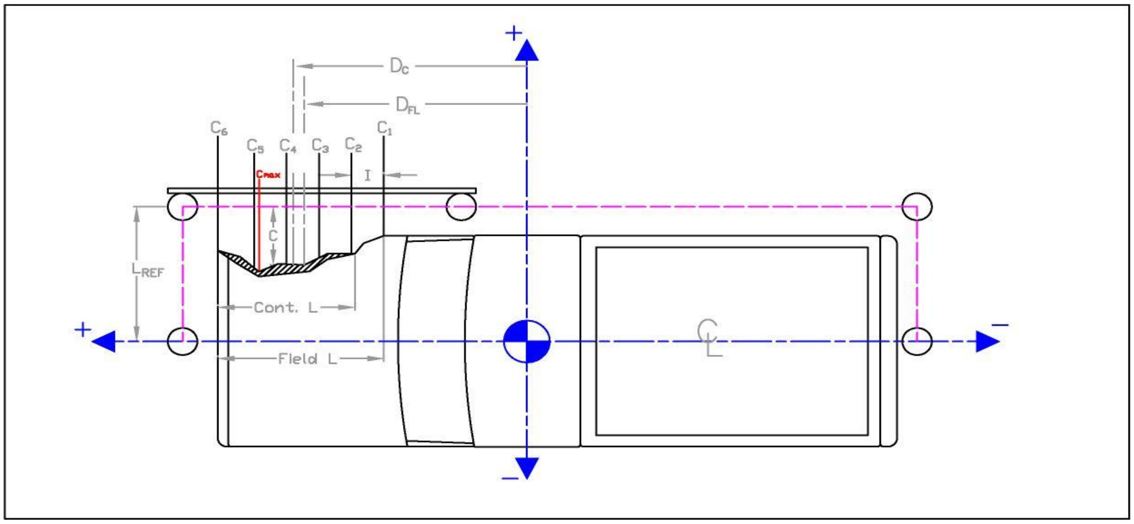
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

	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	NA	N/A	-38 5/8	-(981)	22 1/2	(572)	5 5/8	(143)	N/A	N/A
C_2	28	(711)	-23 1/4	-(591)	6 1/2	(165)			15 7/8	(403)
C_3	10 1/4	(260)	-7 7/8	-(200)	4 1/4	(108)			3/8	(10)
C_4	8 7/8	(225)	7 1/2	(191)	4 1/4	(108)			-1	-(25)
C_5	12 3/8	(314)	22 7/8	(581)	6 1/8	(156)			5/8	(16)
C_6	NA	N/A	38 1/4	(972)	20 1/2	(521)			N/A	N/A
C_{MAX}	28	(711)	-23 1/4	-(591)	6 1/2	(165)			15 7/8	(403)

Figure F-34. Exterior Vehicle Crush (NASS) - Front, Test No. HBIB-9

Test Name: HBIB-9 VIN: 1C6RR6FG0KS526339

Model Year: 2019 Make: Ram Model: 1500



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	45	(1143)
Total Vehicle Length:	229 3/8	(5826)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-9	-(230)
Width of contact and induced crush - Field L:	229 3/8	(5826)
Crush measurement spacing interval (L/5) - I:	45 7/8	(1165)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-9	-(230)
Width of Contact Damage:	229 3/8	(5826)
Distance from vehicle c.g. to center of contact damage - D_C:	9	(230)

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	NA	N/A	-123 3/4	-(3143)	33 1/2	(851)	1	(25)	N/A	N/A
C_2	NA	N/A	-77 7/8	-(1978)	5 1/2	(140)			N/A	N/A
C_3	8 1/4	(210)	-32	-(813)	5 3/4	(146)			1 1/2	(38)
C_4	4	(102)	13 7/8	(352)	5	(127)			-2	-(51)
C_5	NA	N/A	59 3/4	(1518)	5 3/4	(146)			N/A	N/A
C_6	NA	N/A	105 5/8	(2683)	10 3/4	(273)			N/A	N/A
C_{MAX}	25 1/2	(648)	83	(2108)	5	(127)			19 1/2	(495)

Figure F-35. Exterior Vehicle Crush (NASS) - Side, Test No. HBIB-9

Appendix G. Accelerometer and Rate Transducer Data Plots, Test No. HBIB-6

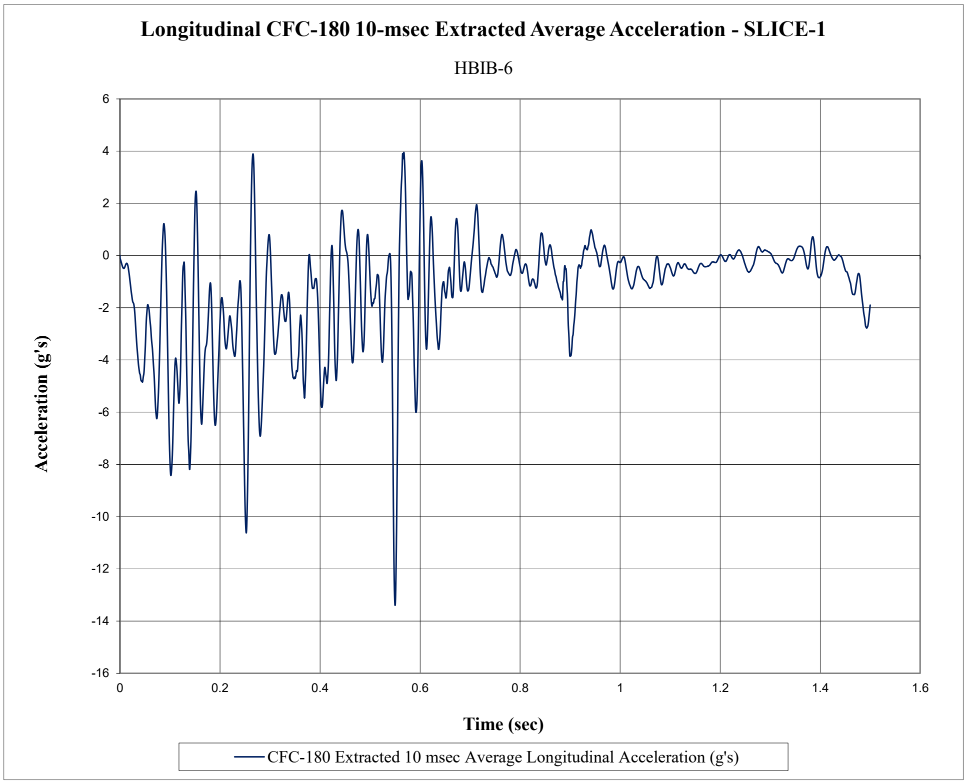


Figure G-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. HBIB-6

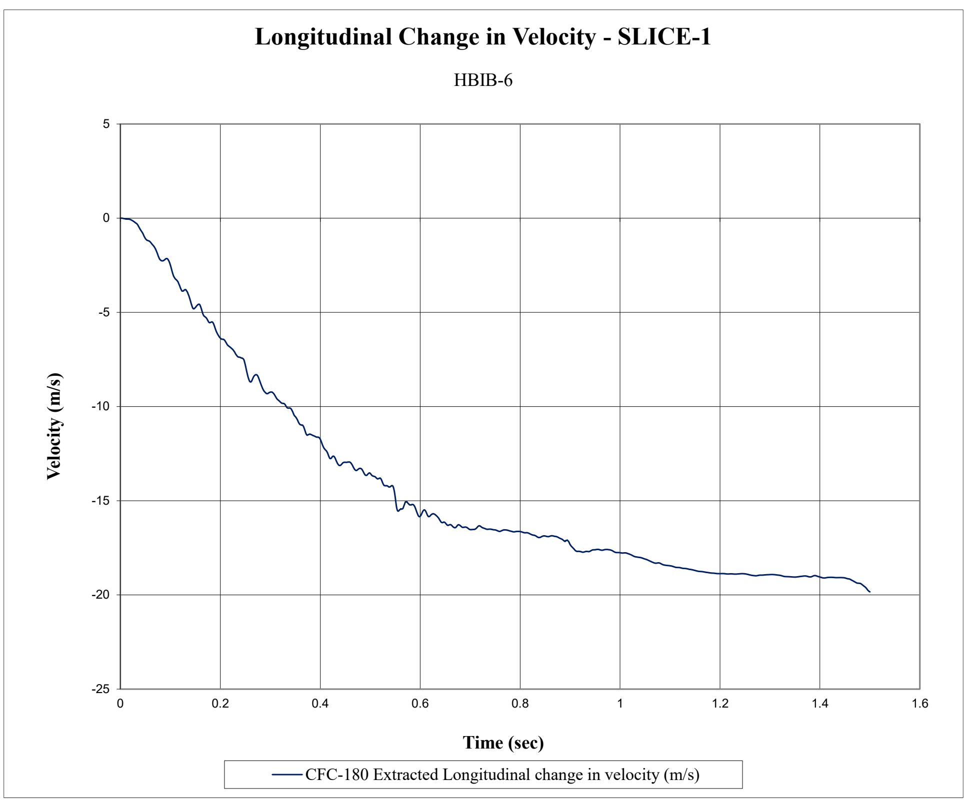


Figure G-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. HBIB-6

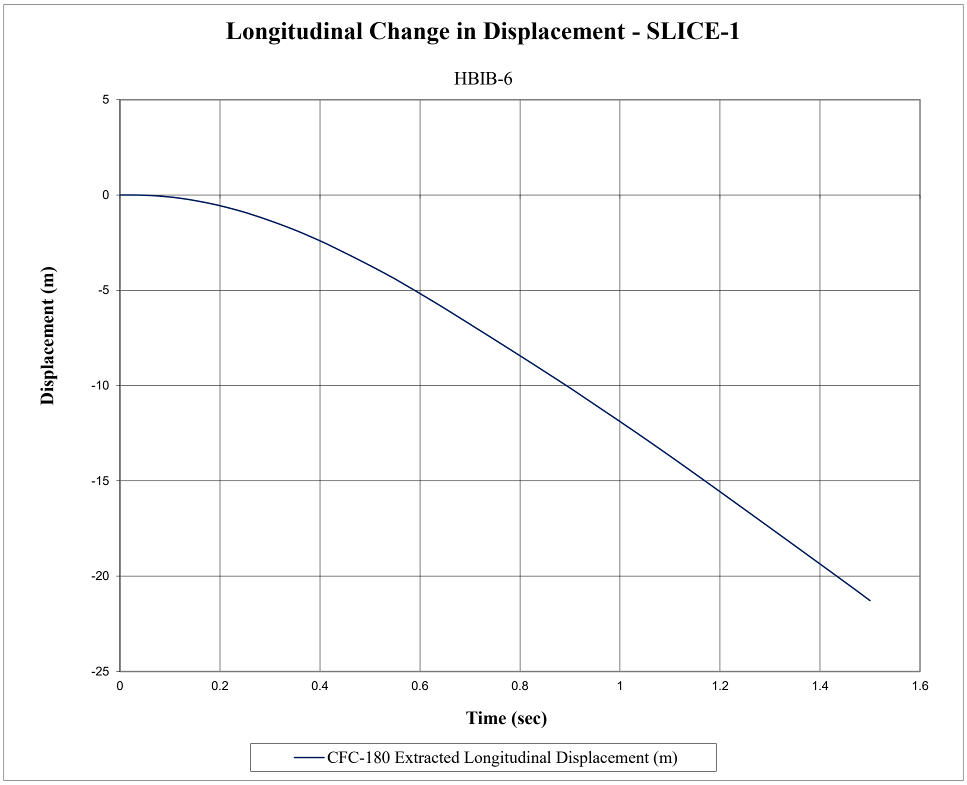


Figure G-3. Longitudinal Occupant Displacement (SLICE-1), Test No. HBIB-6

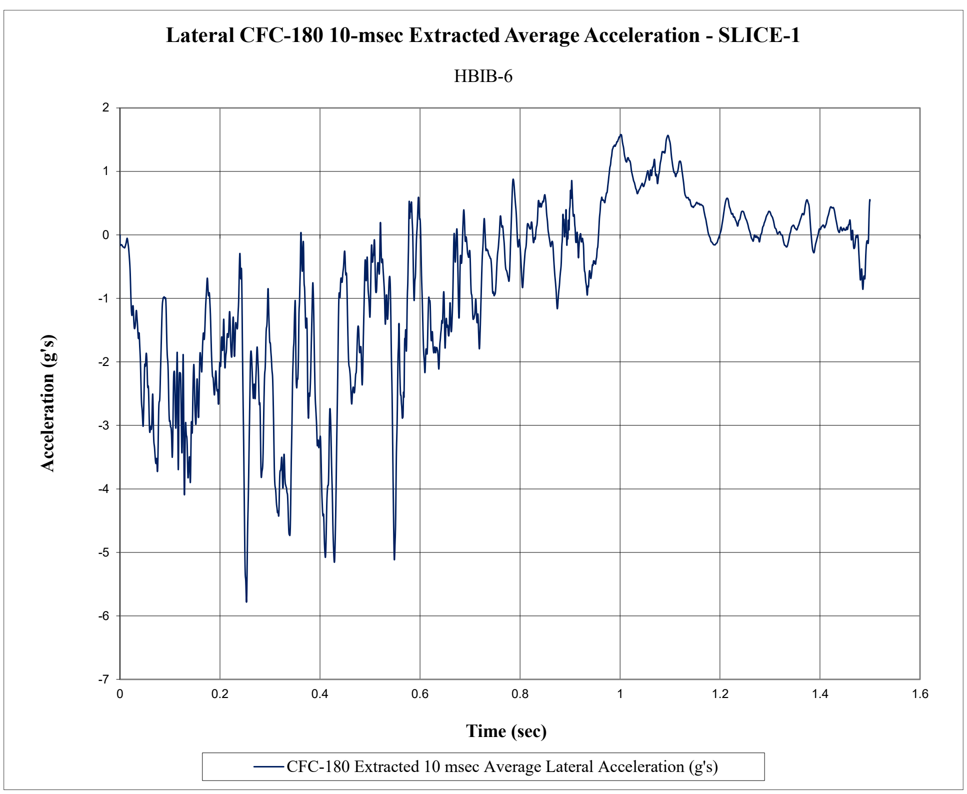


Figure G-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. HBIB-6

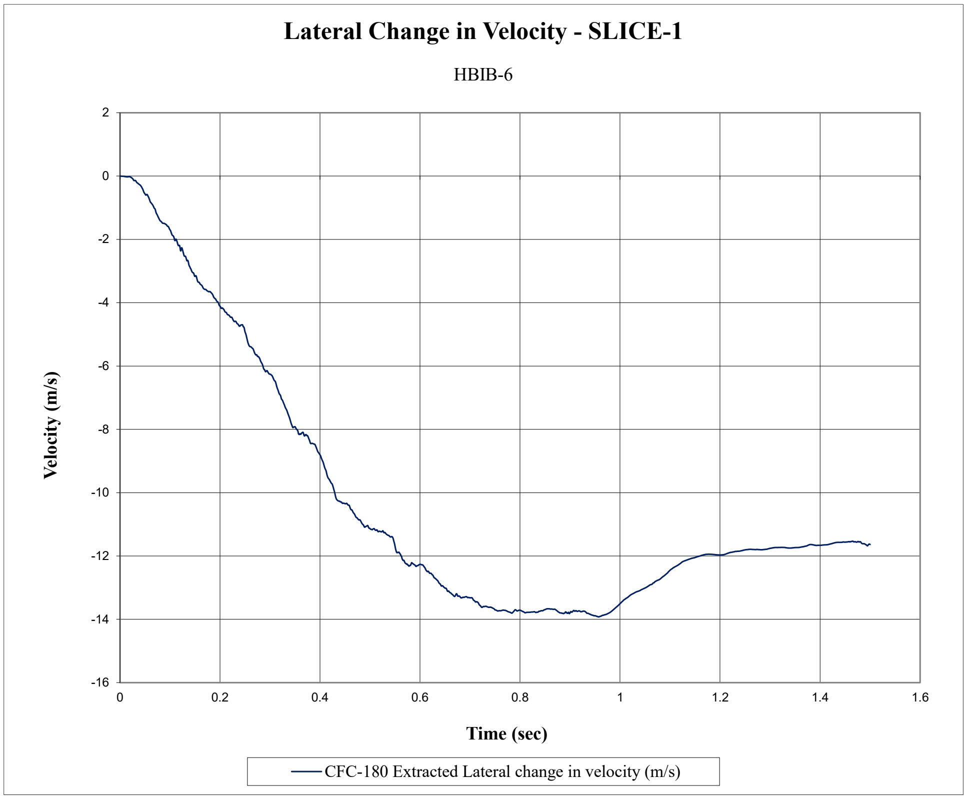


Figure G-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. HBIB-6

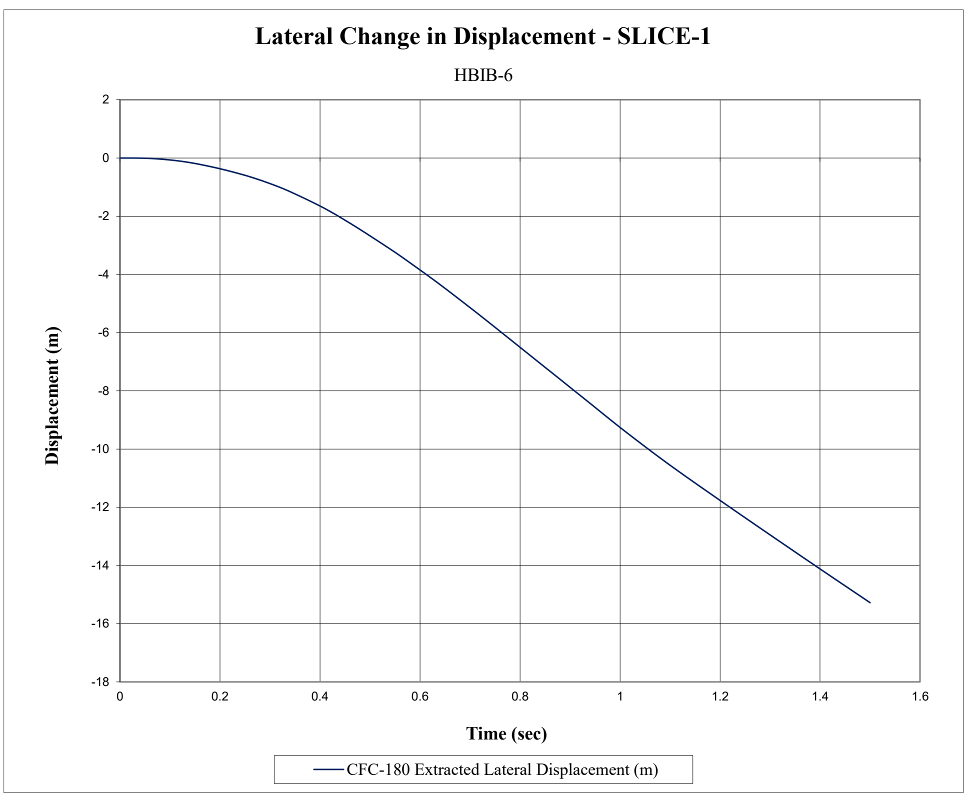


Figure G-6. Lateral Occupant Displacement (SLICE-1), Test No. HBIB-6

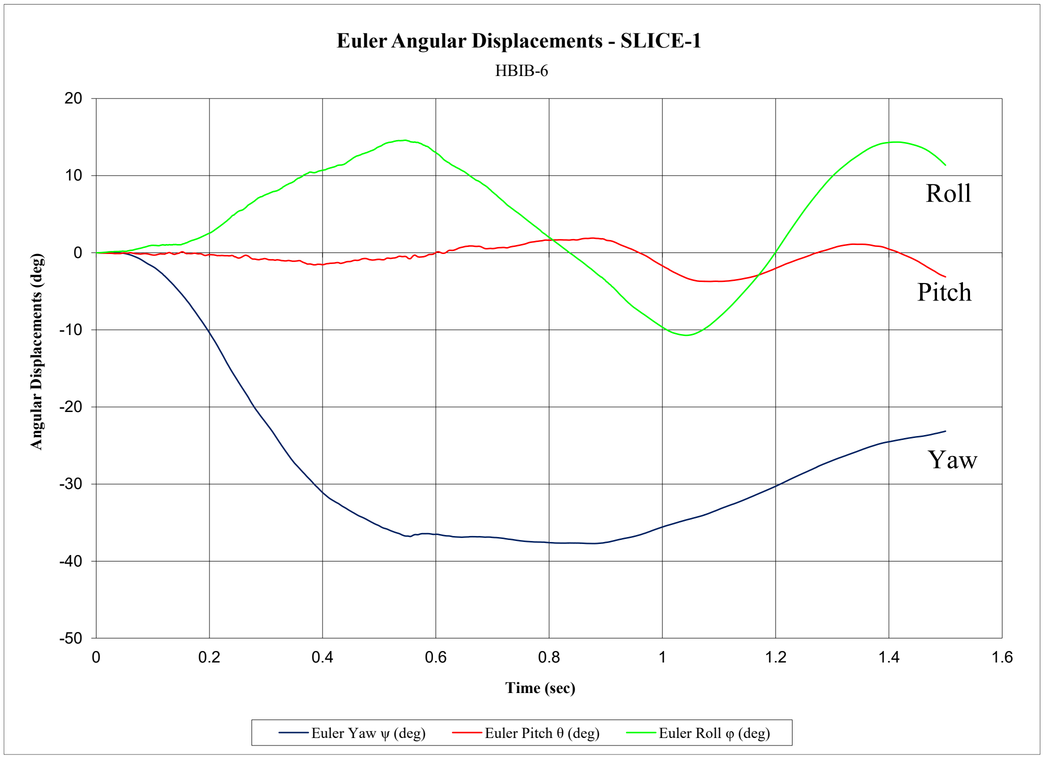


Figure G-7. Vehicle Angular Displacements (SLICE-1), Test No. HBIB-6

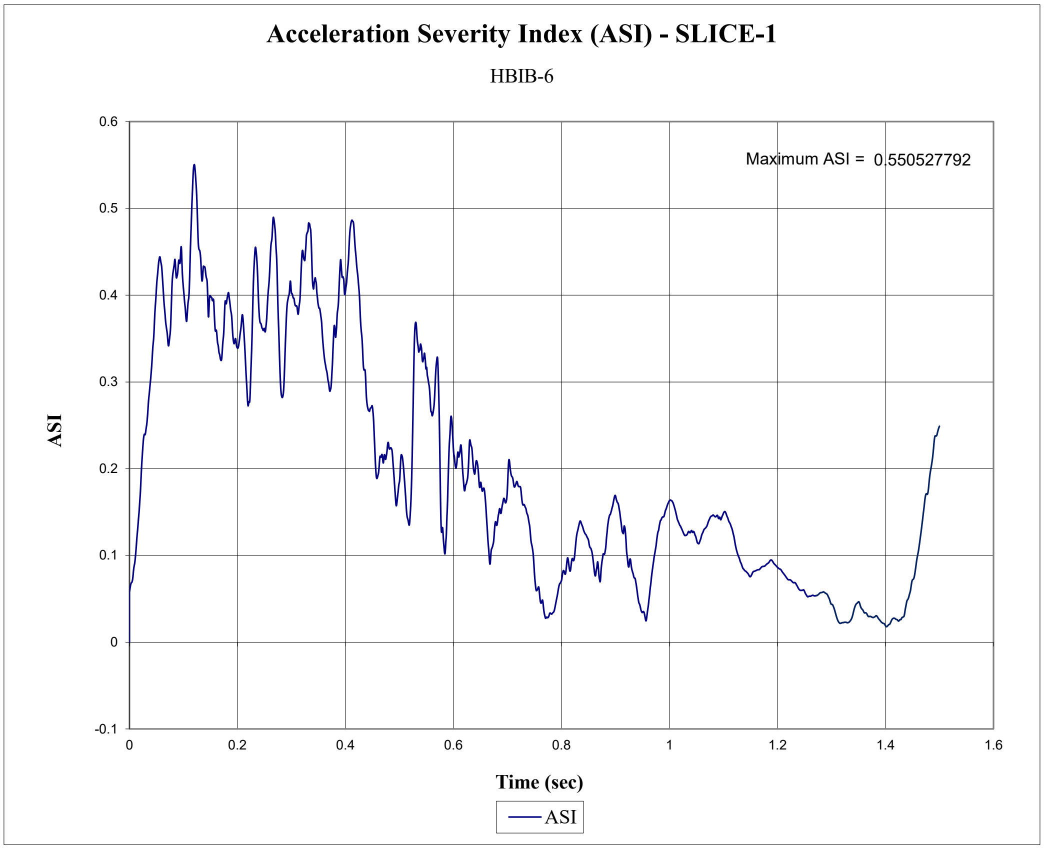


Figure G-8. Acceleration Severity Index (SLICE-1), Test No. HBIB-6

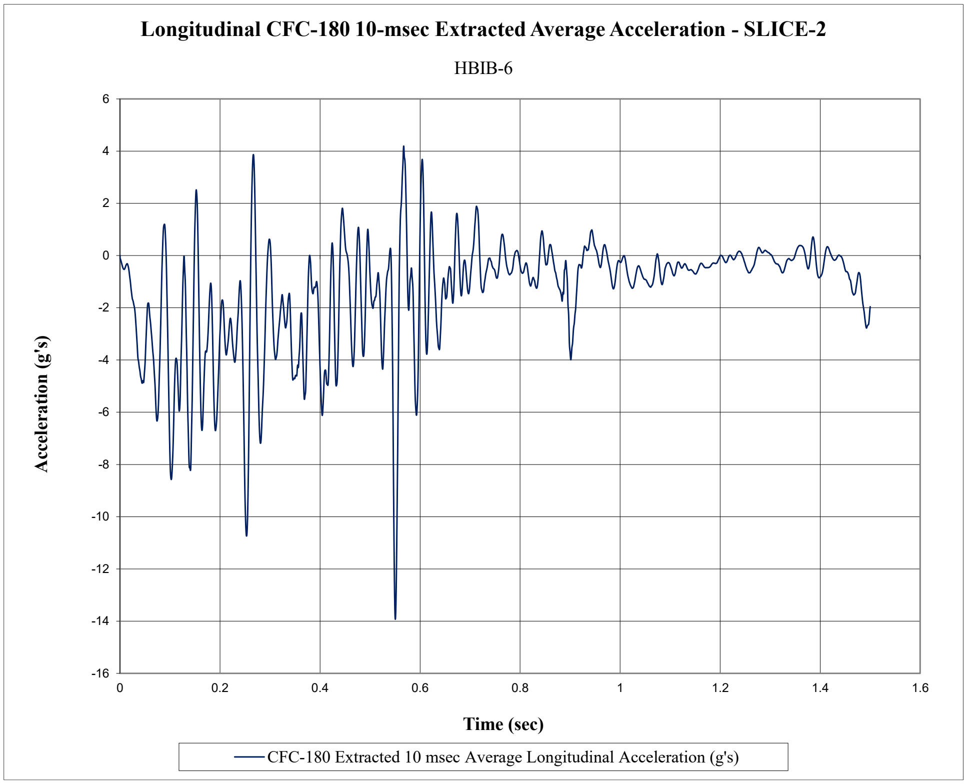


Figure G-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. HBIB-6

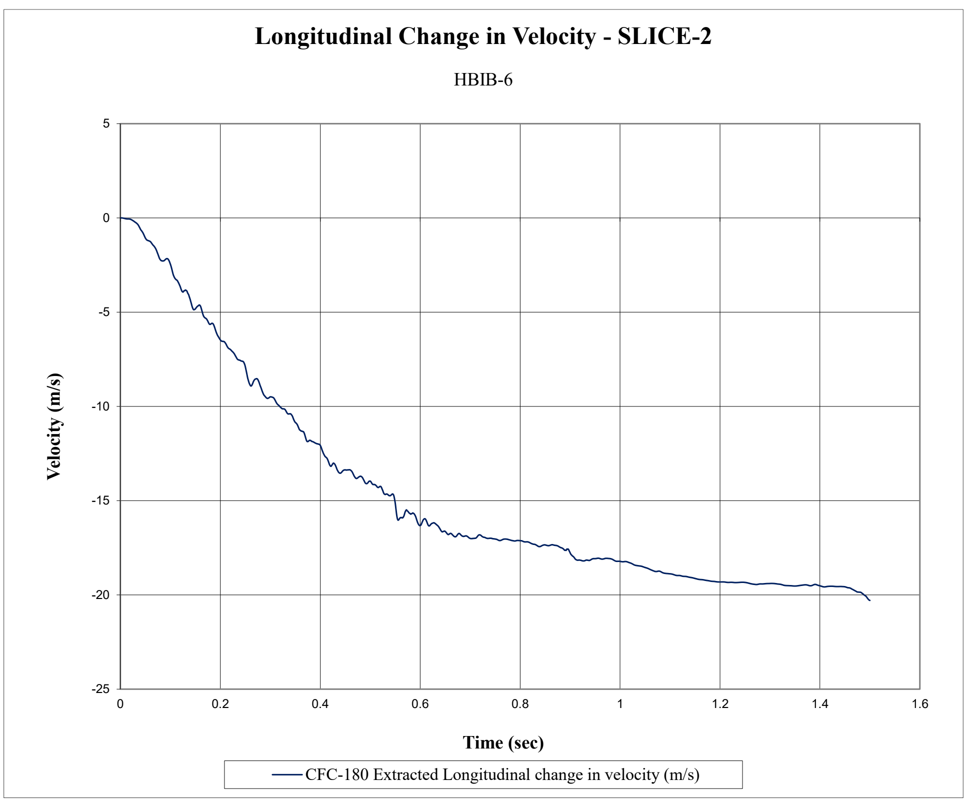


Figure G-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. HBIB-6

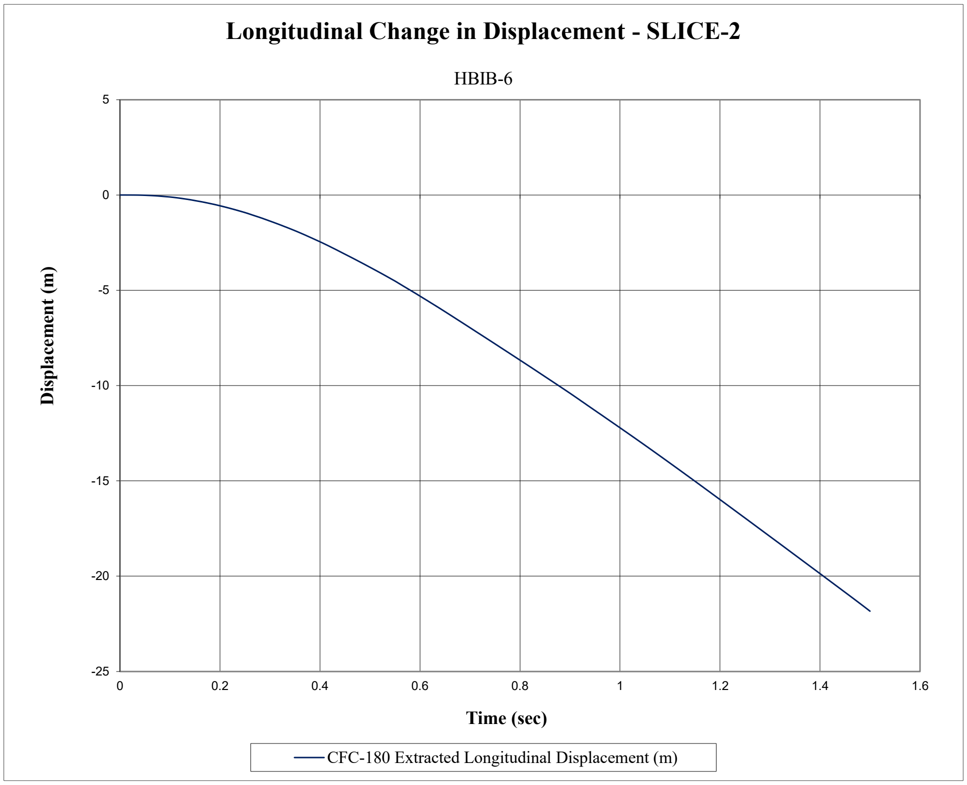


Figure G-11. Longitudinal Occupant Displacement (SLICE-2), Test No. HBIB-6

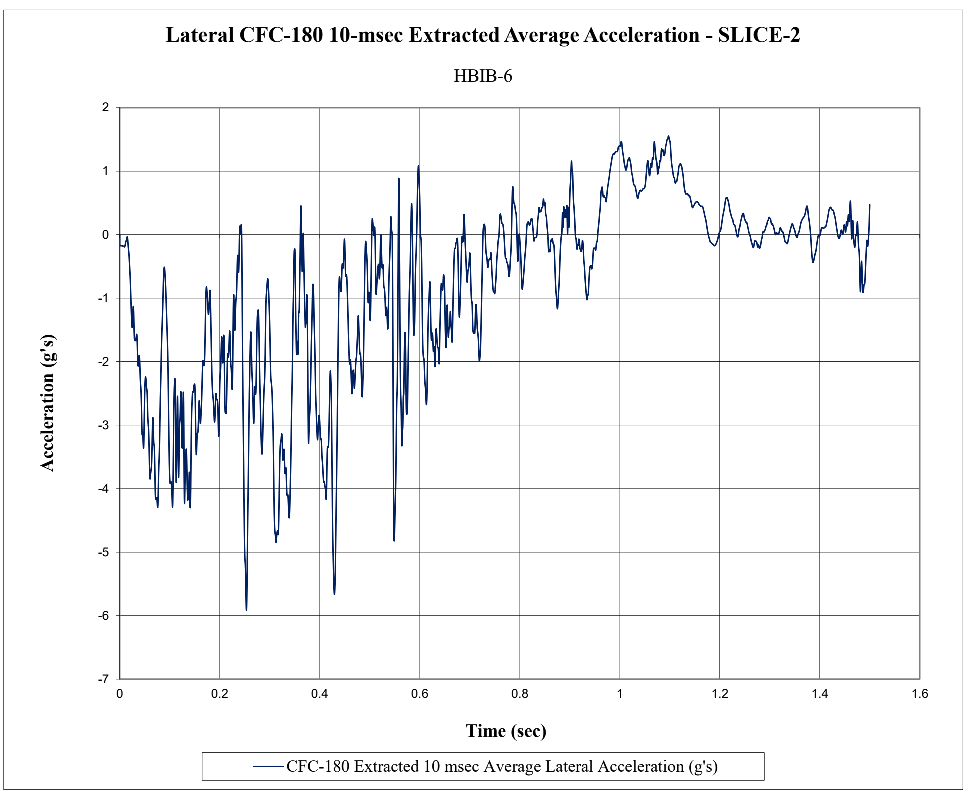


Figure G-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. HBIB-6

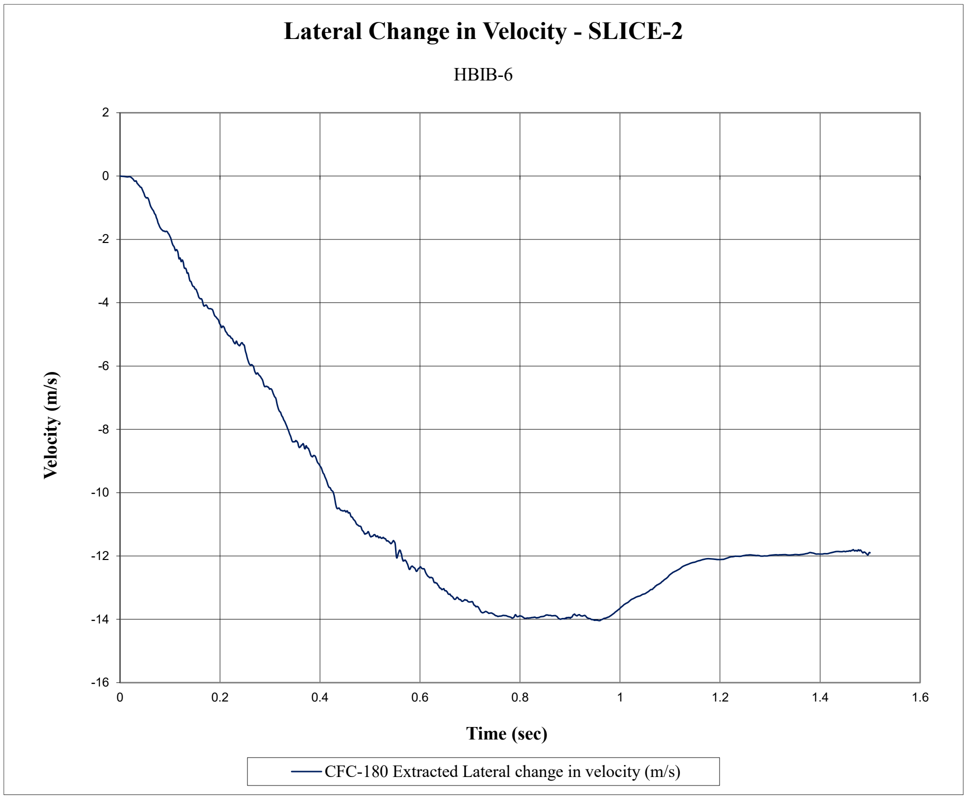


Figure G-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. HBIB-6

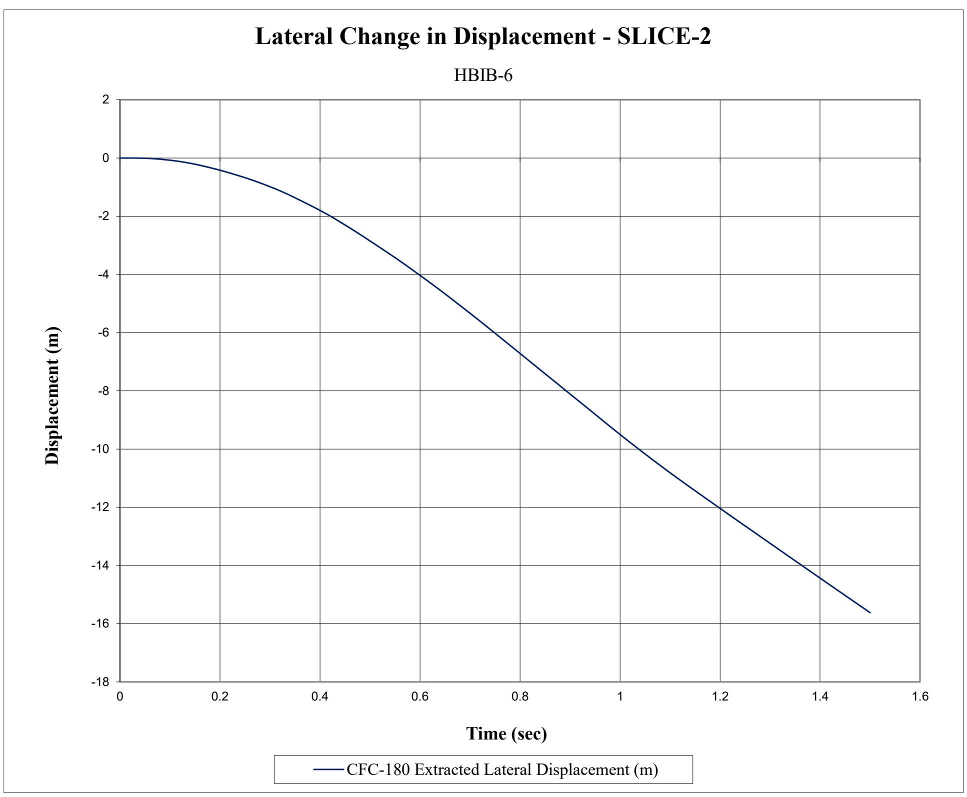


Figure G-14. Lateral Occupant Displacement (SLICE-2), Test No. HBIB-6

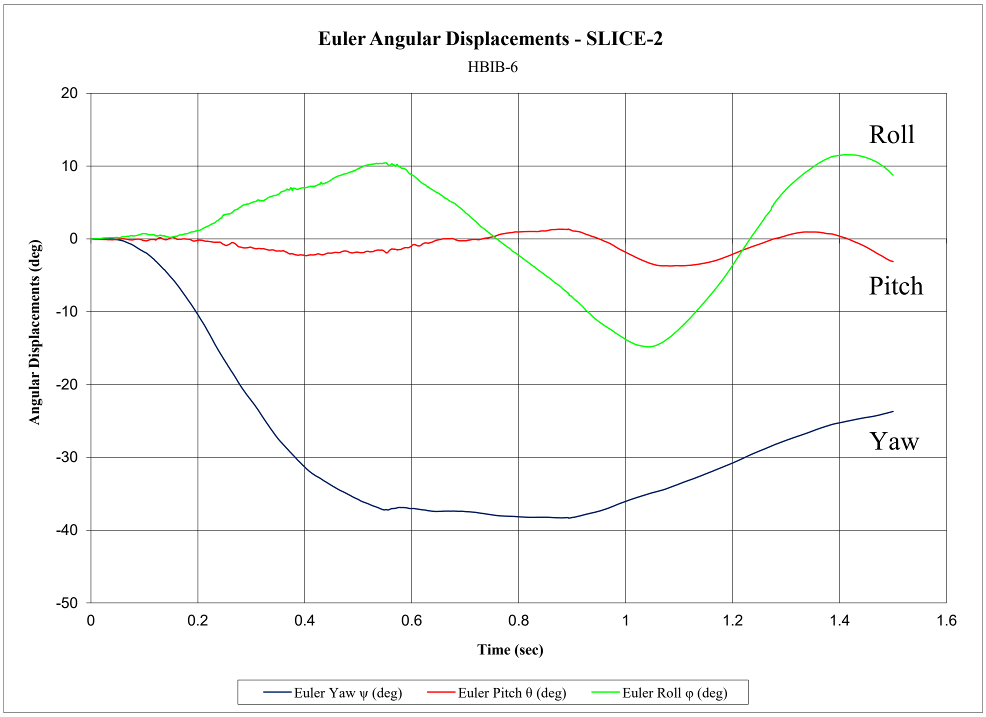


Figure G-15. Vehicle Angular Displacements (SLICE-2), Test No. HBIB-6

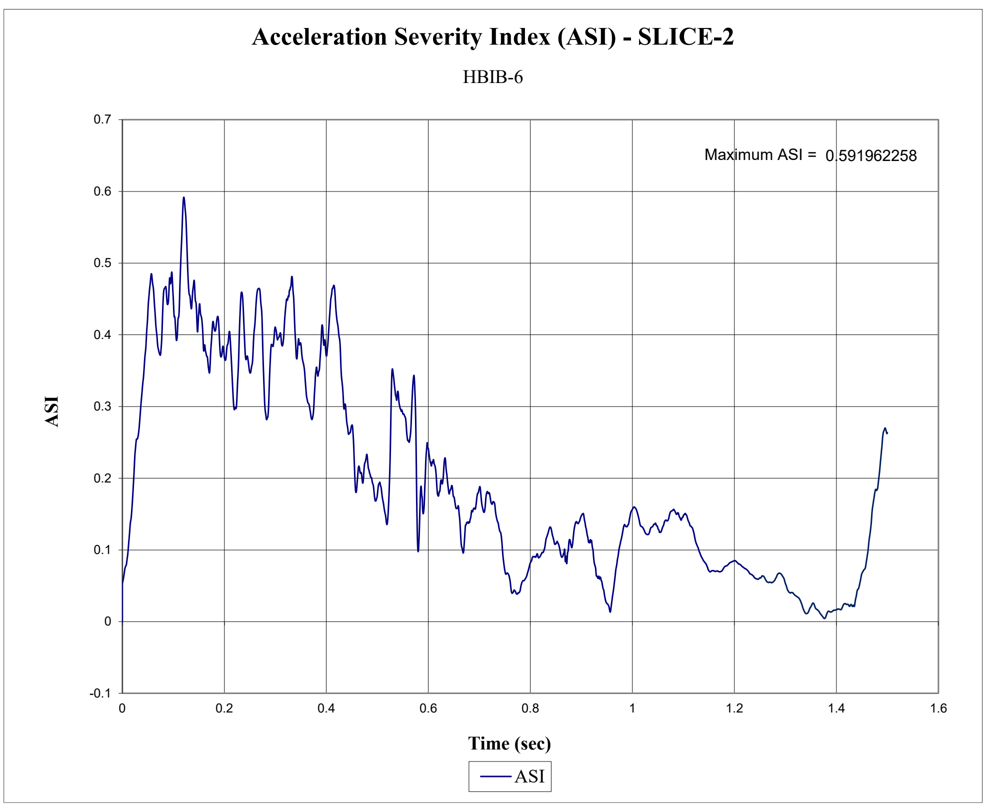


Figure G-16. Acceleration Severity Index (SLICE-2), Test No. HBIB-6

Appendix H. Accelerometer and Rate Transducer Data Plots, Test No. HBIB-7

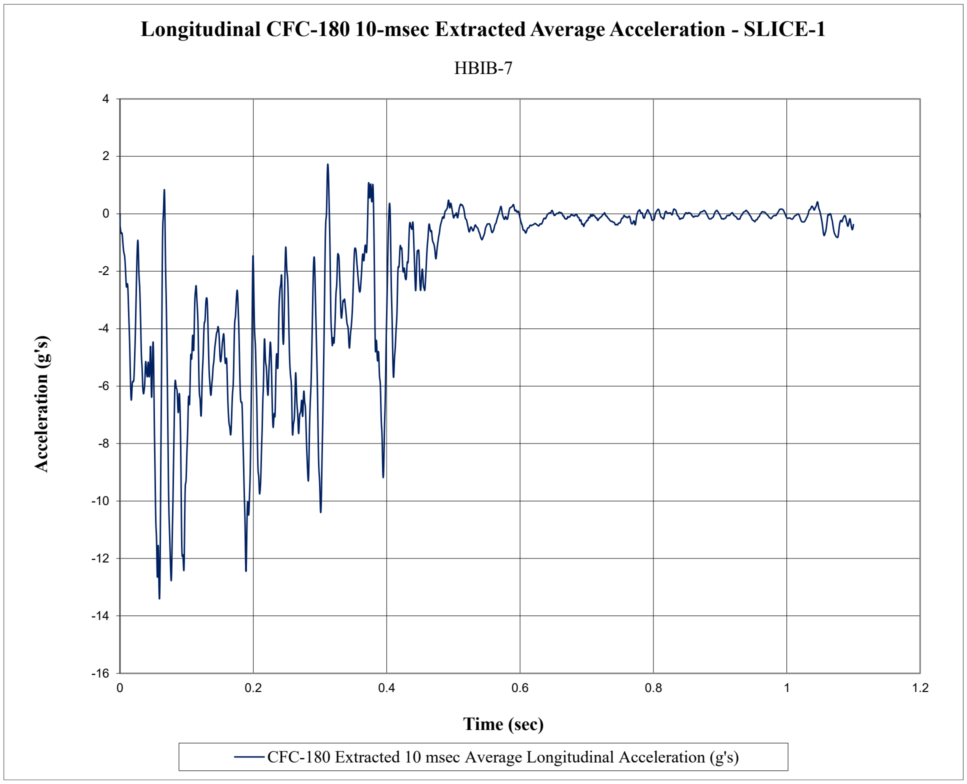


Figure H-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. HBIB-7

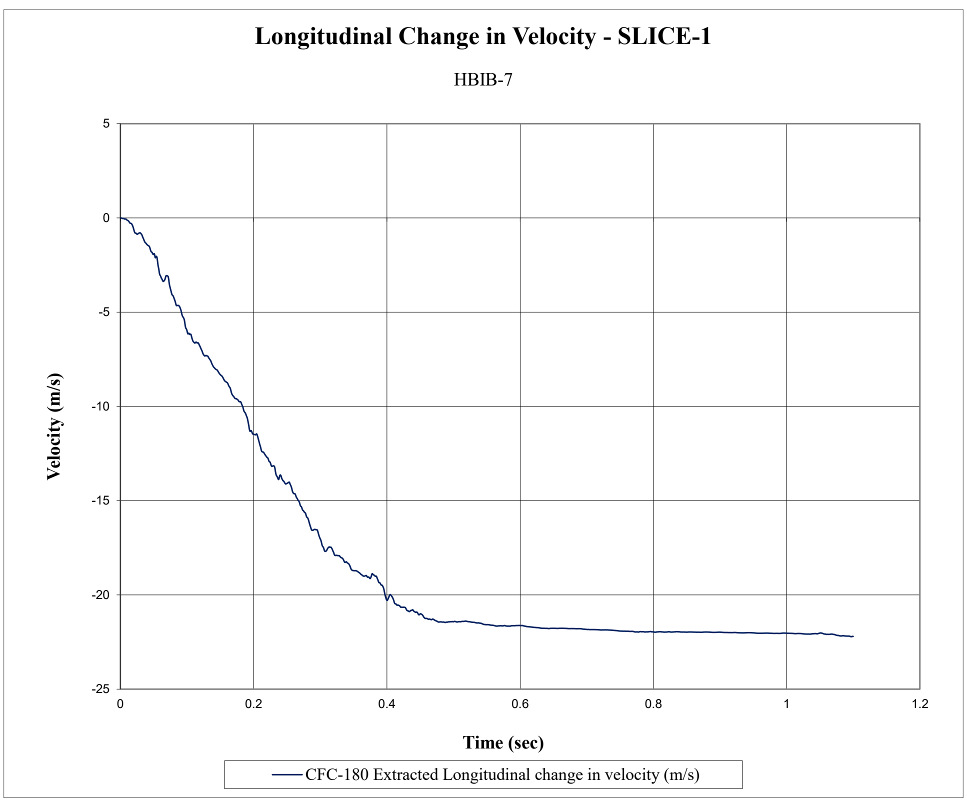


Figure H-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. HBIB-7

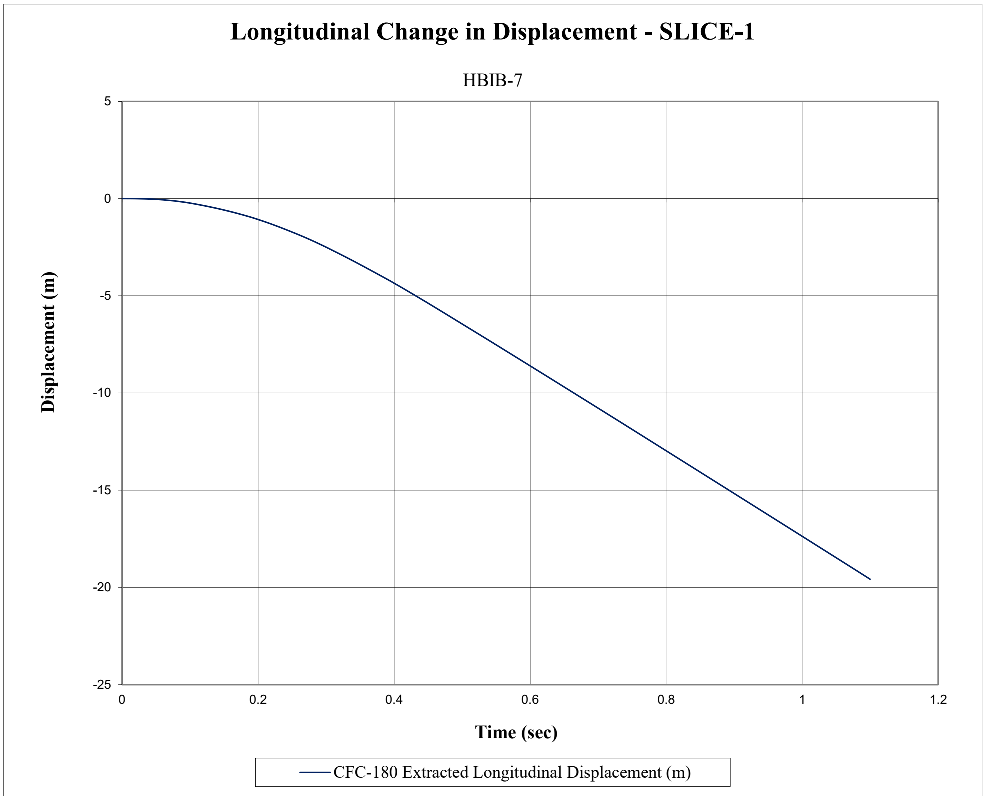


Figure H-3. Longitudinal Occupant Displacement (SLICE-1), Test No. HBIB-7

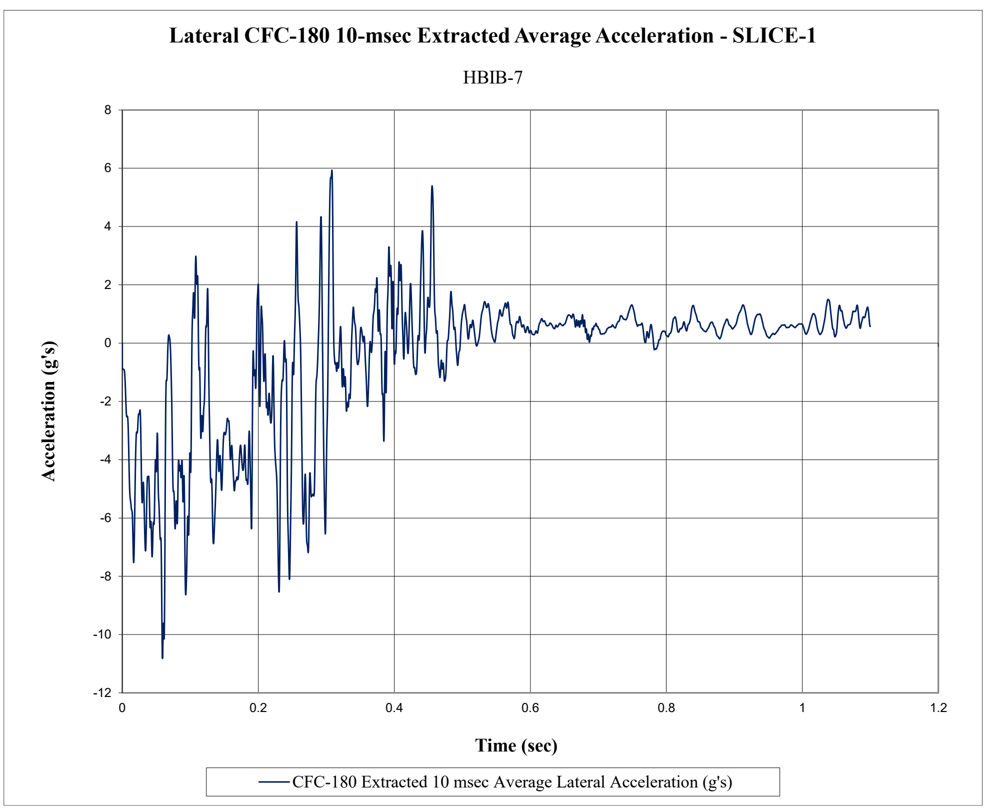


Figure H-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. HBIB-7

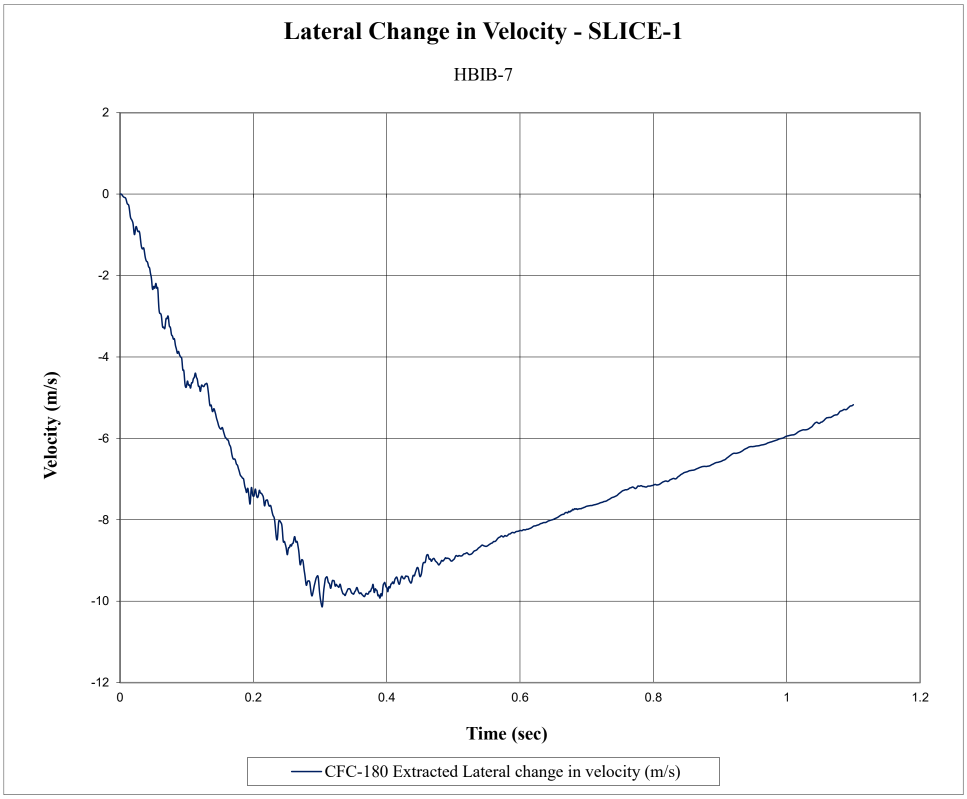


Figure H-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. HBIB-7

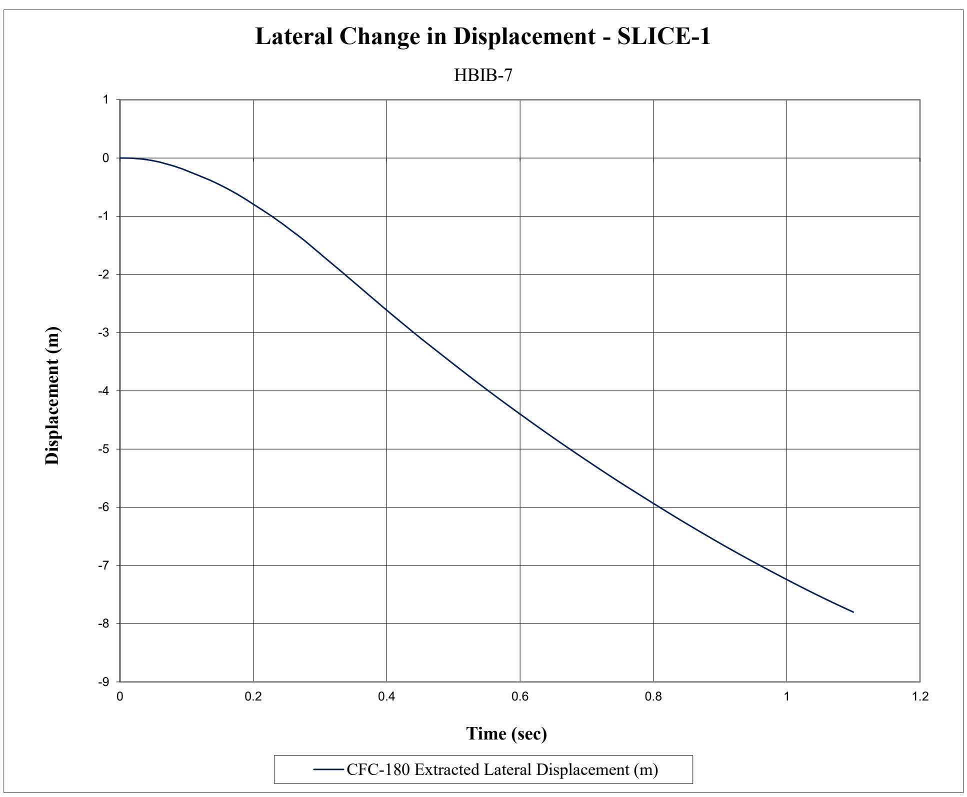


Figure H-6. Lateral Occupant Displacement (SLICE-1), Test No. HBIB-7

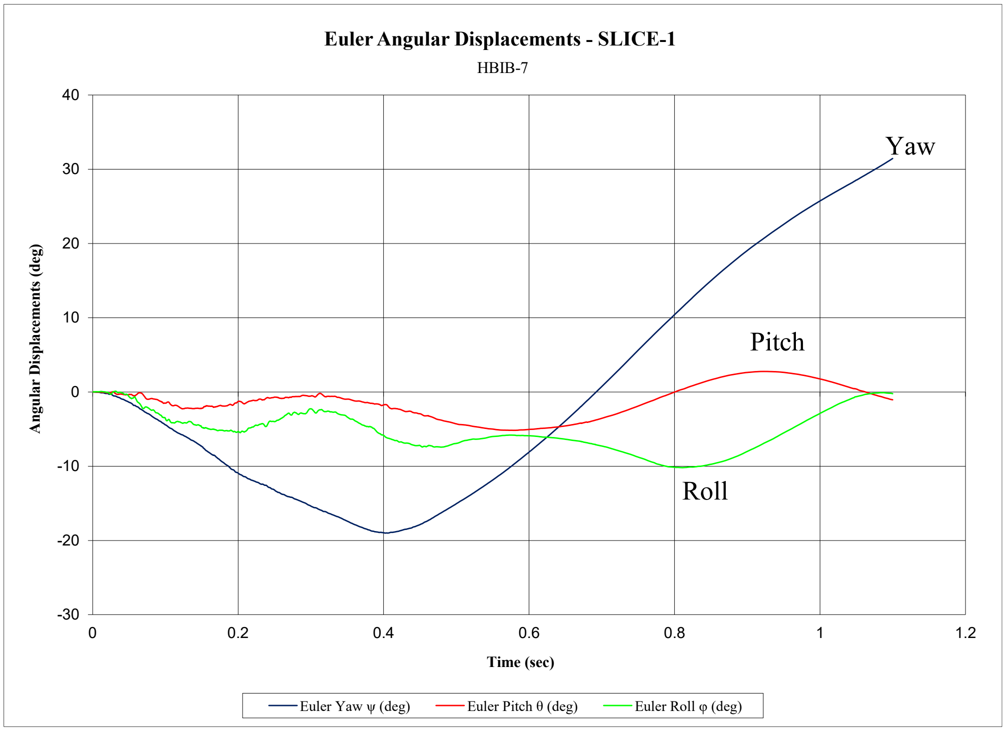


Figure H-7. Vehicle Angular Displacements (SLICE-1), Test No. HBIB-7

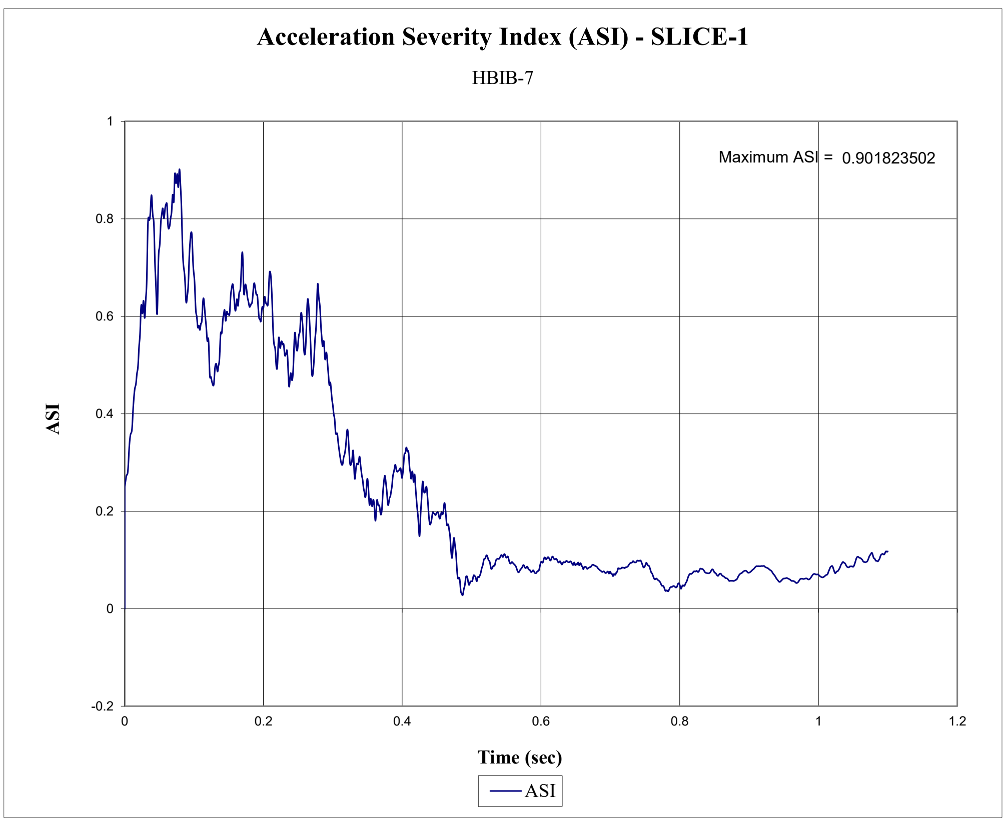


Figure H-8. Acceleration Severity Index (SLICE-1), Test No. HBIB-7

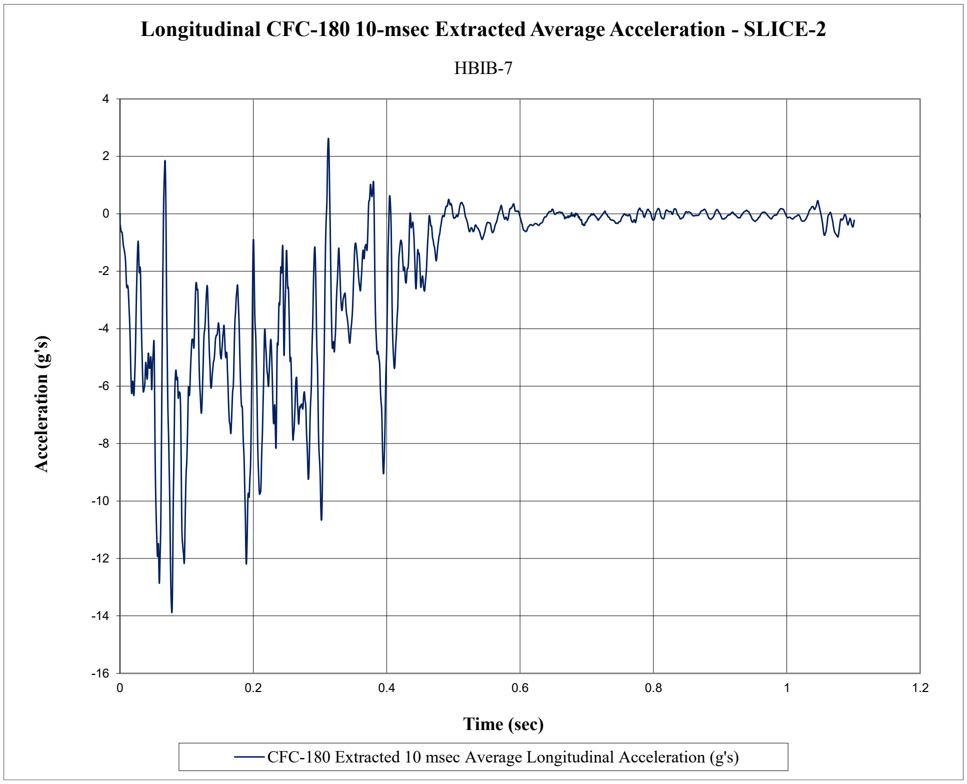


Figure H-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. HBIB-7

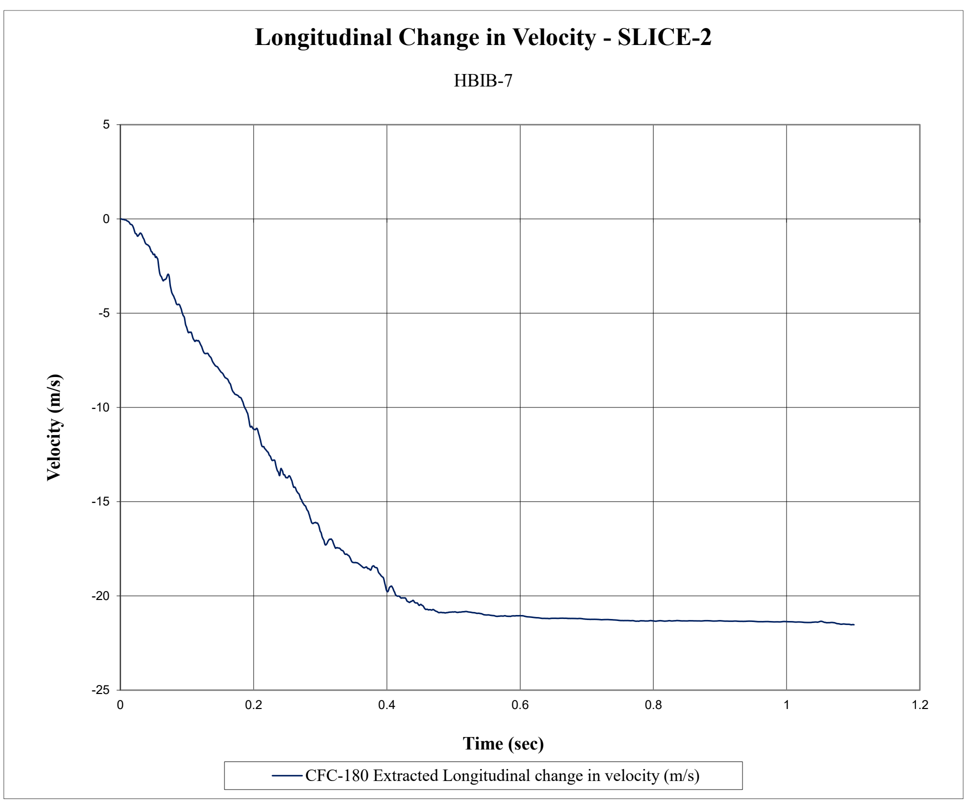


Figure H-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. HBIB-7

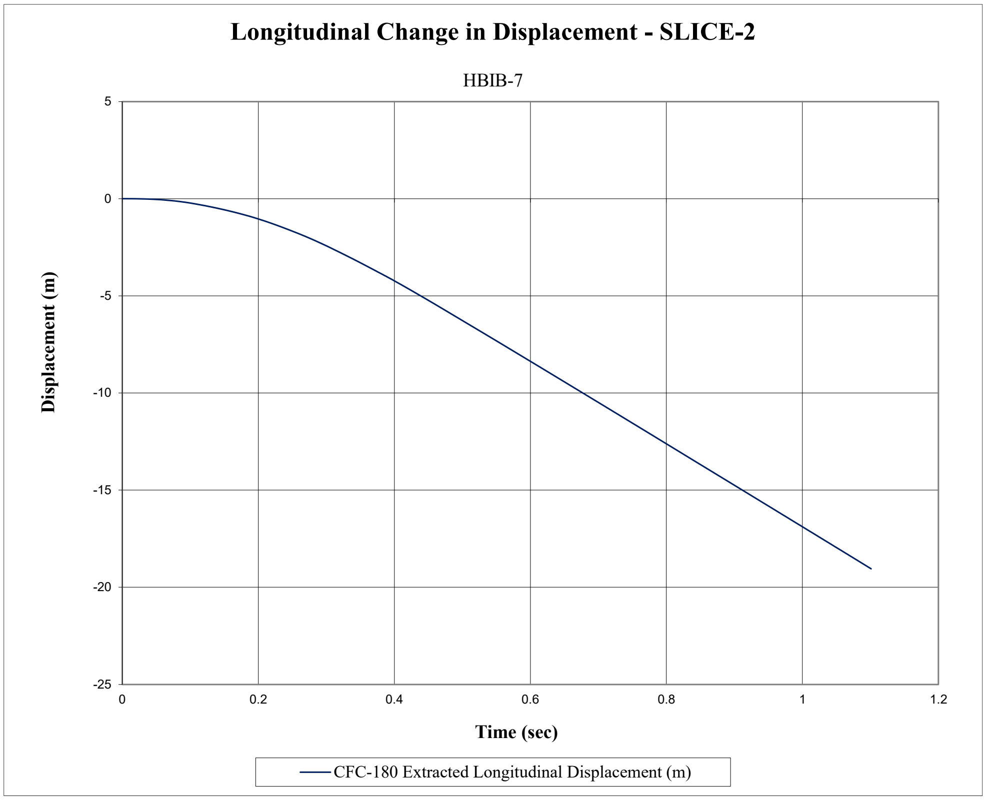


Figure H-11. Longitudinal Occupant Displacement (SLICE-2), Test No. HBIB-7

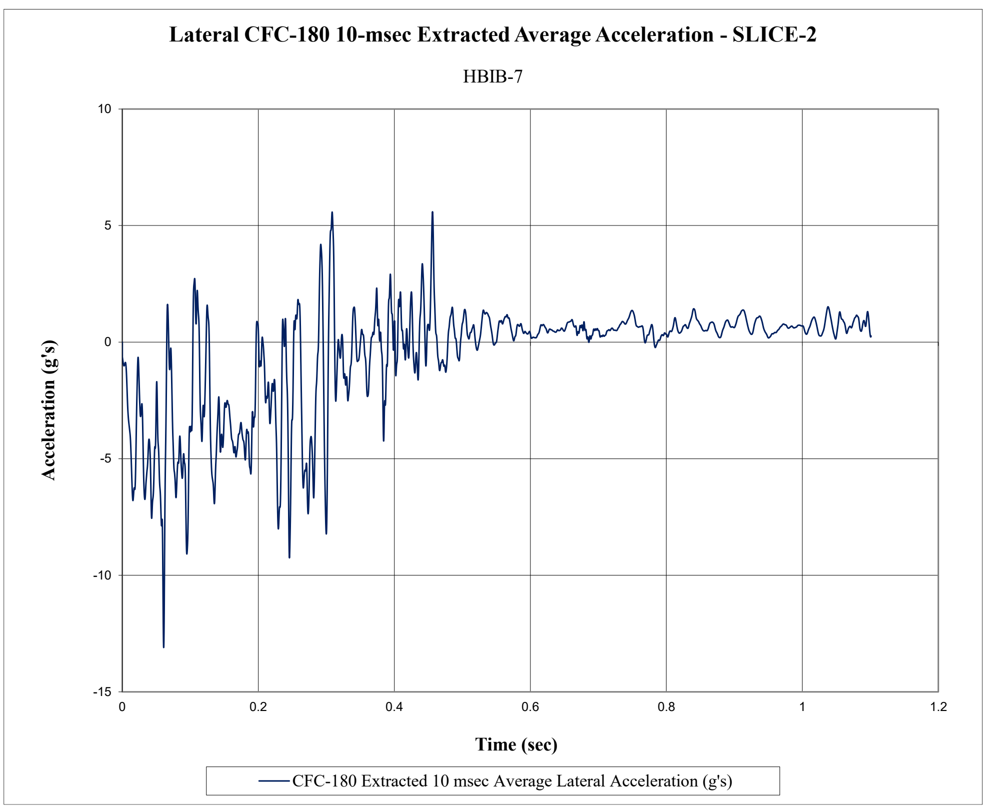


Figure H-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. HBIB-7

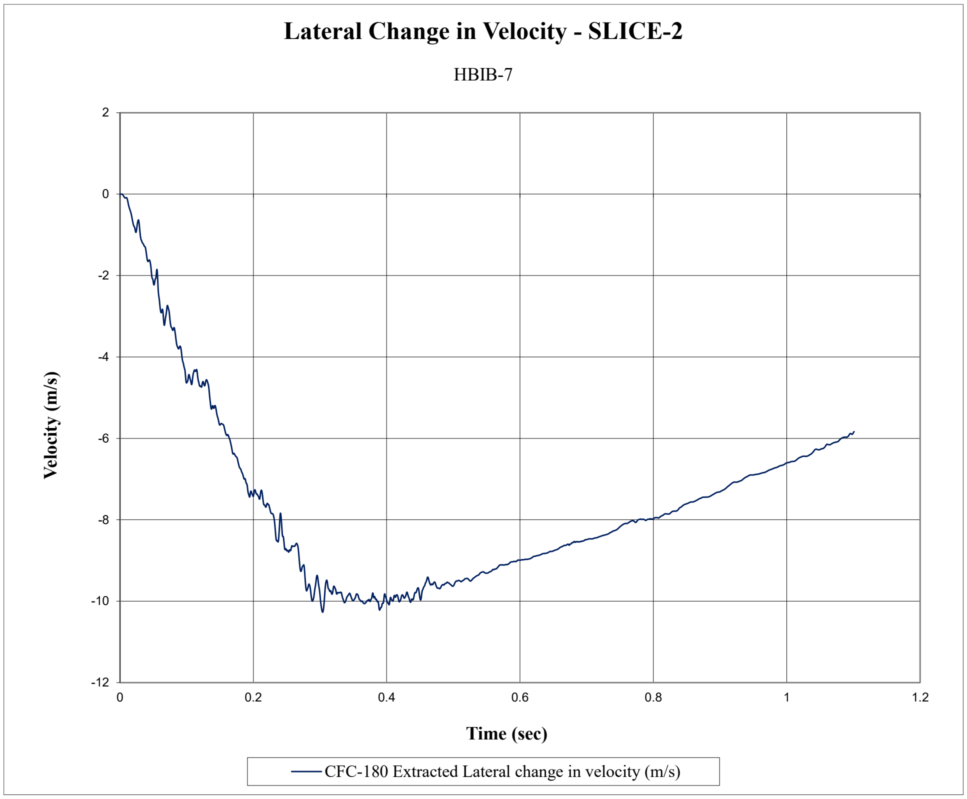


Figure H-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. HBIB-7

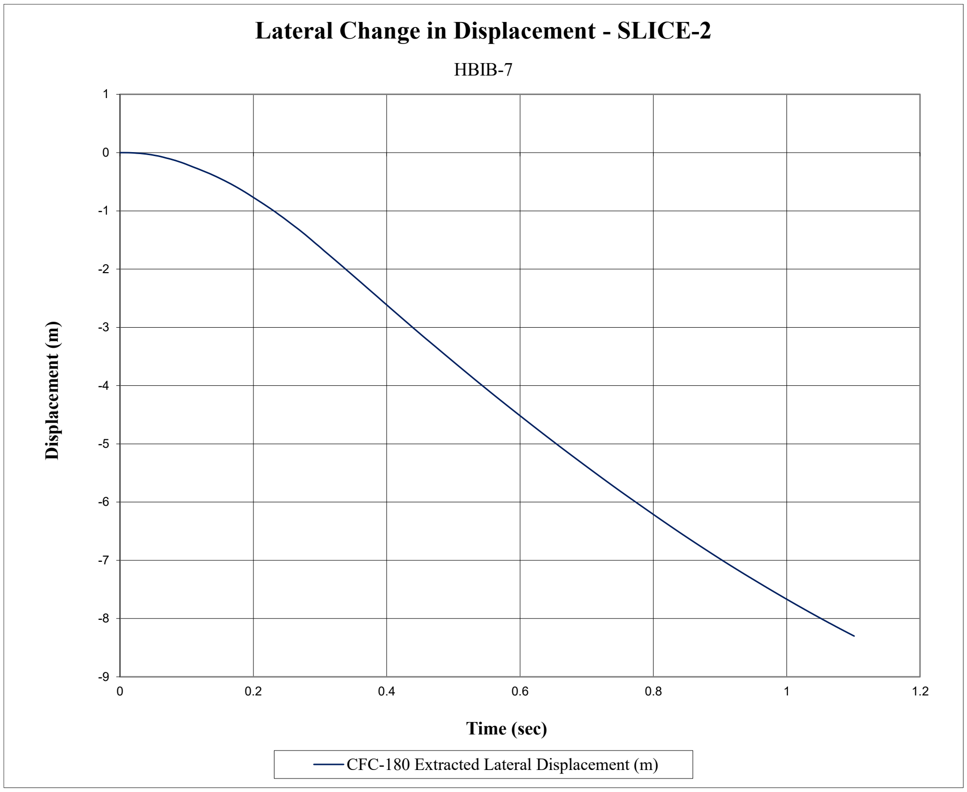


Figure H-14. Lateral Occupant Displacement (SLICE-2), Test No. HBIB-7

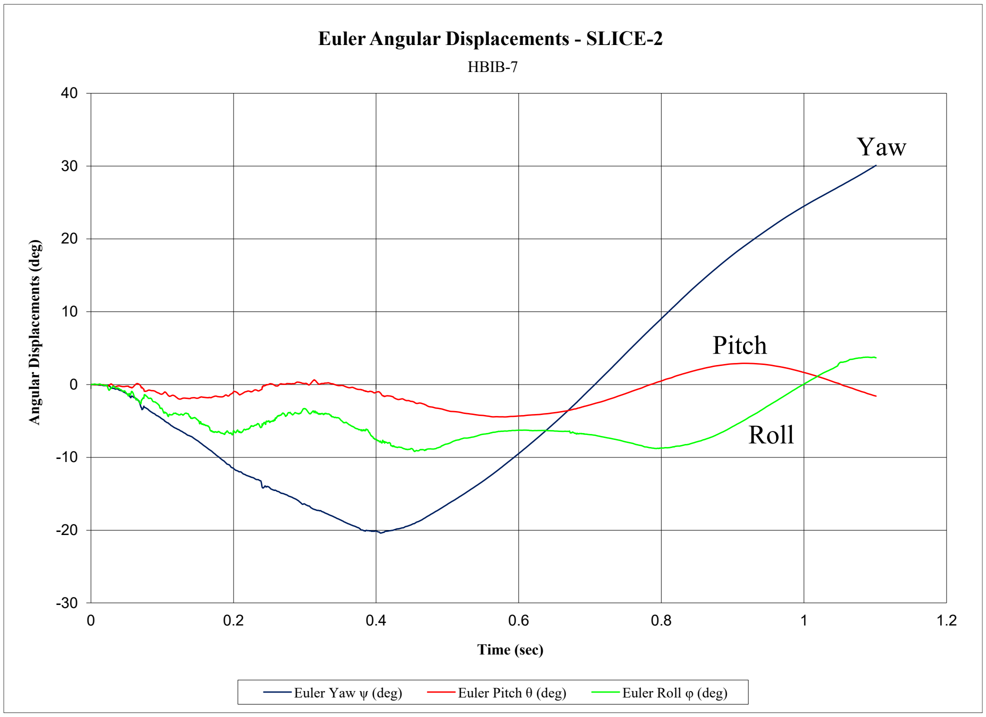


Figure H-15. Vehicle Angular Displacements (SLICE-2), Test No. HBIB-7

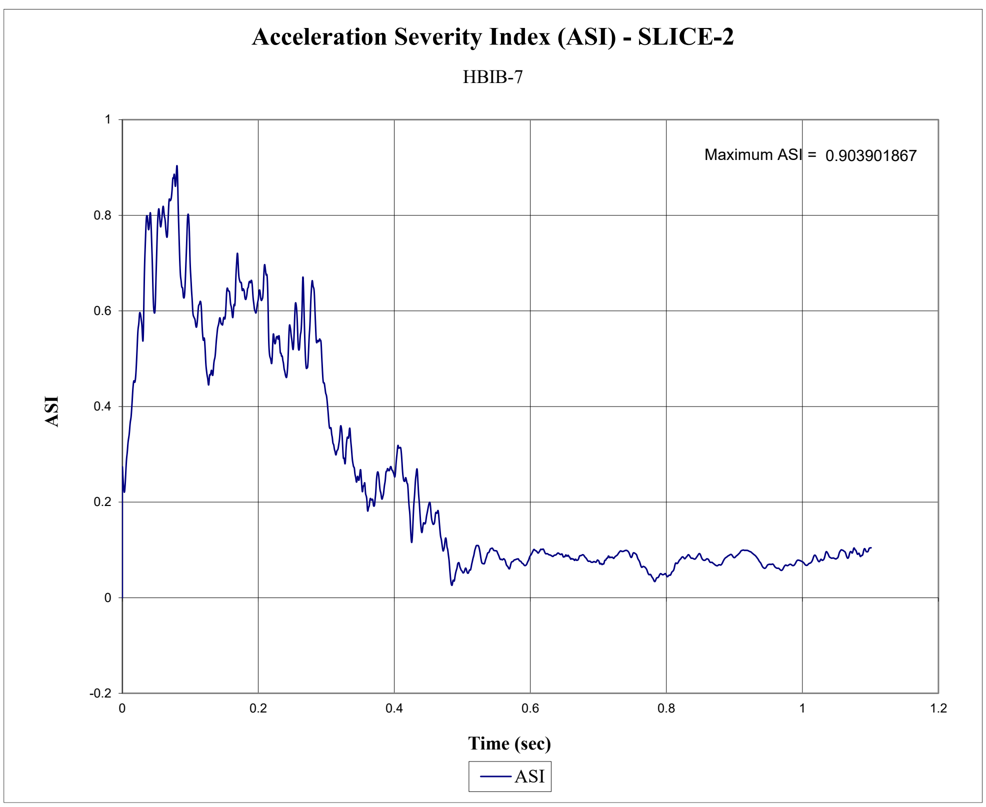


Figure H-16. Acceleration Severity Index (SLICE-2), Test No. HBIB-7

Appendix I. Accelerometer and Rate Transducer Data Plots, Test No. HBIB-8

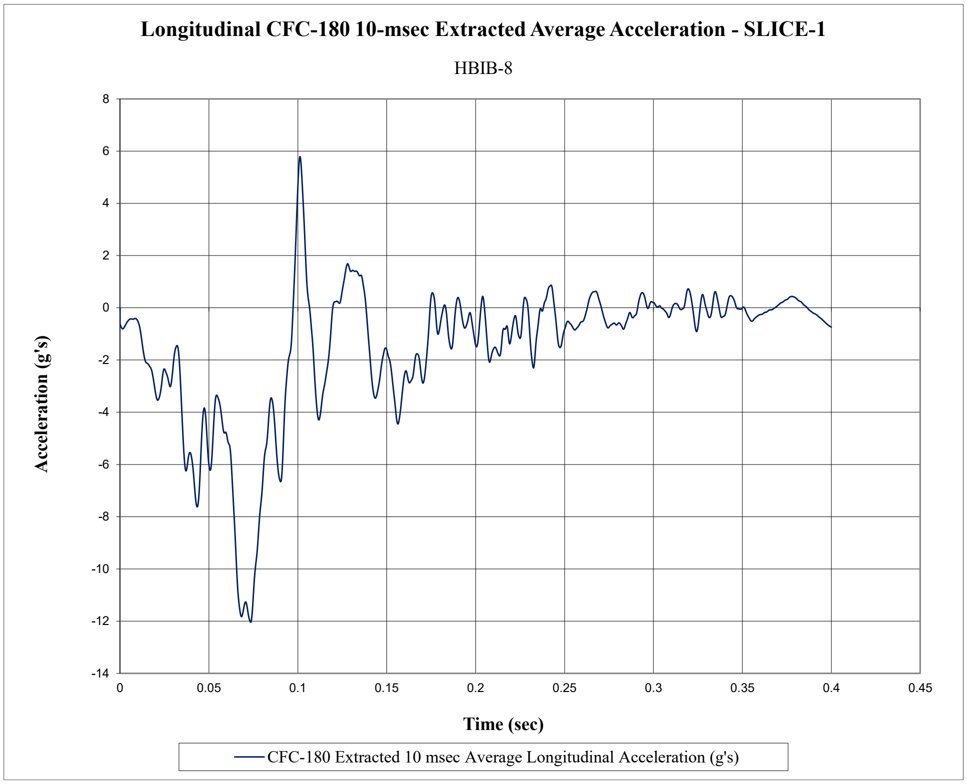


Figure I-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. HBIB-8

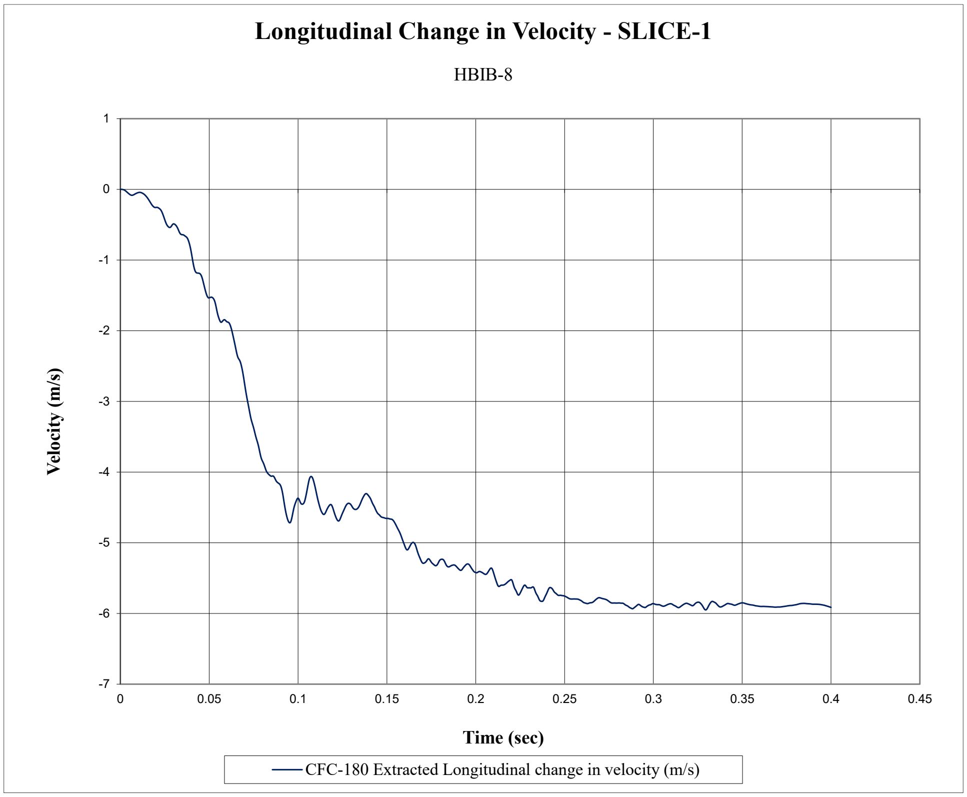


Figure I-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. HBIB-8

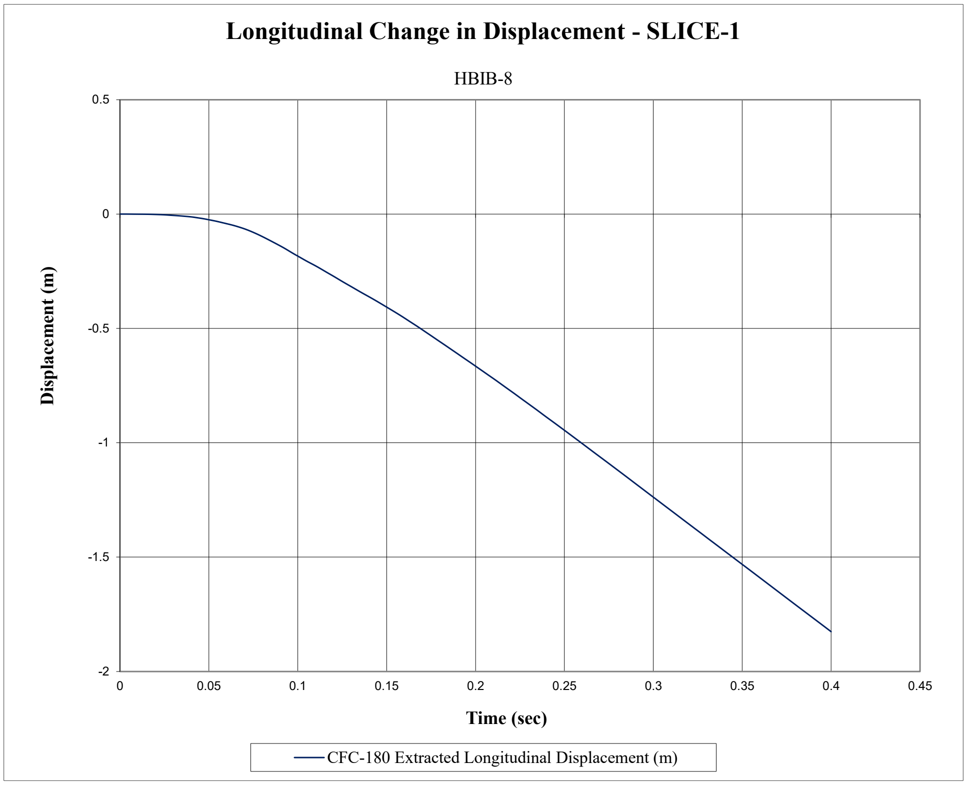


Figure I-3. Longitudinal Occupant Displacement (SLICE-1), Test No. HBIB-8

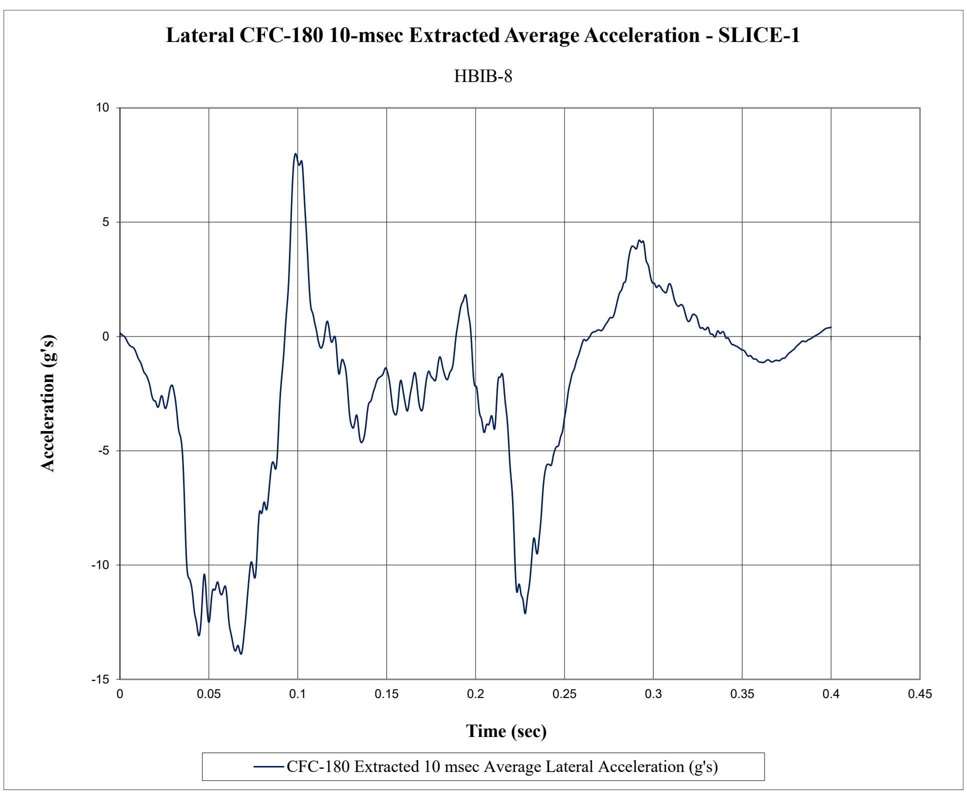


Figure I-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. HBIB-8

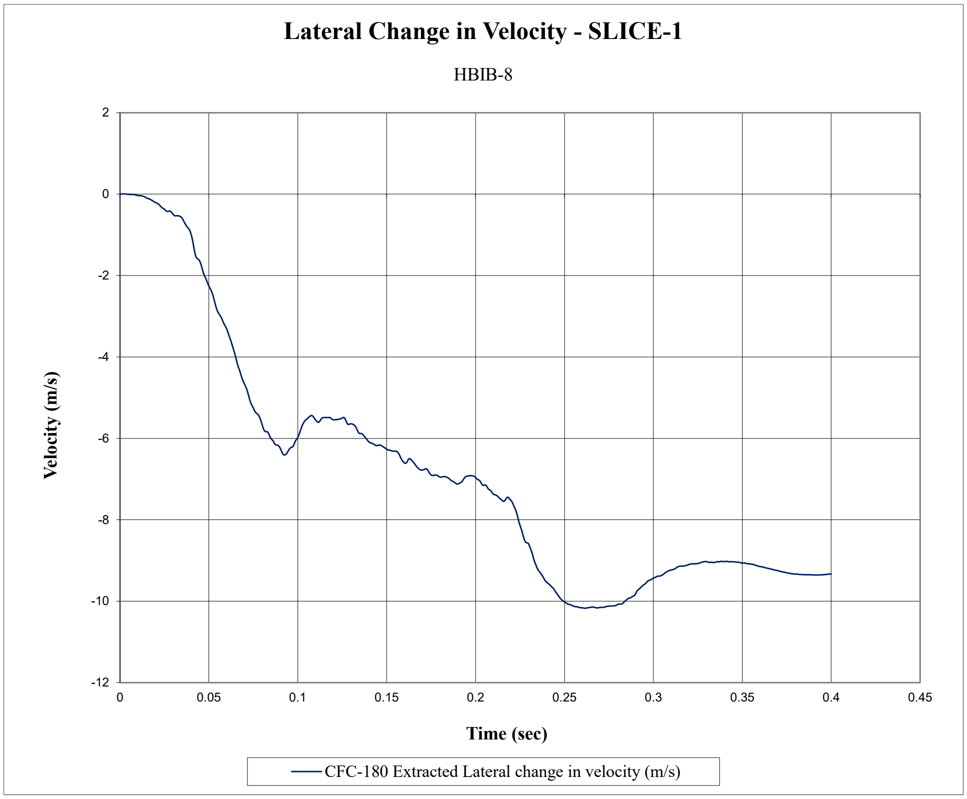


Figure I-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. HBIB-8

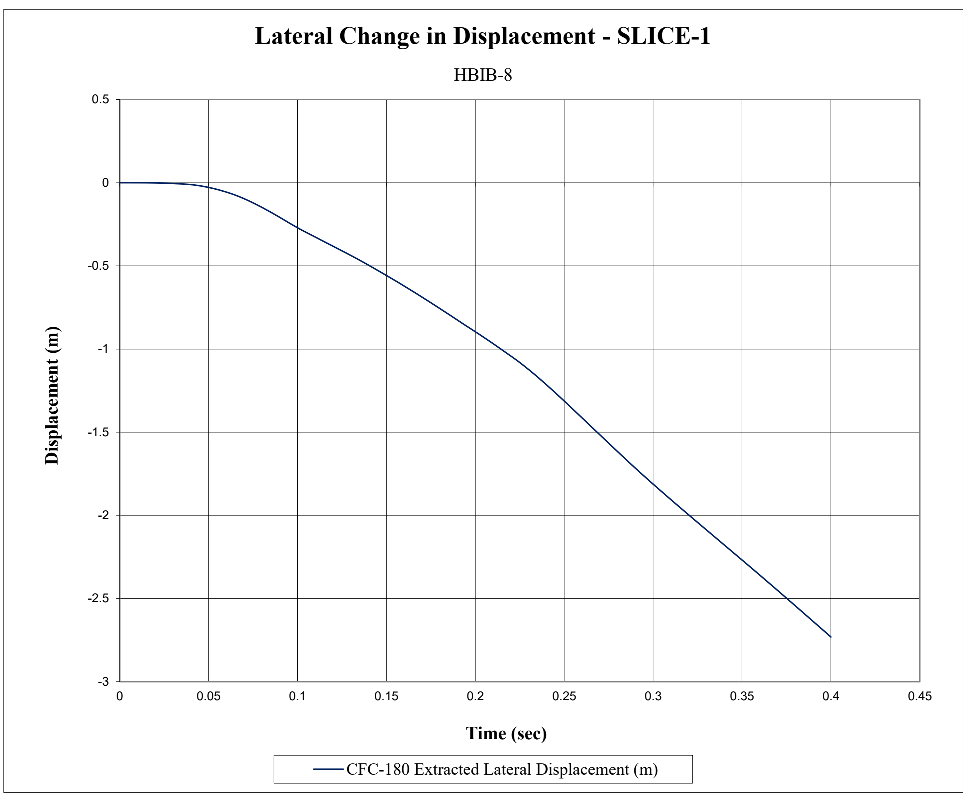


Figure I-6. Lateral Occupant Displacement (SLICE-1), Test No. HBIB-8

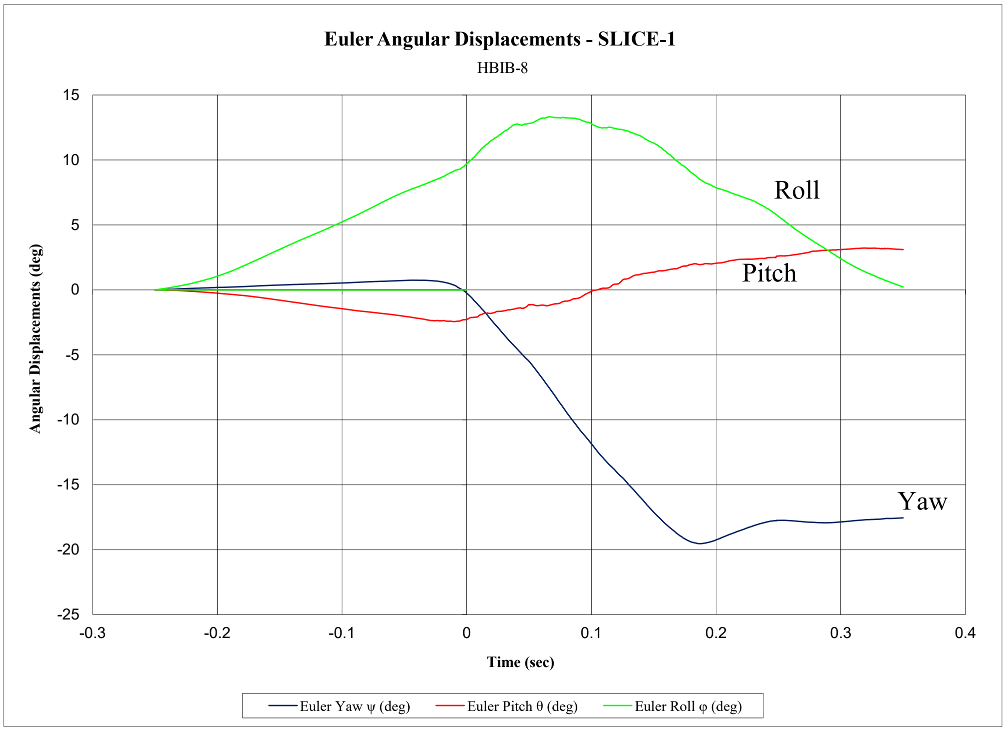


Figure I-7. Vehicle Angular Displacements (SLICE-1), Test No. HBIB-8

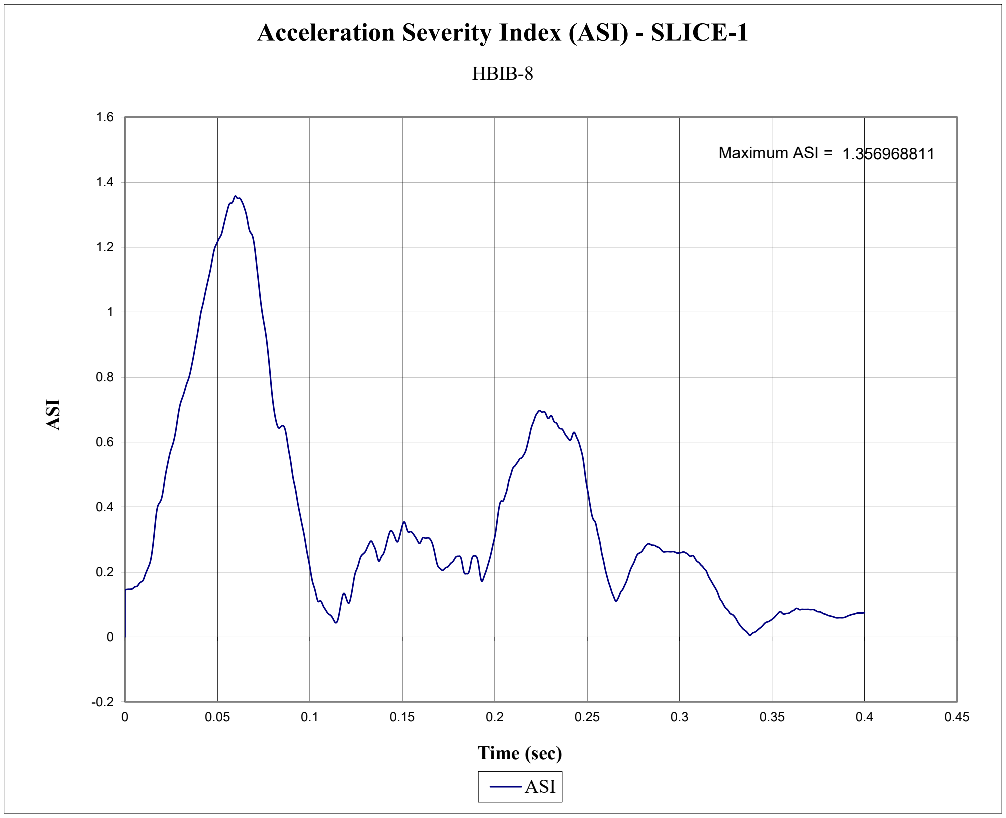


Figure I-8. Acceleration Severity Index (SLICE-1), Test No. HBIB-8

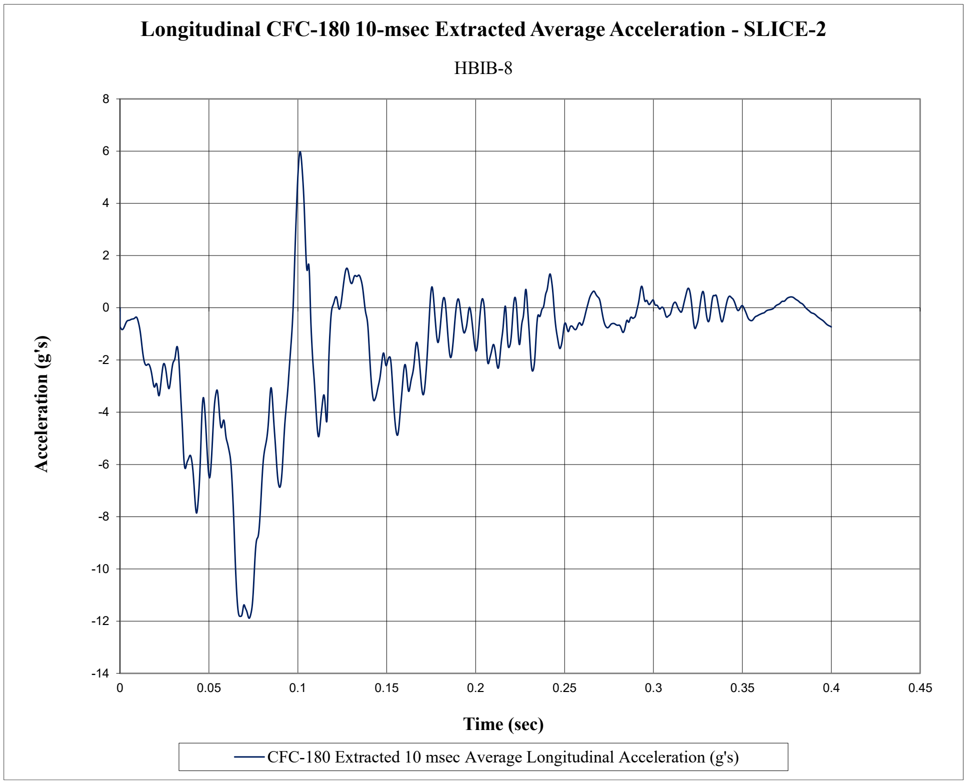


Figure I-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. HBIB-8

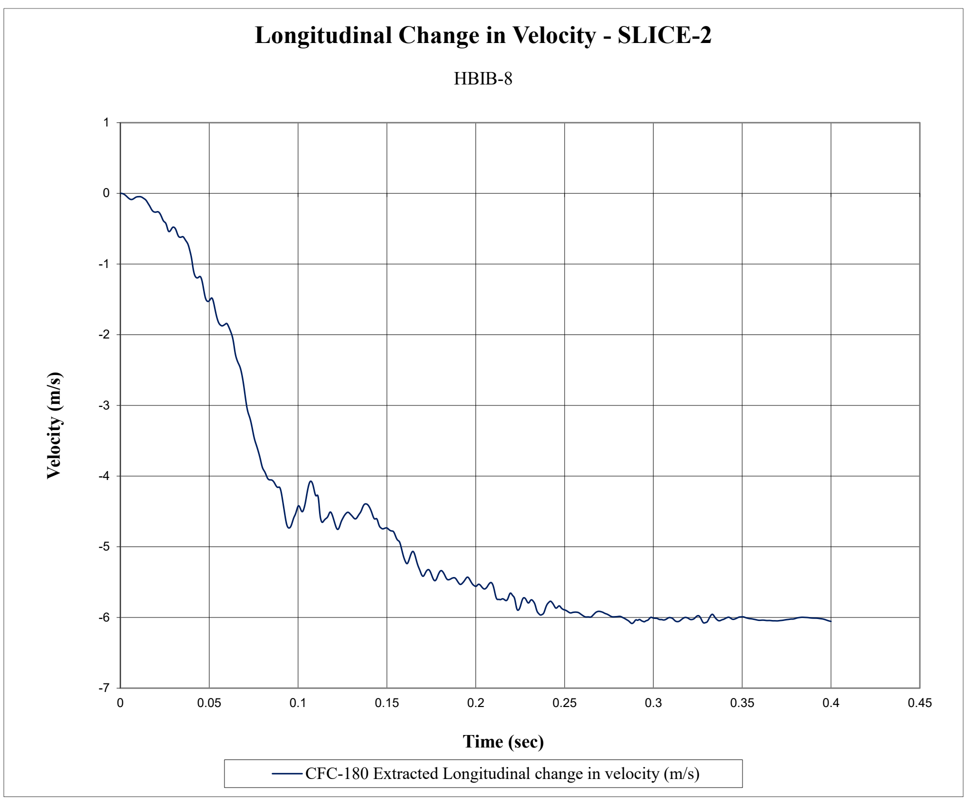


Figure I-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. HBIB-8

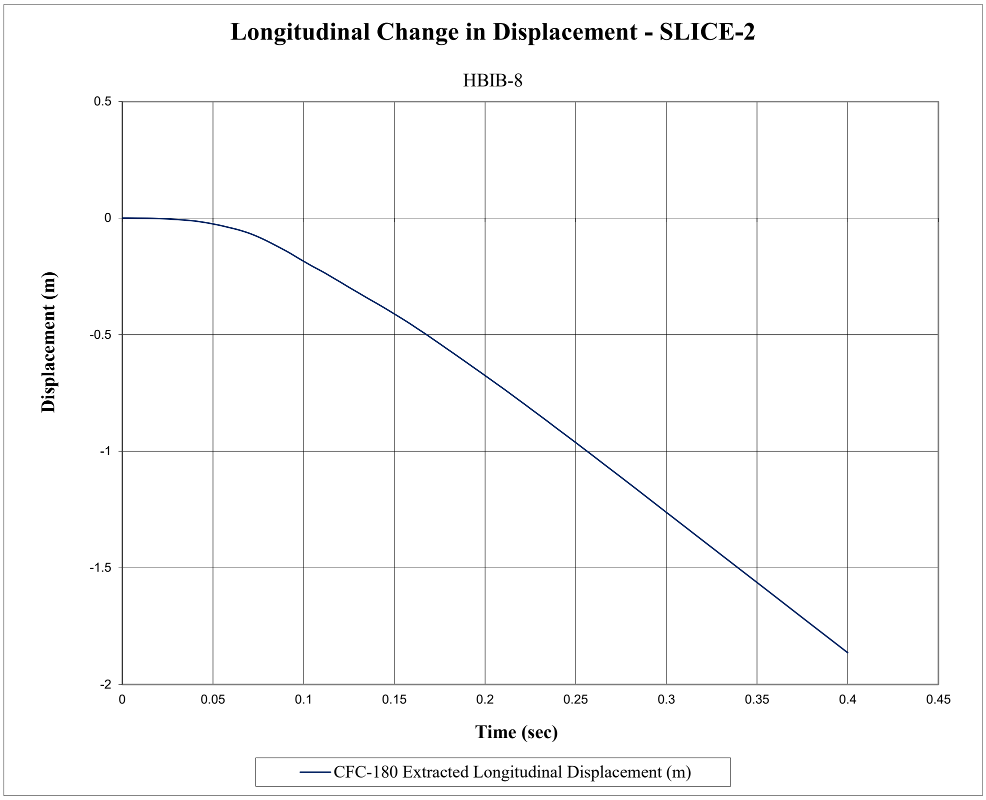


Figure I-11. Longitudinal Occupant Displacement (SLICE-2), Test No. HBIB-8

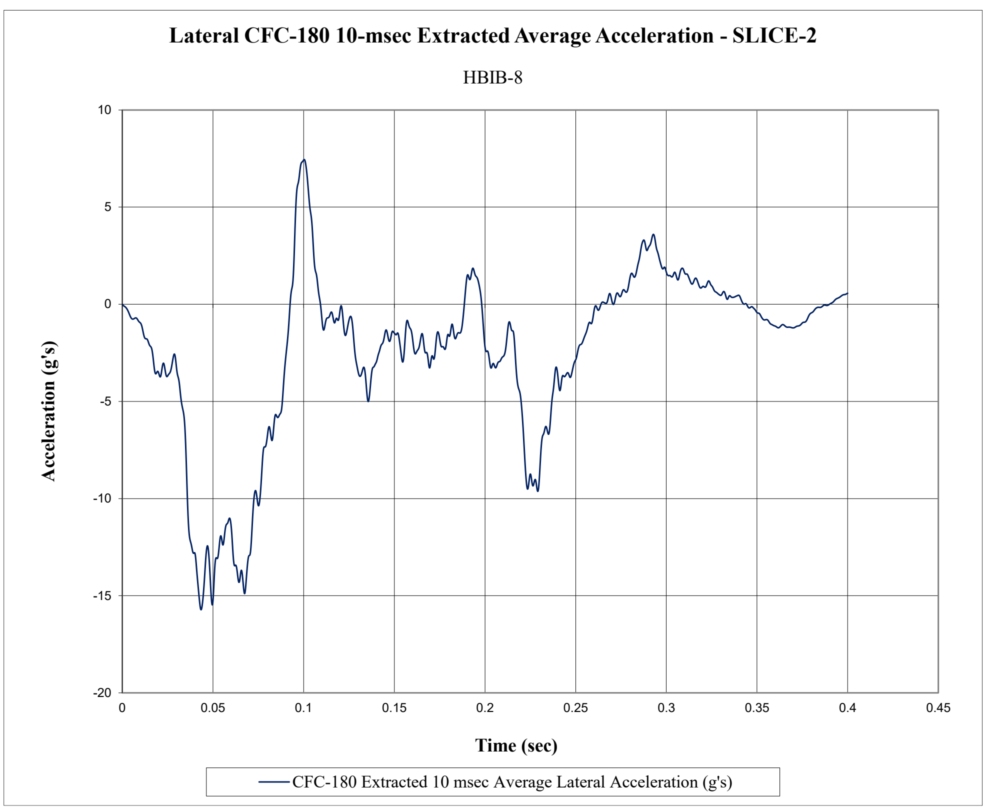


Figure I-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. HBIB-8

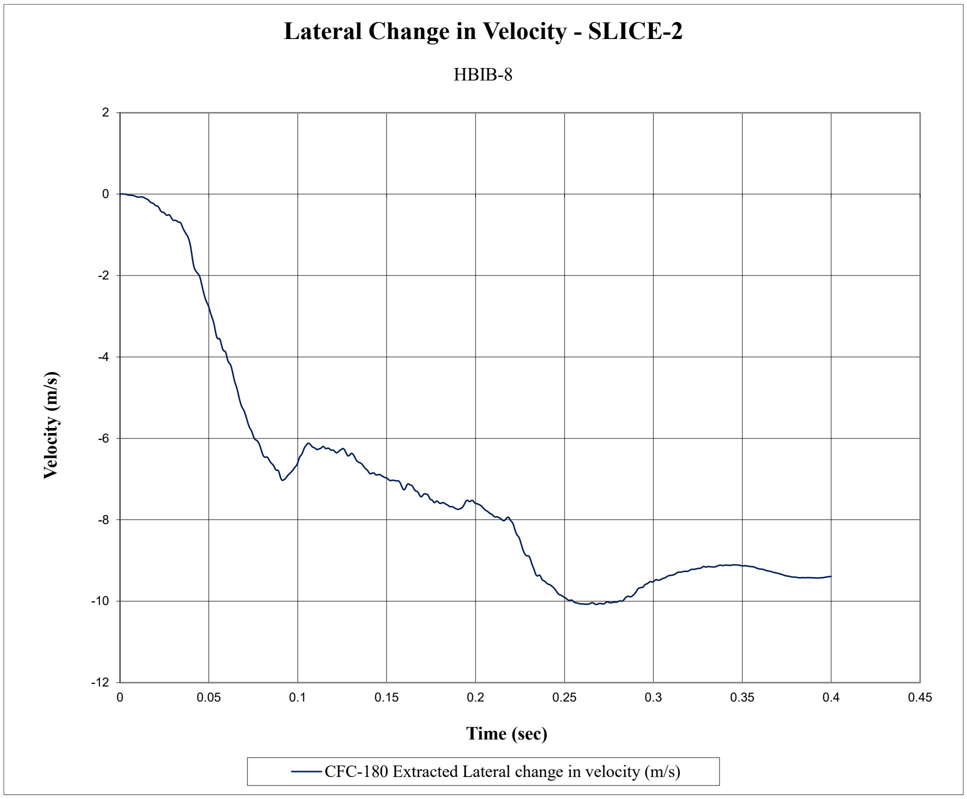


Figure I-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. HBIB-8

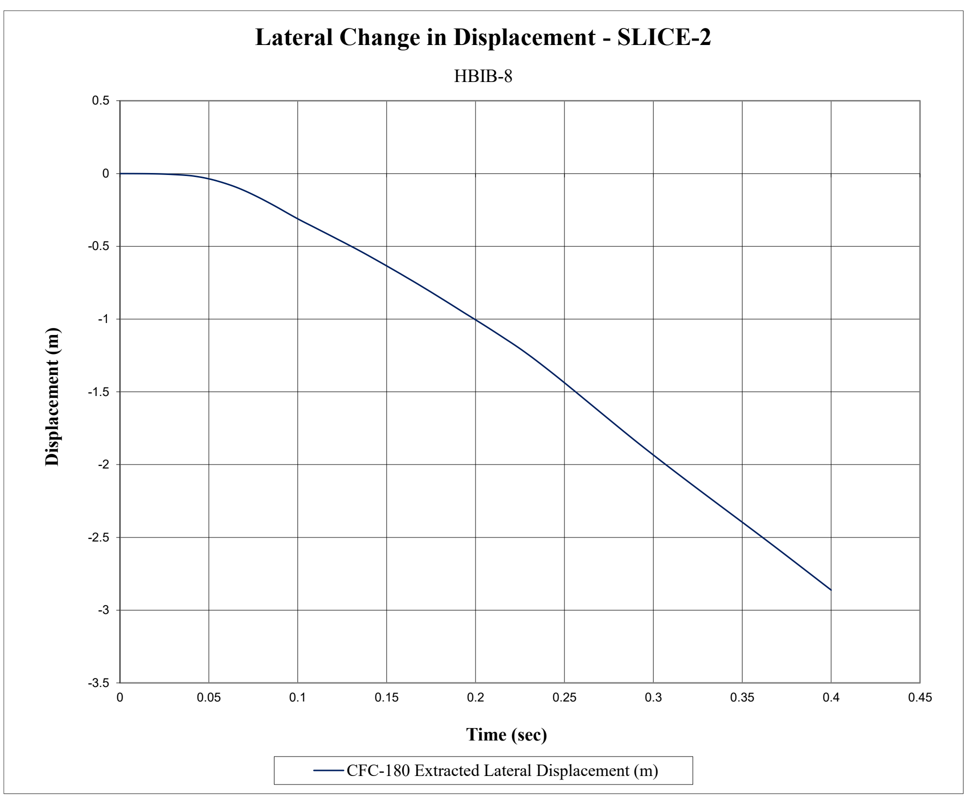


Figure I-14. Lateral Occupant Displacement (SLICE-2), Test No. HBIB-8

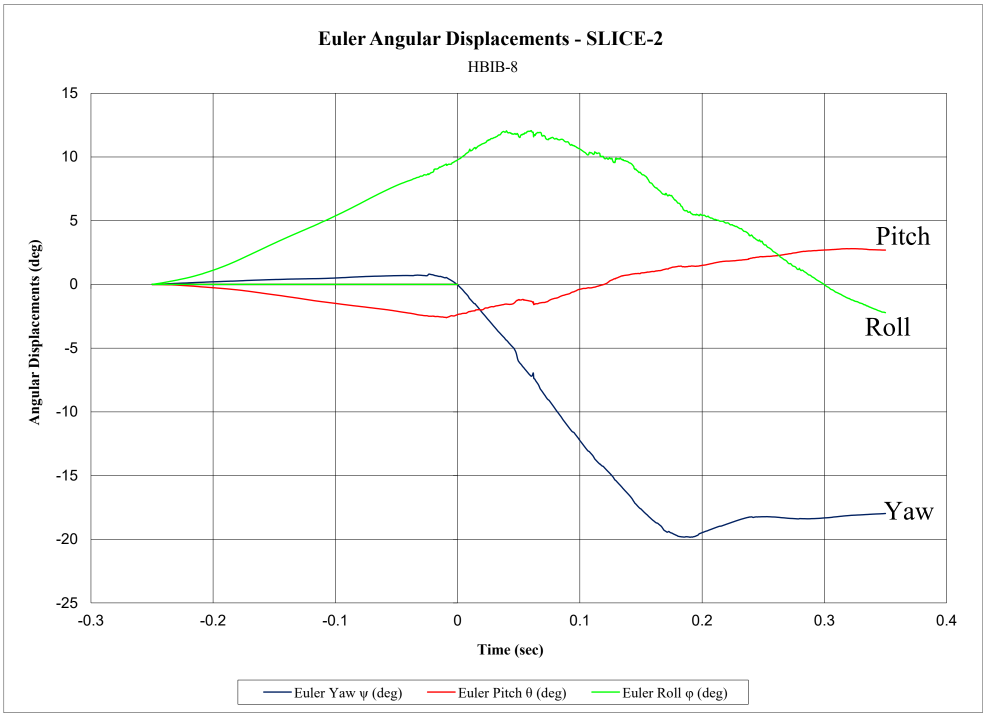


Figure I-15. Vehicle Angular Displacements (SLICE-2), Test No. HBIB-8

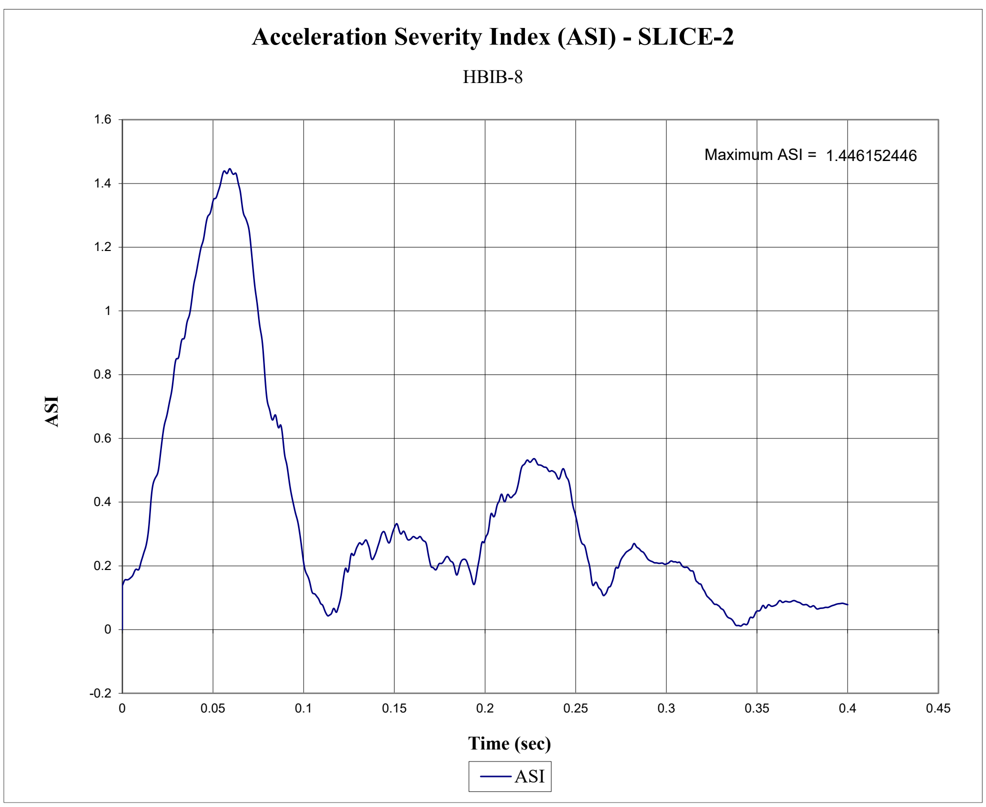


Figure I-16. Acceleration Severity Index (SLICE-2), Test No. HBIB-8

Appendix J. Accelerometer and Rate Transducer Data Plots, Test No. HBIB-10

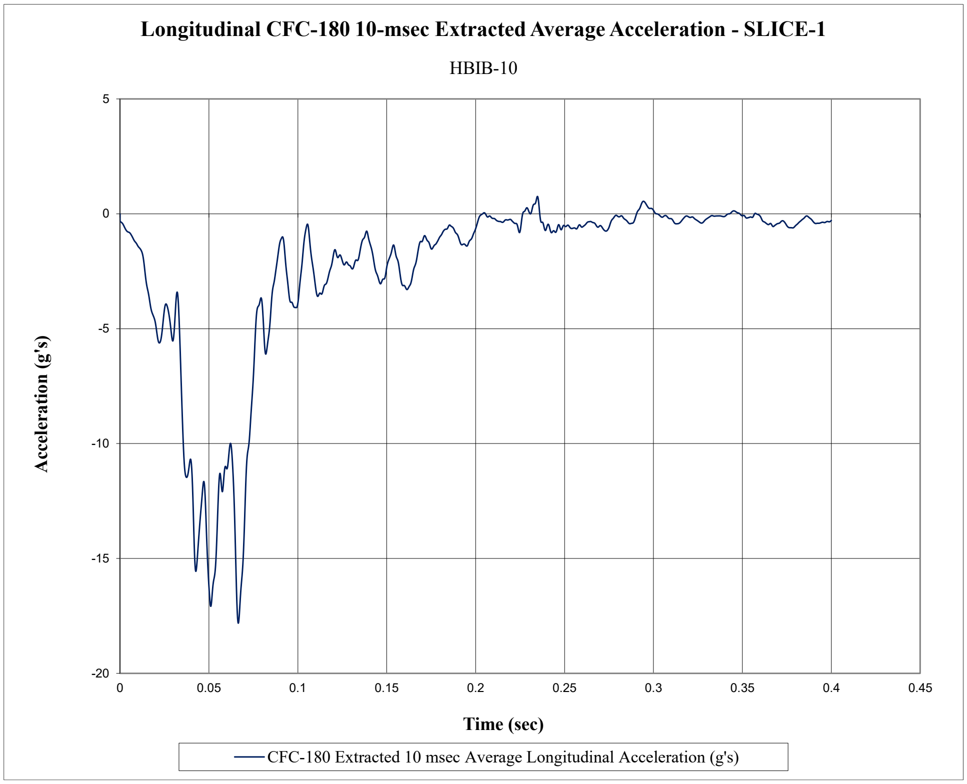


Figure J-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. HBIB-10

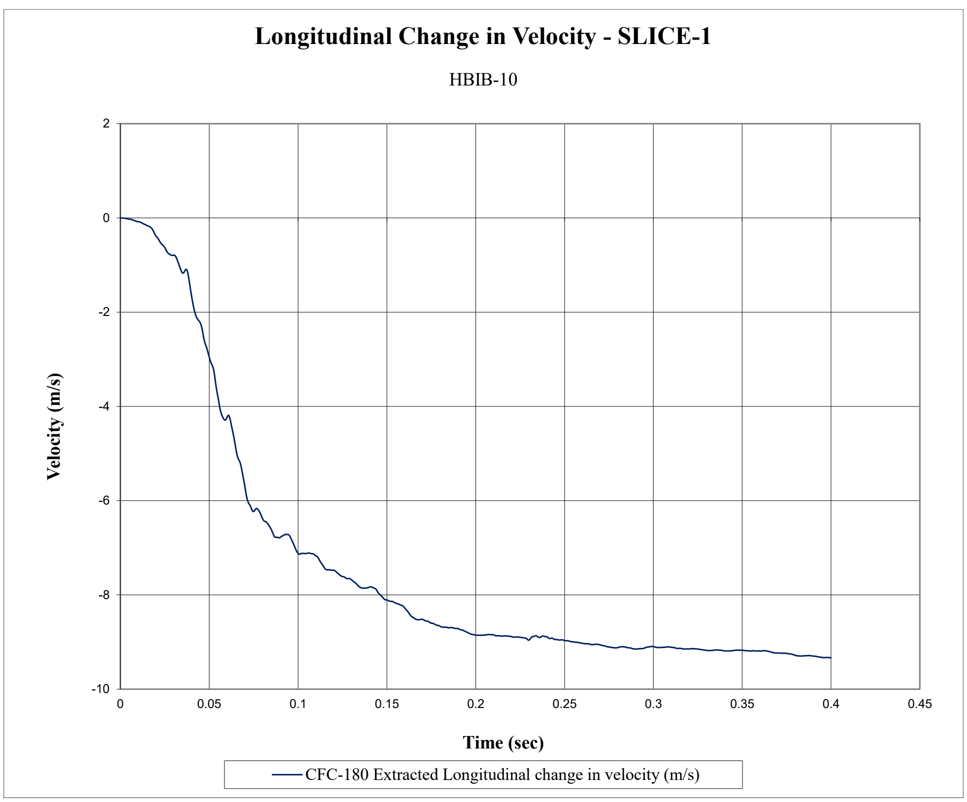


Figure J-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. HBIB-10

Figure J-3. Longitudinal Occupant Displacement (SLICE-1), Test No. HBIB-10

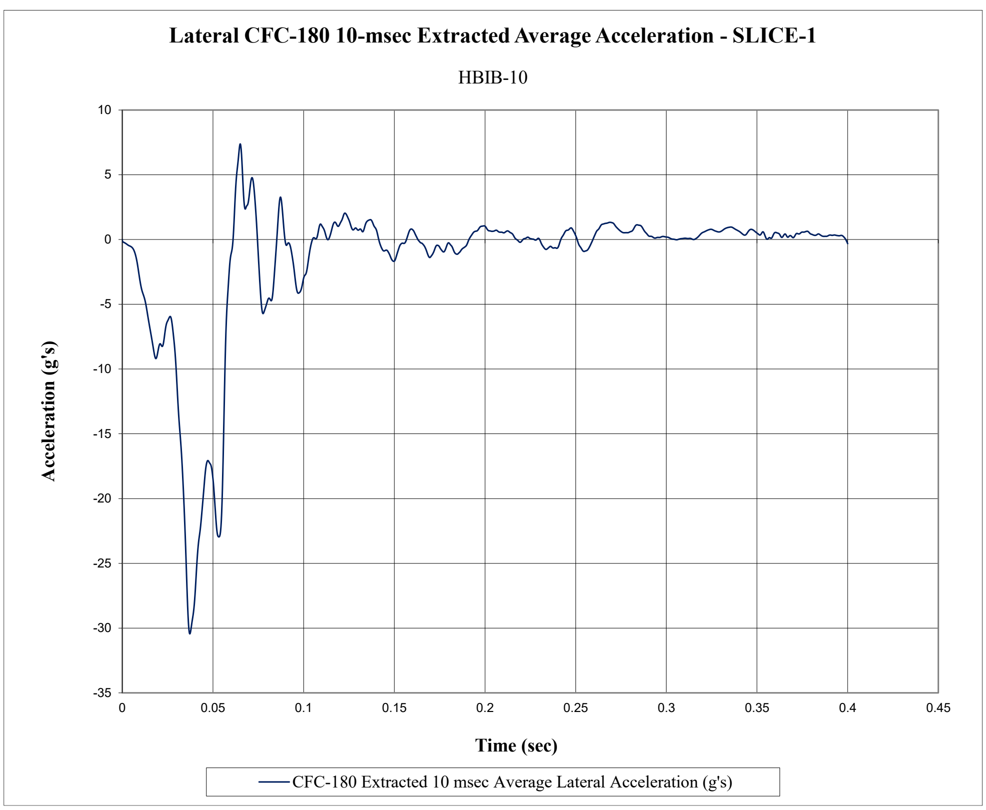


Figure J-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. HBIB-10

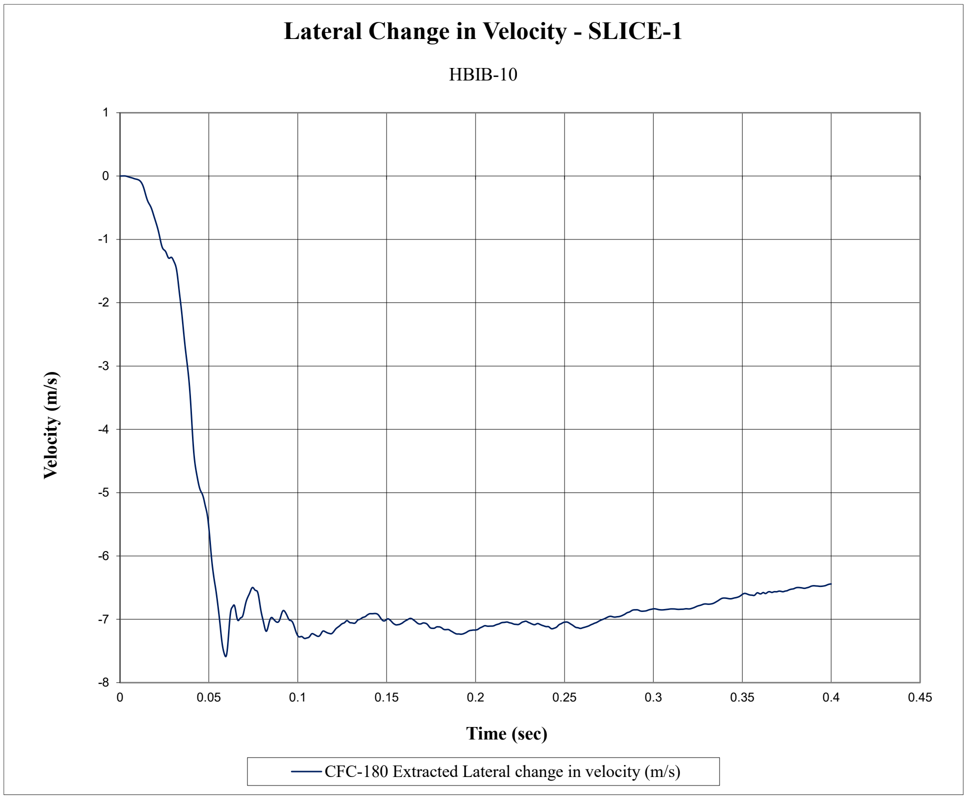


Figure J-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. HBIB-10

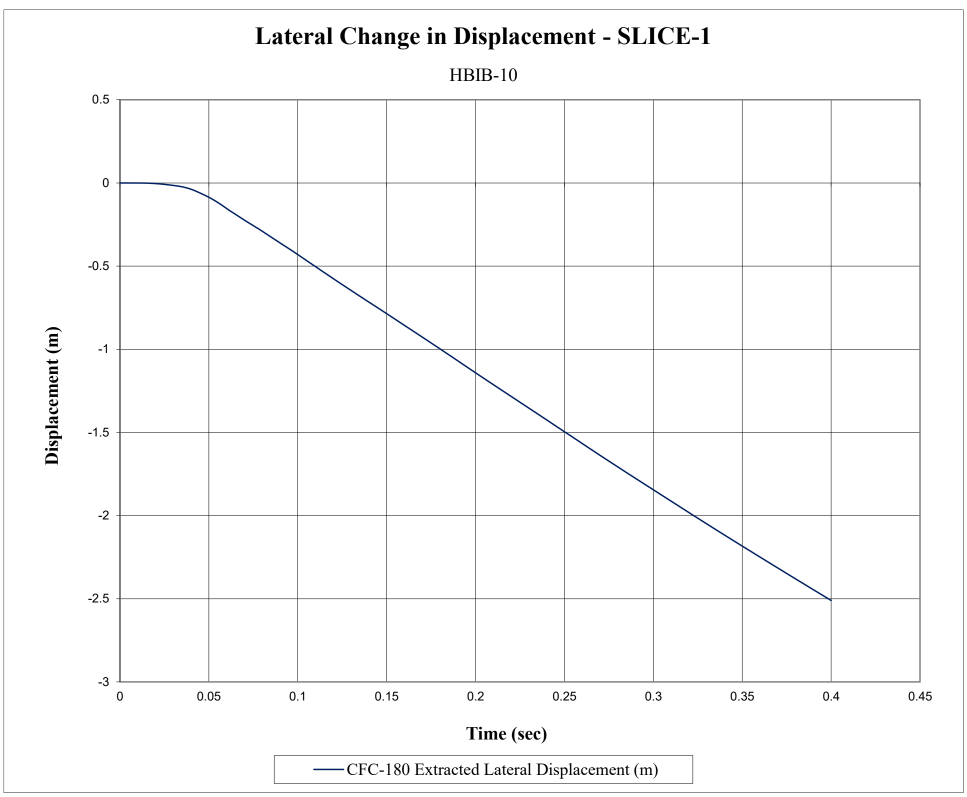


Figure J-6. Lateral Occupant Displacement (SLICE-1), Test No. HBIB-10

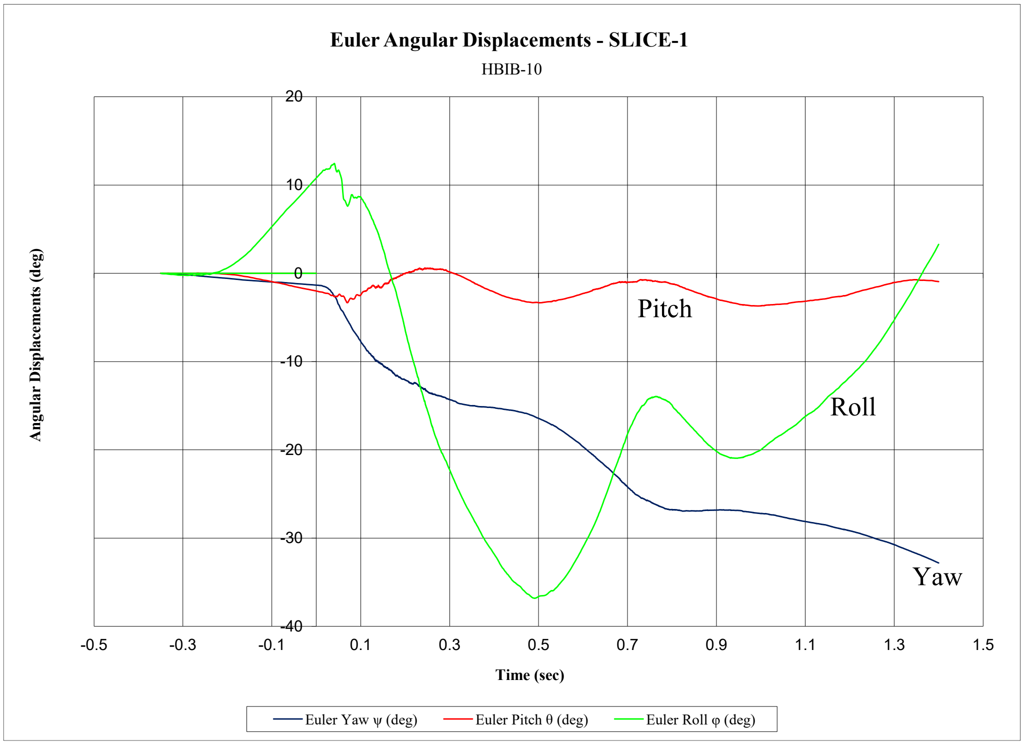


Figure J-7. Vehicle Angular Displacements (SLICE-1), Test No. HBIB-10

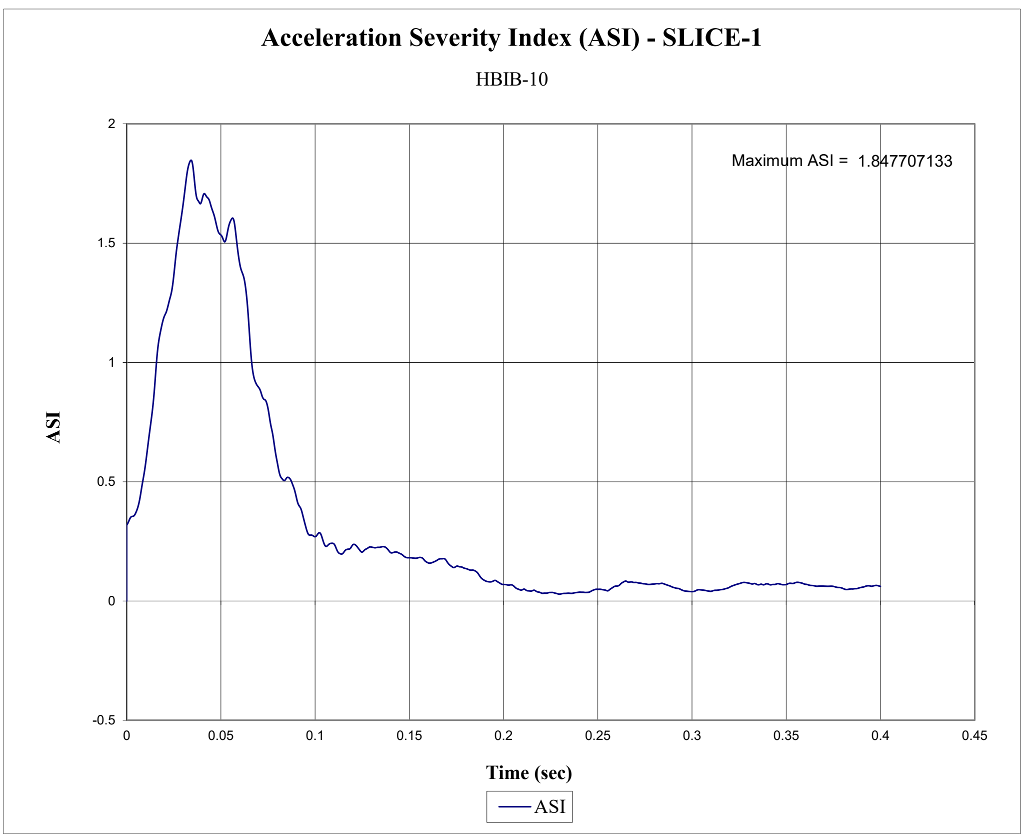


Figure J-8. Acceleration Severity Index (SLICE-1), Test No. HBIB-10

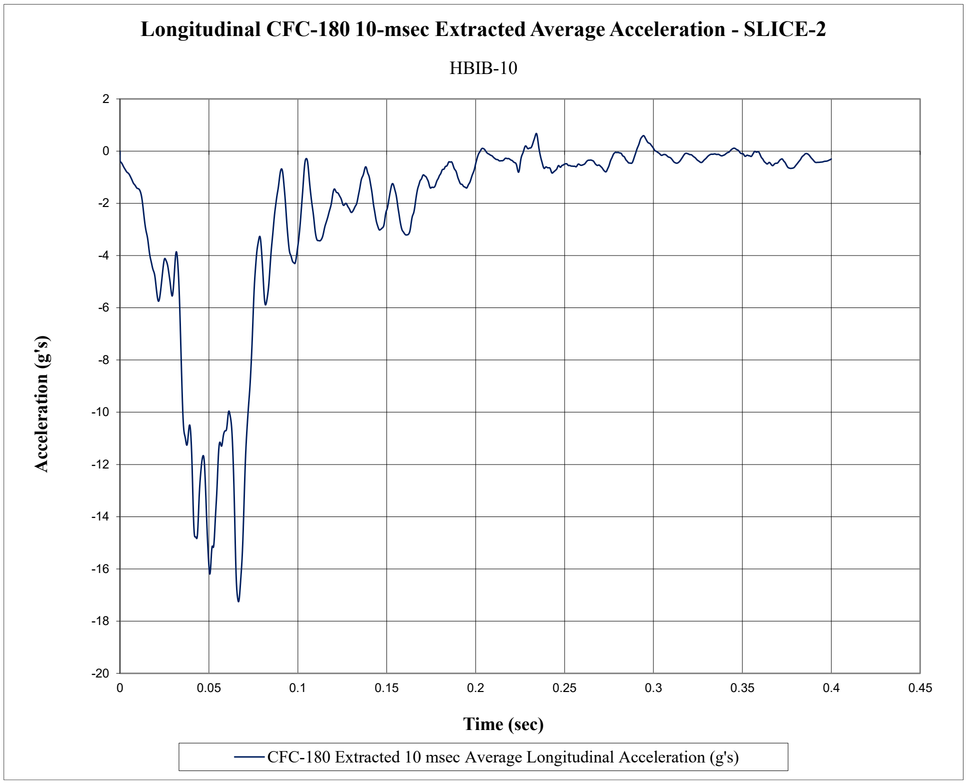


Figure J-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. HBIB-10

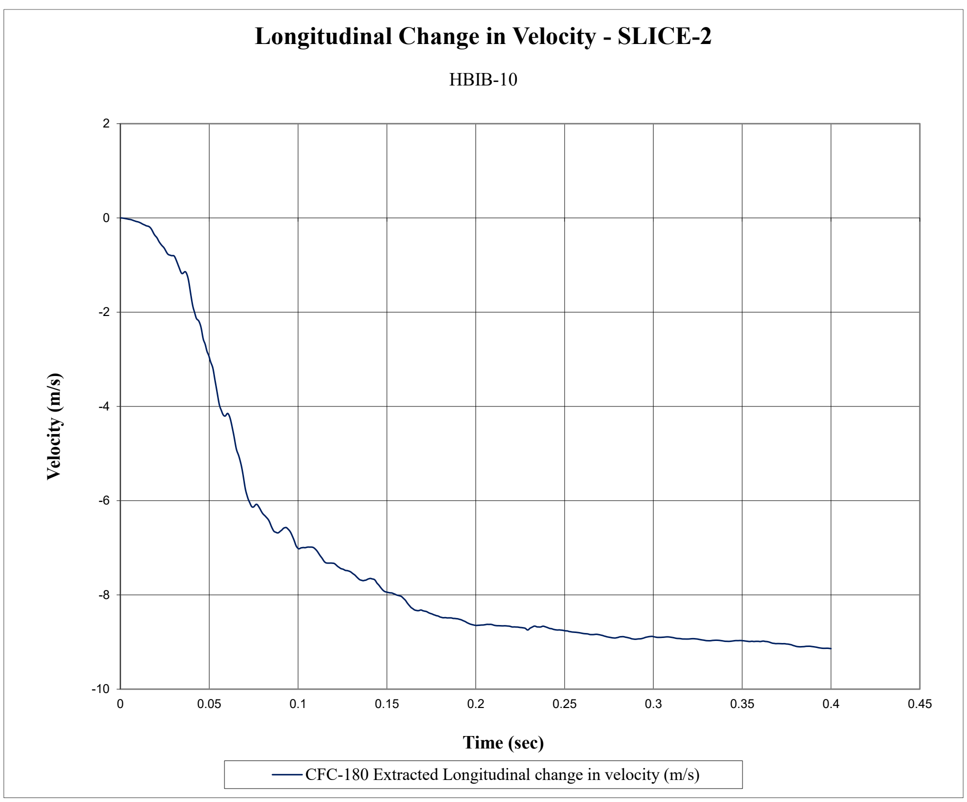


Figure J-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. HBIB-10

Figure J-11. Longitudinal Occupant Displacement (SLICE-2), Test No. HBIB-10

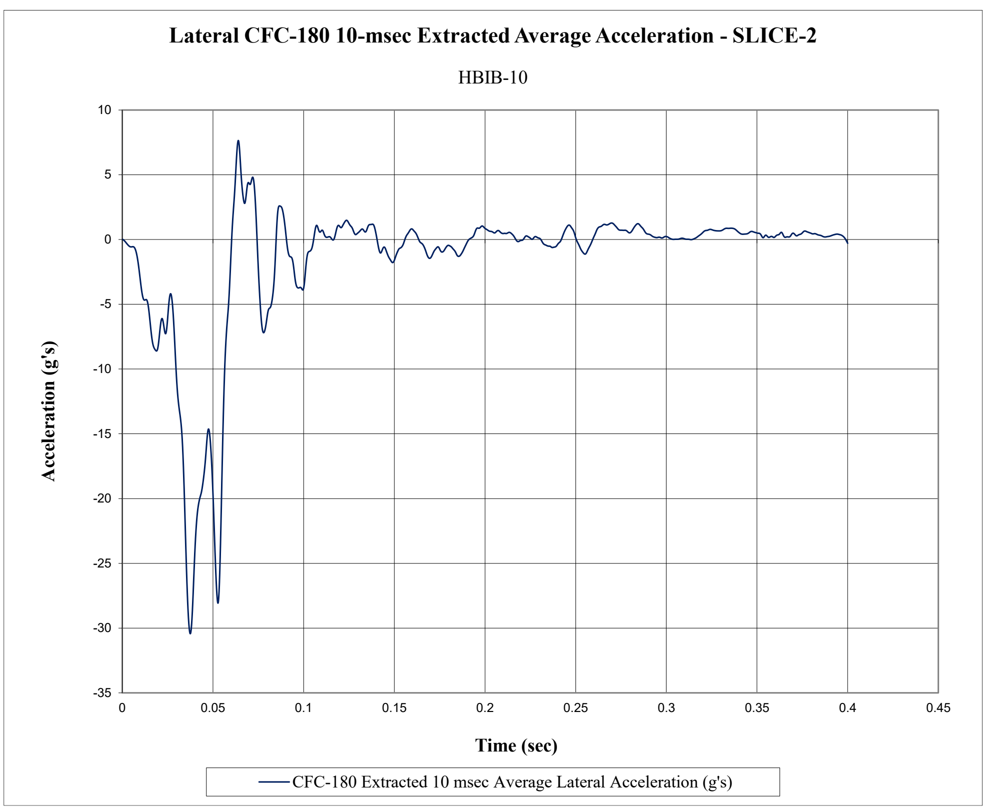


Figure J-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. HBIB-10

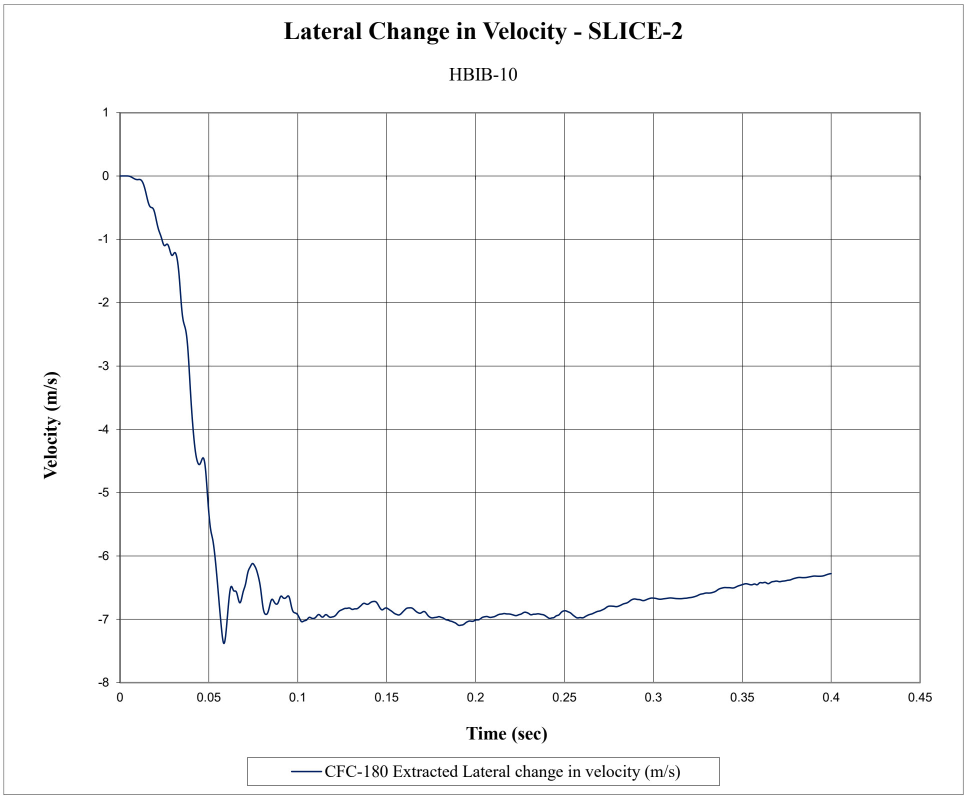


Figure J-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. HBIB-10

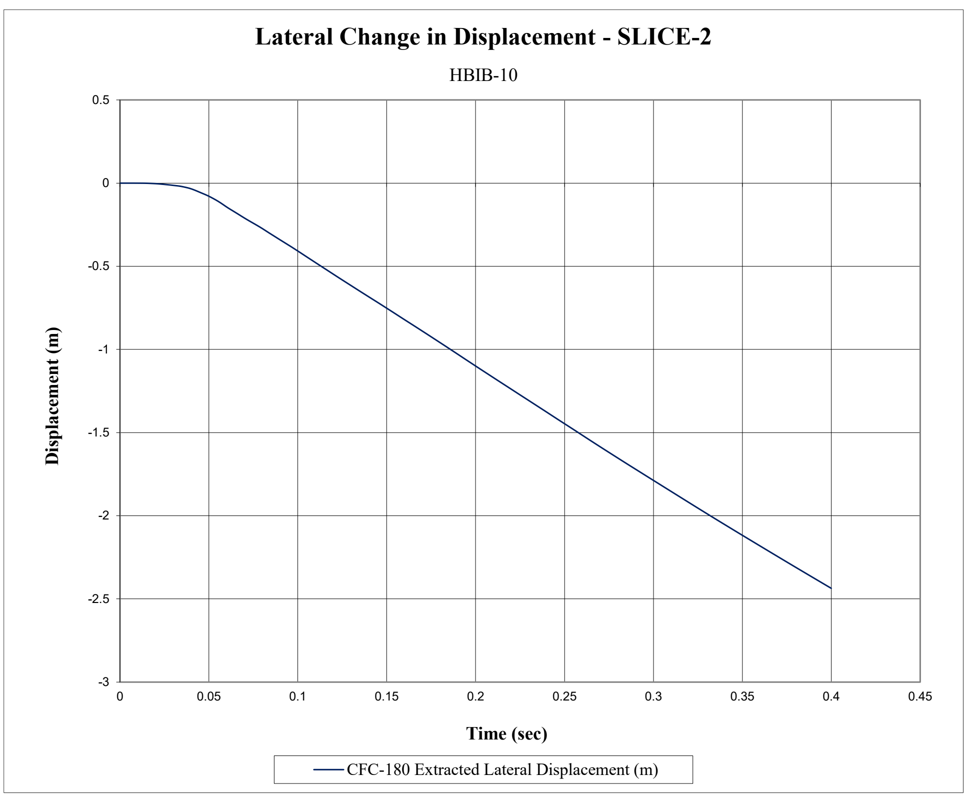


Figure J-14. Lateral Occupant Displacement (SLICE-2), Test No. HBIB-10

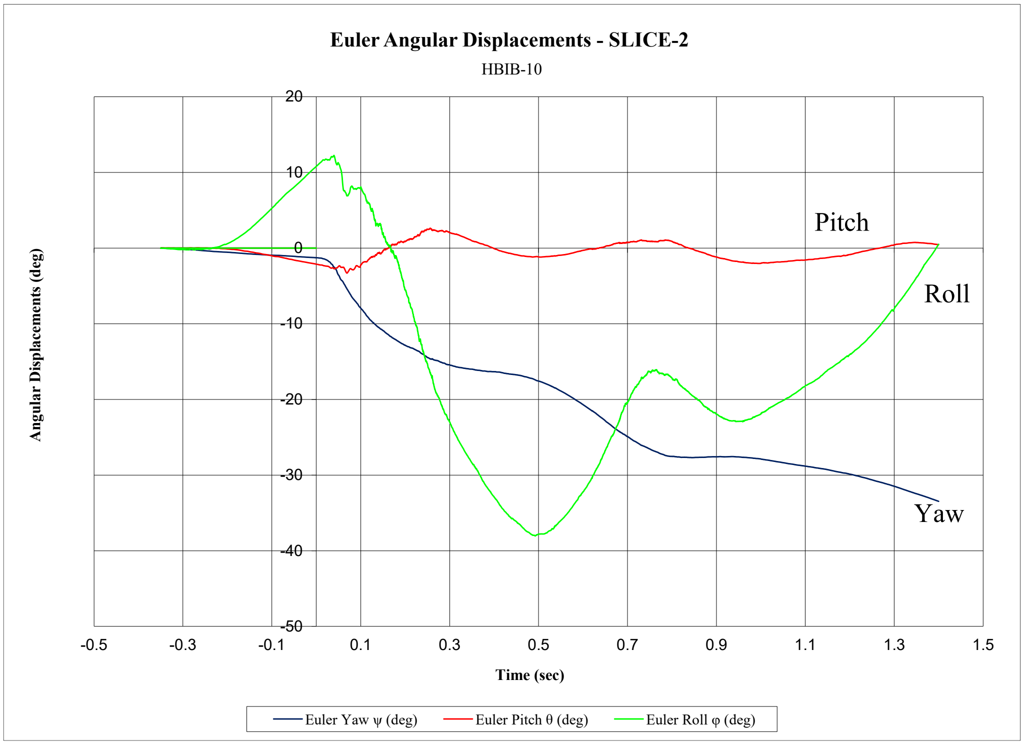


Figure J-15. Vehicle Angular Displacements (SLICE-2), Test No. HBIB-10

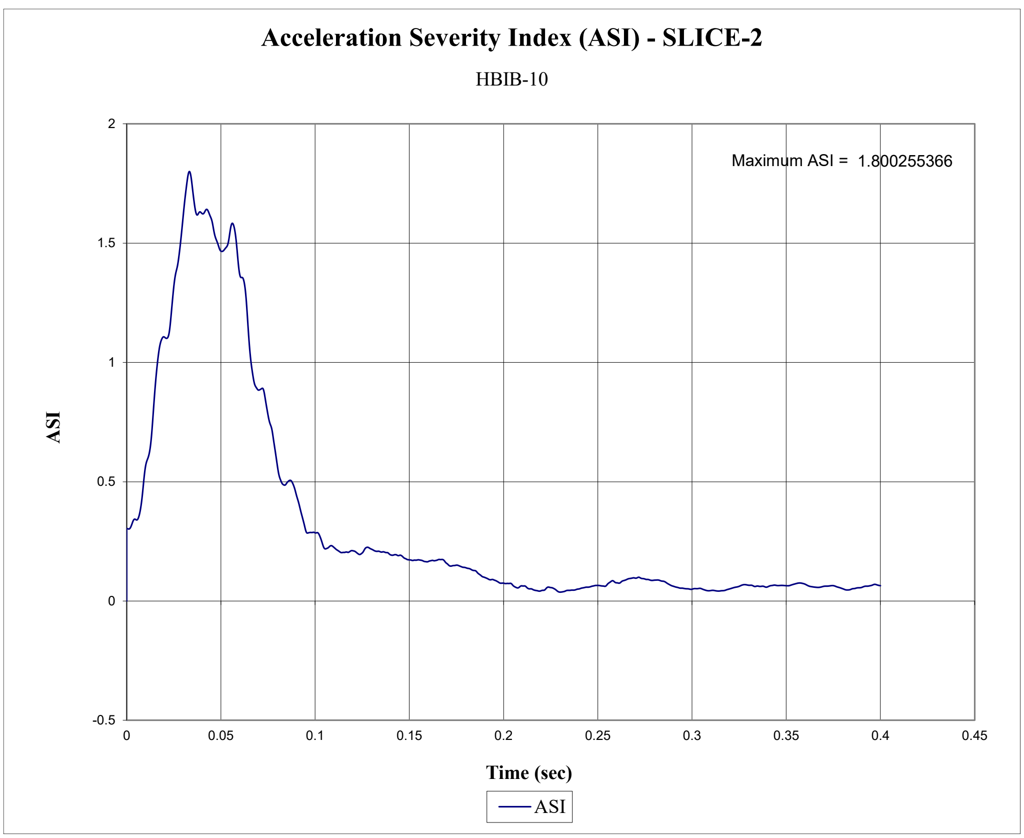


Figure J-16. Acceleration Severity Index (SLICE-2), Test No. HBIB-10

Appendix K. Accelerometer and Rate Transducer Data Plots, Test No. HBIB-9

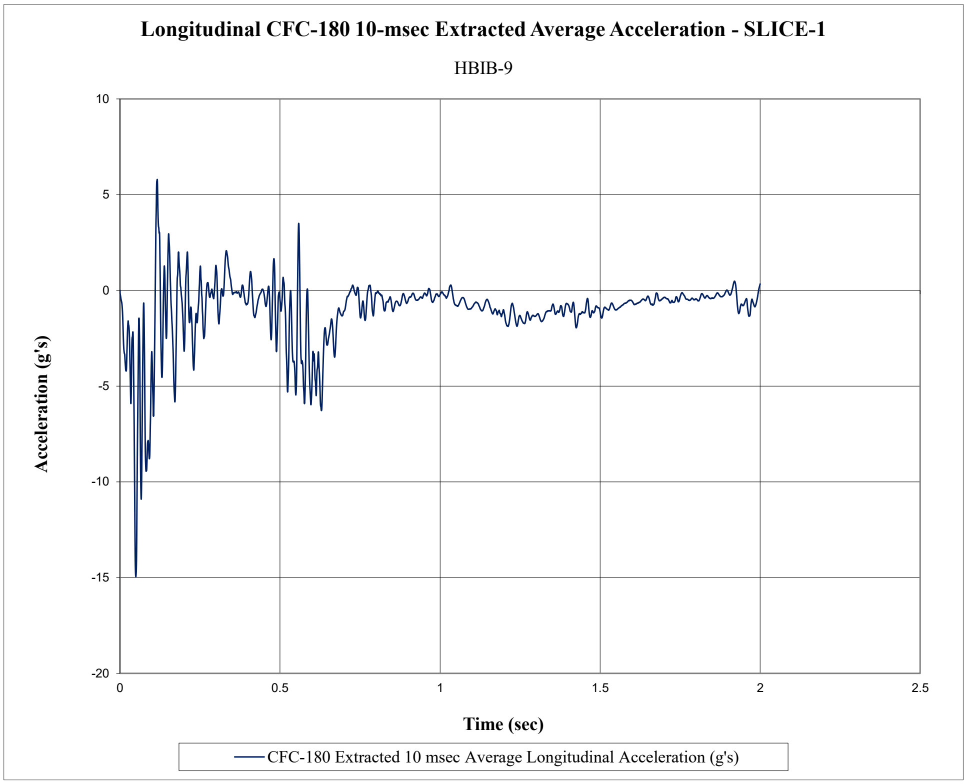


Figure K-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. HBIB-9

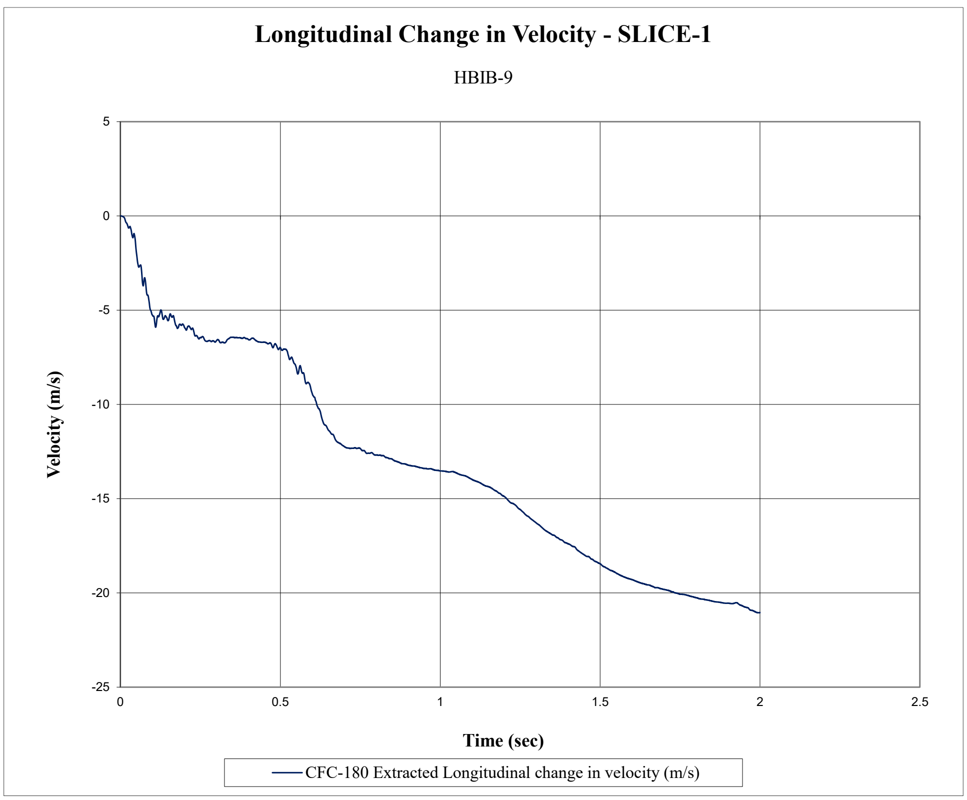


Figure K-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. HBIB-9

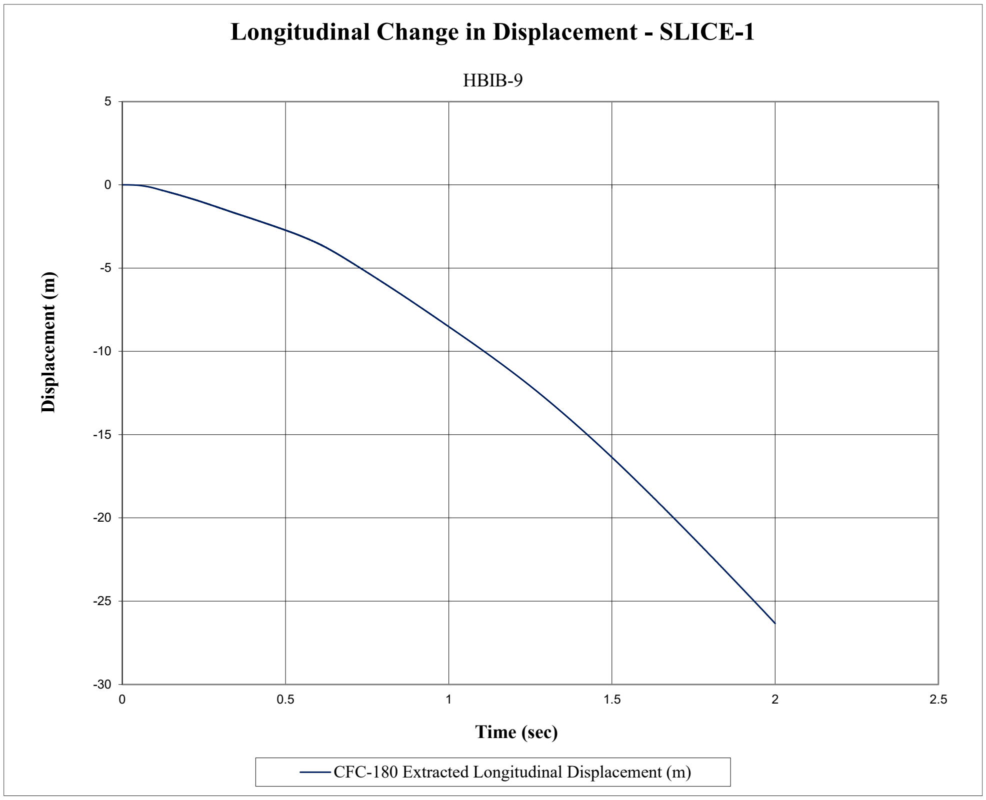


Figure K-3. Longitudinal Occupant Displacement (SLICE-1), Test No. HBIB-9

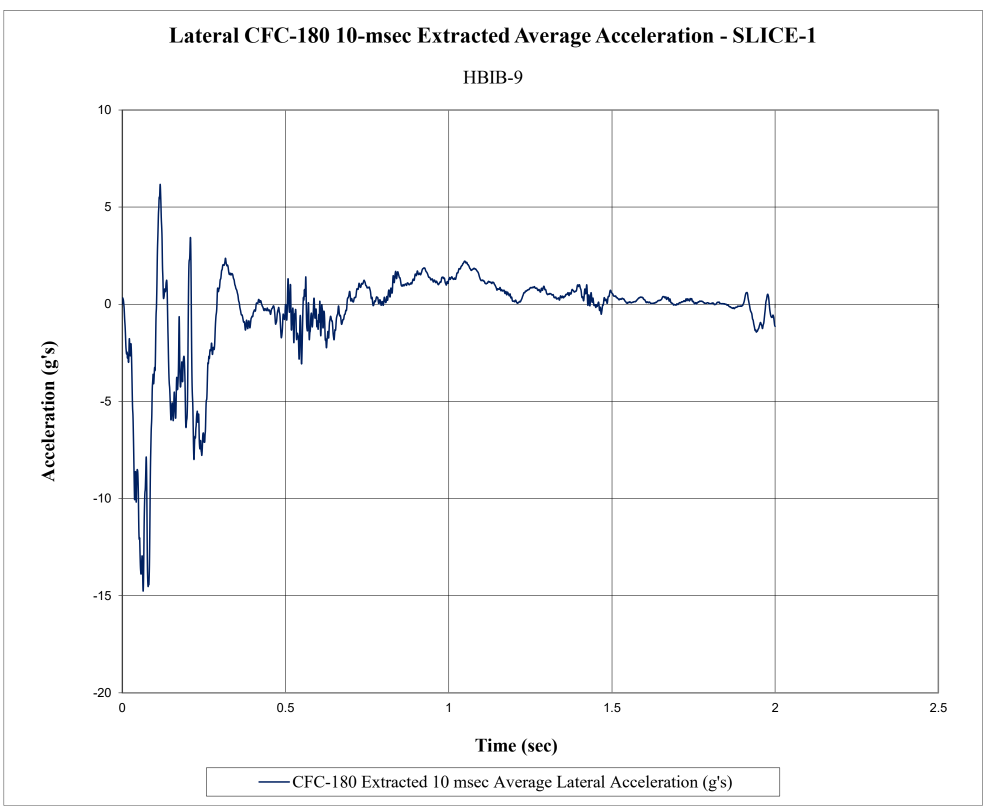


Figure K-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. HBIB-9

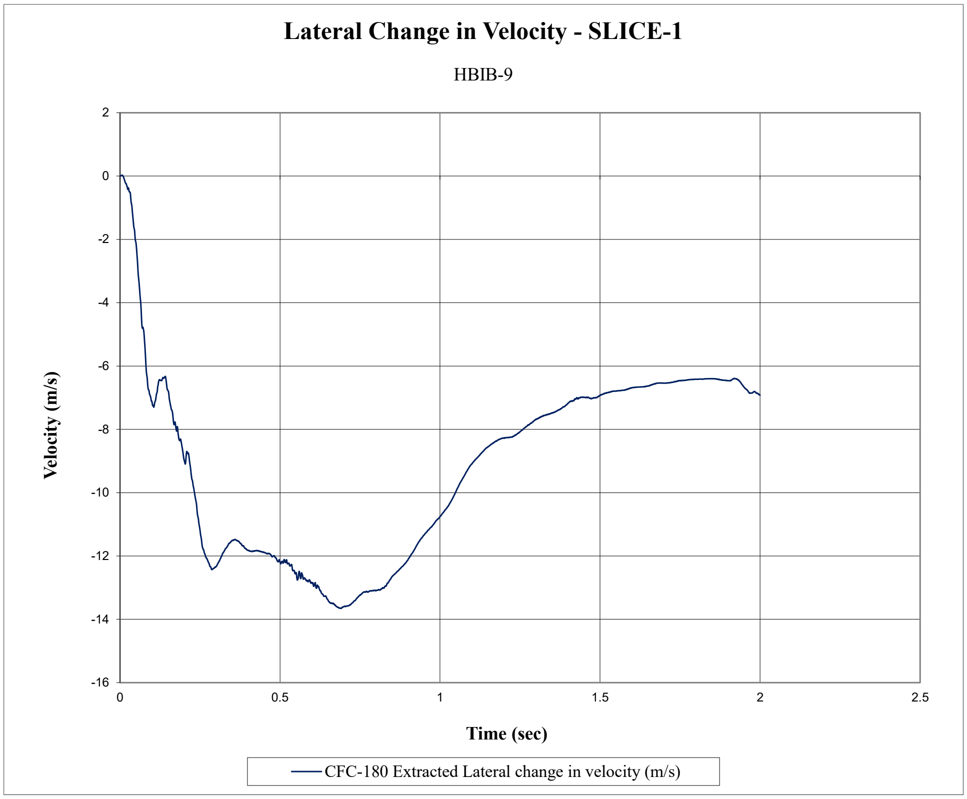


Figure K-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. HBIB-9

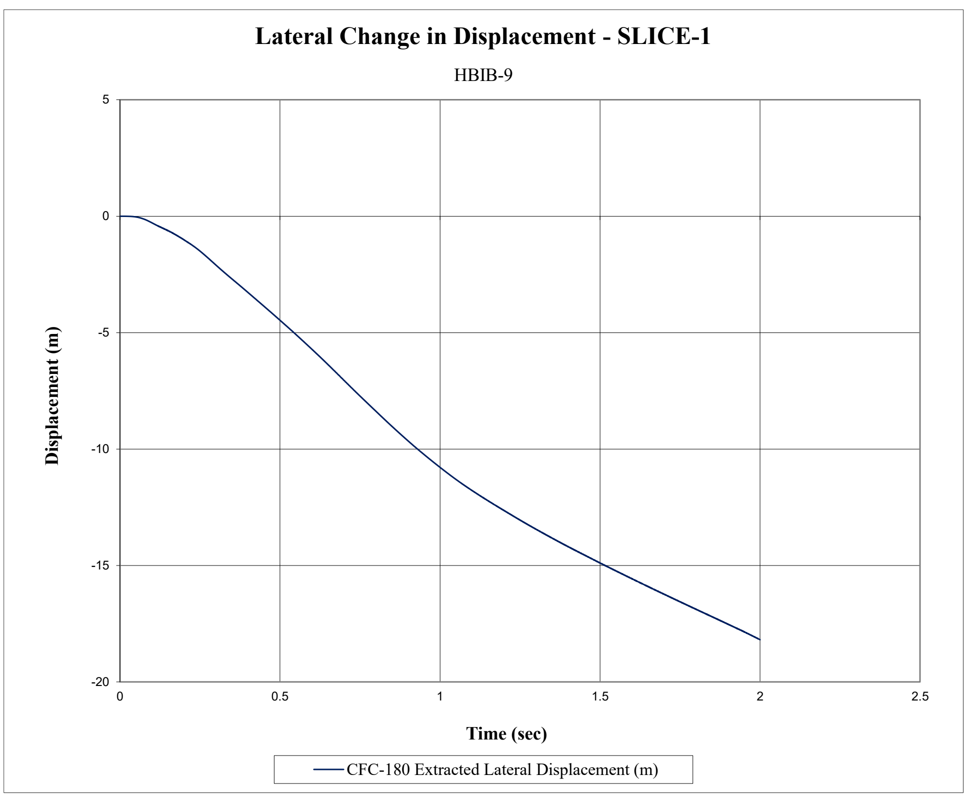


Figure K-6. Lateral Occupant Displacement (SLICE-1), Test No. HBIB-9

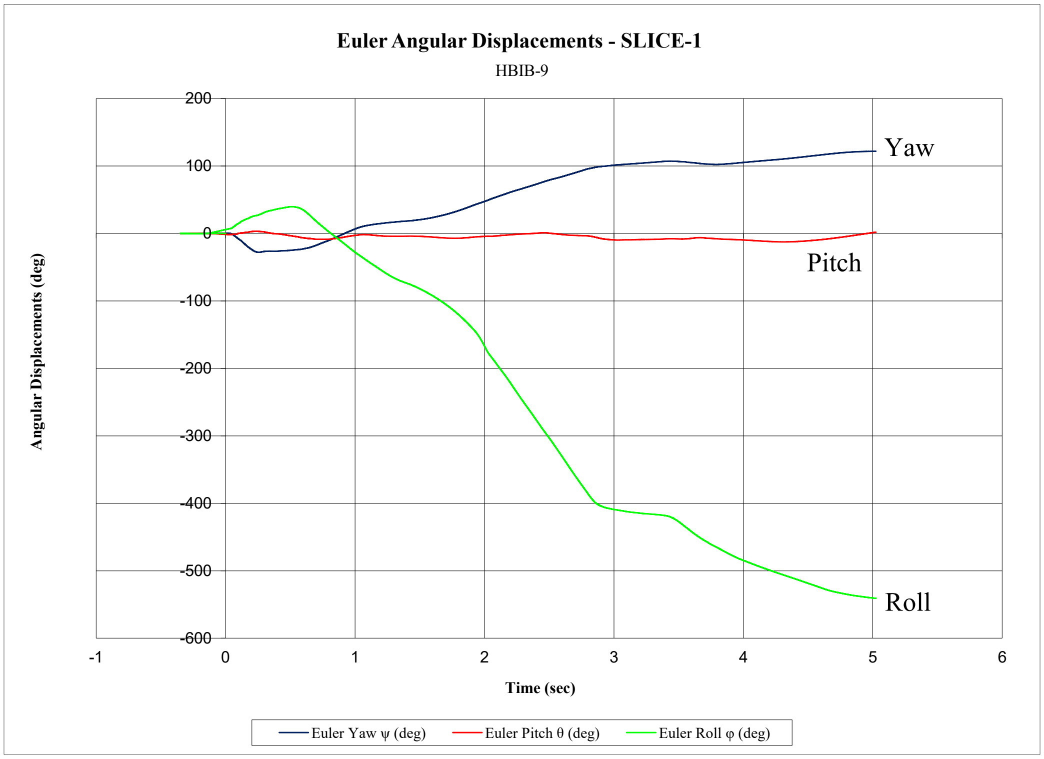


Figure K-7. Vehicle Angular Displacements (SLICE-1), Test No. HBIB-9

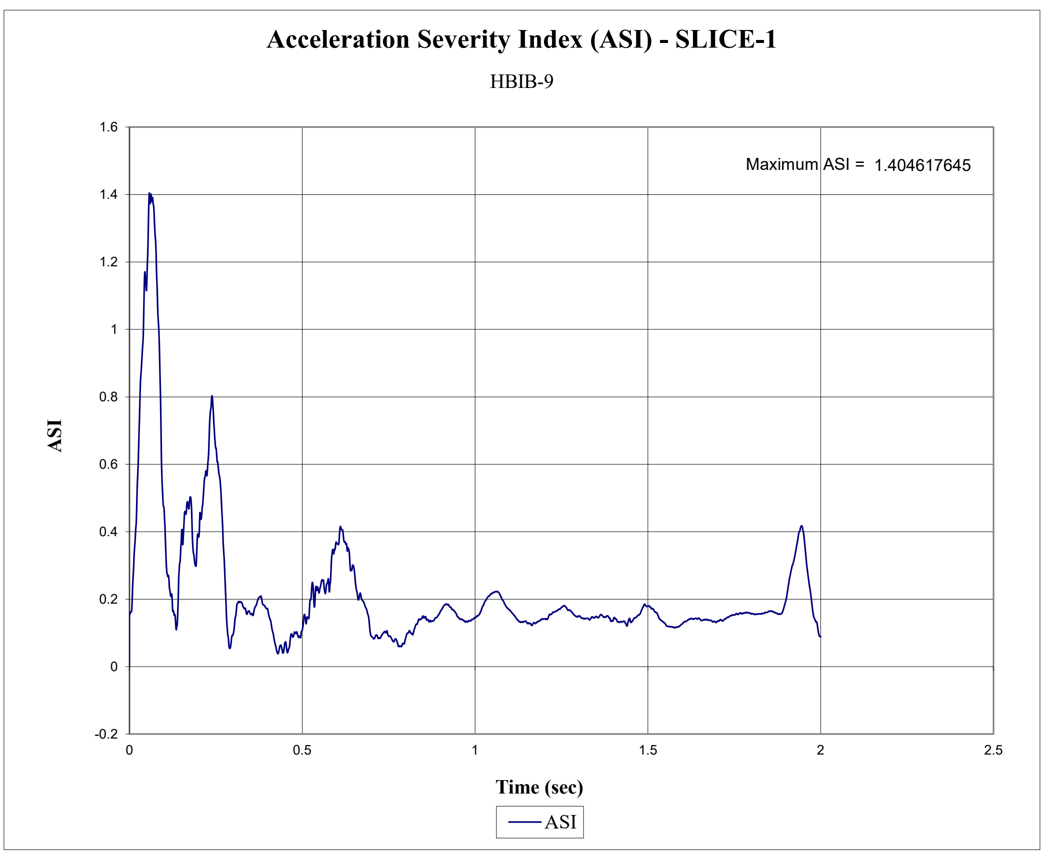


Figure K-8. Acceleration Severity Index (SLICE-1), Test No. HBIB-9

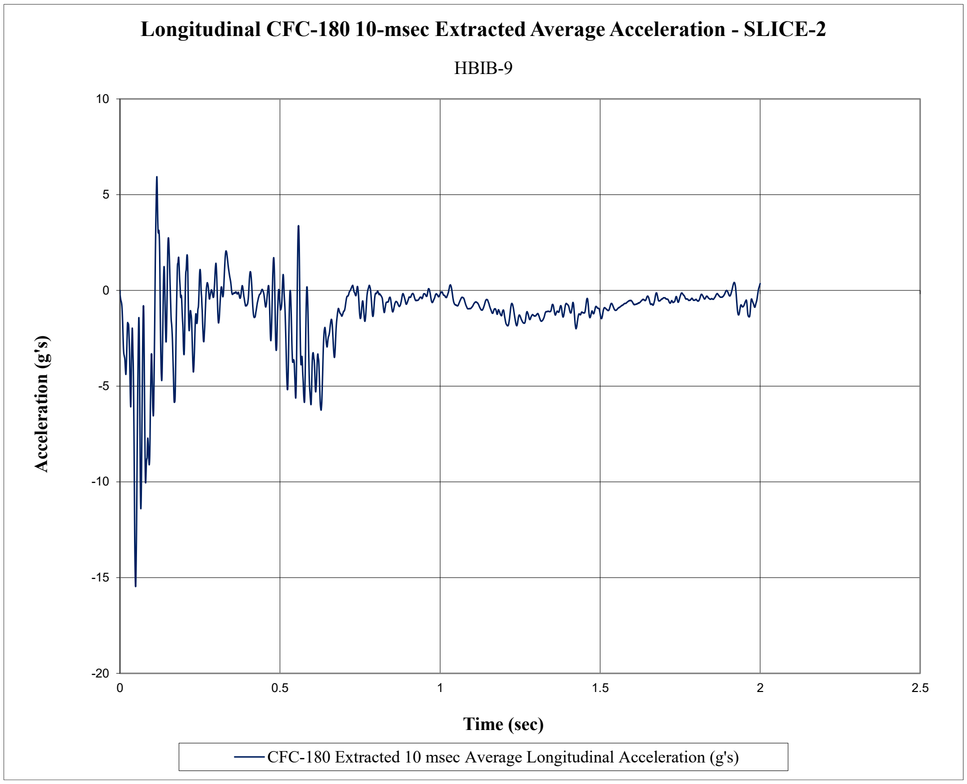


Figure K-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. HBIB-9

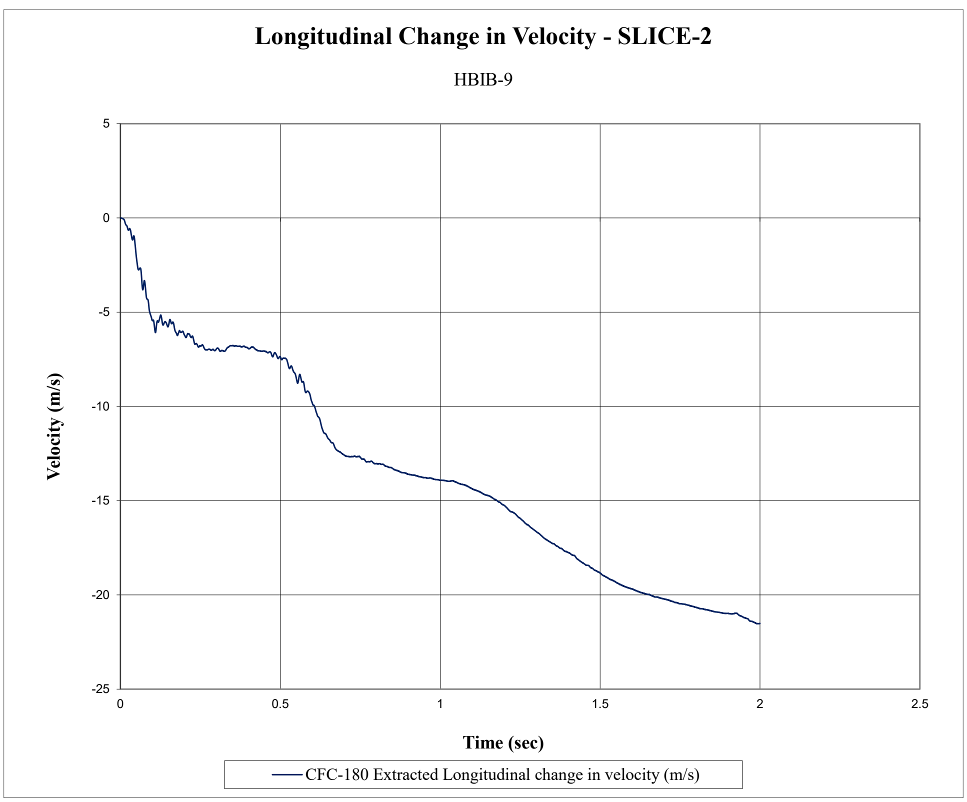


Figure K-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. HBIB-9

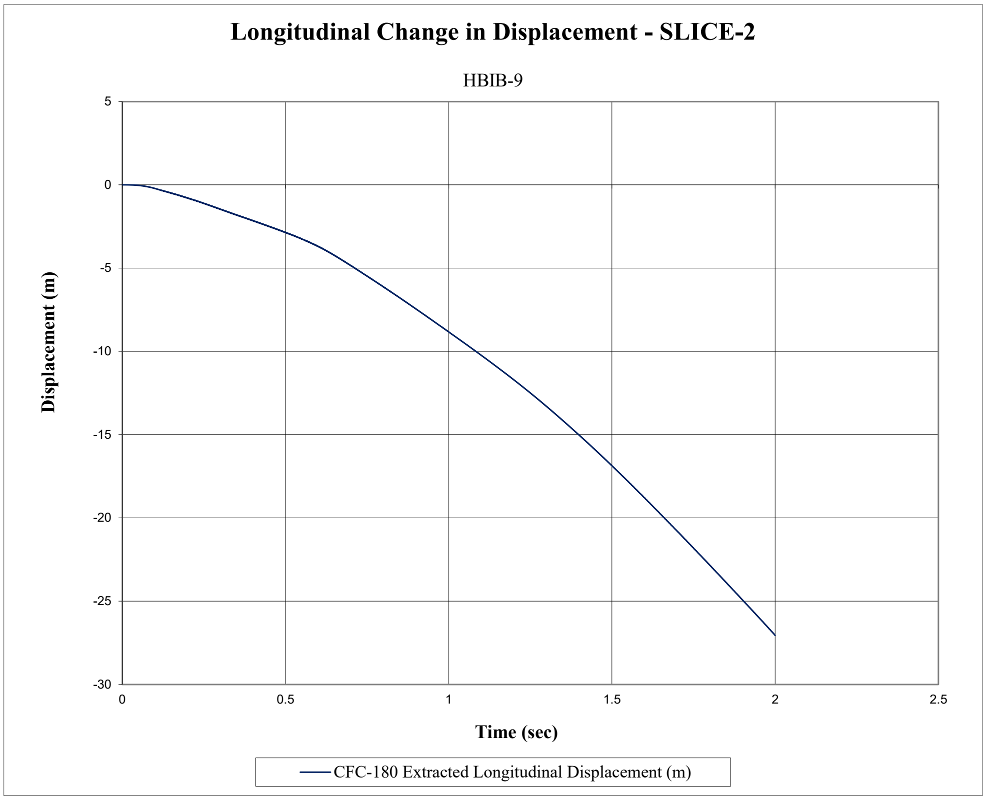


Figure K-11. Longitudinal Occupant Displacement (SLICE-2), Test No. HBIB-9

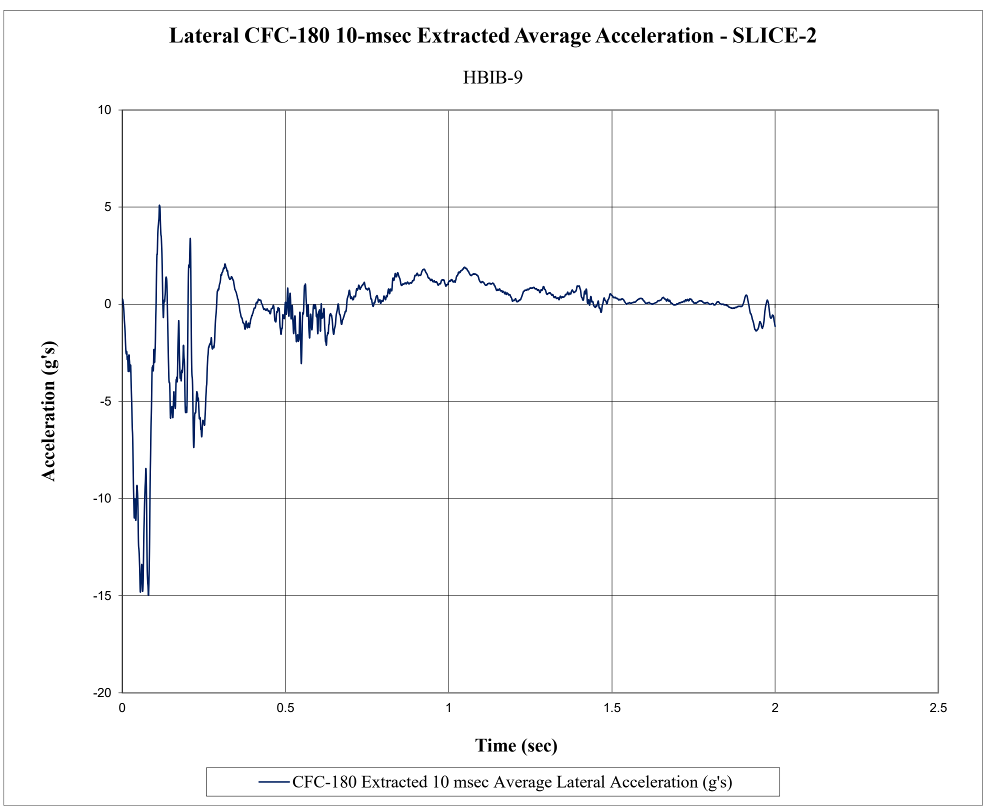


Figure K-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. HBIB-9

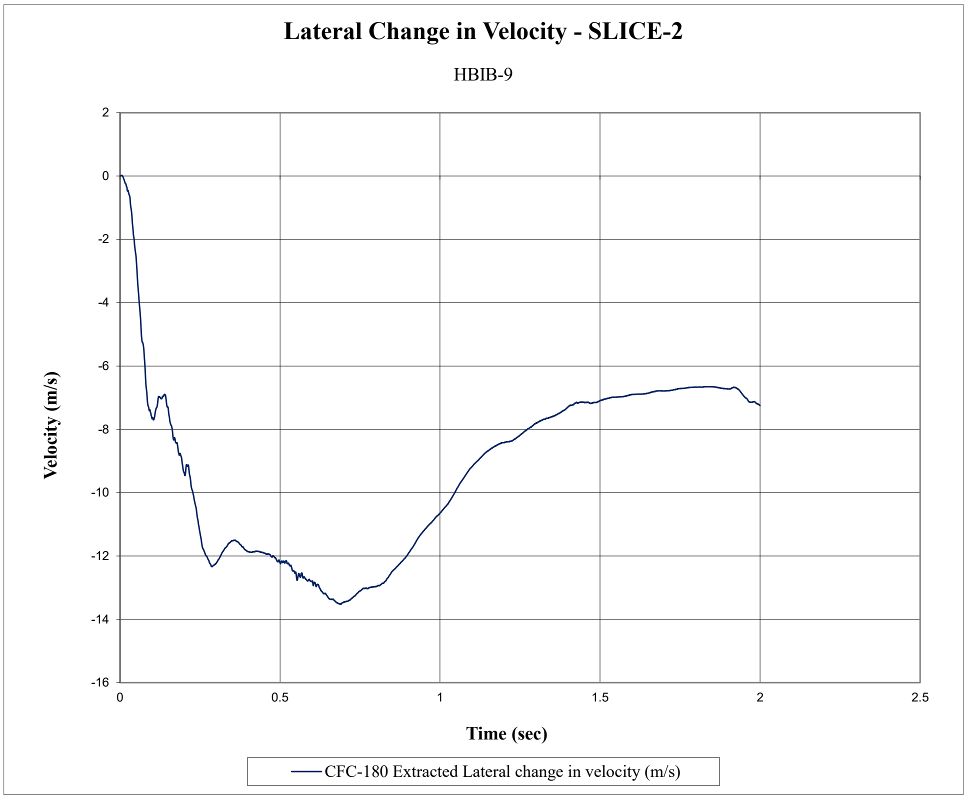


Figure K-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. HBIB-9

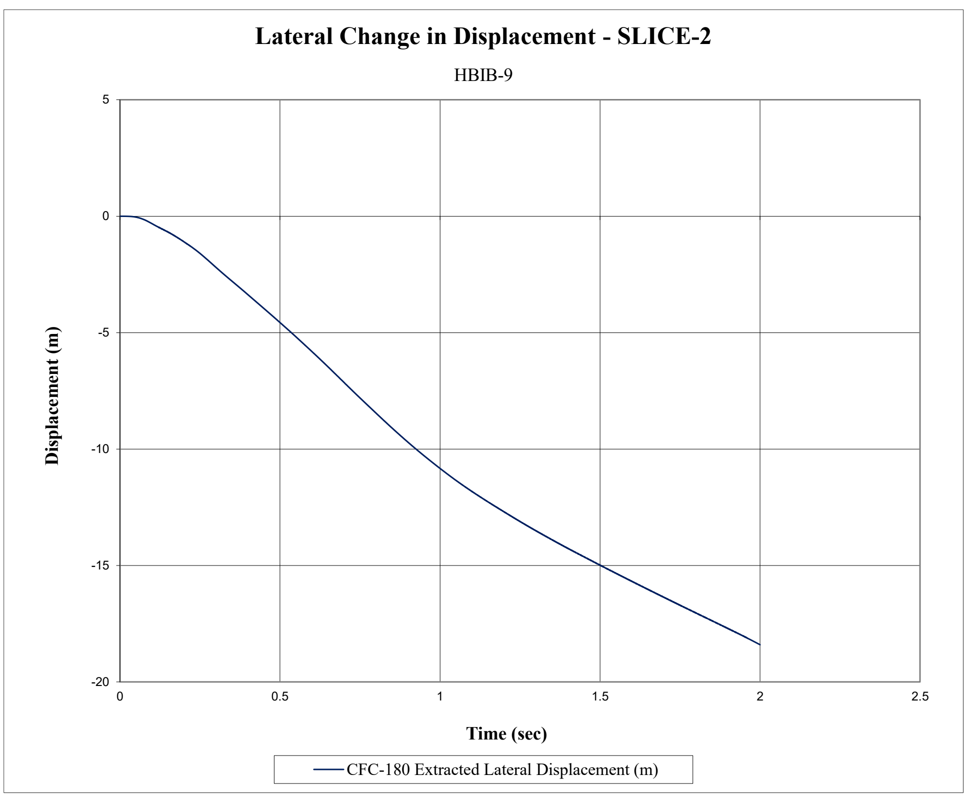


Figure K-14. Lateral Occupant Displacement (SLICE-2), Test No. HBIB-9

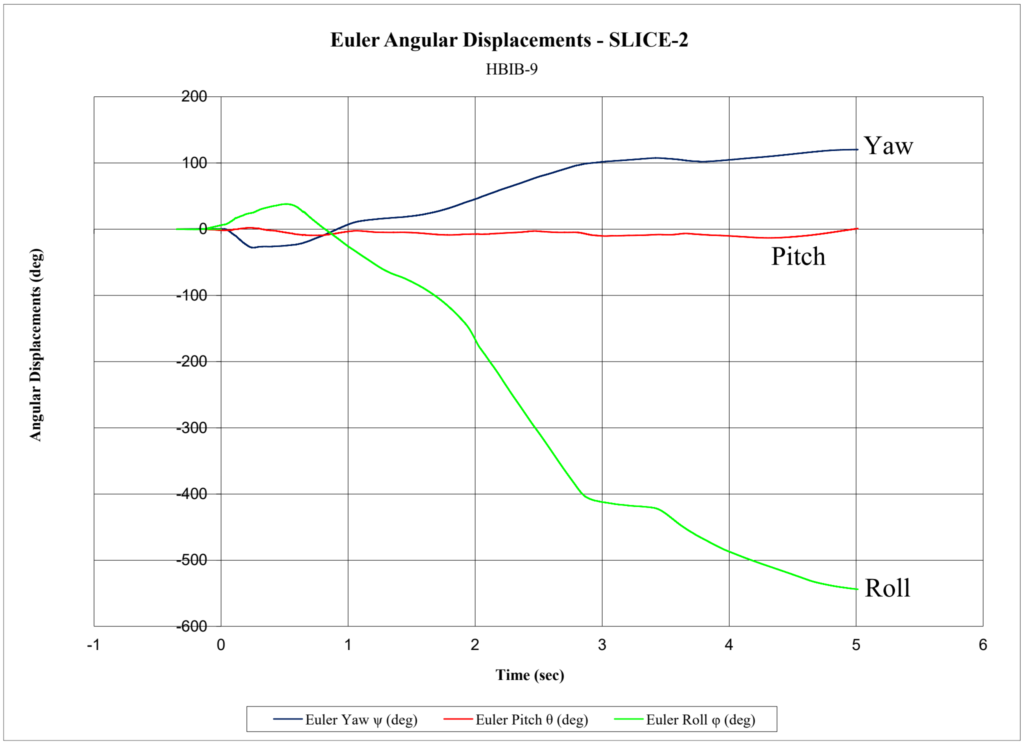


Figure K-15. Vehicle Angular Displacements (SLICE-2), Test No. HBIB-9

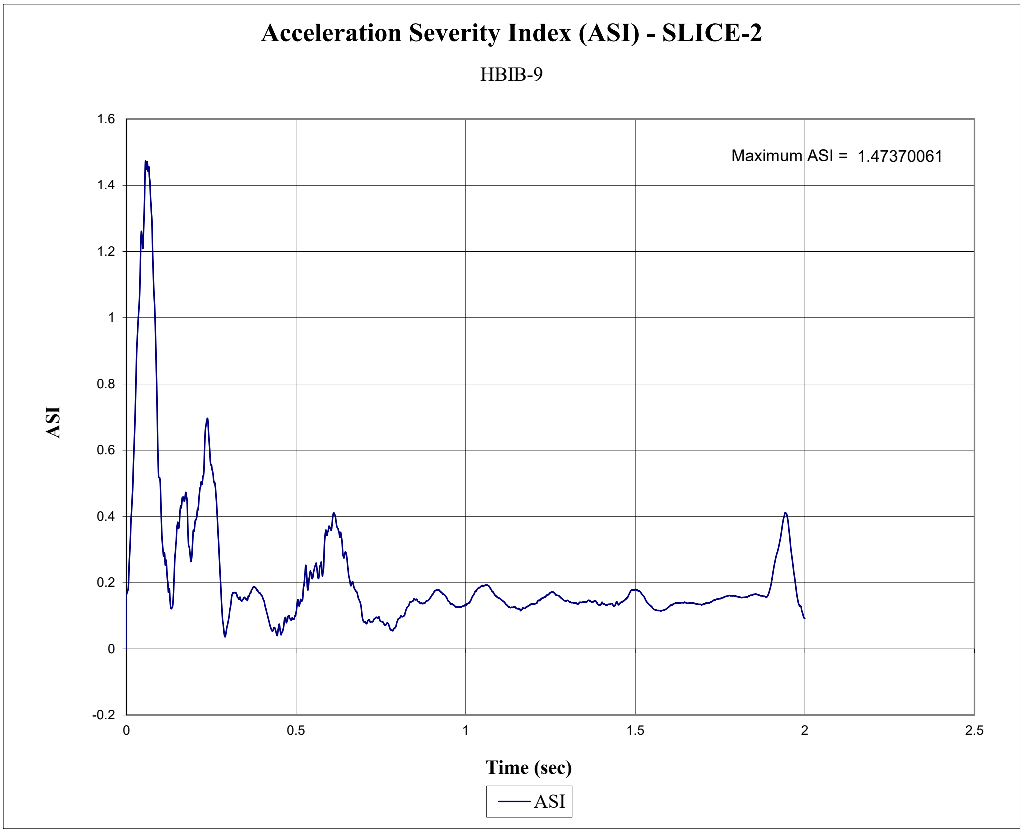


Figure K-16. Acceleration Severity Index (SLICE-2), Test No. HBIB-9

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