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CRASH TESTING AND EVALUATION OF THE HDOT 34-IN. TALL, AESTHETIC CONCRETE BRIDGE RAIL WITH PEDESTRIAN HANDRAIL AND SIDEWALK: MASH TEST DESIGNATION NOS. 3-10 AND 3-11

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16. Abstract

This report documents two-full scale vehicle crash tests that were conducted to investigate the safety performance of the Hawaii Department of Transportation's (HDOT's) 34-in. Tall, Aesthetic Concrete Bridge Rail with Pedestrian Handrail and Sidewalk. The barrier system was 88 ft long and consisted of three 21-ft 11½-in. long concrete parapets anchored to the concrete tarmac. Expansion joints between each adjacent segment consisted of 24½-in. long, No. 8 ASTM A615 Grade 60 steel bars cast into the existing concrete tarmac and inserted into PVC pipes on the upstream side of the expansion joint. The sidewalk was 88 ft long, 6 ft wide, and 6 in. tall. The pedestrian handrail was fabricated using 3-in. x 3-in. x ¼-in. steel square tube supported by 2½-in. x 2½-in. x ¼-in. steel square tube posts mounted on the back side of the bridge rail at a height of 8½ in. above the top surface of the bridge rail. Test nos. HP34S-1 and HP34S-2 were conducted according to American Association of State Highway and Transportation Officials' *Manual for Assessing Safety Hardware 2016* (MASH 2016) criteria using Test Level 3 (TL-3) test designation nos. 3-11 and 3-10, respectively.

In test no. HP34S-1, a 2270P quad cab pickup truck impacted the sidewalk at a speed of 65.7 mph and an angle of 25.2 degrees and impacted the barrier at a speed of 63.6 mph and an angle of 23.7 degrees. Although the sidewalk impact speed nominally exceeded the MASH limits, MASH accepts values in excess of the criteria for longitudinal barriers impacted within the length-of-need. In test no. HP34S-2, a 1100C small car impacted the sidewalk at a speed of 62.0 mph and an angle of 25.0 degrees and impacted the barrier at a speed of 60.2 mph and an angle of 22.8 degrees. In both tests, the bridge rail successfully contained and redirected the vehicle. Thus, test nos. HP34S-1 and HP34S-2 successfully met the TL-3 safety performance criteria defined in MASH 2016.

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DISCLAIMER STATEMENT

UNCERTAINTY OF MEASUREMENT STATEMENT

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

INDEPENDENT APPROVING AUTHORITY

The Independent Approving Authority for the data contained herein was Dr. Joshua Steelman, P.E., Associate Professor in the Department of Civil and Environmental Engineering.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in.	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1,000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short ton (2,000 lb)	0.907	megagrams (or “metric ton”)	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5(F-32)/9 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 several concrete bridge rails with aesthetic treatments. However, the crashworthiness of these bridge railings under current impact safety standards has recently begun and is currently ongoing. To date, the HDOT 34- and 42-in. Tall, Aesthetic Concrete Bridge Rails were successfully evaluated to MASH 2016 TL-3 standards [1, 2]. This report documents full-scale crash tests conducted with the HDOT 34-in. Tall, Aesthetic Bridge Rail with Pedestrian Handrail and Sidewalk with aesthetic recessed rectangular panels added to its traffic-side and back-side surfaces, as well as with a back-side mounted pedestrian handrail. The standard plans of the HDOT 34-in. tall, Aesthetic Concrete Bridge Rail are shown in Figures 1 through 4. The recessed rectangular panels are 60 in. wide, 15 in. tall, and ½ in. deep with an inclination angle of 30 degrees. The concrete bridge rail is anchored through the sidewalk and into a concrete bridge deck. End sections measuring 3 ft – 6 in. long are used at the ends of the bridge rail adjacent to an end buttress structure. However, only the length-of-need (LON) of the barrier was evaluated in this study.

Several years ago, researchers at the Texas A&M Transportation Institute (TTI) published National Cooperative Highway Research Program (NCHRP) Report No. 554 [3], which developed design guidelines for aesthetic treatments for safety shape concrete roadway barriers using a series of Finite Element Modeling (FEM) simulations in conjunction with physical crash testing. The computer simulation effort examined the effect of asperity width and depth as well as the inclination angle of the asperity surface. A parametric FEM analysis was performed for asperity angles of 30, 45, and 90 degrees, as measured from the front face of the barrier, and the simulation outcomes were categorized as acceptable, marginal/unknown, and unacceptable. NCHRP Report No. 554 provided final design guidelines for safety-shape barriers based on simulation and crash testing results, as shown in Figure 5.

NCHRP Report No. 554 also provided guidelines for single-sloped and vertical-face barriers that were developed by the California Department of Transportation (Caltrans) [4] in 2002 and approved by the Federal Highway Administration (FHWA) in acceptance letter B-110. Caltrans conducted crash testing on single-sloped barriers with various architectural treatments in order to develop guidelines for evaluating crashworthiness of barriers with wide-ranging patterns and textures. Six recommendations for single-sloped or vertical-face barriers were developed after full-scale crash testing in accordance with NCHRP Report No. 350 Test Level 3 (TL-3) [5] criteria. As reported in NCHRP Report No. 554, the following types of surface treatment are permitted:

1. Sandblasted textures with a maximum relief of 9.5 mm.

2. Images or geometric patterns cut into the face of the barrier 25 mm or less and having 45-degree or flatter chamfered or beveled edges to minimize vehicular sheet metal or wheel snagging.

3. Textures or patterns of any shape and length inset into the face of the barrier up to 13 mm deep and 25 mm wide.

4. Any pattern or texture with gradual undulation that has a maximum relief of 20 mm over a distance of 300 mm.

5. Gaps, slots, grooves, or joints of any depth with a maximum width of 20 mm and a maximum surface differential across these features of 5 mm.

6. Any pattern or texture with a maximum relief of 64 mm, if such a pattern begins 610 mm or more above the base of the barrier and if all leading edges are rounded or sloped to minimize any vehicle snagging potential.

After comparing the HDOT 34-in. tall, Aesthetic Concrete Bridge Rail to the NCHRP Report No. 554 design guidelines, the research team anticipated that the existing bridge rail profile would likely provide acceptable safety performance under current impact safety standards for passenger vehicles. However, full-scale crash testing was needed to evaluate the bridge rail to the safety performance criteria published in the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware, Second Edition* (MASH 2016) [6].

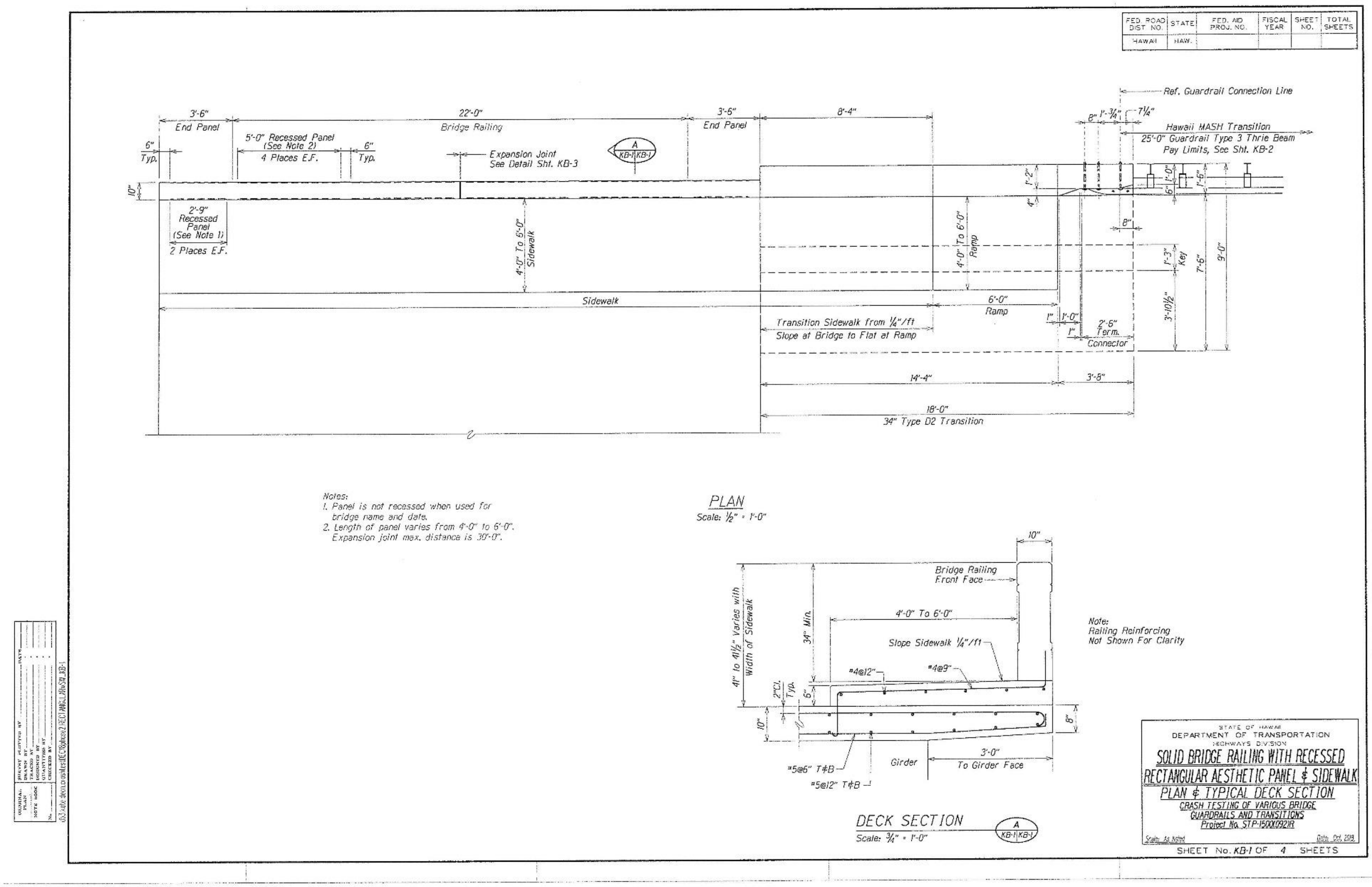


Figure 1. HDOT Standard Detail for the 34-in. Tall, Aesthetic Concrete Bridge Rail with Sidewalk

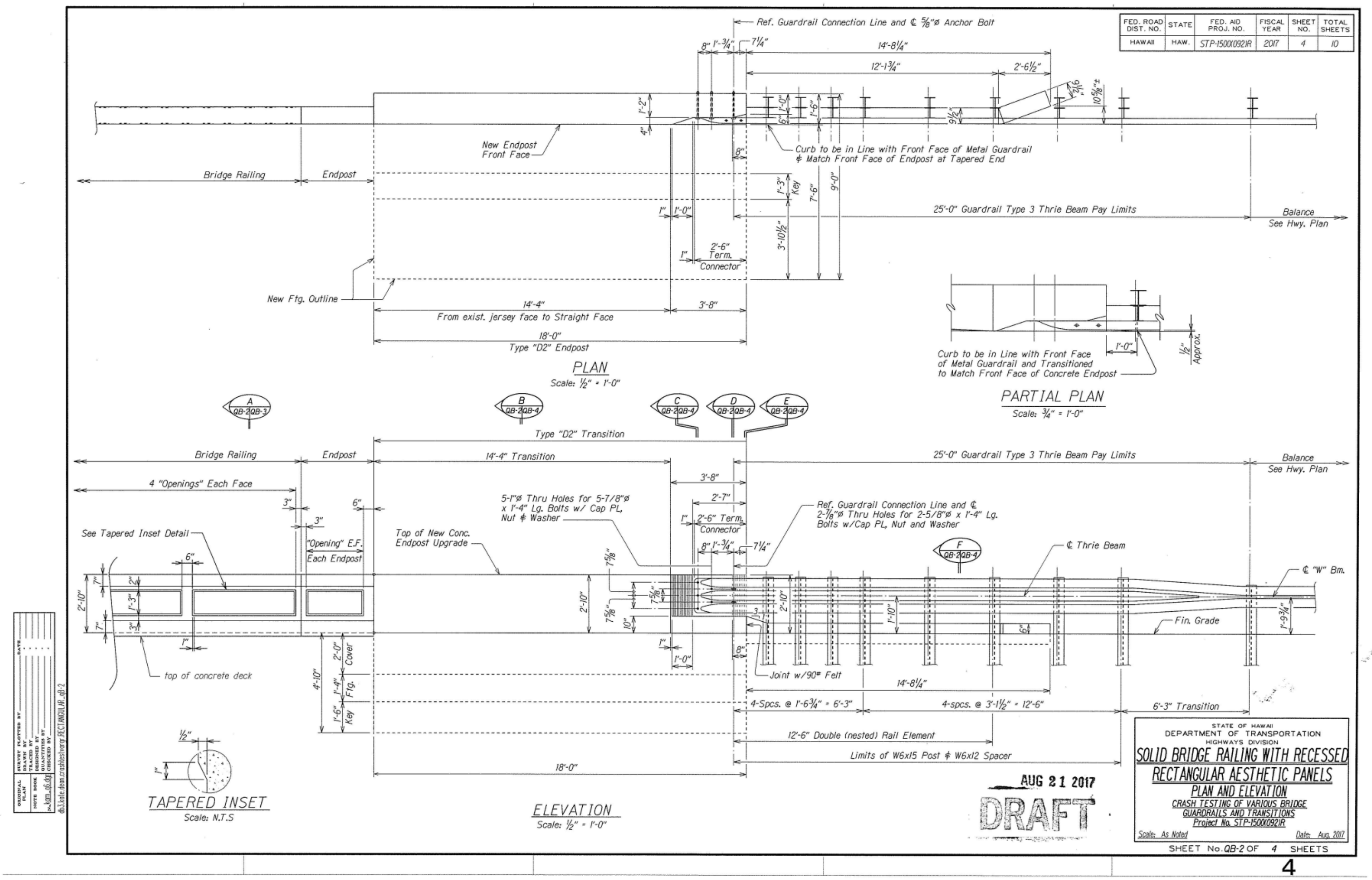


Figure 2. HDOT Standard Detail for Transition to the 34-in. Tall, Aesthetic Concrete Bridge Rail

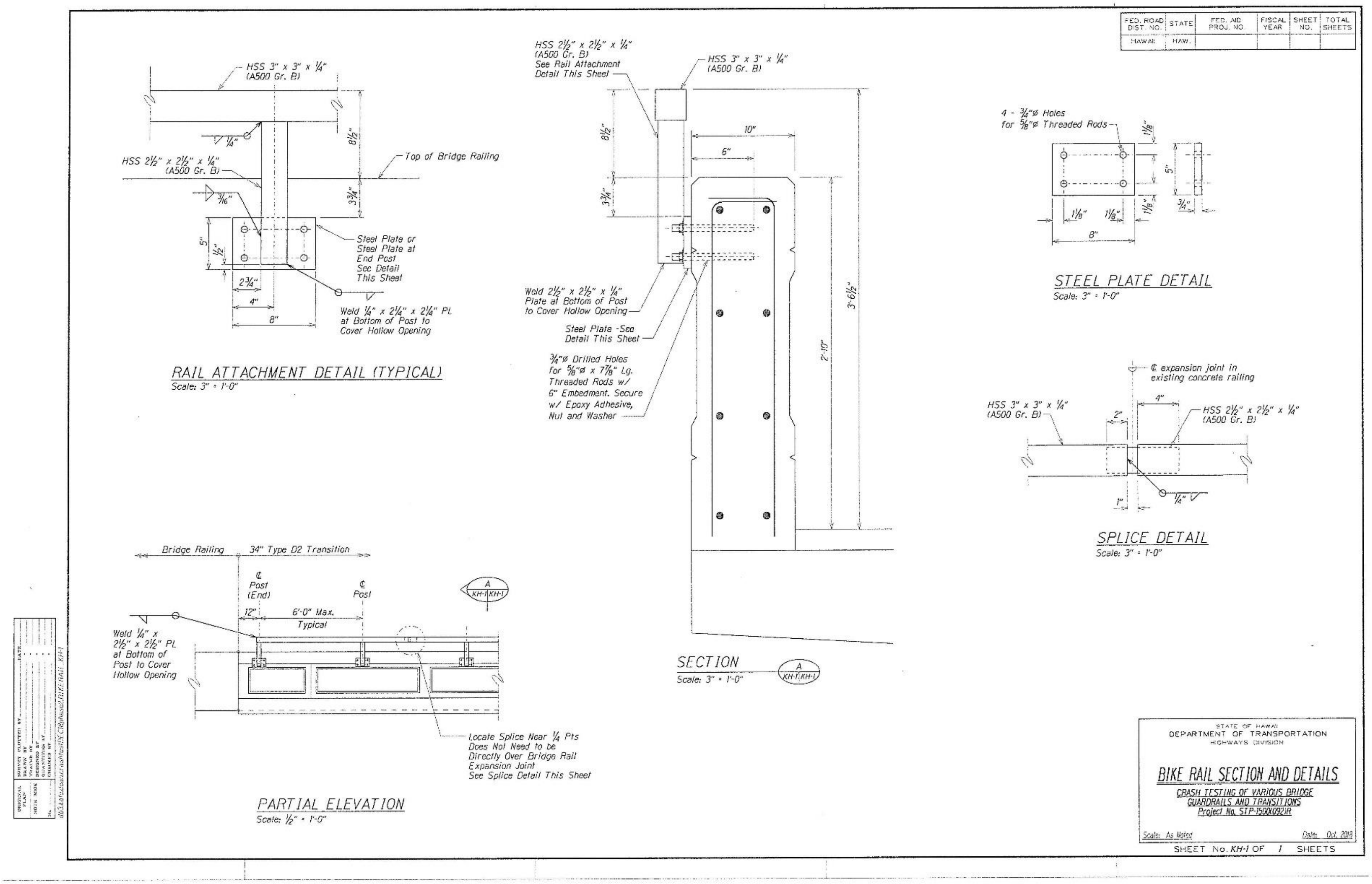


Figure 3. HDOT Standard Detail for the 34-in. Tall, Aesthetic Concrete Bridge Rail with Pedestrian Rail

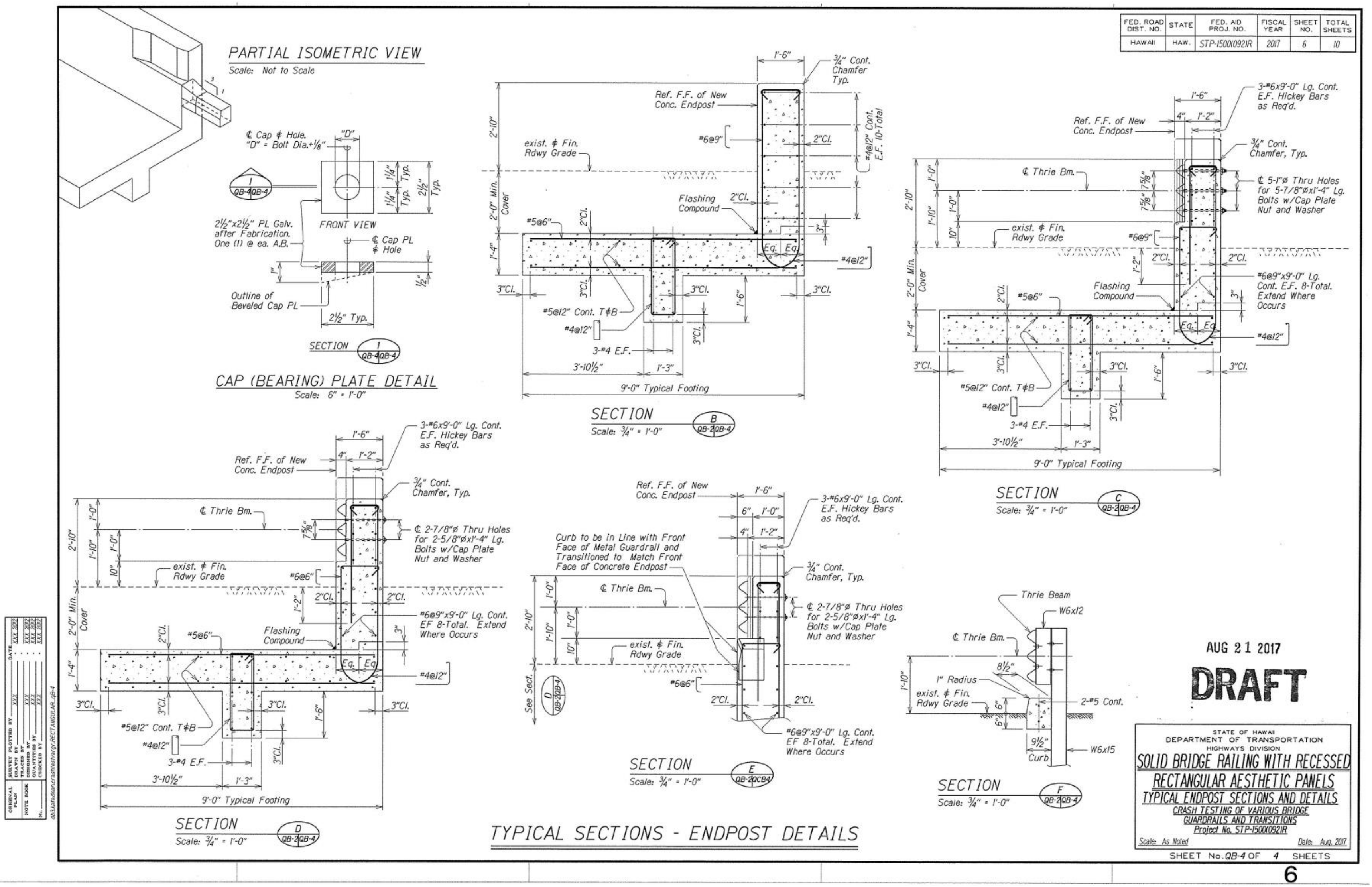


Figure 4. HDOT Reinforcement Detail for the 34-in. Tall, Aesthetic Concrete Bridge Rail

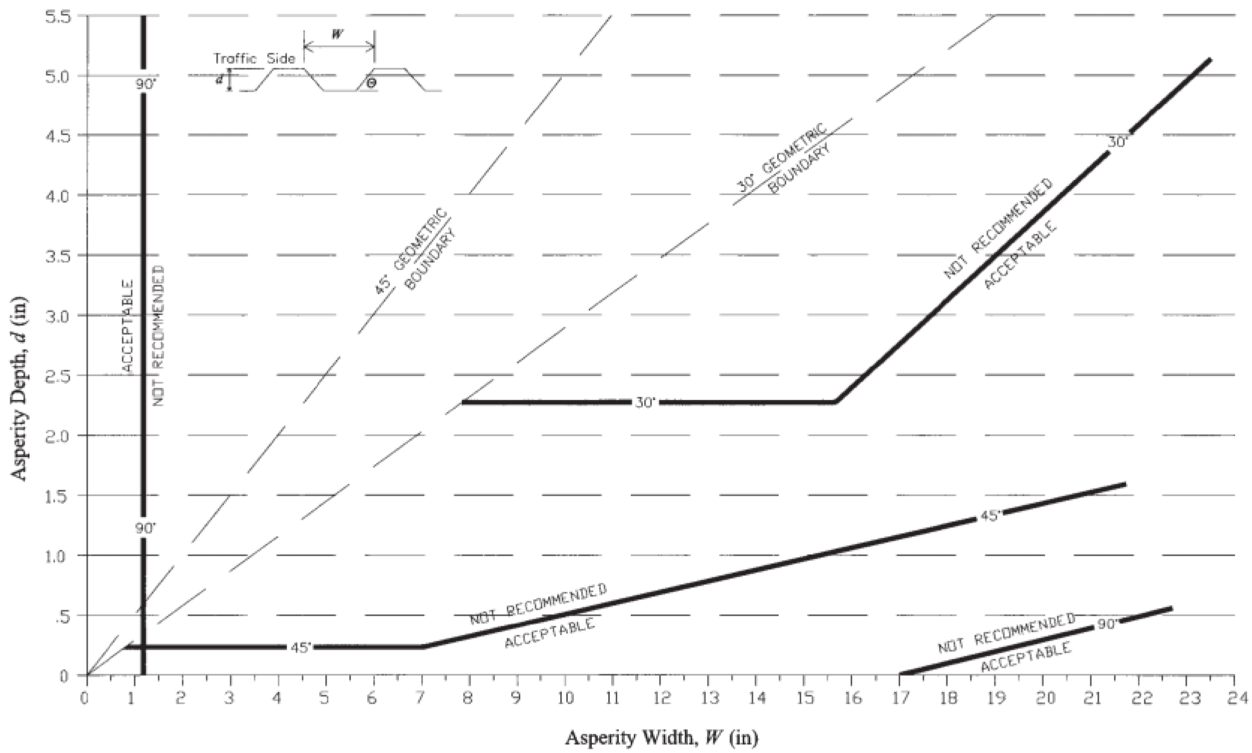


Figure 5. Final Design Guidelines for Aesthetic Surface Treatments of Safety-Shape Concrete Barrier [3]

1.2 Objective

The research objective of this study included a safety performance evaluation of the LON of the HDOT 34-in. Tall, Aesthetic Bridge Rail with Pedestrian Handrail and Sidewalk. The system was tested and evaluated according to the TL-3 criteria found in MASH 2016.

1.3 Scope

The research objective was achieved through the completion of several tasks. Two full-scale crash tests were conducted on the HDOT 34-in. tall, Aesthetic Concrete Bridge Rail with Pedestrian Handrail and Sidewalk according to MASH 2016 test designation nos. 3-10 and 3-11. Next, 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 HDOT 34-in. tall, Aesthetic Concrete Bridge Rail with Pedestrian Handrail and Sidewalk system. A final report was published, which discussed the results and findings from two full-scale crash tests that were conducted on the HDOT 34-in. tall, Aesthetic Concrete Bridge Rail with Pedestrian Handrail and Sidewalk.

2 TEST REQUIREMENTS AND EVALUATION CRITERIA

2.1 Test Requirements

Aesthetic concrete bridge rails must satisfy impact safety standards in order to be declared eligible for federal reimbursement by the Federal Highway Administration (FHWA) for use on the National Highway System (NHS). For new hardware, these safety standards consist of the guidelines and procedures published in MASH 2016 [6]. Note that there is no difference between MASH 2009 [7] and MASH 2016 [6] for longitudinal barriers, such as the system tested in this project, except that additional occupant compartment deformation measurements, photographs, and documentation are required by MASH 2016. According to TL-3 of MASH 2016, longitudinal barrier systems must be subjected to two full-scale vehicle crash tests, as summarized in Table 1.

It should be noted that the test matrix detailed herein represents a practical worst-case condition with respect to the MASH 2016 safety requirements and a crashworthiness evaluation of the barrier system. According to MASH 2016, the HDOT 34-in. Tall, Aesthetic Concrete Bridge Rail with Pedestrian Handrail and Sidewalk should be evaluated at a location that evaluates the greatest propensity for vehicle snag as well as a location that maximizes structural loading of the bridge rail at a critical section. For the HDOT 34-in. tall, Aesthetic Concrete Bridge Rail with Pedestrian Handrail and Sidewalk, the critical impact point for both impact locations occur upstream from the expansion joint in the bridge rail. The HDOT 34-in. Tall, Aesthetic Concrete Bridge Rail with Pedestrian Handrail and Sidewalk has a transition from the recessed panel to the main face of the bridge rail 2¾ in. upstream from the expansion joint in the rail. Thus, impacting upstream from this point provides an evaluation of vehicle snag on both the recessed panel edge and the expansion joint. Additionally, the critical structural section in the rail occurs at the expansion joint because the bridge rail design does not reduce the transverse reinforcement near the expansion joint, and smooth dowel bars are used to transfer shear loading across the opening. As such, the critical impact point distances that are specified for test designation nos. 3-10 and 3-11 for rigid barriers in Table 2.7 of MASH 2016 were applied upstream from the expansion joint. This selection was made to evaluate of vehicle snag and structural loading of the HDOT 34-in. tall, Aesthetic Concrete Bridge Rail with Pedestrian Handrail and Sidewalk.

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

Test Article	Test Designation No.	Test Vehicle	Vehicle Weight lb	Impact Conditions		Evaluation Criteria [1]
				Speed mph	Angle degrees	
Longitudinal Barrier	3-10	1100C	2,420	62	25	A,D,F,H,I
	3-11	2270P	5,000	62	25	A,D,F,H,I

[1] Evaluation criteria explained in Table 2.

The critical impact points for the 3-10 and 3-11 tests were also selected to maximize vehicle interaction with the downstream portion of the asperity. Handrail post positions were similarly selected to maximize vehicle interaction in the anticipated Zone of Intrusion, similar to other studies recently performed by MwRSF [8, 9]. However, the impact point with the parapet may occur downstream from the impact point on the sidewalk, because the sidewalk can apply a lateral change in momentum to the vehicle. Videos from previous tests completed with a sidewalk in front of a rail system were evaluated to determine the change in trajectory. As such, this change in trajectory was used to select an initial impact point with the curb to maximize interactions with the downstream section of the exposed asperity and the pedestrian handrail support.

Table 2. MASH 2016 Evaluation Criteria for Longitudinal Barriers

<table>
<tr><td>Structural Adequacy</td><td>A.</td><td colspan="3">Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.</td></tr>
<tr><td rowspan="10">Occupant Risk</td><td>D.</td><td colspan="3">Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH 2016.</td></tr>
<tr><td>F.</td><td colspan="3">The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</td></tr>
<tr><td rowspan="4">H.</td><td colspan="3">Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:</td></tr>
<tr><td colspan="3">Occupant Impact Velocity Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>30 ft/s</td><td>40 ft/s</td></tr>
<tr><td rowspan="4">I.</td><td colspan="3">The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:</td></tr>
<tr><td colspan="3">Occupant Ridedown Acceleration Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>15.0 g's</td><td>20.49 g's</td></tr>
</table>

2.2 Evaluation Criteria

Evaluation criteria for full-scale vehicle crash testing are based on three factors: (1) structural adequacy, (2) occupant risk, and (3) vehicle trajectory after collision. Criteria for structural adequacy are intended to evaluate the ability of the bridge railing to contain and redirect impacting vehicles. In addition, controlled lateral deflection of the test article is acceptable. Occupant risk evaluates the degree of hazard to occupants in the impacting vehicle. Post-impact vehicle trajectory is a measure of the potential of the vehicle to result in a secondary collision with other vehicles and/or fixed objects, thereby increasing the risk of injury to the occupants of the impacting vehicle and/or other vehicles. These evaluation criteria are summarized in Table 2 and defined in greater detail in MASH 2016. The full-scale vehicle crash test was conducted and reported in accordance with the procedures provided in MASH 2016. In addition to the standard occupant risk measures, the Post-Impact Head Deceleration (PHD), the Theoretical Head Impact Velocity (THIV), and the Acceleration Severity Index (ASI) were determined and reported. Additional discussion on PHD, THIV and ASI is provided in MASH 2016.

3 DESIGN DETAILS

The barrier system test installation consisted of two 10-ft 11¾-in. long and three 21-ft 11½-in. long concrete barrier segments with a pedestrian handrail and sidewalk, as shown in Figures 6 through 22. Photographs of the test installation are shown in Figures 23 and 24. Architectural inserts were slightly misaligned at a form break in the lower left image of Figure 24, creating a visual jog, but the effect was only cosmetic and not structurally significant. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix A.

As noted previously, the HDOT 34-in. Tall, Aesthetic Concrete Bridge Rail with Pedestrian Handrail and Sidewalk was fabricated for evaluation of the LON of the bridge rail. Thus, no end sections of the rail were constructed. The rail was constructed in five segments that were separated by four expansion joints to allow for evaluation of the critical rail section at the expansion joints. The spacing between the expansion joints was limited to 22 ft, which was the smallest rail segment length between joints noted by HDOT. Larger rail segment lengths between expansion joints were considered less critical. The HDOT 34-in. tall, Aesthetic Concrete Bridge Rail with Pedestrian Handrail and Sidewalk was installed on the concrete tarmac at MwRSF's Outdoor Test Site rather than on a simulated bridge deck and cantilevered overhang. Previous testing of a MASH 2016 TL-4 bridge rail on similar 8-in. thick concrete bridge deck did not display significant deck damage [10]. This finding, along with historical results, indicated no potential for deck damage or deflection that would affect the test results of the HDOT 34-in. tall, Aesthetic Concrete Bridge Rail with Pedestrian Handrail and Sidewalk under MASH 2016 TL-3 impact conditions.

The bridge rail was 41½ in. tall relative to the back-side tarmac, 34 in. tall relative to the sidewalk, and 10 in. wide at the top and the bottom surfaces. The traffic-side and back-side edges of the top surface had ¾-in. chamfers. Aesthetic recessed V-shaped horizontal bevel cuts ½ in. deep and ½ in. tall were located 7 in. below the top surface and 7 in. above the sidewalk surface on the traffic- and back-side faces. The main aesthetic features on this concrete bridge rail were 60-in. wide x 15-in. tall x ½-in. deep recessed panels on both the traffic-side and back-side faces. The edges of the panels transitioned to the face of the rail using 2H:1V slope. The concrete mix for the bridge rail sections required a minimum 28-day compressive strength of 4,000 psi. Two concrete cylinder compression tests were conducted, with 18-day compressive strength results of 4,410 psi and 4,270 psi. Steel reinforcement in the barrier consisted of ASTM A615 Grade 60 rebar. Each concrete bridge rail segment consisted of eight no. 5 longitudinal bars (four per face) that were vertically spaced 9½ in. apart. Vertical stirrups were also provided using no. 5 rebar, which were spaced on 12-in. centers on the back-side face and on 6-in. centers on the traffic-side face. Vertical reinforcement bars were anchored through the sidewalk to an existing concrete tarmac on both the traffic-side and back-side faces to a depth of 8 in. and epoxied with Hilti HIT RE-500 V3 in order to develop the full tensile strength of the bars. The minimum bond strength of the epoxy adhesive was 1,560 psi after a two-day cure.

The bridge rail system contained four expansion joints consisting of ½-in. gaps filled by expansion joint sealant. The expansion joint assembly consisted of three 24-in. long, no. 8 smooth rebar cast into the downstream side of the parapet, with PVC tubes and caps cast in the upstream side of the expansion joint. Vertical stirrups were spaced on 4-in. centers at the expansion joints.

The sidewalk was 82 in. wide including a 10-in. wide x 7½-in. tall flat surface beneath the bridge rail along with a downward slope of 1V:48H leading away from the bridge rail. Steel reinforcement in the sidewalk consisted of ASTM A615 Grade 60 rebar. There were seven longitudinal rebars spaced on 12-in. centers, while lateral rebars were spaced on 9-in. centers. Lateral rebars were embedded 9⅜ in. into the bridge rail and 8 in. into the tarmac.

The pedestrian rail consisted of a welded tube, post, and base plate assembly. The rail consisted of HSS3x3x¼ by 21-ft 11-in. long steel tubes, which were welded using a ¼-in. fillet weld all around to HSS2½x2½x¼ by 7-in. long tube posts. The spacing between posts was 66 in., and one post was installed 16½ in. downstream from the upstream end of each parapet. The tube posts were welded to 8-in. x 5-in. x ¾-in. thick, ASTM A36 steel base plates with a $^{3}/_{16}$-in. fillet weld on both sides of the post. At the bottom of the post, a 2¼-in. x 2¼-in. x ¼-in. thick cap was welded to the bottom of the post with a ⅛-in. fillet weld all around. Two ¼-in. diameter, semicircular weep holes were located at the top of the post and one ½-in. diameter weep hole was located in each of the lower post caps to allow air to escape through the post during hot-dip galvanization. The splices consisted of HSS2x2x¼ by 7-in. long tube with 7-in. x 1½-in. x $^{3}/_{16}$-in. thick shims inserted 2 in. into the downstream side of the pedestrian handrail tube and welded on all sides with a $^{3}/_{16}$-in. fillet weld. As a result, approximately 1 in. of the splice tube assembly was exposed at the expansion joints and the remaining 4 in. of the splice tube assembly protruded into the adjacent pedestrian rail end.

The pedestrian rail was fastened to the back side of the parapet with four ⅝-in. diameter, 7⅞-in. long ASTM F1554-15 Grade 105 steel threaded rods located 4⅞ and 7⅝ in. from the top surface of the barrier. The top of the pedestrian rail was located at 50 in. above the MwRSF tarmac, which simulated a bridge deck surface, or 8½ in. above the top surface of the barrier.

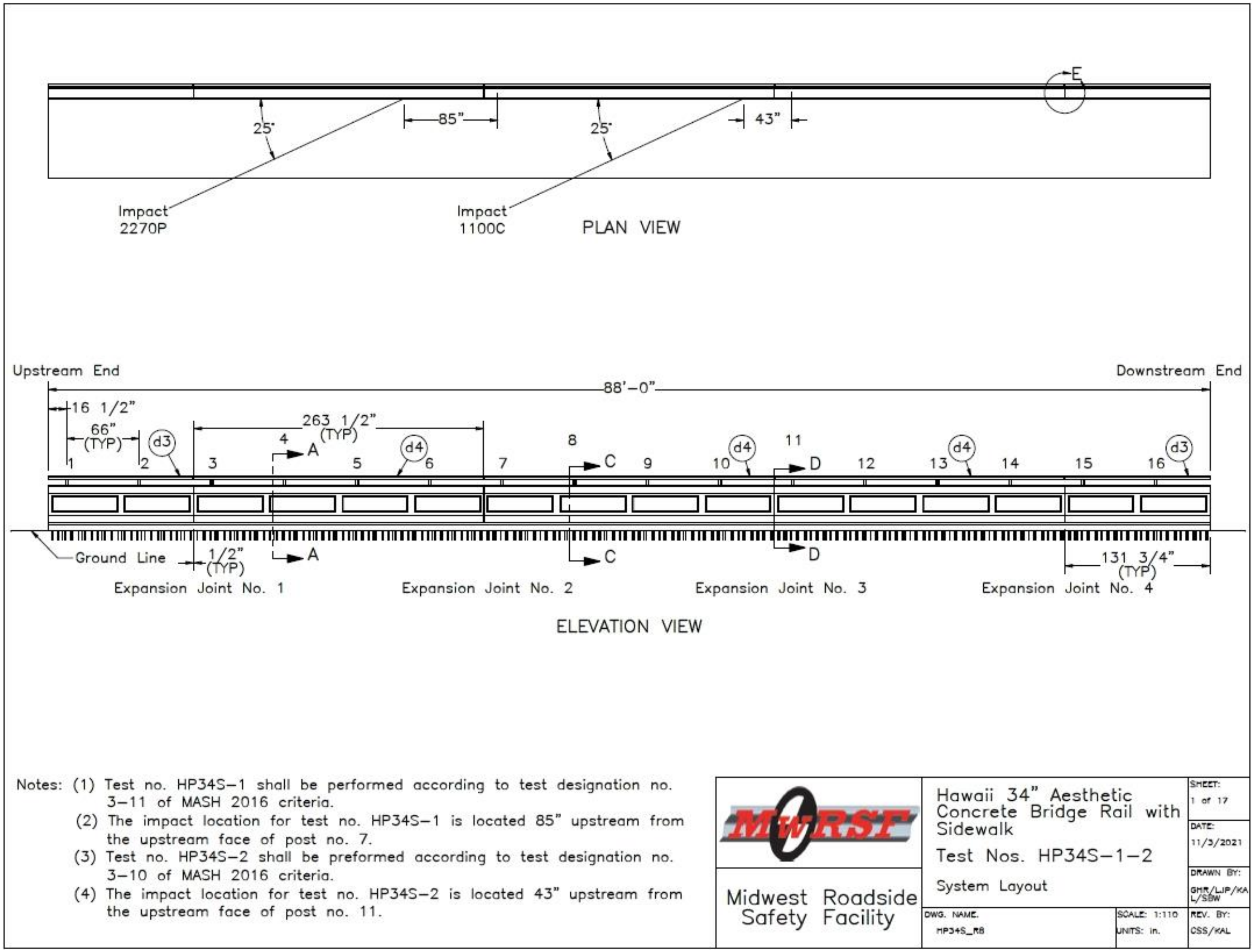


Figure 6. Test Installation Layout, Test Nos. HP34S-1 and HP34S-2

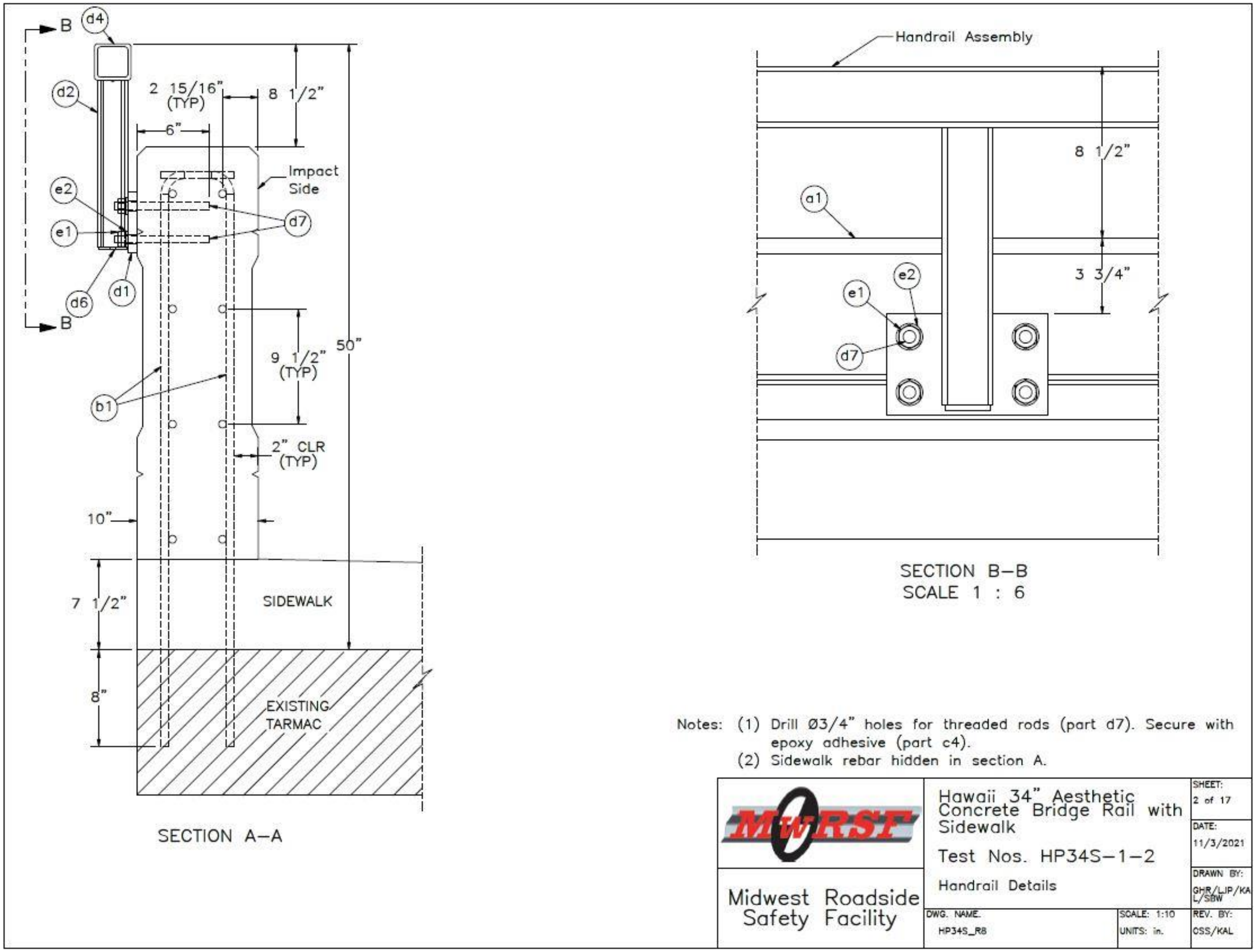


Figure 7. Pedestrian Handrail Details, Test Nos. HP34S-1 and HP34S-2

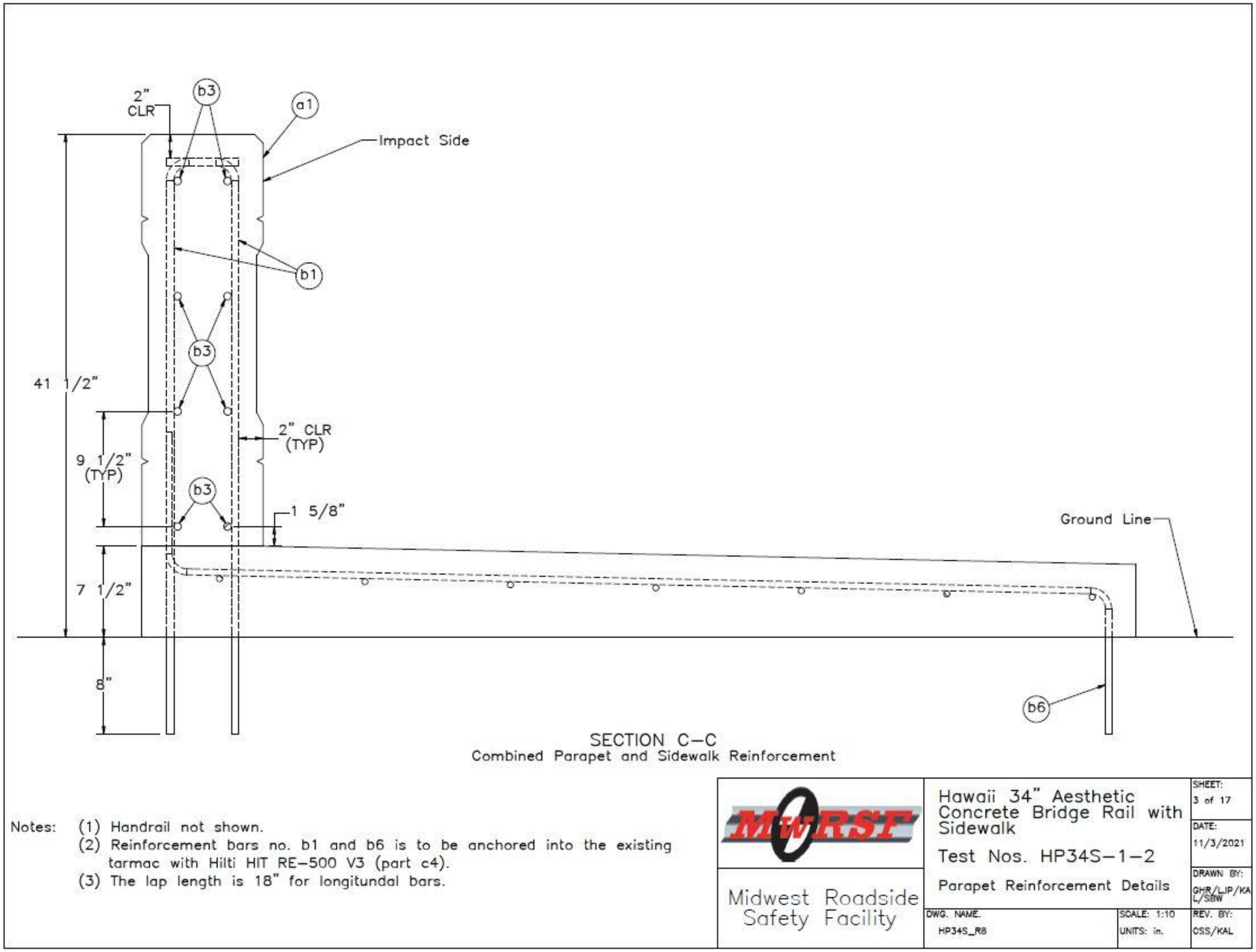


Figure 8. Reinforcement Details, Test Nos. HP34S-1 and HP34S-2

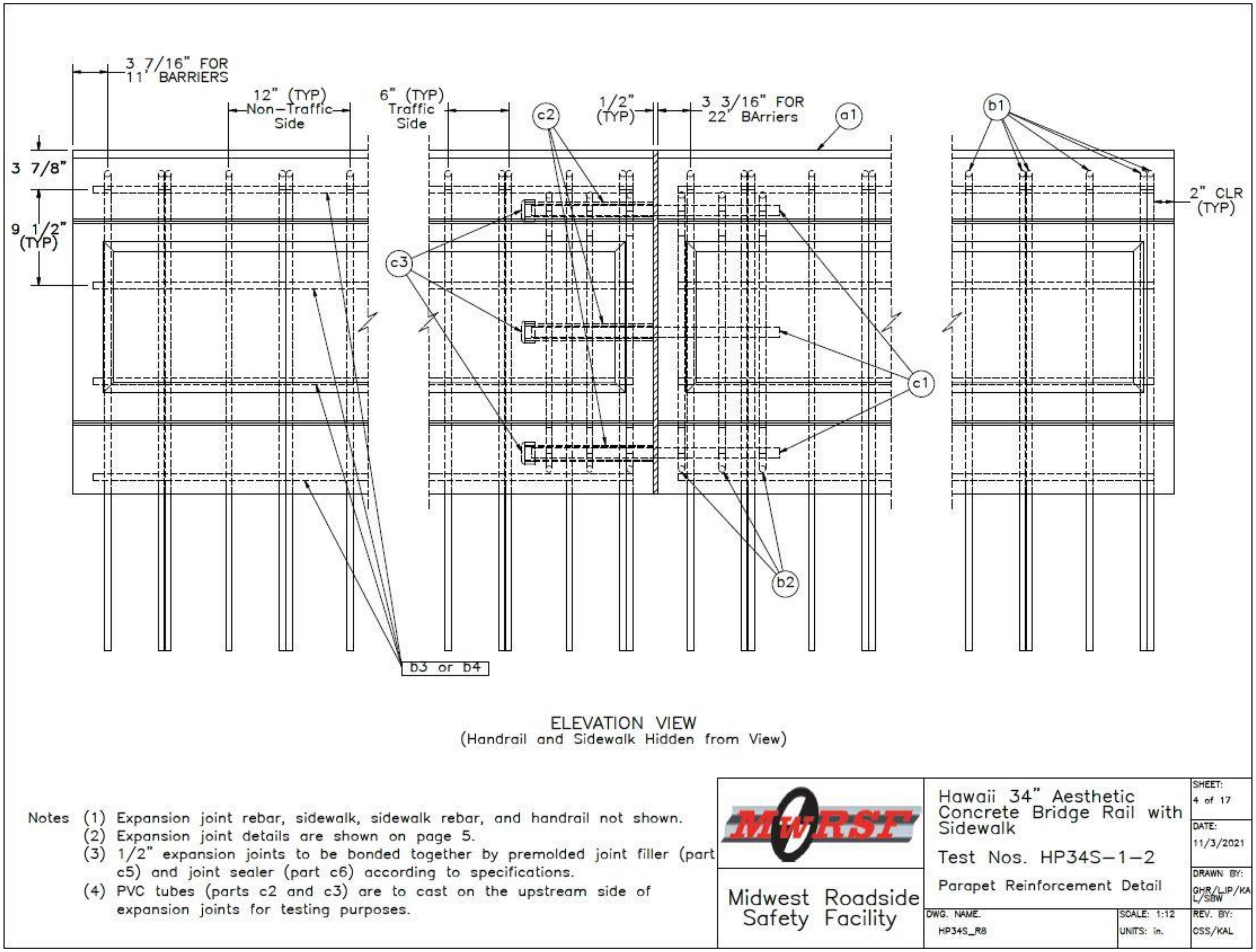


Figure 9. Reinforcement Details, Test Nos. HP34S-1 and HP34S-2

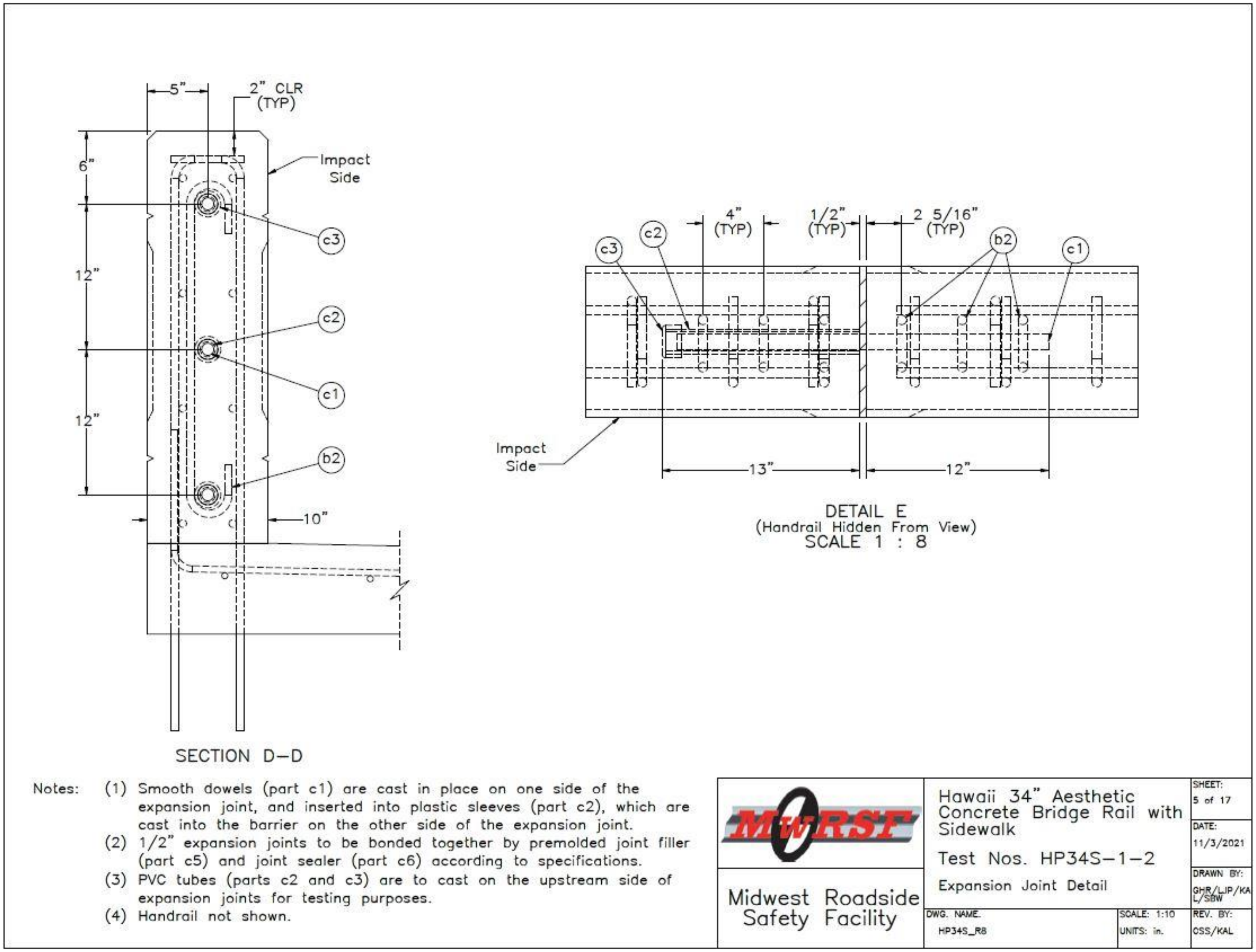


Figure 10. Expansion Joint Details, Test Nos. HP34S-1 and HP34S-2

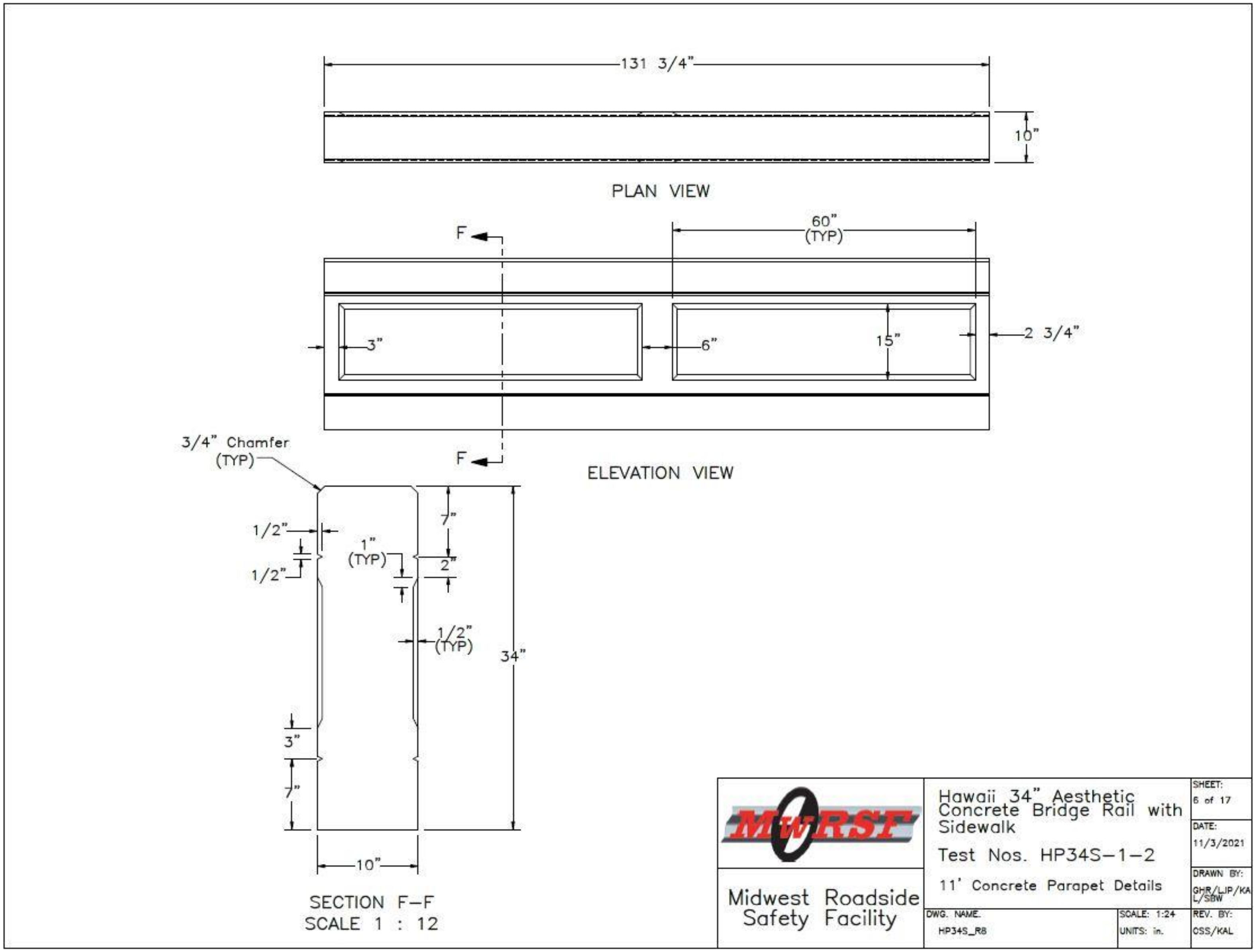


Figure 11. 10-ft 11¾-in. Concrete Parapet Details, Test Nos. HP34S-1 and HP34S-2

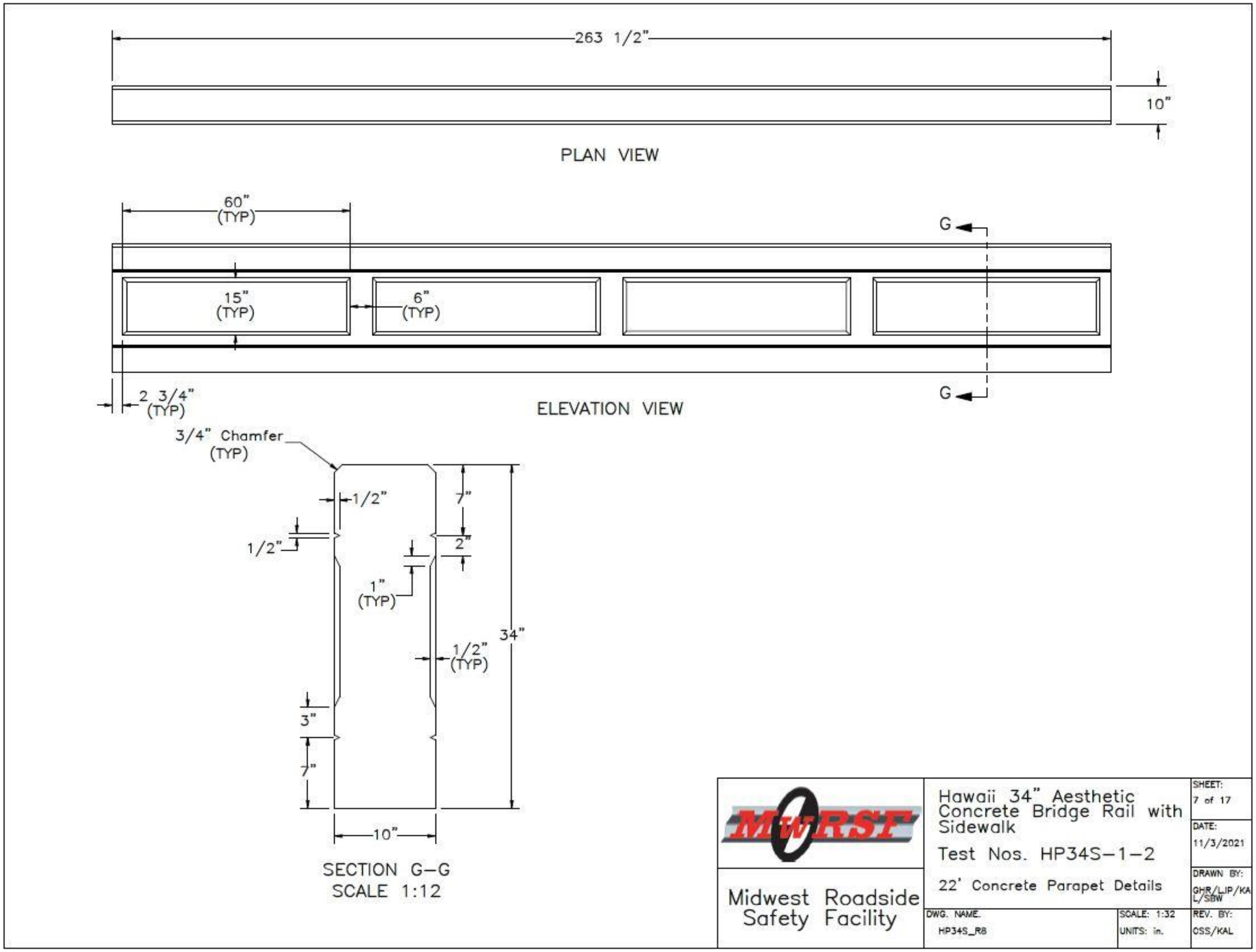


Figure 12. 21-ft 11½-in. Concrete Parapet Details, Test Nos. HP34S-1 and HP34S-2

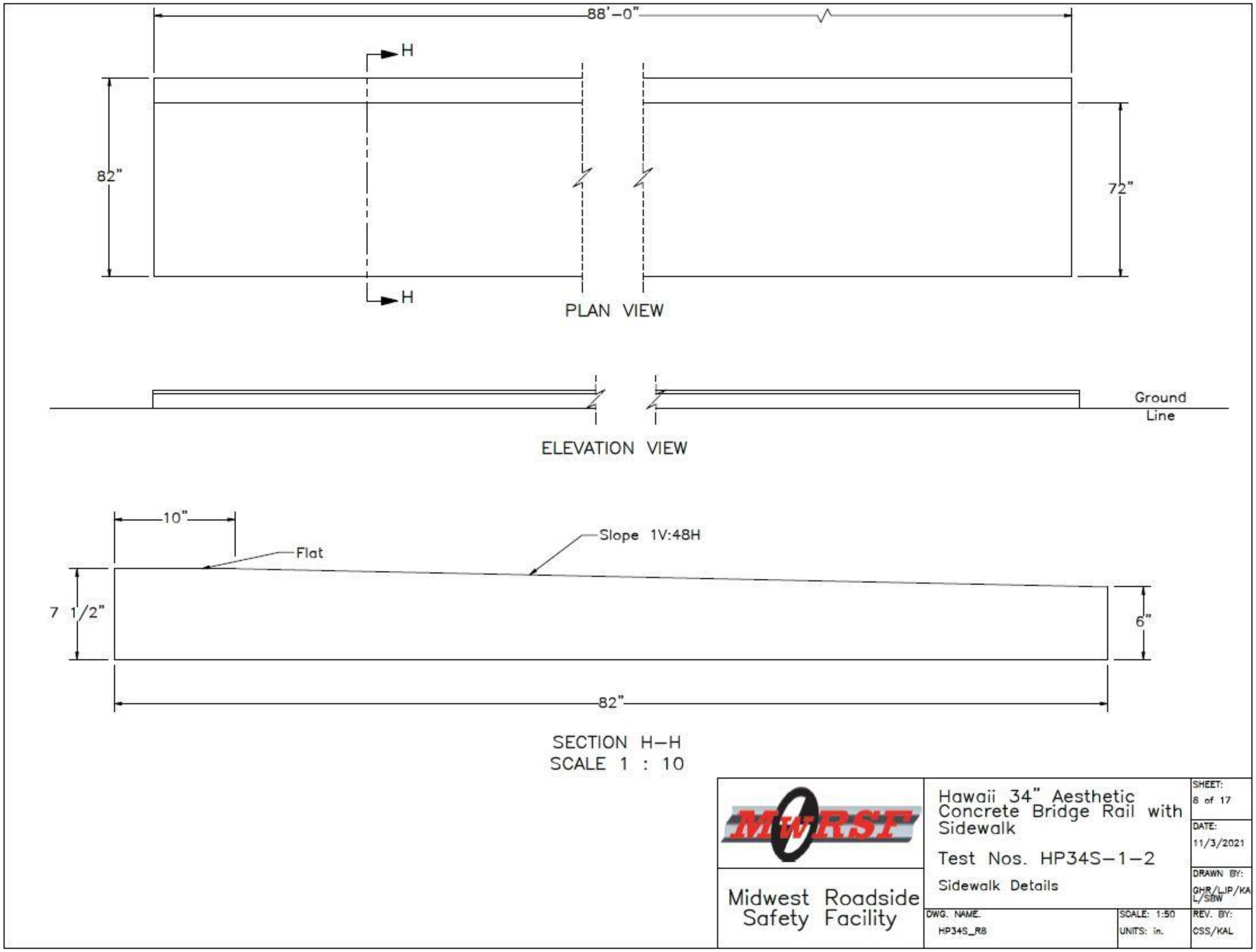


Figure 13. Sidewalk Details, Test Nos. HP34S-1 and HP34S-2

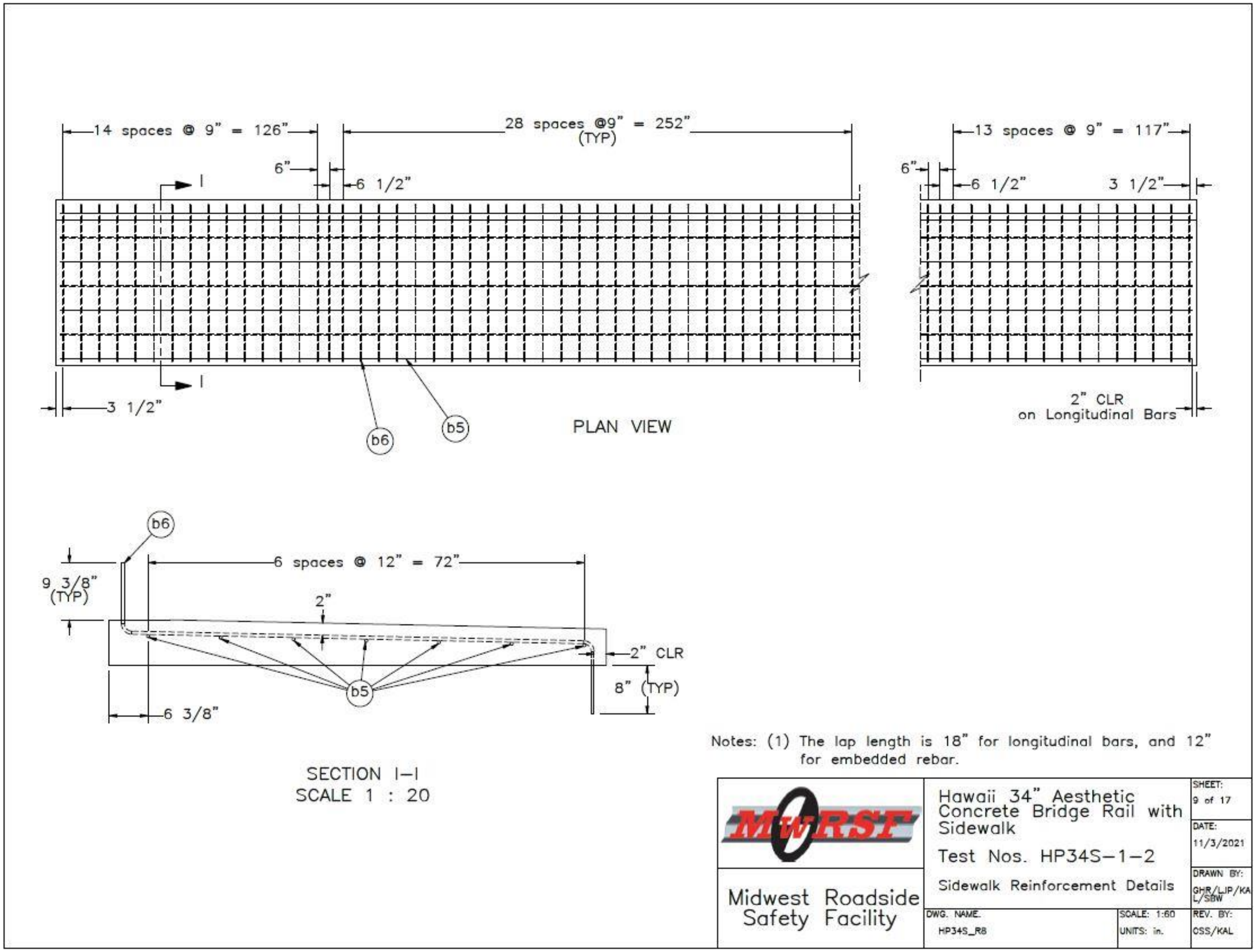
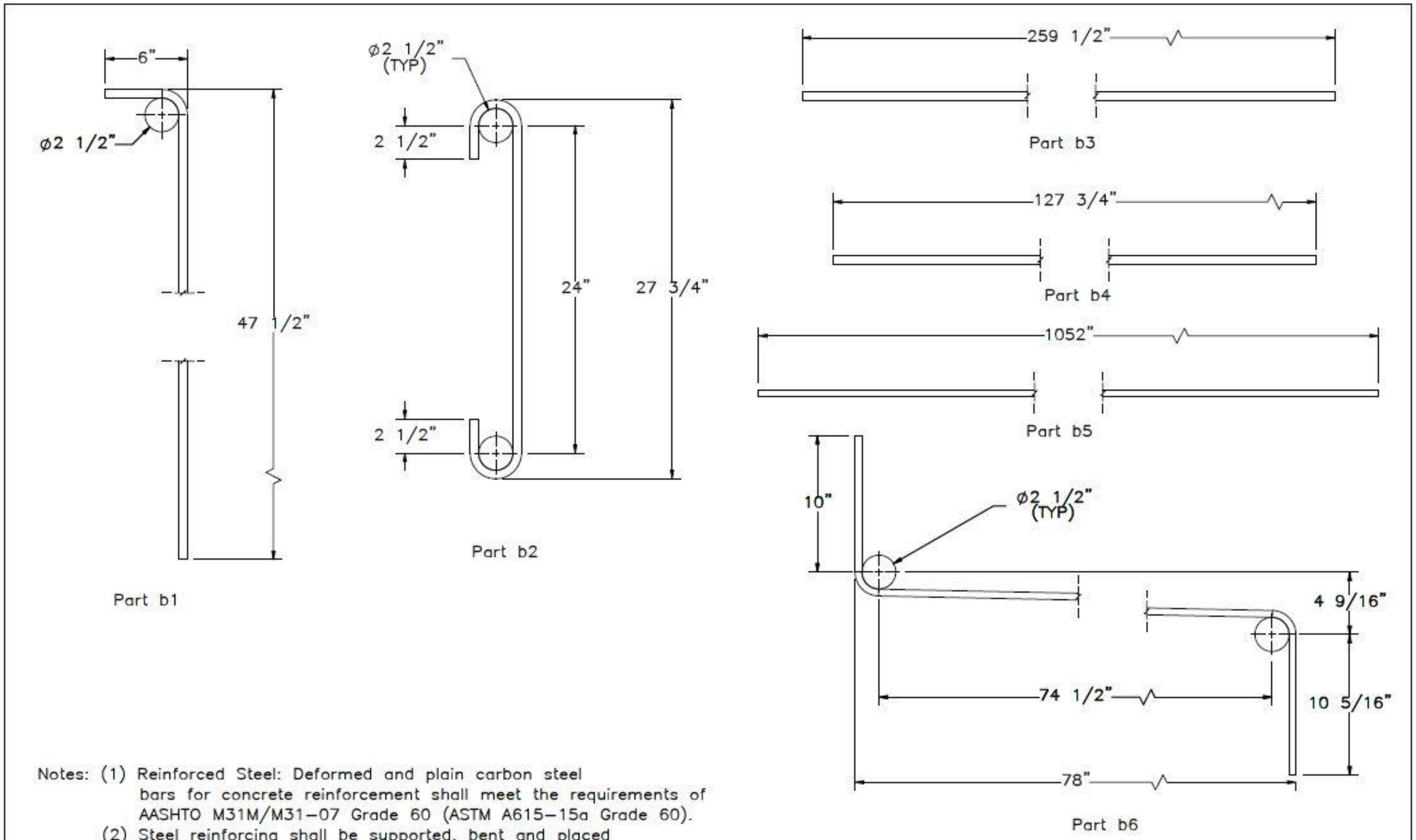


Figure 14. Sidewalk Reinforcement Details, Test Nos. HP34S-1 and HP34S-2



Notes: (1) Reinforced Steel: Deformed and plain carbon steel bars for concrete reinforcement shall meet the requirements of AASHTO M31M/M31-07 Grade 60 (ASTM A615-15a Grade 60).
(2) Steel reinforcing shall be supported, bent and placed as per AASHTO LRFD Bridge Design Specifications, 7th Edition, 2014 including all interim revisions.

Bill of Bars

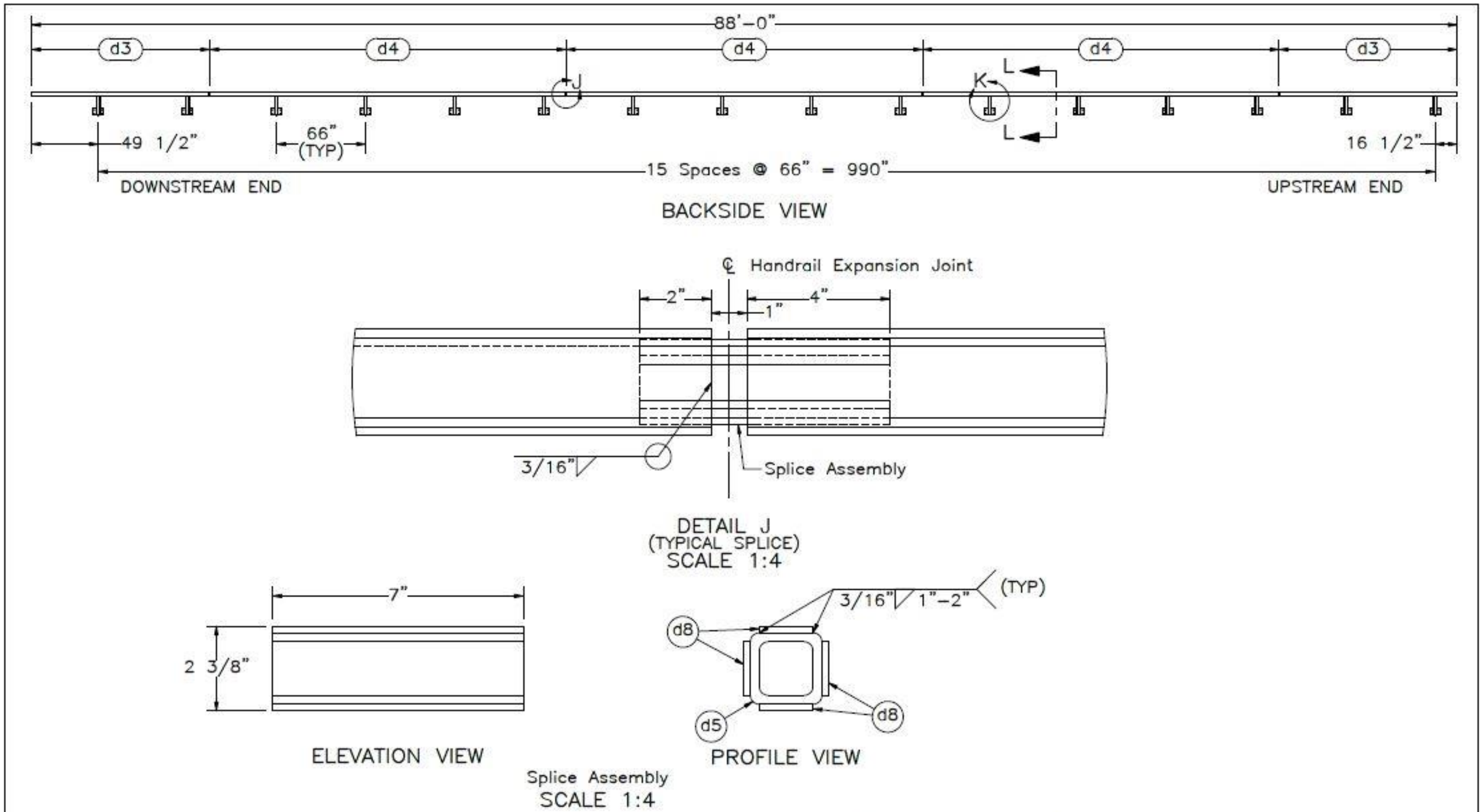
Part No.	Bar Size	Qty.	Unbent Length	Material Specification
b1	#5	264	52 1/4"	ASTM A615 Gr. 60
b2	#5	24	38 7/8"	ASTM A615 Gr. 60
b3	#5	24	259 1/2"	ASTM A615 Gr. 60
b4	#5	16	127 3/4"	ASTM A615 Gr. 60
b5	#4	7	1052"	ASTM A615 Gr. 60
b6	#4	122	99 9/16"	ASTM A615 Gr. 60

MwRSF
Midwest Roadside Safety Facility

Hawaii 34" Aesthetic Concrete Bridge Rail with Sidewalk
Test Nos. HP34S-1-2
Rebar Details

SHEET: 10 of 17
DATE: 11/3/2021
DRAWN BY: GHR/LJP/KAL/SBW
DWG. NAME. HP34S_R8
SCALE: 1:10
UNITS: in.
REV. BY: CSS/KAL

Figure 15. Rebar Details, Test Nos. HP34S-1 and HP34S-2



Note: (1) Handrail tubes (parts d3 and d4) should be welded directly to shims (part d8) before galvanization.
(2) Handrail assemblies shall be galvanzied according to ASTM A123 after welding.

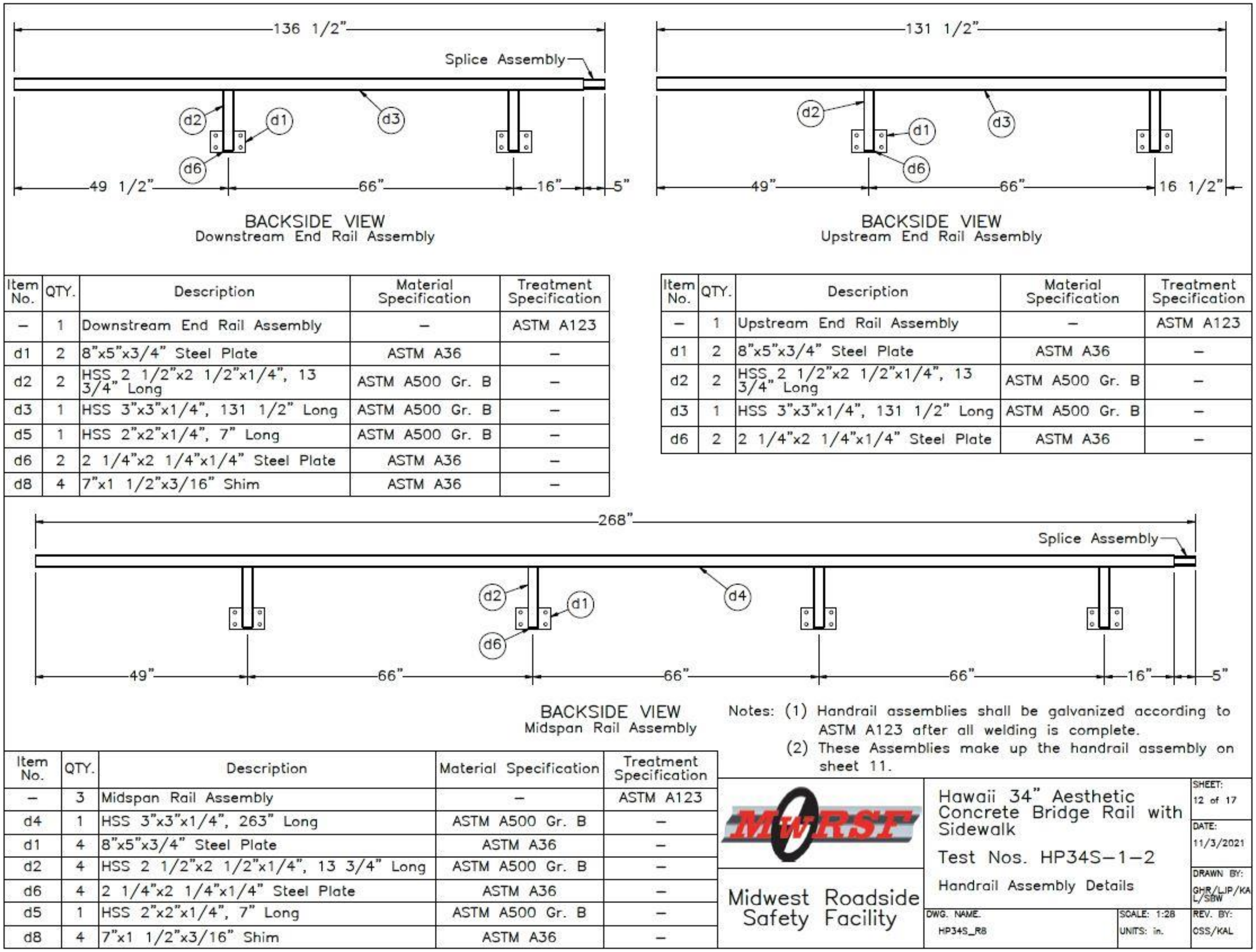
Item No.	QTY.	Description	Material Specification	Treatment Specification
–	1	Handrail Assembly	–	ASTM A123
d1	16	8"x5"x3/4" Steel Plate	ASTM A36	–
d2	16	HSS 2 1/2"x2 1/2"x1/4", 13 3/4" Long	ASTM A500 Gr. B	–
d3	2	HSS 3"x3"x1/4", 131 1/2" Long	ASTM A500 Gr. B	–
d4	3	HSS 3"x3"x1/4", 263" Long	ASTM A500 Gr. B	–
d5	4	HSS 2"x2"x1/4", 7" Long	ASTM A500 Gr. B	–
d6	16	2 1/4"x2 1/4"x1/4" Steel Plate	ASTM A36	–
d8	16	7"x1 1/2"x3/16" Shim	ASTM A36	–

Midwest Roadside Safety Facility

Hawaii 34" Aesthetic Concrete Bridge Rail with Sidewalk
Test Nos. HP34S–1–2
Handrail Assembly

SHEET: 11 of 17
DATE: 11/3/2021
DRAWN BY: GHR/LJP/KAL/SBW
DWG. NAME. HP34S_R8
SCALE: 1:106
UNITS: in.
REV. BY: OSS/KAL

Figure 16. Pedestrian Handrail Assembly, Test Nos. HP34S-1 and HP34S-2



Item No.	QTY.	Description	Material Specification	Treatment Specification
–	1	Downstream End Rail Assembly	–	ASTM A123
d1	2	8"x5"x3/4" Steel Plate	ASTM A36	–
d2	2	HSS 2 1/2"x2 1/2"x1/4", 13 3/4" Long	ASTM A500 Gr. B	–
d3	1	HSS 3"x3"x1/4", 131 1/2" Long	ASTM A500 Gr. B	–
d5	1	HSS 2"x2"x1/4", 7" Long	ASTM A500 Gr. B	–
d6	2	2 1/4"x2 1/4"x1/4" Steel Plate	ASTM A36	–
d8	4	7"x1 1/2"x3/16" Shim	ASTM A36	–

Item No.	QTY.	Description	Material Specification	Treatment Specification
–	1	Upstream End Rail Assembly	–	ASTM A123
d1	2	8"x5"x3/4" Steel Plate	ASTM A36	–
d2	2	HSS 2 1/2"x2 1/2"x1/4", 13 3/4" Long	ASTM A500 Gr. B	–
d3	1	HSS 3"x3"x1/4", 131 1/2" Long	ASTM A500 Gr. B	–
d6	2	2 1/4"x2 1/4"x1/4" Steel Plate	ASTM A36	–

Item No.	QTY.	Description	Material Specification	Treatment Specification
–	3	Midspan Rail Assembly	–	ASTM A123
d4	1	HSS 3"x3"x1/4", 263" Long	ASTM A500 Gr. B	–
d1	4	8"x5"x3/4" Steel Plate	ASTM A36	–
d2	4	HSS 2 1/2"x2 1/2"x1/4", 13 3/4" Long	ASTM A500 Gr. B	–
d6	4	2 1/4"x2 1/4"x1/4" Steel Plate	ASTM A36	–
d5	1	HSS 2"x2"x1/4", 7" Long	ASTM A500 Gr. B	–
d8	4	7"x1 1/2"x3/16" Shim	ASTM A36	–

Figure 17. Pedestrian Handrail Assembly Details, Test Nos. HP34S-1 and HP34S-2

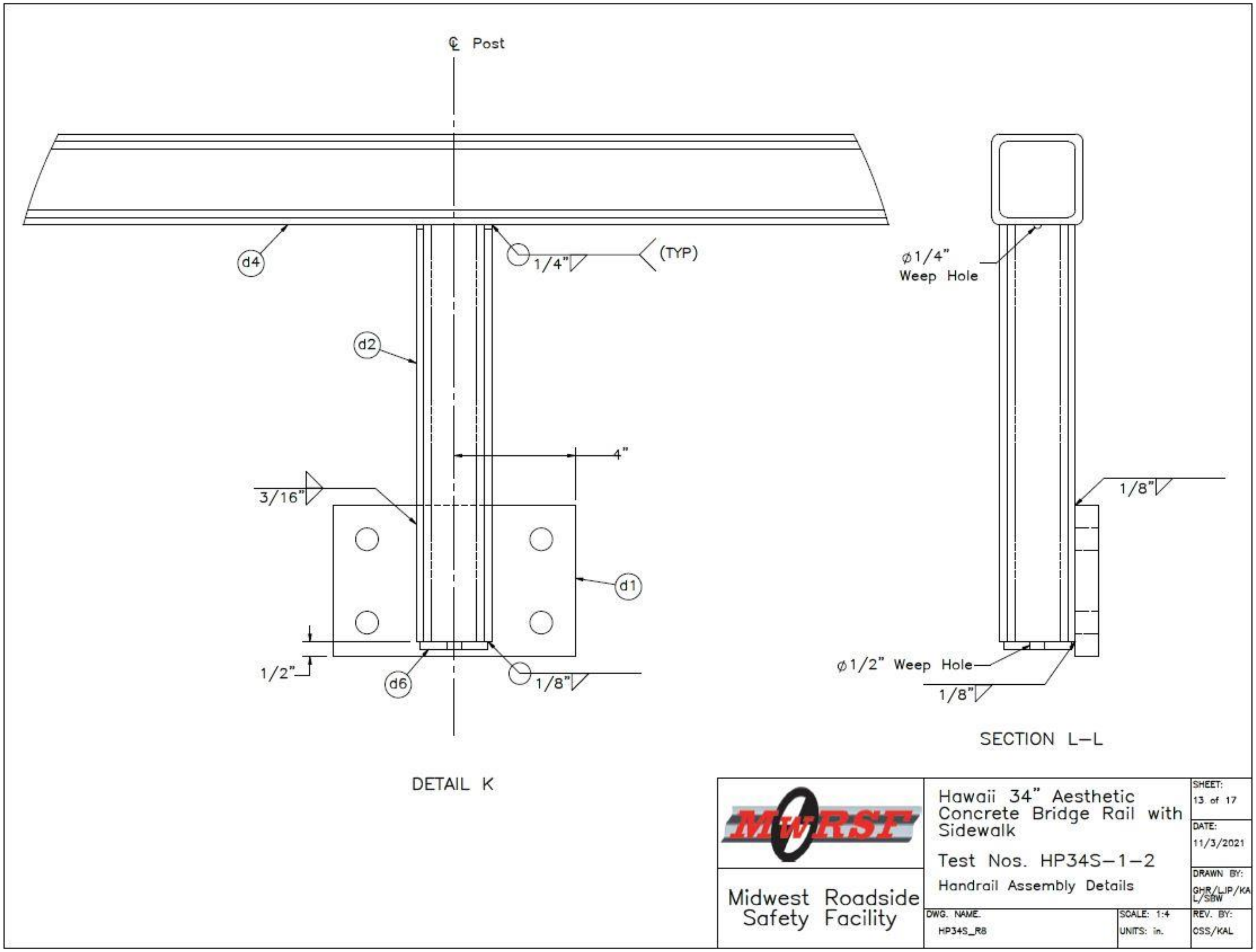


Figure 18. Pedestrian Handrail Assembly Details, Test Nos. HP34S-1 and HP34S-2

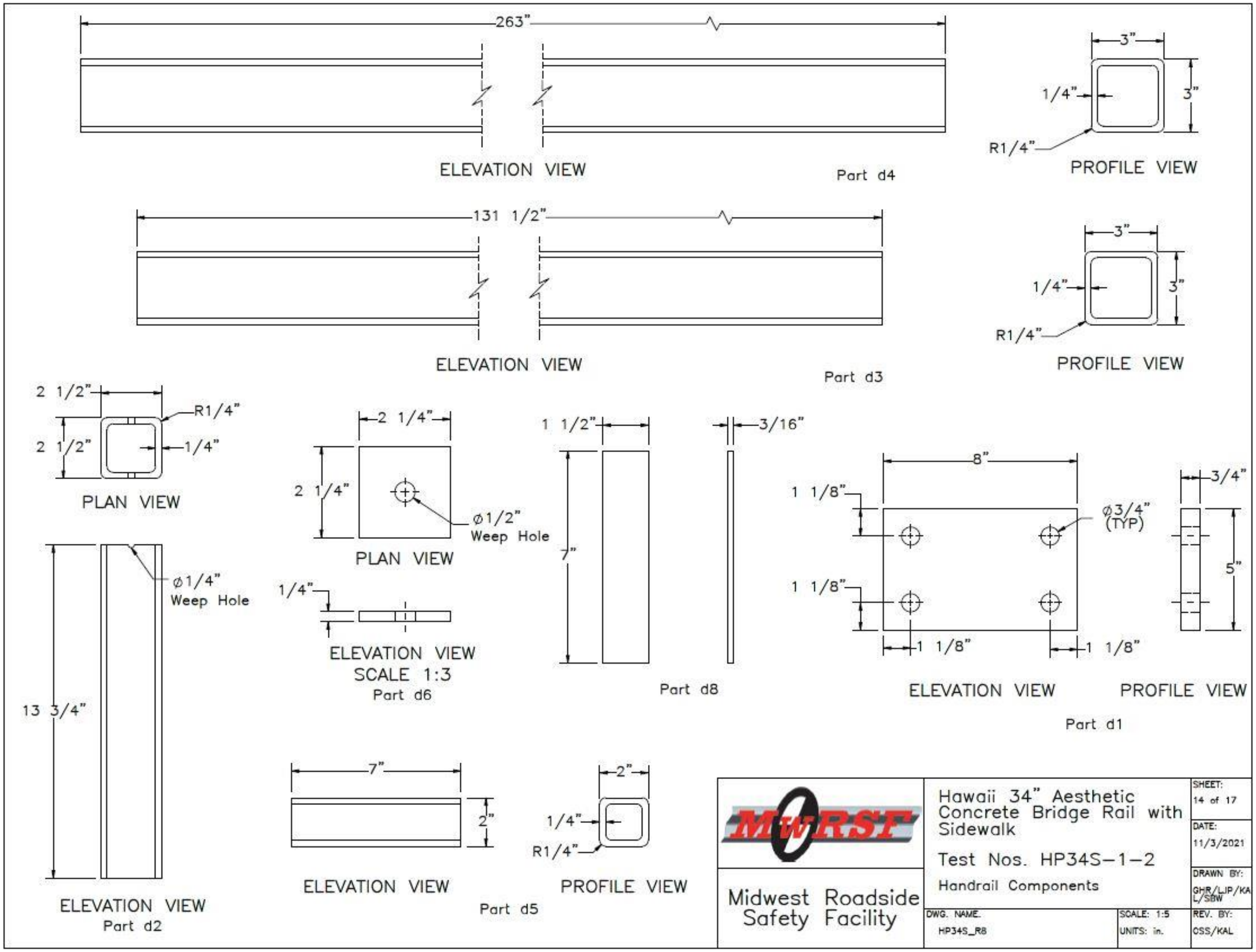


Figure 19. Pedestrian Handrail Components, Test Nos. HP34S-1 and HP34S-2

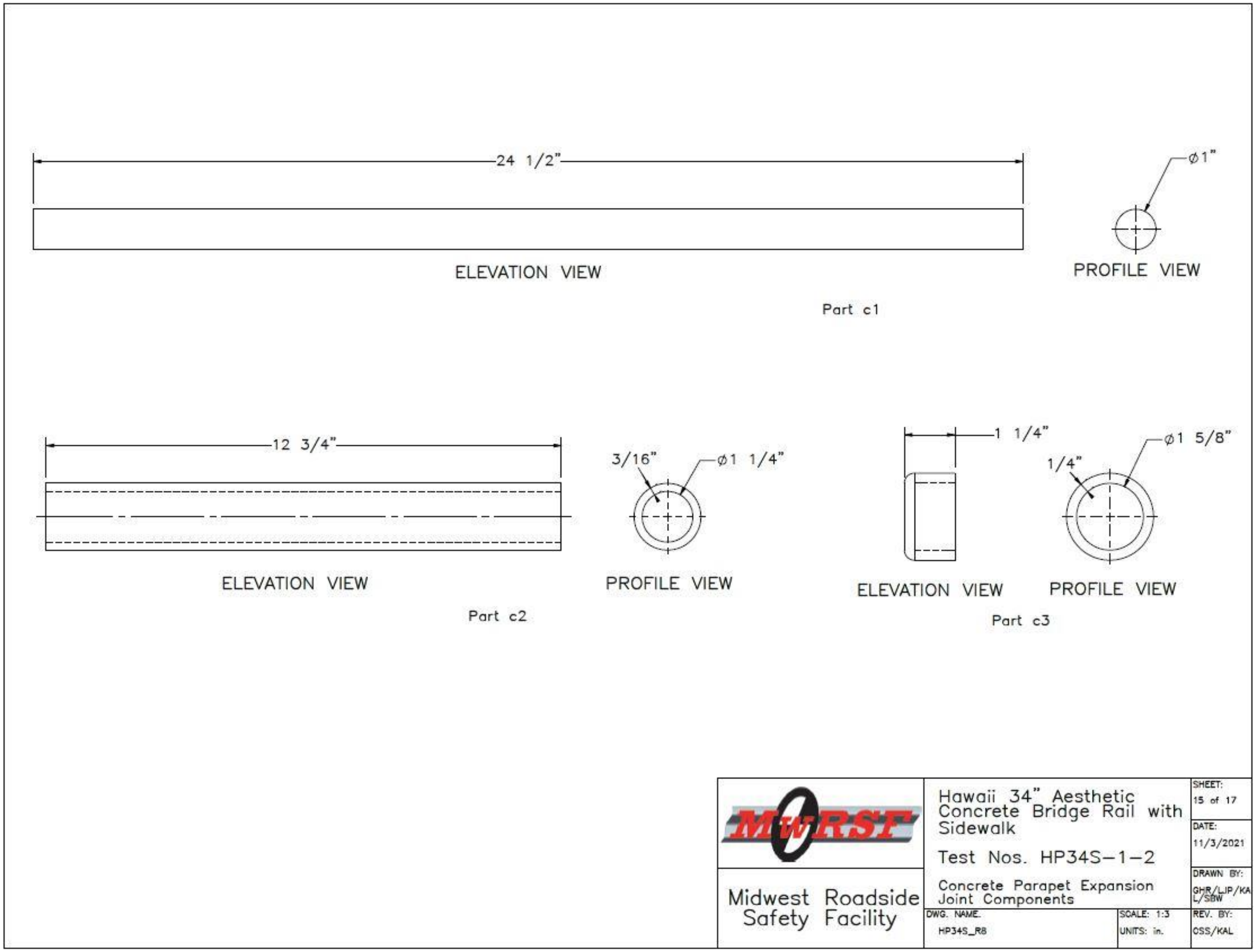


Figure 20. Expansion Joint Components, Test Nos. HP34S-1 and HP34S-2

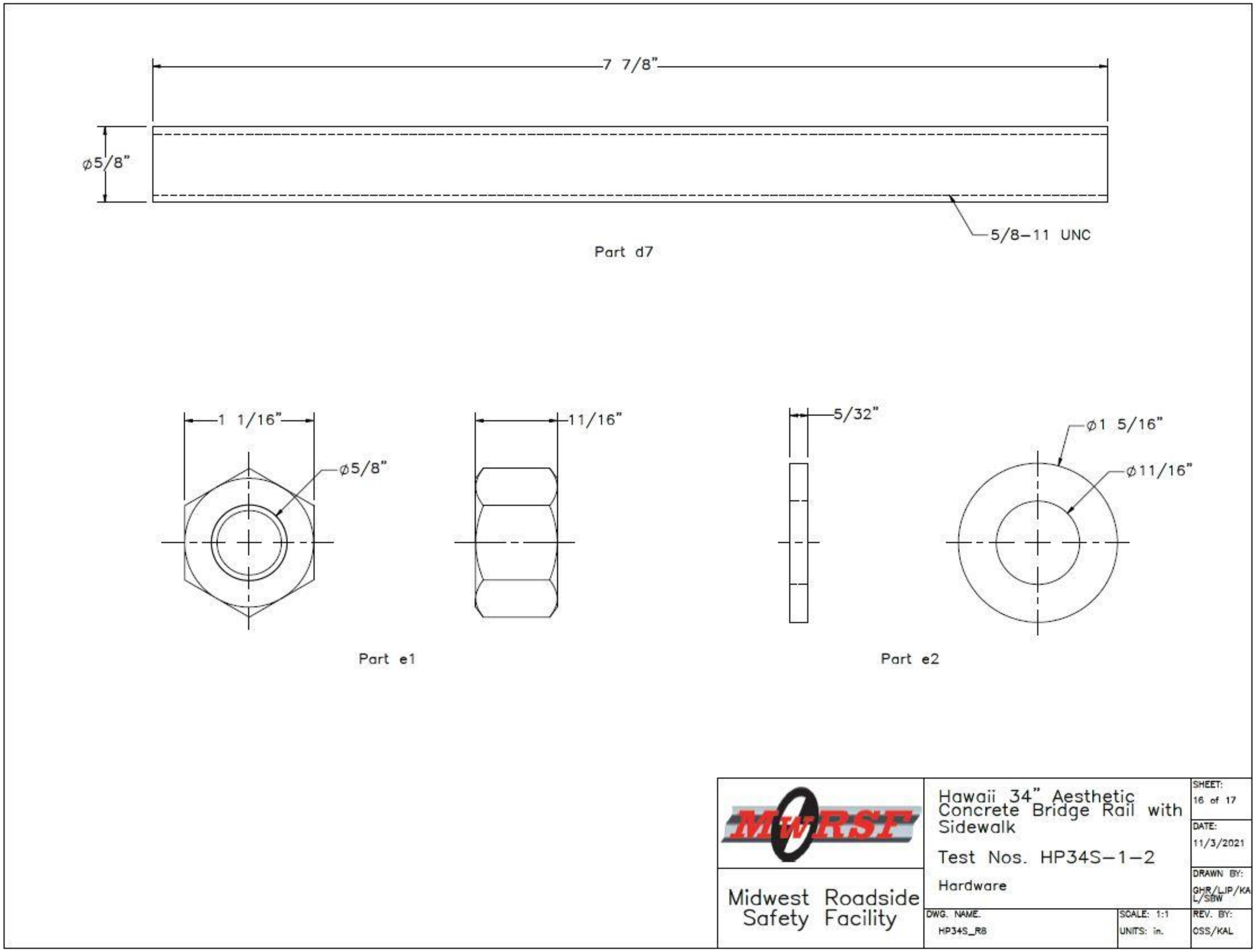


Figure 21. Connection Hardware, Test Nos. HP34S-1 and HP34S-2

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
a1	–	Concrete*	Min. f'c = 4,000 psi	–	–
b1	264	#5 Rebar, 52 1/4" Total Unbent Length	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
b2	24	#5 Rebar, 38 7/8" Total Unbent Length	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
b3	24	#5 Rebar, 259 1/2" Total Length	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
b4	16	#5 Rebar, 127 3/4" Total Length	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
b5	7	#4 Rebar, 1095 1/2" Total Length	ASTM A615 Gr. 60	Epoxy–Coated (ASTM A775 or A934)	–
b6	122	#4 Rebar, 99 9/16" Unbent Length	ASTM A615 Gr. 60	Epoxy–Coated (ASTM A775 or A934)	–
c1	12	#8 Smooth Rebar, 24 1/2" Long	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)	–
c2	12	1 1/4" Dia. PVC Pipe	Schedule 80 PVC Gr. 12454	–	–
c3	12	1 1/4" Dia. PVC End Cap	Schedule 80 PVC Gr. 12454	–	–
c4	–	Epoxy Adhesive	Hilti HIT RE–500 V3	–	–
c5	–	Expansion Joint Filler	AASHTO M33, M153, or M213	–	–
c6	–	Expansion Joint Sealant	AASHTO M173, M282, M301, ASTM D3581, or ASTM D5893	–	–
d1	16	8"x5"x3/4" Steel Plate	ASTM A36	–	–
d2	16	HSS 2 1/2"x2 1/2"x1/4", 13 3/4" Long	ASTM A500 Gr. B	–	–
d3	2	HSS 3"x3"x1/4", 131 1/2" Long	ASTM A500 Gr. B	–	–
d4	3	HSS 3"x3"x1/4", 263" Long	ASTM A500 Gr. B	–	–
d5	4	HSS 2"x2"x1/4", 7" Long	ASTM A500 Gr. B	–	–
d6	16	2 1/4"x2 1/4"x1/4" Steel Plate	ASTM A36	–	–
d7	64	5/8"–11 UNC, 7 7/8" Long Threaded Rod	ASTM F1554–15 Gr. 105	ASTM F2329	–
d8	16	7"x1 1/2"x3/16" Shim	ASTM A36	–	–
e1	64	5/8"–11 UNC Heavy Hex Nut	ASTM A563–15 Grade DH	ASTM F2329	FNX16b
e2	64	5/8" Dia. Hardened Washer	ASTM F436	ASTM F2329	FWC16b

* NE Mix 47BIS/1PF4000 HW was used for testing purposes.

Midwest Roadside Safety Facility

Hawaii 34" Aesthetic Concrete Bridge Rail with Sidewalk

Test Nos. HP34S–1–2

Bill of Materials

SHEET: 17 of 17
DATE: 11/3/2021
DRAWN BY: GHR/LJP/KAL/SBW
REV. BY: OSS/KAL
DWG. NAME. HP34S_R8
SCALE: None
UNITS: in.

Figure 22. Bill of Materials, Test Nos. HP34S-1 and HP34S-2

Figure 23. Test Installation Photographs, Test Nos. HP34S-1 and HP34S-2

Figure 24. Test Installation Photographs, Test Nos. HP34S-1 and HP34S-2

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 ensured the accuracy of the test vehicle impact speed.

A vehicle guidance system developed by Hinch [11] was used to steer the test vehicle. A guide flag, attached to the right-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. HP34S-1, a 2016 Dodge Ram 1500 crew cab pickup truck was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 5,323 lb, 5,045 lb, and 5,208 lb, respectively. The test vehicle is shown in Figures 25 and 26, and vehicle dimensions are shown in Figure 27.

For test no. HP34S-2, a 2016 Hyundai Accent was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 2,461 lb, 2,413 lb, and 2,577 lb, respectively. The test vehicle is shown in Figures 28 and 29, and vehicle dimensions are shown in Figure 30.

The longitudinal component of the center of gravity (c.g.) was determined for both vehicles using the measured axle weights. The Suspension Method [12] was used to determine the vertical component of the c.g. for the 2270P vehicle, used in test no. HP34S-1. 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 vehicle was 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 vehicle used in test no. HP34S-2 was determined utilizing a procedure published by SAE [13]. The final c.g. locations for HP34S-1 and HP34S-2 test vehicles are shown in Figures 31 and 32, respectively. Ballast information and data used to calculate the location of the c.g. are shown in Appendix B.

Square, black-and-white checkered targets were placed on the vehicles for reference, as shown in Figures 31 and 32, to serve as a reference in the high-speed digital video and aid in the video analysis. Round, checkered targets were placed at the c.g. on the left-side door, the right-side door, and the roof of the vehicles.

Figure 25. Test Vehicle, Test No. HP34S-1

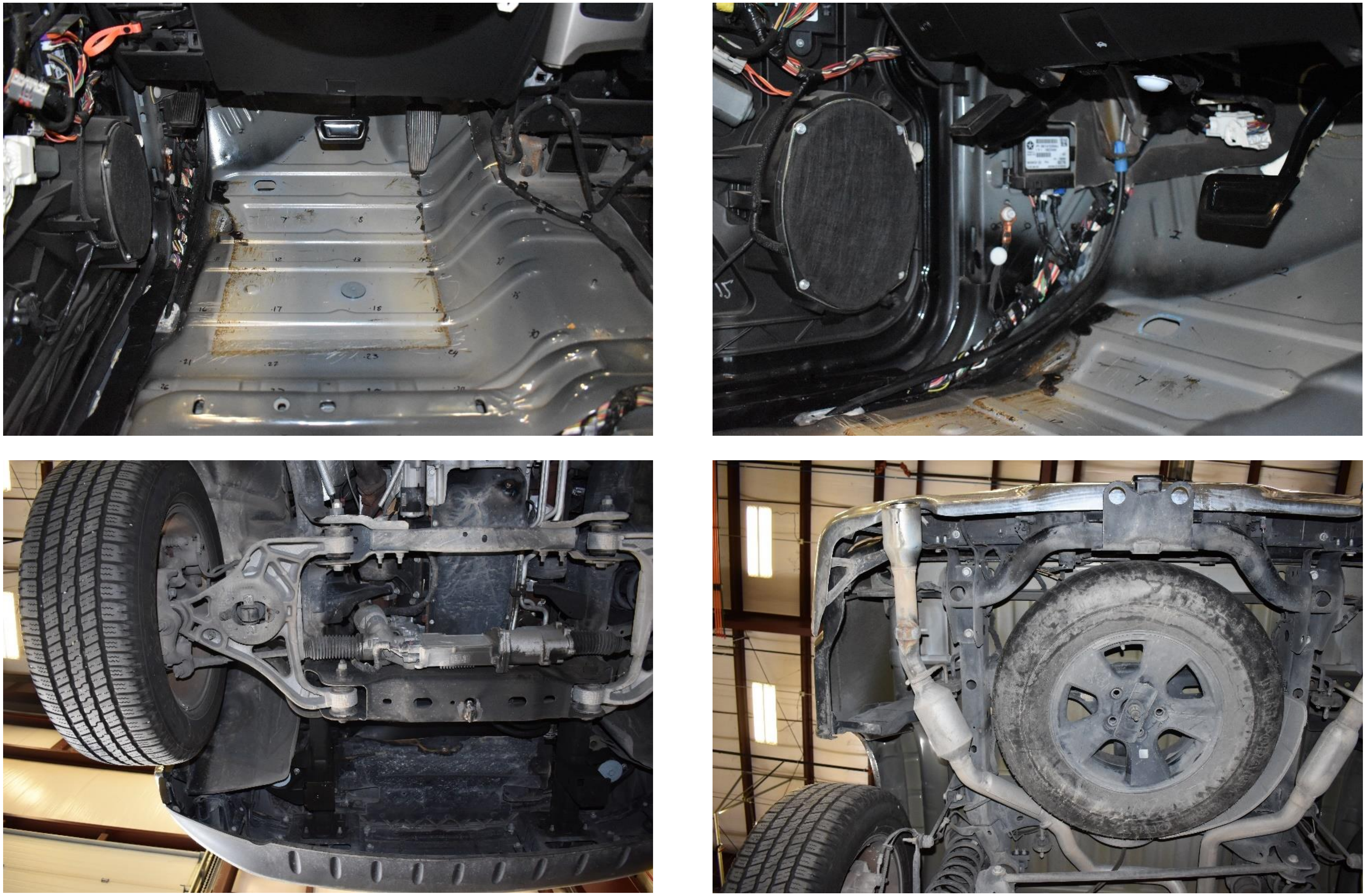
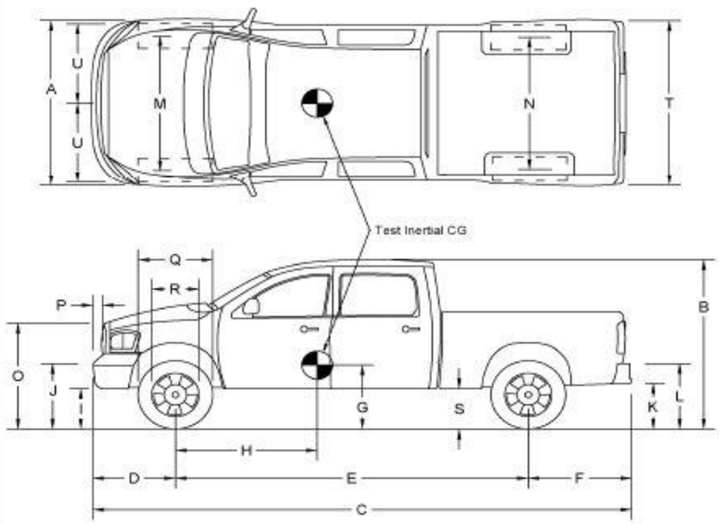


Figure 26. Test Vehicle's Interior Floorboards and Undercarriage, Test No. HP34S-1

		Test Name:	HP34S-1
VIN No:	1C6RR6LT8GS269861		
Model Year:	2016	Make:	Dodge
Model:	Ram 1500		
Tire Size:	p275 60/R20	Tire Inflation Pressure:	39 psi
Odometer:	211869		



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

	in.	(mm)		in.	(mm)
A:	77	1955 4/5	B:	75 3/4	1924 1/20
	78±2 (1950±50)				
C:	229 1/4	5822 19/20	D:	41	1041 2/5
	237±13 (6020±325)			39±3 (1000±75)	
E:	140 1/2	3568 7/10	F:	47 3/4	1212 17/20
	148±12 (3760±300)				
G:	29 1/4	742 19/20	H:	59 11/16	1516 1/16
	min: 28 (710)			63±4 (1575±100)	
I:	14 1/2	368 3/10	J:	25 5/8	650 7/8
K:	21 1/2	546 1/10	L:	29 1/2	749 3/10
M:	68 5/8	1743 3/40	N:	68 1/4	1733 11/20
	67±1.5 (1700±38)			67±1.5 (1700±38)	
O:	45 1/4	1149 7/20	P:	4 1/2	114 3/10
	43±4 (1100±75)				
Q:	32	812 4/5	R:	21 1/2	546 1/10
S:	15	381	T:	77 1/8	1958 39/40

	in.	(mm)
U (impact width):	36 1/2	927 1/10
Wheel Center Height (Front):	15 1/2	393 7/10
Wheel Center Height (Rear):	15 3/4	400 1/20
Wheel Well Clearance (Front):	36 3/8	923 37/40
Wheel Well Clearance (Rear):	39	990 3/5
Bottom Frame Height (Front):	19 1/2	495 3/10
Bottom Frame Height (Rear):	26 1/2	673 1/10
Engine Type:	Gasoline	
Engine Size:	4.7L V8	
Transmission Type:	Automatic	
Drive Type:	RWD	
Cab Style:	Crew Cab	
Bed Length:	67"	

Mass Distribution - lb (kg)

Gross Static	LF	1512 (686)	RF	1491 (676)
	LR	1113 (505)	RR	1092 (495)

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	2985 (1354)	2901 (1316)	3003 (1362)
W-rear	2338 (1060)	2144 (973)	2205 (1000)
W-total	5323 (2414)	5045 (2288)	5208 (2362)
		5000±110 (2270±50)	5165±110 (2343±50)

GVWR Ratings - lb	
Front	3700
Rear	3900
Total	6900

Surrogate Occupant Data	
Type:	Hybrid II
Mass:	163 lb
Seat Position:	Drivers/Left

Note any damage prior to test: Small dent/scrape on right rear door.

Figure 27. Vehicle Dimensions, Test No. HP34S-1

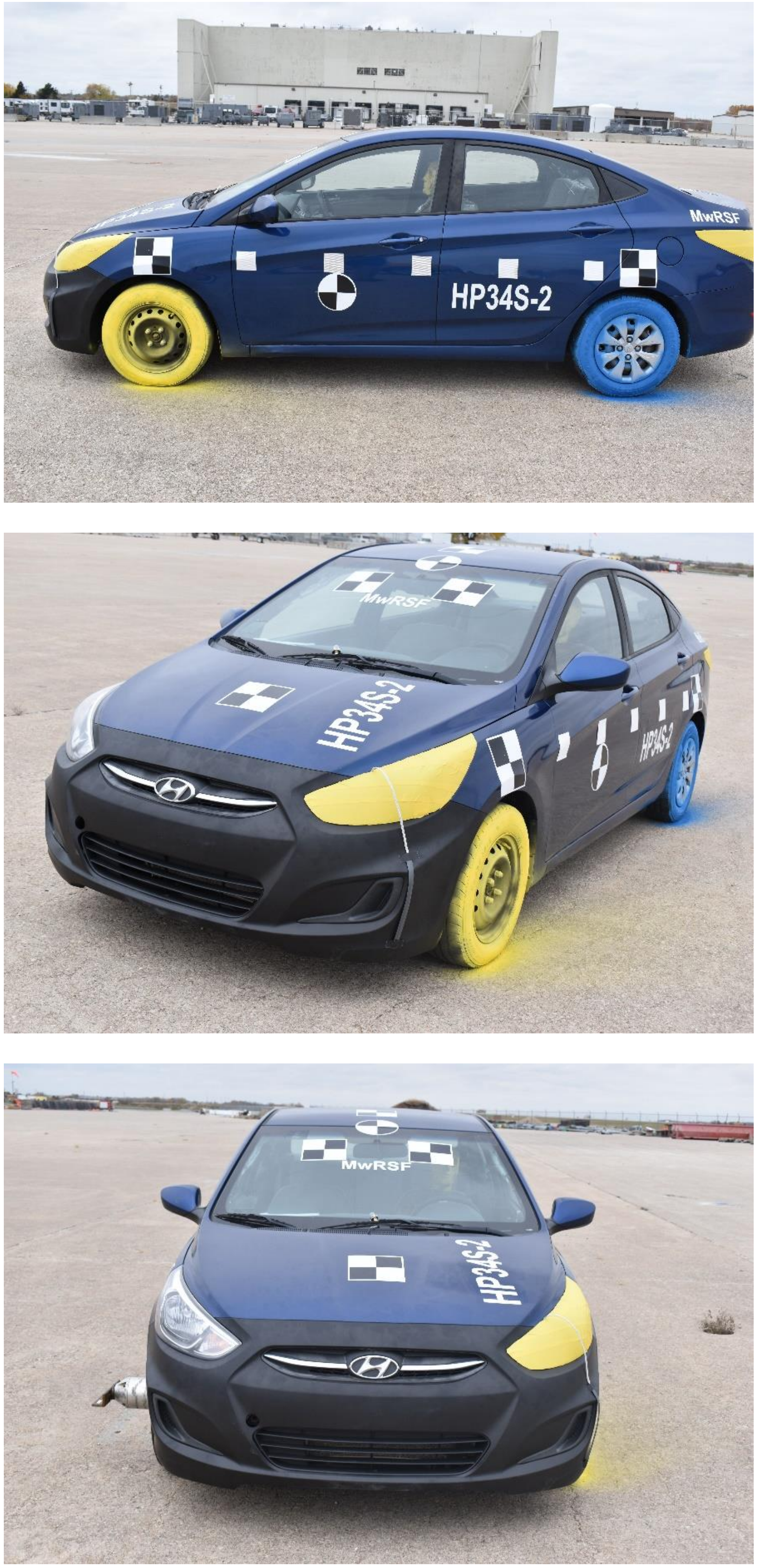


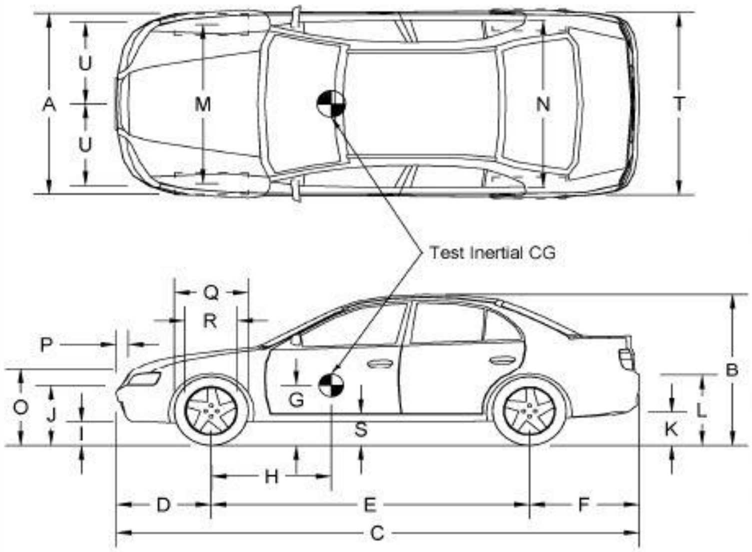
Figure 28. Test Vehicle, Test No. HP34S-2

Figure 29. Test Vehicle's Interior Floorboards and Undercarriage, Test No. HP34S-2

Test Name: HP34S-2 | VIN No: KMHCT4AE9GUO78507

Model Year: 2016 | Make: Hyundai | Model: Accent

Tire Size: P175/70R14 | Tire Inflation Pressure: 33 psi | Odometer: 182225



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

A: 66 3/4 (1695) 65±3 (1650±75)	B: 56 3/4 (1441)
C: 171 3/8 (4353) 169±8 (4300±200)	D: 31 3/8 (797) 35±4 (900±100)
E: 101 (2565) 98±5 (2500±125)	F: 39 (991)
G: 21 7/8 (556)	H: 38 (965) 39±4 (990±100)
I: 6 1/4 (159)	J: 22 1/4 (565)
K: 11 (279)	L: 25 (635)
M: 59 5/8 (1514) 59±2 (1498±50)	N: 59 3/8 (1508) 59±2 (1425±50)
O: 29 1/4 (743) 28±4 (711±100)	P: 2 1/2 (64)
Q: 22 7/8 (581)	R: 15 1/4 (387)
S: 10 1/2 (267)	T: 66 5/8 (1692)

U (impact width): 31 (787)

Top of radiator core support: 28 3/4 (730)
Wheel Center Height (Front): 10 7/8 (276)
Wheel Center Height (Rear): 11 1/4 (286)
Wheel Well Clearance (Front): 24 7/8 (632)
Wheel Well Clearance (Rear): 25 1/4 (641)
Bottom Frame Height (Front): 5 7/8 (149)
Bottom Frame Height (Rear): 16 (406)
Engine Type: Gasoline
Engine Size: 1.6L 4 cyl
Transmission Type: Automatic
Drive Type: FWD

Mass Distribution - lb (kg)

Gross Static				
	LF	843 (382)	RF	746 (338)
	LR	488 (221)	RR	500 (227)

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	1540 (699)	1505 (683)	1589 (721)
W-rear	921 (418)	908 (412)	988 (448)
W-total	2461 (1116)	2413 (1095) 2420±55 (1100±25)	2577 (1169) 2585±55 (1175±50)

GVWR Ratings lb

Front	1874
Rear	1852
Total	3527

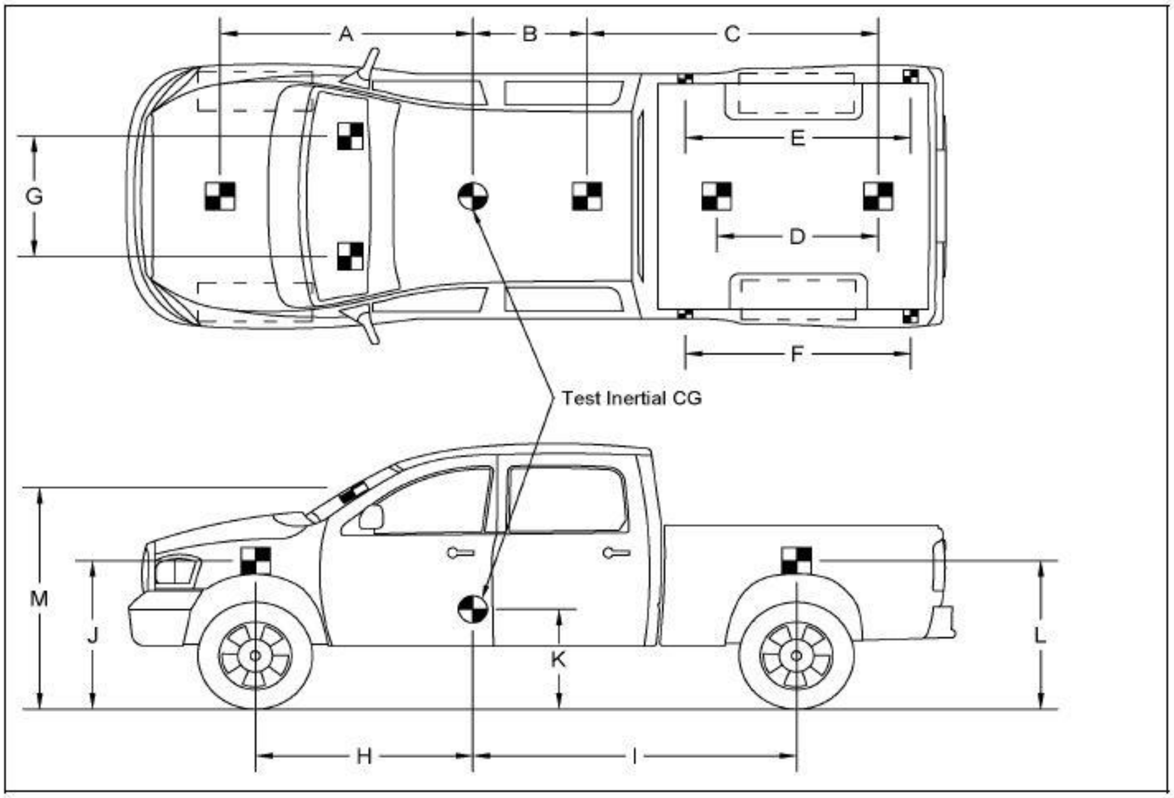
Surrogate Occupant Data

Type: Hybrid II
Mass: 164 lb
Seat Position: Left/Driver

Note any damage prior to test: None

Figure 30. Vehicle Dimensions, Test No. HP34S-2

		Test Name:	HP34S-1	VIN:	1C6RR6LT8GS269861
Model Year:	2016	Make:	Dodge	Model:	Ram 1500

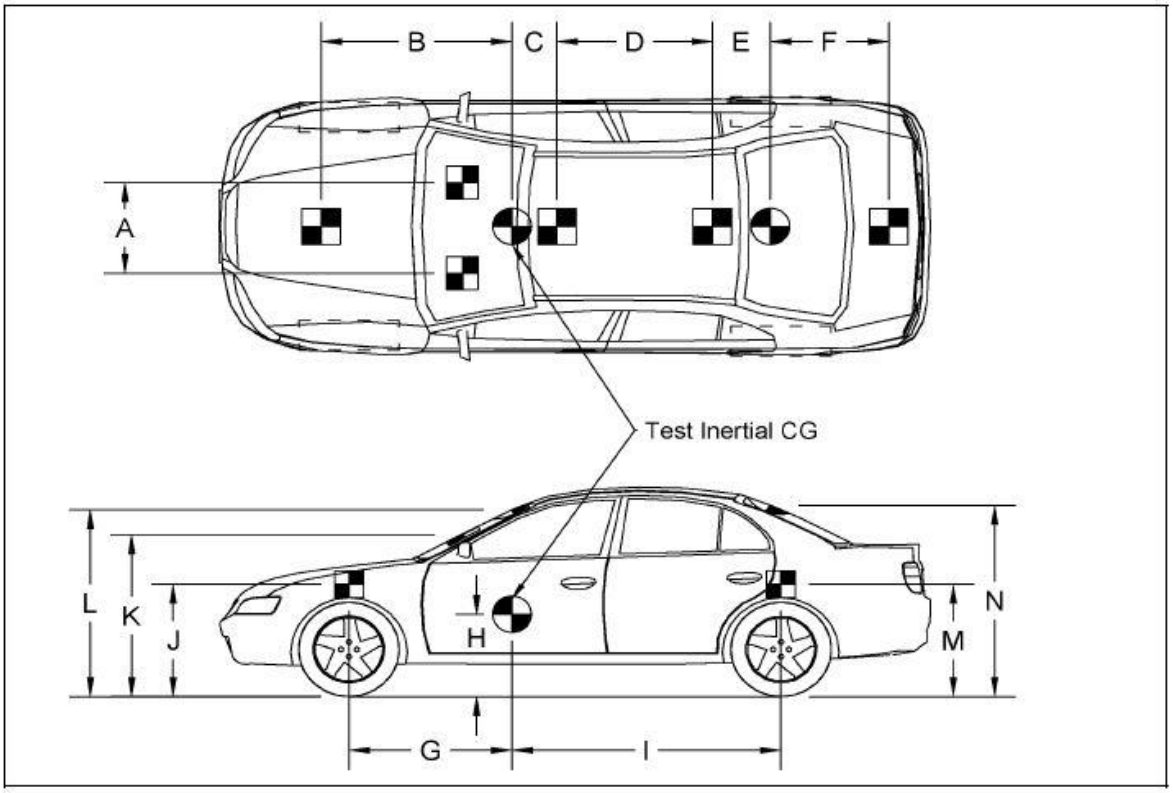


TARGET GEOMETRY-- in. (mm)

A:	77 13/16	(1976)	E:	54 1/2	(1384)	J:	40 5/16	(1024)
B:	36 1/4	(921)	F:	54 7/16	(1383)	K:	29 1/4	(743)
C:	66 5/8	(1692)	G:	33 5/8	(854)	L:	42 7/8	(1089)
D:	35 7/8	(911)	H:	59 11/16	(1516)	M:	65	(1651)
			I:	81	(2057)			

Figure 31. Target Geometry, Test No. HP34S-1

		Test Name:	HP34S-2	VIN:	KMHCT4AE9GUO78507
Model Year:	2016	Make:	Hyundai	Model:	Accent



TARGET GEOMETRY-- in. (mm)

A:	19	(483)	F:	30 5/8	(778)	K: Windshield Target	48 7/8	(1241)
B:	50 7/8	(1292)	G:	38	(965)	L: Front round CG target	53	(1346)
C:	11 1/4	(286)	H:	21 7/8	(556)	M:	28 7/8	(733)
D:	35 5/8	(905)	I:	63	(1600)	N: Rear Round target	53	(1346)
E:	11 5/16	(287)	J:	28 5/16	(719)			

Figure 32. Target Geometry, Test No. HP34S-2

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

4.4 Simulated Occupant

For each test, a Hybrid II 50^{th}-Percentile, Adult Male Dummy equipped with footwear was placed in the left-front seat of the test vehicle with the seat belt fastened. The simulated occupant had a final weight of 163 lb and 164 lb for test nos. HP34S-1 and HP34S-2, respectively. As recommended by MASH 2016, the simulated occupant weight was not included in calculating the c.g. locations.

4.5 Data Acquisition Systems

4.5.1 Accelerometers and Rate Transducers

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 vehicles. The SLICE-2 unit was designated as primary for test no. HP34S-1 whereas the SLICE-1 unit was designated as primary for test no. HP34S-2. 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 [14].

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 7 GB 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.

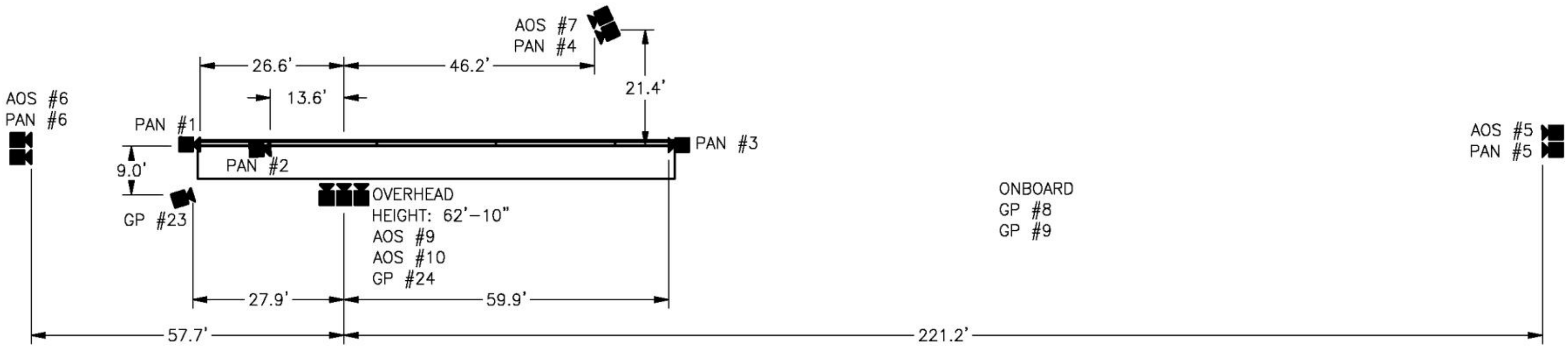
4.5.2 Retroreflective Optic Speed Trap

A retroreflective optic speed trap was used to determine the speed of the test vehicle before impact. Five retroreflective targets, spaced at 18-in. intervals, were applied to the side of the vehicle. When the emitted beam of light was reflected by the targets and returned to the Emitter/Receiver, a signal was sent to the data acquisition computer, recording at 10,000 Hz, as well as the external LED box activating the LED flashes. The speed was then calculated using the spacing between the retroreflective targets and the time between the signals. LED lights and high-speed digital video analysis are used as a backup if vehicle speeds cannot be determined from the electronic data. For test no. HP34S-1, the speed was not captured from the retroreflective optic speed trap or LED lights due to technical difficulties. Therefore, the vehicle speed was determined using video analysis.

4.5.3 Digital Photography

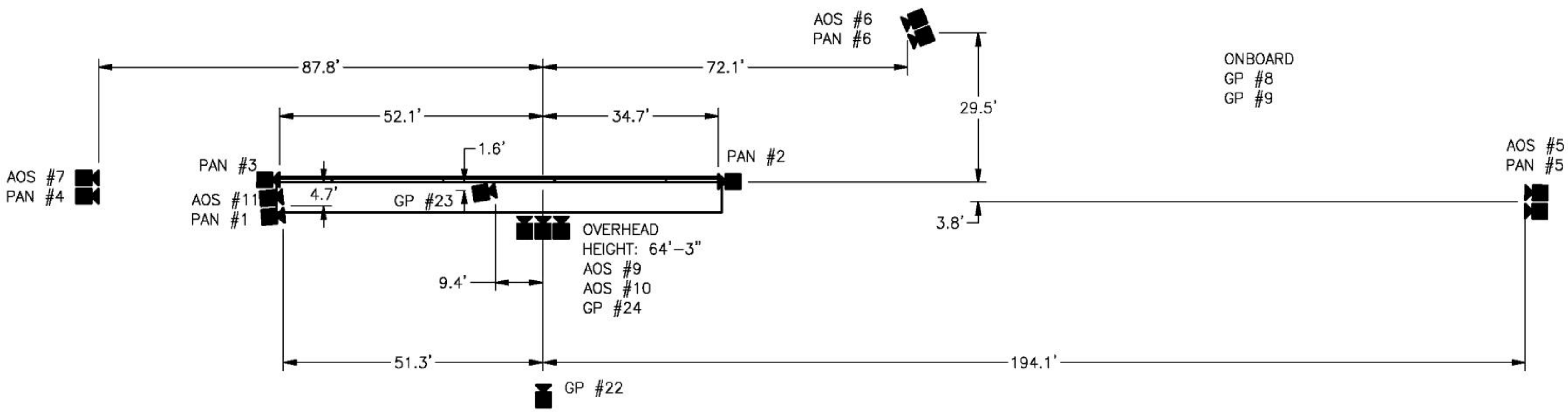
Five AOS high-speed digital video cameras, four GoPro digital video cameras, six Panasonic digital video cameras, and one SoloShot camera were utilized to film test no. HP34S-1. Six AOS high-speed digital video cameras, five GoPro digital video cameras, and six Panasonic digital video cameras were utilized to film test no. HP34S-2. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system are shown in Figures 33 and 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 both tests.



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-5	AOS X-PRI Gigabit	500	100 mm Fixed	-
AOS-6	AOS X-PRI Gigabit	500	Kowa 25 mm Fixed	-
AOS-7	AOS X-PRI Gigabit	500	Fujinon 35 mm Fixed	-
AOS-9	AOS TRI-VIT 2236	1000	Kowa 12 mm Fixed	-
AOS-10	AOS TRI-VIT 2236	500	Kowa 16 mm Fixed	-
GP-8	GoPro Hero 4	120		
GP-9	GoPro Hero 4	120		
GP-23	GoPro Hero 7	240		
GP-24	GoPro Hero 7	240		
PAN-1	Panasonic HC-V770	120		
PAN-2	Panasonic HC-V770	120		
PAN-3	Panasonic HC-V770	120		
PAN-4	Panasonic HC-V770	120		
PAN-5	Panasonic HC-VX981	120		
PAN-6	Panasonic HC-VX981	120		
	SoloShot	120		

Figure 33. Camera Locations, Speeds, and Lens Settings, Test No. HP34S-1



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-5	AOS X-PRI Gigabit	500	100 mm Fixed	-
AOS-6	AOS X-PRI Gigabit	500	Kowa 25 mm Fixed	-
AOS-7	AOS X-PRI Gigabit	500	Fujinon 50 mm Fixed	-
AOS-9	AOS TRI-VIT 2236	1000	Kowa 12 mm Fixed	-
AOS-10	AOS TRI-VIT 2236	500	Kowa 16 mm Fixed	-
AOS-11	AOS J-PRI	500	Sigma 28-70 mm	70
GP-8	GoPro Hero 4	120		
GP-9	GoPro Hero 4	120		
GP-22	GoPro Hero 7	240		
GP-23	GoPro Hero 7	240		
GP-24	GoPro Hero 7	240		
PAN-1	Panasonic HC-V770	120		
PAN-2	Panasonic HC-V770	120		
PAN-3	Panasonic HC-V770	120		
PAN-4	Panasonic HC-V770	120		
PAN-5	Panasonic HC-VX981	120		
PAN-6	Panasonic HC-VX981	120		

Figure 34. Camera Locations, Speeds, and Lens Settings, Test No. HP34S-2

5 FULL-SCALE CRASH TEST NO. HP34S-1

5.1 Weather Conditions

Test no. HP34S-1 was conducted on October 12, 2021 at approximately 2:30 p.m. The weather conditions as reported by the National Oceanic and Atmospheric Administration (station 14939/LNK) are shown in Table 3.

Table 3. Weather Conditions, Test No. HP34S-1

Temperature	80°F
Humidity	28%
Wind Speed	16 mph
Wind Direction	140° from True North
Sky Conditions	Sunny
Visibility	10.0 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.0 in.
Previous 7-Day Precipitation	0.0 in.

5.2 Test Description

Initial vehicle impact was to occur 85 in. upstream from the upstream face of post no. 7, as shown in Figure 35, which was selected using video analysis from previous tests with sidewalks to maximize the probability of wheel snag and vehicle interaction with the pedestrian handrail. The 5,045-lb crew cab pickup truck impacted the sidewalk at a speed of 65.7 mph and an angle of 25.2 degrees and impacted the barrier at a speed of 63.6 mph and an angle of 23.7 degrees. The impact speeds were determined via video analysis due to technical difficulties with the primary data source. Note that the sidewalk impact speed of 65.7 mph was above the MASH nominal impact speed of 62.0 mph ±2.5 mph. However, impact speeds exceeding the nominal criteria are acceptable for longitudinal barriers. The actual point of impact was 0.07 in. upstream from the targeted impact point. After brakes were applied, the vehicle came to rest 216.0 ft downstream from the point of impact with the sidewalk and 31.8 ft laterally in front of the sidewalk.

MASH 2016, Section 5.3 provides guidance for addressing geometric features. As the system tested in current research efforts included a geometric feature in the form of a sidewalk, criteria provided in MASH 2016 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.

The 2270P pickup truck interaction with the curb did not exceed 2.0 g's within a 50-ms period around the time of impact; therefore, event start time, t=0, occurred at the time of impact with the bridge rail. A detailed description of the sequential impact events is contained in Table 4. Sequential photographs are shown in Figures 36 and 37. Documentary photographs of the crash test are shown in Figures 38 through 41. The vehicle trajectory and final position are shown in Figure 42.

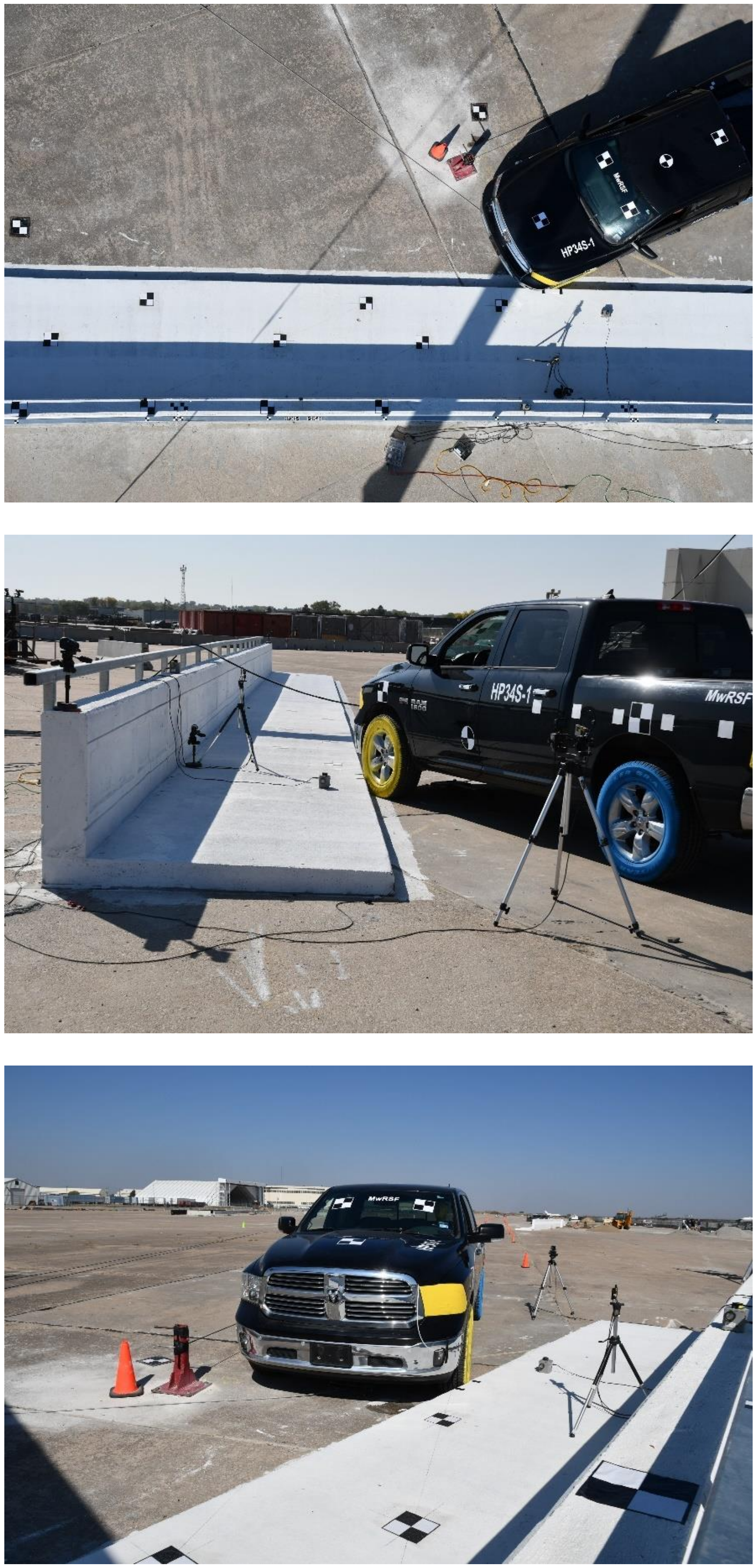


Figure 35. Impact Location, Test No. HP34S-1

Table 4. Sequential Description of Impact Events, Test No. HP34S-1

Time (sec)	Event
-0.138	Vehicle's left-front tire contacted curb.
-0.104	Vehicle rolled away from system.
-0.017	Vehicle's right-front tire contacted curb.
-0.004	Vehicle's left-rear tire contacted curb.
0.000	Vehicle's bumper contacted concrete parapet and deformed. Impact occurred 11¼ in. upstream from the targeted impact point.
0.006	Vehicle's left headlight and left fender contacted concrete parapet and deformed. Left headlight shattered.
0.018	Vehicle's bumper detached. Vehicle's grille contacted concrete parapet and deformed. Vehicle rolled toward system.
0.034	Vehicle's hood deformed. Vehicle's left-fender contacted hand rail.
0.044	Vehicle's left-front door contacted concrete parapet and deformed. Vehicle yawed away from system.
0.056	Top of vehicle’s left-front door deformed such that the top was ajar.
0.070	Vehicle's grille disengaged.
0.082	Vehicle's windshield cracked.
0.094	Simulated occupant's head contacted left-front window and shattered it. Vehicle's right-front tire became airborne.
0.108	Vehicle's right-rear tire became airborne.
0.174	Vehicle's left-rear door contacted concrete parapet and deformed.
0.194	Vehicle pitched downward. Vehicle's left-front wheel disengaged. Vehicle's rear bumper and left taillight contacted concrete parapet. Vehicle's rear bumper deformed.
0.242	Vehicle's tailgate detached.
0.520	Vehicle rolled away from system.
0.782	Vehicle's right-front tire contacted ground.
0.880	Vehicle's right-rear tire contacted ground.
0.902	Vehicle's left-rear wheel rim fractured.
1.034	Vehicle exited system at a speed of 41.3 mph and an angle of 9.1 degrees.

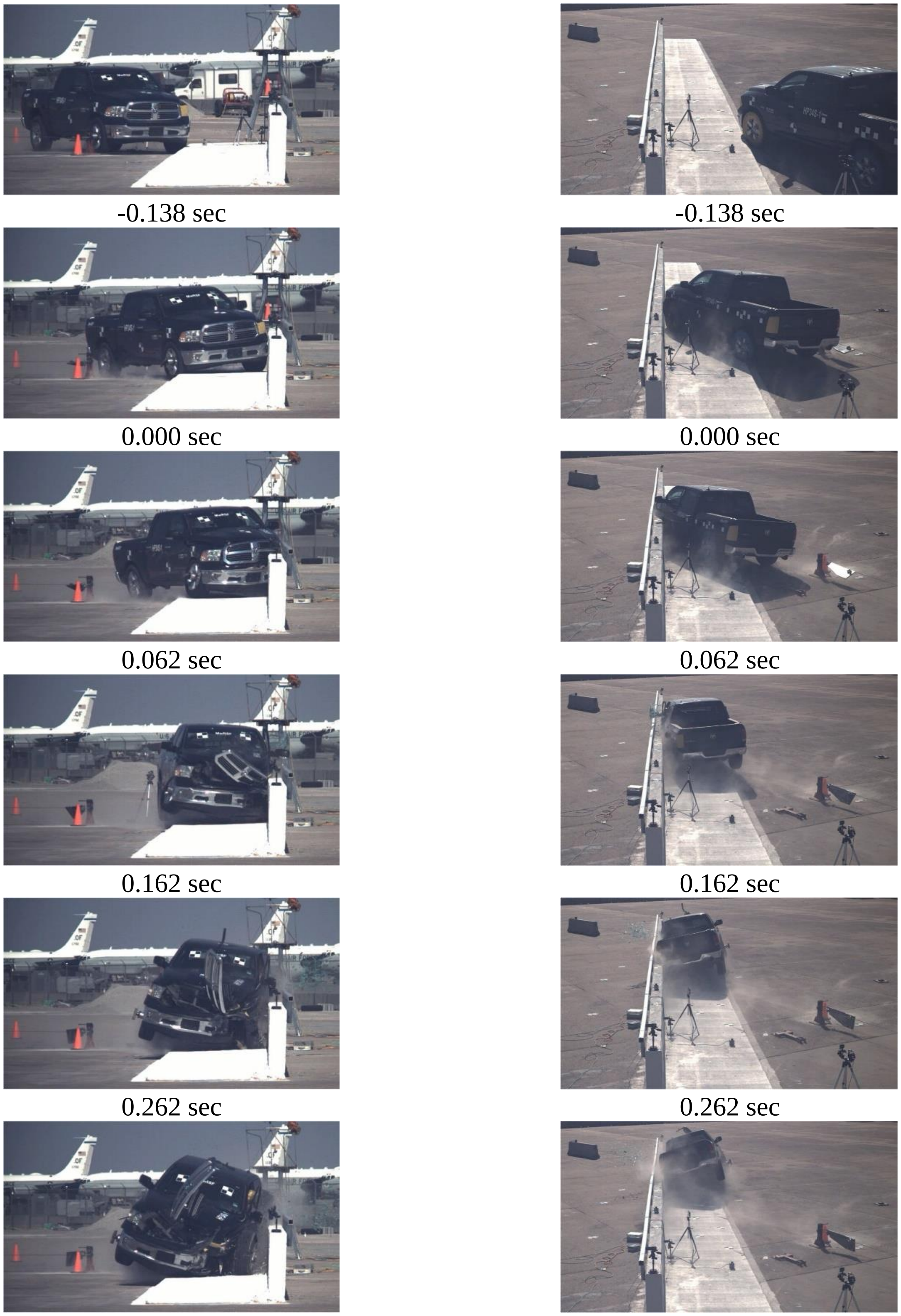


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Figure 36. Sequential Photographs, Test No. HP34S-1

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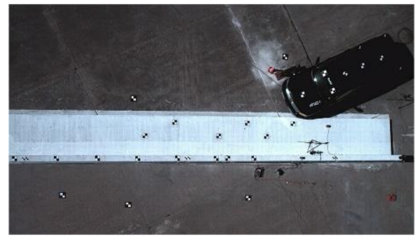

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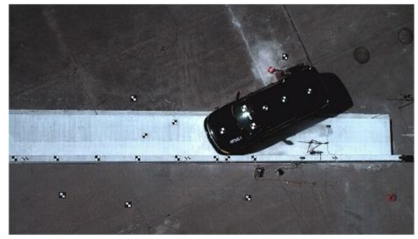

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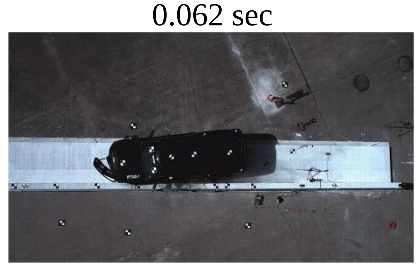

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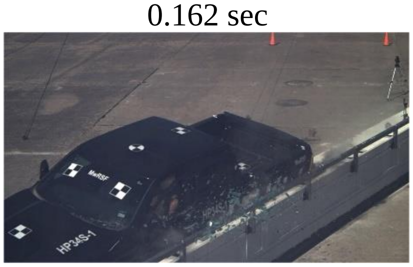

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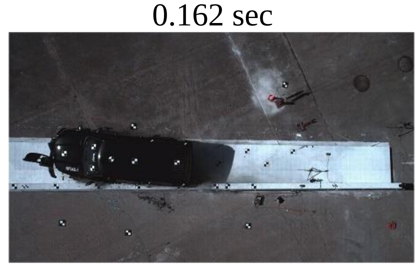

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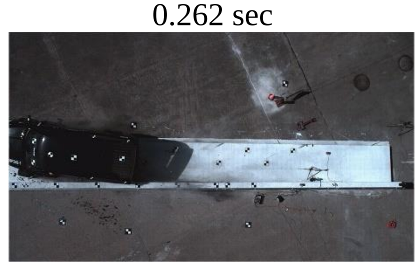
0.362 sec



0.362 sec

Figure 37. Additional Sequential Photographs, Test No. HP34S-1

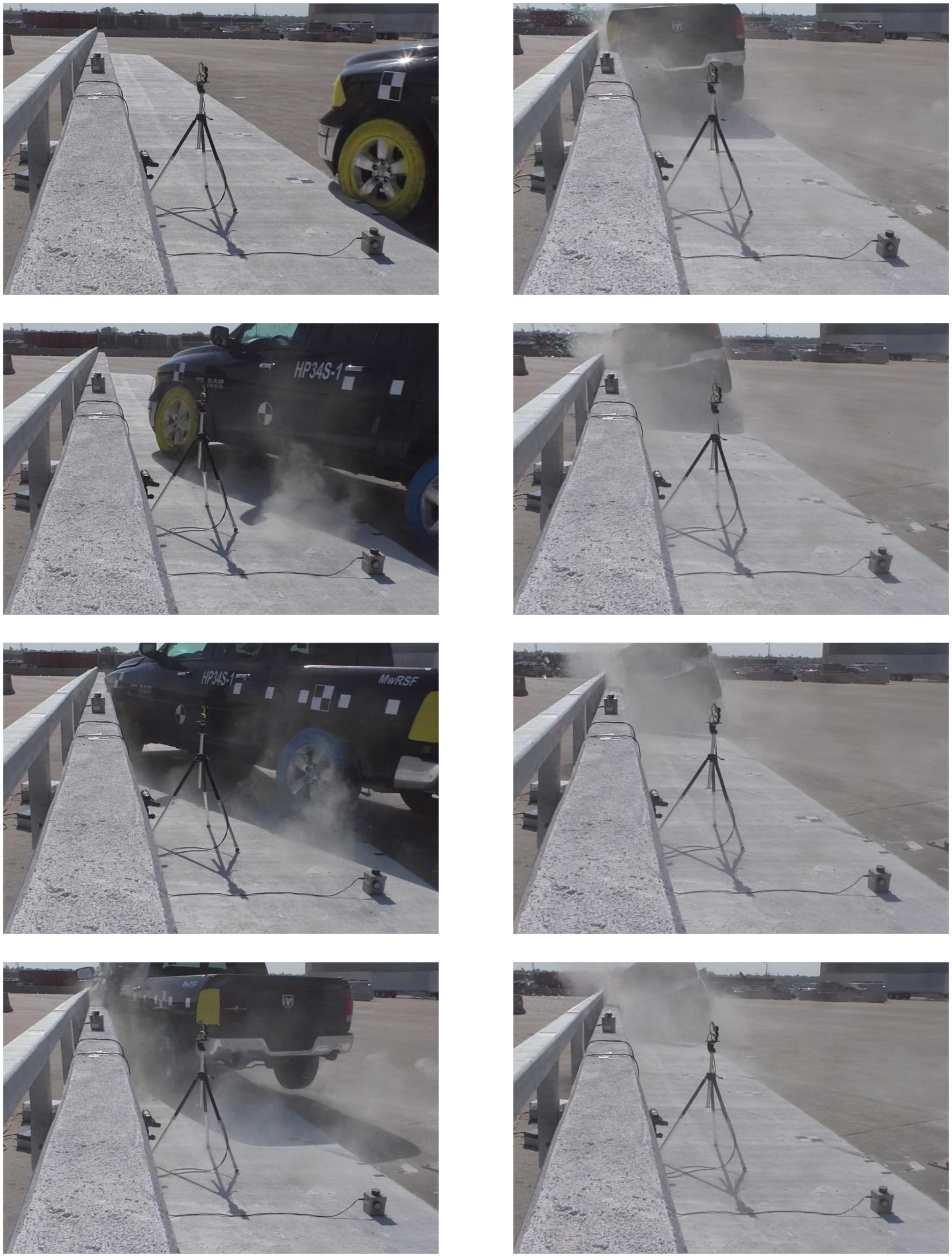


Figure 38. Documentary Photographs, Test No. HP34S-1

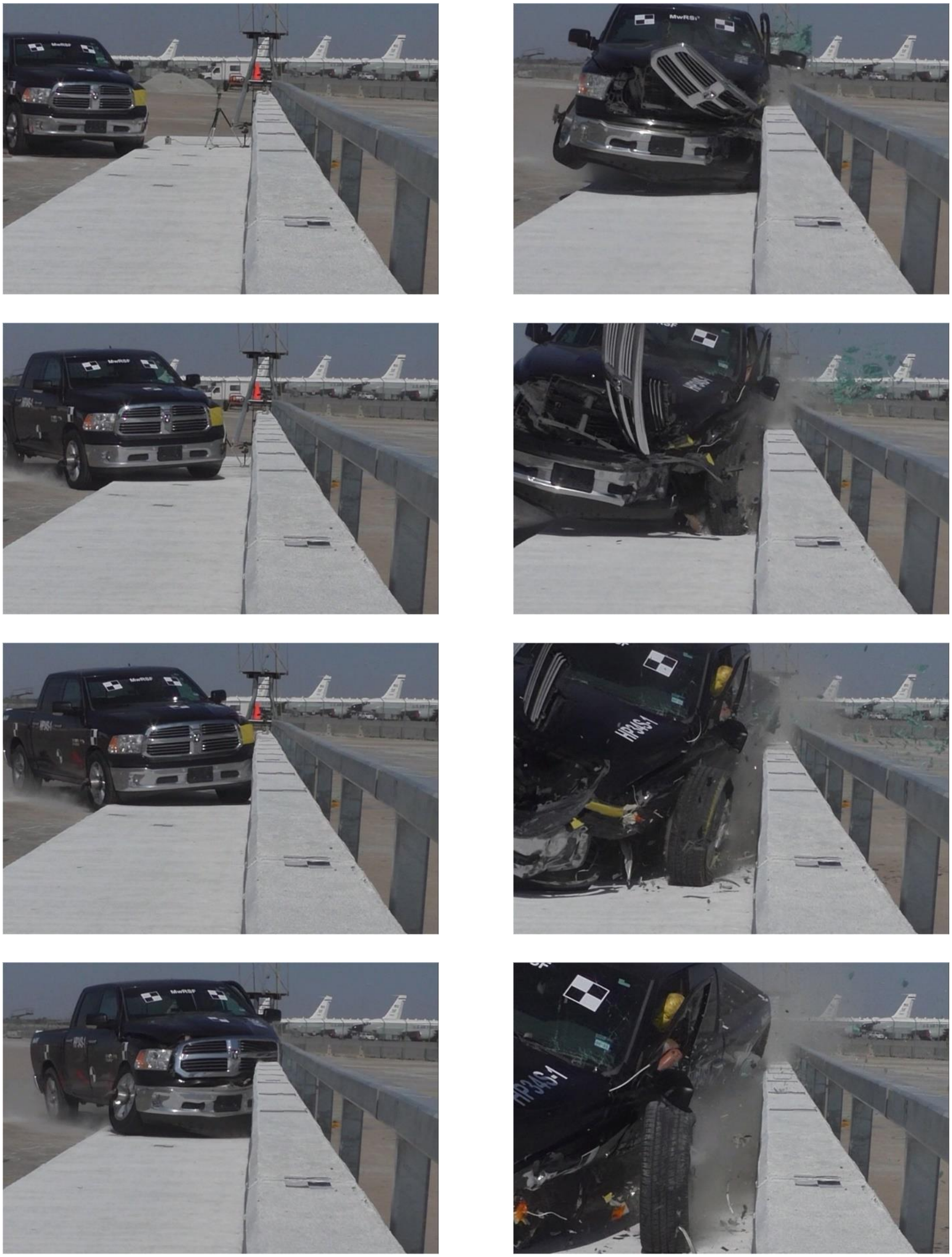


Figure 39. Additional Documentary Photographs, Test No. HP34S-1

Figure 40. Additional Documentary Photographs, Test No. HP34S-1

Figure 41. Additional Documentary Photographs, Test No. HP34S-1

Figure 42. Vehicle Final Position and Trajectory Marks, Test No. HP34S-1

5.3 Barrier Damage

Damage to the barrier was minimal, as shown in Figures 43 through 48. Barrier damage consisted of contact marks on the front face of the concrete segments and minor concrete spalling and cracking. The length of vehicle contact along the barrier was approximately 14 ft – 11 in., which spanned across barrier segment nos. 2 and 3.

There was minor gouging in the concrete near the impact point and along the contact length and gouging at the expansion joint immediately downstream from the impact point. There was a 1¼-in. deep, 20-in. tall gouge that initiated in the recessed window immediately upstream from expansion joint no. 2. There was also a gouge in barrier segment no. 3, initiating at the expansion joint that ended near the slope in the adjacent upstream window. There was a 10½-in. gouge in the sidewalk starting near expansion joint no. 3.

Barrier segment no. 2 had two cracks at expansion joint no. 2. The first crack was at the base that extended 67 in. upstream from the expansion joint, and a second 9½-in. crack originating near the bottom of the chamfer near the top of the barrier. There were two ½-in. cracks at the bottom of base plate no. 7 near the upstream bolt and three cracks ranging from ½ in. to 4 in. at the bottom of base plate no. 8, also near the upstream bolt. There was a 60-in. long contact mark on the pedestrian handrail that initiated 20¼ in. downstream from post no. 6, and the handrail was displaced ½ in. laterally between post nos. 7 and 8.

Figure 43. System Damage, Test No. HP34S-1

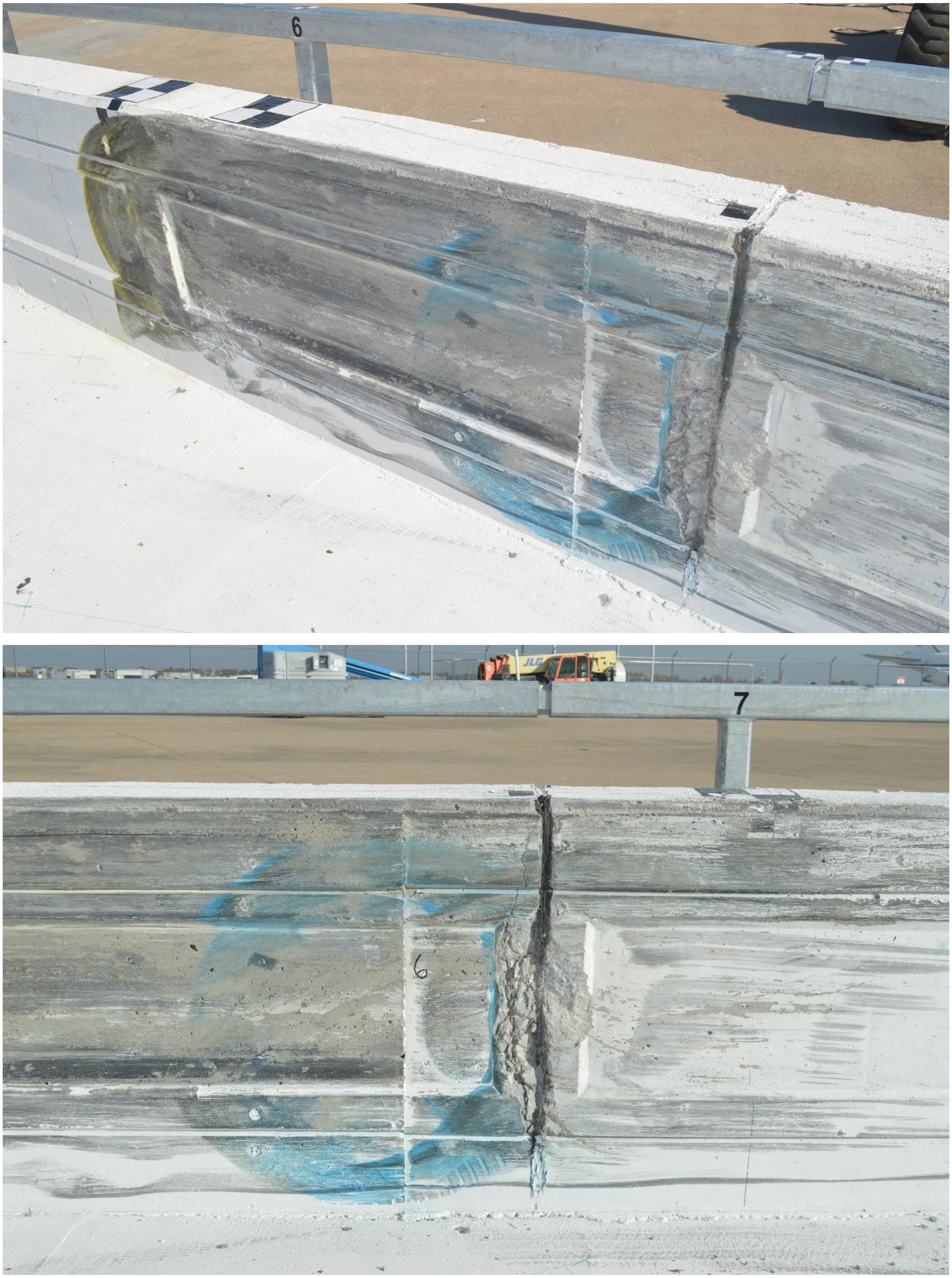


Figure 44. Barrier Damage at Expansion Joint No. 2, Test No. HP34S-1

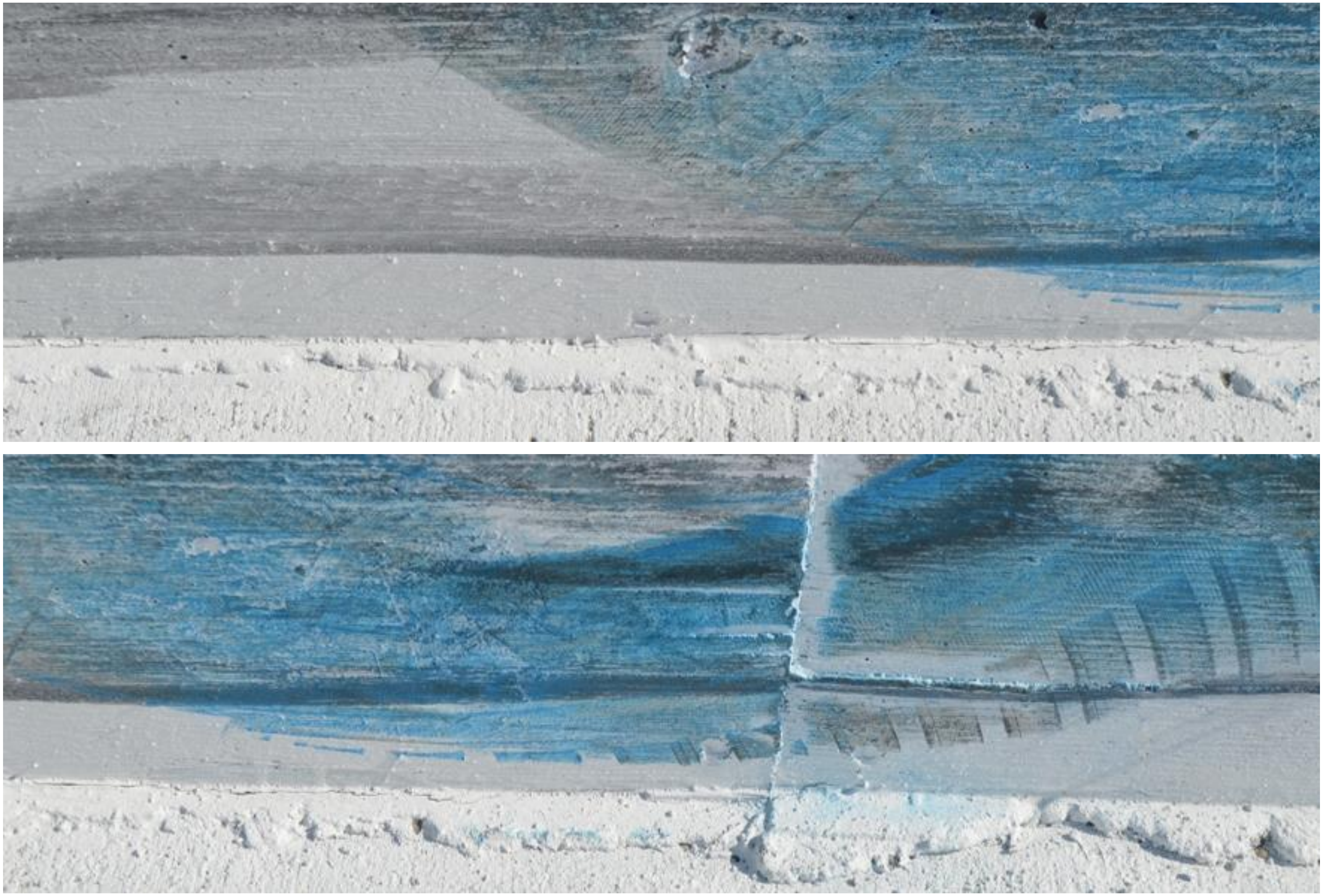


Figure 45. Tire Contact Marks at Expansion Joint No. 2, Test No. HP34S-1

Figure 46. Contact Marks on Pedestrian Handrail and Post No. 7, Test No. HP34S-1

Figure 47. System Damage at Post No. 7, Test No. HP34S-1

Figure 48. System Damage at Post No. 8, Test No. HP34S-1

The maximum lateral permanent set of the barrier system was 0.6 in. at the downstream end of barrier segment no. 2, as measured in the field. The maximum lateral dynamic barrier deflection, including tipping of the barrier along the top surface, was 0.9 in. at the downstream end of barrier segment no. 2, as determined from high-speed digital video analysis. The working width of the system was found to be 14.4 in. measured from the front face of the barrier and 86.4 in. measured from the front face of the sidewalk, respectively, also determined from high-speed digital video analysis. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 49.

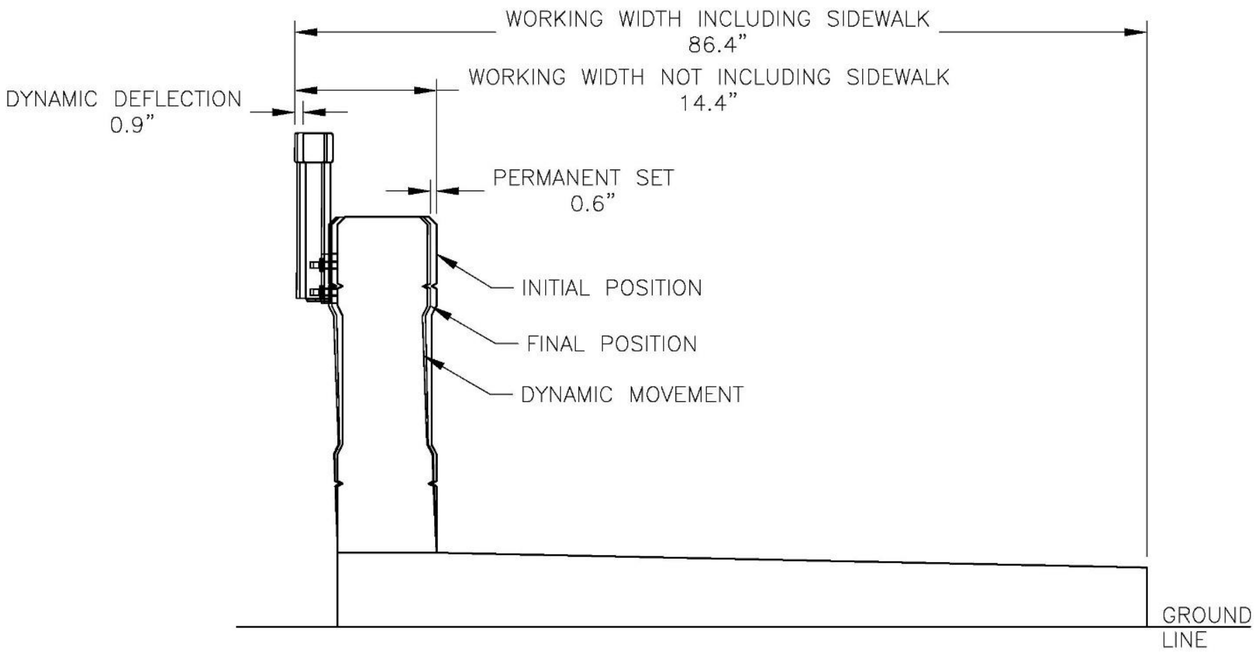


Figure 49. Permanent Set, Dynamic Deflection, and Working Width, Test No. HP34S-1

5.4 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 50 through 53. The maximum occupant compartment intrusions are listed in Table 5, along with the intrusion limits established in MASH 2016 for various areas of the occupant compartment. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix C. MASH 2016 defines intrusion or deformation as the occupant compartment being deformed and reduced in size with no observed penetration. There were no penetrations into the occupant compartment, and none of the established MASH 2016 deformation limits were violated. Outward deformations, which are denoted as negative numbers in Appendix C, are not considered crush toward the occupant and are not evaluated by MASH 2016 criteria.

Majority of the damage was concentrated on the left-front corner and left side of the vehicle where the impact had occurred. The left side of the front bumper was crushed inward and backward. The left-front fender was crushed inward toward the centerline of the vehicle and engine compartment. The left-front wheel was disengaged from the vehicle, the tire was punctured and deflated, and the rim was fractured along three of the five spokes extending from the hub. The left-rear wheel rim was fractured and separated into multiple pieces. The tire remained engaged with the fractured pieces of the rim. The left-front and left-rear fenders, both left-side door panels, and the left-rear bumper were crushed inward and scraped. The grille and left headlight were disengaged from the vehicle. Both left-side doors, the truck bed, and the left side of the rear bumper were crushed inward. The right-front fender was displaced rearward, causing difficulty in opening the right-front door. The bottom of the right-front tire was angled away from the vehicle. The left-front side window shattered, and the windshield was cracked across its entire length. The left-front side window damage was not due to contact with the test article.

The left-front lower control arm was fractured and disengaged from the vehicle. The left-front shock and suspension spring were disengaged from the left-front lower control arm and displaced backwards. The Panhard bar was bent upward, and the left-front control arm was bent but remained engaged with the steering linkage. The anti-roll bar was bent into a “U”-shape and disengaged. The rear bearing joint of the right-front lower control arm was fractured, and the right-front spring and suspension were displaced forward. The lateral engine cradle support beam was bent downward into a “U”-shape. The left-front frame horn was crushed inward. The gas tank was scraped and the oil pan was displaced slightly left and backward.

Figure 50. Vehicle Damage, Test No. HP34S-1

Figure 51. Vehicle Damage, Test No. HP34S-1

Figure 52. Occupant Compartment Damage, Test No. HP34S-1

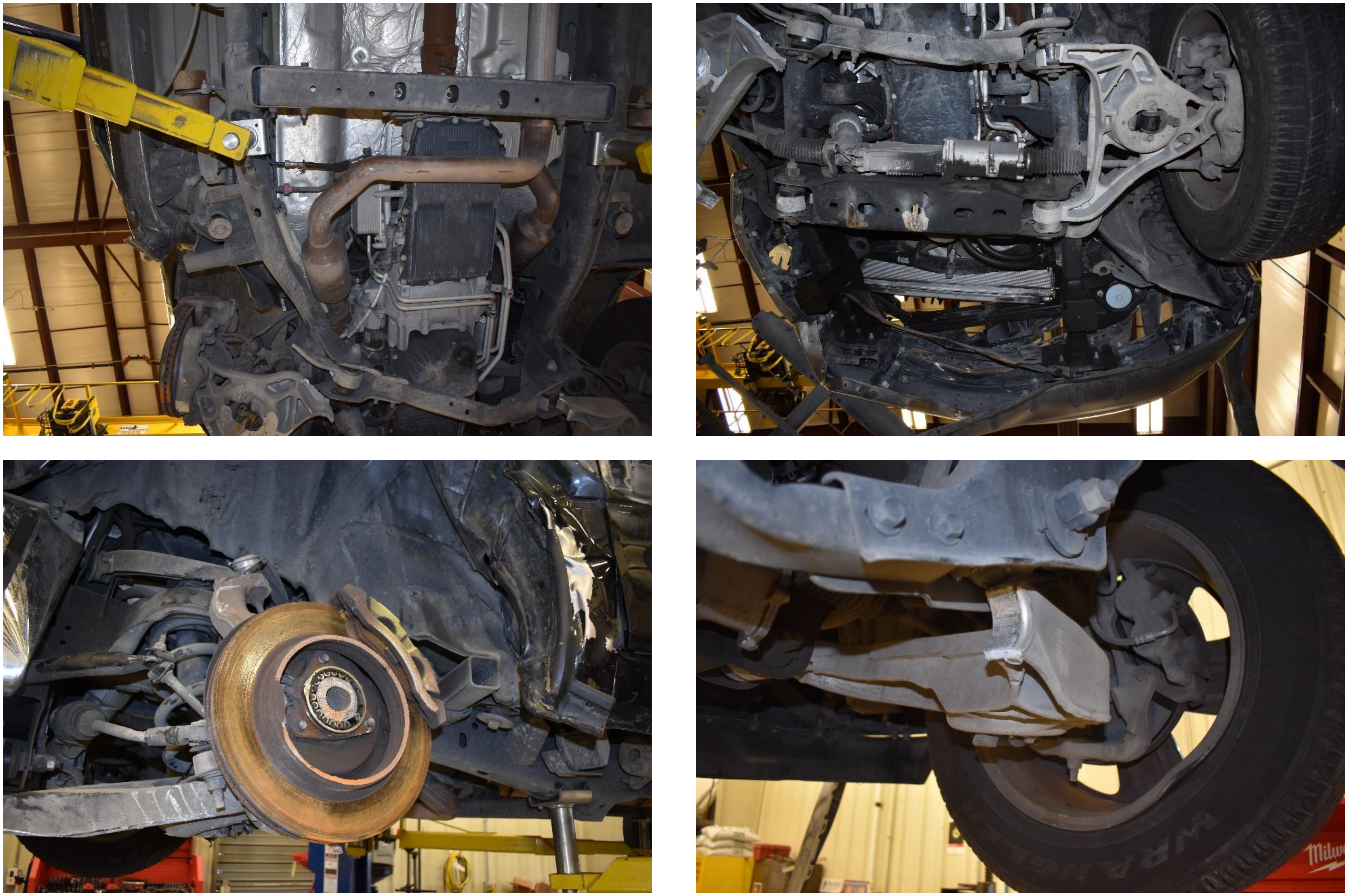


Figure 53. Undercarriage Damage, Test No. HP34S-1

67

Table 5. Maximum Occupant Compartment Intrusion by Location, Test No. HP34S-1

Location	Maximum Intrusion in.	MASH 2016 Allowable Intrusion in.
Wheel Well & Toe Pan	5.2	≤ 9
Floor Pan & Transmission Tunnel	1.7	≤ 12
A-Pillar	0.0	≤ 5
A-Pillar (Lateral)	0.0	≤ 3
B-Pillar	0.2	≤ 5
B-Pillar (Lateral)	0.0	≤ 3
Side Front Panel (in Front of A-Pillar)	2.9	≤ 12
Side Door (Above Seat)	0.0*	≤ 9
Side Door (Below Seat)	0.0*	≤ 12
Roof	0.0*	≤ 4
Windshield	0.0	≤ 3
Side Window	Shattered due to side door crush and contacting surrogate occupant's head	No shattering resulting from contact with structural member of test article
Dash	1.7	N/A

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

5.5 Occupant Risk

MASH evaluation of the vehicle accelerations experienced during an impact event uses the Flail-Space Model to calculate occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs). The time of initial vehicle impact (t=0 sec) is typically easy to determine as it corresponds to vehicle contact with the barrier, crash cushion, or breakaway feature. However, MASH Section 5.3 recognizes that vehicles interacting with roadway geometric features, such as ditches, driveways, embankments, and curbs, typically result in low magnitude accelerations and small vehicular velocity changes. Thus, MASH recommends using the 50-ms average acceleration data to determine if the Flail-Space Model is appropriate in the analysis. MASH Section 5.3 states that if the 50-ms average longitudinal or lateral acceleration data exceed 2 g's, the Flail-Space Model should be used, and the calculation of OIV and ORA values is to begin with contact with the geometric feature. In other words, t=0 sec would correspond with vehicle contact with the geometric feature. If the 2-g limit is not exceeded, then OIV and ORA values should be calculated with t=0 sec beginning when the vehicle contacts the safety feature.

During test no. HP34S-1, the vehicle traversed over a 6-in. tall, elevated sidewalk prior to impacting the concrete bridge rail. Analysis of the acceleration data prior to vehicle impact with the bridge rail revealed maximum longitudinal and lateral 50-ms average accelerations of -0.88 g's and -0.59 g's, respectively. These values did not exceed the MASH recommended 2-g limit, so the OIV and ORA values were computed with t=0 sec corresponding with the vehicle contacting the bridge rail.

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 6. Note that the OIVs and ORAs were within suggested limits, as provided in MASH 2016. The calculated THIV, PHD, and ASI values are also shown in Table 6. The recorded data from the accelerometers and the rate transducers is shown graphically in Appendix D. Note that accelerometer traces are provided in Appendix D for three cases: (1) the primary impact (bridge rail), (2) the curb impact, and (3) the curb impact plus primary impact.

Table 6. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. HP34S-1

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1	SLICE-2 (primary)	
OIV ft/s	Longitudinal	-21.14	-21.03	±40
	Lateral	25.75	28.21	±40
ORA g's	Longitudinal	-4.97	6.55	±20.49
	Lateral	10.57	9.58	±20.49
Maximum Angular Displacement degrees	Roll	-27.19	-23.68	±75
	Pitch	-3.92	-5.79	±75
	Yaw	45.27	45.08	not required
THIV – ft/s		32.23	34.11	not required
PHD – g's		11.09	10.49	not required
ASI		1.67	1.81	not required

The ORA and OIV values would have been different if the Flail-Space Model analysis had been initiated at the time of vehicle contact with the curb/elevated sidewalk. For transparency and to be complete in reporting of data analysis, these alternative ORA and OIV values are shown in Table 7. Note, these values are not compared against the MASH limits as they do not follow the MASH procedure for determining the beginning of the impact event, t=0 sec.

Table 7. OIV and ORA Values if t=0 sec Occurred at Curb Impact, Test No. HP34S-1

Evaluation Criteria		Transducer	
		SLICE-1	SLICE-2 (primary)
OIV ft/s	Longitudinal	-22.04	-21.78
	Lateral	25.44	27.87
ORA g's	Longitudinal	-4.97	6.55
	Lateral	10.57	9.58

5.6 Barrier Loads

The longitudinal and lateral vehicle accelerations, as measured at the vehicle's c.g., were also processed using a SAE CFC-60 filter and a 50-msec moving average. The 50-msec moving average vehicle accelerations were then combined with the uncoupled yaw angle versus time data in order to estimate the vehicular loading applied to the barrier system. From the data analysis, the perpendicular impact forces were determined for the bridge rail, as shown in Figure 54. The maximum perpendicular (i.e., lateral) load imparted to the barrier was 84.5 kips determined by the SLICE-2 (primary) unit.

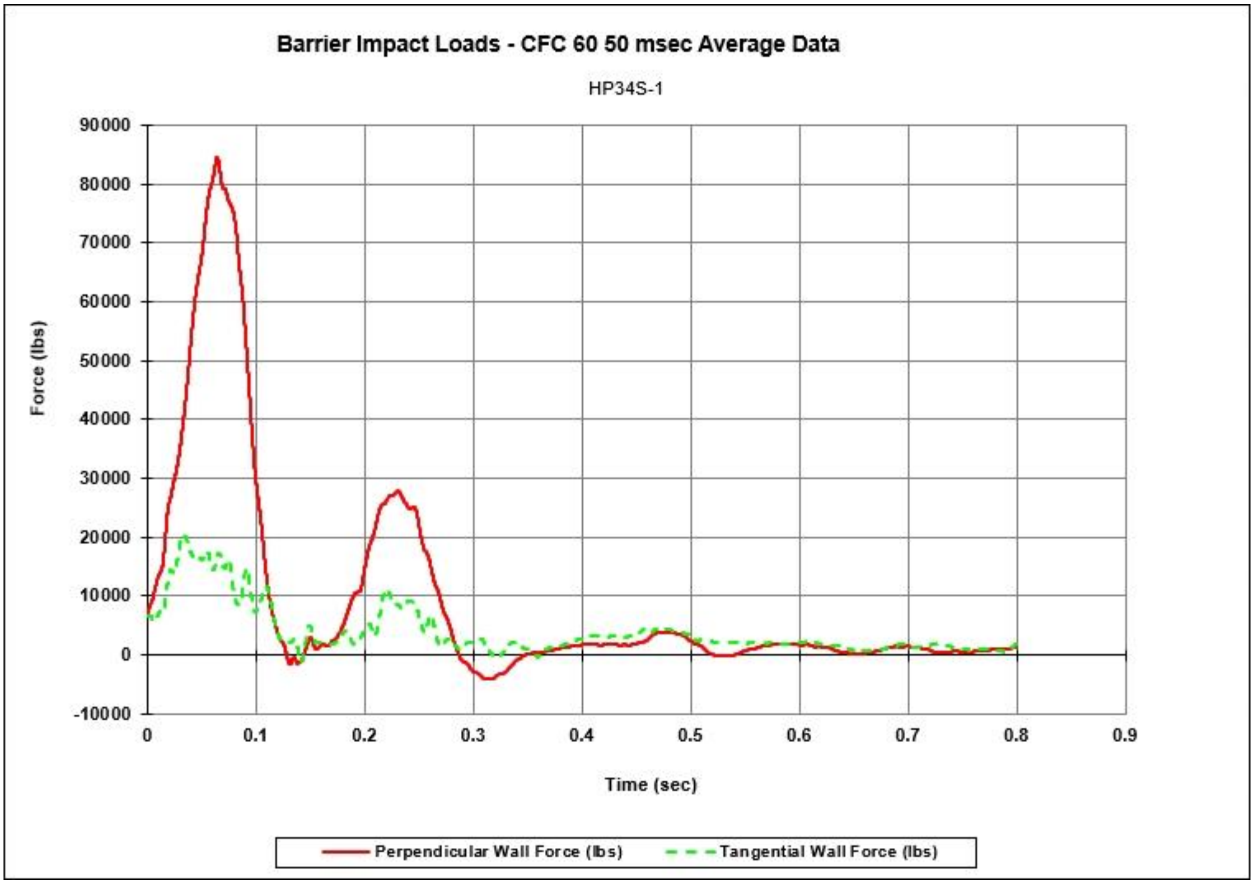


Figure 54. Perpendicular and Tangential Forces Imparted to the Barrier System (SLICE-2), Test No. HP34S-1

5.7 Discussion

The analysis of the test results for test no. HP34S-1 showed that the system adequately contained and redirected the 2270P vehicle with controlled lateral displacements of the barrier. A summary of the test results and sequential photographs are shown in Figure 55.

Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or work-zone personnel. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did not occur. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix D, 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 9.1 degrees, and its trajectory did not violate the bounds of the exit box. Therefore, test no. HP34S-1 was determined to be acceptable according to the MASH 2016 safety performance criteria for test designation no. 3-11.

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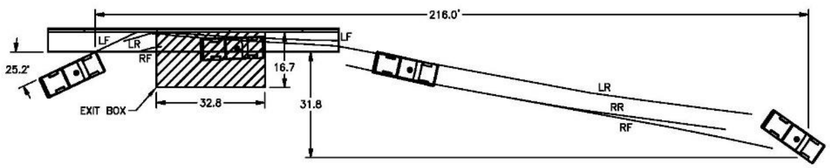

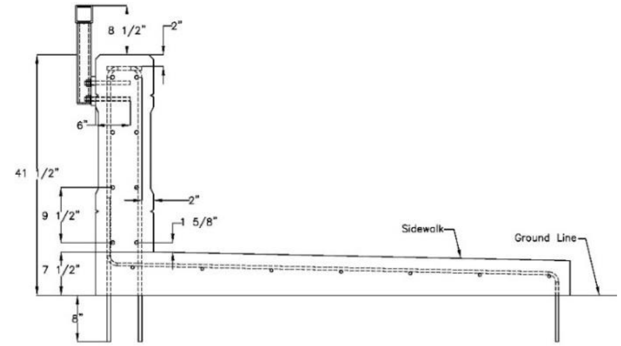

- Test Agency .... MwRSF
- Test Number HP34S-1
- Date 10/12/2021
- MASH 2016 Test Designation No. 3-11
- Test Article .... HDOT 34 in. Tall Aesthetic Bridge Rail with Pedestrian Handrail and Sidewalk
- Total Length .... 88 ft
- Key Component – Concrete Parapet
  - Length .... 21 ft – 11½ in.
  - Height .... 34 in.
  - Depth .... 10 in.
- Key Component – Sidewalk
  - Length .... 88 ft
  - Width .... 6 ft
  - Depth .... 6 ft – 7½ in.
- Vehicle Make /Model .... 2016 Dodge Ram 1500
  - Curb .... 5,323 lb
  - Test Inertial .... 5,045 lb (MASH 2016 Limit 5,000 ± 110 lb)
  - Gross Static .... 5,208 lb
- Impact Conditions - Sidewalk
  - Speed .... 65.7 mph (MASH 2016 Limit 62 ± 2.5 mph)
  - Angle .... 25.2 degrees (MASH 2016 Limit 25 ± 1.5 degrees)
- Impact Conditions - Barrier
  - Speed .... 63.6 mph
  - Angle .... 23.7 degrees
  - Impact Location .... 85.07 in. upstream from post no. 7
- Impact Severity – Sidewalk .... 134.0 kip-ft > 105.6 kip-ft MASH 2016 limit
- Impact Severity – Barrier .... 110.2 kip-ft
- Exit Conditions
  - Speed .... 41.3 mph
  - Angle .... 9.1 degrees
- Exit Box Criterion .... Pass
- Vehicle Stability .... Pass
- Vehicle Stopping Distance .... 216.0 ft downstream 31.8 ft laterally in front
- Vehicle Damage .... Extensive
  - VDS [15] 11-LFQ-5
  - CDC [16] 11LFEW2
  - Maximum Interior Deformation .... 5.2 in.
- Test Article Damage .... Minimal
- Maximum Test Article Deflections
  - Permanent Set .... 0.6 in.
  - Dynamic .... 0.9 in.
  - Working Width (without Sidewalk) .... 14.4 in.
  - Working Width (with Sidewalk) .... 86.4 in.
- Transducer Data

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1	SLICE-2 (primary)	
OIV ft/s	Longitudinal	-21.14	-21.03	±40
	Lateral	25.75	28.21	±40
ORA g's	Longitudinal	-4.97	6.55	±20.49
	Lateral	10.57	9.58	±20.49
Maximum Angular Displacement degrees	Roll	-27.19	-23.68	±75
	Pitch	-3.92	-5.79	±75
	Yaw	45.27	45.08	not required
THIV – ft/s		32.23	34.11	not required
PHD – g's		11.09	10.49	not required
ASI		1.67	1.81	not required

Figure 55. Summary of Test Results and Sequential Photographs, Test No. HP34S-1

6 FULL-SCALE CRASH TEST NO. HP34S-2

6.1 Weather Conditions

Test no. HP34S-2 was conducted on November 3, 2021 at approximately 3:00 p.m. The weather conditions as reported by the National Oceanic and Atmospheric Administration (station 14939/LNK) are shown in Table 8.

Table 8. Weather Conditions, Test No. HP34S-2

Temperature	49°F
Humidity	59%
Wind Speed	15 mph
Wind Direction	210° from True North
Sky Conditions	Overcast
Visibility	10.0 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.07 in.
Previous 7-Day Precipitation	1.7 in.

6.2 Test Description

Initial vehicle impact was to occur 43 in. upstream from the upstream face of post no. 11, as shown in Figure 56, which was selected using video analysis from previous tests with sidewalks to maximize the probability of wheel snag and vehicle interaction with the pedestrian handrail. The 2,413-lb small car impacted the sidewalk at a speed of 62.0 mph and at an angle of 25.0 degrees and impacted the barrier at a speed of 60.2 mph and an angle of 22.8 degrees. The actual point of impact was 2.43 in. downstream from the targeted impact point. After brakes were applied, the vehicle came to rest 183.8 ft downstream from impact and 11.0 ft laterally from the front of the sidewalk, as measured to the center of the right-front wheel.

As discussed in Section 5.2, the current system included a geometric feature in the form of a sidewalk. The 1100C small car interaction with the curb did not exceed 2 g’s during any 50-ms period. Therefore, event start time, t=0 sec, occurred at the time of impact with the bridge rail. A detailed description of the sequential impact events is contained in Table 9. Sequential photographs are shown in Figures 57 and 58. Documentary photographs of the crash test are shown in Figures 59 through 63. The vehicle trajectory and final position are shown in Figure 64.

Figure 56. Impact Location, Test No. HP34S-2

Table 9. Sequential Description of Impact Events, Test No. HP34S-2

Time (sec)	Event
-0.158	Vehicle's front bumper and left-front tire contacted curb.
-0.138	Vehicle's left-front tire deflated. Vehicle rolled away from system.
-0.062	Vehicle's left-rear tire contacted curb and deflated.
-0.036	Vehicle's right-front tire contacted curb.
-0.026	Vehicle's right-front tire deflated.
0.000	Vehicle's front bumper contacted the concrete barrier and the left side of front bumper cover was disconnected from the frame. Impact occurred 1.7 in. downstream from targeted impact point
0.010	Vehicle's left headlight contacted concrete barrier. Vehicle's left fender contacted concrete barrier and deformed. Vehicle's right fender deformed.
0.020	Vehicle's right headlight detached. Vehicle's hood contacted barrier and was crushed. Vehicle yawed away from system.
0.030	Vehicle's left headlight shattered. Top of vehicle’s left-front door deformed such that the top was ajar. Vehicle's left-rear door and roof deformed.
0.048	Vehicle's left-front door contacted concrete barrier. Vehicle rolled toward system.
0.058	Vehicle's left A-pillar deformed. Vehicle's windshield cracked. Vehicle's right-rear tire airborne.
0.082	Simulated occupant's head contacted left-front window and shattered it.
0.098	Vehicle's right-rear tire contacted curb.
0.136	Vehicle's right-rear tire airborne.
0.158	Vehicle's left-rear door contacted concrete barrier.
0.168	Vehicle's left quarter panel and rear bumper contacted concrete barrier and deformed.
0.182	Vehicle's left taillight contacted concrete barrier and cracked.
0.234	Vehicle's right-front tire became airborne.
0.358	Vehicle rolled away from system.
0.500	Vehicle's left-front tire became airborne. Vehicle's right-front tire contacted ground.
0.598	Vehicle's left-front tire contacted ground.
0.616	Vehicle's left-rear tire became airborne. Vehicle exited system at a speed of 43.7 mph and angle of 2.5 degrees.
0.646	Vehicle rolled toward system. Vehicle's right-rear tire contacted ground.
0.668	Vehicle's left-rear tire contacted ground.
4.317	Vehicle came to rest.

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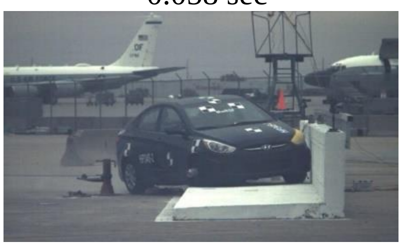
-0.158 sec

-0.058 sec

-0.058 sec



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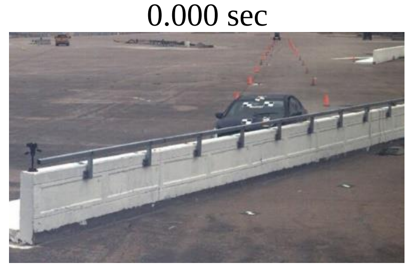

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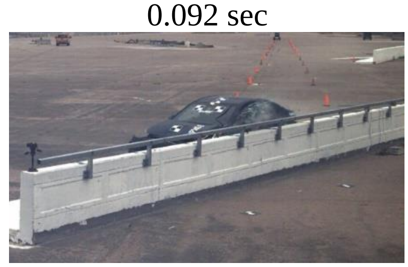

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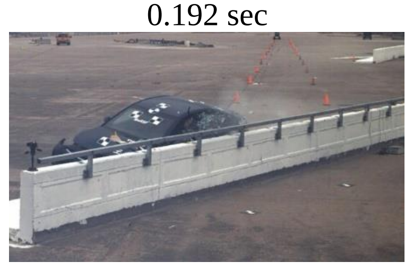

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Figure 57. Sequential Photographs, Test No. HP34S-2

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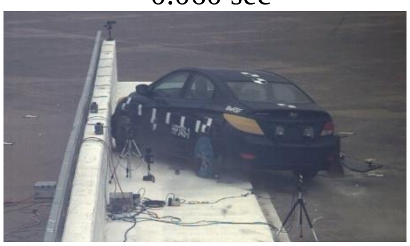

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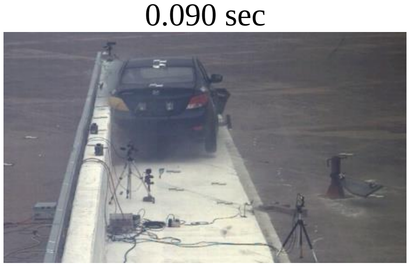

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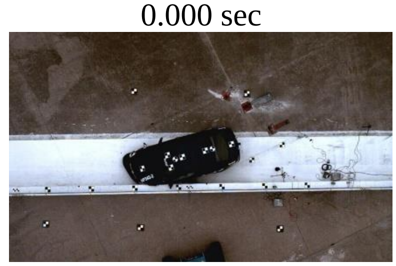

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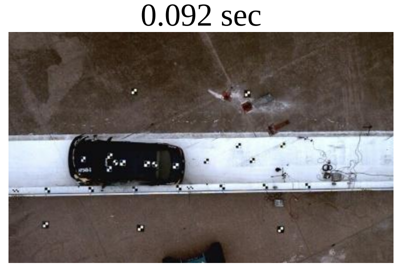

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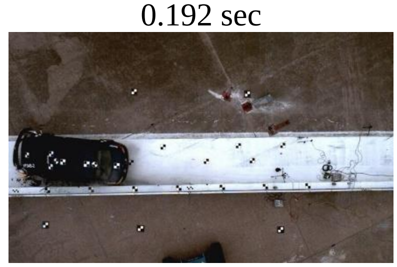


0.292 sec

Figure 58. Sequential Photographs, Test No. HP34S-2

Figure 59. Documentary Photographs, Test No. HP34S-2

Figure 60. Documentary Photographs, Test No. HP34S-2

Figure 61. Documentary Photographs, Test No. HP34S-2

Figure 62. Documentary Photographs, Test No. HP34S-2

Figure 63. Documentary Photographs, Test No. HP34S-2

Figure 64. Vehicle Final Position and Trajectory Marks, Test No. HP34S-2

6.3 Barrier Damage

Damage to the barrier was minimal, as shown in Figures 65 and 66. Barrier damage consisted of contact marks on the front face of the concrete segments and concrete gouging. The length of vehicle contact along the barrier was approximately 9 ft – 11 in. which spanned across barrier segment nos. 3 and 4.

There was minor gouging in the concrete near the impact point and along the contact length and larger gouging at the expansion joint immediately downstream from the impact point. There was a ½-in. deep, 15-in. tall gouge that initiated on the slope in the recessed window immediately upstream from expansion joint no. 3 where steel rebar was exposed. There was also a gouge in barrier segment no. 4, initiating at the expansion joint that ended near the slope in the adjacent downstream window. Concrete scraping and minor chipping were observed along the upstream, lower, upper, and downstream edges of the upstream aesthetic recess of barrier segment no. 3, as well as along the top, impact-side edge of the concrete barrier. No contact marks were observed on the pedestrian rail.

Figure 65. System Damage, Test No. HP34S-2

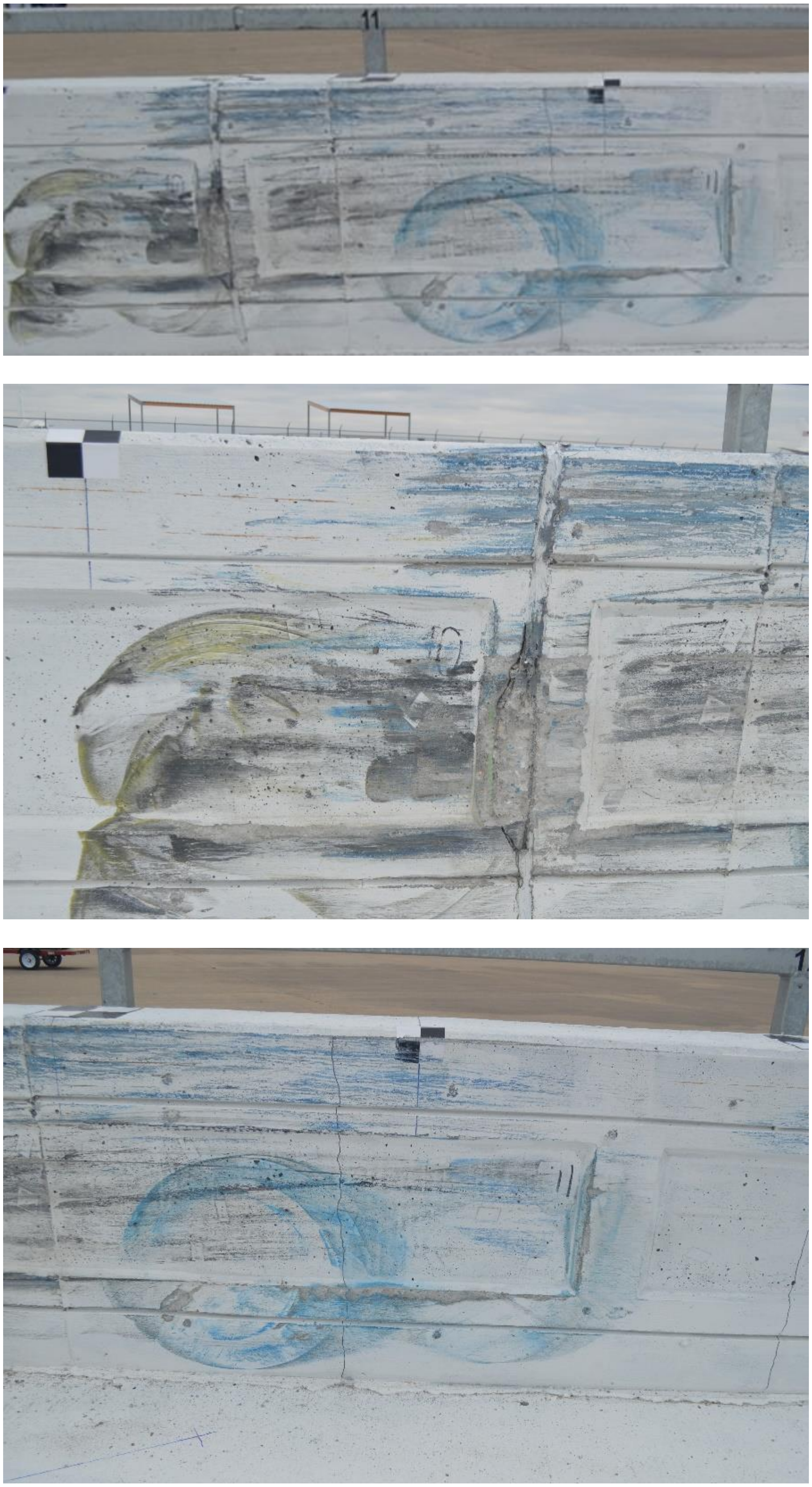


Figure 66. Barrier Damage at Expansion Joint No. 3, Test No. HP34S-2

The maximum lateral permanent set of the barrier system was 0.6 in. at the downstream end of barrier segment no. 3, as measured in the field. The maximum lateral dynamic barrier deflection measurement, including tipping of the barrier along the top surface, was 0.6 in as determined from high-speed digital video analysis. The working width of the system was found to be 14.1 in. measured from the front face of the barrier and 86.1 in. measured from the front face of the sidewalk, respectively, also determined from high-speed digital video analysis. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 67.

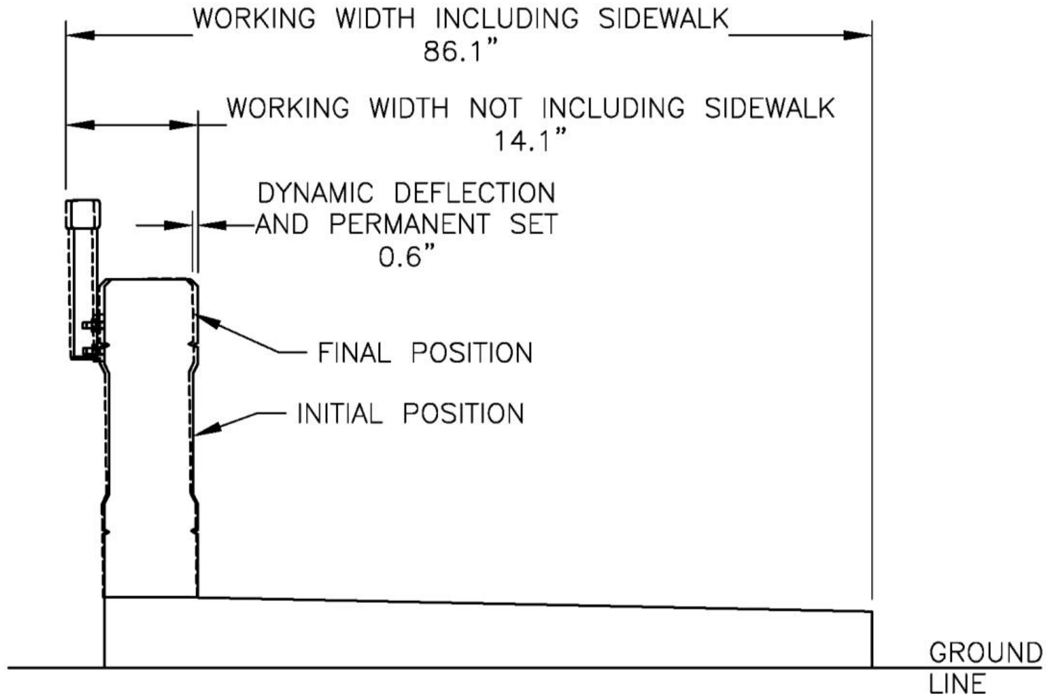


Figure 67. Permanent Set, Dynamic Deflection, and Working Width, Test No. HP34S-2

6.4 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 68 through 73. The maximum occupant compartment intrusions are listed in Table 10, along with the intrusion limits established in MASH 2016 for various areas of the occupant compartment. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix C. MASH 2016 defines intrusion or deformation as the occupant compartment being deformed and reduced in size with no observed penetration. There were no penetrations into the occupant compartment, and none of the established MASH 2016 deformation limits were violated. Outward deformations, which are denoted as negative numbers in Appendix C, are not considered crush toward the occupant and are not evaluated by MASH 2016 criteria.

The majority of the damage was concentrated on the left-front corner and left side of the vehicle, where the impact had occurred. The left side of the bumper was crushed inward toward the center of the vehicle, and the bumper was disconnected from the frame. The front frame crossmember fractured, which allowed the radiator to hang downward, and both headlights were disengaged. The left side of the hood was crushed inwards with most crush occurring near the left fender. The entire left fender and the front of the left-front door were crushed inward. There were multiple dents on the left quarter panel above the wheel well, and the area above the rear bumper connection was crushed inward. Both left-side wheel rims were deformed. The trunk hatch was bent to the left during impact causing the trunk to become wedged shut. The right-side fender was bent outward during impact. The left-front side window shattered, and the windshield was cracked across its entire length. The left-front side window damage was not due to contact with the test article.

The left-front frame horn was bent laterally and upward. The left-front shock was bent backward but remained engaged with the suspension. The anti-roll bar was bent upwards at the left side of the vehicle. The left-side steering connection to the wheel hub was rotated, and the entire steering linkage was warped. The left-front upper control arm was sheared at the connection to the wheel hub, and the lower control arm was bent with scrapes observed along the bottom surface. The left-side tie rod was partially disengaged at both ends. Much of the undercarriage was scraped, including the transmission tunnel, oil pan, floorpan, and gas tank.

Figure 68. Vehicle Damage, Test No. HP34S-2

Figure 69. Vehicle Damage, Test No. HP34S-2

Figure 70. Vehicle Damage, Test No. HP34-2

Figure 71. Vehicle Damage, Test No. HP34-2

Figure 72. Occupant Compartment Damage, Test No. HP34S-2

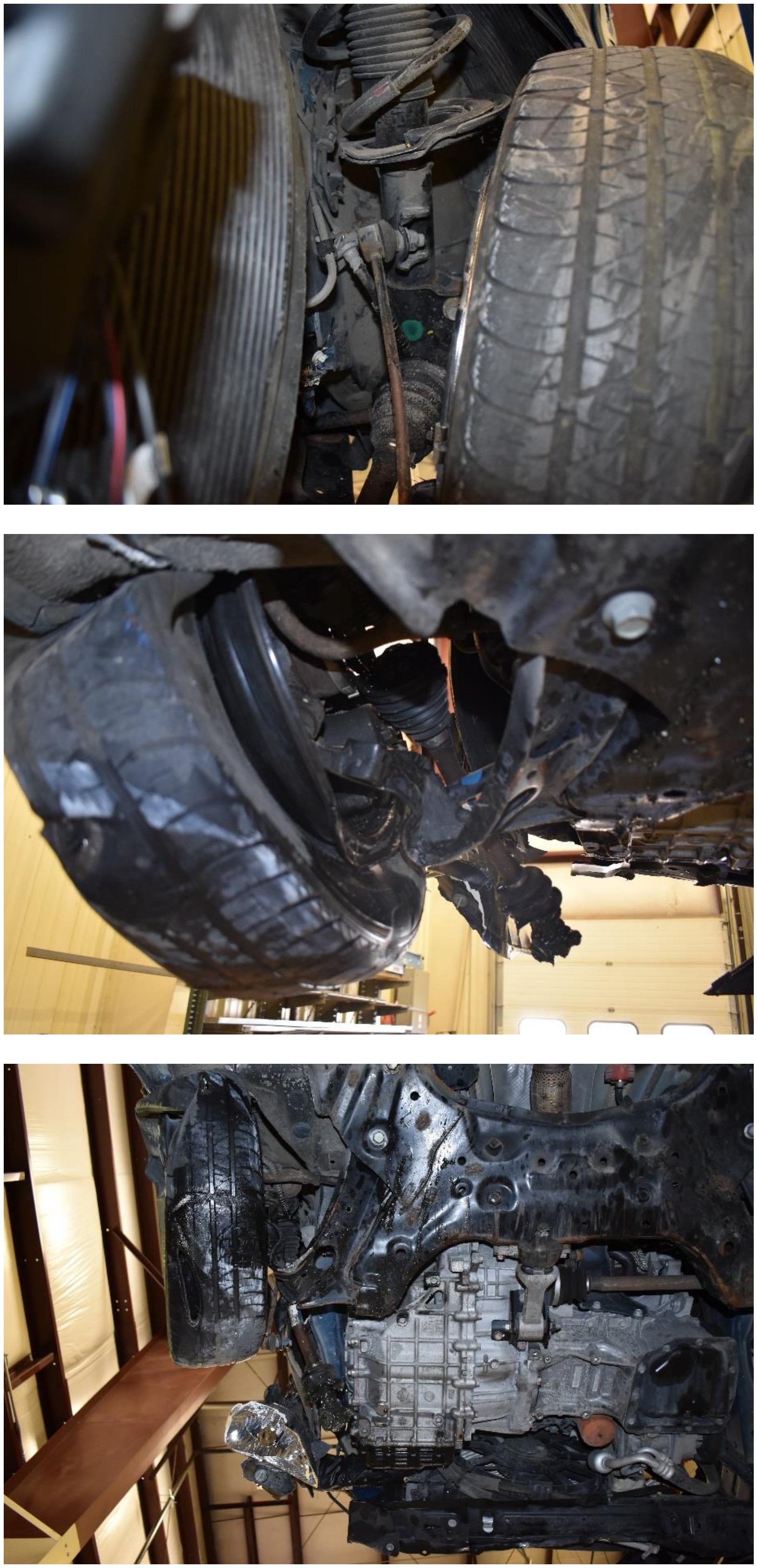


Figure 73. Undercarriage Damage, Test No. HP34S-2

Table 10. Maximum Occupant Compartment Intrusion by Location, Test No. HP34S-2

Location	Maximum Intrusion in.	MASH 2016 Allowable Intrusion in.
Wheel Well & Toe Pan	1.3	≤ 9
Floor Pan & Transmission Tunnel	0.3	≤ 12
A-Pillar	0.1	≤ 5
A-Pillar (Lateral)	0.1	≤ 3
B-Pillar	0.2	≤ 5
B-Pillar (Lateral)	0.1	≤ 3
Side Front Panel (in Front of A-Pillar)	1.2	≤ 12
Side Door (Above Seat)	0.0*	≤ 9
Side Door (Below Seat)	0.2	≤ 12
Roof	0.0*	≤ 4
Windshield	0.0	≤ 3
Side Window	Shattered due to side door crush	No shattering resulting from contact with structural member of test article
Dash	0.6	N/A

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

6.5 Occupant Risk

MASH evaluation of the vehicle accelerations experienced during an impact event uses the Flail-Space Model to calculate occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs). The time of initial vehicle impact (t=0.0 sec) is typically easy to determine as it corresponds to vehicle contact with the barrier, crash cushion, or breakaway feature. However, MASH Section 5.3 recognizes that vehicles interacting with roadway geometric features, such as ditches, driveways, embankments, and curbs, typically result in low magnitude accelerations and small vehicular velocity changes. Thus, MASH recommends using the 50-ms average acceleration data to determine if the Flail-Space Model is appropriate in the analysis. MASH Section 5.3 states that if the 50-ms average longitudinal or lateral acceleration data exceed 2 g's, the Flail-Space Model should be used, and the calculation of OIV and ORA values is to begin with contact with the geometric feature. In other words, t=0 sec would correspond with vehicle contact with the curb. If the 2-g limit is not exceeded, then OIV and ORA values should be calculated with t=0 sec beginning with vehicle contact with the bridge railing.

During test no. HP34S-2, the vehicle traversed over a 6-in. tall, elevated sidewalk prior to impacting the concrete bridge rail. Analysis of the acceleration data prior to vehicle impact with the bridge rail show maximum longitudinal and lateral 50-ms average accelerations of -1.46 g's and 1.64 g's, respectively. These values did not exceed the MASH recommended 2-g limit, so the

OIV and ORA values were computed with t=0 sec corresponding with the vehicle contacting the bridge railing.

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 11. Note that the OIVs and ORAs were within suggested limits, as provided in MASH 2016. Although the SLICE-2 unit provided a lateral ORA that exceeded MASH 2016 limits, the SLICE-1 unit was the primary transducer and located closer to the vehicle c.g.; therefore, the lateral ORA was deemed acceptable. The calculated THIV, PHD, and ASI values are also shown in Table 11. The recorded data from the accelerometers and the rate transducers is shown graphically in Appendix E.

Table 11. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. HP34S-2

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1 (primary)	SLICE-2	
OIV ft/s	Longitudinal	-20.26	-19.72	±40
	Lateral	28.35	25.53	±40
ORA g's	Longitudinal	-5.05	-5.35	±20.49
	Lateral	16.67	22.64*	±20.49
Maximum Angular Displacement degrees	Roll	-18.90	-15.84	±75
	Pitch	3.84	-3.21	±75
	Yaw	42.18	41.67	not required
THIV – ft/s		23.52	6.67	not required
PHD – g's		33.15	34.84	not required
ASI		2.14	2.08	not required

*Results were not from the primary data acquisition unit located at c.g.

The ORA and OIV values would have been different if the Flail-Space Model analysis had been initiated at the time of vehicle contact with the curb/elevated sidewalk. For transparency and to be complete in reporting of data analysis, these alternative ORA and OIV values are shown in Table 12. Note, these values are not compared against the MASH limits as they do not follow the MASH procedure for determining the beginning of the impact event, t=0 sec.

Table 12. OIV and ORA Values if t=0 occurred at Curb Impact, Test No. HP34S-2

Evaluation Criteria		Transducer	
		SLICE-1 (primary)	SLICE-2
OIV ft/s	Longitudinal	-21.64	-21.63
	Lateral	27.73	24.66
ORA g's	Longitudinal	-5.05	-5.35
	Lateral	16.67	22.64*

*Results were not from the primary data acquisition unit located at c.g.

During test no. HP34S-2, processed accelerations from the secondary accelerometer system, SLICE-2, exceeded the MASH evaluation limits of 20 g's for ORA. The SLICE-1 system was designated as the primary accelerometer based on the installation position of the accelerometer to the vehicle's measured c.g., and the secondary accelerometer system, SLICE-2, was located farther from the c.g. location, Consistent with guidelines from the roadside safety community, only the primary accelerometer data were considered for the evaluation of crashworthiness of the HDOT 34-in. Tall, Aesthetic Bridge Rail with Pedestrian Handrail and Sidewalk.

6.6 Barrier Loads

The longitudinal and lateral vehicle accelerations, as measured at the vehicle's c.g., were also processed using a SAE CFC-60 filter and a 50-msec moving average. The 50-msec moving average vehicle accelerations were then combined with the uncoupled yaw angle versus time data in order to estimate the vehicular loading applied to the barrier system. From the data analysis, the perpendicular impact forces were determined for the bridge rail, as shown in Figure 74. The maximum perpendicular (i.e., lateral) load imparted to the barrier was 48.4 kips determined by the SLICE-1 (primary) unit.

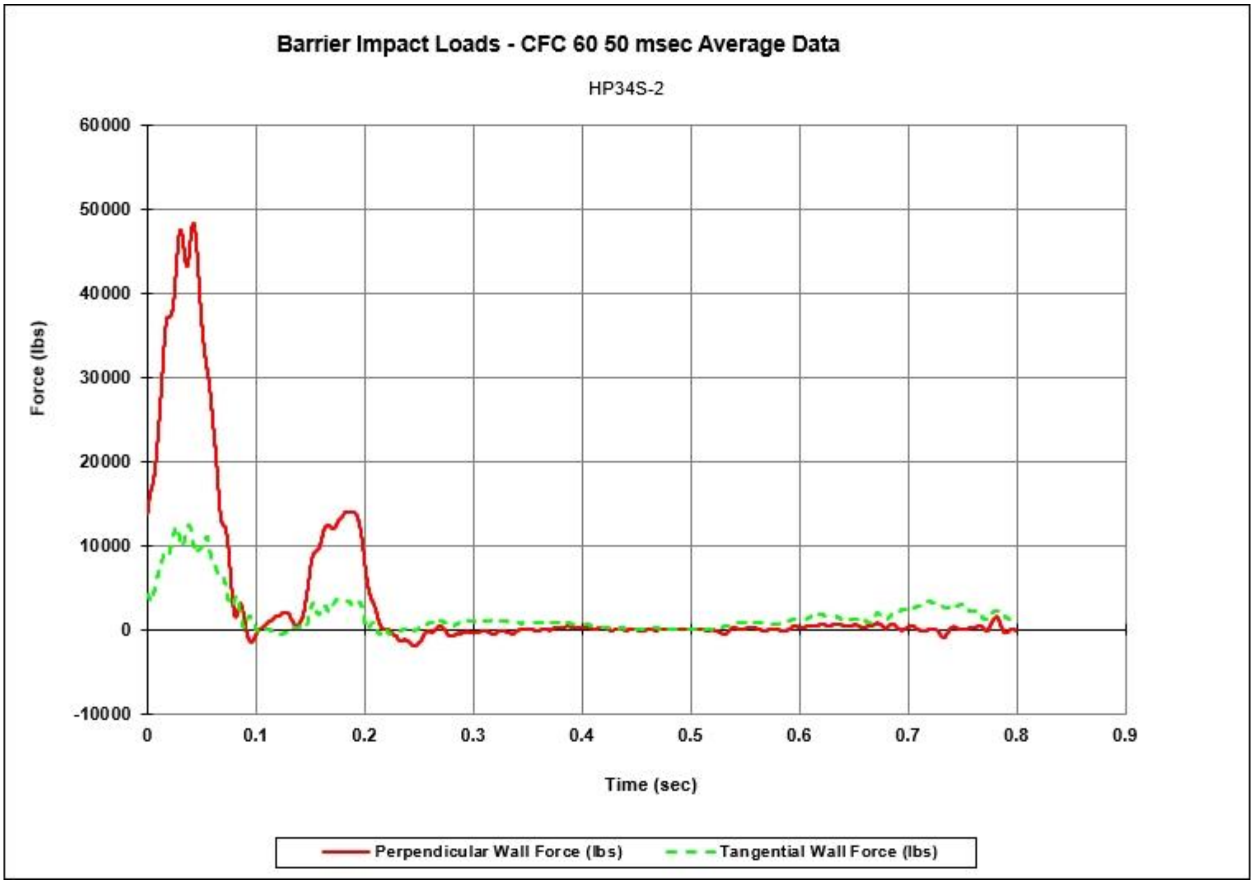


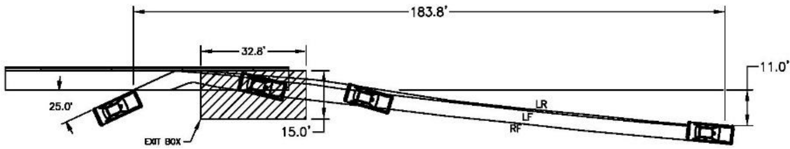
Figure 74. Perpendicular and Tangential Forces Imparted to the Barrier System (SLICE-1), Test No. HP34S-2

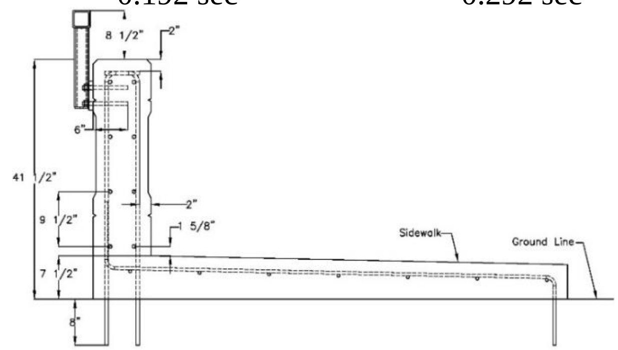
6.7 Discussion

The analysis of the test results for test no. HP34S-2 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 75.

Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or work-zone personnel. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did not occur. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix E, 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 2.5 degrees, and its trajectory did not violate the bounds of the exit box. Therefore, test no. HP34S-2 was determined to be acceptable according to the MASH 2016 safety performance criteria for test designation no. 3-10.

-0.158 sec | 0.000 sec | 0.092 sec | 0.192 sec | 0.292 sec





- Test Agency .... MwRSF
- Test Number HP34S-2
- Date 11/3/2021
- MASH 2016 Test Designation No. 3-10
- Test Article .... HDOT 34 in. Tall Aesthetic Bridge Rail with Pedestrian Handrail and Sidewalk
- Total Length .... 88 ft
- Key Component – 21-ft 11½-in. Concrete Parapet
  - Length .... 21 ft – 11¾ in.
  - Height .... 34 in.
  - Thickness .... 10 in.
- Key Component – 6-ft. Wide Sidewalk
  - Length .... 88 ft
  - Width .... 6 ft
  - Height .... 6 ft – 7½ in.
- Vehicle Make /Model .... 2016 Hyundai Accent
  - Curb .... 2,461 lb
  - Test Inertial .... 2,413 lb (MASH 2016 Limit 2,420 ± 55 lb)
  - Gross Static .... 2,577 lb
- Impact Conditions - Sidewalk
  - Speed .... 62.0 mph (MASH 2016 Limit 62 ± 2.5 mph)
  - Angle .... 25.0 degrees (MASH 2016 Limit 25 ± 1.5 deg.)
- Impact Conditions - Barrier
  - Speed .... 60.2 mph
  - Angle .... 22.8 degrees
  - Impact Location .... 40.57 in. upstream from post no. 11
- Impact Severity - Sidewalk .... 55.4 kip-ft > 51 kip-ft MASH 2016 limit
- Impact Severity – Barrier .... 43.9 kip-ft
- Exit Conditions
  - Speed .... 43.7 mph
  - Angle .... 2.5 degrees
- Exit Box Criterion .... Pass
- Vehicle Stability .... Pass
- Vehicle Stopping Distance .... 183.8 ft downstream 11.0 laterally in front of system
- Vehicle Damage .... Moderate
  - VDS [15] 11-LFQ-4
  - CDC [16] 11LFEW3
  - Maximum Interior Deformation .... 2.2 in.
- Test Article Damage .... Minimal
- Maximum Test Article Deflections
  - Permanent Set .... 0.6 in.
  - Dynamic Deflection .... 0.6 in.
  - Working Width (without Sidewalk) .... 14.1 in.
  - Working Width (with Sidewalk) .... 86.1 in.
- Transducer Data

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1 (primary)	SLICE-2	
OIV ft/s	Longitudinal	-20.26	-19.72	±40
	Lateral	28.35	25.53	±40
ORA g's	Longitudinal	-5.05	-5.35	±20.49
	Lateral	16.67	22.64*	±20.49
Maximum Angular Displacement deg.	Roll	-18.90	-15.84	±75
	Pitch	3.84	-3.21	±75
	Yaw	42.18	41.67	not required
THIV – ft/s		23.52	6.67	not required
PHD – g's		33.15	34.84	not required
ASI		2.14	2.08	not required

*Results were not from the primary data acquisition unit located at c.g.

Figure 75. Summary of Test Results and Sequential Photographs, Test No. HP34S-2

7 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Test nos. HP34S-1 and HP34S-2 were conducted on the HDOT 34-in. Tall, Aesthetic Bridge Rail with Pedestrian Handrail and Sidewalk according to MASH 2016 test designation nos. 3-11 and 3-10, respectively. A summary of the test evaluation is shown in Table 13.

In test no. HP34S-1, the 5,045-lb pickup truck impacted the HDOT 34-in. Tall, Aesthetic Bridge Rail with Pedestrian Handrail and Sidewalk, impacting the sidewalk at a speed of 65.7 mph and an angle of 25.2 degrees and the barrier at a speed of 63.6 mph and an angle of 23.7 degrees 0.07 in. upstream from the targeted impact point. The impact severity with the sidewalk was 134.0 kip-ft, and the impact severity with the barrier was 110.2 kip-ft. After impacting the barrier system, the vehicle exited the system at a speed of 41.3 mph and an angle of 9.1 degrees. The vehicle was successfully contained and smoothly redirected with minimal damage to the barrier system and moderate damage to the vehicle. All vehicle decelerations, ORAs, and OIVs fell within the recommended safety limits established in MASH 2016. Therefore, test no. HP34S-1 was successful according to the safety criteria of MASH 2016 test designation no. 3-11.

In test no. HP34S-2, the 2,413-lb small car impacted the HDOT 34-in. Tall Aesthetic Bridge Rail with Pedestrian Handrail and Sidewalk, impacting the sidewalk at a speed of 62.0 mph and an angle of 25.0 degrees and the barrier at a speed of 60.2 mph and an angle of 22.8 degrees 2.43 in. downstream from the targeted impact point. The impact severity with the sidewalk was 55.4 kip-ft, and the impact severity with the barrier was 43.9 kip-ft. After impacting the barrier system, the vehicle exited the system at a speed of 43.7 mph and an angle of 2.5 degrees. The vehicle was successfully contained and smoothly redirected with minimal damage to the barrier system and moderate damage to the vehicle. All primary system vehicle decelerations, ORAs, and OIVs fell within the recommended safety limits established in MASH 2016. Therefore, test no. HP34S-2 was successful according to the safety criteria of MASH 2016 test designation no. 3-10.

Table 13. Summary of Safety Performance Evaluation

<table>
<tr><th>Evaluation Factors</th><th colspan="4">Evaluation Criteria</th><th>Test No. HP34S-1</th><th>Test No. HP34S-2</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>S</td><td>S</td></tr>
<tr><td rowspan="9">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 2016.</td><td>S

S</td><td>S

S</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>S</td><td>S</td></tr>
<tr><td rowspan="4">H.</td><td colspan="3">Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:</td><td rowspan="4">S</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 2016 for calculation procedure) should satisfy the following limits:</td><td rowspan="4">S</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 2016 Test Designation No.</td><td>3-11</td><td>3-10</td></tr>
<tr><td colspan="5">Final Evaluation (Pass or Fail)</td><td>Pass</td><td>Pass</td></tr>
</table>

S – Satisfactory U – Unsatisfactory N/A – Not Applicable

8 MASH EVALUATION

The research objective of this study was to evaluate the safety performance of the HDOT 34-in. Tall, Aesthetic Bridge Rail with Pedestrian Handrail and Sidewalk. The barrier system test installation consisted of two 10-ft 11¾-in. long and three 21-ft 11½-in. long concrete barrier segments with a pedestrian handrail and sidewalk. According to TL-3 evaluation criteria in MASH 2016, two tests are required for evaluation of longitudinal barrier systems: (1) test designation no. 3-10 – an 1100C small car and (2) test designation no. 3-11 – a 2270P pickup truck.

In test no. HP34S-1, the HDOT 34-in. Tall, Aesthetic Bridge Rail with Pedestrian Handrail and Sidewalk was successfully impacted by a pickup truck weighing 5,045 lb. The sidewalk was impacted at a speed of 65.7 mph and an angle of 25.2 degrees and the barrier was impacted at a speed of 63.6 mph and an angle of 23.7 degrees at a location 0.07 in. upstream from the targeted impact point. The impact severity with the sidewalk was 134.0 kip-ft, and the impact severity with the barrier was 110.2 kip-ft. At 1.034 sec, the vehicle exited the system at a speed of 41.3 mph and at an angle of 9.1 degrees. The vehicle was successfully contained and smoothly redirected. Based on guidance provided for MASH flail space method, the curb impact was not included in the determination of occupant risk or vehicle exit conditions because the 50-ms average accelerations in longitudinal and lateral directions did not exceed 2.0 g's prior to impact with the bridge rail.

Exterior vehicle damage was moderate. Interior occupant compartment deformations were moderate with a maximum of 5.2 in., which did not violate the limits established in MASH 2016. Damage to the barrier was minimal, consisting of contact marks on the front face of the bridge rail as well as gouging concentrated near the aesthetic recessed windows adjacent to the expansion joint immediately downstream from the impact point. The maximum dynamic barrier deflection was 1.0 in., and the working width of the system was 14.5 in., as measured from the front face of the barrier system and 86.5 in. measured from the front face of the curb, respectively. All occupant risk measures were within the recommended limits, and the occupant compartment deformations were also deemed acceptable. Therefore, HDOT 34-in. Tall, Aesthetic Bridge Rail with Pedestrian Handrail and Sidewalk successfully met all the safety performance criteria of MASH 2016 test designation no. 3-11.

In addition, in test no. HP34S-2, the HDOT 34-in. Tall Aesthetic Bridge Rail with Pedestrian Handrail and Sidewalk was successfully impacted by a small car weighing 2,413 lb. The sidewalk was impacted at a speed of 62.0 mph and at an angle of 25.0 degrees and the barrier was impacted at a speed of 60.2 mph and an angle of 22.8 degrees, resulting in impact severities of 55.4 and 43.9 kip-ft, respectively. At 0.616 sec, the vehicle exited the system at a speed of 43.7 mph and at an angle of 2.5 degrees. The vehicle was successfully contained and smoothly redirected.

Exterior vehicle damage was moderate. Interior occupant compartment deformations were moderate with a maximum of 2.2 in., which did not violate the limits established in MASH 2016. Damage to the barrier was minimal, consisting of contact marks on the front face of the bridge rail as well as gouging concentrated near the aesthetic recessed windows adjacent to the expansion joint immediately downstream from the impact point. The maximum dynamic barrier deflection was approximately 0.6 in., and the working width of the system was 14.1 in., as measured from the front face of the bridge railing and 86.1 in. measured from the front face of the sidewalk, respectively. All primary system occupant risk measures were within the recommended limits, and the occupant compartment deformations were also deemed acceptable. Therefore, HDOT 34-in. Tall, Aesthetic Bridge Rail with Pedestrian Handrail and Sidewalk successfully met all the safety performance criteria of MASH 2016 test designation no. 3-10.

During test no. HP34S-2, the occupant risk evaluation criteria from the secondary system were exceeded for ORAs, but the backup system results were not considered for evaluating the crashworthiness of the system, which was consistent with roadside safety community practice.

The HDOT 34-in. Tall, Aesthetic Bridge Rail with Pedestrian Handrail and Sidewalk was successfully crash tested and evaluated according to the AASHTO MASH 2016 TL-3 criteria. This barrier successfully met all the requirements of MASH 2016 test designation nos. 3-10 and 3-11.

9 REFERENCES

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10 APPENDICES

Appendix A. Material Specifications

Table A-1. Bill of Materials, Test Nos. HP34S-1 and HP34S-2

Item No.	Description	Material Specification	Reference
a1	Reinforced Concrete	Min. f'c = 4,000 psi NE Mix 47BD	Ticket#1267559 #1270201 Product Code#QL324504
b1	#5 Rebar, 52¼" Total Unbent Length	ASTM A615 Gr. 60	H#3600014140
b2	#5 Rebar, 38⅞" Total Unbent Length	ASTM A615 Gr. 60	H#3600014140
b3	#5 Rebar, 259½" Total Length	ASTM A615 Gr. 60	H#3600014140
b4	#5 Rebar, 127¾" Total Length	ASTM A615 Gr. 60	H#3600014140
b5	#4 Rebar, 1095½" Total Length	ASTM A615 Gr. 60	H#3600014739
b6	#4 Rebar, 99 9/16" Unbent Length	ASTM A615 Gr. 60	H#3600014739
c1	#8 Smooth Rebar, 24½" Total Length	ASTM A615 Gr. 60	H#256801
c2	1¼" Dia. PVC Pipe	Schedule 80 PVC Gr. 12454	P#0472040 Inv#392987
c3	1¼" Dia. PVC End Cap	Schedule 80 PVC Gr. 12454	P#0470592 Inv#392987
c4	Epoxy Adhesive	Hilti HIT RE-500 V3	COC
c5	Expansion Joint Filler	AASHTO M33, M153, or M213	W.R. Meadows Seal Tight Fiber Expansion Joint that meets M213 Data Product Sheet
c6	Expansion Joint Sealant	AASHTO M173, M282, M301, ASTM D3581, or ASTM D5893	Carroll Invoice#LI061687 Item: "301NS"
d1	8"x5"x¾" Steel Plate	ASTM A36	H#21B2688
d2	HSS 2½"x2½"x¼", 13¾" Long	ASTM A500 Gr. B	H#98987D
d3	HSS 3"x3"x¼", 131½" Long	ASTM A500 Gr. B	H#A018142
d4	HSS 3"x3"x ¼", 263" Long	ASTM A500 Gr. B	H#A018142
d5	HSS 2"x2"x¼", 7" Long	ASTM A500 Gr. B	H#845858
d6	2¼"x2¼"x¼" Steel Plate	ASTM A36	H#A0J157
d7	⅝"-11 UNC, 7⅞" Long Threaded Rod	ASTM F1554-15 Gr. 105	H#10543730 Inv#138847
d8	Shim	ASTM A36	H#21013251
e1	⅝"-11 UNC Heavy Hex Nut	ASTM A563-15 Grade DH	H#J21908483 Ticket#138847 Portland Bolt sent 2H nuts instead of Gr. DH.
e2	⅝" Dia. Hardened Washer	ASTM F436	H#107480 Inv#138847

Ready Mixed Concrete Company
6200 Cornhusker Hwy, Lincoln, NE 68529
Phone: (402) 434-1844 Fax: (402) 434-1877

Customer's Signature:

PLANT	TRUCK	DRIVER	CUSTOMER	PROJECT	TAX	PO NUMBER	DATE	TIME	TICKET
1	147	11014	62461		N01	OCBR-H34S	9/16/21	10:30 AM	1270201

Customer	Delivery Address	Special Instructions
UNL-MIDWEST ROADSIDE SAFETY	4630 NW 38TH ST	NORTH OF OLD GOODYEAR HANGARS

LOAD QUANTITY	CUMULATIVE QUANTITY	ORDERED QUANTITY	PRODUCT CODE	PRODUCT DESCRIPTION	UOM	UNIT PRICE	EXTENDED PRICE
8.00	8.00	24.00	QL324504	LNK47B1PF4000HW	yd	$132.50	$1,060.00

Water Added On Job At Customer's Request:

SLUMP: 4.00 in

Notes:

TICKET SUBTOTAL	$1,060.00
SALES TAX	$0.00
TICKET TOTAL	$1,060.00
PREVIOUS TOTAL	
GRAND TOTAL	$1,060.00

CAUTION FRESH CONCRETE
KEEP CHILDREN AWAY

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

Terms & Conditions

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

Figure A-1. Reinforced Concrete, Test Nos. HP34S-1 and HP34S-2 (Item No. a1)

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Concrete Sample Test Report

Cylinder Compressive Strength

Project Name:	Midwest Roadside Safety - Misc Testing
Project Number:	00110546.00
Client:	Midwest Roadside Safety Facility
Location:	MNPD
Sample:	029
Description:	H34S

Field Data (ASTM C172, C143, C173/C231, C138, C1064)

		Property	Test Result
Supplier:		Slump (in):	
Mix Name:		Air Content (%):	
Ticket Number:		Unit Weight (lb/ft^3):	
Truck Number:		Air Temp (°F):	
Load Volume (yd^3):		Mix Temp (°F):	
Mold Date:	09/16/2021	Min Temp (°F):	
Molded By:		MaxTemp (°F):	
Initial Cure Method:			

Laboratory Test Data (ASTM C39)

Sample Number:	029	029				
Set Number:	001	002				
Specimen Number:	1	1				
Age:	18	18				
Length (in):	12	12				
Diameter (in):	5.97	5.98				
Area (in^2):	27.99	28.09				
Test Date:	10/04/2021	10/04/2021				
Break Type:	6	5				
Max Load (lbf):	123,471	120,017				
Strength (psi):	4,410	4,270				
Spec Strength (psi):						
Excl in Avg Strength:	☐	☐	☐	☐	☐	☐

Remarks:
Average 18-day Compressive Strength (psi): **4,340**

Date received: 10/04/2021
Curing: ☒ Standard ☐ Field
ASTM C511
Submitted by:

Type 1 Type 2 Type 3 Type 4 Type 5 Type 6

Distribution:

Report Date: 10/4/21

Figure A-2. Reinforced Concrete, Test Nos. HP34S-1 and HP34S-2 (Item No. a1)

Ready Mixed Concrete Company
6200 Cornhusker Hwy, Lincoln, NE 68529
Phone: (402) 434-1844 Fax: (402) 434-1877

Customer's Signature: ____________________

PLANT	TRUCK	DRIVER	CUSTOMER	PROJECT	TAX	PO NUMBER	DATE	TIME	TICKET
1	133	7142	62461		NTE	~~HW42~~	7/22/21	9:39 AM	1267559

Customer	Delivery Address	Special Instructions
UNL-MIDWEST ROADSIDE SAFETY	4630 NW 36TH ST H32S	NW 48TH ST & W CUMING ST EAST/NW36TH ST SOUTH/NORTH OF OLD GOODYEAR HANGERS

LOAD QUANTITY	CUMULATIVE QUANTITY	ORDERED QUANTITY	PRODUCT CODE	PRODUCT DESCRIPTION	UOM	UNIT PRICE	EXTENDED PRICE
8.00	16.00	16.00	QL324504	LNK47B1PF4000HW	yd	$132.50	$1,060.00

Water Added On Job At Customer's Request:	SLUMP	Notes:		
________	4.00 in		TICKET SUBTOTAL	$1,060.00
			SALES TAX	$0.00
			TICKET TOTAL	$1,060.00
			PREVIOUS TOTAL	$1,060.00
			GRAND TOTAL	**$2,120.00**

CAUTION FRESH CONCRETE

KEEP CHILDREN AWAY

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

Terms & Conditions

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

Figure A-3. Reinforced Concrete, Test Nos. HP34S-1 and HP34S-2 (Item No. a1)

benesch

Page 1 of 1

Concrete Sample Test Report
Cylinder Compressive Strength

Project Name:	Midwest Roadside Safety - Misc Testing
Project Number:	00110546.00
Client:	Midwest Roadside Safety Facility
Location:	MNPD
Sample:	026
Description:	H34S

Field Data (ASTM C172, C143, C173/C231, C138, C1064)

Supplier:		Property	Test Result
Mix Name:		Slump (in):	
Ticket Number:		Air Content (%):	
Truck Number:		Unit Weight (lb/ft³):	
Load Volume (yd³):		Air Temp (°F):	
Mold Date:	07/22/2021	Mix Temp (°F):	
Molded By:		Min Temp (°F):	
Initial Cure Method:		MaxTemp (°F):	

Laboratory Test Data (ASTM C39)

Sample Number:	026	026				
Set Number:	001	002				
Specimen Number:	1	1				
Age:	41	41				
Length (in):	12	12				
Diameter (in):	5.98	5.98				
Area (in²):	28.09	28.09				
Test Date:	09/01/2021	09/01/2021				
Break Type:	5	6				
Max Load (lbf):	171,667	150,106				
Strength (psi):	6,110	5,340				
Spec Strength (psi):						
Excl in Avg Strength:	☐	☐	☐	☐	☐	☐

Remarks:

Average 41-day Compressive Strength (psi): **5,730**

Date received: 09/01/2021

Curing: ☒ Standard ☐ Field

ASTM C511

Submitted by: Matt Roemler

Type 1 Type 2 Type 3 Type 4 Type 5 Type 6

Distribution:

Report Date: 9/1/21

Figure A-4. Reinforced Concrete, Test Nos. HP34S-1 and HP34S-2 (Item No. a1)

H#3600014140 R#21-808 #5 Rebar, 52 1/4" Total Unbent Length

SIMCOTE, INC.

Date: September 24, 2020

CERTIFICATE OF COMPLIANCE

To: Concrete Industries, Inc.

Re: PO# 143991

Project No: #3, #4, #5 & #6x 40'-0" Straight Bar

County:

Contractor:

To Whom It May Concern:

The representative samples of the coated bars have been coated and tested. They conform to the requirements of the State of *Nebraska* Department of Roads Specification.

Sincerely,

SIMCOTE, INC.

Adam Simmet
President

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 A-5. #5 Rebar, Test Nos. HP34S-1 and HP34S-2 (Item Nos. b1, b2, b3, and b4)

SIMCOTE, INC.

H#3600014739 R#21-808 #4 Rebar, 1095 1/2" Total Length

Date: November 5, 2020

CERTIFICATE OF COMPLIANCE

To: Concrete Industries, Inc.

Re: PO# 144607-1

Project No: #4 & #5 x 40'-0" Epoxy Straight Bar

County:

Contractor:

To Whom It May Concern:

The representative samples of the coated bars have been coated and tested. They conform to the requirements of the State of *Nebraska* Department of Roads Specification.

Sincerely,

SIMCOTE, INC.

Adam Simmet
President

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 A-6. #4 Rebar, Test Nos. HP34S-1 and HP34S-2 (Item Nos. b5 and b6)

CMC Steel Texas

P. O. Box 911
Seguin, Texas 78156-0911
(830) 372-8200

CERTIFIED MILL TEST REPORT

For additional copies call
(830) 372-8485

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

Daniel J. Schacht
Quality Assurance Manager

HEAT NO.: 256801 SECTION: RD 1x45'2" RD 25.4mm x13.768 GRADE: ASTM A615-05a GRADE 60 ASTM A615M-05a GRADE 420	SOLD TO: A B C COATING - TULSA P O BOX 9693 TULSA, OK 74157-	SHIP TO: A B C COATING CO 2236 SOUTH YUKON AVE. TULSA, OK 74107-	SHIP#: 102028/60 BOL #: 460684 INV #: 8000705606 CUST PO#: CUST P/N:

CHEMICAL ANALYSIS		PROPERTIES						
	%	MECHANICAL	TEST I		TEST		TEST	
			IMPERIAL	METRIC	IMPERIAL	METRIC	IMPERIAL	METRIC
C	0.28							
Mn	1.26	Yield Strength	78.3 KSI	539.9 MPA				
P	0.018	Tensile Strength	111.6 KSI	769.5 MPA				
S	0.031	Elongation	18 %	18 %				
Si	0.19	Gauge Length	8 INS	203 MM				
Cu	0.49	Reduction of Area						
Cr	0.16	Bend Test	OK					
Ni	0.14	Diameter	7.90 INS	200.41 MM				
Mo	0.040	Charpy Impact						
Cb	0.011	Test Temp						
V	0.020	Sample Size						
Sn	0.015	Orientation						
B	0.0004	Hardness						
Ti	0.001							
C.Eq.	0.52							

JOMINY RESULTS - Rockwell C hardness at 1/16th inch increments

1	2	3	4	5	6	7	8	9	10	11	12
13	14	15	16	18	20	22	24	26	28	30	32

GRAIN SIZE	
METHOD	
RESULT	

INCLUSION RATING

METHOD								
TYPE								
	T	H	T	H	T	H	T	H
SIZE								

100% MELTED AND MANUFACTURED IN THE USA AND FREE OF MERCURY CONTAMINATION IN THE PROCESS

REMARKS:

AASHTO M 31M/M 31-95

State of Texas, County of Guadalupe
Sworn to and subscribed before me on this day of ______, 2007

MAY-17-2007 09:29
Page 1 OF 1

Figure A-7. #8 Smooth Rebar, Test Nos. HP34S-1 and HP34S-2 (Item No. c1)

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

Packing Slip

Date	Reference No.	Page
3/16/21	NELIN392987	1

DUE DATE: 04/15/2021

Cust. No. NELIN3402
Cust. P.O. E000833460
Job No.

Contract No: 2018.000208

Sold To
UNL / UNMC E-SHOP / PUNCHOUT
UNIVERSITY OF NEBRASKA
1700 Y ST
LINCOLN, NE 68588-0646

Ship To
UNL / UNMC E-SHOP / PUNCHOUT
Shaun M Tighe MIDWEST ROADSIDE SAFETY FACILITY
4630 NW 36 ST
TEST SITE
LINCOLN, NE 68524
402-4720071

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	12	12	0	1-1/4 SOCK CAP PVC	Ilne48985	0470592	472.5000	56.70 G
2	1	1	0	1 1/4 S80PVC Pipe10	whoh15040	0472040	1,861.3000	18.61 G
3	1	1	0	1 1/4 S80PVC Pipe10	160180181	0472040	1,861.3000	18.61 G

Received By

Comments
Contact: University of Nebraska

Tax Exemption
Government

NE

Subtotal	93.92
Shipping & Handling	0.00
State Tax	0.00
County Tax	0.00
City Tax	0.00
TOTAL USD	93.92

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*

An electronic invoice will be available within two days.
All discrepancies must be reported within 10 days. *0*

Thank You !

FORM - IN13

Figure A-8. 1¼ in. Diameter PVC Pipe and End Cap, Test Nos. HP34S-1 and HP34S-2 (Item Nos. c2 and c3)

P.O. Box 21148
Tulsa, OK 74121
Phone (918) 252-6000
Fax No. (918) 252-6520

Certified Quality and Environmental Systems
SQS
ISO 9001 / ISO 14001

Date: 12/13/2016

Subject: Certificate of Conformance

Product: HIT RE-500 V3 Adhesive

To Whom it May Concern:

This is to certify that the HIT-RE 500 V3 is a high-strength, slow cure two-part epoxy adhesive contained in two cartridges separating the resin from the hardener.

Additionally, this certifies that the product has been seismically and cracked concrete qualified as represented in ICC-ES report ESR- 3814.

Sincerely,

Hilti, Inc.

5400 South 122 East Avenue
Tulsa, Oklahoma 74146

800-879-8000
800-879-7000 fax
US-Sales@hilti.com

Figure A-9. Epoxy Adhesive, Test Nos. HP34S-1 and HP34S-2 (Item No. c4)

PRODUCT DATA

W. R. MEADOWS.
SEALTIGHT.

MasterFormat: 03 15 00

NO. 320-F

APRIL 2018
(Supersedes March 2016)

FIBRE EXPANSION JOINT

Multi-Purpose, Expansion-Contraction Joint Filler

DESCRIPTION

FIBRE EXPANSION JOINT is composed of cellular fibers securely bonded together and uniformly saturated with asphalt to assure longevity. Wherever a cost-effective joint filler is required, FIBRE EXPANSION JOINT meets the need. Manufactured and marketed by W. R. MEADOWS since the early 1930s, FIBRE EXPANSION JOINT is backed by over 80 years of proven application experience. FIBRE EXPANSION JOINT is versatile, resilient, flexible, and non-extruding. When compressed to half of its original thickness, it will recover to a minimum of 70% of its original thickness. FIBRE EXPANSION JOINT will not deform, twist, or break with normal on-the-job handling. Breakage, waste and functional failure resulting from the use of inferior, foreign fiber materials can cost you time and dollars and can result in a substandard finished job, generating costly callbacks and rework expenses. However, the purchase and installation of FIBRE EXPANSION JOINT (a small segment of the total project's cost) contributes to both the final cost efficiency and functional success, far greater in proportion than its original cost.

Representative United States patents: USPNs 7,815,722; 8,057,638; 8,038,845; and D558,305. (See also www.wrmeadows.com/patents for further patent/intellectual property information.)

USES

FIBRE EXPANSION JOINT is ideal for use on highways, streets, airport runways, sidewalks, driveways, flatwork, and scores of commercial and industrial applications subject to pedestrian and vehicular traffic.

FEATURES/BENEFITS

- Provides the ideal product for the majority of all expansion/contraction joint requirements.
- Non-extruding ... versatile ... offers a minimum 70% recovery after compression.
- This tough, lightweight, easy-to-use, semi-rigid joint filler is available in strips and shapes fabricated to your requirements.
- Easy to cut ... dimensionally stable ... not sticky in summer or brittle in winter.
- Provides neat, finished joints requiring no trimming.
- Often copied ... but never equaled.
- Remains the standard of the industry today ... with over 80 years of proven and satisfactory performance.
- Can be punched for dowel bars and laminated to thicknesses greater than 1" (25.4 mm).

MADE IN THE U.S.A. W. R. MEADOWS SEALTIGHT FIBRE EXPANSION JOINT

Conforms to or meets:	Thickness	Slab Widths	Standard Lengths	Weight per $ft.^3$
• AASHTO M 213 • ASTM D1751 • Corps of Engineers CRD-C 508 • FAA Specification Item P-610-2.7 • HH-F-341 F, Type 1	3/8", 1/2" 3/4", 1" (9.5, 12.7, 19.1, 25.4 mm)	36", 48" (91, 1.22 m)	10' (3.05 m) Also available: 5', 6', 12' (1.5, 1.83, 3.66 m)	>19 lb.

CONTINUED ON REVERSE SIDE...

W. R. MEADOWS, INC.
P.O. Box 338 • HAMPSHIRE, IL 60140-0338
Phone: 847/214-2100 • Fax: 847/683-4544
1-800-342-5976
www.wrmeadows.com

HAMPSHIRE, IL /CARTERSVILLE, GA /YORK, PA
FORT WORTH, TX /BENICIA, CA /POMONA, CA
GOODYEAR, AZ / MILTON, ON /ST. ALBERT, AB

Figure A-10. Expansion Joint Filler, Test Nos. HP34S-1 and HP34S-2 (Item No. c5)

Pecora 301 NS

Specification Data Sheet

PECORA CORPORATION

Non-Sag Silicone Highway & Pavement Joint Sealant

1. BASIC USES

Sealing of transverse contraction and expansion joints, longitudinal, centerline and shoulder joints in Portland cement concrete (PCC) and asphalt.

2. MANUFACTURER

Pecora Corporation
165 Wambold Road
Harleysville, PA 19438
Phone: 215-723-6051
800-523-6688
Fax: 215-721-0286
Website: www.pecora.com

3. PRODUCT DESCRIPTION

Pecora 301 NS Silicone Pavement Sealant is a one part, ultra low modulus product designed for sealing joints in concrete or asphalt pavement. It has excellent unprimed adhesion to concrete, metal and asphalt substrates, superior weather resistance and remains flexible at extremely low temperatures.

Pecora 301 NS Silicone Pavement Sealant is a non-sag product designed for applications on flat and sloped surfaces.

Advantages:

- Reduces pavement deterioration by restricting surface water penetration into underlying base and sub base layers.
- Convenient one component, neutral moisture curing system.
- Ultra low modulus resulting in high movement capability.
- Ease of application with standard automated bulk dispensing equipment such as Graco or Pyles.
- VOC compliant.
- Primerless adhesion to concrete and asphalt.
- Aids in elimination of non-compressables entering expansion joints.

Limitations:

Pecora 301 NS Silicone Pavement Sealant should not be used:

- for continuous water immersion conditions.
- when ambient temperatures is below 40°F (4°C) or above 120°F (49°C).
- flush with traffic surface. **(Sealant must be recessed below surface.)**
- for applications requiring support of hydrostatic pressures.
- with solvents for dilution purposes.
- with concrete that is cured less than 7 days.
- with newly applied asphalt until cooled to ambient temperature (usually 24-48 hours).
- as a structural component or in longitudinal joints greater than 3/4" in width that are intended to be used as a constant travelling surface.

PACKAGING

- 30 fl. oz. (887ml) cartridges
- 20 fl. oz. (592ml) sausages
- 4.5 gallon pails (17.0L)
- 50 gallon drum (188.9L)

Color: pavement gray

SEALANT COVERAGE CHART
RECESS GUIDELINES

Joint Width (inches)	Sealant Depth (inches)	Recess (inches)	Backer Rod Diameter (in)	Minimum Joint Depth (in)	Linear ft./gal
1/4	1/4	1/8	3/8	3/4	308
3/8	1/4	1/8	1/2	7/8	205
1/2	1/4	1/8	5/8	1-1/4	154
3/4	3/8	1/4	7/8	1-1/4	68
1.0	1/2	1/4	1-1/4	2	38

TABLE 1: TYPICAL UNCURED PROPERTIES

Test Property	Value	Test Procedure
Cure Through (days)	7	0.5" cross section
Extrusion Rate (grams/min)	90-250	Mil-S-8802
Rheological Properties	non-sag	
Tack Free Time (mins)	60	ASTM C679
VOC Content (g/L)	50	ASTM D3960

TABLE 2: TYPICAL CURED PROPERTIES
(After 7 days cure at 77°F (25°C), 50% RH)

Test Property	Value	Test Procedure
Adhesion, minimum elongation		ASTM D5329*
Asphalt	500	
Concrete	500	
Metal	500	
Elongation (%)	>1400	ASTMD412
Resilience (%)	>95	ASTM D5329
Stress @ 150% Elongation (psi)	22	ASTMD412
Hardness, maximum 21 day cure (Shore 00)	60	ASTM C661
Joint Movement Capability +100/-50%; 10 cycles	Pass	ASTM C719

*modified section 14

Since Pecora architectural sealants are applied to varied substrates under diverse environmental conditions and construction situations it is recommended that substrate testing be conducted prior to application.

Figure A-11. Expansion Joint Sealant, Test Nos. HP34S-1 and HP34S-2 (Item No. c6)

NUCOR
NUCOR STEEL TUSCALOOSA, INC.

MILL TEST CERTIFICATE

Nucor Steel Tuscaloosa, Inc.
1700 HOLT RD N.E.
Tuscaloosa, AL 35404-1000
800 800-8204
customerservice@nucortusk.com

Page:1 of 1

Load Number	Tally	Mill Order Number	PO NO | Line NO	Part Number	Certificate Number	Prepared
R265880	00000000972397	N-187229-005	4500357930 5		S97239701-1	01/19/2021 07:56

Grade

Order Description:
Hot Roll Plate From Coil
A36, 0.7500 IN x 72.000 IN x 120.000 IN
Quality Plan Description:
A36/SA36/A70936: ASTM A36-19/ASME SA36-19/ASTM A709-36-18

Customer:
Sold TO:
STEEL AND PIPE SUPPLY CO INC GARDNER KS
Ship TO:
STEEL & PIPE SUPPLY Gardner KS
Sent TO:

Shipped Item	Heat/Slab Number	Certified By	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Cb	V	Al	Ti	N2	B	Ca	Sn	CEV	ACI
1A1414C	21B2688-03 ***	21B2688	0.18	0.88	0.009	0.004	0.06	0.20	0.06	0.07	0.016	0.001	0.005	0.028	0.001	0.006	0.0002	0.0021	0.006	0.36	
1A1414D	21B2688-03 ***	21B2688	0.18	0.88	0.009	0.004	0.06	0.20	0.06	0.07	0.016	0.001	0.005	0.028	0.001	0.006	0.0002	0.0021	0.006	0.36	

Shipped	Certified	Heat/Slab	Yield	Tensile	Y/T	ELONGATION %		Bend	Hard	Charpy Impacts (ft-lbs)					Shear %				Test
Item	By	Number	ksi	ksi	%	2"	8"	OK?	HB	Size mm	1	2	3	Avg	1	2	3	Avg	Temp
1A1414C	S1A1414FTT	21B2688-03 ***	52.5	71.9	73.0	40.2													
1A1414C	S1A1414MTT	21B2688-03 ***	51.3	68.8	74.6	39.9													
1A1414D	S1A1414FTT	21B2688-03 ***	52.5	71.9	73.0	40.2													
1A1414D	S1A1414MTT	21B2688-03 ***	51.3	68.8	74.6	39.9													

Items: 2 **PCS:** 12 **Weight:** 22053 **LBS**

Mercury has not come in contact with this product during the manufacturing process nor has any mercury been used by the manufacturing process. Certified in accordance with EN 10204 3.1. No weld repair has been performed on this material. Yield strength is determined by the 0.2% offset method unless otherwise noted. Manufactured to a fully killed fine grain practice.
NUTEMPER TEMPER PASSED plate from coil
ISO 9001:2015 Registered, PED Certified

We hereby certify that the product described above passed all of the tests required by the specifications.

Qiulin Yu

Dr. Qiulin Yu - Metallurgist

"***" indicates Heats melted and Manufactured in the U.S.A.

Figure A-12. 8-in. x 5-in. x ¾-in. Steel Plate, Test Nos. HP34S-1 and HP34S-2 (Item No. d1)

EXLTUBE

1000 BURLINGTON STREET, NORTH KANSAS CITY, MO 64116 1-816-474-5210 TOLL FREE 1-800-892-TUBE

STEEL VENTURES, LLC dba EXLTUBE

Certified Test Report

Customer:	Size: 02.50X02.50 Gauge: 1/4	Customer Order No: E450000492	Customer Part No: 6521625020
SPS - Tulsa 1020 Fort Gibson Road Catoosa OK 74015-3033	Date: 02/11/2021	Delivery No: 83922364 Load No: 7011501	Length: 20 FT
	Specification: ASTM A500-13 Gr.B/C		

Heat No	Yield KSI	Tensile KSI	Elongation % 2 Inch
98987D	66.0	73.4	30.50

Heat No	C	MN	P	S	SI	CU	NI	CR	MO	V
98987D	0.1500	0.8300	0.0060	0.0080	0.0120	0.0300	0.0100	0.0300	0.0000	0.0000

This material was melted & manufactured in the U.S.A. This material meets the Buy America requirement of 23 CFR 635.410.
Coil Producing Mill: UNITED STATES STEEL, Granite City, IL

We hereby certify that all test results shown in this report are correct as contained in the records of our company. All testing and manufacturing is in accordance to A.S.T.M. parameters encompassed within the scope of the specifications denoted in the specification and grade tiles above. This product was manufactured in accordance with your purchase order requirements.

This material has not come into direct contact with mercury, any of its compounds, or any mercury bearing devices during our manufacturing process, testing, or inspections.

This material is in compliance with EN 10204 Section 4.1 Inspection Certificate Type 3.1

Tensile test completed using test specimen with 3/4" reduced area.

STEEL VENTURES, LLC dba EXLTUBE

Jonathan Wolfe

Jonathan Wolfe
Quality Assurance Manager

Figure A-13. HSS2½x2½x¼ Steel Square Tube, Test Nos. HP34S-1 and HP34S-2 (Item No. d2)

Atlas Tube Plymouth
13101 Eckles Road
Plymouth Michigan USA
48170
Tel: 734-738-5600
Fax: 734-738-5604

Atlas Tube
A DIVISION OF ZEKELMAN INDUSTRIES

REF.B/L: 81002338
Date: 02/23/2021
Customer: 179

MATERIAL TEST REPORT

Sold To
Steel & Pipe Supply Company
PO Box 1688
MANHATTAN KS 66505
USA

Shipped To
Steel & Pipe Supply Company
310 Smith Road
JONESBURG MO 63351
USA

Material: 3.0x3.0x250x24'0"0(6x5). **Material No:** 300302502400 **Made in:** USA
Melted and Poured in: USA
Sales Order: 1616799 **Purchase Order:** C455005811 **Cust Material#:** 6530025024

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
A018142	0.210	0.460	0.005	0.004	0.020	0.025	0.090	0.001	0.010	0.040	0.060	0.001	0.001	0.0002	0.0086	0.0018

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	
MA00094312	30	063870 Psi	082480 Psi	27 %	ASTM A500-21 GRADE B&C	CE: 0.31

Heat	MILL	Mill Location	Method	Recycled_Content	Post_Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
A018142	SDI	Columbus,MS	EAF	76.00%	95.00%	5.00 %	75%	500

Material Note:
Sales Or. Note:

Authorized by Quality Assurance: Jason Richard

The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements.
CE calculated using the AWS D1.1 method. This document is in compliance with the requirements of EN 10204 type 3.1

Steel Tube Institute OF NORTH AMERICA

Metals Service Center Institute

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Figure A-14. HSS3x3x¼ Steel Square Tube, Test Nos. HP34S-1 and HP34S-2 (Item Nos. d3 and d4)

Atlas Tube Alabama
171 Cleage Dr
Birmingham Alabama USA
35217
Tel:
Fax:

Atlas *Tube*
A DIVISION OF ZEKELMAN INDUSTRIES

REF.B/L: 80998064
Date: 02/12/2021
Customer: 179

MATERIAL TEST REPORT

Sold To
Steel & Pipe Supply Company
PO Box 1688
MANHATTAN KS 66505
USA

Shipped To
Steel & Pipe Supply Company
401 New Century Parkway
NEW CENTURY KS 66031
USA

Material: 2.0x2.0x250x40'0"0(10x3). **Material No:** 200202504000 **Made in:** Canada
Melted and Poured in: Canada
Sales Order: 1607249 **Purchase Order:** C455003698 **Cust Material#:** 6520025040

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
845858	0.170	0.760	0.008	0.008	0.018	0.036	0.042	0.002	0.005	0.019	0.035	0.002	0.002	0.0002	0.0060	0.0002

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE: 0.31
M102067416	30	069176 Psi	074225 Psi	23.5 %	ASTM A500-21 GRADE B&C	

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
845858	STELCO	Nanticoke,ON	BOF	36.90%	19.80%	14.40%	100%	1000

Material Note:
Sales Or. Note:

Authorized by Quality Assurance: Jason Richard

The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements.
CE calculated using the AWS D1.1 method. This document is in compliance with the requirements of EN 10204 type 3.1

Steel Tube Institute OF NORTH AMERICA

Metals Service Center Institute

Page: 1 of 1

Figure A-15. HSS2x2x¼ Steel Square Tube, Test Nos. HP34S-1 and HP34S-2 (Item No. d5)

STEEL AND PIPE SUPPLY
SPS Coil Processing Tulsa
5275 Bird Creek Ave.
Port of Catoosa, OK 74015

METALLURGICAL TEST REPORT

PAGE 1 of 1
DATE 02/11/2021
TIME 11:33:35
USER 40CLERK1

SOLD TO

SHIP TO
13716
Kansas City Warehouse
401 New Century Parkway
New Century KS 66031-1127

Order	Material No.	Description	Quantity	Weight	Customer Part	Customer PO	Ship Date
40360461-0190	72896240	1/4 96 X 240 A36 MILL PLATE	2	3,267.200			02/10/2021

Chemical Analysis

Heat No. A0J157 Vendor SSAB - MONTPELIER WORKS DOMESTIC Mill SSAB - MONTPELIER WORKS **Melted and Manufactured in the USA**
Produced from Coil

Carbon	Manganese	Phosphorus	Sulphur	Silicon	Nickel	Chromium	Molybdenum	Boron	Copper	Aluminum	Titanium	Vanadium	Columbium	Nitrogen	Tin
0.1600	0.8400	0.0080	0.0050	0.0300	0.1100	0.1200	0.0300	0.0000	0.3000	0.0250	0.0070	0.0020	0.0000	0.0093	0.0000

Mechanical / Physical Properties

Mill Coil No. A0J1570311

Tensile	Yield	Elong (2 in)	Rckwl	Grain	Charpy	Charpy Dr	Charpy Sz	Temperature	Olsen
71000.000	50500.000	31.50			0	NA			
76100.000	57400.000	28.50			0	NA			
79900.000	62000.000	20.80			0	NA			
80200.000	61800.000	21.40			0	NA			

Batch 1000084126 2 EA 3,267.200 LB

THE CHEMICAL, PHYSICAL, OR MECHANICAL TESTS REPORTED ABOVE ACCURATELY REFLECT INFORMATION AS CONTAINED IN THE RECORDS OF THE CORPORATION.
The material is in compliance with EN 10204 Section 4.1 Inspection Certificate Type 3.1

Figure A-16. 2¼-in. x 2¼-in. x ¼-in. Steel Plate, Test Nos. HP34S-1 and HP34S-2 (Item No. d6)

H#10543730 R#21-805 5/8"-11 UNC, 7-7/8" Long Threaded Rod

Portland Bolt
& MANUFACTURING COMPANY

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

For: MIDWEST ROADSIDE SAFETY FACIL
PB Invoice#: 138847
Cust PO#: HP34S
Date: 2/03/2021
Shipped: 2/03/2021

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.

Product:
ASTM F1554G105 ALL THRD ROD

Nuts:
ASTM A194-2H HVY HEX

Washers:
ASTM F436-1 RND

Coatings:
ITEMS HOT DIP GALVANIZED PER ASTM F2329/A153C

By:
Certification Department Quality Assurance
Dane McKinnon

Figure A-17. ⅝ in. – 11 UNC Threaded Rod, Test Nos. HP34S-1 and HP34S-2 (Item No. d7)

STEEL AND PIPE SUPPLY
SPS Coil Processing Tulsa
5275 Bird Creek Ave.
Port of Catoosa, OK 74015

METALLURGICAL TEST REPORT

PAGE 1 of 1
DATE 03/19/2021
TIME 08:14:03
USER 40CLERK1

SOLD TO

SHIP TO
13716
Kansas City Warehouse
401 New Century Parkway
New Century KS 66031-1127

Order	Material No.	Description	Quantity	Weight	Customer Part	Customer PO	Ship Date
40363783-0060	70672120TM	3/16 72 X 120 A36 TEMPERPASS STPMLPL	9	4,136.400			03/18/2021

Chemical Analysis

Heat No. 21013251 Vendor BIG RIVER STEEL LLC DOMESTIC Mill BIG RIVER STEEL LLC **Melted and Manufactured in the USA**
Produced from Coil

Carbon	Manganese	Phosphorus	Sulphur	Silicon	Nickel	Chromium	Molybdenum	Boron	Copper	Aluminum	Titanium	Vanadium	Columbium	Nitrogen	Tin
0.0600	0.8500	0.0110	0.0030	0.0200	0.0400	0.0500	0.0160	0.0001	0.1100	0.0250	0.0010	0.0040	0.0020	0.0093	0.0043

Mechanical / Physical Properties

Mill Coil No. 21013251-01

Tensile	Yield	Elong (2 in)	Rckwl	Grain	Charpy	Charpy Dr	Charpy Sz	Temperature	Olsen
66500.000	50200.000	30.10			0	NA			
66000.000	48900.000	30.70			0	NA			
65800.000	48900.000	29.50			0	NA			
66100.000	49300.000	31.50			0	NA			

Batch 1000139270 9 EA 4,136.400 LB

THE CHEMICAL, PHYSICAL, OR MECHANICAL TESTS REPORTED ABOVE ACCURATELY REFLECT INFORMATION AS CONTAINED IN THE RECORDS OF THE CORPORATION.
The material is in compliance with EN 10204 Section 4.1 Inspection Certificate Type 3.1
This test report shall not be reproduced, except in full, without the written approval of Steel & Pipe Supply Company, Inc.

Figure A-18. 7-in. x 1½-in. x $^{3}/_{16}$-in. Shim, Test Nos. HP34S-1 and HP34S-2 (Item No. d8)

Certified Material Test Report to ISO16228 F3.1 (EN 10204-2004 3.1)
FOR ASME SA194/ ASTM A194-16 GRADE 2H HVY HEX NUTS

FACTORY: NINGBO HAIXIN HARDWARE CO.,LTD. DATE: MAR.13.2020
ADDRESS: XIJINGTANG,LUOTUO NINGBO ZHEJIANG 315205 CHINA COUNTRY OF ORIGIN: CHINA
MFG LOT NUMBER: 5158130002
CUSTOMER: BRIGHTON-BEST INTERNATIONAL (TAIWAN) INC PO NUMBER: U71705
QNTY SHIPPED: 64.800MPCS PART NO: 313003
SAMPLE SIZE : ACC. TO ASME B18 . 18 . 1 - 11 MANUFACTURER DATE: 2020/2/17
SIZE & DESCRIPTION: 5/8-11+0.020"(HDG/WAX/BLUE DYE)
FINISH:H.T.HOT DIP GAL PER ASTM A153-09/ASTM F2329-13

STEEL PROPERTIES: TEST FACILITY: S
STEEL GRADE: SWRCH45K SIZE: 26mm HEAT NO: J21908483
CHEMISTRY COMPOSITION:

CHEMIST	C %	Mn %	P %	S %	Si %	Cr %	Ni %	Cu %	Mo %	OTHERS
SPE:	MIN 0.40	MAX 1.00	MAX 0.04	MAX 0.05	MAX 0.40					
TEST:	0.45	0.7	0.011	0.006	0.15					

DIMENSIONAL INSPECTIONS SPECIFICATION: ASME /ANSI B18.2.2-2015 TEST FACILITY: M

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
APPEARANCE	ASTM F812-12		PASSED	100	0
WIDTH A/F	1.031"-1.062"		1.044"-1.059"	32	0
WIDTH A/C	1.175"-1.227"		1.183"-1.215"	32	0
THREAD	ASME B1.1-03	2B	PASSED	8	0
HEIGHT	0.587"-0.631"		0.594"-0.615"	32	0
MARK	2HZN LM		PASSED	100	0
HDG THICKNISS	ASTM A153-09/ASTM F2329-13 min:43um		57UM-71UM	20	0

MECHANICAL PROPERTIES: TO 1-1/2" in SPECIFICATION:ASTM/ASME A194/SA194-16 TEST FACILITY: M

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
HARDNESS	ASTM E18-12	24-35HRC	HRC30-31	5	0
PROOF LOAD	ASTM F606-11	MIN39550LBF	39550LBF	5	0
HARDNESS AFTER 24H AT 540°C	ASTM A194	MIN 89 HRB	HRB 95-98	5	0
TEMPERING TEMPERATURE Min455°C			PASSED(520°C)		
MACROETCH	ASTM E381-12	S1/R1/C1~S4/R4/C4	S2/R2/C2	5	0

PARTS ARE MANUFACTURED AND TESTED IN ACCORDANCE WITH ASME SA194/ ASTM A194-16
PARTS MEET ASME SECTION II PART A
ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED SPECIFICATION. WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.

All parts meet the requirements of FQA and records of compliance are on file.
Maker's ISO# ISO9001-0068481

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

Figure A-19. ⅝ in. – 11 UNC Heavy Hex Nut, Test Nos. HP34S-1 and HP34S-2 (Item No. e1)

H#107480 R#21-805 5/8" Dia. Hardened Washer

Portland Bolt
& MANUFACTURING COMPANY

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

For: MIDWEST ROADSIDE SAFETY FACIL
PB Invoice#: 138847
Cust PO#: HP34S
Date: 2/03/2021
Shipped: 2/03/2021

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.

Product:
ASTM F1554G105 ALL THRD ROD

Nuts:
ASTM A194-2H HVY HEX

Washers:
ASTM F436-1 RND

Coatings:
ITEMS HOT DIP GALVANIZED PER ASTM F2329/A153C

By:
Certification Department Quality Assurance
Dane McKinnon

Figure A-20. ⅝-in. Diameter Washer, Test Nos. HP34S-1 and HP34S-2 (Item No. e2)

Appendix B. Vehicle Center of Gravity Determination

	Test Name: HP34S-1	VIN:	1C6RR6LT8GS269861
Model Year: 2016	Make: Dodge	Model:	Ram 1500

Vehicle CG Determination

Vehicle Equipment		Weight (lb)	Vertical CG (in.)	Vertical M (lb-in.)
+	Unballasted Truck (Curb)	5323	29.260655	155754.47
+	Hub	19	15.5	294.5
+	Brake activation cylinder & frame	7	28 1/2	199.5
+	Pneumatic tank (Nitrogen)	22	28 1/2	627
+	Strobe/Brake Battery	10	27 1/4	272.5
+	Brake Receiver/Wires	5	53 1/2	267.5
+	CG Plate including DAQ	50	31	1550
-	Battery	-39	40 1/2	-1579.5
-	Oil	-12	17	-204
-	Interior	-118	44	-5192
-	Fuel	-171	18 1/4	-3120.75
-	Coolant	-2	34	-68
-	Washer fluid	-7	33	-231
+	Water Ballast (In Fuel Tank)			0
+	Onboard Supplemental Battery			0
-	Spare Tire	-54	24 1/2	-1323
				0
				147247.22

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

Estimated Total Weight (lb)	5033
Vertical CG Location (in.)	29.25635

Vehicle Dimensions for C.G. Calculations

Wheel Base: 140.5 in.
Front Track Width: 68.625 in.
Rear Track Width: 68.25 in.

Center of Gravity	2270P MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb)	5000 ± 110	5045	45.0
Longitudinal CG (in.)	63 ± 4	59.709019	-3.29098
Lateral CG (in.)	NA	0.3594834	NA
Vertical CG (in.)	28 or greater	29.26	1.25635

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	1508	1477
Rear	1174	1164

FRONT	2985	lb
REAR	2338	lb
TOTAL	5323	lb

TEST INERTIAL WEIGHT (lb)

	Left	Right
Front	1427	1474
Rear	1069	1075

FRONT	2901	lb
REAR	2144	lb
TOTAL	5045	lb

Figure B-1. Vehicle Mass Distribution, Test No. HP34S-1

Test Name:	HP34S-2	VIN:	KMHCT4AE9GUO78507
Model Year: 2016	Make: Hyundai	Model:	Accent

Vehicle CG Determination

	Vehicle Equipment	Weight (lb)
+	Unballasted Car (Curb)	2461
+	Hub	19
+	Brake activation cylinder & frame	7
+	Pneumatic tank (Nitrogen)	30
+	Strobe/Brake Battery	5
+	Brake Receiver/Wires	5
+	CG Plate including DAQ	20
-	Battery	-31
-	Oil	-12
-	Interior	-78
-	Fuel	-7
-	Coolant	-5
-	Washer fluid	0
+	Water Ballast (In Fuel Tank)	0
+	Onboard Supplemental Battery	0

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

Estimated Total Weight (lb) 2414

Vehicle Dimensions for C.G. Calculations

Wheel Base:	101.0	in.	Front Track Width:	59.625	in.
Roof Height:	56.75	in.	Rear Track Width:	59.375	in.

Center of Gravity	1100C MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb)	2420 ± 55	2413	-7.0
Longitudinal CG (in.)	39 ± 4	38.006	-0.994
Lateral CG (in.)	NA	-0.037	NA
Vertical CG (in.)	NA	21.89	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	810	730
Rear	453	468

FRONT	1540	lb
REAR	921	lb
TOTAL	2461	lb

TEST INERTIAL WEIGHT (lb)

	Left	Right
Front	774	731
Rear	434	474

FRONT	1505	lb
REAR	908	lb
TOTAL	2413	lb

Figure B-2. Vehicle Mass Distribution, Test No. HP34S-2

Appendix C. Vehicle Deformation Records

The following figures and tables describe all occupant compartment measurements taken on the test vehicles used in full-scale crash testing herein. MASH 2016 defines intrusion as the occupant compartment being deformed and reduced in size with no penetration. Outward deformations, which are denoted as negative numbers within this Appendix, are not considered as crush toward the occupant, and are not subject to evaluation by MASH 2016 criteria.

Model Year: 2016

Test Name: HP34S-1
Make: Dodge

VIN: 1C6RR6LT8GS269861
Model: Ram 1500

VEHICLE DEFORMATION
DRIVER SIDE FLOOR PAN - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	63.8812	-43.0319	-5.4444	60.0584	-39.6832	-8.9856	3.8228	3.3487	3.5412	6.1942	5.2109	X, Z
	2	65.3495	-37.7819	-3.9518	63.4947	-36.4895	-5.7434	1.8548	1.2924	1.7916	2.8845	2.5788	X, Z
	3	65.1055	-31.5882	-3.8533	64.4460	-30.9877	-4.4762	0.6595	0.6005	0.6229	1.0879	0.9072	X, Z
	4	63.8484	-27.1295	-5.0385	63.3465	-26.6030	-5.6781	0.5019	0.5265	0.6396	0.9686	0.8130	X, Z
	5	61.9862	-23.3940	-7.1196	61.6294	-23.0029	-8.2832	0.3568	0.3911	1.1636	1.2784	1.2171	X, Z
	6	57.3995	-44.2021	0.2101	55.3409	-41.7734	-1.5650	2.0586	2.4287	1.7751	3.6452	2.7182	X, Z
	7	57.4502	-38.8644	0.1694	56.8516	-37.9366	-0.0400	0.5986	0.9278	0.2094	1.1238	0.6342	X, Z
	8	57.4613	-32.4327	0.1719	57.1369	-31.3778	-0.1739	0.3244	1.0549	0.3458	1.1566	0.4741	X, Z
	9	57.5356	-27.5586	0.1422	57.0709	-26.5809	-0.5819	0.4647	0.9777	0.7241	1.3024	0.8604	X, Z
	10	56.3689	-23.8946	-4.4379	56.0626	-23.7601	-5.7598	0.3063	0.1345	1.3219	1.3636	1.3569	X, Z
FLOOR PAN (Z)	11	52.9223	-44.0010	1.0176	52.6987	-42.9799	1.7459	0.2236	1.0211	-0.7283	1.2740	-0.7283	Z
	12	52.8980	-39.3250	1.0397	52.6017	-38.2486	1.4362	0.2963	1.0764	-0.3965	1.1848	-0.3965	Z
	13	52.8675	-33.0004	1.0786	52.5147	-32.0372	0.7844	0.3528	0.9632	0.2942	1.0671	0.2942	Z
	14	52.9281	-27.8323	1.1132	52.4538	-26.9174	0.2614	0.4743	0.9149	0.8518	1.3370	0.8518	Z
	15	51.6964	-23.9911	-4.3081	51.3459	-24.1108	-5.6307	0.3505	-0.1197	1.3226	1.3735	1.3226	Z
	16	46.9857	-44.1234	0.9882	46.9341	-43.2665	1.5898	0.0516	0.8569	-0.6016	1.0483	-0.6016	Z
	17	46.9886	-38.9857	0.9950	46.7368	-38.1408	1.0236	0.2518	0.8449	-0.0286	0.8821	-0.0286	Z
	18	47.0844	-32.1471	1.0394	46.7424	-31.3913	0.2994	0.3420	0.7558	0.7400	1.1117	0.7400	Z
	19	47.1234	-27.8189	1.0775	46.6226	-27.0453	-0.0330	0.5008	0.7736	1.1105	1.4431	1.1105	Z
	20	46.3253	-24.4032	-3.3576	45.9536	-24.3361	-4.8143	0.3717	0.0671	1.4567	1.5049	1.4567	Z
	21	42.2406	-44.2511	0.9506	42.2435	-43.5777	0.8643	-0.0029	0.6734	0.0863	0.6789	0.0863	Z
	22	41.9709	-39.0225	0.9742	41.7924	-38.3697	0.4066	0.1785	0.6528	0.5676	0.8833	0.5676	Z
	23	42.6027	-32.9507	1.0012	42.2506	-32.2610	-0.1037	0.3521	0.6897	1.1049	1.3492	1.1049	Z
	24	42.8627	-27.7557	1.0500	42.3765	-27.1204	-0.1932	0.4862	0.6353	1.2432	1.4784	1.2432	Z
	25	43.0395	-24.4034	-3.4571	42.6856	-24.7519	-5.1309	0.3539	-0.3485	1.6738	1.7459	1.6738	Z
	26	39.3722	-44.6915	-0.0880	39.3513	-44.1941	-0.2250	0.0209	0.4974	0.1370	0.5163	0.1370	Z
	27	39.2943	-38.6729	0.1727	39.0827	-38.1275	-0.4866	0.2116	0.5454	0.6593	0.8814	0.6593	Z
	28	39.3617	-33.2573	0.2146	38.9098	-32.7713	-0.8552	0.4519	0.4860	1.0698	1.2589	1.0698	Z
	29	39.3893	-28.1270	0.2026	38.8242	-27.5672	-1.0133	0.5651	0.5598	1.2159	1.4530	1.2159	Z
	30	39.9884	-24.4483	-3.4080	39.6040	-24.7223	-5.1475	0.3844	-0.2740	1.7395	1.8024	1.7395	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 C-1. Floor Pan Deformation Data – Set 1, Test No. HP34S-1

Model Year: 2016 | Test Name: HP34S-1 | VIN: 1C6RR6LT8GS269861
Make: Dodge | Model: Ram 1500

VEHICLE DEFORMATION
DRIVER SIDE FLOOR PAN - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	60.9450	-23.8757	-1.1514	57.1593	-20.7038	-3.1600	3.7857	3.1719	2.0086	5.3317	4.2856	X, Z
	2	62.4344	-18.6289	0.3314	60.5331	-17.5302	0.1666	1.9013	1.0987	0.1648	2.2021	1.9084	X, Z
	3	62.2167	-12.4340	0.4166	61.4899	-12.0337	1.4523	0.7268	0.4003	-1.0357	1.3271	0.7268	X
	4	60.9797	-7.9725	-0.7792	60.4526	-7.6429	0.2180	0.5271	0.3296	-0.9972	1.1751	0.5271	X
	5	59.1354	-4.2335	-2.8699	58.8287	-4.0340	-2.4342	0.3067	0.1995	-0.4357	0.5689	0.3067	X
	6	54.4533	-25.0063	4.4997	52.2373	-22.7520	4.1384	2.2160	2.2543	0.3613	3.1817	2.2453	X, Z
	7	54.5268	-19.6690	4.4477	53.7349	-18.9241	5.6981	0.7919	0.7449	-1.2504	1.6569	0.7919	X
	8	54.5654	-13.2374	4.4367	54.0697	-12.3675	5.5649	0.4957	0.8699	-1.1282	1.5084	0.4957	X
	9	54.6606	-8.3637	4.3967	54.0479	-7.5708	5.1505	0.6127	0.7929	-0.7538	1.2539	0.6127	X
	10	53.5136	-4.7045	-0.1922	53.1934	-4.7492	-0.0547	0.3202	-0.0447	-0.1375	0.3513	0.3202	X
FLOOR PAN (Z)	11	49.9763	-24.7843	5.3027	49.5021	-23.9361	7.3812	0.4742	0.8482	-2.0785	2.2944	-2.0785	Z
	12	49.9719	-20.1082	5.3149	49.4464	-19.2046	7.0642	0.5255	0.9036	-1.7493	2.0378	-1.7493	Z
	13	49.9684	-13.7835	5.3404	49.4197	-12.9936	6.4041	0.5487	0.7899	-1.0637	1.4340	-1.0637	Z
	14	50.0510	-8.6157	5.3641	49.4083	-7.8741	5.8746	0.6427	0.7416	-0.5105	1.1062	-0.5105	Z
	15	48.8406	-4.7808	-0.0665	48.4726	-5.0669	-0.0471	0.3680	-0.2861	-0.0194	0.4665	-0.0194	Z
	16	44.0392	-24.8815	5.2683	43.7416	-24.1825	7.0765	0.2976	0.6990	-1.8082	1.9613	-1.8082	Z
	17	44.0641	-19.7439	5.2642	43.5949	-19.0563	6.5002	0.4692	0.6876	-1.2360	1.4902	-1.2360	Z
	18	44.1891	-12.9056	5.2941	43.6666	-12.3079	5.7695	0.5225	0.5977	-0.4754	0.9253	-0.4754	Z
	19	44.2465	-8.5776	5.3232	43.5859	-7.9616	5.4298	0.6606	0.6160	-0.1066	0.9095	-0.1066	Z
	20	43.4669	-5.1679	0.8800	43.0596	-5.2535	0.6300	0.4073	-0.0856	0.2500	0.4855	0.2500	Z
	21	39.2936	-24.9890	5.2266	39.0692	-24.4618	6.2305	0.2244	0.5272	-1.0039	1.1559	-1.0039	Z
	22	39.0463	-19.7593	5.2389	38.6666	-19.2514	5.7560	0.3797	0.5079	-0.5171	0.8182	-0.5171	Z
	23	39.7040	-13.6902	5.2536	39.1807	-13.1466	5.2515	0.5233	0.5436	0.0021	0.7546	0.0021	Z
	24	39.9861	-8.4962	5.2916	39.3450	-8.0072	5.1600	0.6411	0.4890	0.1316	0.8170	0.1316	Z
	25	40.1812	-5.1543	0.7777	39.7980	-5.6468	0.2296	0.3832	-0.4925	0.5481	0.8305	0.5481	Z
	26	36.4244	-25.4194	4.1864	36.2019	-25.0593	5.0675	0.2225	0.3601	-0.8811	0.9775	-0.8811	Z
	27	36.3719	-19.4000	4.4342	35.9826	-18.9914	4.7929	0.3893	0.4086	-0.3587	0.6687	-0.3587	Z
	28	36.4624	-13.9846	4.4648	35.8569	-13.6345	4.4145	0.6055	0.3501	0.0503	0.7012	0.0503	Z
	29	36.5120	-8.8545	4.4419	35.8120	-8.4301	4.2489	0.7000	0.4244	0.1930	0.8410	0.1930	Z
	30	37.1300	-5.1861	0.8240	36.7182	-5.5957	0.1334	0.4118	-0.4096	0.6906	0.9024	0.6906	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 C-2. Floor Pan Deformation Data – Set 2, Test No. HP34S-1

Model Year: 2016 | Test Name: HP34S-1 | VIN: 1C6RR6LT8GS269861
Make: Dodge | Model: Ram 1500

VEHICLE DEFORMATION
DRIVER SIDE INTERIOR CRUSH - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	50.4538	-45.8999	-29.7889	50.2632	-45.4651	-31.1834	0.1906	0.4348	-1.3945	1.4731	1.4731	X, Y, Z
	2	48.7836	-33.5091	-33.9288	48.8091	-32.9991	-35.1157	-0.0255	0.5100	-1.1869	1.2921	1.2921	X, Y, Z
	3	47.0747	-15.2397	-31.0139	47.1948	-14.7481	-31.7582	-0.1201	0.4916	-0.7443	0.9000	0.9000	X, Y, Z
	4	47.5646	-45.6117	-20.1531	47.0360	-45.1478	-21.6952	0.5286	0.4639	-1.5421	1.6949	1.6949	X, Y, Z
	5	45.5541	-34.0289	-19.2452	45.0703	-33.6952	-20.5807	0.4838	0.3337	-1.3355	1.4591	1.4591	X, Y, Z
	6	44.2006	-15.3127	-18.1803	43.9349	-15.1685	-19.0757	0.2657	0.1442	-0.8954	0.9451	0.9451	X, Y, Z
SIDE PANEL (Y)	7	56.1449	-47.5908	-9.4948	54.7829	-44.8749	-10.7062	1.3620	2.7159	-1.2114	3.2709	2.7159	Y
	8	56.1095	-47.6025	-6.1560	54.7845	-44.7021	-7.3400	1.3250	2.9004	-1.1840	3.4014	2.9004	Y
	9	58.2262	-47.5666	-5.8625	56.8302	-44.7276	-7.0796	1.3960	2.8390	-1.2171	3.3897	2.8390	Y
IMPACT SIDE DOOR (Y)	10	22.1603	-50.2506	-19.4746	21.6250	-52.1843	-20.2396	0.5353	-1.9337	-0.7650	2.1473	-1.9337	Y
	11	32.6992	-50.3999	-19.1018	31.9300	-53.2018	-20.0035	0.7692	-2.8019	-0.9017	3.0423	-2.8019	Y
	12	44.3013	-49.9996	-19.4816	43.3629	-51.3430	-20.6439	0.9384	-1.3434	-1.1623	2.0090	-1.3434	Y
	13	23.4831	-50.4750	-3.9853	22.9580	-51.5265	-4.8955	0.5251	-1.0515	-0.9102	1.4866	-1.0515	Y
	14	35.4884	-50.6254	-3.3310	34.9103	-51.3188	-4.2556	0.5781	-0.6934	-0.9246	1.2922	-0.6934	Y
	15	43.3013	-50.5937	-3.7066	42.6340	-50.6126	-4.8106	0.6673	-0.0189	-1.1040	1.2901	-0.0189	Y
ROOF - (Z)	16	39.5468	-38.1986	-46.6699	39.5104	-38.1128	-47.4049	0.0364	0.0858	-0.7350	0.7409	-0.7350	Z
	17	42.2836	-27.6285	-46.8493	42.2607	-27.5506	-47.3692	0.0229	0.0779	-0.5199	0.5262	-0.5199	Z
	18	43.0341	-15.4702	-47.0418	42.9943	-15.3813	-47.3548	0.0398	0.0889	-0.3130	0.3278	-0.3130	Z
	19	20.5954	-36.6416	-50.7003	20.5333	-36.3704	-51.1878	0.0621	0.2712	-0.4875	0.5613	-0.4875	Z
	20	21.7208	-24.4329	-51.2617	21.7205	-24.2169	-51.6903	0.0003	0.2160	-0.4286	0.4800	-0.4286	Z
	21	22.0567	-16.7988	-51.3433	22.0357	-16.5142	-51.6722	0.0210	0.2846	-0.3289	0.4354	-0.3289	Z
	22	3.2755	-36.7437	-51.1967	3.1504	-36.4035	-51.7035	0.1251	0.3402	-0.5068	0.6231	-0.5068	Z
	23	2.3526	-23.9789	-51.7273	2.3965	-23.7571	-52.1090	-0.0439	0.2218	-0.3817	0.4436	-0.3817	Z
	24	1.6937	-16.4896	-51.7789	1.6842	-16.1861	-52.0758	0.0095	0.3035	-0.2969	0.4247	-0.2969	Z
	25	-8.5913	-37.1145	-51.1273	-8.6720	-36.7626	-51.6011	0.0807	0.3519	-0.4738	0.5957	-0.4738	Z
	26	-9.0836	-24.8411	-51.5460	-9.1666	-24.4208	-51.8919	0.0830	0.4203	-0.3459	0.5506	-0.3459	Z
	27	-9.0008	-16.2082	-51.5896	-9.0321	-15.8562	-51.8426	0.0313	0.3520	-0.2530	0.4346	-0.2530	Z
	28	-20.6612	-38.2928	-50.6656	-20.6078	-37.9608	-51.1520	-0.0534	0.3320	-0.4864	0.5913	-0.4864	Z
	29	-20.5989	-26.0888	-51.0959	-20.5909	-25.7515	-51.4674	-0.0080	0.3373	-0.3715	0.5018	-0.3715	Z
	30	-20.5479	-16.5258	-51.1525	-20.4662	-16.1842	-51.4436	-0.0817	0.3416	-0.2911	0.4562	-0.2911	Z
A-PILLAR Maximum (X, Y, Z)	31	57.3751	-46.4838	-32.4390	57.3916	-46.6180	-33.4587	-0.0165	-0.1342	-1.0197	1.0286	0.0000	NA
	32	54.0351	-45.8063	-35.2700	54.0728	-45.8644	-36.2860	-0.0377	-0.0581	-1.0160	1.0184	0.0000	NA
	33	51.1549	-45.2174	-37.5570	51.1129	-45.2284	-38.5321	0.0420	-0.0110	-0.9751	0.9761	0.0420	X
	34	47.6532	-44.4697	-39.9372	47.6600	-44.4657	-40.9188	-0.0068	0.0040	-0.9816	0.9816	0.0040	Y
	35	44.9794	-43.8883	-41.5759	45.0102	-43.9332	-42.5099	-0.0308	-0.0449	-0.9340	0.9356	0.0000	NA
	36	42.2960	-43.3731	-43.4584	42.2924	-43.3689	-44.3621	0.0036	0.0042	-0.9037	0.9037	0.0055	X, Y
A-PILLAR Lateral (Y)	31	57.3751	-46.4838	-32.4390	57.3916	-46.6180	-33.4587	-0.0165	-0.1342	-1.0197	1.0286	-0.1342	Y
	32	54.0351	-45.8063	-35.2700	54.0728	-45.8644	-36.2860	-0.0377	-0.0581	-1.0160	1.0184	-0.0581	Y
	33	51.1549	-45.2174	-37.5570	51.1129	-45.2284	-38.5321	0.0420	-0.0110	-0.9751	0.9761	-0.0110	Y
	34	47.6532	-44.4697	-39.9372	47.6600	-44.4657	-40.9188	-0.0068	0.0040	-0.9816	0.9816	0.0040	Y
	35	44.9794	-43.8883	-41.5759	45.0102	-43.9332	-42.5099	-0.0308	-0.0449	-0.9340	0.9356	-0.0449	Y
	36	42.2960	-43.3731	-43.4584	42.2924	-43.3689	-44.3621	0.0036	0.0042	-0.9037	0.9037	0.0042	Y
B-PILLAR Maximum (X, Y, Z)	37	12.1177	-43.3484	-44.1371	12.1443	-43.0990	-44.6916	-0.0266	0.2494	-0.5545	0.6086	0.2494	Y
	38	15.1361	-44.4615	-41.0231	15.1658	-44.2519	-41.6066	-0.0297	0.2096	-0.5835	0.6207	0.2096	Y
	39	12.5693	-46.6199	-35.0141	12.5896	-46.3965	-35.6074	-0.0203	0.2234	-0.5933	0.6343	0.2234	Y
	40	15.7022	-47.1224	-32.0069	15.7090	-46.9260	-32.6113	-0.0068	0.1964	-0.6044	0.6355	0.1964	Y
B-PILLAR Lateral (Y)	37	12.1177	-43.3484	-44.1371	12.1443	-43.0990	-44.6916	-0.0266	0.2494	-0.5545	0.6086	0.2494	Y
	38	15.1361	-44.4615	-41.0231	15.1658	-44.2519	-41.6066	-0.0297	0.2096	-0.5835	0.6207	0.2096	Y
	39	12.5693	-46.6199	-35.0141	12.5896	-46.3965	-35.6074	-0.0203	0.2234	-0.5933	0.6343	0.2234	Y
	40	15.7022	-47.1224	-32.0069	15.7090	-46.9260	-32.6113	-0.0068	0.1964	-0.6044	0.6355	0.1964	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 C-3. Occupant Compartment Deformation Data – Set 1, Test No. HP34S-1

Model Year: 2016 | Test Name: HP34S-1 | VIN: 1C6RR6LT8GS269861
Make: Dodge | Model: Ram 1500

VEHICLE DEFORMATION
DRIVER SIDE INTERIOR CRUSH - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	47.5325	-26.7274	-25.4918	47.9172	-26.3782	-25.6428	-0.3847	0.3492	-0.1510	0.5411	0.5411	X, Y, Z
	2	45.9174	-14.3381	-29.6579	46.6423	-13.9041	-29.6113	-0.7249	0.4340	0.0466	0.8462	0.8462	X, Y, Z
	3	44.2794	3.9438	-26.7810	45.0557	4.3571	-26.2964	-0.7763	-0.4133	0.4846	1.0041	1.0041	X, Y, Z
	4	44.6336	-26.4085	-15.8599	44.4489	-26.0394	-16.2408	0.1847	0.3691	-0.3809	0.5616	0.5616	X, Y, Z
	5	42.6692	-14.8157	-14.9771	42.5264	-14.5746	-15.1773	0.1428	0.2411	-0.2002	0.3444	0.3444	X, Y, Z
	6	41.3905	3.9079	-13.9505	41.4679	3.9591	-13.7020	-0.0774	-0.0512	0.2485	0.2653	0.2653	X, Y, Z
SIDE PANEL (Y)	7	53.1938	-28.4014	-5.1879	51.9120	-25.8128	-5.0561	1.2818	2.5886	0.1318	2.8916	2.5886	Y
	8	53.1545	-28.4063	-1.8491	51.8281	-25.6395	-1.6910	1.3264	2.7668	0.1581	3.0724	2.7668	Y
	9	55.2711	-28.3784	-1.5533	53.8662	-25.6777	-1.3780	1.4049	2.7007	0.1753	3.0493	2.7007	Y
IMPACT SIDE DOOR (Y)	10	19.2099	-30.9427	-15.2011	18.9656	-32.9175	-15.4395	0.2443	-1.9748	-0.2384	2.0041	-1.9748	Y
	11	29.7477	-31.1342	-14.8160	29.2546	-33.9990	-14.9383	0.4931	-2.8648	-0.1223	2.9095	-2.8648	Y
	12	41.3517	-30.7817	-15.1835	40.7115	-32.2114	-15.2843	0.6402	-1.4297	-0.1008	1.5697	-1.4297	Y
	13	20.5143	-31.1419	0.2901	19.9074	-32.2655	-0.0662	0.6069	-1.1236	-0.3563	1.3258	-1.1236	Y
	14	32.5182	-31.3398	0.9584	31.8404	-32.1321	0.8810	0.6778	-0.7923	-0.0774	1.0455	-0.7923	Y
	15	40.3316	-31.3406	0.5915	39.5800	-31.4740	0.5250	0.7516	-0.1334	-0.0665	0.7662	-0.1334	Y
ROOF - (Z)	16	36.6760	-19.0151	-42.4003	37.6313	-18.9620	-42.1357	-0.9553	0.0531	0.2646	0.9927	0.2646	Z
	17	39.4559	-8.4567	-42.5974	40.4453	-8.4171	-42.0292	-0.9894	0.0396	0.5682	1.1416	0.5682	Z
	18	40.2560	3.6982	-42.8130	41.2540	3.7475	-41.9959	-0.9980	-0.0493	0.8171	1.2908	0.8171	Z
	19	17.7356	-17.3891	-46.4553	18.7690	-17.1022	-46.4056	-1.0334	0.2869	0.0497	1.0736	0.0497	Z
	20	18.9113	-5.1863	-47.0395	20.0443	-4.9564	-46.8774	-1.1330	0.2299	0.1621	1.1674	0.1621	Z
	21	19.2783	2.4462	-47.1358	20.4068	2.7441	-46.8513	-1.1285	-0.2979	0.2845	1.2013	0.2845	Z
	22	0.4160	-17.4219	-46.9712	1.4053	-17.0273	-47.3685	-0.9893	0.3946	-0.3973	1.1368	-0.3973	Z
	23	-0.4544	-4.6545	-47.5280	0.7407	-4.3765	-47.7932	-1.1951	0.2780	-0.2652	1.2553	-0.2652	Z
	24	-1.0828	2.8373	-47.5951	0.0748	3.1988	-47.7784	-1.1576	-0.3615	-0.1833	1.2265	-0.1833	Z
	25	-11.4523	-17.7443	-46.9147	-10.4179	-17.3129	-47.5703	-1.0344	0.4314	-0.6556	1.2984	-0.6556	Z
	26	-11.8942	-5.4698	-47.3581	-10.8281	-4.9684	-47.8737	-1.0661	0.5014	-0.5156	1.2860	-0.5156	Z
	27	-11.7762	3.1625	-47.4185	-10.6416	3.5953	-47.8210	-1.1346	-0.4328	-0.4025	1.2793	-0.4025	Z
	28	-23.5274	-18.8727	-46.4643	-22.3685	-18.4368	-47.4285	-1.1589	0.4359	-0.9642	1.5693	-0.9642	Z
	29	-23.4149	-6.6699	-46.9186	-22.2676	-6.2279	-47.7433	-1.1473	0.4420	-0.8247	1.4805	-0.8247	Z
	30	-23.3251	2.8927	-46.9940	-22.0840	3.3384	-47.7164	-1.2411	-0.4457	-0.7224	1.5036	-0.7224	Z
A-PILLAR Maximum (X, Y, Z)	31	54.4544	-27.3446	-28.1329	55.0944	-27.5758	-27.7339	-0.6400	-0.2312	0.3990	0.7888	0.3990	Z
	32	51.1204	-26.6591	-30.9690	51.8543	-26.8021	-30.6457	-0.7339	-0.1430	0.3233	0.8146	0.3233	Z
	33	48.2451	-26.0630	-33.2604	48.9572	-26.1481	-32.9672	-0.7121	-0.0851	0.2932	0.7748	0.2932	Z
	34	44.7493	-25.3058	-35.6461	45.5716	-25.3643	-35.4419	-0.8223	-0.0585	0.2042	0.8493	0.2042	Z
	35	42.0796	-24.7168	-37.2889	42.9670	-24.8157	-37.1007	-0.8874	-0.0989	0.1882	0.9125	0.1882	Z
	36	39.4005	-24.1944	-39.1755	40.3012	-24.2347	-39.0223	-0.9007	-0.0403	0.1532	0.9145	0.1532	Z
A-PILLAR Lateral (Y)	31	54.4544	-27.3446	-28.1329	55.0944	-27.5758	-27.7339	-0.6400	-0.2312	0.3990	0.7888	-0.2312	Y
	32	51.1204	-26.6591	-30.9690	51.8543	-26.8021	-30.6457	-0.7339	-0.1430	0.3233	0.8146	-0.1430	Y
	33	48.2451	-26.0630	-33.2604	48.9572	-26.1481	-32.9672	-0.7121	-0.0851	0.2932	0.7748	-0.0851	Y
	34	44.7493	-25.3058	-35.6461	45.5716	-25.3643	-35.4419	-0.8223	-0.0585	0.2042	0.8493	-0.0585	Y
	35	42.0796	-24.7168	-37.2889	42.9670	-24.8157	-37.1007	-0.8874	-0.0989	0.1882	0.9125	-0.0989	Y
	36	39.4005	-24.1944	-39.1755	40.3012	-24.2347	-39.0223	-0.9007	-0.0403	0.1532	0.9145	-0.0403	Y
B-PILLAR Maximum (X, Y, Z)	37	9.2233	-24.0485	-39.8886	10.1739	-23.7775	-40.1274	-0.9506	0.2710	-0.2388	1.0169	0.2710	Y
	38	12.2336	-25.1676	-36.7690	13.1078	-24.9486	-36.9656	-0.8742	0.2190	-0.1966	0.9224	0.2190	Y
	39	9.6513	-27.3037	-30.7586	10.3649	-27.0762	-31.0348	-0.7136	0.2275	-0.2762	0.7983	0.2275	Y
	40	12.7788	-27.8131	-27.7469	13.4027	-27.6246	-27.9593	-0.6239	0.1885	-0.2124	0.6855	0.1885	Y
B-PILLAR Lateral (Y)	37	9.2233	-24.0485	-39.8886	10.1739	-23.7775	-40.1274	-0.9506	0.2710	-0.2388	1.0169	0.2710	Y
	38	12.2336	-25.1676	-36.7690	13.1078	-24.9486	-36.9656	-0.8742	0.2190	-0.1966	0.9224	0.2190	Y
	39	9.6513	-27.3037	-30.7586	10.3649	-27.0762	-31.0348	-0.7136	0.2275	-0.2762	0.7983	0.2275	Y
	40	12.7788	-27.8131	-27.7469	13.4027	-27.6246	-27.9593	-0.6239	0.1885	-0.2124	0.6855	0.1885	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 C-4. Occupant Compartment Deformation Data – Set 2, Test No. HP34S-1

Test Name:	HP34S-1	VIN:	1C6RR6LT8GS269861
Model Year: 2016	Make: Dodge		Model: Ram 1500

Driver Side Maximum Deformation

Reference Set 1

Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]
Roof	-0.7	≤ 4	Z
Windshield[D]	0.0	≤ 3	X, Z
A-Pillar Maximum	0.0	≤ 5	X
A-Pillar Lateral	0.0	≤ 3	Y
B-Pillar Maximum	0.2	≤ 5	Y
B-Pillar Lateral	0.0	≤ 3	Y
Toe Pan - Wheel Well	5.2	≤ 9	X, Z
Side Front Panel	2.9	≤ 12	Y
Side Door (above seat)	-2.8	≤ 9	Y
Side Door (below seat)	-1.1	≤ 12	Y
Floor Pan	1.7	≤ 12	Z
Dash - no MASH requirement	1.7	NA	X, Y, Z

Reference Set 2

Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]
Roof	0.8	≤ 4	Z
Windshield[D]	NA	≤ 3	X, Z
A-Pillar Maximum	0.4	≤ 5	Z
A-Pillar Lateral	-0.2	≤ 3	Y
B-Pillar Maximum	0.3	≤ 5	Y
B-Pillar Lateral	0.3	≤ 3	Y
Toe Pan - Wheel Well	4.3	≤ 9	X, Z
Side Front Panel	2.8	≤ 12	Y
Side Door (above seat)	-2.9	≤ 9	Y
Side Door (below seat)	-1.1	≤ 12	Y
Floor Pan	0.7	≤ 12	Z
Dash - no MASH requirement	1.7	NA	X, Y, Z

[A] Items highlighted in red do not meet MASH allowable deformations.

[B] Positive values denote deformation as inward toward the occupant compartment, negative values denote deformations outward away from the occupant compartment.

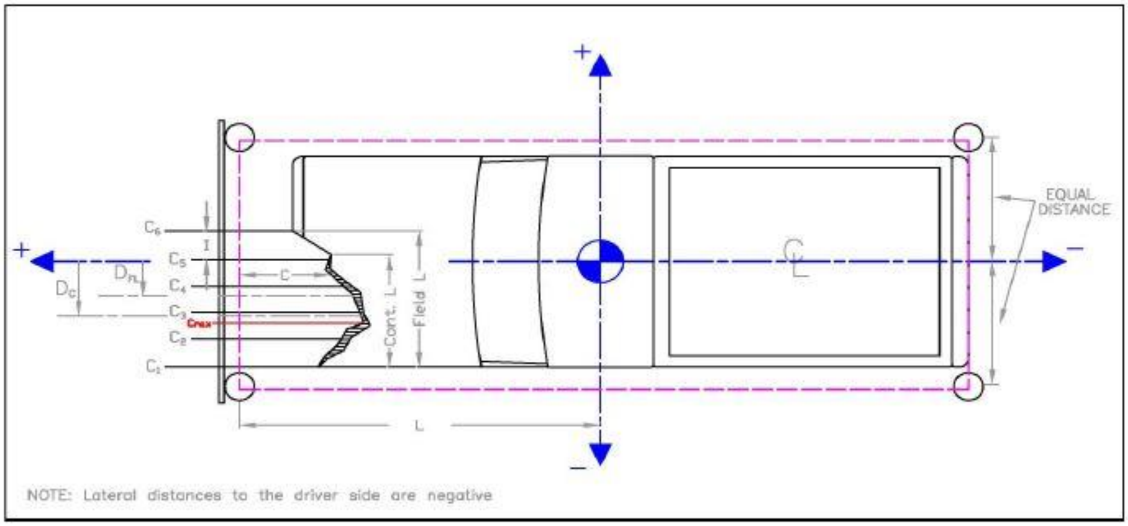
[C] For Toe Pan - Wheel Well the direction of defromation may include X and Z direction. For A-Pillar Maximum and B-Pillar Maximum the direction of deformation may include X, Y, and Z directions. The direction of deformation for Toe Pan -Wheel Well, A-Pillar Maximum, and B-Pillar Maximum only include components where the deformation is positive and intruding into the occupant compartment. If direction of deformation is "NA" then no intrusion is recorded and deformation will be 0.

[D] If deformation is observered for the windshield then the windshield deformation is measured posttest with an examplar vehicle, therefore only one set of reference is measured and recorded.

Notes on vehicle interior crush:

Figure C-5. Maximum Occupant Compartment Deformation by Location, Test No. HP34S-1

		Test Name:	HP34S-1	VIN:	1C6RR6LT8GS269861
Model Year:	2016	Make:	Dodge	Model:	Ram 1500



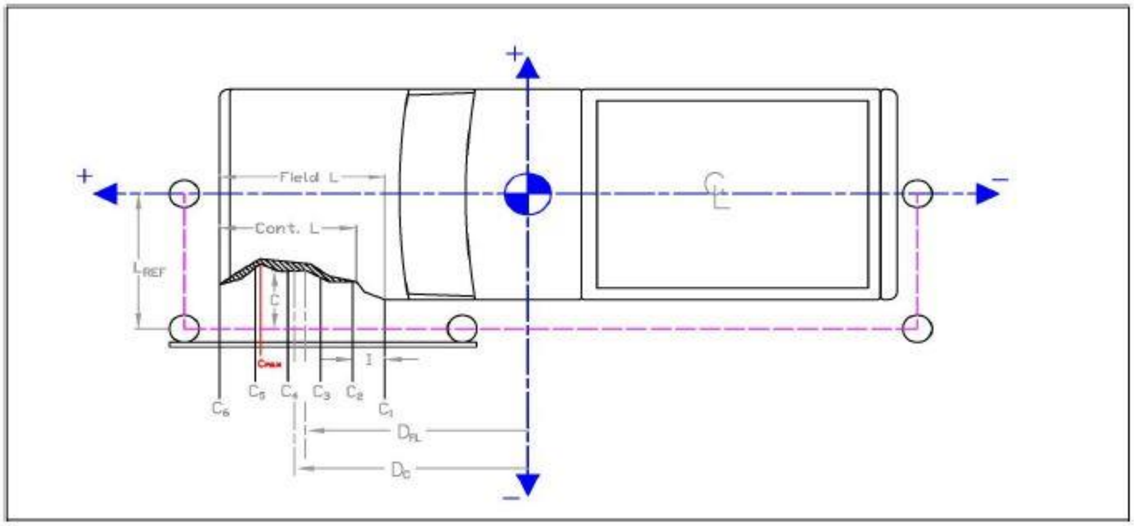
	In.	(mm)
Distance from C.G. to reference line - L_{REF}:	123	(3124)
Total Vehicle Width:	77	(1956)
Width of contact and induced crush - Field L:	77	(1956)
Crush measurement spacing interval (L/5) - I:	15 3/8	(391)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	77	(1956)
Distance from center of vehicle to center of contact damage - D_C:	0	()

NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Lateral Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	In.	(mm)	In.	(mm)	In.	(mm)	In.	(mm)	In.	(mm)
C_1	N/A	N/A	-38 1/2	-(978)	22 1/2	(572)	19 1/3	(491)	N/A	N/A
C_2	47 5/8	(1210)	-23 1/8	-(587)	6 1/2	(165)			21 4/5	(554)
C_3	25	(635)	-7 3/4	-(197)	4 1/4	(108)			1 4/9	(37)
C_4	22 1/8	(562)	7 5/8	(194)	4 1/4	(108)			-1 4/9	-(37)
C_5	24 1/2	(622)	23	(584)	6 1/8	(156)			-1	-(24)
C_6	N/A	N/A	38 3/8	(975)	20 1/2	(521)			N/A	N/A
C_{MAX}	47 5/8	(1210)	-23 1/8	-(587)	6 1/2	(165)			21 4/5	(554)

Figure C-6. Exterior Vehicle Crush (NASS) – Front, Test No. HP34S-1

Test Name:	HP34S-1	VIN:	1C6RR6LT8GS269861
Model Year: 2016	Make: Dodge	Model:	Ram 1500



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	45	(1143)
Total Vehicle Length:	229 1/4	(5823)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-14	-(354)
Width of contact and induced crush - Field L:	229 1/4	(5823)
Crush measurement spacing interval (L/5) - I:	45 7/8	(1165)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-14	-(356)
Width of Contact Damage:	229 1/4	(5823)
Distance from vehicle c.g. to center of contact damage - D_C:	-14	-(356)

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	-128 5/8	-(3267)	33 1/2	(851)	1	(25)	N/A	N/A
C_2	N/A	N/A	-82 3/4	-(2102)	5 1/2	(140)			N/A	N/A
C_3	5 1/2	(140)	-36 7/8	-(937)	5 7/8	(149)			-1 3/8	-(35)
C_4	4 3/4	(121)	9	(229)	5	(127)			-1 1/4	-(32)
C_5	N/A	N/A	54 7/8	(1394)	5 7/8	(149)			N/A	N/A
C_6	N/A	N/A	100 3/4	(2559)	11 3/8	(289)			N/A	N/A
C_{MAX}	29 1/2	(749)	93	(2362)	6 5/8	(168)			21 7/8	(556)

Figure C-7. Exterior Vehicle Crush (NASS) – Side, Test No. HP34S-1

Model Year: 2016

Test Name: HP34S-2
Make: Hyundai

VIN: KMHCT4AE9GUO78507
Model: Accent

VEHICLE DEFORMATION
DRIVER SIDE FLOOR PAN - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	74.6754	-18.0715	0.3092	73.5569	-16.8283	-0.4145	1.1185	1.2432	0.7237	1.8222	1.3322	X, Z
	2	76.8461	-13.0487	3.4590	76.6346	-12.7816	3.0924	0.2115	0.2671	0.3666	0.5005	0.4232	X, Z
	3	75.0946	-7.4526	4.9469	74.9206	-7.2618	4.7220	0.1740	0.1908	0.2249	0.3424	0.2844	X, Z
	4	75.0089	-2.0222	4.4790	74.9149	-1.8897	4.3923	0.0940	0.1325	0.0867	0.1841	0.1279	X, Z
	5	73.5037	0.5796	2.2387	73.4306	0.6412	1.9958	0.0731	-0.0616	0.2429	0.2610	0.2537	X, Z
	6	69.0663	-20.1072	7.6408	69.0159	-19.6337	7.5442	0.0504	0.4735	0.0966	0.4859	0.1090	X, Z
	7	69.5733	-13.3989	6.9898	69.4420	-13.1128	6.8980	0.1313	0.2861	0.0918	0.3279	0.1602	X, Z
	8	69.0638	-8.1756	7.8711	68.9054	-8.0469	7.7025	0.1584	0.1287	0.1686	0.2647	0.2313	X, Z
	9	69.1631	-2.4473	7.8080	69.0974	-2.2691	7.6632	0.0657	0.1782	0.1448	0.2388	0.1590	X, Z
	10	68.3837	0.6516	4.2373	68.3037	0.6980	3.9927	0.0800	-0.0464	0.2446	0.2615	0.2574	X, Z
FLOOR PAN (Z)	11	63.9533	-20.3707	8.7590	63.8869	-20.0622	8.7183	0.0664	0.3085	0.0407	0.3182	0.0407	Z
	12	63.7720	-13.4808	8.0878	63.7497	-13.2295	8.0292	0.0223	0.2513	0.0586	0.2590	0.0586	Z
	13	63.1593	-7.6793	8.9208	63.1336	-7.4237	8.9946	0.0257	0.2556	-0.0738	0.2673	-0.0738	Z
	14	63.1151	-1.6411	8.6626	63.0556	-1.5028	8.5087	0.0595	0.1383	0.1539	0.2153	0.1539	Z
	15	62.9495	0.2231	4.9766	62.8607	0.2400	4.7615	0.0888	-0.0169	0.2151	0.2333	0.2151	Z
	16	59.0224	-19.7610	8.4269	59.0069	-19.6260	8.4413	0.0155	0.1350	-0.0144	0.1366	-0.0144	Z
	17	58.9887	-13.3795	8.0611	58.9613	-13.1638	7.9916	0.0274	0.2157	0.0695	0.2283	0.0695	Z
	18	58.7955	-6.8409	8.7998	58.7415	-6.7715	8.7095	0.0540	0.0694	0.0903	0.1260	0.0903	Z
	19	59.0906	-1.9165	8.7968	58.9747	-1.8153	8.6277	0.1159	0.1012	0.1691	0.2286	0.1691	Z
	20	59.4379	0.2217	4.9032	59.3857	0.2773	4.6940	0.0522	-0.0556	0.2092	0.2227	0.2092	Z
	21	54.3314	-19.7247	8.5270	54.3064	-19.5361	8.4641	0.0250	0.1886	0.0629	0.2004	0.0629	Z
	22	54.7216	-13.5221	8.1190	54.6046	-13.4010	8.0451	0.1170	0.1211	0.0739	0.1839	0.0739	Z
	23	54.1766	-6.8362	8.8551	54.1272	-6.7678	8.6849	0.0494	0.0684	0.1702	0.1900	0.1702	Z
	24	54.2483	-2.1563	8.8634	54.1732	-1.9864	8.6696	0.0751	0.1699	0.1938	0.2684	0.1938	Z
	25	54.5832	0.3421	4.6770	54.5271	0.4167	4.4374	0.0561	-0.0746	0.2396	0.2571	0.2396	Z
	26	51.0952	-19.3565	8.7991	51.0119	-19.1782	8.7738	0.0833	0.1783	0.0253	0.1984	0.0253	Z
	27	50.9563	-13.3982	8.1487	50.9119	-13.2645	8.0792	0.0444	0.1337	0.0695	0.1571	0.0695	Z
	28	50.9647	-6.9409	8.8903	50.9219	-6.8100	8.7317	0.0428	0.1309	0.1586	0.2100	0.1586	Z
	29	50.8359	-2.2390	8.8866	50.7685	-2.0665	8.6994	0.0674	0.1725	0.1872	0.2633	0.1872	Z
	30	51.1506	0.4172	4.5344	51.0373	0.5079	4.2653	0.1133	-0.0907	0.2691	0.3057	0.2691	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 C-8. Floor Pan Deformation Data – Set 1, Test No. HP34S-2

Model Year: 2016

Test Name: HP34S-2
Make: Hyundai

VIN: KMHCT4AE9GUO78507
Model: Accent

VEHICLE DEFORMATION
DRIVER SIDE FLOOR PAN - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	52.3799	-21.4404	-8.3461	51.9816	-20.1147	-6.5553	0.3983	1.3257	-1.7908	2.2634	0.3983	X
	2	54.8738	-16.4927	-5.3191	55.2264	-16.0160	-3.2662	-0.3526	0.4767	-2.0529	2.1368	0.0000	NA
	3	53.4108	-10.8210	-3.8062	53.7158	-10.3700	-1.8870	-0.3050	0.4510	-1.9192	1.9949	0.0000	NA
	4	53.5284	-5.3944	-4.3104	53.8900	-5.0223	-2.4702	-0.3616	0.3721	-1.8402	1.9119	0.0000	NA
	5	52.0450	-2.7461	-6.5103	52.4714	-2.5572	-4.9727	-0.4264	0.1889	-1.5376	1.6068	0.0000	NA
	6	46.9804	-23.2019	-0.7896	47.4188	-22.3850	1.5599	-0.4384	0.8169	-2.3495	2.5258	0.0000	NA
	7	47.7349	-16.5238	-1.5089	48.0608	-15.9203	0.6031	-0.3259	0.6035	-2.1120	2.2206	0.0000	NA
	8	47.4731	-11.2791	-0.6472	47.7041	-10.8067	1.1710	-0.2310	0.4724	-1.8182	1.8927	0.0000	NA
	9	47.8034	-5.5601	-0.7563	48.0922	-5.0471	0.8573	-0.2888	0.5130	-1.6136	1.7176	0.0000	NA
	10	47.0133	-2.4526	-4.3170	47.3674	-2.2302	-2.9435	-0.3541	0.2224	-1.3735	1.4357	0.0000	NA
FLOOR PAN (Z)	11	41.9080	-23.2489	0.5262	42.2887	-22.5811	2.7902	-0.3807	0.6678	-2.2640	2.3909	-2.2640	Z
	12	41.9819	-16.3614	-0.1883	42.3780	-15.7876	1.7799	-0.3961	0.5738	-1.9682	2.0881	-1.9682	Z
	13	41.6389	-10.5349	0.6250	41.9685	-9.9251	2.4742	-0.3296	0.6098	-1.8492	1.9749	-1.8492	Z
	14	41.8309	-4.5016	0.3242	42.0879	-4.0344	1.7096	-0.2570	0.4672	-1.3854	1.4845	-1.3854	Z
	15	41.5989	-2.6535	-3.3664	41.9190	-2.4640	-2.1144	-0.3201	0.1895	-1.2520	1.3061	-1.2520	Z
	16	36.9969	-22.4394	0.3793	37.4242	-21.9907	2.5284	-0.4273	0.4487	-2.1491	2.2366	-2.1491	Z
	17	37.2092	-16.0642	-0.0319	37.5945	-15.5590	1.7741	-0.3853	0.5052	-1.8060	1.9145	-1.8060	Z
	18	37.3114	-9.5190	0.6655	37.5989	-9.1363	2.1906	-0.2875	0.3827	-1.5251	1.5985	-1.5251	Z
	19	37.8067	-4.6109	0.6150	37.9999	-4.2004	1.8729	-0.1932	0.4105	-1.2579	1.3372	-1.2579	Z
	20	38.0899	-2.5113	-3.3048	38.4469	-2.3103	-2.1583	-0.3570	0.2010	-1.1465	1.2175	-1.1465	Z
	21	32.3186	-22.2101	0.6594	32.7298	-21.7381	2.5811	-0.4112	0.4720	-1.9217	2.0211	-1.9217	Z
	22	32.9453	-16.0312	0.1911	33.2330	-15.6433	1.8704	-0.2877	0.3879	-1.6793	1.7474	-1.6793	Z
	23	32.7022	-9.3245	0.8983	32.9873	-8.9749	2.1994	-0.2851	0.3496	-1.3011	1.3771	-1.3011	Z
	24	32.9648	-4.6515	0.8693	33.1959	-4.2039	1.9578	-0.2311	0.4476	-1.0885	1.1994	-1.0885	Z
	25	33.2390	-2.1932	-3.3451	33.5937	-2.0160	-2.3857	-0.3547	0.1772	-0.9594	1.0381	-0.9594	Z
	26	29.1131	-21.7080	1.0529	29.4523	-21.2528	2.8976	-0.3392	0.4552	-1.8447	1.9301	-1.8447	Z
	27	29.1921	-15.7528	0.3645	29.5475	-15.3784	1.9249	-0.3554	0.3744	-1.5604	1.6436	-1.5604	Z
	28	29.4924	-9.2972	1.0576	29.7829	-8.9045	2.2715	-0.2905	0.3927	-1.2139	1.3085	-1.2139	Z
	29	29.5554	-4.5941	1.0243	29.7908	-4.1654	2.0161	-0.2354	0.4287	-0.9918	1.1058	-0.9918	Z
	30	29.8094	-1.9783	-3.3563	30.1076	-1.8129	-2.5365	-0.2982	0.1654	-0.8198	0.8879	-0.8198	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 C-9. Floor Pan Deformation Data – Set 2, Test No. HP34S-2

Model Year: 2016 | Test Name: HP34S-2 | VIN: KMHCT4AE9GUO78507
Make: Hyundai | Model: Accent

VEHICLE DEFORMATION
DRIVER SIDE INTERIOR CRUSH - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	63.2025	-20.3684	-19.2076	63.0956	-20.1935	-19.7110	0.1069	0.1749	-0.5034	0.5435	0.5435	X, Y, Z
	2	59.2057	-8.7096	-23.4369	59.1937	-8.5274	-23.8574	0.0120	0.1822	-0.4205	0.4584	0.4584	X, Y, Z
	3	61.9762	4.8437	-20.3998	62.0316	5.0153	-20.6972	-0.0554	-0.1716	-0.2974	0.3478	0.3478	X, Y, Z
	4	59.4831	-17.6613	-11.3494	59.3467	-17.4869	-11.8718	0.1364	0.1744	-0.5224	0.5674	0.5674	X, Y, Z
	5	61.0515	-8.8966	-8.0383	60.9605	-8.6996	-8.4318	0.0910	0.1970	-0.3935	0.4494	0.4494	X, Y, Z
	6	56.8395	4.5419	-13.7289	56.9261	4.6956	-14.0322	-0.0866	-0.1537	-0.3033	0.3509	0.3509	X, Y, Z
SIDE PANEL (Y)	7	67.2311	-22.2469	-0.9889	66.9899	-21.6030	-1.4868	0.2412	0.6439	-0.4979	0.8489	0.6439	Y
	8	65.9863	-22.3088	2.5801	65.7437	-21.5862	2.1198	0.2426	0.7226	-0.4603	0.8904	0.7226	Y
	9	70.0165	-22.2602	2.7546	69.7429	-21.0324	2.2941	0.2736	1.2278	-0.4605	1.3396	1.2278	Y
IMPACT SIDE DOOR (Y)	10	32.9031	-24.3618	-14.4802	32.5235	-24.7058	-14.7433	0.3796	-0.3440	-0.2631	0.5759	-0.3440	Y
	11	45.9130	-24.4721	-12.8752	45.4945	-24.8759	-13.1797	0.4185	-0.4038	-0.3045	0.6564	-0.4038	Y
	12	52.7177	-23.6698	-13.1587	52.2891	-24.3484	-13.3967	0.4286	-0.6786	-0.2380	0.8372	-0.6786	Y
	13	35.6502	-24.2479	-1.6846	35.3300	-24.0383	-1.9376	0.3202	0.2096	-0.2530	0.4588	0.2096	Y
	14	46.4854	-24.6981	1.8022	46.0639	-24.5032	1.4290	0.4215	0.1949	-0.3732	0.5958	0.1949	Y
	15	56.9897	-23.9505	1.1223	56.7055	-23.8301	0.8602	0.2842	0.1204	-0.2621	0.4049	0.1204	Y
ROOF - (Z)	16	48.9977	-15.1978	-35.1537	48.9926	-15.1062	-35.5330	0.0051	0.0916	-0.3793	0.3902	-0.3793	Z
	17	50.4324	-6.6577	-35.3805	50.4888	-6.5381	-35.6667	-0.0564	0.1196	-0.2862	0.3153	-0.2862	Z
	18	50.7189	1.5925	-35.3578	50.9112	3.9746	-35.5631	-0.1923	-2.3821	-0.2053	2.3987	-0.2053	Z
	19	41.0401	-14.8863	-37.9084	41.0652	-14.7815	-38.2051	-0.0251	0.1048	-0.2967	0.3157	-0.2967	Z
	20	41.0618	-4.9297	-38.4611	41.1448	-4.7809	-38.6802	-0.0830	0.1488	-0.2191	0.2776	-0.2191	Z
	21	41.4370	1.2533	-38.4999	41.5588	1.4232	-38.6690	-0.1218	-0.1699	-0.1691	0.2689	-0.1691	Z
	22	28.6694	-14.4710	-39.2870	28.6760	-14.3315	-39.4188	-0.0066	0.1395	-0.1318	0.1920	-0.1318	Z
	23	28.3382	-5.9166	-39.8058	28.2275	-5.8072	-40.0151	0.1107	0.1094	-0.2093	0.2608	-0.2093	Z
	24	27.9848	0.5175	-39.9721	27.9638	0.6595	-40.1412	0.0210	-0.1420	-0.1691	0.2218	-0.1691	Z
	25	12.1299	-14.4872	-39.1317	12.0659	-14.2654	-39.2859	0.0640	0.2218	-0.1542	0.2776	-0.1542	Z
	26	11.9081	-5.9160	-39.6525	11.8624	-5.7743	-39.7835	0.0457	0.1417	-0.1310	0.1983	-0.1310	Z
	27	11.8404	6.2965	-39.7865	11.8237	6.4328	-39.8684	0.0167	-0.1363	-0.0819	0.1599	-0.0819	Z
	28	-0.3460	-15.7658	-37.3758	-0.4038	-15.5843	-37.5229	0.0578	0.1815	-0.1471	0.2407	-0.1471	Z
	29	-2.1776	-5.9604	-37.8066	-2.1596	-5.8152	-37.9165	-0.0180	0.1452	-0.1099	0.1830	-0.1099	Z
	30	-1.7018	3.2011	-38.1185	-1.7291	3.4183	-38.1778	0.0273	-0.2172	-0.0593	0.2268	-0.0593	Z
A-PILLAR Maximum (X, Y, Z)	31	70.6009	-21.5287	-22.6873	70.5899	-21.4669	-23.1789	0.0110	0.0618	-0.4916	0.4956	0.0628	X, Y
	32	65.7472	-20.6749	-25.8094	65.8065	-20.6401	-26.2688	-0.0593	0.0348	-0.4594	0.4645	0.0348	Y
	33	61.7480	-19.9129	-28.1173	61.7221	-19.8609	-28.6271	0.0259	0.0520	-0.5098	0.5131	0.0581	X, Y
	34	58.8048	-19.3345	-29.7646	58.8042	-19.2787	-30.2639	0.0006	0.0558	-0.4993	0.5024	0.0558	X, Y
	35	55.0205	-18.5801	-31.6250	55.0293	-18.4932	-32.1219	-0.0088	0.0869	-0.4969	0.5045	0.0869	Y
	36	49.8355	-17.7149	-34.0983	49.8731	-17.6054	-34.5527	-0.0376	0.1095	-0.4544	0.4689	0.1095	Y
A-PILLAR Lateral (Y)	31	70.6009	-21.5287	-22.6873	70.5899	-21.4669	-23.1789	0.0110	0.0618	-0.4916	0.4956	0.0618	Y
	32	65.7472	-20.6749	-25.8094	65.8065	-20.6401	-26.2688	-0.0593	0.0348	-0.4594	0.4645	0.0348	Y
	33	61.7480	-19.9129	-28.1173	61.7221	-19.8609	-28.6271	0.0259	0.0520	-0.5098	0.5131	0.0520	Y
	34	58.8048	-19.3345	-29.7646	58.8042	-19.2787	-30.2639	0.0006	0.0558	-0.4993	0.5024	0.0558	Y
	35	55.0205	-18.5801	-31.6250	55.0293	-18.4932	-32.1219	-0.0088	0.0869	-0.4969	0.5045	0.0869	Y
	36	49.8355	-17.7149	-34.0983	49.8731	-17.6054	-34.5527	-0.0376	0.1095	-0.4544	0.4689	0.1095	Y
B-PILLAR Maximum (X, Y, Z)	37	24.7143	-18.6089	-32.7266	24.6151	-18.4646	-32.9228	0.0992	0.1443	-0.1962	0.2630	0.1751	X, Y
	38	27.7018	-19.5257	-30.4950	27.6591	-19.3719	-30.7208	0.0427	0.1538	-0.2258	0.2765	0.1596	X, Y
	39	25.4138	-21.6447	-24.6839	25.3113	-21.4750	-24.9021	0.1025	0.1697	-0.2182	0.2948	0.1983	X, Y
	40	28.9273	-22.6954	-21.8540	28.8211	-22.5725	-22.0223	0.1062	0.1229	-0.1683	0.2339	0.1624	X, Y
B-PILLAR Lateral (Y)	37	24.7143	-18.6089	-32.7266	24.6151	-18.4646	-32.9228	0.0992	0.1443	-0.1962	0.2630	0.1443	Y
	38	27.7018	-19.5257	-30.4950	27.6591	-19.3719	-30.7208	0.0427	0.1538	-0.2258	0.2765	0.1538	Y
	39	25.4138	-21.6447	-24.6839	25.3113	-21.4750	-24.9021	0.1025	0.1697	-0.2182	0.2948	0.1697	Y
	40	28.9273	-22.6954	-21.8540	28.8211	-22.5725	-22.0223	0.1062	0.1229	-0.1683	0.2339	0.1229	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 C-10. Occupant Compartment Deformation Data – Set 1, Test No. HP34S-2

Model Year: 2016 | Test Name: HP34S-2 | VIN: KMHCT4AE9GUO78507
Make: Hyundai | Model: Accent

VEHICLE DEFORMATION
DRIVER SIDE INTERIOR CRUSH - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	40.0538	-23.3731	-27.4519	41.3019	-24.0823	-25.5856	-1.2481	-0.7092	1.8663	2.3545	2.3545	X, Y, Z
	2	36.3655	-11.5871	-31.6085	37.7284	-12.5065	-30.2488	-1.3629	-0.9194	1.3597	2.1334	2.1334	X, Y, Z
	3	39.8014	1.8603	-28.7887	41.0159	1.0733	-27.7536	-1.2145	0.7870	1.0351	1.7793	1.7793	X, Y, Z
	4	36.7651	-20.4690	-19.4730	37.7105	-20.8933	-17.8548	-0.9454	-0.4243	1.6182	1.9216	1.9216	X, Y, Z
	5	38.8182	-11.7554	-16.2947	39.6288	-12.0096	-14.8461	-0.8106	-0.2542	1.4486	1.6793	1.6793	X, Y, Z
	6	34.9283	1.8086	-21.9164	35.9636	1.2285	-21.0423	-1.0353	0.5801	0.8741	1.4739	1.4739	X, Y, Z
SIDE PANEL (Y)	7	44.7306	-25.3031	-9.3942	45.3155	-24.7564	-7.3452	-0.5849	0.5467	2.0490	2.1999	0.5467	Y
	8	43.6284	-25.2926	-5.7780	44.1031	-24.5308	-3.7341	-0.4747	0.7618	2.0439	2.2323	0.7618	Y
	9	47.6611	-25.4071	-5.7645	48.1191	-24.0961	-3.6165	-0.4580	1.3110	2.1480	2.5578	1.3110	Y
IMPACT SIDE DOOR (Y)	10	9.8316	-26.1005	-21.4910	10.6502	-27.3882	-20.1784	-0.8186	-1.2877	1.3126	2.0128	-1.2877	Y
	11	22.8804	-26.7307	-20.4046	23.6233	-27.8944	-18.7070	-0.7429	-1.1637	1.6976	2.1881	-1.1637	Y
	12	29.6951	-26.2079	-20.9650	30.4288	-27.5926	-19.0002	-0.7337	-1.3847	1.9648	2.5132	-1.3847	Y
	13	13.0921	-26.0207	-8.8162	13.5922	-26.2088	-7.4402	-0.5001	-0.1881	1.3760	1.4761	-0.1881	Y
	14	24.0314	-26.8905	-5.7603	24.3364	-26.8539	-4.1369	-0.3050	0.0366	1.6234	1.6522	0.0366	Y
	15	34.5216	-26.5754	-6.8637	34.9883	-26.5448	-4.8176	-0.4667	0.0306	2.0461	2.0989	0.0306	Y
ROOF - (Z)	16	25.4417	-17.7255	-42.8591	27.2215	-19.3011	-41.5228	-1.7798	-1.5756	1.3363	2.7269	1.3363	Z
	17	27.2103	-9.2525	-43.2087	28.9830	-10.8002	-42.0725	-1.7727	-1.5477	1.1362	2.6132	1.1362	Z
	18	27.8310	-1.0207	-43.2610	29.7342	-0.3128	-42.4688	-1.9032	0.7079	0.7922	2.1796	0.7922	Z
	19	17.3991	-17.1070	-45.2970	19.2842	-18.8519	-44.1470	-1.8851	-1.7449	1.1500	2.8144	1.1500	Z
	20	17.8013	-7.1630	-45.9269	19.6714	-8.8922	-45.0947	-1.8701	-1.7292	0.8322	2.6795	0.8322	Z
	21	18.4244	-1.0008	-46.0283	20.2789	-2.7107	-45.3797	-1.8545	-1.7099	0.6486	2.6045	0.6486	Z
	22	5.0100	-16.1967	-46.1850	6.9046	-18.0683	-45.2865	-1.8946	-1.8716	0.8985	2.8106	0.8985	Z
	23	5.0045	-7.6392	-46.7561	6.7169	-9.5715	-46.2814	-1.7124	-1.9323	0.4747	2.6252	0.4747	Z
	24	4.9053	-1.1972	-46.9579	6.6539	-3.1128	-46.7109	-1.7486	-1.9156	0.2470	2.6054	0.2470	Z
	25	-11.4971	-15.5384	-45.3711	-9.6935	-17.4714	-45.0308	-1.8036	-1.9330	0.3403	2.6656	0.3403	Z
	26	-11.3927	-6.9686	-45.9487	-9.6365	-9.0108	-45.9274	-1.7562	-2.0422	0.0213	2.6936	0.0213	Z
	27	-10.9717	5.2355	-46.1740	-9.2950	3.1739	-46.5887	-1.6767	2.0616	-0.4147	2.6895	-0.4147	Z
	28	-23.9340	-16.2972	-43.1098	-22.1817	-18.3113	-43.1129	-1.7523	-2.0141	-0.0031	2.6697	-0.0031	Z
	29	-25.3833	-6.4281	-43.5429	-23.6354	-8.5210	-43.9542	-1.7479	-2.0929	-0.4113	2.7576	-0.4113	Z
	30	-24.5502	2.7043	-43.9443	-22.9195	0.6719	-44.6548	-1.6307	2.0324	-0.7105	2.7009	-0.7105	Z
A-PILLAR Maximum (X, Y, Z)	31	47.2537	-24.8549	-31.2145	48.7210	-25.7534	-29.0463	-1.4673	-0.8985	2.1682	2.7679	2.1682	Z
	32	42.3173	-23.8232	-34.1473	43.9379	-24.9220	-32.1354	-1.6206	-1.0988	2.0119	2.8074	2.0119	Z
	33	38.2628	-22.9130	-36.2999	39.8586	-24.1258	-34.4968	-1.5958	-1.2128	1.8031	2.6960	1.8031	Z
	34	35.2817	-22.2253	-37.8330	36.9456	-23.5293	-36.1371	-1.6639	-1.3040	1.6959	2.7102	1.6959	Z
	35	31.4594	-21.3287	-39.5471	33.1803	-22.7130	-38.0014	-1.7209	-1.3843	1.5457	2.6957	1.5457	Z
	36	26.2187	-20.2681	-41.8185	28.0324	-21.7780	-40.4322	-1.8137	-1.5099	1.3863	2.7370	1.3863	Z
A-PILLAR Lateral (Y)	31	47.2537	-24.8549	-31.2145	48.7210	-25.7534	-29.0463	-1.4673	-0.8985	2.1682	2.7679	-0.8985	Y
	32	42.3173	-23.8232	-34.1473	43.9379	-24.9220	-32.1354	-1.6206	-1.0988	2.0119	2.8074	-1.0988	Y
	33	38.2628	-22.9130	-36.2999	39.8586	-24.1258	-34.4968	-1.5958	-1.2128	1.8031	2.6960	-1.2128	Y
	34	35.2817	-22.2253	-37.8330	36.9456	-23.5293	-36.1371	-1.6639	-1.3040	1.6959	2.7102	-1.3040	Y
	35	31.4594	-21.3287	-39.5471	33.1803	-22.7130	-38.0014	-1.7209	-1.3843	1.5457	2.6957	-1.3843	Y
	36	26.2187	-20.2681	-41.8185	28.0324	-21.7780	-40.4322	-1.8137	-1.5099	1.3863	2.7370	-1.5099	Y
B-PILLAR Maximum (X, Y, Z)	37	1.1571	-20.1301	-39.4406	2.7758	-21.7613	-38.5719	-1.6187	-1.6312	0.8687	2.4568	0.8687	Z
	38	4.1921	-21.1542	-37.3228	5.8098	-22.6598	-36.3527	-1.6177	-1.5056	0.9701	2.4135	0.9701	Z
	39	2.0552	-23.1428	-31.4090	3.4505	-24.4120	-30.4234	-1.3953	-1.2692	0.9856	2.1282	0.9856	Z
	40	5.6340	-24.3185	-28.7132	6.9502	-25.4834	-27.5217	-1.3162	-1.1649	1.1915	2.1235	1.1915	Z
B-PILLAR Lateral (Y)	37	1.1571	-20.1301	-39.4406	2.7758	-21.7613	-38.5719	-1.6187	-1.6312	0.8687	2.4568	-1.6312	Y
	38	4.1921	-21.1542	-37.3228	5.8098	-22.6598	-36.3527	-1.6177	-1.5056	0.9701	2.4135	-1.5056	Y
	39	2.0552	-23.1428	-31.4090	3.4505	-24.4120	-30.4234	-1.3953	-1.2692	0.9856	2.1282	-1.2692	Y
	40	5.6340	-24.3185	-28.7132	6.9502	-25.4834	-27.5217	-1.3162	-1.1649	1.1915	2.1235	-1.1649	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 C-11. Occupant Compartment Deformation Data – Set 2, Test No. HP34S-2

Model Year: 2016	Test Name: HP34S-2	VIN: KMHCT4AE9GUO78507	
	Make: Hyundai	Model: Accent	

Driver Side Maximum Deformations

Reference Set 1					Reference Set 2			
Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]		Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]
Roof	-0.4	≤ 4	Z		Roof	1.3	≤ 4	Z
Windshield[D]	0.0	≤ 3	X, Z		Windshield[D]	NA	≤ 3	X, Z
A-Pillar Maximum	0.1	≤ 5	Y		A-Pillar Maximum	2.2	≤ 5	Z
A-Pillar Lateral	0.1	≤ 3	Y		A-Pillar Lateral	-1.5	≤ 3	Y
B-Pillar Maximum	0.2	≤ 5	X, Y		B-Pillar Maximum	1.2	≤ 5	Z
B-Pillar Lateral	0.1	≤ 3	Y		B-Pillar Lateral	-1.6	≤ 3	Y
Toe Pan - Wheel Well	1.3	≤ 9	X, Z		Toe Pan - Wheel Well	0.4	≤ 9	X
Side Front Panel	1.2	≤ 12	Y		Side Front Panel	1.3	≤ 12	Y
Side Door (above seat)	-0.7	≤ 9	Y		Side Door (above seat)	-1.4	≤ 9	Y
Side Door (below seat)	0.2	≤ 12	Y		Side Door (below seat)	0.0	≤ 12	Y
Floor Pan	0.3	≤ 12	Z		Floor Pan	-2.3	≤ 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.

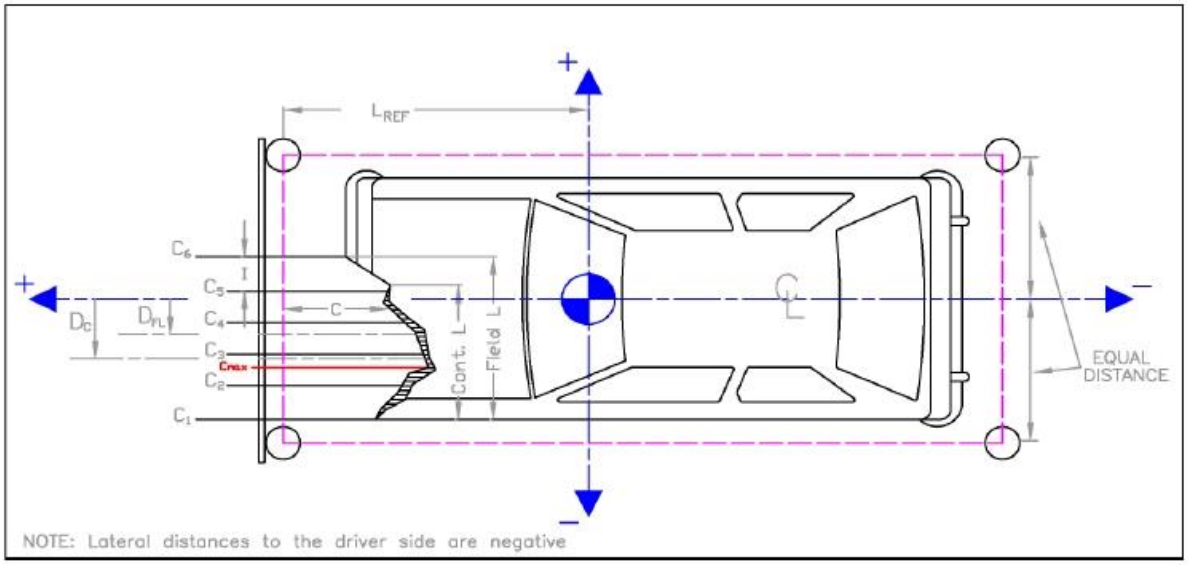
[D] If deformation is observered for the windshield then the windshield deformation is measured posttest with an examplar vehicle, therefore only one set of reference is measured and recorded.

Notes on vehicle crush:

Reference Set 2 has been compromised and therefore the results are invalid.

Figure C-12. Maximum Occupant Compartment Deformation by Location, Test No. HP34S-2

	Test Name: HP34S-2		VIN: KMHCT4AE9GUO78507
Model Year: 2016	Make: Hyundai		Model: Accent



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	82	(2083)
Total Width of Vehicle:	66 3/4	(1695)
Width of contact and induced crush - Field L:	66 3/4	(1695)
Crush measurement spacing interval (L/5) - I:	13 3/8	(340)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	66 3/4	(1695)
Distance from center of vehicle to center of contact damage - D_C:	0	()

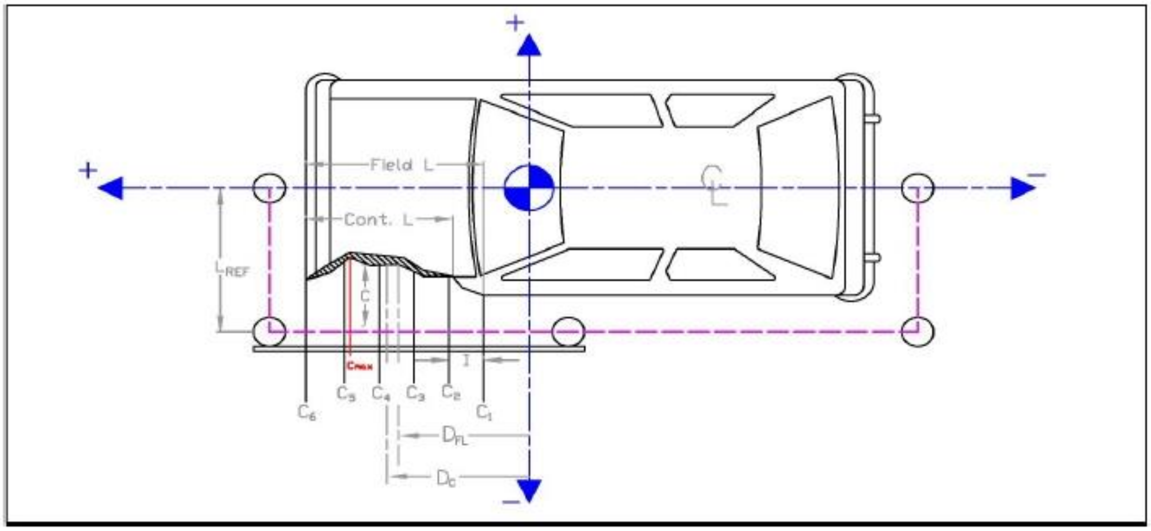
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Lateral Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	N/A	NA	-33 3/8	-(848)	15 5/8	(397)	7 1/2	(191)	NA	NA
C_2	26 1/8	(664)	-20	-(508)	6 7/8	(175)			11 3/4	(298)
C_3	17	(432)	-6 5/8	-(168)	4 3/8	(111)			5 1/8	(130)
C_4	12 3/4	(324)	6 3/4	(171)	4 1/2	(114)			3/4	(19)
C_5	14 1/4	(362)	20 1/8	(511)	6 7/8	(175)			- 1/8	-(3)
C_6	N/A	NA	33 1/2	(851)	15 5/8	(397)			NA	NA
C_{MAX}	26 1/8	(664)	-20	-(508)	6 7/8	(175)			11 3/4	(298)

Figure C-13. Exterior Vehicle Crush (NASS) – Front, Test No. HP34S-2

Test Name: HP34S-2 **VIN:** KMHCT4AE9GUO78507

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



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	38	(965)
Total Vehicle Length:	171 3/8	(4353)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-16 1/3	-(414)
Width of contact and induced crush - Field L:	171 3/8	(4353)
Crush measurement spacing interval (L/5) - I:	34 1/4	(870)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-16 1/3	-(415)
Width of Contact Damage:	171 3/8	(4353)
Distance from vehicle c.g. to center of contact damage - D_C:	-16 1/3	-(415)

NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., front of vehicle has been pushed inward or tire has been removed)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	N/A	NA	-102	-(2591)	41 1/4	(1048)	-3 1/4	-(83)	NA	NA
C_2	N/A	NA	-67 3/4	-(1721)	7	(178)			NA	NA
C_3	6 1/8	(156)	-33 1/2	-(851)	8 1/8	(206)			1 1/4	(32)
C_4	6 1/2	(165)	3/4	(19)	8 1/4	(210)			1 1/2	(38)
C_5	N/A	NA	35	(889)	7	(178)			NA	NA
C_6	N/A	NA	69 1/4	(1759)	25 5/8	(651)			NA	NA
C_{MAX}	23 1/4	(591)	62 1/2	(1588)	11	(279)			15 1/2	(394)

Figure C-14. Exterior Vehicle Crush (NASS) – Side, Test No. HP34S-2

Appendix D. Accelerometer and Rate Transducer Data Plots, Test No. HP34S-1

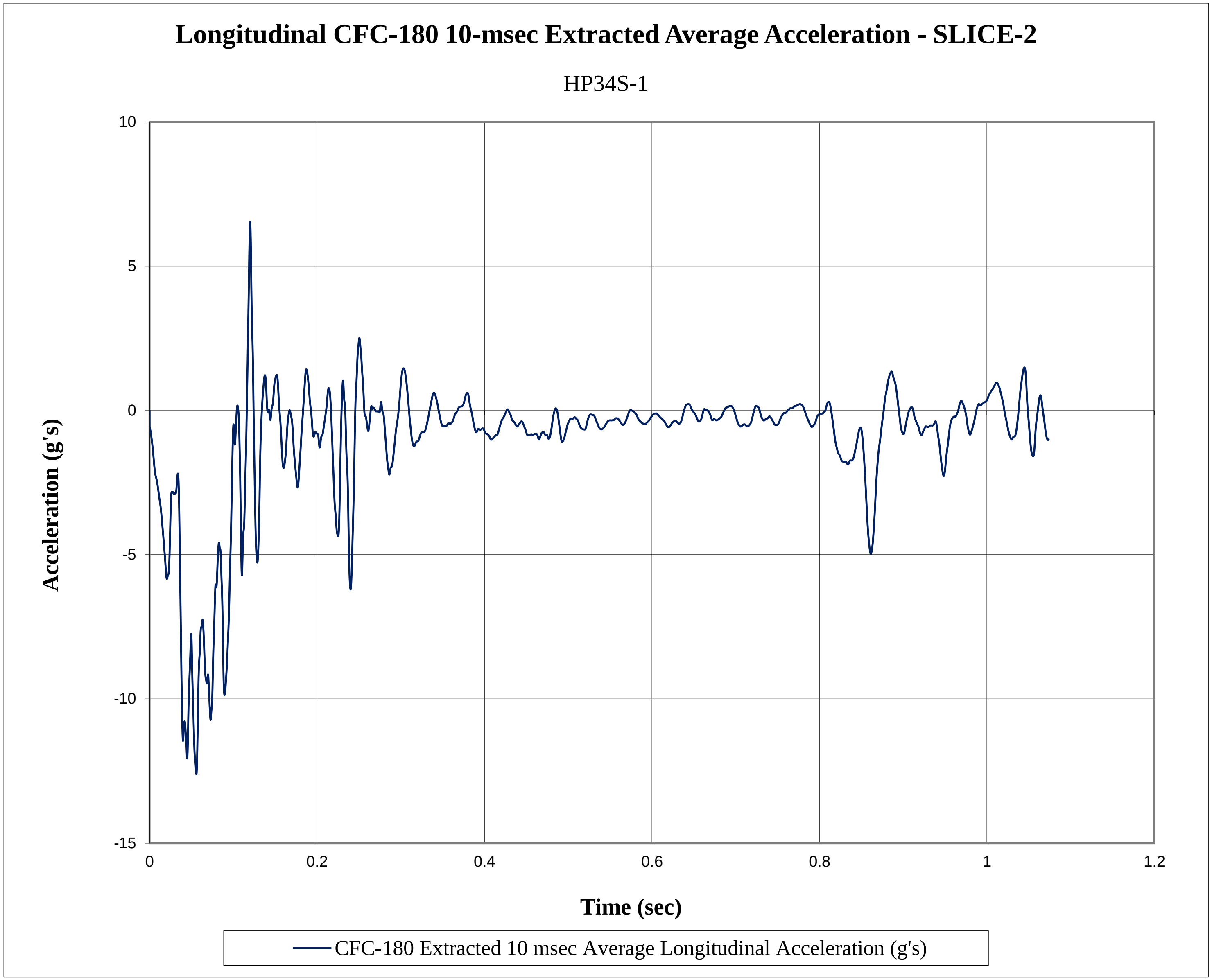


Figure D-1. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. HP34S-1

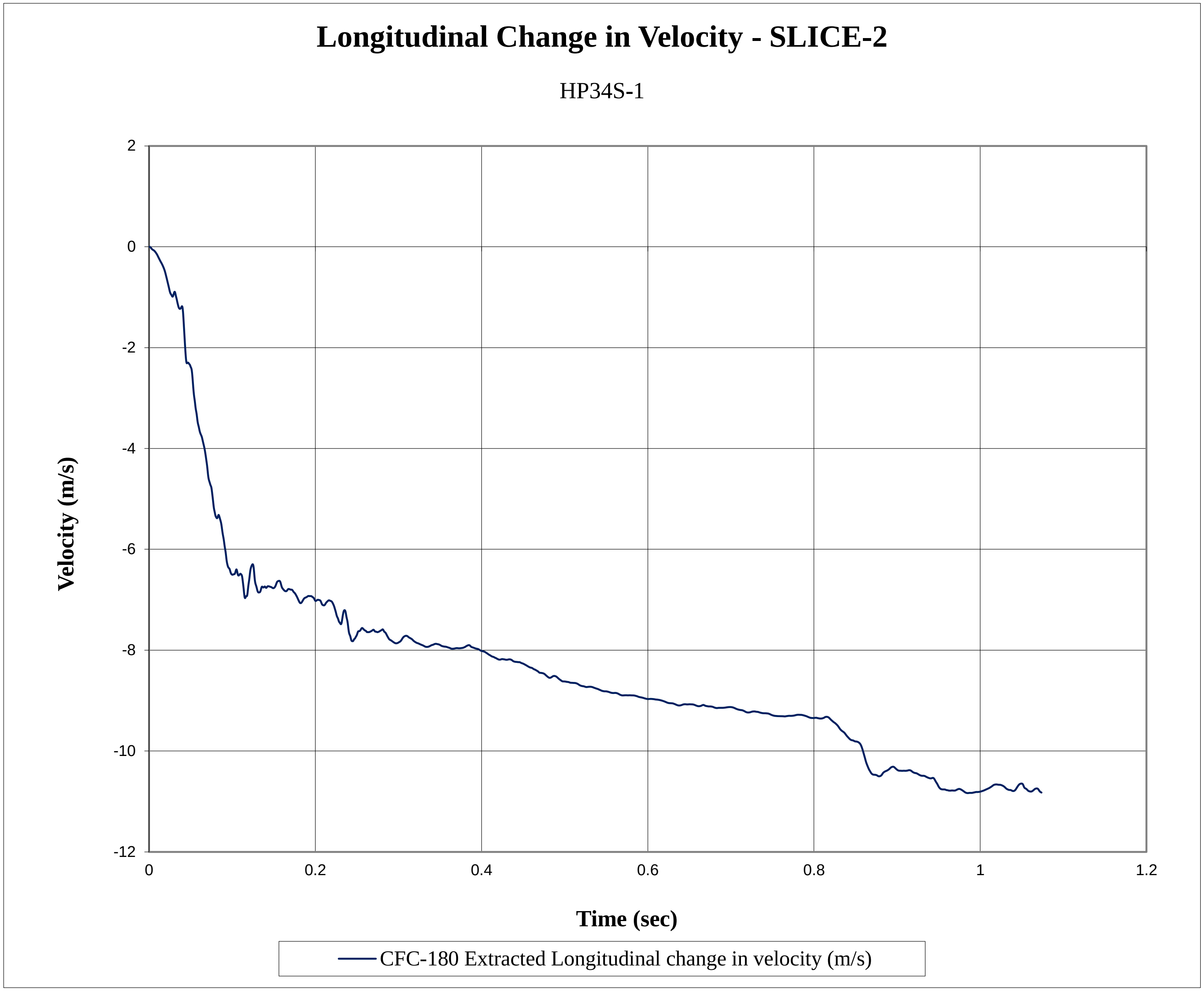


Figure D-2. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. HP34S-1

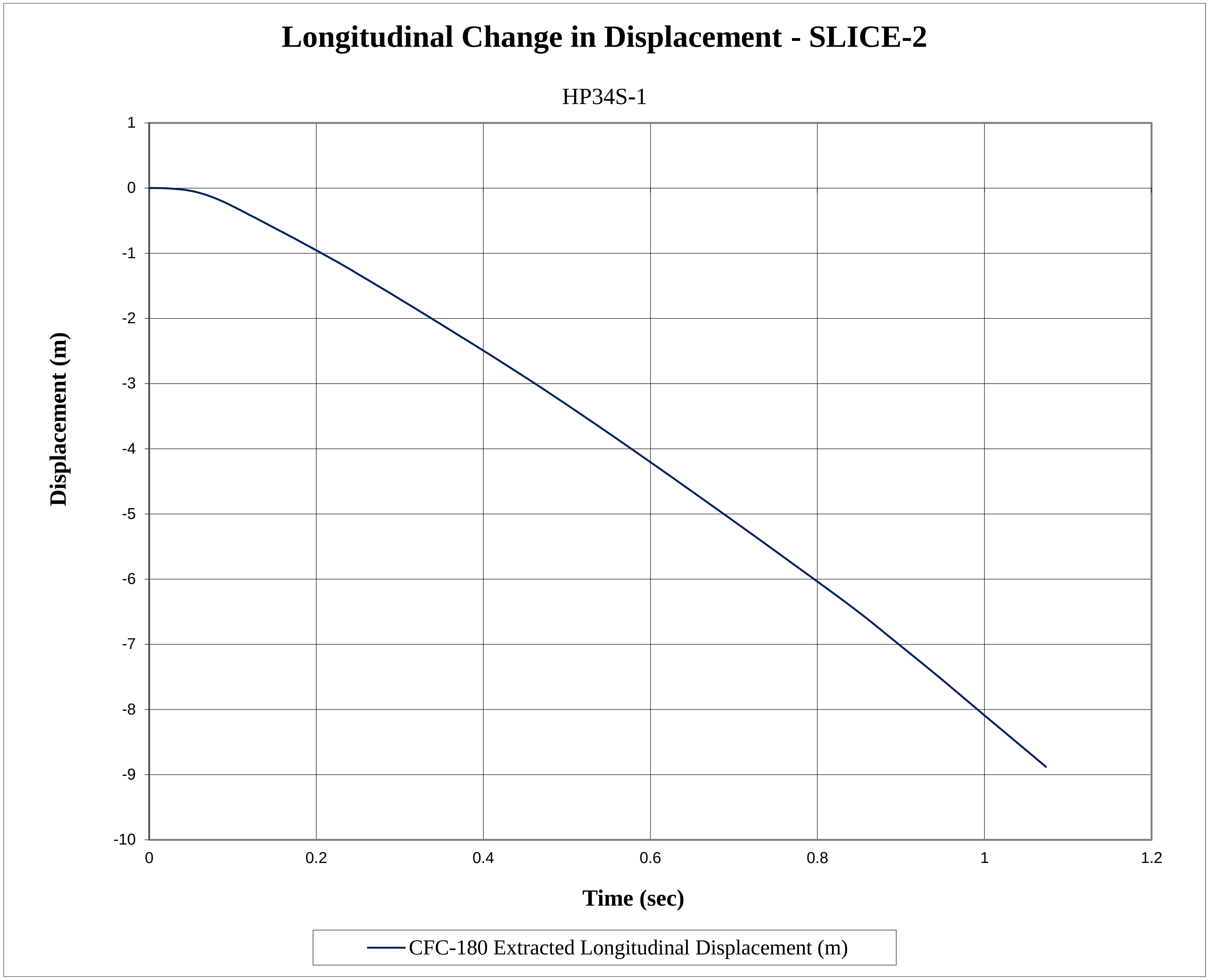


Figure D-3. Longitudinal Occupant Displacement (SLICE-2), Test No. HP34S-1

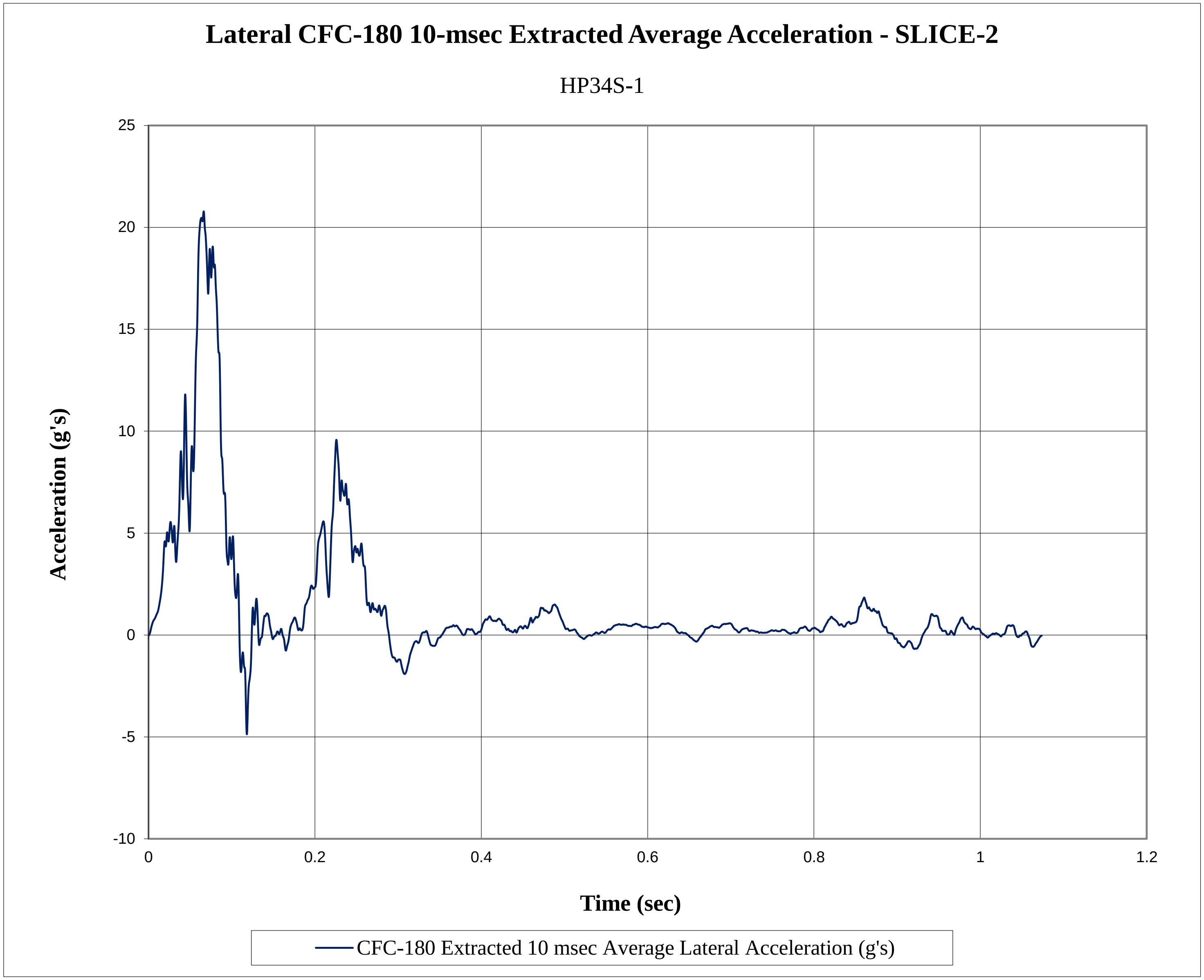


Figure D-4. 10-ms Average Lateral Deceleration (SLICE-2), Test No. HP34S-1

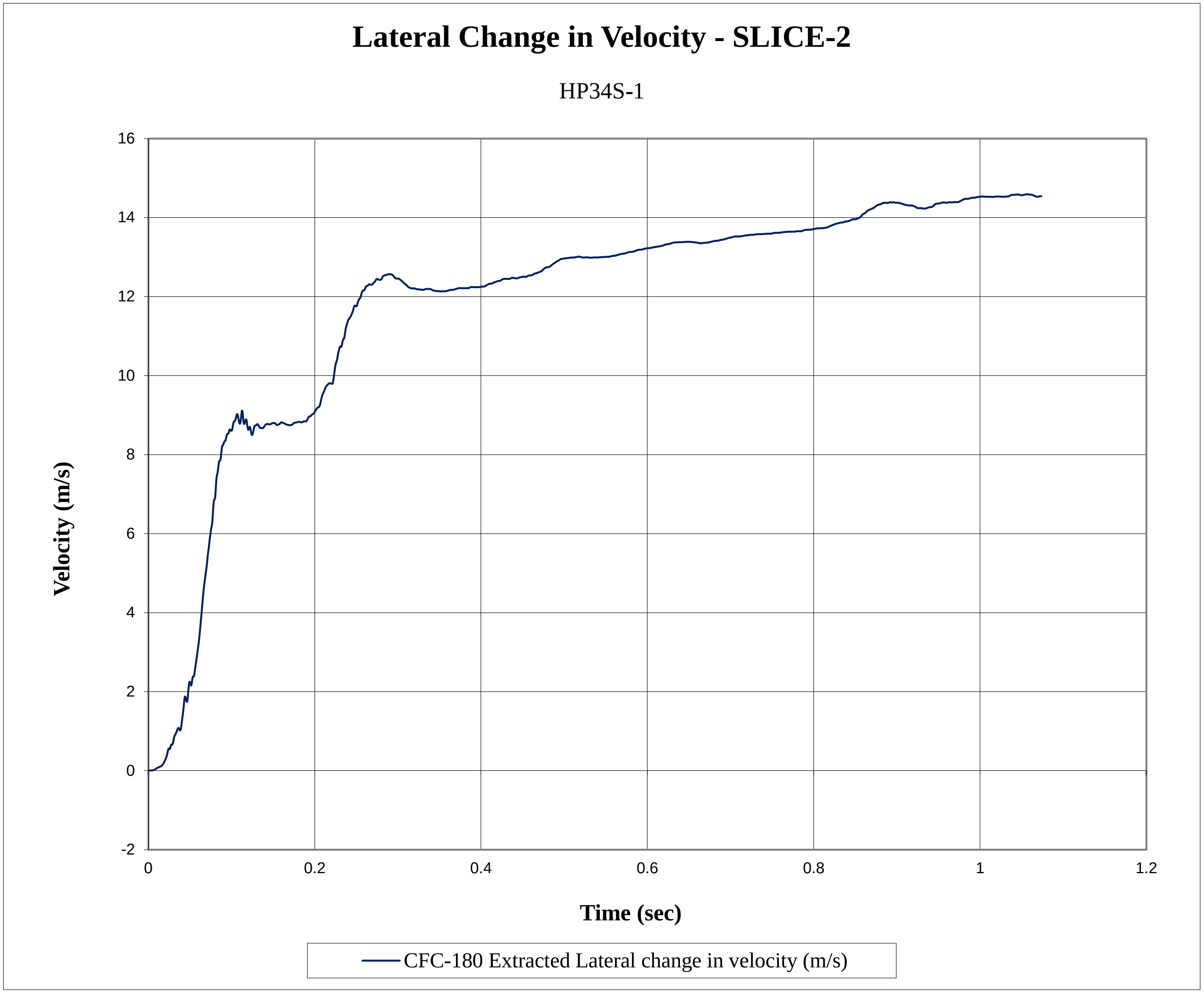


Figure D-5. Lateral Occupant Impact Velocity (SLICE-2), Test No. HP34S-1

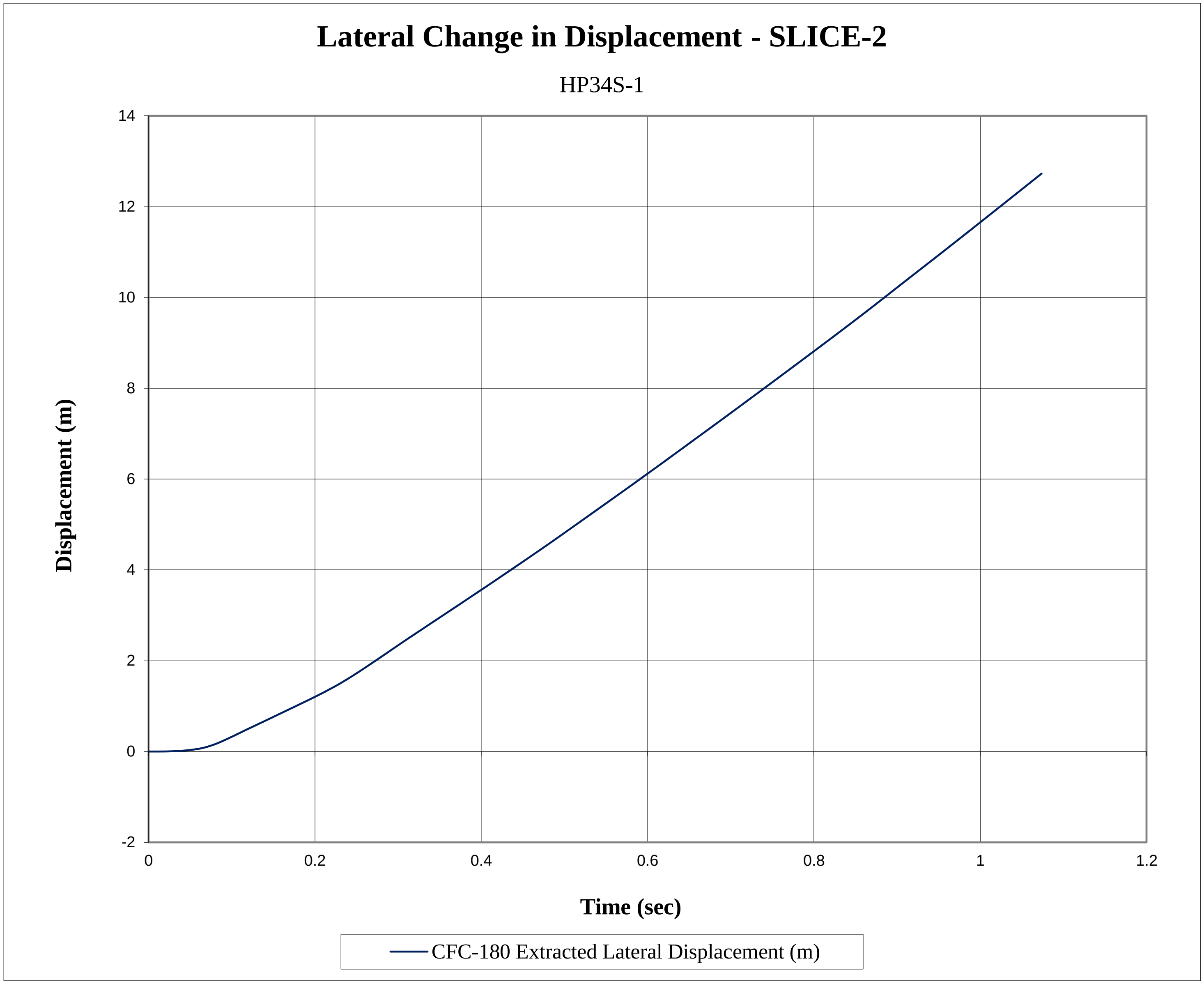


Figure D-6. Lateral Occupant Displacement (SLICE-2), Test No. HP34S-1

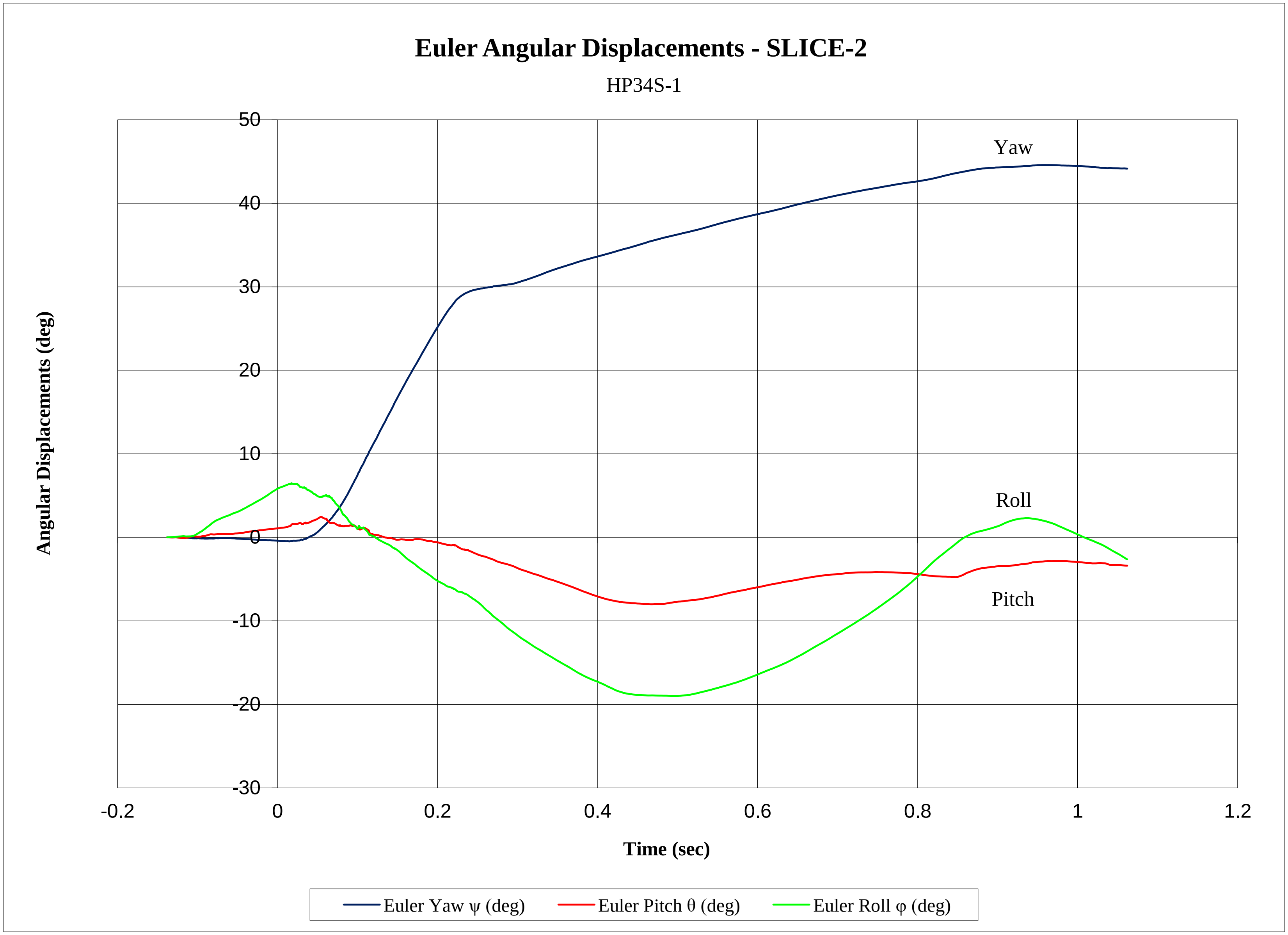


Figure D-7. Vehicle Angular Displacements (SLICE-2), Test No. HP34S-1

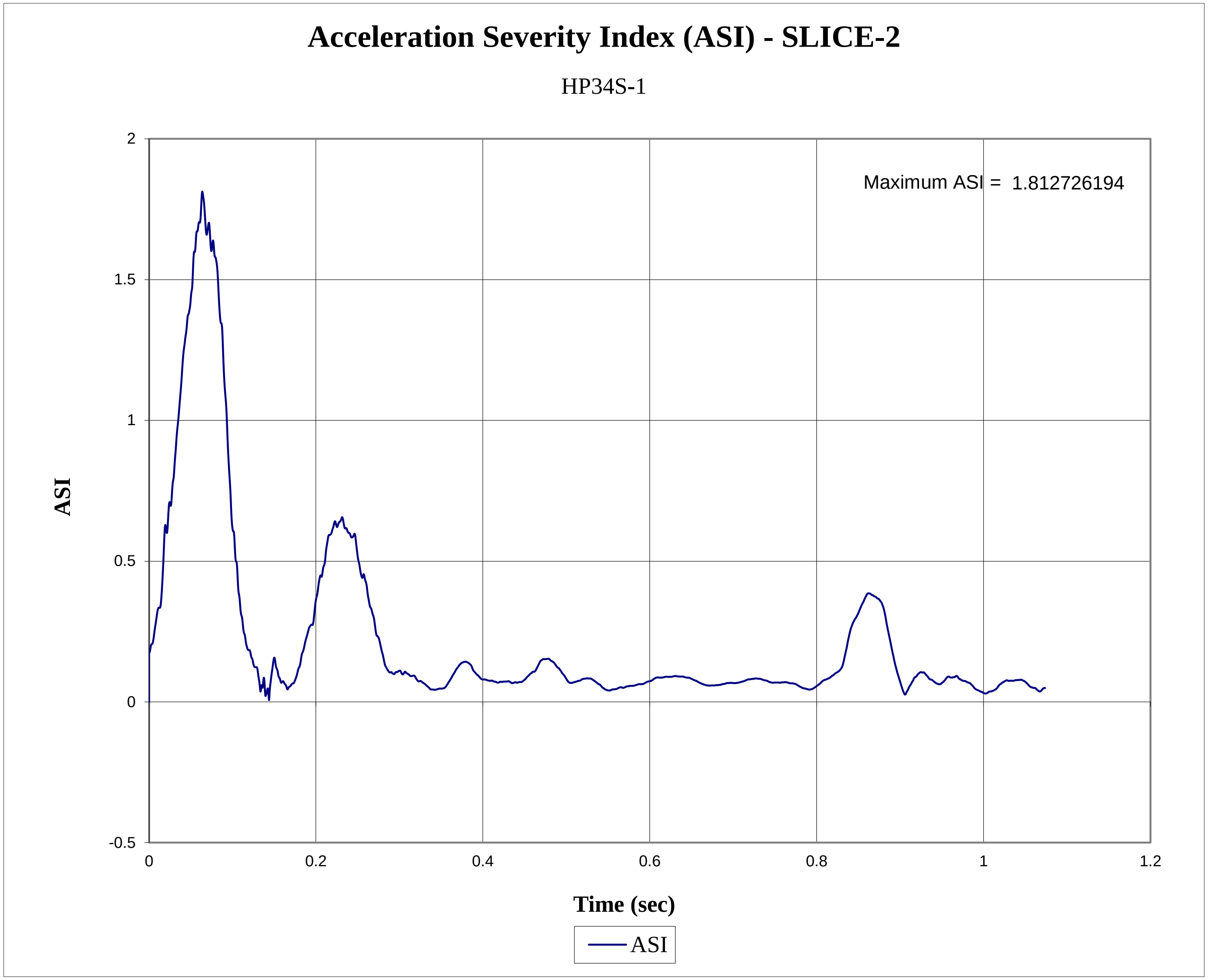


Figure D-8. Acceleration Severity Index (SLICE-2), Test No. HP34S-1

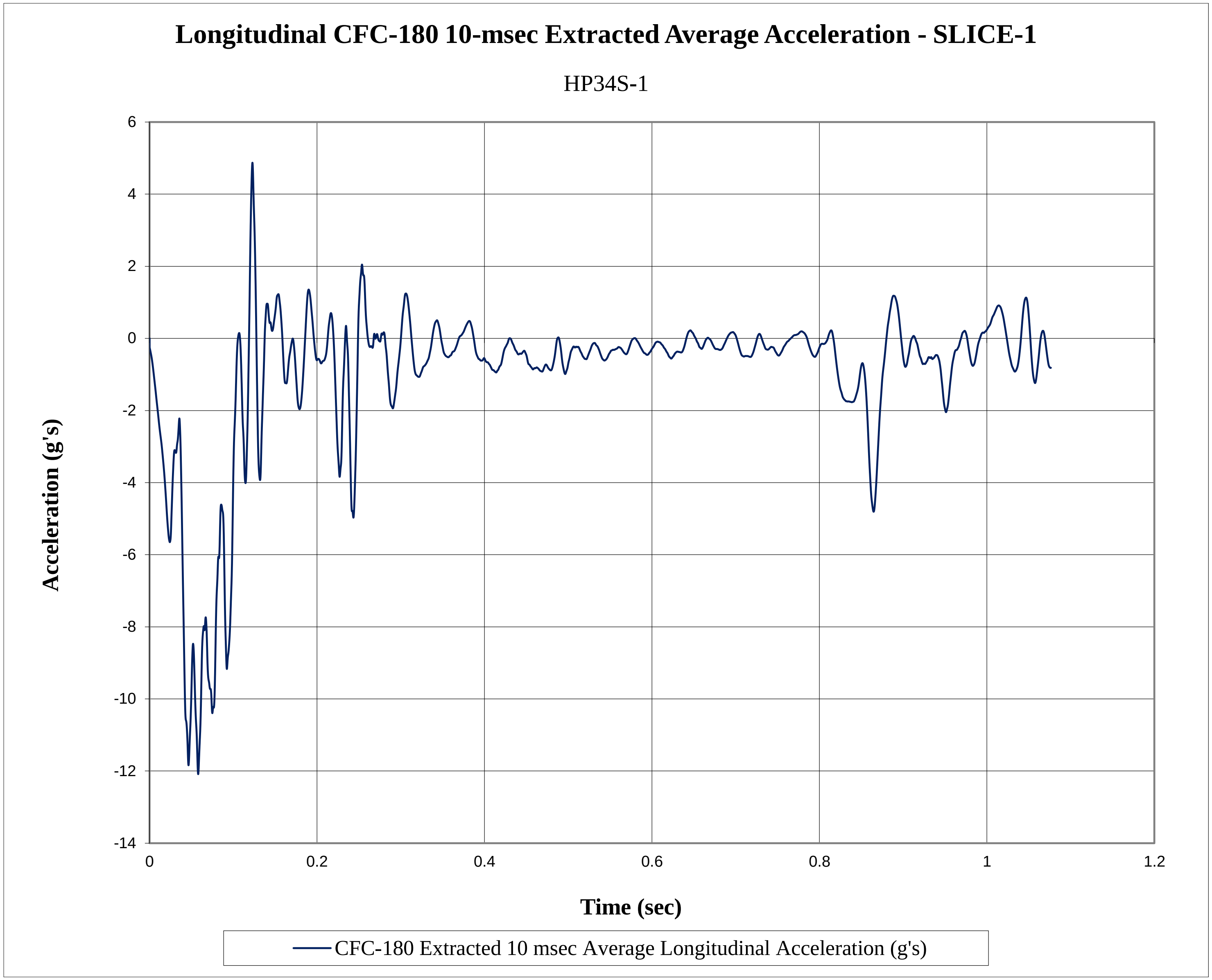


Figure D-9. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. HP34S-1

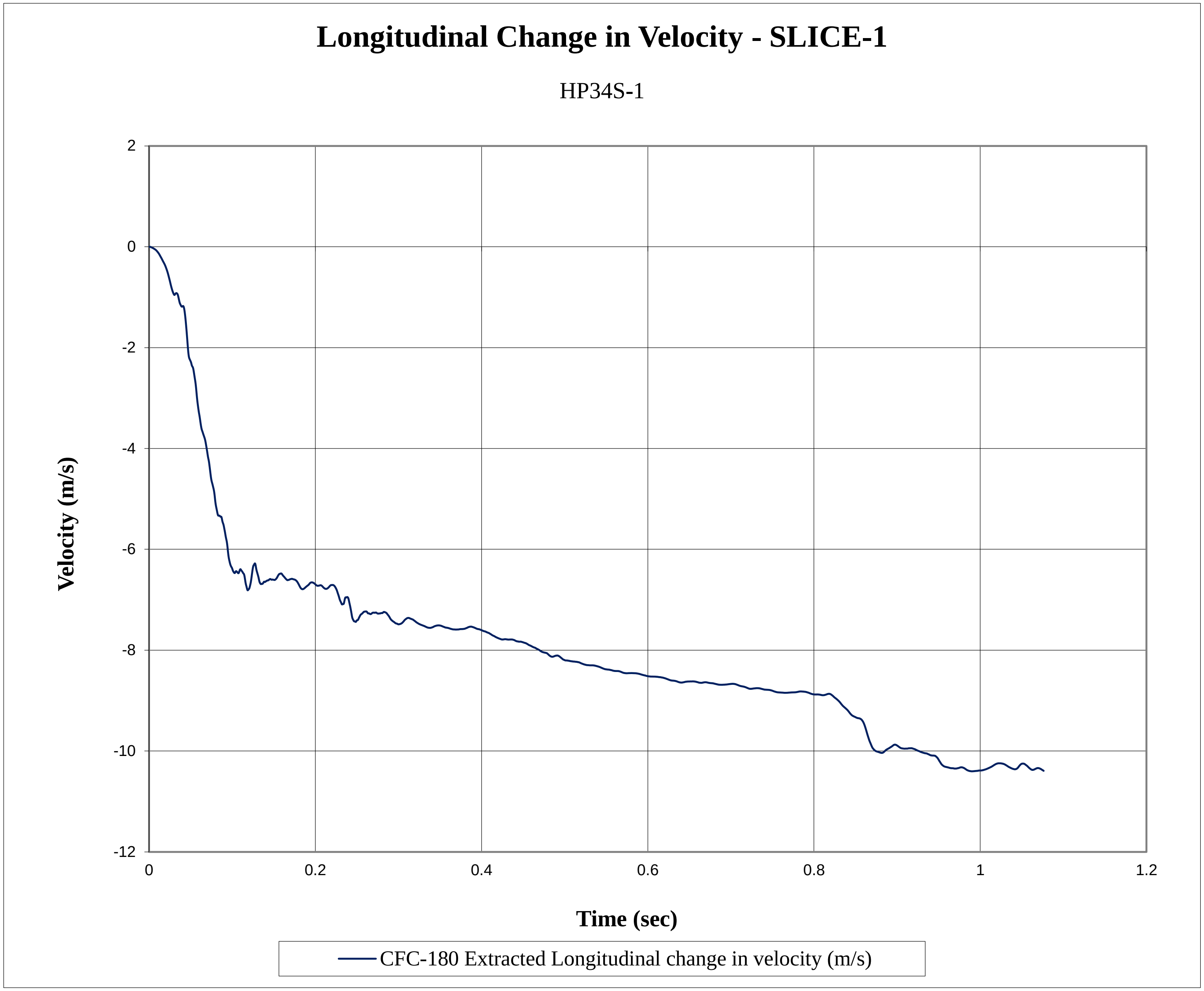


Figure D-10. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. HP34S-1

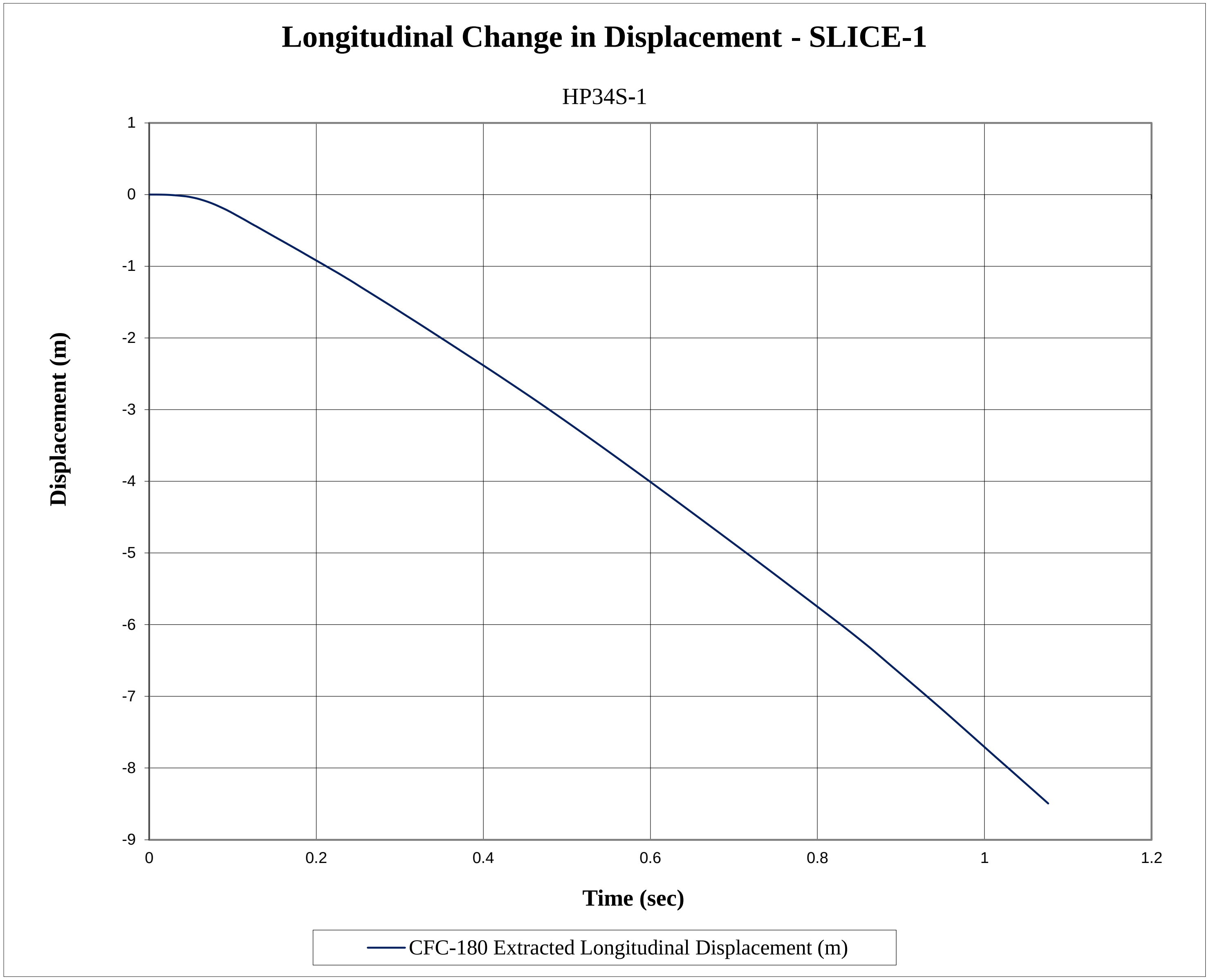


Figure D-11. Longitudinal Occupant Displacement (SLICE-1), Test No. HP34S-1

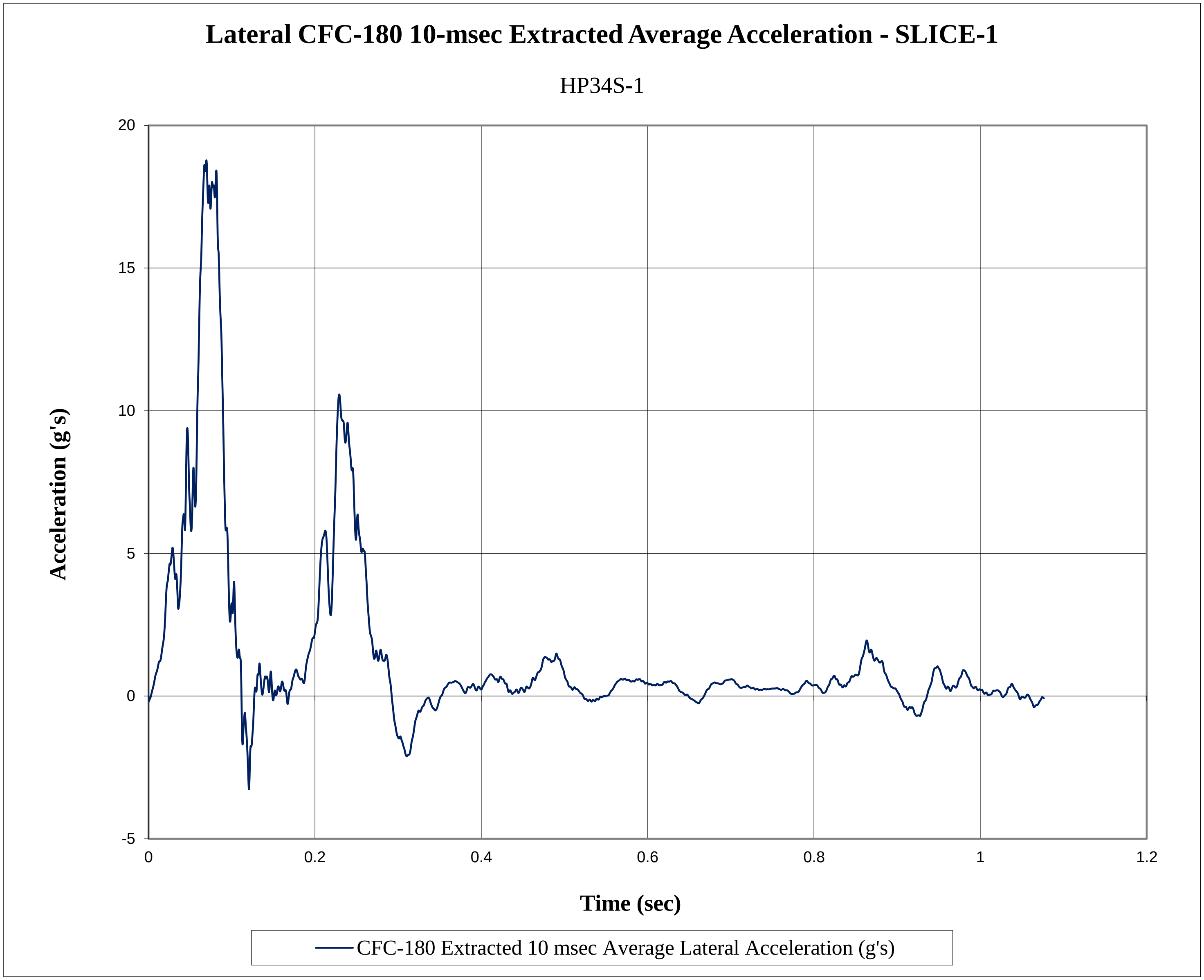


Figure D-12. 10-ms Average Lateral Deceleration (SLICE-1), Test No. HP34S-1

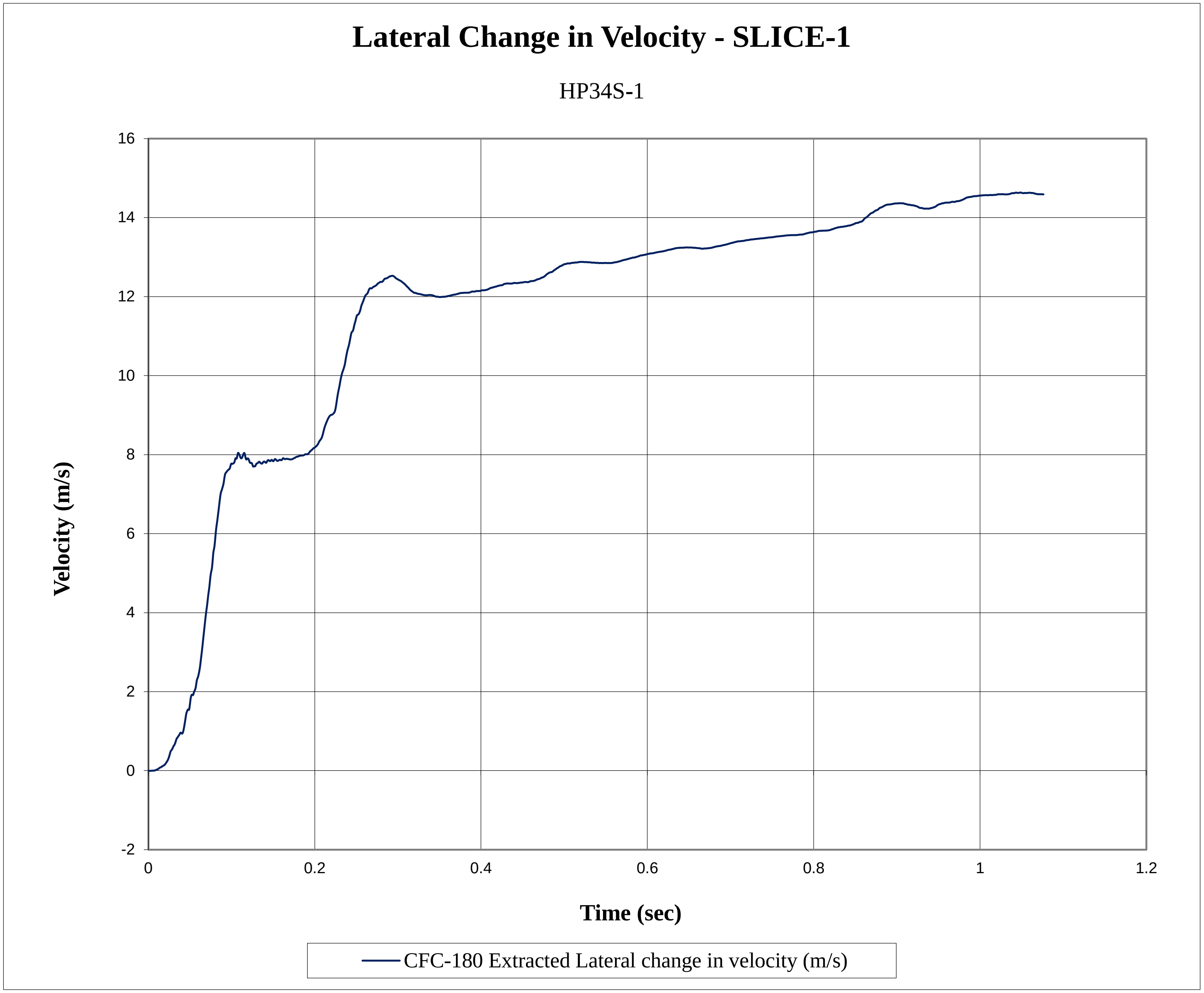


Figure D-13. Lateral Occupant Impact Velocity (SLICE-1), Test No. HP34S-1

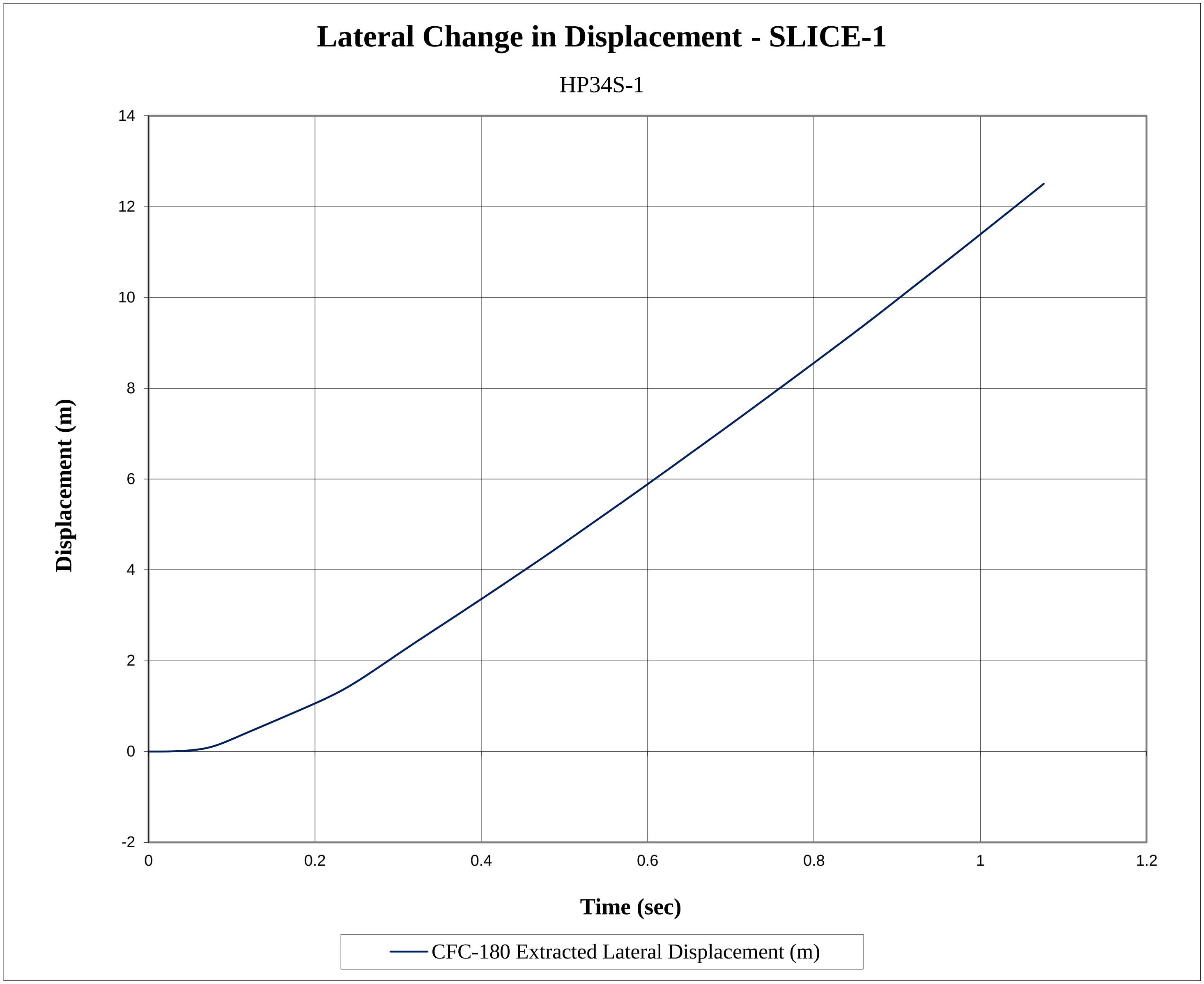


Figure D-14. Lateral Occupant Displacement (SLICE-1), Test No. HP34S-1

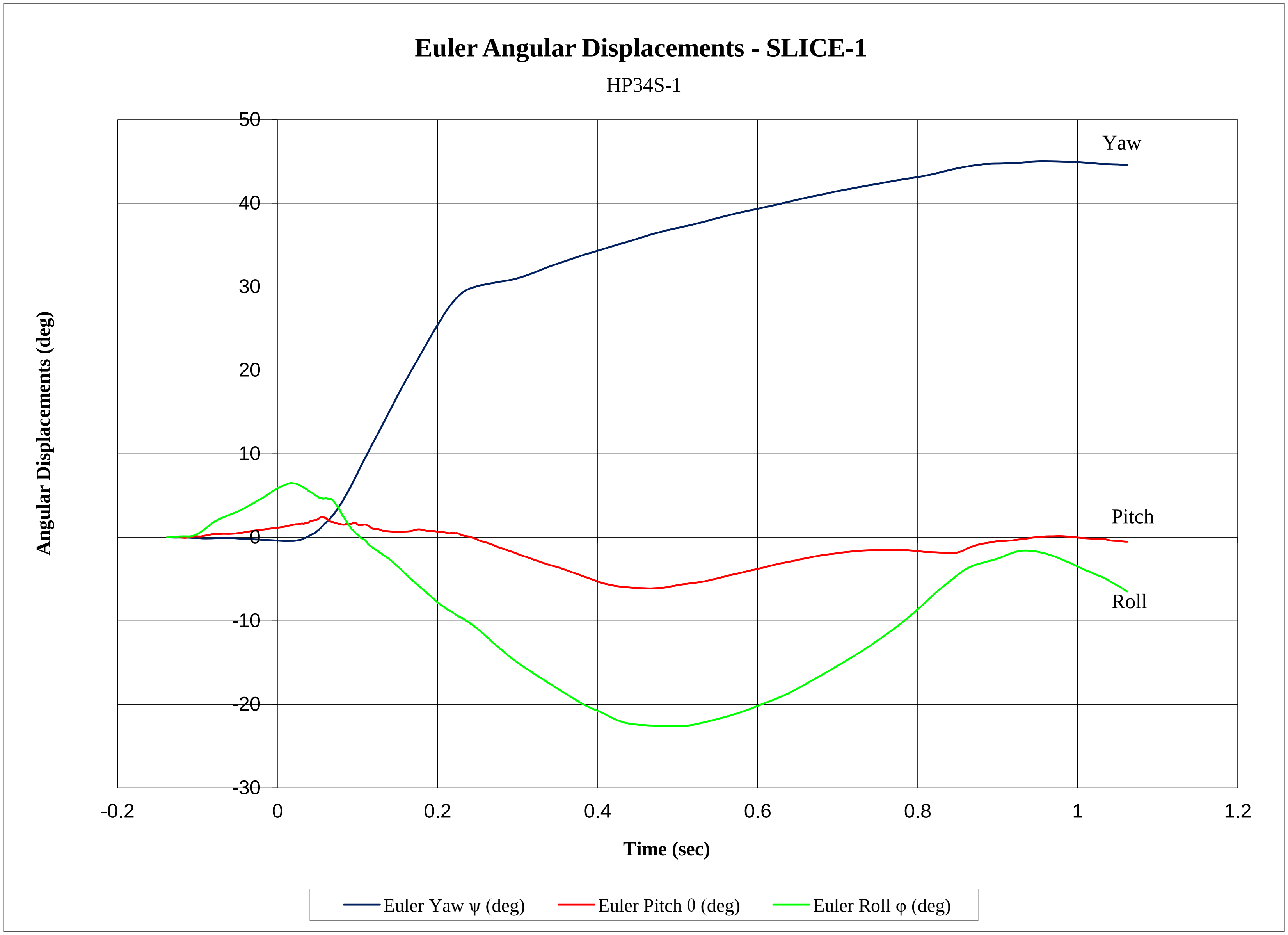


Figure D-15. Vehicle Angular Displacements (SLICE-1), Test No. HP34S-1

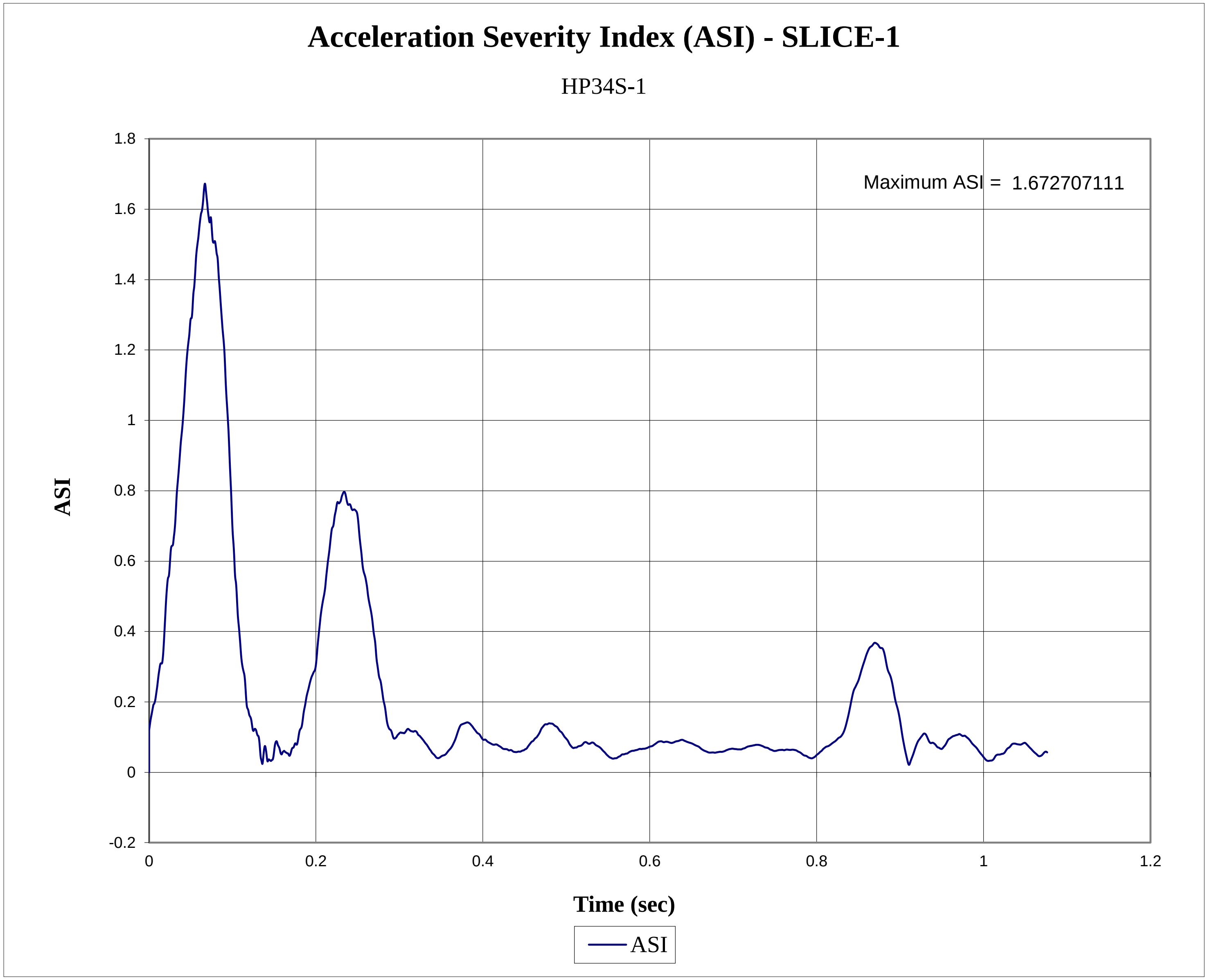


Figure D-16. Acceleration Severity Index (SLICE-1), Test No. HP34S-1

Appendix E. Accelerometer and Rate Transducer Data Plots, Test No. HP34S-2

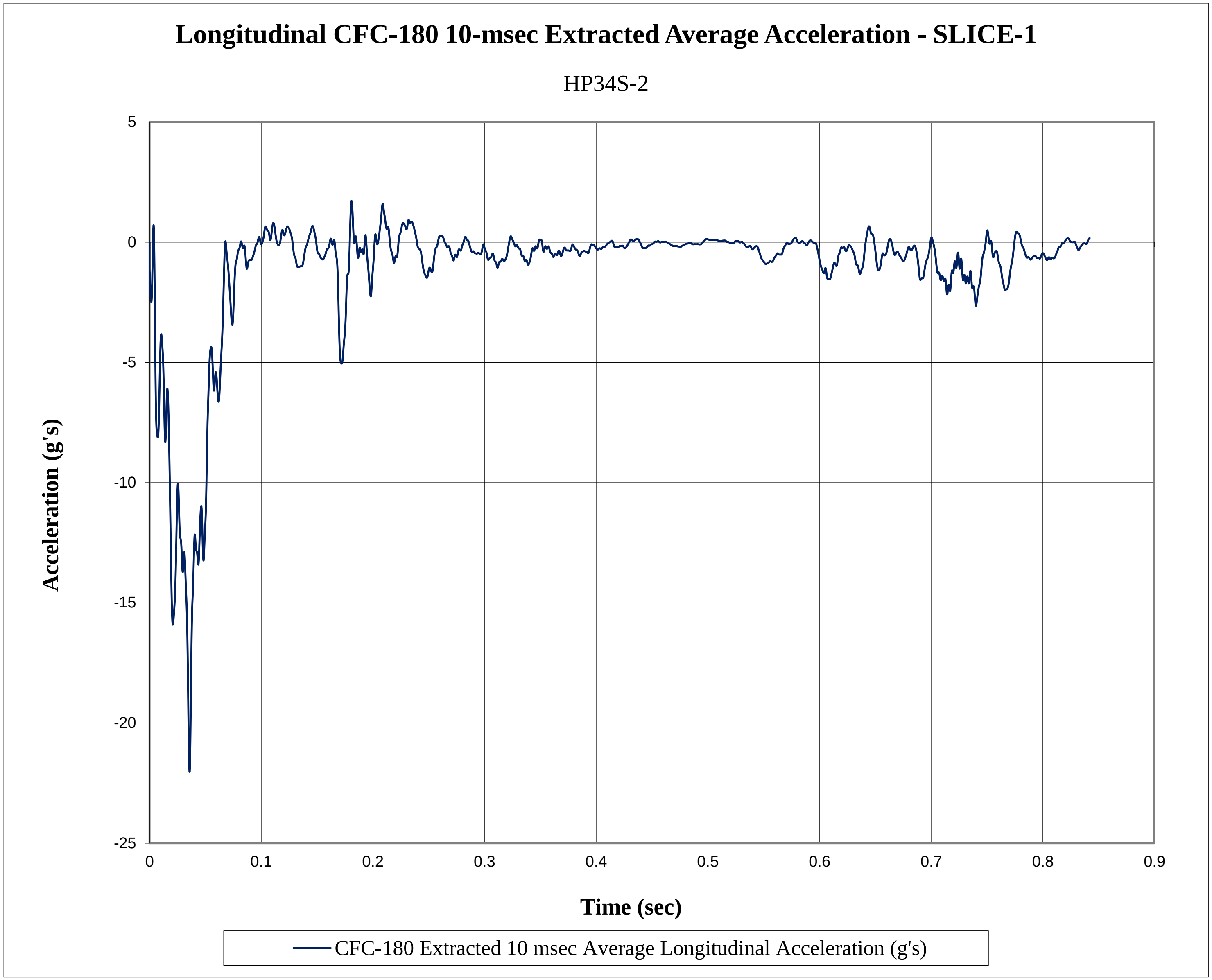


Figure E-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. HP34S-2

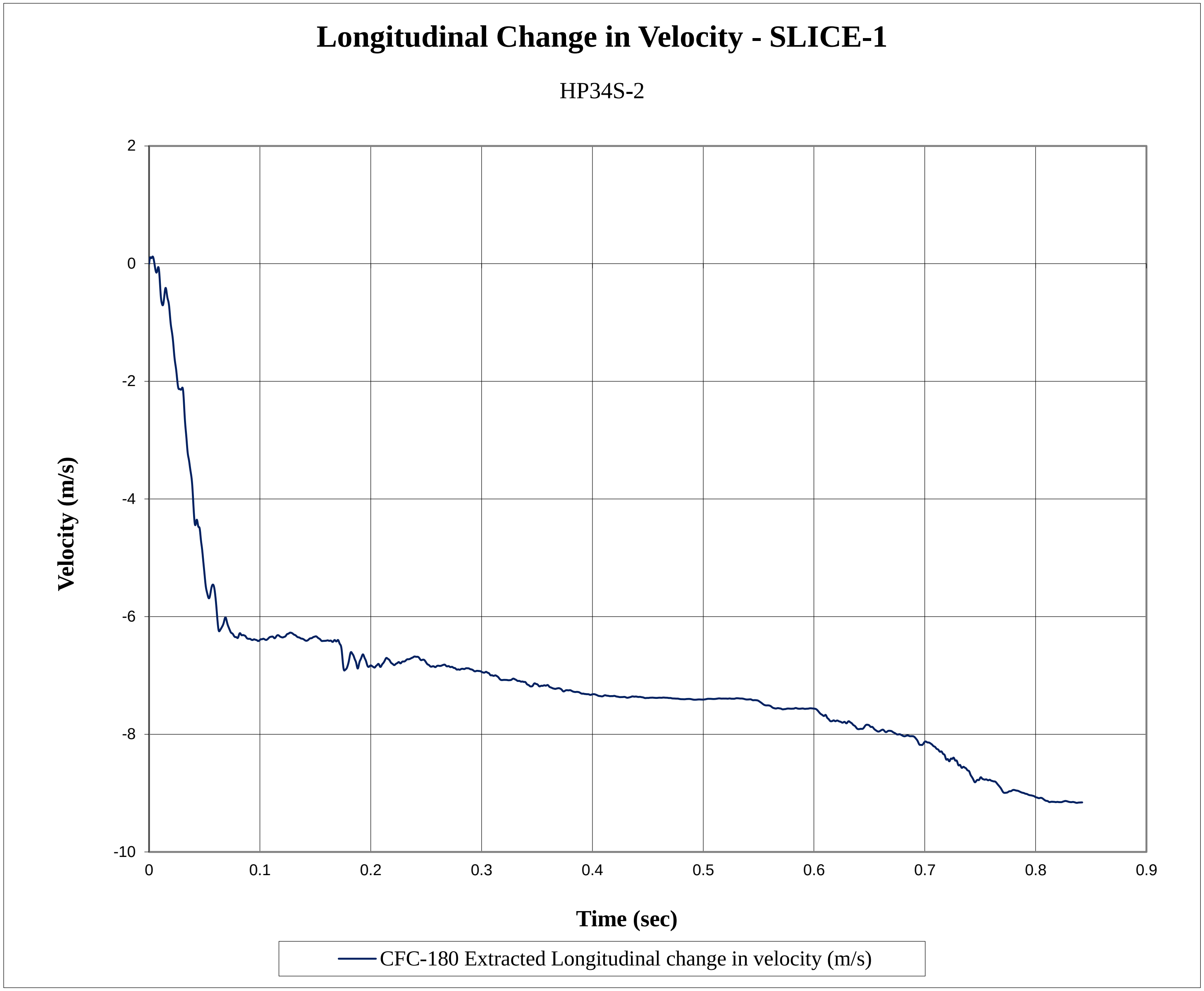


Figure E-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. HP34S-2

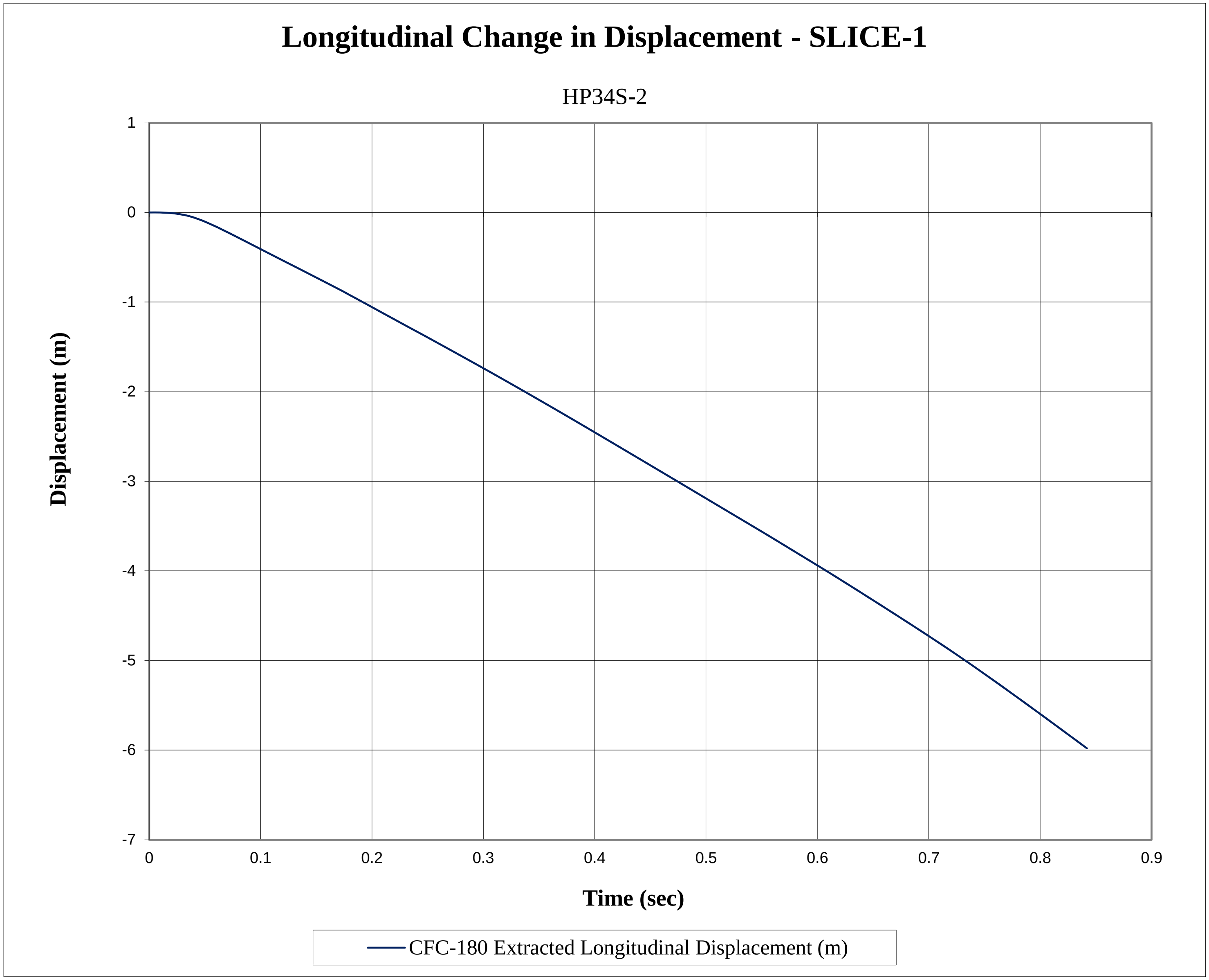


Figure E-3. Longitudinal Occupant Displacement (SLICE-1), Test No. HP34S-2

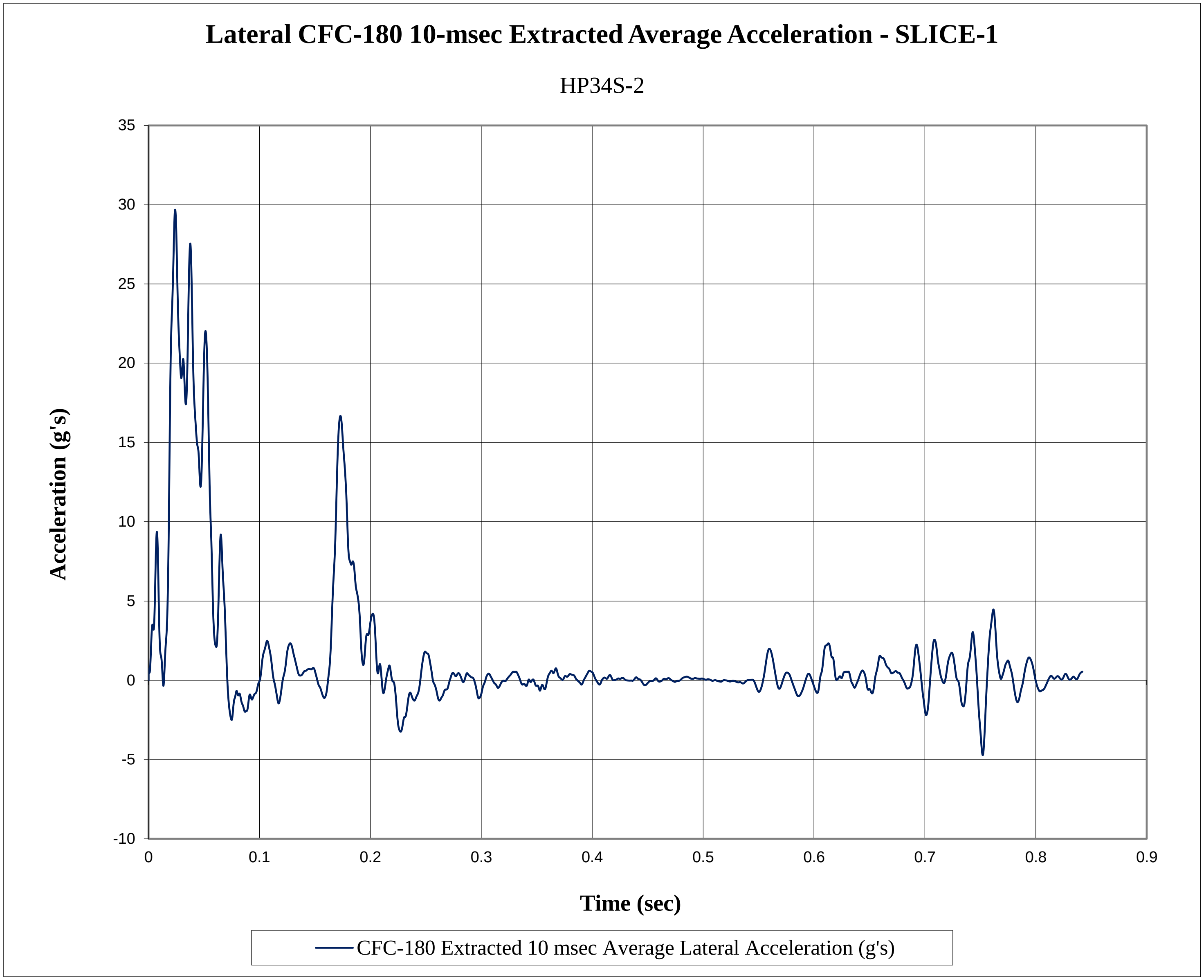


Figure E-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. HP34S-2

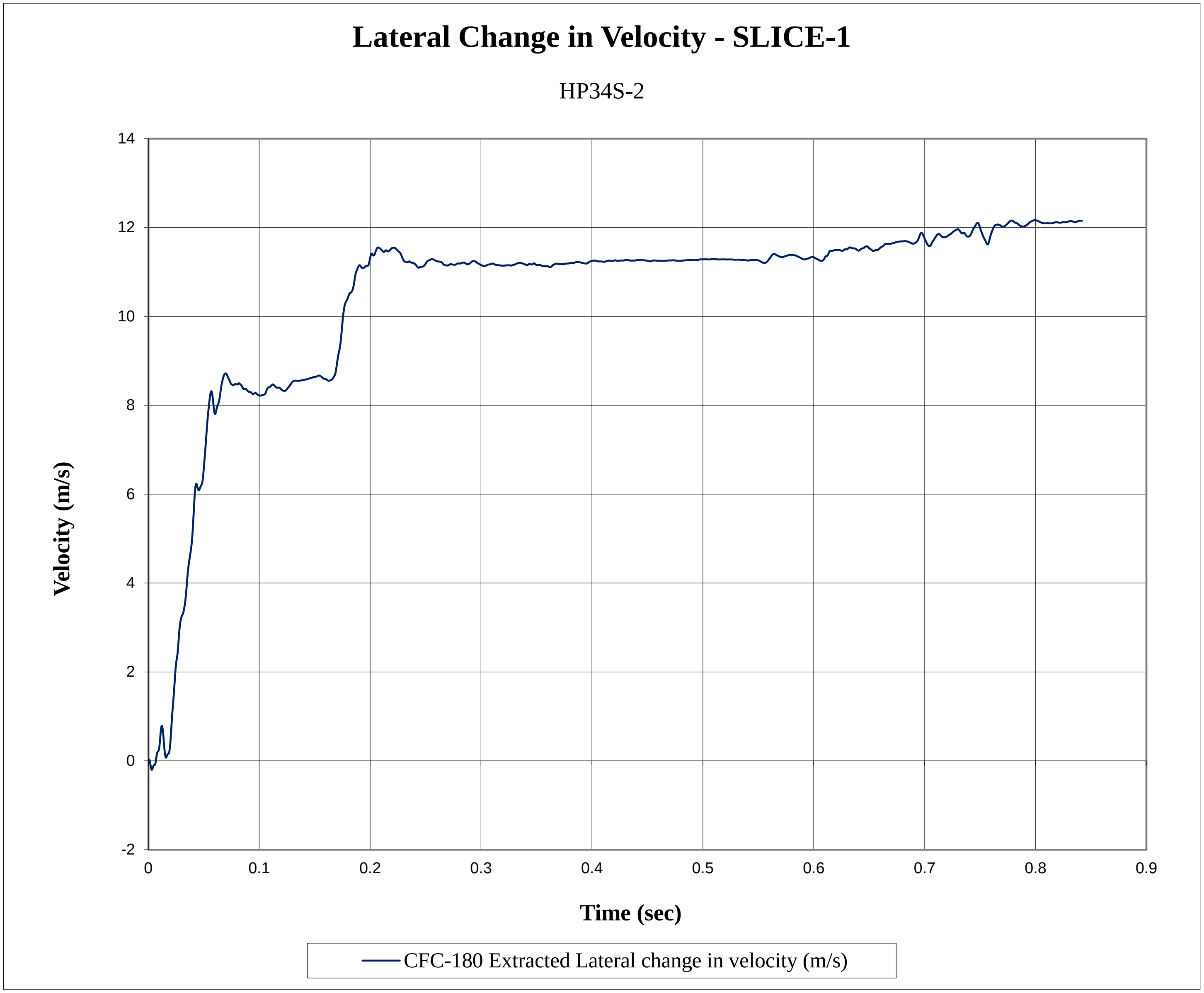


Figure E-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. HP34S-2

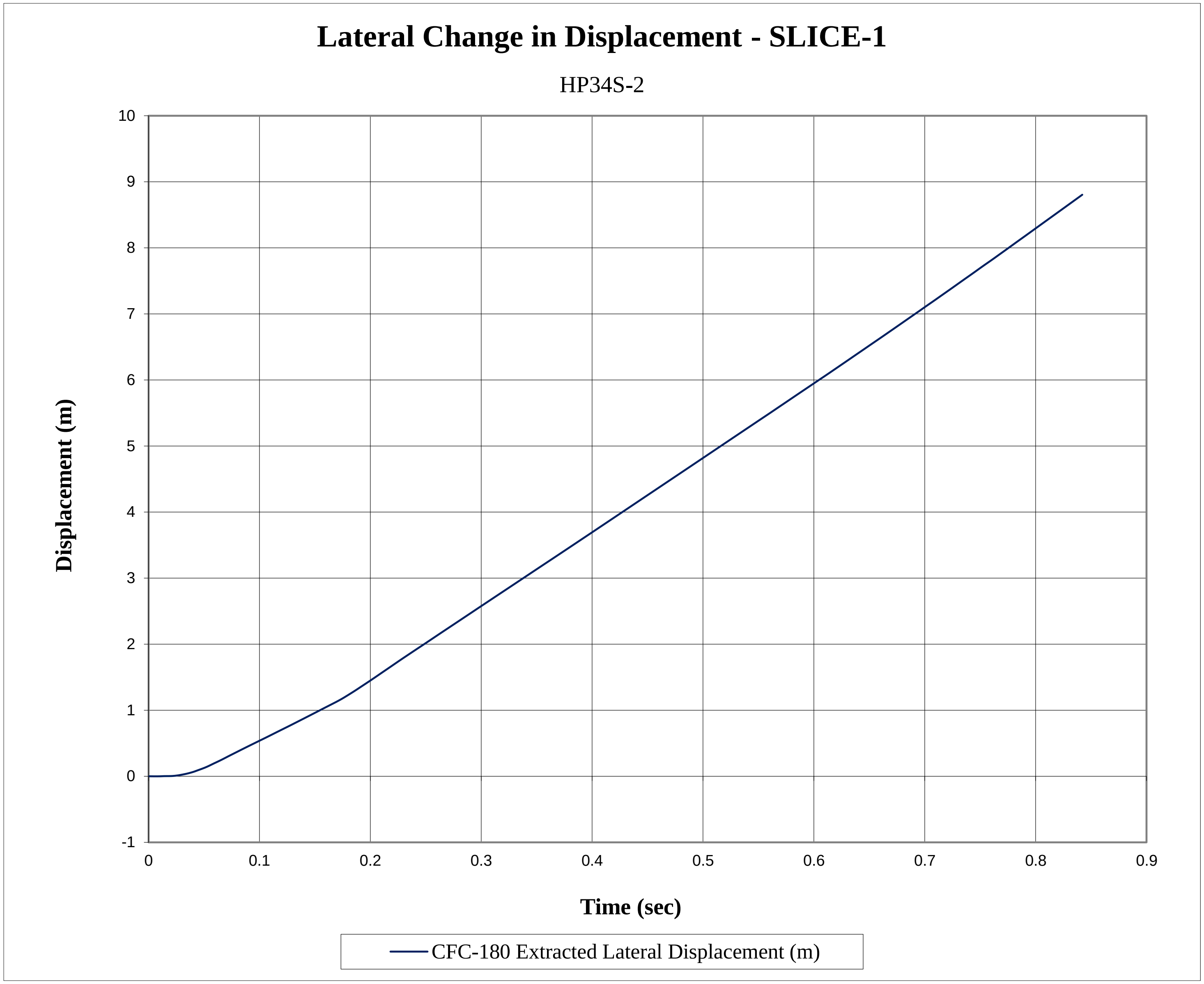


Figure E-6. Lateral Occupant Displacement (SLICE-1), Test No. HP34S-2

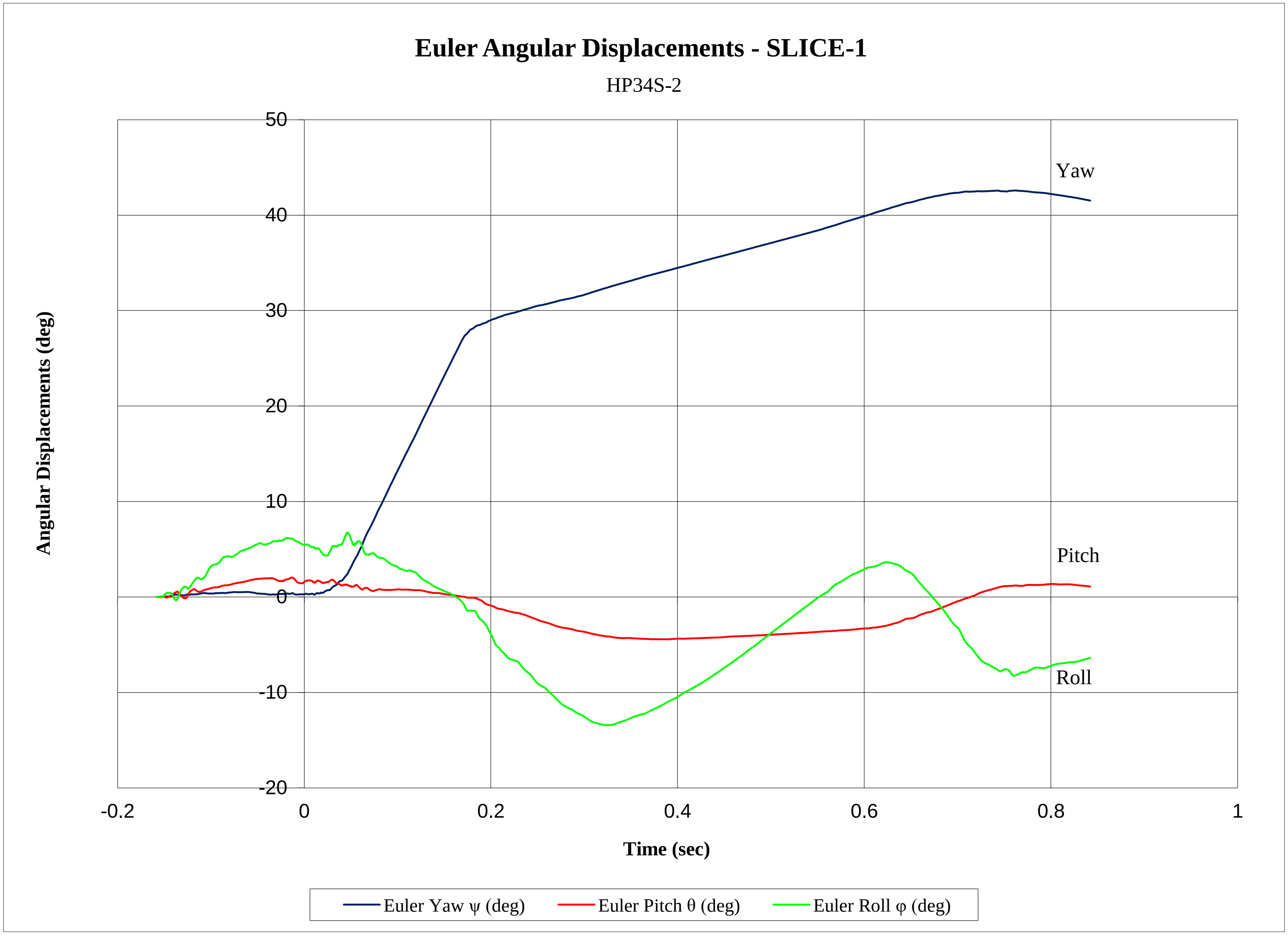


Figure E-7. Vehicle Angular Displacements (SLICE-1), Test No. HP34S-2

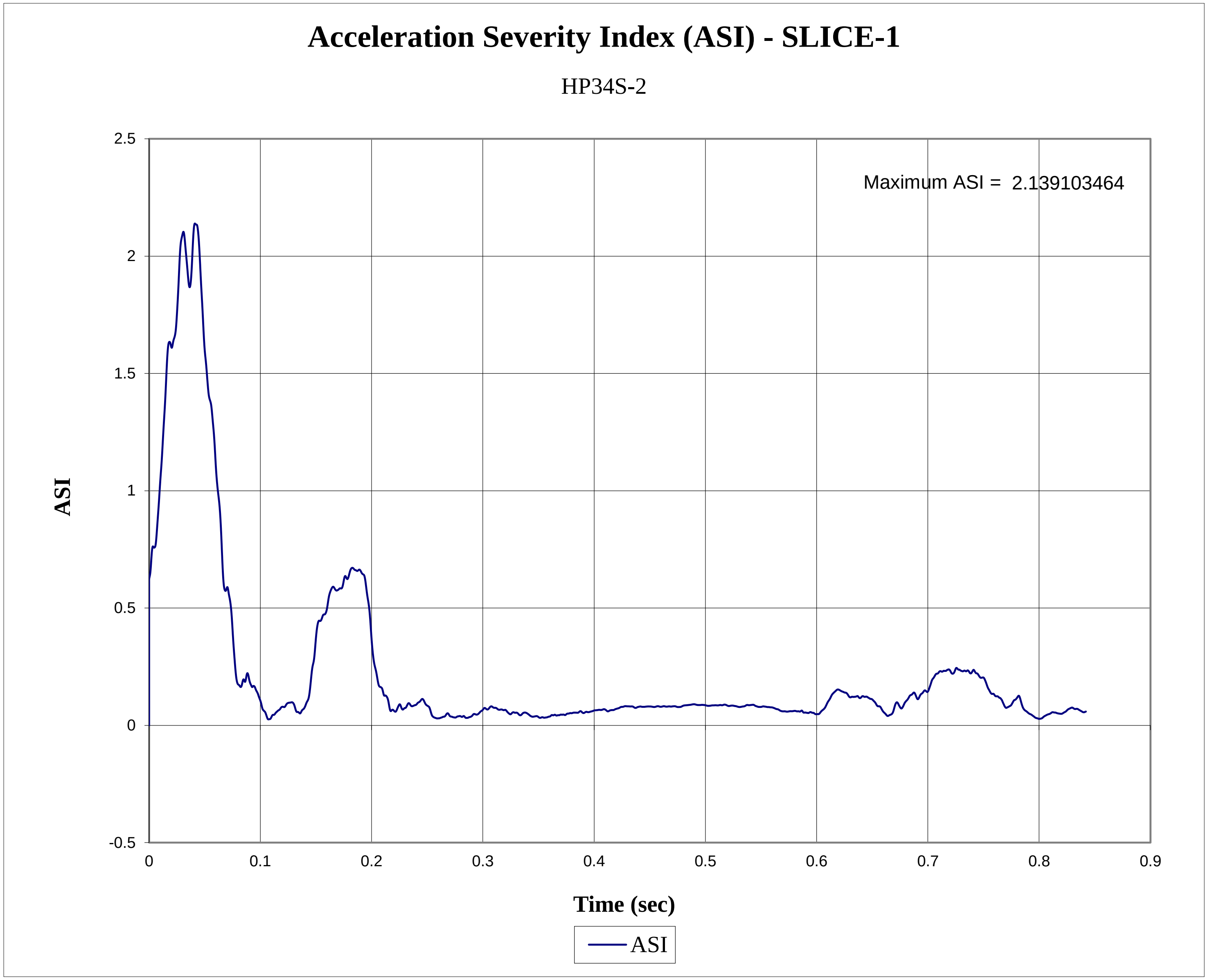


Figure E-8. Acceleration Severity Index (SLICE-1), Test No. HP34S-2

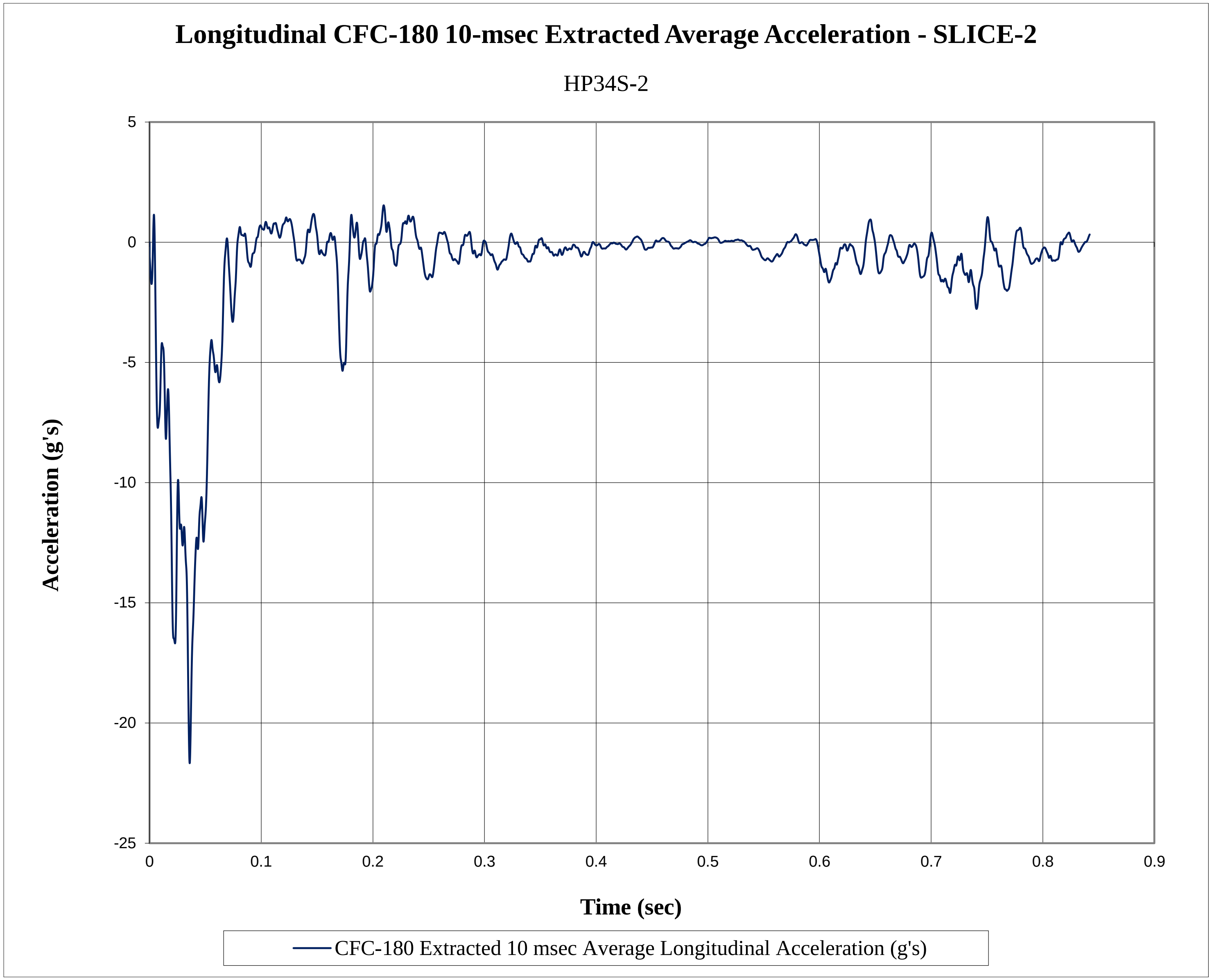


Figure E-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. HP34S-2

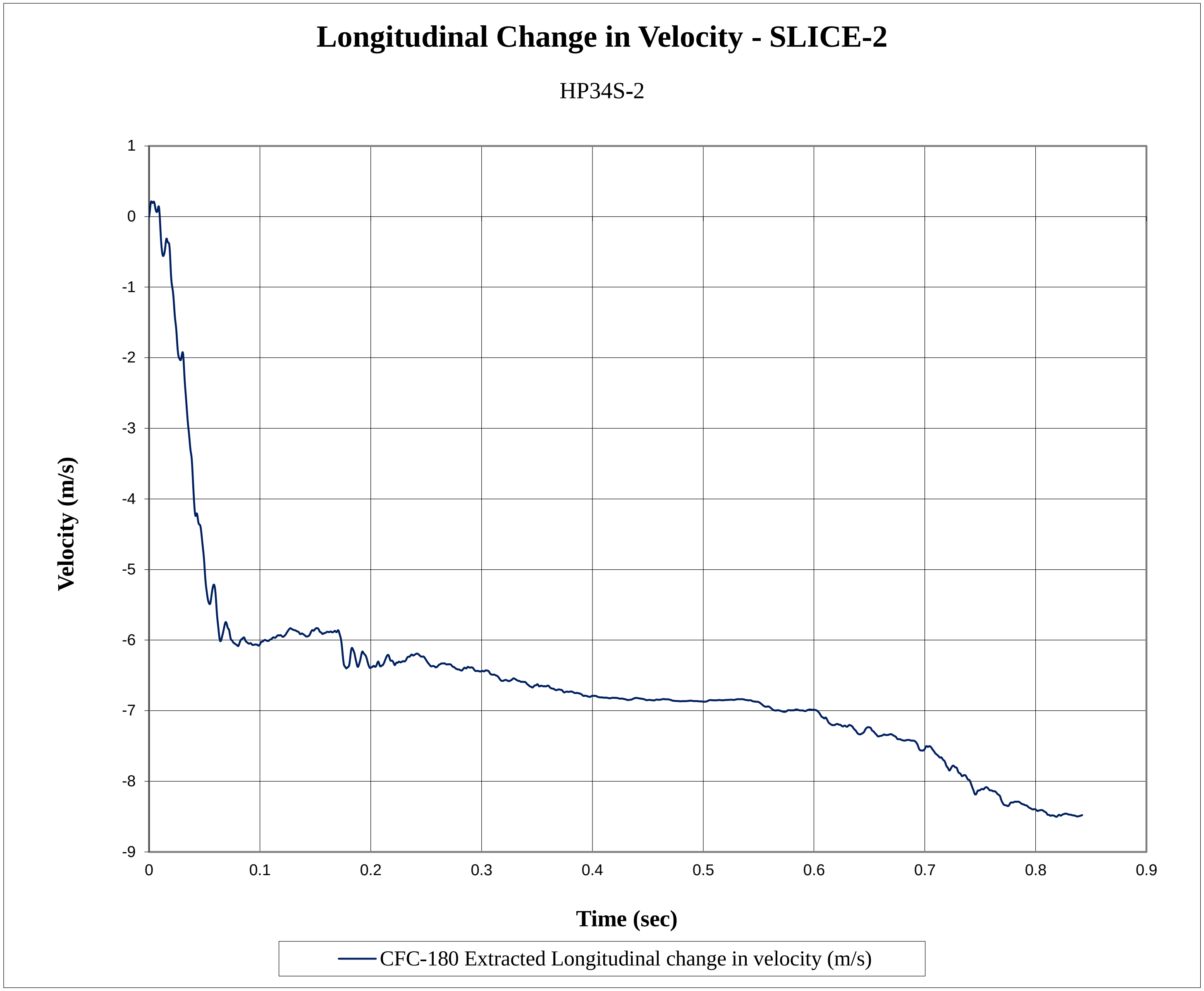


Figure E-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. HP34S-2

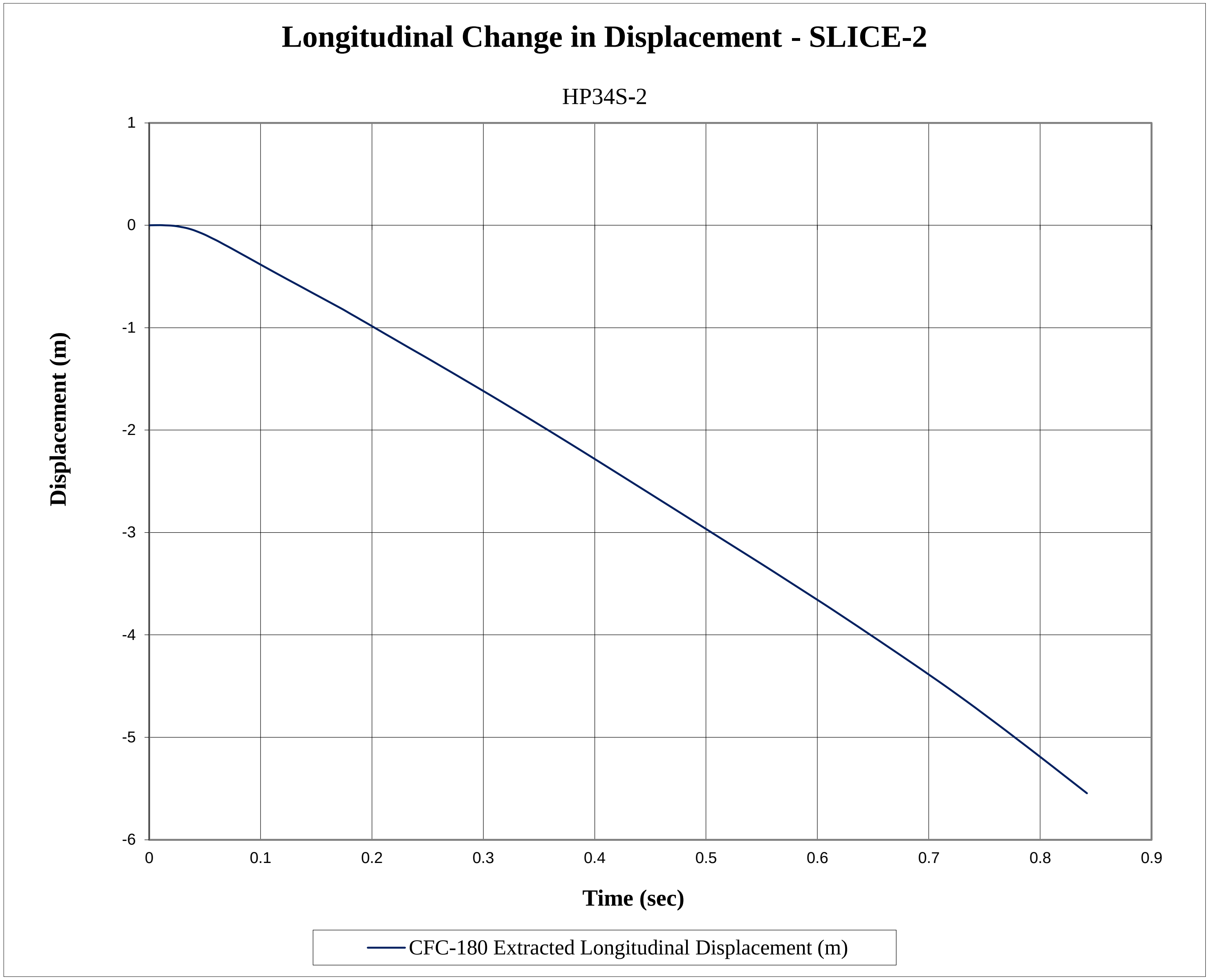


Figure E-11. Longitudinal Occupant Displacement (SLICE-2), Test No. HP34S-2

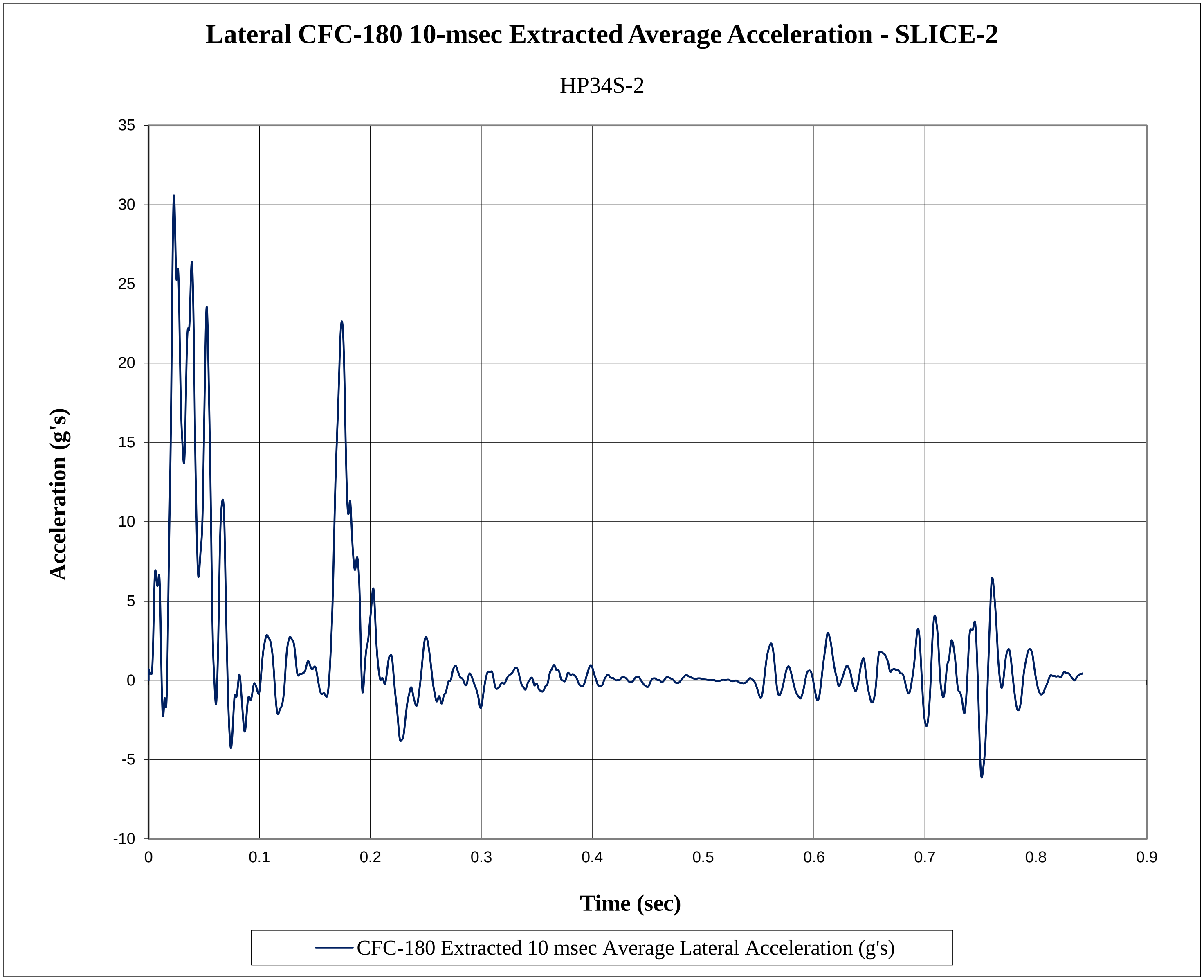


Figure E-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. HP34S-2

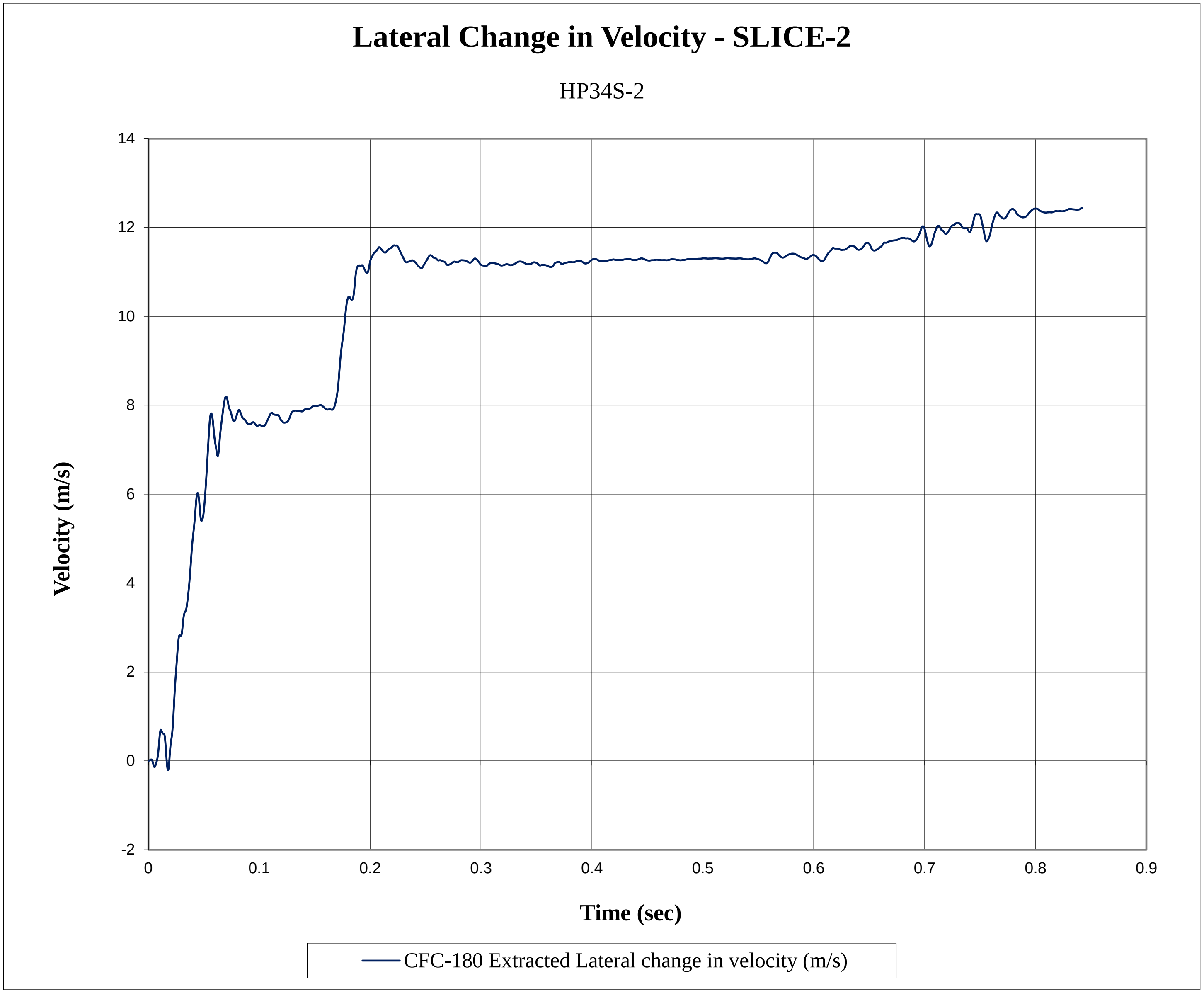


Figure E-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. HP34S-2

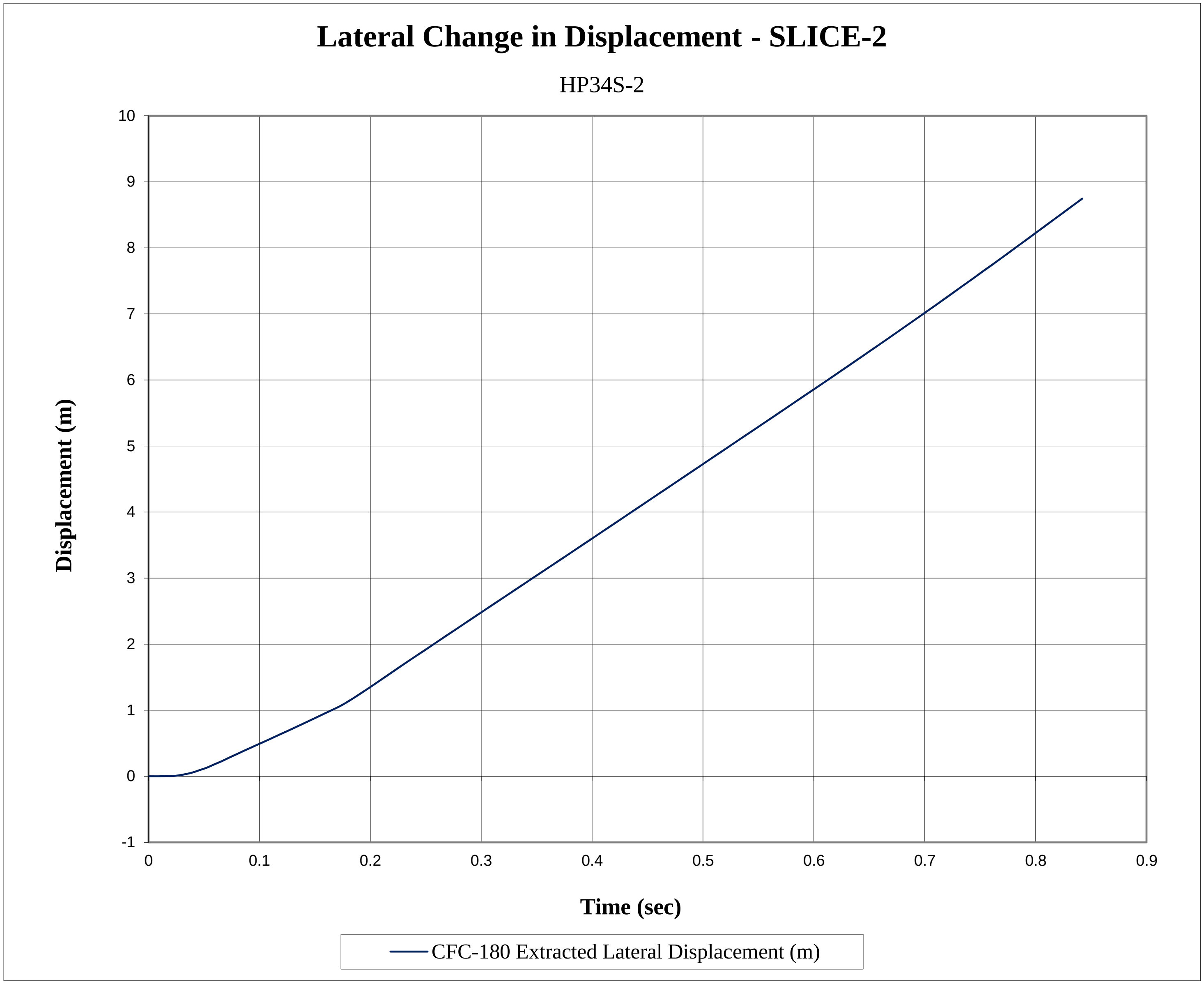


Figure E-14. Lateral Occupant Displacement (SLICE-2), Test No. HP34S-2

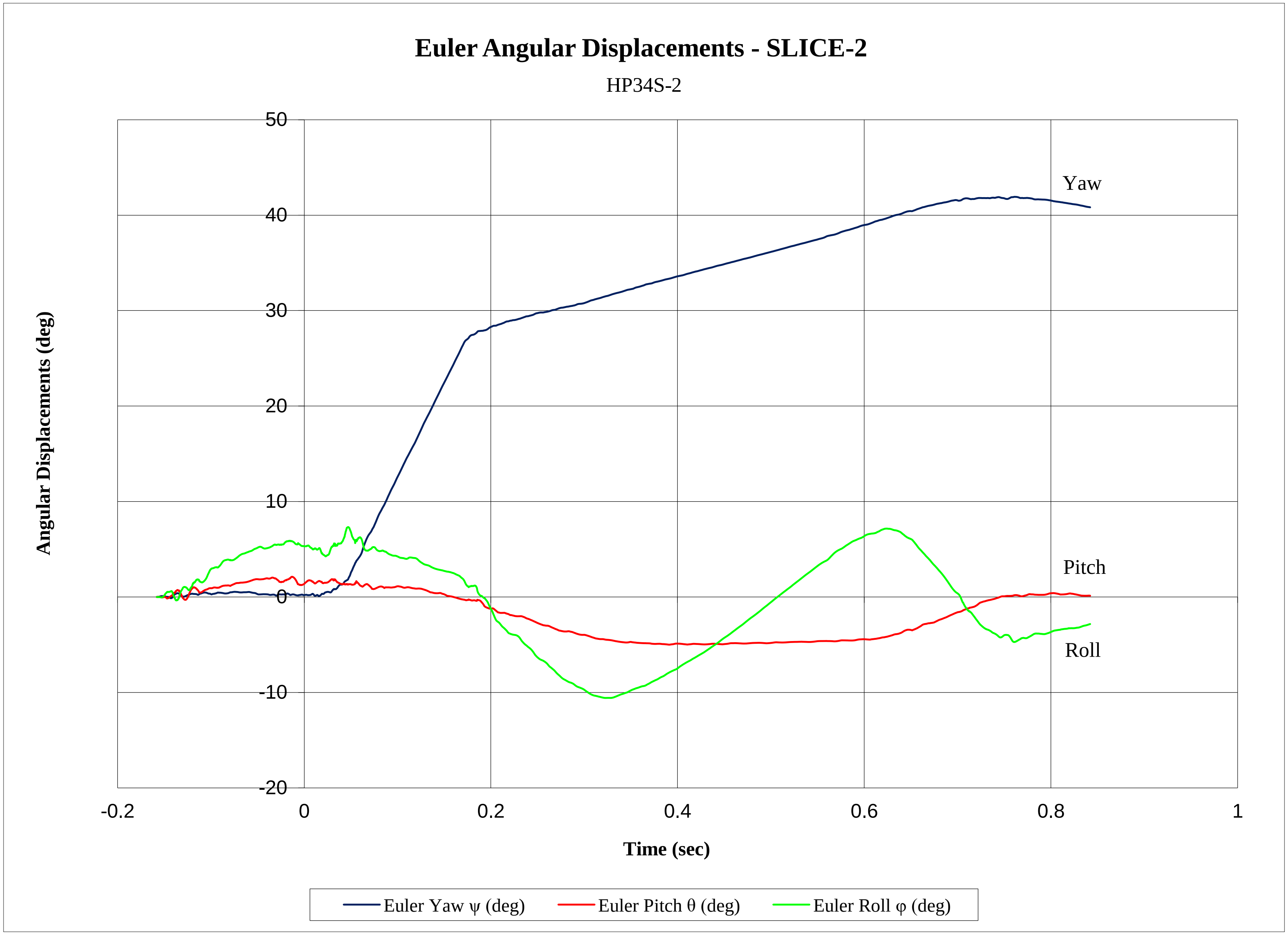


Figure E-15. Vehicle Angular Displacements (SLICE-2), Test No. HP34S-2

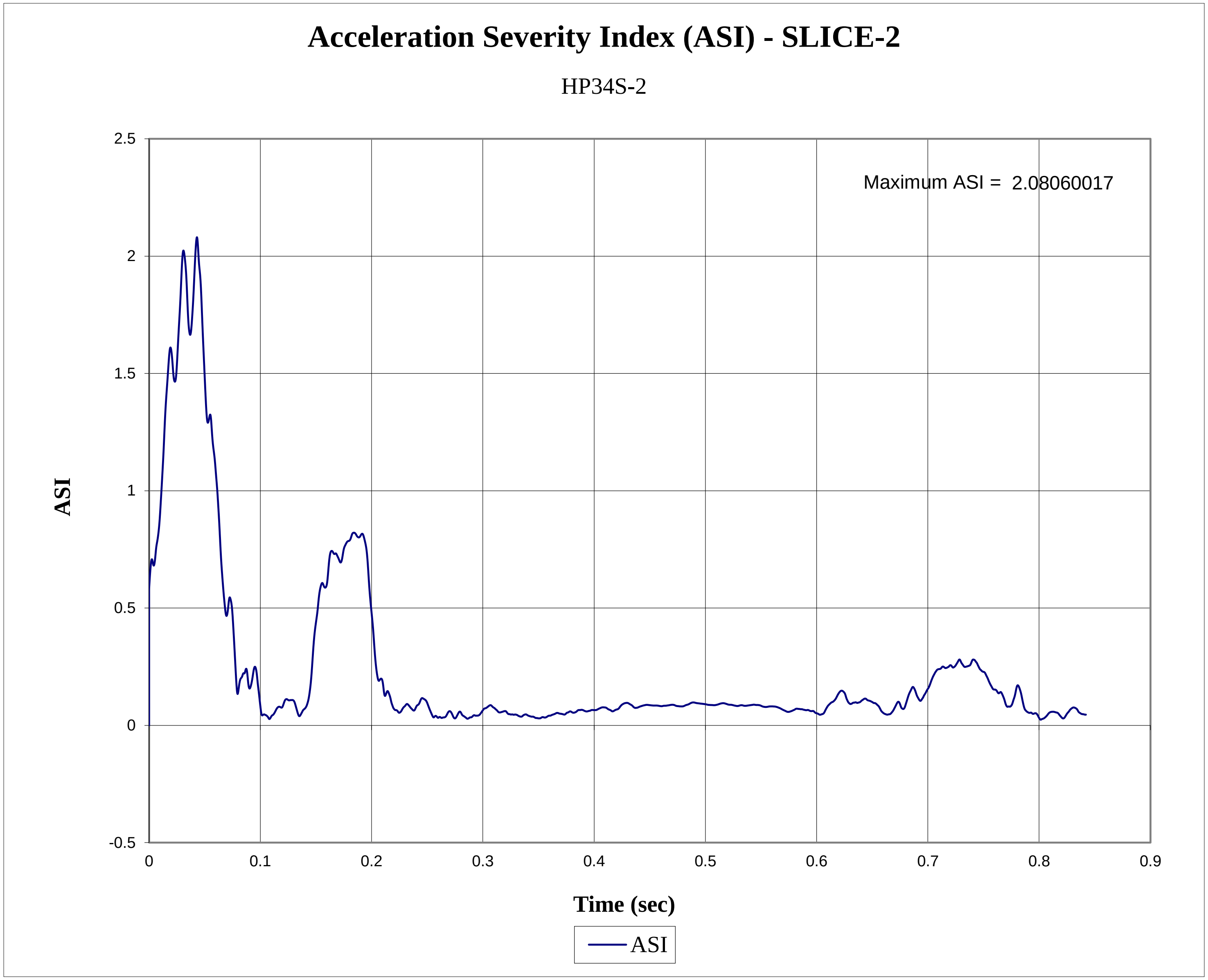


Figure E-16. Acceleration Severity Index (SLICE-2), Test No. HP34S-2

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