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CRASH TESTING AND EVALUATION OF THE HDOT 42-IN. TALL, SOLID CONCRETE BRIDGE RAIL WITH AESTHETIC RECESSED ROUNDED PANELS AND 6-IN. TALL SIDEWALK: MASH TEST DESIGNATION NOS. 3-10 AND 3-11

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16. Abstract

This report documents two full scale-crash tests conducted in support of a study to investigate the safety performance of the Hawaii Department of Transportation's (HDOT's) 42-in. Tall, Aesthetic Recessed Rounded Panels Concrete Bridge Rail system with a 6-ft wide by 6-in. tall sidewalk. The bridge rail consisted of four 22-ft long concrete parapets anchored to the concrete tarmac. Expansion joints between each segment consisted of 24½-in. long, No. 8 ASTM A615 Grade 60 steel bars cast into the concrete and inserted into a PVC pipe on the upstream side of the expansion joint. Test nos. H42S-1 and H42S-2 were conducted according to the *Manual for Assessing Safety Hardware 2016* (MASH 2016) criteria using Test-Level 3 (TL-3) test designation nos. 3-10 and 3-11, respectively.

In test no. H42S-1, a 2270P quad cab pickup truck impacted the sidewalk at a speed of 62.9 mph and an angle of 24.8 degrees and impacted the barrier at a speed of 61.8 mph and an angle of 24.4 degrees. In test no. H42S-2, a 1100C small car impacted the sidewalk at a speed of 62.2 mph and at an angle of 24.8 degrees and impacted the barrier at a speed of 60.6 mph and an angle of 23.5 degrees. In both tests, the bridge rail successfully contained and redirected the vehicle. Thus, test nos. H42S-1 and H42S-2 successfully met the TL-3 safety performance criteria defined in MASH 2016 and the HDOT 42-in. Tall, Aesthetic Recessed Rounded Panels Concrete Bridge Rail system with a 6-ft wide by 6-in. tall sidewalk was determined to be crashworthy according to MASH 2016 TL-3.

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UNCERTAINTY OF MEASUREMENT STATEMENT

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

INDEPENDENT APPROVING AUTHORITY

The Independent Approving Authority for the data contained herein was Dr. Mojdeh Asadollahipajouh, Research Assistant Professor.

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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) employs several concrete bridge rails with aesthetic treatments; however, the crashworthiness of some systems has yet to be proven under current impact safety standards. This report consists of the documentation of two full-scale crash tests conducted in support of a study to evaluate the safety performance of HDOT's 42-in. Tall, Aesthetic Concrete Bridge Rail with recessed rounded panels on both the traffic- and back-side surfaces. The recessed panels were 6 in. wide, 14 in. tall, and ½ in. deep at an inclination angle of 60 degrees. Typically, the bridge rail is anchored to the bridge deck on the traffic-side face of the barrier with the application of a 2-in. thick concrete finishing surface. In the crash testing efforts, the bridge railing and the sidewalk were anchored to the Midwest Roadside Safety Facility's (MwRSF's) existing unreinforced concrete tarmac using epoxied, vertical, steel dowel bars with expansion joints located at 22-ft intervals. This system included a 6-ft wide sidewalk used in the crash testing program as it was deemed a critical part of the system. The original standard plans of the HDOT 42-in. Tall, Aesthetic Concrete Bridge Rail are shown in Figures 1 through 3 [1].

In 2006, researchers at the Texas A&M Transportation Institute (TTI) published National Cooperative Highway Research Program (NCHRP) Report 554 [2]. This report developed design guidelines for aesthetic treatments for safety shape concrete roadway barriers by implementing a series of Finite Element Modeling (FEM) simulations and physical crash testing. The simulations examined the effects of the width, depth, and angle of inclination of the asperity surface. Asperity angles of 30, 45, and 90 degrees were analyzed and categorized as acceptable, marginal/unknown, and unacceptable. As a final deliverable, NCHRP Report 554 provided final design guidelines for safety shape barriers based on simulation and crash testing results, as shown in Figure 4.

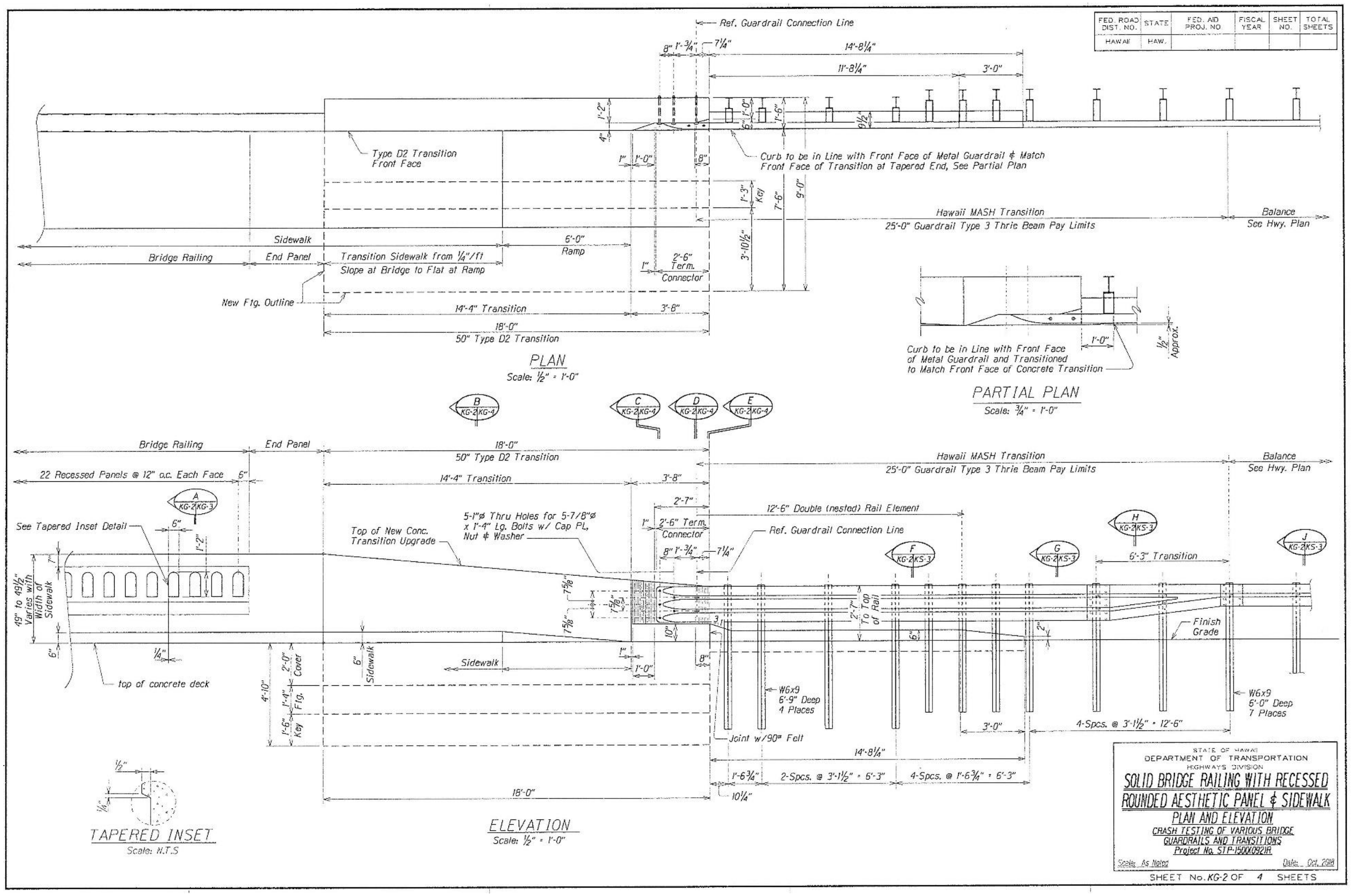


Figure 1. HDOT Standard Detail for 42-in. Tall, Aesthetic Concrete Bridge Rail [1]

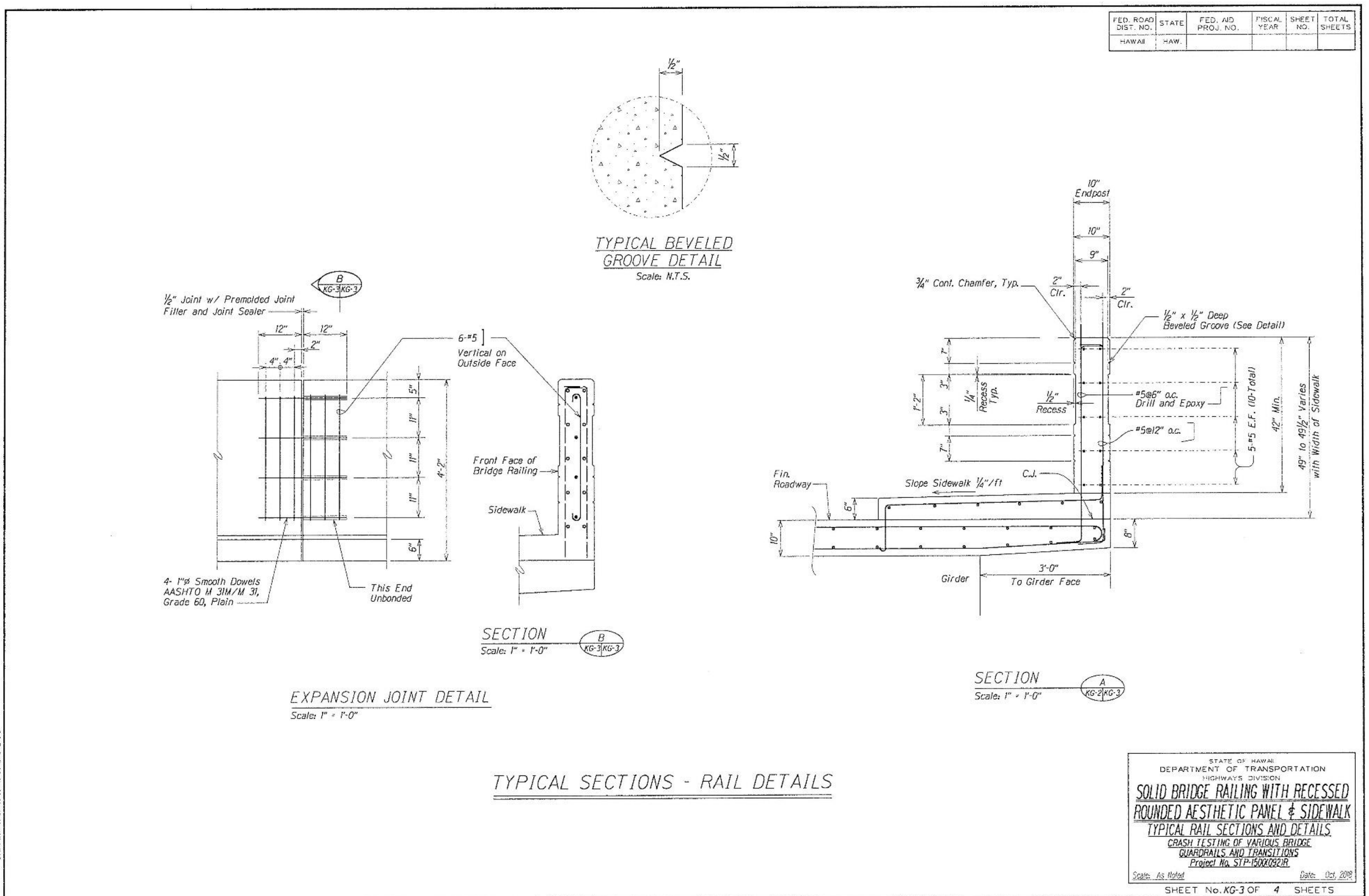


Figure 2. HDOT Standard Detail for 42-in. Tall, Aesthetic Concrete Bridge Rail [1]

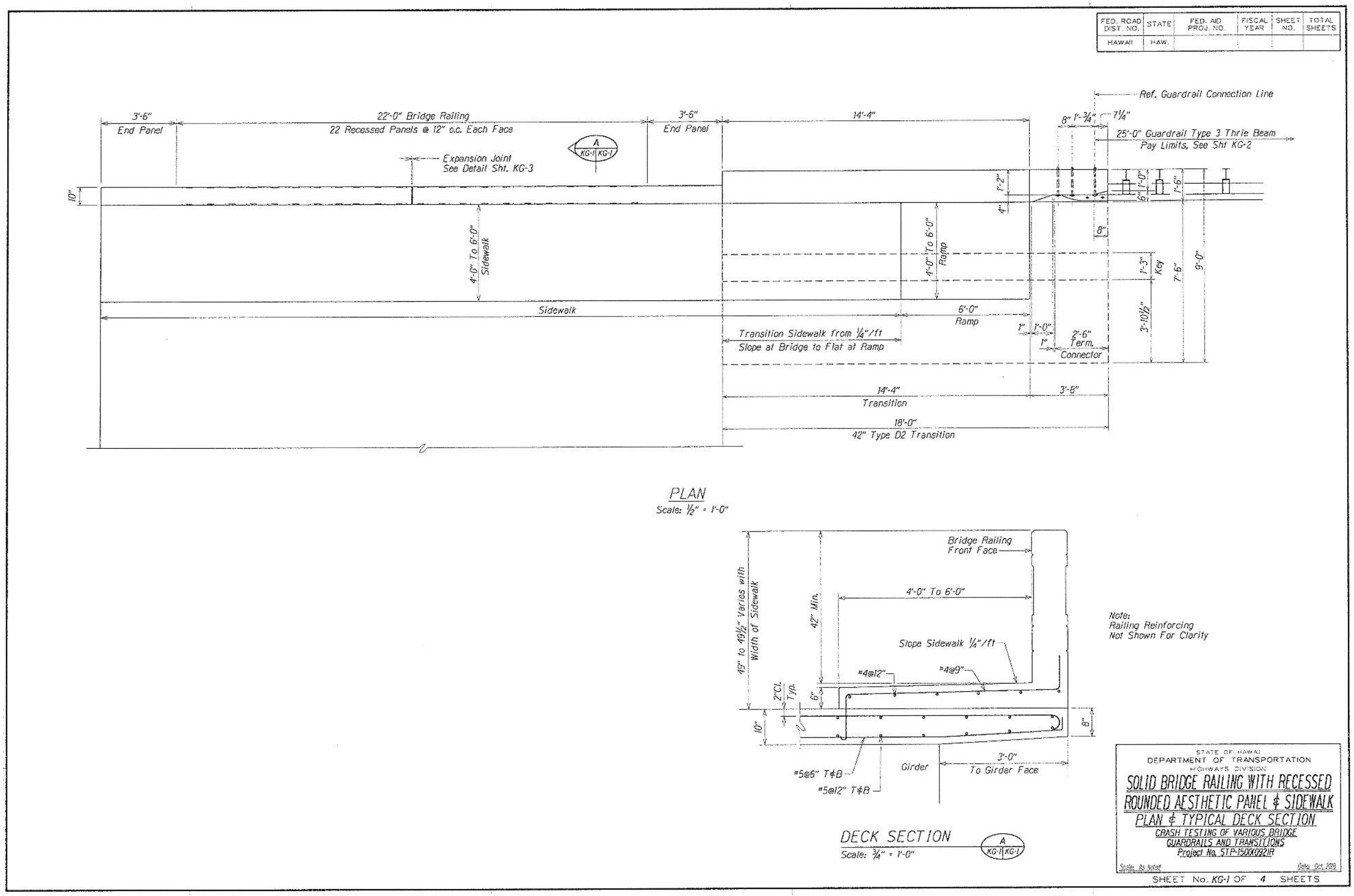


Figure 3. HDOT Standard Detail for 42-in. Tall, Aesthetic Concrete Bridge Rail [1]

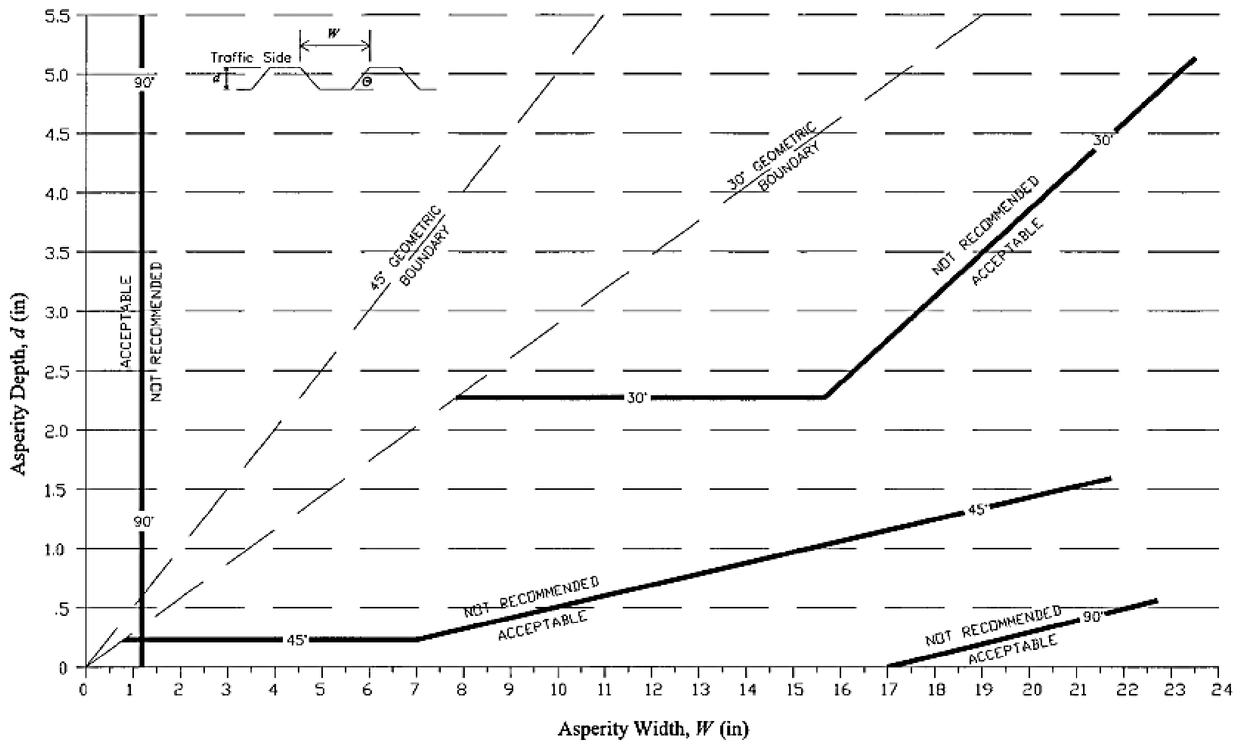


Figure 4. Final Design Guidelines for Aesthetic Surface Treatments of Safety Shape concrete Barriers [2]

NCHRP Report 554 provided guidelines for single-slope and vertical-face barriers that were developed by the California Department of Transportation (Caltrans) [3] in 2002 and approved by the FHWA in acceptance letter B-110 [4]. Caltrans conducted crash testing on single-slope barriers with various architectural treatments to develop guidelines for evaluating the crashworthiness of barriers with wide-ranging patterns and textures. Six recommendations for single-slope or vertical-face barriers were developed after full-scale crash testing in accordance with NCHRP Report 350 [5] criteria. As reported in NCHRP Report 554, the following types of surface treatments are permitted:

1. Sandblasted textures with a maximum relief of ⅜ in.

2. Images or geometric patterns cut into the face of the barrier 1 in. or less and having 45-degree or flatter chambered 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 ½ in. deep by 1 in. wide.

4. Any pattern or texture with gradual undulation that has a maximum relief of ¾ in. over a distance of $11^{13}/_{16}$ in.

5. Gaps, slots, grooves, or joints of any depth with a maximum width of ¾ in. and a maximum surface differential across these features of $^{3}/_{16}$ in.

6. Any pattern or texture with a maximum relief of 2½ in., if such a pattern begins 24 in. or 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 42-in. Tall, Aesthetic Concrete Bridge Rail to the NCHRP Report 554 design guidelines, the research team anticipated that the existing bridge rail would likely provide acceptable safety performance under current impact safety standards for passenger vehicles on its own. However, full-scale crash testing was needed to evaluate the bridge rail with sidewalk to the safety criteria in the American Association of State Highway and Transportation (AASHTO) *Manual for Assessing Safety Hardware, Second Edition* (MASH 2016) [6].

The addition of a 6-ft sidewalk to the bridge railing system is what distinguishes this project from the system proven successful in MwRSF's prior testing detailed in report no. TRP-03-424-20 [7]. There are few systems that were tested under current safety conditions with barriers placed behind a sidewalk. The most relevant test was performed by Caltrans in 2016 where their Type 732SW bridge rail, which is an updated version of their Type 26 with a sidewalk, was crashed tested to meet the MASH 2009 TL-3 criteria for longitudinal barriers [8]. Three full-scale crash tests were conducted on this system under test designation nos. 3-10 and 3-11 as well as 2-10. Test designation no. 3-10 initially did not meet the occupant risk parameters specified in MASH 2009, and therefore the system was determined to be unacceptable according to the MASH safety performance criteria. The lateral ridedown acceleration (ORA) exceeded the MASH 2009 safety requirements. This test failure was based on an incorrectly determined flail-space model start time. The start time was set between the initial contact of the vehicle and the curb instead of initial contact between the vehicle and the concrete barrier. This difference in flail space start time left less space available during the most critical moment of the crash test, resulting in the higher lateral ridedown acceleration value.

1.2 Objective

The objective of this report included an evaluation of the safety performance of the length of need (LON) of HDOT's 42-in. Tall, Aesthetic Concrete Bridge Rail with 6-ft Sidewalk. The system was evaluated according to the TL-3 criteria of 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 42-in. Tall, Aesthetic Concrete Bridge Rail with a 6-ft Sidewalk according to MASH 2016 test designation nos. 3-10 and 3-11. The crash test results were analyzed, evaluated, and documented. Conclusions and recommendations were then made pertaining to the safety performance of the bridge railing and sidewalk system.

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 FHWA for use on the National Highway System. For new hardware, these safety standards consist of the guidelines and procedures published in MASH 2016. Note that there is no difference between MASH 2009 [9] and MASH 2016 for longitudinal barriers such as bridge rails, 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.

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 are explained in Table 2.

Note that the test matrix detailed herein represents the researchers' best engineering judgement of which tests are necessary to assess system crashworthiness according to the MASH 2016 safety requirements. However, future evaluation may be required due to revisions to the MASH criteria or additional knowledge gained over time.

According to MASH 2016, the HDOT 42-in. Tall, Aesthetic Concrete Bridge Rail should be evaluated at a location that evaluates the greatest propensity for vehicle snag and a location that maximizes structural loading of the bridge rail at a critical section. For the HDOT 42-in. Tall, Aesthetic Concrete Bridge Rail, both critical impact points would occur upstream from an expansion joint in the bridge rail. The bridge rail has a transition from the recessed panel to the main face 3¼ in. upstream from an expansion joint. Thus, impacting upstream from this point would provide 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 points for rigid barrier testing under test designation nos. 3-10 and 3-11, specified by MASH 2016, were applied upstream from an expansion joint to evaluate vehicle snag and structural loading of the system.

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="9">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 test installation consisted of a reinforced concrete bridge rail and sidewalk anchored to the existing concrete tarmac at MwRSF's Outdoor Test Site, rather than a simulated bridge deck and overhang. Previous testing of a MASH 2016 TL-4 bridge rail on a similar 8-in. thick concrete bridge deck displayed no deck damage, indicating the potential for deck damage or deflection that would affect the outcome of the full-scale crash test was minimal under MASH 2016 TL-3 impact conditions [10]. HDOT's 42-in. Tall, Aesthetic Concrete Bridge Rail with 6-ft Sidewalk was constructed to an effective rail height of 42 in. relative to the 6-in. tall sidewalk. Design details for the installation are shown in Figures 5 through 27. Photographs of the test installation are shown in Figures 28 through 30. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix A.

The reinforced concrete bridge rail had a total length of 88 ft and measured 42 in. tall and 10 in. wide, as shown in Figures 5 and 7. The barrier had a vertical front face with aesthetic recessed panels spaced 12 in. apart, measuring 6 in. wide and 14 in. tall with a 3-in. top-edge radius. Three ½-in. tall x ½-in. deep V-shaped horizontal bevel cuts were etched into each face located 8, 15, and 35 in. above the sidewalk, as shown in Figure 11. The top edge of the barrier on each side was chamfered at a 45-degree angle, measuring ¾ in. wide. The reinforced concrete sidewalk had a width of 6 ft and measured 6 in. tall with a 1½-in. finish, as shown in Figure 9.

The bridge rail consisted of four distinct segments with ½-in. wide expansion joints, as shown in Figures 5 and 6. Expansion joints were spaced 22 ft apart throughout the length of the bridge rail. The expansion joint spacing was limited to 22 ft due to it being the smallest rail segment length between joints noted by HDOT. Larger rail segments between expansion joints were considered to be less critical. Filler and sealant compounds were used to fill the gap between segments at the expansion joints. A 42-in. x 42-in. end panel that leads to the concrete shape transition and end buttress into the Approach Guardrail Transition System (AGT) and Midwest Guardrail System (MGS) was placed on the downstream end of the bridge rail. These attached systems were built simultaneously with the concrete bridge rail and sidewalk system. 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 21-day compressive strength results of 4,170 psi and 4,510 psi.

Steel reinforcement consisted of ASTM A615 Gr. 60 rebar, as shown in Figures 8, 10, 12, 14 through 16, and 18 through 23. Ten No. 5 longitudinal rebars were located $2^{15}/_{16}$ in. from the outer surface of each segment of the concrete barrier, with five on each side. Longitudinal rebar measuring 260 in. long was used in the barrier segments and located 2⅛, 11⅛, 20⅛, 29⅛, and 38⅛ in. above the sidewalk. Vertical stirrups were also provided using No 5. rebar, which were spaced on 12-in. centers on the backside face and 6-in. centers on the traffic-side face. Vertical reinforcement bars were anchored to the concrete tarmac through the 6-in. tall sidewalk on both the traffic-side and backside 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 bar. All rebar had a 2-in. concrete clear cover. The longitudinal reinforcement for the sidewalk consisted of six No. 4 longitudinal rebars located 2 in. from the traffic-side face, spaced at 12 in. The transverse reinforcement consisted of No. 4 rebar spaced at 9 in. for the entire distance of the sidewalk system.

At each expansion joint, shear continuity was maintained using a pin-receiver casting and a 12¾-in. long x 1¼-in. diameter Schedule 80 PVC pipe with a 1¼-in. diameter along the vertical centerline of one barrier segment. Four No. 8 smooth rebar pins were placed into the PVC tubes that were cast into adjacent concrete barrier segments. The pins were spaced 11 in. apart, and the top pin was located 5 in. from the top surface along the midplane of the barrier.

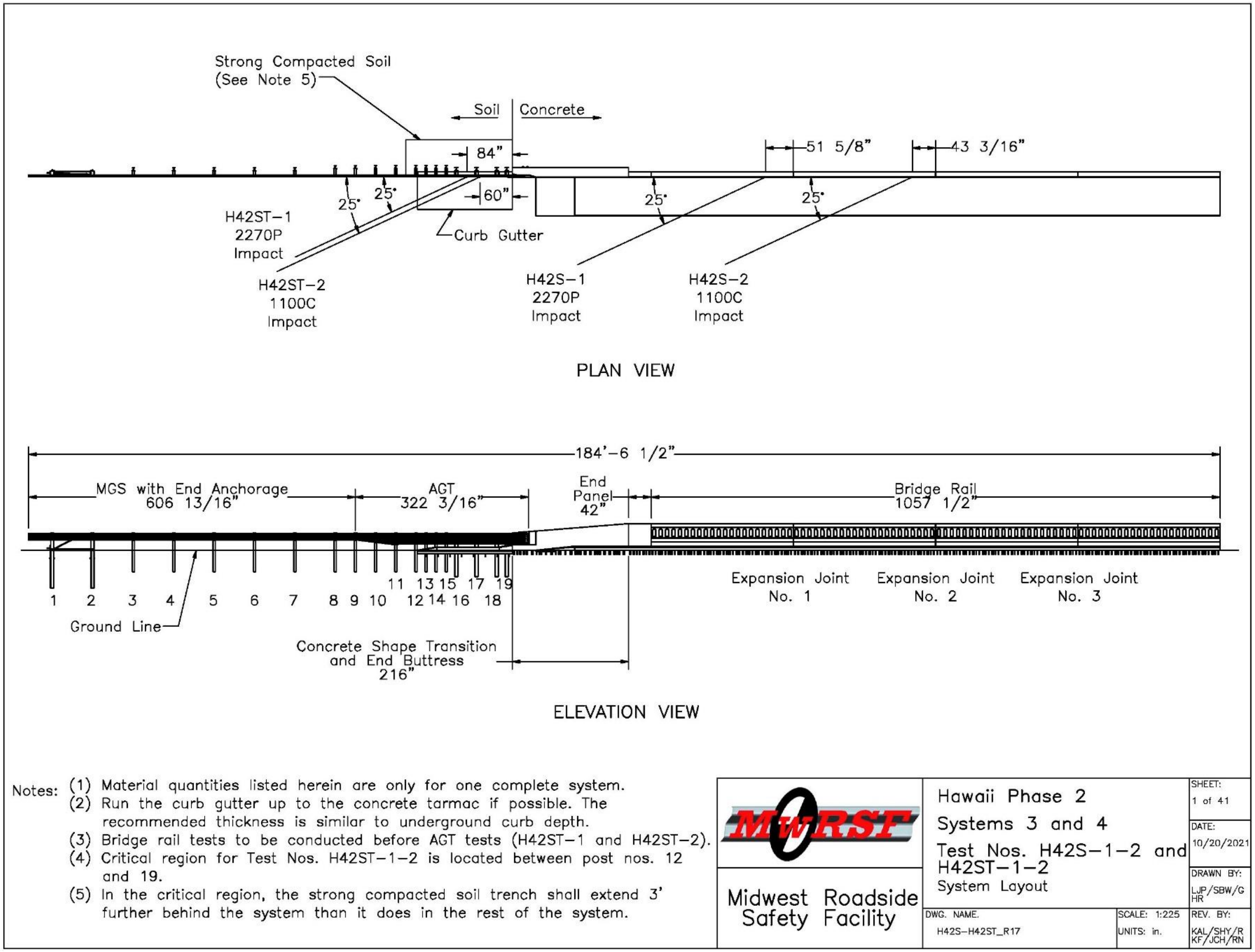


Figure 5. System Layout, Hawaii Phase II System Nos. 3 and 4

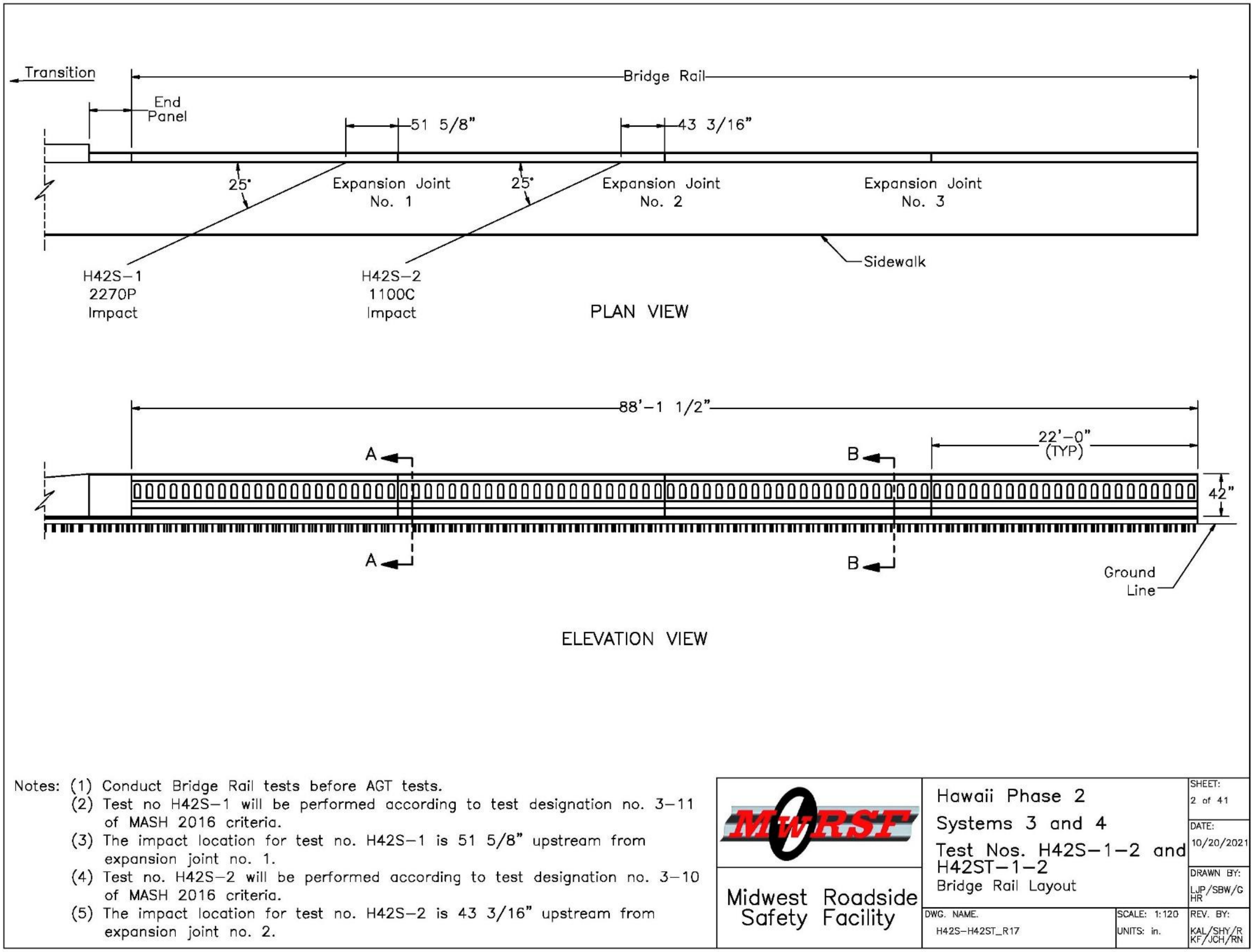
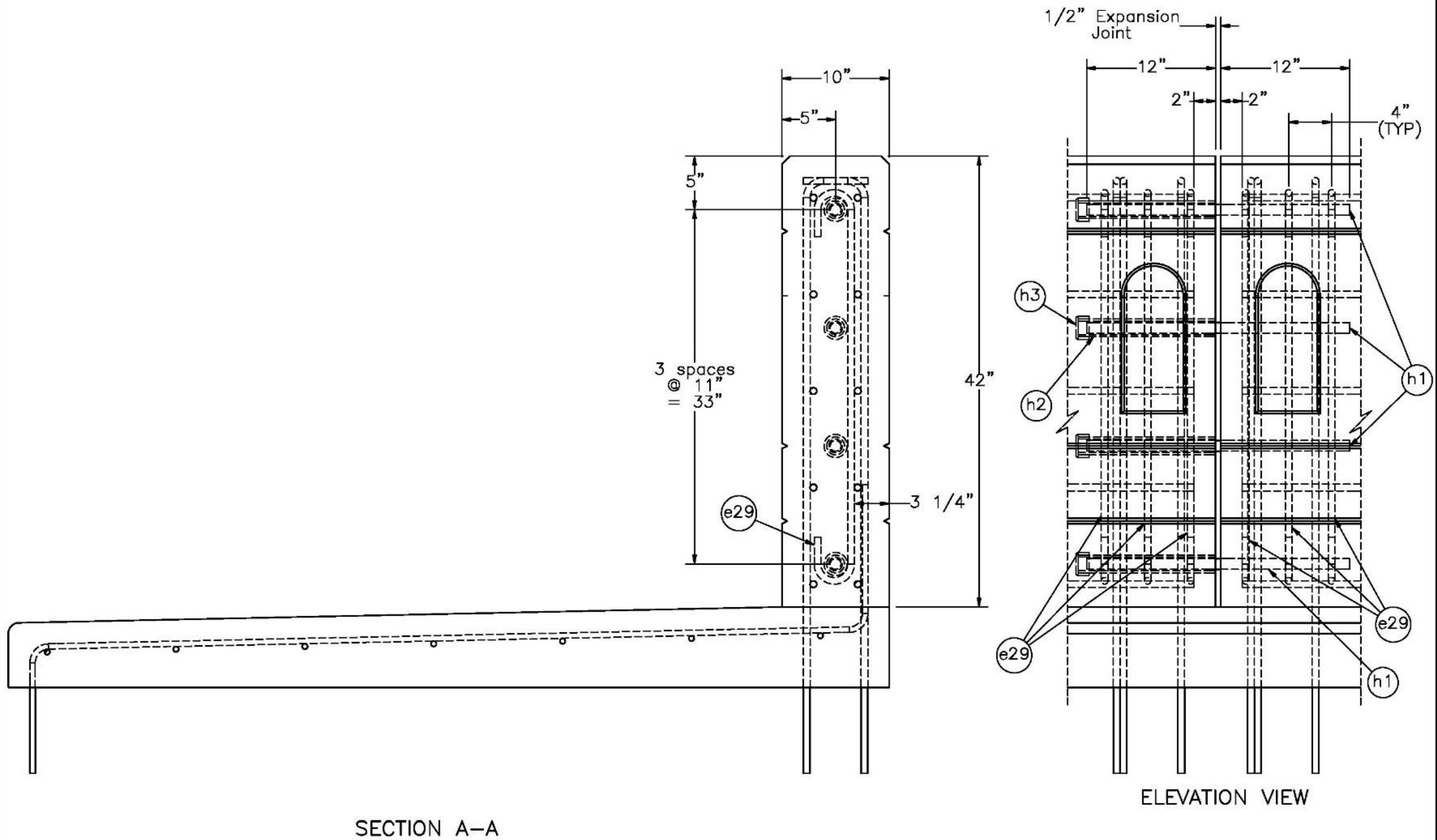


Figure 6. Bridge Rail Layout, Test Nos. H42S-1 and H42S-2



Notes: (1) Smooth dowels (part h1) are cast in place on one side of the expansion joint, and inserted into plastic sleeves (part h2), which are cast into the barrier on the other side of the expansion joint.
(2) 1/2" expansion joints to be bonded together by premolded joint filler and joint sealer according to specifications.
(3) PVC tubes and caps (parts h2 and h3) are to be cast on the upstream side of expansion joints.

MwRSF Midwest Roadside Safety Facility	Hawaii Phase 2 Systems 3 and 4 Test Nos. H42S–1–2 and H42ST–1–2 Expansion Joint Details	SHEET: 3 of 41
		DATE: 10/20/2021
		DRAWN BY: LJP/SBW/GHR
	DWG. NAME. H42S–H42ST_R17 / SCALE: 1:13 UNITS: in.	REV. BY: KAL/SHY/RKF/JCH/RN

Figure 7. Expansion Joint Details, Test Nos. H42S-1 and H42S-2

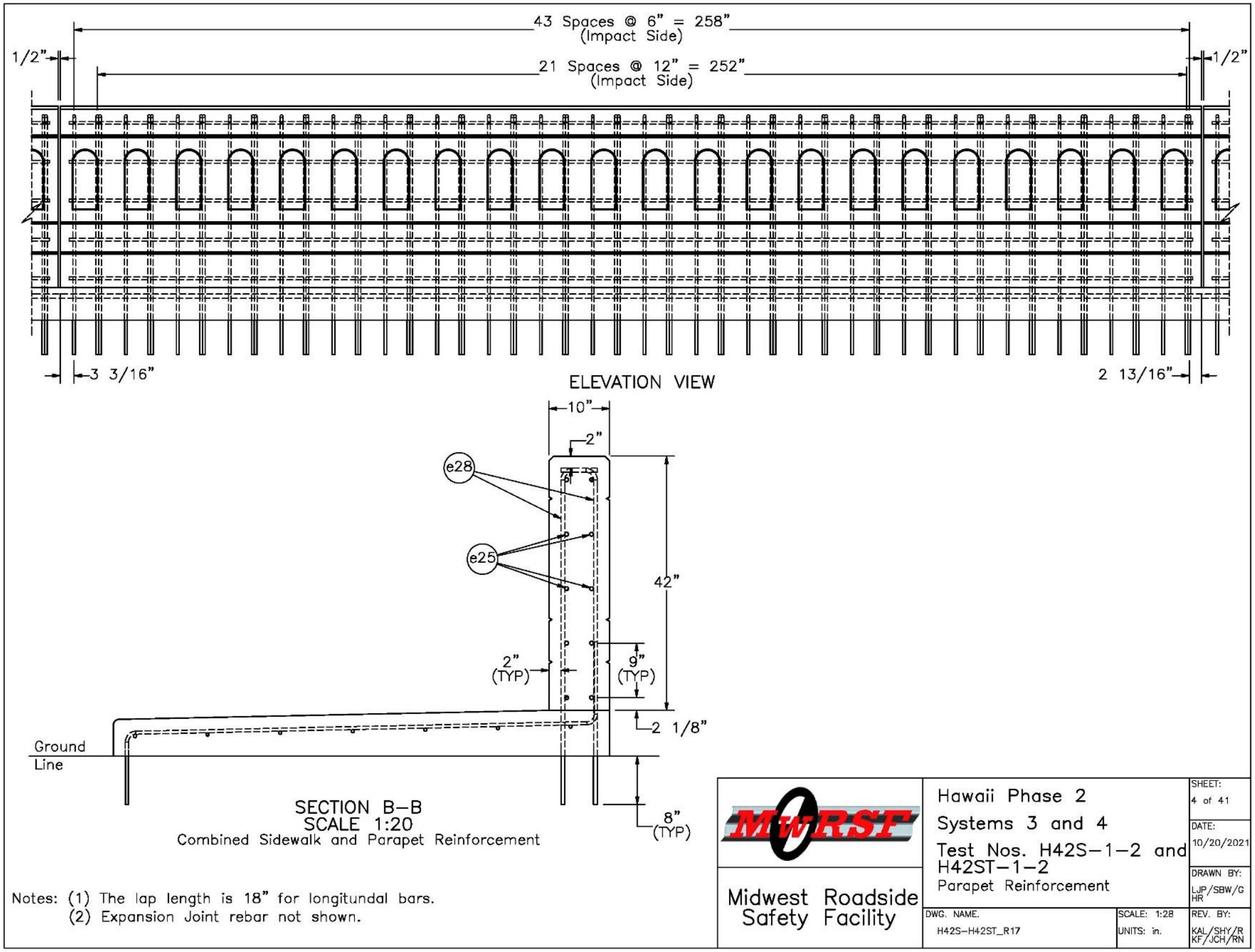


Figure 8. Parapet Reinforcement, Tests Nos. H42S-1 and H42S-2

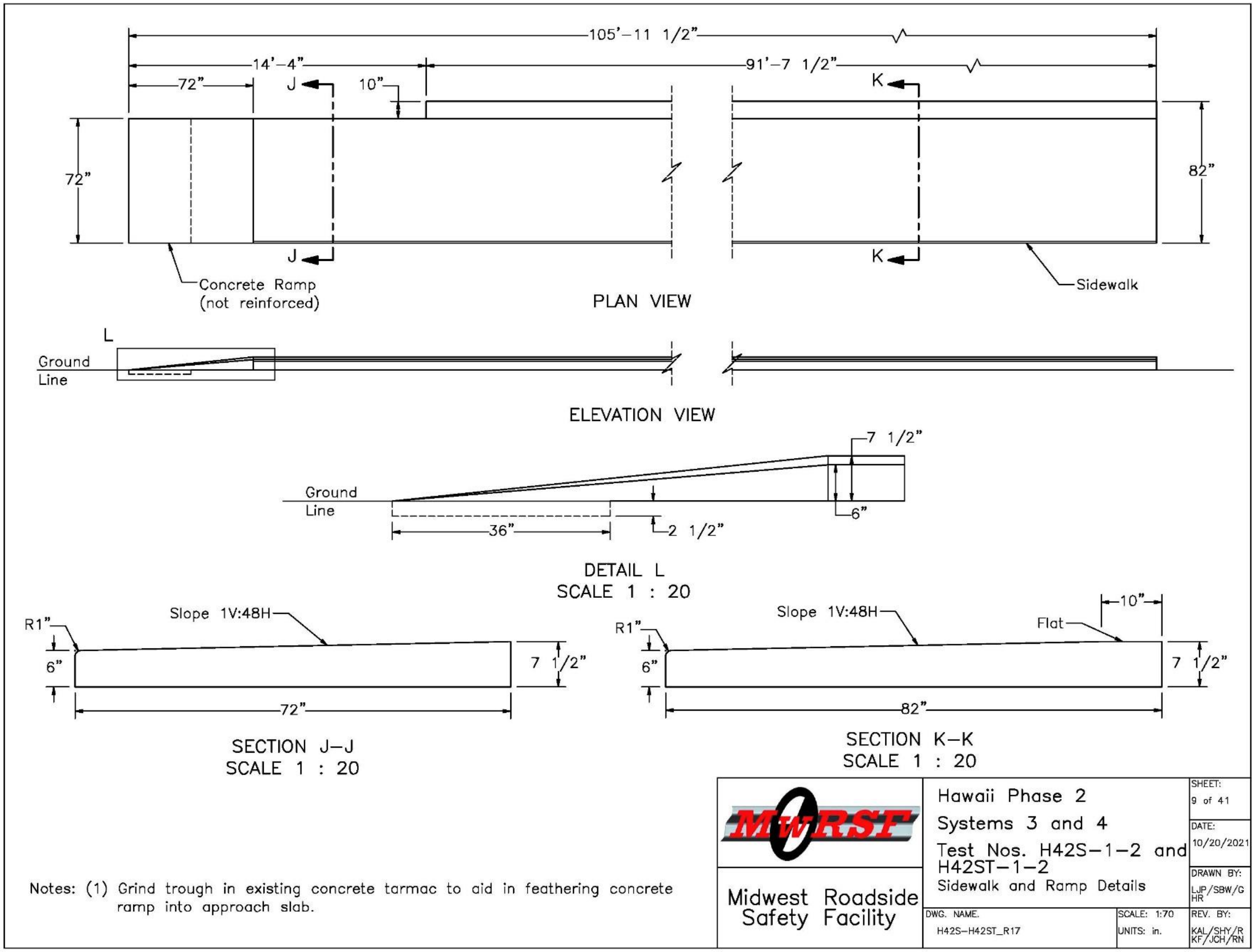


Figure 9. Sidewalk and Ramp Details, Test Nos. H42S-1 and H42S-2

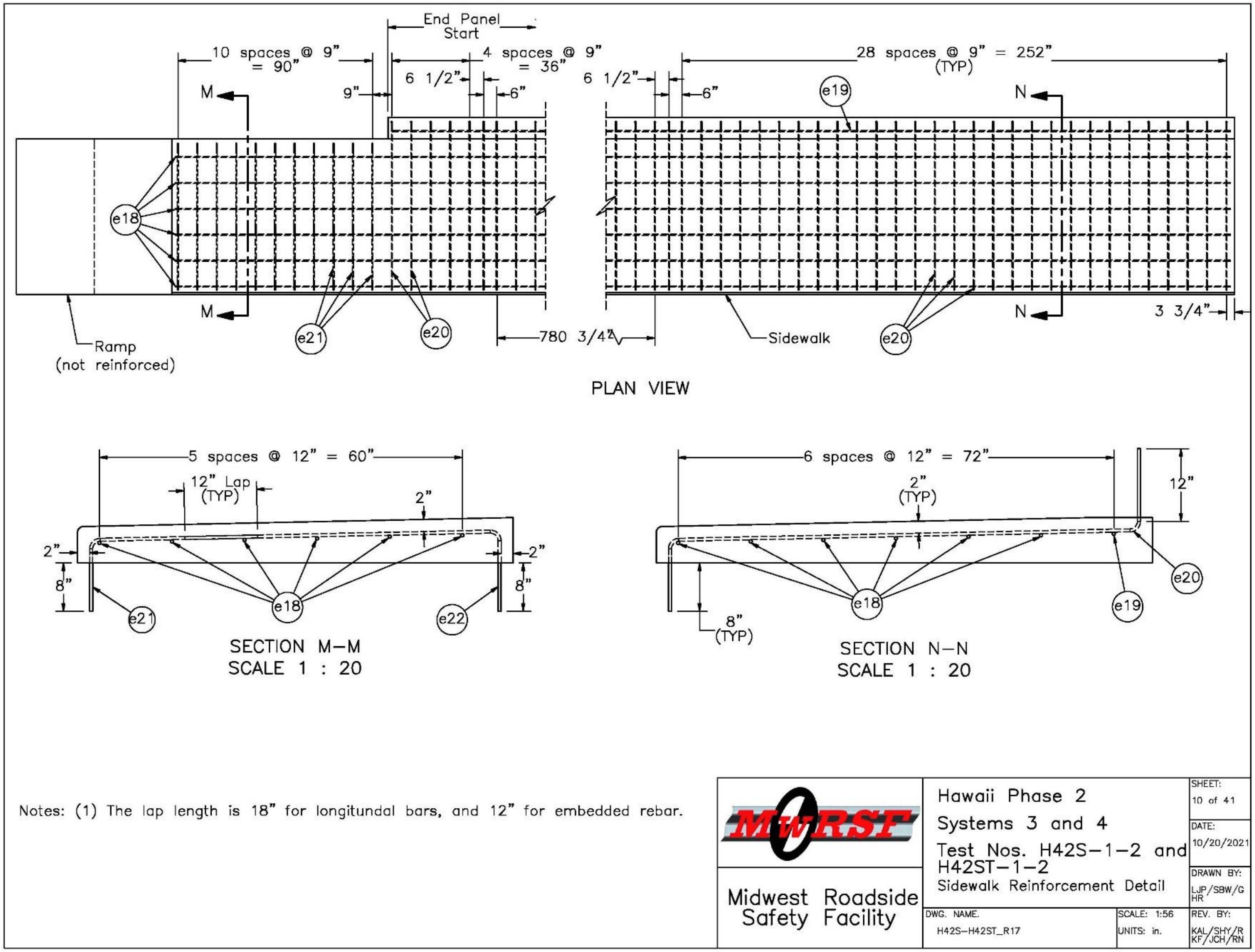


Figure 10. Sidewalk Reinforcement Detail, Test Nos. H42S-1 and H42S-2

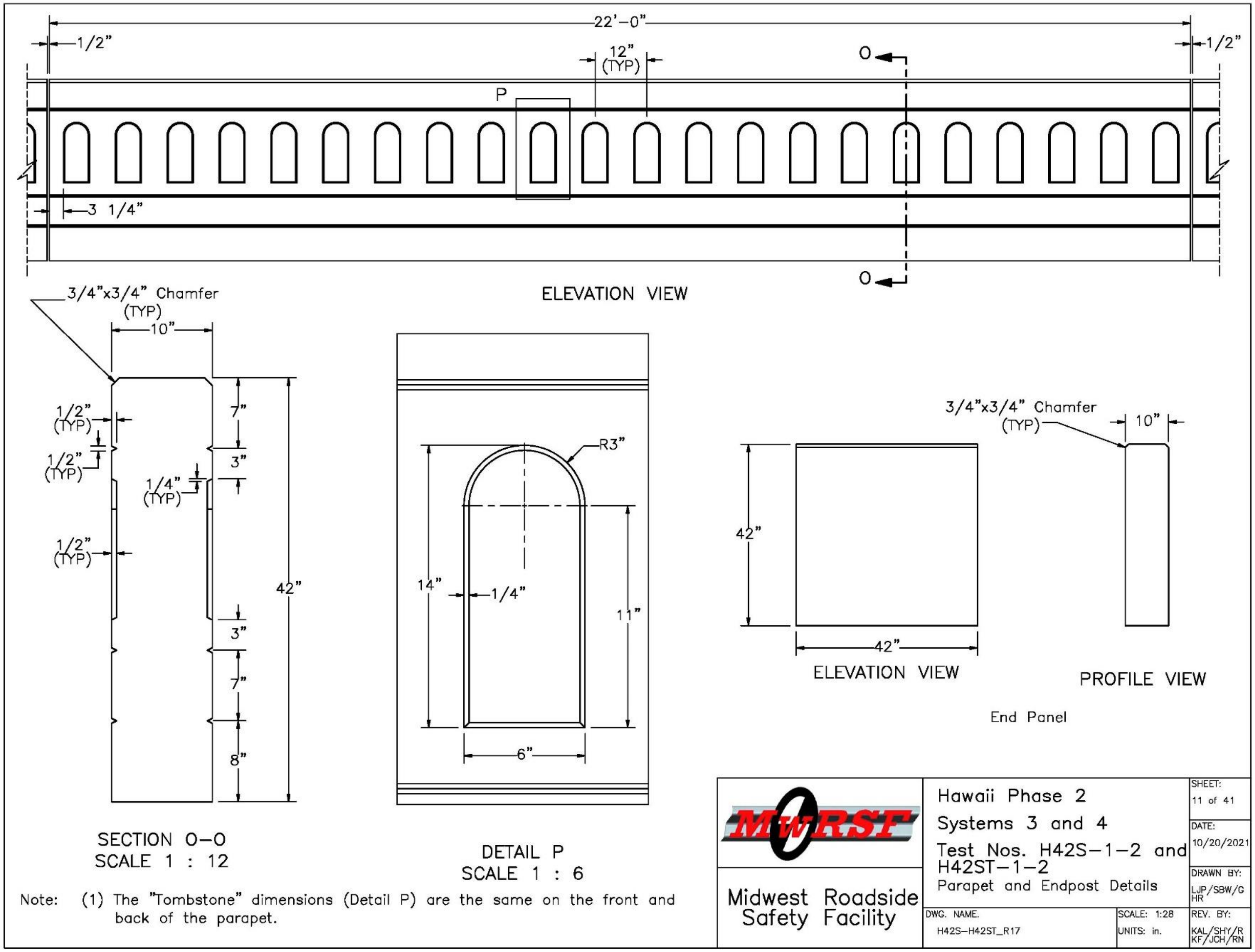


Figure 11. Parapet and Endpost Details, Test Nos. H42S-1 and H42S-2

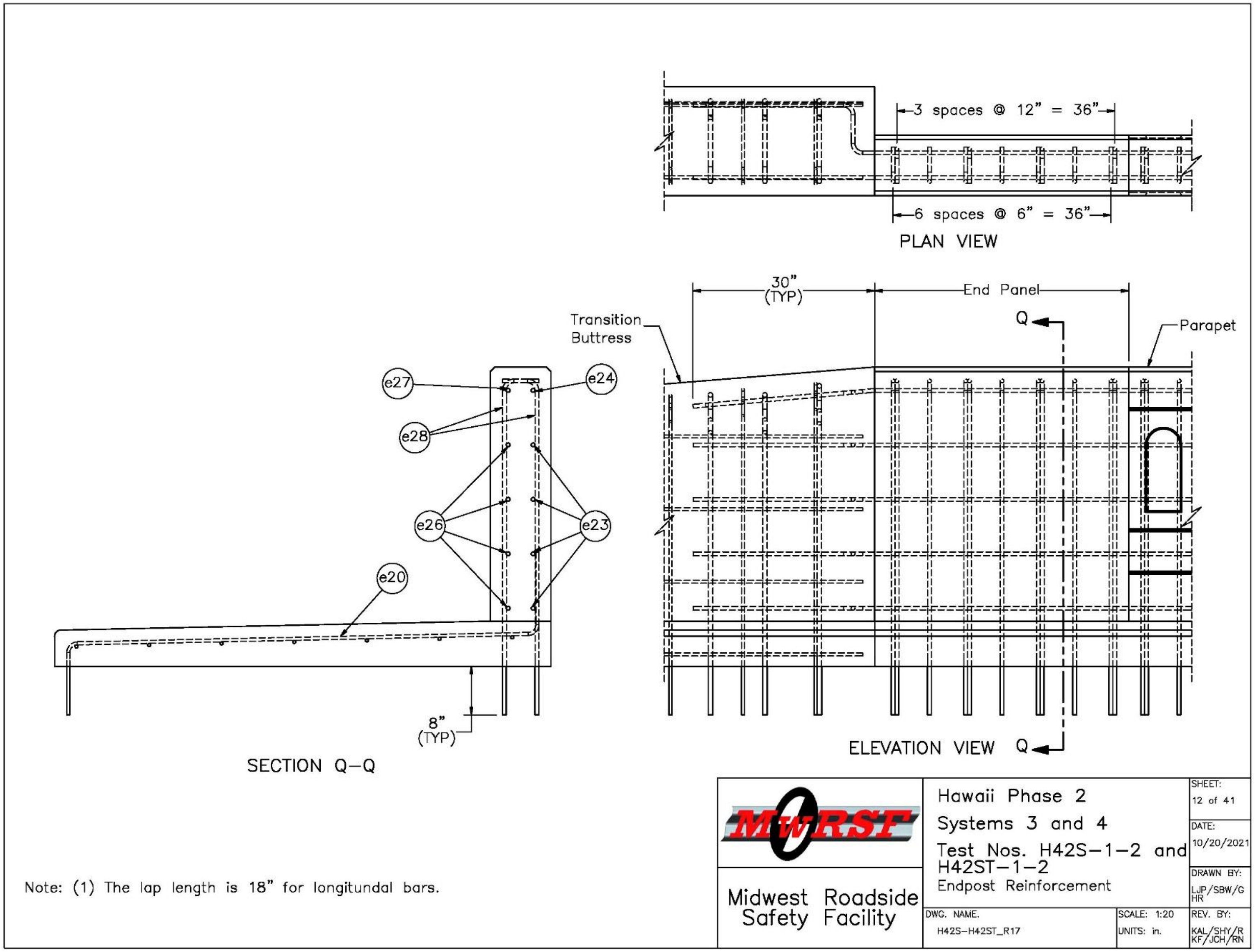


Figure 12. Endpost Reinforcement, Test Nos. H42S-1 and H42S-2

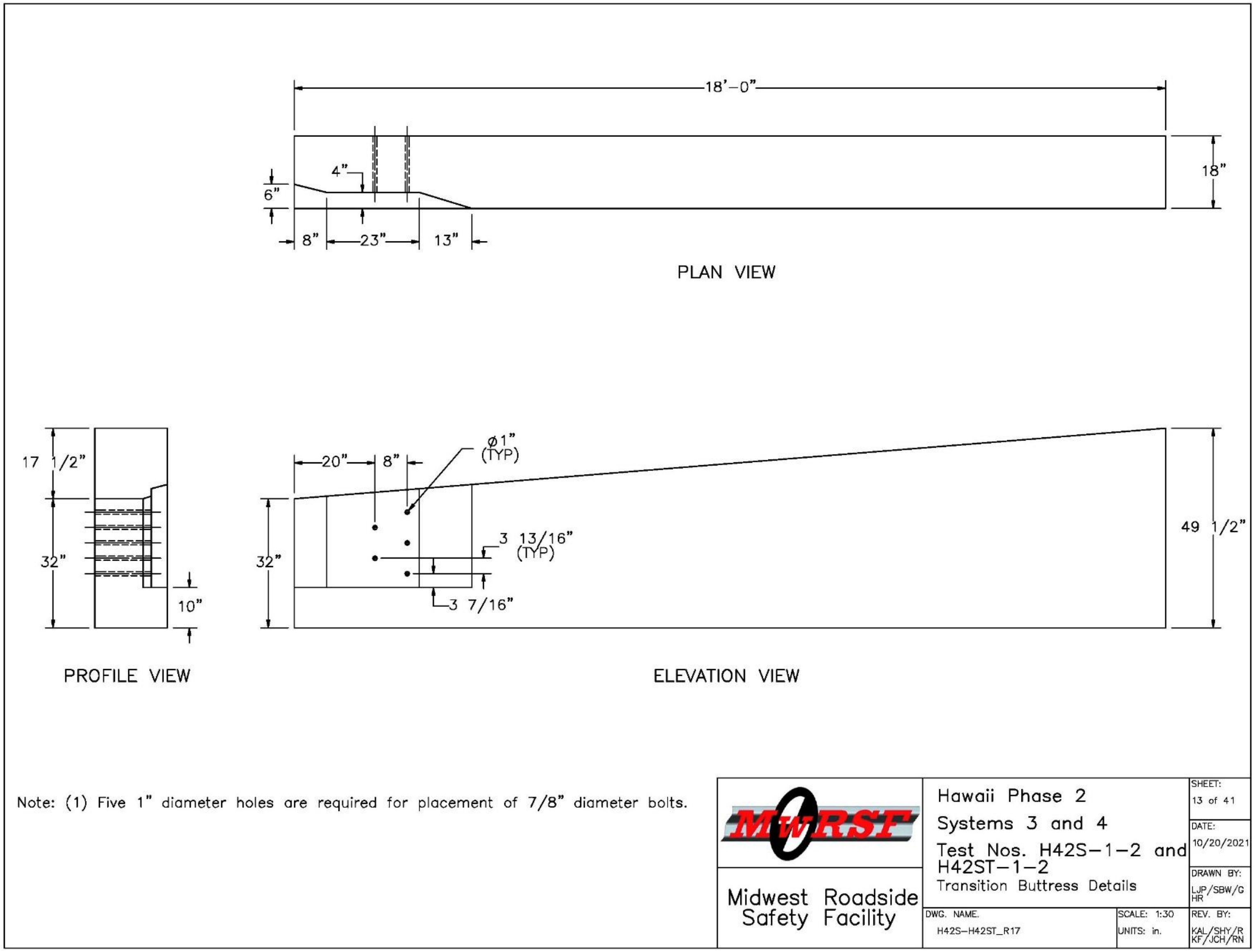


Figure 13. Transition Buttress Details, Test Nos. H42S-1 and H42S-2

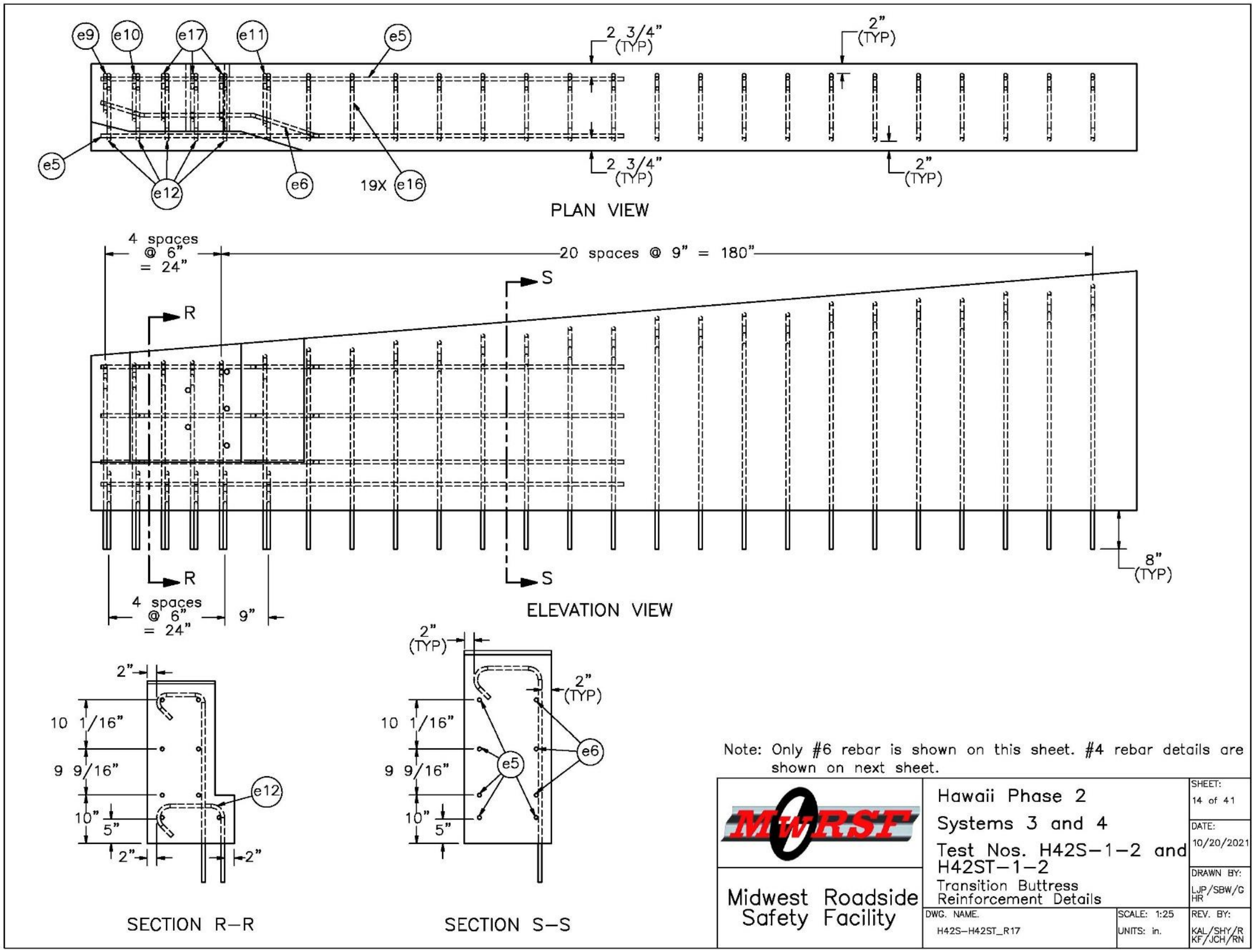


Figure 14. Transition Buttress Reinforcement Details, Test Nos. H42S-1 and H42S-2

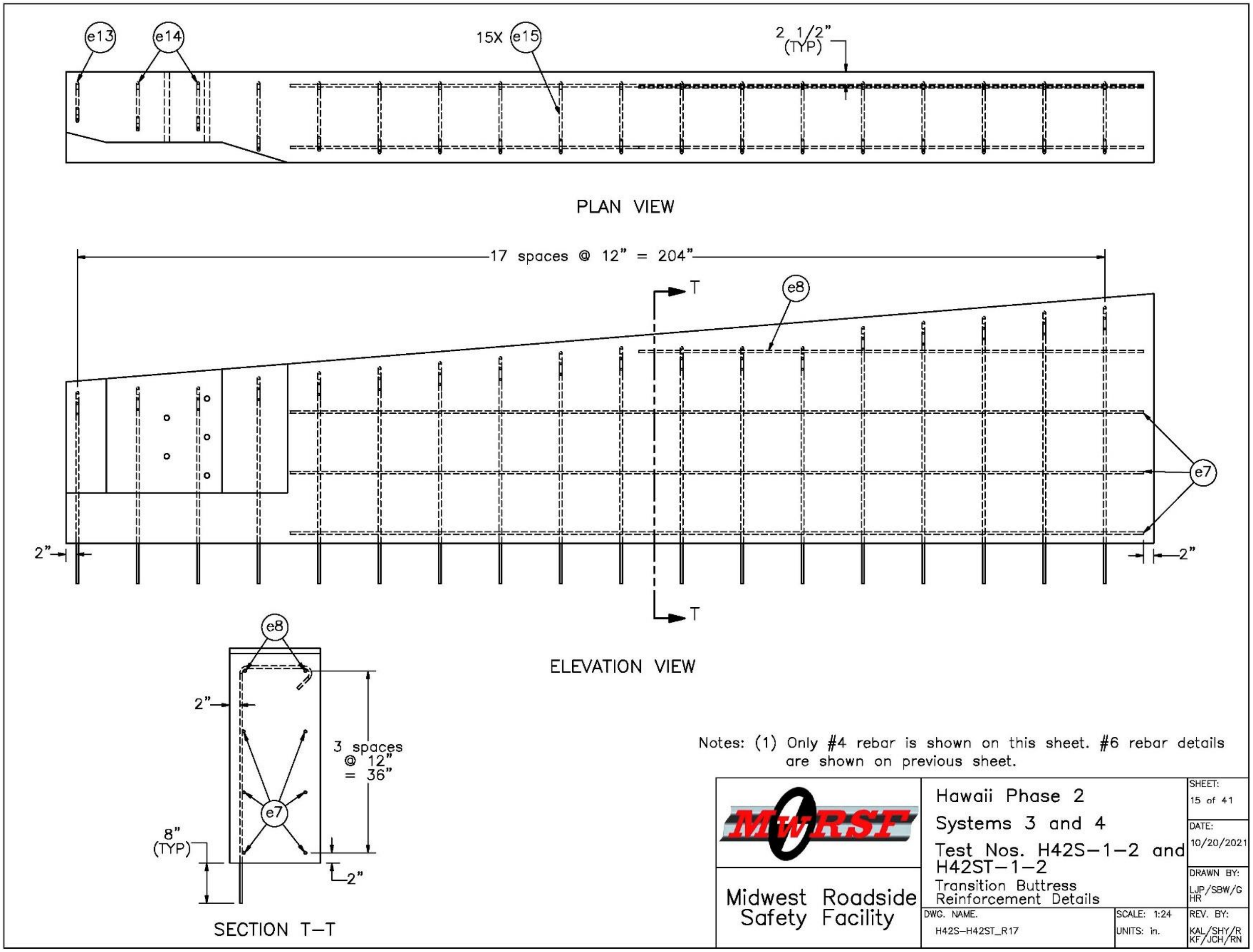


Figure 15. Transition Buttress Reinforcement Details, Test Nos. H42S-1 and H42S-2

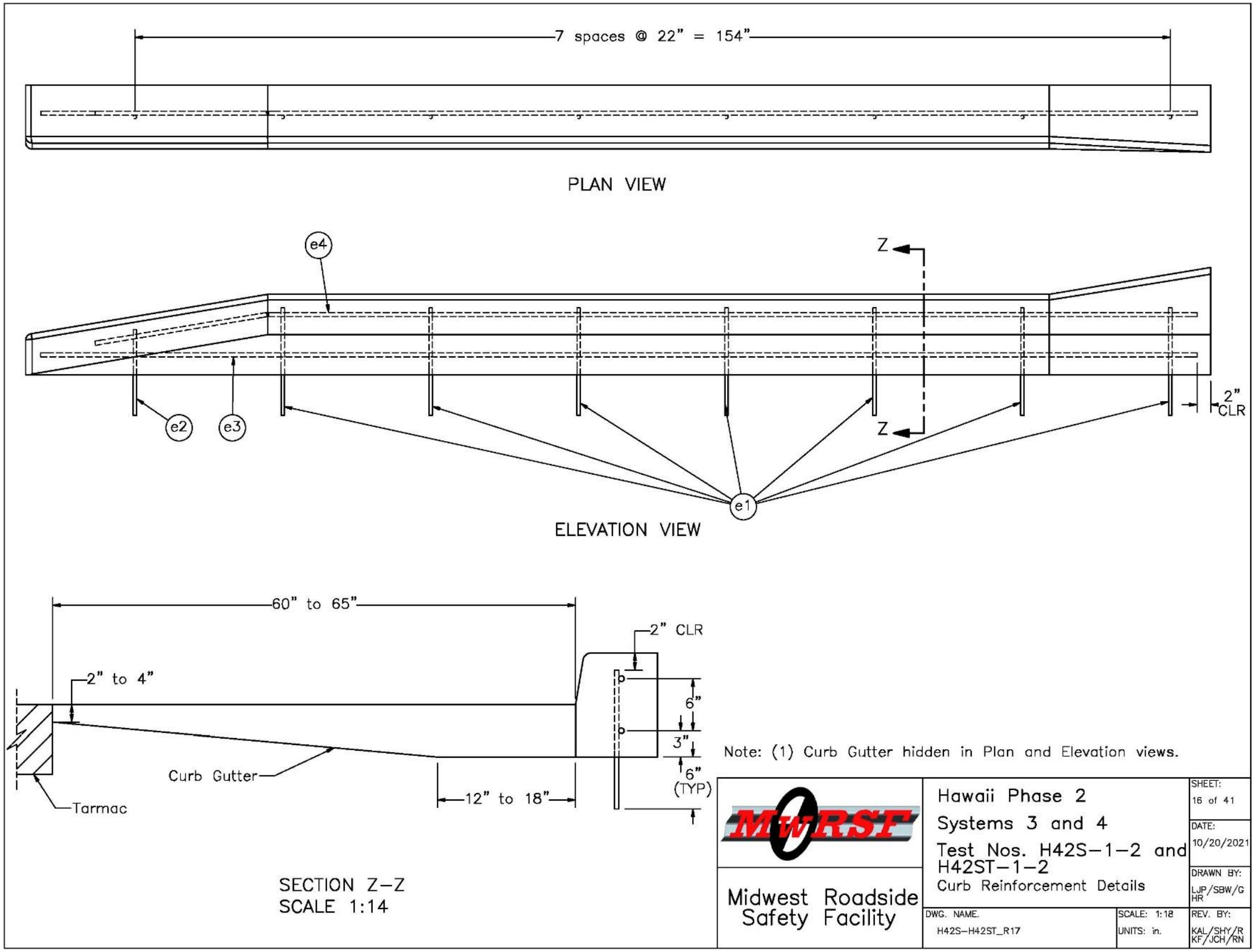


Figure 16. Curb Reinforcement Details, Test Nos. H42S-1 and H42S-2

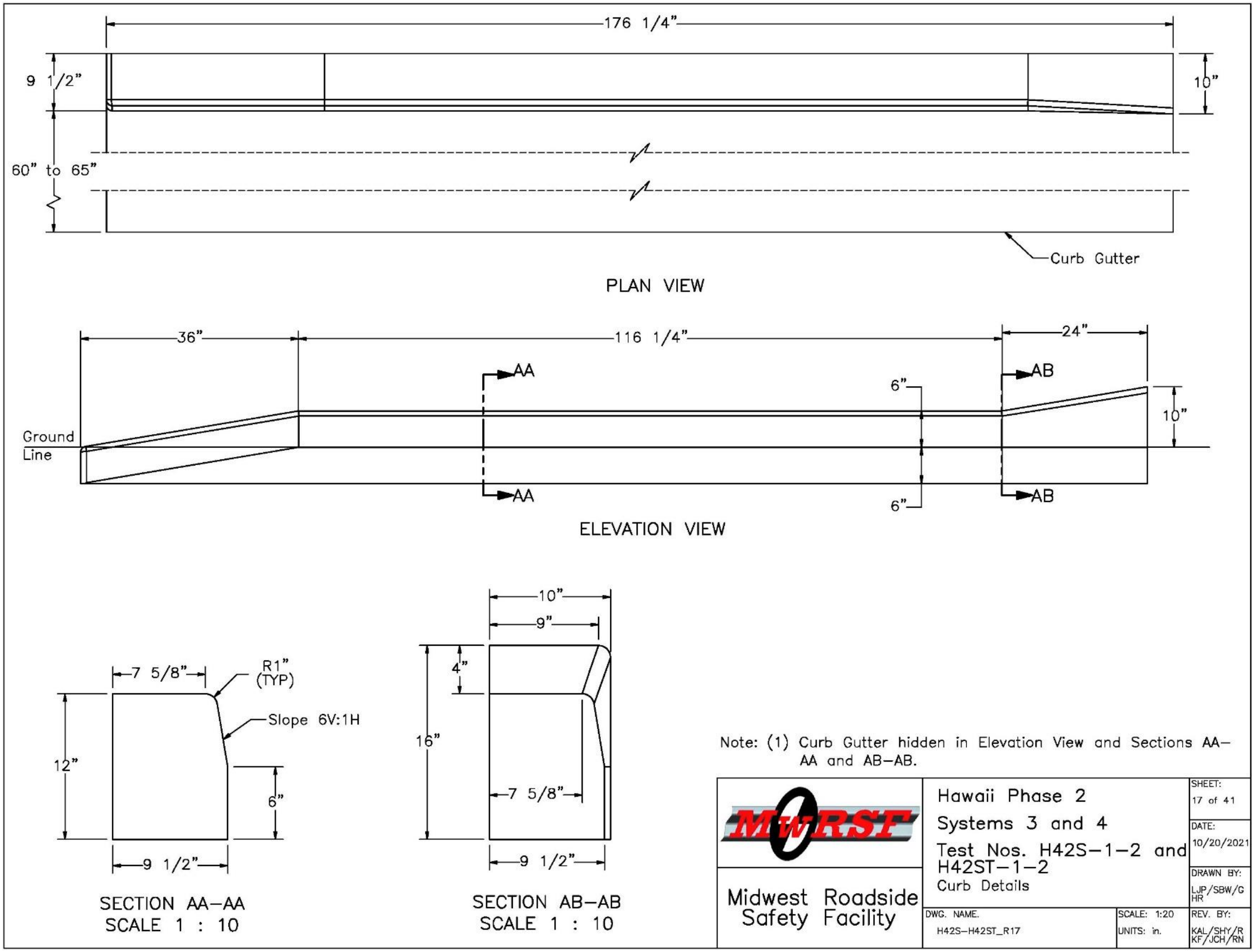
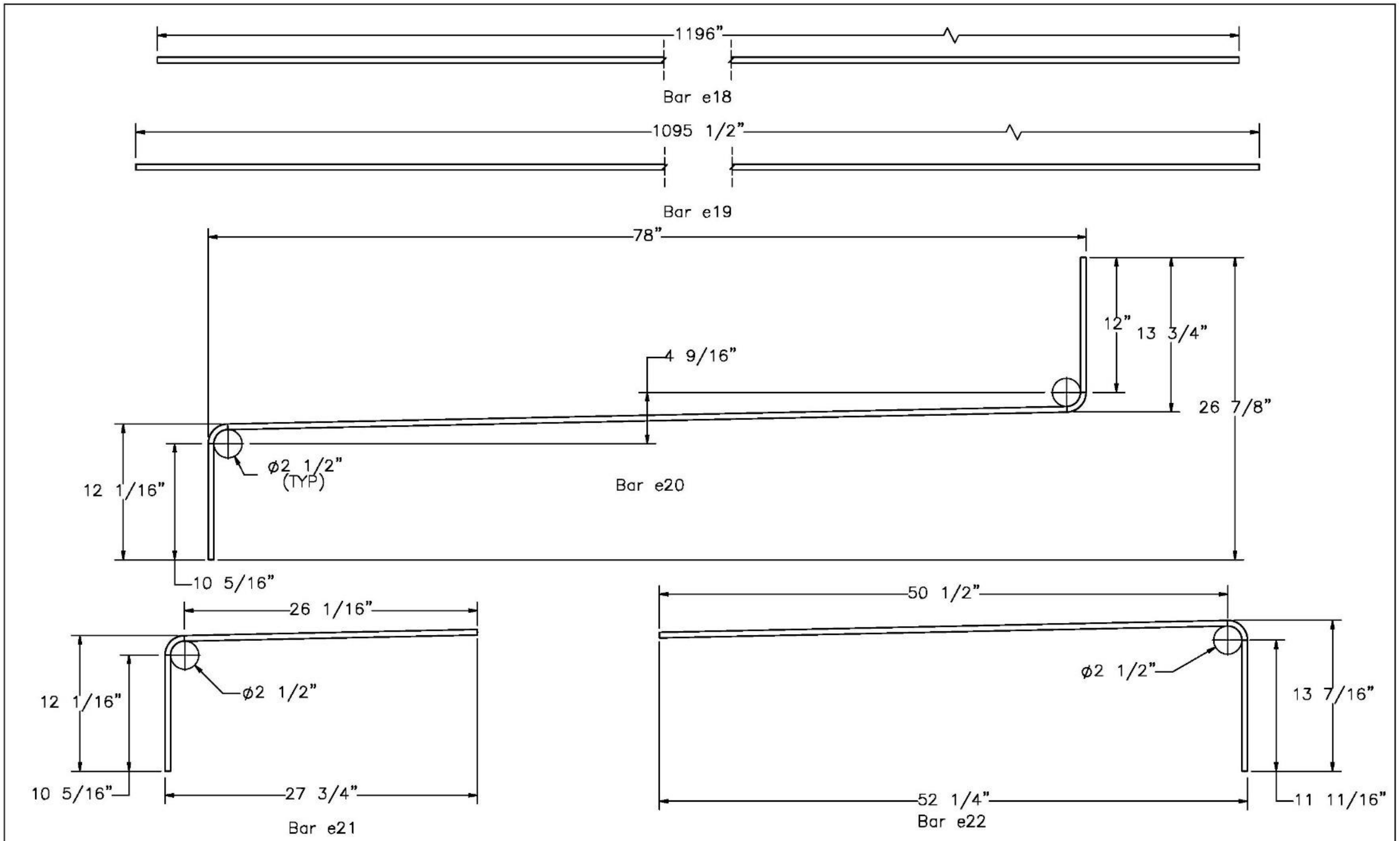


Figure 17. Curb Details, Test Nos. H42S-1 and H42S-2



BILL OF BARS

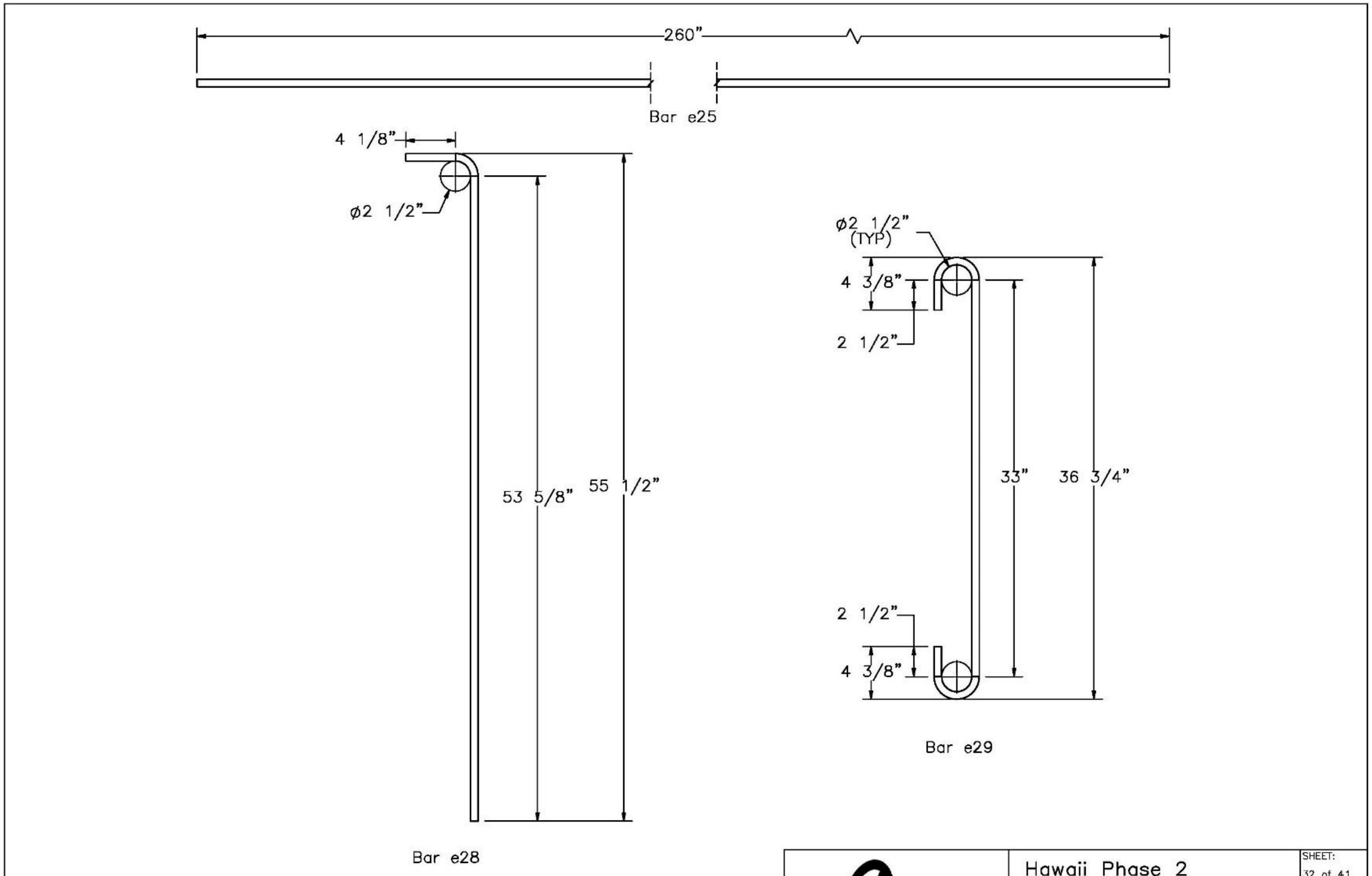
Item No.	Size	QTY	Unbent Length	Material Specification
e18	#4	6	1196"	ASTM A615 Gr. 60
e19	#4	1	1095 1/2"	ASTM A615 Gr. 60
e20	#4	125	101 9/16"	ASTM A615 Gr. 60
e21	#4	11	50 11/16"	ASTM A615 Gr. 60
e22	#4	11	64 1/2"	ASTM A615 Gr. 60

MwRSF
Midwest Roadside Safety Facility

Hawaii Phase 2
Systems 3 and 4
Test Nos. H42S-1-2 and H42ST-1-2
Sidewalk Rebar Details

SHEET: 31 of 41
DATE: 10/20/2021
DRAWN BY: LJP/SBW/G HR
DWG. NAME. H42S-H42ST_R17
SCALE: 1:12
UNITS: in.
REV. BY: KAL/SHY/R KF/JCH/RN

Figure 18. Sidewalk Rebar Details, Test Nos. H42S-1 and H42S-2

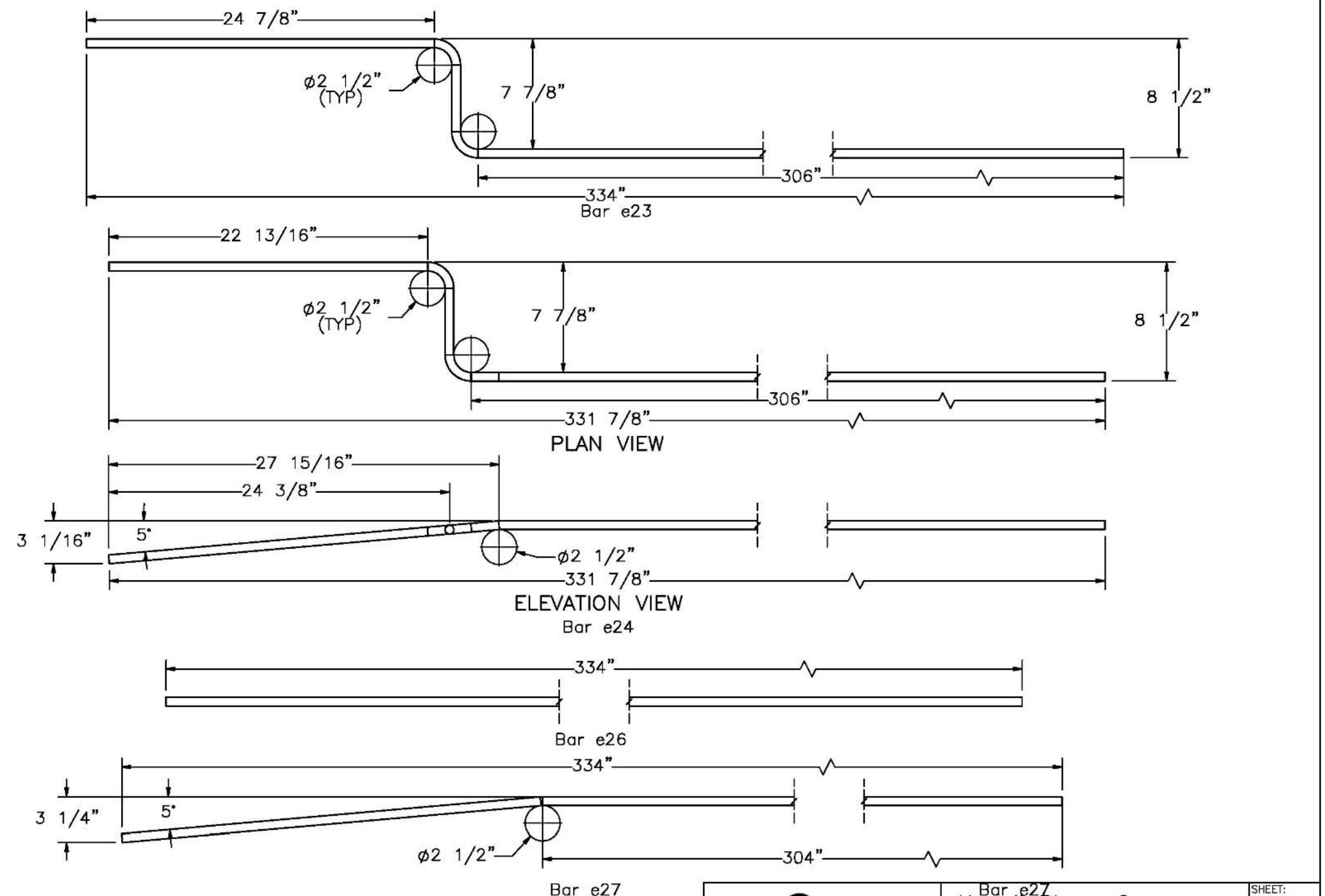


BILL OF BARS

Item No.	Size	QTY	Unbent Length	Material Specification
e25	#5	30	260"	ASTM A615 Gr. 60
e28	#5	275	60 3/16"	ASTM A615 Gr. 60
e29	#5	18	47 13/16"	ASTM A615 Gr. 60

MwRSF Midwest Roadside Safety Facility	Hawaii Phase 2 Systems 3 and 4 Test Nos. H42S-1-2 and H42ST-1-2 Parapet Reinforcement Details		SHEET: 32 of 41 DATE: 10/20/2021 DRAWN BY: LJP/SBW/GHR
	DWG. NAME. H42S-H42ST_R17	SCALE: 1:11 UNITS: in.	REV. BY: KAL/SHY/RKF/JCH/RN

Figure 19. Parapet Reinforcement Details, Test Nos. H42S-1 and H42S-2



BILL OF BARS

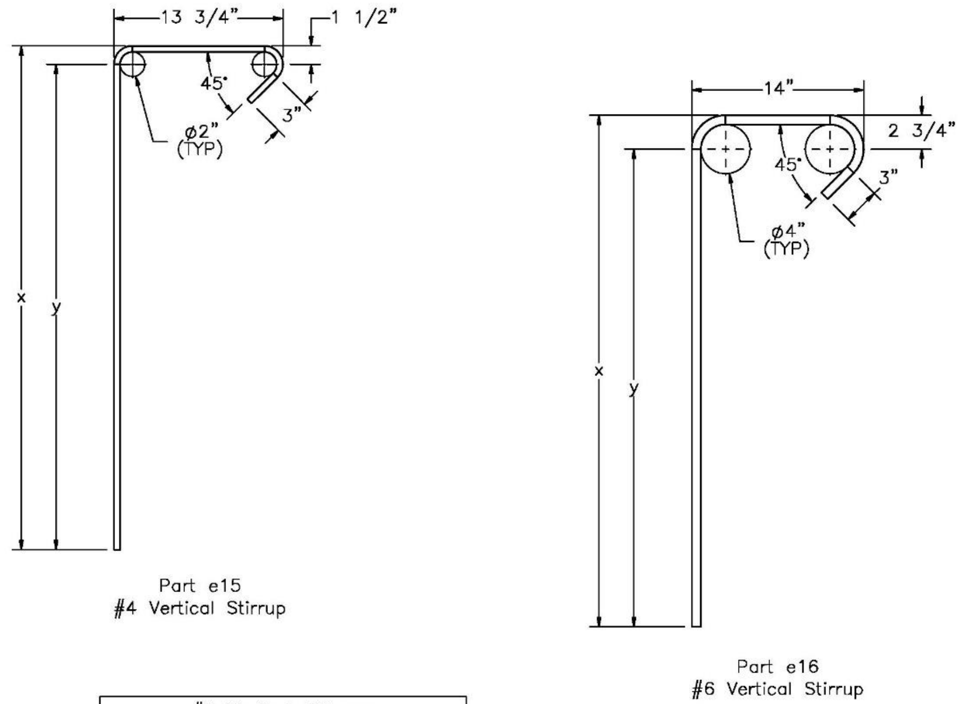
Item No.	Size	QTY	Unbent Length	Material Specification
e23	#5	4	340 9/16"	ASTM A615 Gr. 60
e24	#5	1	340 5/8"	ASTM A615 Gr. 60
e26	#5	4	334"	ASTM A615 Gr. 60
e27	#5	1	334 1/8"	ASTM A615 Gr. 60

Midwest Roadside Safety Facility

Hawaii Phase 2
Systems 3 and 4
Test Nos. H42S-1-2 and H42ST-1-2
End Post Reinforcement Details

SHEET: 33 of 41
DATE: 10/20/2021
DRAWN BY: LJP/SBW/GHR
DWG. NAME. H42S-H42ST_R17
SCALE: 1:10
UNITS: in.
REV. BY: KAL/SHY/RKF/JCH/RN

Figure 20. Endpost Reinforcement Details, Test Nos. H42S-1 and H42S-2



#4 Vertical Stirrups			
Height (x)	QTY	Height (y)	Unbenth Lenght
41"	1	39 1/2"	58 1/8"
42"	1	40 1/2"	59 1/8"
43"	1	41 1/2"	60 1/8"
44"	1	42 1/2"	61 1/8"
45"	1	43 1/2"	62 1/8"
46"	1	44 1/2"	63 1/8"
47"	4	45 1/2"	64 1/8"
51"	1	49 1/2"	68 1/8"
52"	1	50 1/2"	69 1/8"
53"	1	51 1/2"	70 1/8"
54"	1	52 1/2"	71 1/8"
55"	1	53 1/2"	72 1/8"

#6 Vertical Stirrups			
Height (x)	QTY	Height (y)	Unbenth Lenght
41 5/8"	2	38 7/8"	59 3/4"
43 1/8"	2	40 3/8"	61 1/4"
44 1/2"	2	41 3/4"	62 5/8"
46"	2	43 1/4"	64 1/8"
47 1/2"	2	44 3/4"	65 5/8"
48 7/8"	2	46 1/8"	67"
50 3/8"	2	47 5/8"	68 1/2"
51 7/8"	2	49 1/8"	70"
53 1/4"	2	50 1/2"	71 3/8"
54 3/4"	1	52 3/4"	72 7/8"

Midwest Roadside Safety Facility

Hawaii Phase 2
Systems 3 and 4
Test Nos. H42S-1-2 and H42ST-1-2
Transition Buttress Vertical Stirrups

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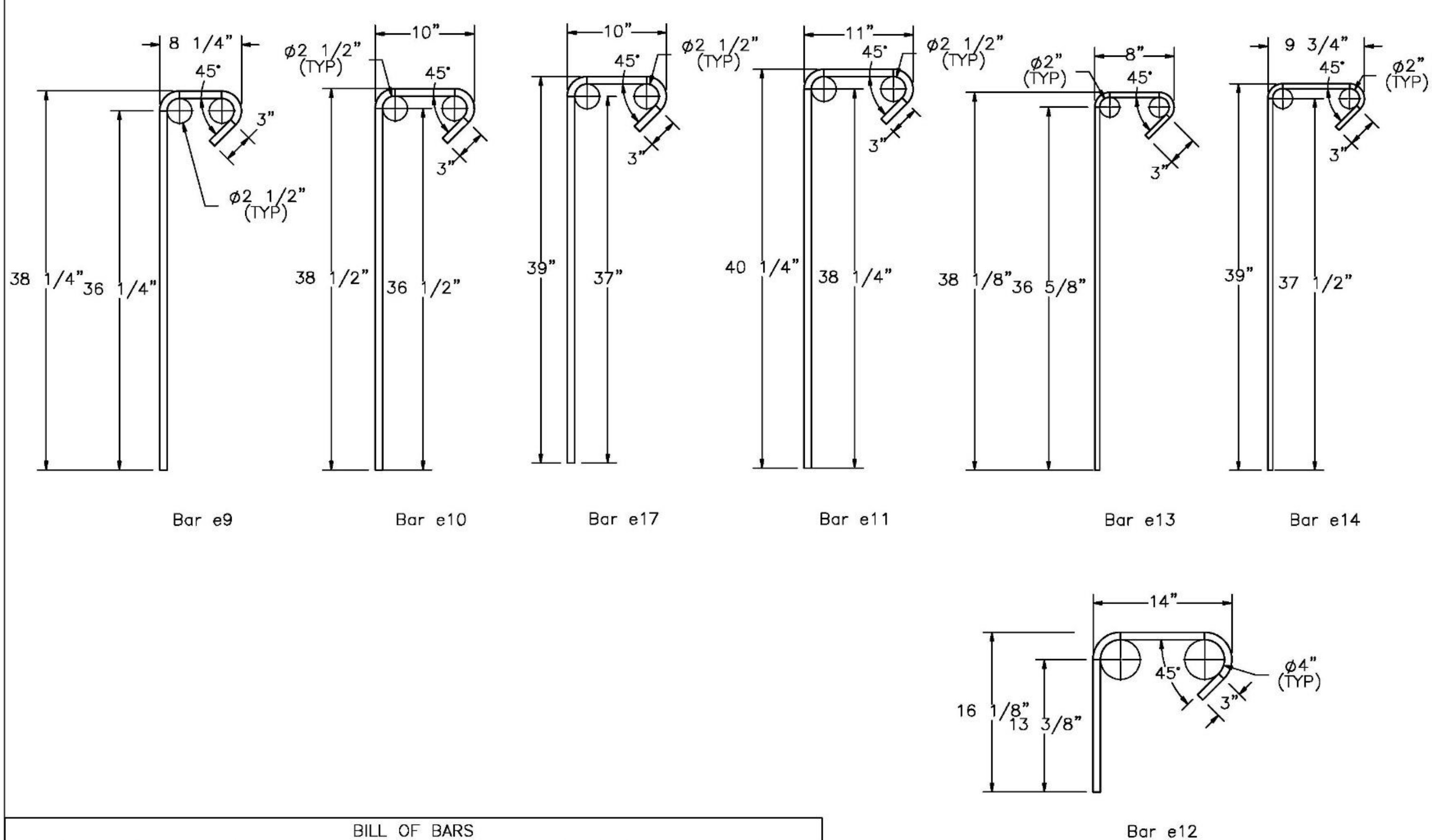
DRAWN BY: LJP/SBW/GHR
DWG. NAME. H42S-H42ST_R17
SCALE: 1:12
UNITS: in.
REV. BY: KAL/SHY/RKF/JCH/RN

Figure 21. Transition Buttress Vertical Stirrups, Test Nos. H42S-1 and H42S-2



BILL OF BARS				
Part No.	Size	QTY	Unbent Length	Material Specification
e9	#6	1	49 7/8"	ASTM A615 Gr. 60
e10	#6	1	51 7/8"	ASTM A615 Gr. 60
e11	#6	1	54 5/8"	ASTM A615 Gr. 60
e12	#6	6	34 3/16"	ASTM A615 Gr. 60
e13	#4	1	49 9/16"	ASTM A615 Gr. 60
e14	#4	2	52 1/8"	ASTM A615 Gr. 60
e17	#6	3	52 3/8"	ASTM A615 Gr. 60

Midwest Roadside Safety Facility

Hawaii Phase 2
Systems 3 and 4
Test Nos. H42S-1-2 and H42ST-1-2
Transition Buttress End Reinforcement

SHEET: 35 of 41
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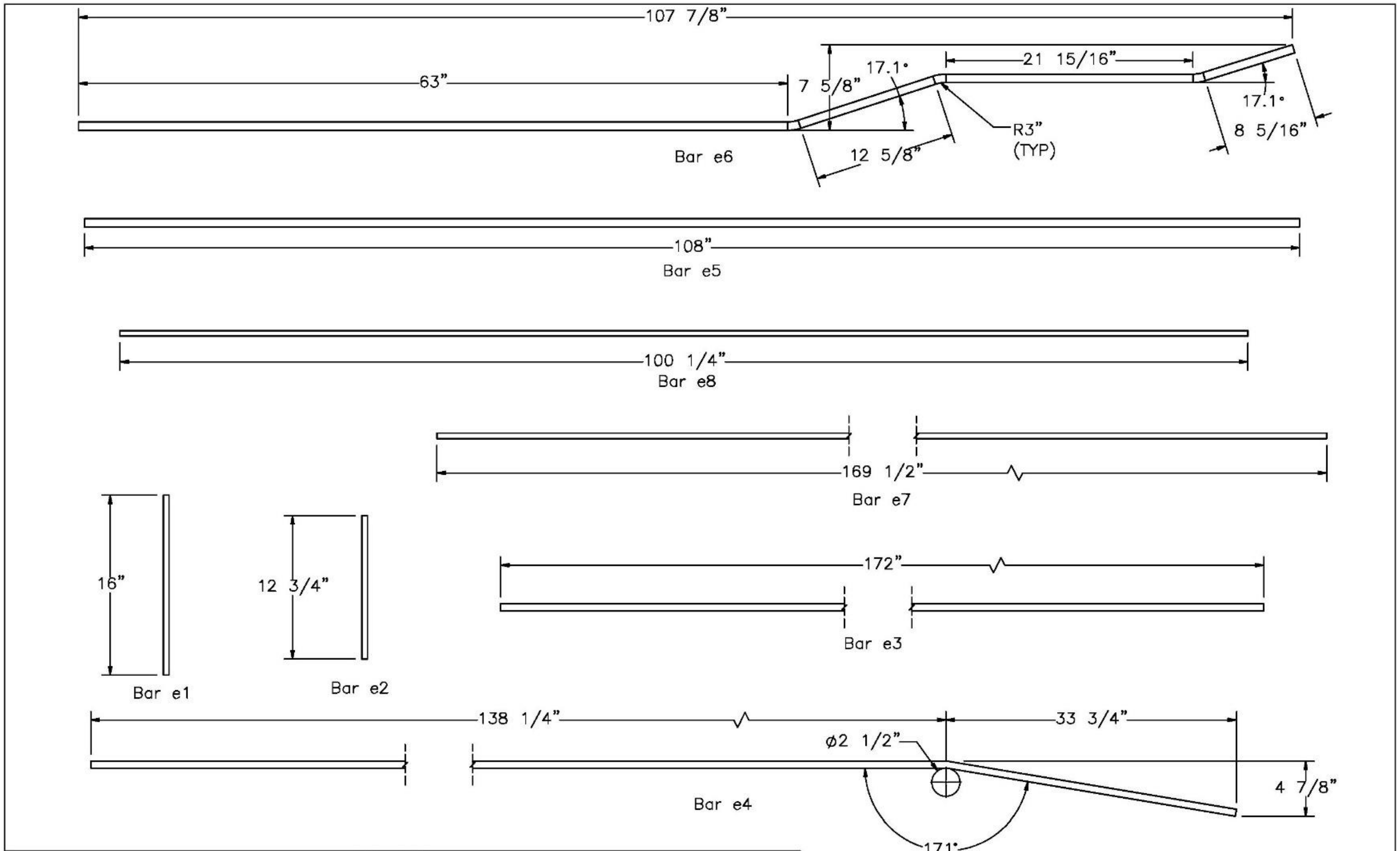
DRAWN BY: LJP/SBW/GHR
DWG. NAME. H42S-H42ST_R17
SCALE: 1:14
UNITS: in.
REV. BY: KAL/SHY/RKF/JCH/RN

Figure 22. Transition Buttress End Reinforcement, Test Nos. H42S-1 and H42S-2



Bill of Bars

Part No.	Bar No.	Qty.	Unbent Length	Material Specification
e1	#4	7	16"	ASTM A615 Gr. 60
e2	#4	1	12 3/4"	ASTM A615 Gr. 60
e3	#5	1	172"	ASTM A615 Gr. 60
e4	#5	1	164 1/4"	ASTM A615 Gr. 60
e5	#6	5	108"	ASTM A615 Gr. 60
e6	#6	3	109"	ASTM A615 Gr. 60
e7	#4	6	169 1/2"	ASTM A615 Gr. 60
e8	#4	2	100 1/4"	ASTM A615 Gr. 60

Midwest Roadside Safety Facility

Hawaii Phase 2
Systems 3 and 4
Test Nos. H42S-1-2 and H42ST-1-2
Longitudinal Buttress and Curb Reinforcement Details

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DATE: 10/20/2021
DRAWN BY: LJP/SBW/CHR
DWG. NAME. H42S-H42ST_R17
SCALE: 1:12
UNITS: in.
REV. BY: KAL/SHY/RKF/JCH/RN

Figure 23. Longitudinal Buttress and Curb Reinforcement Details, Test Nos. H42S-1 and H42S-2

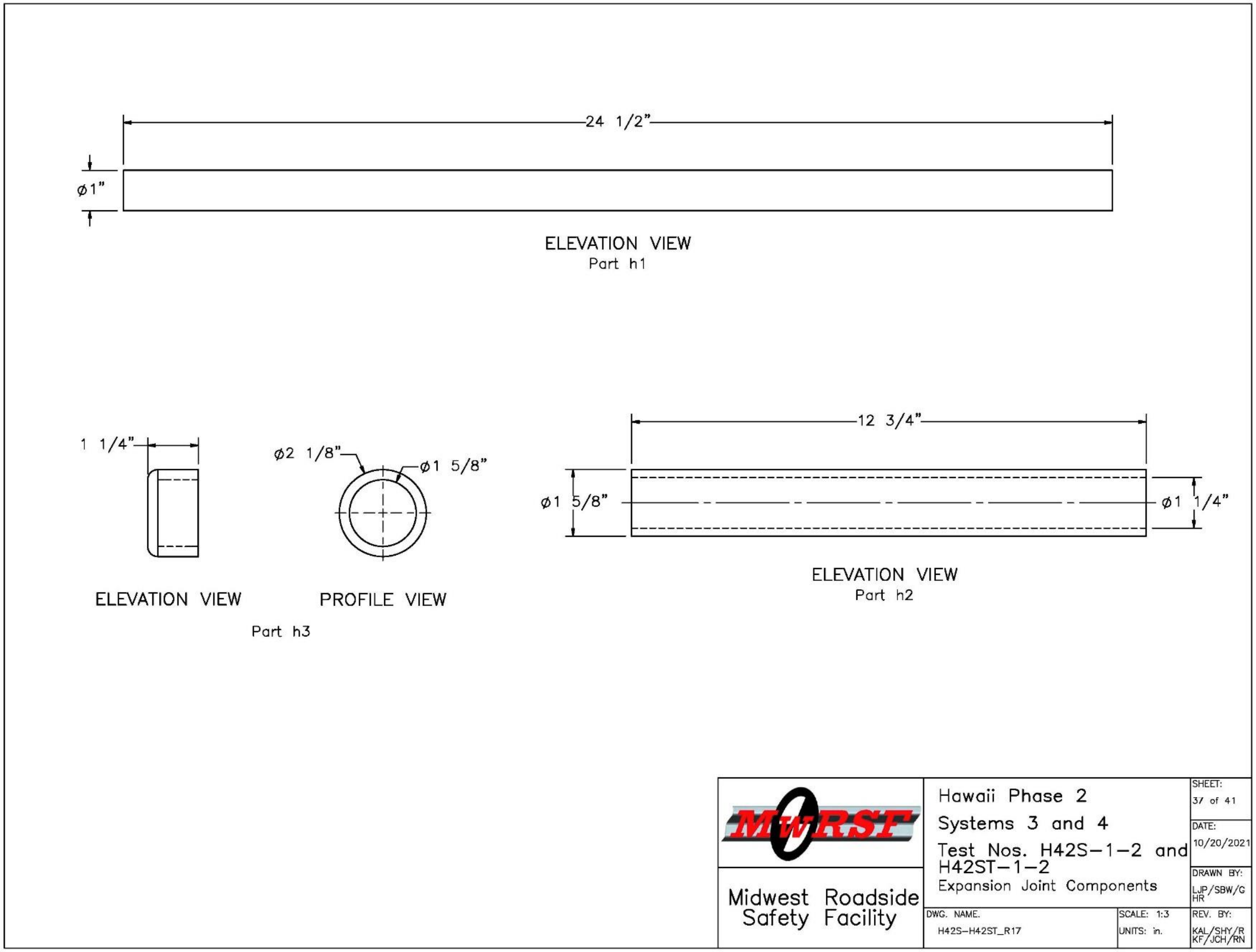

Figure 24. Expansion Joint Components, Test Nos. H42S-1 and H42S-2

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
a1	2	12'–6" 12-gauge Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM08a
a2	1	6'–3" 12-gauge Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM19a
a3	1	6'–3" 10-gauge W-Beam to Thrie-Beam Asymmetric Transition Section	AASHTO M180 Min. yield strength = 50 ksi Min. ultimate strength = 70 ksi	ASTM A123 or A653	RWT02
a4	3	12'–6" 12-gauge W-Beam MGS Section	AASHTO M180	ASTM A123 or A653	RWM04a
a5	1	12'–6" 12-gauge W-Beam MGS End Section	AASHTO M180	ASTM A123 or A653	RWM14a
a6	1	10-gauge Thrie Beam Terminal Connector	AASHTO M180 Min. yield strength = 50 ksi Min. ultimate strength = 70 ksi	ASTM A123 or A653	RTE01b
b1	–	Concrete*	Min. f'c = 4,000 psi	–	–
c1	2	BCT Timber Post – MGS Height	SYP Grade No. 1 or better (No knots +/– 18" from ground on tension face)	AASHTO M133	PDF01
c2	2	72" Long Foundation Tube	ASTM A500 Gr. B	ASTM A123	PTE06
c3	1	Ground Strut Assembly	ASTM A36	ASTM A123	–
c4	2	BCT Anchor Cable End Swaged Fitting	Fitting – ASTM A576 Gr. 1035 Stud – ASTM F568 Class C	Fitting – ASTM A153 Stud – ASTM A153 or B695	–
c5	1	3/4" 6x19 IWRC IPS Wire Rope	ASTM A741 Type 2	Class A Coating	FCA01
c6	1	8"x8"x5/8" Anchor Bearing Plate	ASTM A36	ASTM A123	FPB01
c7	1	2 3/8" O.D. x 6" Long BCT Post Sleeve	ASTM A53 Gr. B Schedule 40	ASTM A123	FMM02
c8	1	Anchor Bracket Assembly	ASTM A36	ASTM A123	FPA01
d1	7	W6x8.5 or W6x9, 72" Long Steel Post	ASTM A992 Gr. 50	**ASTM A123	PWE06
d2	6	W6x8.5 or W6x9, 72" Long Steel Post	ASTM A992 Gr. 50	**ASTM A123	PWE06
d3	4	W6x15, 78" Long Steel Post	ASTM A992 Gr. 50	**ASTM A123	–
d4	4	17 1/2" Long, 8"x6"x1/4" Steel Blockout	ASTM A500 Gr. B	**ASTM A123	–
d5	6	17 1/2" Long, 12"x4"x1/4" Steel Blockout	ASTM A500 Gr. B	**ASTM A123	–
d6	2	14 3/16"x12"x5 1/8" Composite Recycled Blockout	Mondo Polymer MGS14SH or Equivalent	–	–
d7	5	14 3/16"x8"x5 1/8" Composite Recycled Blockout	Mondo Polymer GB14SH2 or Equivalent	–	–
d8	2	16D Double Head Nail	–	–	–

* NE Mix 47B15/1PF4000HW was used for testing purposes.
** Component does not need to be galvanized for testing purposes.

Note: (1) Quanitites listed herein are only for one complete system.

Midwest Roadside Safety Facility

Hawaii Phase 2
Systems 3 and 4
Test Nos. H42S–1–2 and H42ST–1–2
Bill of Materials

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REV. BY: KAL/SHY/RKF/JCH/RN
DWG. NAME. H42S–H42ST_R17
SCALE: None
UNITS: in.

Figure 25. Bill of Materials, Test Nos. H42S-1 and H42S-2

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
e1	7	#4 Rebar, 16" Total Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e2	1	#4 Rebar, 12 3/4" Total Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e3	1	#5 Rebar, 172" Total Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e4	1	#5 Rebar, 164 1/4" Total Unbent Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e5	5	#6 Rebar, 108" Total Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e6	3	#6 Rebar, 109" Unbent Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e7	6	#4 Rebar, 169 1/2" Total Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e8	2	#4 Rebar, 100 1/4" Total Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e9	1	#6 Rebar, 49 7/8" Unbent Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e10	1	#6 Rebar, 51 7/8" Unbent Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e11	1	#6 Rebar, 54 5/8" Unbent Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e12	6	#6 Rebar, 34 3/16" Unbent Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e13	1	#4 Rebar, 49 1/2" Unbent Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e14	2	#4 Rebar, 52 1/8" Unbent Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e15	15	#4 Rebar, Vertical Stirrup Varying Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e16	19	#6 Rebar, Vertical Stirrup Varying Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e17	3	#6 Rebar, 52 3/8" Unbent Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e18	6	#4 Rebar, 1196" Total Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e19	1	#4 Rebar, 1095 1/2" Total Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e20	125	#4 Rebar, 101 9/16" Unbent Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e21	11	#4 Rebar, 50 11/16" Unbent Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e22	11	#4 Rebar, 64 1/2" Unbent Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e23	4	#5 Rebar, 340 9/16" Unbent Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e24	1	#5 Rebar, 340 9/16" Unbent Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e25	30	#5 Rebar, 260" Total Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e26	4	#5 Rebar, 334" Total Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e27	1	#5 Rebar, 334 1/8" Unbent Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e28	275	#5 Rebar, 60 1/4" Total Unbent Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
e29	18	#5 Rebar, 47 13/16" Total Unbent Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–

MwRSF
Midwest Roadside Safety Facility

Hawaii Phase 2
Systems 3 and 4
Test Nos. H42S-1-2 and H42ST-1-2
Bill of Materials

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DRAWN BY: LJP/SBW/GHR
REV. BY: KAL/SHY/RKF/JCH/RN
DWG. NAME. H42S-H42ST_R17
SCALE: None
UNITS: in.

Figure 26. Bill of Materials, Test Nos. H42S-1 and H42S-2

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
f1	13	5/8"-11 UNC, 14" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBB06
f2	15	5/8"-11 UNC, 10" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBB03
f3	44	5/8"-11 UNC, 1 1/4" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBB01
f4	2	5/8"-11 UNC, 10" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f5	8	5/8"-11 UNC, 1 1/2" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX16a
f6	5	7/8"-9 UNC, 16" Long Heavy Hex Head Bolt	ASTM F3125 Gr. A325 or equivalent	ASTM A153 or B695 Class 55 or F1136 Gr. 3 or F2329 or F2833 Gr. 1	FBX22b
f7	2	7/8"-9 UNC, 8" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	ASTM A153 or B695 Class 55 or F2329	FBX22b
f8	24	5/8"-11 UNC, 2" Long Guardrail Bolt	ASTM A307 Gr. A	ASTM A153 or B695 Class 55 or F2329	FBB02
f9	96	5/8"-11 UNC Heavy Hex Nut	ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX16b
f10	2	7/8"-9 UNC Hex Nut	ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX22a
f11	5	7/8"-9 UNC Heavy Hex Nut	ASTM A563DH	ASTM A153 or B695 Class 55 or F2329	FNX22b
f12	2	1"-8 UNC Heavy Hex Nut	ASTM A563DH or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX24b
f13	10	5/8"-11 UNC Hex Nut	ASTM A563A or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX16a
g1	46	5/8" Dia. Plain USS Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC16a
g2	4	7/8" Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC20a
g3	2	1" Dia. Plain USS Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC24a
g4	5	3"x3"x1/4" or 3 1/2"x3 1/2"x1/4" Square Washer Plate	ASTM A572 Gr. 50	ASTM A123	FWR09
h1	12	#8 Smooth Rebar, 24 1/2" Total Length	ASTM A615 Gr. 60	Epoxy-Coated (ASTM A775 or A934)	–
h2	20	1 1/4" Dia. 12 3/4" Long PVC Pipe	Schedule 80 PVC Gr. 12454	–	–
h3	20	1 5/8" Dia. PVC Cap	Schedule 80 PVC Gr. 12454	–	–
i1	–	Epoxy Adhesive	Hilti HIT RE-500 V3	–	–
i2	–	Expansion Joint Filler	AASHTO M33, M153, or M213	–	–
i3	–	Expansion Joint Sealant	AASHTO M173, M282, M301, ASTM D3581, or ASTM D5893	–	–
–	–	Coarse Crushed Limestone (Well Graded Gravel)	–	–	–

Midwest Roadside Safety Facility

Hawaii Phase 2
Systems 3 and 4
Test Nos. H42S-1-2 and H42ST-1-2
Bill of Materials

SHEET: 41 of 41
DATE: 10/20/2021
DRAWN BY: LJP/SBW/GHR
REV. BY: KAL/SHY/RKF/JCH/RN
DWG. NAME. H42S-H42ST_R17
SCALE: None
UNITS: in.

Figure 27. Bill of Materials, Test Nos. H42S-1 and H42S-2

Figure 28. System Construction, Test Nos. H42S-1 and H42S-2

Figure 29. System Installation, Test No. H42S-1

Figure 30. System Installation, Test No. H42S-2

Figure 31. System Installation, Joint Details, Test Nos. H42S-1 (top) and H42S-2 (bottom)

4 TEST CONDITIONS

4.1 Test Facility

The Outdoor Test Site is located at 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 vehicles. The distance traveled and the speed of the tow vehicle was one-half that of the test vehicles. The test vehicles were released from the tow cable before impact with the barrier system. A digital speedometer on the tow vehicle increased the accuracy of the test vehicle impact speed.

A vehicle guidance system developed by Hinch [11] was used to steer the test vehicles. 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. H42S-1, a 2015 Dodge RAM 1500 quad cab pickup truck was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 4,949 lb, 5,019 lb, and 5,175 lb, respectively. The test vehicle is shown in Figures 32 and 33, and vehicle dimensions are shown in Figure 34. Note that dimension D's recorded value of 42¾ in. exceeds the limit of 39 ±3 in., but this limit is a recommendation, not a requirement, as stated in Section 4.2.1 of MASH 2016 [6].

For test no. H42S-2, a, 2015 Hyundai Accent sedan was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 2,493 lb, 2,426 lb, and 2,590 lb, respectively. The test vehicle is shown in Figures 35 and 36, and vehicle dimensions are shown in Figure 37.

Figure 32. Test Vehicle, Test No. H42S-1

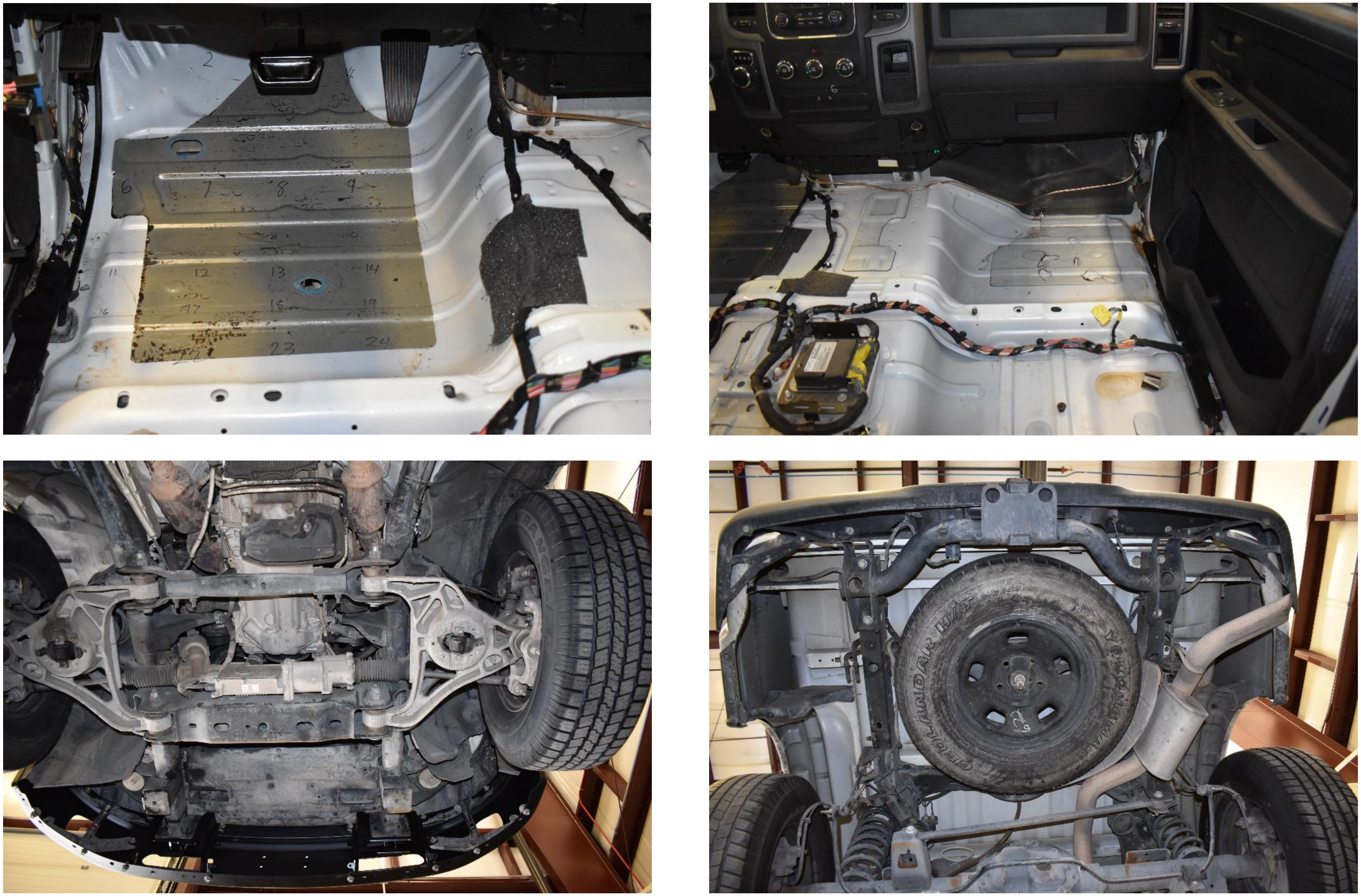
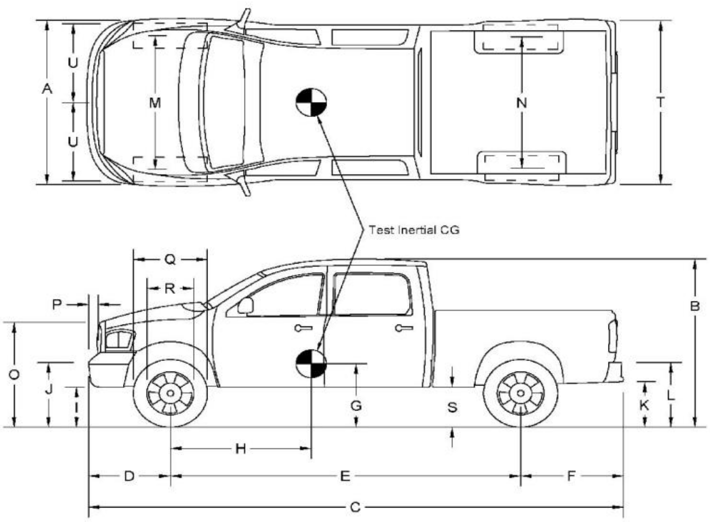


Figure 33. Test Vehicle’s Interior Floorboards and Undercarriage, Test No. H42S-1

		Test Name:	H42S-1	VIN No:	1C6RR6FG6FS703367
Model Year:	2015	Make:	Dodge	Model:	RAM 1500 quad cab
Tire Size:	P265/70R17	Tire Inflation Pressure:	40 psi	Odometer:	180154



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

	in.	mm	Target		in.	mm	Target
A:	76 3/4	1949 9/20	78±2 (1950±50)	B:	73 7/8	1876 17/40	
C:	229	5816 3/5	237±13 (6020±325)	D:	42 3/4	1085 17/20	39±3 (1000±75)
E:	140	3556	148±12 (3760±300)	F:	46 1/4	1174 3/4	
G:	28 1/8	714 3/8	min: 28 (710)	H:	65 3/16	1655 61/80	63±4 (1575±100)
I:	13 1/4	336 11/20		J:	24 1/4	615 19/20	
K:	19 1/4	488 19/20		L:	27 1/2	698 1/2	
M:	67 3/4	1720 17/20	67±1.5 (1700±38)	N:	67 3/4	1720 17/20	67±1.5 (1700±38)
O:	44 5/8	1133 19/40	43±4 (1100±75)	P:	4 5/8	117 19/40	
Q:	31 1/4	793 3/4		R:	18 1/12	459 19/60	
S:	13 1/2	342 9/10		T:	75 1/2	1917 7/10	

	in.	mm
U (impact width):	36	914 2/5
Wheel Center Height (Front):	15	381
Wheel Center Height (Rear):	15	381
Wheel Well Clearance (Front):	34 7/8	885 33/40
Wheel Well Clearance (Rear):	37	939 4/5
Bottom Frame Height (Front):	14	355 3/5
Bottom Frame Height (Rear):	24 1/2	622 3/10

Mass Distribution - lb (kg)

Gross Static					
LF	1436	(651)	RF	1338	(607)
LR	1224	(555)	RR	1177	(534)

Weights lb (kg)	Curb		Test Inertial		Gross Static	
W-front	2704	(1227)	2681	(1216)	2774	(1258)
W-rear	2245	(1018)	2338	(1060)	2401	(1089)
W-total	4949	(2245)	5019	(2277)	5175	(2347)
			5000±110 (2270±50)		5165±110 (2343±50)	

Engine Type:	6 cyl. Gas
Engine Size:	3.6L
Transmission Type:	Automatic
Drive Type:	RWD
Cab Style:	Quad Cab
Bed Length:	76"

GVWR Ratings - lb	
Front	3700
Rear	3900
Total	6800

Surrogate Occupant Data	
Type:	Hybrid II
Mass:	156 lb
Seat Position:	Left Front

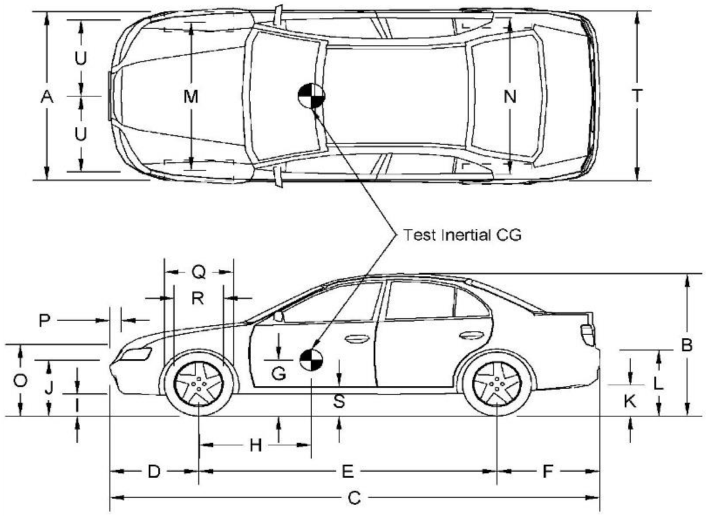
Note any damage prior to test: Tailgatge is dented

Figure 34. Vehicle Dimensions, Test No. H42S-1

Figure 35. Test Vehicle, Test No. H42S-2

Figure 36. Test Vehicle’s Interior Floorboards and Undercarriage, Test No. H42S-2

		Test Name:	H42S-2	VIN No:	KMHCT4AE1FU907729
Model Year:	2015	Make:	Hyundai	Model:	Accent
Tire Size:	175/70R14	Tire Inflation Pressure:	33 psi	Odometer:	155672



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

A: 67 (1702) 65±3 (1650±75)	B: 56 5/8 (1438)
C: 171 3/4 (4362) 169±8 (4300±200)	D: 32 (813) 35±4 (900±100)
E: 101 3/4 (2584) 98±5 (2500±125)	F: 38 (965)
G: 22 1/16 (560)	H: 38 3/8 (975) 39±4 (990±100)
I: 6 1/2 (165)	J: 22 3/4 (578)
K: 11 (279)	L: 25 1/2 (648)
M: 59 3/8 (1508) 59±2 (1498±50)	N: 59 1/4 (1505) 59±2 (1425±50)
O: 29 1/4 (743) 28±4 (711±100)	P: 1 3/4 (44)
Q: 23 1/4 (591)	R: 15 1/4 (387)
S: 10 (254)	T: 66 3/4 (1695)
	U (impact width): 30 3/4 (781)

Top of radiator core support:	28 1/2	(724)
Wheel Center Height (Front):	10 3/4	(273)
Wheel Center Height (Rear):	11	(279)
Wheel Well Clearance (Front):	24 1/2	(622)
Wheel Well Clearance (Rear):	25 1/8	(638)
Bottom Frame Height (Front):	5 1/4	(133)
Bottom Frame Height (Rear):	8	(203)
Engine Type:	Gasoline	
Engine Size:	1.6L 4 cyl	
Transmission Type:	Automatic	
Drive Type:	FWD	

Mass Distribution - lb (kg)

Gross Static	LF	829 (376)		RF	768 (348)
	LR	501 (227)		RR	492 (223)

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	1565 (710)	1511 (685)	1597 (724)
W-rear	928 (421)	915 (415)	993 (450)
W-total	2493 (1131)	2426 (1100) 2420±55 (1100±25)	2590 (1175) 2585±55 (1175±50)

GVWR Ratings lb		Surrogate Occupant Data	
Front	1874	Type:	Hybrid II
Rear	1852	Mass:	164 lb
Total	3527	Seat Position:	Left/Drivers

Note any damage prior to test: Cracks along the windshield. Dent around the rear left tire.

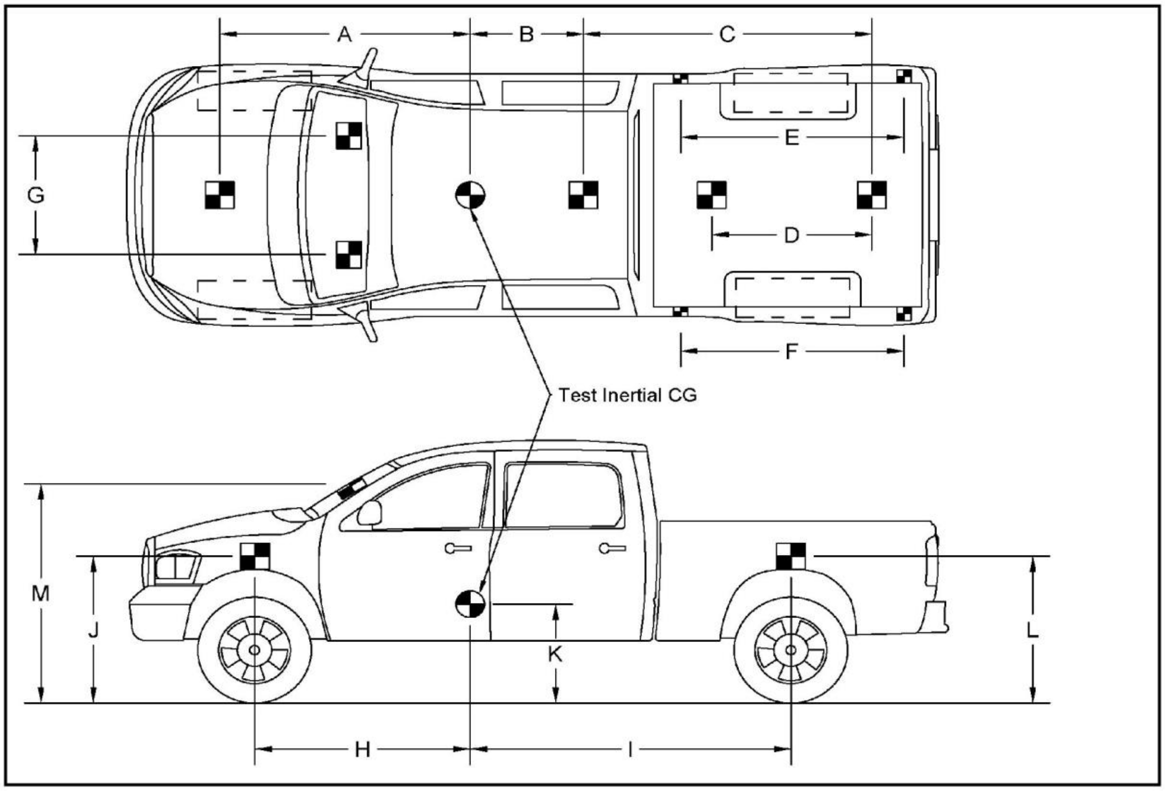
Figure 37. Vehicle Dimensions, Test No. H42S-2

The longitudinal component of the center of gravity (c.g.) was determined using the measured axle weights. The Suspension Method [12] was used to determine the vertical component of the c.g. for the 2270P vehicle. 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 final c.g. location for test no. H42S-1 is shown in Figure 38. The vertical component of the c.g. for the 1100C vehicle was determined utilizing a procedure published by SAE [13]. The final c.g. location for test no. H42S-2 is shown in Figure 39. 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, as shown in Figures 38 and 39, 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.

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 both vehicles' left windshield wipers 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 vehicle so the vehicle could be brought safely to a stop after the test.

		Test Name:	H42S-1	VIN:	1C6RR6FG6FS703367
Model Year:	2015	Make:	Dodge	Model:	RAM 1500 quad cab



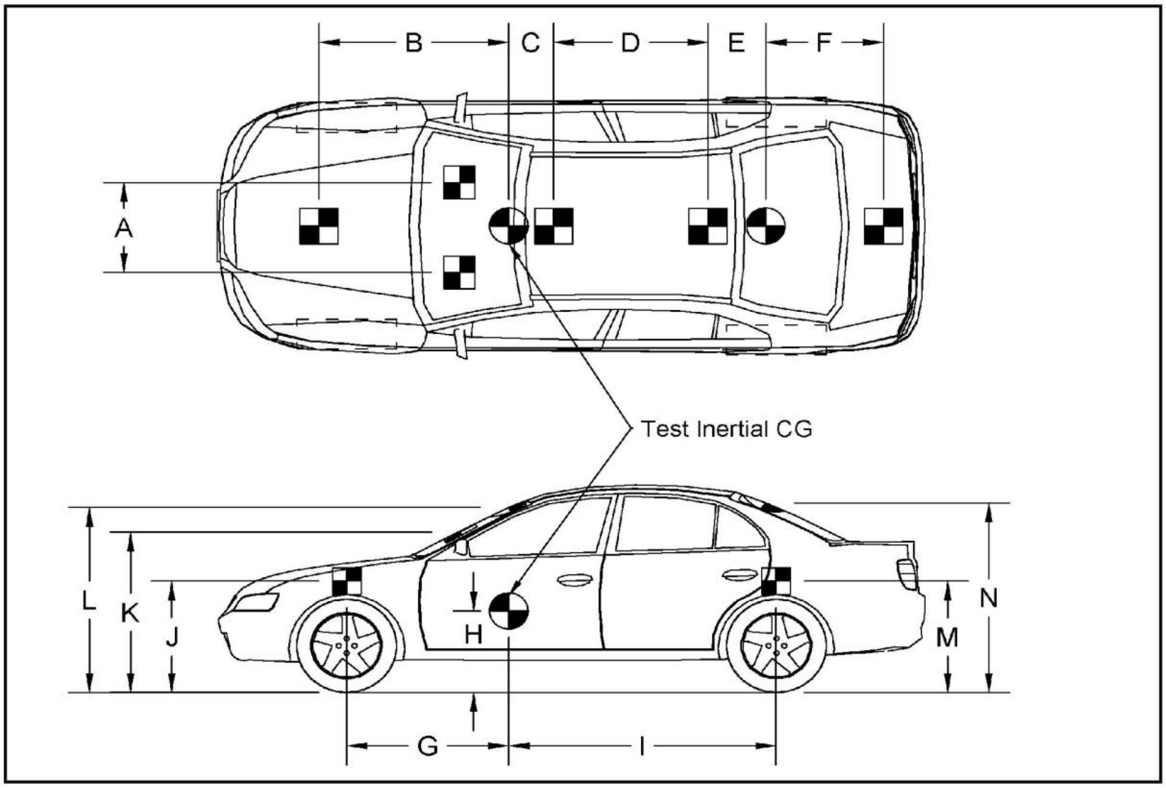
TARGET GEOMETRY-- in. (mm)

A:	80 1/4	(2038)	E:	63 3/8	(1610)	J:	38	(965)
B:	24 3/16	(614)	F:	63 1/4	(1607)	K:	28 1/8	(714)
C:	69 1/4	(1759)	G:	36 7/8	(937)	L:	41 1/8	(1045)
D:	34 1/2	(876)	H:	65 1/4	(1657)	M:	62 3/4	(1594)
			I:	74 7/8	(1902)			

Figure 38. Target Geometry, Test No. H42S-1

Test Name: H42S-2 **VIN:** KMHCT4AE1FU907729

Model Year: 2015 **Make:** Hyundai **Model:** Accent



TARGET GEOMETRY-- in. (mm)

A:	23 1/4	(591)	F:	31 1/4	(794)	K:	48 1/2 Windshield Target	(1232)
B:	49	(1245)	G:	22 1/16	(560)	L:	53 1/8 Front round CG target	(1349)
C:	11 1/4	(286)	H:	38 3/8	(975)	M:	29	(737)
D:	37 1/2	(953)	I:	62 3/4	(1594)	N:	53 1/8 Rear Round target	(1349)
E:	9 3/8	(238)	J:	28 1/2	(724)			

Figure 39. Target Geometry, Test No. H42S-2

4.4 Simulated Occupant

For test nos. H42S-1 and H42S-2, a Hybrid II 50^{th}-Percentile, Adult Male Dummy equipped with a footwear was placed in the left-front seat of both test vehicles with the seat belt fastened. The simulated occupant had a final weight of 156 lb for test no. H42S-1 and 164 lb for test no. H42S-2. As recommended by MASH 2016, the simulated occupant weight was not included in calculating the c.g. location.

4.5 Data Acquisition Systems

4.5.1 Accelerometers 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 vehicle, with the SLICE-2 unit designated as primary for test no. H42S-1 and the SLICE-1 unit designated as primary for test no. H42S-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 7GB of non-volatile flash memory and recorded data at 10,000 Hz to the onboard microprocessor. The accelerometers had a range of ±500g's in each of three directions (longitudinal, lateral, and vertical) and a 1,650 Hz (CFC 1000) anti-aliasing filter. The SLICE MICRO Triax ARS had a range of 1,500 degrees/sec in each of three directions (roll, pitch, and yaw). The raw angular rate measurements were downloaded, converted to the proper Euler angles for analysis, and plotted. The "SLICEWare" computer software program and a customized Microsoft Excel worksheet were used to analyze and plot both the accelerometer and angular rate sensor data.

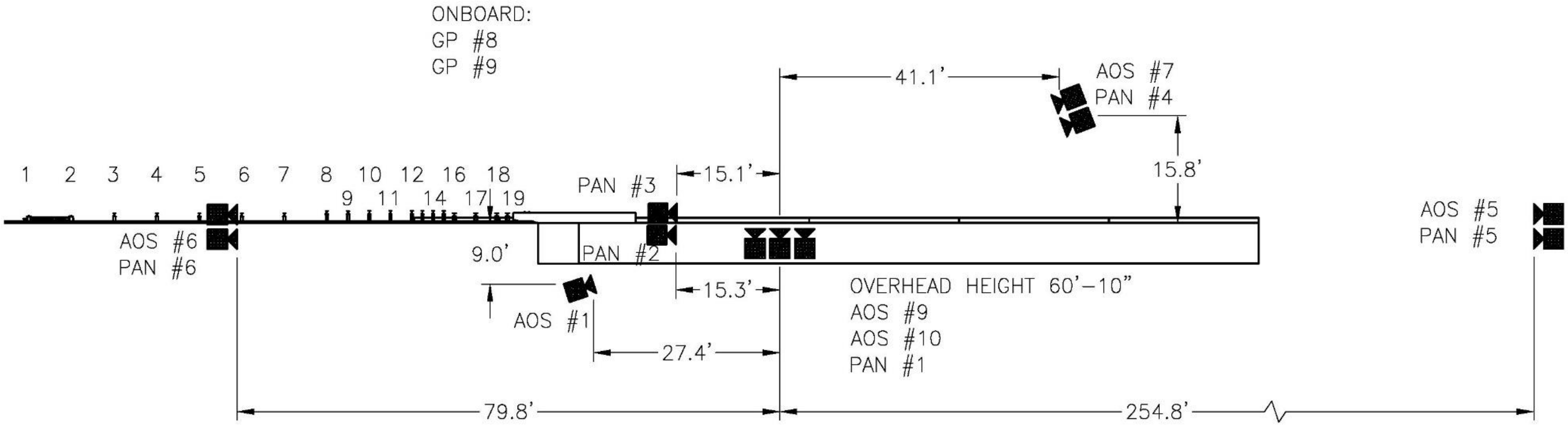
4.5.2 Retroreflective Optic Speed Trap

A retroreflective optic speed trap was used to determine the speed of the test vehicle before impact. Five retroreflective targets, spaced at approximately 18-in. intervals, were applied to the side of the 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.

4.5.3 Digital Photography

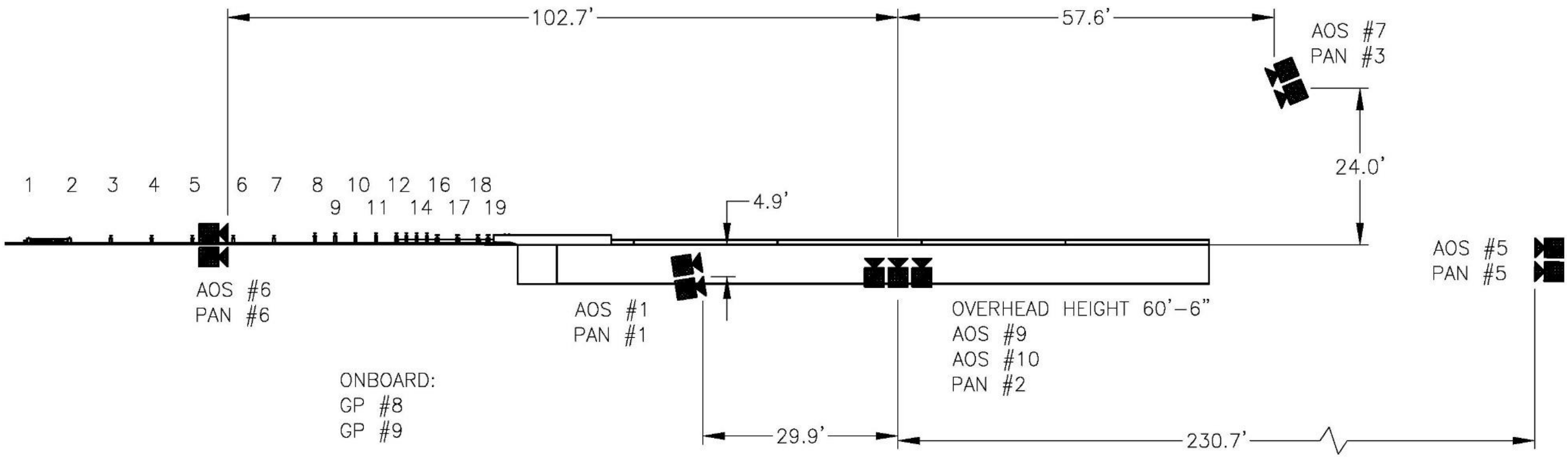
Six AOS high-speed digital video cameras, two GoPro digital video cameras, and six Panasonic digital video cameras were utilized to film test no. H42S-1. For test no. H42S-2, six AOS high-speed digital video cameras, two GoPro digital video cameras, and five Panasonic digital video cameras were utilized. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system for both tests are shown in Figures 40 and 41.

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-1	AOS Vitcam CTM	500	Kowa 25mm Fixed	
AOS-5	AOS X-PRI Gigabit	500	100mm Fixed	
AOS-6	AOS X-PRI Gigabit	500	Fujinon 50mm Fixed	
AOS-7	AOS X-PRI Gigabit	500	Fujinon 35mm Fixed	
AOS-9	AOS TRI-VIT 2236	1000	Kowa 12mm Fixed	
AOS-10	AOS TRI-VIT 2236	500	Kowa 16mm Fixed	
GP-8	GoPro Hero 4	120		
GP-9	GoPro Hero 4	120		
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 40. Camera Locations, Speeds, and Lens Settings, Test No. H42S-1



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-1	AOS Vitcam CTM	500	Kowa 25mm Fixed	
AOS-5	AOS X-PRI Gigabit	500	100mm Fixed	
AOS-6	AOS X-PRI Gigabit	500	Fujinon 50mm Fixed	
AOS-7	AOS X-PRI Gigabit	500	Fujinon 35mm Fixed	
AOS-9	AOS TRI-VIT 2236	1000	Kowa 12mm Fixed	
AOS-10	AOS TRI-VIT 2236	500	Kowa 16mm Fixed	
GP-8	GoPro Hero 4	120		
GP-9	GoPro Hero 4	120		
PAN-1	Panasonic HC-V770	120		
PAN-2	Panasonic HC-V770	120		
PAN-3	Panasonic HC-V770	120		
PAN-5	Panasonic HC-VX981	120		
PAN-6	Panasonic HC-VX981	120		

Figure 41. Camera Locations, Speeds, and Lens Settings, Test No. H42S-2

5 FULL-SCALE CRASH TEST NO. H42S-1

5.1 Weather Conditions

Test no. H42S-1 was conducted on August 25, 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. H42S-1

Temperature	90°F
Humidity	44%
Wind Speed	11 mph
Wind Direction	20° from True North
Sky Conditions	Overcast
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.20 in.
Previous 7-Day Precipitation	0.43 in.

5.2 Test Description

Initial vehicle impact was to occur 51⅝ in. upstream from expansion joint no. 1, as shown in Figure 42, which was selected using Table 2.7 of MASH 2016. The sidewalk impact location was determined based on the targeted impact point and the vehicle's anticipated trajectory. The 5,019-lb quad cab pickup truck impacted the sidewalk at a speed of 62.9 mph and an angle of 24.8 degrees and impacted the barrier at a speed of 61.8 mph and an angle of 24.4 degrees. The actual point of impact was 2.6 in. upstream from the targeted impact point. After brakes were applied and a secondary impact occurred with temporary concrete barriers shielding other areas of the test site, the vehicle came to rest 264.5 ft downstream from the impact point and 17.5 ft laterally behind the traffic side of the barrier. Impact severity is an additional limiting condition required in MASH 2016. The measured impact severity with the sidewalk for test no. H42S-1 was 116.8 kip-ft, which was greater than the 106 kip-ft limit as defined in MASH 2016 for test designation no. 3-11.

A detailed description of the sequential impact events is contained in Table 4. Sequential photographs are shown in Figures 43 and 44. Documentary photographs of the crash test are shown in Figure 45. The vehicle trajectory and final position are shown in Figure 46.

Figure 42. Impact Location, Test No. H42S-1

Table 4. Sequential Description of Impact Events, Test No. H42S-1

Time (sec)	Event
-0.022	Vehicle's left-rear tire contacted curb at a speed of 62.9 mph.
-0.002	Vehicle's right-front tire contacted curb.
0.000	Vehicle's front bumper contacted barrier no. 1 2.6 in. upstream from expansion joint no. 1.
0.002	Vehicle's front bumper deformed.
0.008	Vehicle's left headlight and fender deformed and contacted barrier no. 1.
0.010	Vehicle's left-front tire contacted barrier no. 1.
0.012	Vehicle's hood deformed and contacted barrier no. 1.
0.014	Barrier no. 1 spalled on front side between midspan and downstream end of barrier.
0.022	Vehicle's left headlight shattered. Vehicle's grille deformed and contacted barrier no. 1. Vehicle's left-rear tire became airborne.
0.028	Vehicle's right fender and headlight deformed.
0.038	Vehicle rolled toward system.
0.046	Barrier no. 2 spalled on front side between midspan and downstream end of barrier. Vehicle's left-front door deformed and contacted barrier no. 1.
0.052	Vehicle's left-front tire deflated.
0.056	Top of left-front door deformed to become ajar.
0.066	Vehicle's windshield cracked, and vehicle's right-rear tire became airborne.
0.072	Vehicle's grille and right headlight became disengaged.
0.084	Vehicle's left-rear tire regained contact with ground.
0.088	Surrogate occupant's head contacted left-front window.
0.138	Vehicle's right-front tire became airborne.
0.168	Vehicle's right-rear tire regained contact with ground.
0.170	Vehicle's left-rear door deformed and contacted barrier no. 2.
0.182	Vehicle's left quarter panel deformed and contacted barrier nos. 1 and 2.
0.190	Vehicle's left taillight deformed and contacted barrier no. 1.
0.192	Vehicle's rear bumper deformed and contacted barrier no. 1. Vehicle was parallel to system at a speed of 53.7 mph.
0.218	Vehicle's right-rear tire regained contact with ground.
0.375	Vehicle exited system at a speed of 50.3 mph and at angle of 3.4 degrees.
0.452	Vehicle rolled away from system.
0.580	Vehicle's right-front tire regained contact with ground.
0.776	Vehicle's right-rear tire regained contact with ground.
5.050	Vehicle came to rest 264.5 ft downstream from impact.


-0.146 sec

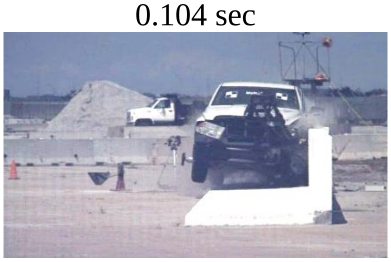

-0.146 sec


0.000 sec


0.000 sec


0.104 sec


0.104 sec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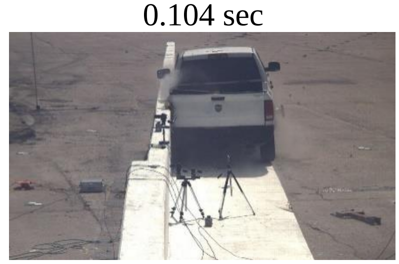
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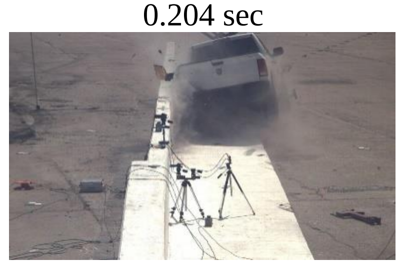
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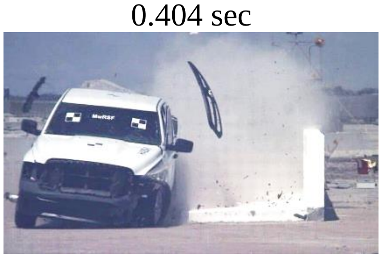
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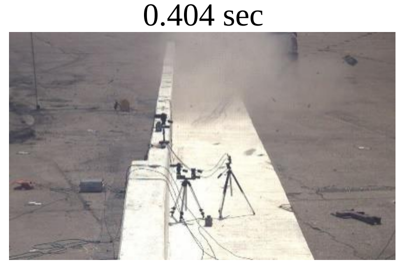
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Figure 43. Sequential Photographs Test No. H42S-1

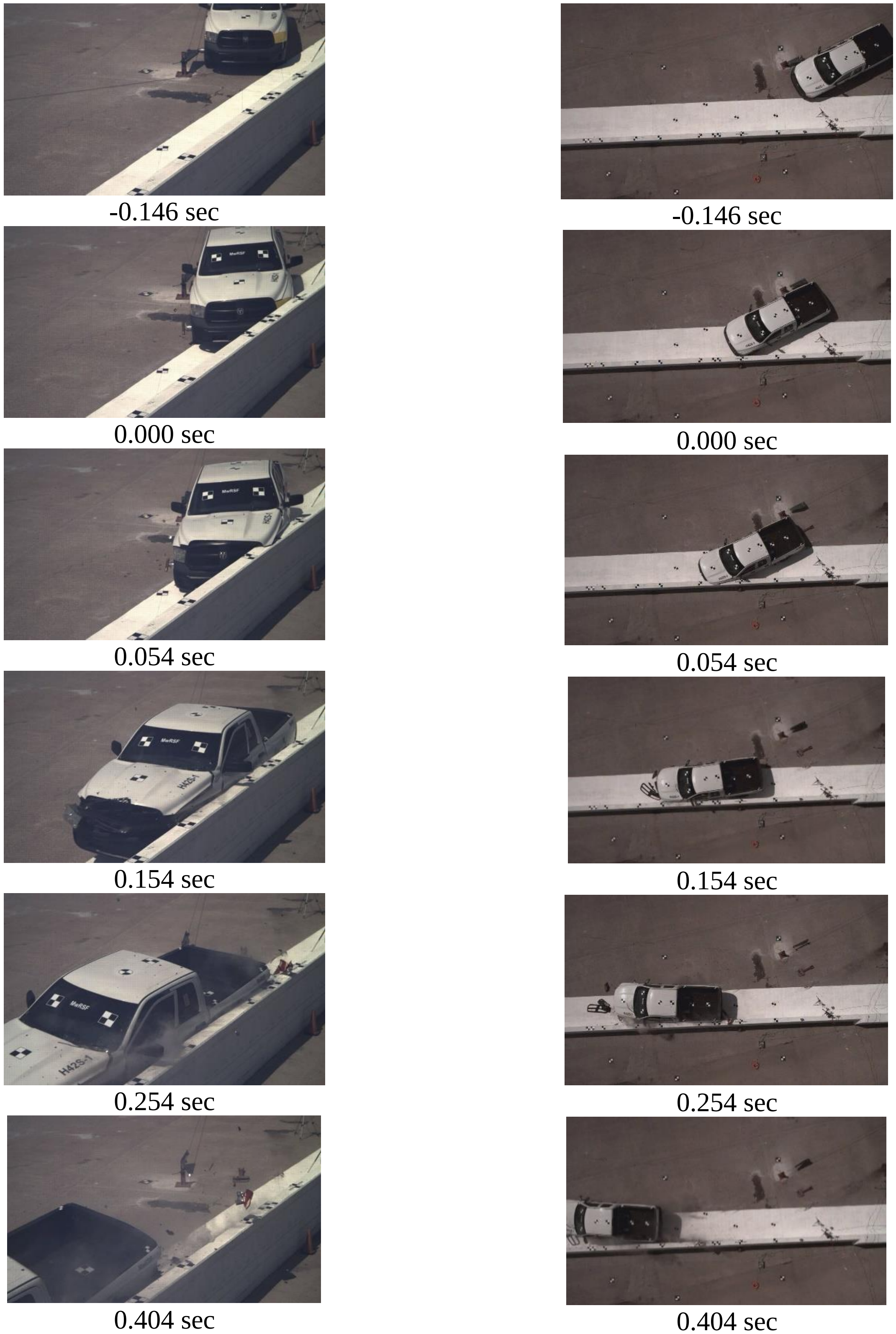


Figure 44. Sequential Photographs, Test No. H42S-1

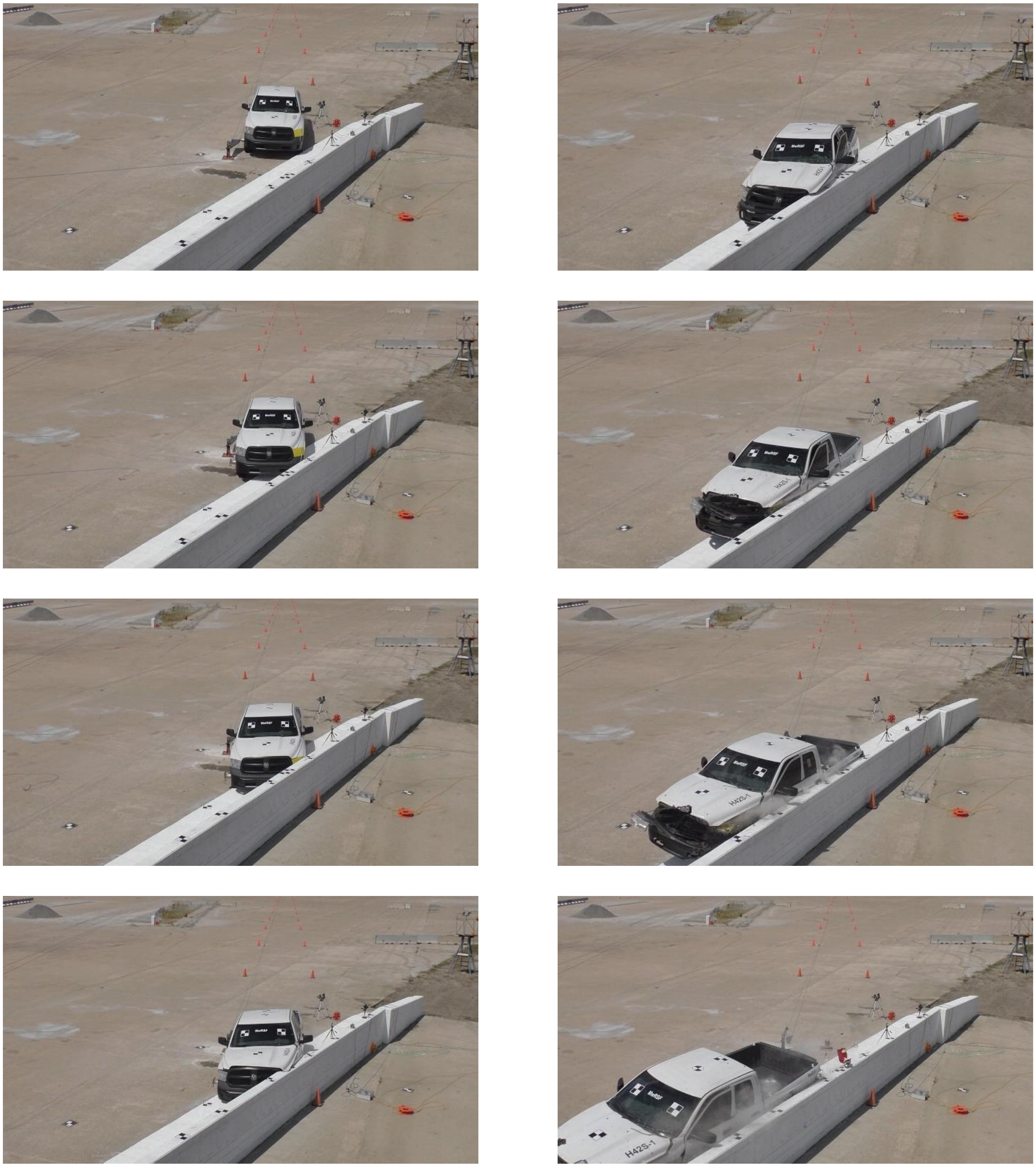


Figure 45. Documentary Photographs, Test No. H42S-1

Figure 46. Vehicle Final Position and Trajectory Marks, Test No. H42S-1

5.3 Barrier Damage

Damage to the barrier was minimal, as shown in Figures 47 through 53. Barrier damage consisted of contact marks on the front and top faces of the concrete segments and concrete gouging. Note that some cracking visible in the system photographs was documented beforehand and did not occur due to the test no. H42S-1 impact. The length of vehicle contact along the barrier was approximately 13½ in., which spanned from 1 ft – 1½ in. upstream from the impact point.

Contact marks were visible on the front and top faces of the barrier. A 143-in. long by 42-in. tall contact mark began upstream from impact at the mid-height of the barrier. An 88-in long by 6-in. wide contact mark was found on the top face of the barrier, beginning 5½ in. downstream from impact.

The barrier sustained minor gouging, beginning 7 in. downstream from the impact point and extending 52¼ in. downstream from expansion joint no. 1, starting from the base of the barrier to 28 in. above the sidewalk. Minor gouging was observed on the downstream, upstream, and bottom edges of the five panels upstream from expansion joint no. 1 and the three panels downstream from the expansion joint. Most gouging occurred on the downstream edges of the four panels upstream from expansion joint no. 1, as shown in Figure 50. Panel gouging is summarized in Table 5. In addition to the recess panel gouging, minor gouging from vehicle wheel contact occurred along the lower half of the barrier upstream from the expansion joint, as shown in Figures 51 and 52. The expansion joint was gouged on the edges with small amounts of joint fill material removed by the vehicle, as shown in Figure 53.

Table 5. Gouging Damage to Aesthetic Recess Panels, Test No. H42S-1

Recess No.	Relative to Expansion Joint	Length (in.)	Height (in.)	Recess Edge
1	Upstream	6	15½	Bottom
	Upstream	1	18½	Upstream
	Upstream	15	18	Bottom
2	Upstream	2	19	Bottom
		10	17½	Upstream Downstream
3	Upstream	10.5	16½	Downstream Bottom
4	Upstream	11	17	Bottom
5	Upstream	5	7	Bottom
		10	16½	Bottom
		8	19½	Downstream
6	Downstream	7.5	18	Upstream Downstream Bottom
7	Downstream	3.5	24	Downstream

Figure 47. System Damage, Test No. H42S-1

Figure 48. System Damage, Sidewalk, Test No. H42S-1

Figure 49. System Damage, Test No. H42S-1

Figure 50. System Damage, Test No. H42S-1

Figure 51. System Damage due to Wheel Contact, Test No. H42S-1

Figure 52. System Damage Due to Wheel Contact, Test No. H42S-1

Figure 53. System Damage at Expansion Joint No. 1, Test No. H42S-1

The maximum lateral permanent set of the barrier system, including barrier and deck panel shift, was 1.3 in. at the rail centerline target as measured in the field. The maximum lateral dynamic barrier deflection, including tipping of the barrier along the top surface, was 1.3 in. at the rail line layout target, as determined from high-speed digital video analysis. The working width of the system was found to be 11.3 in. measured from the front face of the barrier and 83.3 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 54.

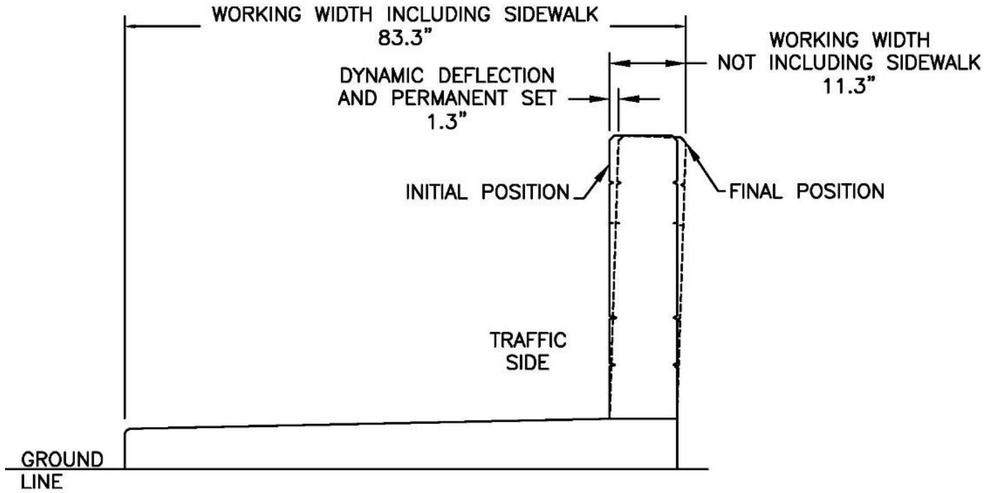


Figure 54. Permanent Set, Dynamic Deflection, and Working Width, Test No. H42S-1

5.4 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 55 through 58. 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 front bumper and the left-front fender were crushed inward and bent. The left-front tire was partially disengaged from the rim, and the left-front rim was deformed. The front headlights and grille were disengaged from the vehicle. The hood was crushed inward on its left edge. The left-front door was crushed in the middle, pinching the latch. The entire left side of the vehicle was scraped. The left side of the bed was crushed inward along its entire length. The left-rear taillight was disengaged from the vehicle. The left side of the rear bumper was crushed inward. The windshield had cracking across its entire length. The vehicle sustained significant damage due to a second impact with the temporary concrete barriers shielding other areas of the test site when coming to rest outside of the system.

The maximum occupant compartment intrusions are listed in Table 6, 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.

Figure 55. Vehicle Damage, Test No. H42S-1

Figure 56. Vehicle Damage, Test No. H42S-1

Figure 57. Vehicle Interior Damage, Test No. H42S-1

Figure 58. Vehicle Undercarriage Damage, Test No. H42S-1

Table 6. Maximum Occupant Compartment Intrusion by Location, Test No. H42S-1

Location	Maximum Intrusion in.	MASH 2016 Allowable Intrusion in.
Wheel Well & Toe Pan	4.0	≤ 9
Floor Pan & Transmission Tunnel	0.4	≤ 12
A-Pillar	0.0	≤ 5
A-Pillar (Lateral)	0.0*	≤ 3
B-Pillar	0.3	≤ 5
B-Pillar (Lateral)	0.0*	≤ 3
Side Front Panel (in Front of A-Pillar)	3.2	≤ 12
Side Door (Above Seat)	0.2	≤ 9
Side Door (Below Seat)	0.2	≤ 12
Roof	0.1	≤ 4
Windshield	0.0	≤ 3
Side Window	Intact	No shattering resulting from contact with structural member of test article
Dash	0.9	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=0.0 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 for the analysis. MASH Section 5.3 states that if the 50-ms average longitudinal or lateral acceleration data exceeds 2 g's, the Flail-Space Model should be used, and the calculation of OIV and ORA values needs to begin with contact with the geometric feature. In other words, t=0 sec would correspond to 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 with vehicle contact with the safety feature.

During test No. H42S-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 showed maximum longitudinal and lateral 50-ms average accelerations of 0.66 g's and 0.86 g's, respectively. These values did not exceed the MASH recommended 2-g limit, thus 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 7. 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 7. Table 8 shows the OIV and ORA values if t=0 sec occurs at the curb impact. The recorded data from the accelerometers and the rate transducers is shown graphically in Appendix D.

Table 7. OIV, ORA, THIV, PHD, and ASI Values for Barrier, Test No. H42S-1

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1	SLICE-2 (primary)	
OIV ft/s	Longitudinal	-18.84	-19.10	±40
	Lateral	22.77	23.77	±40
ORA g's	Longitudinal	-4.72	-4.96	±20.49
	Lateral	10.0	9.06	±20.49
Maximum Angular Displacement deg.	Roll	-19.1	-15.5	±75
	Pitch	-4.1	-5.7	±75
	Yaw	34.6	33.9	not required
THIV – ft/s		30.2	31.0	not required
PHD – g's		10.4	9.40	not required
ASI		1.47	1.54	not required

Table 8. OIV and ORA Values if t=0 sec occurred at Curb Impact, Test No. H42S-1

Evaluation Criteria		Transducer	
		SLICE-1	SLICE-2 (primary)
OIV ft/s	Longitudinal	-19.08	-19.27
	Lateral	22.77	23.74
ORA g's	Longitudinal	-4.72	-4.96
	Lateral	10.03	9.06

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 59. The maximum perpendicular (i.e., lateral) load imparted to the barrier was 72.0 kips, as determined by the SLICE-2 (primary) unit.

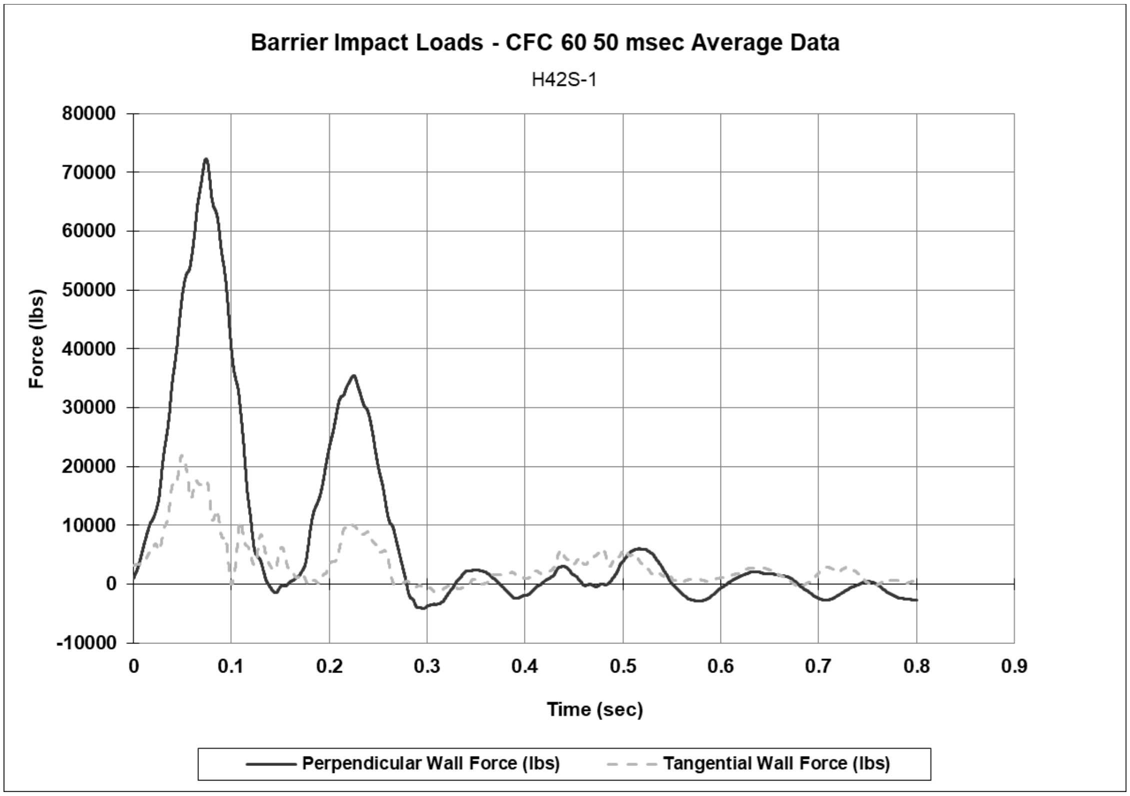
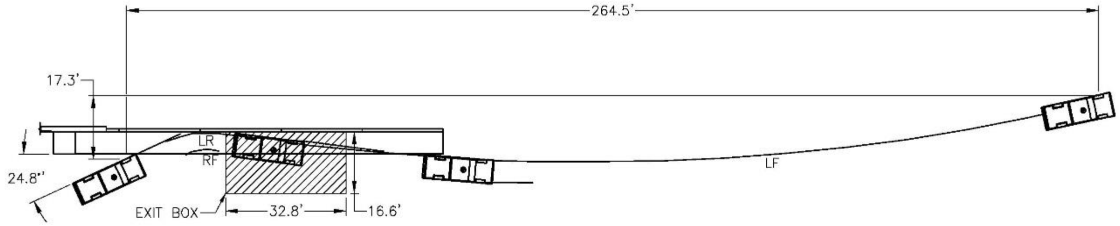


Figure 59. Perpendicular and Tangential Forces Imparted to the Barrier System (SLICE-2), Test No. H42S-1

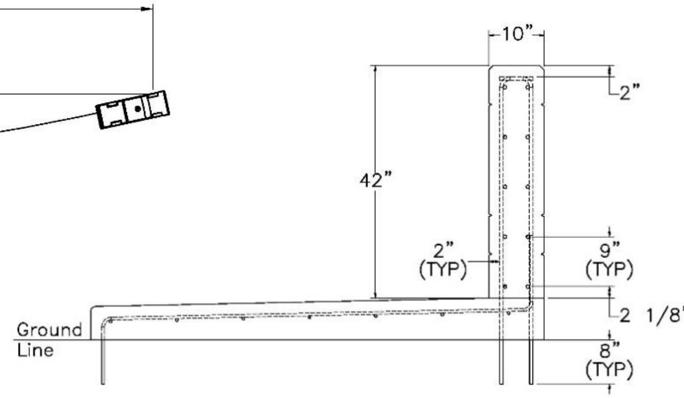
5.7 Discussion

The analysis of the test results for test no. H42S-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 60. 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 windshield experienced several cracks but did not pose a threat to the occupant. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix D, were deemed acceptable because they did not adversely influence occupant risk nor cause a rollover. After impact, the vehicle exited the barrier at an angle of 3.4 degrees, and its trajectory did not violate the bounds of the exit box. Therefore, test no. H42S-1 was determined to be acceptable according to the MASH 2016 safety performance criteria for test designation no. 3-11.

-0.146 sec | 0.000 sec | 0.154 sec | 0.254 sec | 0.404 sec



- Test Agency .... MwRSF
- Test Number.. H42S-1
- Date.. 08/25/2021
- MASH 2016 Test Designation No.. 3-11
- Test Article......... HDOT 42-in. Tall, Aesthetic Concrete Bridge Rail with 6-ft. Sidewalk
- Total Length .... 88 ft
- Key Component – 22-ft Concrete Parapet
  - Length .... 22 ft
  - Width.. 42 in.
  - Depth.. 10 in.
- Key Component – 6-ft Wide Sidewalk
  - Length .... 88 ft
  - Width.. 6 ft
  - Depth.. 6 in.
- Vehicle Make /Model.. 2015 Dodge RAM 1500
  - Curb.. 4,949 lb
  - Test Inertial.. 5,019 lb (MASH 2016 Limit 5,000 ± 110 lb)
  - Gross Static.. 5,175 lb
- Impact Conditions – Sidewalk
  - Speed.. 62.9 mph (MASH 2016 Limit 62 ± 2.5 mph)
  - Angle.. 24.8 deg. (MASH 2016 Limit 25 ± 1.5 degrees)
- Impact Conditions – Barrier
  - Speed.. 61.8 mph
  - Angle.. 24.4 degrees
  - Impact Location.. 54.2 in. upstream from expansion joint no. 1
- Impact Severity – Sidewalk.. 116.8 kip-ft > 106 kip-ft MASH 2016 limit
- Impact Severity – Barrier .... 109.4 kip-ft
- Exit Conditions
  - Speed.. 50.2 mph
  - Angle .... 3.4 degrees
- Exit Box Criterion.. Pass
- Vehicle Stability.. Satisfactory
- Vehicle Stopping Distance .... 264.5 ft downstream
  17.3 ft laterally behind



- Vehicle Damage.. Moderate
  - VDS [15] 11-LFQ-4
  - CDC [16].. 01LFEW3
  - Maximum Interior Deformation .... 4 in. at Wheel Well & Toe Pan
    ≤ 9 in. MASH limit
- Test Article Damage .... Minimal
- Maximum Test Article Deflections
  - Permanent Set.. 1.3 in.
  - Dynamic.. 1.3 in.
  - Working Width (without Sidewalk) .... 11.3 in.
  - Working Width (with Sidewalk) .... 83.3 in.
- Transducer Data

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1	SLICE-2 (primary)	
OIV ft/s	Longitudinal	-18.84	-19.10	±40
	Lateral	22.77	23.77	±40
ORA g's	Longitudinal	-4.72	-4.96	±20.49
	Lateral	10.0	9.06	±20.49
Maximum Angular Displacement degrees	Roll	-19.1	-15.5	±75
	Pitch	-4.1	-5.7	±75
	Yaw	34.6	33.9	not required
THIV – ft/s		30.2	31.0	not required
PHD – g's		10.4	9.40	not required
ASI		1.47	1.54	not required

Figure 60. Summary of Test Results and Sequential Photographs, Test No. H42S-1

6 FULL-SCALE CRASH TEST NO. H42S-2

6.1 Weather Conditions

Test no. H42S-2 was conducted on September 2, 2021, at approximately 1:30 p.m. The weather conditions as reported by the National Oceanic and Atmospheric Administration (station 14939/LNK) are shown in Table 9.

Table 9. Weather Conditions, Test No. H42S-2

Temperature	74°F
Humidity	82%
Wind Speed	7 mph
Wind Direction	160° from True North
Sky Conditions	Overcast
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.21 in.
Previous 7-Day Precipitation	2.21 in.

6.2 Test Description

Initial vehicle impact was to occur $43^3/_{16}$ in. upstream from expansion joint no. 2, as shown in Figure 61, which was selected using Table 2.7 of MASH 2016. The sidewalk impact location was determined based on the targeted impact point and the vehicle's anticipated trajectory. The 2,426-lb small car impacted the sidewalk at a speed of 62.2 mph and at an angle of 24.8 degrees and impacted the barrier at a speed of 60.6 mph and an angle of 23.5 degrees. The actual point of impact was 3.9 in. downstream from the targeted impact location. After brakes were applied and a secondary impact occurred with temporary concrete barriers shielding other areas of the test site, the vehicle came to rest 235 ft downstream from the impact point and 1.5 ft laterally in front of the traffic side of the barrier. Impact severity is an additional limiting condition required in MASH 2016. The measured impact severity with the sidewalk for test no. H42S-2 was 54.8 kip-ft, which was greater than the 51.0 kip-ft limit as defined in MASH 2016 for test designation no. 3-10.

A detailed description of the sequential impact events is contained in Table 10. Sequential photographs are shown in Figures 62 and 63. Documentary photographs of the crash test are shown in Figure 64. The vehicle trajectory and final position are shown in Figure 65.

Figure 61. Impact Location, Test No. H42S-2

Table 10. Sequential Description of Impact Events, Test No. H42S-2

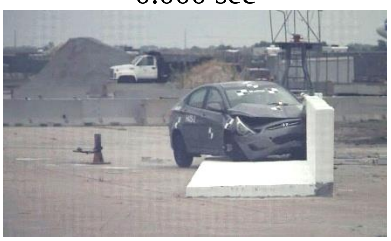
Time (sec)	Event
-0.150	Vehicle’s left-front tire contacted front edge of sidewalk at a speed of 62.2 mph and deflated.
-0.056	Vehicle’s left-rear tire contacted sidewalk and deflated.
-0.042	Vehicle’s left-rear tire became airborne.
-0.034	Vehicle’s front-right tire contacted sidewalk and deflected.
0.000	Vehicle’s front bumper contacted barrier no. 2 3.8 in. upstream from expansion joint no. 2 and deformed.
0.012	Vehicle’s left headlight and left fender contacted barrier no. 2 and deformed.
0.020	Vehicle rolled toward system. Top of left-front door deformed. Vehicle’s left headlight shattered, and hood contacted barrier no. 2 and deformed.
0.034	Vehicle’s right headlight disengaged, left mirror contacted barrier no. 2 and deformed. Vehicle yawed away from system.
0.044	Vehicle’s left mirror detached.
0.052	Vehicle’s front bumper partially detached, left-front door contacted barrier no. 2 and deformed, and right-rear tire became airborne.
0.060	Vehicle’s windshield cracked.
0.070	Surrogate occupant’s head contacted left-front window.
0.114	Vehicle’s left-rear door contacted barrier nos. 2 and 3 and deformed.
0.140	Vehicle produced significant debris from left headlight, left mirror, and left fender.
0.174	Vehicle’s right-front tire became airborne. Vehicle’s quarter panel and left taillight contacted barrier no. 2 and deformed.
0.192	Vehicle’s left taillight shattered.
0.374	Vehicle rolled away from system. Vehicle was parallel to system at a speed of 44.7 mph.
0.458	Vehicle’s right-front tire contacted ground.
0.580	Vehicle exited system at a speed of 43.9 mph and at angle of 4.2 degrees.
0.668	Vehicle rolled toward system.
0.680	Vehicle’s left-front tire became airborne and right-rear tire contacted ground.
0.736	Vehicle’s left-front tire contacted ground.
0.794	Vehicle stopped any roll and vehicle’s front pitched down.
0.806	Vehicle’s left-rear tire became airborne.
1.112	Vehicle’s left-rear tire contacted ground.
4.892	Vehicle came to rest 235 ft downstream from impact.

-0.152 sec

-0.152 sec

0.000 sec

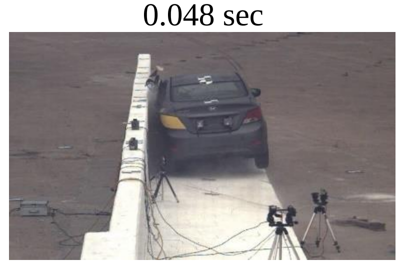
0.000 sec



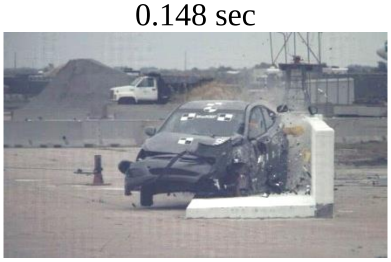
0.048 sec

0.048 sec

0.148 sec



0.148 sec



0.248 sec

0.248 sec

0.848 sec

0.848 sec

Figure 62. Sequential Photographs, Test No. H42S-2

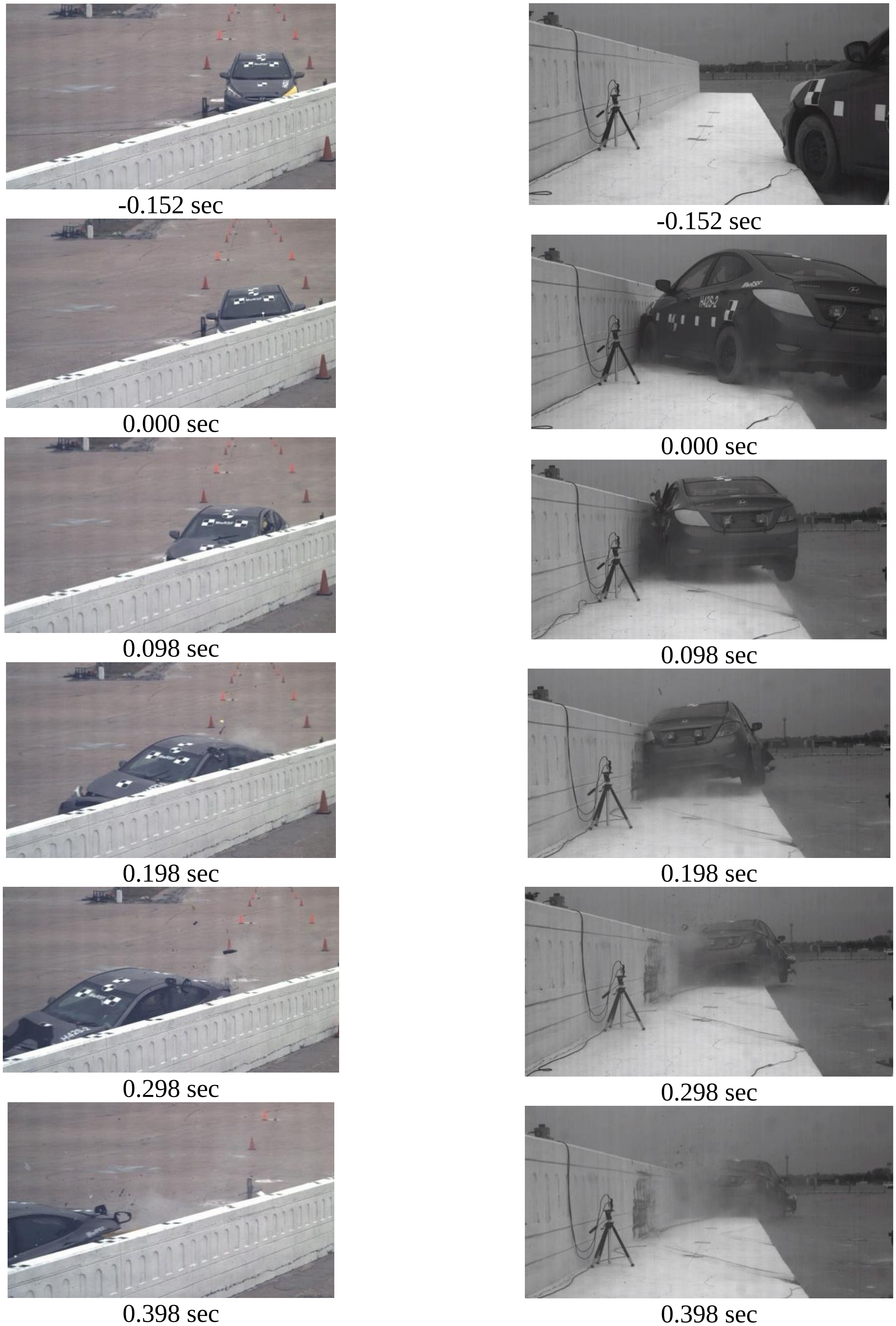


Figure 63. Sequential Photographs, Test No. H42S-2

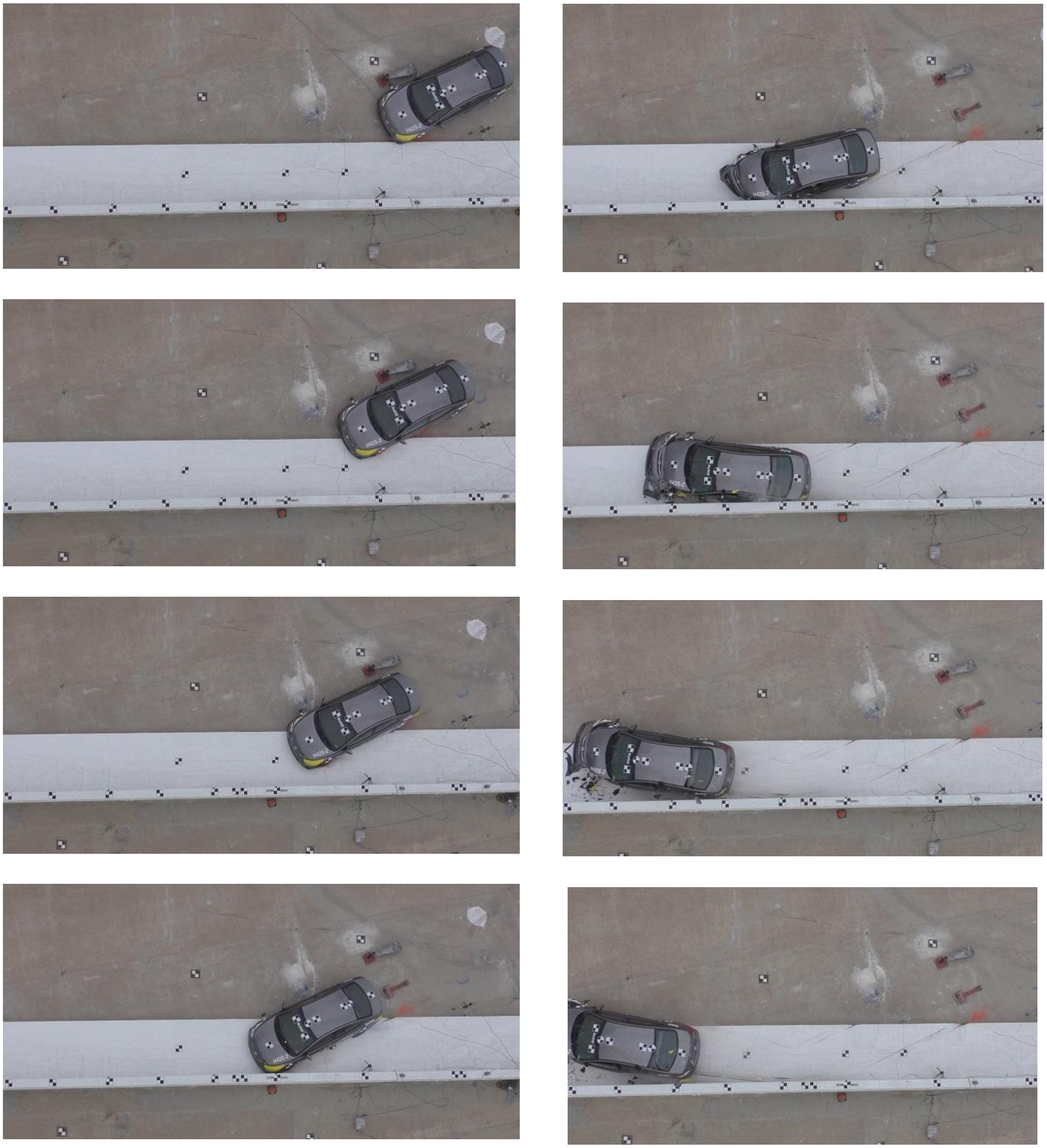


Figure 64. Documentary Photographs, Test No. H42S-2

Figure 65. Vehicle Final Position and Trajectory Marks, Test No. H42S-2

6.3 Barrier Damage

Damage to the barrier was minimal, as shown in Figures 66 through 72. Barrier damage consisted of contact marks on the front of the concrete segments and concrete gouging. Note that some cracking visible in the system photographs was documented beforehand and did not occur as a result due to the test no. H42S-2 impact. The length of vehicle contact along the barrier was approximately 10 ft – 5 in., which spanned from 4 ft – 2 in. upstream from expansion joint no. 2 to 6 ft – 2½ in. downstream from expansion joint no. 2.

Contact marks were visible on the front face of the barrier. A 125-in. long by 39¼ -in. tall contact mark began 50½ in. upstream from the impact point at the mid-height of the barrier. The barrier sustained minor gouging, beginning 5 in. downstream from the impact point and extending to the downstream edge of recess panel no. 9. Gouging was sustained from the lowest horizontal recess to 27¾ in. above the surface of the sidewalk. Majority of gouging occurred along the edges of the aesthetic recess panels, with the most significant gouging occurring on the downstream edges of the four panels upstream from the expansion joint, as shown in Figures 69 and 70. Minor gouging was also sustained on the upstream and downstream edges of the four panels upstream from the expansion joint and the four panels downstream from the expansion joint. Panel gouging is detailed in Figures 69 and 70 and summarized in Table 11. In addition to recess panel gouging, minor gouging from vehicle wheel contact occurred along the lower half of the downstream face of the expansion joint, as shown in Figure 71. The expansion joint sustained minimal gouging at the edges, as shown in Figure 72.

Table 11. Gouging Damage to Aesthetic Recesses, Test No. H42S-2

Recess No.	Relative to Expansion Joint	Length in.	Height in.	Recess Edge
2	Upstream	5	25¾	Downstream
3	Upstream	11¼	20	Downstream
4	Upstream	12¼	23¾	Upstream
		12¼	18	Downstream
5	Upstream	6½	23½	Upstream
		7½	22	Downstream
6	Downstream	9	22½	Upstream
		11	18	Downstream
7	Downstream	8½	18	Downstream
8	Downstream	2	22	Upstream
		7¼	18	Downstream
9	Downstream	2	23½	Upstream
		6¾	18	Downstream

Figure 66. System Damage, Test No. H42S-2

Figure 67. System Damage, Sidewalk, Test No. H42S-2

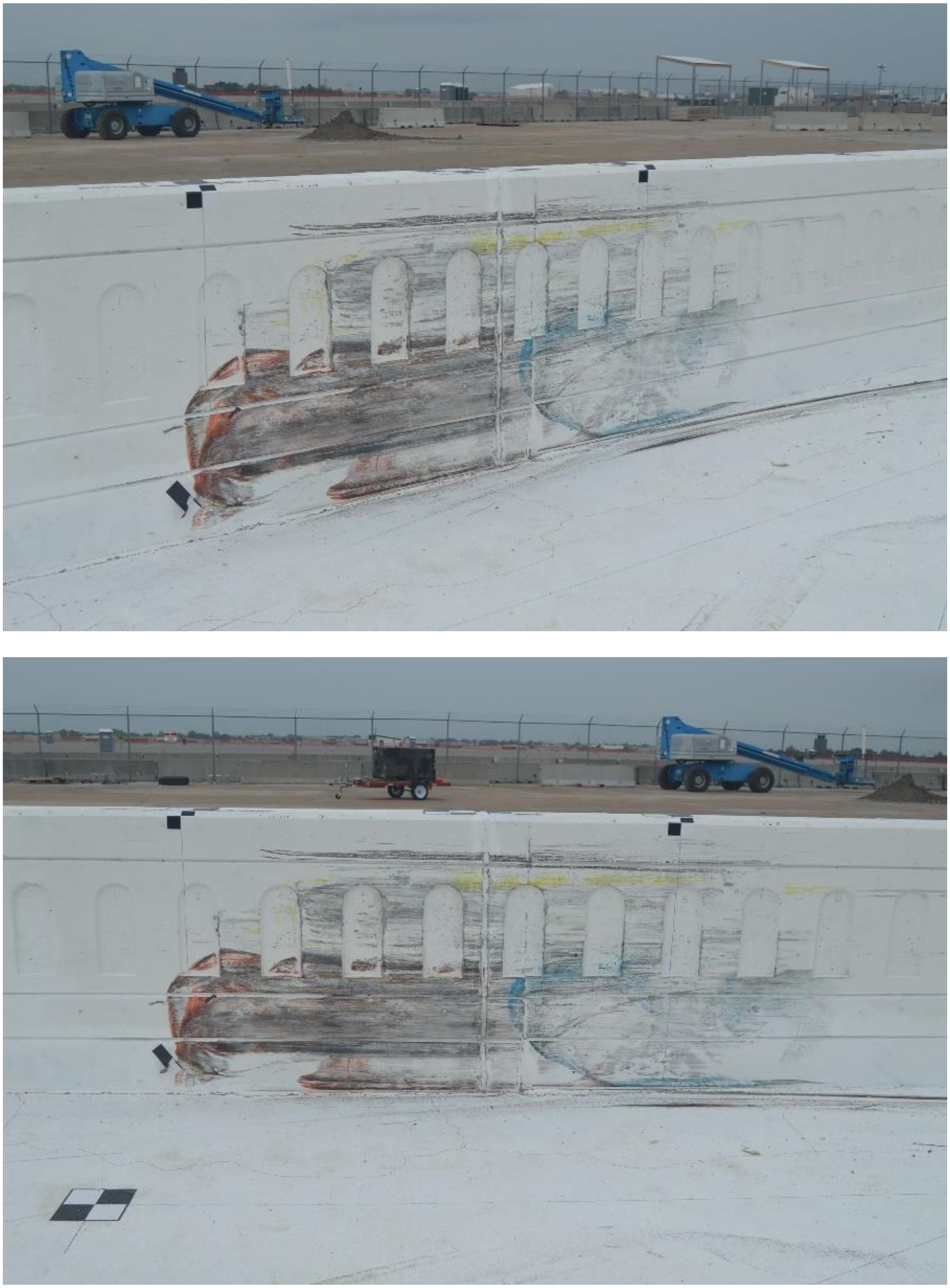


Figure 68. System Damage, Test No. H42S-2

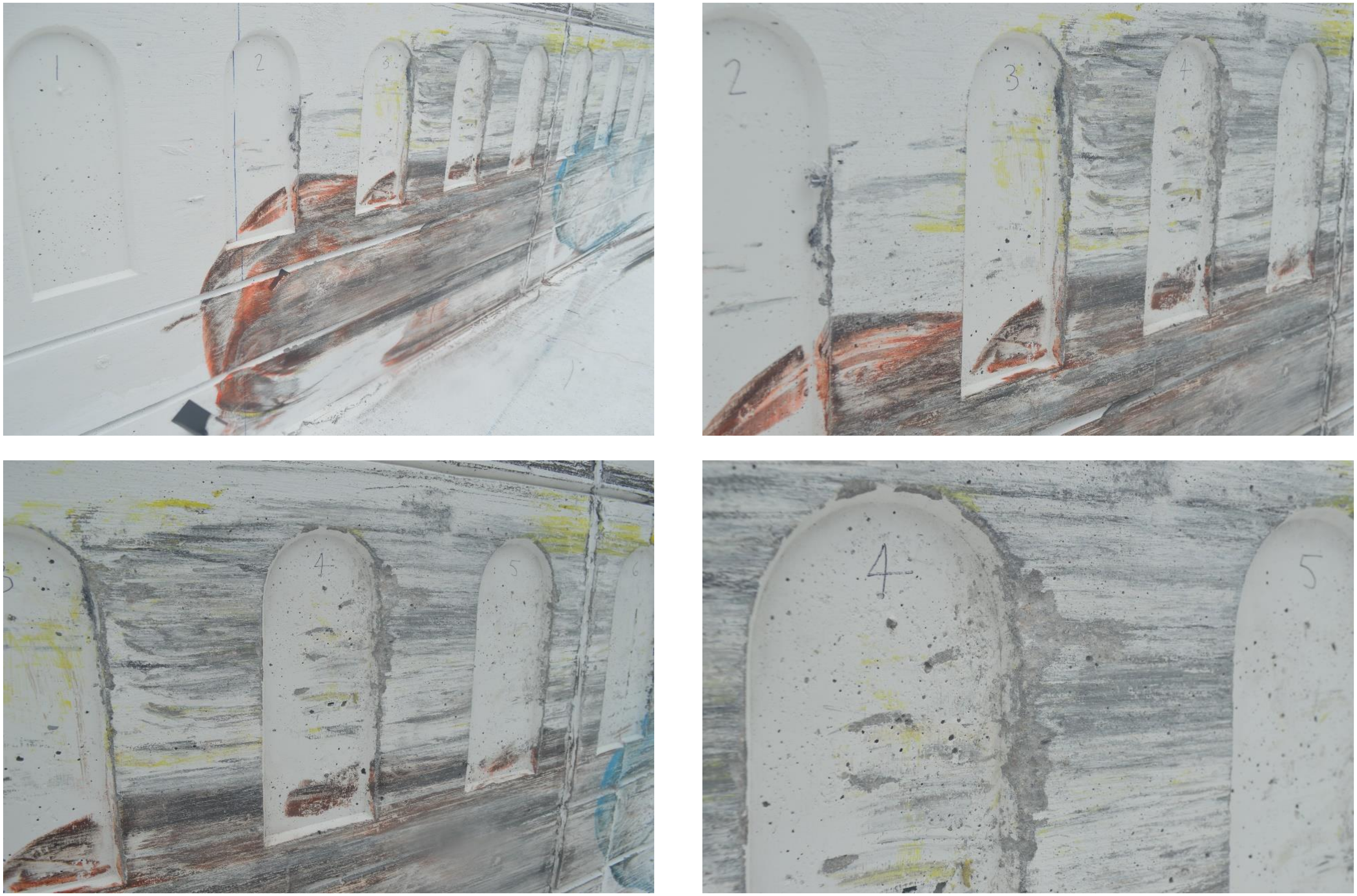
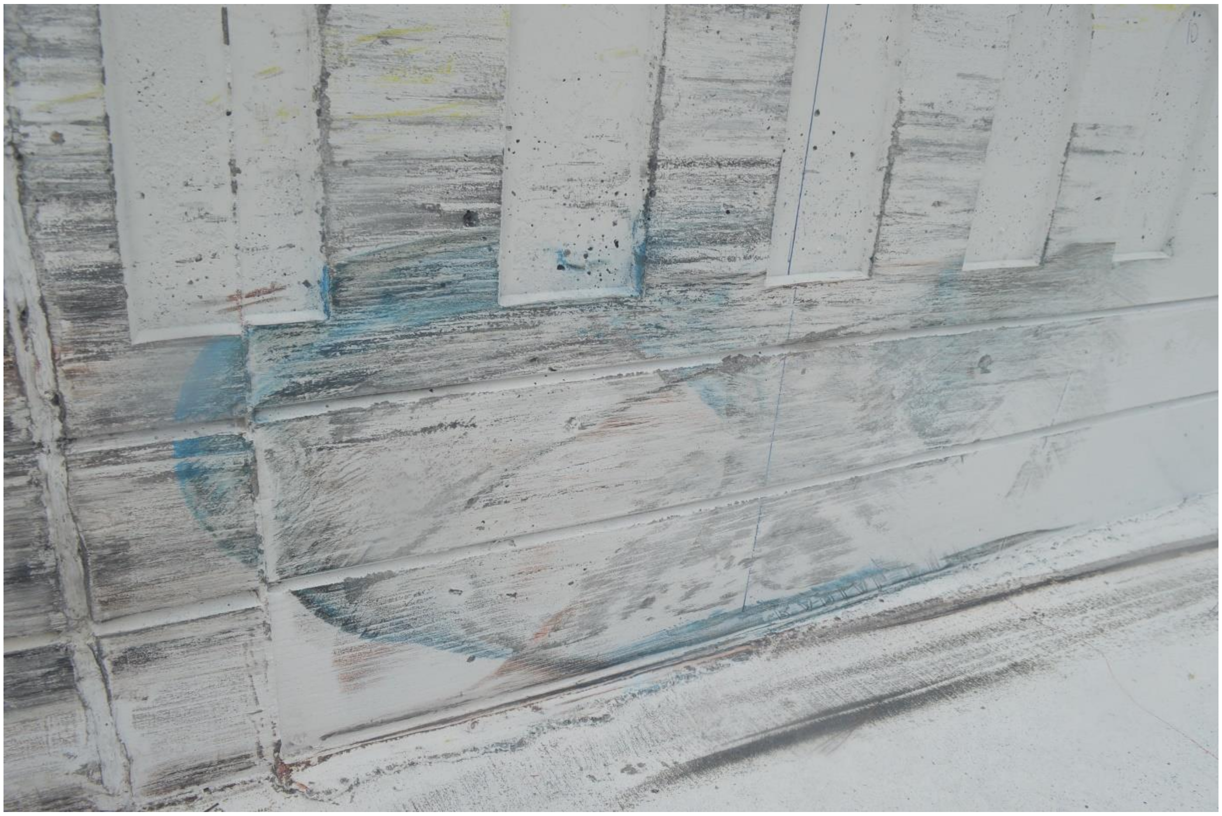


Figure 69. System Damage, Test No. H42S-2

Figure 70. System Damage, Test No. H42S-2



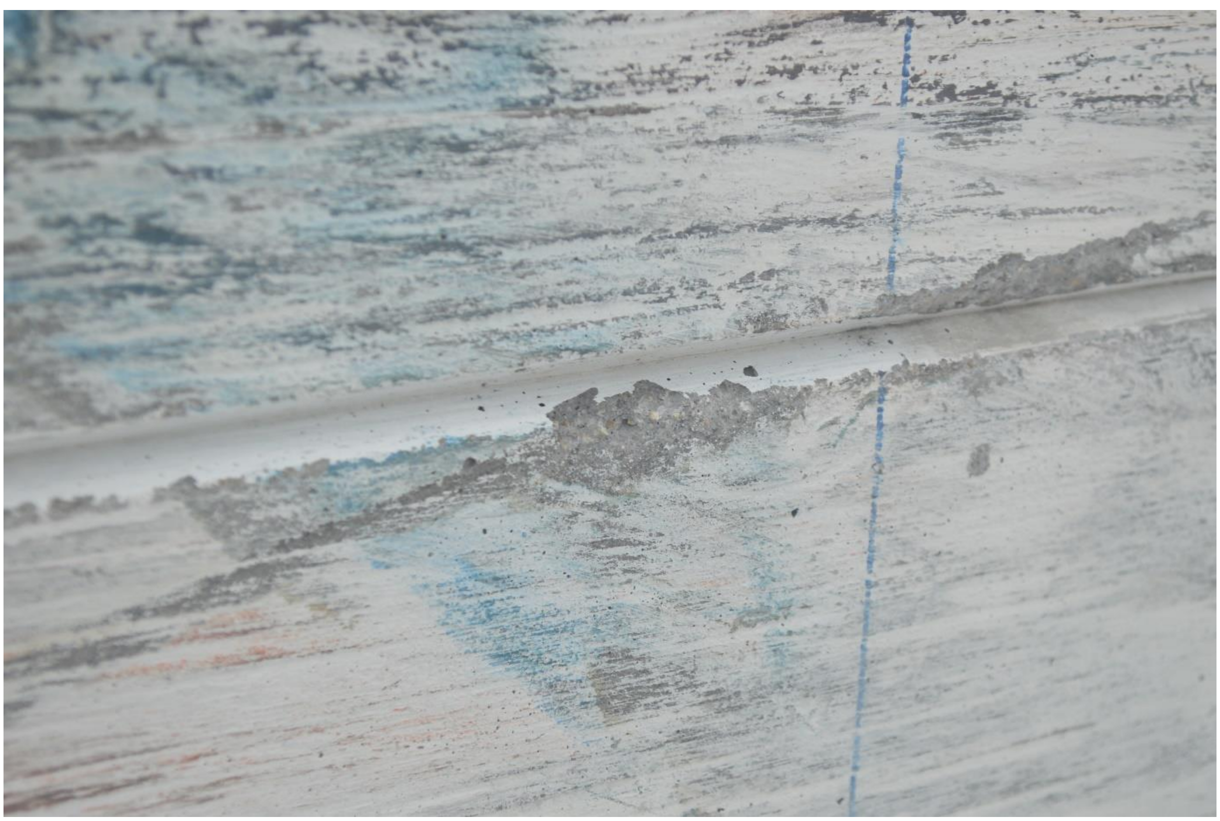


Figure 71. System Damage due to Wheel Contact, Test No. H42S-2

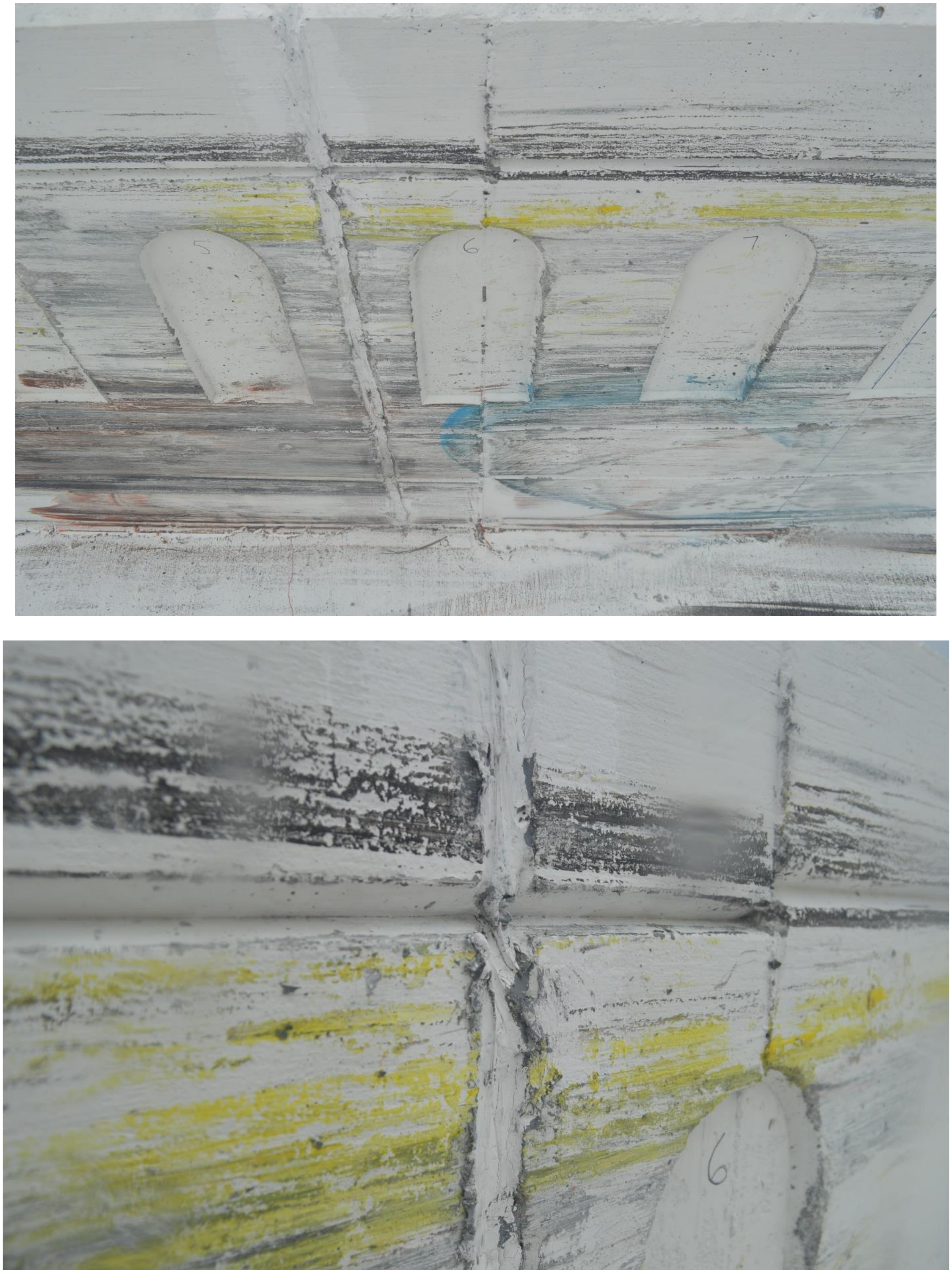


Figure 72. System Damage at Expansion Joint No. 2, Test No. H42S-2

The maximum lateral permanent set of the barrier system, including barrier and deck panel shift, was 1.0 in. at the target at impact, as measured in the field. The maximum lateral dynamic barrier deflection, including tipping of the barrier along the top surface, was 1.0 in. at the target between impact and the centerline target, as determined from high-speed digital video analysis. The working width of the system was found to be 11.0 in. as measured from the front face of the barrier and 83.0 in. as 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 73.

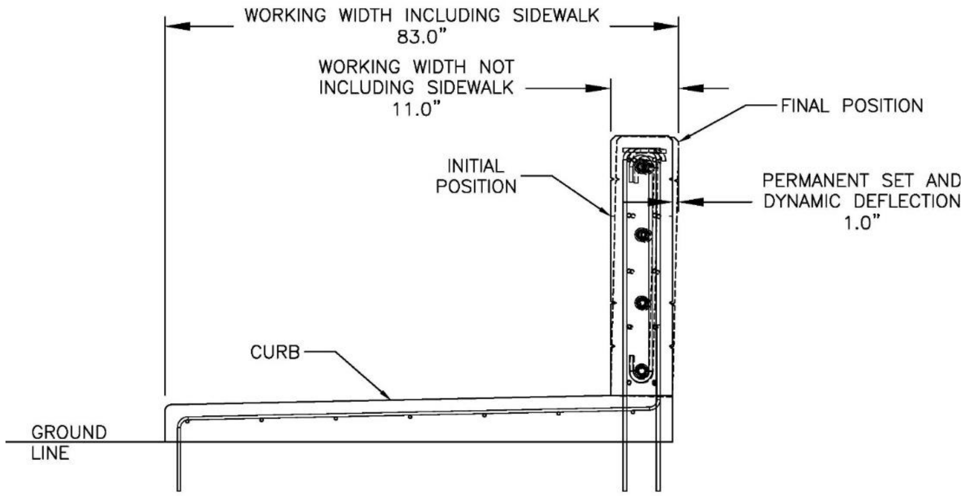


Figure 73. Permanent Set, Dynamic Deflection, and Working Width, Test No. H42S-2

6.4 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 74 through 77. Most 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 and the left-front fender were crushed inward, and the bumper was bent across its entire width. The left-front tire was partially disengaged from the steel rim, and the left-front steel rim was deformed. The front headlights were disengaged from the vehicle. The hood was crushed inward on its left edge and partially disengaged across the length of the front bumper. The left-front door was crushed in the front region, causing the door to partially open. The front and back corners of the vehicle were scraped. The left-rear bumper was crushed inward and partially disengaged from the vehicle. The windshield had severe cracking across its entire length. The vehicle sustained mild damage due to a second impact with the temporary concrete barriers shielding other areas of the test site, when coming to rest outside of the system.

The maximum occupant compartment intrusions are listed in Table 12, 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.

Figure 74. Vehicle Damage, Test No. H42S-2

Figure 75. Vehicle Damage, Test No. H42S-2

Figure 76. Vehicle Interior Damage, Test No. H42S-2

Figure 77. Vehicle Undercarriage Damage, Test No. H42S-2

Table 12. Maximum Occupant Compartment Intrusion by Location, Test No. H42S-2

Location	Maximum Intrusion in.	MASH 2016 Allowable Intrusion in.
Wheel Well & Toe Pan	1.0	≤ 9
Floor Pan & Transmission Tunnel	0.6	≤ 12
A-Pillar	0.4	≤ 5
A-Pillar (Lateral)	0.4	≤ 3
B-Pillar	0.3	≤ 5
B-Pillar (Lateral)	0.4	≤ 3
Side Front Panel (in Front of A-Pillar)	1.3	≤ 12
Side Door (Above Seat)	0.0*	≤ 9
Side Door (Below Seat)	0.1	≤ 12
Roof	0.0*	≤ 4
Windshield	1.1	≤ 3
Side Window	Intact	No shattering resulting from contact with structural member of test article
Dash	0.8	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 exceeds 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 to 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 with vehicle contact with the safety feature.

During Test No. H42S-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 -0.15 g's and 1.7 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 7. 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 13. Table 14 shows the OIV and ORA values if t=0 sec occurs at the curb impact. The recorded data from the accelerometers and the rate transducers is shown graphically in Appendix D.

Table 13. Summary of OIV, ORA, THIV, PHD, and ASI Values for Barrier, Test No. H42S-2

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1 (primary)	SLICE-2	
OIV ft/s	Longitudinal	-20.38	-20.49	±40
	Lateral	29.80	28.15	±40
ORA g's	Longitudinal	-3.79	-4.02	±20.49
	Lateral	14.75	-20.0	±20.49
Maximum Angular Displacement degrees	Roll	-11.7	9.5	±75
	Pitch	4.7	-4.6	±75
	Yaw	41.1	40.6	not required
THIV – ft/s		31.09	27.67	not required
PHD – g's		14.83	20.27	not required
ASI		2.27	2.16	not required

Table 14. OIV and ORA Values if t=0 sec Occurred at Curb Impact, Test No. H42S-2

Evaluation Criteria		Transducer	
		SLICE-1 (primary)	SLICE-2
OIV ft/s	Longitudinal	-21.73	-21.50
	Lateral	28.87	24.82
ORA g's	Longitudinal	-4.49	-6.41
	Lateral	14.75	-14.34

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 78. The maximum perpendicular (i.e., lateral) load imparted to the barrier was 50.8 kips, as determined by the SLICE-1 (primary) unit.

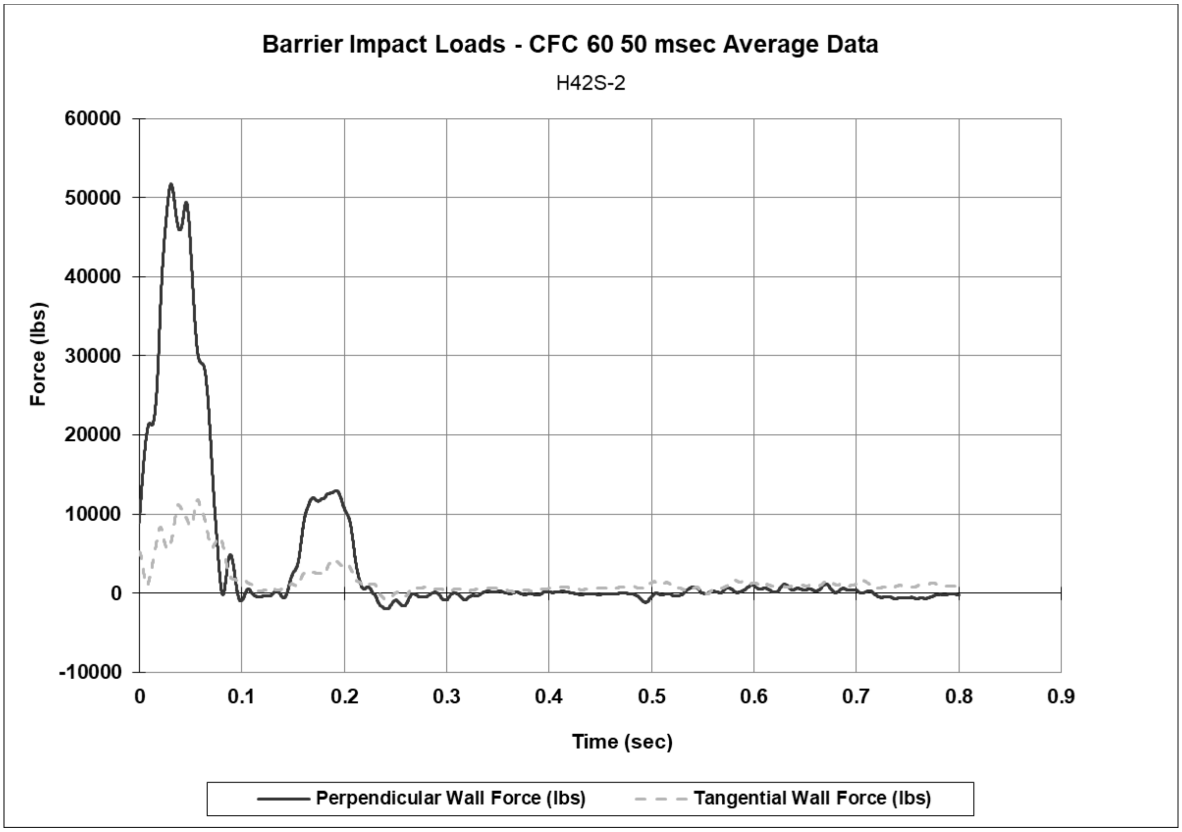
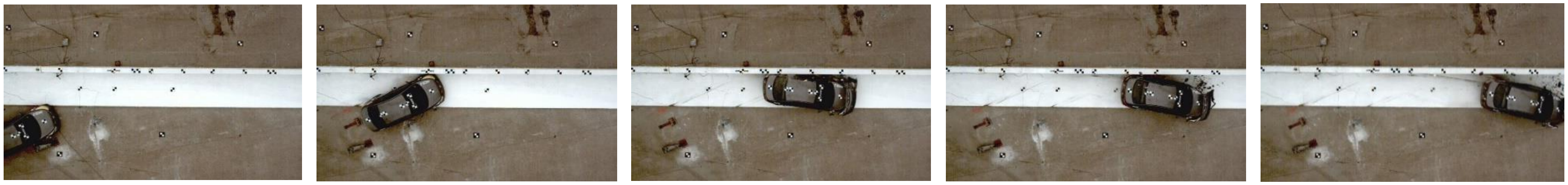
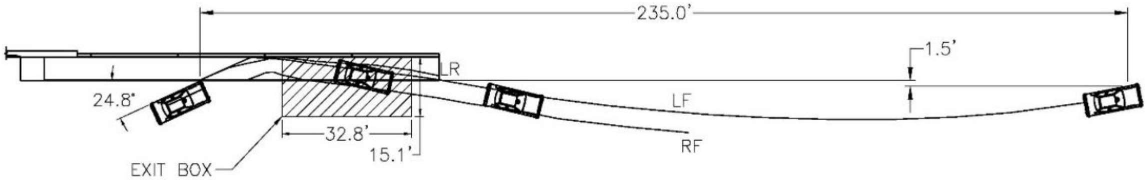


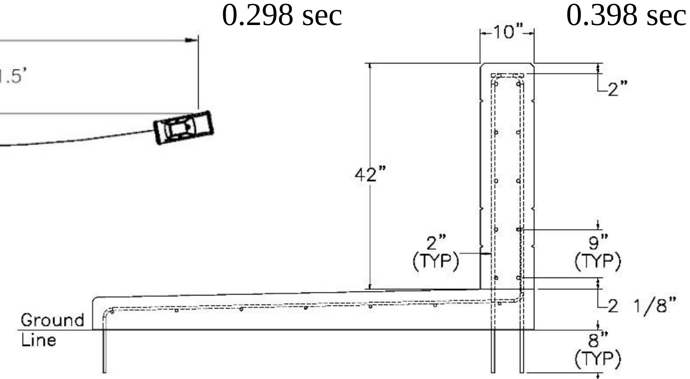
Figure 78. Perpendicular and Tangential Forces Imparted to the Barrier System (SLICE-1), Test No. H42S-2

6.7 Discussion

The analysis of the test results for test no. H42S-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 79. 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 4.2 degrees, and its trajectory did not violate the bounds of the exit box. Therefore, test no. H42S-2 was determined to be acceptable according to the MASH 2016 safety performance criteria for test designation no. 3-10.







- Test Agency .... MwRSF
- Test Number H42S-2
- Date 09/02/2021
- MASH 2016 Test Designation No. 3-10
- Test Article......... HDOT 42-in. Tall, Aesthetic Concrete Bridge Rail with 6-ft. Sidewalk
- Total Length .... 82 ft
- Key Component - 22-ft Concrete Parapet
  - Length .... 22 ft
  - Width .... 12 in.
  - Depth .... 10 in.
- Key Component – 6-ft Wide Sidewalk
  - Length .... 82 ft
  - Width .... 6 ft
  - Depth .... 6 in.
- Vehicle Make /Model .... 2015 Hyundai Accent
  - Curb .... 2,493 lb
  - Test Inertial .... 2,426 lb (MASH 2016 Limit 2,420 ± 55 lb)
  - Gross Static .... 2,590 lb
- Impact Conditions – Sidewalk
  - Speed .... 62.2 mph (MASH 2016 Limit 62 ± 2.5 mph)
  - Angle .... 24.8 degrees (MASH 2016 Limit 25 ± 1.5 degrees)
- Impact Conditions – Barrier
  - Speed .... 60.6 mph
  - Angle .... 23.5 degrees
  - Impact Location .... 39.4 in. upstream from expansion joint no. 2
- Impact Severity – Sidewalk .... 54.8 kip-ft > 51 kip-ft MASH 2016 limit
- Impact Severity – Barrier .... 47.4 kip-ft
- Exit Conditions
  - Speed .... 43.9 mph
  - Angle .... 4.2 degrees
- Exit Box Criterion .... Pass
- Vehicle Stability .... Satisfactory
- Vehicle Stopping Distance .... 235 ft downstream
  1.5 ft laterally in front
- Vehicle Damage .... Moderate
  - VDS [15] 11-LFQ-4
  - CDC [16] 01LFEW3
  - Maximum Interior Deformation .... 1.3 in. at Side Front Panel in front of A-Pillar
    ≤ 12 in. MASH limit
- Test Article Damage .... Minimal
- Maximum Test Article Deflections
  - Permanent Set .... 1.0 in.
  - Dynamic Deflection .... 1.0 in.
  - Working Width (without Sidewalk) .... 11.0 in.
  - Working Width (with Sidewalk) .... 83.0 in.
- Transducer Data

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1 (primary)	SLICE-2	
OIV ft/s	Longitudinal	-20.38	-20.49	±40
	Lateral	29.80	28.15	±40
ORA g's	Longitudinal	-3.79	-4.02	±20.49
	Lateral	14.75	-20.0	±20.49
Maximum Angular Displacement degrees	Roll	-11.7	9.5	±75
	Pitch	4.7	-4.6	±75
	Yaw	41.1	40.6	not required
THIV – ft/s		31.09	27.67	not required
PHD – g's		14.83	20.27	not required
ASI		2.27	2.16	not required

Figure 79. Summary of Test Results and Sequential Photographs, Test No. H42S-2

7 SUMMARY AND CONCLUSIONS

The objective of this project was to evaluate the HDOT 42-in. Tall, Aesthetic Concrete Bridge Rail with recessed rounded panels and a 6-in. tall by 6-ft wide sidewalk. Test nos. H42S-1 and H42S-2 were conducted on a barrier system that was 88 ft long and consisted of four 22-ft long concrete parapets anchored to the concrete tarmac. Expansion joints between each segment consisted of 24½-in. long No. 8 ASTM A615 Grade 60 steel bars cast into the concrete and inserted into a PVC pipe on the upstream side of the expansion joint. Test nos. H42S-1 and H42S-2 were conducted according to MASH 2016 criteria using TL-3 test designation nos. 3-11 and 3-10, respectively. A summary of the test evaluations is shown in Table 15.

In test no. H42S-1, the 5,019-lb pickup truck impacted the system, impacting the sidewalk at a speed of 62.9 mph and an angle of 24.8 degrees, resulting in an impact severity of 116.8 kip-ft, and impacting the barrier at a speed of 61.8 mph and an angle of 24.4 degrees at a location 2.6 in. upstream from the target impact point. After impacting the barrier system, the vehicle exited the system at a speed of 50.2 mph and an angle of 3.4 degrees. The vehicle was successfully contained and smoothly redirected with moderate damage to the barrier system and the vehicle. All vehicle decelerations, ORAs, and OIVs fell within the recommended safety limits established in MASH 2016. Therefore, test no. H42S-1 was successful according to the safety criteria of MASH 2016 test designation no. 3-11.

In test no. H42S-2 the 2,426-lb small car impacted the system, impacting the sidewalk at a speed of 62.2 mph and at an angle of 24.8 degrees thus resulting in an impact severity of 54.8 kip-ft, and impacting the barrier at a speed of 60.6 mph and an angle of 23.5 degrees at a location 39.4 in. upstream from expansion joint no. 2. After impacting the barrier system, the vehicle exited the system at a speed of 43.9 mph and an angle of 4.2 degrees. The vehicle was successfully contained and smoothly redirected with moderate damage to the barrier system and the vehicle. All vehicle decelerations, ORAs, and OIVs fell within the recommended safety limits established in MASH 2016. Therefore, test no. H42S-2 was successful according to the safety criteria of MASH 2016 test designation no. 3-10.

Table 15. Summary of Safety Performance Evaluation, Test Nos. H42S-1 and H42S-2

<table>
<tr><th>Evaluation Factors</th><th colspan="4">Evaluation Criteria</th><th>Test No. H42S-1</th><th>Test No. H42S-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="10">Occupant Risk</td><td>D.</td><td colspan="3">1. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.
2. Deformations of or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH 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>S</td><td>S</td></tr>
<tr><td colspan="3">Occupant Impact Velocity Limits</td><td rowspan="3">S</td><td rowspan="3">S</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>S</td><td>S</td></tr>
<tr><td colspan="3">Occupant Ridedown Acceleration Limits</td><td rowspan="3">S</td><td rowspan="3">S</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

8 MASH EVALUATION

The objective of this research was to evaluate the safety performance of the HDOT 42-in. Tall, Aesthetic Concrete Bridge Rail with recessed rounded panels and a 6-in. tall by 6-ft wide sidewalk. The HDOT system consisted of a reinforced concrete bridge rail and sidewalk anchored to the concrete tarmac. The barrier had a total length of 88 ft and measured 42-in. tall and 10-in. wide. According to TL-3 evaluation criteria in MASH 2016, two tests are required for evaluation of longitudinal barrier systems: (1) test designation no. 3-11 with a 2270P pickup truck and (2) test designation no. 3-10 with an 1100C small car.

During test no. H42S-1, a 5,000-lb pickup truck with a simulated occupant seated in the left-front passenger seat impacted the HDOT concrete barrier system's sidewalk at a speed of 62.9 mph and at an angle of 24.8 degrees, resulting in an impact severity of 116.8 kip-ft. The vehicle was successfully contained and smoothly redirected. Exterior vehicle damage was moderate. Interior occupant compartment deformations were moderate with a maximum of 4 in., which did not violate the limits established in MASH 2016. Damage to the barrier was minimal, consisting of contact marks on the front and top face of the concrete barrier as well as contact marks on the sidewalk. Concrete gouging was present on the front face of the barrier. The maximum dynamic barrier deflection was 1.3 in. The working width of the system was found to be 11.3 in. measured from the front face of the barrier and 83.3 in. measured from the front face of the sidewalk, respectively. All occupant risk measures were within the recommended limits, and the occupant compartment deformations were deemed acceptable. Therefore, the HDOT 42-in. Tall, Aesthetic Concrete Bridge Rail with recessed rounded panels and a 6-in. tall by 6-ft wide sidewalk successfully met all the safety performance criteria of MASH 2016 test designation no. 3-11.

During test no. H42S-2, a 2400-lb sedan with a simulated occupant seated in the left-front passenger seat impacted the HDOT concrete barrier system's sidewalk at a speed of 62.2 mph and at an angle of 24.8 degrees, resulting in an impact severity of 54.8 kip-ft. The vehicle was successfully contained and smoothly redirected. Exterior vehicle damage was moderate. Interior occupant compartment deformations were moderate with a maximum of 1.3 in., which did not violate the limits established in MASH 2016. Damage to the barrier was minimal, consisting of contact marks on the front and top face of the concrete barrier as well as contact marks on the sidewalk. Concrete gouging was present on the front face of the barrier. The maximum dynamic barrier deflection was 1.0 in. The working width of the system was found to be 11.0 in. as measured from the front face of the barrier and 83.0 in. as measured from the front face of the sidewalk, respectively. All occupant risk measures were within the recommended limits, and the occupant compartment deformations were deemed acceptable. Therefore, the HDOT 42-in. Tall, Aesthetic Concrete Bridge Rail with recessed rounded panels and a 6-in. tall by 6-ft wide sidewalk successfully met all the safety performance criteria of MASH 2016 test designation no. 3-10.

The HDOT's 42-in. Tall, Aesthetic Concrete Bridge Rail with recessed rounded panels and a 6-in. tall by 6-ft wide sidewalk was crash tested and evaluated according to the MASH 2016 TL-3 criteria and successfully met all the requirements of MASH 2016 test designation no. 3-11 and test designation no. 3-10. Each crashworthy bridge rail system should be connected to crashworthy transition hardware when the bridge rail is located within the clear zone. One thrie-beam transition system has been evaluated according to MASH criteria, which could be successfully implemented with the HDOT 42-in. Tall, Aesthetic Concrete Bridge Rail with 6-ft Sidewalk [17].

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10 APPENDICES

Appendix A. Material Specifications

Table A-1. Bill of Materials, Test Nos. H42S-1 and H42S-2

Item No.	Description	Material Specification	Reference
b1	Concrete	Min. f'c = 4,000 psi NE Mix 47BD	Ticket#1268281 & 1268282
e18	#4 Rebar, 1196" Total Length	ASTM A615 Gr. 60	H#62150698
e19	#4 Rebar, 1095½" Total Length	ASTM A615 Gr. 60	H#62150698
e20	#4 Rebar, 101 9/16" Unbent Length	ASTM A615 Gr. 60	H#55064958
e21	#4 Rebar, 44 11/16" Unbent Length	ASTM A615 Gr. 60	H#55064958
e22	#4 Rebar, 58 ½" Unbent Length	ASTM A615 Gr. 60	H#55064958
e23	#5 Rebar, 340 9/16" Unbent Length	ASTM A615 Gr. 60	H#3600014140
e24	#5 Rebar, 340 9/16" Unbent Length	ASTM A615 Gr. 60	H#3600014140
e25	#5 Rebar, 260" Total Length	ASTM A615 Gr. 60	H#58042433
e26	#5 Rebar, 334" Total Length	ASTM A615 Gr. 60	H#3600014140
e27	#5 Rebar, 334 1/8" Unbent Length	ASTM A615 Gr. 60	H#3600014140
e28	#5 Rebar, 60¼" Total Unbent Length	ASTM A615 Gr. 60	H#3600014140
e29	#5 Rebar, 47 13/16" Total Unbent Length	ASTM A615 Gr. 60	H#3600014140
h1	#8 Smooth Rebar, 24½" Total Length	ASTM A615 Gr. 60	H#256801
h2	1¼" Dia. 13¾" Long PVC Pipe	Schedule80 PVC Gr. 12454	COC P#0472040
h3	1 5/8" Dia. PVC Cap	Schedule80 PVC Gr. 12454	COC P#0470592
i1	Epoxy Adhesive	Hilti HIT RE-500 V3	COC
i2	Expansion Joint Filler	AASHTO M33, M153, or M213	Tech Sheet
i3	Expansion Joint Sealant	AASHTO M173, M282, M301, ASTM D3581 ASTM D5893	Tech Sheet

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	050	050	62461		NTE	H42	8/4/21	10:47 AM	1268281

Customer	Delivery Address	Special Instructions
UNL-MIDWEST ROADSIDE SAFETY	4630 NW 36TH ST	HWY 34 WEST TO NW 31ST ST & SOUTH TO W CUMING ST & EAST / PUMP

LOAD QUANTITY	CUMULATIVE QUANTITY	ORDERED QUANTITY	PRODUCT CODE	PRODUCT DESCRIPTION	UOM	UNIT PRICE	EXTENDED PRICE
9.00	9.00	17.00	QL324504	LNK47B1PF4000HW	yd	$132.50	$1,192.50

Water Added On Job At Customer's Request:	SLUMP	Notes:		
	4.00 in		TICKET SUBTOTAL	$1,192.50
			SALES TAX	$0.00
			TICKET TOTAL	**$1,192.50**
			PREVIOUS TOTAL	
			GRAND TOTAL	**$1,192.50**

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. Concrete, Test Nos. H42S-1 and H42S-2 (Item No. b1)

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	239	6285	62461		NTE	H42	8/4/21	10:54 AM	1268282

Customer
UNL-MIDWEST ROADSIDE SAFETY

Delivery Address
4630 NW 36TH ST

Special Instructions
HWY 34 WEST TO NW 31ST ST & SOUTH TO W CUMING ST & EAST / PUMP

LOAD QUANTITY	CUMULATIVE QUANTITY	ORDERED QUANTITY	PRODUCT CODE	PRODUCT DESCRIPTION	UOM	UNIT PRICE	EXTENDED PRICE
8.00	17.00	17.00	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	$1,192.50
GRAND TOTAL	**$2,252.50**

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-2. Concrete, Test No. H42S-1 and H42S-2 (Item No. b1)

GERDAU

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

CERTIFIED MATERIAL TEST REPORT

Page 1/1

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
SIMCOTE INC 1645 RED ROCK ROAD SAINT PAUL,MN 55119-6014 USA	SIMCOTE INC 1645 RED ROCK ROAD SAINT PAUL,MN 55119-6014 USA	60 (420)	Rebar / #4 (13MM)	0000033277

LENGTH	WEIGHT	HEAT / BATCH
60'00"	36,913 LB	**62150698**/02

SALES ORDER	CUSTOMER MATERIAL N°
8050886/000010	

SPECIFICATION / DATE or REVISION
ASTM A615/A615M-16

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
MN-3726	1332-0000072465	08/08/2019

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %
0.43	1.02	0.020	0.023	0.18	0.32	0.14	0.23	0.026	0.010	0.004	0.002

MECHANICAL PROPERTIES

YS PSI	YS MPa	UTS PSI	UTS MPa	G/L Inch	G/L mm
70704	488	108274	747	8.000	203.2

MECHANICAL PROPERTIES

Elong. %	BendTest
14.40	OK

GEOMETRIC CHARACTERISTICS

%Light %	Def Hgt Inch	Def Gap Inch	DefSpace Inch
0.25	0.035	0.102	0.333

COMMENTS / NOTES

Material 100% melted and rolled in the USA. Manufacturing processes for this steel, which may include scrap melted in an electric arc furnace and hot rolling, have been performed at Gerdau St. Paul Mill, 1678 Red Rock Road, Saint Paul, Minnesota, USA. All product produced from strand cast billets. Silicon killed (deoxidized) steel. No weld repairmen performed. Steel not exposed to mercury or any liquid alloy which is liquid at ambient temperatures during processing or while in Gerdau St. Paul Mills possession. Any modification to this certification as provided by Gerdau-St. Paul Mill without the expressed written consent of Gerdau St. Paul Mill negates the validity of this test report. This report shall not be reproduced except in full, without the expressed written consent of Gerdau St. Paul Mill. Gerdau St. Paul Mill is not responsible for the inability of this material to meet specific applications.
Roll batch 62150698/02 roll date 7/26/2019

The above figures are certified chemical and physical test records as contained in the permanent records of company. We certify that these data are correct and in compliance with specified requirements. Weld repair has not been performed on this material. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

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

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

Figure A-3. #4 Rebar, Test Nos. H42S-1 and H42S-2 (Item Nos. e18 and e19)

GERDAU

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

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
SIMCOTE INC 1645 RED ROCK SAINT PAUL,MN 55119 USA	SIMCOTE INC 1645 RED ROCK ROAD SAINT PAUL,MN 55119-6014 USA	60 (420)	Rebar / #4 (13MM)	0000448538

LENGTH	WEIGHT	HEAT / BATCH
60'00"	6,012 LB	55064958/03

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
8587123/000070		ASTM A615/A615M-16

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
MN-3736	1327-0000367999	05/01/2020

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %
0.46	0.85	0.018	0.029	0.23	0.30	0.10	0.16	0.023	0.009	0.002	0.014

MECHANICAL PROPERTIES

YS PSI	YS MPa	UTS PSI	UTS MPa	G/L Inch	G/L mm
72545	500	111435	768	8.000	200.0

MECHANICAL PROPERTIES

Elong. %	BendTest
11.80	OK

COMMENTS / NOTES

The above figures are certified chemical and physical test records as contained in the permanent records of company. We certify that these data are correct and in compliance with specified requirements. Weld repair has not been performed on this material. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

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

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

Figure A-4. #4 Rebar, Test Nos. H42S-1 and H42S-2 (Item Nos. e20, e21, and e22)

NUCOR®

Mill Certification

08/26/2020

MTR#:454619-1
Lot #:360001414020
ONE NUCOR WAY
BOURBONNAIS, IL 60914 US
815 937-3131
Fax: 815 939-5599

Sold To: SIMCOTE INC
1645 RED ROCK RD
ST PAUL, MN 55119 US

Ship To: SIMCOTE INC
1645 RED ROCK RD
ST PAUL, MN 55119 US

Customer PO	MN-3748	Sales Order #	36013225 - 2.10
Product Group	Rebar	Product #	2110230
Grade	A615 Gr 60/AASHTO M31	Lot #	360001414020
Size	#5	Heat #	3600014140
BOL #	BOL-562924	Load #	454619
Description	Rebar #5/16mm A615 Gr 60/AASHTO M31 40' 0" [480"] 4001-8000 lbs	Customer Part #	
Production Date	07/17/2020	Qty Shipped LBS	45060
Product Country Of Origin	United States	Qty Shipped EA	1080
Original Item Description		Original Item Number	

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.

Melt Country of Origin : United States   Melting Date: 07/14/2020

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	V (%)	Nb (%)
0.36	0.94	0.012	0.048	0.215	0.23	0.14	0.08	0.37	0.009	0.002

Other Test Results

Yield (PSI) : 66700
Tensile (PSI) : 101600
Average Deformation Height (IN) : 0.043
Elongation in 8" (%) : 13.1
Bend Test : Pass
Weight Percent Variance (%) : -2.40

Comments:

All manufacturing processes of the steel materials in this product, including melting, have occurred within the United States. Products produced are weld free. Mercury, in any form, has not been used in the production or testing of this material.

Zachary Sprintz, Chief Metallurgist

Page 1 of 1

Figure A-5. #5 Rebar, Test Nos. H42S-1 and H42S-2 (Item Nos. e23, e24, e26 through e29)

GERDAU

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

CERTIFIED MATERIAL TEST REPORT

Page 1 / 1

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
SIMCOTE INC 1645 RED ROCK SAINT PAUL,MN 55119 USA	SIMCOTE INC 1645 RED ROCK ROAD SAINT PAUL,MN 55119-6014 USA	60 (420)	Rebar / #5 (16MM)	0000441251

LENGTH	WEIGHT	HEAT / BATCH
60'00"	6,008 LB	58042433/02

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
8587123/000060		ASTM A615/A615M-16

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
MN-3736	1327-0000365893	04/15/2020

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %	Al %
0.43	0.96	0.014	0.026	0.22	0.23	0.30	0.25	0.104	0.005	0.002	0.018	0.003

CHEMICAL COMPOSITION

CEqyA706 %
0.64

MECHANICAL PROPERTIES

YS PSI	YS MPa	UTS PSI	UTS MPa	G/L Inch	G/L mm
80598	556	115987	800	8.000	200.0

MECHANICAL PROPERTIES

Elong. %	BendTest
13.30	OK

COMMENTS / NOTES

The above figures are certified chemical and physical test records as contained in the permanent records of company. We certify that these data are correct and in compliance with specified requirements. Weld repair has not been performed on this material. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

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

Figure A-6. #5 Rebar, Test Nos. H42S-1 and H42S-2 (Item No. e25)

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

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

Daniel J. Schacht
Quality Assurance Manager

HEAT NO.: 256601 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	%	MECHANICAL	TEST I IMPERIAL	TEST I METRIC	TEST IMPERIAL	TEST METRIC	TEST IMPERIAL	TEST 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

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

State of Texas, County of Guadalupe
... subscribed before me on this day of ______, 2007

Figure A-7. #8 Smooth Rebar, Test Nos. H42S-1 and H42S-2 (Item No. h1)

FASTENAL®

Fastenal Company
P.O Box 1286
WINONA, MN 55987-1286

Packing Slip

Date	Reference No.	Page
1/19/21	NELIN389099	1

DUE DATE: 02/18/2021

Cust. No. NELIN3402
Cust. P.O. E000826391
Job No. Shawn call asap

The store serving you is
3201 N. 23rd Street STE 1

LINCOLN, NE 68521
Phone #: (402)476-7900
Fax #: 402/476-7958

Contract No:
2018.000208

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

Ship To
Picked up at Fastenal Store

This Order and Document are subject to the "Terms of Purchase" posted on www.fastenal.com.

Line No.	Quantity Ordered	Quantity Shipped	Quantity Backorder	Description	Control No.	Part No.	Price / Hundred	Amount
1	2	2	0	1 1/4 S80PVC Pipe10	hdil0616	0472040	1,861.3000	37.23 G

Received By

Comments
Contact: University of Nebraska

Tax Exemption
Government
NE

Subtotal	37.23
Shipping & Handling	0.00
State Tax	0.00
County Tax	0.00
City Tax	0.00
TOTAL USD	37.23

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. PVC Pipe, Test Nos. H42S-1 and H42S-2 (Item No. h2)

FASTENAL®

Fastenal Company
P.O Box 1286
WINONA, MN 55987-1286

Packing Slip

Date	Reference No.	Page
1/28/21	NELIN389719	1

DUE DATE: 02/27/2021

The store serving you is
3201 N. 23rd Street STE 1

LINCOLN, NE 68521
Phone #: (402)476-7900
Fax #: 402/476-7958

Cust. No. NELIN3402
Cust. P.O. E000829627
Job No. Call Shawn 402-580-8095

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

Contract No:
2018.000208

Ship To
Picked up at Fastenal Store

This Order and Document are subject to the "Terms of Purchase" posted on www.fastenal.com.

Line No.	Quantity Ordered	Quantity Shipped	Quantity Backorder	Description	Control No.	Part No.	Price / Hundred	Amount
1	11	11	0	1-1/4 SOCK CAP PVC	GFharv	0470592	483.0000	53.13 G

Received By

Comments
Contact: University of Nebraska

Tax Exemption
Government

NE

Subtotal	53.13
Shipping & Handling	0.00
State Tax	0.00
County Tax	0.00
City Tax	0.00
TOTAL USD	53.13

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-9. PVC Cap, Test Nos. H42S-1 and H42S-2 (Item No. h3)

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
Reg. No. 12455-03

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-10. Epoxy Adhesive, Test Nos. H42S-1 and H42S-2 (Item No. i1)

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-11. Expansion Joint Filler, Test Nos. H42S-1 and H42S-2 (Item No. i2)

Pecora 301 NS

Specification Data Sheet

PECORA CORPORATION®
Architectural Weatherproofing Products
U.S.A. • since 1862

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-12. Expansion Joint Sealant, Test Nos. H42S-1 and H42S-2 (Item No. i3)

Appendix B. Vehicle Center of Gravity Determination

	Test Name: H42S-1	VIN:	1C6RR6FG6FS703367
Model Year: 2015	Make: Dodge	Model:	RAM 1500 quad cab

Vehicle CG Determination

	Vehicle Equipment	Weight (lb)	Vertical CG (in.)	Vertical M (lb-in.)
+	Unballasted Truck (Curb)	4949	28.189129	139508
+	Hub	19	15	285
+	Brake activation cylinder & frame	7	28.5	199.5
+	Pneumatic tank (Nitrogen)	22	27.5	605
+	Strobe/Brake Battery	10	26	260
+	Brake Receiver/Wires	6	52.25	313.5
+	CG Plate including DAQ	30	29 7/8	896.25
-	Battery	-52	40	-2080
-	Oil	-11	17	-187
-	Interior	-93	36	-3348
-	Fuel	-172	19	-3268
-	Coolant	-13	35	-455
-	Washer fluid	-8	35.5	-284
+	Water Ballast (In Fuel Tank)	232	19	4408
+	Onboard Supplemental Battery			0
+	Steel plate ballast	135	36 1/2	4927.5
-	Spare Tire	-67	21.625	-1448.875
				140331.88

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

Estimated Total Weight (lb)	4994
Vertical CG Location (in.)	28.1001

Vehicle Dimensions for C.G. Calculations

Wheel Base: 140 in. Front Track Width: 67.75 in.
Rear Track Width: 67.75 in.

Center of Gravity	2270P MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb)	5000 ± 110	5019	19.0
Longitudinal CG (in.)	63 ± 4	65.216179	2.21618
Lateral CG (in.)	NA	-0.182233	NA
Vertical CG (in.)	28 or greater	28.10	0.10010

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	1385	1319
Rear	1134	1111
FRONT	2704	lb
REAR	2245	lb
TOTAL	4949	lb

TEST INERTIAL WEIGHT (lb)

	Left	Right
Front	1347	1334
Rear	1176	1162
FRONT	2681	lb
REAR	2338	lb
TOTAL	5019	lb

Figure B-1. Vehicle Mass Distribution, Test No. H42S-1

	Test Name: H42S-2	VIN:	KMHCT4AE1FU907729
Model Year: 2015	Make: Hyundai	Model:	Accent

Vehicle CG Determination

	Vehicle Equipment	Weight (lb)
+	Unballasted Car (Curb)	2493
+	Hub	19
+	Brake activation cylinder & frame	7
+	Pneumatic tank (Nitrogen)	30
+	Strobe/Brake Battery	5
+	Brake Receiver/Wires	5
+	CG Plate including DAQ	16
-	Battery	-31
-	Oil	-16
-	Interior	-73
-	Fuel	-26
-	Coolant	-7
-	Washer fluid	0
+	Water Ballast (In Fuel Tank)	0
+	Onboard Supplemental Battery	

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

Estimated Total Weight (lb) 2422

Vehicle Dimensions for C.G. Calculations

Wheel Base:	101.75 in.	Front Track Width:	59.375 in.
Roof Height:	56.625 in.	Rear Track Width:	59.25 in.

Center of Gravity	1100C MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb)	2420 ± 55	2426	6.0
Longitudinal CG (in.)	39 ± 4	38.376	-0.624
Lateral CG (in.)	NA	0.024	NA
Vertical CG (in.)	NA	22.066	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	814	751
Rear	468	460

FRONT	1565	lb
REAR	928	lb
TOTAL	2493	lb

TEST INERTIAL WEIGHT (lb)

	Left	Right
Front	763	748
Rear	449	466

FRONT	1511	lb
REAR	915	lb
TOTAL	2426	lb

Figure B-2. Vehicle Mass Distribution, Test No. H42S-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: 2015 | Test Name: H42S-1 | Make: Dodge | VIN: 1C6RR6FG6FS703367 | Model: RAM 1500 quad cab

VEHICLE DEFORMATION
DRIVER SIDE FLOOR PAN - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	56.8648	-25.2857	-2.8761	53.5890	-22.2261	-5.0936	3.2758	3.0596	2.2175	5.0009	3.9558	X, Z
	2	58.3408	-20.8571	-1.1192	55.4542	-18.3053	-3.1642	2.8866	2.5518	2.0450	4.3619	3.5376	X, Z
	3	58.5765	-16.8605	-0.2991	57.7847	-16.9155	-0.1695	0.7918	-0.0550	-0.1296	0.8042	0.7918	X
	4	57.6927	-11.6124	-0.1118	57.1821	-11.6874	0.1324	0.5106	-0.0750	-0.2442	0.5709	0.5106	X
	5	54.4818	-4.7556	-2.8505	54.3610	-4.6981	-2.6198	0.1208	0.0575	-0.2307	0.2667	0.1208	X
	6	50.6762	-25.7161	3.9505	48.2222	-22.7601	2.5420	2.4540	2.9560	1.4085	4.0919	2.8295	X, Z
	7	50.3526	-20.9645	4.0874	49.0585	-19.9832	3.9768	1.2941	0.9813	0.1106	1.6278	1.2988	X, Z
	8	50.3602	-16.4165	4.0793	50.1766	-16.1156	5.2069	0.1836	0.3009	-1.1276	1.1814	0.1836	X
	9	50.4441	-11.8568	4.0158	50.2498	-11.5544	4.6834	0.1943	0.3024	-0.6676	0.7582	0.1943	X
	10	48.5659	-5.1890	-0.1925	48.3268	-5.0876	-0.1663	0.2391	0.1014	-0.0262	0.2610	0.2391	X
FLOOR PAN (Z)	11	43.2899	-25.6375	5.2387	42.8497	-25.1094	7.1789	0.4402	0.5281	-1.9402	2.0584	-1.9402	Z
	12	43.0288	-20.8920	5.1832	42.9762	-20.3730	7.2001	0.0526	0.5190	-2.0169	2.0833	-2.0169	Z
	13	43.0076	-16.5335	5.1624	42.9107	-16.1653	6.4129	0.0969	0.3682	-1.2505	1.3072	-1.2505	Z
	14	43.0281	-11.5998	5.1388	42.8697	-11.1458	5.7108	0.1584	0.4540	-0.5720	0.7473	-0.5720	Z
	15	42.7818	-5.6405	0.3975	42.6828	-5.5672	0.4541	0.0990	0.0733	-0.0566	0.1356	-0.0566	Z
	16	39.5121	-25.6391	5.2519	39.3811	-24.9716	7.6146	0.1310	0.6675	-2.3627	2.4587	-2.3627	Z
	17	39.5213	-21.1697	5.1771	39.4252	-20.7562	6.6541	0.0961	0.4135	-1.4770	1.5368	-1.4770	Z
	18	39.6915	-16.7558	5.1489	39.6115	-16.4048	6.1490	0.0800	0.3510	-1.0001	1.0629	-1.0001	Z
	19	39.7018	-11.9034	5.1352	39.5850	-11.5103	5.5657	0.1168	0.3931	-0.4305	0.5946	-0.4305	Z
	20	39.6506	-5.6669	1.1765	39.5295	-5.5931	1.1647	0.1211	0.0738	0.0118	0.1423	0.0118	Z
	21	36.3093	-25.6988	5.2092	36.1991	-25.2210	6.8346	0.1102	0.4778	-1.6254	1.6978	-1.6254	Z
	22	35.8157	-21.3864	5.1739	35.7823	-21.0609	6.2650	0.0334	0.3255	-1.0911	1.1391	-1.0911	Z
	23	36.1669	-16.8323	5.1491	36.1266	-16.4237	5.9834	0.0403	0.4086	-0.8343	0.9299	-0.8343	Z
	24	36.4526	-11.9279	5.1373	36.3439	-11.5587	5.3885	0.1087	0.3692	-0.2512	0.4596	-0.2512	Z
	25	36.7336	-6.0997	2.3782	36.5824	-6.1020	2.1659	0.1512	-0.0023	0.2123	0.2606	0.2123	Z
	26	32.8392	-25.9557	4.5252	32.7878	-25.6832	5.6364	0.0514	0.2725	-1.1112	1.1453	-1.1112	Z
	27	33.0855	-21.1971	4.6863	33.0260	-20.9434	5.5910	0.0595	0.2537	-0.9047	0.9415	-0.9047	Z
	28	33.1952	-16.6027	4.7342	33.1247	-16.3294	5.3806	0.0705	0.2733	-0.6464	0.7053	-0.6464	Z
	29	33.4197	-11.4701	4.8446	33.3207	-11.2453	5.1783	0.0990	0.2248	-0.3337	0.4144	-0.3337	Z
	30	33.6252	-6.3960	3.1451	33.5703	-6.9230	2.7323	0.0549	-0.5270	0.4128	0.6717	0.4128	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. H42S-1

Model Year: 2015 | Test Name: H42S-1 | VIN: 1C6RR6FG6FS703367
Make: Dodge | Model: RAM 1500 quad cab

VEHICLE DEFORMATION
DRIVER SIDE FLOOR PAN - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	56.8910	-45.2504	-6.6825	53.5648	-42.2105	-9.6584	3.3262	3.0399	2.9759	5.4001	4.4631	X, Z
	2	58.3896	-40.8301	-4.9235	55.4733	-38.3228	-7.7046	2.9163	2.5073	2.7811	4.7461	4.0298	X, Z
	3	58.6477	-36.8347	-4.1047	57.8336	-36.9795	-4.7120	0.8141	-0.1448	0.6073	1.0259	1.0157	X, Z
	4	57.7962	-31.5811	-3.9227	57.2745	-31.7498	-4.3577	0.5217	-0.1687	0.4350	0.6999	0.6793	X, Z
	5	54.6363	-24.7058	-6.6744	54.4920	-24.7131	-7.0268	0.1443	-0.0073	0.3524	0.3809	0.3808	X, Z
	6	50.6798	-45.6385	0.1260	48.2421	-42.7733	-1.9941	2.4377	2.8652	2.1201	4.3182	3.2307	X, Z
	7	50.3855	-40.8849	0.2595	49.1096	-40.0167	-0.5388	1.2759	0.8682	0.7983	1.7375	1.5051	X, Z
	8	50.4216	-36.3371	0.2492	50.2661	-36.1697	0.7200	0.1555	0.1674	-0.4708	0.5233	0.1555	X
	9	50.5341	-31.7780	0.1835	50.3724	-31.6046	0.2384	0.1617	0.1734	-0.0549	0.2434	0.1617	X
	10	48.7100	-25.1009	-4.0336	48.4705	-25.0777	-4.5387	0.2395	0.0232	0.5051	0.5595	0.5590	X, Z
FLOOR PAN (Z)	11	43.2904	-45.5131	1.3924	42.8803	-45.1233	2.6550	0.4101	0.3898	-1.2626	1.3836	-1.2626	Z
	12	43.0591	-40.7661	1.3337	43.0447	-40.3885	2.7194	0.0144	0.3776	-1.3857	1.4363	-1.3857	Z
	13	43.0652	-36.4076	1.3106	43.0078	-36.1732	1.9717	0.0574	0.2344	-0.6611	0.7038	-0.6611	Z
	14	43.1165	-31.4741	1.2845	43.0023	-31.1472	1.3165	0.1142	0.3269	-0.0320	0.3477	-0.0320	Z
	15	42.9215	-25.5158	-3.4605	42.8268	-25.5185	-3.8868	0.0947	-0.0027	0.4263	0.4367	0.4263	Z
	16	39.5127	-45.4911	1.3945	39.4158	-44.9621	3.1140	0.0969	0.5290	-1.7195	1.8016	-1.7195	Z
	17	39.5500	-41.0219	1.3175	39.4874	-40.7384	2.1925	0.0626	0.2835	-0.8750	0.9219	-0.8750	Z
	18	39.7478	-36.6092	1.2875	39.7052	-36.3841	1.7266	0.0426	0.2251	-0.4391	0.4953	-0.4391	Z
	19	39.7885	-31.7569	1.2713	39.7140	-31.4843	1.1890	0.0745	0.2726	0.0823	0.2943	0.0823	Z
	20	39.7879	-25.5224	-2.6907	39.6779	-25.5260	-3.1565	0.1100	-0.0036	0.4658	0.4786	0.4658	Z
	21	36.3096	-45.5308	1.3424	36.2270	-45.1791	2.3520	0.0826	0.3517	-1.0096	1.0723	-1.0096	Z
	22	35.8431	-41.2155	1.3034	35.8398	-41.0107	1.8238	0.0033	0.2048	-0.5204	0.5593	-0.5204	Z
	23	36.2228	-36.6637	1.2773	36.2192	-36.3739	1.5831	0.0036	0.2898	-0.3058	0.4213	-0.3058	Z
	24	36.5391	-31.7611	1.2638	36.4716	-31.5055	1.0320	0.0675	0.2556	0.2318	0.3516	0.2318	Z
	25	36.8647	-25.9363	-1.4974	36.7332	-26.0210	-2.1412	0.1315	-0.0847	0.6438	0.6625	0.6438	Z
	26	32.8401	-45.7664	0.6482	32.8047	-45.6030	1.1713	0.0354	0.1634	-0.5231	0.5492	-0.5231	Z
	27	33.1156	-41.0094	0.8076	33.0804	-40.8651	1.1685	0.0352	0.1443	-0.3609	0.3903	-0.3609	Z
	28	33.2539	-36.4157	0.8535	33.2144	-36.2502	1.0003	0.0395	0.1655	-0.1468	0.2247	-0.1468	Z
	29	33.5101	-31.2846	0.9619	33.4497	-31.1661	0.8439	0.0604	0.1185	0.1180	0.1778	0.1180	Z
	30	33.7523	-26.2127	-0.7395	33.7183	-26.8234	-1.5633	0.0340	-0.6107	0.8238	1.0260	0.8238	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. H42S-1

Model Year: 2015 | Test Name: H42S-1 | VIN: 1C6RR6FG6FS703367
Make: Dodge | Model: RAM 1500 quad cab

VEHICLE DEFORMATION
DRIVER SIDE INTERIOR CRUSH - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	42.8517	-27.4329	-25.6783	43.0188	-27.2954	-26.2820	-0.1671	0.1375	-0.6037	0.6413	0.6413	X, Y, Z
	2	40.6809	-15.1514	-29.4940	41.1494	-14.9773	-30.0752	-0.4685	0.1741	-0.5812	0.7665	0.7665	X, Y, Z
	3	39.8393	3.1307	-27.0539	40.2879	3.2103	-27.2762	-0.4486	-0.0796	-0.2223	0.5069	0.5069	X, Y, Z
	4	39.9492	-27.1251	-16.1325	39.7094	-26.8485	-16.8998	0.2398	0.2766	-0.7673	0.8502	0.8502	X, Y, Z
	5	38.1788	-14.8794	-14.9827	37.5877	-14.5915	-15.3018	0.5911	0.2879	-0.3191	0.7308	0.7308	X, Y, Z
	6	36.8630	3.7548	-16.3379	37.0865	3.7850	-16.5077	-0.2235	-0.0302	-0.1698	0.2823	0.2823	X, Y, Z
SIDE PANEL (Y)	7	50.7330	-28.8285	-2.7897	49.6016	-26.8345	-3.2110	1.1314	1.9940	-0.4213	2.3310	1.9940	Y
	8	48.0219	-28.7302	2.1103	46.8074	-26.2458	2.0007	1.2145	2.4844	-0.1096	2.7675	2.4844	Y
	9	52.3656	-28.7568	0.0247	50.6743	-25.5465	-0.6048	1.6913	3.2103	-0.6295	3.6828	3.2103	Y
IMPACT SIDE DOOR (Y)	10	17.0960	-31.6685	-16.2623	16.6683	-32.6069	-16.1277	0.4277	-0.9384	0.1346	1.0400	-0.9384	Y
	11	29.5924	-31.9865	-15.3986	29.1918	-32.5043	-15.4517	0.4006	-0.5178	-0.0531	0.6568	-0.5178	Y
	12	39.3615	-31.2337	-16.0204	38.8664	-30.9973	-16.1340	0.4951	0.2364	-0.1136	0.5603	0.2364	Y
	13	16.9281	-31.2242	-2.5901	16.5831	-31.5938	-2.5336	0.3450	-0.3696	0.0565	0.5087	-0.3696	Y
	14	29.9185	-31.9179	-2.6104	29.6312	-32.0473	-2.6164	0.2873	-0.1294	-0.0060	0.3152	-0.1294	Y
	15	35.1368	-31.8148	-1.4008	34.6850	-31.6449	-1.4961	0.4518	0.1699	-0.0953	0.4920	0.1699	Y
ROOF - (Z)	16	32.1939	-19.3650	-42.4582	32.6187	-20.0081	-42.4801	-0.4248	-0.6431	-0.0219	0.7710	-0.0219	Z
	17	34.6445	-9.6673	-42.8029	35.0039	-10.3007	-42.7778	-0.3594	-0.6334	0.0251	0.7287	0.0251	Z
	18	35.7988	2.4051	-43.0469	36.1482	1.8303	-42.9651	-0.3494	0.5748	0.0818	0.6776	0.0818	Z
	19	24.1178	-18.1819	-45.6241	24.5011	-18.7196	-45.6202	-0.3833	-0.5377	0.0039	0.6603	0.0039	Z
	20	25.5062	-8.8011	-46.1484	25.9196	-9.3462	-46.1653	-0.4134	-0.5451	-0.0169	0.6843	-0.0169	Z
	21	25.6186	1.2680	-46.4247	26.0063	0.6882	-46.4741	-0.3877	0.5798	-0.0494	0.6992	-0.0494	Z
	22	12.2373	-17.3536	-46.6275	12.6204	-17.9624	-46.6097	-0.3831	-0.6088	0.0178	0.7195	0.0178	Z
	23	12.7023	-8.9373	-47.0917	13.0310	-9.6298	-47.1752	-0.3287	-0.6925	-0.0835	0.7711	-0.0835	Z
	24	13.4606	0.0008	-47.2975	13.8010	-0.6618	-47.4123	-0.3404	0.6626	-0.1148	0.7537	-0.1148	Z
	25	-4.2949	-17.6197	-46.9714	-3.9511	-18.1625	-47.0105	-0.3438	-0.5428	-0.0391	0.6437	-0.0391	Z
	26	-4.3378	-7.9038	-47.4483	-3.9038	-8.4655	-47.5599	-0.4340	-0.5617	-0.1116	0.7186	-0.1116	Z
	27	-4.5370	-0.2212	-47.4697	-4.1243	-0.7846	-47.6250	-0.4127	-0.5634	-0.1553	0.7154	-0.1553	Z
	28	-20.0281	-17.7010	-46.7356	-19.5949	-18.2474	-46.8082	-0.4332	-0.5464	-0.0726	0.7011	-0.0726	Z
	29	-20.0096	-7.6745	-47.0634	-19.6135	-8.2639	-47.2582	-0.3961	-0.5894	-0.1948	0.7364	-0.1948	Z
	30	-19.7461	0.1256	-47.0263	-19.3752	-0.4073	-47.2942	-0.3709	0.5329	-0.2679	0.7024	-0.2679	Z
A-PILLAR Maximum (X, Y, Z)	31	49.6190	-27.7336	-27.9986	50.1468	-28.2314	-28.2195	-0.5278	-0.4978	-0.2209	0.7584	0.0000	NA
	32	46.1710	-27.1392	-31.5684	46.7851	-27.7300	-31.6864	-0.6141	-0.5908	-0.1180	0.8603	0.0000	NA
	33	42.8146	-26.4254	-34.0538	43.3481	-27.0246	-34.2973	-0.5335	-0.5992	-0.2435	0.8384	0.0000	NA
	34	39.4886	-25.6943	-36.4836	40.0321	-26.3190	-36.7561	-0.5435	-0.6247	-0.2725	0.8717	0.0000	NA
	35	36.5289	-25.0403	-38.4102	36.9730	-25.6558	-38.5559	-0.4441	-0.6155	-0.1457	0.7728	0.0000	NA
	36	32.1599	-24.0484	-40.7217	32.6531	-24.7027	-40.8515	-0.4932	-0.6543	-0.1298	0.8296	0.0000	NA
A-PILLAR Lateral (Y)	31	49.6190	-27.7336	-27.9986	50.1468	-28.2314	-28.2195	-0.5278	-0.4978	-0.2209	0.7584	-0.4978	Y
	32	46.1710	-27.1392	-31.5684	46.7851	-27.7300	-31.6864	-0.6141	-0.5908	-0.1180	0.8603	-0.5908	Y
	33	42.8146	-26.4254	-34.0538	43.3481	-27.0246	-34.2973	-0.5335	-0.5992	-0.2435	0.8384	-0.5992	Y
	34	39.4886	-25.6943	-36.4836	40.0321	-26.3190	-36.7561	-0.5435	-0.6247	-0.2725	0.8717	-0.6247	Y
	35	36.5289	-25.0403	-38.4102	36.9730	-25.6558	-38.5559	-0.4441	-0.6155	-0.1457	0.7728	-0.6155	Y
	36	32.1599	-24.0484	-40.7217	32.6531	-24.7027	-40.8515	-0.4932	-0.6543	-0.1298	0.8296	-0.6543	Y
B-PILLAR Maximum (X, Y, Z)	37	4.5098	-24.1867	-39.9363	4.8307	-24.6100	-39.8418	-0.3209	-0.4233	0.0945	0.5395	0.0945	Z
	38	7.5476	-25.3112	-36.8554	7.8765	-25.7446	-36.6417	-0.3289	-0.4334	0.2137	0.5845	0.2137	Z
	39	4.8783	-26.9929	-32.3896	5.1407	-27.3121	-32.1942	-0.2624	-0.3192	0.1954	0.4571	0.1954	Z
	40	8.1729	-27.8473	-28.6159	8.4456	-28.1389	-28.3236	-0.2727	-0.2916	0.2923	0.4948	0.2923	Z
B-PILLAR Lateral (Y)	37	4.5098	-24.1867	-39.9363	4.8307	-24.6100	-39.8418	-0.3209	-0.4233	0.0945	0.5395	-0.4233	Y
	38	7.5476	-25.3112	-36.8554	7.8765	-25.7446	-36.6417	-0.3289	-0.4334	0.2137	0.5845	-0.4334	Y
	39	4.8783	-26.9929	-32.3896	5.1407	-27.3121	-32.1942	-0.2624	-0.3192	0.1954	0.4571	-0.3192	Y
	40	8.1729	-27.8473	-28.6159	8.4456	-28.1389	-28.3236	-0.2727	-0.2916	0.2923	0.4948	-0.2916	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. H42S-1

Model Year: 2015 | Test Name: H42S-1 | VIN: 1C6RR6FG6FS703367
Make: Dodge | Model: RAM 1500 quad cab

VEHICLE DEFORMATION
DRIVER SIDE INTERIOR CRUSH - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	42.9589	-47.4063	-29.3764	42.8938	-46.9423	-30.7674	0.0651	0.4640	-1.3910	1.4678	1.4678	X, Y, Z
	2	40.8795	-35.1261	-33.2467	41.0851	-34.5783	-34.4391	-0.2056	0.5478	-1.1924	1.3282	1.3282	X, Y, Z
	3	40.1431	-16.8300	-30.8789	40.3557	-16.4119	-31.4708	-0.2126	0.4181	-0.5919	0.7552	0.7552	X, Y, Z
	4	40.0221	-47.0442	-19.8430	39.6346	-46.5596	-21.3648	0.3875	0.4846	-1.5218	1.6434	1.6434	X, Y, Z
	5	38.3240	-34.7834	-18.7462	37.6005	-34.3042	-19.6449	0.7235	0.4792	-0.8987	1.2493	1.2493	X, Y, Z
	6	37.1299	-16.1466	-20.1768	37.2124	-15.9146	-20.6814	-0.0825	0.2320	-0.5046	0.5615	0.5615	X, Y, Z
SIDE PANEL (Y)	7	50.7442	-48.7640	-6.4526	49.5956	-46.7338	-7.7271	1.1486	2.0302	-1.2745	2.6581	2.0302	Y
	8	48.0151	-48.6303	-1.5634	46.8316	-46.1747	-2.4960	1.1835	2.4556	-0.9326	2.8810	2.4556	Y
	9	52.3665	-48.6919	-3.6323	50.6898	-45.4766	-5.1147	1.6767	3.2153	-1.4824	3.9175	3.2153	Y
IMPACT SIDE DOOR (Y)	10	17.1416	-51.4454	-20.0432	16.5610	-52.1763	-20.5275	0.5806	-0.7309	-0.4843	1.0516	-0.7309	Y
	11	29.6324	-51.8380	-19.1304	29.0880	-52.1605	-19.9145	0.5444	-0.3225	-0.7841	1.0076	-0.3225	Y
	12	39.4083	-51.1485	-19.7176	38.7687	-50.7096	-20.6323	0.6396	0.4389	-0.9147	1.1993	0.4389	Y
	13	16.9245	-50.9481	-6.3735	16.5507	-51.2866	-6.9245	0.3738	-0.3385	-0.5510	0.7469	-0.3385	Y
	14	29.9102	-51.7229	-6.3414	29.5950	-51.8232	-7.0780	0.3152	-0.1003	-0.7366	0.8075	-0.1003	Y
	15	35.1244	-51.6477	-5.1122	34.6570	-51.4635	-5.9798	0.4674	0.1842	-0.8676	1.0026	0.1842	Y
ROOF - (Z)	16	32.4159	-39.3359	-46.2273	32.4596	-39.4410	-46.8455	-0.0437	-0.1051	-0.6182	0.6286	-0.6182	Z
	17	34.9283	-29.6551	-46.5993	34.9062	-29.7469	-47.0673	0.0221	-0.0918	-0.4680	0.4774	-0.4680	Z
	18	36.1590	-17.5911	-46.8844	36.1281	-17.6223	-47.1503	0.0309	-0.0312	-0.2659	0.2695	-0.2659	Z
	19	24.3594	-38.1145	-49.4286	24.3349	-38.0718	-49.9324	0.0245	0.0427	-0.5038	0.5062	-0.5038	Z
	20	25.8084	-28.7446	-49.9830	25.8113	-28.7032	-50.3996	-0.0029	0.0414	-0.4166	0.4187	-0.4166	Z
	21	25.9848	-18.6775	-50.2969	25.9615	-18.6671	-50.6178	0.0233	0.0104	-0.3209	0.3219	-0.3209	Z
	22	12.4883	-37.2159	-50.4807	12.4544	-37.2291	-50.8544	0.0339	-0.0132	-0.3737	0.3755	-0.3737	Z
	23	13.0077	-28.8046	-50.9748	12.9163	-28.8946	-51.3463	0.0914	-0.0900	-0.3715	0.3930	-0.3715	Z
	24	13.8225	-19.8721	-51.2114	13.7431	-19.9300	-51.5060	0.0794	-0.0579	-0.2946	0.3106	-0.2946	Z
	25	-4.0438	-37.3802	-50.8869	-4.1198	-37.3190	-51.1725	0.0760	0.0612	-0.2856	0.3018	-0.2856	Z
	26	-4.0242	-27.6661	-51.4006	-4.0124	-27.6179	-51.6341	-0.0118	0.0482	-0.2335	0.2387	-0.2335	Z
	27	-4.1753	-19.9826	-51.4518	-4.1834	-19.9355	-51.6284	0.0081	0.0471	-0.1766	0.1830	-0.1766	Z
	28	-19.7781	-37.3625	-50.7111	-19.7626	-37.3051	-50.8913	-0.0155	0.0574	-0.1802	0.1898	-0.1802	Z
	29	-19.6957	-27.3376	-51.0766	-19.7188	-27.3179	-51.2506	0.0231	0.0197	-0.1740	0.1766	-0.1740	Z
	30	-19.3835	-19.5392	-51.0680	-19.4297	-19.4631	-51.2165	0.0462	0.0761	-0.1485	0.1731	-0.1485	Z
A-PILLAR Maximum (X, Y, Z)	31	49.7331	-47.7581	-31.6695	50.0058	-47.9064	-32.7496	-0.2727	-0.1483	-1.0801	1.1238	0.0000	NA
	32	46.3024	-47.1557	-35.2547	46.6299	-47.3519	-36.1946	-0.3275	-0.1962	-0.9399	1.0145	0.0000	NA
	33	42.9601	-46.4305	-37.7557	43.1844	-46.6007	-38.7815	-0.2243	-0.1702	-1.0258	1.0637	0.0000	NA
	34	39.6480	-45.6878	-40.2010	39.8607	-45.8513	-41.2168	-0.2127	-0.1635	-1.0158	1.0506	0.0000	NA
	35	36.6998	-45.0227	-42.1413	36.7970	-45.1521	-42.9949	-0.0972	-0.1294	-0.8536	0.8688	0.0000	NA
	36	32.3460	-44.0124	-44.4733	32.4718	-44.1504	-45.2597	-0.1258	-0.1380	-0.7864	0.8083	0.0000	NA
A-PILLAR Lateral (Y)	31	49.7331	-47.7581	-31.6695	50.0058	-47.9064	-32.7496	-0.2727	-0.1483	-1.0801	1.1238	-0.1483	Y
	32	46.3024	-47.1557	-35.2547	46.6299	-47.3519	-36.1946	-0.3275	-0.1962	-0.9399	1.0145	-0.1962	Y
	33	42.9601	-46.4305	-37.7557	43.1844	-46.6007	-38.7815	-0.2243	-0.1702	-1.0258	1.0637	-0.1702	Y
	34	39.6480	-45.6878	-40.2010	39.8607	-45.8513	-41.2168	-0.2127	-0.1635	-1.0158	1.0506	-0.1635	Y
	35	36.6998	-45.0227	-42.1413	36.7970	-45.1521	-42.9949	-0.0972	-0.1294	-0.8536	0.8688	-0.1294	Y
	36	32.3460	-44.0124	-44.4733	32.4718	-44.1504	-45.2597	-0.1258	-0.1380	-0.7864	0.8083	-0.1380	Y
B-PILLAR Maximum (X, Y, Z)	37	4.6927	-43.9752	-43.7934	4.6561	-43.8879	-44.1075	0.0366	0.0873	-0.3141	0.3281	0.0947	X, Y
	38	7.7117	-45.1069	-40.6966	7.7105	-45.0711	-40.9334	0.0012	0.0358	-0.2368	0.2395	0.0358	X, Y
	39	5.0149	-46.7550	-36.2347	4.9870	-46.6614	-36.4864	0.0279	0.0936	-0.2517	0.2700	0.0977	X, Y
	40	8.2897	-47.6156	-32.4453	8.3060	-47.5446	-32.6403	-0.0163	0.0710	-0.1950	0.2082	0.0710	Y
B-PILLAR Lateral (Y)	37	4.6927	-43.9752	-43.7934	4.6561	-43.8879	-44.1075	0.0366	0.0873	-0.3141	0.3281	0.0873	Y
	38	7.7117	-45.1069	-40.6966	7.7105	-45.0711	-40.9334	0.0012	0.0358	-0.2368	0.2395	0.0358	Y
	39	5.0149	-46.7550	-36.2347	4.9870	-46.6614	-36.4864	0.0279	0.0936	-0.2517	0.2700	0.0936	Y
	40	8.2897	-47.6156	-32.4453	8.3060	-47.5446	-32.6403	-0.0163	0.0710	-0.1950	0.2082	0.0710	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. H42S-1

Model Year: 2015	Test Name: H42S-1	VIN: 1C6RR6FG6FS703367	
	Make: Dodge	Model: RAM 1500 quad cab	

Driver Side Maximum Deformation

Reference Set 1				Reference Set 2			
Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]	Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]
Roof	0.1	≤ 4	Z	Roof	-0.6	≤ 4	Z
Windshield[D]	0.0	≤ 3	X, Z	Windshield[D]	NA	≤ 3	X, Z
A-Pillar Maximum	0.0	≤ 5	NA	A-Pillar Maximum	0.0	≤ 5	NA
A-Pillar Lateral	-0.7	≤ 3	Y	A-Pillar Lateral	-0.2	≤ 3	Y
B-Pillar Maximum	0.3	≤ 5	Z	B-Pillar Maximum	0.1	≤ 5	X, Y
B-Pillar Lateral	-0.7	≤ 3	Y	B-Pillar Lateral	0.1	≤ 3	Y
Toe Pan - Wheel Well	4.0	≤ 9	X, Z	Toe Pan - Wheel Well	4.5	≤ 9	X, Z
Side Front Panel	3.2	≤ 12	Y	Side Front Panel	3.2	≤ 12	Y
Side Door (above seat)	0.2	≤ 9	Y	Side Door (above seat)	0.4	≤ 9	Y
Side Door (below seat)	0.2	≤ 12	Y	Side Door (below seat)	0.2	≤ 12	Y
Floor Pan	0.4	≤ 12	Z	Floor Pan	0.8	≤ 12	Z
Dash - no MASH requirement	0.9	NA	X, Y, Z	Dash - no MASH requirement	0.9	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.

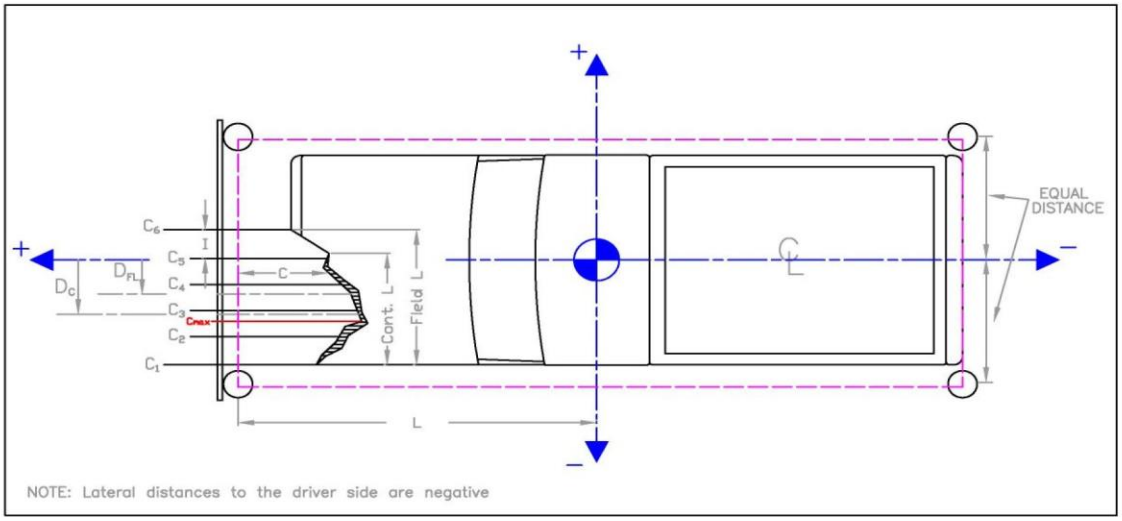
[D] If deformation is observered for the windshield then the windshield deformation is measured posttest with an examplar vehicle, therefore only one set of reference is measured and recorded.

Notes on vehicle interior crush:

Figure C-5. Maximum Occupant Compartment Deformation by Location, Test No. H42S-1

Test Name: H42S-1 **VIN:** 1C6RR6FG6FS703367

Model Year: 2015 **Make:** Dodge **Model:** RAM 1500 quad cab



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	112	(2845)
Total Vehicle Width:	76 3/4	(1949)
Width of contact and induced crush - Field L:	76 3/4	(1949)
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:	76 3/4	(1949)
Distance from center of vehicle to center of contact damage - D_C:	0	()

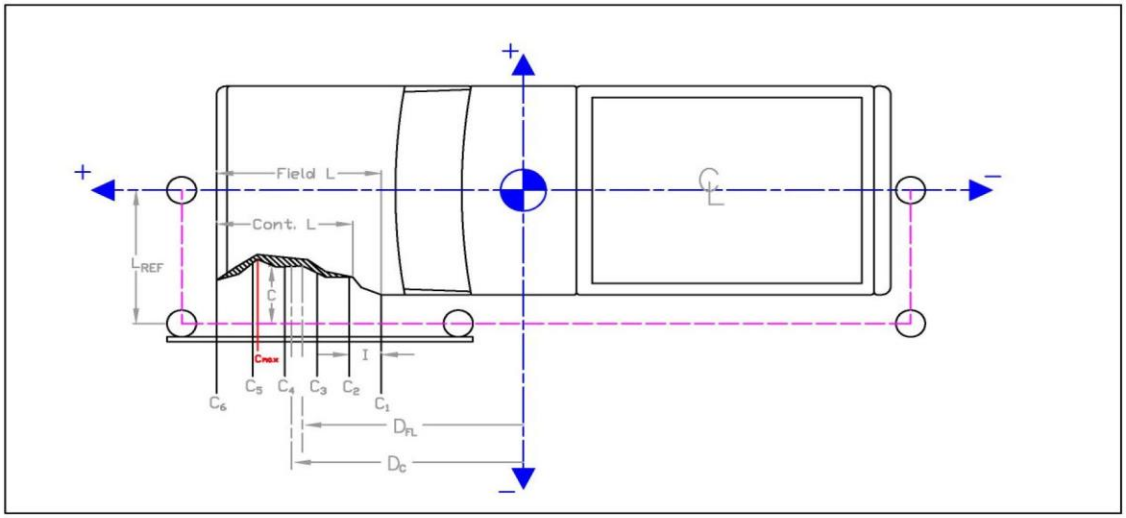
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Lateral Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	n/a	N/A	-38 3/8	-(975)	22 1/2	(572)	2 1/3	(59)	N/A	N/A
C_2	27 5/8	(702)	-23	-(584)	6 1/2	(165)			18 4/5	(478)
C_3	20 3/4	(527)	-7 5/8	-(194)	4 1/4	(108)			14 1/5	(360)
C_4	22 1/4	(565)	7 3/4	(197)	4 1/4	(108)			15 2/3	(398)
C_5	24 3/4	(629)	23 1/8	(587)	6 1/8	(156)			16 1/3	(414)
C_6	29 1/2	(749)	38 1/2	(978)	20 1/2	(521)			6 2/3	(170)
C_{MAX}	37 3/8	(949)	32 3/4	(832)	11 5/8	(295)			23 4/9	(595)

Figure C-6. Exterior Vehicle Crush (NASS) – Front, Test No. H42S-1

Test Name: H42S-1 **VIN:** 1C6RR6FG6FS703367

Model Year: 2015 **Make:** Dodge **Model:** RAM 1500 quad cab



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	48	(1219)
Total Vehicle Length:	229	(5817)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-6 4/7	-(167)
Width of contact and induced crush - Field L:	229	(5817)
Crush measurement spacing interval (L/5) - I:	45 3/4	(1162)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-6 4/7	-(167)
Width of Contact Damage:	229	(5817)
Distance from vehicle c.g. to center of contact damage - D_C:	-6 4/7	-(167)

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	14 3/8	(365)	-121 1/8	-(3077)	33 1/2	(851)	4	(102)	-23 1/8	-(587)
C_2	n/a	N/A	-75 3/8	-(1915)	5 1/2	(140)			N/A	N/A
C_3	9 1/4	(235)	-29 5/8	-(752)	5 7/8	(149)			- 5/8	-(16)
C_4	8 3/4	(222)	16 1/8	(410)	5	(127)			- 1/4	-(6)
C_5	n/a	N/A	61 7/8	(1572)	5 1/4	(133)			N/A	N/A
C_6	n/a	N/A	107 5/8	(2734)	15 3/8	(391)			N/A	N/A
C_{MAX}	28 1/2	(724)	87 1/4	(2216)	5 3/4	(146)			18 3/4	(476)

Figure C-7. Exterior Vehicle Crush (NASS) – Side, Test No. H42S-1

Model Year: 2015 Test Name: H42S-2 VIN: KMHCT4AE1FU907729
Make: Hyundai Model: Accent

VEHICLE DEFORMATION
DRIVER SIDE FLOOR PAN - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	73.6783	-18.9314	0.2242	73.0602	-17.7863	-0.5214	0.6181	1.1451	0.7456	1.4997	0.9685	X, Z
	2	76.7222	-14.3188	2.1640	76.5093	-13.5501	1.6395	0.2129	0.7687	0.5245	0.9546	0.5661	X, Z
	3	74.4691	-7.1885	4.6607	74.3884	-6.6712	4.3001	0.0807	0.5173	0.3606	0.6357	0.3695	X, Z
	4	73.9190	-2.0199	4.4403	73.9598	-1.6215	4.1978	-0.0408	0.3984	0.2425	0.4682	0.2425	Z
	5	71.5903	0.3836	2.4407	71.5975	0.6481	2.0651	-0.0072	-0.2645	0.3756	0.4594	0.3756	Z
	6	67.0517	-19.3413	8.0890	67.0073	-18.7222	7.6583	0.0444	0.6191	0.4307	0.7555	0.4330	X, Z
	7	67.2061	-13.3405	7.3836	67.1518	-12.8218	7.0584	0.0543	0.5187	0.3252	0.6146	0.3297	X, Z
	8	66.7897	-7.7186	8.1311	66.6401	-7.1342	7.7226	0.1496	0.5844	0.4085	0.7285	0.4350	X, Z
	9	65.3901	-3.4875	8.4417	65.2944	-3.0273	7.9069	0.0957	0.4602	0.5348	0.7120	0.5433	X, Z
	10	66.1850	0.2852	4.4047	66.2532	0.5626	3.9316	-0.0682	-0.2774	0.4731	0.5527	0.4731	Z
FLOOR PAN (Z)	11	60.8136	-19.6482	8.3162	60.8015	-19.0844	8.0121	0.0121	0.5638	0.3041	0.6407	0.3041	Z
	12	60.0283	-13.3184	7.8494	59.9995	-12.9102	7.5770	0.0288	0.4082	0.2724	0.4916	0.2724	Z
	13	60.3003	-7.3509	8.5132	60.3019	-6.9725	8.4713	-0.0016	0.3784	0.0419	0.3807	0.0419	Z
	14	60.6323	-3.2678	8.4260	60.5971	-2.9680	7.9591	0.0352	0.2998	0.4669	0.5560	0.4669	Z
	15	60.7805	0.2574	4.3300	60.7863	0.5472	3.8130	-0.0058	-0.2898	0.5170	0.5927	0.5170	Z
	16	57.0835	-19.6582	8.3330	57.0474	-19.1684	8.0374	0.0361	0.4898	0.2956	0.5732	0.2956	Z
	17	57.1649	-13.4331	7.9073	57.1255	-12.9493	7.6418	0.0394	0.4838	0.2655	0.5533	0.2655	Z
	18	56.9010	-7.4628	8.4969	56.8609	-7.0538	8.2956	0.0401	0.4090	0.2013	0.4576	0.2013	Z
	19	56.6616	-3.2931	8.4127	56.6126	-2.8976	7.9335	0.0490	0.3955	0.4792	0.6233	0.4792	Z
	20	57.2618	0.3660	4.3750	57.1278	0.6602	3.7938	0.1340	-0.2942	0.5812	0.6651	0.5812	Z
	21	54.2832	-19.7014	8.4177	54.3068	-19.2178	8.1338	-0.0236	0.4836	0.2839	0.5613	0.2839	Z
	22	53.9839	-13.2804	7.9630	53.9220	-12.8478	7.7072	0.0619	0.4326	0.2558	0.5064	0.2558	Z
	23	53.5811	-7.2042	8.5708	53.5978	-6.7975	8.1256	-0.0167	0.4067	0.4452	0.6032	0.4452	Z
	24	53.2697	-3.2673	8.4997	53.2339	-2.8999	7.9990	0.0358	0.3674	0.5007	0.6221	0.5007	Z
	25	54.2403	0.5154	3.9401	54.1930	0.7989	3.3999	0.0473	-0.2835	0.5402	0.6119	0.5402	Z
	26	50.2306	-19.0652	8.7938	50.3214	-18.5639	8.5530	-0.0908	0.5013	0.2408	0.5635	0.2408	Z
	27	50.3707	-13.3147	8.0141	50.3186	-12.8728	7.7550	0.0521	0.4419	0.2591	0.5149	0.2591	Z
	28	50.4710	-7.0803	8.6577	50.4999	-6.7079	8.2264	-0.0289	0.3724	0.4313	0.5706	0.4313	Z
	29	50.3870	-2.6753	8.5687	50.3213	-2.2836	8.0469	0.0657	0.3917	0.5218	0.6558	0.5218	Z
	30	51.2888	0.6530	3.5945	51.3523	0.9378	3.0125	-0.0635	-0.2848	0.5820	0.6511	0.5820	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. H42S-2

Model Year: 2015

Test Name: H42S-2
Make: Hyundai

VIN: KMHCT4AE1FU907729
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	62.2915	-21.0015	-19.3997	62.2436	-20.4565	-20.0209	0.0479	0.5450	-0.6212	0.8278	0.8278	X, Y, Z
	2	58.4816	-9.9901	-23.7851	58.3970	-9.3884	-24.3030	0.0846	0.6017	-0.5179	0.7984	0.7984	X, Y, Z
	3	61.1125	4.4795	-20.7499	61.1089	4.9661	-21.1237	0.0036	-0.4866	-0.3738	0.6136	0.6136	X, Y, Z
	4	58.6864	-18.3288	-11.5813	58.5893	-17.8052	-12.2435	0.0971	0.5236	-0.6622	0.8498	0.8498	X, Y, Z
	5	60.1860	-9.6757	-8.5737	60.1580	-9.1947	-9.0361	0.0280	0.4810	-0.4624	0.6678	0.6678	X, Y, Z
	6	56.0344	4.2737	-11.7159	56.0450	4.7260	-12.0994	-0.0106	-0.4523	-0.3835	0.5931	0.5931	X, Y, Z
SIDE PANEL (Y)	7	67.2374	-22.7921	-2.5289	67.0417	-21.9673	-3.0628	0.1957	0.8248	-0.5339	1.0018	0.8248	Y
	8	65.8996	-22.7617	1.5212	65.8963	-21.7655	1.0265	0.0033	0.9962	-0.4947	1.1123	0.9962	Y
	9	70.4063	-22.7768	0.4078	70.1883	-21.4640	-0.1452	0.2180	1.3128	-0.5530	1.4411	1.3128	Y
IMPACT SIDE DOOR (Y)	10	32.6483	-24.5455	-17.7181	32.4250	-25.5856	-17.9469	0.2233	-1.0401	-0.2288	1.0881	-1.0401	Y
	11	45.8743	-24.7383	-16.1881	45.5485	-25.9193	-16.4892	0.3258	-1.1810	-0.3011	1.2616	-1.1810	Y
	12	53.2073	-23.9502	-14.7045	52.8049	-25.3525	-14.9128	0.4024	-1.4023	-0.2083	1.4737	-1.4023	Y
	13	35.4517	-24.3071	-1.3159	35.4208	-24.2418	-1.7020	0.0309	0.0653	-0.3861	0.3928	0.0653	Y
	14	45.0738	-24.8927	0.9759	45.0181	-25.2159	0.5335	0.0557	-0.3232	-0.4424	0.5507	-0.3232	Y
	15	56.9009	-24.3085	1.1025	56.6601	-24.8056	0.6896	0.2408	-0.4971	-0.4129	0.6896	-0.4971	Y
ROOF - (Z)	16	48.0783	-15.9799	-35.3109	47.9919	-15.7057	-35.7279	0.0864	0.2742	-0.4170	0.5065	-0.4170	Z
	17	49.7814	-5.8428	-35.7182	49.7396	-5.5148	-36.0124	0.0418	0.3280	-0.2942	0.4426	-0.2942	Z
	18	50.2228	3.1403	-35.8701	50.2370	3.4887	-36.0388	-0.0142	-0.3484	-0.1687	0.3874	-0.1687	Z
	19	40.9197	-14.9467	-37.9472	40.8553	-14.5718	-38.2902	0.0644	0.3749	-0.3430	0.5122	-0.3430	Z
	20	42.4118	-4.9627	-38.3621	42.3014	-4.6590	-38.6325	0.1104	0.3037	-0.2704	0.4214	-0.2704	Z
	21	43.1369	2.3325	-38.4242	43.0752	2.6653	-38.6358	0.0617	-0.3328	-0.2116	0.3992	-0.2116	Z
	22	27.6320	-13.6314	-39.4498	27.5109	-13.2838	-39.6277	0.1211	0.3476	-0.1779	0.4088	-0.1779	Z
	23	28.1343	-5.5844	-39.9782	27.9891	-4.9236	-40.1881	0.1452	0.6608	-0.2099	0.7084	-0.2099	Z
	24	27.5957	1.8726	-40.2375	27.4868	2.2511	-40.3908	0.1089	-0.3785	-0.1533	0.4226	-0.1533	Z
	25	11.1784	-13.8634	-39.1183	11.0908	-13.5441	-39.2521	0.0876	0.3193	-0.1338	0.3571	-0.1338	Z
	26	11.4525	-6.2361	-39.6937	11.3750	-5.8520	-39.8197	0.0775	0.3841	-0.1260	0.4116	-0.1260	Z
	27	11.6916	1.3494	-39.9771	11.5874	1.6619	-40.0717	0.1042	-0.3125	-0.0946	0.3427	-0.0946	Z
	28	-1.6981	-14.5832	-37.2286	-1.7843	-14.2551	-37.3326	0.0862	0.3281	-0.1040	0.3548	-0.1040	Z
	29	-2.7013	-6.8513	-37.7153	-2.7422	-6.4775	-37.8266	0.0409	0.3738	-0.1113	0.3922	-0.1113	Z
	30	-2.9334	-0.5646	-37.9770	-3.0061	-0.2281	-38.0643	0.0727	0.3365	-0.0873	0.3552	-0.0873	Z
A-PILLAR Maximum (X, Y, Z)	31	68.6615	-22.2066	-23.3032	68.7088	-21.7680	-23.6946	-0.0473	0.4386	-0.3914	0.5897	0.4386	Y
	32	67.3586	-21.9816	-24.1672	67.3422	-21.5551	-24.6680	0.0164	0.4265	-0.5008	0.6580	0.4268	X, Y
	33	64.8118	-21.5408	-25.9510	64.8334	-21.1012	-26.4807	-0.0216	0.4396	-0.5297	0.6887	0.4396	Y
	34	61.7802	-20.9371	-27.8316	61.7706	-20.5419	-28.3726	0.0096	0.3952	-0.5410	0.6700	0.3953	X, Y
	35	57.5745	-20.0626	-30.0844	57.6394	-19.7257	-30.5504	-0.0649	0.3369	-0.4660	0.5787	0.3369	Y
	36	54.0696	-19.3205	-31.9056	54.0157	-18.9794	-32.3711	0.0539	0.3411	-0.4655	0.5796	0.3453	X, Y
A-PILLAR Lateral (Y)	31	68.6615	-22.2066	-23.3032	68.7088	-21.7680	-23.6946	-0.0473	0.4386	-0.3914	0.5897	0.4386	Y
	32	67.3586	-21.9816	-24.1672	67.3422	-21.5551	-24.6680	0.0164	0.4265	-0.5008	0.6580	0.4265	Y
	33	64.8118	-21.5408	-25.9510	64.8334	-21.1012	-26.4807	-0.0216	0.4396	-0.5297	0.6887	0.4396	Y
	34	61.7802	-20.9371	-27.8316	61.7706	-20.5419	-28.3726	0.0096	0.3952	-0.5410	0.6700	0.3952	Y
	35	57.5745	-20.0626	-30.0844	57.6394	-19.7257	-30.5504	-0.0649	0.3369	-0.4660	0.5787	0.3369	Y
	36	54.0696	-19.3205	-31.9056	54.0157	-18.9794	-32.3711	0.0539	0.3411	-0.4655	0.5796	0.3411	Y
B-PILLAR Maximum (X, Y, Z)	37	23.6478	-18.7252	-33.0580	23.5619	-18.3986	-33.2906	0.0859	0.3266	-0.2326	0.4101	0.3377	X, Y
	38	26.6505	-19.5972	-30.9693	26.6251	-19.2934	-31.1572	0.0254	0.3038	-0.1879	0.3581	0.3049	X, Y
	39	24.2958	-21.1908	-26.7954	24.2648	-20.8631	-26.9736	0.0310	0.3277	-0.1782	0.3743	0.3292	X, Y
	40	27.9160	-22.3546	-23.8861	27.8699	-22.0199	-24.0977	0.0461	0.3347	-0.2116	0.3987	0.3379	X, Y
B-PILLAR Lateral (Y)	37	23.6478	-18.7252	-33.0580	23.5619	-18.3986	-33.2906	0.0859	0.3266	-0.2326	0.4101	0.3266	Y
	38	26.6505	-19.5972	-30.9693	26.6251	-19.2934	-31.1572	0.0254	0.3038	-0.1879	0.3581	0.3038	Y
	39	24.2958	-21.1908	-26.7954	24.2648	-20.8631	-26.9736	0.0310	0.3277	-0.1782	0.3743	0.3277	Y
	40	27.9160	-22.3546	-23.8861	27.8699	-22.0199	-24.0977	0.0461	0.3347	-0.2116	0.3987	0.3347	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-9. Occupant Compartment Deformation Data – Set 1, Test No. H42S-2

Model Year: 2015 | Test Name: H42S-2 | VIN: KMHCT4AE1FU907729
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	0.0	≤ 4	Z
Windshield[D]	1.1	≤ 3	X, Z		Windshield[D]	NA	≤ 3	X, Z
A-Pillar Maximum	0.4	≤ 5	Y		A-Pillar Maximum	0.0	≤ 5	NA
A-Pillar Lateral	0.4	≤ 3	Y		A-Pillar Lateral	0.0	≤ 3	Y
B-Pillar Maximum	0.3	≤ 5	X, Y		B-Pillar Maximum	0.0	≤ 5	NA
B-Pillar Lateral	0.4	≤ 3	Y		B-Pillar Lateral	0.0	≤ 3	Y
Toe Pan - Wheel Well	1.0	≤ 9	X, Z		Toe Pan - Wheel Well	0.0	≤ 9	NA
Side Front Panel	1.3	≤ 12	Y		Side Front Panel	0.0	≤ 12	Y
Side Door (above seat)	-1.4	≤ 9	Y		Side Door (above seat)	0.0	≤ 9	Y
Side Door (below seat)	0.1	≤ 12	Y		Side Door (below seat)	0.0	≤ 12	Y
Floor Pan	0.6	≤ 12	Z		Floor Pan	0.0	≤ 12	Z
Dash - no MASH requirement	0.8	NA	X, Y, Z		Dash - no MASH requirement	0.8	NA	X, Y, Z

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

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

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

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

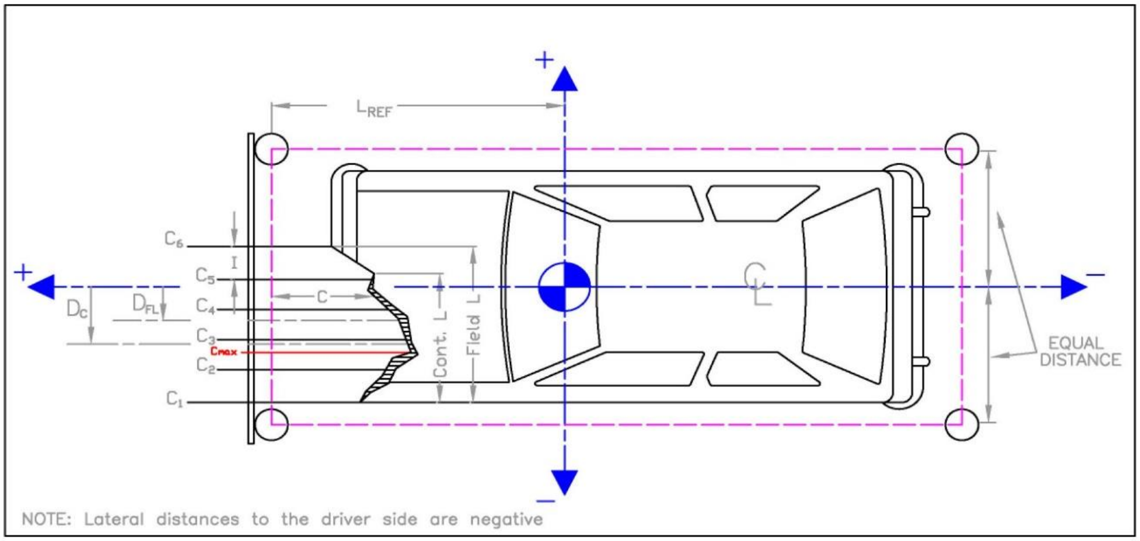
Notes on vehicle crush:

The secondary reference points were visibly compromised so these measurements were omited.

Figure C-10. Maximum Occupant Compartment Deformation by Location, Test No. H42S-2

Test Name: H42S-2 **VIN:** KMHCT4AE1FU907729

Model Year: 2015 **Make:** Hyundai **Model:** Accent



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	91	(2311)
Total Width of Vehicle:	67	(1702)
Width of contact and induced crush - Field L:	67	(1702)
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:	67	(1702)
Distance from center of vehicle to center of contact damage - D_C:	0	()

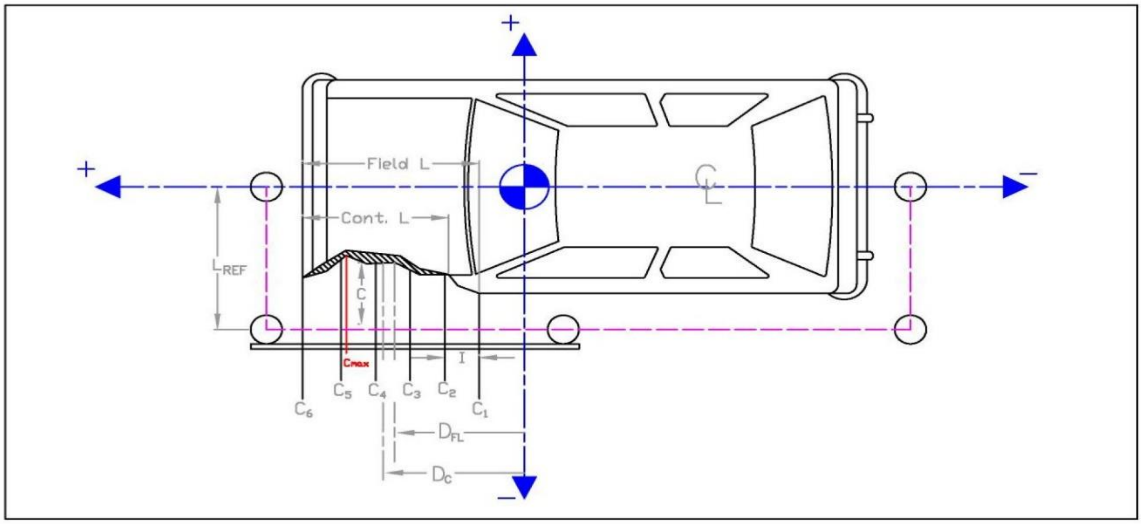
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Lateral Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	N/a	NA	-33 1/2	-(851)	15 5/8	(397)	16 7/8	(429)	NA	NA
C_2	28 3/4	(730)	-20 1/8	-(511)	7	(178)			4 7/8	(124)
C_3	24 1/4	(616)	-6 3/4	-(171)	4 3/8	(111)			3	(76)
C_4	22 7/8	(581)	6 5/8	(168)	4 1/2	(114)			1 1/2	(38)
C_5	24	(610)	20	(508)	6 7/8	(175)			1/4	(6)
C_6	N/a	NA	33 3/8	(848)	15 5/8	(397)			NA	NA
C_{MAX}	28 3/4	(730)	-20 1/8	-(511)	7	(178)			4 7/8	(124)

Figure C-11. Exterior Vehicle Crush (NASS) – Front, Test No. H42S-2

Test Name: H42S-2 **VIN:** KMHCT4AE1FU907729

Model Year: 2015 **Make:** Hyundai **Model:** Accent



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	39 1/2	(1003)
Total Vehicle Length:	171 3/4	(4362)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-15 1/2	-(394)
Width of contact and induced crush - Field L:	171 3/4	(4362)
Crush measurement spacing interval (L/5) - I:	34 3/8	(873)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-15 1/2	-(394)
Width of Contact Damage:	171 3/4	(4362)
Distance from vehicle c.g. to center of contact damage - D_C:	15 1/2	(394)

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

	Crush Measurement		Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	N/A	NA	-101 3/8	-(2575)	41 1/4	(1048)	-1 3/4	-(44)	NA	NA
C_2	N/A	NA	-67	-(1702)	7	(178)			NA	NA
C_3	6 7/8	(175)	-32 5/8	-(829)	8 1/8	(206)			1/2	(13)
C_4	6 1/2	(165)	1 3/4	(44)	8 1/4	(210)			0	()
C_5	N/A	NA	36 1/8	(918)	7	(178)			NA	NA
C_6	N/A	NA	70 1/2	(1791)	27 1/2	(699)			NA	NA
C_{MAX}	11 3/4	(298)	55	(1397)	8 1/2	(216)			5	(127)

Figure C-12. Exterior Vehicle Crush (NASS) – Side, Test No. H42S-2

Appendix D. Accelerometer and Rate Transducer Data Plots, Test No. H42S-1

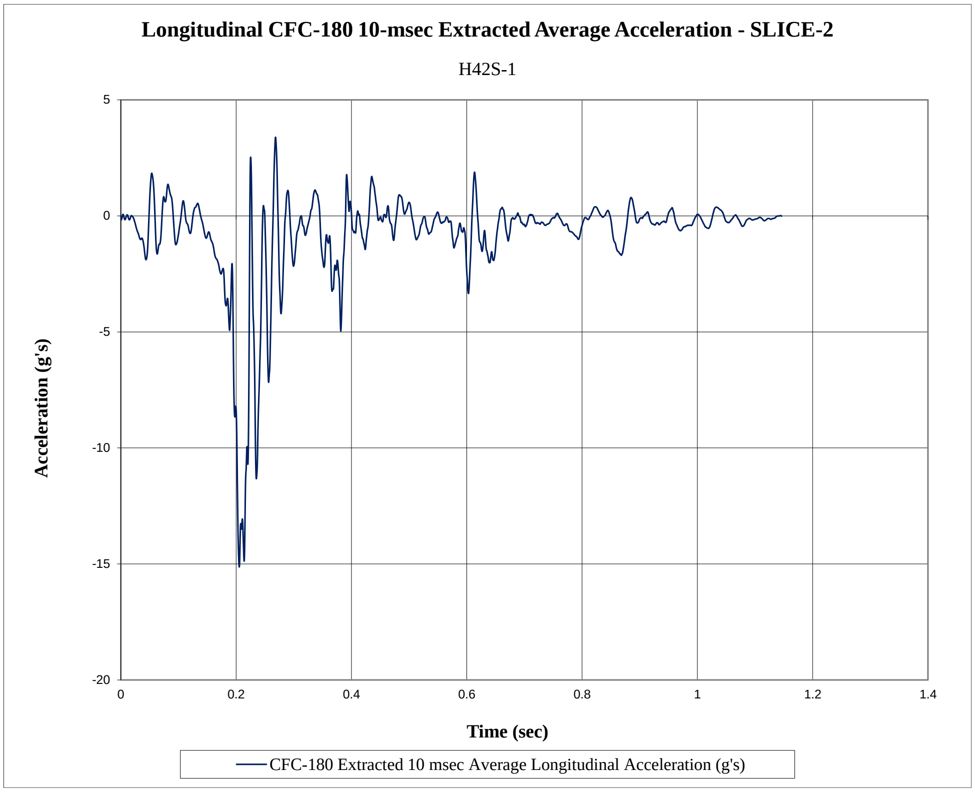


Figure D-1. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. H42S-1

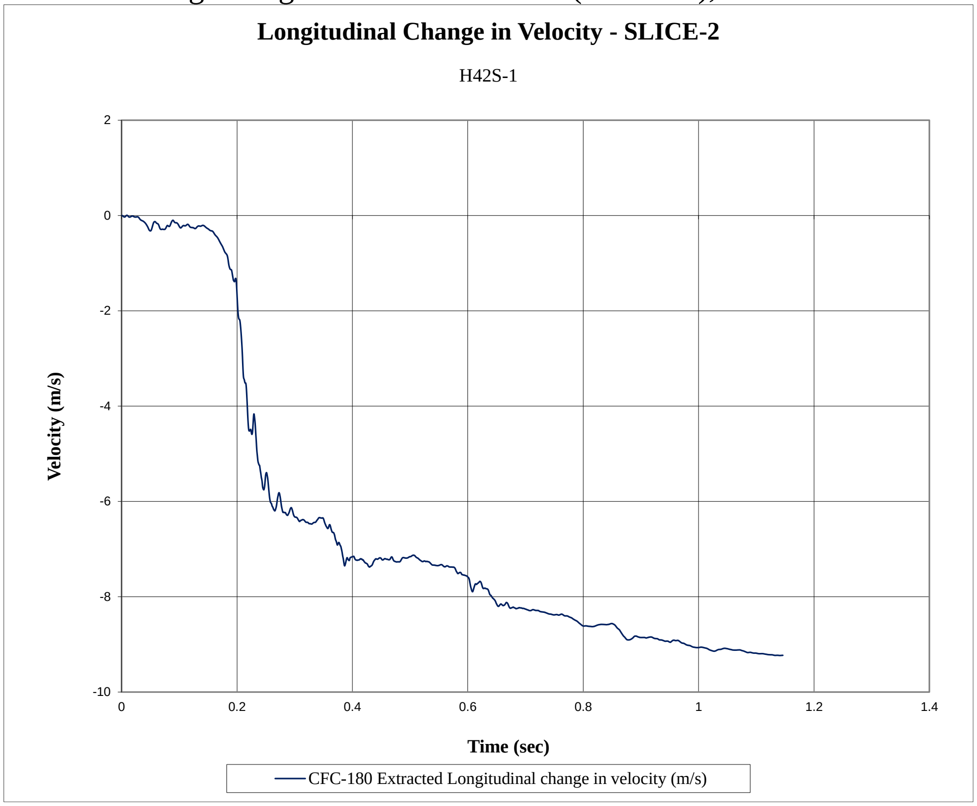


Figure D-2. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. H42S-1

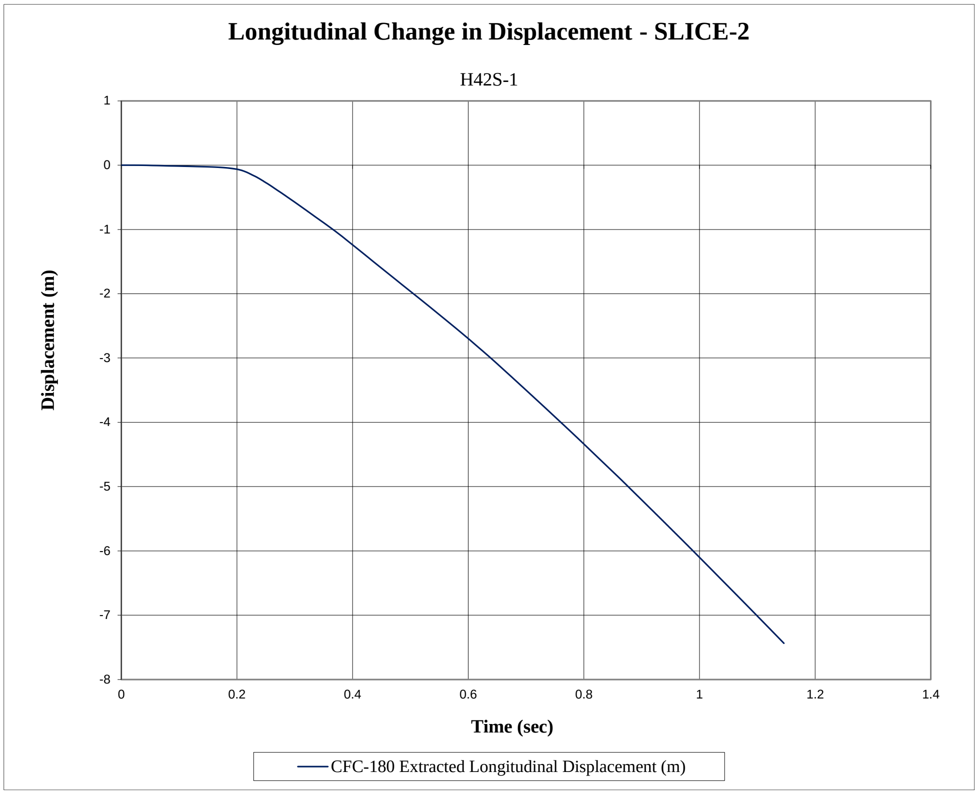


Figure D-3. Longitudinal Occupant Displacement (SLICE-2), Test No. H42S-1

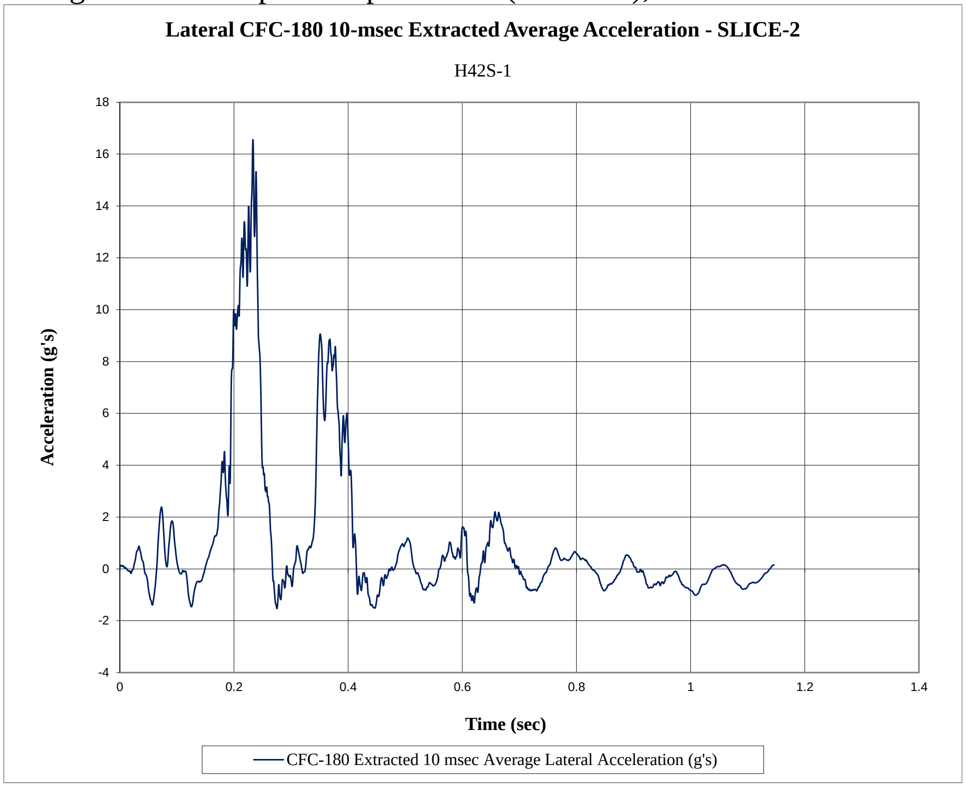


Figure D-4. 10-ms Average Lateral Deceleration (SLICE-2), Test No. H42S-1

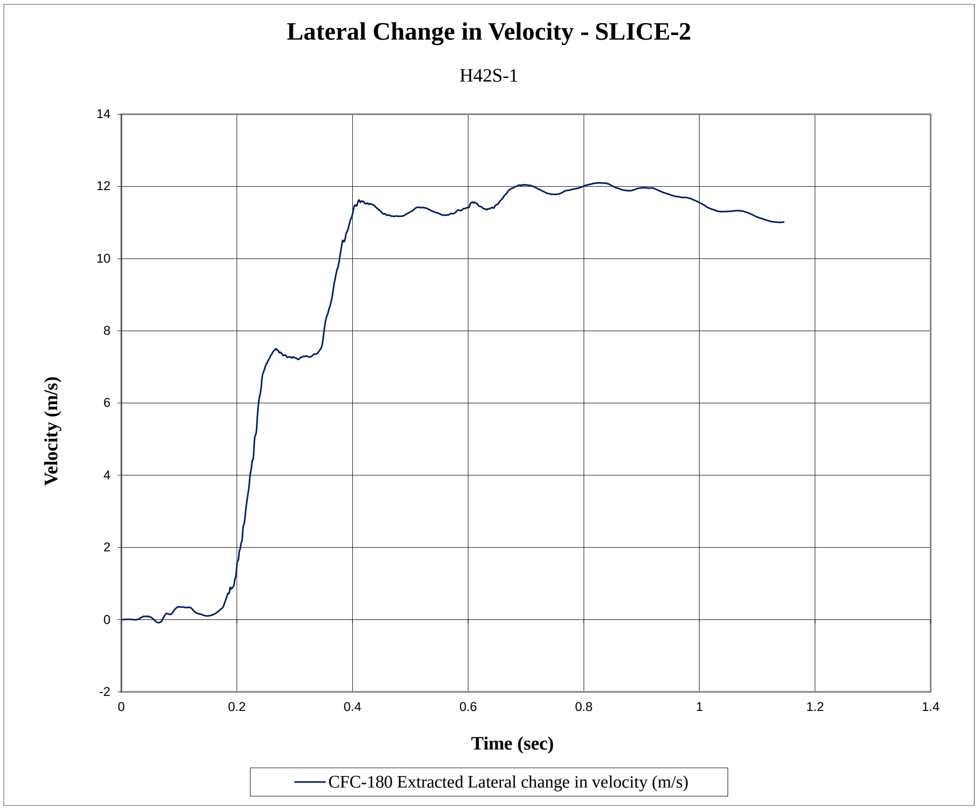


Figure D-5. Lateral Occupant Impact Velocity (SLICE-2), Test No. H42S-1

Figure D-6. Lateral Occupant Displacement (SLICE-2), Test No. H42S-1

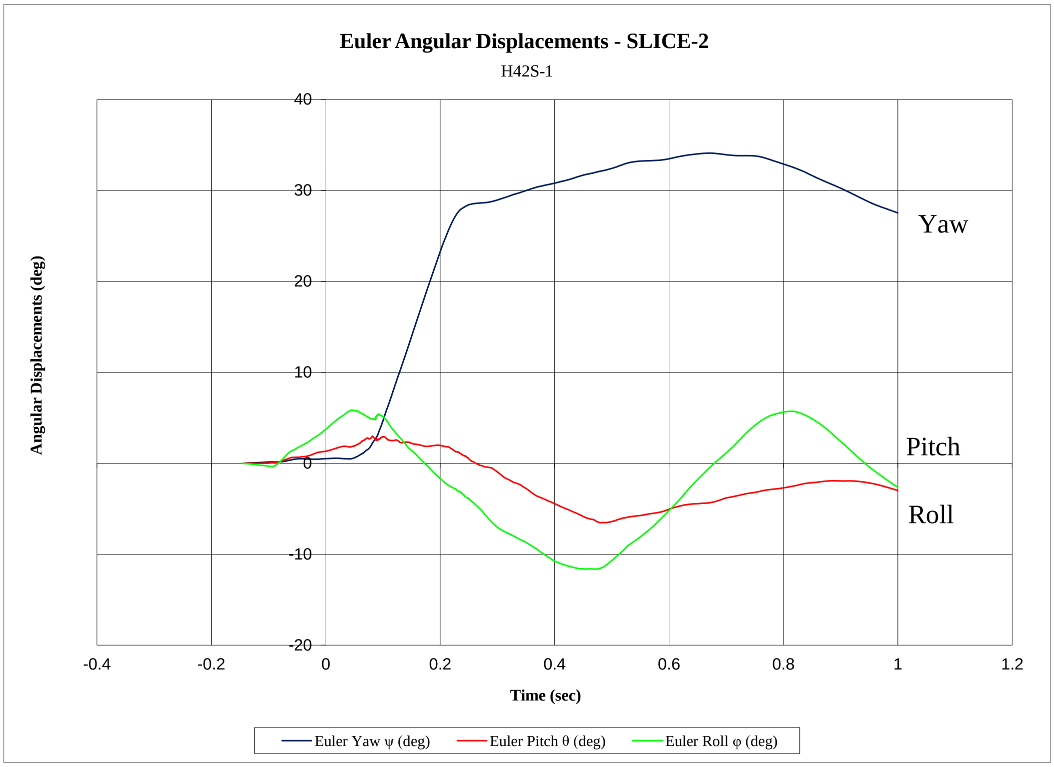


Figure D-7. Vehicle Angular Displacements (SLICE-2), Test No. H42S-1

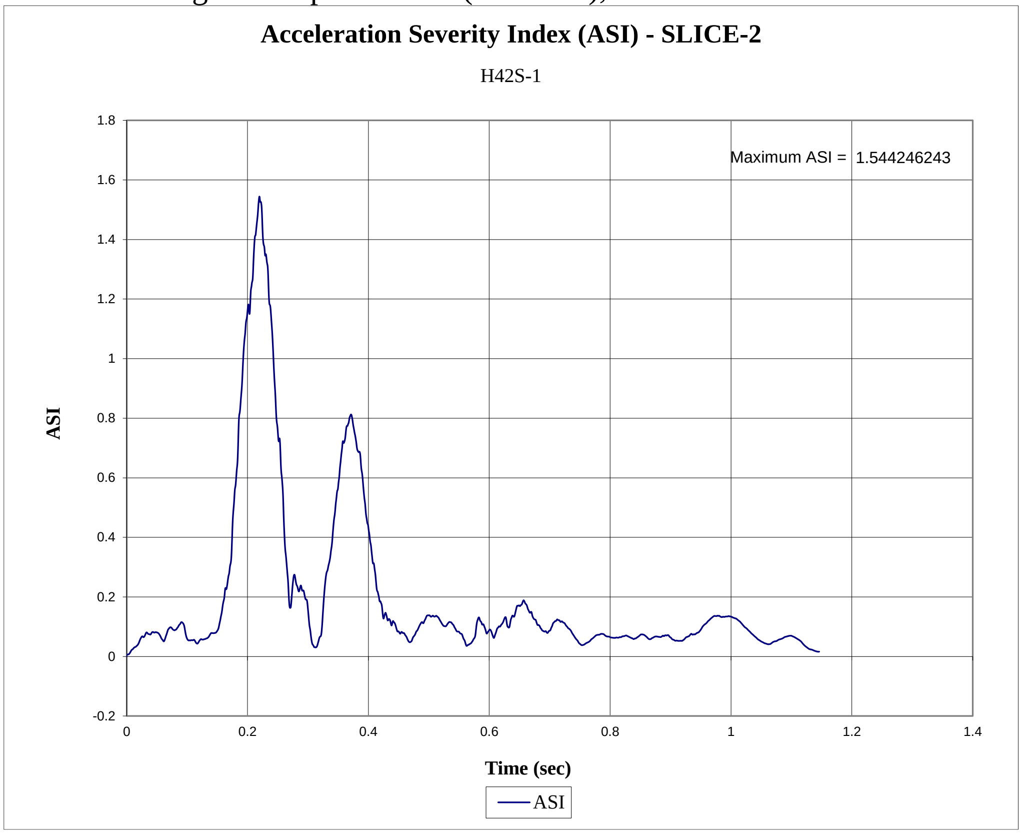


Figure D-8. Acceleration Severity Index (SLICE-2), Test No. H42S-1

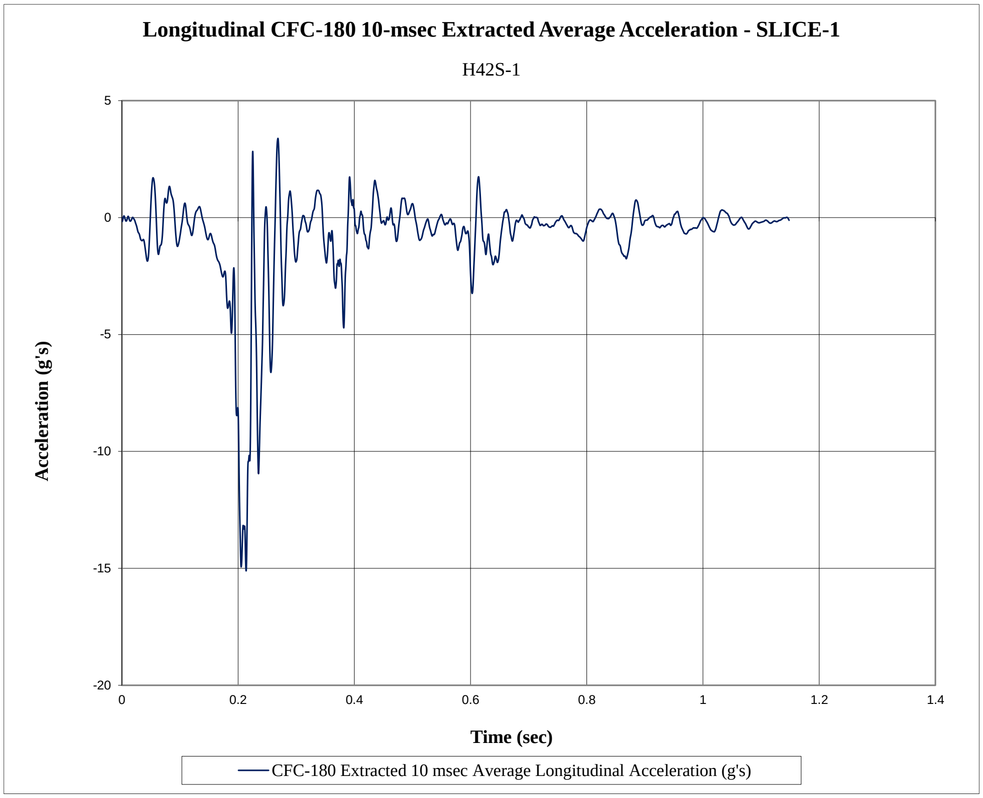


Figure D-9. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. H42S-1

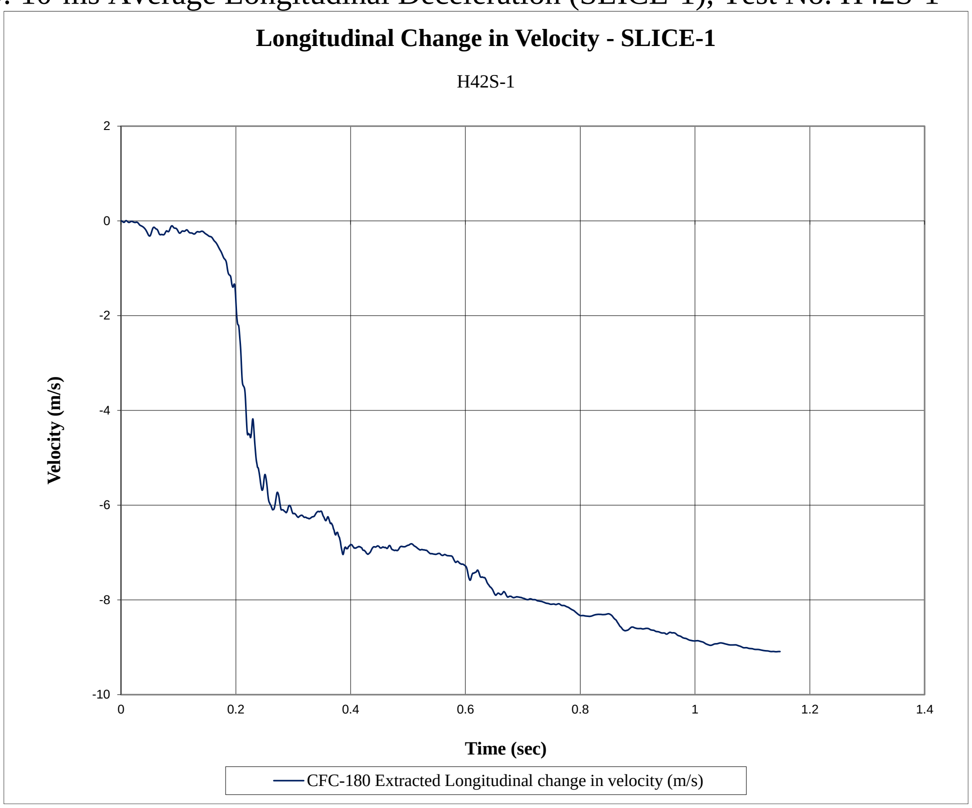


Figure D-10. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. H42S-1

Figure D-11. Longitudinal Occupant Displacement (SLICE-1), Test No. H42S-1

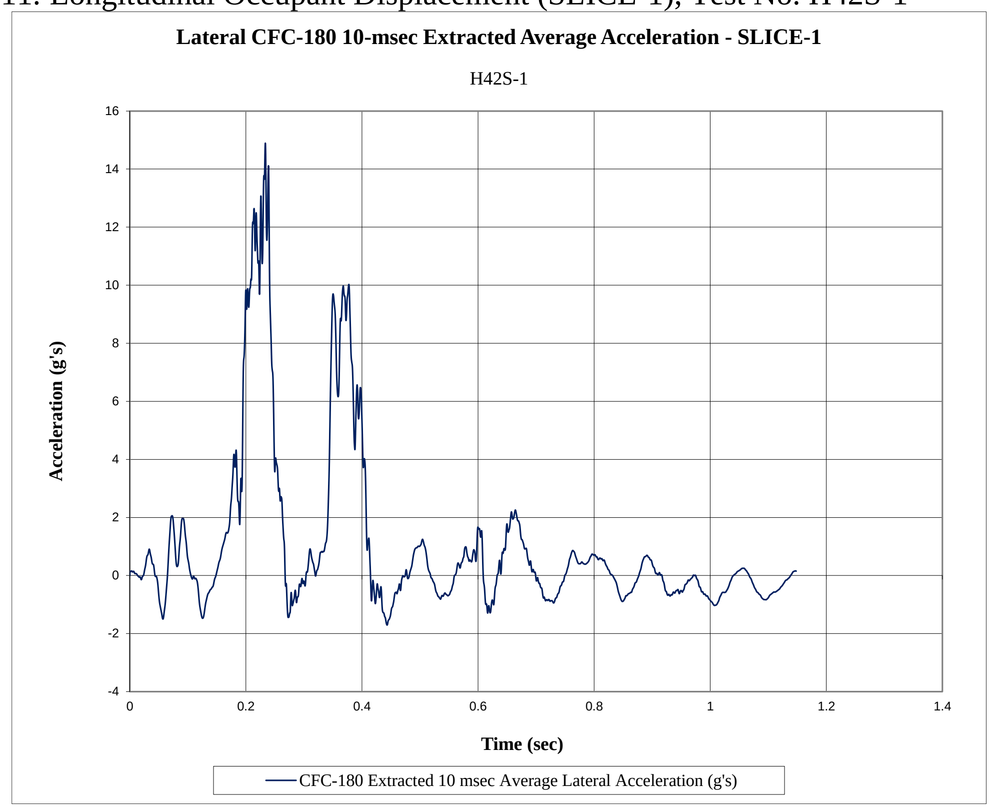


Figure D-12. 10-ms Average Lateral Deceleration (SLICE-1), Test No. H42S-1

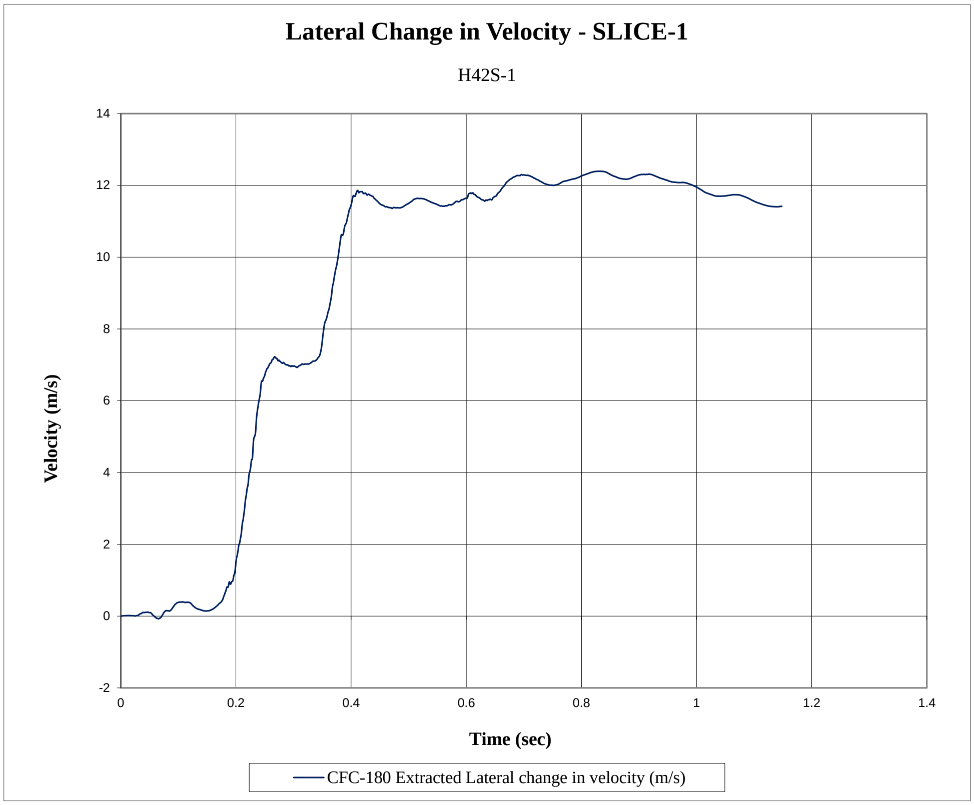


Figure D-13. Lateral Occupant Impact Velocity (SLICE-1), Test No. H42S-1

Figure D-14. Lateral Occupant Displacement (SLICE-1), Test No. H42S-1

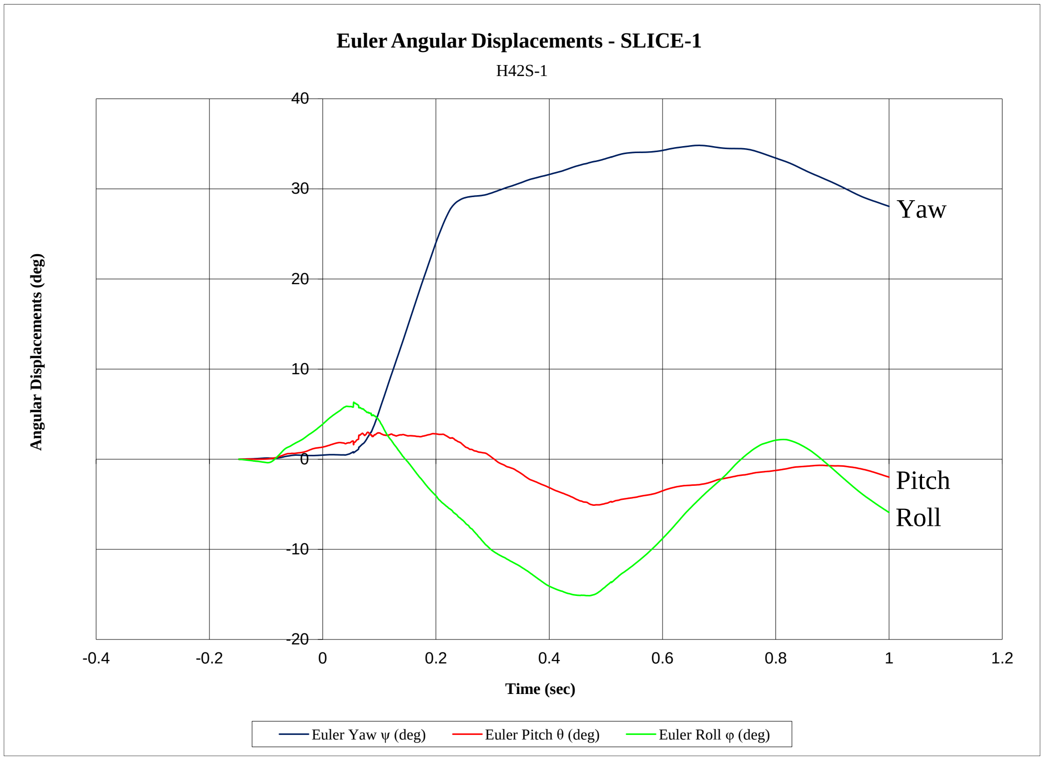


Figure D-15. Vehicle Angular Displacements (SLICE-1), Test No. H42S-1

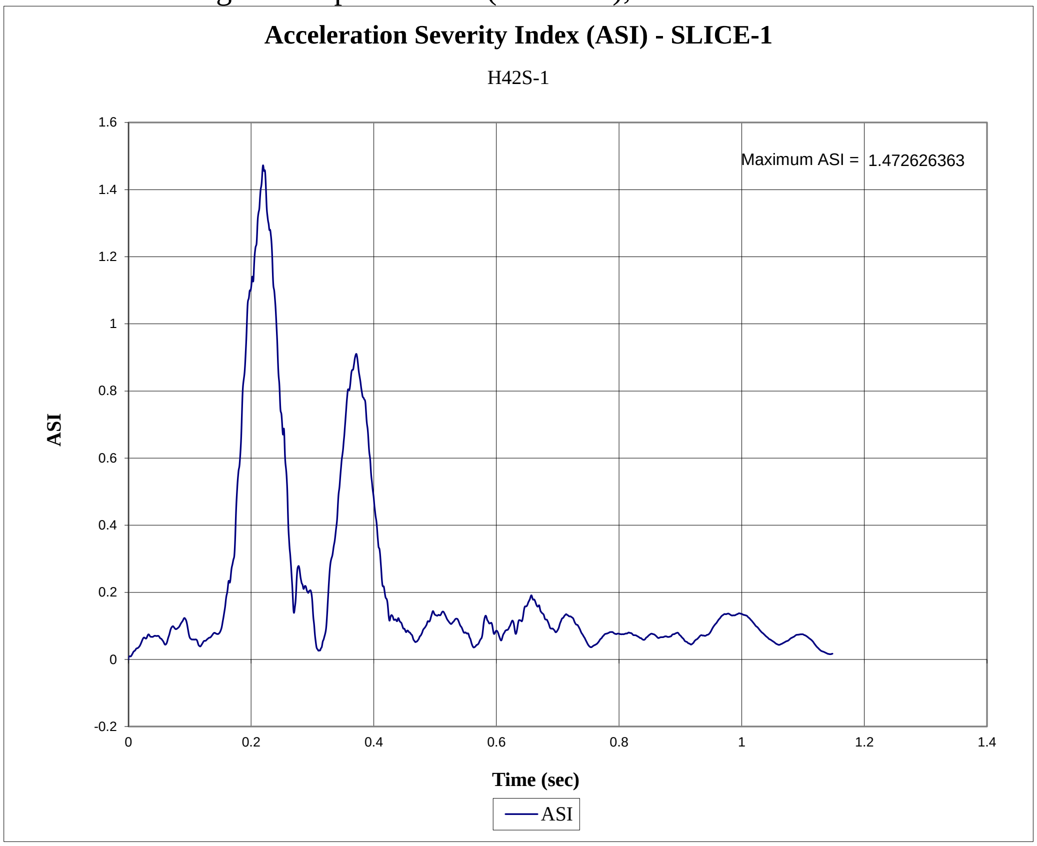


Figure D-16. Acceleration Severity Index (SLICE-1), Test No. H42S-1

Appendix E. Accelerometer and Rate Transducer Data Plots, Test No. H42S-2

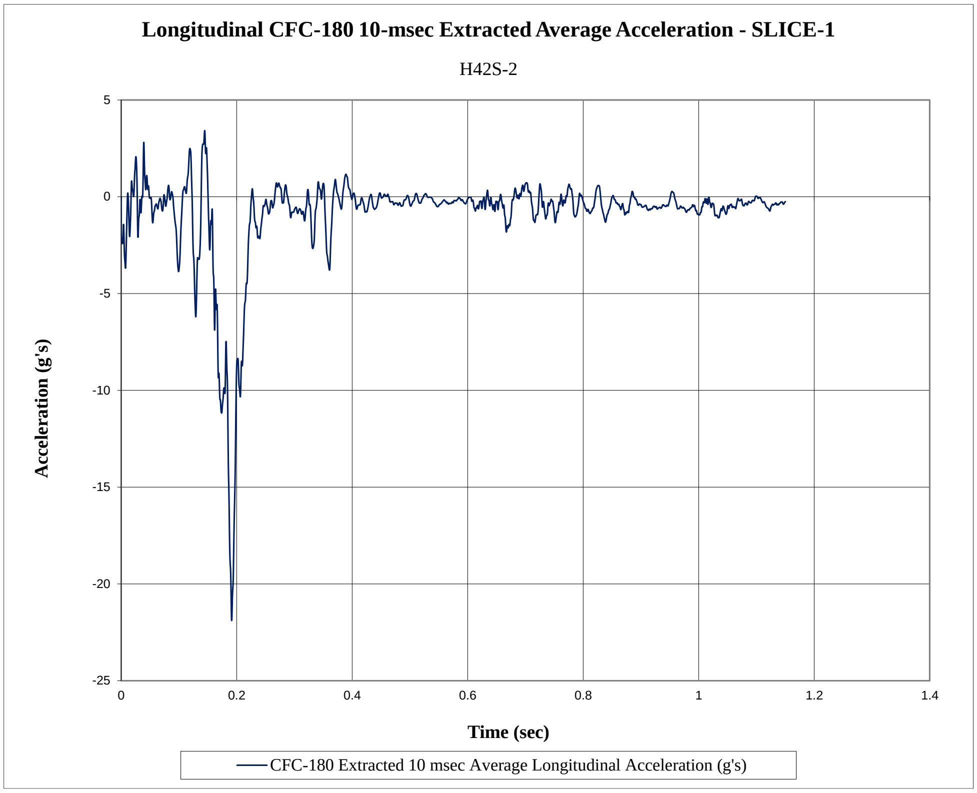


Figure E-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. H42S-2

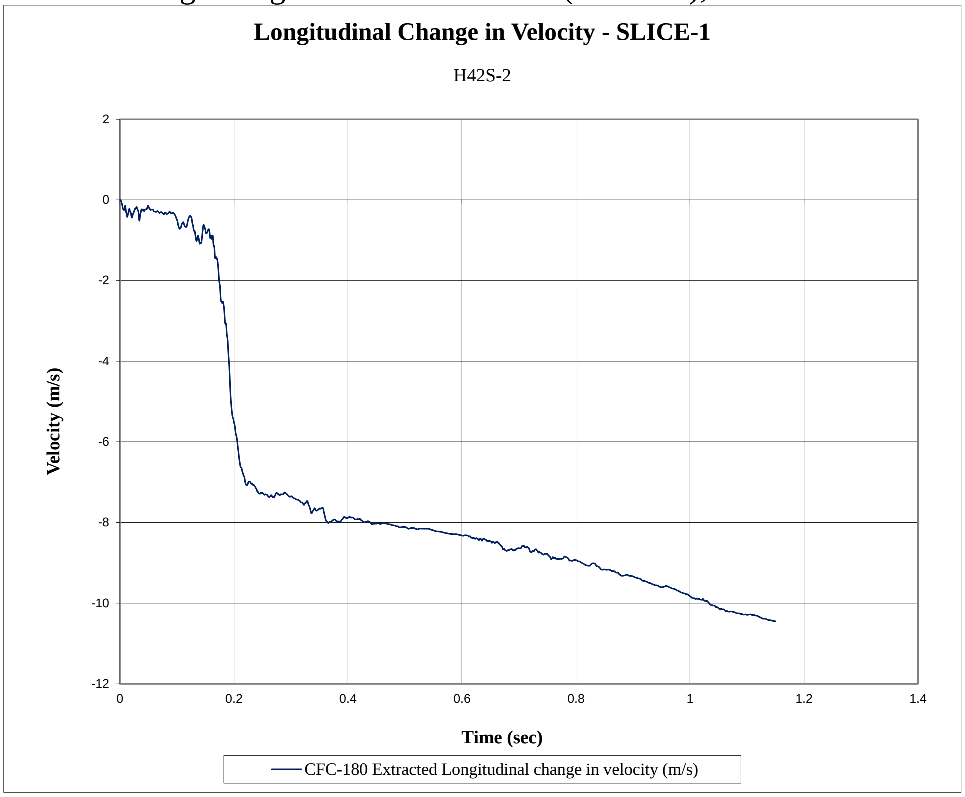


Figure E-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. H42S-2

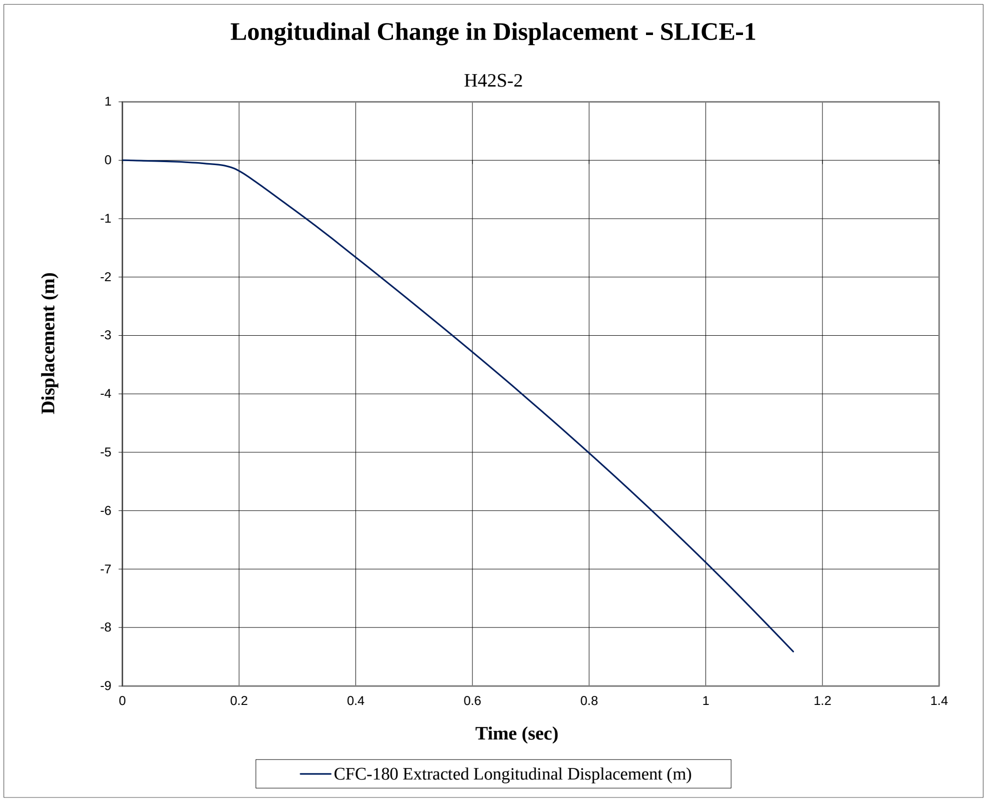


Figure E-3. Longitudinal Occupant Displacement (SLICE-1), Test No. H42S-2

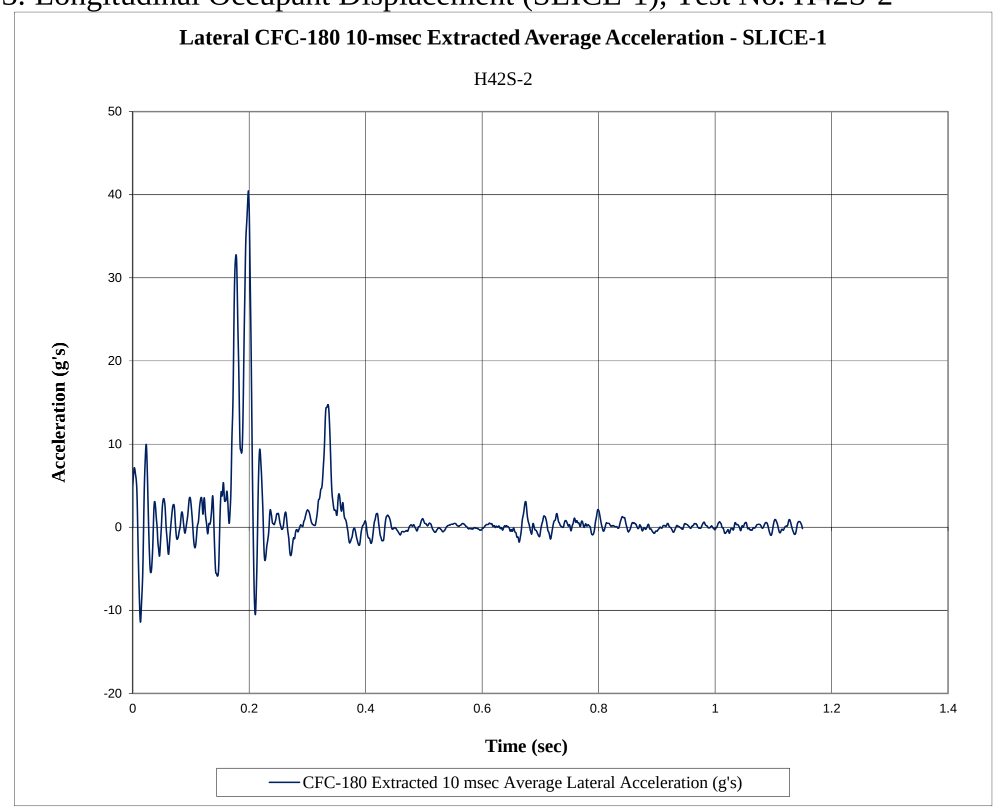


Figure E-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. H42S-2

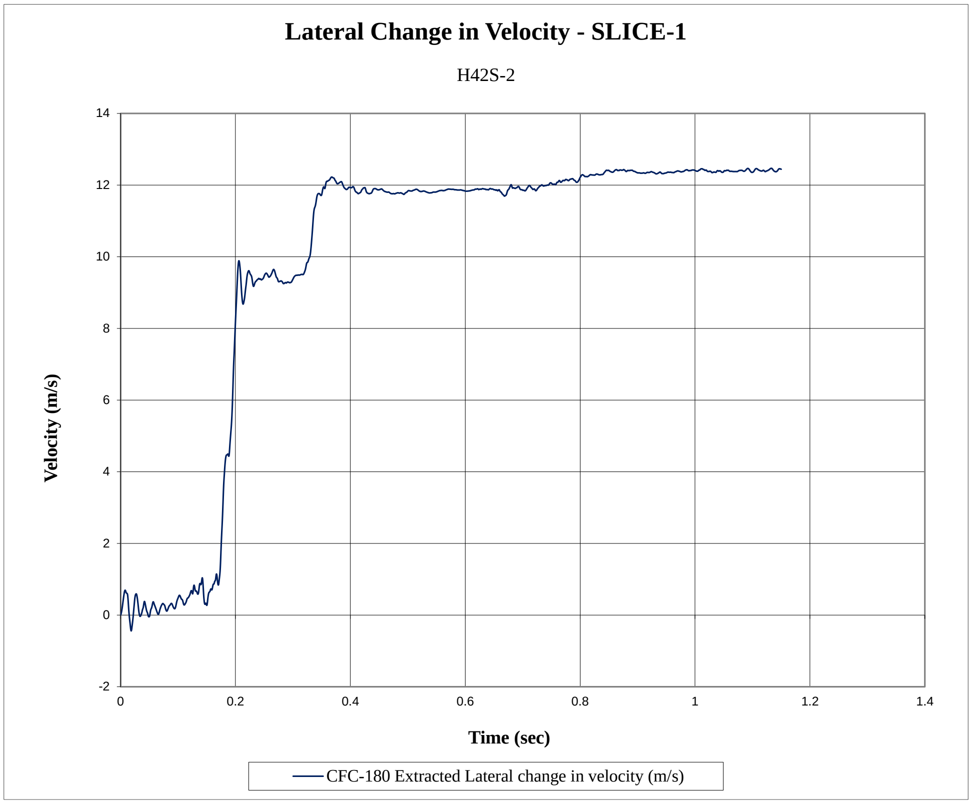


Figure E-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. H42S-2

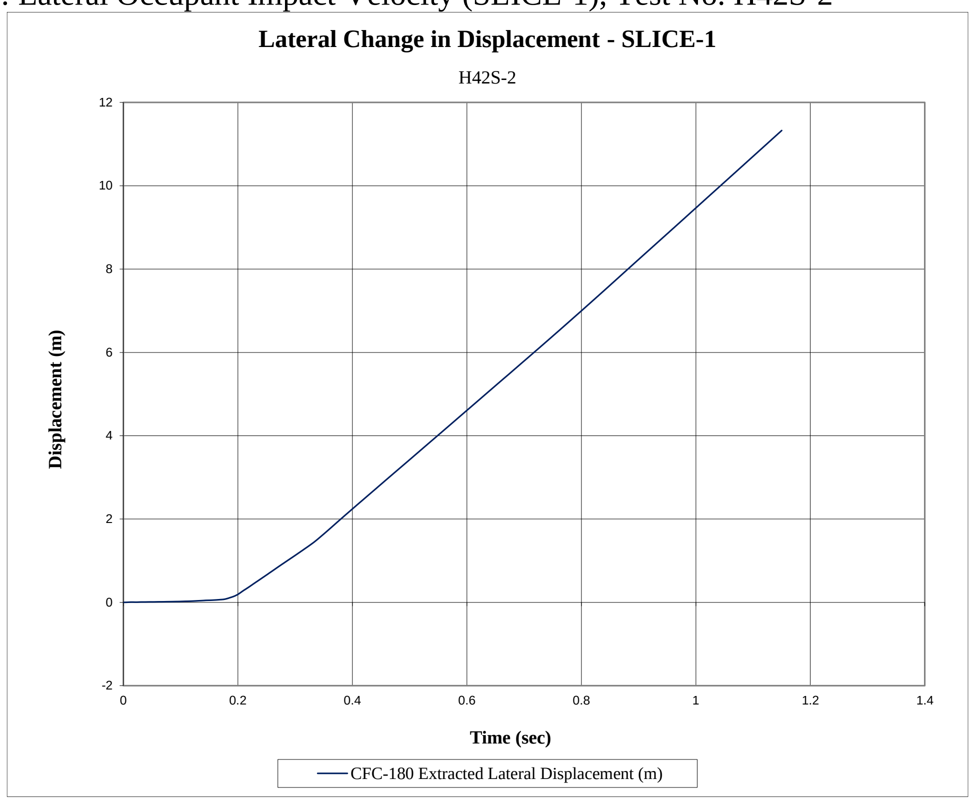


Figure E-6. Lateral Occupant Displacement (SLICE-1), Test No. H42S-2

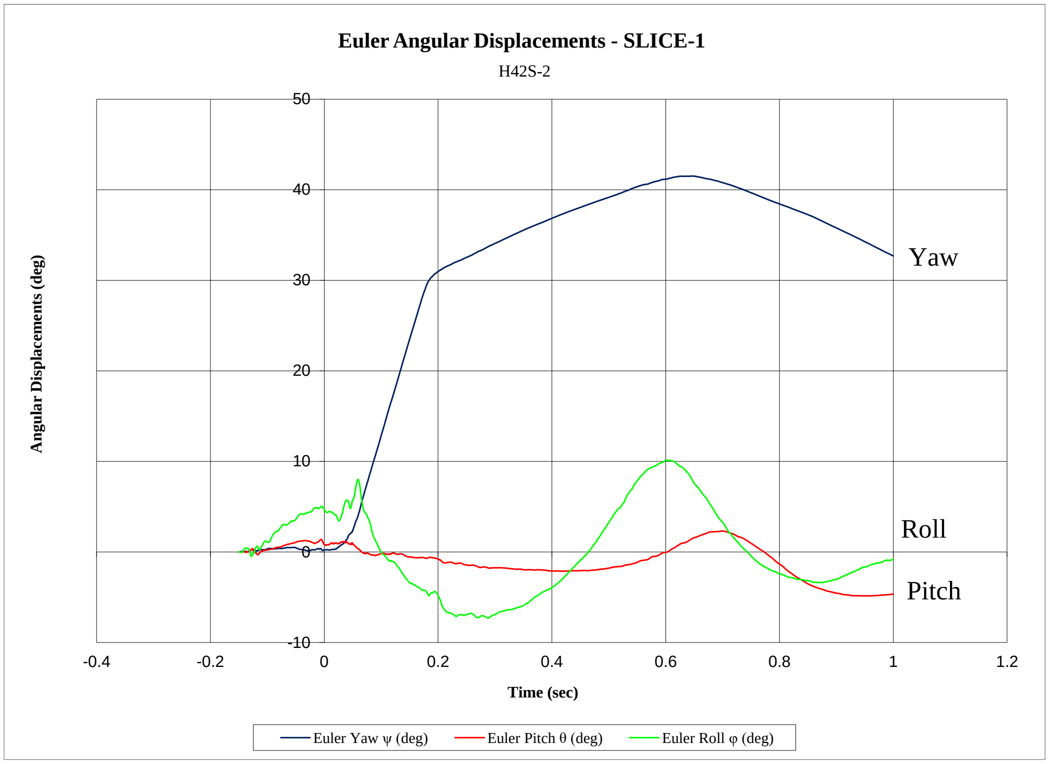


Figure E-7. Vehicle Angular Displacements (SLICE-1), Test No. H42S-2

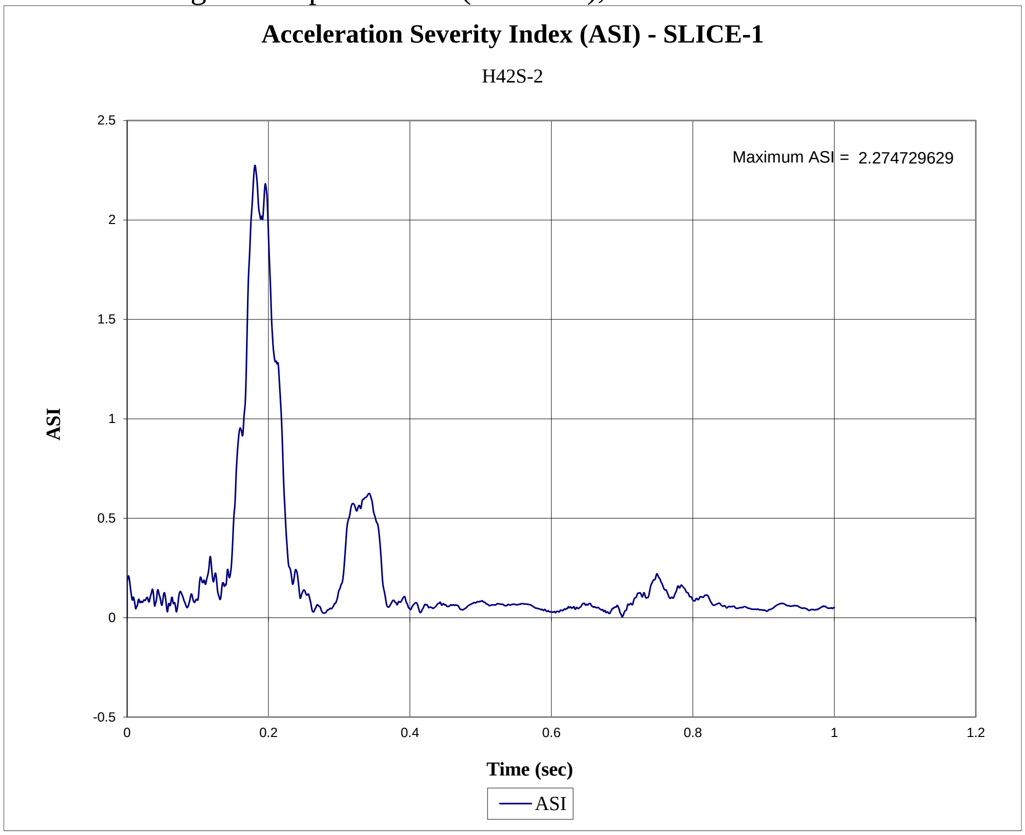


Figure E-8. Acceleration Severity Index (SLICE-1), Test No. H42S-2

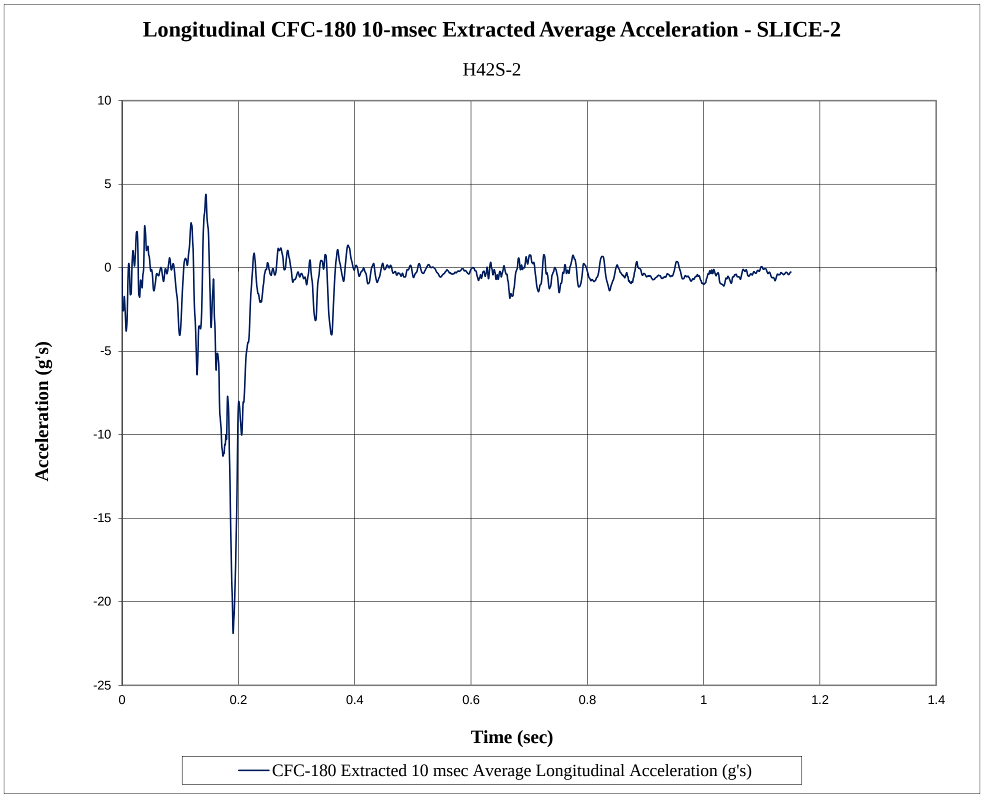


Figure E-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. H42S-2

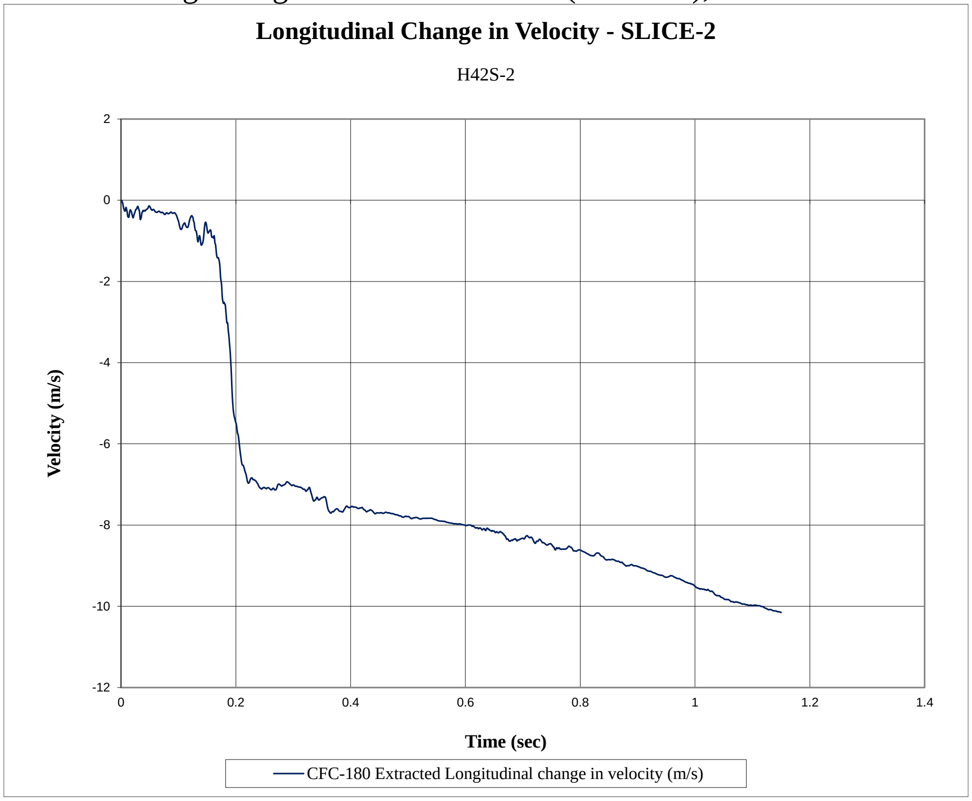


Figure E-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. H42S-2

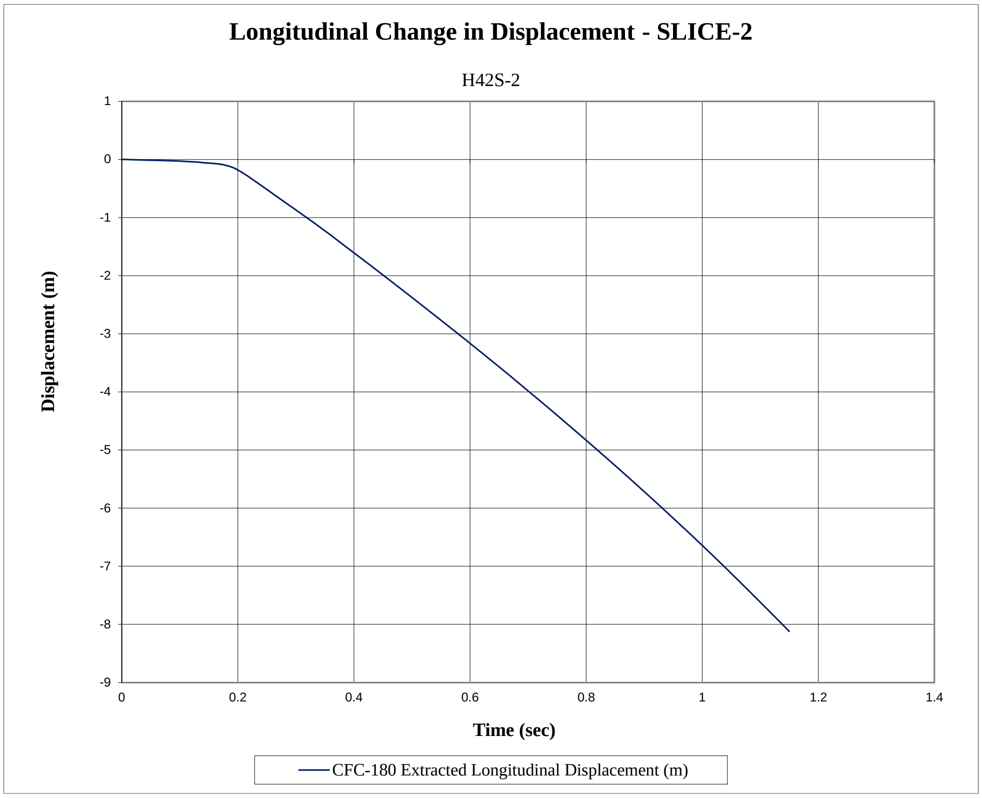


Figure E-11. Longitudinal Occupant Displacement (SLICE-2), Test No. H42S-2

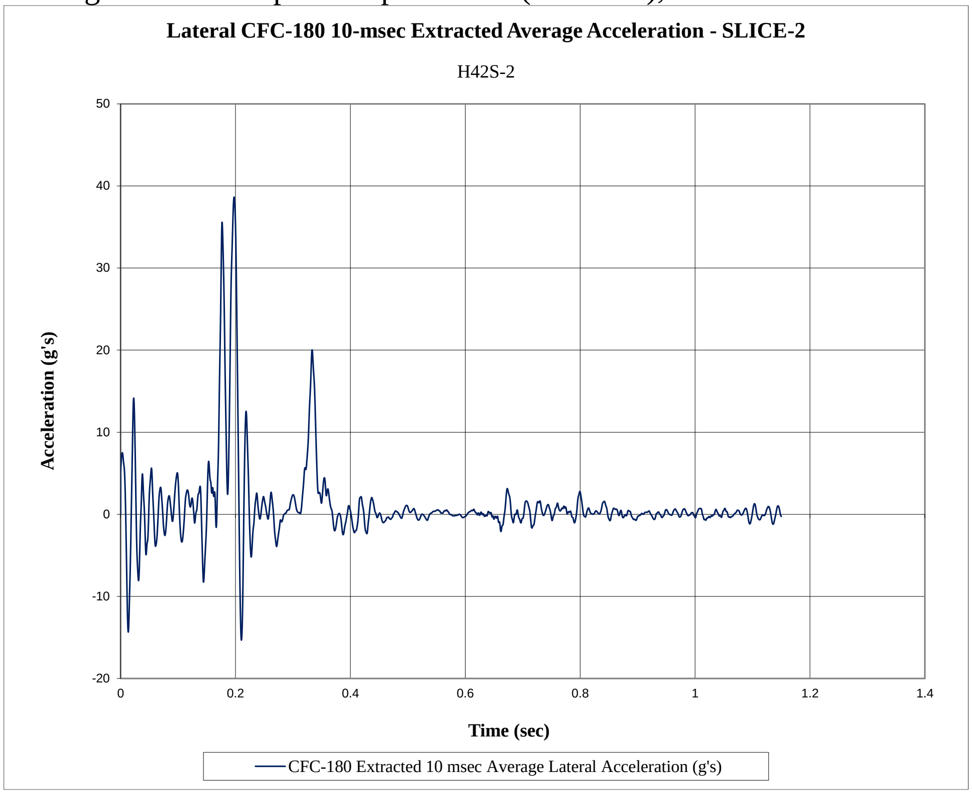


Figure E-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. H42S-2

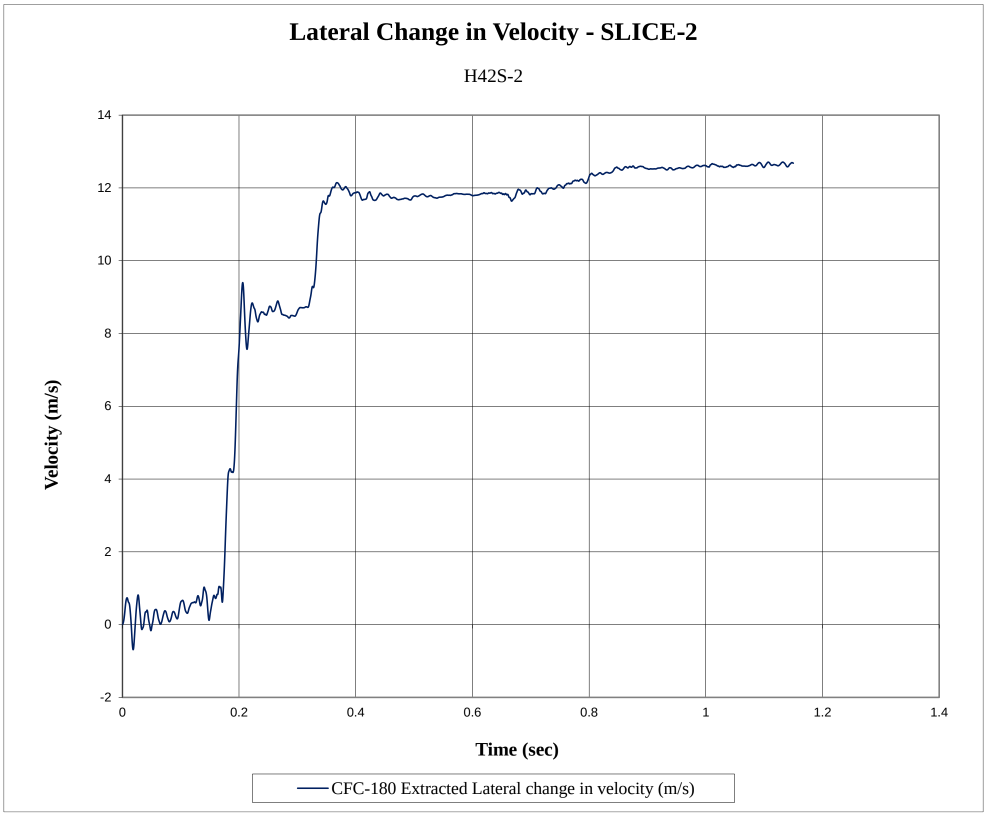


Figure E-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. H42S-2

Figure E-14. Lateral Occupant Displacement (SLICE-2), Test No. H42S-2

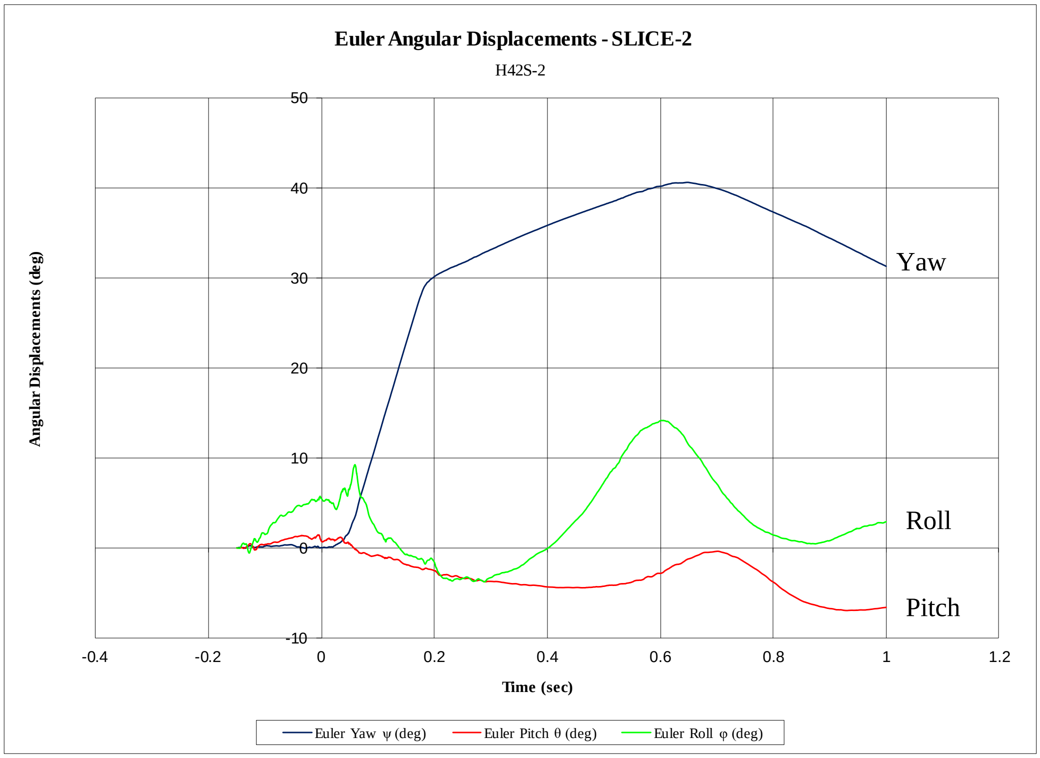


Figure E-15. Vehicle Angular Displacements (SLICE-2), Test No. H42S-2

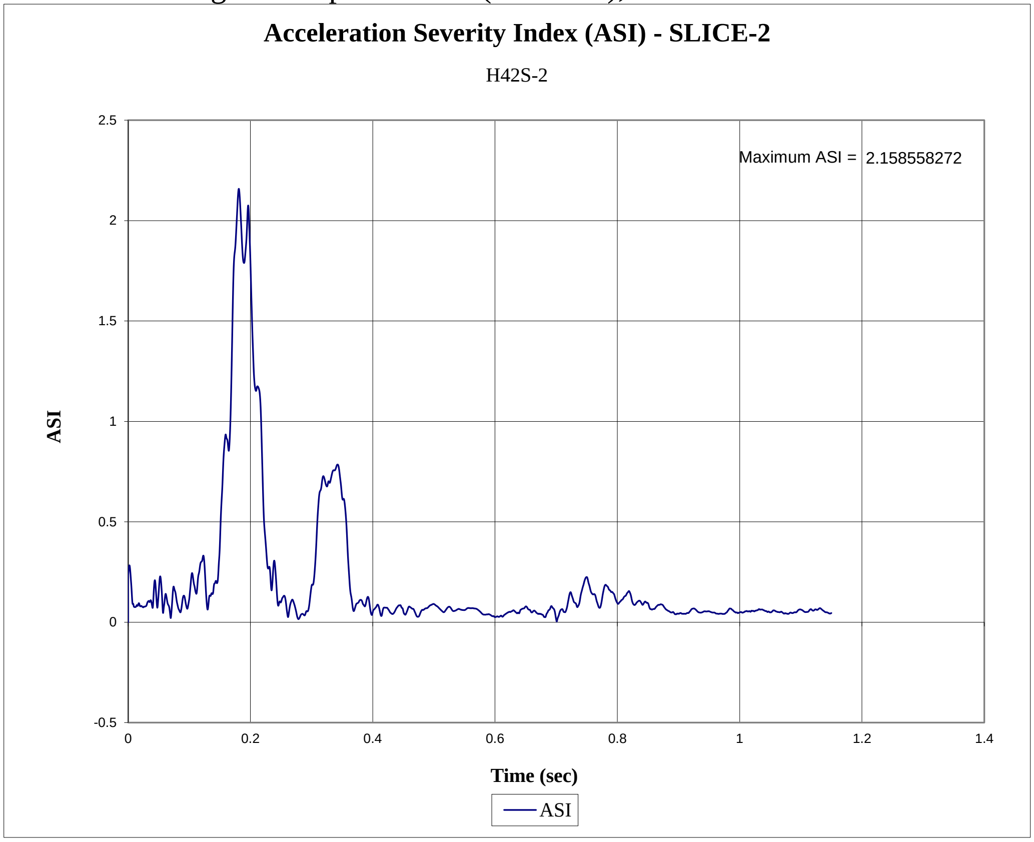


Figure E-16. Acceleration Severity Index (SLICE-2), Test No. H42S-2

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