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EVALUATION OF THE HAWAII MODIFIED NATCHEZ TRACE BRIDGE RAIL: MASH TEST DESIGNATION NO. 3-11

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16. Abstract

The Hawaii Department of Transportation (HDOT) utilizes the Hawaii Modified Natchez Trace Bridge Rail to safely redirect vehicles on bridges. However, the crashworthiness of this bridge rail has not been investigated under current impact safety standards. This report documents one full-scale crash test conducted to evaluate the safety performance of HDOT's Hawaii Modified Natchez Trace Bridge Rail. The system had a mounting height of 36 in. and varied in width from 18¼ in. at the top to 24 in. at the bottom. The bridge rail design utilized 12-in. long by 12-in. wide posts that were spaced 90 in. apart on centerlines and mounted on top of a 10-in. high curb. The test installation had an overall length of 70 ft – 7 in. and incorporated three railing segments with ½-in. expansion joints placed at the end of each rail segment. Test no. HNTBR-1 was conducted according to the *Manual for Assessing Safety Hardware* (MASH) test designation no. 3-11.

In test no. HNTBR-1, a 2270P vehicle impacted the Hawaii Modified Natchez Trace Bridge Rail at a speed of 62.3 mph and an angle of 25.0 degrees. The vehicle was safely contained and redirected with minimal damage to the bridge rail. However, the occupant compartment intrusion at the wheel well and toe pan measured 12.7 in., which exceeded the MASH limit of 9 in. Thus, test no. HNTBR-1 failed to satisfy the safety standards of MASH. The system will need to be redesigned and re-tested in future research efforts.

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DISCLAIMER STATEMENT

This material is based upon work supported by the Federal Highway Administration, U.S. Department of Transportation, and the Hawaii Department of Transportation under Research Contract No. 69876. The contents of this report reflect the views and opinions of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the University of Nebraska-Lincoln, Hawaii Department of Transportation nor the Federal Highway Administration, U.S. Department of Transportation. This report does not constitute a standard, specification, or regulation. Trade or manufacturers' names, which may appear in this report, are cited only because they are considered essential to the objectives of the report. The United States (U.S.) government and the States of Nebraska and Hawaii do not endorse products or manufacturers.

UNCERTAINTY OF MEASUREMENT STATEMENT

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

INDEPENDENT APPROVING AUTHORITY

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

A2LA ACCREDITATION

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

ACKNOWLEDGEMENTS

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in.	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1,000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short ton (2,000 lb)	0.907	megagrams (or “metric ton”)	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5(F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela per square meter	cd/m^2
		FORCE & PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in.
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yard	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliter	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or “metric ton”)	1.103	short ton (2,000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela per square meter	0.2919	foot-Lamberts	fl
		FORCE & PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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

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1 INTRODUCTION

1.1 Background

The Hawaii Department of Transportation (HDOT) utilizes the Hawaii Modified Natchez Trace Bridge Rail to safely redirect vehicles on bridges. However, the crashworthiness of this bridge rail has not been investigated under current impact safety standards. This report documents full-scale crash testing conducted to evaluate the safety performance of the Hawaii Modified Natchez Trace Bridge Rail according to the Test Level 3 (TL-3) criteria of the *Manual for Assessing Safety Hardware* (MASH) [1].

In 1992, the original Natchez Trace Parkway Bridge Rail [2] was evaluated to Performance Level 1 (PL-1) criteria according to the *AASHTO Guide Specifications for Bridge Railings* [3] at the Midwest Roadside Safety Facility (MwRSF). The Natchez Trace Bridge Rail was an open concrete bridge rail positioned atop a 10-in. tall curb, as shown in Figure 1. The railing incorporated a 13-in. tall by 12-in. wide concrete rail supported by 9-in. x 18-in. concrete posts spaced 7 ft – 6¾ in. apart. The face of the curb extended approximately 4½ in. out from the face of the concrete railing.

In test no. NTBR-1, a 1984 Chevrolet Custom Deluxe 20 pickup truck impacted the bridge rail at 45.2 mph and an angle of 22.4 degrees. Upon impact, the test vehicle was smoothly redirected. There was no intrusion or deformation of the occupant compartment, and the bridge rail received only superficial damage. Therefore, test no. NTBR-1 was deemed acceptable according to the NCHRP Report 230 safety performance criteria for test designation PL-1. In test no. NTBR-2, a 1984 Renault Encore small car impacted the bridge rail at 51.5 mph and an angle of 19.5 degrees. Similarly, the vehicle was smoothly redirected with minimal bridge rail damage. Thus, the Natchez Trace Bridge Rail successfully passed all requirements for AASHTO PL-1.

In 2001, researchers at the Texas A&M Transportation Institute (TTI) conducted crash tests to evaluate the Natchez Trace Bridge Rail in accordance with NCHRP Report 350 [4, 5]. The test installation, shown in Figure 2, was identical to the system crash tested at MwRSF except for minor variations in reinforcement.

In test no. 405181-11, a 1997 Geo Metro small car impacted the Natchez Trace Bridge Rail at 62.1 mph and an impact angle of 19.8 degrees. The bridge rail safely contained and redirected the passenger car, resulting in the test successfully passing NCHRP 350 test designation no. 3-10 safety requirements. In test no. 405181-12, a 1997 Chevrolet 2500 pickup truck impacted the Natchez Trace Bridge Rail at 61.1 mph and an impact angle of 26.1 degrees. The bridge rail safely contained and redirected the pickup truck, and the test successfully met NCHRP 350 test designation no. 3-11 evaluation criteria.

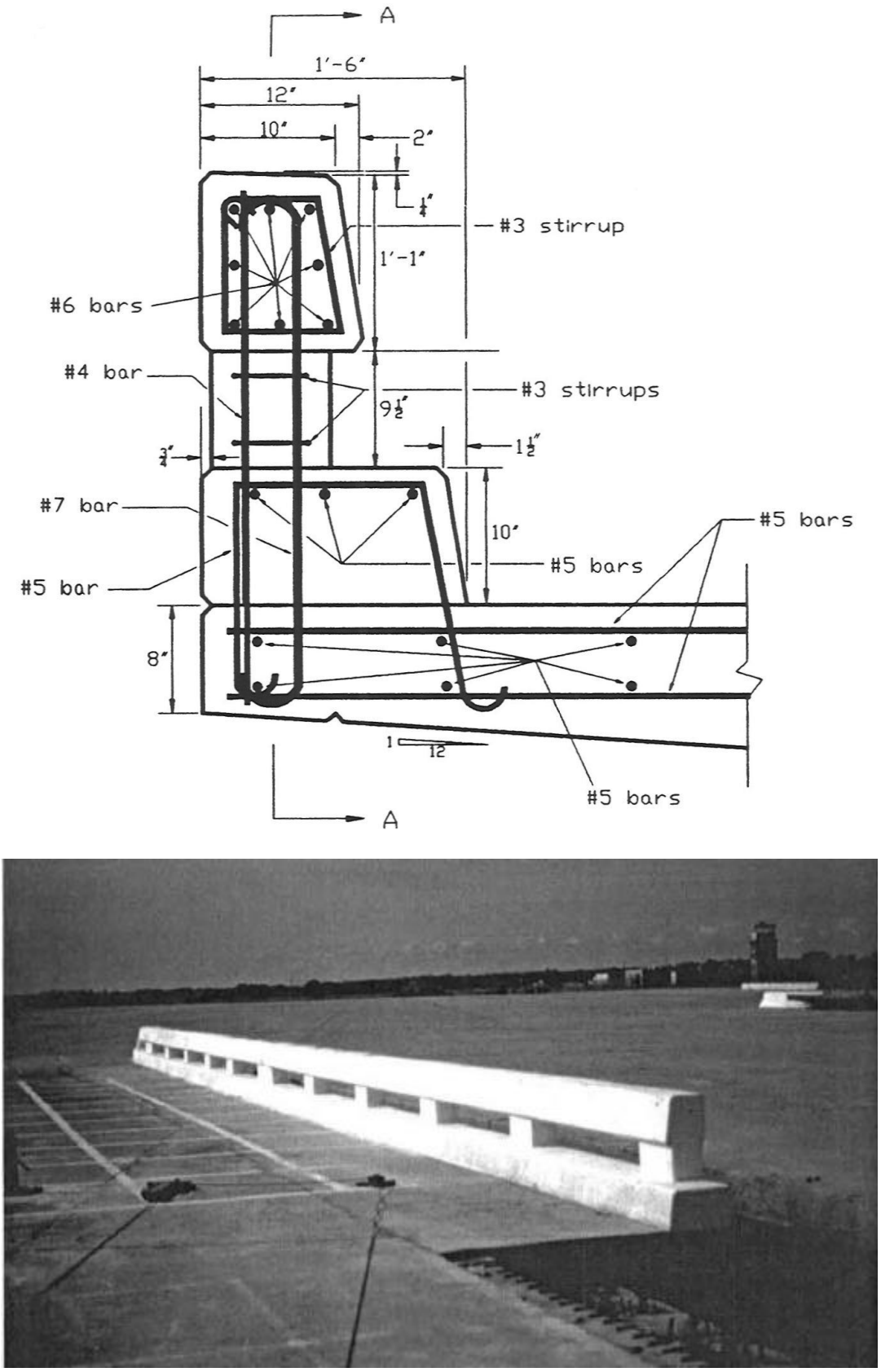


Figure 1. Natchez Trace Bridge Rail Design Details, Test No. NTBR-1 [2]

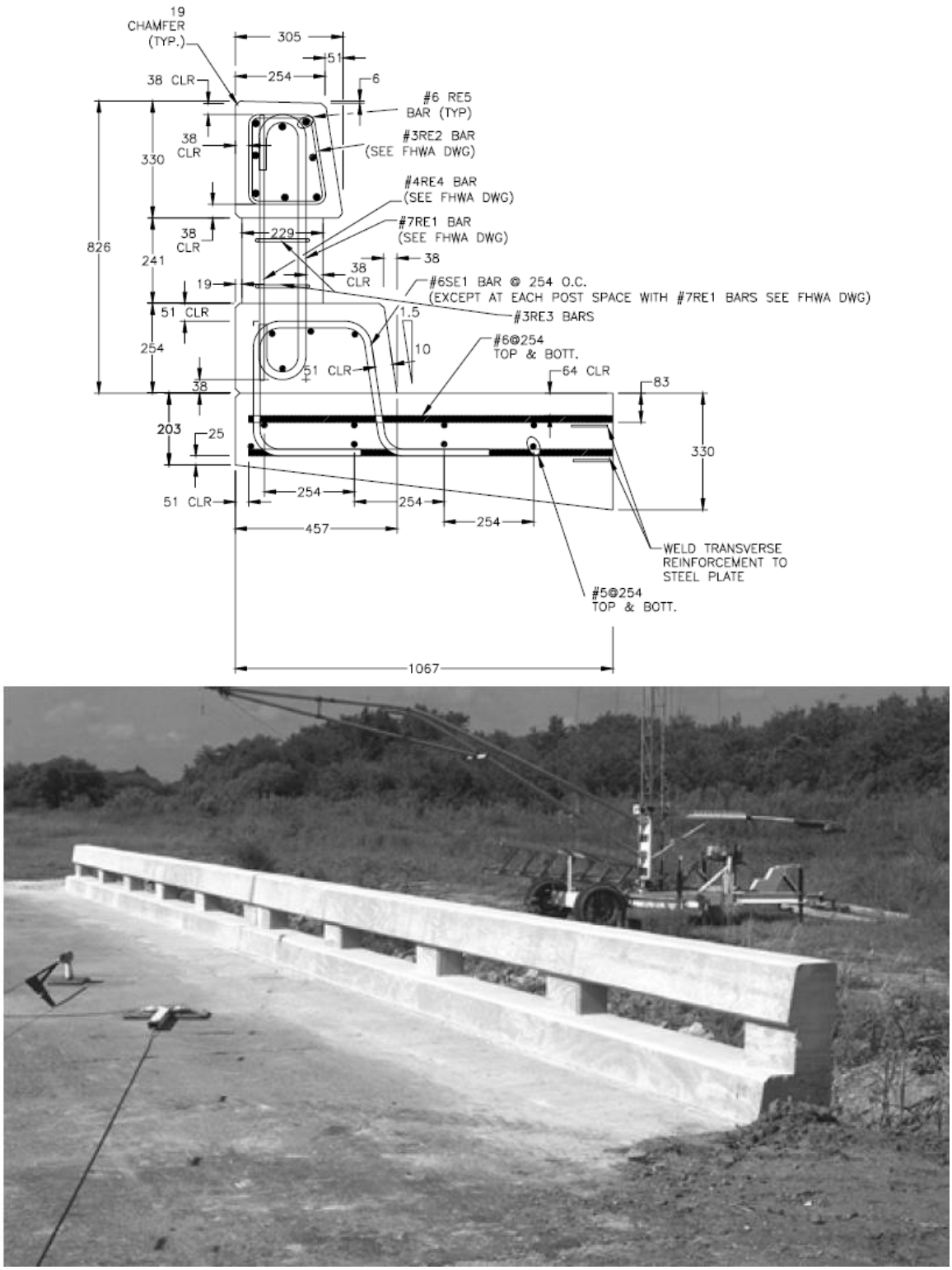


Figure 2. Natchez Trace Bridge Rail Design Details, Test Nos. 405181-11 and 405181-12 (dimensions in mm) [4]

Recently, HDOT desired to have its modified version of the Natchez Trace Bridge Rail evaluated according to MASH TL-3 criteria [1]. The Hawaii-modified version of the Natchez Trace Bridge Rail had several differences compared to the original design previously crash tested at MwRSF [2] and TTI [5]. The height of the Hawaii modified design increased from 32½ in. to 36 in., and the width of the railing also increased significantly. The original Natchez Trace Bridge Rail had a top width of 10 in., a base width of 18 in., and a 4½-in offset between the bottom corner of the rail and the top corner of the curb. The Hawaii modified design had a top width of 18¼ in., a base width of 24 in., and a 1½-in. offset between the bottom corner of the rail and the top corner of the curb. Note, this offset effectively gave the Hawaii modified design a single slope profile when combining the rail and the curb. The Hawaii modified design used smaller, 12-in. long by 12-in. wide posts to support the rail. Finally, the Hawaii design incorporated a steel tube, pedestrian handrail mounted to the back side of the concrete rail. Details for the Hawaii Modified Natchez Trace Bridge Railing are shown in Figure 3.

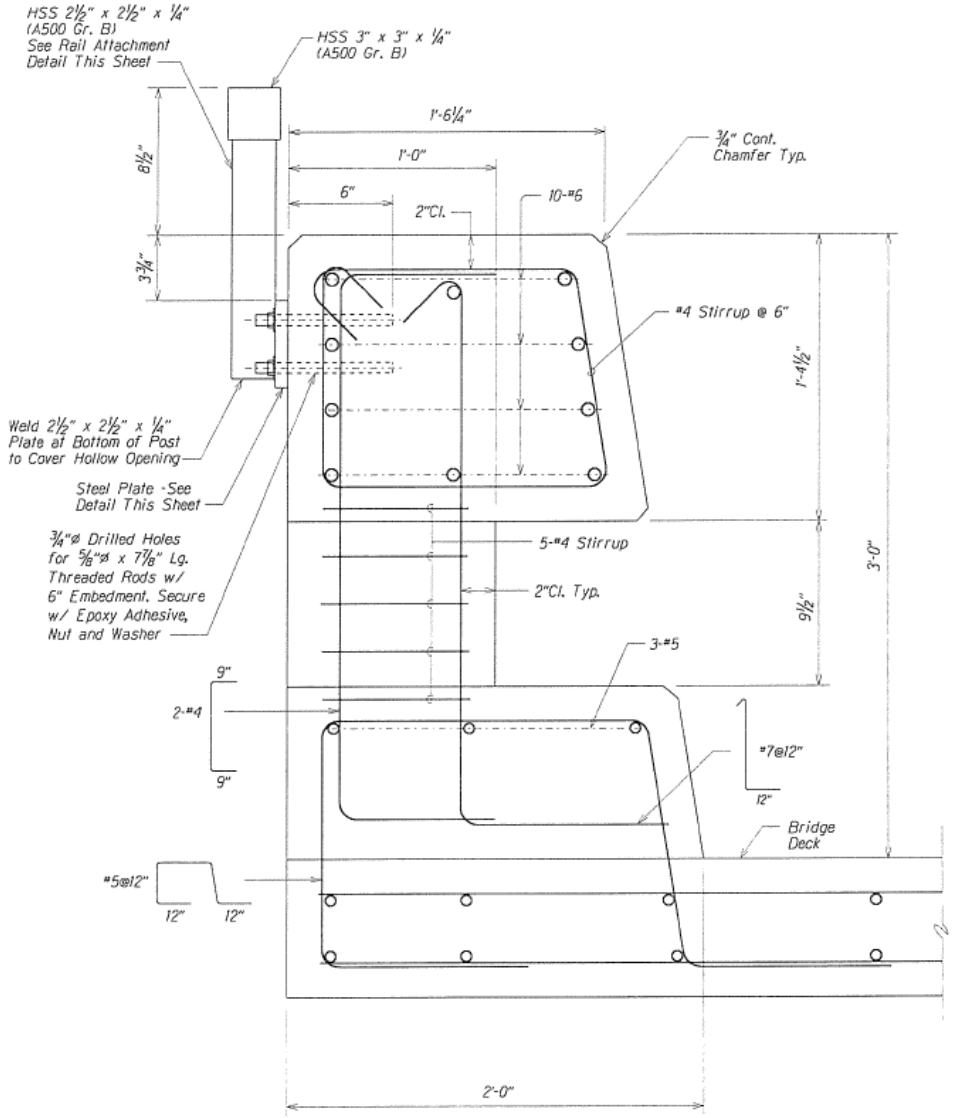


Figure 3. Hawaii Modified Natchez Trace Bridge Rail Design Details

1.2 Objective

The objective of this project was to evaluate the safety performance of the Hawaii Modified Natchez Trace Bridge Rail according to the TL-3 criteria of MASH [1].

1.3 Scope

The research objective was achieved through the completion of several tasks. The first task included a review of HDOT's existing standard plans for the Hawaii Modified Natchez Trace Bridge Rail, identification of potential safety issues, and recommendation of system modifications to improve the crashworthiness of the bridge rail. Next, one full-scale crash test was conducted on the Hawaii Modified Natchez Trace Bridge Rail according to MASH test designation no. 3-11. The full-scale vehicle crash test results were analyzed, evaluated, and documented. Conclusions and recommendations were then made pertaining to the safety performance of the bridge rail and future research.

2 DESIGN DETAILS

The Hawaii Modified Natchez Bridge Railing consisted of a curb-mounted, open concrete bridge railing with a single slope front profile, as shown in Figures 4 through 14. Photographs of the test installation are shown in Figures 15 and 16.

The test installation had an overall length of 70 ft – 7 in. and incorporated three railing segments with ½-in. expansion joins placed between adjacent rail segments. The design featured a 16½-in. tall by 20⅞-in. wide concrete rail with a top height of 36 in. The width of the bridge rail varied from 18¼ in. at the top to 24 in. at the bottom. The back side of the railing was vertical, and the front face maintained a continuous slope from top to bottom, including the curb. The design used 12-in. long by 12-in. wide concrete posts spaced 7 ft – 6 in. apart. The open concrete bridge railing was positioned on a 10-in. tall concrete curb.

The rail, posts, and curb were reinforced with a combination of transverse and longitudinal rebar. Reinforcement in the rail consisted of ten #6 bars located inside #4 enclosed stirrups. There were four #6 bars on each face of the rail and two additional #6 bars on the top and bottom of the rail. Vertical reinforcement in the posts consisted of four #7 hooked bars on the traffic face of the posts with four #4 bars on the non-traffic side. The vertical bars in the posts were enclosed by five #4 stirrups that were evenly spaced at 2¾ in. between the top of the curb and the bottom of the rail. Longitudinal reinforcement in the curb consisted of three longitudinal #5 bars located inside #5 transverse U-bars. The U-bars were epoxied into the concrete tarmac to a depth of 6 in. using Hilti HIT RE-500 epoxy to develop their full tensile strength.

The pedestrian handrail installed on the back side of the bridge rail had a top mounting height of 42½ in. The handrail assembly consisted of HSS3x3x¼ steel tubes supported by 13¾-in. long HSS2½x2½x¼ tube posts. The tube posts were welded to 8-in. x 5-in. x ¾-in. thick mounting plates, which were attached to the back-side of the concrete railing using four ⅝-in. diameter threaded rods epoxied into the railing. The handrail segments were spliced together using 7-in. long HSS2x2x¼ tubes with $^{3}/_{16}$-in. thick shims. One end of the splice tube was inserted 2 in. and welded to the downstream end of the handrail tube, while the other end extended into the upstream end of the adjacent handrail tube.

The concrete mix for the bridge railing required a minimum 28-day compressive strength of 4,000 psi. The cylinder break strength 1 week prior to testing was 4,060 psi. All reinforcement was epoxy-coated ASTM A615 Grade 60 bars. The handrail was assembled from ASTM A500 Grade B tubes and ASTM A16 steel plates. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix B.

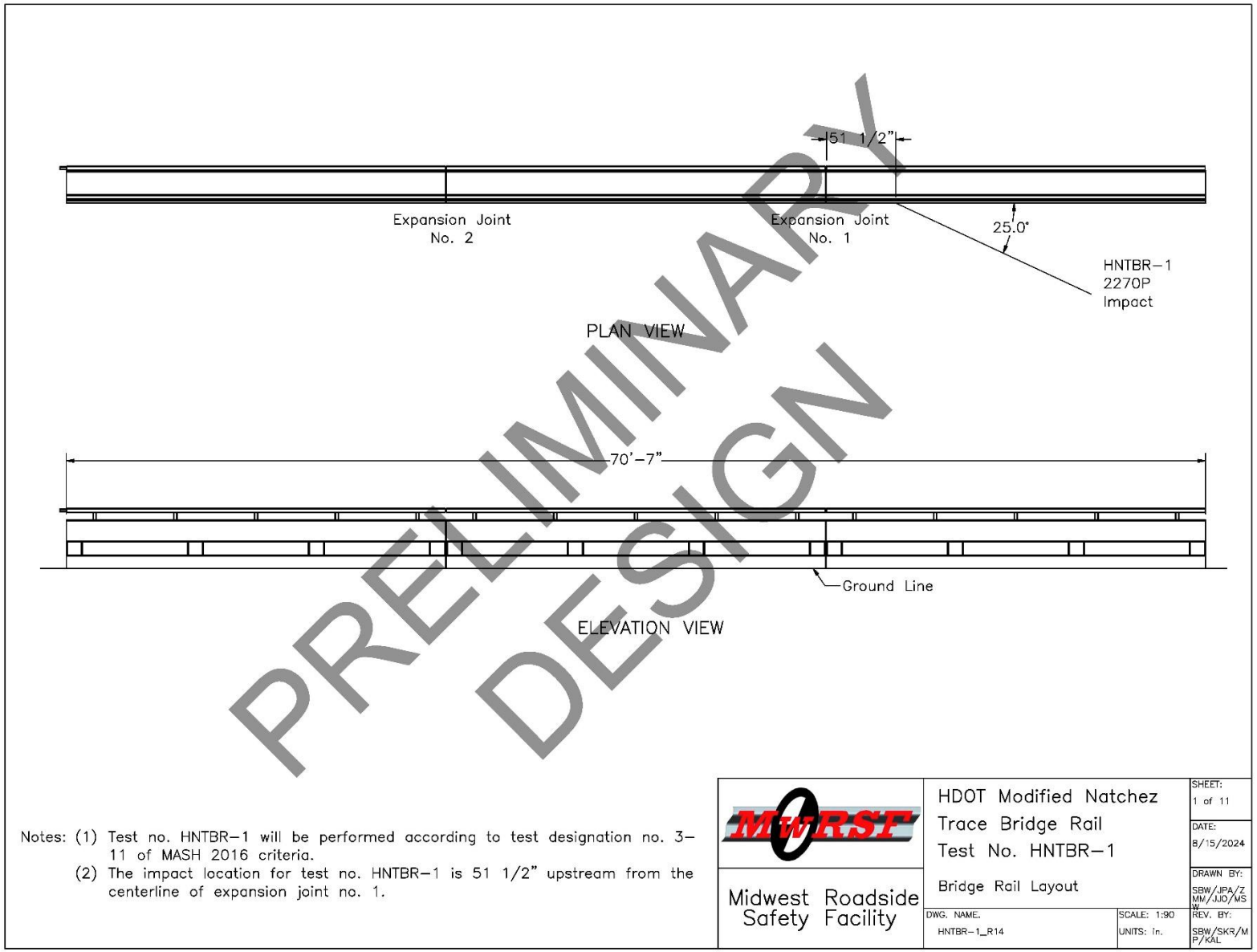


Figure 4. Test Installation Layout, Test No. HNTBR-1

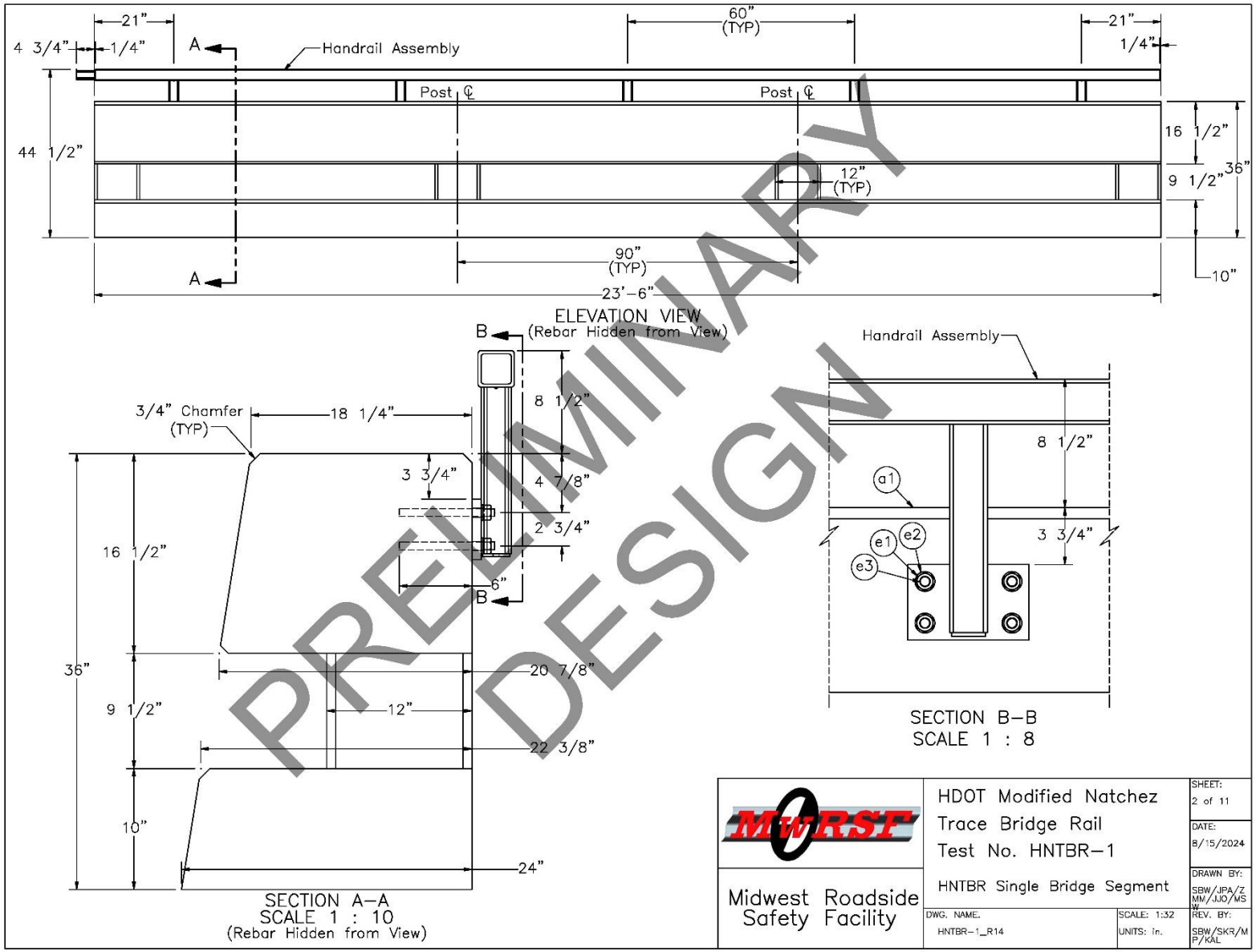


Figure 5. Bridge Rail Layout, Test No. HNTBR-1

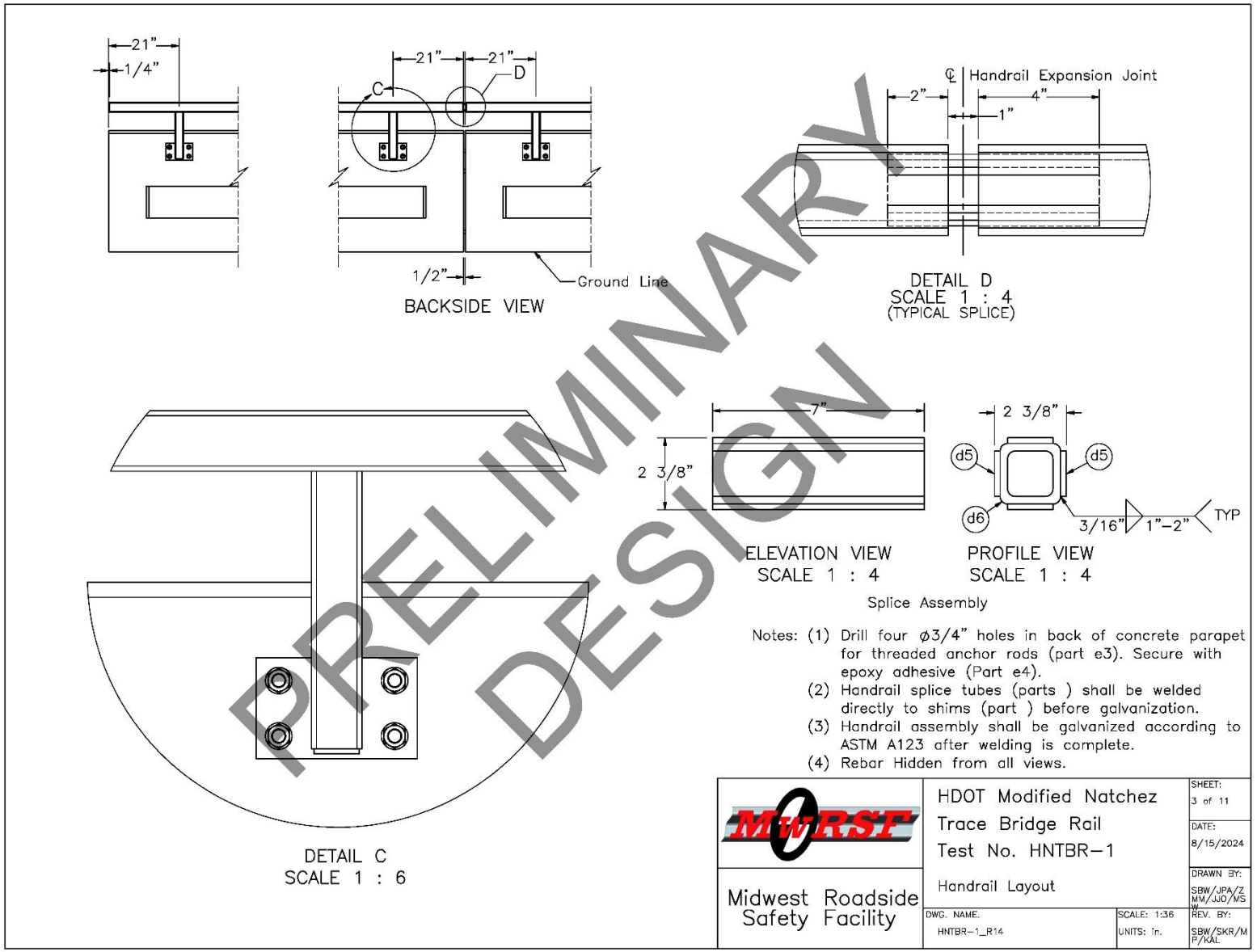
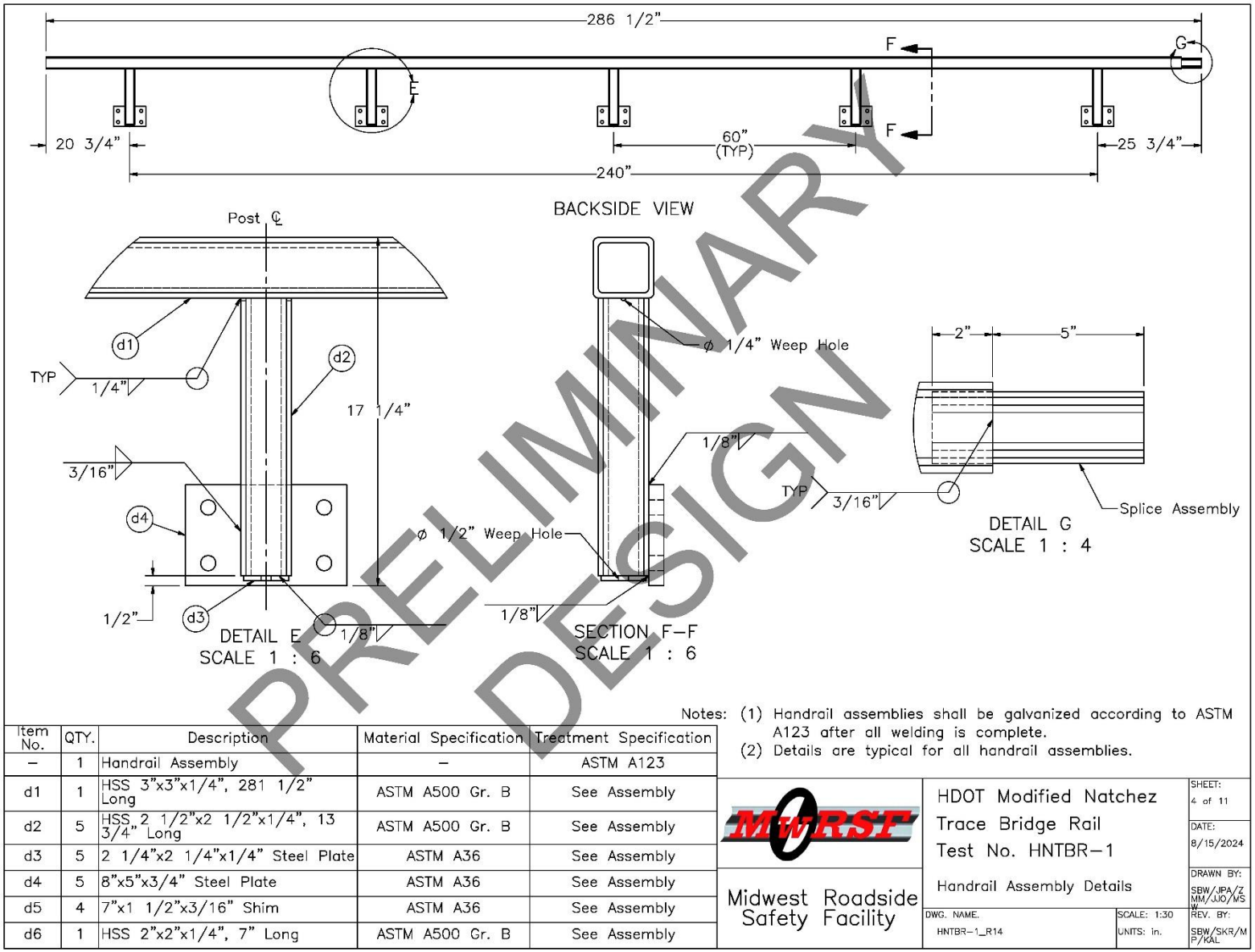


Figure 6. Handrail Detail, Test No. HNTBR-1



Item No.	QTY.	Description	Material Specification	Treatment Specification
–	1	Handrail Assembly	–	ASTM A123
d1	1	HSS 3"x3"x1/4", 281 1/2" Long	ASTM A500 Gr. B	See Assembly
d2	5	HSS 2 1/2"x2 1/2"x1/4", 13 3/4" Long	ASTM A500 Gr. B	See Assembly
d3	5	2 1/4"x2 1/4"x1/4" Steel Plate	ASTM A36	See Assembly
d4	5	8"x5"x3/4" Steel Plate	ASTM A36	See Assembly
d5	4	7"x1 1/2"x3/16" Shim	ASTM A36	See Assembly
d6	1	HSS 2"x2"x1/4", 7" Long	ASTM A500 Gr. B	See Assembly

Notes: (1) Handrail assemblies shall be galvanized according to ASTM A123 after all welding is complete.
(2) Details are typical for all handrail assemblies.

Midwest Roadside Safety Facility

HDOT Modified Natchez Trace Bridge Rail
Test No. HNTBR–1
Handrail Assembly Details

SHEET: 4 of 11
DATE: 8/15/2024
DRAWN BY: SBW/JPA/ZMM/JJO/MSW
REV. BY: SBW/SKR/MP/KAL
DWG. NAME. HNTBR–1_R14
SCALE: 1:30
UNITS: in.

Figure 7. Handrail Detail, Test No. HNTBR-1

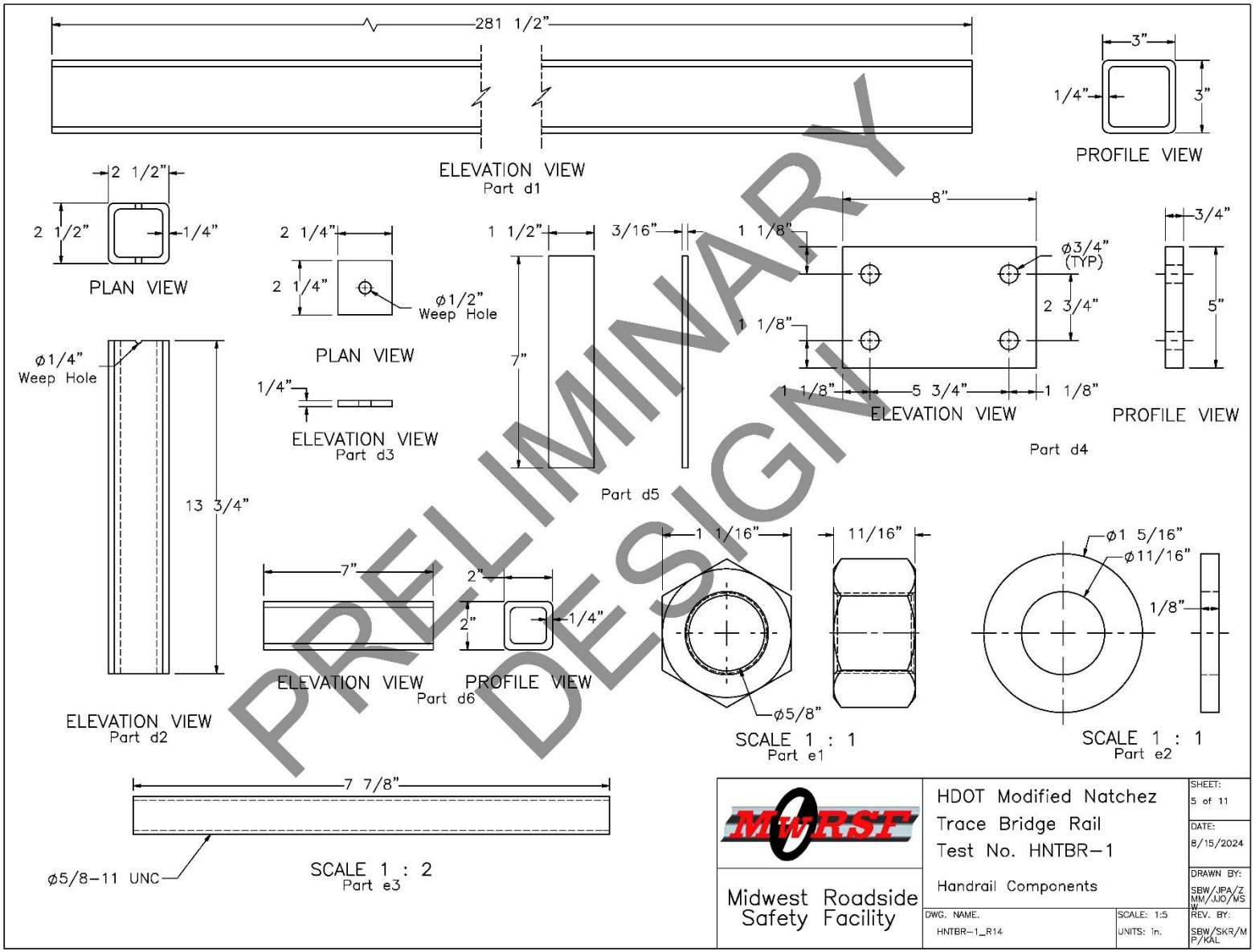


Figure 8. Handrail Assembly Components, Test No. HNTBR-1

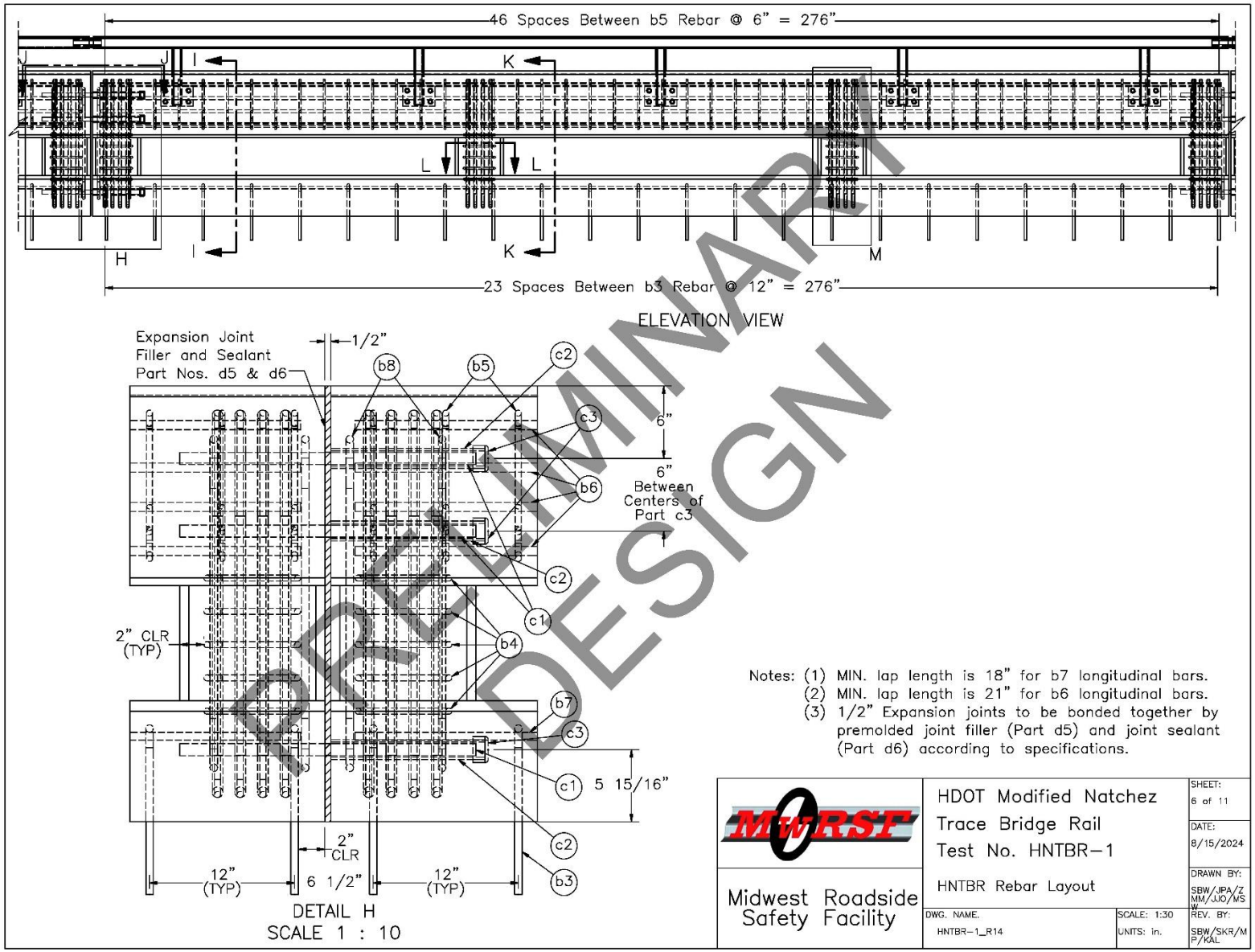


Figure 9. Rails Rebar Detail, Test No. HNTBR-1

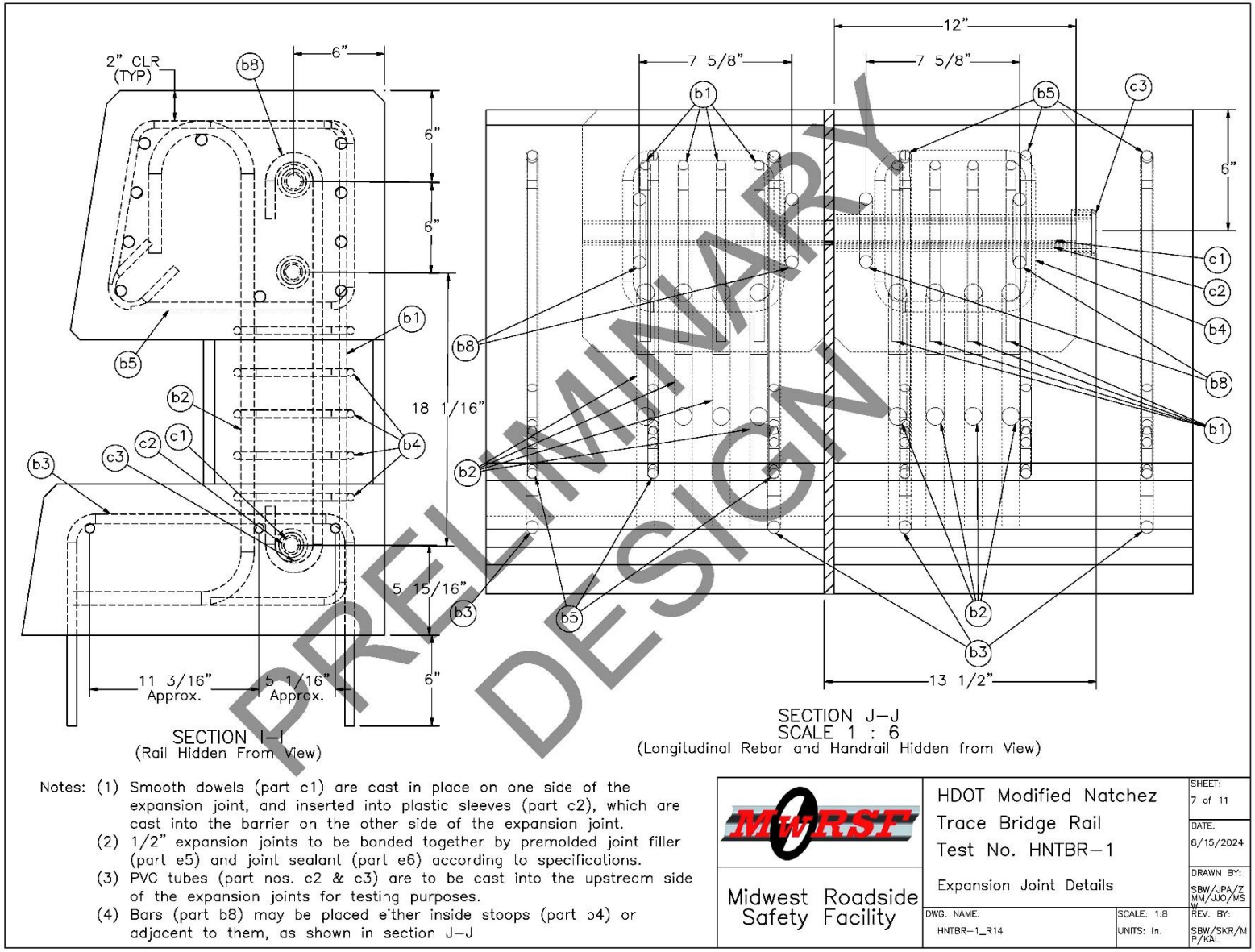


Figure 10. Post-Rail Rebar Arrangement, Test No. HNTBR-1

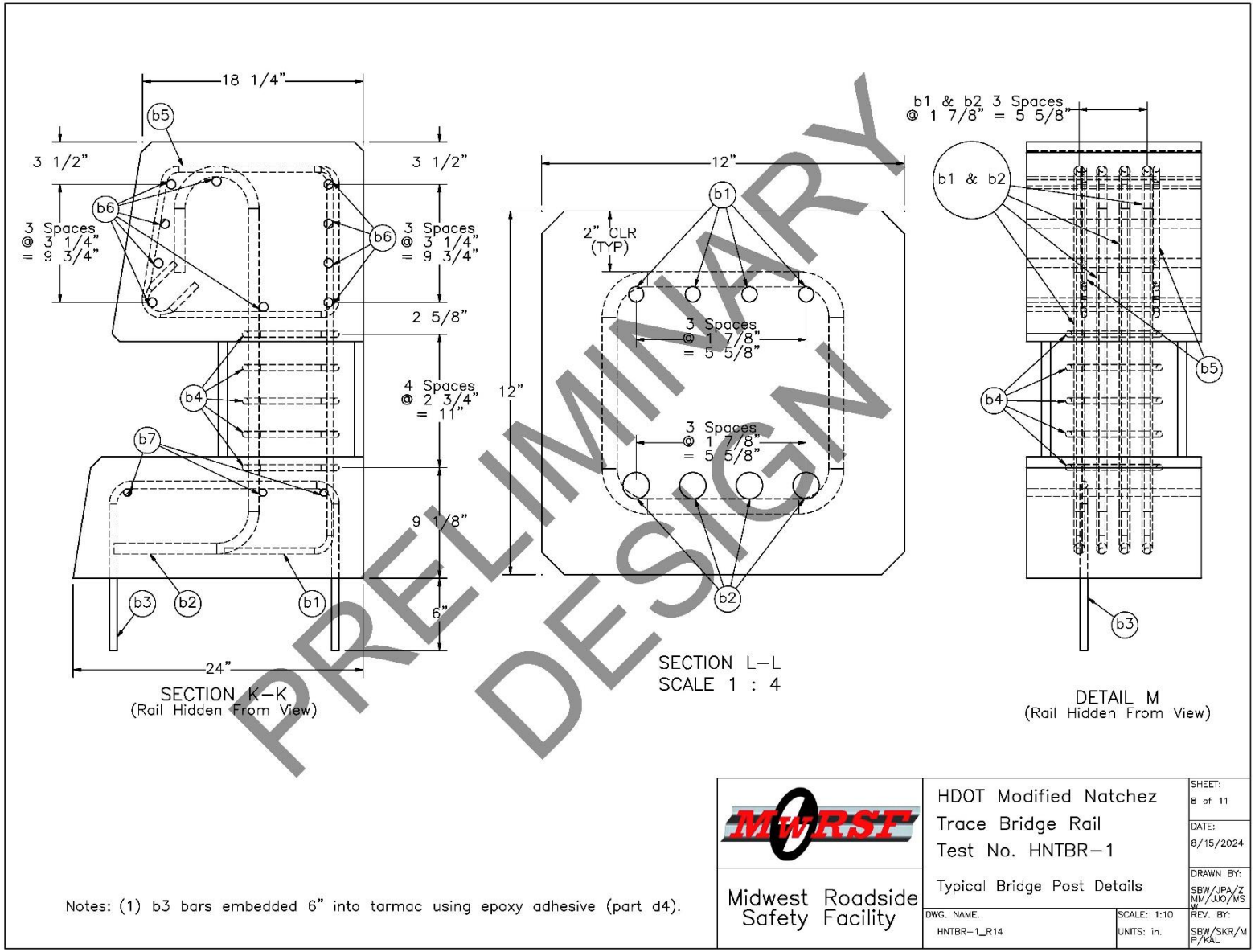
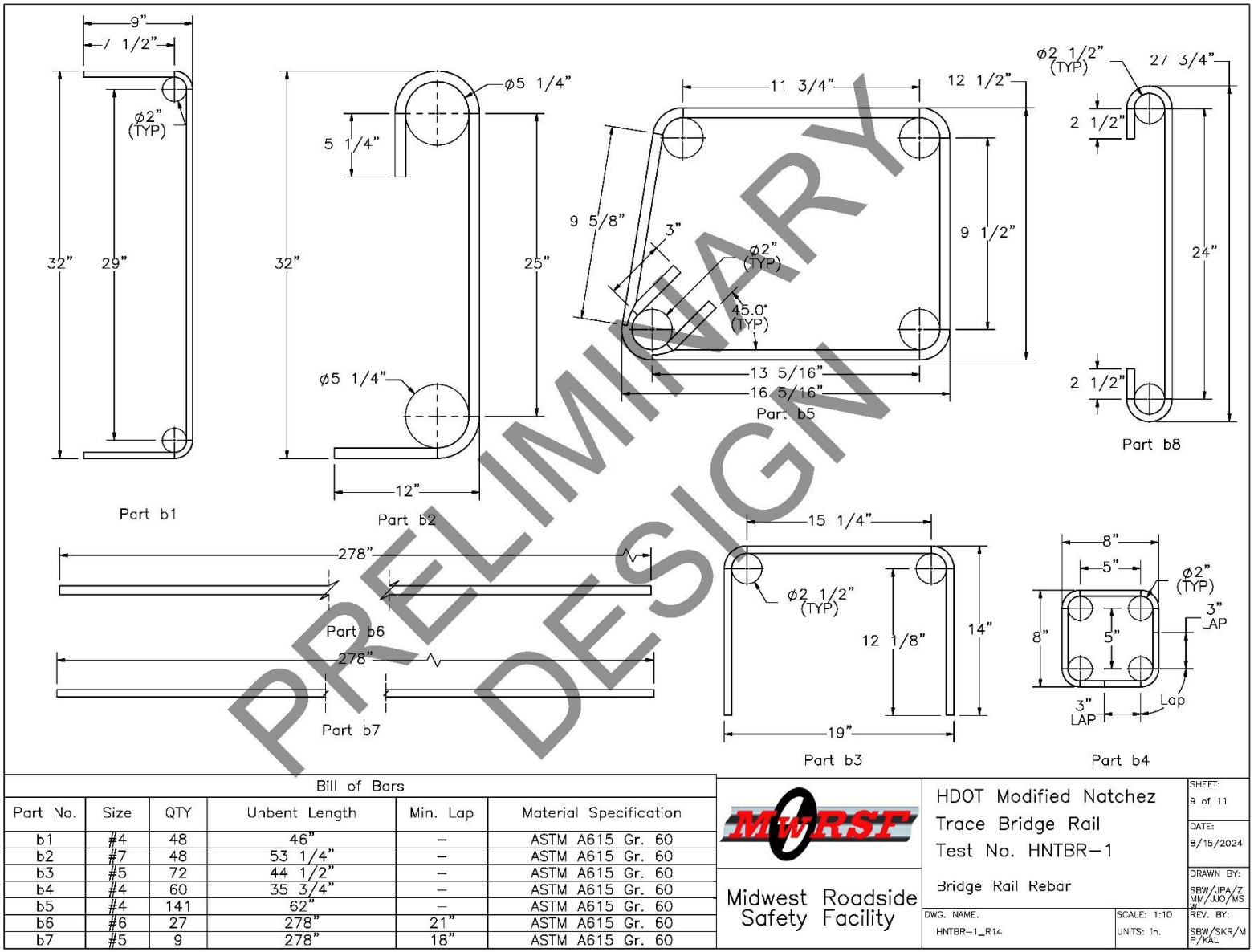


Figure 11. Post-Rail Rebar Arrangement, Test No. HNTBR-1



Bill of Bars

Part No.	Size	QTY	Unbent Length	Min. Lap	Material Specification
b1	#4	48	46"	–	ASTM A615 Gr. 60
b2	#7	48	53 1/4"	–	ASTM A615 Gr. 60
b3	#5	72	44 1/2"	–	ASTM A615 Gr. 60
b4	#4	60	35 3/4"	–	ASTM A615 Gr. 60
b5	#4	141	62"	–	ASTM A615 Gr. 60
b6	#6	27	278"	21"	ASTM A615 Gr. 60
b7	#5	9	278"	18"	ASTM A615 Gr. 60

Midwest Roadside Safety Facility

HDOT Modified Natchez Trace Bridge Rail
Test No. HNTBR–1
Bridge Rail Rebar

DWG. NAME. HNTBR–1_R14
SCALE: 1:10
UNITS: in.

SHEET: 9 of 11
DATE: 8/15/2024
DRAWN BY: SBW/JPA/ZMM/JJO/MSW
REV. BY: SBW/SKR/MP/KAL

Figure 12. Rebar Details, Test No. HNTBR-1

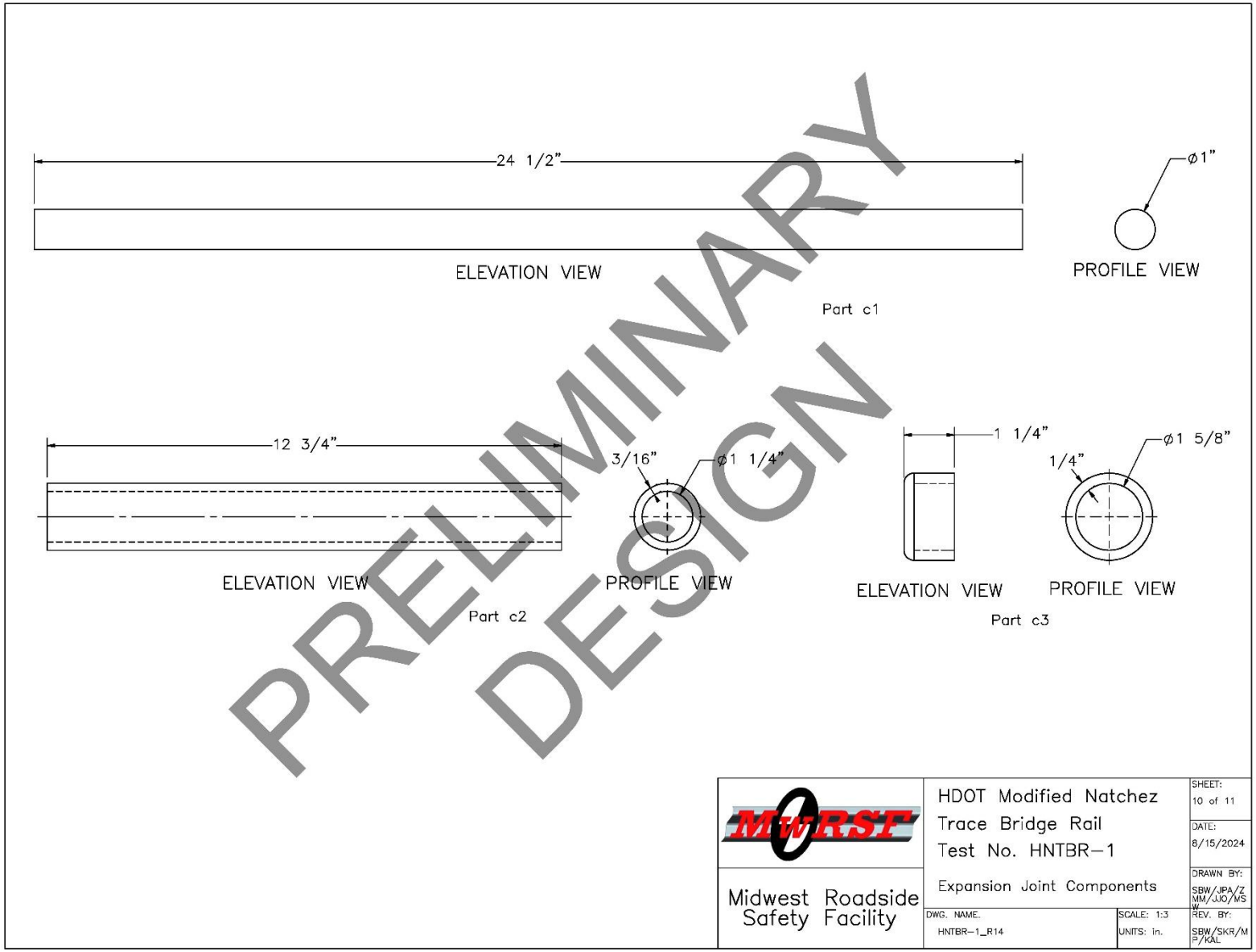


Figure 13. Pipe Details, Test No. HNTBR-1

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
a1	3	Concrete*	Min. f'c = 4,000 psi	–	–
b1	48	#4 Rebar, 46" Total Unbent Length	ASTM A615 Gr. 60	**Epxoy–Coated (ASTM A775 or A934)	–
b2	48	#7 Rebar, 53 1/4" Total Unbent Length	ASTM A615 Gr. 60	**Epoxy–Coated (ASTM A775 or A934)	–
b3	72	#5 Rebar, 44 1/2" Total Unbent Length	ASTM A615 Gr. 60	**Epoxy–Coated (ASTM A775 or A934)	–
b4	60	#4 Rebar, 35 3/4" Total Unbent Length	ASTM A615 Gr. 60	**Epoxy–Coated (ASTM A775 or A934)	–
b5	141	#4 Rebar, 62" Total Unbent Length	ASTM A615 Gr. 60	**Epoxy–Coated (ASTM A775 or A934)	–
b6	30	#6 Rebar, 278" Total Length	ASTM A615 Gr. 60	**Epoxy–Coated (ASTM A775 or A934)	–
b7	9	#5 Rebar, 278" Total Length	ASTM A615 Gr. 60	**Epoxy–Coated (ASTM A775 or A934)	–
b8	8	#5 Rebar, 38 7/8" Total Unbent Length	ASTM A615 Gr. 60	**Epoxy Coated (ASTM A775 or A934)	–
c1	6	#8 Smooth Rebar, 24 1/2" Long	ASTM A615 Gr. 60	**Epoxy Coated (ASTM A775 or A934)	–
c2	6	1 1/4" Dia. PVC Pipe	Schedule 80 PVC Gr. 12454	–	–
c3	6	1 1/4" Dia. PVC End Cap	Schedule 80 PVC Gr. 12454	–	–
d1	3	HSS 3"x3"x1/4", 281 1/2" Long	ASTM A500 Gr. B	See Assembly	–
d2	15	HSS 2 1/2"x2 1/2"x1/4", 13 3/4" Long	ASTM A500 Gr. B	See Assembly	–
d3	15	2 1/4"x2 1/4"x1/4" Steel Plate	ASTM A36	See Assembly	–
d4	15	8"x5"x3/4" Steel Plate	ASTM A36	See Assembly	–
d5	12	7"x1 1/2"x3/16" Shim	ASTM A36	See Assembly	–
d6	3	HSS 2"x2"x1/4", 7" Long	ASTM A500 Gr. B	See Assembly	–
e1	60	5/8"–11 UNC Heavy Hex Nut	ASTM A563–15 Grade DH	ASTM F2329	FNX18b
e2	60	5/8" Dia. Hardened Washer	ASTM F436	ASTM F2329	FWC18b
e3	60	5/8"–11 UNC, 7 7/8" Long Threaded Rod	ASTM F1554–15 Gr. 105	ASTM F2329	–
e4	–	Epoxy Adhesive	Hilti HIT RE–500 V3	–	–
e5	–	Joint Filler	AASHTO M33, M153, or M213	–	–
e6	–	Expansion Joint Sealant	AASHTO M173, M282, M301, ASTM D3581, or ASTM D5893	–	–

* NE Mix 47B15/1PF4000HW was used for testing purposes.
** Rebar does not need to be epoxy–coated for testing purposes.

MwRSF

Midwest Roadside Safety Facility

HDOT Modified Natchez Trace Bridge Rail
Test No. HNTBR–1
HNTBR BOM

DWG. NAME. HNTBR–1_R14
SCALE: 1:192
UNITS: in.

SHEET: 11 of 11
DATE: 8/15/2024
DRAWN BY: SBW/JPA/ZMM/JJO/MSW
REV. BY: SBW/SKR/MP/KAL

Figure 14. Bill of Materials, Test No. HNTBR-1

Figure 15. Test Installation Photographs, Test No. HNTBR-1

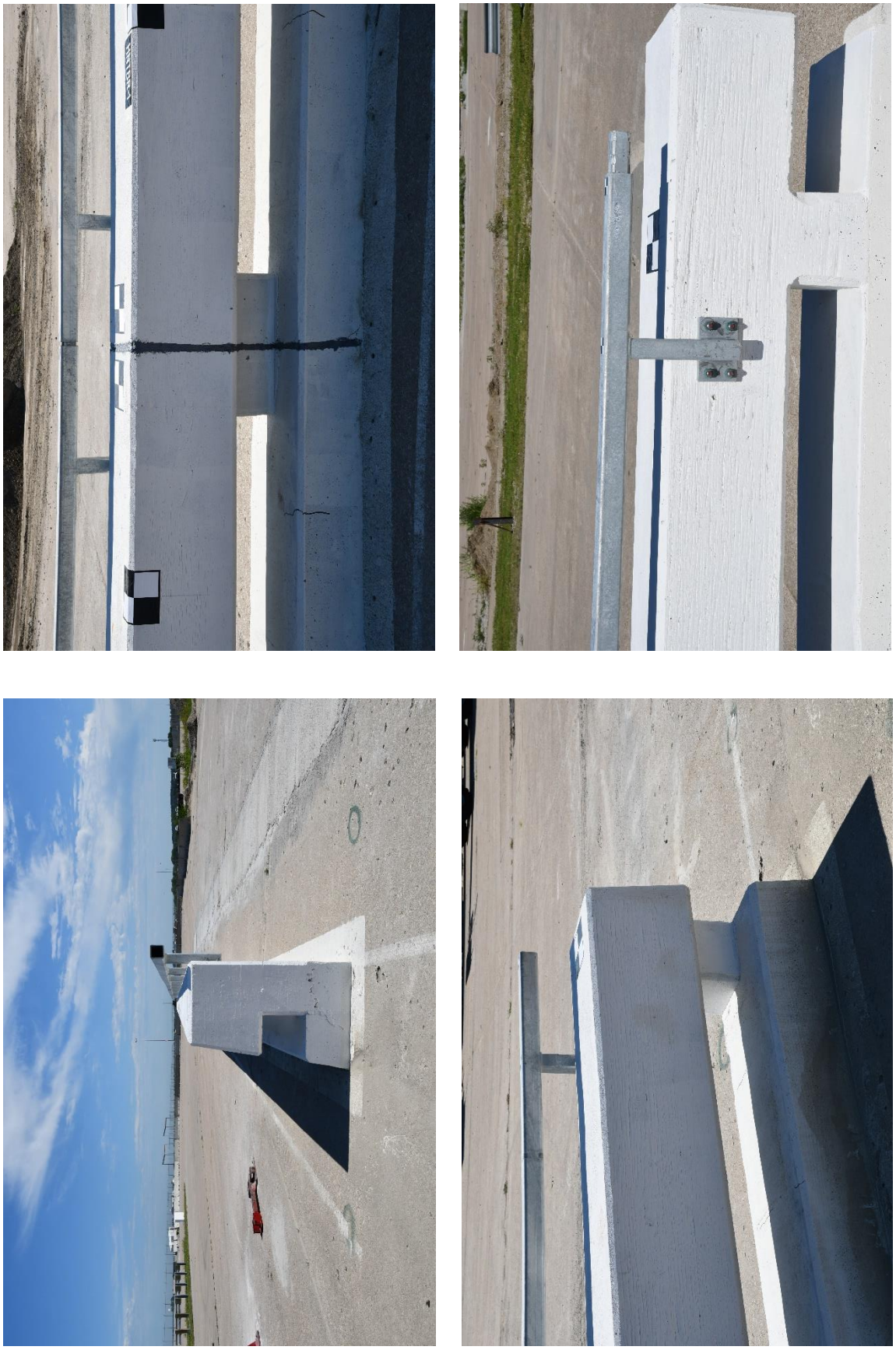


Figure 16. Test Installation Photographs, Handrail Assembly, Test No. HNTBR-1

3 TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1 Test Requirements

Longitudinal barriers, such as bridge rails, must satisfy impact safety standards to be declared eligible for federal reimbursement by the Federal Highway Administration (FHWA) for use on the National Highway System. For new hardware, these safety standards consist of the guidelines and procedures published in the 2016 edition of MASH. Note that for longitudinal barriers there is no difference between 2009 edition of MASH [6] and the current 2016 edition except that additional occupant compartment deformation measurements, photographs, and documentation are required by the 2016 edition. According to TL-3 of MASH, longitudinal barriers must be subjected to two full-scale vehicle crash tests, as summarized in Table 1. MASH test designation no. 3-11 was conducted on the Hawaii Modified Natchez Trace Bridge Railing and was documented herein.

Table 1. MASH 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 deg.	
Longitudinal Barrier	3-10	1100C	2,420	62	25	A,D,F,H,I
	3-11	2270P	5,000	62	25	A,D,F,H,I

1 Evaluation criteria explained in Table 2.

Table 2. MASH Evaluation Criteria for Longitudinal Barrier

Structural Adequacy	A.	Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.		
Occupant Risk	D.	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.		
	F.	The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.		
	H.	Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:		
		Occupant Impact Velocity Limits		
		Component	Preferred	Maximum
		Longitudinal and Lateral	30 ft/s	40 ft/s
	I.	The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:		
		Occupant Ridedown Acceleration Limits		
		Component	Preferred	Maximum
		Longitudinal and Lateral	15.0 g's	20.49 g's

3.2 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.

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.

4 TEST CONDITIONS

4.1 Test Facility

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

4.2 Vehicle Tow and Guidance System

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

A vehicle guidance system developed by Hinch [7] was used to steer the test vehicle. A guide flag, attached to the left-front wheel and the guide cable, was sheared off before impact with the barrier system. The ⅜-in. diameter guide cable was tensioned to approximately 3,500 lb and supported both laterally and vertically every 100 ft by hinged stanchions. The hinged stanchions stood upright while holding up the guide cable, but as the vehicle was towed down the line, the guide flag struck and knocked each stanchion to the ground.

4.3 Test Vehicle

In test no. HNTBR-1, a 2017 Dodge Ram 1500 crew cab pickup truck was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 5,264 lb, 5,032 lb, and 5,192 lb, respectively. The test vehicle is shown in Figures 17 and 18, and vehicle dimensions are shown in Figure 19. Note, the impact side of the vehicle, or the passenger's side, is referred to as the vehicle's right side throughout this report. The non-impact side, or driver's side, is referred to as the vehicle's left side.

The longitudinal component of the center of gravity (c.g.) was determined using the measured axle weights. The Suspension Method [8] 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 is shown in Figure 19. Ballast information and data used to calculate the location of the c.g. are shown in Appendix C.

Square, black-and-white checkered targets were placed on the vehicle for reference, shown in Figure 20, 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 vehicle.

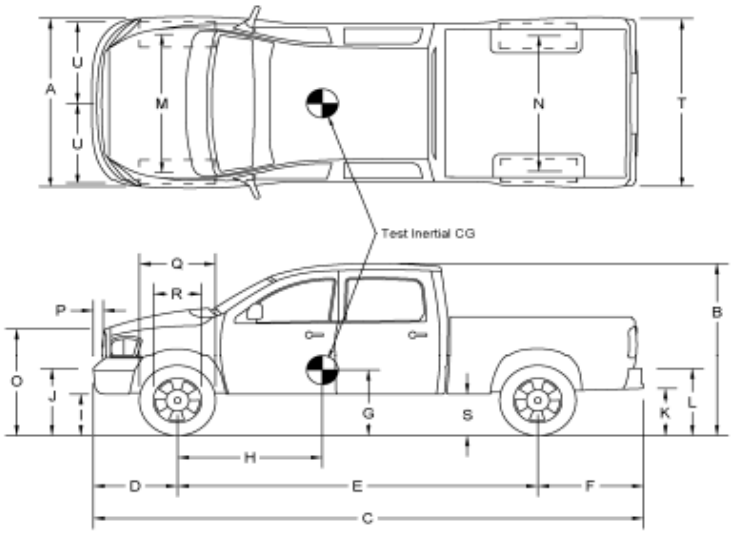
The front wheels of the test vehicle were aligned to vehicle standards except the toe-in value was adjusted to zero such that the vehicle would track properly along the guide cable. A 5B flash bulb was mounted under the vehicle's right-side windshield wiper and was fired by a pressure

tape switch mounted at the impact corner of the bumper. The flash bulb was fired upon initial impact with the test article to create a visual indicator of the precise time of impact on the high-speed digital videos. A radio-controlled brake system was installed in the test vehicle so the vehicle could be brought safely to a stop after the test.

Figure 17. Test Vehicle, Test No. HNTBR-1

Figure 18. Vehicle's Interior Floorboards and Undercarriage, Test No. HNTBR-1

Test Name:	HNTBR-1			VIN No:	1C6RR6LTXHS514323
Model Year:	2017	Make:	Dodge	Model:	Ram 1500
Tire Size:	275/60R20	Tire Inflation Pressure:	39 psi	Odometer:	148148



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

A:	78		1981	1/5	B:	75	1/2	1917	7/10
	78±2 (1950±50)								
C:	229		5816	3/5	D:	39	1/2	1003	3/10
	237±13 (6020±325)					39±3 (1000±75)			
E:	140	3/4	3575	1/20	F:	48	3/4	1238	1/4
	148±12 (3760±300)								
G:	28	15/16	735	1/80	H:	59	7/16	1509	57/80
	min: 28 (710)					63±4 (1575±100)			
I:	13		330	1/5	J:	26		660	2/5
K:	22		558	4/5	L:	30	3/4	781	1/20
M:	68	5/8	1743	3/40	N:	68	1/2	1739	9/10
	67±1.5 (1700±38)					67±1.5 (1700±38)			
O:	45	1/4	1149	7/20	P:	4	1/4	107	19/20
	43±4 (1100±75)								
Q:	32	1/4	819	3/20	R:	21	3/8	542	37/40
S:	16	1/4	412	3/4	T:	77	1/4	1962	3/20

U (impact width): 37 5/8 955 27/40

Mass Distribution - lb (kg)

Gross Static	LF	1504	(682)	RF	1500	(680)
	LR	1073	(487)	RR	1115	(506)

Weights lb (kg)	Curb		Test Inertial		Gross Static	
W-front	3008	(1364)	2906	(1318)	3004	(1363)
W-rear	2256	(1023)	2126	(964)	2188	(992)
W-total	5264	(2388)	5032	(2282)	5192	(2355)
			5000±110 (2270±50)		5165±110 (2343±50)	

Wheel Center Height (Front):	15 1/4	387	7/20
Wheel Center Height (Rear):	15 1/2	393	7/10
Wheel Well Clearance (Front):	35 3/4	908	1/20
Wheel Well Clearance (Rear):	39	990	3/5
Bottom Frame Height (Front):	19 1/8	485	31/40
Bottom Frame Height (Rear):	26 5/8	676	11/40

Engine Type:	Gasoline
Engine Size:	5.7L V8
Transmission Type:	Automatic
Drive Type:	RWD
Cab Style:	Crew Cab
Bed Length:	67"

GVWR Ratings - lb

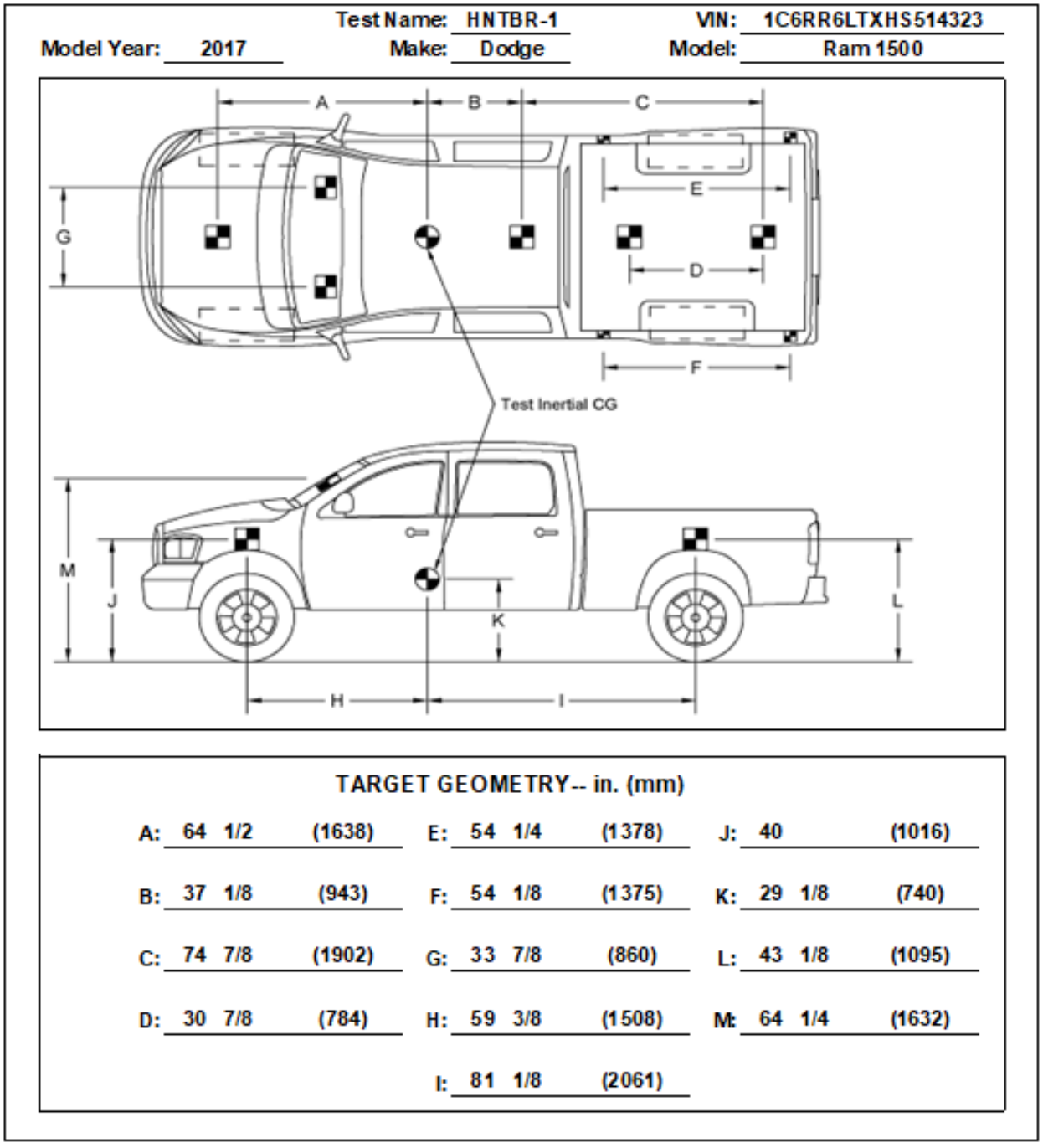
Front	3700
Rear	3900
Total	6900

Surrogate Occupant Data

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

Note any damage prior to test: Crack in windshield, Minor hail, Small dents in between driver side windows

Figure 19. Vehicle Dimensions, Test No. HNTBR-1



TARGET GEOMETRY-- in. (mm)

A:	64 1/2	(1638)	E:	54 1/4	(1378)	J:	40	(1016)
B:	37 1/8	(943)	F:	54 1/8	(1375)	K:	29 1/8	(740)
C:	74 7/8	(1902)	G:	33 7/8	(860)	L:	43 1/8	(1095)
D:	30 7/8	(784)	H:	59 3/8	(1508)	M:	64 1/4	(1632)
			I:	81 1/8	(2061)			

Figure 20. Target Geometry, Test No. HNTBR-1

4.4 Simulated Occupant

For test no. HNTBR-1, a Hybrid II 50th-Percentile Adult Male Dummy equipped with footwear was placed in the right-front seat of the test vehicle with the seat belt fastened. The simulated occupant had a final weight of 160 lb. As recommended by MASH, 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-2 and TDAS units described below. Units were positioned near the c.g. of the test vehicle and the SLICE-2 unit was designated as primary. Data obtained in dynamic testing was filtered using the SAE Class 60 and the SAE Class 180 Butterworth filter conforming to the SAEJ211/1 specifications [9].

The SLICE-2 unit was a modular data acquisition system 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.

The TDAS unit was a data acquisition system developed and manufactured by Diversified Technical Systems, Inc. of Seal Beach, California. Sensor data was collected using a DTS Sensor Input Module (SIM), Model TDAS3-SIM-16M mounted on the TDAS3-R4 module rack. The SIM was configured with 16 MB SRAM and eight sensor input channels with 250kB SRAM/channel. The module rack was configured with isolated power/event/communications, 10BaseT Ethernet and RS232 communication, and an internal backup battery. Both the SIM and module rack were crashworthy. The unit was configured to record one set of triaxial acceleration data and one set of triaxial angular rate data. The two-arm piezoresistive accelerometer module manufactured by Endevco of San Juan Capistrano, California measured longitudinal, lateral, and vertical accelerations independently at a sample rate of 10,000 Hz. The ARS-1500 angular rate sensors with a range of 1,500 degrees/sec measured the rates of rotation of the test vehicle in three directions (roll, pitch, and yaw) and recorded data at 10,000 Hz to the DTS SIM. The raw data measurements were downloaded, converted to the proper Euler angles for analysis, and plotted. The "DTS TDAS Control" computer software program and a customized Microsoft Excel worksheet were used to analyze and plot both the accelerometer and angular rate sensor data.

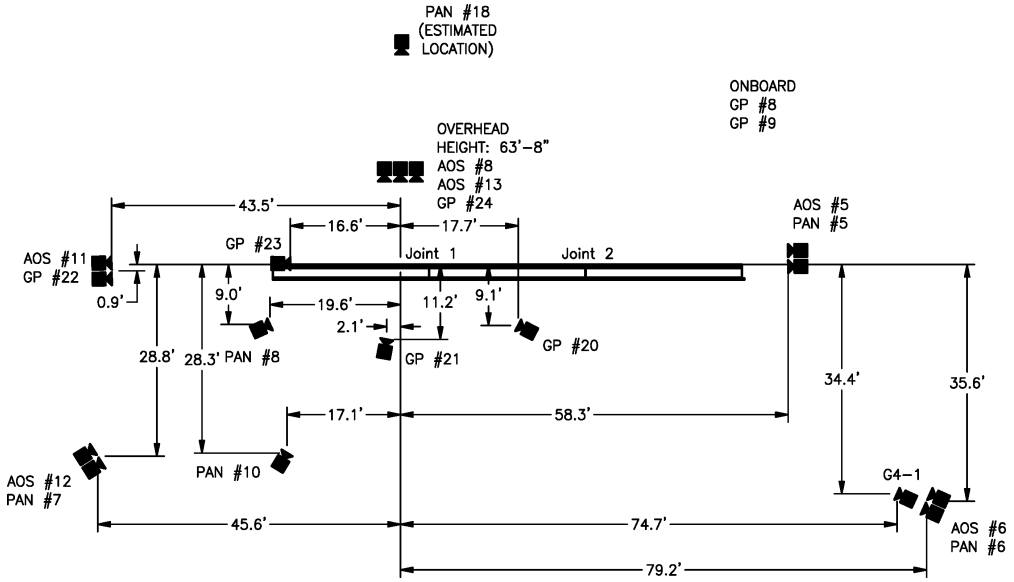
4.5.2 Retroreflective Optic Speed Trap

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 electronic data.

4.5.3 Digital Photography

Six AOS high-speed digital video cameras, eight GoPro digital video cameras, five Panasonic digital video cameras, and one Ubiquiti G4 Plus camera were utilized to film test no. HNTBR-1. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system are shown in Figure 21.

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 all tests.



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-5	AOS X-PRI	500	100 mm Fixed	-
AOS-6	AOS X-PRI	500	KOWA 25 mm Fixed	-
AOS-8	AOS S-VIT 1531	500	KOWA 12 mm Fixed	-
AOS-11	AOS J-PRI	500	Sigma 17-50	35
AOS-12	AOS J-PRI	500	2Sigma 24-135	24
AOS-13	AOS J-PRI	500	Rokinon 12 mm Fixed	-
GP-8	GoPro Hero 4	120		
GP-9	GoPro Hero 4	120		
GP-18	GoPro Hero 6	240		
GP-20	GoPro Hero 6	240		
GP-21	GoPro Hero 6	240		
GP-22	GoPro Hero 7	120		
GP-23	GoPro Hero 7	240		
GP-24	GoPro Hero 7	240		
PAN-5	Panasonic HC-VX981	120		
PAN-6	Panasonic HC-VX981	120		
PAN-7	Panasonic HC-VX981	120		
PAN-8	Panasonic HC-VX981	120		
PAN-10	Panasonic HC-VX981	120		
G4-1	Ubiquiti G4 Plus	20		

Figure 21. Camera Locations, Speeds, and Lens Settings, Test No. HNTBR-1

5 FULL-SCALE CRASH TEST NO. HNTBR-1

5.1 Weather Conditions

Test no. HNTBR-1 was conducted on July 17, 2023, at approximately 1:30 p.m. The weather conditions as reported by the National Oceanic and Atmospheric Administration (station 14939/KLNK) are shown in Table 3.

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

Temperature	78°F
Humidity	54%
Wind Speed	10 mph
Wind Direction	80° from True North
Sky Conditions	Partly Cloudy
Visibility	10
Pavement Surface	Dry
Previous 3-Day Precipitation	0.79 in.
Previous 7-Day Precipitation	1.07 in.

5.2 Test Description

Initial vehicle impact was to occur 51½ in. upstream from the centerline of the expansion joint between post nos. 4 and 5, as shown in Figure 22, which was selected using MASH Table 2-7 to maximize loading to the railing joint. The 5,032-lb crew cab pickup truck impacted the concrete bridge rail at a speed of 62.3 mph and at an angle of 25.0 degrees. The actual point of impact was 56.5 in. upstream from the centerline of the expansion joint. The vehicle was contained and redirected and remained stable throughout the impact event. After exiting the bridge rail, the brakes were applied remotely and the vehicle came to rest 175.6 ft downstream from impact and 47.1 ft behind the system.

A detailed description of the sequential impact events is contained in Table 4. Sequential photographs are shown in Figures 23 and 24. Documentary photographs of the crash test are shown in Figure 25. The vehicle trajectory and final position are shown in Figure 26.

Figure 22. Target Impact Location, Test No. HNTBR-1

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

Time (sec)	Event
0.000	Vehicle's front bumper and right-front tire contacted concrete bridge rail between post nos. 3 and 4. Concrete spalled.
0.008	Vehicle's right headlight crushed and disengaged, and fender deformed and dented. Vehicle's right-front tire deflated.
0.020	Vehicle's grille contacted railing and deformed.
0.030	Vehicle yawed away from and rolled toward system. Vehicle's right-front door contacted concrete bridge segment and deformed.
0.044	Vehicle's hood bent.
0.060	Vehicle's left headlight and right-front window glass disengaged.
0.070	Vehicle's grille disengaged. Vehicle's windshield cracked throughout.
0.114	Vehicle's left-front tire became airborne.
0.140	Vehicle's left-rear tire became airborne.
0.196	Vehicle's right-rear door contacted the railing.
0.246	Vehicle was parallel to system at a speed of 47.8 mph.
0.268	Vehicle's right quarter panel contacted railing and deformed. Vehicle pitched downward.
0.282	Vehicle's rear bumper contacted railing and deformed.
0.476	Vehicle rolled away from system.
0.512	Vehicle exited system at a speed of 44.0 mph and an angle of 10 degrees. Vehicle's front bumper contacted ground.
0.618	Vehicle's left-front tire contacted ground.
0.662	Vehicle's right-front tire detached.
0.796	Vehicle steered toward system.
0.860	Vehicle's left-rear tire contacted ground.
4.750	Vehicle came to rest.

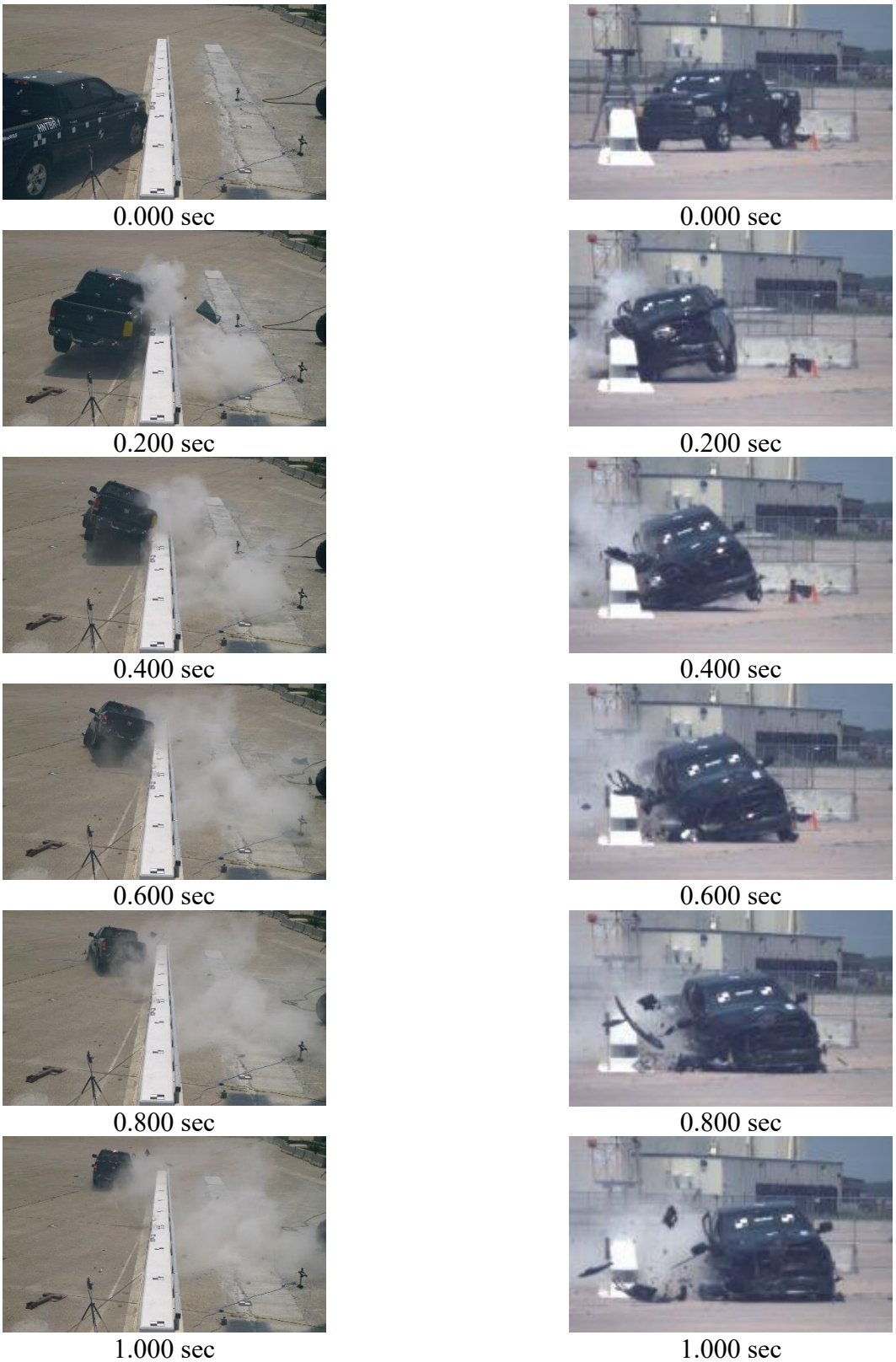


Figure 23. Sequential Photographs, Test No. HNTBR-1


0.000 sec


0.000 sec


0.100 sec


0.100 sec

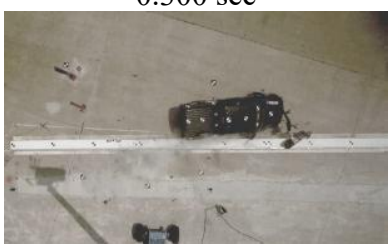

0.200 sec


0.200 sec


0.300 sec


0.300 sec


0.400 sec


0.400 sec


0.500 sec


0.500 sec

Figure 24. Sequential Photographs, Test No. HNTBR-1

Figure 25. Documentary Photographs, Test No. HNTBR-1

Figure 26. Vehicle Final Position and Trajectory Marks, Test No. HNTBR-1

5.3 Barrier Damage

Damage to the barrier was minimal, as shown in Figures 27 through 29. Barrier damage consisted of concrete spalling, contact marks on the front face of the concrete segments, and concrete cracking. The length of vehicle contact along the upper rail was 19 ft – 8 in., beginning approximately 11 in. upstream from the impact point and continuing downstream. The length of vehicle contact along the lower curb was 20 ft – 10 in., beginning 18 in. upstream from the impact point and continuing downstream.

Concrete spalling and cracking occurred during the impact event, including a 23-in. long by 8-in. wide spall located along the bottom edge of the upper concrete rail. Another significant spalled section was located on the top edge of the curb below the spalled section on the upper rail. Several other small gouges and cracks were observed on curb and upper railing around these spalled sections near initial impact. The curb was cracked on the top face adjacent to post no. 4, and a crack was found along the base of post no. 4.

Figure 27. System Damage, Test No. HNTBR-1

Figure 28. Curb and Concrete Rail Damage, Test No. HNTBR-1

Figure 29. Curb and Concrete Rail Damage, Test No. HNTBR-1

The maximum lateral dynamic barrier deflection was 1.0 in. at railing post no. 4, which was just upstream from the impacted expansion joint, as determined from high-speed digital video analysis. The maximum lateral permanent set of the barrier system was 0.7 in. measured at the handrail just downstream from the expansion joint, as measured in the field. The working width of the system was found to be 28.5 in., also determined from high-speed digital video analysis. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 30.

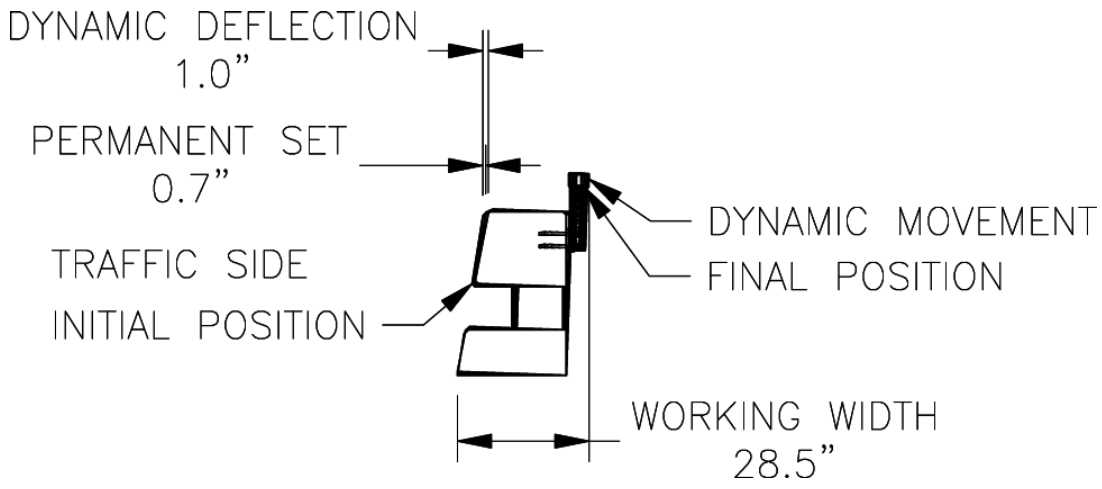


Figure 30. Permanent Set, Dynamic Deflection, and Working Width, Test No. HNTBR-1

5.4 Vehicle Damage

Damage to the vehicle was severe, as shown in Figures 31 through 34. The impact side of the vehicle, or the passenger's side, is referred to as the vehicle's right side. The non-impact side, or driver's side, is referred to as the vehicle's left side. Majority of the damage was concentrated on the right-front corner and right side of the vehicle where the impact occurred. The right side of the front bumper was dented and scraped, and the left side of the front bumper was bent. The headlights and grille were disengaged from the vehicle. The right side of the hood was dented and scraped. Scrapes and dents were observed throughout the right-side of the vehicle. The right fender and right-front door were crushed inward. The windshield was cracked, concentrated on the right side, and the right-front side window was shattered and disengaged.

The right-front suspension spring was disengaged, and the right-front shock was bent. The right-side end link was bent and detached, and the front and rear sway bar shifted. The right ball joint, right steering knuckle, and right lower control arm disengaged, and the right upper control arm was bent. The right outer tie rod disconnected from the control arm. The passenger side frame rail was bent and buckled. The right-front engine cross member was scraped and bent. The right side of the frame horn bent inward severely. The cab mounts were bent and shifted, and there were large deformations to the toe pan and floorboard on the right side of the vehicle.

The maximum occupant compartment intrusions are listed in Table 5, along with the intrusion limits established in MASH for various areas of the occupant compartment. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in

Appendix D. MASH defines intrusion or deformation as the occupant compartment being deformed and reduced in size with no observed penetration. The vehicle's toe pan was deformed 12.7 in., which exceeded the 9-in. MASH intrusion limit. Outward deformations, which are denoted as negative numbers in Appendix D, are not considered crush toward the occupant, and are not evaluated by MASH criteria.

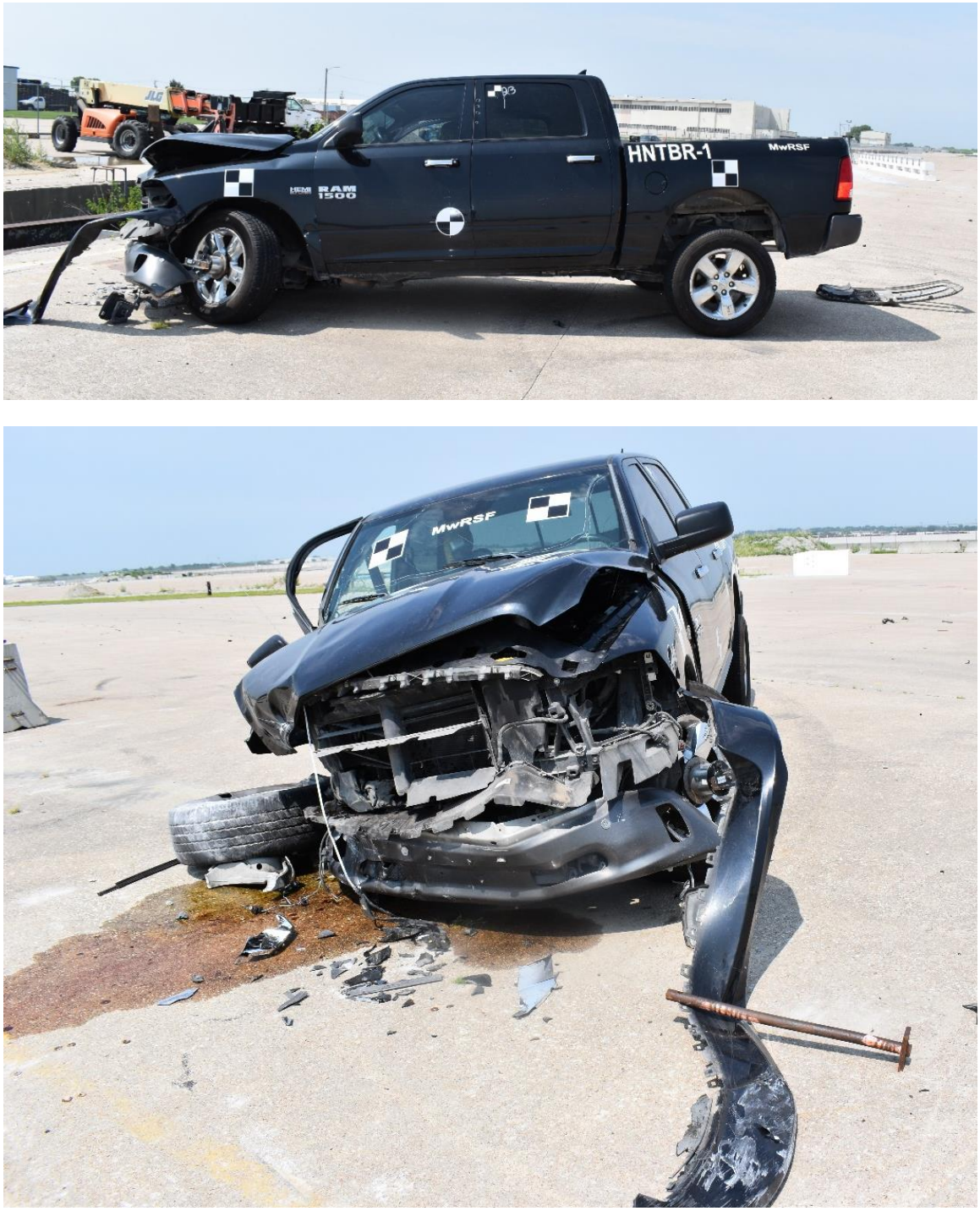


Figure 31. Vehicle Damage, Test No. HNTBR-1

Figure 32. Vehicle Damage, Test No. HNTBR-1

Figure 33. Vehicle's Interior Compartment Damage, Test No. HNTBR-1

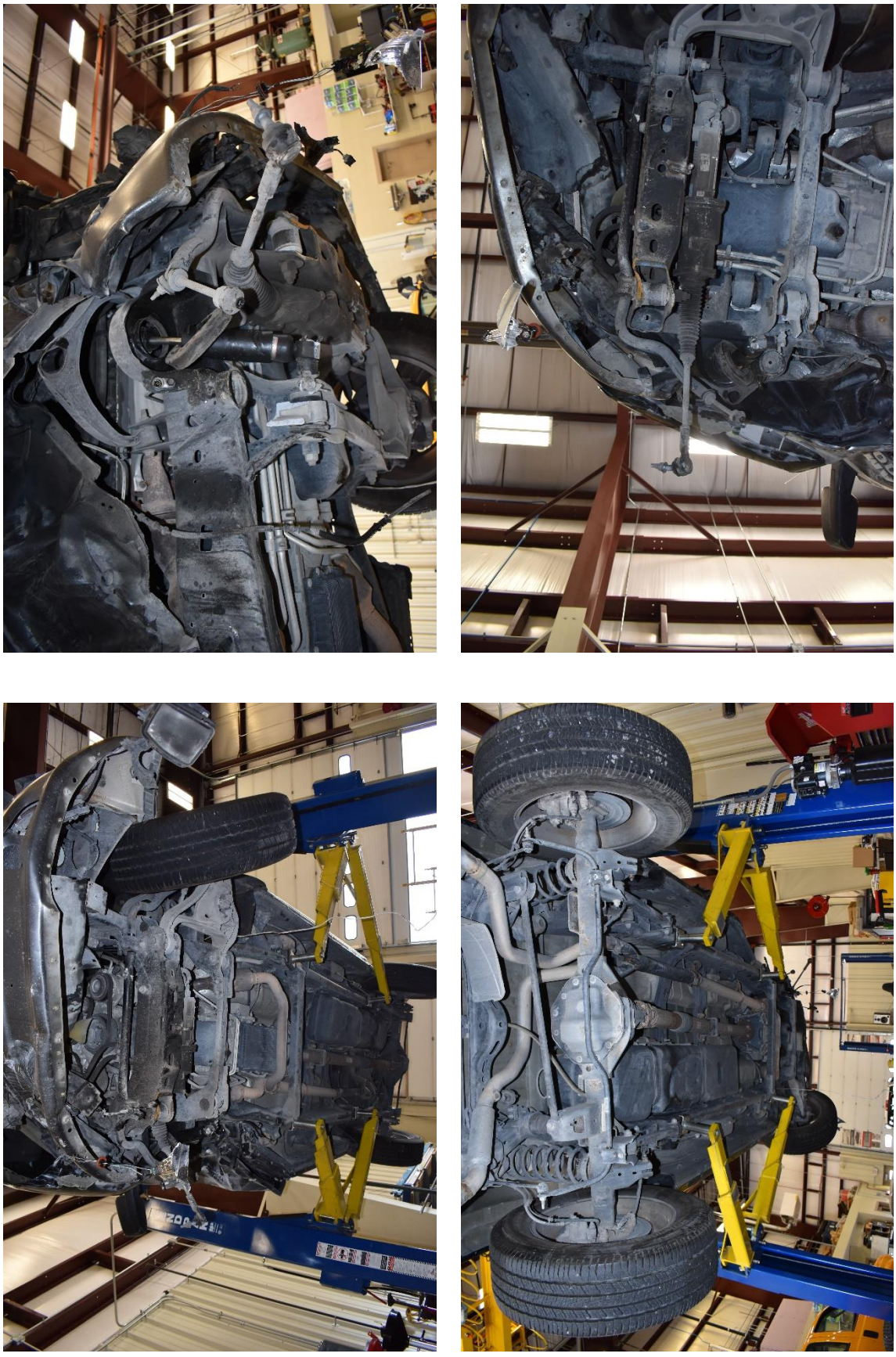


Figure 34. Vehicle's Undercarriage Damage, Test No. HNTBR-1

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

Location	Maximum Intrusion in.	MASH 2016 Allowable Intrusion in.
Wheel Well & Toe Pan	12.7	≤ 9
Floor Pan & Transmission Tunnel	5.4	≤ 12
A-Pillar	2.0	≤ 5
A-Pillar (Lateral)	0.0*	≤ 3
B-Pillar	0.5	≤ 5
B-Pillar (Lateral)	0.0*	≤ 3
Side Front Panel (in Front of A-Pillar)	11.9	≤ 12
Side Door (Above Seat)	0.0*	≤ 9
Side Door (Below Seat)	0.0*	≤ 12
Roof	0.0*	≤ 4
Windshield	0.0	≤ 3
Side Window	Shattered/disengaged due to contact with simulated occupant's head	No shattering resulting from contact with structural member of test article
Dash	5.2	N/A

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

5.5 Occupant Risk

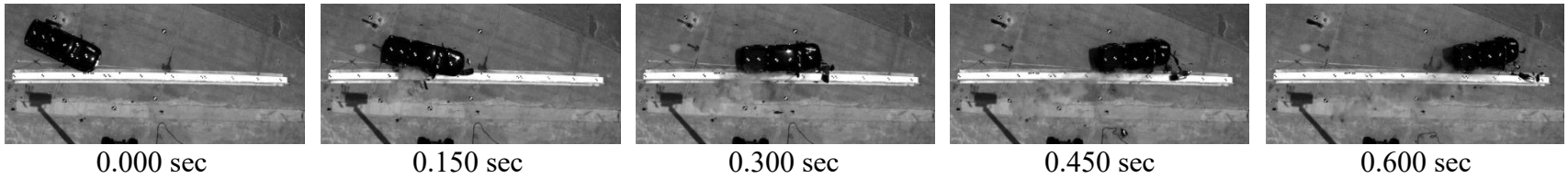
The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined from the accelerometer data, are shown in Table 6. Note that the OIVs and ORAs were within suggested limits, as provided in MASH. The calculated THIV, PHD, and ASI values are also shown in Table 6. The recorded data from the accelerometers and the rate transducers is shown graphically in Appendix E.

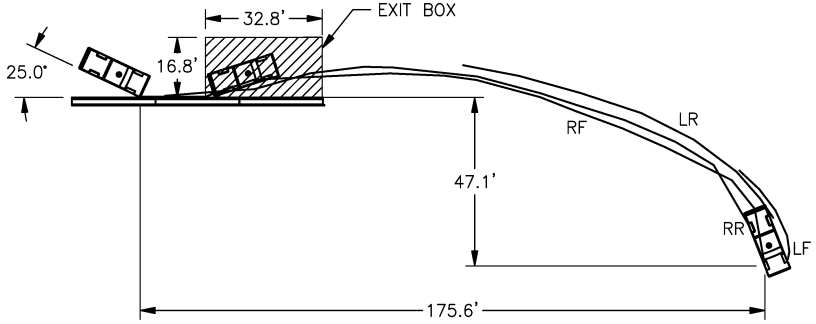
Table 6. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. HNTBR-1

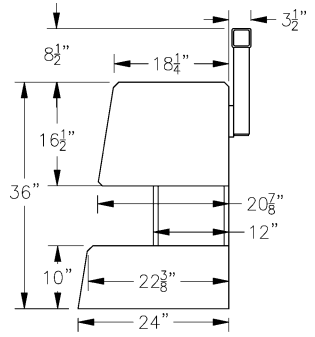
Evaluation Criteria		Transducer		MASH 2016 Limits
		TDAS	SLICE-2 (primary)	
OIV ft/s	Longitudinal	-24.4	-24.5	±40
	Lateral	-22.1	-23.1	±40
ORA g's	Longitudinal	-4.6	-5.6	±20.49
	Lateral	-8.9	-7.6	±20.49
Maximum Angular Displacement deg.	Roll	20.62	18.85	±75
	Pitch	-7.86	-7.23	±75
	Yaw	-38.95	-39.34	not required
THIV – ft/s		31.90	32.35	not required
PHD – g's		9.29	10.41	not required
ASI		1.27	1.35	not required

5.6 Discussion

The analysis of the test results for test no. HNTBR-1 showed that the system contained and redirected the 2270P vehicle with minimal lateral displacements of the barrier. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix E, were deemed acceptable because they did not adversely influence occupant risk nor cause rollover. After impact, the vehicle exited the barrier at an angle of 10.0 degrees, and its trajectory did not violate the bounds of the exit box. However, deformations of, or intrusions into, the occupant compartment could have caused serious injury. The floor pan deformation of 12.7 in. exceeded the MASH limit of 9 in. Therefore, test no. HNTBR-1 was determined to be unsatisfactory according to the safety performance criteria for MASH test designation no. 3-11. A summary of the test results and sequential photographs are shown in Figure 35.







- Test Agency ..... MwRSF
- Test Number HNTBR-1
- Date 07/17/2023
- MASH Test Designation No. 3-11
- Test Article ..... Hawaii Modified Natchez Trace Bridge Rail
- Total Length ..... 70 ft – 7 in.
- Key Component – Concrete Bridge Rail
  - Height ..... 36 in.
  - Curb Height ..... 10 in.
  - Top Width ..... 18¼ in.
  - Base Width ..... 24 in.
  - Post Cross Section ..... 12 in. x 12 in.
  - Post Spacing ..... 90 in.
- Key Component – Pedestrian Handrail
  - Top Mounting Height ..... 44½ in.
  - Handrail Section HSS3x3x¼
  - Post Spacing ..... 60 in.
- Vehicle Make /Model ..... 2017 Dodge Ram 1500 crew cab
  - Curb ..... 5,264 lb
  - Test Inertial ..... 5,032 lb (MASH Limit 5,000 ± 110 lb)
  - Gross Static ..... 5,192 lb (MASH Limit 5,165 ± 110 lb
- Impact Conditions
  - Speed ..... 62.3 mph (MASH Limit 62 ± 2.5 mph)
  - Angle ..... 25.0 deg. (MASH Limit 25 ± 1.5 deg.)
  - Impact Location ..... 56½ in. upstream from expansion joint
- Impact Severity ..... 116.6 kip-ft > 106 kip-ft MASH limit
- Exit Conditions
  - Speed ..... 44.0 mph
  - Angle ..... 10.0 deg.
- Exit Box Criterion ..... Pass
- Vehicle Stability ..... Pass
- Vehicle Stopping Distance ..... 275.6 ft downstream, 47.1 ft laterally behind
- Vehicle Damage ..... Severe
  - VDS [10] 01-RFQ-6
  - CDC [11] 01-RFEW-3
  - Maximum Interior Deformation ..... 12.7 in. at toe pan ≥ 9 in. MASH limit
- Test Article Damage ..... Minimal
- Maximum Test Article Deflections
  - Permanent Set ..... 0.7 in.
  - Dynamic ..... 1.0 in.
  - Working Width ..... 28.5 in.
- Transducer Data

Evaluation Criteria		Transducer		MASH Limits
		TADAS	SLICE-2 (primary)	
OIV ft/s	Longitudinal	-24.4	-24.5	±40
	Lateral	-22.1	-23.1	±40
ORA g's	Longitudinal	-4.6	-5.6	±20.49
	Lateral	-8.9	-7.6	±20.49
Maximum Angular Displacement deg.	Roll	20.62	18.85	±75
	Pitch	-7.86	-7.23	±75
	Yaw	-38.95	-39.34	not required
THIV – ft/s		31.90	32.35	not required
PHD – g's		9.29	10.41	not required
ASI		1.27	1.35	not required

Figure 35. Summary of Test Results and Sequential Photographs, Test No. HNTBR-1

6 SUMMARY AND CONCLUSIONS

The Hawaii Modified Natchez Trace Bridge Rail evaluated herein consisted of a curb-mounted open concrete bridge rail and a pedestrian handrail. The concrete railing had a height of 36 in. and varied in width from 18¼ in. at the top to 24 in. at the bottom. The front of the concrete railing had a consistent single-slope face between the upper rail and the lower curb. The bridge rail design utilized 12-in. x 12-in. posts spaced 90 in. apart to support the upper rail. An HSS 3x3x¼ steel tube pedestrian handrail was mounted to the backside of the concrete railing with a top mounting height of 44½ in. The test installation had an overall length of 70 ft – 7 in. and incorporated three equal-length railing segments with ½-in. expansion joints placed between each segment.

The Hawaii Modified Natchez Trace Bridge Rail was subjected to one full-scale crash test in accordance with MASH test designation no. 3-11. The test evaluation is summarized in Table 7. In test no. HNTBR-1, a 5,032-lb crew cab pickup truck impacted the Hawaii Modified Natchez Trace Bridge Rail at a speed of 62.3 mph and an angle of 25.0 degrees. The impact occurred 56½ in. upstream from the expansion joint between post nos. 4 and 5 with an impact severity of 116.6 kip-ft. The vehicle was contained and redirected and exited the system at a speed of 44.0 mph and an angle of 10 degrees. Damage to the barrier was minimal, while damage to the vehicle was extensive. Intrusion to the occupant compartment at the toe pan was 12.7 in., which exceeded the MASH limit of 9 in. Therefore, test no. HNTBR-1 was unsatisfactory according to the safety performance criteria of MASH test designation no. 3-11.

Table 7. Summary of Safety Performance Evaluation

<table>
<tr><th>Evaluation Factors</th><th colspan="4">Evaluation Criteria</th><th>Test No. HNTBR-1</th></tr>
<tr><td>Structural Adequacy</td><td colspan="4">A. Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.</td><td>S</td></tr>
<tr><td rowspan="5">Occupant Risk</td><td colspan="4">D. 1. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.

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

U</td></tr>
<tr><td colspan="4">F. 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></tr>
<tr><td colspan="4">H. Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:
<table><tr><th colspan="3">Occupant Impact Velocity Limits</th></tr><tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr><tr><td>Longitudinal and Lateral</td><td>30 ft/s</td><td>40 ft/s</td></tr></table></td><td>S</td></tr>
<tr><td colspan="4">I. The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:
<table><tr><th colspan="3">Occupant Ridedown Acceleration Limits</th></tr><tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr><tr><td>Longitudinal and Lateral</td><td>15.0 g’s</td><td>20.49 g’s</td></tr></table></td><td>S</td></tr>
<tr><td colspan="4"></td><td></td></tr>
<tr><td colspan="5">MASH 2016 Test Designation No.</td><td>3-11</td></tr>
<tr><td colspan="5">Final Evaluation (Pass or Fail)</td><td>Fail</td></tr>
</table>

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

7 REFERENCES

1. *Manual for Assessing Safety Hardware* (MASH), Second Edition, American Association of State Highway and Transportation Officials (AASHTO), Washington, D.C., 2016.

2. Faller, R.K., Holloway, J.C., Pfeifer, B.G., and Luedke, J. K., *AASHTO PL-1 Performance Crash Tests on the Natchez Trace Parkway Bridge Rail*, Report No. TRP-03-34-92, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, October 1992.

3. *Guide Specifications for Bridge Railings*, American Association of State Highway and Transportation Officials, Washington, DC, 1989.

4. Bullard, D.L., Menges, W.L., Eugene C.B., and Haug, R.R., *Guardrail Testing Program IV Volume I: Technical Report*, Report No. FHWA-HRT-04-086, Texas Transportation Institute, TX, October 2003.

5. Ross, H. E. Sicking, D. L., Zimmer, R. A. and Michie, J. D., *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, National Cooperative Highway Research Program Report 350, Transportation Research Board, National Research Council, Washington, D.C., 1993.

6. *Manual for Assessing Safety Hardware* (MASH), American Association of State Highway and Transportation Officials (AASHTO), Washington, D.C., 2009.

7. Hinch, J., Yang, T.L., and Owings, R., Guidance Systems for Vehicle Testing, ENSCO, Inc., Springfield, Virginia, 1986.

8. Center of Gravity Test Code - SAE J874 March 1981, SAE Handbook Vol. 4, Society of Automotive Engineers, Inc., Warrendale, Pennsylvania, 1986.

9. Society of Automotive Engineers (SAE), *Instrumentation for Impact Test – Part 1 – Electronic Instrumentation*, SAE J211/1 MAR95, New York City, New York, July 2007.

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

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

8 APPENDICES

Appendix A. A2LA Accreditation Documents

Accredited Laboratory

A2LA has accredited

MIDWEST ROADSIDE SAFETY FACILITY (MwRSF)

Lincoln, NE

for technical competence in the field of

Mechanical Testing

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2017 *General requirements for the competence of testing and calibration laboratories*. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (*refer to joint ISO-ILAC-IAF Communiqué dated April 2017*).

Presented this 27th day of June 2024.

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

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

Figure A-1. Midwest Roadside Safety Facility A2LA Accreditation Certificate No. 2937.01

SCOPE OF ACCREDITATION TO ISO/IEC 17025:2017

MIDWEST ROADSIDE SAFETY FACILITY (MwRSF)[1]
University of Nebraska-Lincoln
4630 NW 36th Street
Lincoln, NE 68524
Ms. Karla Lechtenberg Phone: 402 472 9070

MECHANICAL

Valid To: November 30, 2025 Certificate Number: 2937.01

In recognition of the successful completion of the A2LA evaluation process, accreditation is granted to this laboratory to perform the following tests:

Tests	Test Methods
Full-Scale Vehicle Crash Tests of Highway Safety Features	NCHRP Report 350; MASH; EN 1317
Full-Scale Vehicle Crash Tests of Perimeter Protection Systems and Access Control Devices	ASTM F2656; SD-STD-02.01 Revision A
Bogie Dynamic Tests of Highway Safety Features	Non-Standard Test Method: Dynamic Testing of Steel Post and Rigid Foundation; Non-Standard Test Method: Dynamic Testing of Post in Soil; Non-Standard Test Method: Dynamic Testing of Spacer Blocks
Crushable Nose Bogie Testing for Breakaway Supports	Non-Standard Test Method: Dynamic Testing of Breakaway Supports; AASHTO Breakaway Poles and Supports; NCHRP Report 350

On the following types of products, materials, and/or structures:
Metal, Wood, Concrete and Plastic Structures, Components of Structures, Fasteners, and Roadway Pavements.

[1] Administrative office located at: 2200 Vine Street, 130 Whittier Building, Lincoln, NE 68583-0853.

(A2LA Cert. No. 2937.01) 06/27/2024 Page 1 of 1

5202 Presidents Court, Suite 220 | Frederick, MD 21703-8515 | Phone: 301 644 3248 | Fax: 240 454 9449 | www.A2LA.org

Figure A-2. Midwest Roadside Safety Facility Scope of Accreditation to ISO/IEC 17025

Appendix B. Material Specifications, Test No. HNTBR-1

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

Item No.	Description	Material Specification	Reference
a1	Concrete	Min. f'c = 4,000 psi	Sample 06052023.2
b1	#4 Rebar, 46" Total Unbent Length	ASTM A615 Gr. 60	H#44000302131
b2	#7 Rebar, 53¼" Total Unbent Length	ASTM A615 Gr. 60	H#7021691
b3	#5 Rebar, 44½" Total Unbent Length	ASTM A615 Gr. 60	H#9700018828
b4	#4 Rebar, 35¾" Total Unbent Length	ASTM A615 Gr. 60	H#44000302131
b5	#4 Rebar, 62" Total Unbent Length	ASTM A615 Gr. 60	H#44000302131
b6	#6 Rebar, 278" Total Length	ASTM A615 Gr. 60	H#9700017142
b7	#5 Rebar, 278" Total Length	ASTM A615 Gr. 60	H#9700018828
b8	#5 Rebar, 38⅞" Total Unbent Length	ASTM A615 Gr. 60	H#9700018828
c1	#8 Smooth Rebar, 24½" Long	ASTM A615 Gr. 60	H#88924
c2	1¼" Dia. PVC Pipe	Schedule 80 PVC Gr. 12454	C.o.C. 5/5/2021
c3	1¼" Dia. PVC End Cap	Schedule 80 PVC Gr. 12454	C.o.C. 5/5/2021
d1	HSS 3" x 3" x ¼", 281½" Long	ASTM A500 Gr. B	H#NM5532
d2	HSS 2½" x 2½" x ¼", 13¾" Long	ASTM A500 Gr. B	H#05606D
d3	2¼" x 2¼" x ¼" Steel Plate	ASTM A36	H#B2209440
d4	8" x 5" x ¾" Steel Plate	ASTM A36	H#A2K317
d5	7" x1½" x $^{3}/_{16}$" Shim	ASTM A36	H#22112982
d6	HSS 2" x 2" x ¼", 7" Long	ASTM A500 Gr. B	H#2125151
e1	⅝"-11 UNC Heavy Hex Nut	ASTM A563-15 Grade DH	H#1000113771
e2	⅝" Dia. Hardened Washer	ASTM F436	H#22203720
e3	⅝"-11 UNC, 7⅞" Long Threaded Rod	ASTM F1554-15 Gr. 105	H#100209239
e4	Epoxy Adhesive	Hilti HIT RE-500 V3	COC
e5	Joint Filler	AASHTO M33, M153, or M213	Data Tech Sheet
e6	Expansion Joint Sealant	AASHTO M173, M282, M301, ASTM D3581, or ASTM D5893	Data Tech Sheet

benesch

Concrete Sample Test Report
Cylinder Compressive Strength

Project Name:	Midwest Roadside Safety - Misc Testing
Project Number:	00110546.00
Client:	Midwest Roadside Safety Facility
Location:	Midwest Roadside Safety
Sample:	06052023.2
Description:	HNTBR-1-2 , H3 Rail 3

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

Supplier:		Property	Test Result
Mix Name:		Slump (in):	
Ticket Number:		Air Content (%):	
Truck Number:		Unit Weight (lb/ft³):	
Load Volume (yd³):		Air Temp (°F):	
Mold Date:	06/05/2023	Mix Temp (°F):	
Molded By:		Min Temp (°F):	
Initial Cure Method:		Max Temp (°F):	

Laboratory Test Data (ASTM C39)

Sample Number:	06052023.2					
Set Number:	1					
Specimen Number:	1					
Age:	36					
Length (in):	12					
Diameter (in):	6					
Area (in²):	28.27					
Density (lb/ft³):	135					
Test Date:	07/11/2023					
Break Type:	5					
Max Load (lbf):	114,832					
Strength (psi):	4,060					
Spec Strength (psi):						
Excl in Avg Strength:	☐	☐	☐	☐	☐	☐

Remarks:
Set 1, Specimen 1, 36-day Compressive Strength (psi): **4,060**

Sample Receive Date: 07/11/2023

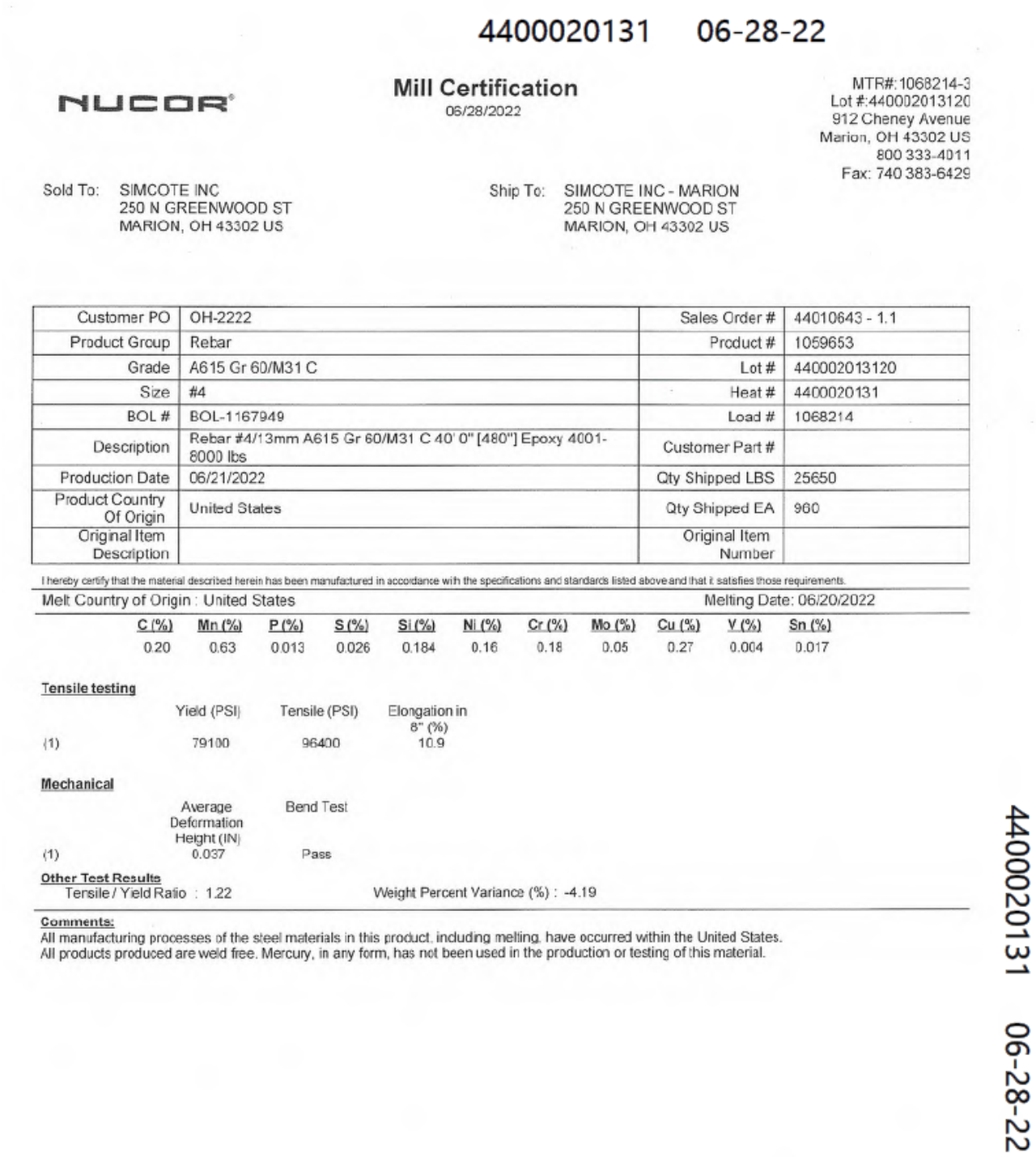
Approved by:

Matt Roessler Manager

Date: 07/11/2023

825 M Street Suite 100
Lincoln, NE 68508
Benesch

Figure B-1. Concrete, Test No. HNTBR-1 (Item No. a1)



4400020131 06-28-22

NUCOR

Mill Certification
06/28/2022

MTR#:1068214-3
Lot #:440002013120
912 Cheney Avenue
Marion, OH 43302 US
800 333-4011
Fax: 740 383-6429

Sold To: SIMCOTE INC
250 N GREENWOOD ST
MARION, OH 43302 US

Ship To: SIMCOTE INC - MARION
250 N GREENWOOD ST
MARION, OH 43302 US

Customer PO	OH-2222	Sales Order #	44010643 - 1.1
Product Group	Rebar	Product #	1059653
Grade	A615 Gr 60/M31 C	Lot #	440002013120
Size	#4	Heat #	4400020131
BOL #	BOL-1167949	Load #	1068214
Description	Rebar #4/13mm A615 Gr 60/M31 C 40' 0" [480"] Epoxy 4001-8000 lbs	Customer Part #	
Production Date	06/21/2022	Qty Shipped LBS	25650
Product Country Of Origin	United States	Qty Shipped EA	960
Original Item Description		Original Item Number	

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

Melt Country of Origin : United States — Melting Date: 06/20/2022

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	V (%)	Sn (%)
0.20	0.63	0.013	0.026	0.184	0.16	0.18	0.05	0.27	0.004	0.017

Tensile testing

	Yield (PSI)	Tensile (PSI)	Elongation in 8" (%)
(1)	79100	96400	10.9

Mechanical

	Average Deformation Height (IN)	Bend Test
(1)	0.037	Pass

Other Test Results
Tensile / Yield Ratio : 1.22
Weight Percent Variance (%) : -4.19

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

4400020131 06-28-22

Figure B-2. #4 Rebar, Test No. HNTBR-1 (Item Nos. b1, b4, and b5)

CMC STEEL TENNESSEE
1919 Tennessee Avenue
Knoxville TN 37921-2686

CERTIFIED MILL TEST REPORT
For additional copies call
865-202-5972/888-870-0766

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

Jim Hall
Quality Assurance Manager

HEAT NO.:7021691 SECTION: REBAR 22MM (#7) 60'0" 420/60 SIM GRADE: ASTM A615-20 Gr 420/60 SIM ROLL DATE: 10/25/2021 MELT DATE: 10/25/2021 Cert. No.: 83638480 / 021691L792	SOLD TO	Simcote Inc 1645 Red Rock Rd Saint Paul MN US 55119-6014 6517359660	SHIP TO	Simcote Inc 1645 Red Rock Rd Saint Paul MN US 55119-6014 6517359660	Delivery#: 83638480 BOL#: 2159834 CUST PO#: MN-3782 CUST P/N: DLVRY LBS / HEAT: 117732.000 LB DLVRY PCS / HEAT: 960 EA

Characteristic	Value
C	0.33%
Mn	0.69%
P	0.015%
S	0.048%
Si	0.22%
Cu	0.27%
Cr	0.19%
Ni	0.10%
Mo	0.019%
V	0.003%
Sn	0.005%
Yield Strength test 1	87.1ksi
Yield Strength test 1 (metri	601MPa
Tensile Strength test 1	106.0ksi
Tensile Strength 1 (metric)	731MPa
Elongation test 1	12%
Elongation Gage Lgth test 1	8IN
Tensile to Yield ratio test1	1.22
Elongation Gage Lgth 1(metri	200mm

Characteristic	Value
Bend Test 1	Passed
Rebar Deformation Avg. Spaci	0.535IN
Rebar Deformation Avg. Heigh	0.053IN
Rebar Deformation Max. Gap	0.135IN

The Following is true of the material represented by this MTR:

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

REMARKS :

Figure B-3. #7 Rebar, Test No. HNTBR-1 (Item No. b2)

NUCOR

Mill Certification

09/24/2022

MTR#:1144239-4
Lot #:970001882820
500 REBAR RD
SEDALIA, MO 65301 US
660 951-1679
Fax: 660 951-1698

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-3825	Sales Order #	97007522 - 7.1
Product Group	Rebar	Product #	2110230
Grade	A615 Gr 60/AASHTO M31	Lot #	970001882820
Size	#5	Heat #	9700018828
BOL #	BOL-1242869	Load #	1144239
Description	Rebar #5/16mm A615 Gr 60/AASHTO M31 40' 0" [480"] 4001-8000 lbs	Customer Part #	
Production Date	09/20/2022	Qty Shipped LBS	71343
Product Country Of Origin	United States	Qty Shipped EA	1710
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: 09/20/2022

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	V (%)	Nb (%)
0.24	0.77	0.007	0.027	0.234	0.12	0.11	0.03	0.004	0.001

Tensile testing

	Yield (PSI)	Tensile (PSI)	Elongation in 8" (%)
(1)	77100	91000	13.7

Mechanical

	Average Deformation Height (IN)	Bend Test
(1)	0.039	Pass

Comments:

1. All manufacturing processes of the steel materials in this product, including melting, casting and rolling were performed in the USA.
2. Mercury, Radium, Hexavalent Chrome or Alpha source materials in any form have not been used in the production and testing of this material.
3. Weld repair was not performed on this material.

Figure B-4. #5 Rebar, Test No. HNTBR-1 (Item No. b3, b7, and b8)

NUCOR

Mill Certification
07/19/2022

MTR#:1087642-4
Lot #:970001714220
500 REBAR RD
SEDALIA, MO 65301 US
660 951-1679
Fax: 660 951-1698

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

Ship To: SIMCOTE DNS 232752 000
NEWPORT MN N11
NEWPORT, MN 55055 US

Customer PO	MN-3814	Sales Order #	97006876 - 3.1
Product Group	Rebar	Product #	2110264
Grade	A615 Gr 60/AASHTO M31	Lot #	970001714220
Size	#6	Heat #	9700017142
BOL #	BOL-1185401	Load #	1087642
Description	Rebar #6/19mm A615 Gr 60/AASHTO M31 40' 0" [480"] 6001-10000 lbs	Customer Part #	
Production Date	07/10/2022	Qty Shipped LBS	54670
Product Country Of Origin	United States	Qty Shipped EA	910
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: 07/10/2022

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	V (%)	Nb (%)
0.29	0.98	0.009	0.020	0.177	0.14	0.16	0.04	0.005	0.002

Tensile testing

	Yield (PSI)	Tensile (PSI)	Elongation in 8" (%)
(1)	76300	95000	13.3

Mechanical

	Average Deformation Height (IN)	Bend Test
(1)	0.045	Pass

Comments:
1. All manufacturing processes of the steel materials in this product, including melting, casting and rolling were performed in the USA.
2. Mercury, Radium, Hexavalent Chrome or Alpha source materials in any form have not been used in the production and testing of this material.
3. Weld repair was not performed on this material.

Figure B-5. #6 Rebar, Test No. HNTBR-1 (Item No. b6)

CERTIFIED MILL TEST REPORT

ASI
ALTON STEEL INC

Alton Steel Test Lab
#5 Cut Street
Alton, IL. 62002-9011
(618) 463-4490 EXT 2486
(618) 463-4491 (Fax)

BILL TO
WADY Industries, Inc
510 East Grove Street
Maquoketa, IA 52060

SHIP TO
WADY Industries, Inc
510 East Grove Street
Maquoketa, IA 52060

Date	11/12/2018	Customer PO	11352	Specifications
ASI Ord No.	96071	Customer PT.	1.000-GRADE80-362	
ASI Ord Line Item	1			AASHTO M227 GR 80, ASTM A615-16 GR40

Item Description
Steel Bar, Hot Rolled, 1.0000, 30' 2 "

Strand Cast, RR =62.39:1

Heat Number	Yield PSI	Tensile PSI	% Elongation	% ROA	Bend Test
188397	65100	97100	15 in 8"	32	Pass
188829	74400	99700	15 in 8"	37	Pass
188830	60200	90400	20 in 8"	36	Pass
188924	66400	98900	19 in 8"	37	Pass
188925	63500	94800	17 in 8"	36	Pass

CHEMICAL ANALYSIS TEST METHODS ASTM E-415 & E-1019

Heat #	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Sn	Al	Nb/Cb	V	B	Ti	N	Pb	Ca
88397	0.38	0.82	0.011	0.021	0.20	0.24	0.101	0.170	0.029	0.011	0.025	0.002	0.005	0.0002	0.0018	0.0107	0.0044	0.0024
88829	0.34	0.75	0.010	0.023	0.23	0.27	0.079	0.139	0.024	0.010	0.001	0.001	0.046	0.0004	0.0007	0.0095	0.0023	0.0017
88830	0.31	0.79	0.013	0.026	0.26	0.26	0.104	0.194	0.034	0.010	0.002	0.001	0.006	0.0003	0.0008	0.0104	0.0027	0.0023
88924	0.32	0.78	0.012	0.023	0.25	0.28	0.110	0.207	0.033	0.011	0.002	0.002	0.006	0.0003	0.0006	0.0115	0.0034	0.0019
88925	0.32	0.83	0.017	0.022	0.25	0.29	0.093	0.202	0.028	0.011	0.002	0.002	0.006	0.0004	0.0007	0.0115	0.0039	0.0015

JOMINY HARDENABILITY USING ASTM A-255 CALCULATED FROM CHEMICAL DI

Heat Number	GS	DI
88397	8	1.50
88829	8	1.27
88830		1.28
88924		1.35
88925		1.40

SPECIAL TEST RESULTS

	ASTM E-45 Method A:								ASTM E-45 Method C:		SAE J422		ASTM E-381			Charpy	Hardness		
Heat Number	TA	TB	TC	TD	HA	HB	HC	HD	S	O	S	O	S	R	C		RC	RB	BHN
88397																			172
88829																			195
88830																			176
88924																			172
88925																			185

ADDITIONAL COMMENTS

Figure B-6. #8 Smooth Rebar, Test No. HNTBR-1 (Item No. c1)

FASTENAL®

Certificate of Compliance

Sold To:

UNL / UNMC E-SHOP / PUNCHOUT

Purchase Order: E000848414

Job: Shaun

Invoice Date: 05/5/2021

THIS IS TO CERTIFY THAT WE HAVE SUPPLIED YOU WITH THE FOLLOWING PARTS.
THESE PARTS WERE PURCHASED TO THE FOLLOWING SPECIFICATIONS.

12 PCS 1-1/4" Slip 300 lb PVC Flat Pipe Cap SUPPLIED UNDER OUR TRACE NUMBER lne49403 AND UNDER PART NUMBER 0470592

2 PCS 1-1/4" x 10 ft Gray Schedule 80 PVC Plain End Pipe SUPPLIED UNDER OUR TRACE NUMBER a042821 AND UNDER PART NUMBER 0472040

This is to certify that the above document is true and accurate to the best of my knowledge.

Tom Schall

Fastenal Account Representative Signature

Ross Schall

Printed Name

5/5/2021

Date

Please check current revision to avoid using obsolete copies.

This document was printed on 05/05/2021 and was current at that time.

Fastenal Store Location/Address

3201 N. 23rd Street STE 1
LINCOLN, NE 68521
Phone #: (402)476-7900
Fax #: 402/476-7958

Page 1 of 1

Figure B-7. PVC Tube Specifications, Test No. HNTBR-1 (Item Nos. c2 and c3)

NUCOR TUBULAR PRODUCTS

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

https://www.nucortubular.com
https://www.ntpportal.com
Certificate Number: BHM 872827

Sold By:
NUCOR TUBULAR PRODUCTS INC.
BIRMINGHAM DIVISION
3525 RICHARD ARRINGTON JR. BLVD N
BIRMINGHAM, AL 35201
Tel: 205 251-1884
Fax: 205 251-1553

Purchase Order No: 4500539383
Sales Order No: BHM 593391 - 2
Bill of Lading No: BHM 51194 - 4
Invoice No:

Shipped: 10/28/2022
Invoiced:

Sold To:
5018 - STEEL & PIPE SUPPLY
4750 W. MARSHALL AVENUE
LONGVIEW, TX 75604

Ship To:
1 - STEEL & PIPE SUPPLY
4750 W. MARSHALL AVENUE
LONGVIEW, TX 75604

CERTIFICATE of ANALYSIS and TESTS

Certificate No: BHM 872827
Customer Part No:
Test Date: 10/26/2022

TUBING A500 GRADE B(C)
3" SQ X 1/4" X 24'

Total Pieces	Total Weight Lbs
100	21,145

Bundle Tag	Mill	Heat	Specs	Y/T Ratio	Pieces	Weight Lbs
197201	40N	SM5708	YLD=65000/TEN=73500/ELG=25.5	0.8844	20	4,229
197206	40N	NM5532	YLD=61800/TEN=74300/ELG=26	0.8318	20	4,229
197207	40N	NM5532	YLD=61800/TEN=74300/ELG=26	0.8318	20	4,229
197210	40N	NM5148	YLD=63500/TEN=72900/ELG=23	0.8711	20	4,229
197211	40N	NM5148	YLD=63500/TEN=72900/ELG=23	0.8711	20	4,229

Mill #: 40N Heat #: NM5148 Carbon Eq: 0.2841 Heat Src Origin: MELTED AND MANUFACTURED IN THE USA

C	Mn	P	S	Si	Al	Cu	Cr	Mo	V	Ni	Nb	Sn
0.2000	0.3900	0.0040	0.0020	0.0270	0.0340	0.1000	0.0400	0.0100	0.0020	0.0300	0.0060	0.0020

N	B	Ti	Ca
0.0050	0.0001	0.0020	0.0020

Mill #: 40N Heat #: NM5532 Carbon Eq: 0.2894 Heat Src Origin: MELTED AND MANUFACTURED IN THE USA

C	Mn	P	S	Si	Al	Cu	Cr	Mo	V	Ni	Nb	Sn
0.2000	0.4100	0.0070	0.0010	0.0200	0.0290	0.1200	0.0400	0.0100	0.0020	0.0400	0.0060	0.0030

N	B	Ti	Ca
0.0060	0.0002	0.0010	0.0011

Mill #: 40N Heat #: SM5708 Carbon Eq: 0.2667 Heat Src Origin: MELTED AND MANUFACTURED IN THE USA

C	Mn	P	S	Si	Al	Cu	Cr	Mo	V	Ni	Nb	Sn
0.1900	0.3500	0.0050	0.0040	0.0230	0.0380	0.1200	0.0300	0.0100	0.0020	0.0300	0.0070	0.0020

N	B	Ti	Ca
0.0053	0.0004	0.0010	0.0017

Figure B-8. 3 x 3 x ¼-in., 281½-in. Long HSS, Test No. HNTBR-1 (Item No. d1)

EXLTUBE®

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

STEEL VENTURES, LLC dba EXLTUBE

Certified Test Report

Customer:	Size: 02.50X02.50	Customer Order No:	Customer Part No:
SPS - Tulsa 1020 Fort Gibson Road Catoosa OK 74015-3033	Gauge: 1/4	4500524183	6521625040
	Date: 02/09/2022	Delivery No: 85142099 Load No: 7138474	Length: 40 FT
	Specification: ASTM A500-21 Gr.B/C		

Heat No	Yield KSI	Tensile KSI	Elongation % 2 Inch
05606D	61.7	70.4	30.00

Heat No	C	MN	P	S	SI	CU	NI	CR	MO	V
05606D	0.1600	0.7900	0.0120	0.0070	0.0110	0.0400	0.0200	0.0600	0.0000	0.0000

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

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

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

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

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

STEEL VENTURES, LLC dba EXLTUBE

Jonathan Wolfe
Quality Assurance Manager

Figure B-9. 2½ x 2½ x ¼-in., 13¾-in. Long HSS, Test No. HNTBR-1 (Item No. d2)

STEEL AND PIPE SUPPLY

SPS Coil Processing Tulsa
5275 Bird Creek Ave.
Port of Catoosa, OK 74015

METALLURGICAL TEST REPORT

PAGE 1 of 1
DATE 01/26/2023
TIME 07:05:13

SOLD TO

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

Order	Material No.	Description	Quantity	Weight	Customer Part	Customer PO	Ship Date
40397361-0020	70872120	1/4 72 X 120 A36 STP MIL PLT	16	9,801.600			01/25/2023

Chemical Analysis

Heat No. B2209440 Vendor STEEL DYNAMICS SOUTHWEST, LLC DOMESTIC Mill STEEL DYNAMICS SOUTHWEST, LLC **Melted and Manufactured in the USA**

Produced from Coil

Carbon	Manganese	Phosphorus	Sulphur	Silicon	Nickel	Chromium	Molybdenum	Boron	Copper	Aluminum	Titanium	Vanadium	Columbium	Nitrogen	Tin
0.0500	0.8600	0.0060	0.0040	0.0200	0.0400	0.0400	0.0100	0.0000	0.1000	0.0290	0.0000	0.0040	0.0020	0.0080	0.0050

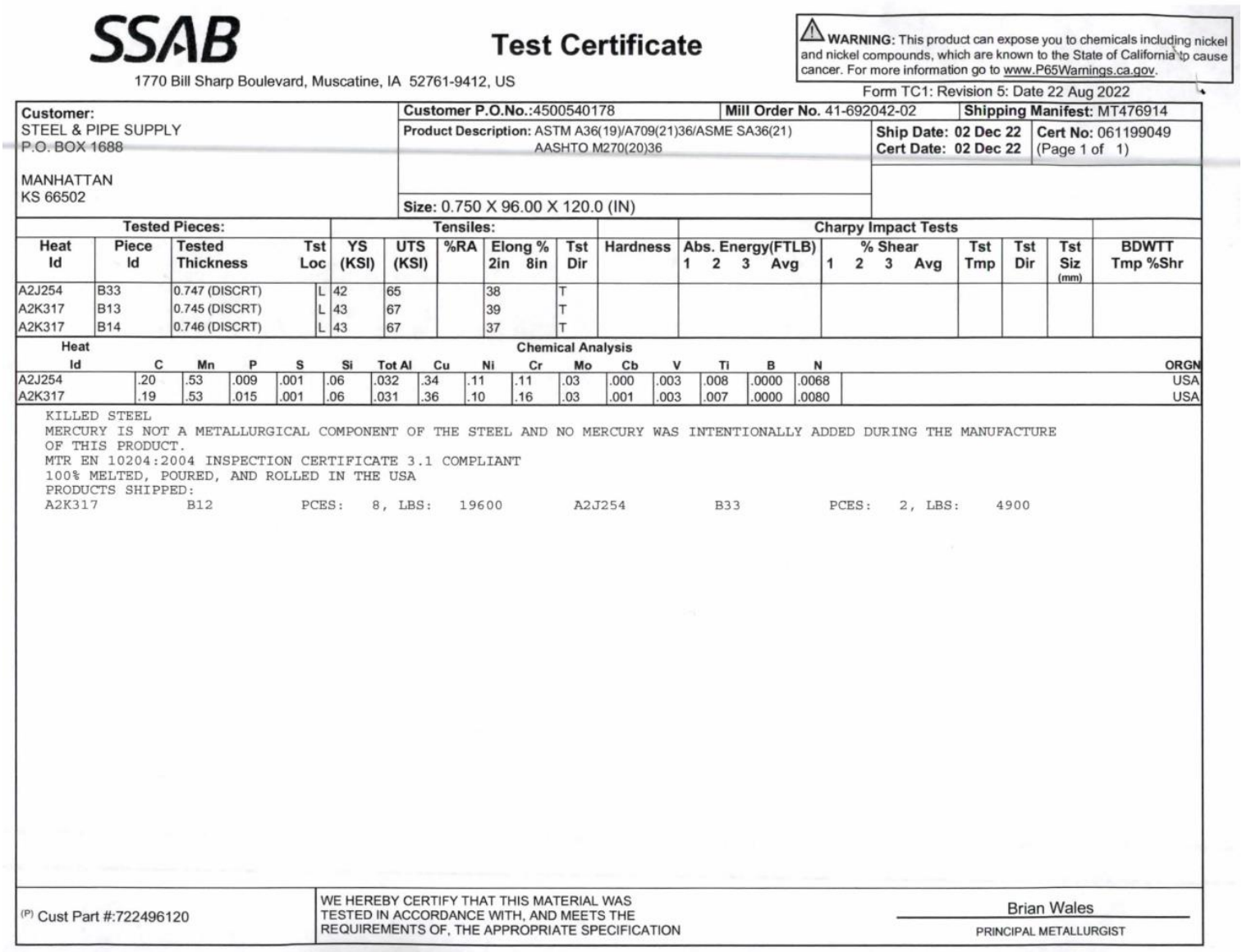
Mechanical / Physical Properties

Mill Coil No. 22B114642

Tensile (PSI)	Yield (PSI)	% Elong (2 in)	Rckwl	Grain	Charpy	Charpy Dr	Charpy Sz	Temperature	Olsen
64000.000	50700.000	36.50			0	NA			
62600.000	47600.000	36.50			0	NA			
64200.000	46300.000	37.50			0	NA			
63200.000	45800.000	36.00			0	NA			

Batch 1001159632 16 EA 9,801.600 LB

Figure B-10. 2¼ x 2¼ x ¼-in. Steel Plate, Test No. HNTBR-1 (Item No. d3)



SSAB

Test Certificate

1770 Bill Sharp Boulevard, Muscatine, IA 52761-9412, US

WARNING: This product can expose you to chemicals including nickel and nickel compounds, which are known to the State of California to cause cancer. For more information go to www.P65Warnings.ca.gov.

Form TC1: Revision 5: Date 22 Aug 2022

Customer:
STEEL & PIPE SUPPLY
P.O. BOX 1688

MANHATTAN
KS 66502

Customer P.O.No.: 4500540178 | **Mill Order No.** 41-692042-02 | **Shipping Manifest:** MT476914

Product Description: ASTM A36(19)/A709(21)36/ASME SA36(21)
AASHTO M270(20)36

Ship Date: 02 Dec 22 | **Cert No:** 061199049
Cert Date: 02 Dec 22 | (Page 1 of 1)

Size: 0.750 X 96.00 X 120.0 (IN)

Tested Pieces:				Tensiles:					Hardness	Charpy Impact Tests							
Heat Id	Piece Id	Tested Thickness	Tst Loc	YS (KSI)	UTS (KSI)	%RA	Elong % 2in 8in	Tst Dir		Abs. Energy(FTLB) 1 2 3 Avg	% Shear 1 2 3 Avg	Tst Tmp	Tst Dir	Tst Siz (mm)	BDWTT Tmp %Shr
A2J254	B33	0.747 (DISCRT)	L	42	65		38	T							
A2K317	B13	0.745 (DISCRT)	L	43	67		39	T							
A2K317	B14	0.746 (DISCRT)	L	43	67		37	T							

Heat Id	Chemical Analysis C	Mn	P	S	Si	Tot Al	Cu	Ni	Cr	Mo	Cb	V	Ti	B	N	ORGN
A2J254	.20	.53	.009	.001	.06	.032	.34	.11	.11	.03	.000	.003	.008	.0000	.0068	USA
A2K317	.19	.53	.015	.001	.06	.031	.36	.10	.16	.03	.001	.003	.007	.0000	.0080	USA

KILLED STEEL
MERCURY IS NOT A METALLURGICAL COMPONENT OF THE STEEL AND NO MERCURY WAS INTENTIONALLY ADDED DURING THE MANUFACTURE OF THIS PRODUCT.
MTR EN 10204:2004 INSPECTION CERTIFICATE 3.1 COMPLIANT
100% MELTED, POURED, AND ROLLED IN THE USA
PRODUCTS SHIPPED:
A2K317 B12 PCES: 8, LBS: 19600 A2J254 B33 PCES: 2, LBS: 4900

(P) Cust Part #:722496120

WE HEREBY CERTIFY THAT THIS MATERIAL WAS TESTED IN ACCORDANCE WITH, AND MEETS THE REQUIREMENTS OF, THE APPROPRIATE SPECIFICATION

Brian Wales
PRINCIPAL METALLURGIST

Figure B-11. 8 x 5 x ¾-in. Steel Plate, Test No. HNTBR-1 (Item No. d4)

STEEL AND PIPE SUPPLY

SPS Coil Processing Tulsa
5275 Bird Creek Ave.
Port of Catoosa, OK 74015

METALLURGICAL TEST REPORT

PAGE 1 of 1
DATE 12/13/2022
TIME 07:22:11

SOLD TO

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

Order	Material No.	Description	Quantity	Weight	Customer Part	Customer PO	Ship Date
40395681-0020	70672120	3/16 72 X 120 A36 STP MIL PLT	6	2,757.600			12/12/2022

Chemical Analysis

Heat No. 22112982 Vendor BIG RIVER STEEL LLC DOMESTIC Mill BIG RIVER STEEL LLC **Melted and Manufactured in the USA**
Produced from Coil

Carbon	Manganese	Phosphorus	Sulphur	Silicon	Nickel	Chromium	Molybdenum	Boron	Copper	Aluminum	Titanium	Vanadium	Columbium	Nitrogen	Tin
0.0600	0.8100	0.0060	0.0030	0.0200	0.0300	0.0300	0.0100	0.0001	0.0600	0.0250	0.0000	0.0020	0.0010	0.0095	0.0028

Mechanical / Physical Properties

Mill Coil No. 22112982-03

Tensile (PSI)	Yield (PSI)	% Elong (2 in)	Rckwl	Grain	Charpy	Charpy Dr	Charpy Sz	Temperature	Olsen
64100.000	46800.000	31.00			0	NA			
64100.000	47200.000	30.00			0	NA			
66700.000	48000.000	27.50			0	NA			
66200.000	48300.000	31.00			0	NA			

Batch 1001086664 6 EA 2,757.600 LB

Batch 1001086661 21 EA 9,651.600 LB

Figure B-12. 7 x 1½ x $^{3}/_{16}$-in. Shim, Test No. HNTBR-1 (Item No. d5)

Atlas Tube Arkansas
6651 E Hwy 137
Blytheville Arkansas USA
72315
Tel:
Fax:

Atlas Tube
A DIVISION OF ZEKELMAN INDUSTRIES

REF.B/L: 81115225
Date: 10/13/2022
Customer: 179

MATERIAL TEST REPORT

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

Shipped To
Steel & Pipe c/o Longview Whse
4750 West Marshall Avenue
LONGVIEW TX 75604
USA

Material: 2.0x2.0x250x40'0"0(10x3). **Material No:** 200202504000 **Made in:** USA
Melted and Poured in: USA
Sales Order: 1832937 **Purchase Order:** 4500537759 **Cust Material#:** 6520025040

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
2125151	0.200	0.780	0.011	0.002	0.030	0.020	0.080	0.002	0.010	0.040	0.040	0.003	0.002	0.0000	0.0060	0.0020

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE: 0.35
M400217625	30	066583 Psi	081008 Psi	29 %	ASTM A500-21 GRADE B&C	

Heat	MILL	Mill Location	Method	Recycled_Content	Post_Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
2125151	NUCOR	HICKMAN,AR	EAF	52.50%	31.80%	20.70%	74%	500

Material Note:
Sales Or. Note:

Authorized by Quality Assurance: Jason Richard
Jason Richard

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

Steel Tube Institute OF NORTH AMERICA

Metals Service Center Institute

Page: 1 of 1

Figure B-13. 2 x 2 x ¼-in., 7-in. Long HSS, Test No. HNTBR-1 (Item No. d6)

NUCOR
FASTENER DIVISION

LOT NO.
469660C

Post Office Box 6100
Saint Joe, Indiana 46785
Telephone 260/337-1600

CUSTOMER NO/NAME
9311 STELFAST INC.

NUCOR ORDER # 335684
TEST REPORT SERIAL# FB707265
CUST PART # ADHHGBW0625CSKD
TEST REPORT ISSUE DATE 6/03/22
DATE SHIPPED 6/13/22
CUSTOMER P.O. # A-32815
NAME OF LAB SAMPLER: AMY HULLINGER, LAB TECHNICIAN

**********CERTIFIED MATERIAL TEST REPORT**********

NUCOR PART NO	QUANTITY	LOT NO.	DESCRIPTION
175747C	6800	469660C	5/8-11 GR DH HV H.D.G.
MANUFACTURE DATE 3/16/22			HEX NUT HOT DIP GAL.

--CHEMISTRY MATERIAL GRADE -1026L

MATERIAL NUMBER	HEAT NUMBER	**CHEMISTRY COMPOSITION (WT% HEAT ANALYSIS) BY MATERIAL SUPPLIER C	MN	P	S	SI	
RM035653	1000113771	.25	.70	.015	.011	.25	NUCOR STEEL - NEBRASKA 2911 EAST NUCOR RD NORFOLK, NE 68701

--MECHANICAL PROPERTIES IN ACCORDANCE WITH ASTM A563/A563M-21ae1

SURFACE HARDNESS (R30N)	CORE HARDNESS (RC)	PROOF LOAD 33900 LBS	TENSILE STRENGTH (LBS)	DEG-WEDGE STRESS (PSI)
N/A	30.7	PASS	N/A	N/A
N/A	29.4	PASS	N/A	N/A
N/A	30.9	PASS	N/A	N/A
N/A	30.6	PASS	N/A	N/A
N/A	28.8	PASS	N/A	N/A

AVERAGE VALUES FROM TESTS
30.1
PRODUCTION LOT SIZE 188000 PCS

--VISUAL INSPECTION IN ACCORDANCE WITH ASTM A563/A563M-21ae1 160 PCS. SAMPLED LOT PASSED

--COATING - HOT DIP GALVANIZED TO ASTM F2329-15 - GALVANIZING PERFORMED IN THE U.S.A.
1. 0.00331 2. 0.00517 3. 0.00220 4. 0.00328 5. 0.00412 6. 0.00407 7. 0.00285
8. 0.00282 9. 0.00316 10. 0.00225 11. 0.00429 12. 0.00270 13. 0.00264 14. 0.00335
15. 0.00265
AVERAGE THICKNESS FROM 15 TESTS .00326 (INCHES) THICKNESS METHODS PER ASTM E375,B487, AND B499 UNLESS CUSTOMER SPECIFIES

--HEAT TREATMENT - AUSTENITIZED, OIL QUENCHED & TEMPERED (MIN 800 DEG F)

--DIMENSIONS PER ASME B18.2.6-2010

CHARACTERISTIC	#SAMPLES TESTED	MINIMUM	MAXIMUM (in IN/MM)
Width Across Corners	8	1.187	1.193
Thickness	32	0.596	0.612

--SAMPLING PLAN PER ASTM F1470-19 UNLESS SPECIFIED BY CUSTOMER

ALL TESTS ARE IN ACCORDANCE WITH THE LATEST REVISIONS OF THE METHODS PRESCRIBED IN THE APPLICABLE SAE AND ASTM SPECIFICATIONS. THE SAMPLES TESTED CONFORM TO THE SPECIFICATIONS AS DESCRIBED/LISTED ABOVE AND WERE MANUFACTURED FREE OF MERCURY CONTAMINATION. NO INTENTIONAL ADDITIONS OF BISMUTH, SELENIUM, TELLURIUM, OR LEAD WERE USED IN THE STEEL USED TO PRODUCE THIS PRODUCT.
THE STEEL WAS MELTED AND MANUFACTURED IN THE U.S.A. AND THE PRODUCT WAS MANUFACTURED AND TESTED IN THE U.S.A.
PRODUCT COMPLIES WITH DFARS 252.225-7014. WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY. THIS CERTIFIED MATERIAL TEST REPORT RELATES ONLY TO THE ITEMS LISTED ON THIS DOCUMENT AND MAY NOT BE REPRODUCED EXCEPT IN FULL. CERTIFICATION FORMAT MEETS EN10204 3.1

A2LA ACCREDITED
MECHANICAL FASTENER
CERTIFICATE NO. A2LA 0139.01
EXPIRATION DATE 12/31/23

NUCOR FASTENER
A DIVISION OF NUCOR CORPORATION
SAHIL PRABHUDESAI
QUALITY ASSURANCE SUPERVISOR

Page 1 of 1

Figure B-14. ⅝-in.-11 UNC Heavy Hex Nut, Test No. HNTBR-1 (Item No. e1)

TECHNICAL STAMPING TSI EST. 1991

TECHNICAL STAMPING, INC.

50600 E. RUSSELL SCHMIDT BLVD.
CHESTERFIELD TWP., MI 48051
PH(586)948-3285 / FX(586)948-3286

MATERIAL CERTIFICATION

CUSTOMER NAME	CUSTOMER ORDER NUMBER	DATE
Portland Bolt & Mfg Co	54763	6/2/2022

PART NUMBER - CUSTOMER LOT NO.	LOT NUMBER	QUANTITY
5/8" F436 Hdg	0322-248	10,000

STEEL GRADE	HEAT	C	MN	P	S	SI	AL	REVISION
	22203720	.53	.73	.008	.002	.23	.020	F436-19

SPECIFICATION		ACTUAL	GAUGE
O.D -	1.281 - 1.345	1.286 - 1.289	CALIPER
I.D -	.688 - .720	.715 - .718	CALIPER, PIN GAUGE
THICKNESS-	.122 - .177	.134 - .137	MICROMETER
FLAT-	Max .010	.009	CALIPER
HEAT TREAT -	38 - 45HRC	41 - 44	
PLATING-		See Attached Cert	
OTHER		N/A	

WE HEARBY CERTIFY THIS PRODUCT WAS PRODUCED UNDER A ISO-9001:2015 QUALITY ASSURANCE SYSTEM ISO-9001:2015
ALL MATERIALS ARE MADE AND MELTED IN THE U.S.A. THIS PRODUCT WAS MANUFACTURED IN CHESTERFIELD, MICHIGAN, U.S.A. THIS PRODUCT CONFORMS TO ALL REQUIREMENTS FOR WASHERS AS PRODUCED ACCORDING TO A.S.T.M. F-436-19. THE ABOVE TEST RESULTS APPLY ONLY TO THE ITEMS TESTED. THIS TEST REPORT MUST NOT BE REPRODUCED EXCEPT IN FULL WITHOUT PRIOR WRITTEN APPROVAL

CERTIFIED
ISO 9001:

AUTHORIZED SIGNATURE

" MADE AND MANUFACTURED IN THE USA"

Qty.3058 Rev. 2 11/28/01

54763 - 2

Figure B-15. ⅝-in. Dia. Hardened Washer, Test No. HNTBR-1 (Item No. e2)

Job Material Certification

Page 1 of 6

Vulcan
THREADED PRODUCTS, INC.

Vulcan Threaded Products
10 Cross Creek Trail
Pelham, AL 35124
Tel (205) 620-5100
Fax (205) 620-5150

JOB MATERIAL CERTIFICATION

Job No: 721458 **Job Information** **Certified Date:** 7/7/21

Containers: S18661829 S18663941

Customer: Conklin and Conklin **Ship To:** 34201 Seventh Street Union City, CA 94587

Vulcan Part No: BAR B7 .5626x144 SC

Customer Part No: BAR B7 .562x144

Customer PO No: 20594 **Shipped Qty:** 6018 lbs

Order No: 432165 **Line No:** 2

Note:

Applicable Specifications

Type	Specification	Rev	Amend	Option
	ASTM F1554 Gd 105 S4	2020		
Heat Treat	ASME SA-193/SA-193M B7	2019		
	ASTM A193 B7	2020		

Test Results

See following pages for tests

Certified Chemical Analysis

Heat No: 100209239 Lot 5/8 **Origin**: USA

C	Mn	P	S	Si	Cr	Mo	Ni	V	Cu	Al	Cb
0.41	0.93	0.008	0.025	0.28	0.98	0.18	0.07	0.004	0.18	0.026	0.004
Sn	**Ti**	**B**	**Ca**	**As**	**DI**	**RR**	**G.S.**	**Macro S**	**Macro R**	**Macro C**	**J1**
0.008	0.001	0.0004	0.0021	0.005	5.65	143.06:1	8	1	1	2	57
J2	**J3**	**J4**	**J5**	**J6**	**J7**	**J8**	**J9**	**J10**	**J11**	**J12**	**J13**
57	57	57	57	57	57	57	56	54	53	51	51
J14	**J15**	**J16**	**J18**	**J20**	**J22**	**J24**	**J26**	**J28**	**J30**	**J32**	
50	49	48	48	47	46	45	44	43	41	40	

Notes

Processed material is Tempered - Stress Relieved. No weld repair performed on the material. No Mercury used in the production of this material. Melted and Manufactured in the USA.
Grade - 4140/42
EAF Melted

Plex 7/7/21 3:46 PM vulc.sano Page 1 of 2

PORTLAND BOLT
PO 53756
INV 084399
100 5/8" x 144" B7 ATR HDG 1OF2
JAN 24, 2022

Figure B-16. ⅝-in. 11 UNC, 7⅞-in. Long Threaded Rod, Test No. HNTBR-1 (Item No. e3)

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

Certified Quality and Environmental Systems
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 B-17. Epoxy Adhesive, Test No. HNTBR-1 (Item No. e4)

PRODUCT DATA

NO. 320-F

MasterFormat: 03 15 00

W. R. MEADOWS, SEALTIGHT

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 B-18. Joint Filler, Test No. HNTBR-1 (Item No. e5)

Pecora 301 NS

Specification Data Sheet

Non-Sag Silicone Highway & Pavement Joint Sealant

PECORA CORPORATION
Architectural Waterproofing Products
U.S.A. • since 1862

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) Joint	60	ASTM C661
Movement Capability		
+100/-50%; 10 cycles	Pass	ASTM C719

*modified section 14

Figure B-19. Expansion Joint Sealant, Test No. HNTBR-1 (Item No. e6)

Appendix C. Vehicle Center of Gravity Determination

		Test Name:	**HNTBR-1**	**VIN:**	**1C6RR6LTXHS514323**
Model Year:	**2017**	**Make:**	**Dodge**	**Model:**	**Ram 1500**

Vehicle CG Determination

Vehicle Equipment		Weight (lb)	Vertical CG (in.)	Vertical M (lb-in.)
+	Unballasted Truck (Curb)	5264	28.901833	152139.25
+	Hub	19	15.25	289.75
+	Brake activation cylinder & frame	7	28 1/4	197.75
+	Pneumatic tank (Nitrogen)	23	27 1/2	632.5
+	Strobe/Brake Battery	5	26	130
+	Brake Receiver/Wires	5	54	270
+	CG Plate including DAQ	46	30 5/8	1408.75
-	Battery	-39	42	-1638
-	Oil	-11	16 1/2	-181.5
-	Interior	-98	39	-3822
-	Fuel	-191	19	-3629
-	Coolant	-10	33	-330
-	Washer fluid	-3	37	-111
+	Water Ballast (In Fuel Tank)			0
+	Air bag Battery	5	26	130
+	Tdas	17	26	442
				0
Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle				145928.5

Estimated Total Weight (lb)	5039
Vertical CG Location (in.)	28.95981

Vehicle Dimensions for C.G. Calculations

Wheel Base: 140.75 in. Front Track Width: 68.625 in.
Rear Track Width: 68.5 in.

Center of Gravity	**2270P MASH Targets**	**Test Inertial**	**Difference**
Test Inertial Weight (lb)	5000 ± 110	5032	32.0
Longitudinal CG (in.)	63 ± 4	59.466316	-3.53368
Lateral CG (in.)	NA	-0.313382	NA
Vertical CG (in.)	28 or greater	28.96	0.95981

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	1555	1453	
Rear	1125	1131	
FRONT	3008	lb	
REAR	2256	lb	
TOTAL	5264	lb	

TEST INERTIAL WEIGHT (lb)

	Left	Right	
Front	1488	1418	
Rear	1051	1075	
FRONT	2906	lb	
REAR	2126	lb	
TOTAL	5032	lb	

Figure C-1. Vehicle Mass Distribution, Test No. HNTBR-1

Appendix D. Vehicle Deformation Records

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

Model Year: 2017 Test Name: HNTBR-1 Make: Dodge VIN: 1C6RR6LTXHS514323 Model: Ram 1500

VEHICLE DEFORMATION
PASSENGER SIDE FLOOR PAN - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	34.6283	-6.8382	0.0000	34.2294	-7.1555		0.3989	-0.3173		NA	NA	X, Z
	2	37.1975	-3.7676	0.0000	28.6616	-44.4173		8.5359	-40.6497		NA	No Data	X, Z
	3	40.9450	-2.9387	0.0000	26.6542	-45.0397		14.2908	-42.1010		NA	No Data	X, Z
	4	44.9446	-3.0245	0.0000	36.0955	-8.7948		8.8491	-5.7703		NA	NA	X, Z
	5	49.1562	-4.7291	0.0000	38.8020	-11.0080		10.3542	-6.2789		NA	NA	X, Z
	6	30.9834	-5.6677	0.0000	30.0330	-7.2325		0.9504	-1.5648		NA	NA	X, Z
	7	34.7572	-3.3744	0.0000	33.5831	-4.4074		1.1741	-1.0330		NA	NA	X, Z
	8	39.6091	-0.2123	0.0000	21.7519	-46.9958		17.8572	-46.7835		NA	No Data	X, Z
	9	44.3116	-0.1149	0.0000	24.8171	-43.4117		19.4945	-43.2968		NA	No Data	X, Z
	10	49.6969	-0.0911	0.0000	37.7111	-7.4751		11.9858	-7.3840		NA	NA	X, Z
FLOOR PAN (Z)	11	30.5309	-3.3790	0.0000	28.0977	-4.4101		2.4332	-1.0311		NA		Z
	12	34.5631	-0.1294	0.0000	25.8412	-34.0492		8.7219	-33.9198		NA	No Data	Z
	13	38.8103	1.0368	0.0000	27.3256	-32.6122		11.4847	33.6490		NA	No Data	Z
	14	44.5867	1.0597	0.0000	27.6542	-32.2440		16.9325	33.3037		NA	No Data	Z
	15	48.6031	1.1536	0.0000	39.0098	-4.2249		9.5933	5.3785		NA		Z
	16	29.8357	-1.5679	0.0000	28.4890	-2.6868		1.3467	-1.1189		NA		Z
	17	33.1920	1.0320	0.0000	34.7974	-27.9448		-1.6054	28.9768		NA	No Data	Z
	18	39.3200	1.0571	0.0000	33.1866	-27.0560		6.1334	28.1131		NA	No Data	Z
	19	44.4828	1.0609	0.0000	35.8601	-22.8640		8.6227	23.9249		NA	No Data	Z
	20	48.4132	1.1684	0.0000	40.9658	-1.4744		7.4474	2.6428		NA		Z
	21	29.4942	-1.5141	0.0000	29.5199	-2.5416		-0.0257	-1.0275		NA		Z
	22	32.8898	1.1364	0.0000	33.0205	-0.2432		-0.1307	1.3796		NA		Z
	23	38.6943	1.1066	0.0000	38.3670	-1.7528		0.3273	2.8594		NA		Z
	24	43.8995	1.1275	0.0000	42.5119	-0.8357		1.3876	1.9632		NA		Z
	25	48.8743	1.1419	0.0000	28.2488	-38.6772		20.6255	39.8191		NA	No Data	Z
	26	29.5614	-1.5277	0.0000	30.1884	-2.3887		-0.6270	-0.8610		NA		Z
	27	34.2050	0.3231	0.0000	34.3558	-0.3168		-0.1508	0.6399		NA		Z
	28	39.3983	0.1061	0.0000	39.5161	-0.8096		-0.1178	0.9157		NA		Z
	29	43.9499	0.1186	0.0000	44.0087	-1.1572		-0.0588	1.2758		NA		Z
	30	49.0133	0.1000	0.0000	-3.8951	-25.4815		52.9084	25.5815		NA	No Data	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.

Due to damage points 2-3, 8-9, 12-14, 17-19, 25, & 30 are unusable

Pretest Floor Pan

Posttest Floor Pan

Figure D-1. Passenger Side Floor Pan Deformation Data – Set 1, Test No. HNTBR-1

Model Year: 2017 | Test Name: HNTBR-1 | Make: Dodge | VIN: 1C6RR6LTXHS514323 | Model: Ram 1500

VEHICLE DEFORMATION
PASSENGER SIDE FLOOR PAN - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	59.6794	18.5962	-2.3991	56.7822	18.3406	-3.1998	2.8972	0.2556	0.8007	3.0167	3.0058	X, Z
	2	60.6310	21.1691	0.6725	18.8485	13.1526	-40.0792	41.7825	8.0165	40.7517	58.9130	No Data	X, Z
	3	60.8902	24.9177	1.5010	18.3797	11.1526	-40.7267	42.5105	13.7651	42.2277	61.4801	No Data	X, Z
	4	61.3180	28.9187	1.4150	53.3418	20.2142	-4.7681	7.9762	8.7045	6.1831	13.3274	10.0921	X, Z
	5	60.8978	33.1285	-0.2913	50.7575	22.9412	-6.9080	10.1403	10.1873	6.6167	15.8236	12.1081	X, Z
	6	53.9494	14.9333	-1.2378	52.2159	14.1225	-3.2850	1.7335	0.8108	2.0472	2.8024	2.6825	X, Z
	7	54.8453	18.7105	1.0563	52.1908	17.6287	-0.4053	2.6545	1.0818	1.4616	3.2176	3.0303	X, Z
	8	55.9262	23.5666	4.2191	1.0008	6.1921	-42.5443	54.9254	17.3745	46.7634	74.1990	No Data	X, Z
	9	55.8339	28.2689	4.3153	-2.8982	9.1818	-38.8655	58.7321	19.0871	43.1808	75.3549	No Data	X, Z
	10	56.1048	33.6551	4.3383	45.8647	21.7711	-3.3319	10.2401	11.8840	7.6702	17.4620	12.7942	X, Z
FLOOR PAN (Z)	11	50.4739	14.4703	1.0450	50.3328	12.1343	-0.4692	0.1411	2.3360	1.5142	2.7874	1.5142	Z
	12	51.8288	18.5076	4.2961	3.1268	10.0927	-29.5616	48.7020	8.4149	33.8577	59.9086	No Data	Z
	13	52.3774	22.7569	5.4623	2.7968	11.5531	-28.0979	49.5806	11.2038	33.5602	60.9102	No Data	Z
	14	52.4827	28.5336	5.4840	2.7171	11.8756	-27.7237	49.7656	16.6580	33.2077	62.1036	No Data	Z
	15	52.5537	32.5503	5.5772	44.6641	23.0135	-0.0472	7.8896	9.5368	5.6244	13.5952	5.6244	Z
	16	47.1865	13.7651	2.8507	46.9306	12.4818	1.3018	0.2559	1.2833	1.5489	2.0277	1.5489	Z
	17	48.1872	17.1252	5.4515	3.3075	18.9549	-23.3225	44.8797	-1.8297	28.7740	53.3430	No Data	Z
	18	48.3195	23.2537	5.4754	3.9624	17.3340	-22.4666	44.3571	5.9197	27.9420	52.7575	No Data	Z
	19	48.7508	28.4178	5.4788	3.3147	19.9394	-18.2258	45.4361	8.4784	23.7046	51.9445	No Data	Z
	20	48.5491	32.3477	5.5850	43.1594	24.9193	2.7516	5.3897	7.4284	2.8334	9.6051	2.8334	Z
	21	41.8000	13.4065	2.8952	41.6159	13.4831	1.5281	0.1841	-0.0766	1.3671	1.3816	1.3671	Z
	22	41.5769	16.8020	5.5445	41.6653	16.9482	3.8794	-0.0884	-0.1462	1.6651	1.6738	1.6651	Z
	23	41.4390	22.6062	5.5132	40.9763	22.3138	2.4602	0.4627	0.2924	3.0530	3.1017	3.0530	Z
	24	41.5300	27.8116	5.5330	40.2220	26.4404	3.4500	1.3080	1.3712	2.0830	2.8160	2.0830	Z
	25	42.9424	32.7909	5.5488	0.0403	12.5554	-34.1147	42.9021	20.2355	39.6635	61.8325	No Data	Z
	26	37.4289	13.4598	2.8740	37.3249	14.1273	1.7440	0.1040	-0.6675	1.1300	1.3165	1.1300	Z
	27	37.2201	18.1032	4.7234	37.1990	18.2617	3.8812	0.0211	-0.1585	0.8422	0.8572	0.8422	Z
	28	37.5232	23.2974	4.5057	37.5629	23.4309	3.4629	-0.0397	-0.1335	1.0428	1.0521	1.0428	Z
	29	37.6273	27.8494	4.5173	37.5431	27.9282	3.1844	0.0842	-0.0788	1.3329	1.3379	1.3329	Z
	30	37.4951	32.9125	4.4974	1.9788	-19.7782	-21.4357	35.5163	52.6907	25.9331	68.6312	No Data	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.

Due to damage points 2-3, 8-9, 12-14, 17-19, 25, & 30 are unusable

Pretest Floor Pan

Posttest Floor Pan

Figure D-2. Passenger Side Floor Pan Deformation Data – Set 2, Test No. HNTBR-1

Model Year: 2017 Test Name: HNTBR-1 Make: Dodge VIN: 1C6RR6LTXHS514323 Model: Ram 1500

VEHICLE DEFORMATION
PASSENGER SIDE INTERIOR CRUSH - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	46.1303	20.9117	-30.8991	44.9173	20.1409	-31.9748	1.2130	0.7708	-1.0757	1.7952	1.7952	X, Y, Z
	2	49.2774	36.0297	-30.1571	47.3351	35.4721	-31.6238	1.9423	0.5576	-1.4667	2.4969	2.4969	X, Y, Z
	3	49.5438	49.4135	-29.6590	46.7254	48.8669	-31.5042	2.8184	0.5466	-1.8452	3.4128	3.4128	X, Y, Z
	4	43.3421	21.6144	-20.2152	40.6863	21.1551	-21.7037	2.6558	0.4593	-1.4885	3.0789	3.0789	X, Y, Z
	5	45.6565	38.2316	-20.4787	42.6534	37.0375	-22.4899	3.0031	1.1941	-2.0112	3.8065	3.8065	X, Y, Z
	6	46.7121	50.2547	-20.1757	42.3116	49.2129	-22.6437	4.4005	1.0418	-2.4680	5.1518	5.1518	X, Y, Z
SIDE PANEL (Y)	7	55.7826	51.9105	-10.5619	48.3338	43.8914	-13.2715	7.4488	8.0191	-2.7096	11.2753	8.0191	Y
	8	55.5094	51.9094	-3.4563	47.0756	40.0055	-7.2327	8.4338	11.9039	-3.7764	15.0696	11.9039	Y
	9	60.0648	51.7271	-7.1702	51.5480	41.4193	-10.3244	8.5168	10.3078	-3.1542	13.7381	10.3078	Y
IMPACT SIDE DOOR (Y)	10	45.9721	53.3625	-26.6047	42.7463	59.1036	-26.6437	3.2258	-5.7411	-0.0390	6.5854	-5.7411	Y
	11	34.6387	53.6728	-26.8670	31.6462	58.2875	-27.7972	2.9925	-4.6147	-0.9302	5.5782	-4.6147	Y
	12	21.6159	54.0449	-27.0125	19.1348	56.5343	-27.9481	2.4811	-2.4894	-0.9356	3.6371	-2.4894	Y
	13	42.0019	55.1108	-5.1116	35.6022	55.2495	-6.1210	6.3997	-0.1387	-1.0094	6.4803	-0.1387	Y
	14	34.5653	54.9492	-3.2989	28.2402	57.1190	-4.9128	6.3251	-2.1698	-1.6139	6.8789	-2.1698	Y
	15	21.6514	54.5671	-7.7269	18.9227	58.3607	-9.4285	2.7287	-3.7936	-1.7016	4.9732	-3.7936	Y
ROOF - (Z)	16	42.0888	21.1023	-46.9817	41.7629	21.3703	-47.4826	0.3259	-0.2680	-0.5009	0.6549	-0.5009	Z
	17	40.6675	34.3895	-46.7899	40.2029	34.6522	-47.6441	0.4646	-0.2627	-0.8542	1.0072	-0.8542	Z
	18	38.1686	44.3840	-46.1709	37.6549	44.6488	-47.3222	0.5137	-0.2648	-1.1513	1.2882	-1.1513	Z
	19	32.1853	22.4173	-50.3309	31.8784	22.5189	-50.9674	0.3069	-0.1016	-0.6365	0.7139	-0.6365	Z
	20	31.6426	30.4965	-50.2043	31.2649	30.6284	-51.0020	0.3777	-0.1319	-0.7977	0.8924	-0.7977	Z
	21	30.1140	41.0119	-49.7121	29.6035	41.1950	-50.7759	0.5105	-0.1831	-1.0638	1.1941	-1.0638	Z
	22	15.8247	23.5973	-51.4759	15.5146	23.5362	-52.0805	0.3101	0.0611	-0.6046	0.6822	-0.6046	Z
	23	15.7334	32.6578	-51.2227	15.2857	32.6064	-52.0842	0.4477	0.0514	-0.8615	0.9722	-0.8615	Z
	24	15.8742	41.3566	-50.6662	15.3457	41.2833	-51.4617	0.5285	0.0733	-0.7955	0.9579	-0.7955	Z
	25	-4.9722	22.5199	-51.6843	-5.4013	22.2275	-52.1641	0.4291	0.2924	-0.4798	0.7070	-0.4798	Z
	26	-5.0146	31.8246	-51.5320	-5.4752	31.5497	-52.1272	0.4606	0.2749	-0.5952	0.8012	-0.5952	Z
	27	-4.8418	41.7295	-51.0400	-5.4343	41.4412	-51.7441	0.5925	0.2883	-0.7041	0.9643	-0.7041	Z
	28	-21.8418	23.1315	-51.1232	-22.3068	22.7379	-51.4773	0.4650	0.3936	-0.3541	0.7047	-0.3541	Z
	29	-21.5876	32.3738	-51.0002	-22.1483	31.9756	-51.4740	0.5607	0.3982	-0.4738	0.8351	-0.4738	Z
	30	-21.0668	42.4851	-50.6133	-21.6971	42.0790	-51.1897	0.6303	0.4061	-0.5764	0.9457	-0.5764	Z
A-PILLAR Maximum (X, Y, Z)	31	52.9063	50.3056	-33.3799	50.9249	50.7606	-33.2933	1.9814	-0.4550	0.0866	2.0348	1.9833	X, Z
	32	50.0415	49.0085	-35.5712	48.4866	49.2874	-35.8000	1.5549	-0.2789	-0.2288	1.5962	1.5549	X
	33	47.7846	48.1451	-36.6944	46.3250	48.4611	-37.1255	1.4596	-0.3160	-0.4311	1.5544	1.4596	X
	34	44.3807	47.7281	-39.5964	43.2182	48.0719	-40.3294	1.1625	-0.3438	-0.7330	1.4166	1.1625	X
	35	41.1245	46.6748	-41.1903	40.1195	47.0245	-42.2224	1.0050	-0.3497	-1.0321	1.4824	1.0050	X
	36	38.6190	46.8857	-44.2027	37.9881	47.1889	-45.3609	0.6309	-0.3032	-1.1582	1.3533	0.6309	X
A-PILLAR Lateral (Y)	31	52.9063	50.3056	-33.3799	50.9249	50.7606	-33.2933	1.9814	-0.4550	0.0866	2.0348	-0.4550	Y
	32	50.0415	49.0085	-35.5712	48.4866	49.2874	-35.8000	1.5549	-0.2789	-0.2288	1.5962	-0.2789	Y
	33	47.7846	48.1451	-36.6944	46.3250	48.4611	-37.1255	1.4596	-0.3160	-0.4311	1.5544	-0.3160	Y
	34	44.3807	47.7281	-39.5964	43.2182	48.0719	-40.3294	1.1625	-0.3438	-0.7330	1.4166	-0.3438	Y
	35	41.1245	46.6748	-41.1903	40.1195	47.0245	-42.2224	1.0050	-0.3497	-1.0321	1.4824	-0.3497	Y
	36	38.6190	46.8857	-44.2027	37.9881	47.1889	-45.3609	0.6309	-0.3032	-1.1582	1.3533	-0.3032	Y
B-PILLAR Maximum (X, Y, Z)	37	14.4012	47.1759	-45.7805	13.8813	47.2248	-46.6408	0.5199	-0.0489	-0.8603	1.0064	0.5199	X
	38	11.4054	48.8463	-41.3177	10.9493	48.8553	-42.1572	0.4561	-0.0090	-0.8395	0.9554	0.4561	X
	39	14.8776	50.6679	-36.1135	14.4241	50.8012	-37.0100	0.4535	-0.1333	-0.8965	1.0135	0.4535	X
	40	11.9306	51.9339	-29.7208	11.4852	52.0392	-30.6014	0.4454	-0.1053	-0.8806	0.9924	0.4454	X
B-PILLAR Lateral (Y)	37	14.4012	47.1759	-45.7805	13.8813	47.2248	-46.6408	0.5199	-0.0489	-0.8603	1.0064	-0.0489	Y
	38	11.4054	48.8463	-41.3177	10.9493	48.8553	-42.1572	0.4561	-0.0090	-0.8395	0.9554	-0.0090	Y
	39	14.8776	50.6679	-36.1135	14.4241	50.8012	-37.0100	0.4535	-0.1333	-0.8965	1.0135	-0.1333	Y
	40	11.9306	51.9339	-29.7208	11.4852	52.0392	-30.6014	0.4454	-0.1053	-0.8806	0.9924	-0.1053	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 D-3. Occupant Compartment Deformation Data - Passenger Side – Set 1, Test No. HNTBR-1

Model Year: 2017 Test Name: HNTBR-1 Make: Dodge VIN: 1C6RR6LTXHS514323 Model: Ram 1500

VEHICLE DEFORMATION
PASSENGER SIDE INTERIOR CRUSH - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	45.0548	4.8990	-26.4950	43.4868	4.5872	-28.0633	1.5680	0.3118	-1.5683	2.2395	2.2395	X, Y, Z
	2	48.1159	20.0348	-25.7557	45.8205	19.9255	-27.5099	2.2954	0.1093	-1.7542	2.8910	2.8910	X, Y, Z
	3	48.3064	33.4201	-25.2636	45.1352	33.3131	-27.1802	3.1712	0.1070	-1.9166	3.7069	3.7069	X, Y, Z
	4	42.2480	5.5910	-15.8153	39.3768	5.4215	-17.7270	2.8712	0.1695	-1.9117	3.4536	3.4536	X, Y, Z
	5	44.4693	22.2209	-16.0834	41.2427	21.3253	-18.2968	3.2266	0.8956	-2.2134	4.0140	4.0140	X, Y, Z
	6	45.4569	34.2498	-15.7847	40.8290	33.4993	-18.2621	4.6279	0.7505	-2.4774	5.3027	5.3027	X, Y, Z
SIDE PANEL (Y)	7	54.5047	35.9611	-6.1592	46.9967	28.0732	-9.0458	7.5080	7.8879	-2.8866	11.2659	7.8879	Y
	8	54.2216	35.9617	0.9461	45.8354	24.0894	-3.0516	8.3862	11.8723	-3.9977	15.0752	11.8723	Y
	9	58.7832	35.8034	-2.7615	50.2611	25.5761	-6.1761	8.5221	10.2273	-3.4146	13.7435	10.2273	Y
IMPACT SIDE DOOR (Y)	10	44.7083	37.3504	-22.2162	41.1574	43.4516	-22.1170	3.5509	-6.1012	0.0992	7.0600	-6.1012	Y
	11	33.3738	37.5969	-22.4943	30.0488	42.5871	-23.1468	3.3250	-4.9902	-0.6525	6.0319	-4.9902	Y
	12	20.3493	37.8957	-22.6578	17.5468	40.7621	-23.1712	2.8025	-2.8664	-0.5134	4.0415	-2.8664	Y
	13	40.6987	39.0864	-0.7294	34.2889	39.2465	-1.5691	6.4098	-0.1601	-0.8397	6.4665	-0.1601	Y
	14	33.2607	38.8839	1.0732	26.9317	41.0537	-0.2428	6.3290	-2.1698	-1.3160	6.8188	-2.1698	Y
	15	20.3552	38.4271	-3.3725	17.5523	42.3080	-4.6250	2.8029	-3.8809	-1.2525	4.9484	-3.8809	Y
ROOF - (Z)	16	41.0345	5.0594	-42.5832	40.1346	6.0313	-43.5110	0.8999	-0.9719	-0.9278	1.6172	-0.9278	Z
	17	39.5384	18.3385	-42.3996	38.4963	19.3047	-43.4524	1.0421	-0.9662	-1.0528	1.7686	-1.0528	Z
	18	36.9824	28.3190	-41.7889	35.8950	29.2800	-42.9481	1.0874	-0.9610	-1.1592	1.8573	-1.1592	Z
	19	31.1284	6.3171	-45.9467	30.2015	7.1736	-46.8569	0.9269	-0.8565	-0.9102	1.5560	-0.9102	Z
	20	30.5401	14.3932	-45.8246	29.5410	15.2789	-46.7613	0.9991	-0.8857	-0.9367	1.6310	-0.9367	Z
	21	28.9518	24.9001	-45.3396	27.8217	25.8308	-46.3550	1.1301	-0.9307	-1.0154	1.7817	-1.0154	Z
	22	14.7631	7.4047	-47.1148	13.8196	8.1103	-47.7543	0.9435	-0.7056	-0.6395	1.3405	-0.6395	Z
	23	14.6205	16.4647	-46.8660	13.5385	17.1780	-47.6179	1.0820	-0.7133	-0.7519	1.4983	-0.7519	Z
	24	14.7117	25.1643	-46.3135	13.5563	25.8447	-46.8649	1.1554	-0.6804	-0.5514	1.4498	-0.5514	Z
	25	-6.0272	6.2104	-47.3513	-7.0879	6.6788	-47.6019	1.0607	-0.4684	-0.2506	1.1863	-0.2506	Z
	26	-6.1220	15.5147	-47.2035	-7.2149	15.9988	-47.4230	1.0929	-0.4841	-0.2195	1.2153	-0.2195	Z
	27	-6.0056	25.4207	-46.7160	-7.2263	25.8834	-46.8908	1.2207	-0.4627	-0.1748	1.3171	-0.1748	Z
	28	-22.9007	6.7274	-46.8138	-23.9862	7.0784	-46.7007	1.0855	-0.3510	0.1131	1.1464	0.1131	Z
	29	-22.6986	15.9710	-46.6948	-23.8809	16.3157	-46.5596	1.1823	-0.3447	0.1352	1.2389	0.1352	Z
	30	-22.2351	26.0852	-46.3119	-23.4844	26.4162	-46.1279	1.2493	-0.3310	0.1840	1.3054	0.1840	Z
A-PILLAR Maximum (X, Y, Z)	31	51.6689	34.3294	-28.9804	49.3014	35.2585	-28.9916	2.3675	-0.9291	-0.0112	2.5433	2.3675	X
	32	48.8145	33.0152	-31.1750	46.8409	33.8088	-31.4903	1.9736	-0.7936	-0.3153	2.1504	1.9736	X
	33	46.5641	32.1385	-32.3009	44.6680	32.9897	-32.8016	1.8961	-0.8512	-0.5007	2.1379	1.8961	X
	34	43.1666	31.7011	-35.2074	41.5242	32.6303	-35.9729	1.6424	-0.9292	-0.7655	2.0364	1.6424	X
	35	39.9186	30.6288	-36.8053	38.4086	31.5932	-37.8434	1.5100	-0.9644	-1.0381	2.0707	1.5100	X
	36	37.4161	30.8242	-39.8212	36.2377	31.7922	-40.9528	1.1784	-0.9680	-1.1316	1.8990	1.1784	X
A-PILLAR Lateral (Y)	31	51.6689	34.3294	-28.9804	49.3014	35.2585	-28.9916	2.3675	-0.9291	-0.0112	2.5433	-0.9291	Y
	32	48.8145	33.0152	-31.1750	46.8409	33.8088	-31.4903	1.9736	-0.7936	-0.3153	2.1504	-0.7936	Y
	33	46.5641	32.1385	-32.3009	44.6680	32.9897	-32.8016	1.8961	-0.8512	-0.5007	2.1379	-0.8512	Y
	34	43.1666	31.7011	-35.2074	41.5242	32.6303	-35.9729	1.6424	-0.9292	-0.7655	2.0364	-0.9292	Y
	35	39.9186	30.6288	-36.8053	38.4086	31.5932	-37.8434	1.5100	-0.9644	-1.0381	2.0707	-0.9644	Y
	36	37.4161	30.8242	-39.8212	36.2377	31.7922	-40.9528	1.1784	-0.9680	-1.1316	1.8990	-0.9680	Y
B-PILLAR Maximum (X, Y, Z)	37	13.1993	30.9776	-41.4325	12.1171	31.7041	-41.9371	1.0822	-0.7265	-0.5046	1.3977	1.0822	X
	38	10.1879	32.6332	-36.9746	9.2313	33.2495	-37.3939	0.9566	-0.6163	-0.4193	1.2127	0.9566	X
	39	13.6427	34.4767	-31.7666	12.7579	35.1383	-32.2606	0.8848	-0.6616	-0.4940	1.2102	0.8848	X
	40	10.6798	35.7291	-25.3785	9.8912	36.2621	-25.7986	0.7886	-0.5330	-0.4201	1.0404	0.7886	X
B-PILLAR Lateral (Y)	37	13.1993	30.9776	-41.4325	12.1171	31.7041	-41.9371	1.0822	-0.7265	-0.5046	1.3977	-0.7265	Y
	38	10.1879	32.6332	-36.9746	9.2313	33.2495	-37.3939	0.9566	-0.6163	-0.4193	1.2127	-0.6163	Y
	39	13.6427	34.4767	-31.7666	12.7579	35.1383	-32.2606	0.8848	-0.6616	-0.4940	1.2102	-0.6616	Y
	40	10.6798	35.7291	-25.3785	9.8912	36.2621	-25.7986	0.7886	-0.5330	-0.4201	1.0404	-0.5330	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 D-4. Occupant Compartment Deformation Data - Passenger Side – Set 2, Test No. HNTBR-1

Model Year: 2017 Test Name: HNTBR-1 Make: Dodge VIN: 1C6RR6LTXHS514323 Model: Ram 1500

VEHICLE DEFORMATION
DRIVER SIDE FLOOR PAN - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	61.8218	-10.1403	-5.7352	61.8020	-10.0477	-5.8829	0.0198	0.0926	0.1477	0.1754	0.1490	X, Z
	2	62.9436	-6.2632	-4.4636	62.8957	-6.1265	-4.5981	0.0479	0.1367	0.1345	0.1977	0.1428	X, Z
	3	62.1074	-3.0644	-2.8220	62.0435	-2.9357	-2.8736	0.0639	0.1287	0.0516	0.1527	0.0821	X, Z
	4	62.1883	4.3594	-2.8601	62.1564	4.4780	-2.6870	0.0319	-0.1186	-0.1731	0.2122	0.0319	X
	5	59.7479	10.8749	-5.1837	59.6608	11.0073	-4.9285	0.0871	-0.1324	-0.2552	0.3004	0.0871	X
	6	56.4943	-10.3309	0.1859	56.5150	-10.2766	0.0125	-0.0207	0.0543	0.1734	0.1829	0.1734	Z
	7	57.4428	-6.0594	-0.6638	57.4474	-5.9985	-0.7066	-0.0046	0.0609	0.0428	0.0746	0.0428	Z
	8	57.6269	0.0378	-0.7389	57.5933	0.1048	-0.6896	0.0336	-0.0670	-0.0493	0.0897	0.0336	X
	9	57.6771	6.1765	-0.7232	57.6163	6.2441	-0.5608	0.0608	-0.0676	-0.1624	0.1861	0.0608	X
	10	55.8076	10.8596	-3.4249	55.7179	11.0412	-3.0929	0.0897	-0.1816	-0.3320	0.3889	0.0897	X
FLOOR PAN (Z)	11	52.4785	-9.2792	1.3475	52.4854	-9.2746	1.1722	-0.0069	0.0046	0.1753	0.1755	0.1753	Z
	12	53.0201	-5.7353	1.2434	53.0146	-5.6866	1.1791	0.0055	0.0487	0.0643	0.0808	0.0643	Z
	13	53.2398	0.0949	1.2409	53.2464	0.1426	1.3329	-0.0066	-0.0477	-0.0920	0.1038	-0.0920	Z
	14	53.3234	6.2793	1.2335	53.3254	6.2927	1.4611	-0.0020	-0.0134	-0.2276	0.2280	-0.2276	Z
	15	52.1966	10.3874	-2.0114	52.1303	10.5260	-1.6888	0.0663	-0.1386	-0.3226	0.3573	-0.3226	Z
	16	48.8300	-9.2114	1.3410	48.8462	-9.1674	1.1835	-0.0162	0.0440	0.1575	0.1643	0.1575	Z
	17	49.2268	-5.1543	1.2433	49.2168	-5.1094	1.1935	0.0100	0.0449	0.0498	0.0678	0.0498	Z
	18	49.3319	0.0736	1.2319	49.3332	0.0903	1.3298	-0.0013	-0.0167	-0.0979	0.0993	-0.0979	Z
	19	49.2329	5.9593	1.2283	49.2036	5.9853	1.4489	0.0293	-0.0260	-0.2206	0.2241	-0.2206	Z
	20	48.2041	10.3174	-1.6643	48.1690	10.2861	-1.3994	0.0351	0.0313	-0.2649	0.2690	-0.2649	Z
	21	42.3068	-9.4769	1.2748	42.3239	-9.4699	1.1591	-0.0171	0.0070	0.1157	0.1172	0.1157	Z
	22	42.0653	-4.5232	1.2361	42.0584	-4.5361	1.2026	0.0069	-0.0129	0.0335	0.0366	0.0335	Z
	23	42.2120	0.2688	1.2305	42.1771	0.3087	1.3068	0.0349	-0.0399	-0.0763	0.0929	-0.0763	Z
	24	42.5420	6.1409	1.2438	42.5245	6.1396	1.4312	0.0175	0.0013	-0.1874	0.1882	-0.1874	Z
	25	42.6756	10.3031	-1.4116	42.6425	10.3875	-1.1280	0.0331	-0.0844	-0.2836	0.2977	-0.2836	Z
	26	38.1637	-9.0982	0.2554	38.2149	-9.0607	0.1654	-0.0512	0.0375	0.0900	0.1101	0.0900	Z
	27	38.2515	-4.1161	0.2566	38.2231	-4.0226	0.2386	0.0284	0.0935	0.0180	0.0994	0.0180	Z
	28	38.2873	0.2430	0.2438	38.2670	0.3187	0.2994	0.0203	-0.0757	-0.0556	0.0961	-0.0556	Z
	29	38.1739	5.6702	0.4394	38.1468	5.6609	0.5826	0.0271	0.0093	-0.1432	0.1460	-0.1432	Z
	30	38.2900	10.3054	-1.3699	38.2689	10.3863	-1.1354	0.0211	-0.0809	-0.2345	0.2490	-0.2345	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 D-5. Driver Side Floor Pan Deformation Data – Set 1, Test No. HNTBR-1

Model Year: 2017 Test Name: HNTBR-1 Make: Dodge VIN: 1C6RR6LTXHS514323 Model: Ram 1500

VEHICLE DEFORMATION
DRIVER SIDE FLOOR PAN - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	60.8848	-26.0569	-1.2869	60.8737	-25.8540	-2.6295	0.0111	0.2029	1.3426	1.3579	1.3426	X, Z
	2	61.9828	-22.1723	-0.0176	61.9585	-21.9435	-1.3051	0.0243	0.2288	1.2875	1.3079	1.2877	X, Z
	3	61.1263	-18.9766	1.6195	61.1077	-18.7819	0.4733	0.0186	0.1947	1.1462	1.1628	1.1464	X, Z
	4	61.1658	-11.5525	1.5740	61.1756	-11.3709	0.7595	-0.0098	0.1816	0.8145	0.8346	0.8145	Z
	5	58.6928	-5.0530	-0.7601	58.6101	-4.8283	-1.3613	0.0827	0.2247	0.6012	0.6471	0.6069	X, Z
	6	55.5490	-26.2712	4.6259	55.6631	-26.1974	3.3280	-0.1141	0.0738	1.2979	1.3050	1.2979	Z
	7	56.4751	-21.9954	3.7734	56.5589	-21.9040	2.6557	-0.0838	0.0914	1.1177	1.1246	1.1177	Z
	8	56.6253	-15.8973	3.6924	56.6660	-15.8006	2.7541	-0.0407	0.0967	0.9383	0.9441	0.9383	Z
	9	56.6412	-9.7584	3.7020	56.6514	-9.6636	2.9663	-0.0102	0.0948	0.7357	0.7419	0.7357	Z
	10	54.7499	-5.0885	0.9926	54.6906	-4.8453	0.5238	0.0593	0.2432	0.4688	0.5314	0.4725	X, Z
FLOOR PAN (Z)	11	51.5256	-25.2408	5.7802	51.6421	-25.2377	4.5517	-0.1165	0.0031	1.2285	1.2340	1.2285	Z
	12	52.0476	-21.6940	5.6733	52.1484	-21.6468	4.6008	-0.1008	0.0472	1.0725	1.0783	1.0725	Z
	13	52.2348	-15.8627	5.6652	52.3448	-15.8188	4.8312	-0.1100	0.0439	0.8340	0.8424	0.8340	Z
	14	52.2839	-9.6779	5.6517	52.3861	-9.6706	5.0423	-0.1022	0.0073	0.6094	0.6180	0.6094	Z
	15	51.1393	-5.5794	2.4009	51.1244	-5.4029	1.9655	0.0149	0.1765	0.4354	0.4701	0.4354	Z
	16	47.8768	-25.1933	5.7679	48.0027	-25.1546	4.6100	-0.1259	0.0387	1.1579	1.1654	1.1579	Z
	17	48.2511	-21.1341	5.6666	48.3475	-21.0948	4.6707	-0.0964	0.0393	0.9959	1.0013	0.9959	Z
	18	48.3271	-15.9058	5.6501	48.4323	-15.8967	4.8764	-0.1052	0.0091	0.7737	0.7809	0.7737	Z
	19	48.1953	-10.0208	5.6404	48.2665	-10.0049	5.0774	-0.0712	0.0159	0.5630	0.5677	0.5630	Z
	20	47.1467	-5.6713	2.7417	47.1686	-5.6727	2.3013	-0.0219	-0.0014	0.4404	0.4409	0.4404	Z
	21	41.3553	-25.4953	5.6917	41.4827	-25.4995	4.6631	-0.1274	-0.0042	1.0286	1.0365	1.0286	Z
	22	41.0862	-20.5431	5.6476	41.1862	-20.5687	4.7772	-0.1000	-0.0256	0.8704	0.8765	0.8704	Z
	23	41.2063	-15.7503	5.6373	41.2752	-15.7250	4.9460	-0.0689	0.0253	0.6913	0.6952	0.6913	Z
	24	41.5034	-9.8765	5.6452	41.5869	-9.8942	5.1455	-0.0835	-0.0177	0.4997	0.5069	0.4997	Z
	25	41.6181	-5.7162	2.9858	41.6454	-5.6114	2.6432	-0.0273	0.1048	0.3426	0.3593	0.3426	Z
	26	37.2117	-25.1407	4.6654	37.3590	-25.1040	3.7266	-0.1473	0.0367	0.9388	0.9510	0.9388	Z
	27	37.2717	-20.1582	4.6617	37.3358	-20.0673	3.8684	-0.0641	0.0909	0.7933	0.8011	0.7933	Z
	28	37.2833	-15.7990	4.6445	37.3527	-15.7271	3.9878	-0.0694	0.0719	0.6567	0.6643	0.6567	Z
	29	37.1393	-10.3723	4.8344	37.2020	-10.3901	4.3453	-0.0627	-0.0178	0.4891	0.4934	0.4891	Z
	30	37.2324	-5.7383	3.0206	37.2722	-5.6411	2.6906	-0.0398	0.0972	0.3300	0.3463	0.3300	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 D-6. Driver Side Floor Pan Deformation Data – Set 2, Test No. HNTBR-1

Model Year: 2017 Test Name: HNTBR-1 Make: Dodge VIN: 1C6RR6LTXHS514323 Model: Ram 1500

VEHICLE DEFORMATION
DRIVER SIDE INTERIOR CRUSH - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	48.8207	-10.4865	-29.5464	48.9153	-10.6130	-29.7431	-0.0946	-0.1265	-0.1967	0.2523	0.2523	X, Y, Z
	2	47.2740	0.4057	-33.6677	47.2346	-0.0318	-34.1372	0.0394	0.4375	-0.4695	0.6430	0.6430	X, Y, Z
	3	46.0525	17.6892	-30.8582	45.0758	16.9744	-31.7083	0.9767	0.7148	-0.8501	1.4790	1.4790	X, Y, Z
	4	45.9447	-10.8609	-20.0142	45.9352	-11.1234	-20.2643	0.0095	-0.2625	-0.2501	0.3627	0.3627	X, Y, Z
	5	44.1232	0.4326	-19.5130	43.7001	0.0150	-19.8075	0.4231	0.4176	-0.2945	0.6634	0.6634	X, Y, Z
	6	43.2753	16.7647	-20.1723	41.2413	16.3601	-21.3556	2.0340	0.4046	-1.1833	2.3877	2.3877	X, Y, Z
SIDE PANEL (Y)	7	54.6711	-12.4111	-8.1718	54.6914	-12.3120	-8.3338	-0.0203	0.0991	-0.1620	0.1910	0.0991	Y
	8	54.5026	-12.5339	-3.4009	54.5310	-12.4770	-3.5456	-0.0284	0.0569	-0.1447	0.1581	0.0569	Y
	9	58.9020	-12.4929	-6.5330	58.9552	-12.3611	-6.6954	-0.0532	0.1318	-0.1624	0.2158	0.1318	Y
IMPACT SIDE DOOR (Y)	10	19.9049	-13.8350	-27.0064	19.9577	-13.7455	-27.1011	-0.0528	0.0895	-0.0947	0.1406	0.0895	Y
	11	30.8418	-13.8456	-26.7849	30.8954	-13.7103	-26.8970	-0.0536	0.1353	-0.1121	0.1837	0.1353	Y
	12	42.0128	-13.8010	-26.6440	42.0705	-13.6155	-26.7549	-0.0577	0.1855	-0.1109	0.2237	0.1855	Y
	13	20.5645	-14.3385	-7.5840	20.6121	-14.3599	-7.6992	-0.0476	-0.0214	-0.1152	0.1265	-0.0214	Y
	14	32.6503	-15.0346	-4.0395	32.7164	-15.0118	-4.1359	-0.0661	0.0228	-0.0964	0.1191	0.0228	Y
	15	40.2197	-15.4441	-5.2580	40.2583	-15.3970	-5.3955	-0.0386	0.0471	-0.1375	0.1504	0.0471	Y
ROOF - (Z)	16	37.4691	-5.2250	-46.0621	37.4004	-4.9943	-46.1369	0.0687	0.2307	-0.0748	0.2521	-0.0748	Z
	17	40.3262	4.8520	-46.7031	40.1335	5.1463	-46.9180	0.1927	-0.2943	-0.2149	0.4122	-0.2149	Z
	18	42.0956	16.8720	-46.9067	41.6832	17.1689	-47.3846	0.4124	-0.2969	-0.4779	0.6976	-0.4779	Z
	19	29.7180	-3.2758	-49.3864	29.6063	-3.1667	-49.5402	0.1117	0.1091	-0.1538	0.2192	-0.1538	Z
	20	30.3039	5.1243	-50.0854	30.1284	5.2653	-50.3889	0.1755	-0.1410	-0.3035	0.3779	-0.3035	Z
	21	31.3583	15.4064	-50.3779	31.0994	15.5529	-50.8797	0.2589	-0.1465	-0.5018	0.5833	-0.5018	Z
	22	15.3053	-1.9748	-50.5510	15.1878	-1.9640	-50.7163	0.1175	0.0108	-0.1653	0.2031	-0.1653	Z
	23	15.6364	8.8477	-51.2526	15.4434	8.7725	-51.6113	0.1930	0.0752	-0.3587	0.4142	-0.3587	Z
	24	15.6018	17.5369	-51.4680	15.3067	17.4722	-51.9736	0.2951	0.0647	-0.5056	0.5890	-0.5056	Z
	25	-5.2872	-1.7258	-50.8835	-5.5025	-1.9689	-51.0176	0.2153	-0.2431	-0.1341	0.3513	-0.1341	Z
	26	-5.2825	7.5941	-51.4279	-5.5165	7.3296	-51.6796	0.2340	0.2645	-0.2517	0.4337	-0.2517	Z
	27	-5.2816	17.0853	-51.6460	-5.6120	16.7913	-52.0367	0.3304	0.2940	-0.3907	0.5901	-0.3907	Z
	28	-21.8582	-1.9946	-50.4425	-22.0262	-2.3941	-50.5487	0.1680	-0.3995	-0.1062	0.4462	-0.1062	Z
	29	-21.7321	7.9861	-50.9269	-21.9319	7.5407	-51.1492	0.1998	0.4454	-0.2223	0.5364	-0.2223	Z
	30	-21.9191	16.9386	-51.0773	-22.1889	16.5480	-51.3944	0.2698	0.3906	-0.3171	0.5709	-0.3171	Z
A-PILLAR Maximum (X, Y, Z)	31	52.0910	-10.8523	-33.5286	52.0894	-10.5820	-33.5931	0.0016	0.2703	-0.0645	0.2779	0.2703	X, Y
	32	49.2691	-9.7432	-35.2558	49.2213	-9.4651	-35.3338	0.0478	0.2781	-0.0780	0.2928	0.2822	X, Y
	33	46.9836	-8.7275	-36.5946	46.9427	-8.4417	-36.6795	0.0409	0.2858	-0.0849	0.3009	0.2887	X, Y
	34	43.4636	-8.2209	-39.5772	43.4180	-7.9667	-39.6370	0.0456	0.2542	-0.0598	0.2651	0.2583	X, Y
	35	40.7081	-7.2639	-40.8078	40.6381	-7.0354	-40.8598	0.0700	0.2285	-0.0520	0.2446	0.2390	X, Y
	36	37.8752	-7.3637	-43.9462	37.7728	-7.1184	-44.0333	0.1024	0.2453	-0.0871	0.2797	0.2658	X, Y
A-PILLAR Lateral (Y)	31	52.0910	-10.8523	-33.5286	52.0894	-10.5820	-33.5931	0.0016	0.2703	-0.0645	0.2779	0.2703	Y
	32	49.2691	-9.7432	-35.2558	49.2213	-9.4651	-35.3338	0.0478	0.2781	-0.0780	0.2928	0.2781	Y
	33	46.9836	-8.7275	-36.5946	46.9427	-8.4417	-36.6795	0.0409	0.2858	-0.0849	0.3009	0.2858	Y
	34	43.4636	-8.2209	-39.5772	43.4180	-7.9667	-39.6370	0.0456	0.2542	-0.0598	0.2651	0.2542	Y
	35	40.7081	-7.2639	-40.8078	40.6381	-7.0354	-40.8598	0.0700	0.2285	-0.0520	0.2446	0.2285	Y
	36	37.8752	-7.3637	-43.9462	37.7728	-7.1184	-44.0333	0.1024	0.2453	-0.0871	0.2797	0.2453	Y
B-PILLAR Maximum (X, Y, Z)	37	13.2797	-6.8285	-45.9986	13.2091	-6.9034	-46.0018	0.0706	-0.0749	-0.0032	0.1030	0.0706	X
	38	10.6732	-8.5499	-41.0407	10.6233	-8.6069	-41.1181	0.0499	-0.0570	-0.0774	0.1083	0.0499	X
	39	14.3893	-10.9436	-33.7418	14.3679	-10.9868	-33.8060	0.0214	-0.0432	-0.0642	0.0803	0.0214	X
	40	11.0715	-11.5300	-29.3358	11.0188	-11.5914	-29.3783	0.0527	-0.0614	-0.0425	0.0914	0.0527	X
B-PILLAR Lateral (Y)	37	13.2797	-6.8285	-45.9986	13.2091	-6.9034	-46.0018	0.0706	-0.0749	-0.0032	0.1030	-0.0749	Y
	38	10.6732	-8.5499	-41.0407	10.6233	-8.6069	-41.1181	0.0499	-0.0570	-0.0774	0.1083	-0.0570	Y
	39	14.3893	-10.9436	-33.7418	14.3679	-10.9868	-33.8060	0.0214	-0.0432	-0.0642	0.0803	-0.0432	Y
	40	11.0715	-11.5300	-29.3358	11.0188	-11.5914	-29.3783	0.0527	-0.0614	-0.0425	0.0914	-0.0614	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 D-7. Occupant Compartment Deformation Data - Driver Side – Set 1, Test No. HNTBR-1

Model Year: 2017 Test Name: HNTBR-1 Make: Dodge VIN: 1C6RR6LTXHS514323 Model: Ram 1500

VEHICLE DEFORMATION
DRIVER SIDE INTERIOR CRUSH - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	47.9180	-26.4960	-25.1321	47.6693	-26.2058	-26.3493	0.2487	0.2902	-1.2172	1.2758	1.2758	X, Y, Z
	2	46.3172	-15.6157	-29.2641	45.8746	-15.5731	-30.5705	0.4426	0.0426	-1.3064	1.3800	1.3800	X, Y, Z
	3	44.9962	1.6629	-26.4697	43.6520	1.3842	-27.8722	1.3442	0.2787	-1.4025	1.9625	1.9625	X, Y, Z
	4	45.0300	-26.8791	-15.6039	44.8114	-26.8680	-16.8421	0.2186	0.0111	-1.2382	1.2574	1.2574	X, Y, Z
	5	43.1454	-15.5954	-15.1140	42.5203	-15.7501	-16.1986	0.6251	-0.1547	-1.0846	1.2614	1.2614	X, Y, Z
	6	42.2084	0.7313	-15.7872	39.9513	0.6009	-17.4823	2.2571	0.1304	-1.6951	2.8258	2.8258	X, Y, Z
SIDE PANEL (Y)	7	53.7473	-28.3720	-3.7474	53.7234	-28.1756	-5.0401	0.0239	0.1964	-1.2927	1.3078	0.1964	Y
	8	53.5724	-28.4921	1.0233	53.6241	-28.4095	-0.2532	-0.0517	0.0826	-1.2765	1.2802	0.0826	Y
	9	57.9762	-28.4292	-2.1023	58.0076	-28.2235	-3.4560	-0.0314	0.2057	-1.3537	1.3696	0.2057	Y
IMPACT SIDE DOOR (Y)	10	19.0173	-30.0022	-22.6322	18.7650	-29.5417	-23.3909	0.2523	0.4605	-0.7587	0.9227	0.4605	Y
	11	29.9539	-29.9522	-22.3945	29.7041	-29.4467	-23.3228	0.2498	0.5055	-0.9283	1.0861	0.5055	Y
	12	41.1241	-29.8459	-22.2372	40.8794	-29.2897	-23.3189	0.2447	0.5562	-1.0817	1.2407	0.5562	Y
	13	19.6510	-30.4872	-3.2085	19.6666	-30.4279	-4.0094	-0.0156	0.0593	-0.8009	0.8032	0.0593	Y
	14	31.7352	-31.1139	0.3544	31.8182	-31.0609	-0.6071	-0.0830	0.0530	-0.9615	0.9665	0.0530	Y
	15	39.3085	-31.4826	-0.8526	39.3457	-31.3848	-1.9662	-0.0372	0.0978	-1.1136	1.1185	0.0978	Y
ROOF - (Z)	16	36.5619	-21.3099	-41.6686	35.9182	-20.4210	-42.5161	0.6437	0.8889	-0.8475	1.3866	-0.8475	Z
	17	39.3643	-11.2177	-42.3131	38.5847	-10.2548	-43.1864	0.7796	0.9629	-0.8733	1.5158	-0.8733	Z
	18	41.0676	0.8116	-42.5234	40.0615	1.7819	-43.5006	1.0061	-0.9703	-0.9772	1.7055	-0.9772	Z
	19	28.8051	-19.4061	-45.0058	28.0719	-18.5900	-45.7953	0.7332	0.8161	-0.7895	1.3516	-0.7895	Z
	20	29.3457	-11.0034	-45.7104	28.5363	-10.1440	-46.5300	0.8094	0.8594	-0.8196	1.4372	-0.8196	Z
	21	30.3438	-0.7158	-46.0093	29.4438	0.1549	-46.8860	0.9000	0.8707	-0.8767	1.5286	-0.8767	Z
	22	14.3872	-18.1855	-46.1927	13.6333	-17.4536	-46.7740	0.7539	0.7319	-0.5813	1.2008	-0.5813	Z
	23	14.6596	-7.3619	-46.9022	13.8178	-6.7042	-47.5187	0.8418	0.6577	-0.6165	1.2334	-0.6165	Z
	24	14.5774	1.3268	-47.1243	13.6282	1.9989	-47.7551	0.9492	-0.6721	-0.6308	1.3231	-0.6308	Z
	25	-6.2059	-18.0505	-46.5557	-7.0589	-17.5730	-46.8169	0.8530	0.4775	-0.2612	1.0119	-0.2612	Z
	26	-6.2518	-8.7311	-47.1073	-7.1329	-8.2663	-47.3459	0.8811	0.4648	-0.2386	1.0244	-0.2386	Z
	27	-6.3029	0.7597	-47.3328	-7.2855	1.1988	-47.5667	0.9826	-0.4391	-0.2339	1.1014	-0.2339	Z
	28	-22.7758	-18.4104	-46.1390	-23.5728	-18.0997	-46.1479	0.7970	0.3107	-0.0089	0.8555	-0.0089	Z
	29	-22.7040	-8.4296	-46.6309	-23.5413	-8.1570	-46.6076	0.8373	0.2726	0.0233	0.8809	0.0233	Z
	30	-22.9403	0.5216	-46.7885	-23.8514	0.8512	-46.7210	0.9111	-0.3296	0.0675	0.9712	0.0675	Z
A-PILLAR Maximum (X, Y, Z)	31	51.1961	-26.8468	-29.1092	50.7945	-26.1019	-30.2377	0.4016	0.7449	-1.1285	1.4106	0.8463	X, Y
	32	48.3707	-25.7547	-30.8414	47.8986	-24.9769	-31.9263	0.4721	0.7778	-1.0849	1.4159	0.9099	X, Y
	33	46.0816	-24.7526	-32.1844	45.5976	-23.9475	-33.2287	0.4840	0.8051	-1.0443	1.4046	0.9394	X, Y
	34	42.5632	-24.2677	-35.1725	42.0335	-23.4508	-36.1349	0.5297	0.8169	-0.9624	1.3690	0.9736	X, Y
	35	39.8043	-23.3269	-36.4079	39.2332	-22.5183	-37.3095	0.5711	0.8086	-0.9016	1.3390	0.9899	X, Y
	36	36.9767	-23.4447	-39.5504	36.3288	-22.5726	-40.4478	0.6479	0.8721	-0.8974	1.4091	1.0864	X, Y
A-PILLAR Lateral (Y)	31	51.1961	-26.8468	-29.1092	50.7945	-26.1019	-30.2377	0.4016	0.7449	-1.1285	1.4106	0.7449	Y
	32	48.3707	-25.7547	-30.8414	47.8986	-24.9769	-31.9263	0.4721	0.7778	-1.0849	1.4159	0.7778	Y
	33	46.0816	-24.7526	-32.1844	45.5976	-23.9475	-33.2287	0.4840	0.8051	-1.0443	1.4046	0.8051	Y
	34	42.5632	-24.2677	-35.1725	42.0335	-23.4508	-36.1349	0.5297	0.8169	-0.9624	1.3690	0.8169	Y
	35	39.8043	-23.3269	-36.4079	39.2332	-22.5183	-37.3095	0.5711	0.8086	-0.9016	1.3390	0.8086	Y
	36	36.9767	-23.4447	-39.5504	36.3288	-22.5726	-40.4478	0.6479	0.8721	-0.8974	1.4091	0.8721	Y
B-PILLAR Maximum (X, Y, Z)	37	12.3816	-23.0469	-41.6395	11.7415	-22.4708	-42.1062	0.6401	0.5761	-0.4667	0.9795	0.8612	X, Y
	38	9.7774	-24.7789	-36.6842	9.2268	-24.2583	-37.2154	0.5506	0.5206	-0.5312	0.9254	0.7577	X, Y
	39	13.4958	-27.1465	-29.3779	13.0761	-26.7202	-29.9854	0.4197	0.4263	-0.6075	0.8526	0.5982	X, Y
	40	10.1748	-27.7477	-24.9764	9.7863	-27.4069	-25.5253	0.3885	0.3408	-0.5489	0.7539	0.5168	X, Y
B-PILLAR Lateral (Y)	37	12.3816	-23.0469	-41.6395	11.7415	-22.4708	-42.1062	0.6401	0.5761	-0.4667	0.9795	0.5761	Y
	38	9.7774	-24.7789	-36.6842	9.2268	-24.2583	-37.2154	0.5506	0.5206	-0.5312	0.9254	0.5206	Y
	39	13.4958	-27.1465	-29.3779	13.0761	-26.7202	-29.9854	0.4197	0.4263	-0.6075	0.8526	0.4263	Y
	40	10.1748	-27.7477	-24.9764	9.7863	-27.4069	-25.5253	0.3885	0.3408	-0.5489	0.7539	0.3408	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 D-8. Occupant Compartment Deformation Data - Driver Side – Set 2, Test No. HNTBR-1

Model Year: 2017 Test Name: HNTBR-1 Make: Dodge VIN: 1C6RR6LTXHS514323 Model: Ram 1500

Passenger Side Maximum Deformation

Reference Set 1				Reference Set 2			
Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]	Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]
Roof	-1.2	≤ 4	Z	Roof	0.2	≤ 4	Z
Windshield[D]	0.0	≤ 3	X, Z	Windshield[D]	NA	≤ 3	X, Z
A-Pillar Maximum	2.0	≤ 5	X, Z	A-Pillar Maximum	2.4	≤ 5	X
A-Pillar Lateral	-0.5	≤ 3	Y	A-Pillar Lateral	-1.0	≤ 3	Y
B-Pillar Maximum	0.5	≤ 5	X	B-Pillar Maximum	1.1	≤ 5	X
B-Pillar Lateral	-0.1	≤ 3	Y	B-Pillar Lateral	-0.7	≤ 3	Y
Toe Pan - Wheel Well	12.7	≤ 9	X, Z	Toe Pan - Wheel Well	12.8	≤ 9	X, Z
Side Front Panel	11.9	≤ 12	Y	Side Front Panel	11.9	≤ 12	Y
Side Door (above seat)	-5.7	≤ 9	Y	Side Door (above seat)	-6.1	≤ 9	Y
Side Door (below seat)	-3.8	≤ 12	Y	Side Door (below seat)	-3.9	≤ 12	Y
Floor Pan	5.4	≤ 12	Z	Floor Pan	5.6	≤ 12	Z
Dash - no MASH requirement	5.2	NA	X, Y, Z	Dash - no MASH requirement	5.3	NA	X, Y, Z

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

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

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

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

Notes on vehicle interior crush:

Figure D-9. Maximum Occupant Compartment Deformation by Location – Passenger Side, Test No. HNTBR-1

Test Name: HNTBR-1 VIN: 1C6RR6LTXHS514323
Model Year: 2017 Make: Dodge Model: Ram 1500

Driver Side Maximum Deformation

Reference Set 1				Reference Set 2			
Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]	Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]
Roof	-0.5	≤ 4	Z	Roof	0.1	≤ 4	Z
Windshield[D]	0.0	≤ 3	X, Z	Windshield[D]	NA	≤ 3	X, Z
A-Pillar Maximum	0.3	≤ 5	X, Y	A-Pillar Maximum	1.1	≤ 5	X, Y
A-Pillar Lateral	0.3	≤ 3	Y	A-Pillar Lateral	0.9	≤ 3	Y
B-Pillar Maximum	0.1	≤ 5	X	B-Pillar Maximum	0.9	≤ 5	X, Y
B-Pillar Lateral	0.3	≤ 3	Y	B-Pillar Lateral	0.6	≤ 3	Y
Toe Pan - Wheel Well	0.2	≤ 9	Z	Toe Pan - Wheel Well	1.3	≤ 9	X, Z
Side Front Panel	0.1	≤ 12	Y	Side Front Panel	0.2	≤ 12	Y
Side Door (above seat)	0.2	≤ 9	Y	Side Door (above seat)	0.6	≤ 9	Y
Side Door (below seat)	0.0	≤ 12	Y	Side Door (below seat)	0.1	≤ 12	Y
Floor Pan	0.2	≤ 12	Z	Floor Pan	1.2	≤ 12	Z
Dash - no MASH requirement	2.4	NA	X, Y, Z	Dash - no MASH requirement	2.4	NA	X, Y, Z

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

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

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

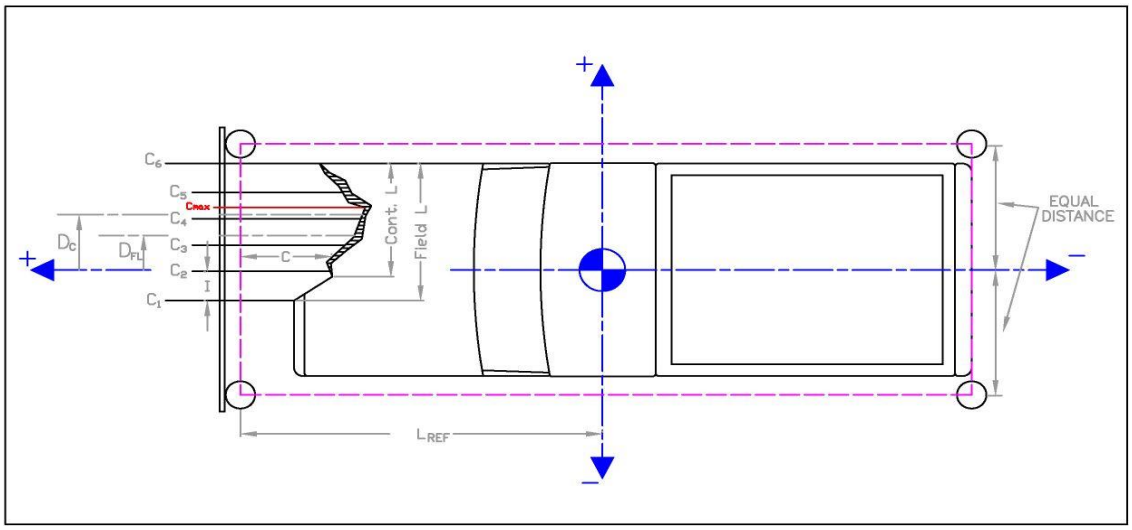
[D] If deformation is observered for the windshield then the windshield deformation is measured posttest with an examplar vehicle, therefore only one set of reference is measured and recorded.

Notes on vehicle interior crush:

Figure D-10. Maximum Occupant Compartment Deformation by Location – Driver Side, Test No. HNTBR-1

Test Name: HNTBR-1 VIN: 1C6RR6LTXHS514323

Model Year: 2017 Make: Dodge Model: Ram 1500



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	107 1/2	(2731)
Total Vehicle Width:	78	(1981)
Width of contact and induced crush - Field L:	78	(1981)
Crush measurement spacing interval (L/5) - I:	15 5/8	(397)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	78	(1981)
Distance from center of vehicle to center of contact damage - D_C:	0	()

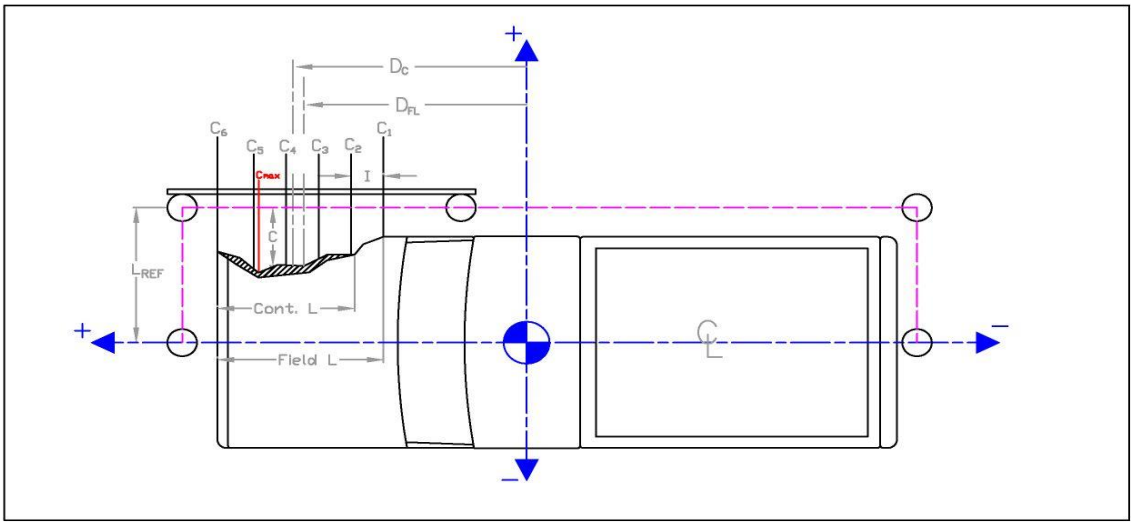
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Lateral Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	N/a	N/A	-39	-(991)	22 1/2	(572)	4 1/3	(110)	N/A	N/A
C_2	11	(279)	-23 3/8	-(594)	6 5/8	(168)			0	(2)
C_3	10 1/8	(257)	-7 3/4	-(197)	4 1/4	(108)			1 4/7	(40)
C_4	16 1/8	(410)	7 7/8	(200)	4 1/4	(108)			7 4/7	(192)
C_5	28	(711)	23 1/2	(597)	6 1/4	(159)			17 4/9	(443)
C_6	N/a	N/A	39 1/8	(994)	20 1/2	(521)			N/A	N/A
C_{MAX}	33 1/4	(845)	28	(711)	8	(203)			21	(532)

Figure D-11. Exterior Vehicle Crush (NASS) – Front, Test No. HNTBR-1

Test Name: HNTBR-1 VIN: 1C6RR6LTXHS514323

Model Year: 2017 Make: Dodge Model: Ram 1500



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	43 3/4	(1111)
Total Vehicle Length:	229	(5817)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-15 4/7	-(395)
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}:	-15 4/7	-(396)
Width of Contact Damage:	229	(5817)
Distance from vehicle c.g. to center of contact damage - D_C:	-15 4/7	-(396)

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

	Crush Measurement		Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual	Crush
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	N/a	N/A	-130 1/8	-(3305)	33 1/2	(851)	- 1/4	-(6)	N/A	N/A
C_2	N/a	N/A	-84 3/8	-(2143)	5 1/2	(140)			N/A	N/A
C_3	7	(178)	-38 5/8	-(981)	5 3/4	(146)			1 1/2	(38)
C_4	7	(178)	7 1/8	(181)	5	(127)			2 1/4	(57)
C_5	N/a	N/A	52 7/8	(1343)	5 5/8	(143)			N/A	N/A
C_6	N/a	N/A	98 5/8	(2505)	8 3/8	(213)			N/A	N/A
C_{MAX}	23 1/4	(591)	28	(711)	5 1/8	(130)			18 3/8	(467)

Figure D-12. Exterior Vehicle Crush (NASS) – Side, Test No. HNTBR-1

Appendix E. Accelerometer and Rate Transducer Data Plots, Test No. HNTBR-1

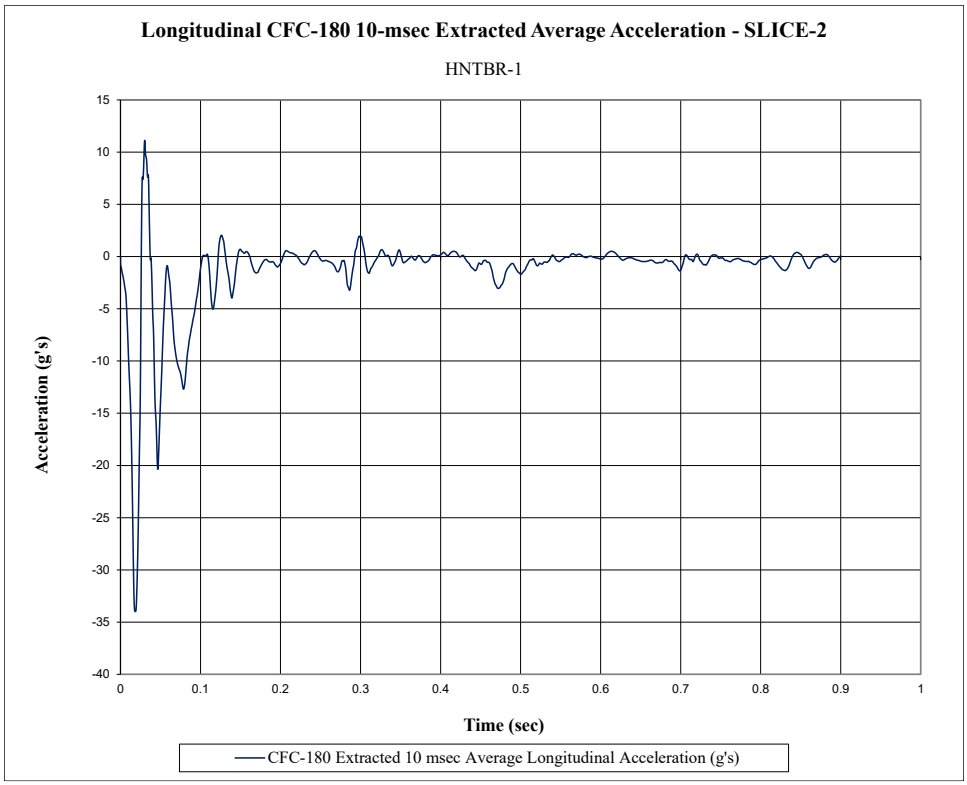


Figure E-1. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. HNTBR-1

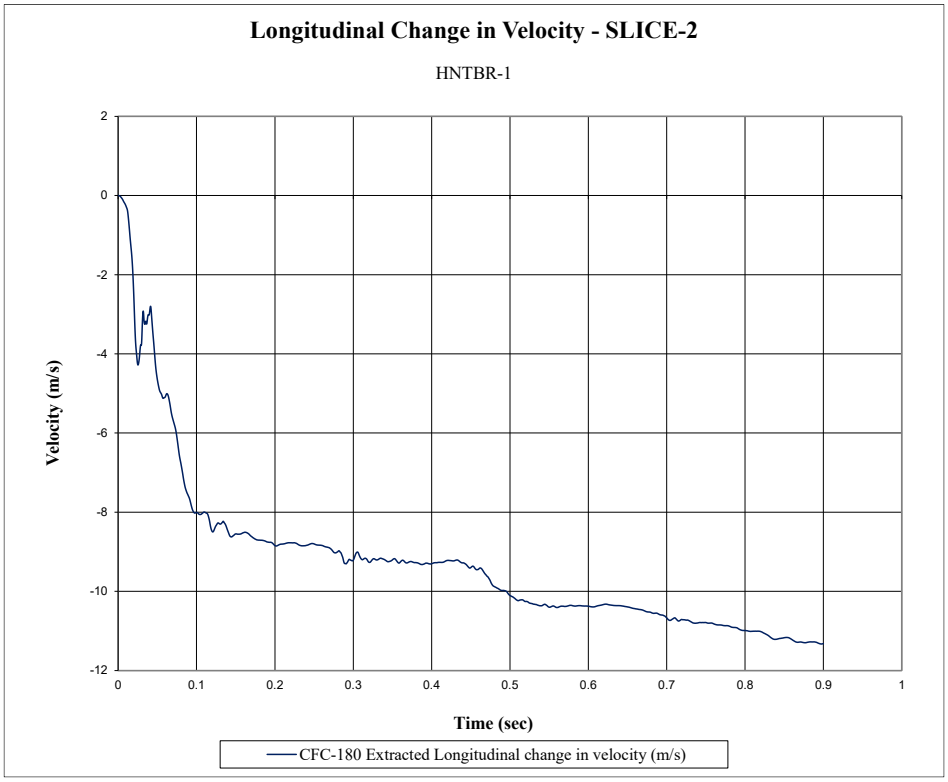


Figure E-2. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. HNTBR-1

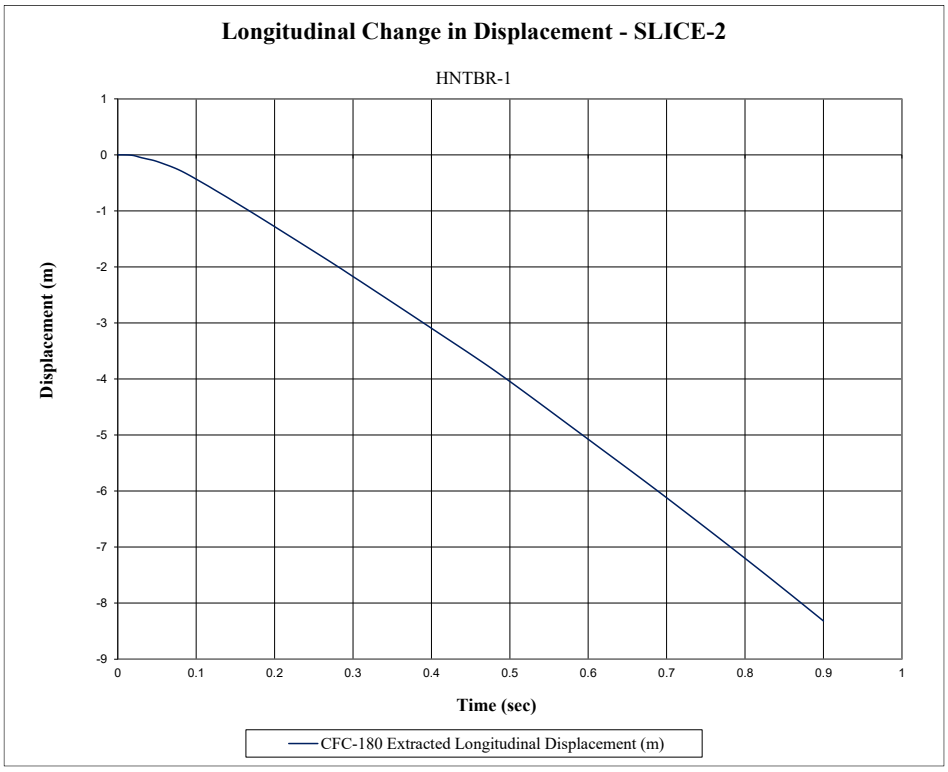


Figure E-3. Longitudinal Occupant Displacement (SLICE-2), Test No. HNTBR-1

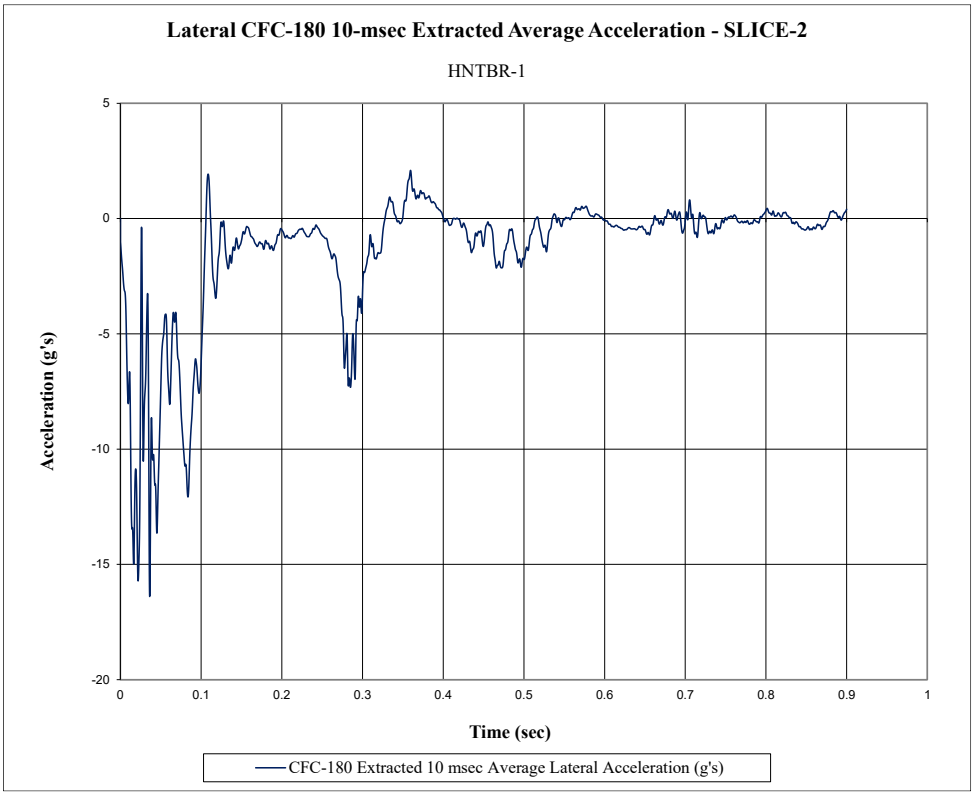


Figure E-4. 10-ms Average Lateral Deceleration (SLICE-2), Test No. HNTBR-1

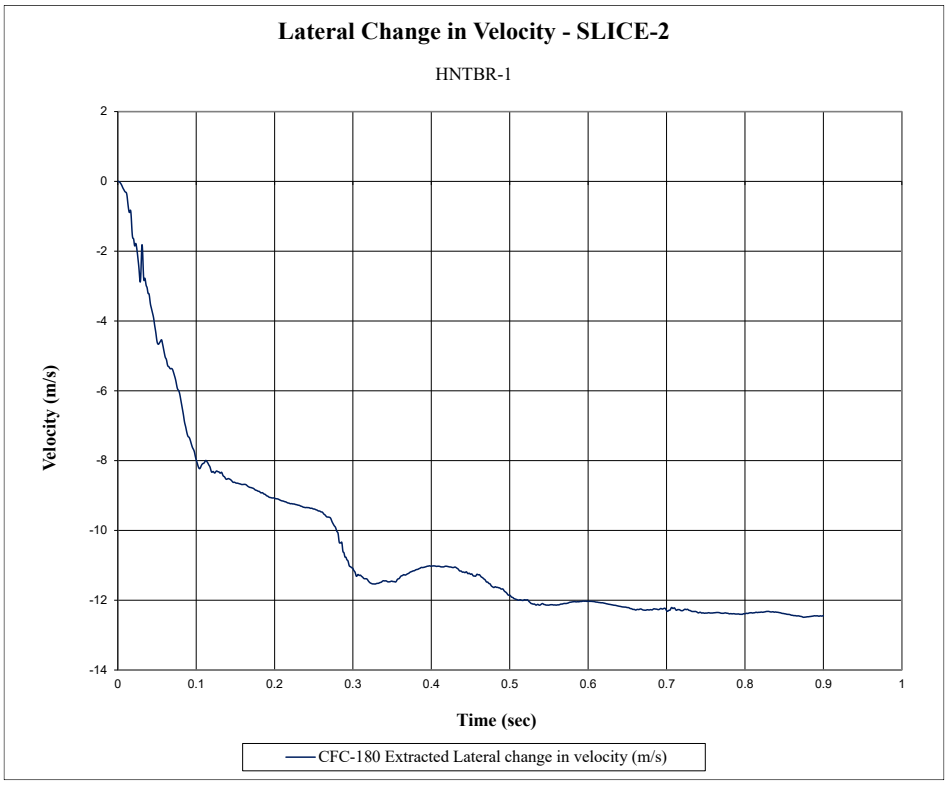


Figure E-5. Lateral Occupant Impact Velocity (SLICE-2), Test No. HNTBR-1

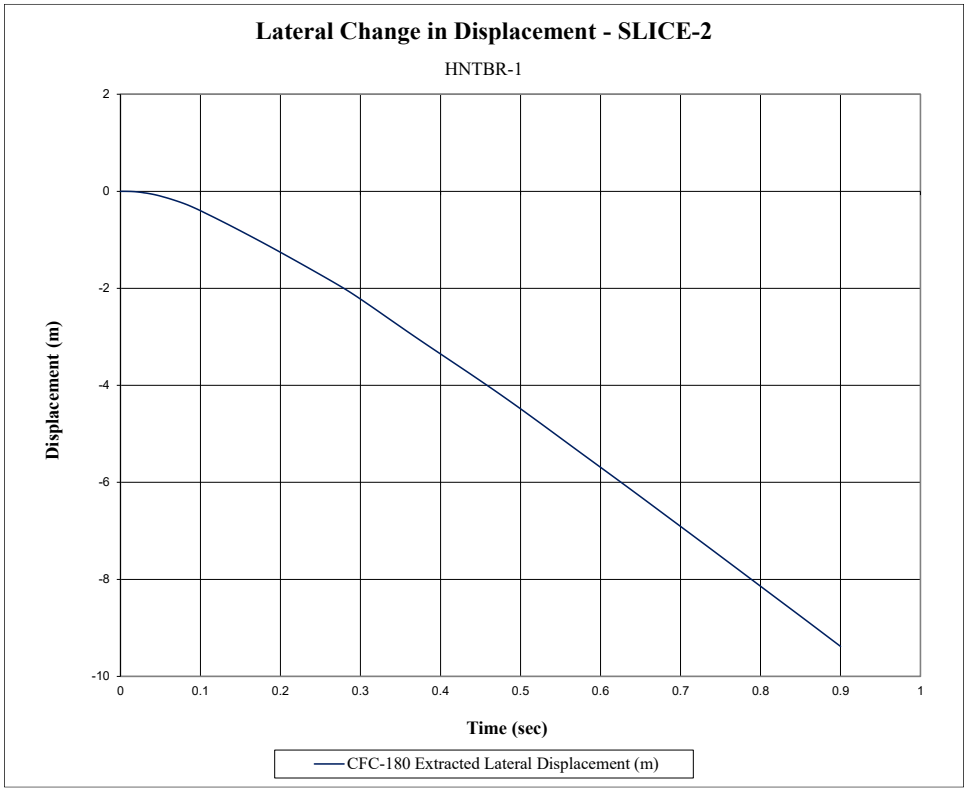


Figure E-6. Lateral Occupant Displacement (SLICE-2), Test No. HNTBR-1

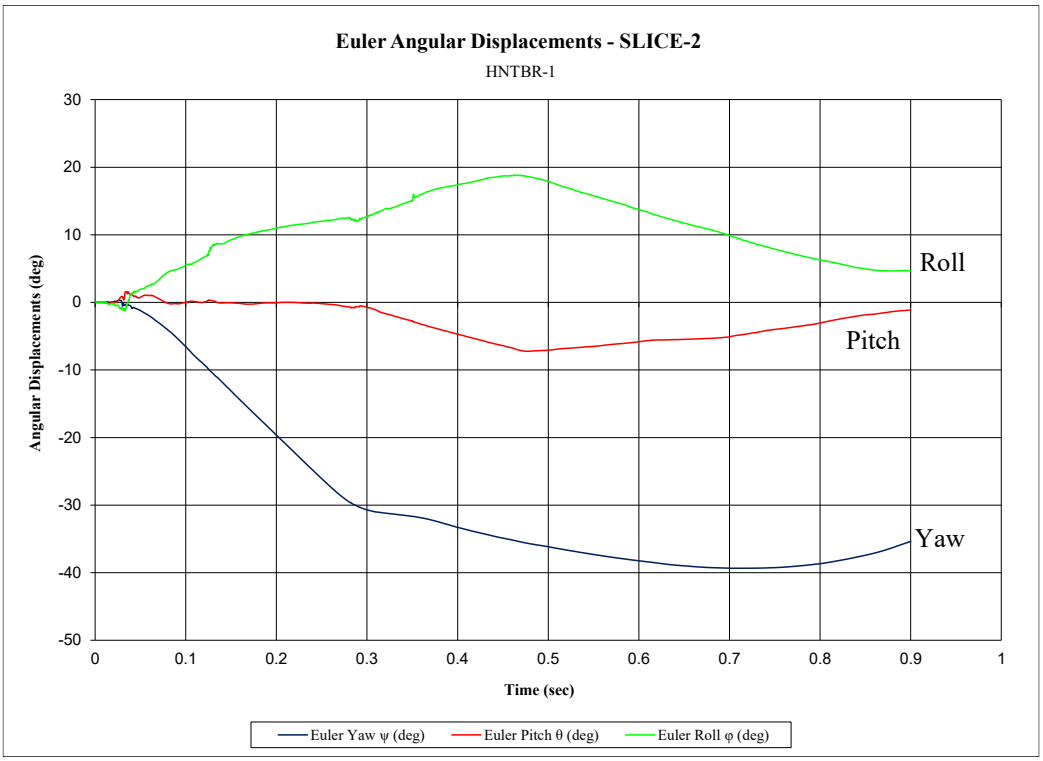


Figure E-7. Vehicle Angular Displacements (SLICE-2), Test No. HNTBR-1

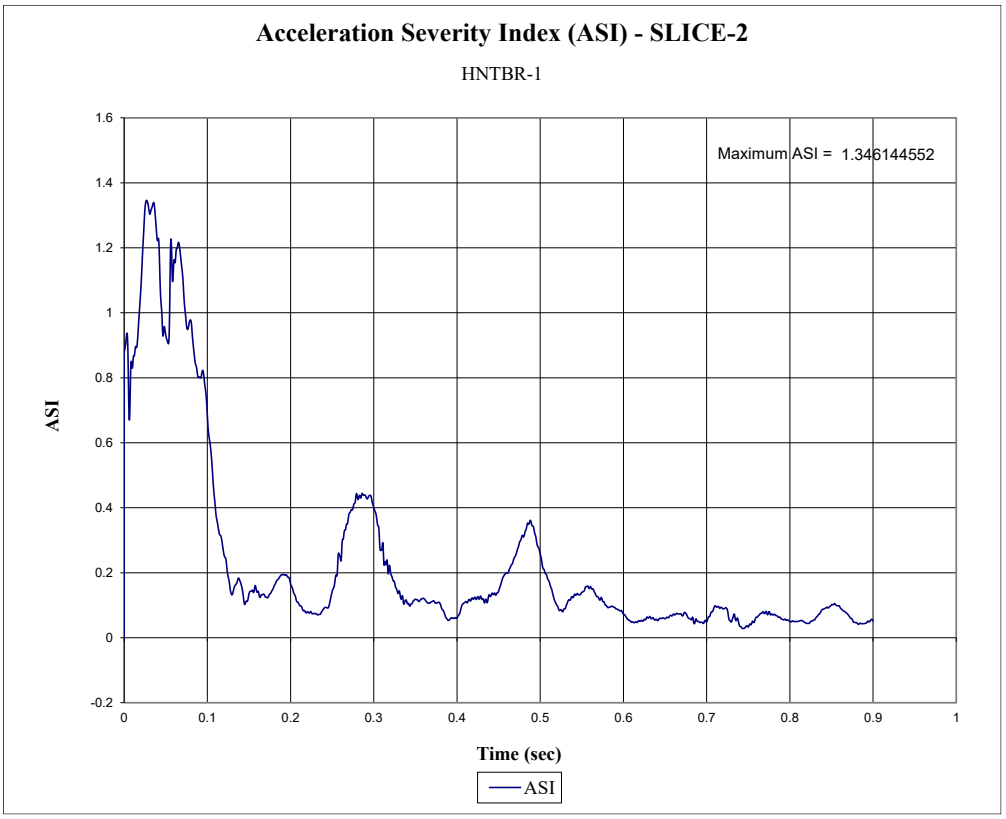


Figure E-8. Acceleration Severity Index (SLICE-2), Test No. HNTBR-1

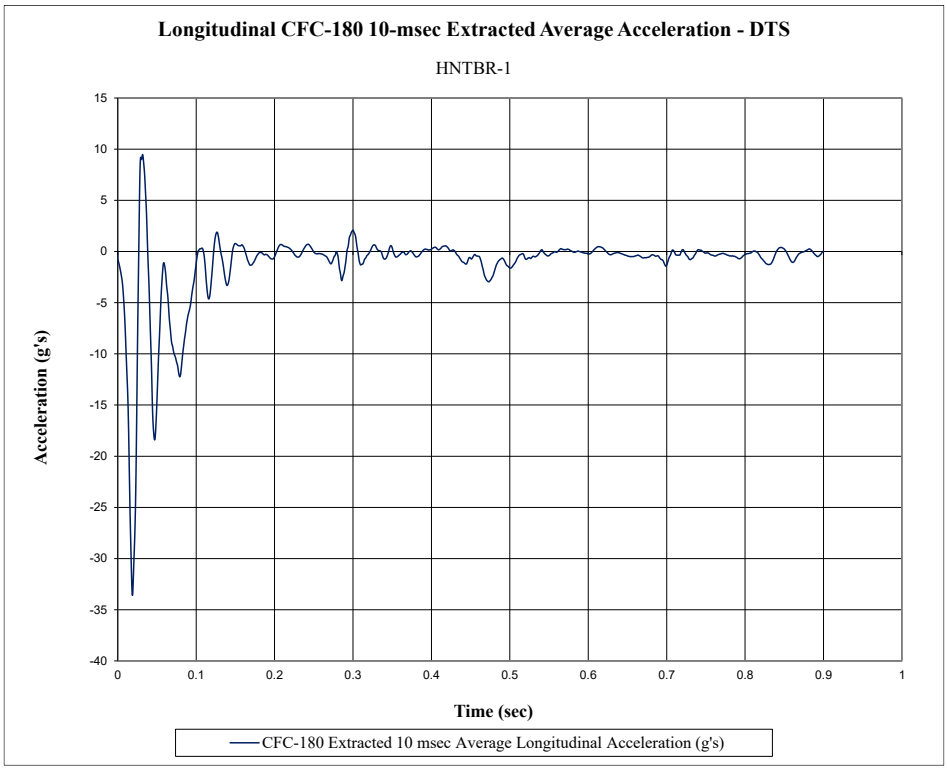


Figure E-9. 10-ms Average Longitudinal Deceleration (DTS), Test No. HNTBR-1

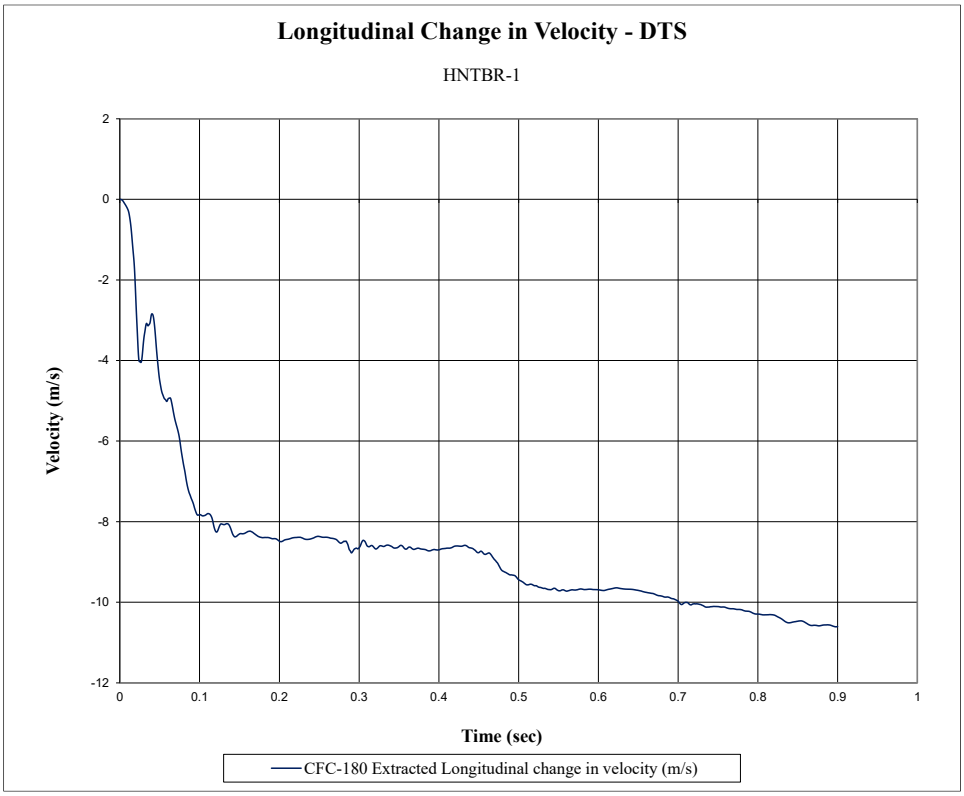


Figure E-10. Longitudinal Occupant Impact Velocity (DTS), Test No. HNTBR-1

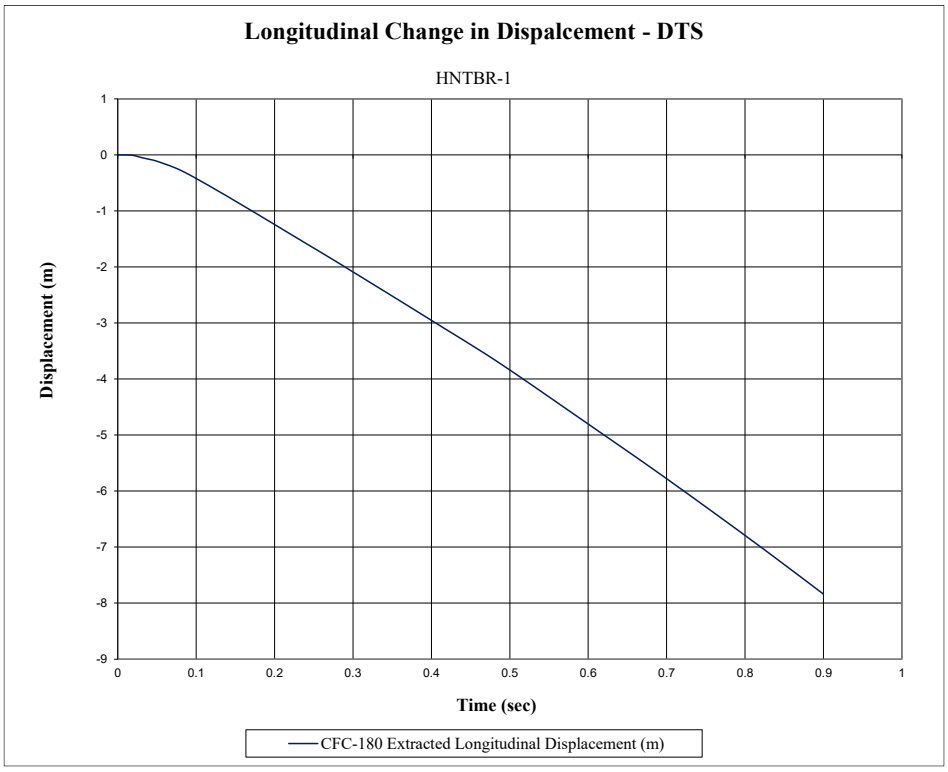


Figure E-11. Longitudinal Occupant Displacement (DTS), Test No. HNTBR-1

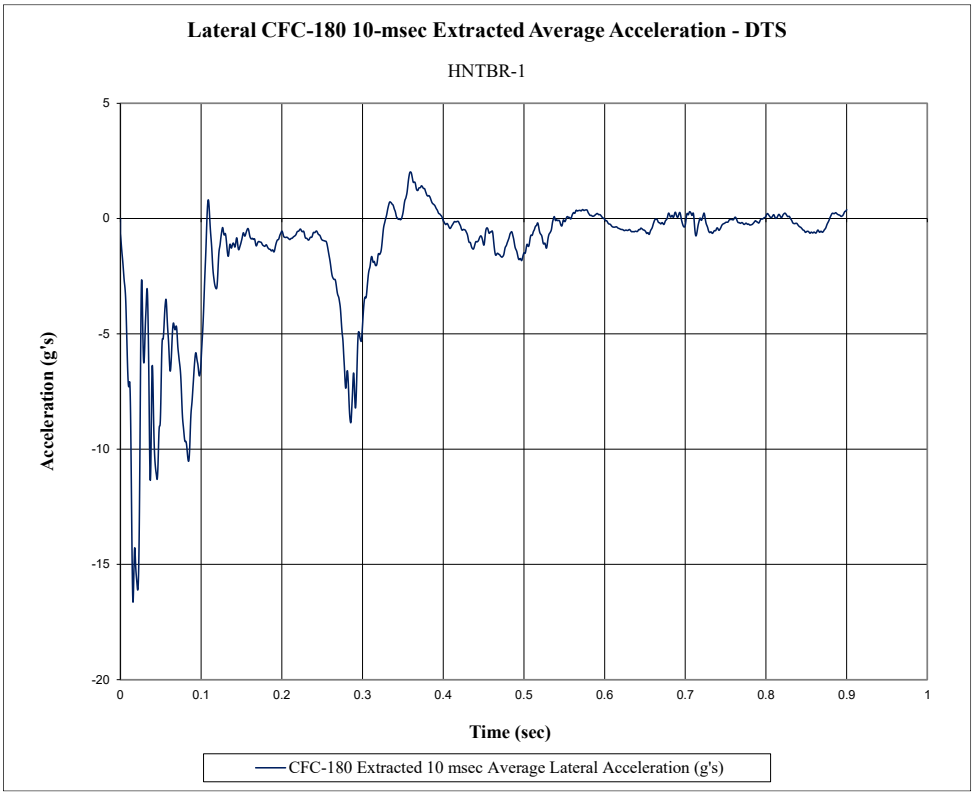


Figure E-12. 10-ms Average Lateral Deceleration (DTS), Test No. HNTBR-1

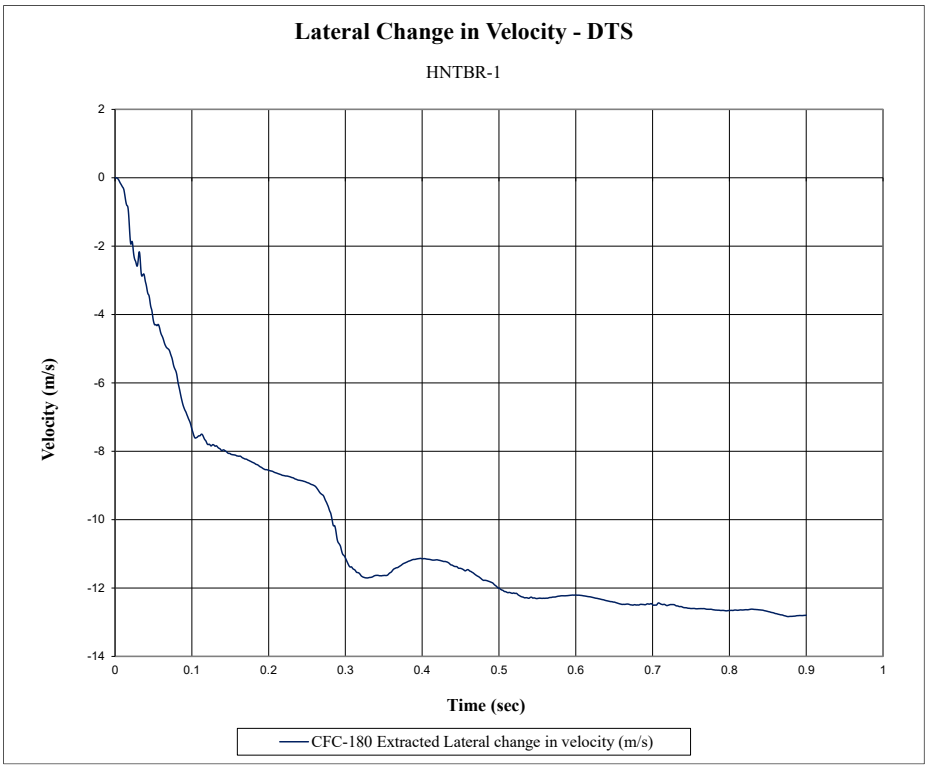


Figure E-13. Lateral Occupant Impact Velocity (DTS), Test No. HNTBR-1

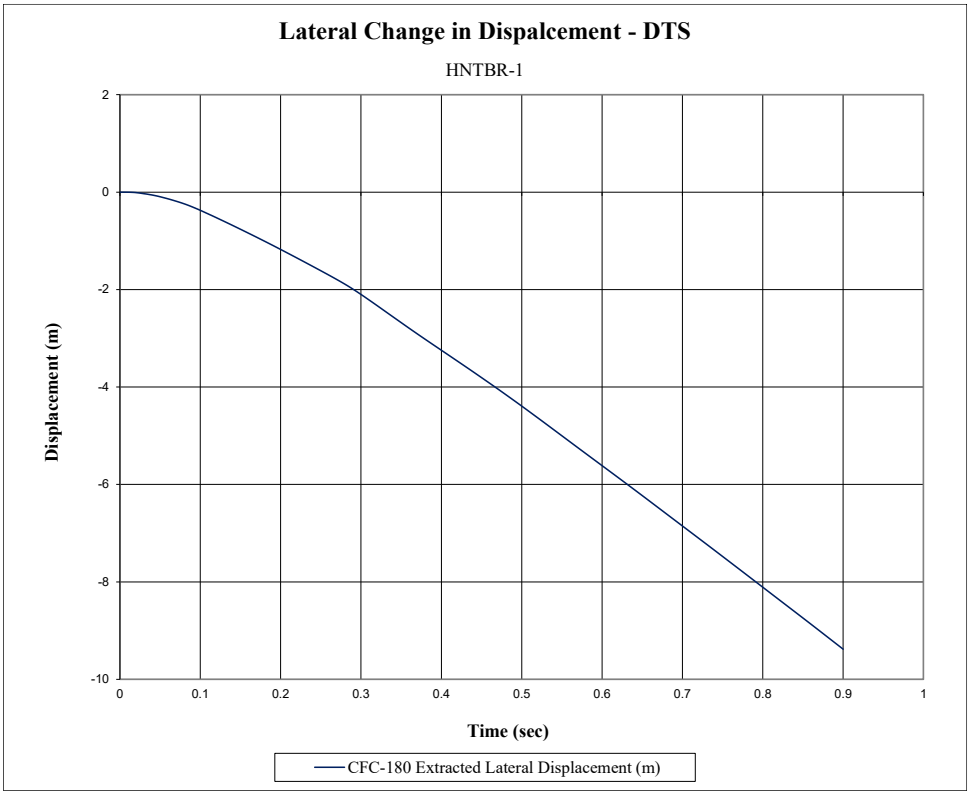


Figure E-14. Lateral Occupant Displacement (DTS), Test No. HNTBR-1

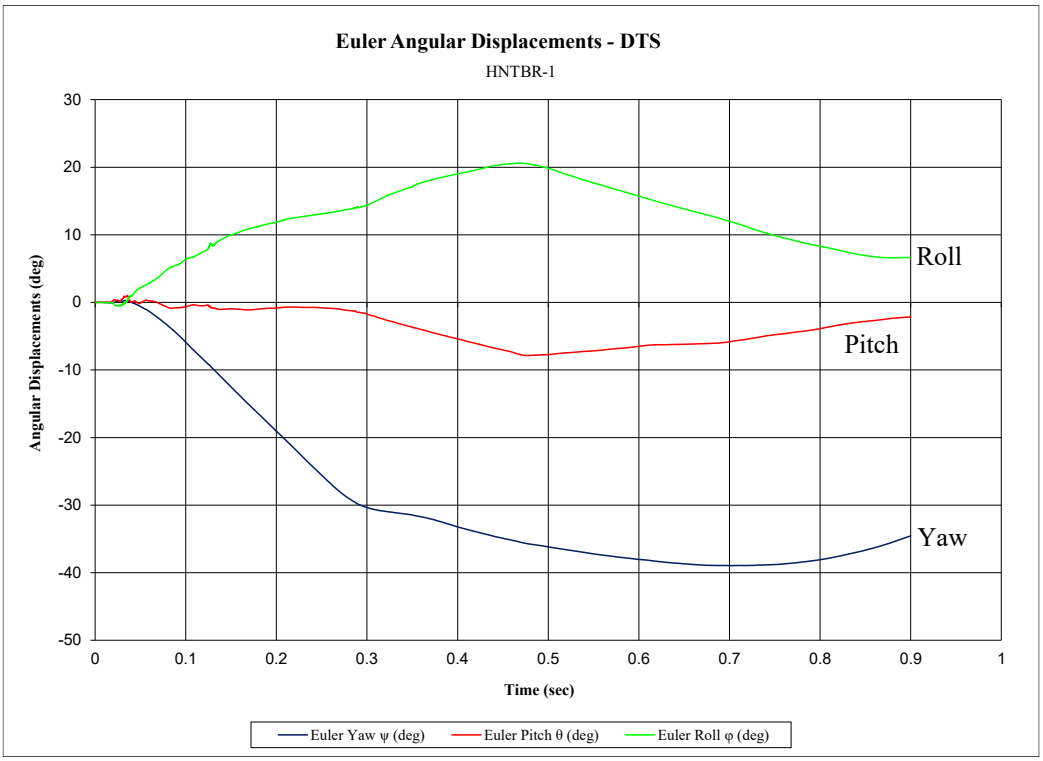


Figure E-15. Vehicle Angular Displacements (DTS), Test No. HNTBR-1

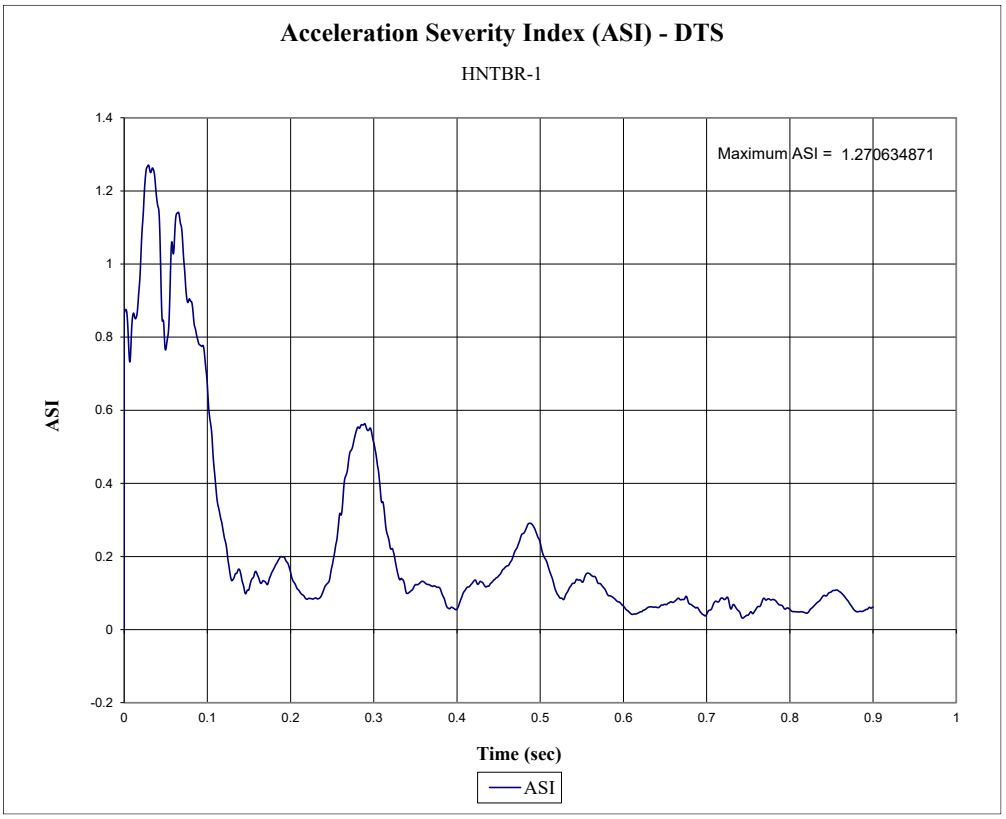


Figure E-16. Acceleration Severity Index (DTS), Test No. HNTBR-1

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