Hawaii Department of Transportation
Research Contract No. 68212 Project 2, Phase II, System No. 4
Research Project No. STP-1500(092) – Phase II

CRASH TESTING AND EVALUATION OF HDOT'S THRIE-BEAM APPROACH GUARDRAIL TRANSITION ATTACHED TO 42-IN. TALL, SOLID CONCRETE BRIDGE RAIL WITH AESTHETIC, RECESSED, ROUNDED PANELS AND 6-FT WIDE SIDEWALK: MASH TEST NOS. 3-20 AND 3-21

Submitted by

Tewodros Y. Yosef, Ph.D.
Post-Doctoral Research Associate

Joshua S. Steelman, Ph.D., P.E
Associate Professor

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

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

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

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

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

Submitted to

Hawaii Department of Transportation
Aliiaimoku Building
869 Punchbowl Street
Honolulu, Hawaii 96813

MwRSF Research Report No. TRP-03-472-22

December 13, 2022

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. TRP-03-472-22	**2. Government Accession No.**	**3. Recipient's Catalog No.**
4. Title and Subtitle Crash Testing and Evaluation of HDOT's Thrie-Beam Approach Guardrail Transition Attached to 42-in. Tall, Solid Concrete Bridge Rail with Aesthetic, Recessed, Rounded Panels and 6-ft Wide Sidewalk: MASH Test Nos. 3-20 and 3-21		**5. Report Date** December 13, 2022 **6. Performing Organization Code**
7. Author(s) Yosef, T.Y., Steelman, J.S., Faller, R.K., and Urbank, E.L.		**8. Performing Organization Report No.** TRP-03-472-22
9. Performing Organization Name and Address Midwest Roadside Safety Facility (MwRSF) Nebraska Transportation Center University of Nebraska-Lincoln Main Office: Prem S. Paul Research Center at Whittier School Room 130, 2200 Vine Street Lincoln, Nebraska 68583-0853 Outdoor Test Site: 4630 N.W. 36th Street Lincoln, Nebraska 68524		**10. Work Unit No.** **11. Contract** Research Contract No. 68212 Research Project No. STP-1500(092) – Project 2, Phase II, System No. 4
12. Sponsoring Agency Name and Address Hawaii Department of Transportation Aliiaimoku Building 869 Punchbowl Street Honolulu, Hawaii 96813		**13. Type of Report and Period Covered** Final Report: 2020 – 2022
15. Supplementary Notes Prepared in cooperation with U.S. Department of Transportation, Federal Highway Administration		

16. Abstract

This report documents two full-scale crash tests conducted to evaluate the safety performance of the Hawaii Department of Transportation's (HDOT's) Thrie-Beam, Approach Guardrail Transition (AGT) attached to the 42-in. tall, solid concrete bridge rail with aesthetic, recessed, rounded panels and 6-ft wide sidewalk according to the Test Level 3 (TL-3) criteria of the Association of State Highway and Transportation Official (AASHTO) *Manual for Assessing Safety Hardware, Second Edition* (MASH 2016). The AGT consisted of nested thrie-beam rail supported by W6x15 and W6x8.5/W6x9 steel posts and was attached to a reinforced concrete buttress and 42-in. tall solid concrete bridge rail. The upstream section included the Midwest Guardrail System (MGS) stiffness transition utilizing an asymmetrical W-to-thrie transition segment to ensure a crashworthy connection between the upstream W-beam and the downstream nested thrie beam. The thrie-beam AGT was full-scale crash tested in conjunction with a 6-in. tall curb placed below the thrie-beam rail.

Test nos. H42ST-1 and H42ST-2 were conducted in accordance with MASH 2016 test designation nos. 3-21 and 3-20, respectively. In test no. H42ST-1, a 2270P pickup truck impacted the barrier at a speed of 64.7 mph and an angle of 24.8 degrees. Although the impact speed exceeded the MASH limits, MASH accepts values in excess of the criteria for longitudinal barriers. In test no. H42ST-2, an 1100C small car impacted the barrier at a speed of 62.4 mph and an angle of 25.1 degrees. In both tests, the thrie-beam AGT successfully contained and safely redirected the vehicles. All occupant risk measurements were found to be within the established MASH 2016 limits. Therefore, test nos. H42ST-1 and H42ST-2 were deemed to have satisfied all safety performance criteria, and the HDOT thrie-beam AGT attached to the 42-in. tall, solid concrete bridge rail with aesthetic, recessed, rounded panels and 6-ft sidewalk was determined to be crashworthy to MASH 2016 TL-3.

17. Key Words Highway Safety, Crash Test, Roadside Appurtenances, Compliance Test, MASH 2016, Approach Guardrail Transition, Thrie-Beam, Concrete Parapet, Sidewalk, Concrete Bridge Rail		**18. Distribution Statement** No restrictions. This document is available through the National Technical Information Service. 5285 Port Royal Road Springfield, VA 22161	
19. Security Classification (of this report) Unclassified	**20. Security Classification (of this page)** Unclassified	**21. No. of Pages** 226	**22. Price**

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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. 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, the 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 State of 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. Mojdeh Asadollahipajouh, Research Assistant Professor.

ACKNOWLEDGEMENTS

The authors wish to acknowledge several sources that made a contribution to this project: (1) the Hawaii Department of Transportation for sponsoring this project and (2) MwRSF personnel for constructing the barriers and conducting the crash tests.

Acknowledgement is also given to the following individuals who contributed to the completion of this research project.

Midwest Roadside Safety Facility
J.C. Holloway, M.S.C.E., Research Engineer & Assistant Director –Physical Testing Division
K.A. Lechtenberg, M.S.M.E., Research Engineer
R.W. Bielenberg, M.S.M.E., Research Engineer
S.K. Rosenbaugh, M.S.C.E., Research Engineer
C.S. Stolle, Ph.D., Research Assistant Professor
M. Asadollahi Pajouh, Ph.D., P.E., Research Assistant Professor
B.J. Perry, M.E.M.E., Research Associate Engineer
C. Sim, Ph.D., P.E., Associate Professor
A.T. Russell, B.S.B.A., Testing and Maintenance Technician II
E.W. Krier, B.S., Former Engineering Testing Technician II
D.S. Charroin, Engineering Testing Technician II
R.M. Novak, Engineering Testing Technician II
S.M. Tighe, Engineering Testing Technician I
T.C. Donahoo, Engineering Testing Technician I
J.T. Jones, Engineering Testing Technician I
C. Charroin, Temporary Engineering Construction Testing Technician I
T. Shapland, Temporary Engineering Construction Testing Technician I
Z.Z. Jabr, Engineering Technician
J. Oliver, Solidworks Drafting Coordinator
Undergraduate and Graduate Research Assistants

Hawaii Department of Transportation
James Fu, P.E., Chief, State Bridge Engineer
Dean Takiguchi, P.E., Engineer, Bridge Design Section
Kimberly Okamura, Engineer, Bridge Design Section

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.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 Background

The Hawaii Department of Transportation (HDOT) utilizes a thrie-beam, approach guardrail transition (AGT) to connect W-beam guardrail to concrete bridge rails. However, the crashworthiness of this transition attached to the 42-in. tall, solid concrete bridge rail with aesthetic, recessed, rounded panels and 6-ft sidewalk with approach ramp has not been demonstrated under current impact safety standards. This report documents full-scale crash testing conducted to evaluate the safety performance of HDOT's thrie-beam AGT attached to a 42-in. tall, solid concrete bridge railing with aesthetic, recessed, rounded panels and a 6-ft sidewalk with approach ramp according to the Test Level 3 (TL-3) criteria of the Association of State Highway and Transportation Officials' (AASHTO) *Manual for Assessing Safety Hardware, Second Edition* (MASH 2016) [1].

Researchers at the Midwest Roadside Safety Facility (MwRSF) modified HDOT's thrie beam AGT design to safely transition from W-beam guardrail to a rigid concrete parapet [2]. The modified AGT consisted of nested thrie-beam rail supported by W6x15 and W6x9/W6x8.5 steel posts and was attached to HDOT's specially-designed, reinforced concrete end post, the Type D2 End Post. The AGT was also designed for use with a 6-in. tall curb placed below the thrie beam. Although not originally part of HDOT's AGT design, the upstream section was modified to include the Midwest Guardrail System (MGS) stiffness transition utilizing an asymmetrical W-to-thrie transition segment to ensure a crashworthy connection between the upstream W-beam and the downstream nested thrie-beam. The modified HDOT thrie-beam AGT, including a concrete parapet, transition, MGS, and a guardrail anchorage system, is shown in Figures 1 through 3. Details regarding the design modification of the HDOT thrie-beam AGT can be found in MwRSF's previously published report [2]. It should be noted that the 42-in. tall, aesthetic concrete bridge rail system without a sidewalk was previously evaluated to the MASH 2016 TL-3 criteria [3].

Furthermore, two full-scale crash tests were conducted on the modified HDOT thrie-beam AGT to investigate the safety performance according to TL-3 criteria in MASH 2016 [2]. Test nos. HWTT-1 and HWTT-2 were conducted per MASH 2016 test designation nos. 3-20 and 3-21, respectively. In both tests, the transition successfully contained and safely redirected the vehicles. All occupant risk measurements were within the established MASH 2016 limits. Therefore, test nos. HWTT-1 and HWTT-2 were deemed to have satisfied all safety performance criteria, and the modified HDOT thrie-beam AGT to concrete parapet was determined to be crashworthy to MASH 2016 TL-3 criteria.

The modified HDOT AGT system in this research study was similar to HDOT's AGT system that was full-scale crash tested in test nos. HWTT-1 and HWTT-2. However, the current AGT was connected to a 42-in. tall, solid concrete bridge railing with aesthetic, recessed, rounded panels with a 6-ft wide by 6-in. tall, tapered sidewalk with an approach ramp on the upstream end, which was previously crash tested and met MASH 2016 criteria [4]. The sidewalk was anchored to MwRSF's existing, unreinforced concrete tarmac using epoxied, vertical, steel dowel bars. A curb was located under a portion of the thrie-beam AGT system. The upstream stiffness transition utilized the MGS and asymmetric W-beam to thrie-beam transition section.

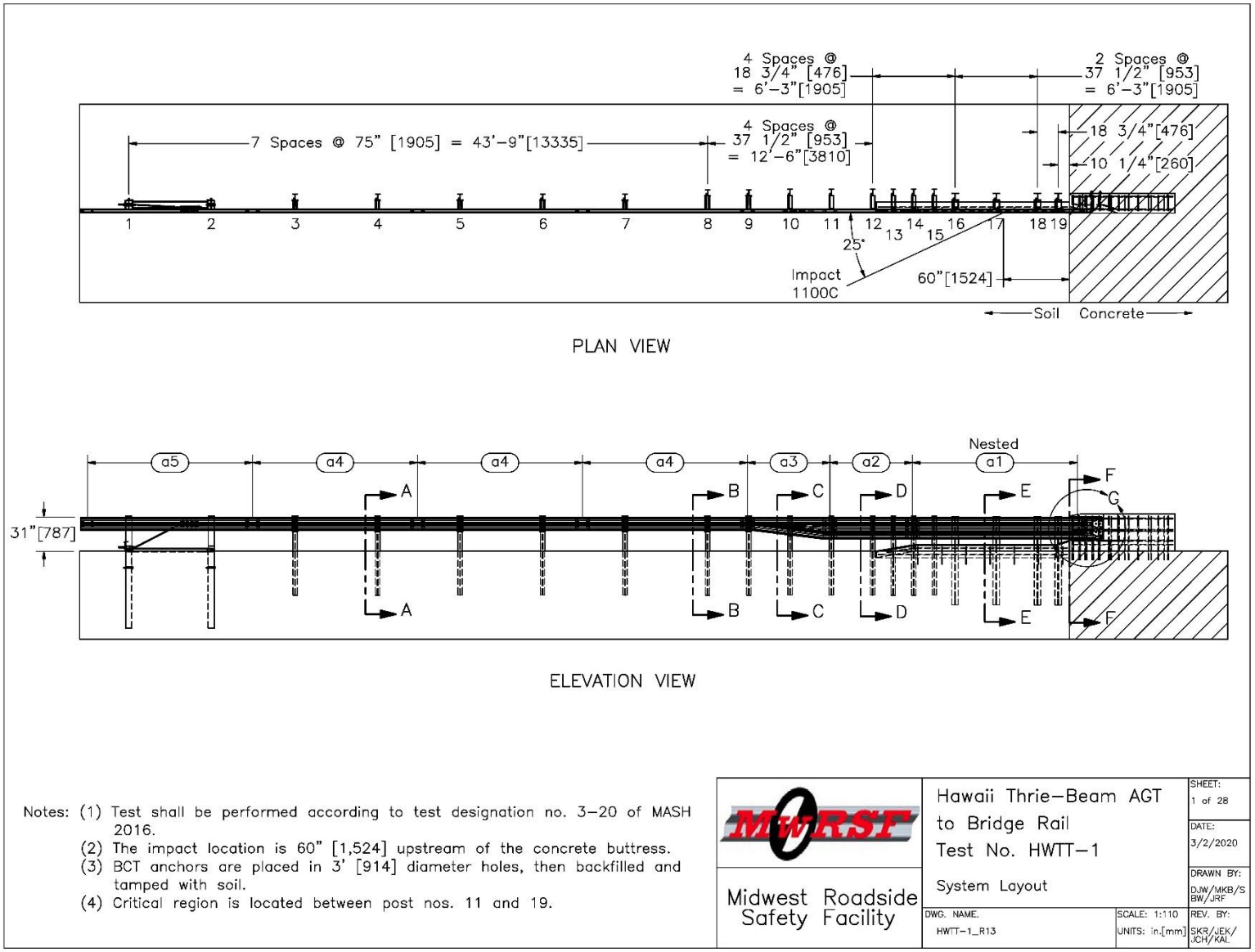


Figure 1. System Layout, Test No. HWTT-1 [2]

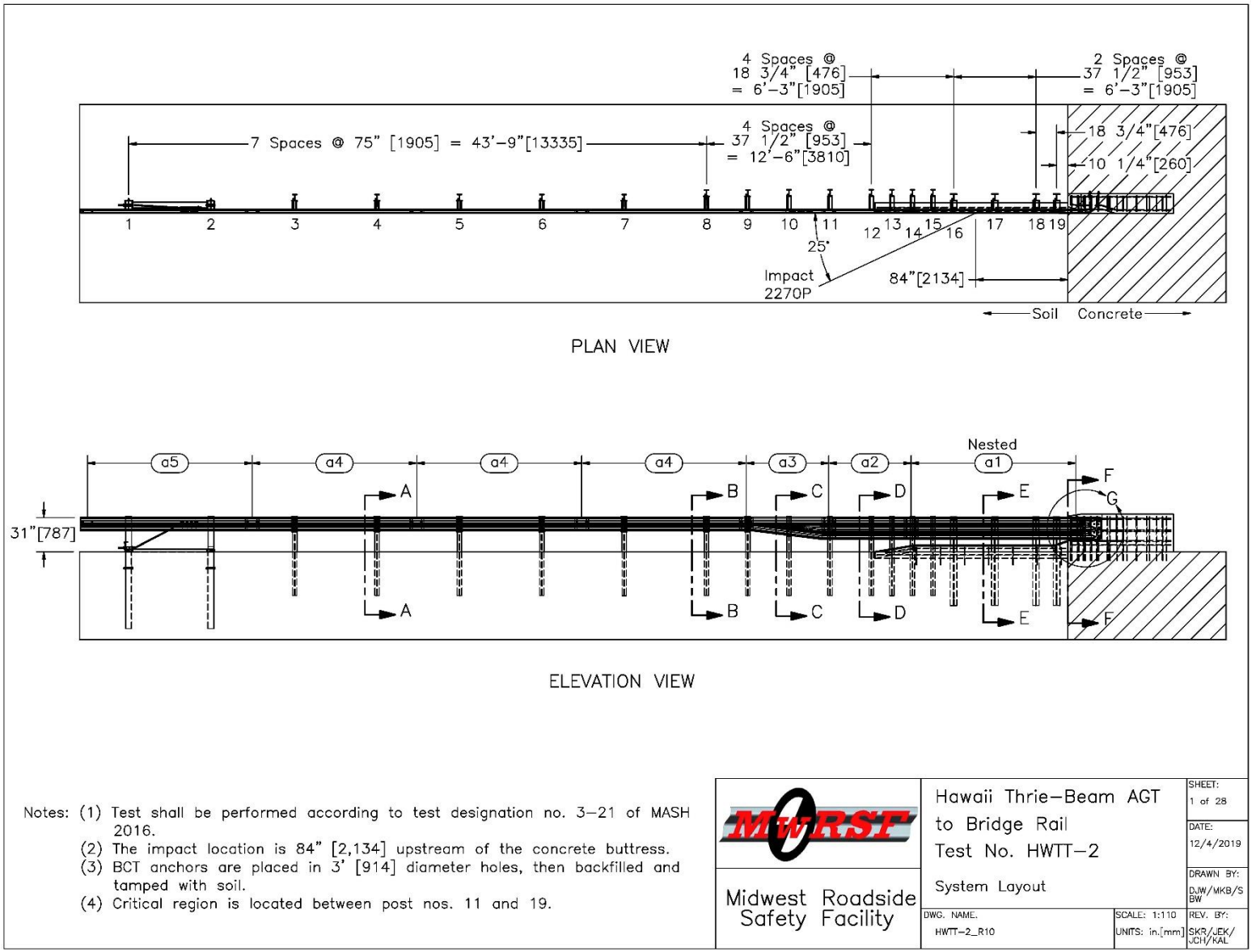


Figure 2. System Layout, Test No. HWTT-2 [2]

Figure 3. Test Installation Photographs, Test Nos. HWTT-1 and HWTT-2 [2]

1.2 Objective

The objective of this research was to conduct a safety performance evaluation of HDOT's thrie-beam AGT attached to the 42-in. tall, solid concrete bridge railing with aesthetic, recessed, rounded panels with a 6-ft wide by 6-in. tall sidewalk with an approach ramp. The system was evaluated according to the TL-3 criteria of the MASH 2016.

1.3 Scope

Two full-scale crash tests were conducted on HDOT's thrie beam AGT attached to the 42-in. tall, solid concrete bridge railing with aesthetic, recessed, rounded panels with a 6-ft wide by 6-in. tall sidewalk according to MASH 2016 test designation nos. 3-20 and 3-21. Next, the full-scale vehicle crash test results were analyzed, evaluated, and documented. Conclusions and recommendations were then made about the safety performance of the HDOT system.

2 DESIGN DETAILS

The barrier system used for the test installation had a total length of 184 ft – 6½ in. and consisted of a concrete parapet, thrie-beam AGT, MGS, a guardrail anchorage system, and concrete bridge rail with 6-ft wide sidewalk and an approach ramp, as shown in Figures 4 through 39. Photographs of the test installation are shown in Figures 40 through 43. Material specifications, mill certificates, and certificates of conformity for the system materials are shown in Appendix A. Note that the drawings include details for the entire system, inclusive of the thrie-beam AGT, W-beam rail installation, and end anchorage system. The downstream end of the barrier system consisted of a reinforced concrete bridge rail with a total length of 88 ft – 1½ in. and measured 42 in. tall and 10 in. wide, as shown in Figure 4.

The downstream end of HDOT's thrie-beam AGT comprised 12.5 ft of nested thrie-beam rail supported by W6x9 and W6x15 steel posts at various spacings. The upstream end of the AGT incorporated the previously MASH-tested MGS upstream stiffness transition to connect the AGT to the adjacent MGS. Approximately 51 ft of the MGS extended from the upstream end of the AGT and was anchored using an MGS trailing end anchor system. The anchorage system was originally designed to simulate the strength of other crashworthy end terminals. The anchorage system consisted of timber posts, foundation tubes, anchor cables, bearing plates, rail brackets, and channel struts, which closely resembled the hardware used in the Modified Breakaway Cable Terminal (BCT) system. The guardrail anchorage has been MASH TL-3 crash-tested as a downstream trailing-end terminal system [5-8].

The W6x15 posts were 6 ft – 6 in. long and the W6x8.5/W6x9 posts were 6 ft long. All guardrail segments had a top mounting height of 31 in. Blockouts within the AGT consisted of rectangular HSS steel tubes. To ensure the width of the blockouts matched the width of the posts, 6-in. wide blockouts were utilized with W6x15 posts, and 4-in. wide blockouts were used with W6x8.5/W6x9 posts. Posts were embedded into a compacted, coarse, crushed limestone material, alternatively classified as well-graded gravel by the Unified Soil Classification System that met American Association of State Highway and Transportation Officials (AASHTO) standard soil designation M147 Grade B. The MGS region of the test installation utilized plastic blockouts manufactured by Mondo Polymer Technologies.

An 18-ft long concrete transition buttress was attached at the upstream end of the bridge rail. The upstream end of the buttress was 32 in. tall, and the downstream end was 49½ in. tall. The concrete transition buttress was 18 in. wide and reinforced with a combination of longitudinal and lateral steel reinforcement bars. The vertical steel bars of the concrete buttress were directly anchored to the non-reinforced concrete tarmac using a chemical epoxy with a minimum bond strength of 1,450 psi. The concrete for the transition buttress was found to have a compressive strength of approximately 4,340 psi before crash testing.

A 6-in. tall concrete curb was placed below the AGT with its front face tapered with a 6V:1H slope and flush with the face of the guardrail. The curb began at the upstream end of the concrete end post and extended 176¼ in. upstream. The curb was terminated with a taper measuring 6 in. vertically by 36 in. longitudinally prior to extending below the asymmetrical W-to-thrie transition segment. A 4-in. vertical x 24-in. longitudinal taper was applied to the downstream end of the curb adjacent to the concrete end post to mitigate wheel snag on the end post.

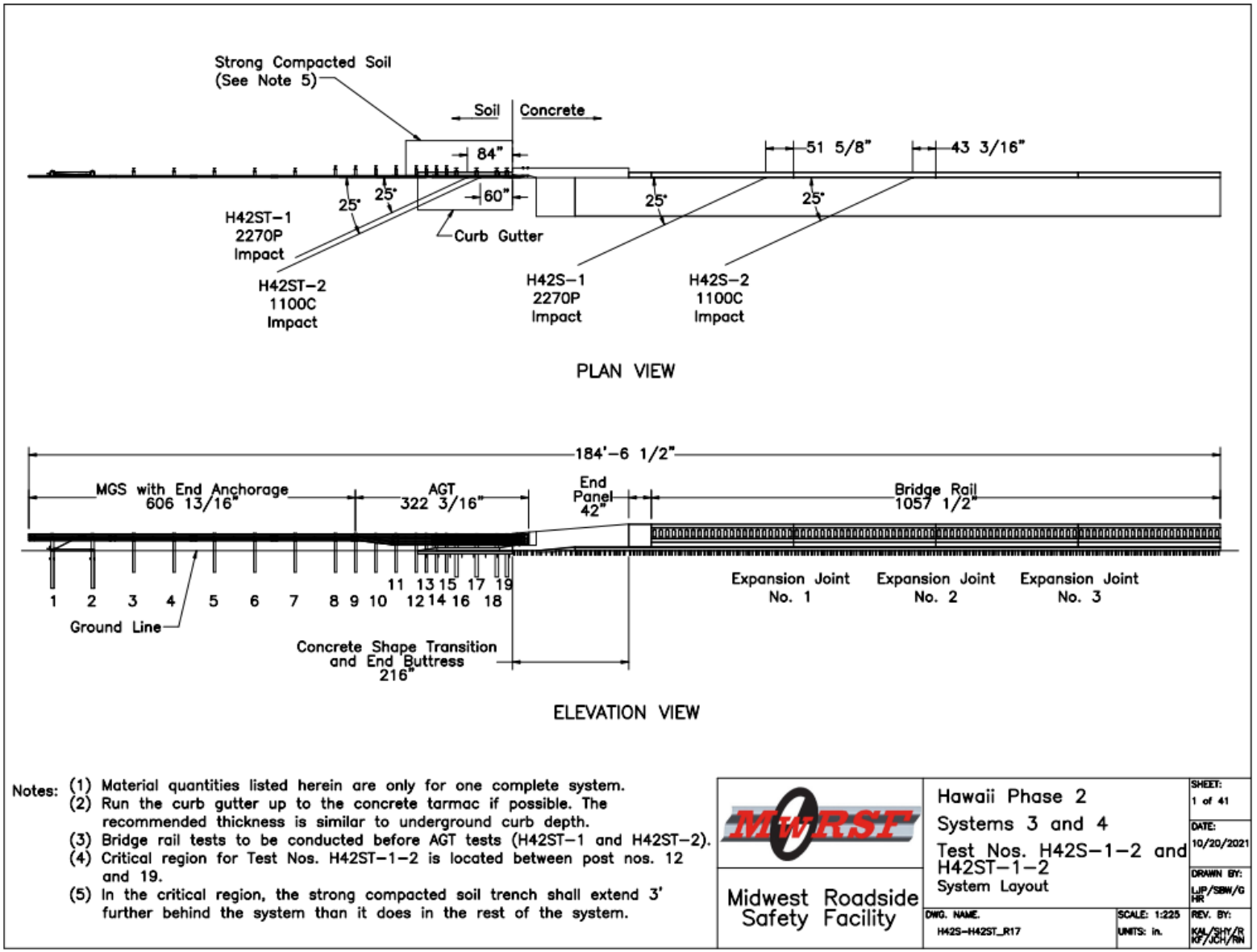


Figure 4. System Layout, Test Nos. H42ST-1 and H42ST-2

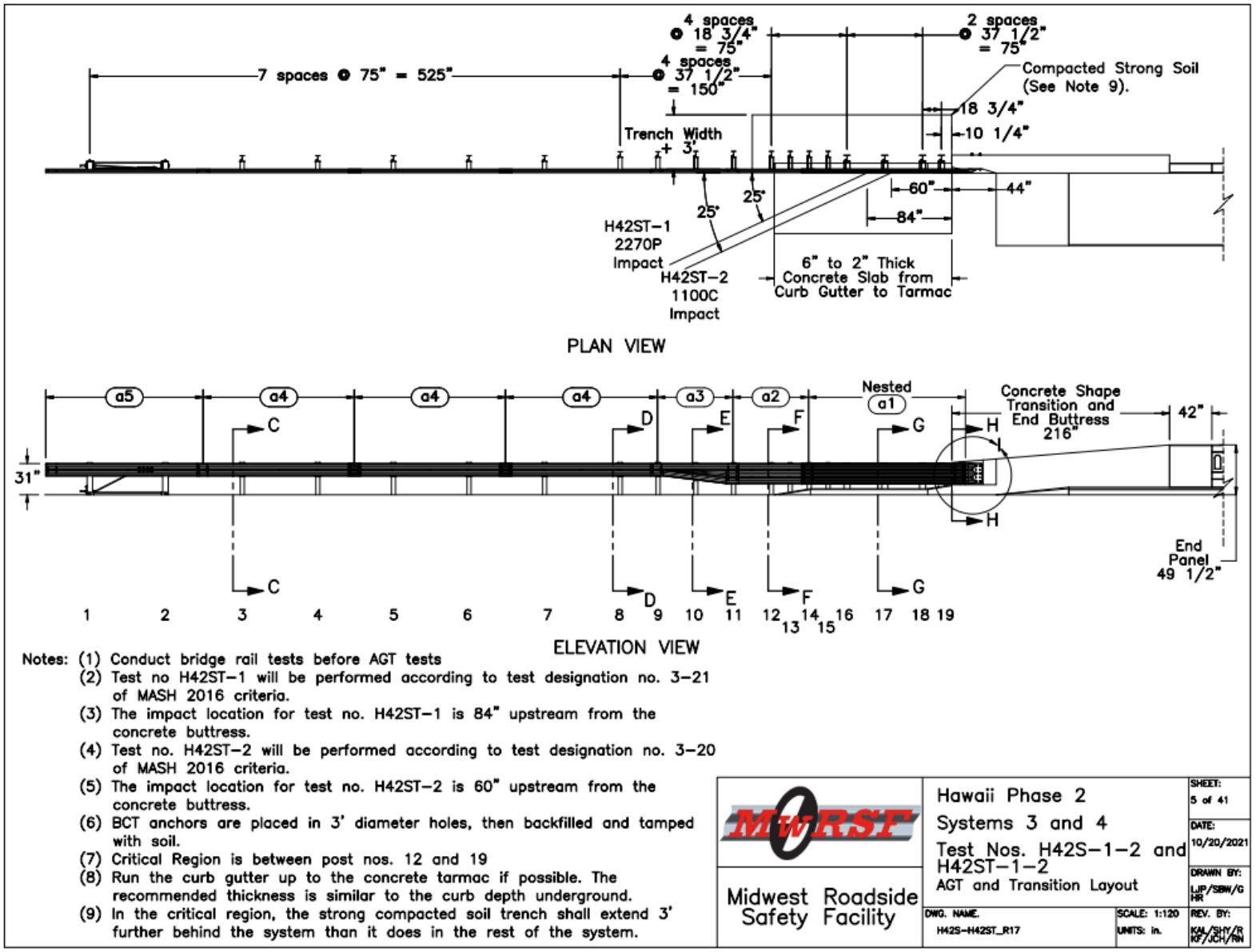


Figure 5. AGT and Transition Layout, Test Nos. H42ST-1 and H42ST-2

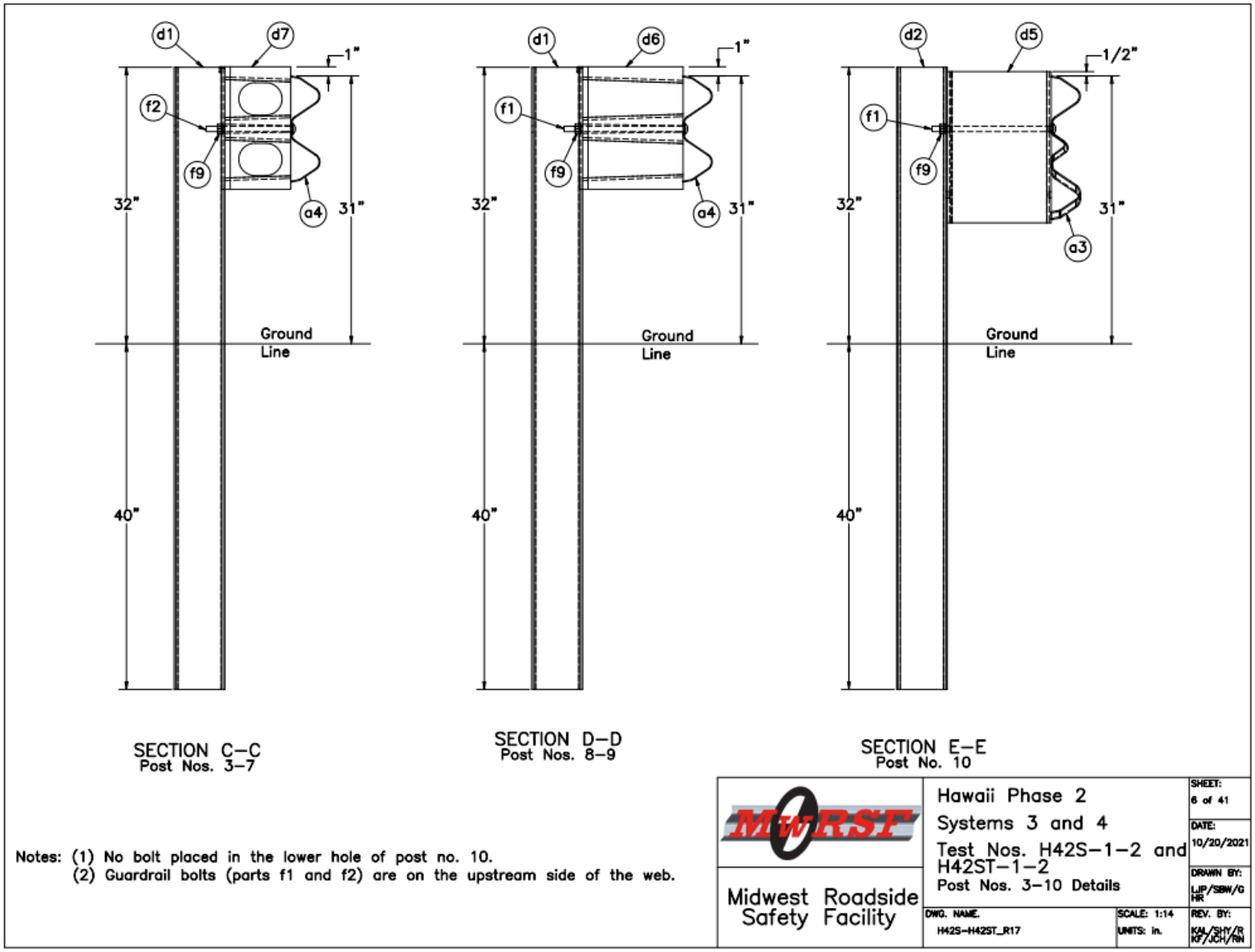


Figure 6. Post Nos. 3 through 10 Details, Test Nos. H42ST-1 and H42ST-2

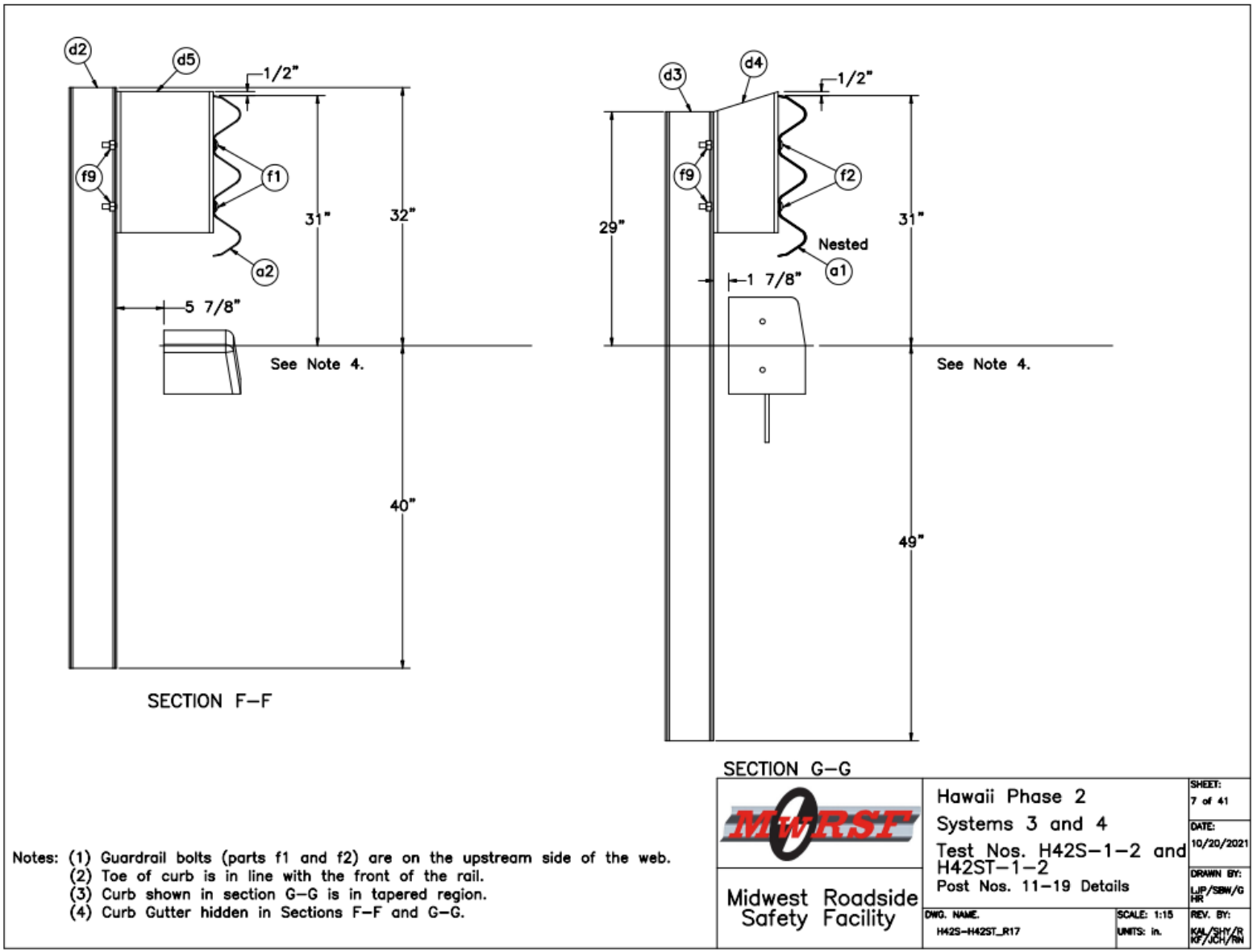


Figure 7. Post Nos. 11 through 19 Details, Test Nos. H42ST-1 and H42ST-2

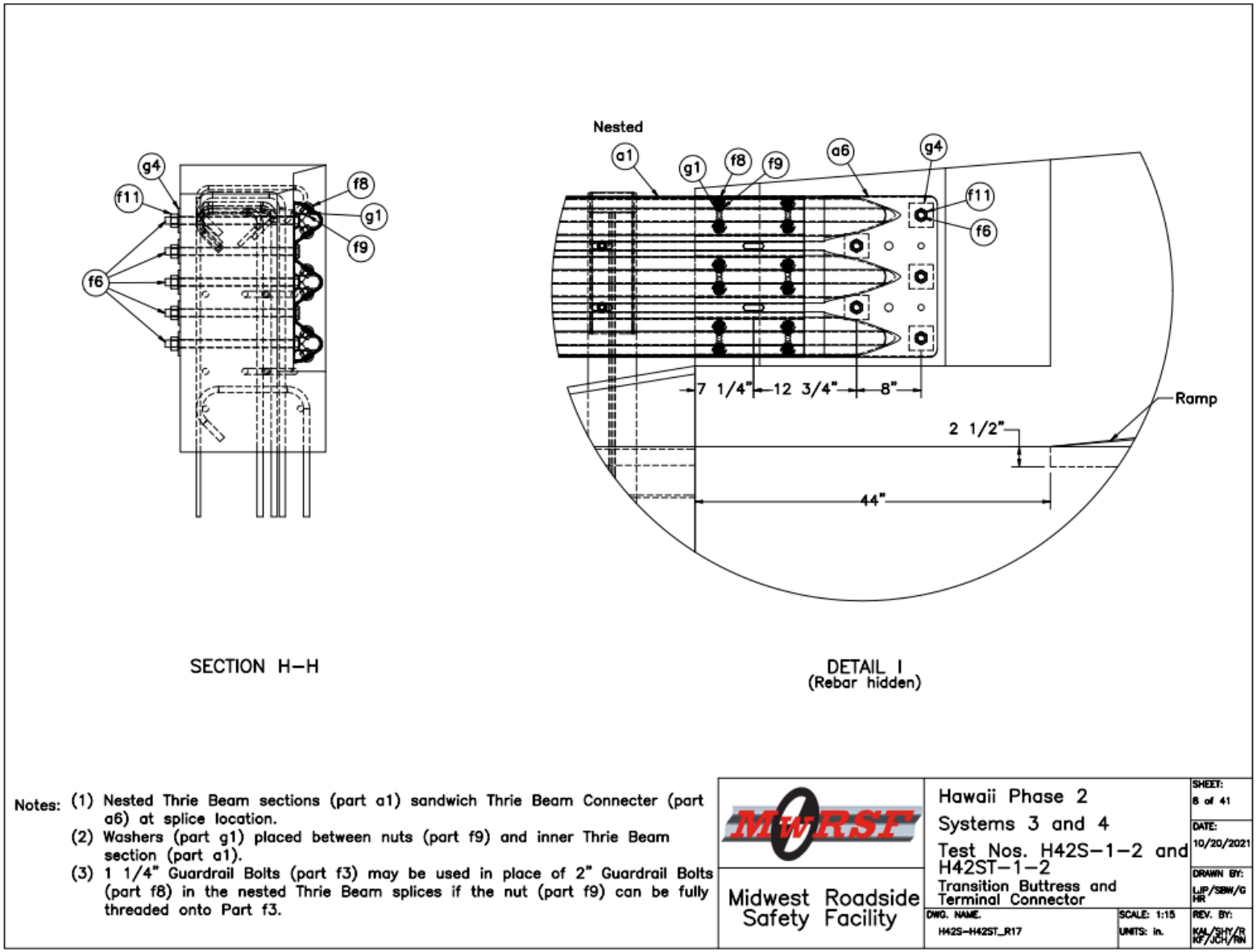


Figure 8. Transition Buttress and Terminal Connector, Test Nos. H42ST-1 and H42ST-2

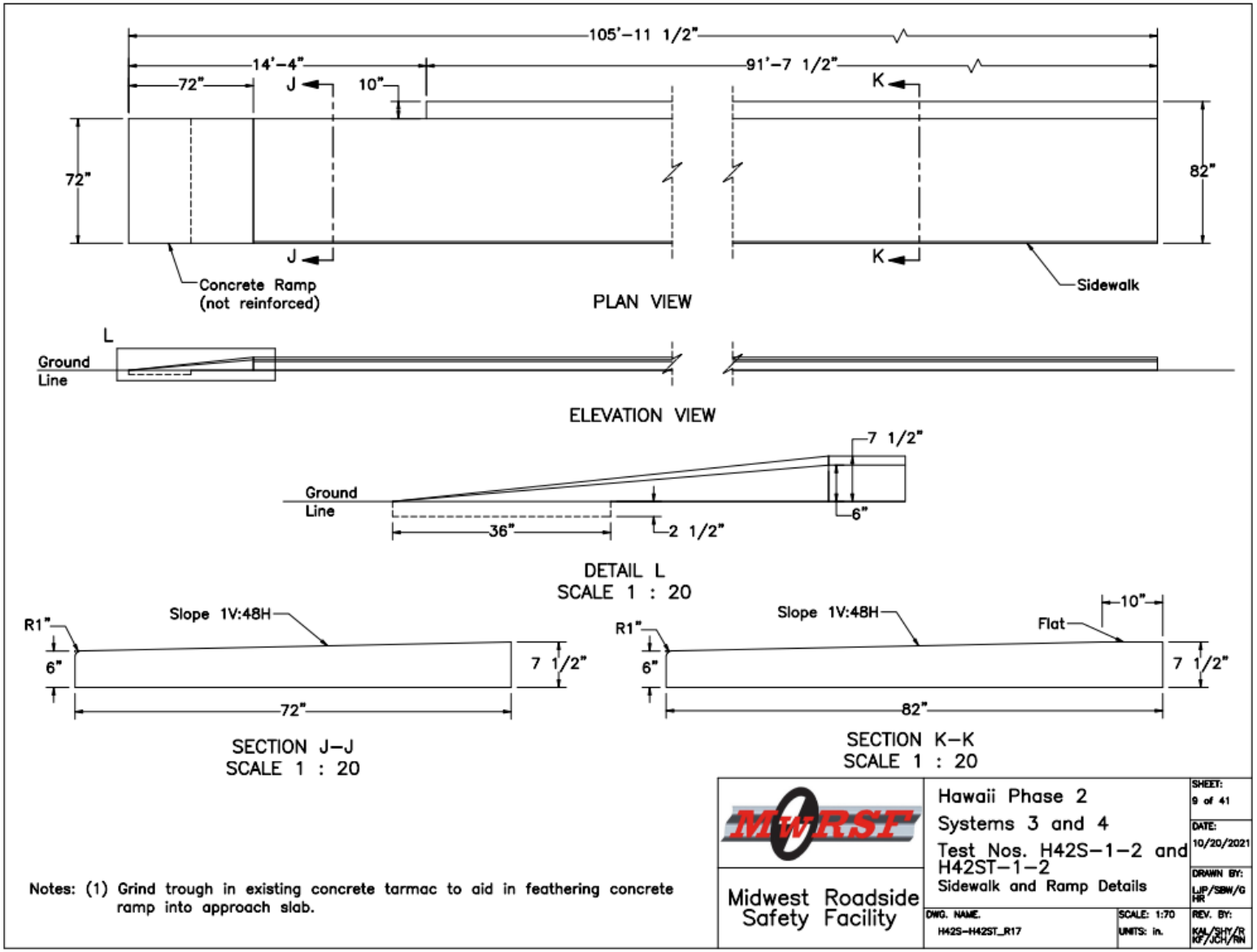


Figure 9. Sidewalk and Ramp Details, Test Nos. H42ST-1 and H42ST-2

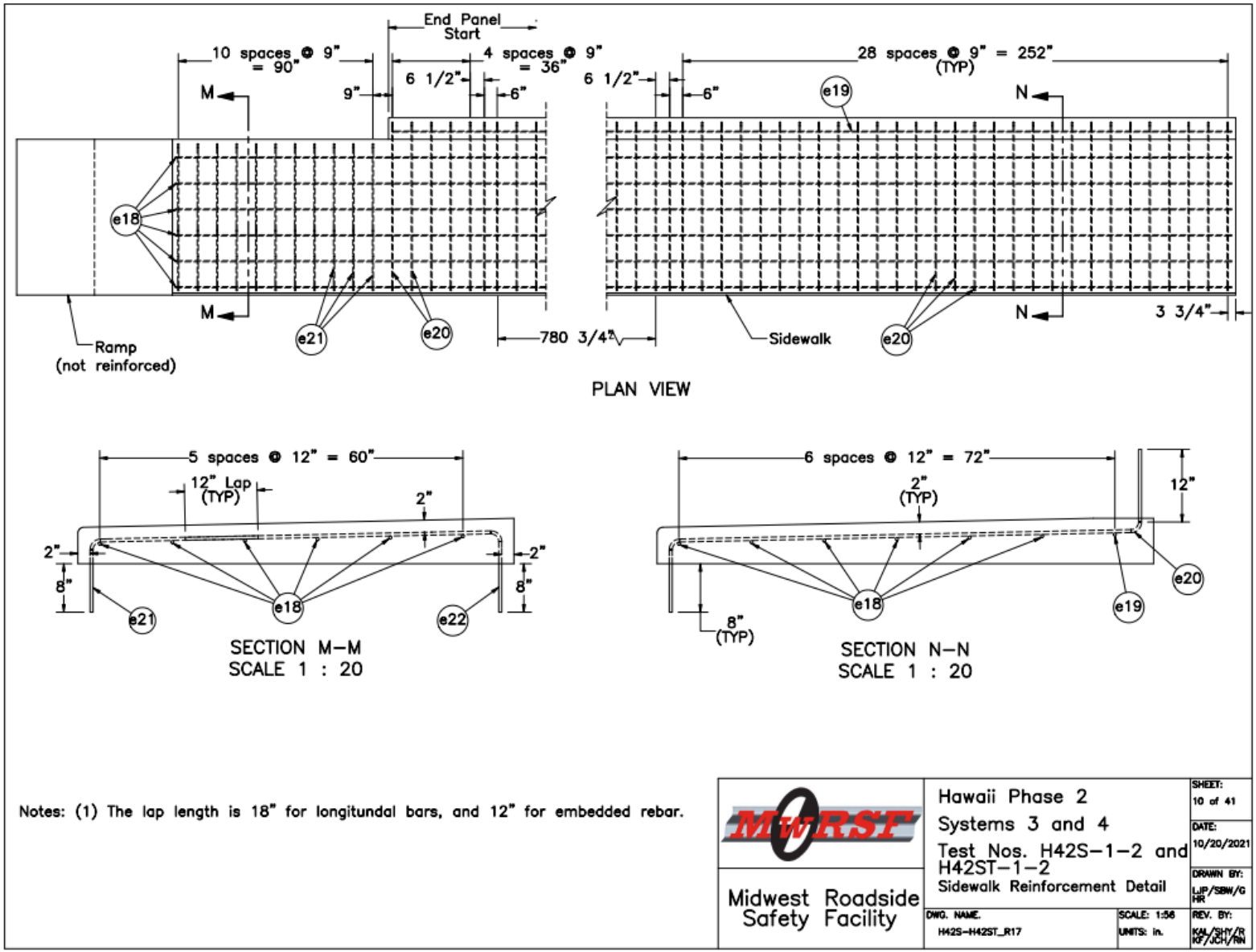


Figure 10. Sidewalk Reinforcement Detail, Test Nos. H42ST-1 and H42ST-2

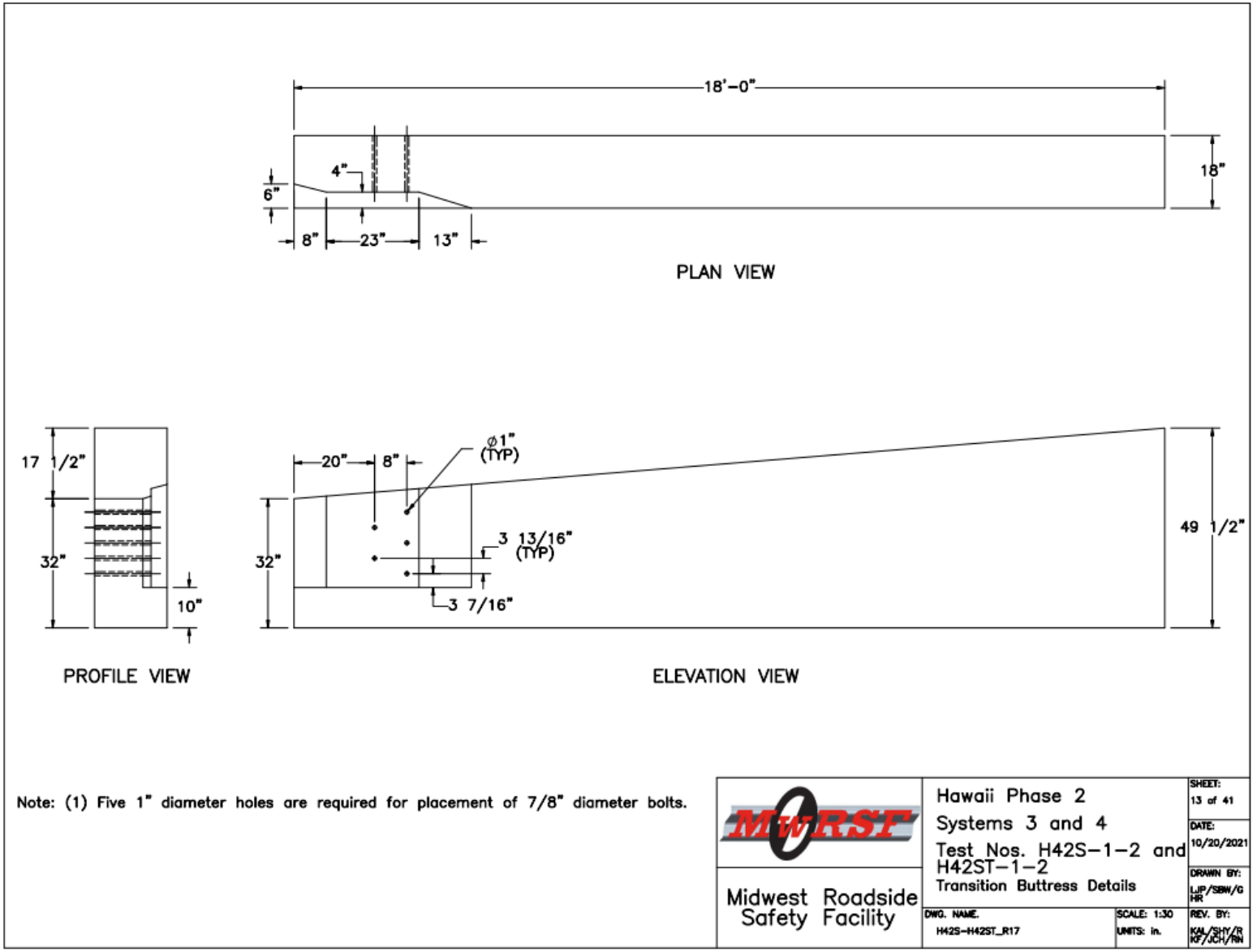


Figure 11. Transition Buttress Details, Test Nos. H42ST-1 and H42ST-2

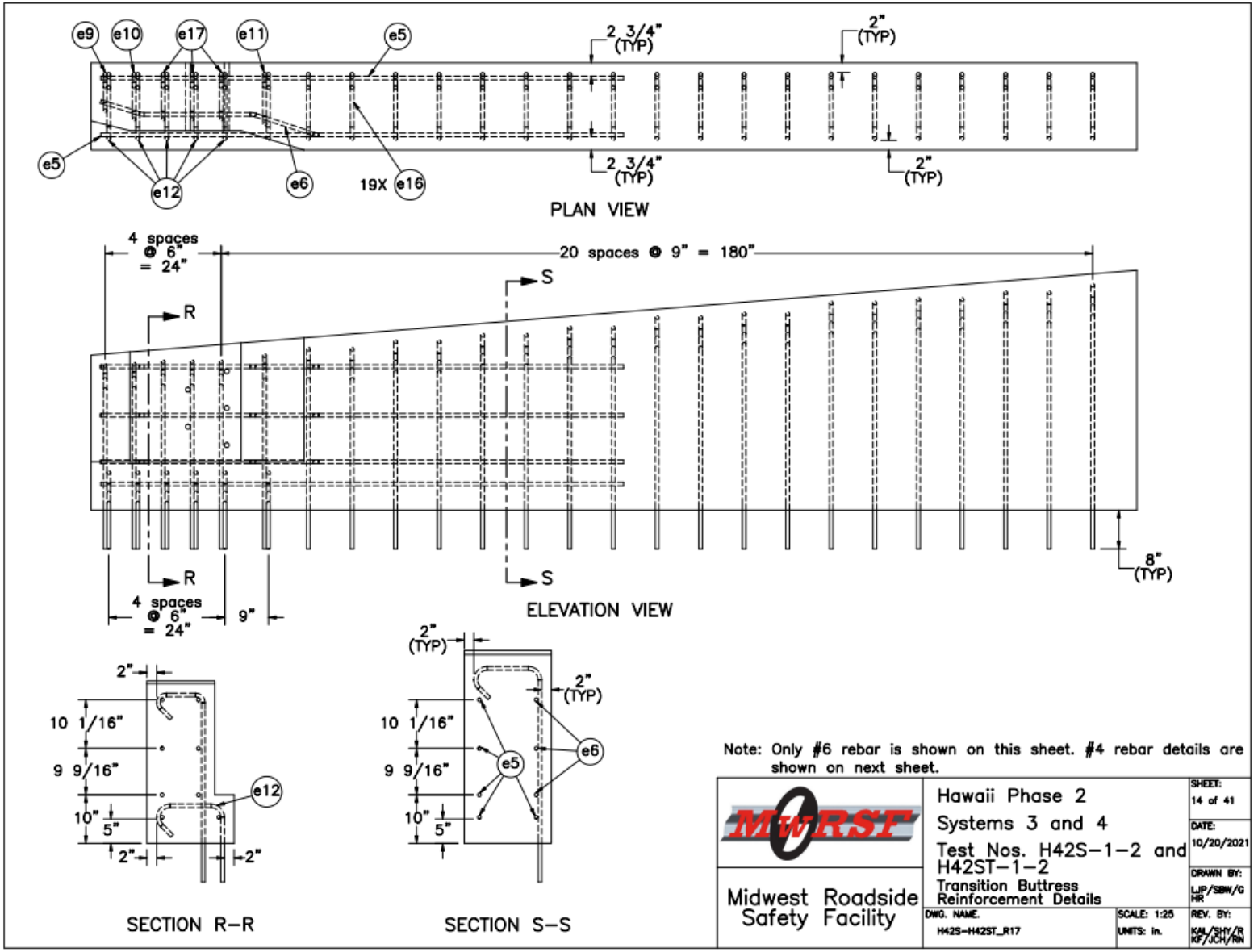


Figure 12. Transition Buttress Reinforcement Details, Test Nos. H42ST-1 and H42ST-2

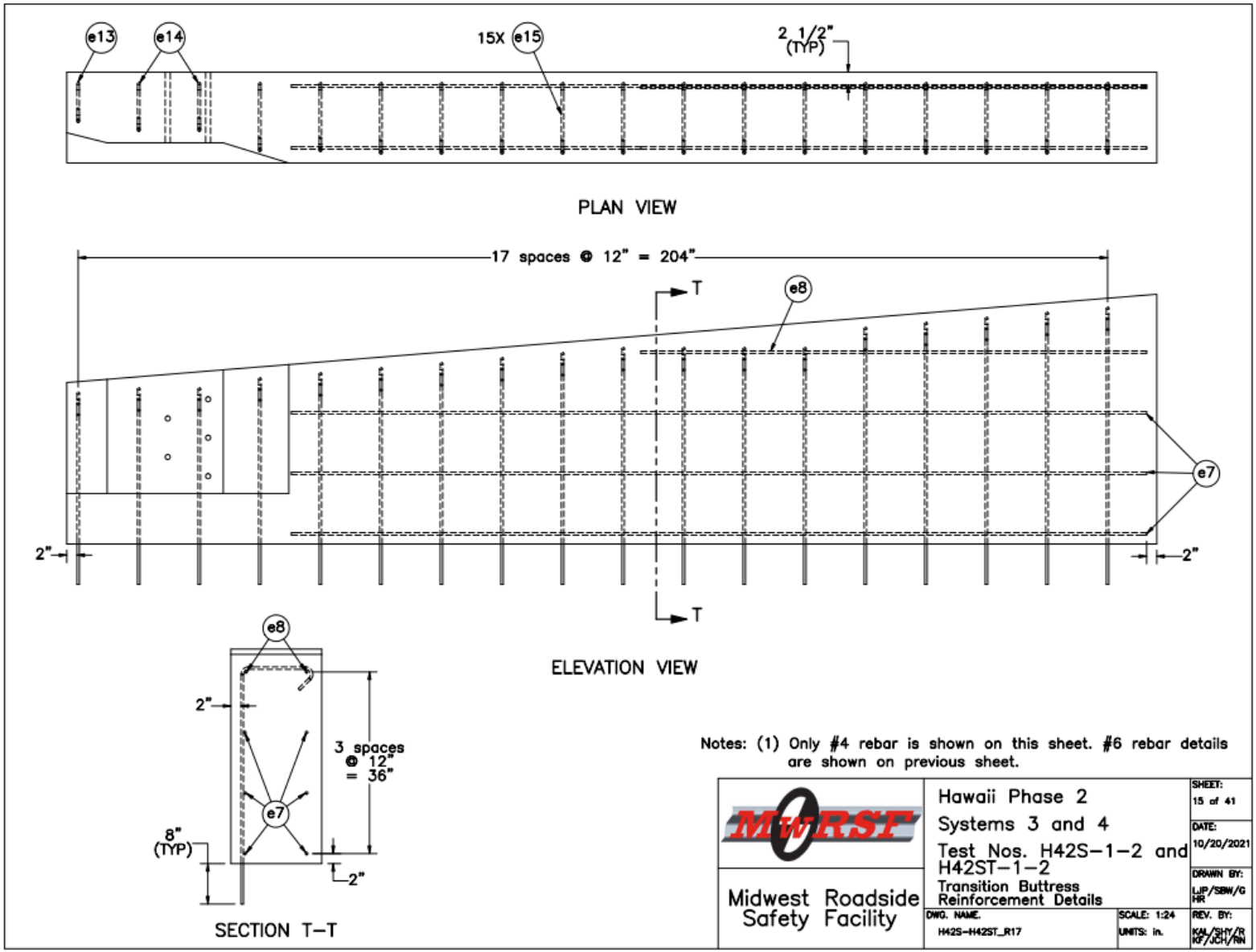


Figure 13. Transition Buttress Reinforcement Details, Test Nos. H42ST-1 and H42ST-2

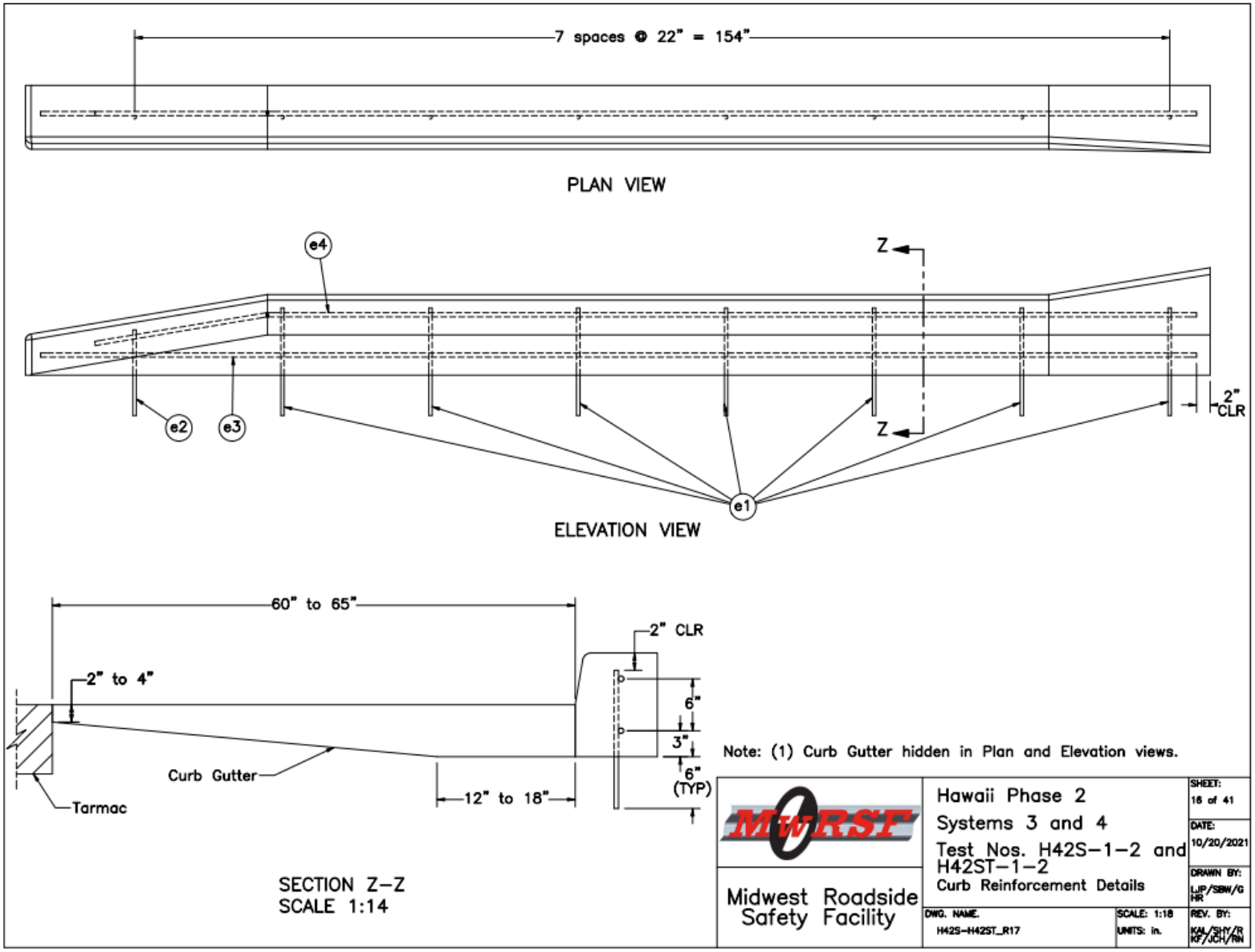


Figure 14. Curb Reinforcement Details, Test Nos. H42ST-1 and H42ST-2

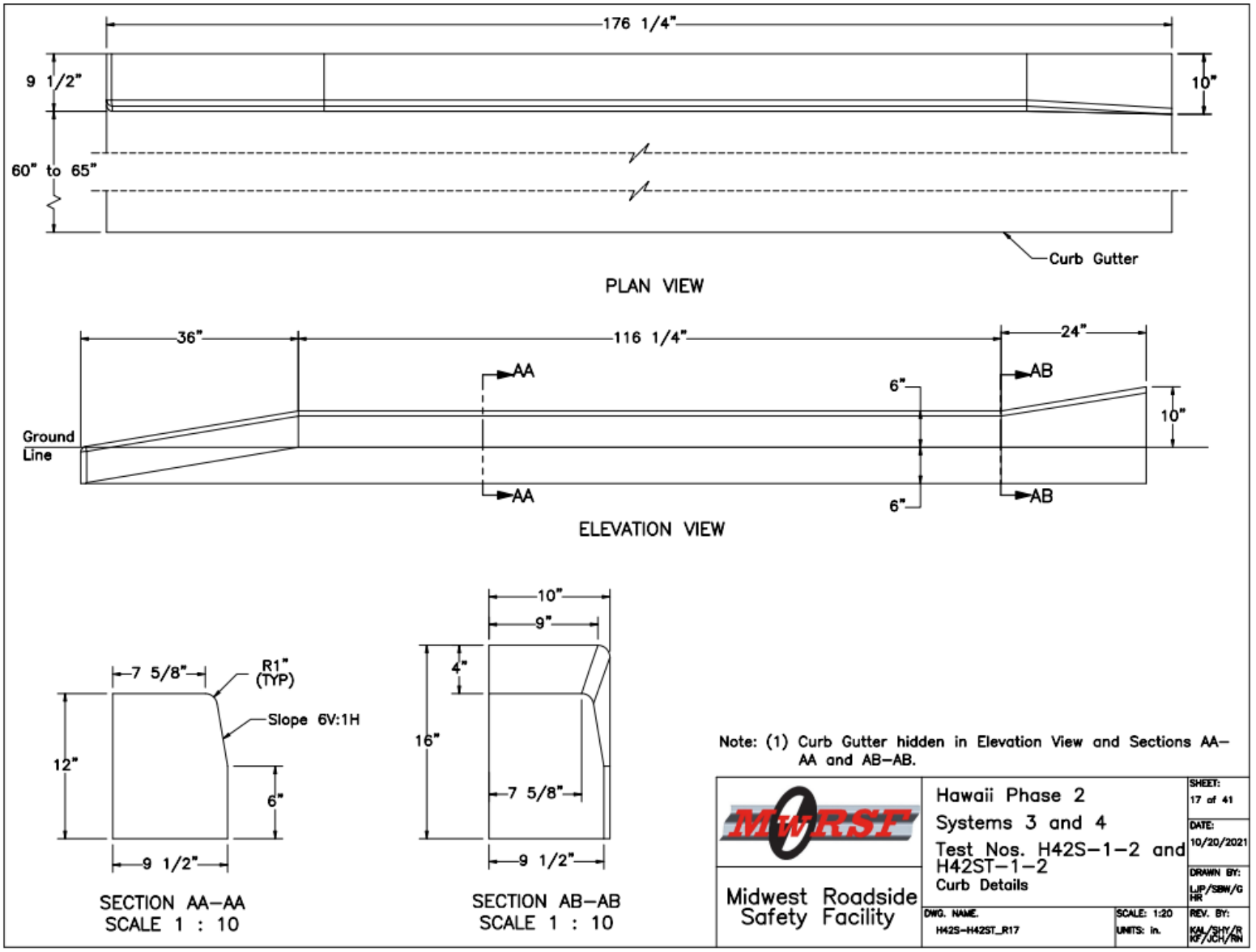


Figure 15. Curb Details, Test Nos. H42ST-1 and H42ST-2

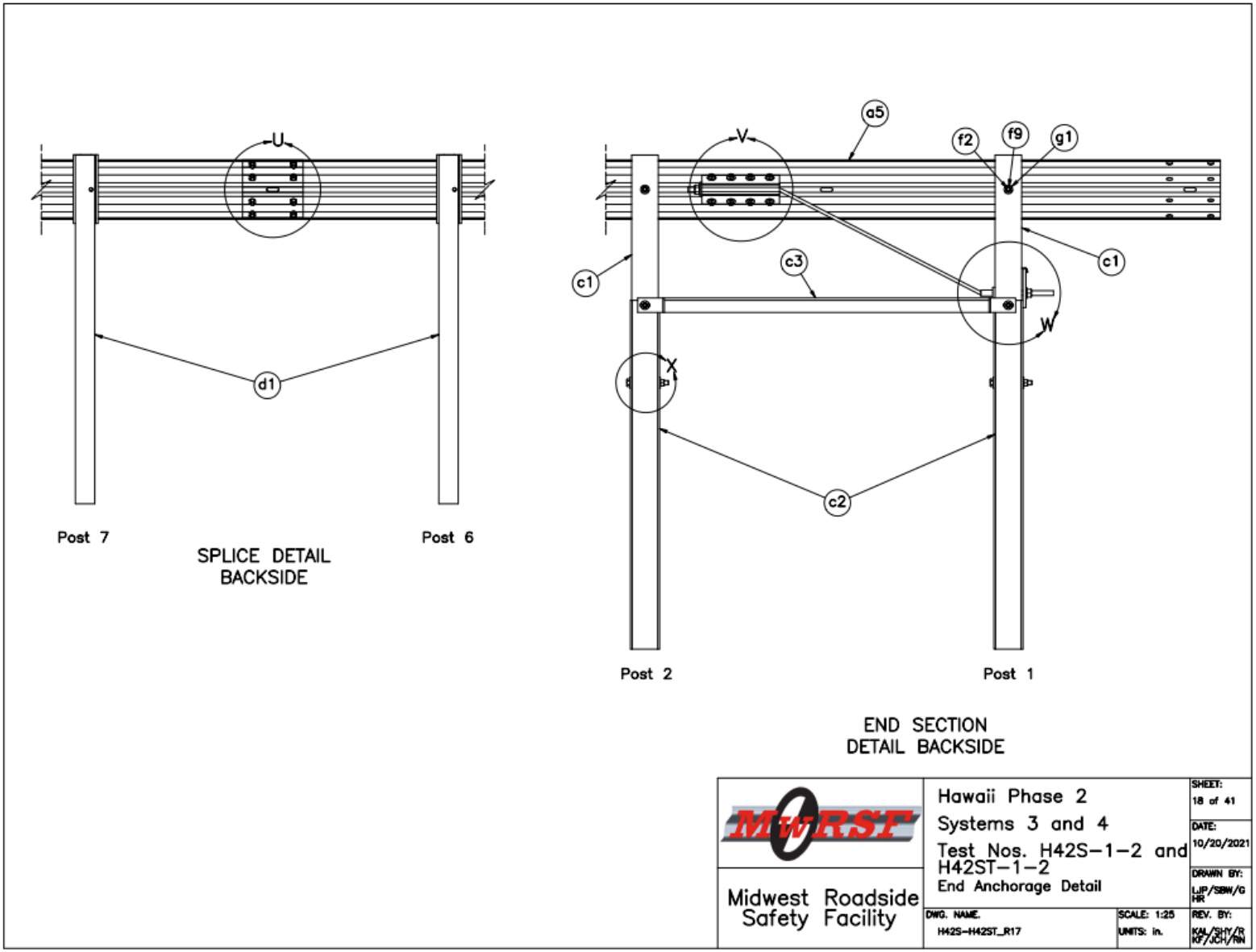


Figure 16. End Anchorage Detail, Test Nos. H42ST-1 and H42ST-2

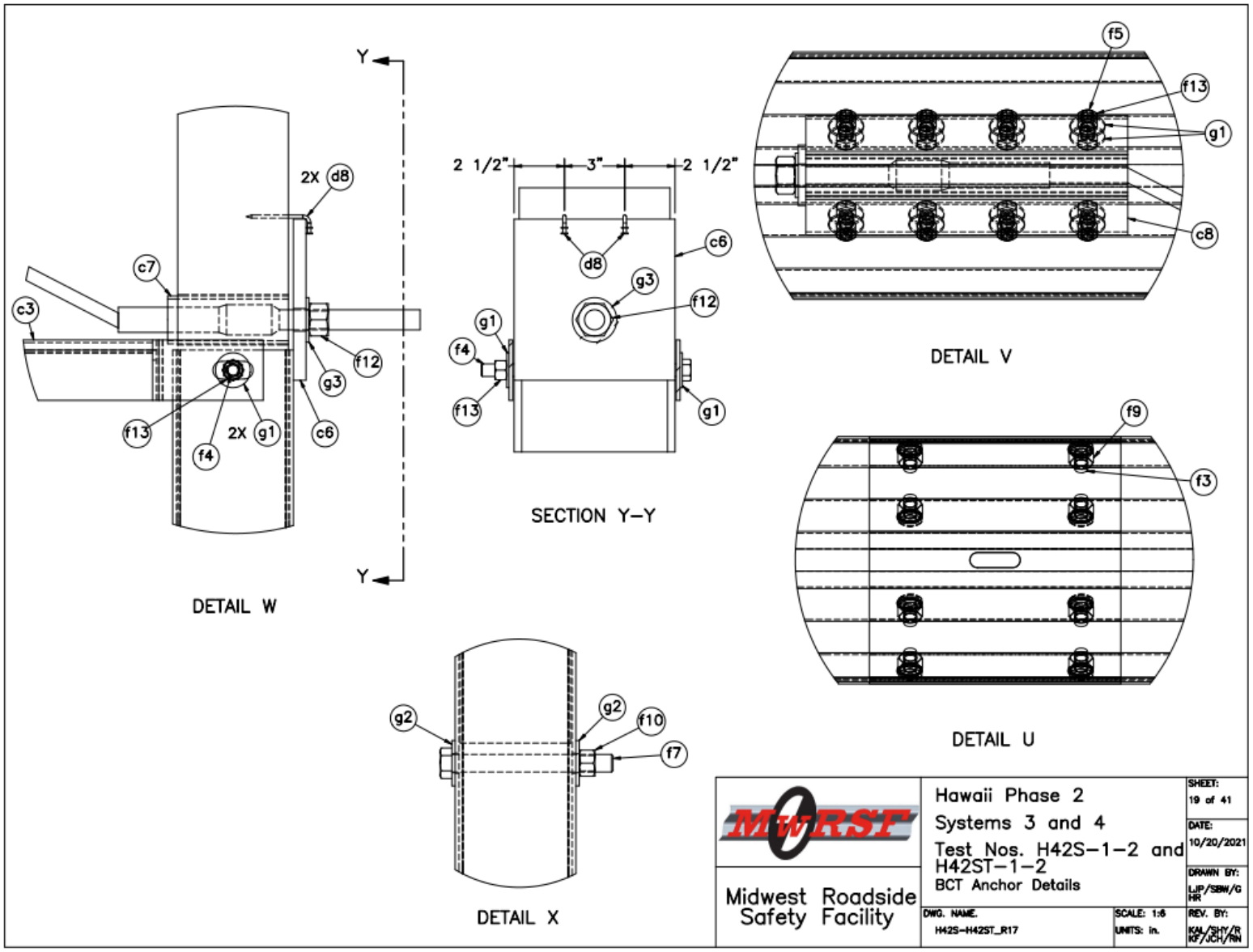


Figure 17. BCT Anchor Detail, Test Nos. H42ST-1 and H42ST-2

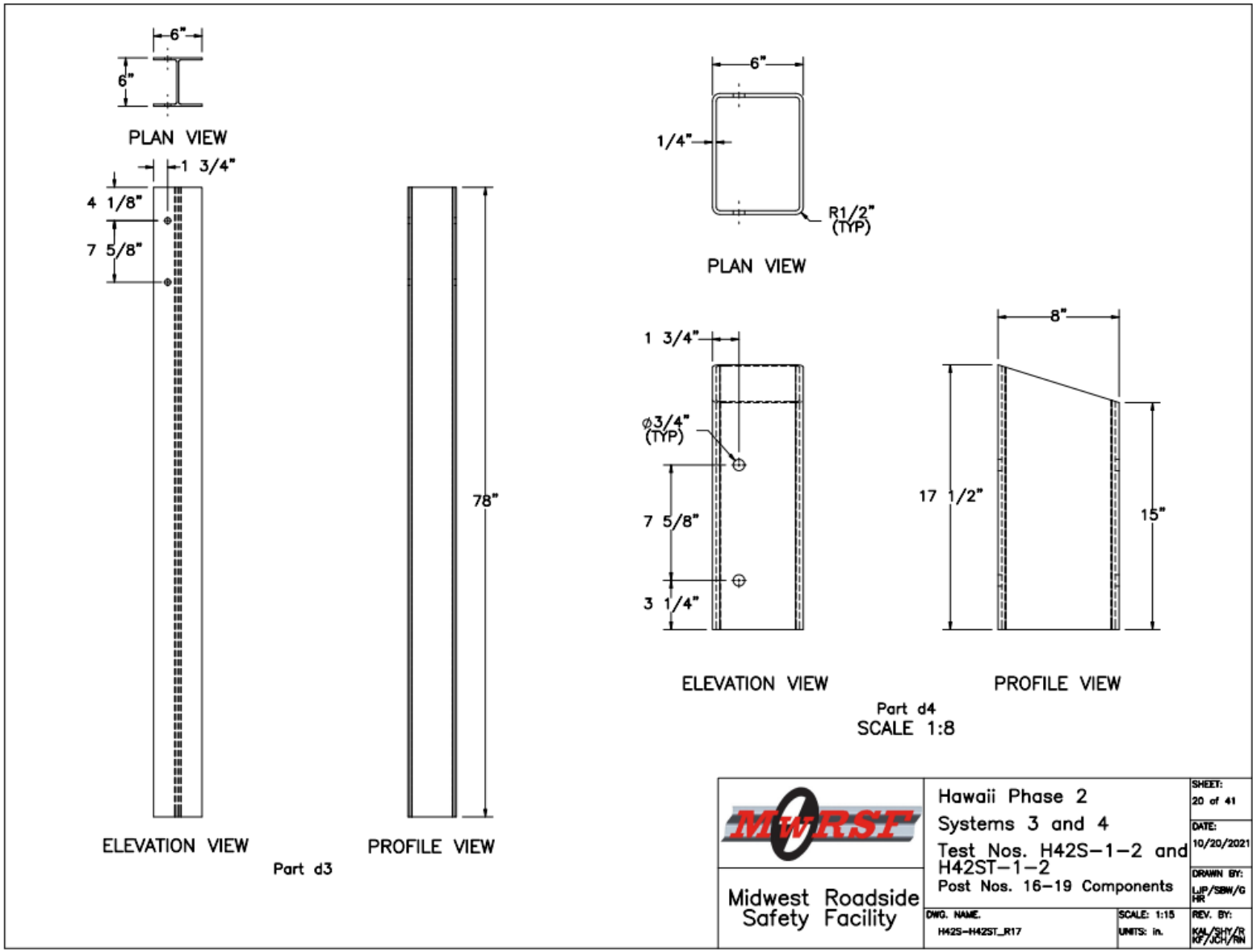


Figure 18. Post Nos. 16 through 19 Components, Test Nos. H42ST-1 and H42ST-2

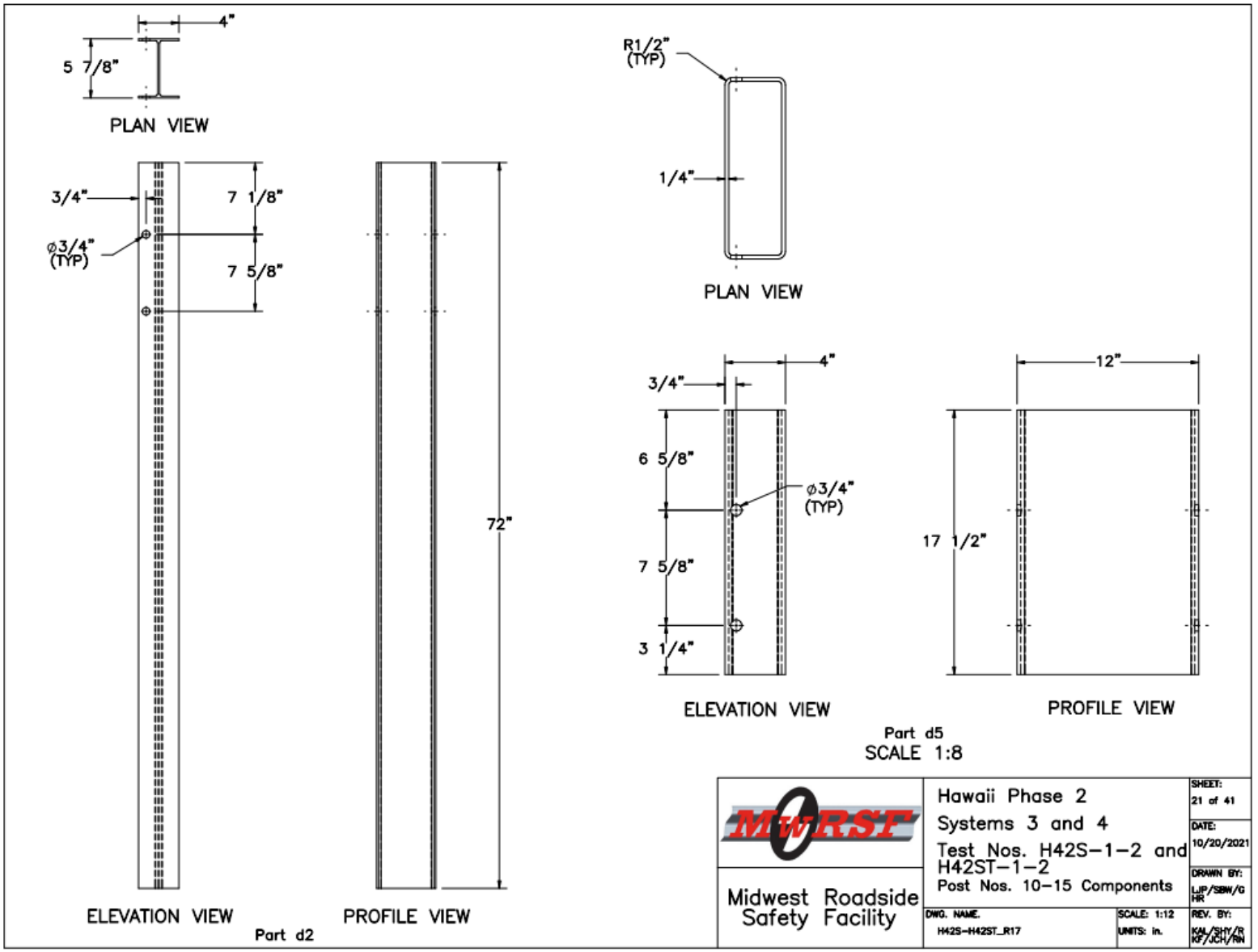


Figure 19. Post Nos. 10 through 15 Components, Test Nos. H42ST-1 and H42ST-2

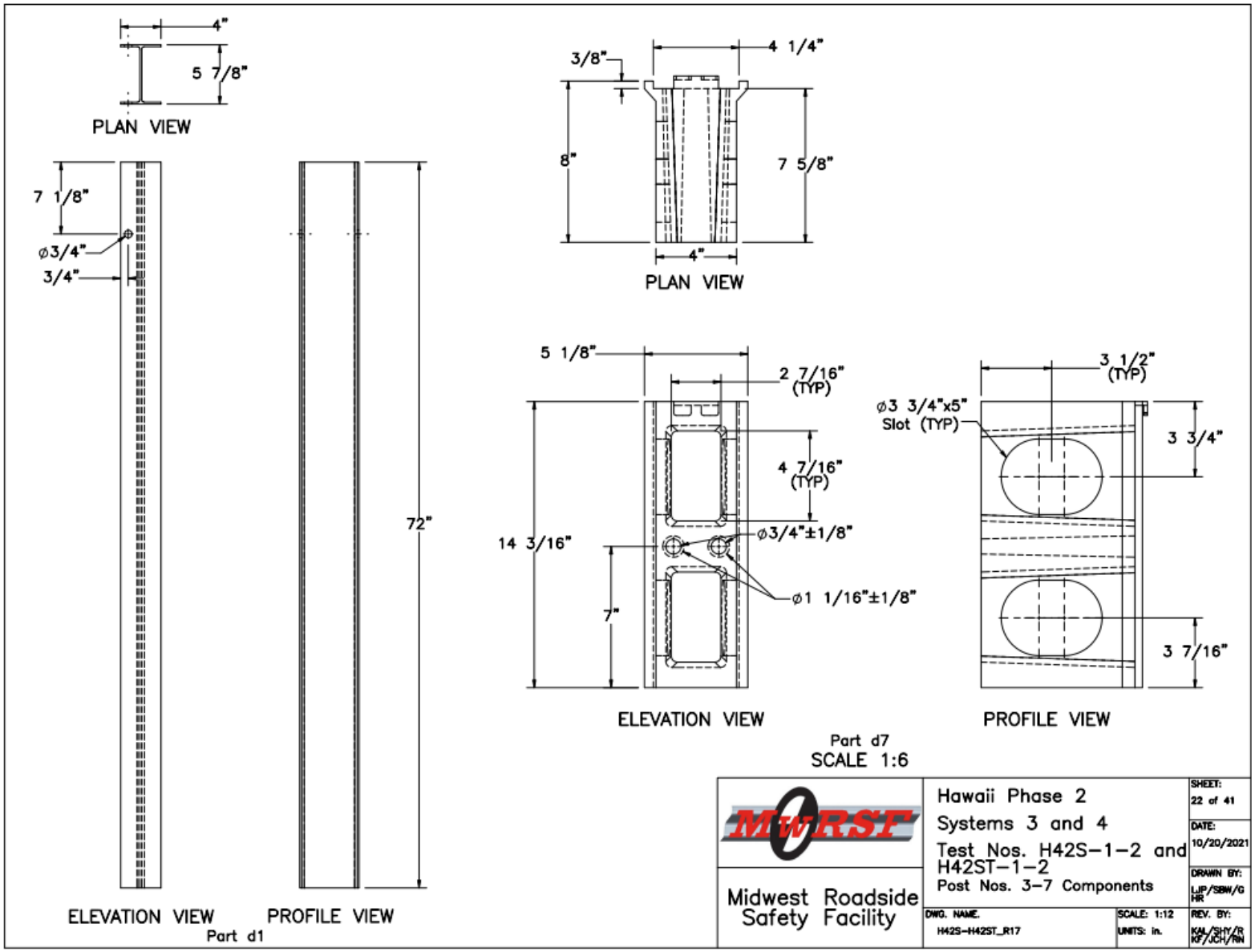


Figure 20. Post Nos. 3 through 7 Components, Test Nos. H42ST-1 and H42ST-2

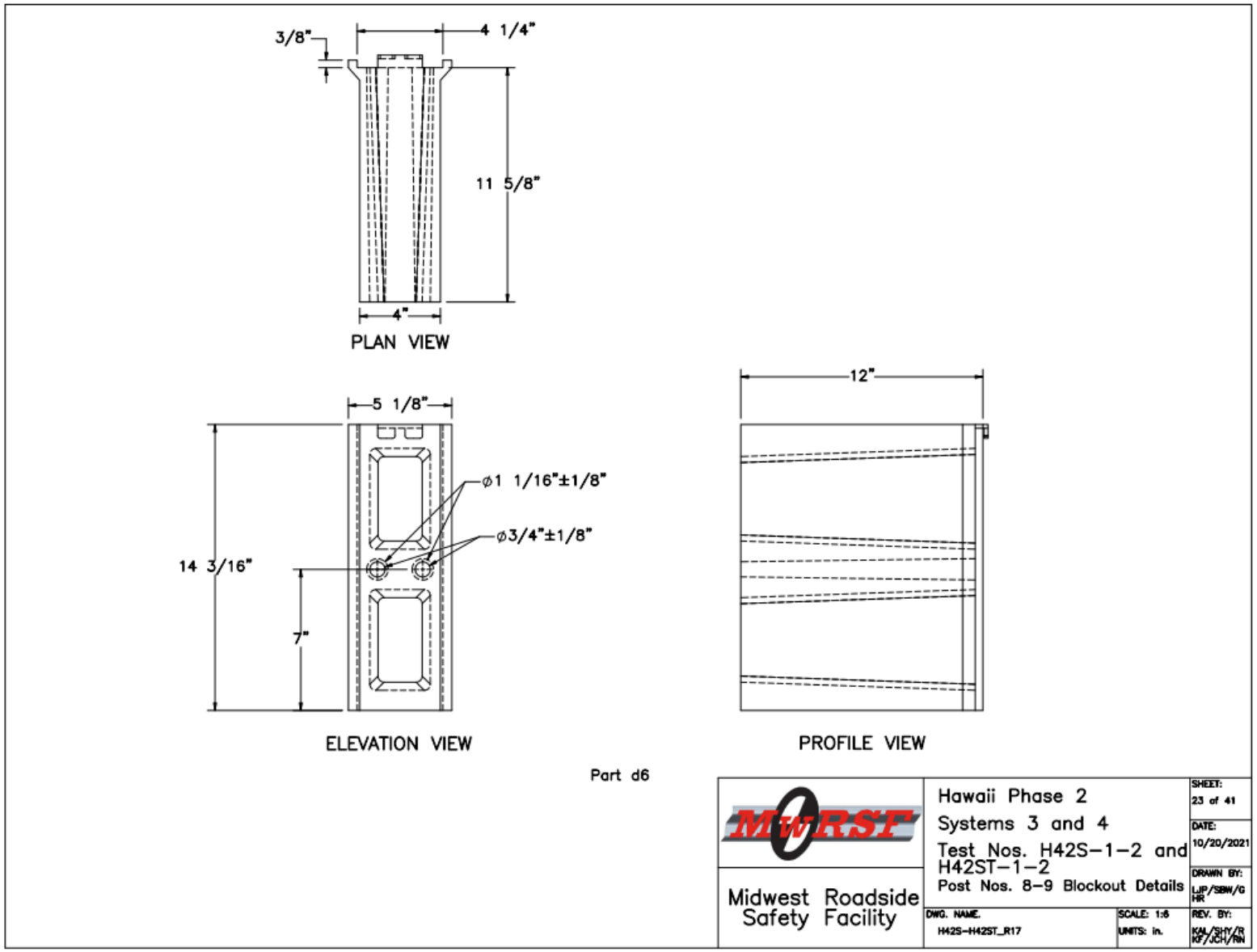


Figure 21. Post Nos. 8 through 9 Blockout Details, Test Nos. H42ST-1 and H42ST-2

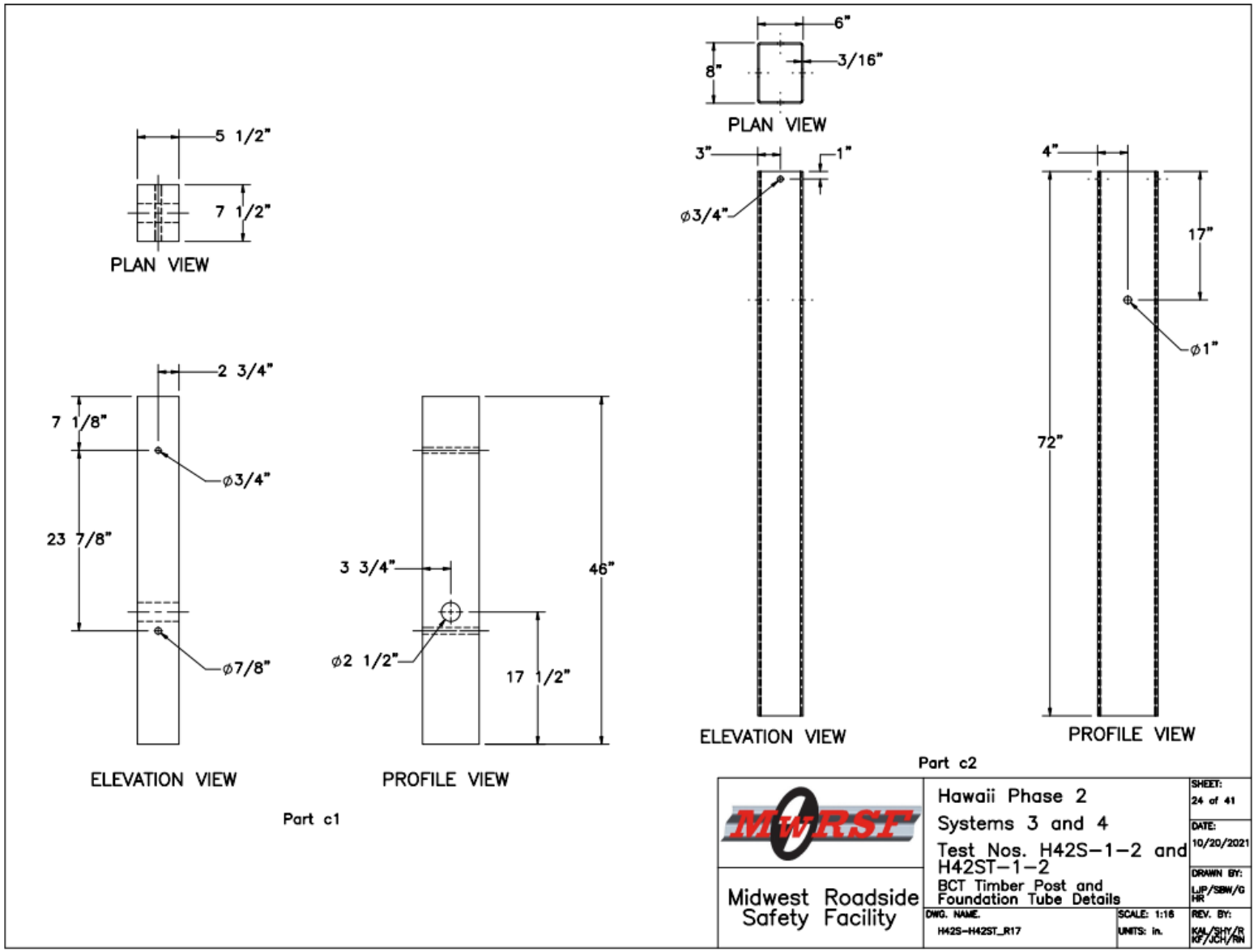
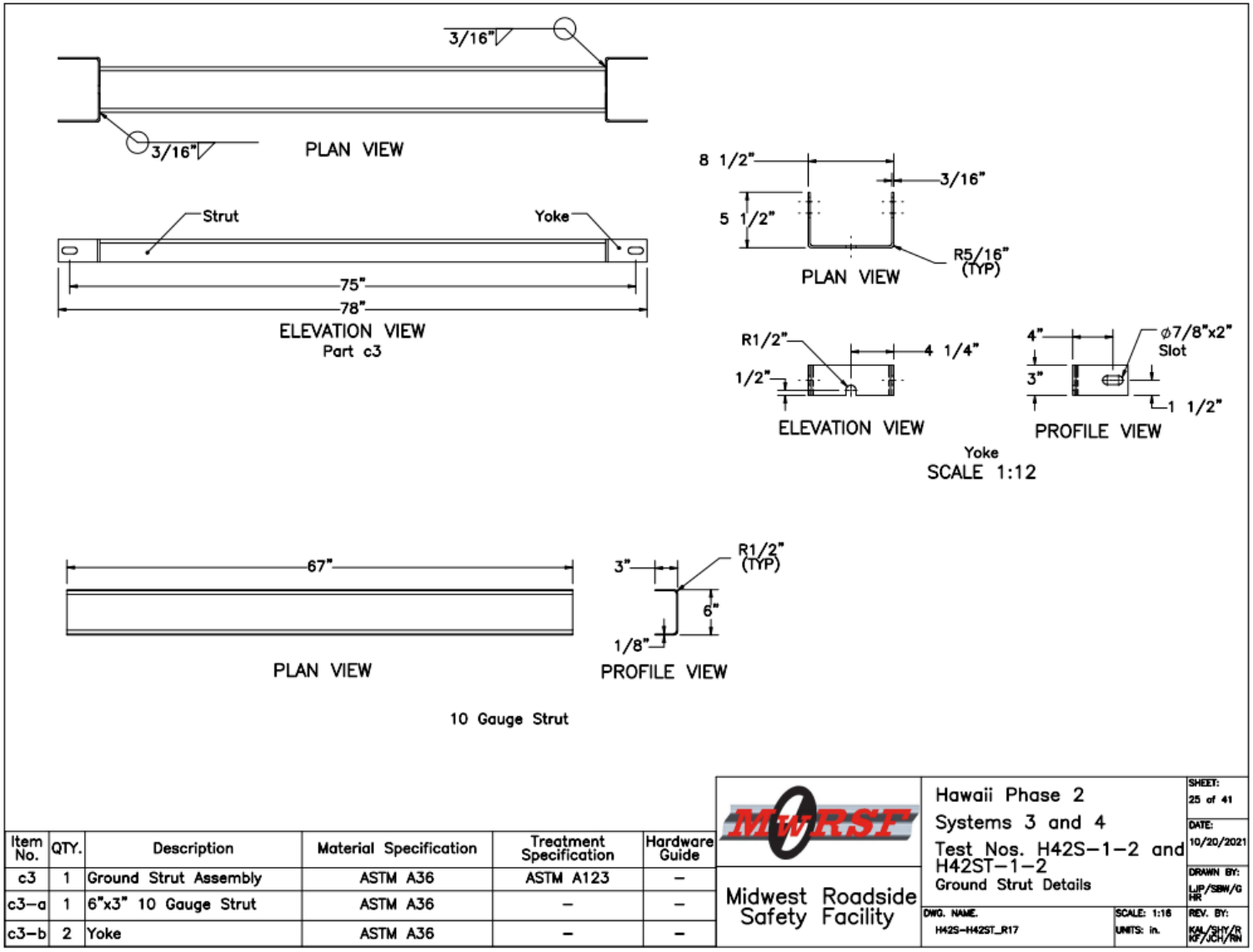


Figure 22. BCT Timber Post and Foundation Tube Details, Test Nos. H42ST-1 and H42ST-2



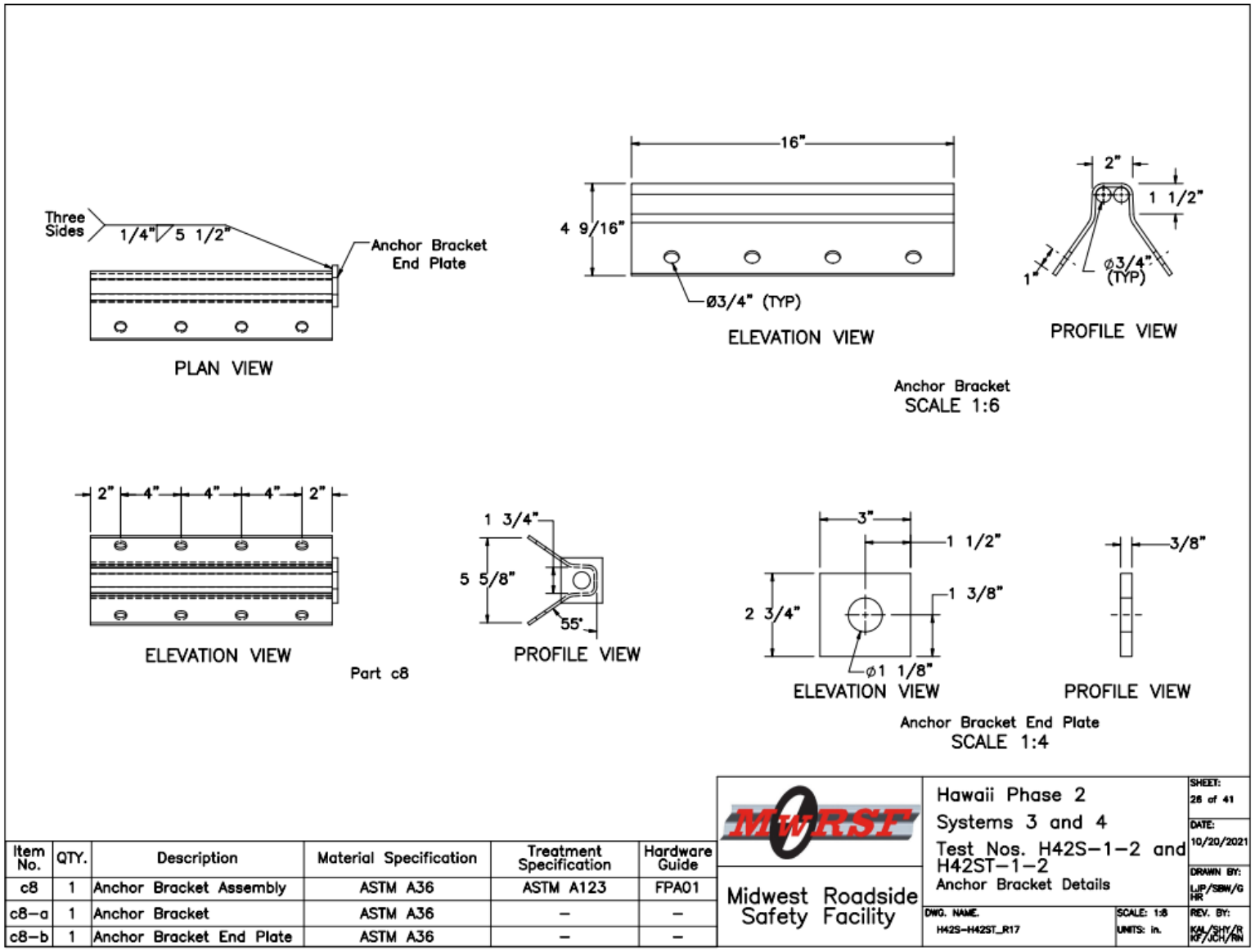
Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
c3	1	Ground Strut Assembly	ASTM A36	ASTM A123	–
c3–a	1	6"x3" 10 Gauge Strut	ASTM A36	–	–
c3–b	2	Yoke	ASTM A36	–	–

Midwest Roadside Safety Facility

Hawaii Phase 2
Systems 3 and 4
Test Nos. H42S–1–2 and H42ST–1–2
Ground Strut Details

SHEET: 25 of 41
DATE: 10/20/2021
DRAWN BY: LJP/SBW/G HR
REV. BY: KM/SHY/R KF/JCH/RN
DWG. NAME: H42S–H42ST_R17
SCALE: 1:16
UNITS: in.

Figure 23. Ground Strut Details, Test Nos. H42ST-1 and H42ST-2



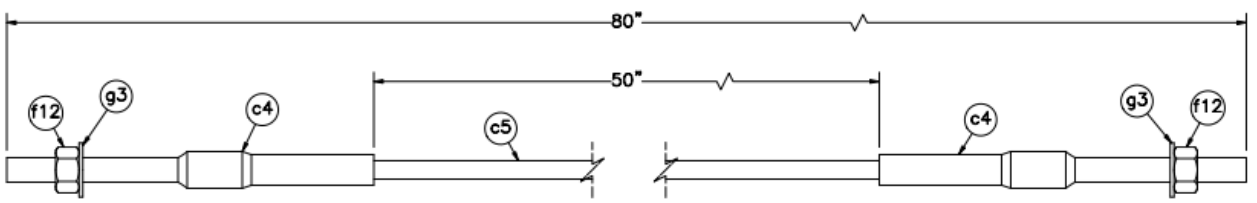
Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
c8	1	Anchor Bracket Assembly	ASTM A36	ASTM A123	FPA01
c8–a	1	Anchor Bracket	ASTM A36	–	–
c8–b	1	Anchor Bracket End Plate	ASTM A36	–	–

Midwest Roadside Safety Facility

Hawaii Phase 2
Systems 3 and 4
Test Nos. H42S–1–2 and H42ST–1–2
Anchor Bracket Details

SHEET: 28 of 41
DATE: 10/20/2021
DRAWN BY: LJP/SBW/GHR
REV. BY: KAN/SHY/DKF/JCH/TRN
DWG. NAME: H42S–H42ST_R17
SCALE: 1:8
UNITS: in.

Figure 24. Anchor Bracket Details, Test Nos. H42ST-1 and H42ST-2



Cable Assembly

Item No.	QTY.	Description	Material Specification	Treatment Specification	Hardware Guide
–	1	Cable Assembly	–	–	FCA01
c4	2	BCT Anchor Cable End Swaged Fitting	Fitting – ASTM A576 Gr. 1035 Stud – ASTM F568 Class C	Fitting – ASTM A153 Stud – ASTM A153 or B695	–
c5	1	3/4" Dia. 6x19 IWRC IPS Wire Rope	ASTM A741 Type 2	Class A Coating	–
f12	2	1"–8 UNC Heavy Hex Nut	ASTM A563DH or equivalent	ASTM A153 or B695 Class 55 or F2329	FNX24b
g3	2	1" Dia. Plain USS Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC24a

Midwest Roadside Safety Facility

Hawaii Phase 2
Systems 3 and 4
Test Nos. H42S–1–2 and H42ST–1–2
BCT Anchor Cable

SHEET: 27 of 41
DATE: 10/20/2021
DRAWN BY: LJP/SBW/GHR
REV. BY: KAL/SHY/RKF/JCH/RN
DWG. NAME. H42S–H42ST_R17
SCALE: 1:6
UNITS: in.

Figure 25. BCT Anchor Cable, Test Nos. H42ST-1 and H42ST-2

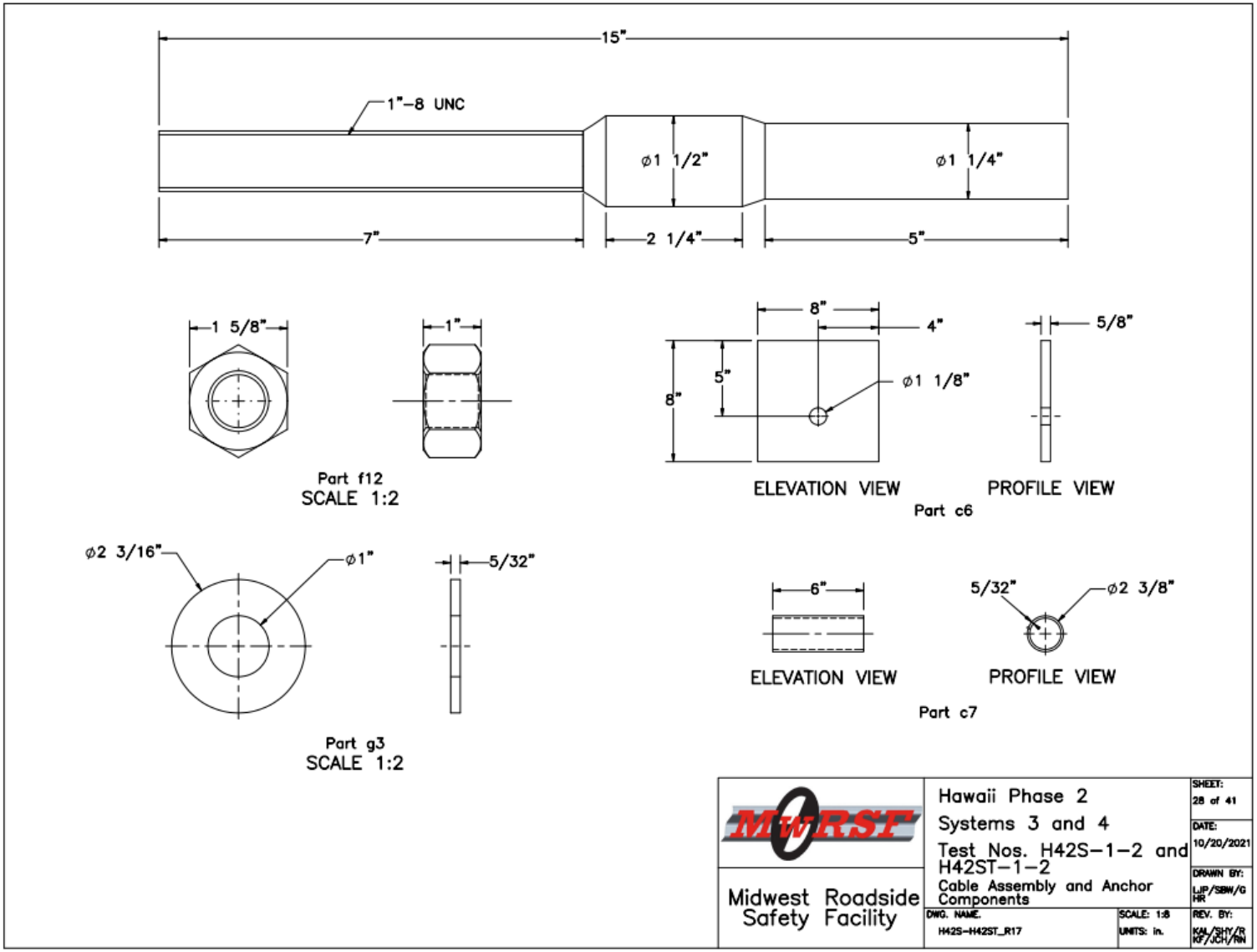


Figure 26. Cable Assembly and Anchor Components, Test Nos. H42ST-1 and H42ST-2

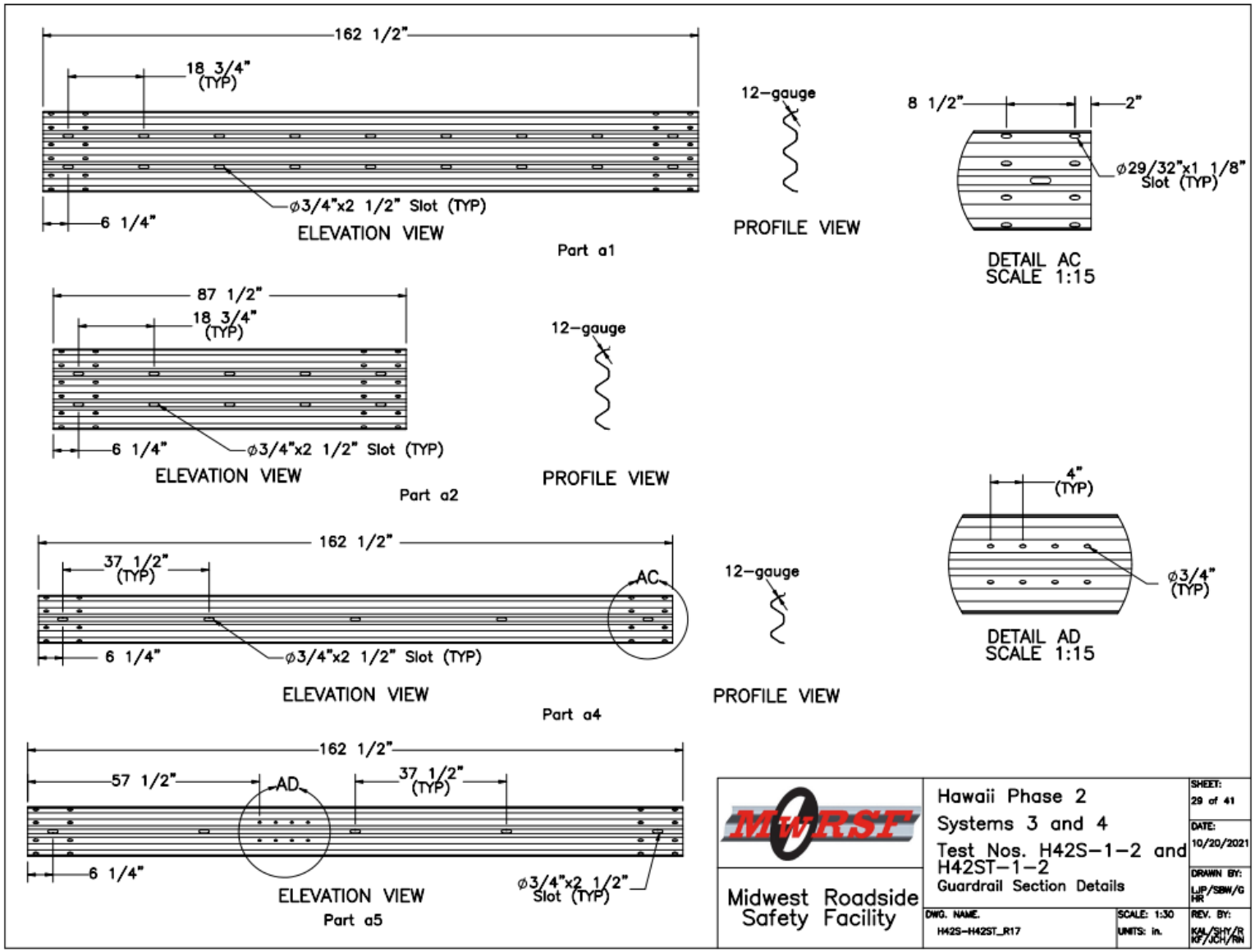


Figure 27. Guardrail Section Details, Test Nos. H42ST-1 and H42ST-2

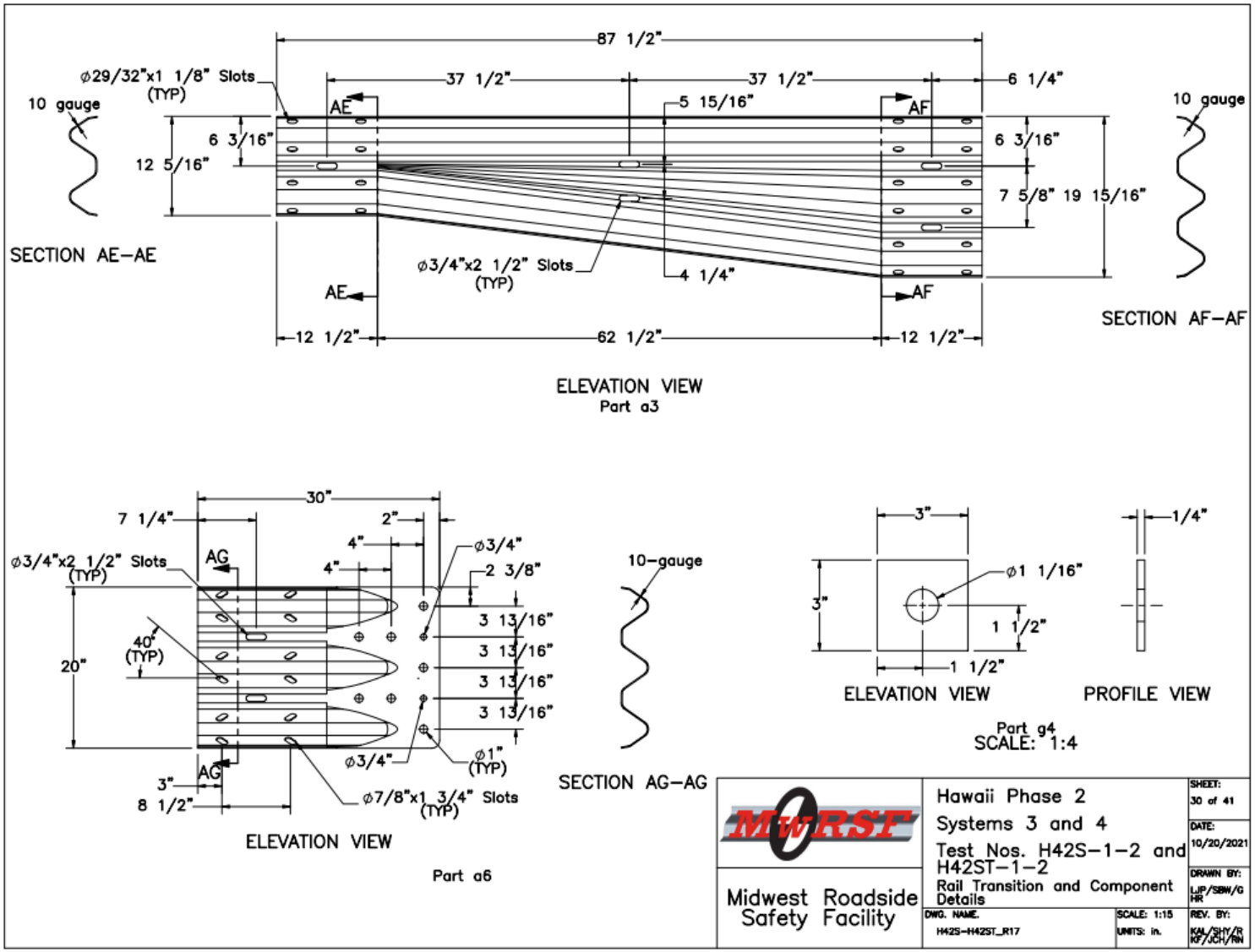
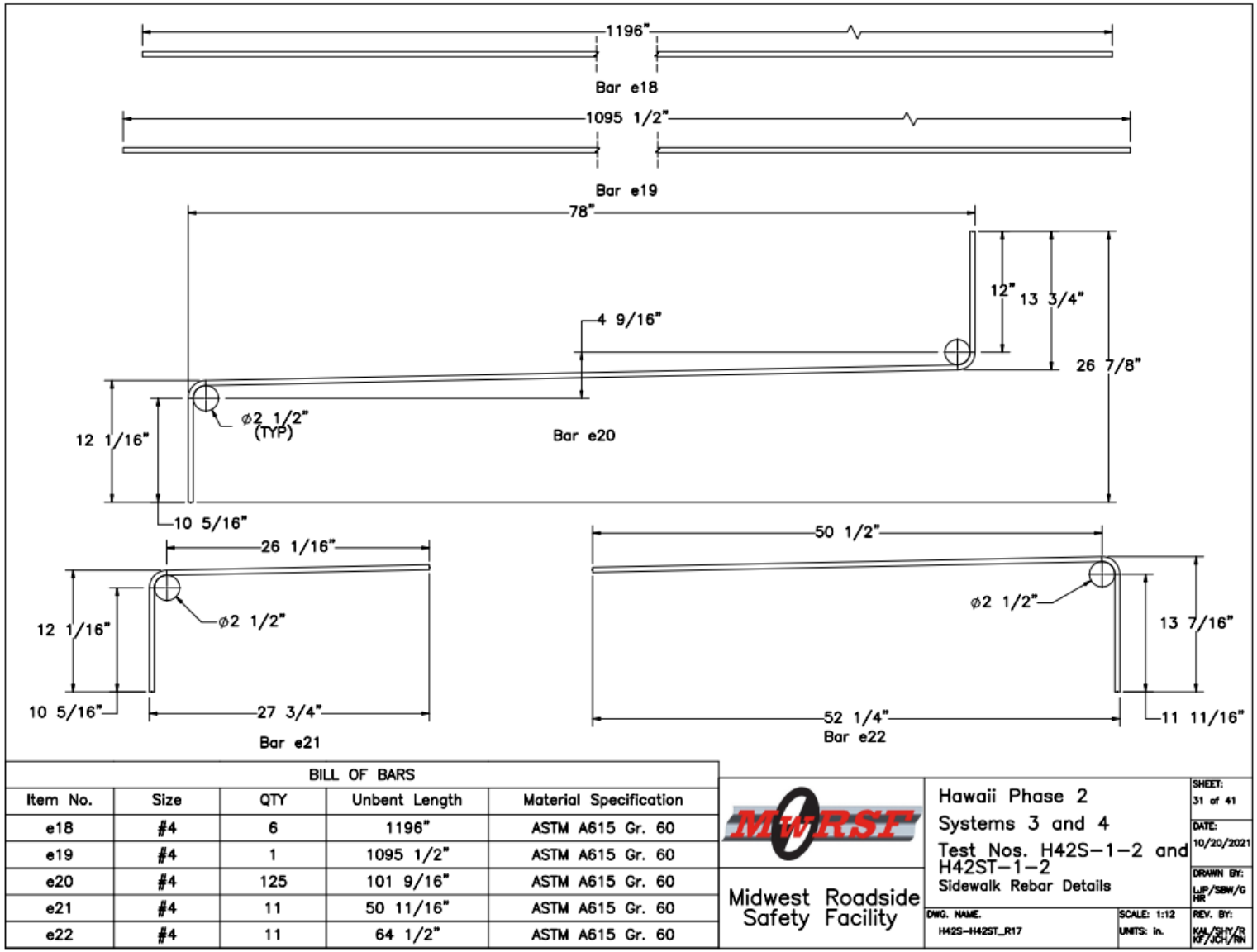


Figure 28. Rail Transition and Component Details, Test Nos. H42ST-1 and H42ST-2



BILL OF BARS

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

MwRSF

Midwest Roadside Safety Facility

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

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

Figure 29. Sidewalk Rebar Details, Test Nos. H42ST-1 and H42ST-2

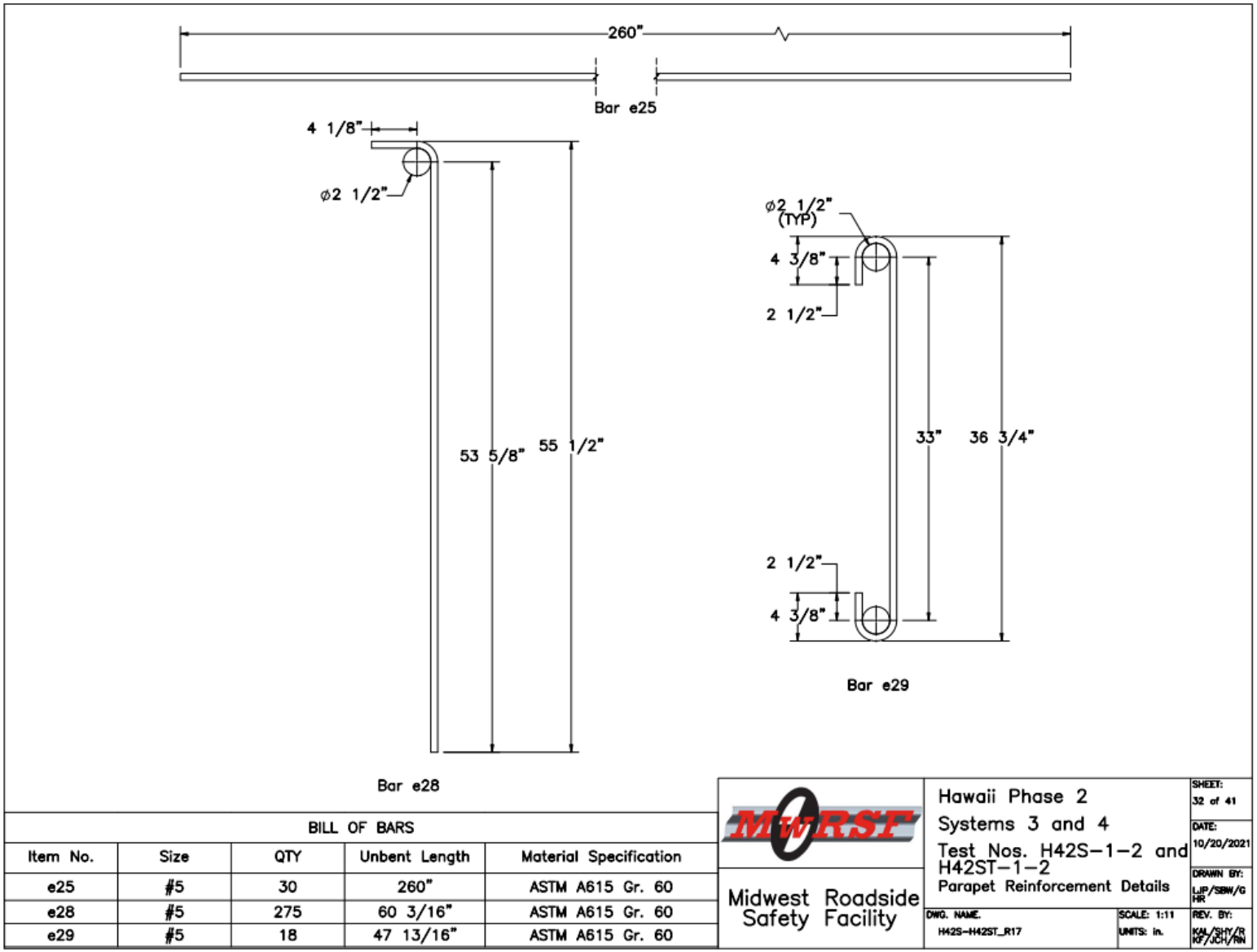
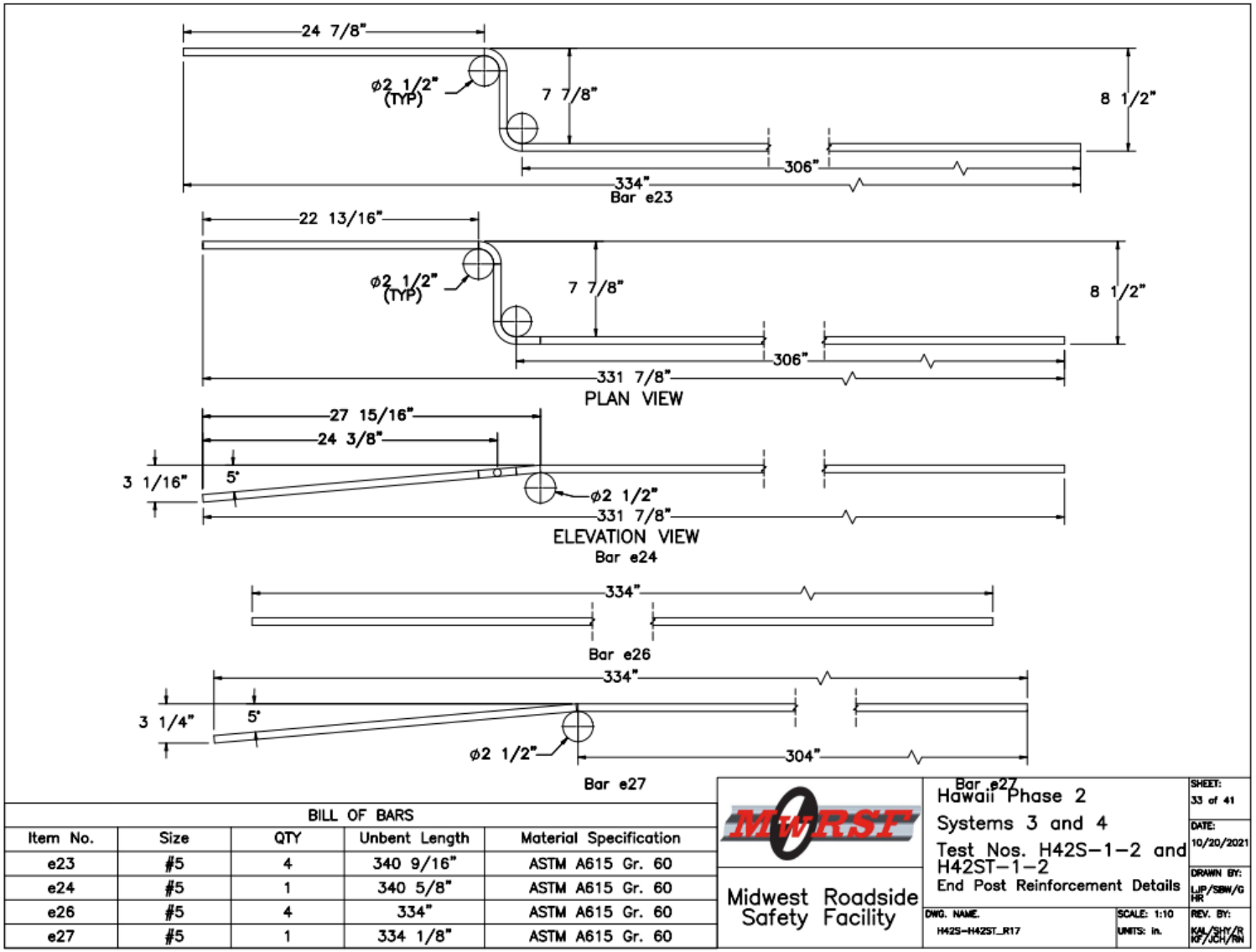


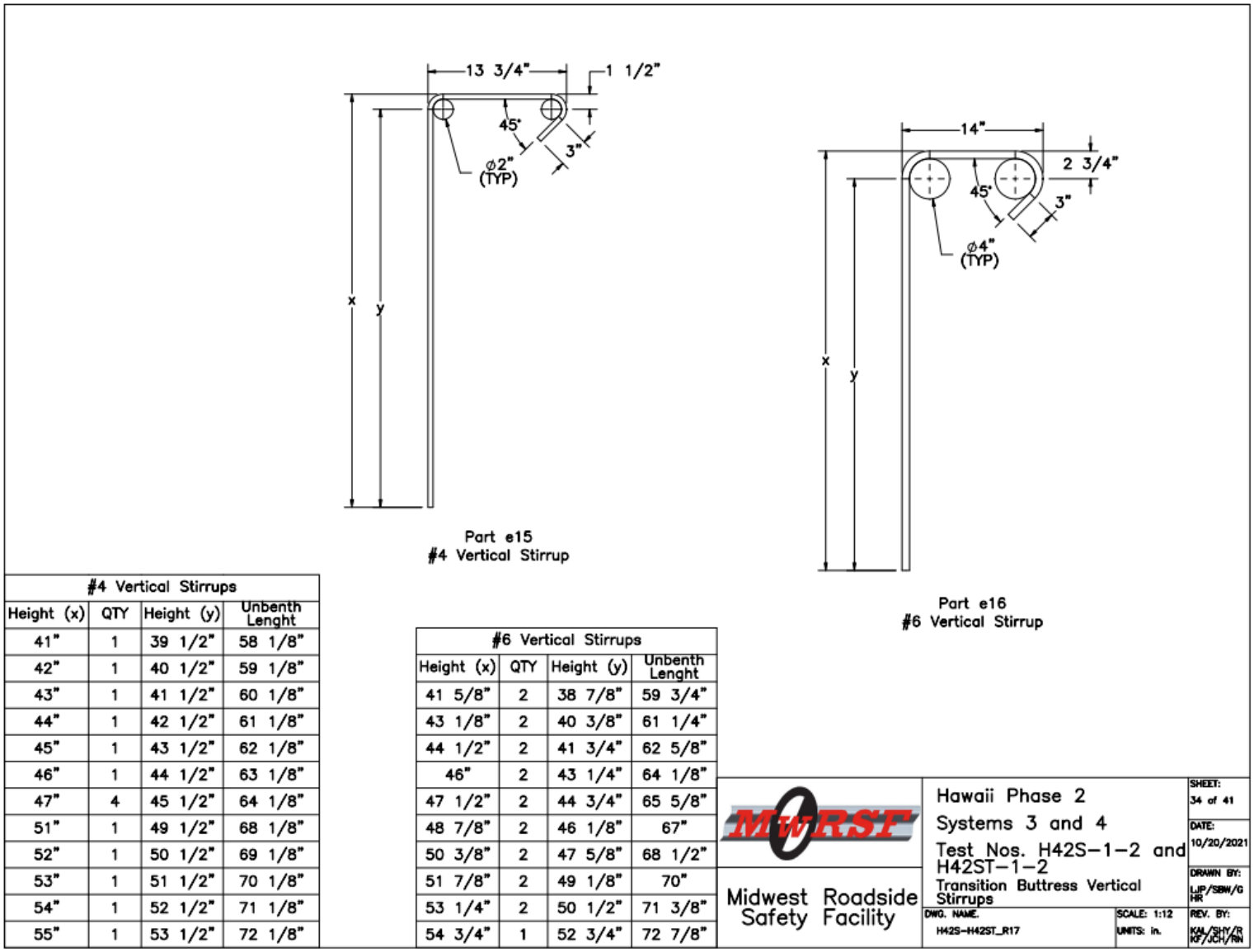
Figure 30. Parapet Reinforcement Details, Test Nos. H42ST-1 and H42ST-2



BILL OF BARS

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

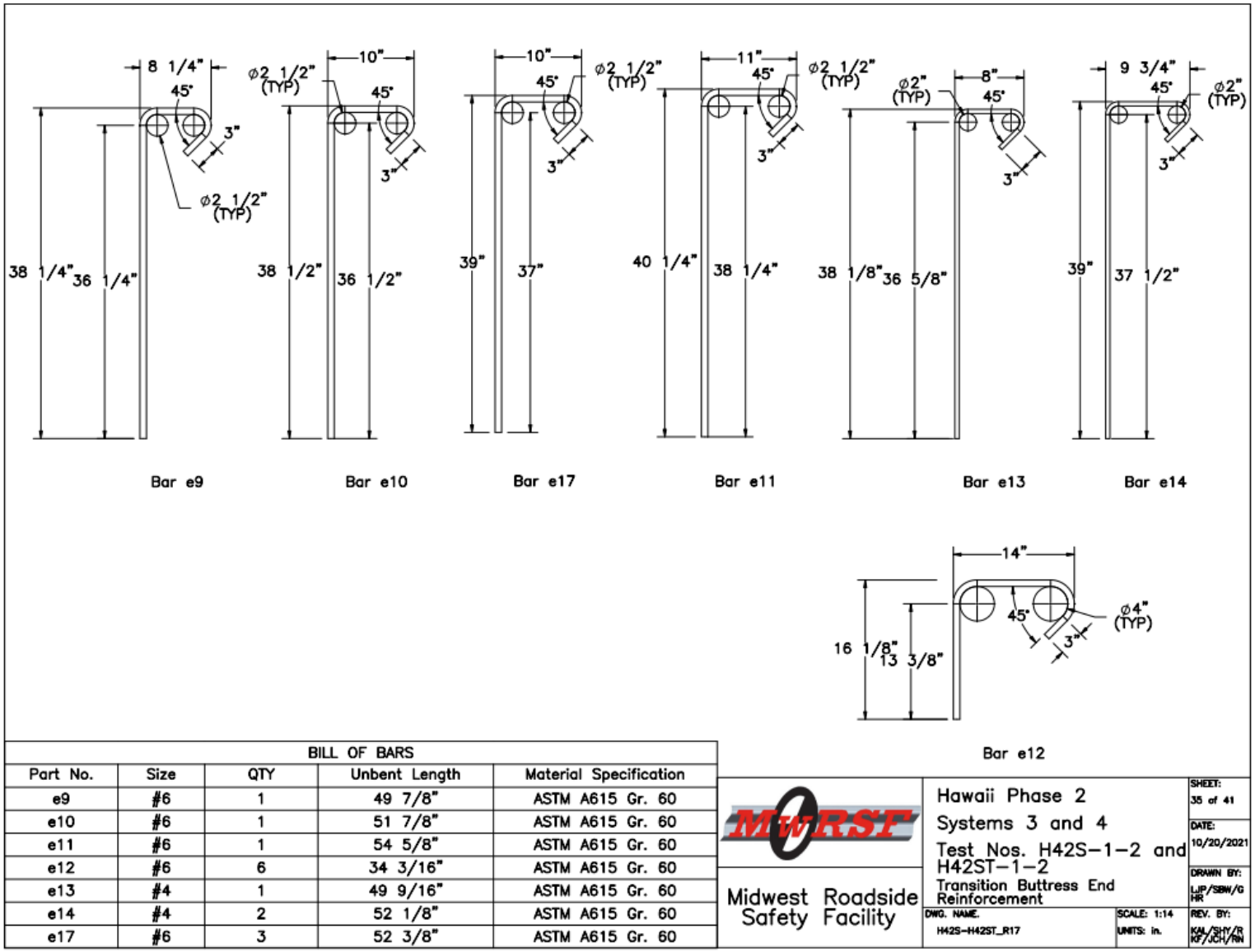
Figure 31. End Post Reinforcement Details, Test Nos. H42ST-1 and H42ST-2



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

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

Figure 32. Transition Buttress Vertical Stirrups, Test Nos. H42ST-1 and H42ST-2



BILL OF BARS

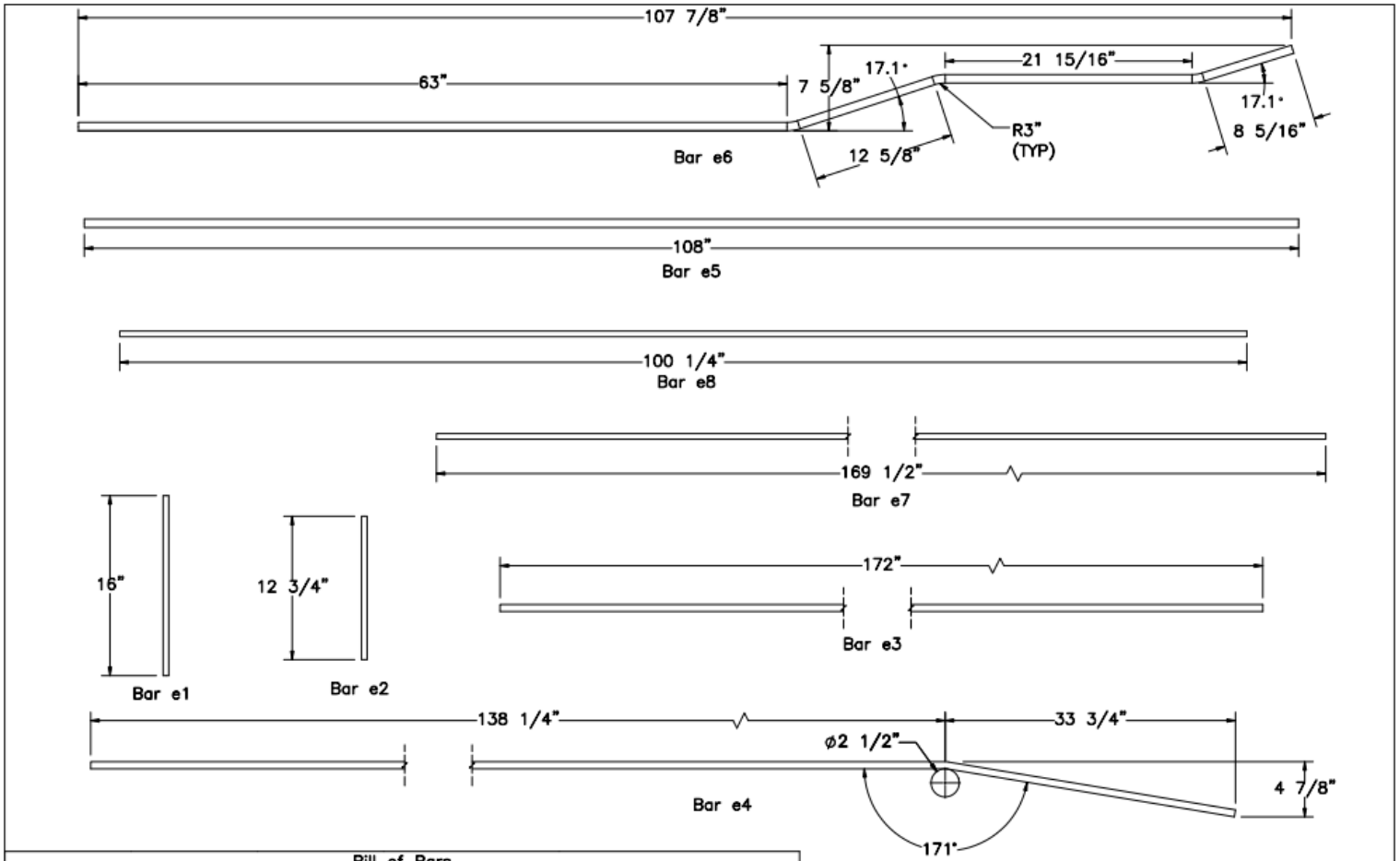
Part No.	Size	QTY	Unbent Length	Material Specification
e9	#6	1	49 7/8"	ASTM A615 Gr. 60
e10	#6	1	51 7/8"	ASTM A615 Gr. 60
e11	#6	1	54 5/8"	ASTM A615 Gr. 60
e12	#6	6	34 3/16"	ASTM A615 Gr. 60
e13	#4	1	49 9/16"	ASTM A615 Gr. 60
e14	#4	2	52 1/8"	ASTM A615 Gr. 60
e17	#6	3	52 3/8"	ASTM A615 Gr. 60

Midwest Roadside Safety Facility

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

DWG. NAME. H42S-H42ST_R17
SCALE: 1:14
UNITS: in.
SHEET: 35 of 41
DATE: 10/20/2021
DRAWN BY: LJP/SBW/GHR
REV. BY: KAL/SHY/RKF/JCH/RN

Figure 33. Transition Buttress End Reinforcement, Test Nos. H42ST-1 and H42ST-2



Bill of Bars

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

MwRSF
Midwest Roadside Safety Facility

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

DWG. NAME. H42S-H42ST_R17
SCALE: 1:12
UNITS: in.
SHEET: 36 of 41
DATE: 10/20/2021
DRAWN BY: LJP/SBW/GHR
REV. BY: KM/SHY/RKF/JCH/RN

Figure 34. Longitudinal Buttress and Curb Reinforcement Details, Test Nos. H42ST-1 and H42ST-2

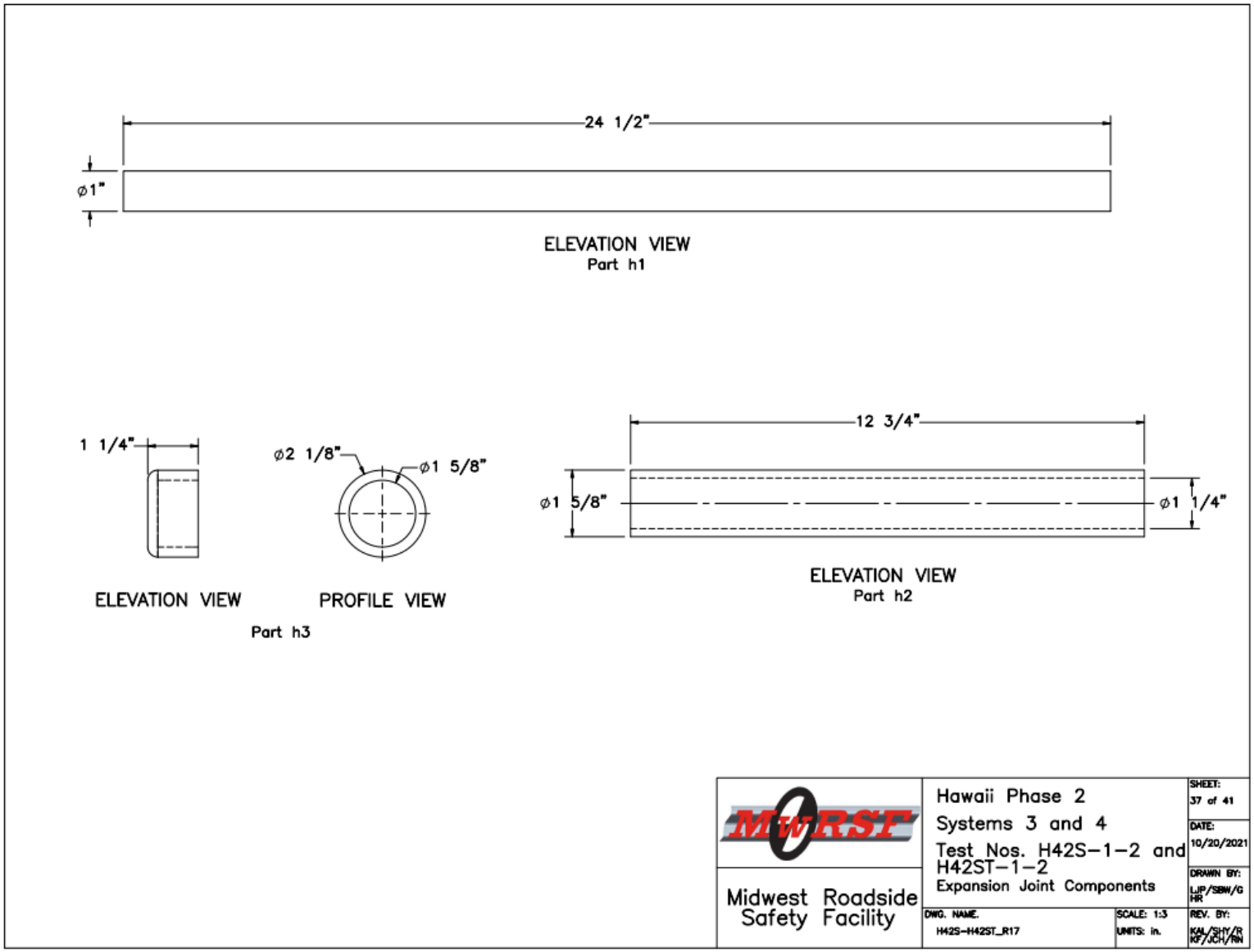


Figure 35. Expansion Joint Components, Test Nos. H42ST-1 and H42ST-2

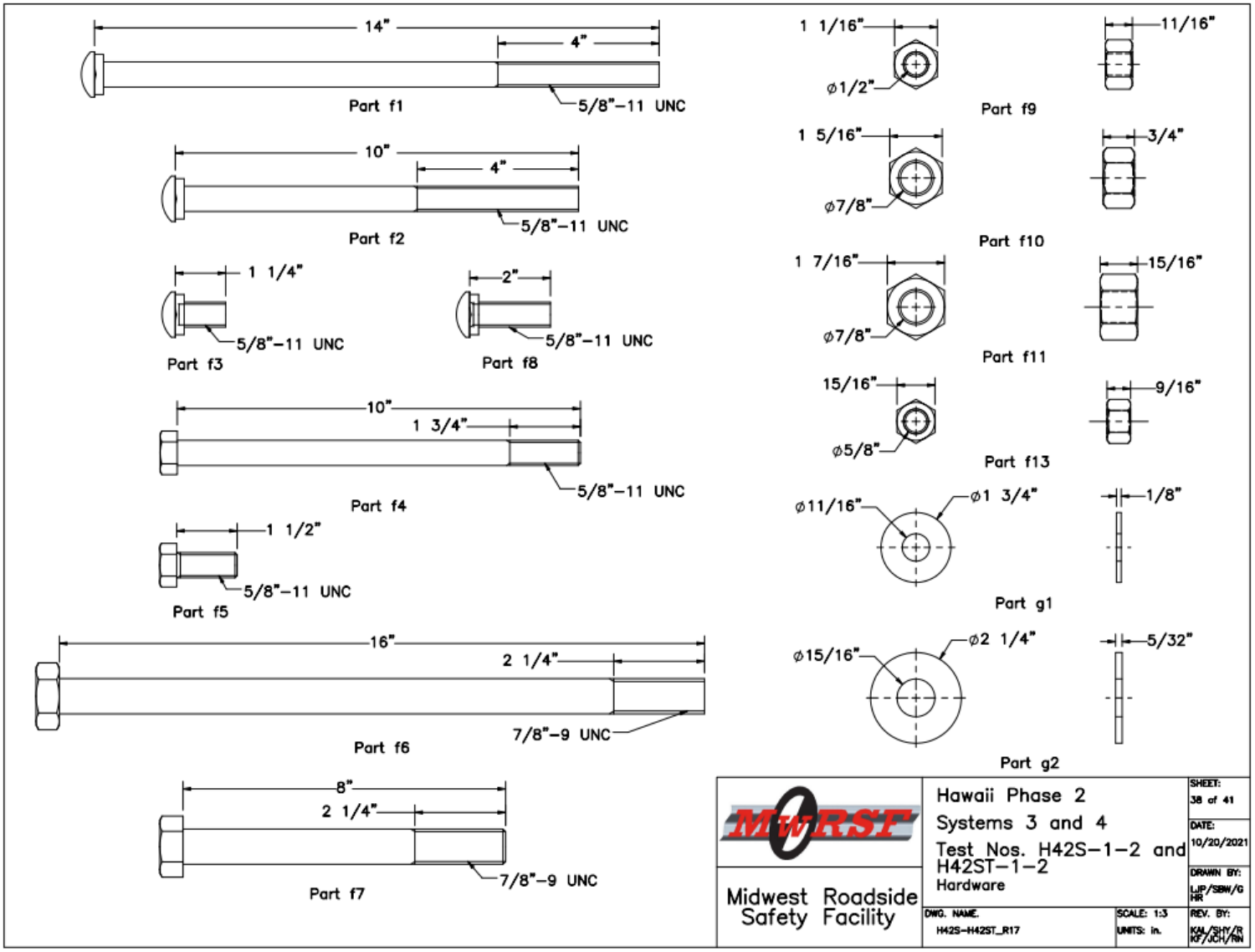


Figure 36. Hardware, Test Nos. H42ST-1 and H42ST-2

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

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

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

MwRSF
Midwest Roadside Safety Facility

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

SHEET: 39 of 41
DATE: 10/20/2021
DRAWN BY: LJP/SBW/GHR
REV. BY: KAL/SHY/RKF/JCH/RN
DWG. NAME. H42S-H42ST_R17
SCALE: None
UNITS: in.

Figure 37. Bill of Materials, Test Nos. H42ST-1 and H42ST-2

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

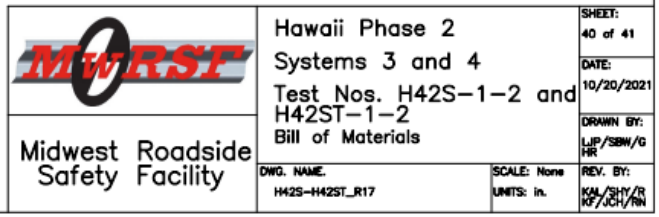


Figure 38. Bill of Materials, Cont., Test Nos. H42ST-1 and H42ST-2

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

Midwest Roadside Safety Facility

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

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

Figure 39. Bill of Materials, Cont., Test Nos. H42ST-1 and H42ST-2

Figure 40. Test Installation Photographs, Test Nos. H42ST-1 and H42ST-2

Figure 41. Test Installation Photographs, Test Nos. H42ST-1 and H42ST-2

Figure 42. Test Installation Photographs, Test Nos. H42ST-1 and H42ST-2

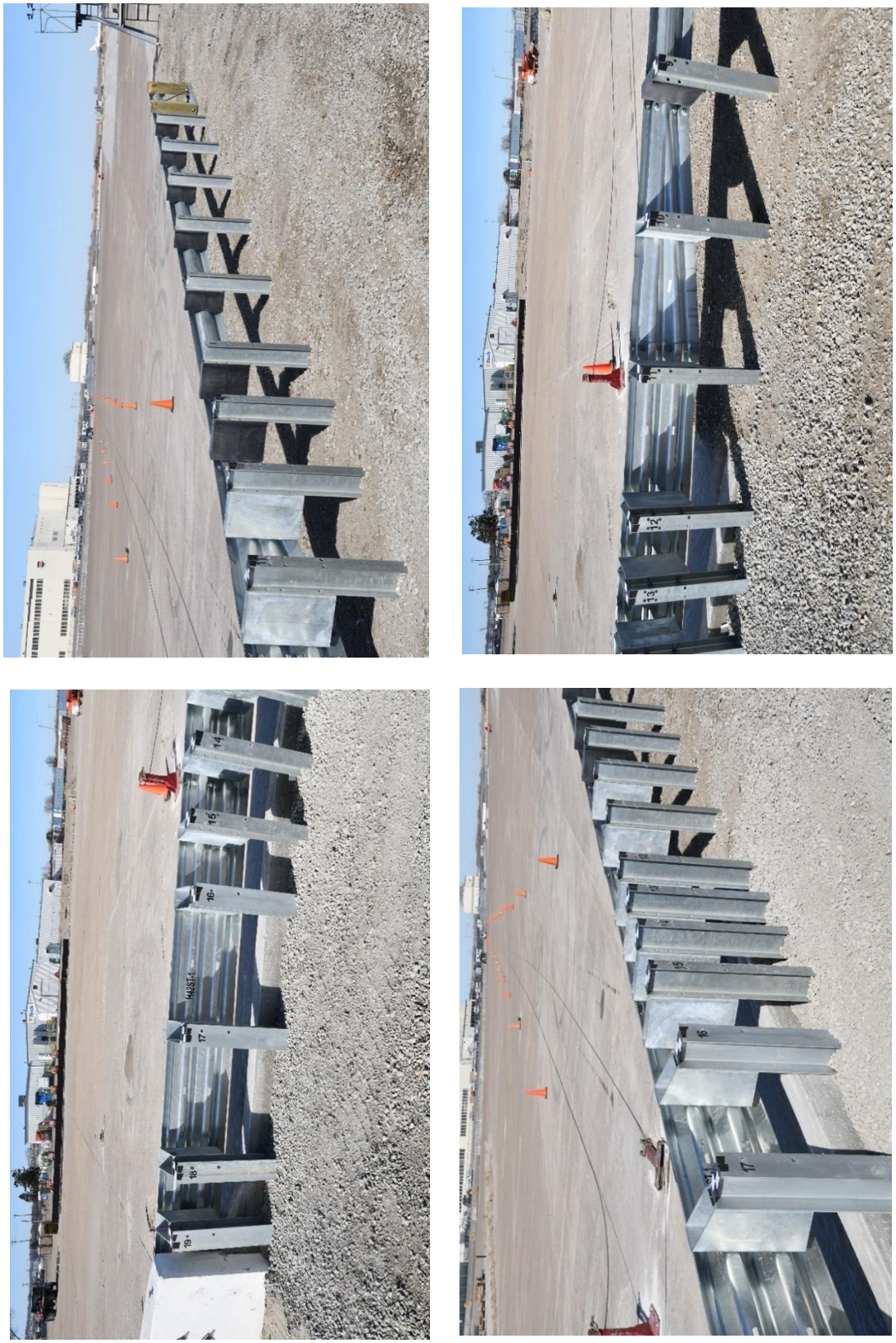


Figure 43. Test Installation Photographs, Test Nos. H42ST-1 and H42ST-2

3 TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1 Test Requirements

Longitudinal barriers, such as AGTs, 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 (NHS). For new hardware, these safety standards consist of the guidelines and procedures published in MASH 2016. According to TL-3 of MASH 2016, longitudinal barrier systems must be subjected to two full-scale vehicle crash tests, as summarized in Table 1. Note that there is no difference between MASH 2009 [9] and MASH 2016 [1] for longitudinal barriers such as the system tested in this project, except that additional occupant compartment deformation measurements, photographs, and documentation are required by MASH 2016.

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

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

[1] Evaluation criteria explained in Table 2.

Recent AGT testing has illustrated the importance of evaluating two different transition regions along the length of the AGT: (1) the downstream stiffness transition where the thrie-beam rail connects to the rigid parapet and (2) the upstream stiffness transition where the W-beam guardrail transitions to a stiffer thrie-beam barrier. However, the upstream stiffness transition of this HDOT thrie-beam AGT was specifically designed to replicate the MASH-crashworthy MGS stiffness transition [10]. Thus, crash testing of the upstream stiffness transition was deemed non-critical.

It should be noted that the test matrix detailed herein represents the researchers' best engineering judgment with respect to the MASH 2016 safety requirements and their internal evaluation of critical tests necessary to evaluate the crashworthiness of the guardrail transition system. However, these opinions may change in the future due to the development of new knowledge (crash testing, real-world performance, etc.) or changes to the evaluation criteria. Therefore, any tests within the evaluation matrix deemed non-critical may eventually need to be evaluated based on additional knowledge gained over time or revisions to the MASH 2016 criteria.

Table 2. MASH 2016 Evaluation Criteria for Longitudinal Barrier

<table>
<tr><td>Structural Adequacy</td><td>A.</td><td colspan="4">Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.</td></tr>
<tr><td rowspan="8">Occupant Risk</td><td>D.</td><td colspan="4">Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH 2016.</td></tr>
<tr><td>F.</td><td colspan="4">The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</td></tr>
<tr><td rowspan="4">H.</td><td colspan="4">Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:</td></tr>
<tr><td colspan="3">Occupant Impact Velocity Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>30 ft/s</td><td>40 ft/s</td></tr>
<tr><td rowspan="4">I.</td><td colspan="4">The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:</td></tr>
<tr><td colspan="3">Occupant Ridedown Acceleration Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>15.0 g’s</td><td>20.49 g’s</td></tr>
</table>

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 thrie-beam guardrail transition system 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 tests were conducted and reported in accordance with the procedures provided in MASH 2016.

In addition to the standard occupant risk measures, the Post-Impact Head Deceleration (PHD), the Theoretical Head Impact Velocity (THIV), and the Acceleration Severity Index (ASI) were determined and reported. Additional discussion on PHD, THIV and ASI is provided in MASH 2016.

3.3 Soil Strength Requirements

In accordance with Chapter 3 and Appendix B of MASH 2016, foundation soil strength must be verified before any full-scale crash testing can occur. During the installation of a soil-dependent system, W6x16 posts were installed near the impact region utilizing the same installation procedures as the system itself. Prior to full-scale testing, a dynamic impact test must be conducted to verify a minimum dynamic soil resistance of 7.5 kips at post deflections between 5 and 20 in. measured at a height of 25 in. If dynamic testing near the system is not desired, MASH 2016 permits a static test to be conducted instead and compared against the results of a previously established baseline test. In this situation, the soil must provide a resistance of at least 90 percent of the static baseline test at deflections of 5, 10, and 15 in. Further details can be found in Appendix B of MASH 2016.

4 TEST CONDITIONS

4.1 Test Facility

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

4.2 Vehicle Tow and Guidance System

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

A vehicle guidance system developed by Hinch [11] was used to steer the test vehicle. A guide flag, attached to the right-front wheel and the guide cable, was sheared off before impact with the barrier system. The ⅜-in. diameter guide cable was tensioned to approximately 3,500 lb and supported both laterally and vertically every 100 ft by hinged stanchions. The hinged stanchions stood upright while holding up the guide cable, but as the vehicle was towed down the line, the guide flag struck and knocked each stanchion to the ground.

4.3 Test Vehicles

For test no. H42ST-1, a 2016 Dodge Ram 1500 Quad cab pickup truck was used as the test vehicle. The test vehicle is shown in Figures 44 and 45, and vehicle dimensions are shown in Figure 46. The curb, test inertial, and gross static vehicle weights were 5,258 lb, 5,041 lb, and 5,199 lb, respectively. The authors acknowledge that the track width measurement of 68¾ in., measurement M in Figure 46, was ¼ in. outside of the MASH recommended limits of 67±1½ in. This measurement was deemed acceptable as ¼ in. beyond the limit would not affect the safety performance of the system or vehicle behavior. MASH states that these recommendations should be adhered to when practical.

For test no. H42ST-2, a 2016 Hyundai Accent passenger car was used as the test vehicle. The test vehicle is shown in Figures 47 and 48, and vehicle dimensions are shown in Figure 49. The curb, test inertial, and gross static vehicle weights were 2,543 lb, 2,430 lb, and 2,592 lb, respectively.

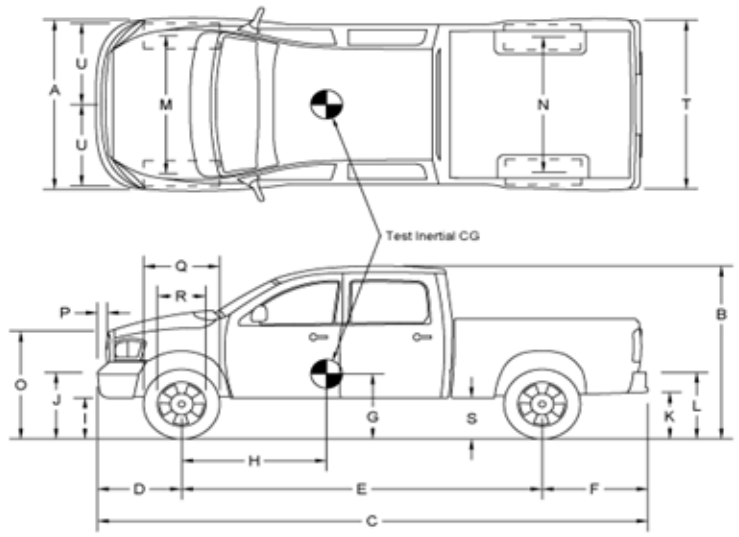
Figure 44. Test Vehicle, Test No. H42ST-1

Figure 45. Test Vehicle's Interior Floorboards and Undercarriage, Test No. H42ST-1

Test Name: H42ST-1 VIN No: 1C6RR6GT2GS269090

Model Year: 2016 Make: Ram Model: 1500

Tire Size: P275/60R20 Tire Inflation Pressure: 39 psi Odometer: 271900



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

A:	78 1/8	1984 3/8		B:	75 1/4	1911 7/20	
	78±2 (1950±50)						
C:	229 3/8	5826 1/8		D:	41 3/8	1050 37/40	
	237±13 (6020±325)				39±3 (1000±75)		
E:	140 3/8	3565 21/40		F:	48	1219 1/5	
	148±12 (3760±300)						
G:	28 7/8	733 17/40		H:	59 15/16	1522 33/80	
	min. 28 (710)				63±4 (1575±100)		
I:	13 3/4	349 1/4		J:	25 3/4	654 1/20	
K:	18 7/8	479 17/40		L:	30 3/8	771 21/40	
M:	68 3/4	1746 1/4		N:	68 1/4	1733 11/20	
	67±1.5 (1700±38)				67±1.5 (1700±38)		
O:	45 1/2	1155 7/10		P:	4 1/2	114 3/10	
	43±4 (1100±75)						
Q:	31 7/8	809 5/8		R:	21 1/2	546 1/10	
S:	16 1/8	409 23/40		T:	76	1930 2/5	

U (impact width): 36 7/16 925 41/80

Mass Distribution - lb (kg)

Gross Static	LF	1506	(683)	RF	1478	(670)
	LR	1102	(500)	RR	1113	(505)

Weights lb (kg)	Curb		Test Inertial		Gross Static	
W-front	2994	(1358)	2889	(1310)	2984	(1354)
W-rear	2264	(1027)	2152	(976)	2215	(1005)
W-total	5258	(2385)	5041	(2287)	5199	(2358)
			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):	36 1/8 917 23/40
Wheel Well Clearance (Rear):	38 7/8 987 17/40
Bottom Frame Height (Front):	20 1/4 514 7/20
Bottom Frame Height (Rear):	26 1/4 666 3/4
Engine Type:	Gasoline
Engine Size:	5.7L V8
Transmission Type:	Automatic
Drive Type:	RWD
Cab Style:	Quad Cab
Bed Length:	76"

GVWR Ratings - lb

Front	3700
Rear	3900
Total	6900

Surrogate Occupant Data

Type:	Hybrid II
Mass:	158 lb
Seat Position:	Left/Driver

Note any damage prior to test: Small dent in left front door

Figure 46. Vehicle Dimensions, Test No. H42ST-1

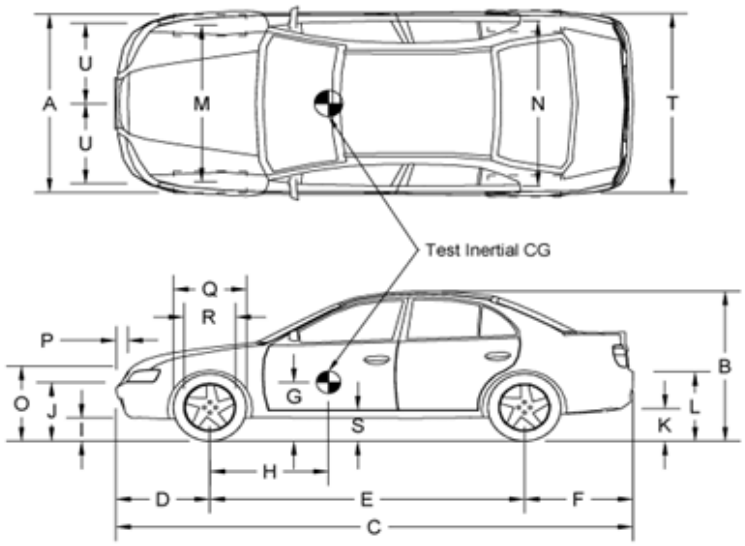
Figure 47. Test Vehicle, Test No. H42ST-2

Figure 48. Test Vehicle's Interior Floorboards and Undercarriage, Test No. H42ST-2

Test Name: H42ST-2 VIN No: kmhct4ae8gu947887

Model Year: 2016 Make: Hyundai Model: Accent

Tire Size: 185/70 R14 Tire Inflation Pressure: 33 psi Odometer: 187302



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

A:	66 3/8	(1686)	B:	56 3/4	(1441)
	65±3 (1650±75)				
C:	171 7/8	(4366)	D:	32 1/8	(816)
	169±8 (4300±200)			35±4 (900±100)	
E:	101	(2565)	F:	38 3/4	(984)
	98±5 (2500±125)				
G:	22 7/16	(570)	H:	37 15/16	(964)
				39±4 (990±100)	
I:	6 1/2	(165)	J:	23	(584)
K:	11	(279)	L:	25	(635)
M:	58 7/8	(1495)	N:	59 1/4	(1505)
	59±2 (1498±50)			59±2 (1425±50)	
O:	29	(737)	P:	4	(102)
	28±4 (711±100)				
Q:	23 1/2	(597)	R:	15 1/4	(387)
S:	10 7/8	(276)	T:	66 1/4	(1683)

U (impact width): 30 3/4 (781)

Mass Distribution - lb (kg)

Gross Static LF 828 (376) RF 770 (349)
LR 514 (233) RR 480 (218)

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	1569 (712)	1517 (688)	1598 (725)
W-rear	974 (442)	913 (414)	994 (451)
W-total	2543 (1153)	2430 (1102)	2592 (1176)
		2420±55 (1100±25)	2585±55 (1175±50)

Top of radiator core support:	28 3/8 (721)
Wheel Center Height (Front):	11 1/8 (283)
Wheel Center Height (Rear):	11 1/2 (292)
Wheel Well Clearance (Front):	24 7/8 (632)
Wheel Well Clearance (Rear):	25 1/4 (641)
Bottom Frame Height (Front):	15 1/2 (394)
Bottom Frame Height (Rear):	15 3/4 (400)
Engine Type:	Gasoline
Engine Size:	1.6l 4 cyl
Transmission Type:	Automatic
Drive Type:	FWD

GVWR Ratings lb

Front 1874
Rear 1852
Total 3527

Surrogate Occupant Data

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

Note any damage prior to test: None

Figure 49. Vehicle Dimensions, Test No. H42ST-2

The longitudinal component of the center of gravity (c.g.) was determined using the measured axle weights. The Suspension Method [12] was used to determine the vertical component of the c.g. for the 2270P vehicle. This method is based on the principle that the c.g. of any freely suspended body is in the vertical plane through the point of suspension. The vehicle was suspended successively in three positions, and the respective planes containing the c.g. were established. The intersection of these planes pinpointed the final c.g. location for the test inertial condition. The location of the final c.g. for the 2270P vehicle is shown in Figures 46 and 50. The vertical component of the c.g. for the 1100C vehicle was determined utilizing a procedure published by SAE [13]. The final c.g. location is shown in Figures 49 and 51. Ballast information and data used to calculate the location of the c.g. are shown in Appendix B.

Square, black-and-white checkered targets were placed on the vehicles to serve as a reference in the high-speed digital video and aid in the video analysis, as shown in Figures 50 and 51. Round, checkered targets were placed at the c.g. on the left-side door, the right-side door, and the roof of the vehicle.

The front wheels of the test vehicles were aligned to vehicle standards except the toe-in value was adjusted to zero such that the vehicles would track properly along the guide cable. A 5B flash bulb was mounted under the vehicles' left-side and right-side windshield wipers for test nos. H42ST-1 and H42ST-2, respectively, and was fired by a pressure tape switch mounted at the impact corner of the bumper for both tests. 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 vehicles could be brought safely to a stop after the test.

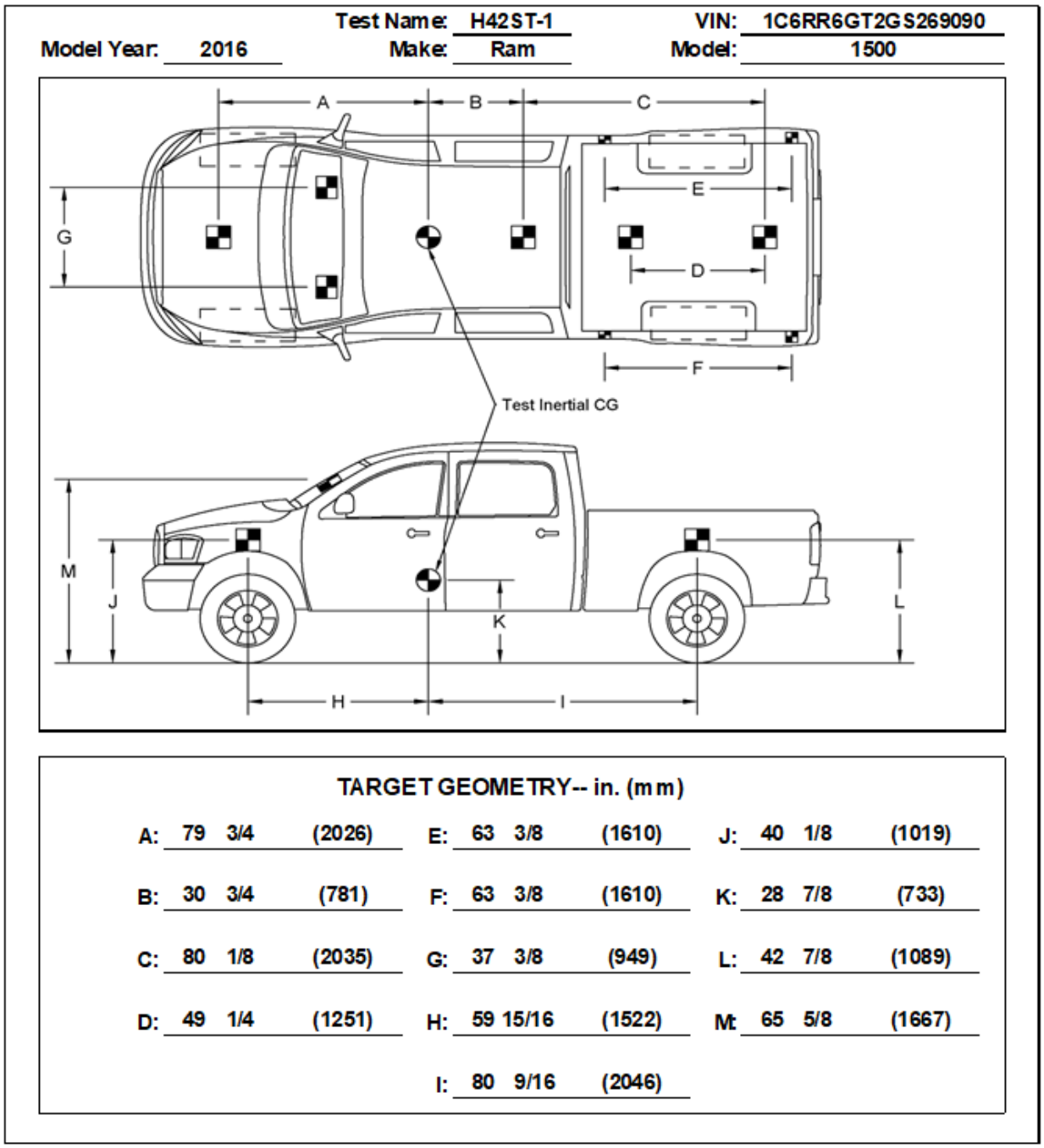


Figure 50. Target Geometry, Test No. H42ST-1

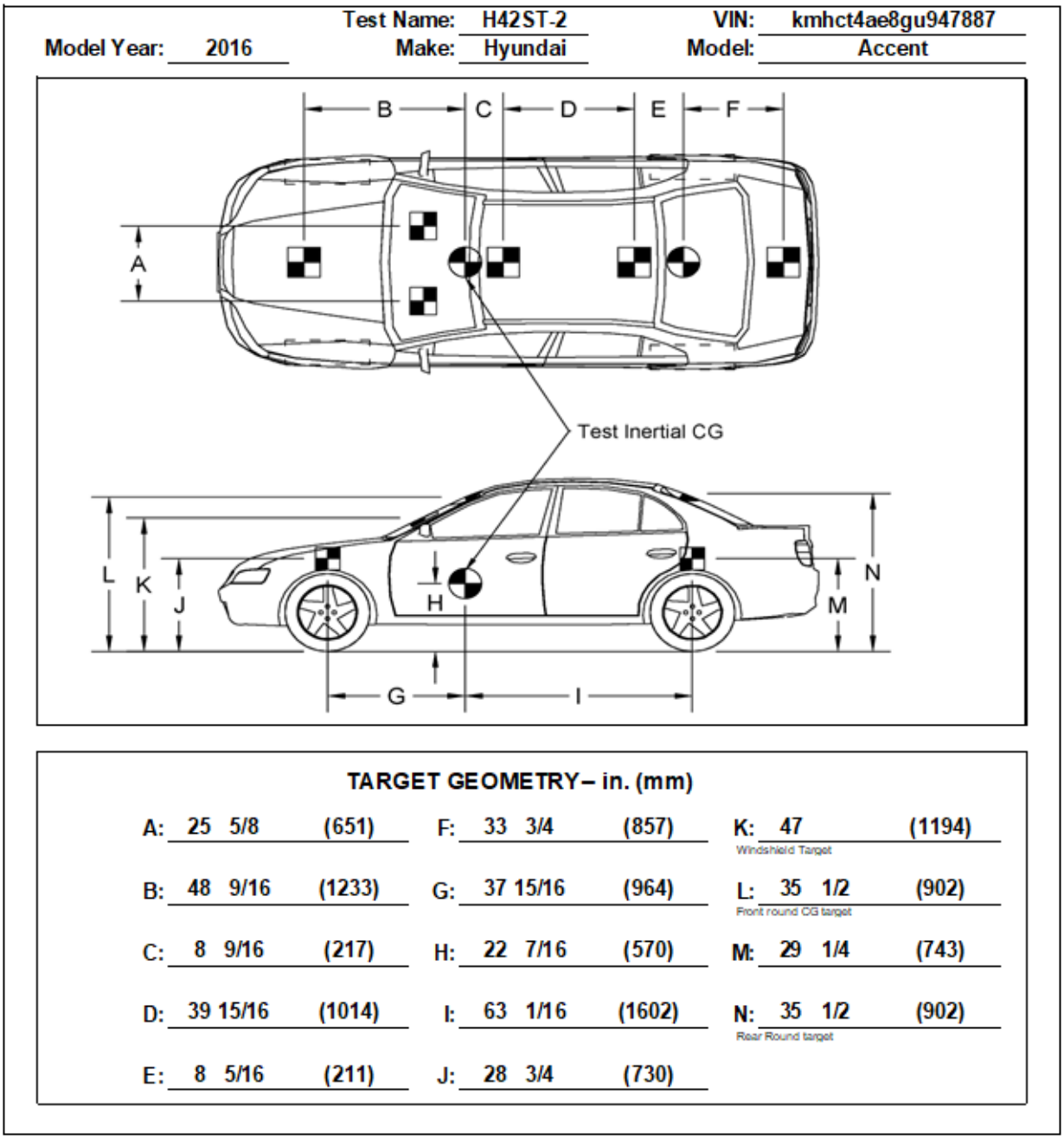


Figure 51. Target Geometry, Test No. H42ST-2

4.4 Simulated Occupant

For test nos. H42ST-1 and H42ST-2, a Hybrid II 50th-Percentile, Adult Male Dummy equipped with footwear was placed in the left-front seat of the test vehicles with the seat belt fastened. The simulated occupant had a final weight of 158 lb and 162 lb for test nos. H42ST-1 and H42ST-2, respectively. As recommended by MASH 2016, the simulated occupant weight was not included in calculating the c.g. location.

4.5 Data Acquisition Systems

4.5.1 Accelerometers

In each test, two environmental shock and vibration sensor/recorder systems mounted near the c.g. of the test vehicle were used to measure the accelerations in the longitudinal, lateral, and vertical directions. The electronic data obtained in dynamic testing was filtered using the SAE Class 60 and the SAE Class 180 Butterworth filter conforming to the SAEJ211/1 specifications [14].

The two systems, the SLICE-1 and SLICE-2 units were modular data acquisition systems manufactured by Diversified Technical Systems, Inc. of Seal Beach, California. The SLICE-2 unit was designated as the primary system for test no. H42ST-1, and the SLICE-1 unit was designated as the primary system for test no. H42ST-2. The acceleration sensors were mounted inside the bodies of custom-built, SLICE 6DX event data recorders and recorded data at 10,000 Hz to the onboard microprocessor. Each SLICE 6DX was configured with 7 GB of non-volatile flash memory, a range of ±500 g's, a sample rate of 10,000 Hz, and a 1,650 Hz (CFC 1000) anti-aliasing filter. The "SLICEWare" computer software program and a customized Microsoft Excel worksheet were used to analyze and plot the accelerometer data.

4.5.2 Rate Transducers

Two identical angular rate sensor systems mounted inside the bodies of the SLICE-1 and SLICE-2 event data recorders were used to measure the rates of rotation of the test vehicle. Each SLICE MICRO Triax ARS had a range of 1,500 degrees/sec in each of the three directions (roll, pitch, and yaw) and recorded data at 10,000 Hz to the onboard microprocessors. The raw data measurements were then downloaded, converted to the proper Euler angles for analysis, and plotted. The "SLICEWare" computer software program and a customized Microsoft Excel worksheet were used to analyze and plot the angular rate sensor data.

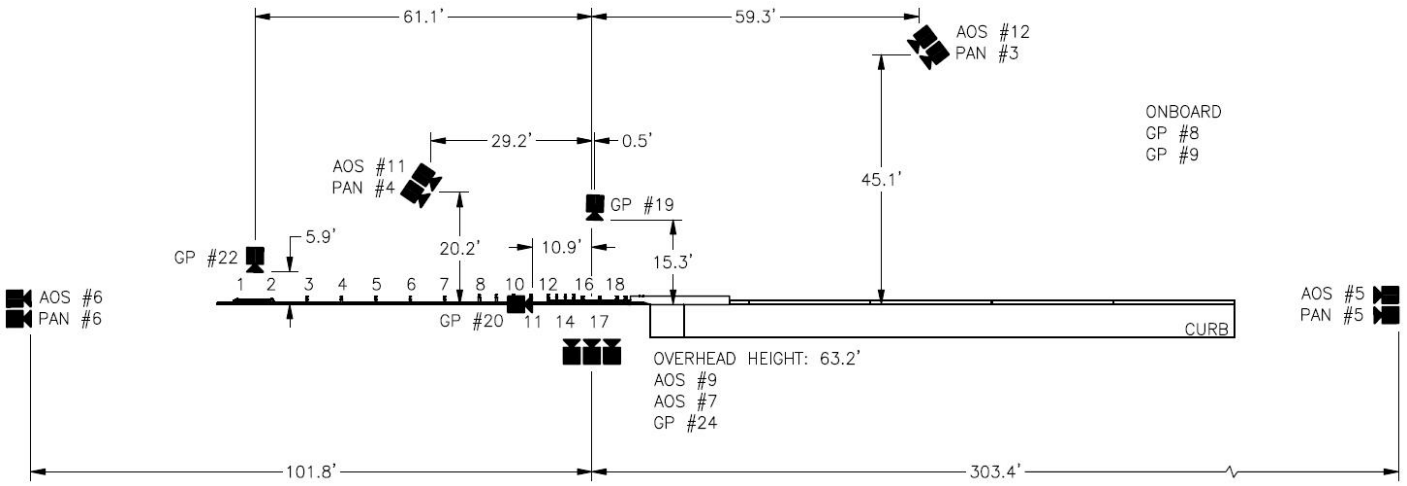
4.5.3 Retroreflective Optic Speed Trap

A retroreflective optic speed trap was used to determine the speed of the test vehicles before impact. Two retroreflective targets, spaced at approximately 18-in. intervals, were applied to the side of the vehicles. When the emitted beam of light was reflected by the targets and returned to the Emitter/Receiver, a signal was sent to the data acquisition computer, recording at 10,000 Hz, as well as the external LED box activating the LED flashes. The speed was then calculated using the spacing between the retroreflective targets and the time between the signals. LED lights and high-speed digital video analysis are used as a backup if vehicle speeds cannot be determined from the electronic data.

4.5.4 Digital Photography

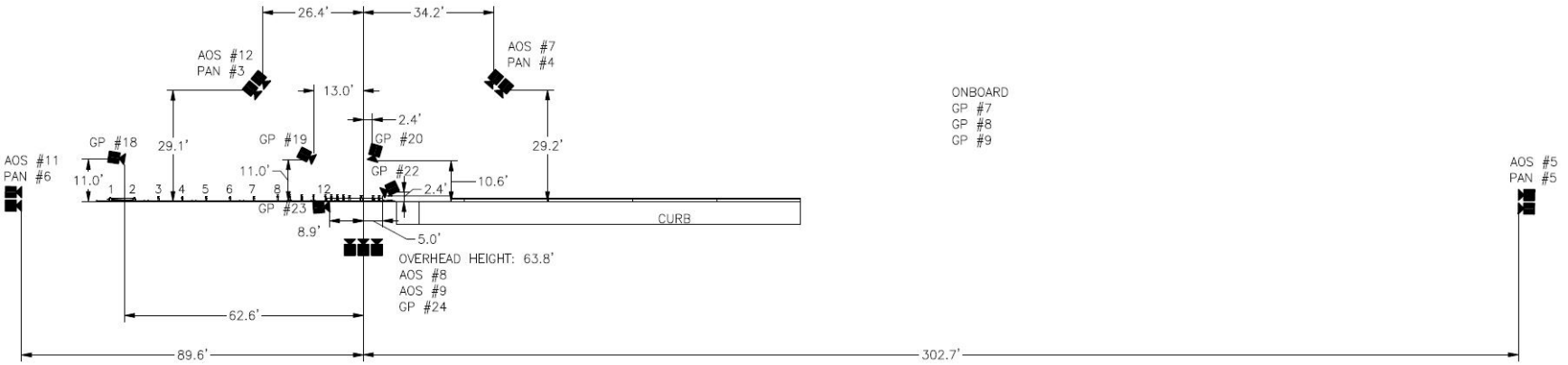
Six AOS high-speed digital video cameras, six GoPro digital video cameras, and four Panasonic digital video cameras were utilized to film test no. H42ST-1. Six AOS high-speed digital video cameras, nine GoPro digital video cameras, and four Panasonic digital video cameras were utilized to film test no. H42ST-2. Due to technical difficulties, GP-18 did not capture the impact event. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system for test nos. H42ST-1 and H42ST-2 are shown in Figures 52 and 53, respectively.

The high-speed videos were analyzed using TEMA Motion and Redlake MotionScope software programs. Actual camera speed and camera divergence factors were considered in the analysis of the high-speed videos. A digital still camera was also used to document pre- and post-test conditions for the test.



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-5	AOS X-PRI Gigabit	500	100 mm Fixed	-
AOS-6	AOS X-PRI Gigabit	500	Fujinon 50mm Fixed	-
AOS-7	AOS X-PRI Gigabit	500	Kowa 16mm Fixed	-
AOS-9	AOS TRI-VIT 2236	1000	Kowa 12mm Fixed	-
AOS-11	AOS J-PRI	500	Sigma 24-135	100
AOS-12	AOS J-PRI	500	Sigma 18-50	50
GP-8	GoPro Hero 4	120		
GP-9	GoPro Hero 4	120		
GP-19	GoPro Hero 6	240		
GP-20	GoPro Hero 6	120		
GP-22	GoPro Hero 7	240		
GP-24	GoPro Hero 7	240		
PAN-3	Panasonic HC-V770	120		
PAN-4	Panasonic HC-V770	120		
PAN-5	Panasonic HC-VX981	120		
PAN-6	Panasonic HC-V981	120		

Figure 52. Camera Locations, Speeds, and Lens Settings, Test No. H42ST-1



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-5	AOS X-PRI Gigabit	500	Sigma 24-135	135
AOS-7	AOS X-PRI Gigabit	500	Fujinon 50mm Fixed	-
AOS-8	AOS X-PRI Gigabit	500	Kowa 16mm Fixed	-
AOS-9	AOS TRI-VIT 2236	1000	Kowa 12mm Fixed	-
AOS-11	AOS J-PRI	500	Nikon 50mm Fixed	-
AOS-12	AOS J-PRI	500	Nikon 17-50	50
GP-7	GoPro Hero 4	120		
GP-8	GoPro Hero 4	120		
GP-9	GoPro Hero 4	120		
GP-18	GoPro Hero 6	240		
GP-19	GoPro Hero 6	240		
GP-20	GoPro Hero 6	240		
GP-22	GoPro Hero 7	240		
GP-23	GoPro Hero 7	240		
GP-24	GoPro Hero 7	240		
PAN-3	Panasonic HC-V770	120		
PAN-4	Panasonic HC-V770	120		
PAN-5	Panasonic HC-VX981	120		
PAN-6	Panasonic HC-V981	120		

*Due to technical difficulties, GP-18 did not capture the impact event.

Figure 53. Camera Locations, Speeds, and Lens Settings, Test No. H42ST-2

5 FULL-SCALE CRASH TEST NO. H42ST-1

5.1 Static Soil Test

Before full-scale crash test no. H42ST-1 was conducted, the strength of the foundation soil was evaluated with a static test, as described in MASH 2016. The static test results, as shown in Appendix C, demonstrated a soil resistance above the baseline test limits. Thus, the soil provided adequate strength, and full-scale crash testing could be conducted on the barrier system.

5.2 Weather Conditions

Test no. H42ST-1 was conducted on February 7, 2022 at approximately 2:30 p.m. The weather conditions as reported by the National Oceanic and Atmospheric Administration (station 14939/LNK) are shown in Table 3.

Table 3. Weather Conditions, Test No. H42ST-1

Temperature	60.5°F
Humidity	22%
Wind Speed	14 mph
Wind Direction	290° from True North
Sky Conditions	Clear
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0 in.
Previous 7-Day Precipitation	0 in.

5.3 Test Description

Initial vehicle impact was to occur 84 in. upstream from the upstream end of the concrete buttress, as shown in Figure 54, which was selected using the CIP plots found in Figure 2-17 of MASH 2016 to maximize pocketing and the probability of wheel snag on the concrete parapet. The 5,041-lb pickup truck impacted the HDOT 42-in. bridge rail transition with sidewalk at a speed of 64.7 mph and at an angle of 24.8 degrees. Note that the impact speed of 64.7 mph was above the MASH nominal impact speed of 62.0 mph ±2.5 mph. However, impact speeds exceeding the nominal criteria are acceptable for longitudinal barriers. The actual point of impact was 4.1 in. downstream from the targeted impact location. The impact severity for the crash test was 124.1 kip-ft, which was greater than the minimum value of 105.6 kip-ft defined in MASH 2016. As such, the crash test results could be used as a valid indicator of the system's overall safety performance. The vehicle was captured and redirected with minor deflections of the barrier system. The vehicle remained stable throughout the impact event. During the redirection of the vehicle, the simulated occupant's head contacted the side window, but the window remained intact. Moreover, the occupant's head did not strike any component of the barrier. All measured accelerations resulted in occupant risk values (OIV and ORA) within MASH limits. A detailed description of the sequential impact events is contained in Table 4. Sequential photographs are shown in Figures 55 and 56. Documentary photographs of the crash test are shown in Figures 57 through 61. The vehicle trajectory and final position are shown in Figure 62.

Figure 54. Target Impact Location, Test No. H42ST-1

Table 4. Sequential Description of Impact Events, Test No. H42ST-1

Time (sec)	Event
0.000	Vehicle's front bumper impacted rail 79.9 in. upstream from upstream end concrete buttress.
0.006	Vehicle's left-front tire contacted rail.
0.007	Vehicle left fender contacted rail and was crushed inward.
0.012	Post no. 17 rotated backward.
0.014	Post no. 16 rotated backward, and post no. 18 rotated backward and flange bent.
0.020	Vehicle's hood deformed, and post no. 19 rotated backward.
0.034	Vehicle pitched up.
0.036	Vehicle yawed away from barrier.
0.048	Vehicle's grille contacted rail and deformed.
0.050	Post no. 18 rotated downstream.
0.052	Vehicle's right headlight deformed and detached, and vehicle rolled away from barrier.
0.056	Vehicle's left-front door contacted rail and was crushed inward, and vehicle's left-front door became ajar.
0.058	Post no. 16 rotated clockwise.
0.070	Vehicle's roof deformed.
0.072	Post no. 17 rotated counterclockwise, and vehicle's left-front tire deflated.
0.078	Vehicle's left headlight contacted concrete transition and shattered.
0.083	Vehicle's windshield cracked.
0.090	Vehicle pitched down.
0.092	Post no. 17 rotated clockwise, and post no. 18 rotated upstream.
0.094	Post no. 16 rotated clockwise.
0.110	Vehicle's right-front tire became airborne.
0.146	Simulated occupant's head contacted left-front window.
0.148	Vehicle's right-rear became airborne.
0.243	Vehicle became parallel to system at 40.2 mph.
0.256	Vehicle's rear bumper contacted rail and deformed.
0.294	Vehicle's left quarter panel contacted rail and deformed.
0.437	Vehicle exited system at a speed of 40.2 mph and an angle of 10.5 degrees.
0.439	System came to rest.
0.454	Vehicle's tailgate right side hinge disengaged.
0.704	Vehicle pitched up.
0.756	Vehicle rolled toward barrier.
0.817	Vehicle's left-rear tire contacted ground.
1.412	Vehicle yawed toward barrier.
1.972	Vehicle's right-front tire contacted ground.
2.092	Vehicle's right-rear tire contacted ground.
4.450	Vehicle came to rest.


0.000 sec


0.10 sec


0.200 sec


0.300 sec


0.400 sec


0.500 sec


0.000 sec


0.050 sec


0.150 sec


0.300 sec


0.500 sec


0.850 sec

Figure 55. Sequential Photographs, Test No. H42ST-1


0.000 sec

0.050 sec


0.100 sec


0.150 sec


0.250 sec


0.350 sec


0.000 sec


0.050 sec


0.100 sec


0.150 sec


0.200 sec


0.250 sec

Figure 56. Additional Sequential Photographs, Test No. H42ST-1

Figure 57. Documentary Photographs, Test No. H42ST-1

Figure 58. Additional Documentary Photographs, Test No. H42ST-1

Figure 59. Additional Documentary Photographs, Test No. H42ST-1

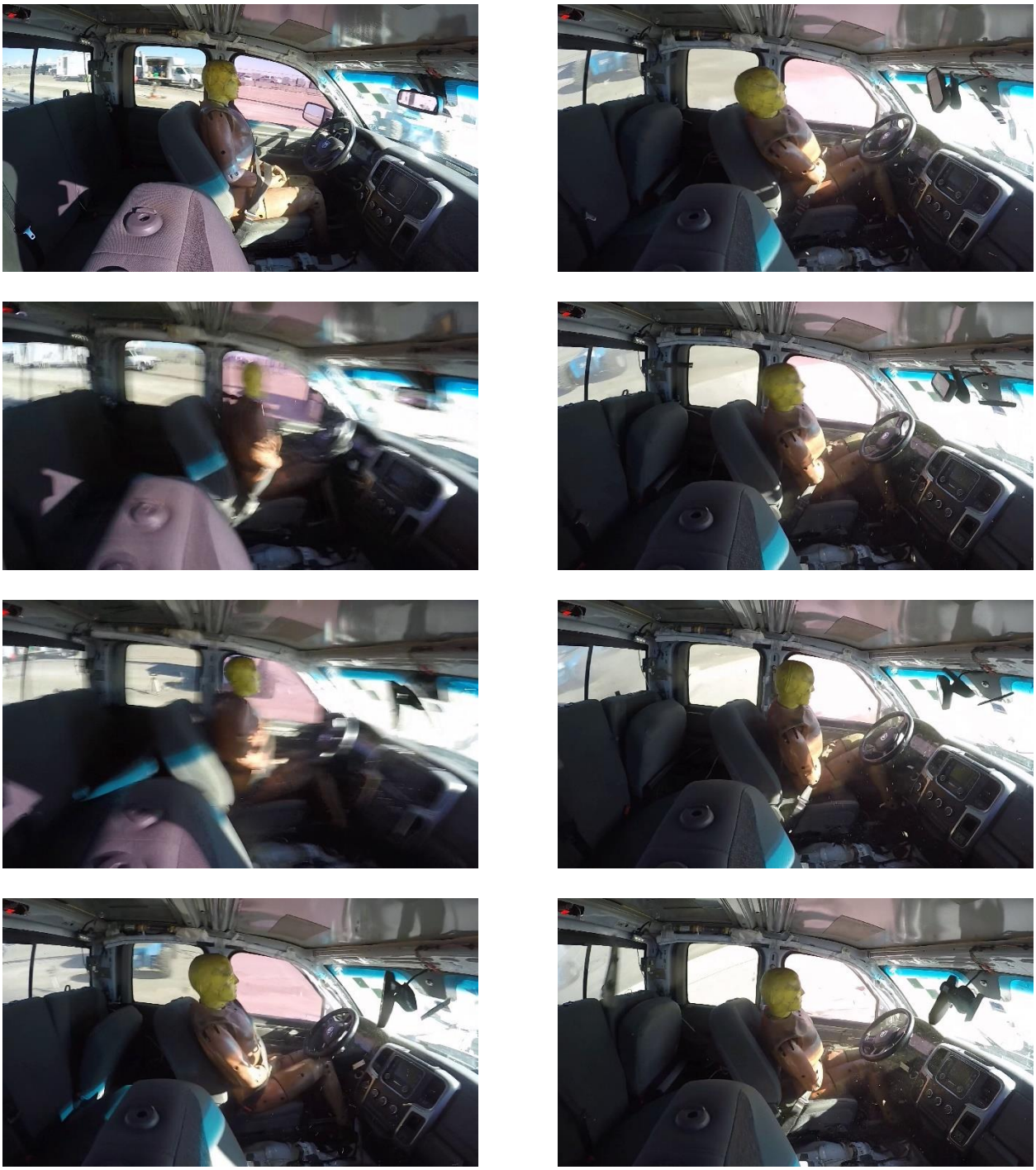


Figure 60. Additional Documentary Photographs, Test No. H42ST-1

Figure 61. Additional Documentary Photographs, Test No. H42ST-1

Figure 62. Vehicle Final Position and Trajectory Marks, Test No. H42ST-1

5.4 Barrier Damage

Damage to the barrier was moderate, as shown in Figures 63 through 66. Barrier damage consisted of post deflections, contact marks, rail kinking, and gouging and spalling of the concrete buttress and curb. The length of vehicle contact along the barrier was approximately 17 ft – 2 in., which spanned from 11 in. downstream from the center of post no. 16 and extended downstream onto the concrete buttress.

Contact marks on the thrie-beam rails were concentrated on the upper-middle and bottom corrugations. The marks started 13 in. downstream from the center of post no. 16 and onto the front and top face of the curb extending to the front and top of the concrete buttress. The upper half of the thrie-beam rails between post nos. 16 and 19 were flattened. Various rail kinking was found on the guardrail spanning from post no. 13 to post no. 19. The largest rail kinks were found around post nos. 17 and 19. The lower corrugation was also bent backward between post nos. 16 and 18.

Post no. 1 had a 1-in. soil gap on the upstream side, but no other damage was documented to the upstream anchorage. Post nos. 3 through 17 experienced slight counterclockwise rotation around the vertical axis. Post nos. 16 through 19 rotated backward, leaving soil gaps adjacent to the front flange, the largest of which were measured to be around 1 in. at post nos. 17 and 18. In addition to being deflected backward, post no. 18 experienced clockwise rotation, resulting in minor localized plastic deformations to the upstream sides of the front flanges adjacent to the blockouts.

The concrete curb had tire marks on the front and top face, starting 13 in. downstream from post no. 16 and extending onto the front and top face of the curb and front and top of the concrete buttress. The tire mark on the curb was 12 ft – 4 in long and 8 in. wide. A 6 ft – 10 in. long contact mark was found at the upstream end of the top face of the concrete buttress and extended across the entire width. Concrete spalling was found on the top-front edge of the concrete buttress behind the nested thrie beam, as depicted in Figure 66. Minor concrete spalling also occurred at the joint between the curb and the concrete buttress. Concrete cracking was observed on the back face of the curb (i.e., 3 in. from the top of the curb), starting 1 in. from the upstream face of the concrete buttress.

Figure 63. System Damage, Test No. H42ST-1

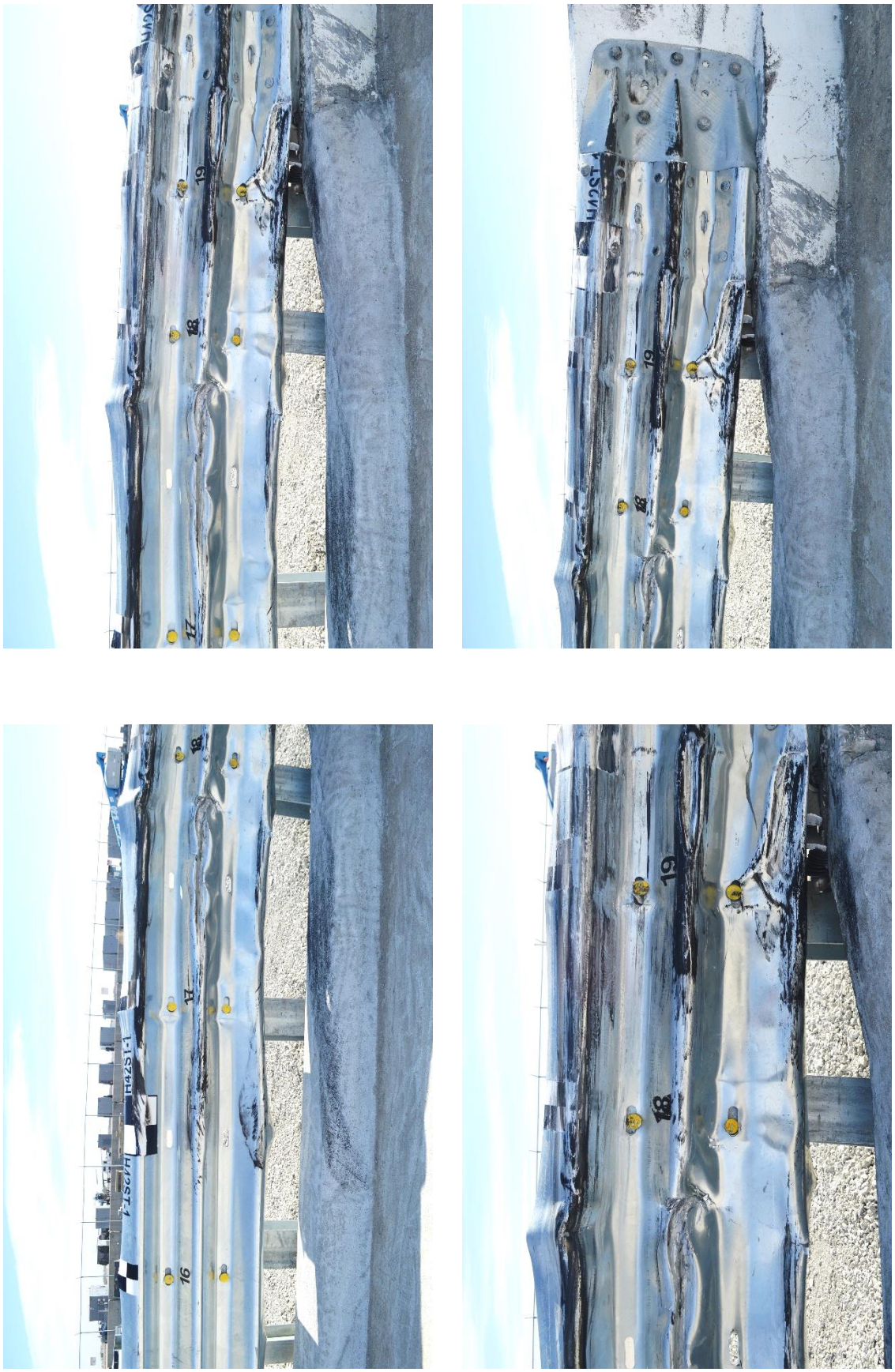


Figure 64. Thrie Beam Damage, Test No. H42ST-1

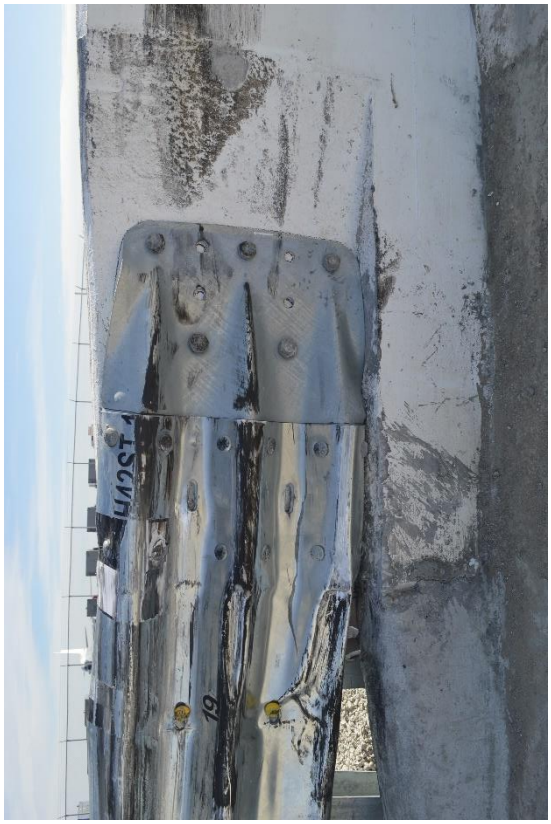


Figure 65. Rail Connection Terminal, Buttress, and Post Damage, Test No. H42ST-1

Figure 66. Buttress Damage, Test No. H42ST-1

The maximum lateral permanent set of the barrier system was 6.9 in. at post no. 18, as measured in the field. The maximum lateral dynamic barrier deflection was 11.0 in. at rail no. 17, as determined from high-speed digital video analysis. The working width of the system was found to be 27.8 in. at post no. 18, also determined from high-speed digital video analysis. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 67.

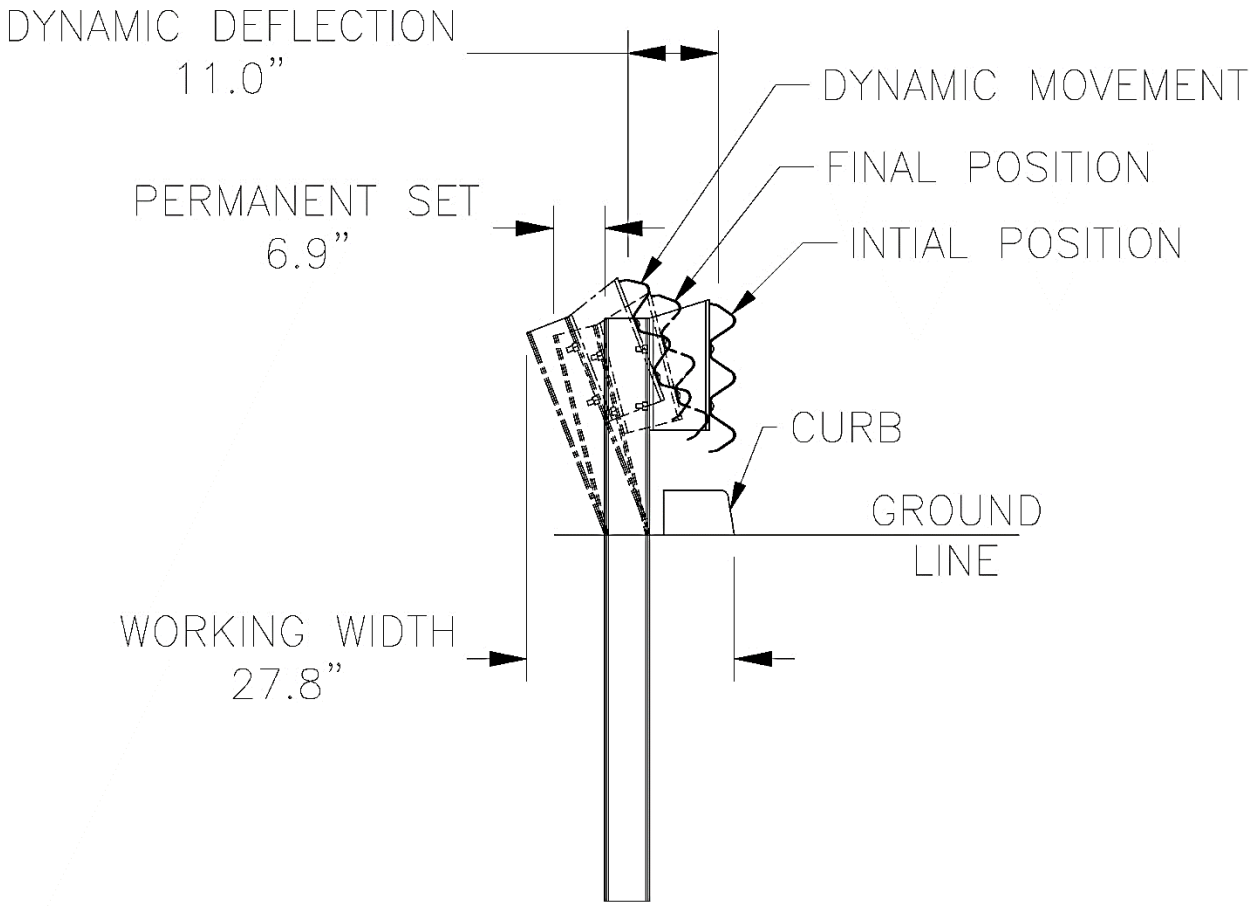


Figure 67. Permanent Set, Dynamic Deflection, and Working Width, Test No. H42ST-1

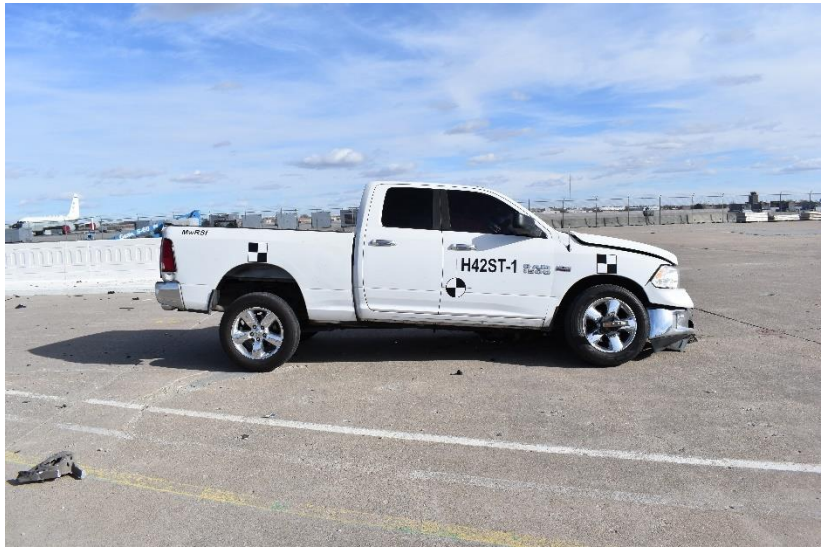
5.5 Vehicle Damage

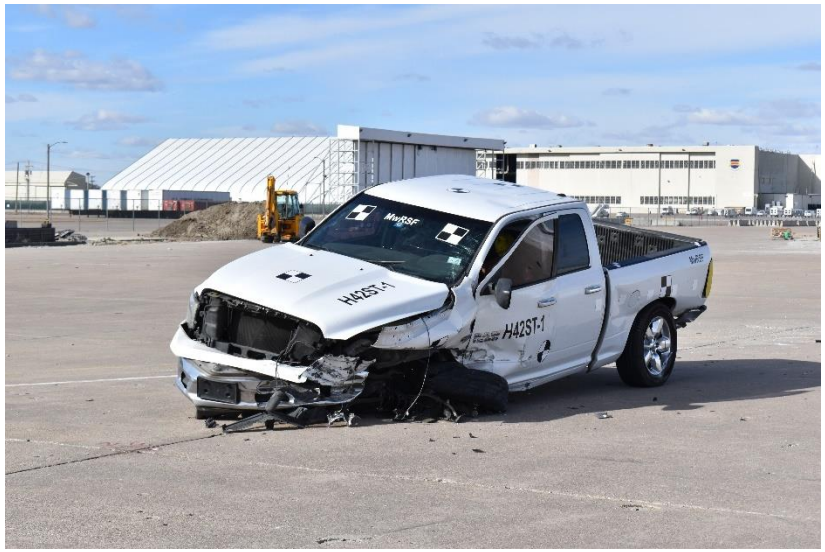
The damage to the vehicle was moderate to severe, as shown in Figures 68 through 72. The maximum occupant compartment intrusions are listed in Table 5, along with the intrusion limits established in MASH 2016 for various areas of the occupant compartment. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix D. MASH 2016 defines intrusion or deformation as the occupant compartment being deformed and reduced in size with no observed penetration. There were no penetrations into the occupant compartment, and none of the established MASH 2016 deformation limits were violated. Outward deformations, which are denoted as negative numbers in Appendix D, are not considered crush toward the occupant, and are not evaluated by MASH 2016 criteria.

The majority of the damage was concentrated on the left-front corner and left side of the vehicle where the impact had occurred. The grille disengaged from the vehicle, and the front

bumper was crushed inward. The left headlight was disengaged from the vehicle, while the hood remained intact. Significant damage was imparted to the left-front fender, including being crushed inward and folded at the bottom of the panel. The region by the lower A-pillar was severely crushed and dented by the wheel opening. The left-front door was scraped and crushed inward along its entire length, causing the door to bow outward in its center with the window frame severely bent; nonetheless, the glass remained intact. The left-rear door and fender remained intact. The left side of the windshield was cracked. The left box side was dented and scraped along its entire length, with the dent starting in the vertical center of the panel and ending at the lower edge of the panel behind the rear wheel opening.

The left-front shock was bent rearward with the bend at the top of the shock, and the bump stop showed an indication of contact with the lower control arm. The spring was disengaged from the vehicle. The sway and anti-roll bar linkage was detached from the lower control arm. The left-front steering knuckle was detached from both control arms and tie rod. The knuckle assembly was attached to the wheel hub and brake assembly but only attached to the vehicle by the brake line. The left-side upper control arm was bent and torn through the upper ball joint. The lower control arm was disengaged from the vehicle. The lower-left control arm was broken off at the ball joint and frame pivot mounts. The left tie rod was disengaged from the vehicle, and both inner and outer tie rods were detached from their mounting points. The engine mount on the left-front side was broken, and the engine tilted down on the left side. This fracture caused stress on the right-side engine and transmission mounts. The vehicle frame was bent near the right side of the wheel assembly. The front cross member was bent on the extreme right lower end, and the middle cross member buckled in the middle. On the right side, the horn frame bent inward.





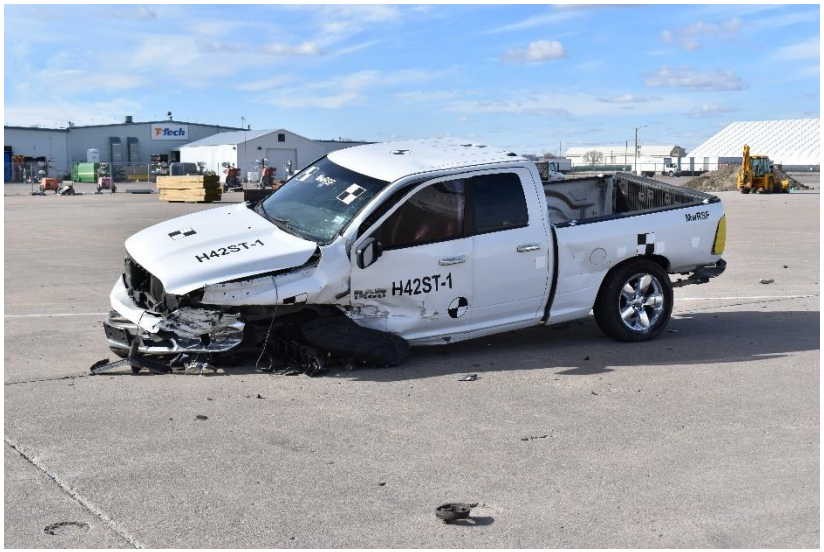
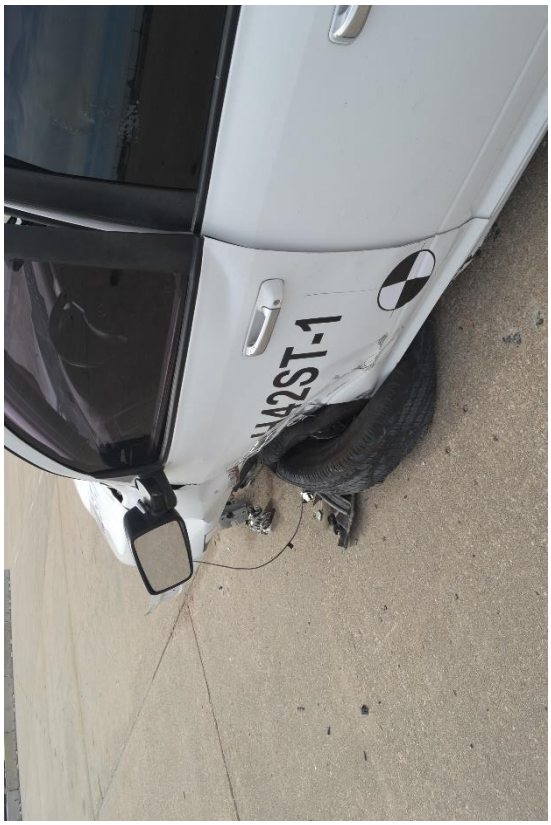


Figure 68. Vehicle Damage, Test No. H42ST-1

Figure 69. Vehicle Damage, Test No. H42ST-1



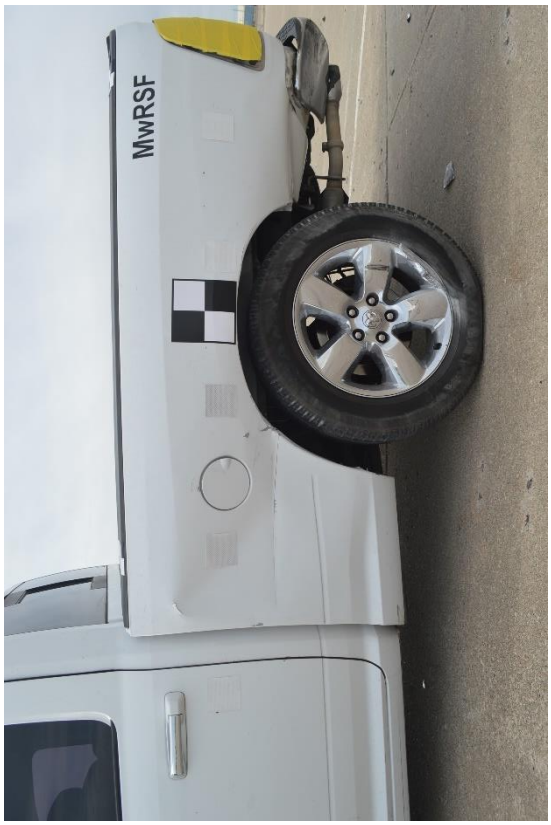


Figure 70. Vehicle Damage, Test No. H42ST-1

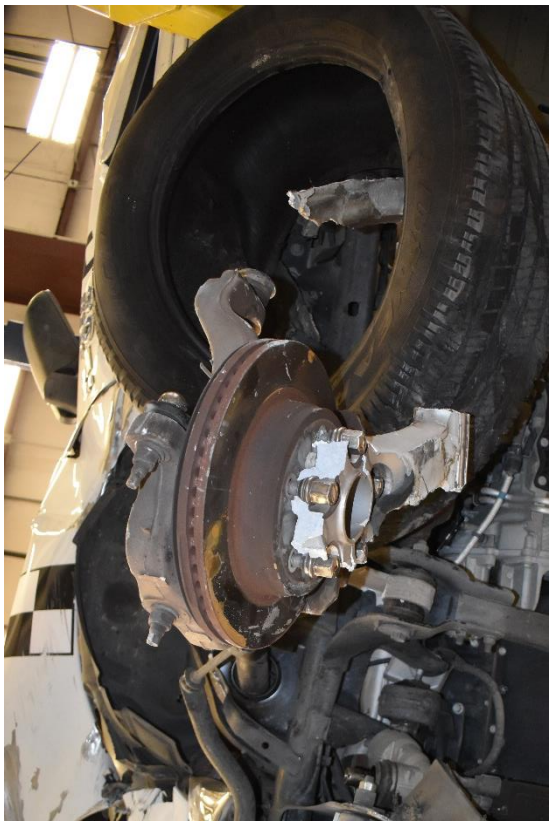
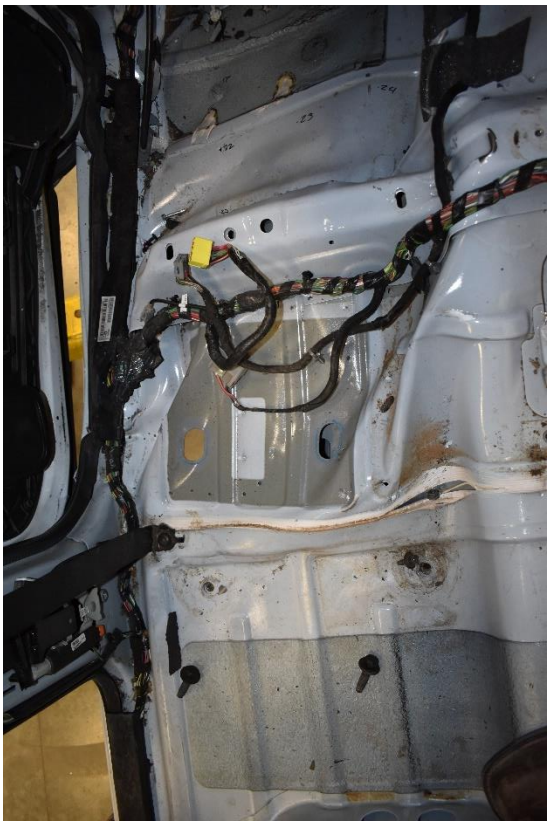


Figure 71. Vehicle's Left-Front Rim Damage and Debris, Test No. H42ST-1



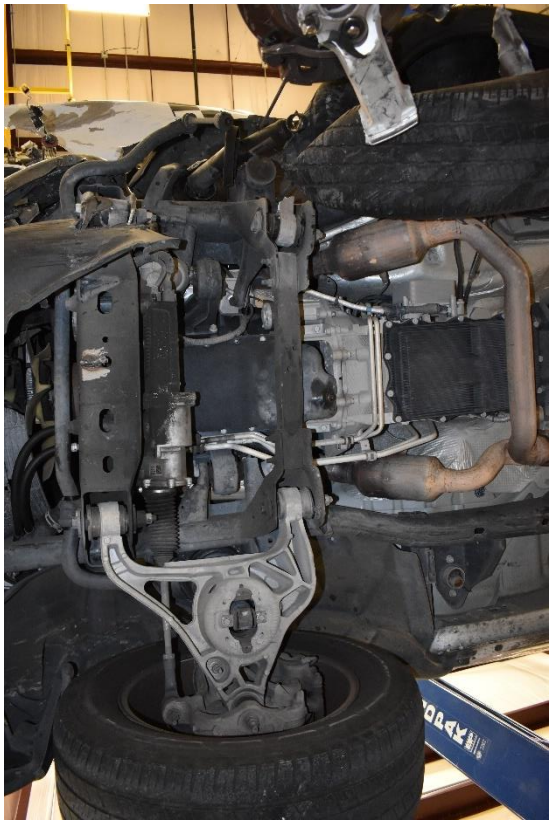


Figure 72. Vehicle Floorboard and Undercarriage Damage, Test No. H42ST-1

Table 5. Maximum Occupant Compartment Intrusion by Location, Test No. H42ST-1

Location	Maximum Intrusion in.	MASH 2016 Allowable Intrusion in.
Wheel Well & Toe Pan	6.1	≤ 9
Floor Pan & Transmission Tunnel	3.5	≤ 12
A-Pillar	0.4	≤ 5
A-Pillar (Lateral)	0.0*	≤ 3
B-Pillar	1.3	≤ 5
B-Pillar (Lateral)	0.0*	≤ 3
Side Front Panel (in Front of A-Pillar)	5.4	≤ 12
Side Door (Above Seat)	0.0*	≤ 9
Side Door (Below Seat)	0.0	≤ 12
Roof	1.1	≤ 4
Windshield	0.0	≤ 3
Side Window	Remained intact	No shattering resulting from contact with structural member of test article
Dash	3.0	N/A

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

5.6 Occupant Risk

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined from the accelerometer data, are shown in Table 6. Note that the OIVs and ORAs were within suggested limits, as provided in MASH 2016. The calculated THIV, PHD, and ASI values are also shown in Table 6. The recorded data from the accelerometers and the rate transducers is graphically demonstrated in Appendix E.

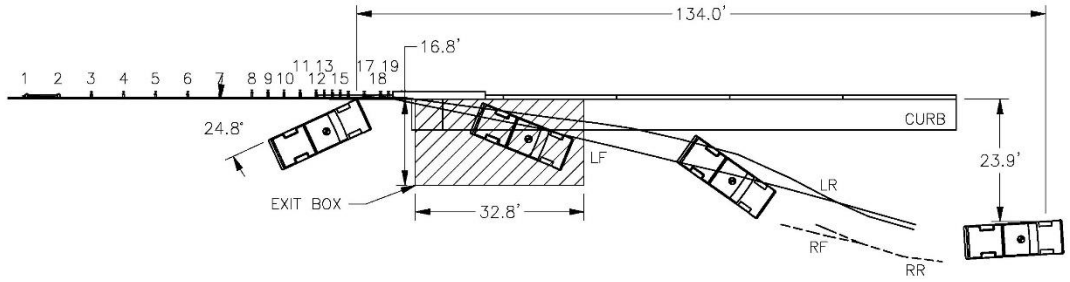
Table 6. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. H42ST-1

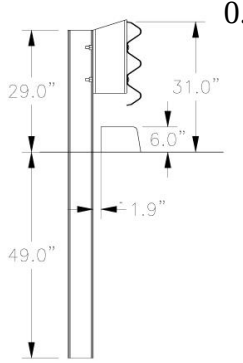
Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-2 (primary)	SLICE-1 (backup)	
OIV ft/s	Longitudinal	-32.53	-34.61	±40
	Lateral	25.05	23.20	±40
ORA g's	Longitudinal	-15.26	-14.96	±20.49
	Lateral	19.60	14.44	±20.49
Maximum Angular Displacement degrees	Roll	-29.6	-33.8	±75
	Pitch	-16.4	-14.6	±75
	Yaw	74.1	74.3	not required
THIV – ft/s		39.22	39.86	not required
PHD – g's		20.21	15.21	not required
ASI		1.78	1.77	not required

5.7 Discussion

During test no. H42ST-1, the left-front wheel contacted the thrie-beam rail and produced a more aggressive interaction between the elements than was observed in test no. HWTT-2 [2].. It should be noted that the 2270P test vehicle for test no. H42ST-1 had an aluminum rim, while a steel rim was used in test no. HWTT-2. A snag event occurred at the middle corrugation of the middle of the 37.5-in. long span nearest to the concrete buttress, resulting in some vehicle pocketing near the concrete buttress as well as rim gouging and/or snagging on the middle and lower rail humps. Again, these noted behaviors did not occur in test no. HWTT-2 as that thrie-beam rail appears to be smoother as compared to the test no. H42ST-1 observations. In test no. H42ST-1, this snagging behavior did not violate MASH 2016 evaluation criteria. Further details regarding test no. HWTT-2 can be found in the MwRSF report [2].

The analysis of the test results for test no. H42ST-1 showed that the system adequately contained and redirected the 2270P vehicle with controlled lateral displacements of the barrier. A summary of the test results and sequential photographs are shown in Figure 73. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or work-zone personnel. Deformations of, or intrusions into, the occupant compartment that could have caused severe injury did not occur. As shown in Appendix E, vehicle roll, pitch, and yaw angular displacements were deemed acceptable because they did not adversely influence occupant risk nor cause a rollover. After impact, the vehicle exited the barrier at an angle of 10.5 degrees, and its trajectory did not violate the bounds of the exit box. Therefore, test no. H42ST-1 was determined to be acceptable according to the MASH 2016 safety performance criteria for test designation no.3-21.





- Test Agency ..... MwRSF
- Test Number H42ST-1
- Date 2/7/2022
- MASH 2016 Test Designation No. 3-21
- Test Article ..... Thrie-beam AGT Attached to 42-in. Tall, Solid Concrete Bridge Rail with Aesthetic, Recessed, Rounded Panels and 6-ft. Wide Sidewalk and Approach Ramp
- Total Length ..... 184 ft – 6½ in.
- Key Component – 12 ft – 6 in. Nested and 6 ft – 3 in. Single Thrie-beam Guardrail
  - Thickness ..... 12 gauge
  - Mounting Height ..... 31 in.
- Key Component - ASTM A992 W6x15 Steel Post
  - Length ..... 78 in.
  - Width ..... 49 in.
  - Spacing ..... 37½ in.
- Soil Type ..... Coarse, Crushed Limestone (Well-Graded Gravel)
- Vehicle Make/Model ..... Dodge Ram 1500
  - Curb ..... 5,258 lb
  - Test Inertial ..... 5,041 lb (MASH 2016 Limit 5,000 ±110 lb)
  - Gross Static ..... 5,199 lb (MASH 2016 Limit 5,165 ±110 lb)
- Impact Conditions
  - Speed ..... 64.7 mph (MASH 2016 Limit 62 ±2.5 mph)
  - Angle ..... 24.8 degrees (MASH 2016 Limit 25 ±1.5 degrees)
  - Impact Location ..... 79.9 in. upstream from the upstream end of concrete buttress
- Impact Severity ..... 124.1 kip-ft > 105.6 kip-ft MASH 2016 limit
- Exit Conditions
  - Speed ..... 40.2 mph
  - Angle ..... 10.5 degrees
- Exit Box Criterion ..... Pass
- Vehicle Stability ..... Satisfactory
- Vehicle Stopping Distance ..... 134 ft downstream, 23.9 ft laterally in front

Vehicle Damage ..... Moderate
- VDS [15] 10-LFQ-5
- CDC [16] 11-LFEW-4
- Maximum Interior Deformation ..... 6 in. ≤ 9 in. toe pan MASH 2016 limit

- Test Article Damage ..... Moderate
- Maximum Test Article Deflections
  - Permanent Set ..... 6.9 in.
  - Dynamic Deflection ..... 11.0 in.
  - Working Width ..... 27.8 in.
- Transducer Data

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-2 (Primary)	SLICE-1 (Backup)	
OIV ft/s	Longitudinal	-32.53	-34.61	±40
	Lateral	25.05	23.20	±40
ORA g's	Longitudinal	-15.26	-14.96	±20.49
	Lateral	19.60	14.44	±20.49
Maximum Angular Displacement degrees	Roll	-29.6	-33.8	±75
	Pitch	-16.4	-14.6	±75
	Yaw	74.1	74.3	not required
THIV – ft/s		39.22	39.86	not required
PHD – g's		20.21	15.21	not required
ASI		1.78	1.77	not required

Figure 73. Summary of Test Results and Sequential Photographs, Test No. H42ST-1

6 FULL-SCALE CRASH TEST NO. H42ST-2

6.1 Static Soil Test

Before full-scale crash test no. H42ST-2 was conducted, the strength of the foundation soil was evaluated with a static test, as described in MASH 2016. The static test results, as shown in Appendix C, demonstrated a soil resistance above the baseline test limits. Thus, the soil provided adequate strength, and full-scale crash testing could be conducted on the barrier system.

6.2 Weather Conditions

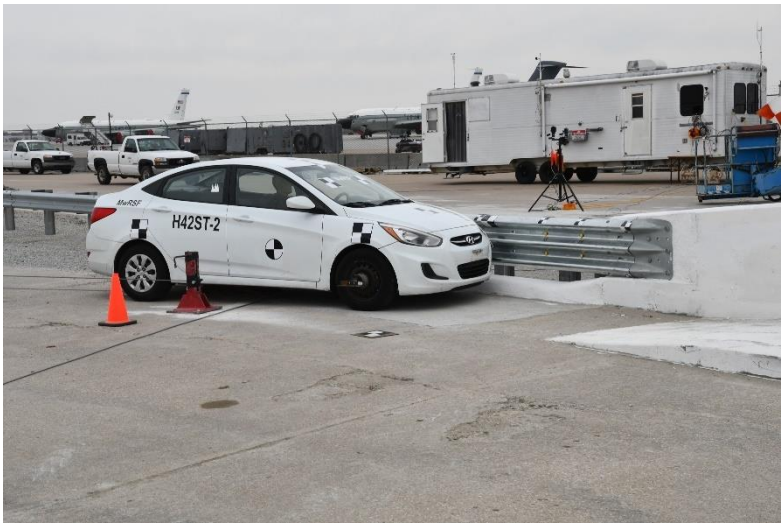
Test no. H42ST-2 was conducted on March 29, 2022 at approximately 2:15 p.m. The weather conditions as reported by the National Oceanic and Atmospheric Administration (station 14939/LNK) are shown in Table 7.

Table 7. Weather Conditions, Test No. H42ST-2

Temperature	65°F
Humidity	45%
Wind Speed	22 mph
Wind Direction	120° from True North
Sky Conditions	Clear
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0 in.
Previous 7-Day Precipitation	0.45 in.

6.3 Test Description

Initial vehicle impact was to occur 60 in. upstream from the upstream end of the concrete buttress, as shown in Figure 74, which was selected using the CIP plots found in Figure 2-14 of MASH 2016 to maximize the probability of pocketing and vehicle snag on the concrete parapet. The 2,430-lb passenger car impacted the thrie-beam AGT attached to the 42-in. tall, solid concrete bridge rail with aesthetic, recessed, rounded panels and 6-ft wide sidewalk at a speed of 62.4 mph and at an angle of 25.1 degrees. The TL-3 impact severity for test no. H42ST-2 was 56.9 kip-ft, which was greater than the minimum value of 51.1 kip-ft. As such, results from test no. H42ST-2 could be considered as a valid indicator of the system's overall safety performance. The actual point of impact was 1.1 in. upstream from the targeted impact location. The vehicle was contained and redirected with only minor system deflections. During the redirection of the vehicle, the simulated occupant's head contacted the side window and caused the window to shatter but did not strike any barrier components. All measured accelerations resulted in occupant risk values (OIV and ORA) within the MASH allowed limits. The vehicle remained stable throughout the impact event. After exiting the system, the vehicle continued traveling downstream before the remote brakes were applied, and the vehicle came to a stop 156.8 ft downstream and 51.7 ft in front of the system. A detailed description of the sequential impact events is contained in Table 8. Sequential photographs are shown in Figures 75 and 76. Documentary photographs of the crash test are shown in Figures 77 and 80. The vehicle trajectory and final position are shown in Figure 81.



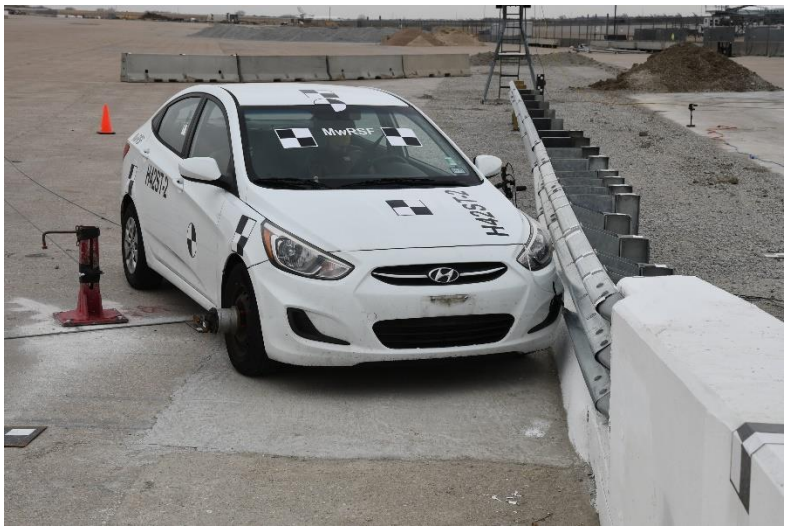


Figure 74. Target Impact Location, Test No. H42ST-2

Table 8. Sequential Description of Impact Events, Test No. H42ST-2

Time (sec)	Event
0.000	Vehicle's front bumper contacted rail 60 in. upstream from end of concrete buttress.
0.006	Vehicle's left fender contacted rail and was crushed inward and scraped along its entire length.
0.010	Vehicle's left headlight contacted rail and shattered.
0.012	Rail between post no. 17 and post no. 18 deflected backward.
0.016	Post no. 17 rotated backward.
0.017	Vehicle's left-front tire contacted curb. Rail between post no. 18 and post no. 19 deflected backward.
0.020	Post nos. 18, 19, and 20 rotated backward.
0.030	Vehicle's right headlight disengaged.
0.032	Vehicle's left A-pillar deformed.
0.036	Vehicle's left-front door contracted rail and was crushed inward. Vehicle yawed away from barrier.
0.040	Vehicle's windshield cracked and vehicle's left-front tire deflected. Vehicle's left-front door became ajar. Vehicle's roof deformed.
0.052	Vehicle rolled toward barrier.
0.058	Vehicle's rear-view mirror disengaged.
0.090	Vehicle rolled away from barrier.
0.100	Simulated occupant's head contacted left-front window and shattered it.
0.118	Vehicle's front bumper and grille disengaged.
0.167	Vehicle became parallel to system at a speed of 46.8 mph.
0.196	Vehicle's rear bumper contacted rail and deformed.
0.214	Vehicle's left quarter panel contacted rail and deformed.
0.222	Vehicle's right-front tire became airborne, vehicle's left quarter panel contacted concrete parapet and deformed, and vehicle's left-rear door contacted concrete parapet and deformed.
0.260	Vehicle's left taillight contacted concrete parapet and shattered.
0.282	Vehicle's right-rear tire become airborne.
0.292	Vehicle exited system at a speed of 38.5 mph and 10.8 degrees.
0.294	System came to rest.
0.380	Vehicle pitched downward.
0.424	Vehicle's left-rear tire become airborne.
0.536	Vehicle's right-front tire contacted ground.
0.660	Vehicle pitched upward.
0.858	Vehicle's left-rear tire contacted ground.
1.036	Vehicle's right-rear tire became airborne.
1.612	Vehicle's right rear tire contacted ground.
3.726	Vehicle came to rest.


0.000 sec


0.000 sec


0.10 sec


0.100 sec


0.200 sec


0.200 sec


0.300 sec


0.300 sec


0.500 sec


0.500 sec


0.800 sec


0.800 sec

Figure 75. Sequential Photographs, Test No. H42ST-2


0.000 sec

0.050 sec

0.100 sec

0.150 sec

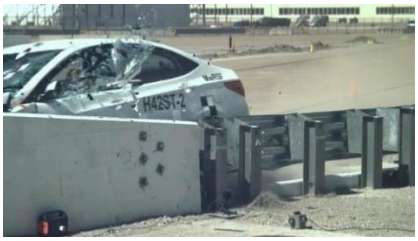

0.200 sec


0.250 sec


0.000 sec


0.050 sec

0.100 sec



0.150 sec

0.200 sec


0.250 sec

Figure 76. Additional Sequential Photographs, Test No. H42ST-2

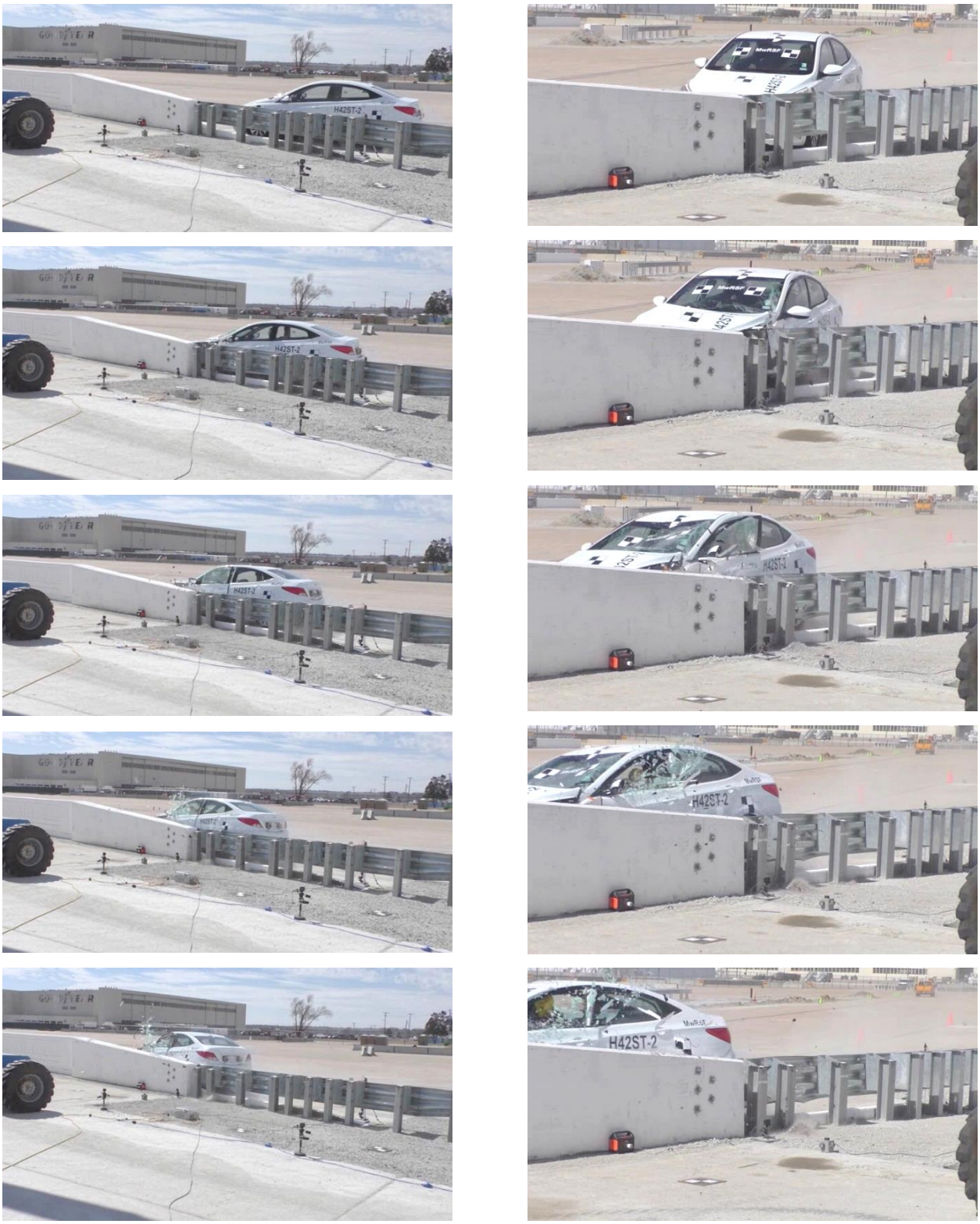


Figure 77. Documentary Photographs, Test No. H42ST-2

Figure 78. Additional Documentary Photographs, Test No. H42ST-2

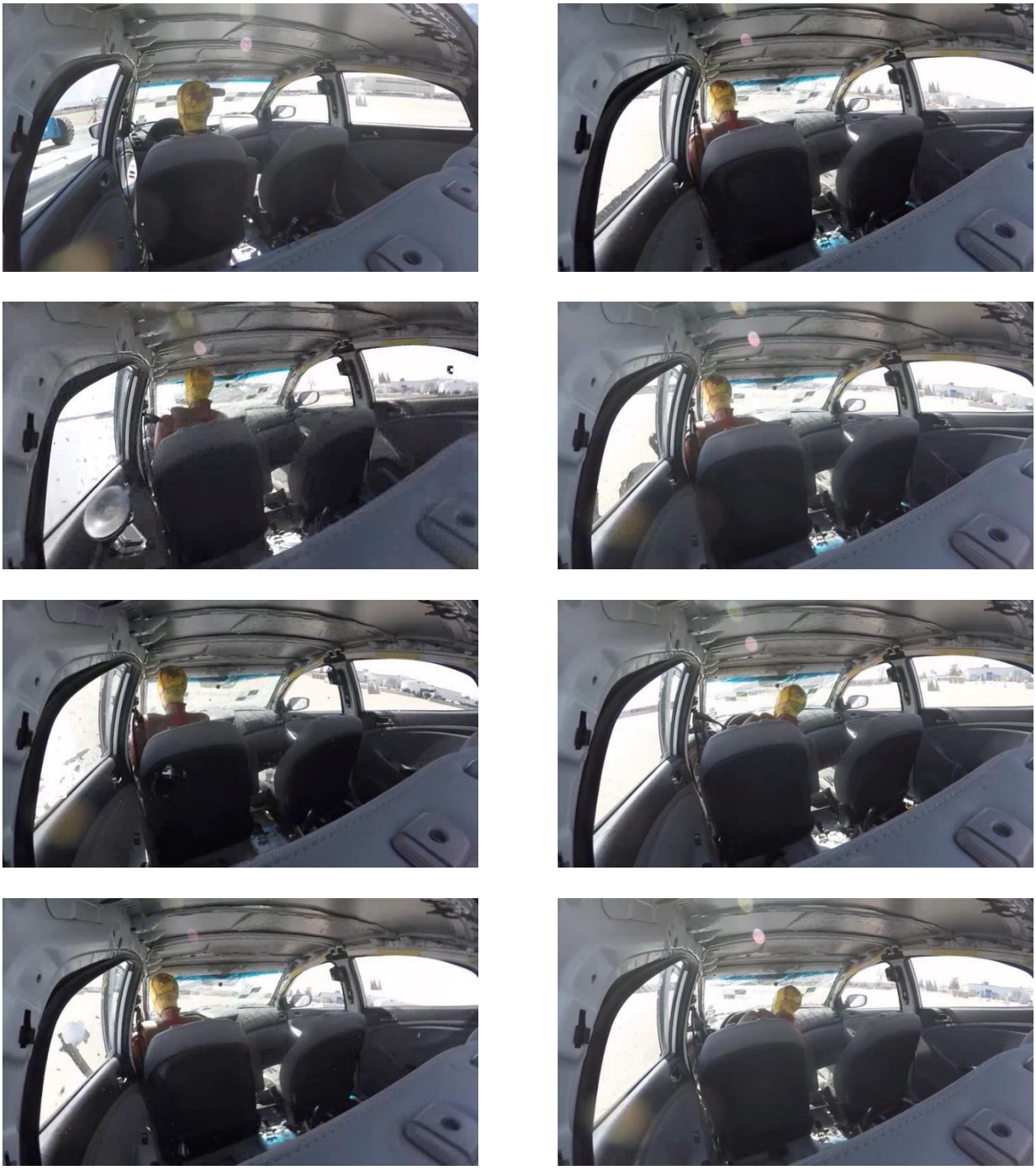


Figure 79. Additional Documentary Photographs, Test No. H42ST-2

Figure 80. Additional Documentary Photographs, Test No. H42ST-2

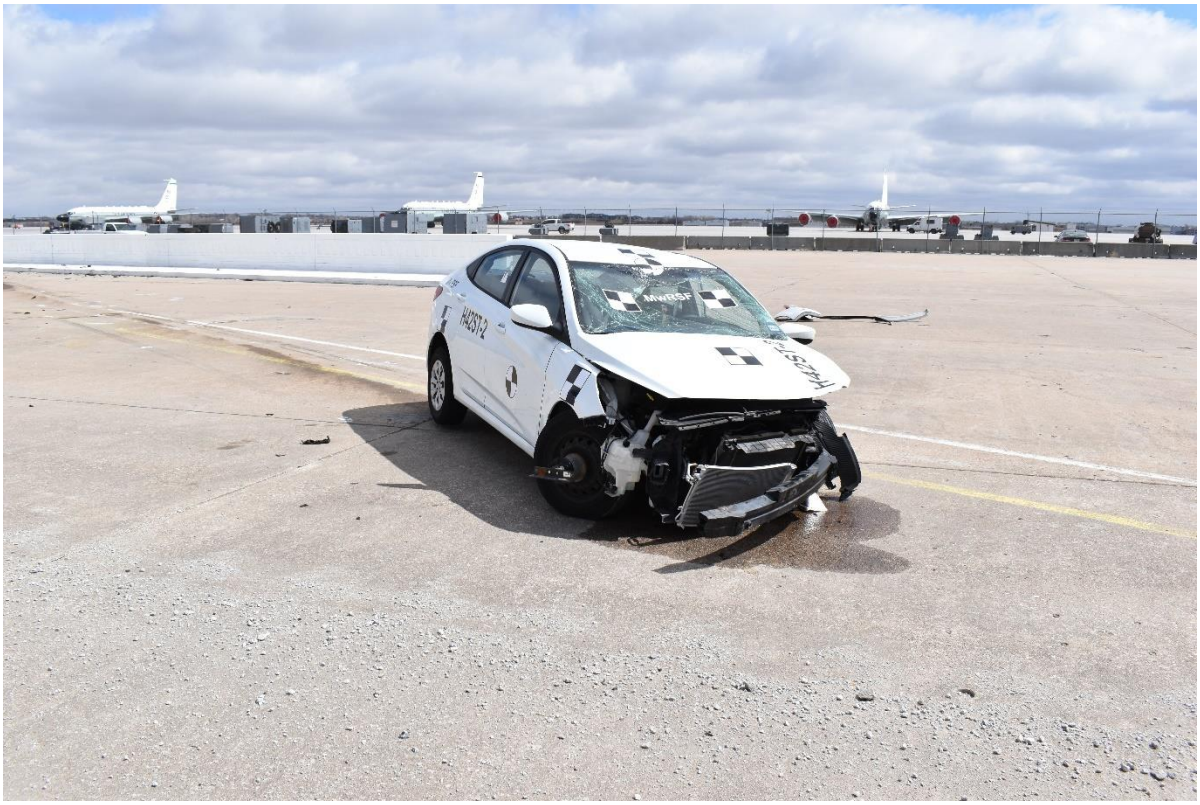


Figure 81. Vehicle Final Position and Trajectory Marks, Test No. H42ST-2

6.4 Barrier Damage

Damage to the barrier was minimal, as shown in Figure 82 through 84. Barrier damage consisted of contact marks and kinking of the thrie-beam sections, contact marks on the front face of the concrete buttress, and gouging of the concrete. The length of vehicle contact along the barrier was approximately 10 ft – 9 in., which began 2 in. downstream from the center of post no. 17 and extended onto the concrete parapet.

Contact marks on the thrie beam began 2 in. downstream from the centerline of post no. 17 and extended to the downstream end of thrie beam and onto the anchor plate for a total length of 6 ft – 9½ in. A contact mark was found on the upstream face of the concrete parapet with a length of 5 ft – 3 in. and extended to the downstream end of the curb. The bottom corrugation sustained various degrees of flattening damage beginning 9 in. downstream from the center of post no. 17. Multiple kinks were found on the top and bottom of the thrie beam around post nos. 13, 14, 17, and 19. Post nos. 18 and 19 slightly rotated counterclockwise, but there was no damage to the posts.

A contact mark was found on the concrete curb starting 2½ in. downstream from the centerline of post no. 17 and extending to the downstream edge of the concrete parapet. The length of this contact mark was approximately 5 ft – 4 in. The top and front edge of the curb was gouged beginning 9½ in. downstream from the centerline of post no. 19 and continued downstream onto the upstream edge of the concrete parapet. The most significant gouging occurred 21 in. downstream from the upstream edge of the concrete parapet. A ¼-in. soil gap was observed behind the back of the curb starting 15 in. upstream from the centerline of post no. 17 and extending to the upstream face of the concrete parapet.

Figure 82. System Damage, Test No. H42ST-2

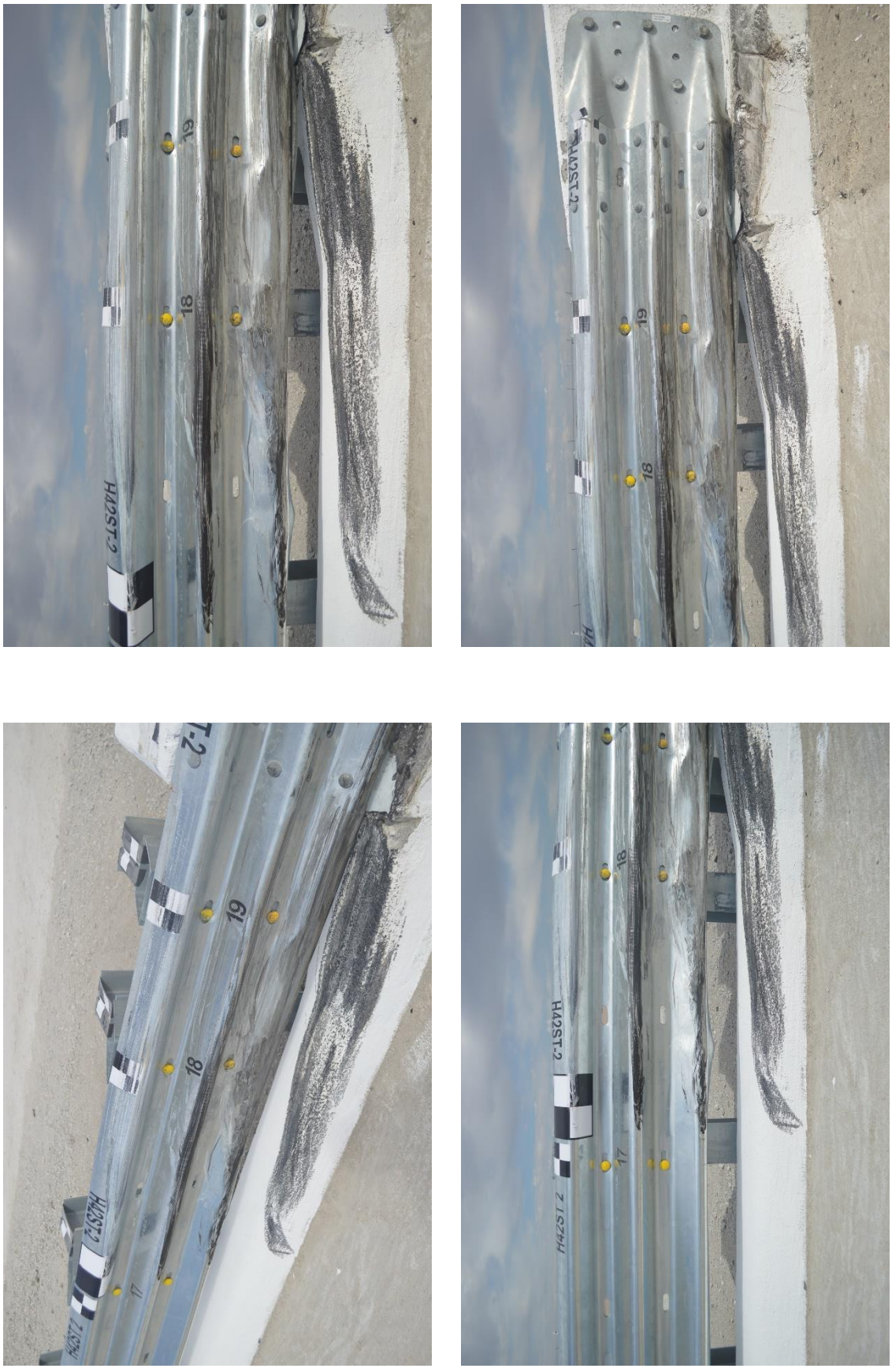


Figure 83. Thrie Beam Damage, Test No. H42ST-2

Figure 84. Rail Connection Terminal, Buttress, and Post Damage, Test No. H42ST-2

The maximum lateral permanent set of the barrier system was 1.3 in., which occurred in the thrie beam between post nos. 17 and 18, as measured in the field. The maximum lateral dynamic barrier deflection was 2.5 in. at post no. 18, as determined from high-speed digital video analysis. The working width of the system was found to be 21.9 in. at post no. 15, also determined from high-speed digital video analysis. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 85.

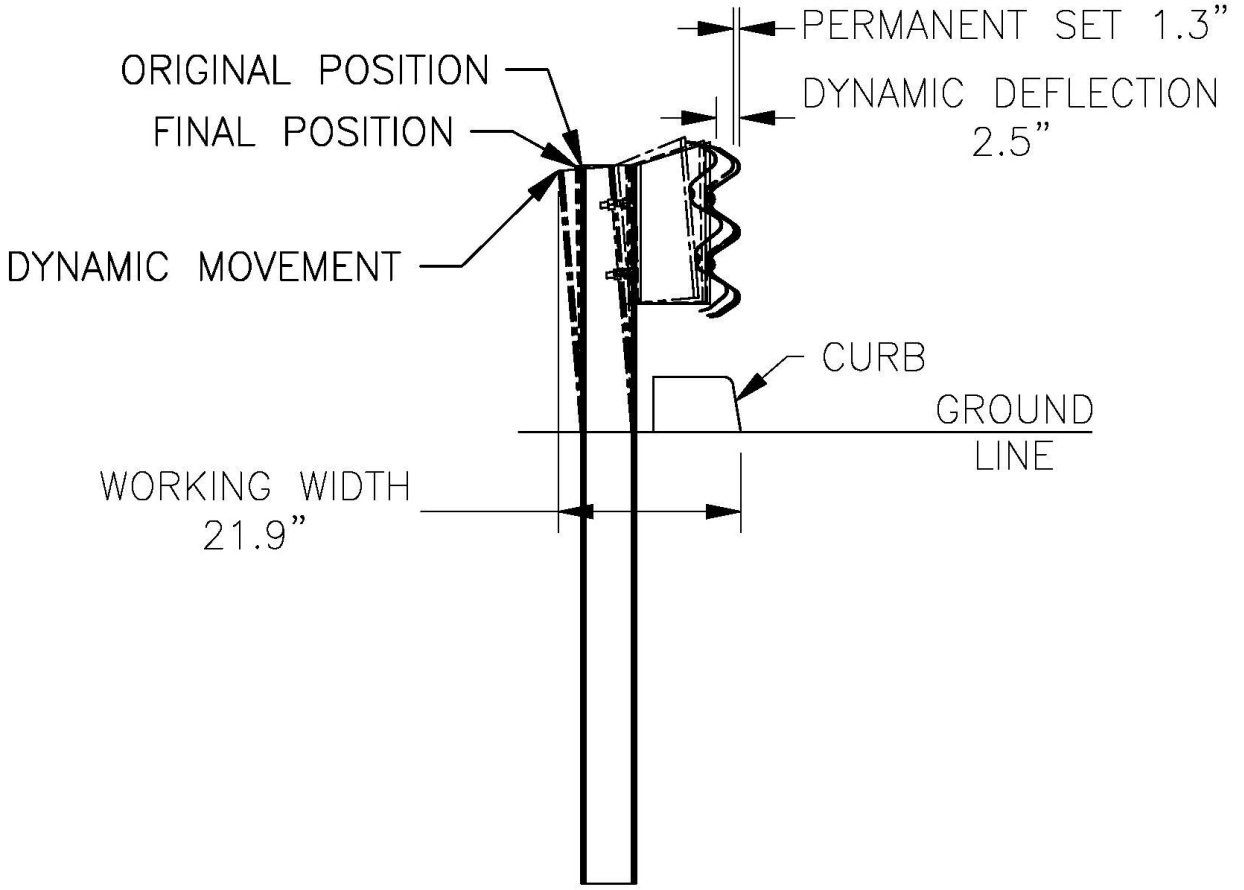


Figure 85. Permanent Set, Dynamic Deflection, and Working Width, Test No. H42ST-2

6.5 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 86 through 89. The maximum occupant compartment intrusions are listed in Table 9, along with the intrusion limits established in MASH 2016 for various areas of the occupant compartment. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix D. MASH 2016 defines intrusion or deformation as the occupant compartment being deformed and reduced in size with no observed penetration. Outward deformations, which are denoted as negative numbers in Appendix D, are not considered crush toward the occupant, and are not evaluated by MASH 2016 criteria.

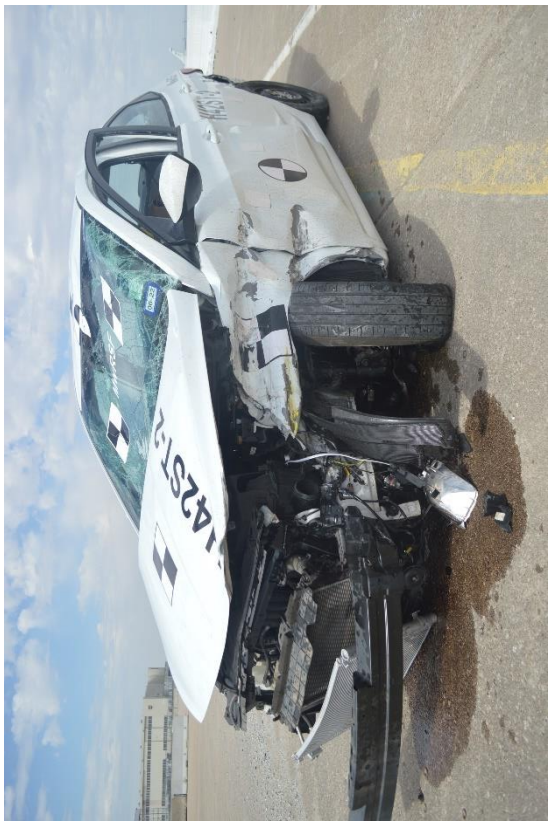
The majority of the damage was concentrated on the left-front corner and left side of the vehicle where the impact occurred. The left side of the vehicle hood was bent and slightly scraped.

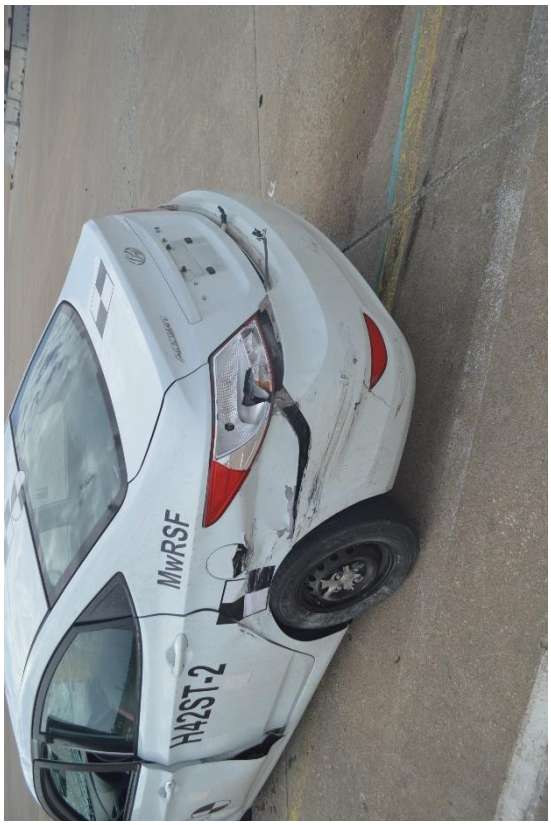
Scraping and inward crushing were recorded on the left-front fender. The front bumper cover disengaged from the vehicle, with the bumper structure detached on the right side after snagging between the thrie beam and curb. The left side of the leading edge of the hood was bent and slightly scraped. The left-front and right-front headlights shattered, and the left-front door was crushed inward at its leading edge and dented throughout. The left-front door panel was separated from the inner panel at the rear edge and protruded outward. The left-rear door was slightly scraped, starting at the panel's trailing edge about 10 in. below the door handle. The left-rear quarter panel was dented and scraped above the wheel opening, extending rearwards to the taillight area. The left-rear taillight was intact, but the lens was disengaged. The rear bumper cover was scraped along the extreme left end of the cover, wrapping around and slightly extending to the lateral section of the bumper. Contact with the head of the simulated occupant caused the left-front window to shatter.

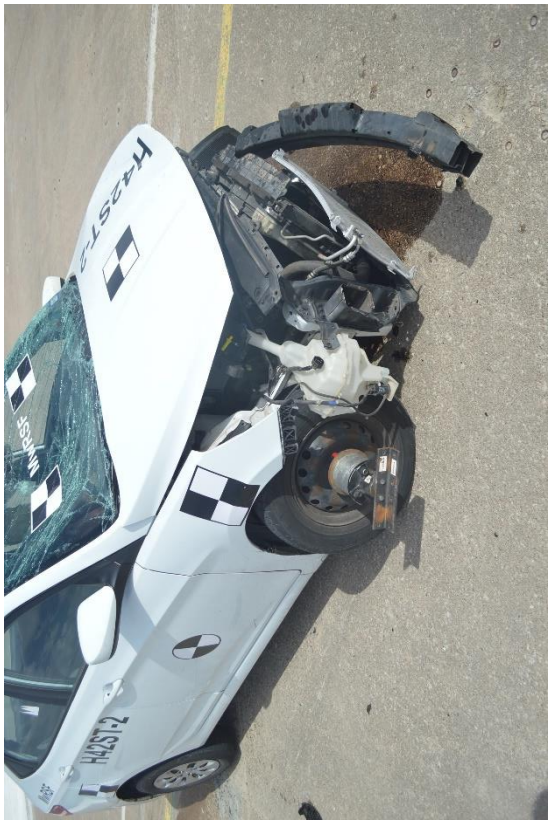
Undercarriage damage was moderate. No damage occurred to the left-front shock and springs, including the bump stops. The front-left side link of the sway and anti-roll bar were bent, and there was no damage to the rear side. The left-front steering knuckle was fractured at the strut mount. The left control arm was bent and slightly twisted with scraping along the trailing edge of the arm in the center of the test vehicle. The left outer tie rod of the steering control arm was significantly bent. The transmission case was cracked on the very left end. There was no damage to the oil pan, engine, or transmission mounts. The front engine cross member was bent and twisted, with the majority of the damage on the left side. The right side of the frame horn was slightly bent outward, while the left side was slightly bent inward.

The windshield was cracked across its entire width and was deformed inward 3.5 in., which exceeded the MASH 2016 limit of 3 in. However, the deformation was due to the translation of the base of the bottom-left A-pillar and did not occur due to direct contact with the test article, nor pose a penetration hazard to the vehicle occupant. Thus, this damage was not a violation of MASH 2016 criteria. Similar windshield damage and deformation had been observed in other recent MASH 1100C tests into rigid barriers, including full-scale crash testing of the Hawaii 34-in. tall (i.e., test no. H34BR-1) and 42-in. (i.e., test no. H42BR-1) tall concrete bridge rails [3, 17] as well as full-scale crash testing of the North Carolina two-bar metal bridge rail (i.e., test no. NCBR-1) [18]. Windshield damage in the form of tearing and deformations have been allowed for these other systems/tests when the barrier does not make direct contact with the windshield, as seen in the FHWA eligibility letters provided for each system [19-21].

Figure 86. Vehicle Damage, Test No. H42ST-2







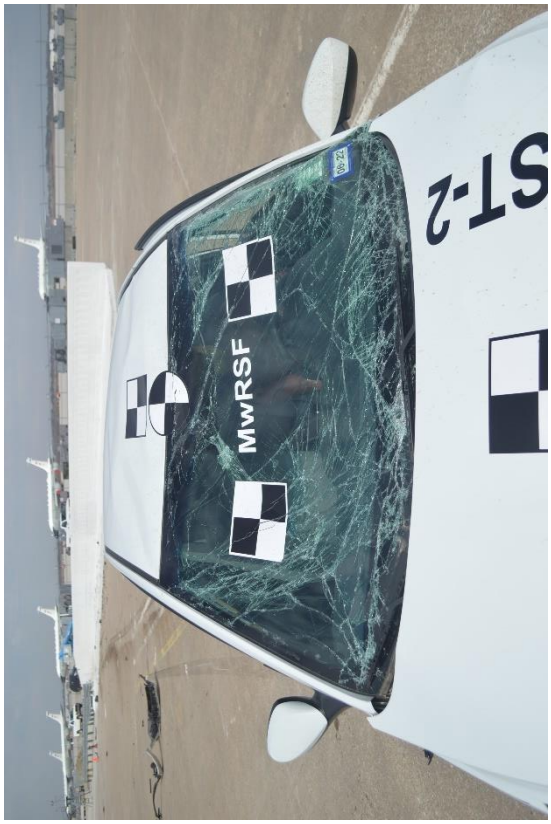
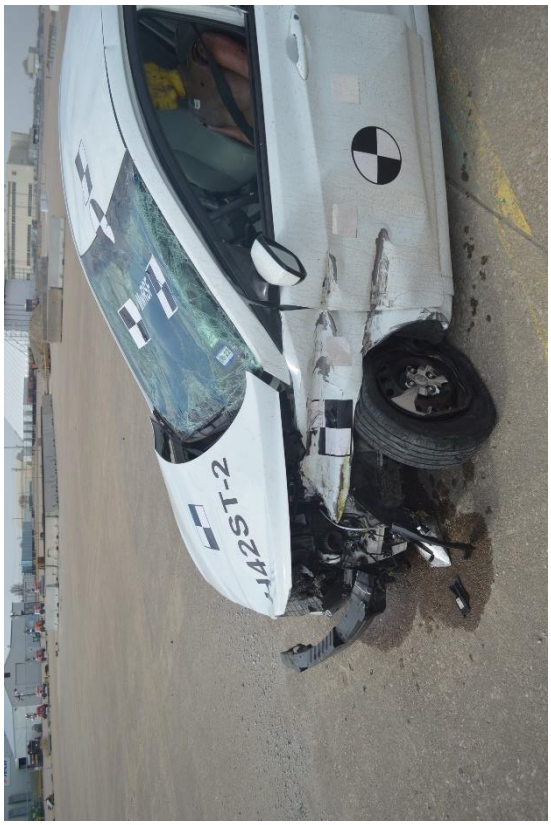


Figure 87. Vehicle Damage, Test No. H42ST-2



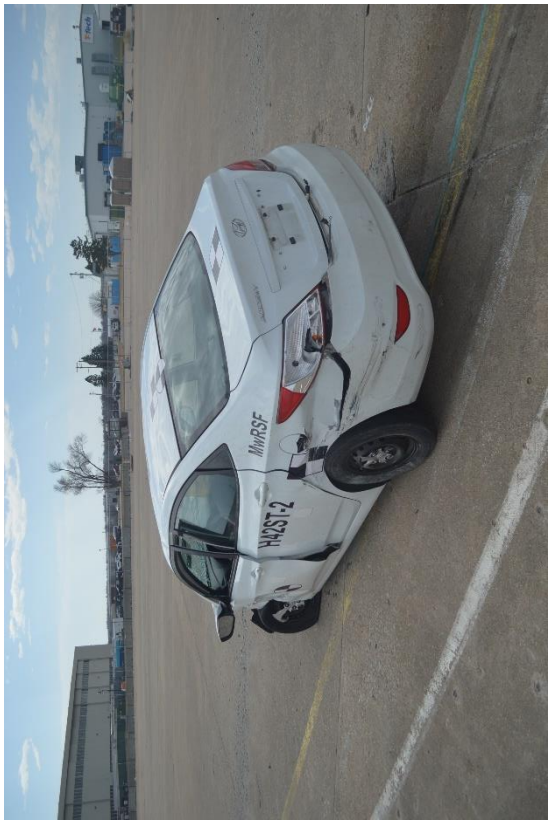


Figure 88. Vehicle Damage, Test No. H42ST-2

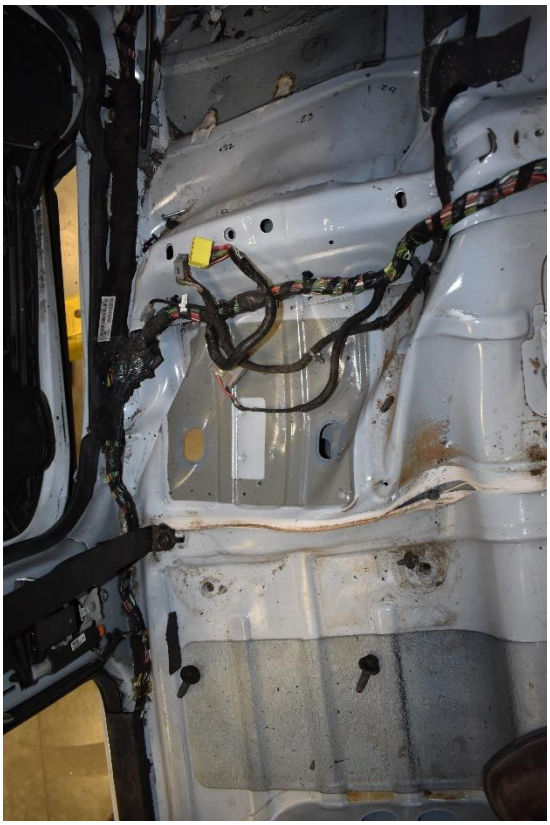


Figure 89. Vehicle Damage, Test No. H42ST-2

Table 9. Maximum Occupant Compartment Intrusion by Location, Test No. H42ST-2

Location	Maximum Intrusion in.	MASH 2016 Allowable Intrusion in.
Wheel Well & Toe Pan	1.2	≤ 9
Floor Pan & Transmission Tunnel	0.9	≤ 12
A-Pillar	0.6	≤ 5
A-Pillar (Lateral)	0.6	≤ 3
B-Pillar	0.3	≤ 5
B-Pillar (Lateral)	0.6	≤ 3
Side Front Panel (in Front of A-Pillar)	2.7	≤ 12
Side Door (Above Seat)	0.0*	≤ 9
Side Door (Below Seat)	0.0*	≤ 12
Roof	0.2	≤ 4
Windshield	3.5†	≤ 3
Side Window	Shattered due to contact with dummy's head	No shattering resulting from contact with structural member of test article
Dash	2.2	N/A

N/A – No MASH 2016 criteria exist for this location.

*Negative value reported as 0.0. See Appendix D for further information.

†The windshield damage occurred due to translation of the base of the vehicle's bottom-left A-pillar. The windshield experienced lateral flexure, which resulted in vertical creases, but this deformation was unrelated to impact and does not violate MASH 2016 evaluation criteria.

6.6 Occupant Risk

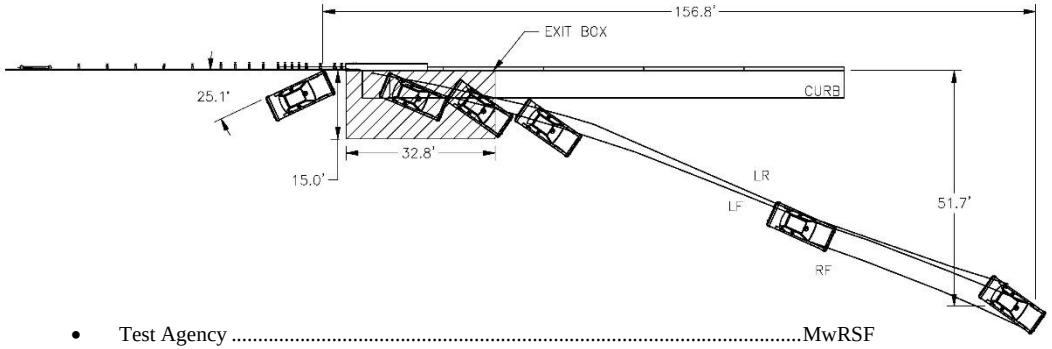
The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions, as determined from the accelerometer data, are shown in Table 10. Note that the OIVs and ORAs were within suggested limits, as provided in MASH 2016. The calculated THIV, PHD, and ASI values are also shown in Table 10. The recorded data from the accelerometers and the rate transducers is shown graphically in Appendix F.

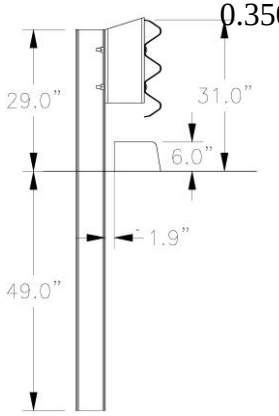
Table 10. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. H42ST-2

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1 (primary)	SLICE-2 (backup)	
OIV ft/s	Longitudinal	-30.24	-30.19	±40
	Lateral	33.49	30.29	±40
ORA g's	Longitudinal	-11.79	-10.52	±20.49
	Lateral	10.92	13.77	±20.49
Maximum Angular Displacement degrees	Roll	8.8	9.4	±75
	Pitch	-7.2	-10.0	±75
	Yaw	61.5	60.5	not required
THIV – ft/s		39.65	38.32	not required
PHD – g's		11.02	13.85	not required
ASI		2.76	2.69	not required

6.7 Discussion

The analysis of the test results of test no. H42ST-2 showed that the system adequately contained and redirected the 1100C vehicle with controlled lateral displacements of the barrier. A summary of test results and sequential photographs are shown in Figure 85. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or work-zone personnel. Deformations of, or intrusion into, the occupant compartment that could have caused severe injury did not occur. The simulated occupant's head extended out the side window but did not contact any barrier components. Deformation of the windshield measuring 3.5 in. exceeded the MASH 2016 limit of 3 in. However, the deformation was due to the translation of the base of the bottom-left A-pillar and did not occur due to direct contact with the test article, nor pose a penetration hazard to the vehicle occupant. Thus, this damage was not a violation of MASH 2016 criteria. The test vehicle did not penetrate nor override the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix F, were deemed acceptable as they did not adversely influence occupant risk nor caused rollover. After impact, the vehicle exited the barrier at angle of 10.8 degrees, and its trajectory did not violate the bounds of the exit box. Thus, test no. H42ST-2 was determined to be acceptable according to the MASH 2016 safety performance criteria for test designation no. 3-20.





- Test Agency ..... MwRSF
- Test Number H42ST-2
- Date 3/29/2022
- MASH 2016 Test Designation No. 3-20
- Test Article ..... Thrie-beam AGT Attached to 42-in. Tall, Solid Concrete Bridge Rail with Aesthetic, Recessed, Rounded Panels and 6-ft. Wide Sidewalk and Approach Ramp
- Total Length ..... 184 ft – 6½ in.
- Key Component – 12 ft – 6 in. Nested and 6 ft – 3 in. Single Thrie-beam Guardrail
  - Thickness ..... 12 gauge
  - Mounting Height ..... 31 in.
- Key Component - ASTM A992 W6x15 Steel Post
  - Length ..... 78 in.
  - Width ..... 49 in.
  - Spacing ..... 37½ in.
- Soil Type ..... Coarse, Crushed Limestone (Well-Graded Gravel)
- Vehicle Make /Model ..... Hyundai Accent
  - Curb ..... 2,543 lb
  - Test Inertial ..... 2,430 lb (MASH 2016 Limit 2,420 ±55 lb)
  - Gross Static ..... 2,592 lb (MASH 2016 Limit 2,585 ±55 lb)
- Impact Conditions
  - Speed ..... 62.4 mph (MASH 2016 Limit 62 ±2.5 mph)
  - Angle ..... 25.1 degrees (MASH 2016 Limit 25 ±1.5 degrees)
  - Impact Location ..... 61.1 in. upstream from target impact location
- Impact Severity ..... 56.9 kip-ft > 51.1 kip-ft MASH 2016 limit
- Exit Conditions
  - Speed ..... 38.5 mph
  - Angle ..... 10.8 degrees
- Exit Box Criterion ..... Pass
- Vehicle Stability ..... Satisfactory
- Vehicle Stopping Distance ..... 156.8 ft downstream, 51.7 ft laterally in front
- Vehicle Damage ..... Moderate
  - VDS [15] 10-LFQ-5
  - CDC [16] 10-LFEW-3
  - Maximum Interior Deformation ..... 3½ in. ≥ 2 in. MASH 2016 limit for windshield
- Test Article Damage ..... Minimal
- Maximum Test Article Deflections
  - Permanent Set ..... 1.3 in.
  - Dynamic Deflection ..... 2.5 in.
  - Working Width ..... 21.9 in.
- Transducer Data

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1 (Primary)	SLICE-2 (Backup)	
OIV ft/s	Longitudinal	-30.58	-30.19	±40
	Lateral	33.49	30.29	±40
ORA g's	Longitudinal	-11.79	-10.52	±20.49
	Lateral	10.92	13.77	±20.49
Maximum Angular Displacement degrees	Roll	8.8	9.4	±75
	Pitch	-7.2	-10.0	±75
	Yaw	61.5	60.5	not required
THIV – ft/s		39.65	38.32	not required
PHD – g's		11.02	13.85	not required
ASI		2.76	2.69	not required

Figure 90. Summary of Test Results and Sequential Photographs, Test No. H42ST-2

7 SUMMARY AND CONCLUSIONS

HDOT desired to test and evaluate their thrie-beam AGT attached to the 42-in. tall solid concrete bridge rail with aesthetic, recessed, rounded panels and 6-ft sidewalk according to MASH 2016 TL-3 criteria. Although MASH 2016 only specifies two full-scale crash tests to evaluate longitudinal transitions, recent research has illustrated the importance of evaluating two different regions within AGTs: (1) the upstream stiffness transition where W-beam connects to stiffened thrie beam and (2) the downstream stiffness transition of an AGT where the guardrail attaches to the rigid concrete parapet. The upstream region of the HDOT thrie-beam AGT includes the MGS upstream stiffness transition, which has already been successfully crash tested to MASH TL-3 [2]. Therefore, the thrie-beam approach guardrail transition attached to the 42-in. tall solid concrete bridge rail was subjected to test designation nos. 3-21 (test no. H42ST-1) and 3-20 (test no. H42ST-2). Summaries of the full-scale crash test evaluations are shown in Table 11.

In test no. H42ST-1, the 2270P vehicle impacted the HDOT thrie-beam AGT attached to the 42-in. tall solid concrete bridge rail with aesthetic, recessed, rounded panels and 6-ft wide sidewalk at a speed of 64.7 mph, an impact angle of 24.8 degrees, and at a location of 79.9 in. upstream from the upstream end of the concrete buttress. Note that the impact speed of 64.7 mph was above the MASH nominal impact speed of 62.0 mph ±2.5 mph. However, impact speeds exceeding the nominal criteria are acceptable for longitudinal barriers. The TL-3 impact severity for the crash test was 124.1 kip-ft, which was greater than the minimum value of 105.6 kip-ft. As such, the crash test results could be used as a valid indicator of the system's overall safety performance. The vehicle was captured and safely redirected by the barrier system. The vehicle exited the system at a speed of 40.2 mph and an angle of 10.5 deg, which did not violate the bounds of the exit box and came to rest 134.0 ft downstream from the impact and 23.9 ft laterally in front of the barrier system. All vehicle decelerations, ORAs, and OIVs fell within the recommended safety limits established in MASH 2016.

During test no. H42ST-1, the left-front wheel contacted the thrie-beam rail and produced a more aggressive interaction between the elements than was observed in test no. HWTT-2 [2]. It should be noted that the 2270P test vehicle used in test no. H42ST-1 had aluminum rims, while the test vehicle had steel rims in test no. HWTT-2. A snag event occurred at the middle corrugation of the middle of the 37.5-in. long span nearest to the concrete buttress. Some vehicle pocketing occurred near the concrete buttress as well as rim gouging and/or snagging on the middle and lower rail humps. Again, these noted behaviors did not occur in test no. HWTT-2 as that thrie-beam rail appeared to be smoother when compared to the test no. H42ST-1 observations. Regardless, test no. H42ST-1 successfully met the safety performance criteria for MASH 2016 test no. 3-21.

In test no. H42ST-2, the 1100C vehicle impacted the HDOT thrie-beam AGT attached to the 42-in. tall solid concrete bridge rail with aesthetic, recessed, rounded panels and 6-ft wide sidewalk at a speed of 62.4 mph, an impact angle of 25.1 degrees, and at a location of 61.1 in. upstream from the upstream end of the concrete buttress. The TL-3 impact severity for the crash test was 56.9 kip-ft, which was greater than the minimum value of 51.1 kip-ft. As such, the crash test results could be used as a valid indicator of the system's overall safety performance. The vehicle exited the system at a speed of 38.5 mph and an angle of 10.8 degrees, which did not violate the bounds of the exit box, and came to rest 156.8 ft downstream from impact and 51.7 ft

laterally in front of the barrier. All vehicle decelerations, ORAs, and OIVs fell within the recommended safety limits established in MASH 2016.

During test no. H42ST-2, the windshield was fractured across its entire width and length and deformed inward 3.5 in., which exceeded the MASH 2016 limits of 3 in. As the deformation was due to the translation of the base of the lower-left A-pillar instead of direct contact with the test article and did not pose a penetration hazard to the vehicle occupant. This damage was not a violation of MASH 2016 criteria. Similar windshield damage and deformation had been observed in other recent MASH 1100C tests into rigid barriers, including full-scale crash testing of the Hawaii 34-in. tall (i.e., test no. H34BR-1) and 42-in. tall (i.e., test no. H42BR-1) concrete bridge rails [3, 17] as well as full-scale crash testing of the North Carolina two-bar metal bridge rail (i.e., test no. NCBR-1) [18]. Windshield damage in the form of tearing and deformation have been allowed for these other systems when the barrier did not make direct contact with the system, as seen in FHWA eligibility letters for each system [19-21]. Therefore, test no. H42ST-2 was determined to be acceptable according to the MASH 2016 safety performance criteria for test designation no. 3-20.

With the successful crash tests documented herein, the downstream region of the thrie beam AGT attached to the 42-in. tall solid concrete bridge rail with aesthetic, recessed, rounded panels and 6-ft wide sidewalk has been proven crashworthy. Therefore, the HDOT AGT attached to the 42-in. tall solid concrete bridge rail with aesthetic, recessed, rounded panels and 6-ft sidewalk meets the safety performance criteria for MASH 2016 TL-3.

8 MASH EVALUATION

The research objective of this study was to evaluate the safety performance of the HDOT thrie-beam AGT attached to the 42-in. tall solid concrete bridge rail with aesthetic, recessed, rounded panels and 6-ft wide sidewalk according to MASH 2016 TL-3 criteria. The thrie-beam approach guardrail transition consisted of 51 ft of MGS connected to an 18-ft long concrete transition buttress, which attached to an 88-ft 1½-in. long, 42-in. tall, and 10-in. wide reinforced concrete bridge rail. According to TL-3 evaluation criteria in MASH 2016, two tests are required to evaluate longitudinal barrier systems: (1) test designation no. 3-21 (test no. H42ST-1) and (2) test designation no. 3-20 (test no. H42ST-2).

During test no. H42ST-1, a 5,041-lb pickup truck with a simulated occupant seated in the left-front passenger seat impacted the HDOT transition system at a speed of 64.7 mph and at an angle of 24.8 degrees, resulting in an impact severity of 124.1 kip-ft. Note that the impact speed of 64.7 mph was above the MASH nominal impact speed of 62.0 mph ±2.5 mph. However, impact speeds exceeding the nominal criteria are acceptable for longitudinal barriers. The vehicle was successfully contained and smoothly redirected. Exterior vehicle damage was moderate. Interior occupant compartment deformations were moderate with a maximum of 6 in., which did not violate the limits established in MASH 2016. Damage to the barrier was moderate, consisting of post deflections, contact marks, rail kinking, and some gouging of the concrete buttress and curb. The maximum dynamic barrier deflection was 11.0 in. The working width of the system was found to be 27.8 in. at post no. 18. All occupant risk measures were within the recommended limits, and the occupant compartment deformations were deemed acceptable. Therefore, the HDOT thrie-beam AGT attached to the 42-in. tall solid concrete bridge rail with aesthetic, recessed, rounded panels and 6-ft wide sidewalk successfully met all the safety performance criteria of MASH 2016 test designation no. 3-21.

During test no. H42ST-2, a 2,430-lb small car with a simulated occupant seated in the left-front passenger seat impacted the HDOT transition system at a speed of 62.4 mph and at an angle of 25.1 degrees, resulting in an impact severity of 56.9 kip-ft. The vehicle was successfully contained and smoothly redirected. Exterior vehicle damage was moderate. Deformation of the windshield measuring 3.5 in. exceeded the MASH 2016 limit of 3 in. However, the deformation was due to the translation of the base of the bottom-left A-pillar and did not occur due to direct contact with the test article, nor pose a penetration hazard to the vehicle occupant. Thus, this damage was not a violation of MASH 2016 criteria. Damage to the barrier was minimal, consisting of contact marks and kinking of the thrie beam sections, contact marks on the front face of the concrete buttress, and some concrete gouging. The maximum dynamic barrier deflection was 2.5 in. The working width of the system was found to be 21.9 in. at post no. 15. All occupant risk measures were within the recommended limits, and the occupant compartment deformations were deemed acceptable. Therefore, the HDOT thrie-beam AGT attached to the 42-in. tall solid concrete bridge rail with aesthetic, recessed, rounded panels and 6-ft sidewalk successfully met all the safety performance criteria of MASH 2016 test designation no. 3-20.

HDOT's thrie-beam AGT attached to the 42-in. tall solid concrete bridge rail with aesthetic, recessed, rounded panels and 6-ft wide sidewalk was crash tested and evaluated according to the MASH 2016 TL-3 criteria and successfully met all the requirements of MASH 2016 test designation no. 3-20 and test designation no. 3-21.

Table 11. Summary of Safety Performance Evaluation

Evaluation Factors	Evaluation Criteria				Test No. H42ST-1	Test No. H42ST-2
Structural Adequacy	A.	Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.			S	S
Occupant Risk	D.	1. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.			S	S
		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.			S	S
	F.	The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.			S	S
	H.	Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:			S	S
		Occupant Impact Velocity Limits				
		Component	Preferred	Maximum		
		Longitudinal and Lateral	30 ft/s	40 ft/s		
	I.	The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:			S	S
		Occupant Ridedown Acceleration Limits				
		Component	Preferred	Maximum		
		Longitudinal and Lateral	15.0 g's	20.49 g's		
MASH 2016 Test Designation No.					3-21	3-20
Final Evaluation (Pass or Fail)					Pass	Pass

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

9 REFERENCES

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

2. Rosenbaugh, S.K., Hovde, S.E., Faller, R.K., and Urbank, E.L., *Crash Testing and Evaluation of the Hawaii Thrie Beam Approach Guardrail Transition MASH Test Nos. 3-20 and 3-21*, Report No. TRP-03-425-20, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, March 20, 2020.

3. Bielenberg, R.W., Dowler, N.T., Faller, R.K., and Urbank, E.L., *Crash Testing and Evaluation of the HDOT 42-in. Tall Aesthetic Concrete Bridge Rail: MASH Test Designation Nos. 3-10 and 3-11*, Report No. TRP-03-424-20, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, NE, January 2020.

4. Quintero, R.A., Sim, C., Faller, R.K., and Urbank, E.L., *Crash Testing and Evaluation of the HDOT 42-in. Tall, Solid Concrete Bridge Rail with Aesthetic Recessed Rounded Panels and 6-in. Tall Sidewalk: MASH Test Designation Nos. 3-10 and 3-11*, Report No. TRP-03-455-22, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, NE, December 2022.

5. Mongiardini, M., Faller, R.K., Reid, J.D., Sicking, D.L., Stolle, C.S., and Lechtenberg, K.A., *Downstream Anchoring Requirements for the Midwest Guardrail System*, Report No. TRP-03-279-13, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, October 28, 2013.

6. Mongiardini, M., Faller, R.K., Reid, J.D., and Sicking, D.L., *Dynamic Evaluation and Implementation Guidelines for a Non-Proprietary W-Beam Guardrail Trailing-End Terminal*, Paper No. 13-5277, Transportation Research Record No. 2377, Journal of the Transportation Research Board, TRB AFB20 Committee on Roadside Safety Design, Transportation Research Board, Washington D.C., January 2013, pages 61-73.

7. Stolle, C.S., Reid, J.D., Faller, R.K., and Mongiardini, M., *Dynamic Strength of a Modified W-Beam BCT Trailing-End Termination*, Paper No. IJCR 886R1, Manuscript ID 1009308, International Journal of Crashworthiness, Taylor & Francis, Vol. 20, Issue 3, Published online February 23, 2015, pages 301-315.

8. Griffith, M.S., Federal Highway Administration (FHWA), *Eligibility Letter HSST/B-256 for: Trailing-End Anchorage for 31" Tall Guardrail,* December 18, 2015.

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

10. Rosenbaugh, S.K., Lechtenberg, K.A., Faller, R.K., Sicking, D.L., Bielenberg, R.W., and Reid, J.D., *Development of the MGS Approach Guardrail Transition Using Standardized Steel Posts*, Report No. TRP-03-210-10, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, December 21, 2010.

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

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

13. MacInnis, D., Cliff, W., and Ising, K., *A Comparison of the Moment of Inerita Estimation Techniques for Vehicle Dynamics Simulation,* SAE Technical Paper Series – 970951, Society of Automotive Engineers, Inc., Warrendale, Pennsylvania, 1997.

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

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

16. *Collision Deformation Classification – Recommended Practice J224 March 1980*, Handbook Volume 4, Society of Automotive Engineers (SAE), Warrendale, Pennsylvania, 1985.

17. Bielenberg, R.W., Yoo, S.H., Faller, R.K., and Urbank, E.L., *Crash Testing and Evaluation of the HDOT 34-in. Tall Aesthetic Concrete Bridge Rail: MASH Test Designation Nos. 3-10 and 3-11,* Report No. TRP-03-420-19, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, NE, October 2019.

18. Dowler, N.T., Stolle, C.S., Hinojosa, M.A., and Fang. G., *Full-Scale Crash Test of a Two-Bar Metal Bridge Rail*, Report No. TRP-03-419-19, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, NE, November 2019.

19. Griffith, M.S., Federal Highway Administration (FHWA), *Eligibility Letter HSST-1/B-345 for: HDOT 34" Tall Aesthetic Concrete Bridge Rail,* August 14, 2020.

20. Griffith, M.S., Federal Highway Administration (FHWA), *Eligibility Letter HSST-1/B-346 for: HDOT 42" Tall Aesthetic Concrete Bridge Rail,* August 14, 2020.

21. Griffith, M.S., Federal Highway Administration (FHWA), *Eligibility Letter HSST-1/B-358 for: NC Two-Bar Metal Bridge Rail,* August 9, 2021.

10 APPENDICES

Appendix A. Material Specifications, Test Nos. H42ST-1 and H42ST-2

Table A-1. Bill of Materials, Test Nos. H42ST-1 and H42ST-2

Item No.	Description	Material Specification	Reference
a1	12'-6" 12-gauge Thrie Beam Section	AASHTO M180	H#L33720
a2	6'-3" 12-gauge Thrie Beam Section	AASHTO M180	H#L33720
a3	6'-3" 10-gauge W-Beam to Thrie Beam Asymmetric Transition Section	AASHTO M180 Min. yield strength = 50 ksi Min. ultimate strength = 70 ksi"	H#248953
a4	12'-6" 12-gauge W-Beam MGS Section	AASHTO M180	H#C84187 HCode#1207 UNL PO#4500281503
a5	12'-6" 12-gauge W-Beam MGS End Section	AASHTO M180	H#9411949 HCode#8534
a6	10-gauge Thrie Beam Terminal Connector	AASHTO M180 Min. yield strength = 50 ksi Min. ultimate strength = 70 ksi"	H#A90588
b1	Concrete	Min. f'c = 4,000 psi NE Mix 47BD"	Ticket#1263368 & 1263375 and Ticket#1268281 & 1268282
c1	BCT Timber Post - MGS Height	SYP Grade No. 1 or better (No knots +/- 18" from ground on tension face)	Ch#4697
c2	72" Long Foundation Tube	ASTM A500 Gr. B	H#821T08220 R#18-642 Black Paint
c3	Ground Strut Assembly	ASTM A36	Black Paint R#18-642
c4	BCT Anchor Cable End Swaged Fitting	Fitting - ASTM A576 Gr. 1035 Stud - ASTM F568 Class C	R#22-107 White Paint
c5	¾" 6x19 IWRC IPS Wire Rope	ASTM A741 Type 2	Reel#0243493
c6	8"x8"x⅝" Anchor Bearing Plate	ASTM A36	H#4181496
c7	2⅜" O.D. x 6" Long BCT Post Sleeve	ASTM A53 Gr. B Schedule 40	H#712810
c8	Anchor Bracket Assembly	ASTM A36	H#JK16101488
d1	W6x8.5 or W6x9, 72" Long Steel Post	ASTM A992 Gr. 50	H#55069378 (both); H#55048942 (H42ST-2)
d2	W6x8.5 or W6x9, 72" Long Steel Post	ASTM A992 Gr. 50	H#55069378 (both); H#55048942 (H42ST-2)
d3	W6x15, 78" Long Steel Post	ASTM A992 Gr. 50	H#59094758/02

Table A-2. Bill of Materials, Test Nos. H42ST-1 and H42ST-2, Cont.

Item No.	Description	Material Specification	Reference
d4	17½" Long, 8"x6"x¼" Steel Blockout	ASTM A500 Gr. B	H#A97575 (H42ST-1); H#841P04950 (H42ST-2)
d5	17½" Long, 12"x4"x¼" Steel Blockout	ASTM A500 Gr. B	H#SK1853 R#21-807
d6	"14 3/16"x12"x5⅛" Composite Recycled Blockout"	Mondo Polymer MGS14SH or Equivalent	COC
d7	14 3/16"x8"x5⅛" Composite Recycled Blockout	Mondo Polymer GB14SH2 or Equivalent	COC
d8	16D Double Head Nail	-	PO E000548963
e1	#4 Rebar, 16" Total Length	ASTM A615 Gr. 60	H#55064958
e2	#4 Rebar, 12¾" Total Length	ASTM A615 Gr. 60	H#55064958
e3	#5 Rebar, 172" Total Length	ASTM A615 Gr. 60	H#3600014140
e4	#5 Rebar, 164¼" Total Unbent Length	ASTM A615 Gr. 60	H#3600014140
e5	#6 Rebar, 108" Total Length	ASTM A615 Gr. 60	H#7011423
e6	#6 Rebar, 109" Unbent Length	ASTM A615 Gr. 60	H#7011423
e7	#4 Rebar, 169½" Total Length	ASTM A615 Gr. 60	H#55064958
e8	#4 Rebar, 100¼" Total Length	ASTM A615 Gr. 60	H#55064958
e9	#6 Rebar, 49⅞" Unbent Length	ASTM A615 Gr. 60	H#7011423
e10	#6 Rebar, 51⅞" Unbent Length	ASTM A615 Gr. 60	H#7011423
e11	#6 Rebar, 54⅝" Unbent Length	ASTM A615 Gr. 60	H#7011423
e12	#6 Rebar, 34 3/16" Unbent Length	ASTM A615 Gr. 60	H#7011423
e13	#4 Rebar, 49½" Unbent Length	ASTM A615 Gr. 60	H#55064958
e14	#4 Rebar, 52⅛" Unbent Length	ASTM A615 Gr. 60	H#55064958
e15	#4 Rebar, Vertical Stirrup Varying Length	ASTM A615 Gr. 60	H#55064958
e16	#6 Rebar, Vertical Stirrup Varying Length	ASTM A615 Gr. 60	H#7011423
e17	#6 Rebar, 52⅜" Unbent Length	ASTM A615 Gr. 60	H#7011423
f1	⅝"-11 UNC, 14" Long Guardrail Bolt	ASTM A307 Gr. A	H#100104009 L#33076
f2	⅝"-11 UNC, 10" Long Guardrail Bolt	ASTM A307 Gr. A	H#10666100 L#931491-7 R#21-155 Yellow
f3	⅝"-11 UNC, 1¼" Long Guardrail Bolt	ASTM A307 Gr. A	H#10653380 Lot#32756-B
f4	⅝"-11 UNC, 10" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	H#JK18104124 L#81342 Light Blue Paint
f5	⅝"-11 UNC, 1½" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	P#91919 T#180170611 (H42ST-1); H#17301484-3 P#1191919 (H42ST-2)

Table A-3. Bill of Materials, Test Nos. H42ST-1 and H42ST-2, Cont.

Item No.	Description	Material Specification	Reference
f6	⅞"-9 UNC, 16" Long Heavy Hex Head Bolt	ASTM F3125 Gr. A325 or equivalent	H#100794352 Inv#138185
f7	⅞"-9 UNC, 8" Long Hex Head Bolt	ASTM A307 Gr. A or equivalent	R#18-758 P#92005 C#llne35042 COC ONLY
f8	⅝"-11 UNC, 2" Long Guardrail Bolt	ASTM A307 Gr. A	H#10621520 L#848773-13
f9	⅝"-11 UNC Heavy Hex Nut	ASTM A563A or equivalent	H#10635460 L#20-35-006
f10	⅞"-9 UNC Hex Nut	ASTM A563A or equivalent	H#331704677 L#1N1810005 P#36717 C#110254885
f11	⅞"-9 UNC Heavy Hex Nut	ASTM A563DH	H#100894559 Inv#138185
f12	1"-8 UNC Heavy Hex Nut	ASTM A563DH or equivalent	P#38210 C#210157128 COC
f13	⅝"-11 UNC Hex Nut	ASTM A563A or equivalent	H#331608011 P#36713 R#17-507
g1	⅝" Dia. Plain USS Washer	ASTM F844	L#1851805 P#1133185 C#200152825 R#21-191
g2	⅞" Dia. Plain Round Washer	ASTM F844	P#33187 C#170089822 L#1844804
g3	1" Dia. Plain USS Washer	ASTM F844	P#33188 C#210151571
g4	3"x3"x¼" or 3½"x3½"x¼" Square Washer Plate	ASTM A572 Gr. 50	H#A9F220 R#21-196 Inv#57199
i1	Epoxy Adhesive	Hilti HIT Re-500 V3	COC
i2	Expansion Joint Filler	AASHTO M33, M153, or M213	Tech Sheet
i3	Expansion joint Sealant	AASHTO M173, M282, M301, ASTM D3581, or ASTM D5893	Tech Sheet

Certified Analysis

Trinity Highway Products LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296
Customer: MIDWEST MACH & SUPPLY CO
P. O. BOX 703

MILFORD, NE 68405
Project: STOCK

Order Number: 1328797 Prod Ln Grp: 0-OE2.0
Customer PO: 4006
BOL Number: 113647 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 9/30/20

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
			M-180	A	2	245021	64,480	83,940	22.2	0.190	0.700	0.013	0.004	0.020	0.060	0.000	0.060	0.001	4
			M-180	A	2	245984	62,860	80,840	26.2	0.190	0.720	0.008	0.003	0.010	0.080	0.000	0.050	0.000	4
155	12365G	T12/12'6/8@1'6.75/S			2	L33720													
			M-180	A	2	254833	62,344	82,251	25.5	0.190	0.720	0.015	0.002	0.020	0.150	0.000	0.070	0.002	4
			M-180	A	2	255300	62,065	80,722	24.9	0.200	0.730	0.008	0.004	0.010	0.060	0.000	0.040	0.002	4
27	32218G	T10/TRAN/TB:WB/ASYM/R	M-180	B	2	833M66260	66,600	74,800	29.0	0.060	0.820	0.015	0.005	0.029	0.019	0.042	0.030	0.001	4
22	32219G	T10/TRAN/TB:WB/ASYM/LT	M-180	B	2	248834	59,940	78,890	27.2	0.210	0.720	0.013	0.003	0.020	0.100	0.000	0.050	0.000	4

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy QMS-LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT, 23 CFR 635.410.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36 UNLESS OTHERWISE STATED.

ALL COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT", 23 CFR 635.410.
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 (US DOMESTIC SHIPMENTS)
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 & ISO 1461 (INTERNATIONAL SHIPMENTS)

FINISHED GOOD PART NUMBERS ENDING IN SUFFIX B,P, OR S, ARE UNCOATED

BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.

NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
WASHERS COMPLY WITH ASTM F-436 SPECIFICATION AND/OR F-844 AND ARE GALVANIZED IN ACCORDANCE WITH ASTM F-2329, UNLESS OTHERWISE STATED.
3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH – 46000 LB

Figure A-1. 12-ft 6-in. 12-Gauge Thrie Beam Section, Test Nos. H42ST-1 and H42ST-2 (Item No. a1)

Certified Analysis

Trinity Highway Products LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296
Customer: MIDWEST MACH & SUPPLY CO
P. O. BOX 703
MILFORD, NE 68405
Project: STOCK

Order Number: 1328797 Prod Ln Grp: 0-OE2.0
Customer PO: 4006
BOL Number: 113647 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 9/30/20

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
30	261G	T12/25/3'1.5/S			2	L33820													
			M-180	A	2	255300	62,065	80,722	24.9	0.200	0.730	0.008	0.004	0.010	0.060	0.000	0.040	0.002	4
10	738A	5'TUBE SL.188X6X8 1/4 /PL	A-500			823L69130	56,796	75,727	31.0	0.150	0.850	0.013	0.004	0.007	0.017	0.002	0.030	0.001	4
20	749G	TS 8X6X3/16X6'-0" SLEEVE	A-500			A712224	79,860	80,000	25.8	0.050	0.810	0.008	0.002	0.030	0.090	0.000	0.050	0.003	4
12	929G	10/END SHOE/KS/2 EXT			2	L13520													
			M-180	A	2	251391	62,050	80,960	23.0	0.200	0.730	0.011	0.001	0.020	0.100	0.000	0.070	0.000	4
			M-180	A	2	251392	62,580	81,450	21.6	0.190	0.730	0.009	0.003	0.020	0.100	0.000	0.070	0.002	4
			M-180	A	2	253045	67,090	84,510	24.6	0.190	0.720	0.012	0.002	0.020	0.120	0.000	0.070	0.023	4
			M-180	A	2	253236	64,040	81,570	24.1	0.190	0.710	0.014	0.020	0.020	0.110	0.000	0.080	0.000	4
			M-180	A	2	253968	62,900	80,220	25.1	0.190	0.730	0.013	0.002	0.020	0.120	0.000	0.060	0.002	4
			M-180	B	2	253972	62,480	79,220	25.9	0.190	0.730	0.016	0.001	0.020	0.080	0.000	0.080	0.002	4
20	950A	T12/FLARE/12 HOLE ASS'Y			2	L23820													
			M-180	A	2	254834	62,484	81,174	25.8	0.190	0.730	0.010	0.003	0.020	0.120	0.000	0.060	0.001	4
			M-180	A	2	254835	62,594	81,284	23.3	0.190	0.730	0.012	0.005	0.010	0.140	0.000	0.070	0.002	4
			M-180	A	2	254836	65,000	84,343	26.6	0.190	0.720	0.013	0.001	0.020	0.130	0.000	0.070	0.001	4
			M-180	A	2	255522	62,070	79,830	24.9	0.190	0.720	0.010	0.004	0.010	0.100	0.000	0.050	0.002	4
			M-180	A	2	255523	61,380	79,990	22.0	0.200	0.730	0.013	0.003	0.020	0.100	0.000	0.080	0.001	4
			M-180	A	2	255524	62,050	81,610	26.4	0.190	0.730	0.010	0.002	0.010	0.110	0.000	0.050	0.002	4
6	957G	T12/BUFFER/ROLLED	A-36			31847970	48,400	62,300	35.0	0.060	0.450	0.015	0.001	0.030	0.090	0.001	0.070	0.002	4
78	12173G	T12/6'3/4@1'6.75"/S			2	L33720													
			M-180	A	2	254833	62,344	82,251	25.5	0.190	0.720	0.015	0.002	0.020	0.150	0.000	0.070	0.002	4
			M-180	A	2	255300	62,065	80,722	24.9	0.200	0.730	0.008	0.004	0.010	0.060	0.000	0.040	0.002	4
	12173G				2	L34919													

Figure A-2. 6-ft 3-in. 12-gauge Thrie Beam Section, Test Nos. H42ST-1 and H42ST-2 (Item No. a2)

IMH PRODUCTS, INC.
CNC FABRICATION

Date: May 21, 2020

To: Universal Rollforming
435 N. 1200 West
Lindon, UT 84042

CERTIFICATE OF COMPLIANCE

IMH PRODUCTS, INC. hereby certifies that all materials used in the manufacture of parts called for on Purchase Order No. 28540 conform to the material and/or manufacturing specifications indicated in drawings or specifications as called for on the said purchase order. Test reports are on file with us or with our suppliers for the examination and indicate conformance with applicable specification requirements (AASHTO M180, section 8.1.2).

Further, **IMH PRODUCTS, INC.** certifies that all materials and services used in the manufacture of these parts were made or performed in the USA.

Part No.: RWT-ATbB
Heat# .: 248953
Quantity: 200
Description: asymmetrical transition, LH (Trailing end)

By **IMH PRODUCTS, INC.**

Joe Gillen

Joe Gillen
(Authorized Signature)

General Manager
(Title or Position in Firm)

Figure A-3. 6-ft 3-in. 10-gauge W-Beam to Thrie-Beam Asymmetric Section, Test Nos. H42ST-1 and H42ST-2 (Item No. a3)

Certified Test Report

NORTH STAR BLUESCOPE STEEL LLC
6767 County Road 9
Delta Ohio 43515
Telephone: (888) 822-2112

Customer:	TriAmerica Steel Resources			**Ordered Width (mm/in)**	1384.808 / 54.52	**Weight(kg/lb)**
1617 Akron Peninsula Rd		**Order #**	456584	**Ordered Gauge (mm/in)**	3.607 / 0.142 N	19808 / 43669
Akron, OH 44313		**Line Item #**	1	**Produced Date/Time**	2/17/20 09:38	
Customer P.O:	076169	**Heat #**	248953	**Coil #**	2003535	
Cust. Ref/Part #	ip	**Material Desc:**	InvPrime			

Chemical Analysis (wt%)

Type	C	Mn	P	S	Si	Al	Cu	Cr	Ni	Mo	Sn	N	B	V	Nb	Ti	Ca	Pb
Heat	0.05	0.58	0.011	0.002	0.02	0.02	0.11	0.07	0.04	0.02	0.00	0.007	0.0000	0.001	0.021	0.001	0.002	0.000
Coil Hea	0.05	0.58	0.011	0.002	0.02	0.02	0.11	0.07	0.04	0.02	0.00	0.007	0.0000	0.001	0.021	0.001	0.002	0.000
Coil Tail	0.05	0.58	0.011	0.002	0.18	0.03	0.10	0.06	0.04	0.01	0.00	0.008	0.0000	0.003	0.019	0.064	0.001	0.000

This hot rolled steel has been produced to conform to DIN EN 10204:2005 3.1 and has been manufactured to a fully killed fine grain practice. This hot rolled steel has been produced and tested in accordance with each of the following applicable standards:ASTM E1806-09, ASTM E415-14, ASTM A751-14, ASTM A370-14, JIS Z2201:1998, JIS Z2241:2011. Pressure Equipment Directive (PED) 2014/68/EU, Annex I, Paragraph 4.3 Compliant. This report certifies that the above test results are representative of those contained in the records of North Star BlueScope Steel LLC for the material identified in this test report and is intended to comply with the requirements of the material description. North Star BlueScope Steel LLC is not responsible for the inability of this material to meet specific applications. Any modifications to this certification as provided negates the validity of this test report. All reproductions must have the written approval of North Star BlueScope Steel.This product was manufactured, melted, cast, and hot-rolled (min. 3:1 reduction ratio), entirely within the U.S.A at North Star BlueScope Steel LLC, Delta, Ohio. This material was not exposed to Mercury or any alloy which is liquid at ambient temperature during processing or while in North Star BlueScope Steel LLC possession. Test equipment calibration certificates are available upon request. NIST traceability is established through test equipment calibration certificates which are available upon request. Uncertainty calculations are calculated in accordance with NIST standards and are maintained at a 4:1 ratio in accordance with NIST standards. Uncertainty data is available upon request.

John Meece Manager Quality Assurance and Technology

Date Issued: Feb 27, 2020 1:03 PM
Revision#: 01

8100219

Figure A-4. 6-ft 3-in. 10-gauge W-Beam to Thrie-Beam Asymmetric Section, Test Nos. H42ST-1 and H42ST-2, Cont. (Item No. a3)

NUCOR
NUCOR STEEL GALLATIN

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

METALLURGICAL TEST REPORT

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

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

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

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

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

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

Coil Number(s): 1465177

CHEMICAL ANALYSIS (Weight %)

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

MECHANICAL PROPERTIES

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

BEND TEST RESULTS

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

Ht code
1207

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

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

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

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

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

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

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

Figure A-5. 12-ft 6-in. 12-gauge W-Beam MGS Section, Test Nos. H42ST-1 and H42ST-2 (Item No. a4)

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

Customer: UNIVERSITY OF NEBRASKA-LINCOLN
401 CANFIELD ADMIN BLDG
P O BOX 880439
LINCOLN,NE,68588-0439

Test Report
Ship Date: 7/9/2015
Customer P.O.: 4500274709/ 07/07/2015
Shipped to: UNIVERSITY OF NEBRASKA-LINCOLN
Project: TESTING COIL
GHP Order No.: 183306

HT # code	Heat #	C.	Mn.	P.	S.	Si.	Tensile	Yield	Elong.	Quantity	Class	Type	Description
8534	9411949	0.21	0.75	0.01	0.006	0.01	75774	56527	27.15	10	A	2	12GA 25FT WB T2 MGS ANCHOR PANEL
8534	9411949	0.21	0.75	0.01	0.006	0.01	75774	56527	27.15	100	A	2	12GA 12FT6IN/3FT1 1/2IN WB T2
8534	9411949	0.21	0.75	0.01	0.006	0.01	75774	56527	27.15	20	A	2	12GA 25FT0IN 3FT1 1/2IN WB T2

Bolts comply with ASTM A-307 specifications and are galvanized in accordance with ASTM A-153, unless otherwise stated.
Nuts comply with ASTM A-563 specifications and are galvanized in accordance with ASTM A-153, unless otherwise stated.
All other galvanized material conforms with ASTM-123 & ASTM-653
All Galvanizing has occurred in the United States
All steel used in the manufacture is of Domestic Origin, "Made and Melted in the United States"
All Steel used meets Title 23CFR 635.410 - Buy America
All Guardrail and Terminal Sections meets AASHTO M-180, All structural steel meets AASHTO M-183 & M270
All Bolts and Nuts are of Domestic Origin
All material fabricated in accordance with Nebraska Department of Transportation
All controlled oxidized/corrosion resistant Guardrail and terminal sections meet ASTM A606, Type 4.

By:
Andrew Artar, VP of Sales & Marketing
Gregory Highway Products, Inc.

STATE OF OHIO: COUNTY OF STARK
Sworn to and subscribed before me, a Notary Public, by
Andrew Artar this 17 day of
Notary Public, State of Ohio

NOTARIAL SEAL
STATE OF OHIO
DAWN R. BATTON
NOTARY PUBLIC
STATE OF OHIO
Comm. Expires
March 03, 2018
Recorded in
Portage County

Figure A-6. 12-ft 6-in. 12-gauge W-Beam MGS End Section, Test Nos. H42ST-1 and H42ST-2 (Item No. a5)

NUCOR
NUCOR STEEL GALLATIN

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

METALLURGICAL CERTIFICATION

Invoice To: Metals USA-Flat Rolled-Jeffersonville
702 Port Rd
Jeffersonville, IN 47130

Ship To: Metals USA-Flat
Rolled-Jeffersonville
Metals USA -Flat
Rolled-Jeffersonville
702 Port Road
Jeffersonville, IN 47130

Date: 10/15/2018
Customer No: 27599
Customer P.O.: C44390

Mill Order No: 220897-1 **Customer Reference No:** NA **Load No:** 766606

This product was melted and manufactured in the USA to meet the requirements of: ASTM A1011-18 SS Gr 50 modified w/ 70 ksi min ten, C 0.26 max, P 0.02max, S 0.05 max, Si 0.04 max
HR Sheet Steel Bands

Coil Number(s): 1515933

Ordered Size: Min 0.125 (In.) X 62.00 (In.) X Coil
Min 3.175 (mm) X 1575 (mm) X Coil

CHEMICAL ANALYSIS (Weight %)

Heat No	C	Mn	P	S	Si	Cu	Ni	Cr	Mo
A90588	0.20	0.49	0.008	0.004	0.02	0.12	0.05	0.06	0.02
	Al	Ca	Nb	V	B	Ti	N	Sn	
	0.032	0.0017	0.002	0.001	0.0001	0.001	0.0052	0.006	

MECHANICAL PROPERTIES

Coil Tested	1515931	1515931	1515936	1515936				
Yield Strength(ksi)	55.1			51.3				
Yield Strength(mpa)	380			354				
Tensile Strength(ksi)	75.0			73.7				
Tensile Strength(mpa)	517			508				
% Elongation	25.1			29.6				
N-Value	0.16	0.15	0.17	0.17				
N-Value Range	5-15%	5-15%	5-15%	5-15%				
Hardness(HRBW)	83.2	83.2	80.8	80.8				
Test Section	YARD	YARD	YARD	YARD				
Orientation	Long	Long	Long	Long				
Test Method	ASTM	ASTM	ASTM	ASTM				

BEND TEST RESULTS

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

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

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

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

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

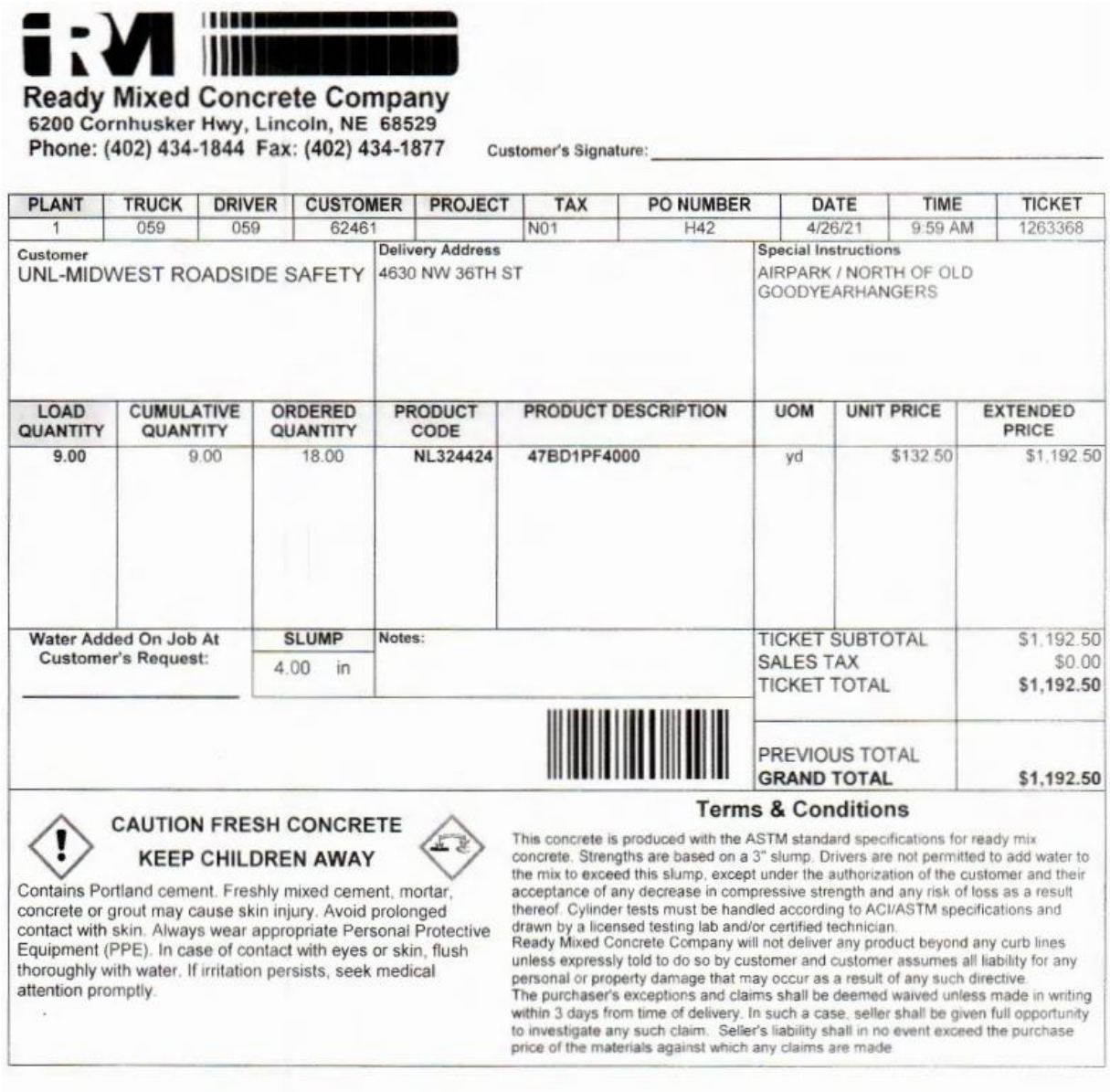
Bend tests were conducted in accordance with ISO 7438, ASTM E290, or JIS Z2248 using the press, guided, two support and a mandrel bend method at a 180 degree bend. Bend test specimen is longer than 6" and wider than 0.8"

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

David Duncan II
Chief Metallurgist
dave.duncan@nucor.com

Page 1 of 1

Figure A-7. 10-gauge Thrie Beam Terminal Connector, Test Nos. H42ST-1 and H42ST-2, Cont. (Item No. a6)



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

Customer's Signature: _____

PLANT	TRUCK	DRIVER	CUSTOMER	PROJECT	TAX	PO NUMBER	DATE	TIME	TICKET
1	059	059	62461		N01	H42	4/26/21	9:59 AM	1263368

Customer	Delivery Address	Special Instructions
UNL-MIDWEST ROADSIDE SAFETY	4630 NW 36TH ST	AIRPARK / NORTH OF OLD GOODYEARHANGERS

LOAD QUANTITY	CUMULATIVE QUANTITY	ORDERED QUANTITY	PRODUCT CODE	PRODUCT DESCRIPTION	UOM	UNIT PRICE	EXTENDED PRICE
9.00	9.00	18.00	NL324424	47BD1PF4000	yd	$132.50	$1,192.50

Water Added On Job At Customer's Request: _____

SLUMP: 4.00 in

Notes:

TICKET SUBTOTAL	$1,192.50
SALES TAX	$0.00
TICKET TOTAL	**$1,192.50**
PREVIOUS TOTAL	
GRAND TOTAL	**$1,192.50**

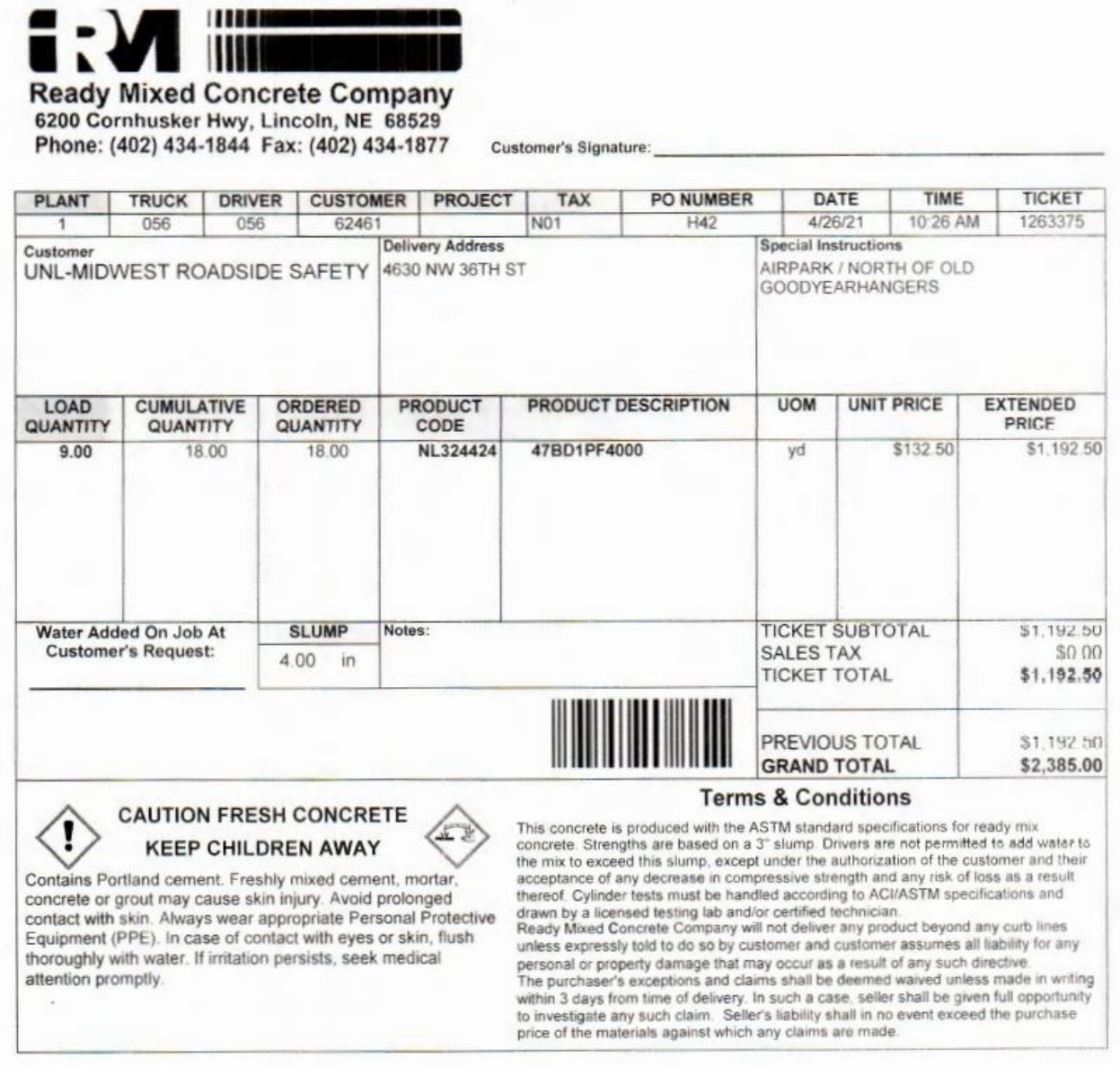
CAUTION FRESH CONCRETE
KEEP CHILDREN AWAY

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

Terms & Conditions

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

Figure A-8. Concrete, Test Nos. H42ST-1 and H42ST-2 (Item No. b1)



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

Customer's Signature: _____

PLANT	TRUCK	DRIVER	CUSTOMER	PROJECT	TAX	PO NUMBER	DATE	TIME	TICKET
1	056	056	62461		N01	H42	4/26/21	10:26 AM	1263375

Customer	Delivery Address	Special Instructions
UNL-MIDWEST ROADSIDE SAFETY	4630 NW 36TH ST	AIRPARK / NORTH OF OLD GOODYEARHANGERS

LOAD QUANTITY	CUMULATIVE QUANTITY	ORDERED QUANTITY	PRODUCT CODE	PRODUCT DESCRIPTION	UOM	UNIT PRICE	EXTENDED PRICE
9.00	18.00	18.00	NL324424	47BD1PF4000	yd	$132.50	$1,192.50

Water Added On Job At Customer's Request: _____

SLUMP: 4.00 in

Notes:

TICKET SUBTOTAL	$1,192.50
SALES TAX	$0.00
TICKET TOTAL	$1,192.50
PREVIOUS TOTAL	$1,192.50
GRAND TOTAL	**$2,385.00**

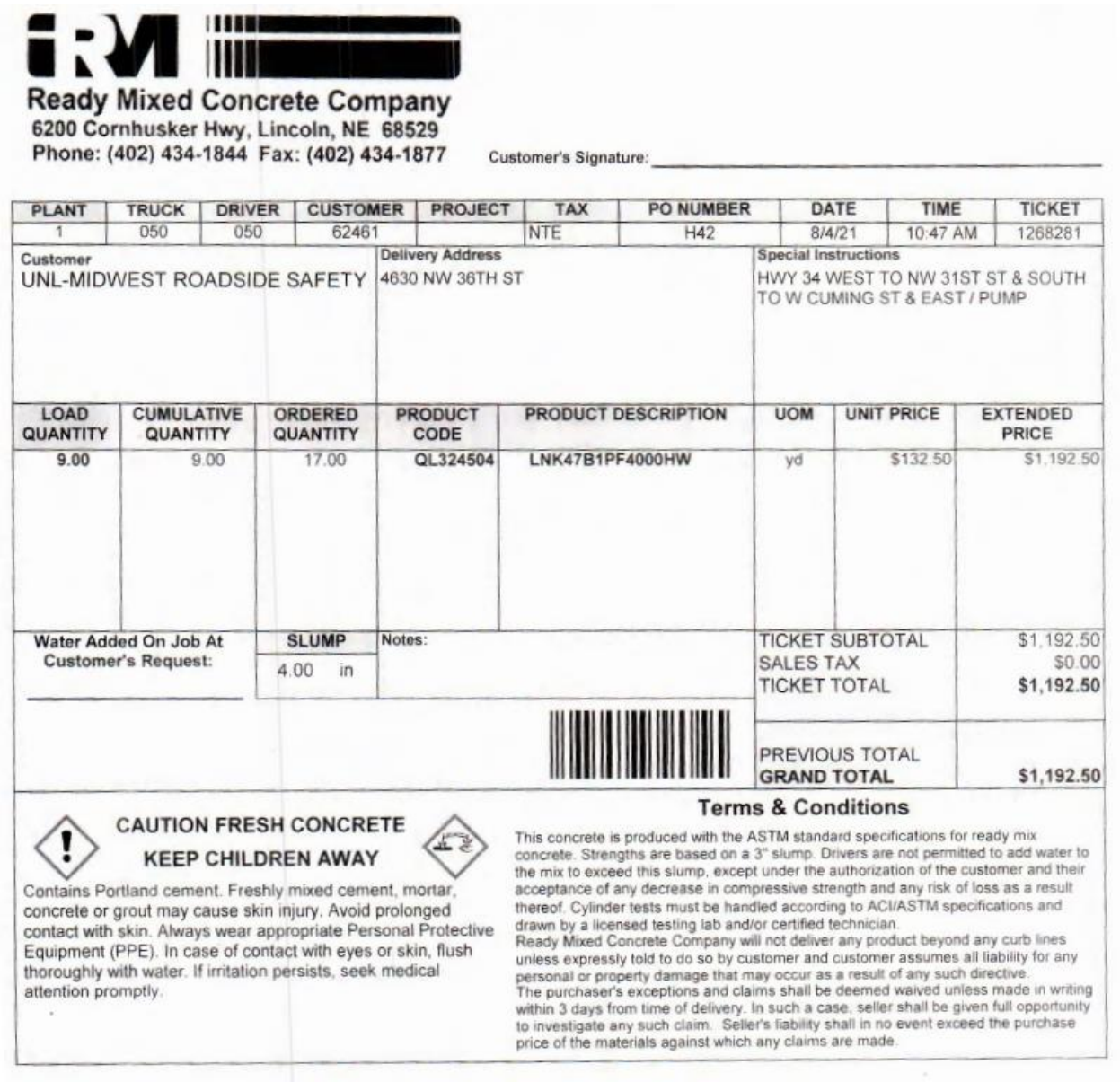
CAUTION FRESH CONCRETE
KEEP CHILDREN AWAY

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

Terms & Conditions

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

Figure A-9. Concrete, Test Nos. H42ST-1 and H42ST-2, Cont. (Item No. b1)



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

Customer's Signature: _____

PLANT	TRUCK	DRIVER	CUSTOMER	PROJECT	TAX	PO NUMBER	DATE	TIME	TICKET
1	050	050	62461		NTE	H42	8/4/21	10:47 AM	1268281

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

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

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

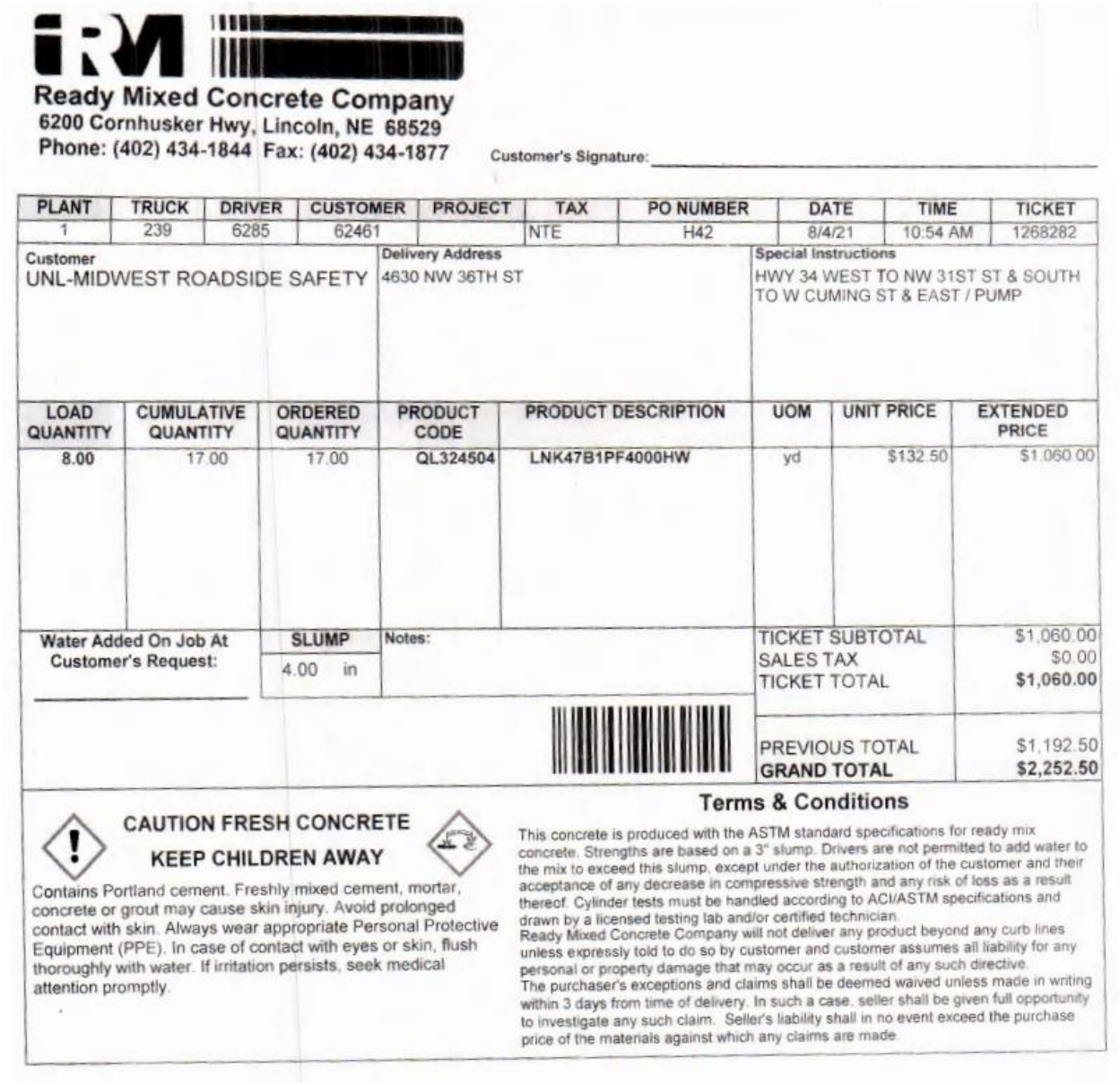
CAUTION FRESH CONCRETE
KEEP CHILDREN AWAY

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

Terms & Conditions

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

Figure A-10. Concrete, Test Nos. H42ST-1 and H42ST-2, Cont. (Item No. b1)



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

Customer's Signature: _____

PLANT	TRUCK	DRIVER	CUSTOMER	PROJECT	TAX	PO NUMBER	DATE	TIME	TICKET
1	239	6285	62461		NTE	H42	8/4/21	10:54 AM	1268282

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

LOAD QUANTITY	CUMULATIVE QUANTITY	ORDERED QUANTITY	PRODUCT CODE	PRODUCT DESCRIPTION	UOM	UNIT PRICE	EXTENDED PRICE
8.00	17.00	17.00	QL324504	LNK47B1PF4000HW	yd	$132.50	$1,060.00

Water Added On Job At Customer's Request: _____

SLUMP: 4.00 in

Notes:

TICKET SUBTOTAL	$1,060.00
SALES TAX	$0.00
TICKET TOTAL	**$1,060.00**
PREVIOUS TOTAL	$1,192.50
GRAND TOTAL	**$2,252.50**

CAUTION FRESH CONCRETE

KEEP CHILDREN AWAY

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

Terms & Conditions

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

Figure A-11. Concrete, Test Nos. H42ST-1 and H42ST-2, Cont. (Item No. b1)

benesch

Page 1 of 1

Concrete Sample Test Report
Cylinder Compressive Strength

Project Name:	Midwest Roadside Safety - Misc Testing
Project Number:	00110546.00
Client:	Midwest Roadside Safety Facility
Location:	MNPD
Sample:	025
Description:	H42

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

		Property	Test Result
Supplier:		Slump (in):	
Mix Name:		Air Content (%):	
Ticket Number:		Unit Weight (lb/ft³):	
Truck Number:		Air Temp (°F):	
Load Volume (yd³):		Mix Temp (°F):	
Mold Date:	08/04/2021	Min Temp (°F):	
Molded By:		MaxTemp (°F):	
Initial Cure Method:		MaxTemp (°F):	

Laboratory Test Data (ASTM C39)

Sample Number:	025	025				
Set Number:	001	002				
Specimen Number:	1	1				
Age:	9	9				
Length (in):	12	12				
Diameter (in):	6	5.99				
Area (in²):	28.27	28.18				
Test Date:	08/13/2021	08/13/2021				
Break Type:	6	5				
Max Load (lbf):	117,979	127,070				
Strength (psi):	4,170	4,510				
Spec Strength (psi):						
Excl in Avg Strength:	☐	☐	☐	☐	☐	☐

Remarks:

Average 9-day Compressive Strength (psi): **4,340**

Date received: 08/13/2021

Curing: ☒ Standard ☐ Field
ASTM C511

Submitted by: Matt Roeuler

Distribution:

Report Date: 8/13/21

825 M Street Suite 100
Lincoln, NE 68508

Alfred Benesch & Company

Figure A-12. Concrete, Test Nos. H42ST-1 and H42ST-2, Cont. (Item No. b1)

CNWP
CENTRAL NEBRASKA WOOD PRESERVERS

1098 East Maple St
Sutton, NE 68979
Phone: 402.773.4319
Email: nick@nebraskawood.com

CERTIFICATE OF COMPLIANCE

Shipped To: Midwest Machinery and Supply
BOL# N45211
Customer PO# 5055
Preservative: CCA – C 0.60D pcf AWPA UC4

Part #	Physical Description	# Pieces	Charge #	Retention
GS6846PST	5.5x7.5-46" BCT	42	4697	.615

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

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

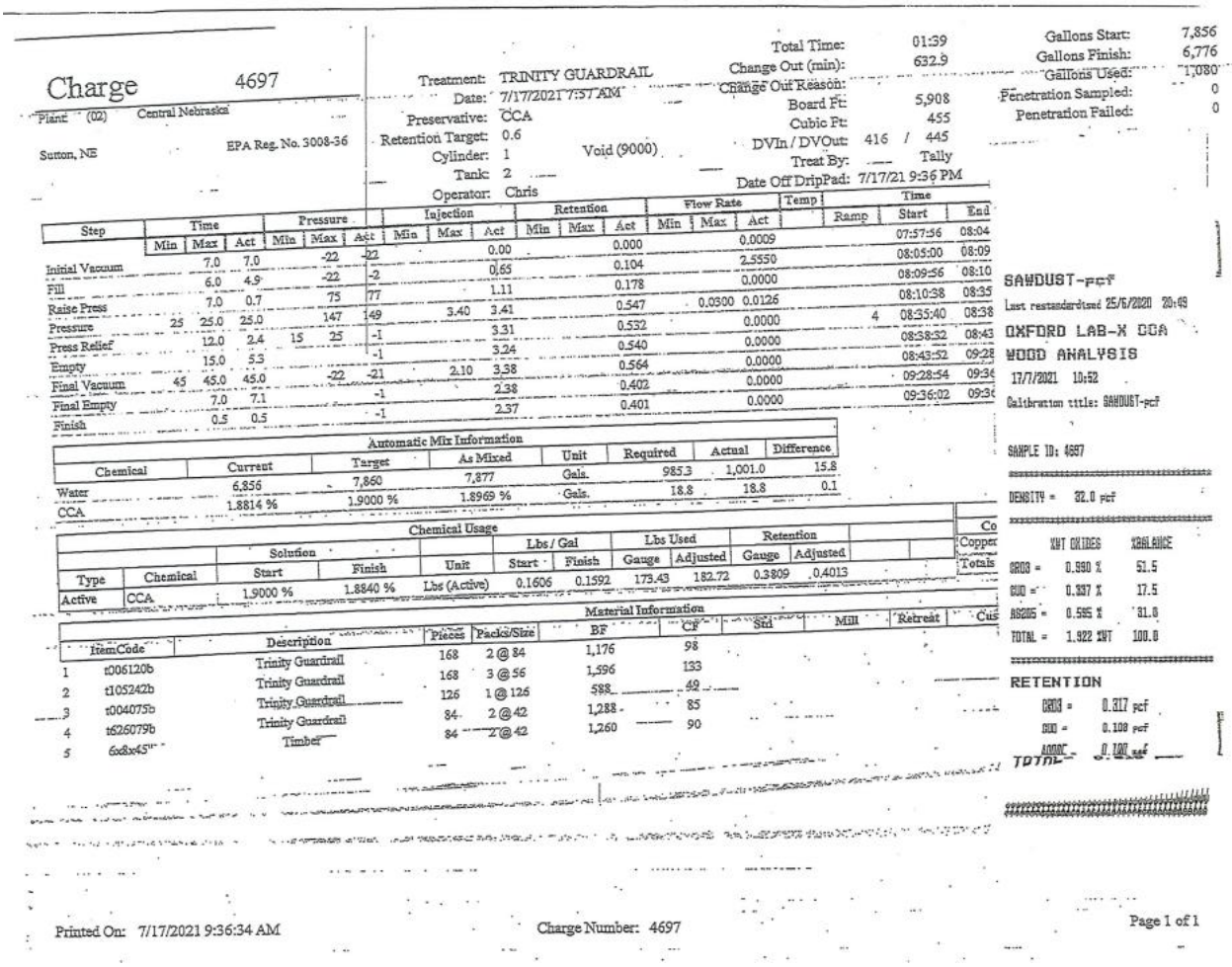
Nick Sowl, General Counsel

7/20/21
Date

Rebecca A Becker

GENERAL NOTARY - State of Nebraska
REBECCA A. BECKER
My Comm. Exp. May 21, 2023

Figure A-13. BCT Timber Post – MGS Height, Test Nos. H42ST-1 and H42ST-2 (Item No. c1)



Charge 4697

Plant (02) Central Nebraska
Sutton, NE EPA Reg. No. 3008-36

Treatment: TRINITY GUARDRAIL
Date: 7/17/2021 7:57 AM
Preservative: CCA
Retention Target: 0.6
Cylinder: 1 Void (9000)
Tank: 2
Operator: Chris

Total Time: 01:39
Change Out (min): 632.9
Change Out Reason:
Board Ft: 5,908
Cubic Ft: 455
DVIn / DVOut: 416 / 445
Treat By: Tally
Date Off DripPad: 7/17/21 9:36 PM

Gallons Start: 7,856
Gallons Finish: 6,776
Gallons Used: 1,080
Penetration Sampled: 0
Penetration Failed: 0

Step	Time Min	Time Max	Time Act	Pressure Min	Pressure Max	Pressure Act	Injection Min	Injection Max	Injection Act	Retention Min	Retention Max	Retention Act	Flow Rate Min	Flow Rate Max	Flow Rate Act	Temp	Ramp	Time Start	Time End
Initial Vacuum		7.0	7.0			-22	-22		0.00			0.000			0.0009			07:57:56	08:04
Fill		6.0	4.9			-22	-2		0.65			0.104			2.5550			08:05:00	08:09
Raise Press		7.0	0.7			75	77		1.11			0.178			0.0000			08:09:56	08:10
Pressure	25	25.0	25.0			147	149	3.40	3.41			0.547	0.0300	0.0126				08:10:38	08:35
Press Relief		12.0	2.4	15	25		-1		3.31			0.532			0.0000		4	08:35:40	08:38
Empty		15.0	5.3				-1		3.24			0.540			0.0000			08:38:32	08:43
Final Vacuum	45	45.0	45.0			-22	-21	2.10	3.38			0.564			0.0000			08:43:52	09:28
Final Empty		7.0	7.1				-1		2.38			0.402			0.0000			09:28:54	09:36
Finish		0.5	0.5				-1		2.37			0.401			0.0000			09:36:02	09:36

Automatic Mix Information

Chemical	Current	Target	As Mixed	Unit	Required	Actual	Difference
Water	6,856	7,860	7,877	Gals.	985.3	1,001.0	15.8
CCA	1.8814 %	1.9000 %	1.8969 %	Gals.	18.8	18.8	0.1

Chemical Usage

Type	Chemical	Solution Start	Solution Finish	Unit	Lbs / Gal Start	Lbs / Gal Finish	Lbs Used Gauge	Lbs Used Adjusted	Retention Gauge	Retention Adjusted
Active	CCA	1.9000 %	1.8840 %	Lbs (Active)	0.1606	0.1592	173.43	182.72	0.3809	0.4013

Material Information

	ItemCode	Description	Pieces	Packs/Size	BF	CF	Std	Mill	Retreat	Cus
1	t006120b	Trinity Guardrail	168	2 @ 84	1,176	98				
2	t105242b	Trinity Guardrail	168	3 @ 56	1,596	133				
3	t004075b	Trinity Guardrail	126	1 @ 126	588	49				
4	t626079b	Trinity Guardrail	84	2 @ 42	1,288	85				
5	6x8x45"	Timber	84	2 @ 42	1,260	90				

SAWDUST-pcf
Last restandardized 25/6/2020 20:49
OXFORD LAB-X OCA
WOOD ANALYSIS
17/7/2021 10:52
Calibration title: SAWDUST-pcf

SAMPLE ID: 4697

DENSITY = 32.0 pcf

	XWT OXIDES	XBALANCE
CROS =	0.990 %	51.5
CUO =	0.337 %	17.5
AS205 =	0.595 %	31.0
TOTAL =	1.922 XWT	100.0

RETENTION
CROS = 0.317 pcf
CUO = 0.108 pcf
ACQAC = 0.107 pcf
TOTAL = 0.532 pcf

Printed On: 7/17/2021 9:36:34 AM Charge Number: 4697 Page 1 of 1

Figure A-14. BCT Timber Post – MGS Height, Test Nos. H42ST-1 and H42ST-2, Cont. (Item No. c1)

3046H06

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

Atlas Tube
A DIVISION OF ZEKELMAN INDUSTRIES

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

MATERIAL TEST REPORT

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

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

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

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

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

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

Material Note:
Sales Or.Note:

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

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

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

Material Note:
Sales Or.Note:

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

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

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

Material Note:
Sales Or.Note:

Jason Richard
Jason Richard

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

Steel Tube Institute OF NORTH AMERICA

Page : 1 Of 6

Metals Service Center Institute

Figure A-15. 72-in. Long Foundation Tube, Test Nos. H42ST-1 and H42ST-2 (Item No. c2)

Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 703

MILFORD, NE 68405
Project: RESALE

Order Number: 1275017 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: 3400
BOL Number: 99202 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 3/22/17

R#18-642 Black Paint Ground Strut Assembly

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
400	3380G	5/8"X1.5" HEX BOLT A307	HW			0052429-113200													
600	3400G	5/8"X2" GR BOLT	HW			29221													
500	3480G	5/8"X8" GR BOLT A307	HW			29369													
450	3500G	5/8"X10" GR BOLT A307	HW			29550-B													
700	3540G	5/8"X14" GR BOLT A307	HW			29567													
300	3580G	5/8"X18" GR BOLT A307	HW			29338													
600	4235G	3/16"X1.75"X3" WSHR	HW			C7001													
10	9852A	STRUT & YOKE ASSY	A-36			195070	52,940	69,970	31.1	0.190	0.520	0.014	0.004	0.020	0.110	0.000	0.050	0.000	4
	9852A		A-36			A82292	54,000	73,300	31.0	0.200	0.460	0.010	0.003	0.020	0.150	0.000	0.060	0.001	4
	9852A		A-36			645887	39,900	62,500	32.0	0.190	0.400	0.009	0.015	0.009	0.054	0.001	0.038	0.001	4
	9852A		A-36			645887	39,900	62,500	32.0	0.190	0.400	0.009	0.015	0.009	0.054	0.001	0.038	0.001	4
	9852A		HW			15056184													
20	12173G	T12/6'3/4@1'6.75"/S			2	L35216													
			M-180	A	2	209331	62,090	81,500	28.1	0.190	0.720	0.013	0.002	0.020	0.110	0.000	0.070	0.002	4
			M-180	A	2	209332	61,400	81,290	25.3	0.190	0.730	0.014	0.003	0.020	0.120	0.000	0.060	0.001	4
			M-180	A	2	209333	61,200	80,050	25.8	0.200	0.740	0.016	0.005	0.010	0.120	0.000	0.070	0.002	4

2 of 4

Figure A-16. Ground Strut Assembly, Test Nos. H42ST-1 and H42ST-2 (Item No. c3)

Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 703

MILFORD, NE 68405
Project: RESALE

Order Number: 1275956 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: 3415
BOL Number: 99204 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 3/22/17

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
			M-180	A	2	208318	64,140	81,540	24.5	0.190	0.720	0.011	0.003	0.020	0.110	0.000	0.060	0.000	4
			M-180	A	2	208674	63,250	82,410	22.7	0.190	0.730	0.011	0.003	0.020	0.100	0.000	0.060	0.002	4
			M-180	A	2	208675	62,100	81,170	22.7	0.190	0.730	0.012	0.004	0.020	0.090	0.000	0.050	0.001	4
			M-180	A	2	208676	62,920	82,040	25.4	0.190	0.720	0.012	0.004	0.010	0.100	0.000	0.060	0.002	4
	12365G				2	L35216													
			M-180	A	2	209331	62,090	81,500	28.1	0.190	0.720	0.013	0.002	0.020	0.110	0.000	0.070	0.002	4
			M-180	A	2	209332	61,400	81,290	25.3	0.190	0.730	0.014	0.003	0.020	0.120	0.000	0.060	0.001	4
			M-180	A	2	209333	61,200	80,050	25.8	0.200	0.740	0.016	0.005	0.010	0.120	0.000	0.070	0.002	4

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy QMS-LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT , 23 CFR 635.410.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36 UNLESS OTHERWISE STATED.

ALL COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT", 23 CFR 635.410.
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 (US DOMESTIC SHIPMENTS)
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 & ISO 1461 (INTERNATIONAL SHIPMENTS)

FINISHED GOOD PART NUMBERS ENDING IN SUFFIX B,P, OR S, ARE UNCOATED
BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.

NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
WASHERS COMPLY WITH ASTM F-436 SPECIFICATION AND/OR F-844 AND ARE GALVANIZED IN ACCORDANCE WITH ASTM F-2329.
3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH – 46000 LB

Figure A-17. Ground Strut Assembly, Test Nos. H42ST-1 and H42ST-2, Cont. (Item No. c3)

Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 703
MILFORD, NE 68405
Project: RESALE

Order Number: 1275956 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: 3415
BOL Number: 99204 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 3/22/17

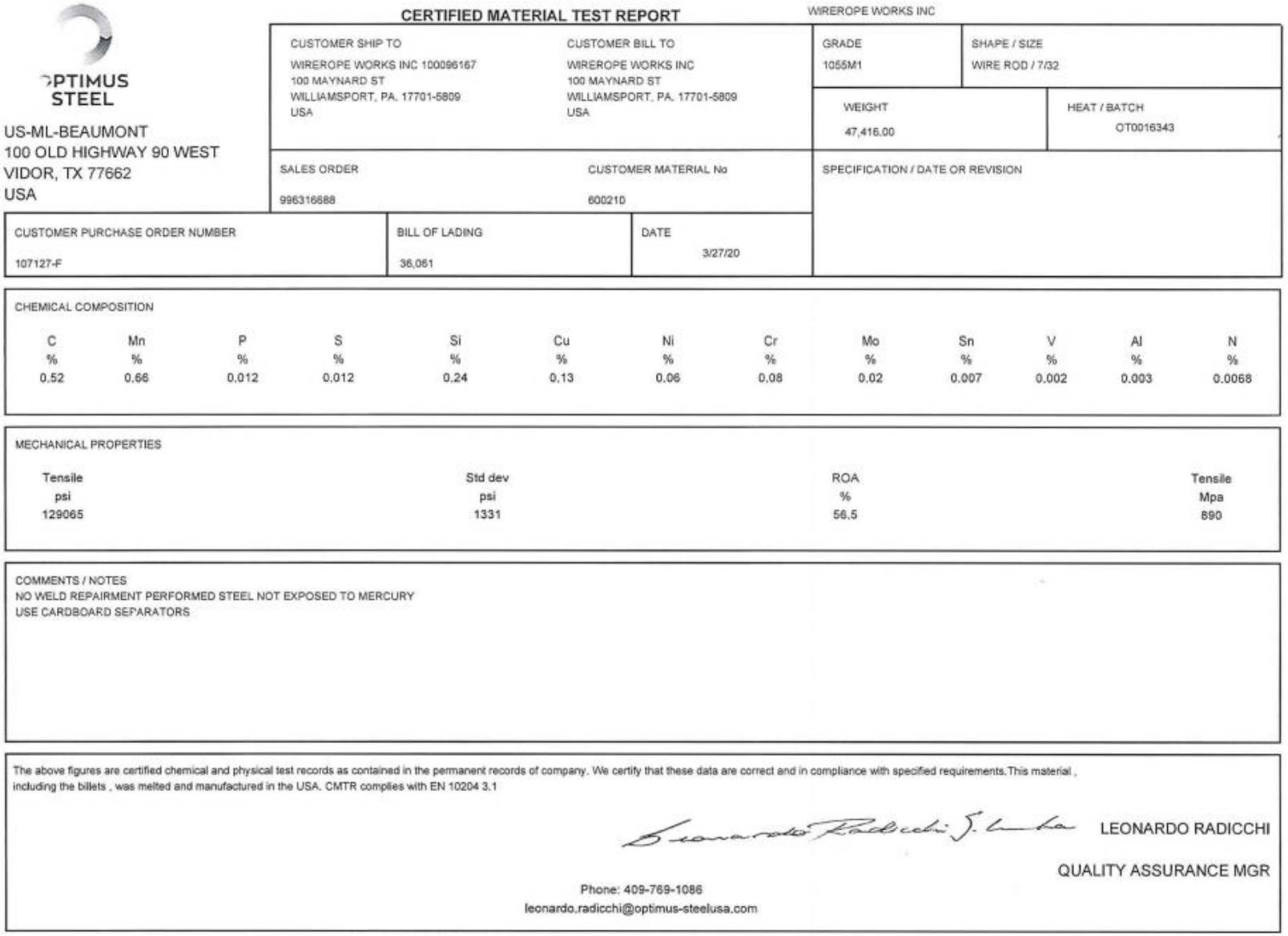
State of Ohio, County of Allen. Sworn and subscribed before me this 22nd day of March, 2017 .

Notary Public: Jamie L Davis
Commission Expires: 3-22-2021

NOTARIAL SEAL STATE OF OHIO
JAMIE L DAVIS
Notary Public, State of Ohio
My Commission Expires
March 22, 2021

Certified By: Trinity Highway Products , LLC
Quality Assurance

Figure A-18. Ground Strut Assembly, Test Nos. H42ST-1 and H42ST-2, Cont. (Item No. c3)



OPTIMUS STEEL

US-ML-BEAUMONT
100 OLD HIGHWAY 90 WEST
VIDOR, TX 77662
USA

CERTIFIED MATERIAL TEST REPORT

WIREROPE WORKS INC

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE
WIREROPE WORKS INC 100096167 100 MAYNARD ST WILLIAMSPORT, PA. 17701-5809 USA	WIREROPE WORKS INC 100 MAYNARD ST WILLIAMSPORT, PA. 17701-5809 USA	1055M1	WIRE ROD / 7/32

WEIGHT	HEAT / BATCH
47,416.00	OT0016343

SALES ORDER	CUSTOMER MATERIAL No	SPECIFICATION / DATE OR REVISION
996316688	600210	

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
107127-F	36,061	3/27/20

CHEMICAL COMPOSITION

C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Sn	V	Al	N
%	%	%	%	%	%	%	%	%	%	%	%	%
0.52	0.66	0.012	0.012	0.24	0.13	0.06	0.08	0.02	0.007	0.002	0.003	0.0068

MECHANICAL PROPERTIES

Tensile	Std dev	ROA	Tensile
psi	psi	%	Mpa
129065	1331	56.5	890

COMMENTS / NOTES
NO WELD REPAIRMENT PERFORMED STEEL NOT EXPOSED TO MERCURY
USE CARDBOARD SEPARATORS

The above figures are certified chemical and physical test records as contained in the permanent records of company. We certify that these data are correct and in compliance with specified requirements.This material , including the billets , was melted and manufactured in the USA. CMTR complies with EN 10204 3.1

LEONARDO RADICCHI

QUALITY ASSURANCE MGR

Phone: 409-769-1086
leonardo.radicchi@optimus-steelusa.com

Figure A-19. BCT Anchor Cable End Swaged Fitting, Test Nos. H42ST-1 and H42ST-2 (Item No. c4)

Wirerope Works, Inc. 100 Maynard St Williamsport, PA 17701
Manufacturer of Bethlehem Wire Rope ®
"Our Quality Management Systems are registered to ISO 9001: 2015 and API-Q1"

CERTIFICATE OF COMPLIANCE

CUSTOMER: MAZZELLA LIFTING TECHNOLOGIES
ORD# 267872
CUST. PO P202954 **WW FILE NAME 267872ORD**

REEL# 0243493

DESCRIPTION: 3/4" 0619 W GA IPS RR SAC GALVANIZED WIRE ROPE
IN ACCORDANCE WITH AASHTO DESIGNATION M30-02

ACTUAL TEST RESULTS
ACTUAL BREAKING STRENGTH: 63,400 LBS
REQUIRED BREAKING STRENGTH: 42,800 LBS

MINIMUM MASS OF COATING:
WIRE DIAMETER MAINWIRES
.054" MINIMUM CLASS A COATING .40- ACTUAL RANGE .55/.66 oz/fl2
.040" MINIMUM CLASS A COATING .40- ACTUAL RANGE .52/.53 oz/fl2

STEEL CERTIFICATES FOR ROD MANUFACTURER ARE ATTACHED
The following are heat numbers and wire diameters as shown on the Steel Certificates

.054" HEAT # OT0016343 20676920
.040" HEAT # 614442 OT0013913
.061" HEAT # 20676920 20643620 OT0009792
.046" HEAT # 531380084/02

ALL MATERIALS " MELTED AND MANUFACTURED IN THE USA"

Patti Watkins **DATE: 09/08/2020 CERTIFICATE# AA30816**
PATTI WATKINS, Inv. Control/QA Customer Coordinator
Per the authority of, **ROGER GILLILAND, DIRECTOR OF ENGINEERING**

Figure A-20. ¾-in. 6x19 IWRC IPS Wire Rope BCT, Test Nos. H42ST-1 and H42ST-2 (Item No. c5)

H#4181496 R#18-642 Black Paint

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

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

MILFORD,NE,68405

Test Report
Ship Date: 11/17/2017
Customer P.O.: 3515
Shipped to: MIDWEST MACHINERY & SUPPLY CO.
Project:
GHP Order No: 128AA

HT # code	LOT#	C.	Mn.	P.	S.	Si.	Tensile	Yield	Elong.	Quantity	Class	Type	Description
A74070		0.21	0.46	0.012	0.002	0.03	76100	56800	25.2	4	A	2	12GA TB TRANS
4181496		0.24	0.84	0.014	0.01	0.01	72400	44800	34	4		2	5/8IN X 8IN X 8IN BRG. PL
4181469		0.09	0.45	0.012	0.004	0.01	58000	43100	27	4		2	350 STRUT & YOKE
196828BM		0.04	0.84	0.014	0.003		76000	74000	25			2	350 STRUT & YOKE
E22985		0.17	0.51	0.013	0.008	0.008	72510	64310	29.5	4		2	2IN X 5 1/2IN PIPE SLEEVE
811T08220		0.22	0.81	0.013	0.006	0.005	71412	56323	35	8		2	3/16IN X 6IN X 8IN X 6FT0IN TUBE SLEEVE

All Galvanizing has occurred in the United States
All steel used in the manufacture is of Domestic Origin, "Made and Melted in the United States"
All Steel used meets Title 23CFR 635.410 - Buy America
All Guardrail and Terminal Sections meets AASHTO M-180, All structural steel meets AASHTO M-183 & M270
All Bolts and Nuts are of Domestic Origin
All material fabricated in accordance with Nebraska Department of Transportation
All controlled oxidized/corrosion resistant Guardrail and terminal sections meet ASTM A606, Type 4.

By: _____

James P. Dehnke
Notary Public, State of Ohio
My Commission Expires 10-19-2019

STATE OF OHIO: COUNTY OF STARK
Sworn to and subscribed before me, a Notary Public, by Andrew Allar this 21 day of November, 2017

_____
Notary Public, State of Ohio

Figure A-21. 8-in. x 8-in. x ⅝-in. Anchor Bearing Plate, Test Nos. H42ST-1 and H42ST-2 (Item No. c6)

Atlas Tube (Alabama), Inc.
171 Cleage Dr
Birmingham, Alabama, USA
35217
Tel:
Fax:

Atlas Tube
A DIVISION OF ZEKELMAN INDUSTRIES

Ref.B/L: 80791452
Date: 11.10.2017
Customer: 179

MATERIAL TEST REPORT

Sold to

Steel & Pipe Supply Compan
PO Box 1688
MANHATTAN KS 66505
USA

Shipped to

Steel & Pipe Supply Compan
401 New Century Parkway
NEW CENTURY KS 66031
USA

H#712810 R#18-773 2 3/8" O.D. x 6" Long BCT Post Sleeve

Material: 3.0x2.0x188x40'0"0(5x4). Material No: 0300201884000-B Made in: USA
Melted in: USA
Sales order: 1226976 Purchase Order: 4500296656 Cust Material #: 6630020018840

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
B704212	0.200	0.450	0.010	0.004	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE: 0.28
40867002	20	064649 Psi	087652 Psi	24 %	ASTM A500-13 GRADE B&C	

Material Note:
Sales Or.Note:

Material: 2.375x154x42'0"0(34x1). Material No: R023751544200 Made in: USA
Melted in: USA
Sales order: 1226976 Purchase Order: 4500296656 Cust Material #: 642004042

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
B712810	0.210	0.460	0.012	0.002	0.020	0.024	0.100	0.002	0.020	0.030	0.060	0.004	0.002	0.000	0.008

Bundle No	PCs	Yield	Tensile	Eln.2in	Rb	Certification	CE: 0.32
MC00006947	34	063688 Psi	083220 Psi	25 %	91	ASTM A500-13 GRADE B&C	

Material Note:
Sales Or.Note:

Material: 2.375x154x42'0"0(34x1). Material No: R023751544200 Made in: USA
Melted in: USA
Sales order: 1226976 Purchase Order: 4500296656 Cust Material #: 642004042

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
17037261	0.210	0.810	0.005	0.004	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE: 0.35
41532001	34	066144 Psi	082159 Psi	27 %	ASTM A500-13 GRADE B&C	

Material Note:
Sales Or.Note:

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

Steel Tube Institute

Page : 3 Of 4

Metals Service Center Institute

Figure A-22. 2⅜-in. O.D. x 6-in. Long BCT Post Sleeve, Test Nos. H42ST-1 and H42ST-2 (Item No. c7)

Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801 Phn:(419) 227-1296
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 703

MILFORD, NE 68405
Project: RESALE

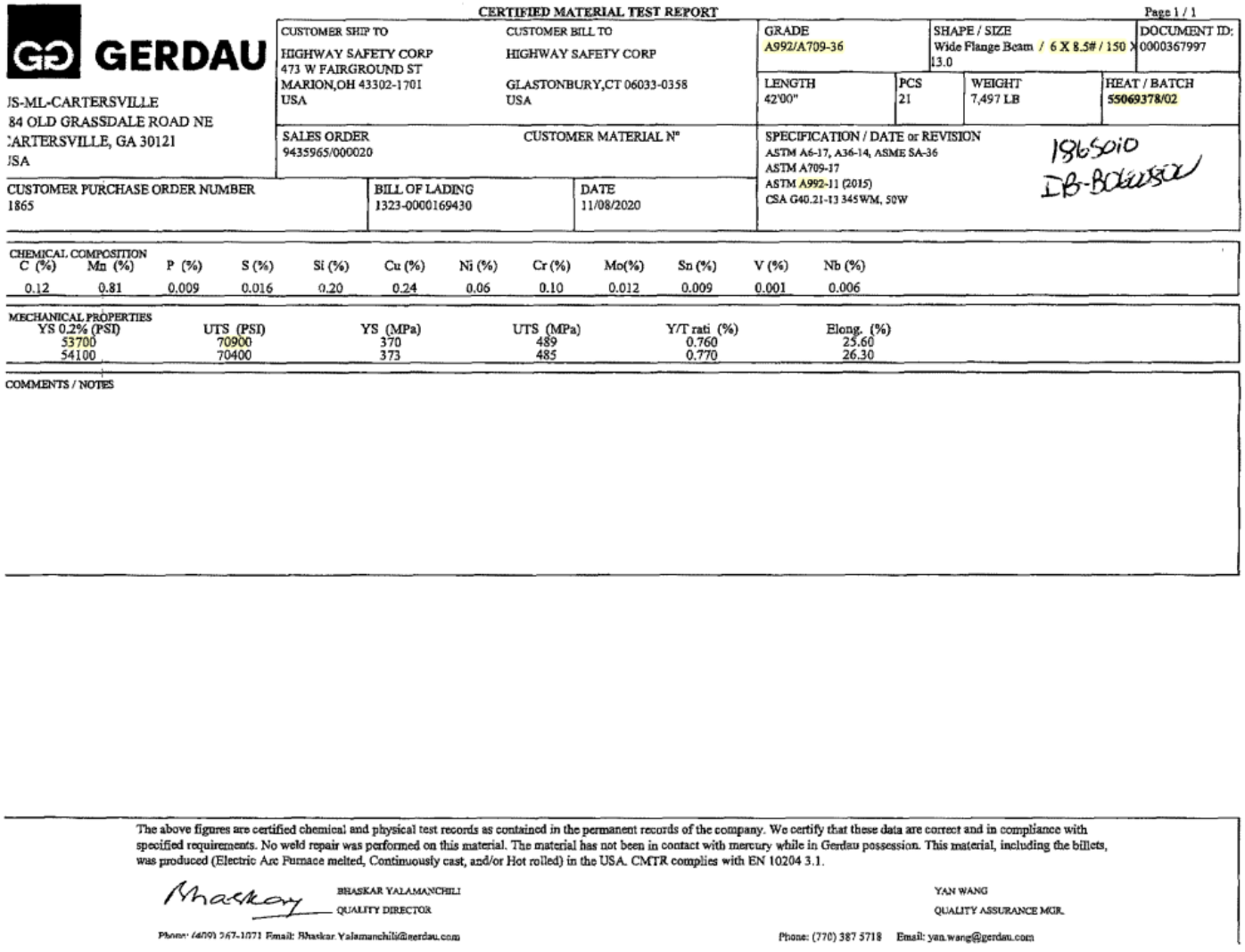
Order Number: 1269489 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: 3346
BOL Number: 97457 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 11/7/16

H#JK16101488 R#17-282 Anchor Bracket Assembly

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Va	ACW
	701A	Anchor Box	A-36			JK16101488	56,172	75,460	25.0	0.160	0.780	0.017	0.028	0.200	0.280	0.001	0.140	0.028	4
	701A		A-36			535133	43,300	68,500	33.0	0.019	0.460	0.013	0.016	0.013	0.090	0.001	0.090	0.002	4
4	729G	TS 8X6X3/16X8'-0" SLEEVE	A-500			A49248	64,818	78,412	32.0	0.200	0.810	0.014	0.002	0.040	0.020	0.000	0.040	0.001	4
20	738A	5'TUBE SL.188X6X8 1/4 /PL	A-36		2	4182164	45,000	67,900	31.0	0.210	0.760	0.012	0.008	0.010	0.050	0.001	0.030	0.002	4
	738A		A-500			A49248	64,818	78,412	32.0	0.200	0.810	0.014	0.002	0.040	0.020	0.000	0.040	0.001	4
6	749G	TS 8X6X3/16X6'-0" SLEEVE	A-500			A49248	64,818	78,412	32.0	0.200	0.810	0.014	0.002	0.040	0.020	0.000	0.040	0.001	4
6	782G	5/8"X8"X8" BEAR PL/OF	A-36			DL15103543	58,000	74,000	25.0	0.150	0.750	0.013	0.025	0.200	0.360	0.003	0.090	0.000	4
20	783A	5/8X8X8 BEAR PL 3/16 STP	A-36			PL14107973	48,167	69,811	25.0	0.160	0.740	0.012	0.041	0.190	0.370	0.000	0.220	0.002	4
	783A		A-36			DL15103543	58,000	74,000	25.0	0.150	0.750	0.013	0.025	0.200	0.360	0.003	0.090	0.000	4
45	3000G	CBL 3/4X6'6/DBL	HW			119048													
7,000	3340G	5/8" GR HEX NUT	HW			0055551-116146													
4,000	3360G	5/8"X1.25" GR BOLT	HW			0053777-115516													
450	3500G	5/8"X10" GR BOLT A307	HW			28971-B													
1,225	3540G	5/8"X14" GR BOLT A307	HW			29053-B													

Figure A-23. Anchor Bracket Assembly, Test Nos. H42ST-1 and H42ST-2 (Item No. c8)



CERTIFIED MATERIAL TEST REPORT

Page 1 / 1

GERDAU

JS-ML-CARTERSVILLE
84 OLD GRASSDALE ROAD NE
CARTERSVILLE, GA 30121
USA

CUSTOMER SHIP TO
HIGHWAY SAFETY CORP
473 W FAIRGROUND ST
MARION,OH 43302-1701
USA

CUSTOMER BILL TO
HIGHWAY SAFETY CORP
GLASTONBURY,CT 06033-0358
USA

GRADE: A992/A709-36
SHAPE / SIZE: Wide Flange Beam / 6 X 8.5# / 150 X 13.0
DOCUMENT ID: 0000367997
LENGTH: 42'00"
PCS: 21
WEIGHT: 7,497 LB
HEAT / BATCH: 55069378/02

SALES ORDER: 9435965/000020
CUSTOMER MATERIAL N°:
SPECIFICATION / DATE or REVISION: ASTM A6-17, A36-14, ASME SA-36; ASTM A709-17; ASTM A992-11 (2015); CSA G40.21-13 345WM, 50W

1865010
DB-BOLTED

CUSTOMER PURCHASE ORDER NUMBER: 1865
BILL OF LADING: 1323-0000169430
DATE: 11/08/2020

CHEMICAL COMPOSITION

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cu (%)	Ni (%)	Cr (%)	Mo(%)	Sn (%)	V (%)	Nb (%)
0.12	0.81	0.009	0.016	0.20	0.24	0.06	0.10	0.012	0.009	0.001	0.006

MECHANICAL PROPERTIES

YS 0.2% (PSI)	UTS (PSI)	YS (MPa)	UTS (MPa)	Y/T rati (%)	Elong. (%)
53700	70900	370	489	0.760	25.60
54100	70400	373	485	0.770	26.30

COMMENTS / NOTES

The above figures are certified chemical and physical test records as contained in the permanent records of the company. We certify that these data are correct and in compliance with specified requirements. No weld repair was performed on this material. The material has not been in contact with mercury while in Gerdau possession. This material, including the billets, was produced (Electric Arc Furnace melted, Continuously cast, and/or Hot rolled) in the USA. CMTR complies with EN 10204 3.1.

BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (469) 267-1071 Email: Bhaskar.Yalamanchili@gerdau.com

YAN WANG
QUALITY ASSURANCE MGR.
Phone: (770) 387 5718 Email: yan.wang@gerdau.com

Figure A-24. W6x8.5 or W6x9, 72-in. Long Steel Post, Test Nos. H42ST-1 and H42ST-2 (Item Nos. d1 and d2)

HIGHWAY SAFETY CORP

P.O. BOX 358
GLASTONBURY, CT 06033

CERTIFICATE OF COMPLIANCE/ANALYSIS REPORT

SOLD TO:
MIDWEST MACHINERY & SUPPLY
974-238th Road

Milford, NE, USA

SHIP TO:
MIDWEST MACHINERY & SUPPLY
974 238TH ROAD
MILFORD,

INVOICE / S.O.: 0201778 / 0148102
CUSTOMER P.O.: 3508

REFERENCE: STOCK
DATE SHIPPED: 10/23/2017

QTY:	ITEM NUMBER: / HEAT/LOT NO:	YIELD:	CC: / TENSILE:	%ELONG:	DESCRIPTION: / C:	Mn:	P:	S:	Si:	Cl:	Type	ACW
550	T-POG060080600		IB-B0600800		THRIE POST W06 x 008.5# x 06'00 GALV							
(200)	1702411											
(350)	55048942											
400	PSG030050503-20		IBSB03005000		POST S03@05.7 x 05'03.0 3 HL 2 SD W/PLT 3.5-3-3 SPGLV							
	1703040											
			PL-B025-080240									
	B76745											

ALL STEEL USED IN MANUFACTURING IS MADE AND MELTED IN THE USA, INCLUDING HARDWARE FASTENERS, AND COMPLIES WITH THE BUY AMERICA ACT. ALL COATINGS PROCESSES ARE PERFORMED IN THE USA AND COMPLY WITH THE BUY AMERICA ACT. BOLTS COMPLY WITH ASTMA-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTMA-153, UNLESS OTHERWISE STATED. NUTS COMPLY WITH ASTMA-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTMA-153, UNLESS OTHERWISE STATED. WASHERS COMPLY WITH ASTM F-436 AND/OR F-844 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTMA-153, UNLESS OTHERWISE STATED. ALL GUARDRAIL MEETS AASHTO M-180 AND ALL STRUCTURAL STEEL MEETS AASHTO M-270. ALL OTHER GALVANIZED MATERIAL CONFORMS WITH ASTMA-123. ALL OTHER ITEMS COMPLY WITH AASHTO M-111, M-165, M-133, M-265, ASTM A36, ASTMA-709, ASTMA-123, ASTM A505, AND ASTMA588 SPECIFICATIONS IF APPLICABLE. COMPLIANCE WITH ALL SPECIFICATIONS OF DEPARTMENT OF PUBLIC WORKS, DEPARTMENT OF HIGHWAYS AND TRANSPORTATION, DIVISION OF ROADS AND BRIDGES AND STATE HIGHWAY ADMINISTRATION IS MET IN ALL RESPECTS.

HIGHWAY SAFETY CORPORATION

QUALITY ASSURANCE MANAGER

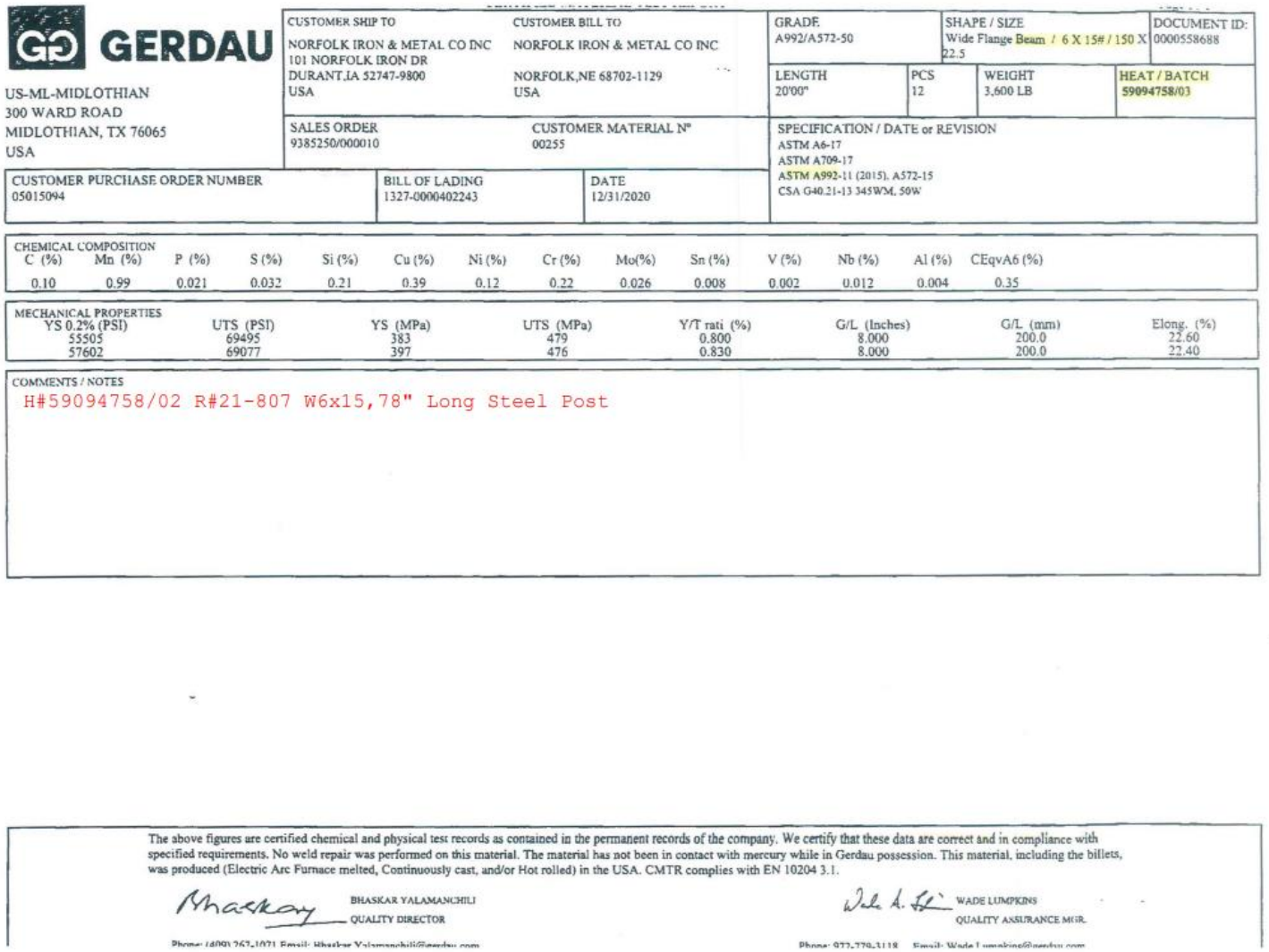
NOTARIZED UPON REQUEST:
STATE OF CONNECTICUT COUNTY OF HARTFORD
SWORN AND SUBSCRIBED BEFORE ME THIS 3rd DAY OF NOV, 20 17

Margaret J Satalino
Notary Public

MARGARET J. SATALINO
NOTARY PUBLIC
MY COMMISSION EXPIRES OCT. 31, 2021

Page 1 - 0148102

Figure A-25. W6x8.5 or W6x9, 72-in. Long Steel Post, Test No. H42ST-2 (Item Nos. d1 and d2)



GERDAU

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

CUSTOMER SHIP TO
NORFOLK IRON & METAL CO INC
101 NORFOLK IRON DR
DURANT,IA 52747-9800
USA

CUSTOMER BILL TO
NORFOLK IRON & METAL CO INC
NORFOLK,NE 68702-1129
USA

GRADE
A992/A572-50

SHAPE / SIZE
Wide Flange Beam / 6 X 15# / 150 X 22.5

DOCUMENT ID:
0000558688

LENGTH
20'00"

PCS
12

WEIGHT
3,600 LB

HEAT / BATCH
59094758/03

SALES ORDER
9385250/000010

CUSTOMER MATERIAL N°
00255

SPECIFICATION / DATE or REVISION
ASTM A6-17
ASTM A709-17
ASTM A992-11 (2015), A572-15
CSA G40.21-13 345WM, 50W

CUSTOMER PURCHASE ORDER NUMBER
05015094

BILL OF LADING
1327-0000402243

DATE
12/31/2020

CHEMICAL COMPOSITION

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Cu (%)	Ni (%)	Cr (%)	Mo(%)	Sn (%)	V (%)	Nb (%)	Al (%)	CEqvA6 (%)
0.10	0.99	0.021	0.032	0.21	0.39	0.12	0.22	0.026	0.008	0.002	0.012	0.004	0.35

MECHANICAL PROPERTIES

YS 0.2% (PSI)	UTS (PSI)	YS (MPa)	UTS (MPa)	Y/T rati (%)	G/L (Inches)	G/L (mm)	Elong. (%)
55505	69495	383	479	0.800	8.000	200.0	22.60
57602	69077	397	476	0.830	8.000	200.0	22.40

COMMENTS / NOTES
H#59094758/02 R#21-807 W6x15,78" Long Steel Post

The above figures are certified chemical and physical test records as contained in the permanent records of the company. We certify that these data are correct and in compliance with specified requirements. No weld repair was performed on this material. The material has not been in contact with mercury while in Gerdau possession. This material, including the billets, was produced (Electric Arc Furnace melted, Continuously cast, and/or Hot rolled) in the USA. CMTR complies with EN 10204 3.1.

BHASKAR YALAMANCHILI
QUALITY DIRECTOR

WADE LUMPKINS
QUALITY ASSURANCE MGR.

Figure A-26. W6x15 or W6x9, 72-in. Long Steel Post, Test Nos. H42ST-1 and H42ST-2 (Item No. d3)

30Jul20 3: 3 T E S T C E R T I F I C A T E No: MAR 380309

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

P/O No 01031988
Rel
S/O No MAR 396220-002
B/L No MAR 235650-006 Shp 30Jul20
Inv No Inv

Sold To: (1403)
NORFOLK IRON & METAL
P.O. BOX 1129
NORFOLK, NE 68701

Ship To: (1)
NORFOLK IRON & METAL
3001 NORTH VICTORY RD
NORFOLK, NE 68702

Tel: 402-371-1810 Fax: 402 379-5409

CERTIFICATE of ANALYSIS and TESTS Cert. No: MAR 380309
24Jul20

Part No 01209
TUBING A500 GRADE B(C) Pcs Wgt
8" X 6" X 1/4" X 20' 12 5,380

Heat Number	Tag No	Pcs	Wgt
A97575	914842	6	2,690
	YLD=58050/TEN=66570/ELG=32.6		
A97575	914843	6	2,690

Heat Number *** Chemical Analysis ***
A97575 C=0.0500 Mn=0.4100 P=0.0090 S=0.0030 Si=0.0300 Al=0.0360
Cu=0.1500 Cr=0.0700 Mo=0.0200 V=0.0030 Ni=0.0400 Nb=0.0160
Sn=0.0100 N=0.0070 B=0.0002 Ti=0.0020 Ca=0.0023
MELTED AND MANUFACTURED IN THE USA

THE SPECIFICATIONS LISTED BELOW REPRESENT THE CURRENT ISSUED DATES OF THESE STANDARDS. THIS DOES NOT INDICATE THAT THE MATERIAL ABOVE CONFORMS TO EACH OR ALL OF THE STANDARDS. WE CERTIFY THE MATERIAL ABOVE TO THE SPECIFICATION LISTED IN THE LINE DESCRIPTION.

CURRENT STANDARDS:
A252-19
A500/A500M-20
A513/A513M-20
ASTM A53/A53M-18| ASME SA-53/SA-53M-18
A847/A847M-14
A1085/A1085M-15
IN COMPLIANCE WITH EN 10204 SECTION 4.1
INSPECTION CERTIFICATE TYPE 3.1

Page: 1 .... Last

Figure A-27. 17½-in. Long, 8-in. x 6-in. x ¼-in. Steel Blockout, Test No. H42ST-1 (Item No. d4)

H#841P04950 R#21-807 17-1/2" Long, 8"x6"x1/4" Steel Blockout

BULL MOOSE TUBE COMPANY
1819 Clarkson Rd.
Chesterfield, Missouri 63017
636-537-2600

BULL MOOSE TUBE - ELKHART FACILITY 12/09/2020
CERTIFICATION OF TESTS Page 2 of 2
EN 10204:2004 TYPE 3.1 CERT

BILL TO : Norfolk Iron & Metal Company
P.O. Box 1129
Norfolk NE 68701

SHIP TO : Norfolk Iron & Metal Company (NE)
3001 Victory Rd.
Norfolk NE 68701-0000

B/L Number 510494 Ship Via IK4886_J19553

8" X 6" X 0.250 HR X 40'
152.4 X 203.2 mm
ASTM A500-20 GRADE B & C
=

Ladle Analysis and Physicals

Order # 680352
Purchase Order # 01032930
Item # 101394 3844
Customer Item # 01211

Raw Material is of Domestic Origin - Melted and Manufactured in the USA

Heat # = Y6523

C	Mn	P	S	Al	Si	Cb	Cu	Cr	Ni	V	Mo	B	Ti	N	Ceq	P YLD psi	NG TSN psi	ELN %
.050	.650	.013	.005	.030	.020	.022	.120	.090	.040	.002	.000	.010	.000	.000	.191	59840	71430	32

8" X 6" X 0.250 HR X 40'
152.4 X 203.2 mm
ASTM A500-20 GRADE B & C
=

Ladle Analysis and Physicals

Order # 680352
Purchase Order # 01032930
Item # 101394 3844
Customer Item # 01211

Raw Material is of Domestic Origin - Melted and Manufactured in the USA

Heat # = 841P04950

C	Mn	P	S	Al	Si	Cb	Cu	Cr	Ni	V	Mo	B	Ti	N	Ceq	P YLD psi	NG TSN psi	ELN %
.060	.640	.009	.005	.049	.027	.029	.025	.020	.010	.001	.000	.004	.000	.000	.178	58298	68553	31

THIS WELDED STEEL TUBING IS MANUFACTURED IN THE UNITED STATES OF AMERICA AND HAS BEEN PRODUCED IN ACCORDANCE WITH THE STATED SPECIFICATION. LADLE CHEMISTRIES ARE REPORTED FROM DOCUMENTS PROVIDED BY THE SUPPLYING STEEL MILL. ANY PHYSICAL AND MECHANICAL TESTING RESULTS SHOWN ON THIS CERTIFICATION ARE CORRECT AS CONTAINED IN THE RECORDS OF THE COMPANY.

Figure A-28. 17½-in. Long, 8-in. x 6-in. x ¼-in. Steel Blockout, Test No. H42ST-2 (Item No. d4)

H#SK1853 R#21-807 17-1/2" Long, 12"x4"x1/4"

20Oct20 21:30 T E S T C E R T I F I C A T E No: MAR 448355

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

P/O No 03054578
Rel
S/O No MAR 404424-002
B/L No MAR 239794-003 Shp 20Oct20
Inv No Inv

Sold To: (1403)
NORFOLK IRON & METAL
P.O. BOX 1129
NORFOLK, NE 68701

Ship To: (3)
NORFOLK (GREELEY)
31181 COUNTY RD 39 1/2
970-352-6722
GREELEY, CO 80631

Tel: 402-371-1810 Fax: 402 379-5409

CERTIFICATE of ANALYSIS and TESTS Cert. No: MAR 448355
20Oct20

Part No 01239
TUBING A500 GRADE B(C) Pcs 6 Wgt 3,098
12" X 4" X 1/4" X 20'

Heat Number Tag No Pcs 6 Wgt 3,098
SK1853 936109
YLD=59010/TEN=73730/ELG=32.2

Heat Number *** Chemical Analysis ***
SK1853 C=0.2000 Mn=0.3800 P=0.0080 S=0.0020 Si=0.0300 Al=0.0270
Cu=0.1000 Cr=0.0500 Mo=0.0100 V=0.0020 Ni=0.0300 Nb=0.0060
N=0.0059 B=0.0001 Ti=0.0010 Ca=0.0018
MELTED AND MANUFACTURED IN THE USA

THE SPECIFICATIONS LISTED BELOW REPRESENT THE CURRENT ISSUED DATES OF THESE STANDARDS. THIS DOES NOT INDICATE THAT THE MATERIAL ABOVE CONFORMS TO EACH OR ALL OF THE STANDARDS. WE CERTIFY THE MATERIAL ABOVE TO THE SPECIFICATION LISTED IN THE LINE DESCRIPTION.

CURRENT STANDARDS:
A252-19
A500/A500M-20
A513/A513M-20
ASTM A53/A53M-18| ASME SA-53/SA-53M-18
A847/A847M-14
A1085/A1085M-15
IN COMPLIANCE WITH EN 10204 SECTION 4.1
INSPECTION CERTIFICATE TYPE 3.1

Page: 1 .... Last

Figure A-29. 17½-in. Long, 12-in. x 4-in. x ¼-in. Steel Blockout, Test Nos. H42ST-1 and H42ST-2 (Item No. d5)

21Oct20 9:16 T E S T C E R T I F I C A T E No: MAR 442180

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

P/O No 01033046
Rel
S/O No MAR 403523-001
B/L No MAR 239466-002 Shp 21Oct20
Inv No Inv

Sold To: (1403)
NORFOLK IRON & METAL
P.O. BOX 1129
NORFOLK, NE 68701

Ship To: (1)
NORFOLK IRON & METAL
3001 NORTH VICTORY RD
NORFOLK, NE 68702

Tel: 402-371-1810 Fax: 402 379-5409

CERTIFICATE of ANALYSIS and TESTS Cert. No: MAR 442180
12Oct20

Part No 01245		Pcs	Wgt
TUBING A500 GRADE B(C)			
12" X 4" X 1/4" X 40'		6	6,197
Heat Number	Tag No	Pcs	Wgt
SK1853	435482	6	6,197
	YLD=59010/TEN=73730/ELG=32.2		

Heat Number *** Chemical Analysis ***
SK1853 C=0.2000 Mn=0.3800 P=0.0080 S=0.0020 Si=0.0300 Al=0.0270
Cu=0.1000 Cr=0.0500 Mo=0.0100 V=0.0020 Ni=0.0300 Nb=0.0060
N=0.0059 B=0.0001 Ti=0.0010 Ca=0.0018
MELTED AND MANUFACTURED IN THE USA

THE SPECIFICATIONS LISTED BELOW REPRESENT THE CURRENT ISSUED DATES OF THESE STANDARDS. THIS DOES NOT INDICATE THAT THE MATERIAL ABOVE CONFORMS TO EACH OR ALL OF THE STANDARDS. WE CERTIFY THE MATERIAL ABOVE TO THE SPECIFICATION LISTED IN THE LINE DESCRIPTION.

CURRENT STANDARDS:
A252-19
A500/A500M-20
A513/A513M-20
ASTM A53/A53M-18| ASME SA-53/SA-53M-18
A847/A847M-14
A1085/A1085M-15
IN COMPLIANCE WITH EN 10204 SECTION 4.1
INSPECTION CERTIFICATE TYPE 3.1

Page: 1 .... Last

Figure A-30. 17½-in. Long, 12-in. x 4-in. x ¼-in. Steel Blockout, Test Nos. H42ST-1 and H42ST-2, Cont. (Item No. d5)

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

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

Phone: 740-376-9396
Fax: 740-376-9960

PACKING LIST

PAGE: 1
FOB RENO
TERMS NET30
SHIP METHOD FEDEXF

SOLD TO

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

SHIP TO

Midwest Roadside Safety

4630 NW 36th Street
Lincoln, NE 68524

COC 14-3/16"x12"x5-1/8" Composite Recycled Blockout

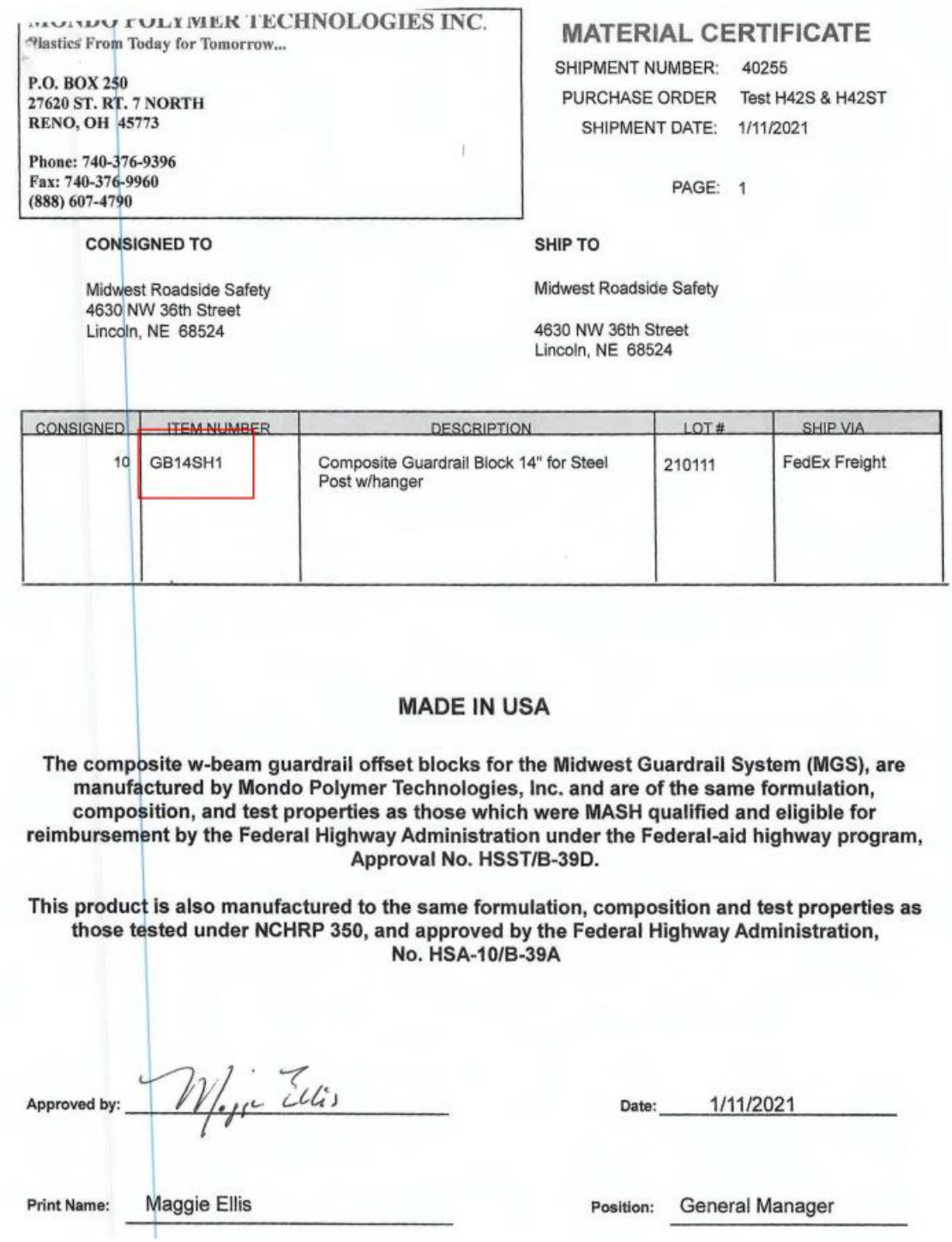
ORDER NUMBER	ORDER DATE	CUSTOMER ID	PURCHASE ORDER	SHIP DATE
40255	01/11/21	MIDWEST	Test H42S & H42ST	1/14/2021

LINE	ORDERED	SHIPPED	UOM	ITEM NUMBER	DESCRIPTION
1	10.0000	10.0000	EACH	GB14SH1	Composite Guardrail Block 14" for Steel Post w/hanger *210111*
2	4.0000	4.0000	EACH	MGS14SH	Midwest Composite Block 14" h x 12" d for Steel Post *210111*
3	1.0000	1.0000	EACH	FREIGHT-GUARDRAIL	FREIGHT-GUARDRAIL BLOCK

THANK YOU FOR YOUR BUSINESS

AUTHORIZED SIGNATURE

Figure A-31. $14^{3}/_{16}$-in. x 8-in. x $5\frac{1}{8}$-in. Composite Recycled Blockout, Test Nos. H42ST-1 and H42ST-2 (Item No. d6)



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

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

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

MATERIAL CERTIFICATE

SHIPMENT NUMBER: 40255
PURCHASE ORDER Test H42S & H42ST
SHIPMENT DATE: 1/11/2021

PAGE: 1

CONSIGNED TO

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

SHIP TO

Midwest Roadside Safety

4630 NW 36th Street
Lincoln, NE 68524

CONSIGNED	ITEM NUMBER	DESCRIPTION	LOT #	SHIP VIA
10	GB14SH1	Composite Guardrail Block 14" for Steel Post w/hanger	210111	FedEx Freight

MADE IN USA

The composite w-beam guardrail offset blocks for the Midwest Guardrail System (MGS), are manufactured by Mondo Polymer Technologies, Inc. and are of the same formulation, composition, and test properties as those which were MASH qualified and eligible for reimbursement by the Federal Highway Administration under the Federal-aid highway program, Approval No. HSST/B-39D.

This product is also manufactured to the same formulation, composition and test properties as those tested under NCHRP 350, and approved by the Federal Highway Administration, No. HSA-10/B-39A

Approved by: Maggie Ellis Date: 1/11/2021

Print Name: Maggie Ellis Position: General Manager

Figure A-32. $14^{3}/_{16}$-in. x 8-in. x $5\frac{1}{8}$-in. Composite Recycled Blockout, Test Nos. H42ST-1 and H42ST-2 (Item No. d7)

McMASTER-CARR

Certificate of Compliance

600 N County Line Rd
Elmhurst IL 60126-2081
630-600-3600
chi.sales@mcmaster.com

University of Nebraska
Midwest Roadside Safety Facility
M W R S F
4630 Nw 36TH St
Lincoln NE 68524-1802
Attention: Shaun M Tighe
Midwest Roadside Safety Facility

Purchase Order
E000548963

Order Placed By
Shaun M Tighe

McMaster-Carr Number
7204107-01

Page 1 of 1

08/02/2018

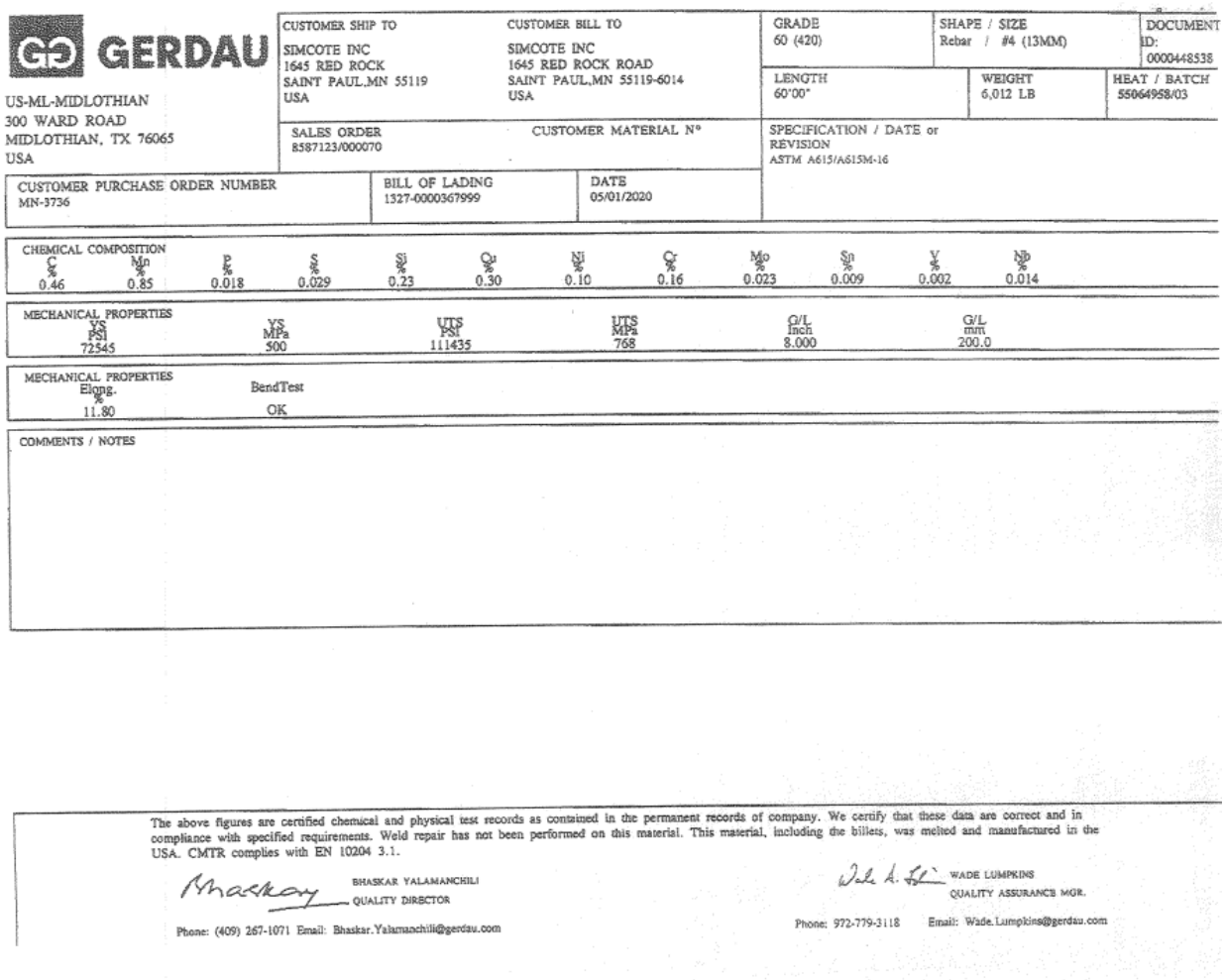
Line	Product	Ordered	Shipped
1	**97812A109** Raised-Head Removable Nails, 16D Penny Size, 3" Long, Packs of 5	**5 Packs**	**5**

Certificate of compliance

This is to certify that the above items were supplied in accordance with the description and as illustrated in the catalog. Your order is subject only to our terms and conditions, available at www.mcmaster.com or from our Sales Department.

Sarah Weinberg
Compliance Manager

Figure A-33. 16D Double Head Nail, Test Nos. H42ST-1 and H42ST-2 (Item No. d8)



GERDAU

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

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

SALES ORDER	CUSTOMER MATERIAL N°	LENGTH	WEIGHT	HEAT / BATCH
8587123/000070		60'00"	6,012 LB	55064958/03

SPECIFICATION / DATE or REVISION: ASTM A615/A615M-16

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

CHEMICAL COMPOSITION

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

MECHANICAL PROPERTIES

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

MECHANICAL PROPERTIES

Elong. %	BendTest
11.80	OK

COMMENTS / NOTES

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

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

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

Figure A-34. #4 Rebar, 16-in. Total Length, Test Nos. H42ST-1 and H42ST-2 (Item Nos. e1, e2, e7, e8, e14, and e15)

NUCOR

Mill Certification
08/26/2020

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

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

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

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

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

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

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

Other Test Results

Yield (PSI) : 66700 — Tensile (PSI) : 101600 — Average Deformation Height (IN) : 0.043

Elongation in 8" (%) : 13.1 — Bend Test : Pass — Weight Percent Variance (%) : -2.40

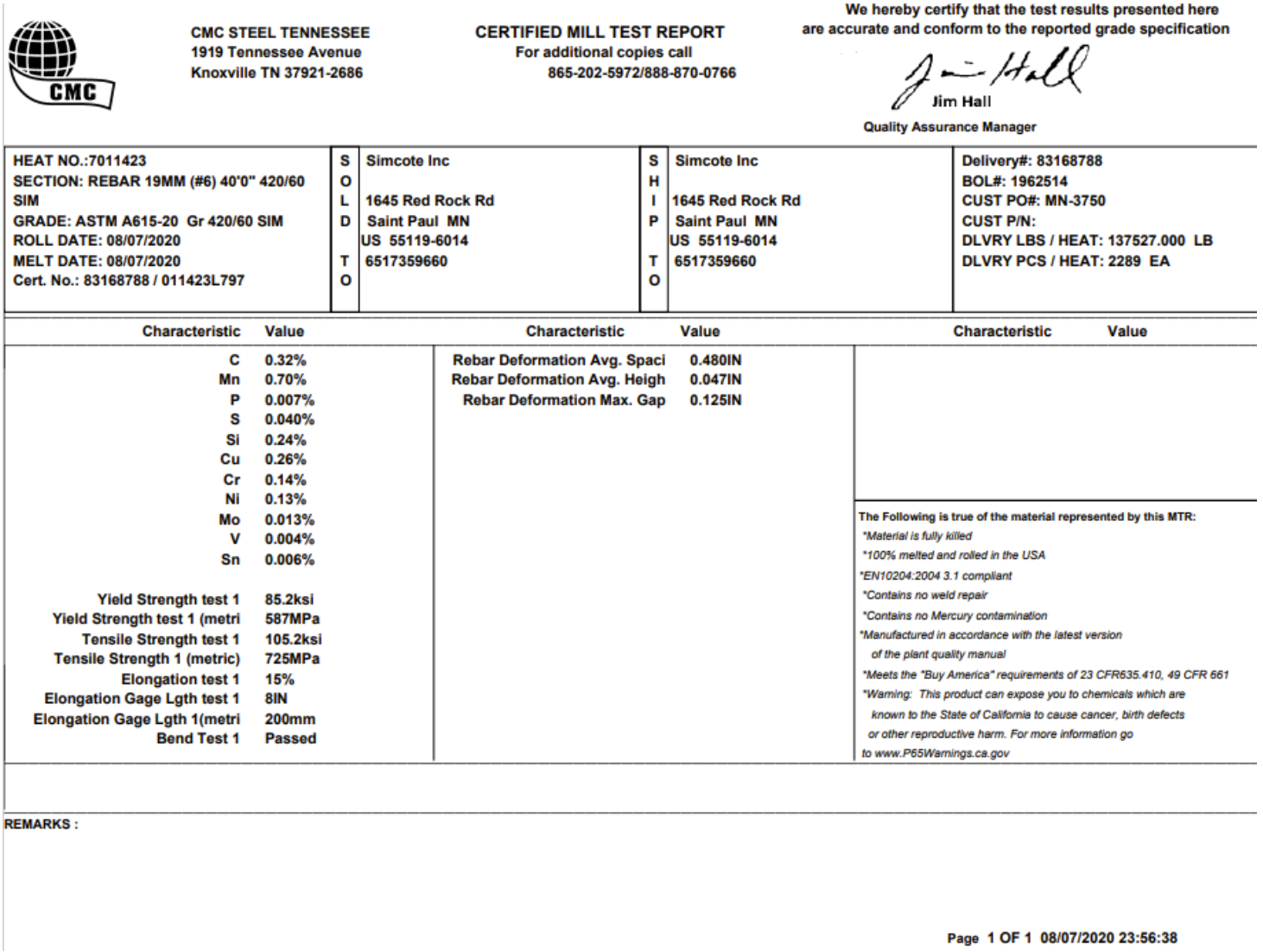
Comments:

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

Zachary Sprintz, Chief Metallurgist

Page 1 of 1

Figure A-35. #5 Rebar, 172-in. Total Length, Test Nos. H42ST-1 and H42ST-2 (Item Nos. e3 and e4)



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.:7011423 SECTION: REBAR 19MM (#6) 40'0" 420/60 SIM GRADE: ASTM A615-20 Gr 420/60 SIM ROLL DATE: 08/07/2020 MELT DATE: 08/07/2020 Cert. No.: 83168788 / 011423L797	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#: 83168788 BOL#: 1962514 CUST PO#: MN-3750 CUST P/N: DLVRY LBS / HEAT: 137527.000 LB DLVRY PCS / HEAT: 2289 EA

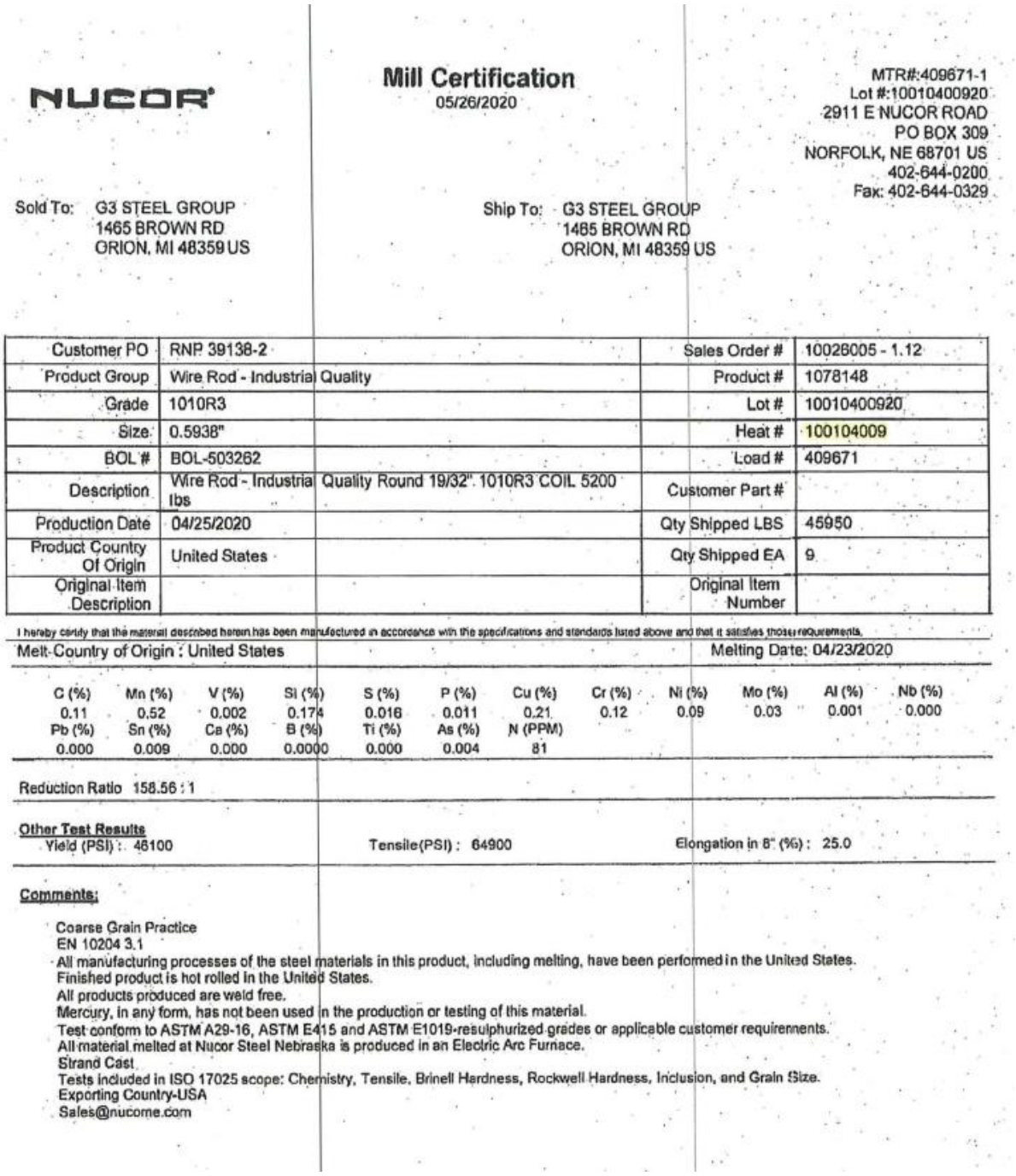
Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.32%	Rebar Deformation Avg. Spaci	0.480IN		
Mn	0.70%	Rebar Deformation Avg. Heigh	0.047IN		
P	0.007%	Rebar Deformation Max. Gap	0.125IN		
S	0.040%				
Si	0.24%				
Cu	0.26%				
Cr	0.14%				
Ni	0.13%				
Mo	0.013%				
V	0.004%				
Sn	0.006%				
Yield Strength test 1	85.2ksi				
Yield Strength test 1 (metri	587MPa				
Tensile Strength test 1	105.2ksi				
Tensile Strength 1 (metric)	725MPa				
Elongation test 1	15%				
Elongation Gage Lgth test 1	8IN				
Elongation Gage Lgth 1(metri	200mm				
Bend Test 1	Passed				

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 :

Page 1 OF 1 08/07/2020 23:56:38

Figure A-36. #6 Rebar, 109-in. Unbent Length, Test Nos. H42ST-1 and H42ST-2 (Item Nos. e5, e6, e9, e10, e11, e12, e16 and e17)



NUCOR

Mill Certification
05/26/2020

MTR#:409671-1
Lot #:10010400920
2911 E NUCOR ROAD
PO BOX 309
NORFOLK, NE 68701 US
402-644-0200
Fax: 402-644-0329

Sold To: G3 STEEL GROUP
1465 BROWN RD
ORION, MI 48359 US

Ship To: G3 STEEL GROUP
1485 BROWN RD
ORION, MI 48359 US

Customer PO	RNP 39138-2	Sales Order #	10026005 - 1.12
Product Group	Wire Rod - Industrial Quality	Product #	1078148
Grade	1010R3	Lot #	10010400920
Size	0.5938"	Heat #	10010400 9
BOL #	BOL-503262	Load #	409671
Description	Wire Rod - Industrial Quality Round 19/32" 1010R3 COIL 5200 lbs	Customer Part #	
Production Date	04/25/2020	Qty Shipped LBS	45950
Product Country Of Origin	United States	Qty Shipped EA	9
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: 04/23/2020

C (%)	Mn (%)	V (%)	Si (%)	S (%)	P (%)	Cu (%)	Cr (%)	Ni (%)	Mo (%)	Al (%)	Nb (%)
0.11	0.52	0.002	0.174	0.016	0.011	0.21	0.12	0.09	0.03	0.001	0.000
Pb (%)	Sn (%)	Ca (%)	B (%)	Ti (%)	As (%)	N (PPM)					
0.000	0.009	0.000	0.0000	0.000	0.004	81					

Reduction Ratio 158.56 : 1

Other Test Results
Yield (PSI) : 46100 — Tensile(PSI) : 64900 — Elongation in 8" (%) : 25.0

Comments:

Coarse Grain Practice
EN 10204 3.1
All manufacturing processes of the steel materials in this product, including melting, have been performed in the United States.
Finished product is hot rolled in the United States.
All products produced are weld free.
Mercury, in any form, has not been used in the production or testing of this material.
Test conform to ASTM A29-16, ASTM E415 and ASTM E1019-resulphurized grades or applicable customer requirements.
All material melted at Nucor Steel Nebraska is produced in an Electric Arc Furnace.
Strand Cast
Tests included in ISO 17025 scope: Chemistry, Tensile, Brinell Hardness, Rockwell Hardness, Inclusion, and Grain Size.
Exporting Country-USA
Sales@nucome.com

Figure A-37. ⅝-in. Dia. 11 UNC, 14-in. Long Guardrail Bolt, Test Nos. H42ST-1 and H42ST-2 (Item No. f1)

AZZ GALVANIZING™
ROCKFORD

CERTIFICATE OF COMPLIANCE

FOR HOT DIP GALVANIZING

CUSTOMER: FASTENAL

DATE: SEPTEMBER 14, 2020

PO#: 040050891

ORDER#: 480015970

This is to certify that the hot dip galvanizing of the following material conforms to specification ASTM A-153. The following sizes and lot numbers comply with the coating, workmanship, finish, and appearance requirements of ASTM F2329 specifications. The hot dip galvanizing is ROHS compliant. The galvanizing process was conducted in a temperature range of 830F to 850F.

HEAT#	PART#	DESCRIPTION	ESTIMATED PIECES	LOT#	MIL
10666100	10406631	5/8-11 X 10 GUARD RAIL BOLT	2485	931491-7	5.6

This certification in no way implies anything other than the quality of our hot dip galvanizing as it pertains to your order.

This product was galvanized in Rockford, IL USA

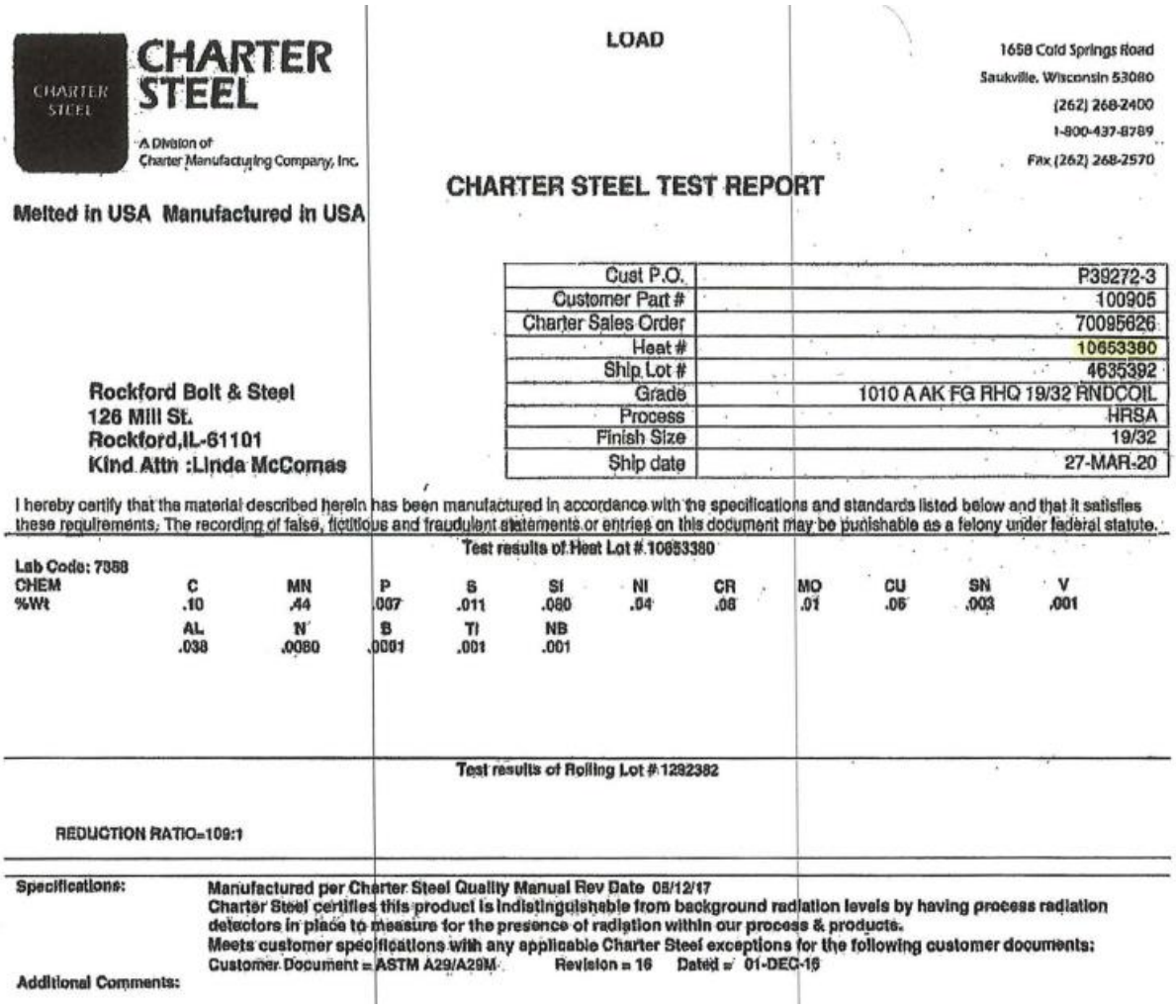
AZZ Galvanizing Rockford, IL

Peggy Doering

Peggy Doering
Office Manager

PD:ac

Figure A-38. ⅝-in. Dia. 11 UNC, 10-in. Long Guardrail Bolt, Test Nos. H42ST-1 and H42ST-2 (Item No. f2)



LOAD

CHARTER STEEL
A Division of Charter Manufacturing Company, Inc.

1658 Cold Springs Road
Saukville, Wisconsin 53080
(262) 268-2400
1-800-437-8789
Fax (262) 268-2570

Melted in USA Manufactured in USA

CHARTER STEEL TEST REPORT

Cust P.O.	P39272-3
Customer Part #	100905
Charter Sales Order	70095626
Heat #	10653380
Ship Lot #	4635392
Grade	1010 A AK FG RHQ 19/32 RNDCOIL
Process	HRSA
Finish Size	19/32
Ship date	27-MAR-20

Rockford Bolt & Steel
126 Mill St.
Rockford,IL-61101
Kind Attn :Linda McComas

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed below and that it satisfies these requirements. The recording of false, fictitious and fraudulent statements or entries on this document may be punishable as a felony under federal statute.

Test results of Heat Lot # 10653380

Lab Code: 7358

CHEM	C	MN	P	S	SI	NI	CR	MO	CU	SN	V
%Wt	.10	.44	.007	.011	.080	.04	.08	.01	.05	.003	.001
	AL	N	B	TI	NB						
	.038	.0080	.0001	.001	.001						

Test results of Rolling Lot # 1292382

REDUCTION RATIO=109:1

Specifications: Manufactured per Charter Steel Quality Manual Rev Date 05/12/17
Charter Steel certifies this product is indistinguishable from background radiation levels by having process radiation detectors in place to measure for the presence of radiation within our process & products.
Meets customer specifications with any applicable Charter Steel exceptions for the following customer documents:
Customer Document = ASTM A29/A29M Revision = 16 Dated = 01-DEC-16

Additional Comments:

Figure A-39. ⅝-in. Dia. 11 UNC, 1½-in. Long Guardrail Bolt, Test Nos. H42ST-1 and H42ST-2 (Item No. f3)

The following statements are applicable to the material described on the front of this Test Report:

1. Except as noted, the steel supplied for this order was melted, rolled, and processed in the United States meeting DFARS compliance, LEEDS compliance, REACH compliance, ROHS-WEEE compliance, and Conflict Materials Restrictions.
2. Mercury was not used during the manufacture of this product, nor was the steel contaminated with mercury during processing.
3. Unless directed by the customer, there are no welds in any of the coils produced for this order.
4. The laboratory that generated the analytical or test results can be identified by the following key:

Certificate Number	Lab Code	Laboratory		Address
0358-01	7388	CSSM	Charter Steel Melting Division	1658 Cold Springs Road, Saukville, WI 53080
0358-02	8171	CSSR	Charter Steel Rolling	1658 Cold Springs Road, Saukville, WI 53080
0358-07	8171	CSSP	Charter Steel Processing Division	1658 Cold Springs Road, Saukville, WI 53080
0358-03	123633	CSFP	Charter Steel Ohio Processing Division	6255 US Highway 23, Rising Sun, OH 43457
0358-04	125544	CSCM/ CSCR	Charter Steel Cleveland	4300 E. 49th St., Cuyahoga Heights, OH 44125-1004
*	*	--	Subcontracted test performed by laboratory not in Charter Steel System	

5. When run by a Charter Steel laboratory, the following tests were performed according to the latest revisions of the specifications listed below, as noted in the Charter Steel Laboratory Quality Manual:

Test	Specifications	CSSM	CSSR/ CSSP	CSFP	CSCM/ CSCR
Chemistry Analysis	ASTM E415; ASTM E1019	X			X
Macroetch	ASTM E381	X			X
Hardenability (Jominy)	ASTM A255; SAE J406; JIS G0561	X			X
Grain Size	ASTM E112	X	X	X	X
Tensile Test	ASTM E8; ASTM A370		X	X	X
Rockwell Hardness	ASTM E18; ASTM A370	X	X	X	X
Microstructure (spheroidization)	ASTM A892		X	X	
Inclusion Content (Methods A, E)	ASTM E45		X		X
Decarburization	ASTM E1077		X	X	X

Charter Steel has been accredited to perform all of the above tests by the American Association for Laboratory Accreditation (A2LA). These accreditations expire 01/31/21. All other test results associated with a Charter Steel laboratory that appear on the front of this report, if any, were performed according to documented procedures developed by Charter Steel and are not accredited by A2LA.

6. The test results on the front of this report are the true values measured on the samples taken from the production lot. They do not apply to any other sample.
7. This test report cannot be reproduced or distributed except in full without the written permission of Charter Steel. The primary customer whose name and address appear on the front of this form may reproduce this test report subject to the following restrictions:
   - It may be distributed only to their customers
   - Both sides of all pages must be reproduced in full
8. This certification is given subject to the terms and conditions of sale provided in Charter Steel's acknowledgement (designated by our Sales Order number) to the customer's purchase order. Both order numbers appear on the front page of this Report.
9. Where the customer has provided a specification, the results on the front of this test report conform to that specification unless otherwise noted on this test report.

A2LA ACCREDITED Testing Laboratory

Figure A-40. ⅝-in. Dia. 11 UNC, 1½-in. Long Guardrail Bolt, Test Nos. H42ST-1 and H42ST-2, Cont. (Item No. f3)

Certificate of Compliance

Birmingham Fastener Manufacturing
PO Box 10323
Birmingham, AL 35202
(205) 595-3512

Customer	Midwest Machinery & Supply	**Date Shipped**	11/28/2018
Customer Order Number	3664	**BFM Order Number**	1553751

Item Description

Description	5/8"-11 x 10" Hex Bolt	**Qty**	298
Lot #	81342	**Specification**	ASTM A307-14 Gr A
Finish	ASTM F2329		

Raw Material Analysis

Heat# JK18104124

Chemical Composition (wt% Heat Analysis) By Material Supplier

C	Mn	P	S	Si	Cu	Ni	Cr	Mo
0.18	1.19	0.012	0.034	0.20	0.29	0.13	0.11	0.04

Mechanical Properties

Sample #	Hardness	Tensile Strength (lbs)	Tensile Strength (psi)
1	93 HRBW	22,049	99,410
2			
3			
4			
5			

This information represents the most recent analysis of the product supplied on the stated customer order. The samples tested conform to the ASTM standard listed above.
All steel melted and manufactured in the U.S.A.

Authorized Signature: _____ **Date:** 11/29/2018

Brian Hughes
Quality Assurance

Figure A-41. ⅝-in. Dia. 11 UNC, 10-in. Long Hex Head Bolt, Test Nos. H42ST-1 and H42ST-2 (Item No. f4)

FASTENAL®

Certificate of Compliance

Sold To:

UNL / UNMC E-SHOP / PUNCHOUT

Purchase Order: E000810303

Job:

Invoice Date: 11/11/2020

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

60 PCS 5/8"-11 x 1-1/2" ASTM A307 Grade A Hot Dipped Galvanized Hex Bolt SUPPLIED UNDER OUR TRACE NUMBER 180170611 AND UNDER PART NUMBER 91919

100 PCS 5/8" x 1.750" OD Low Carbon Hot Dipped Galvanized Finish Steel USS General Purpose Flat Washer SUPPLIED UNDER OUR TRACE NUMBER 210215887 AND UNDER PART NUMBER 1133185

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

Tom Schall

Fastenal Account Representative Signature

Ross Schall

Printed Name

11-11-2020

Date

Please check current revision to avoid using obsolete copies.

This document was printed on 11/11/2020 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 A-42. ⅝-in. Dia. 11 UNC, 1½-in. Long Hex Head Bolt, Test Nos. H42ST-1 (Item No. f5)

ISO/TS 16949 BUREAU VERITAS Certification

GEM-YEAR TESTING LABORATORY
CERTIFICATE OF INSPECTION

MANUFACTURER :GEM-YEAR INDUSTRIAL CO., LTD.
ADDRESS : NO.8 GEM-YEAR ROAD,E.D.Z.,JIASHAN,ZHEJIANG,P.R.CHINA
Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2017/12/04

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 220024456
COMMODITY : HEX MACHINE BOLT GR-A
SIZE : 5/8-11X1-1/2 NC
LOT NO : 1B1740865
SHIP QUANTITY : 11,840 PCS
LOT QUANTITY 12,009 PCS
HEADMARKS : CYI & 307A

PACKING NO : GEM170525004
INVOICE NO : GEM/FNL-170608IN-4
PART NO : 1191919
SAMPLING PLAN :
ASME B18.18-2011(Category.2)/ASTM F1470-2012
HEAT NO : 17301484-3
MATERIAL : X1008A
FINISH : HOT DIP GALVANIZED PER ASTM A153-2009/ASTM F2329-2013

MANUFACTURE DATE : 2017/05/19
COUNTRY OF ORIGIN : CHINA

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A307-2014

Chemistry	AL%	C%	MN%	P%	S%	SI%
Spec. : MIN.						
MAX.		0.3300	1.2500	0.0410		
Test Value	0.0270	0.0600	0.2900	0.0110	0.0070	0.0300

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.1-2012

SAMPLED BY : HXNAN

INSPECTIONS ITEM	SAMPLE	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
MAJOR DIAMETER	15 PCS	0.6130-0.6250 inch	0.6220-0.6230 inch	15	0
WIDTH ACROSS CORNERS	4 PCS	1.0330-1.0830 inch	1.0630-1.0650 inch	4	0
HEIGHT	4 PCS	0.3780-0.4440 inch	0.3940-0.3940 inch	4	0
NOMINAL LENGTH	15 PCS	1.4200-1.5600 inch	1.4330-1.4370 inch	15	0
WIDTH ACROSS FLATS	4 PCS	0.9060-0.9380 inch	0.9340-0.9350 inch	4	0
SURFACE DISCONTINUITIES	29 PCS	ASTM F788-2013	PASSED	29	0
THREAD	15 PCS	ASME B1.1-2003 nut	PASSED	15	0

MECHANICAL PROPERTIES : ACCORDING TO ASTM A 307-2014

SAMPLED BY : GDAN LIAN

INSPECTIONS ITEM	SAMPLE	TEST METHOD	REF	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS	15 PCS	ASTM F606-2016		69-100 HRB	82-84 HRB	15	0
TENSILE STRENGTH	4 PCS	ASTM F606-2016		Min. 60 KSI	76-78 KSI	4	0
PLATING THICKNESS(μm)	5 PCS	ASTM B568-1998		>=53	70.25-78.47	5	0

WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY .WHICH ACCREDITED BY ISO/IEC17025(CERTIFICATE NUMBER:3358.01)
WE CERTIFY THAT THE PRODUCTS SUPPLIED ARE IN COMPLIANCE WITH THE REQUIREMENTS OF THE ORDER

Quality Supervisor:

page 1 of 1

Figure A-43. ⅝-in. Dia. 11 UNC, 1½-in. Long Hex Head Bolt, Test Nos. H42ST-2 (Item No. f5)

Portland Bolt & MANUFACTURING COMPANY

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

CERTIFICATE OF CONFORMANCE

For: MIDWEST ROADSIDE SAFETY FACIL
PB Invoice#: 138185
Cust PO#: H42
Date: 1/15/2021
Shipped: 1/18/2021

We certify that the following items were manufactured and tested in accordance with the chemical, mechanical, dimensional and thread fit requirements of the specifications referenced.

Description: 7/8 X 16 GALV ASTM F3125 GRADE A325 HEAVY HEX BOLT

Heat#: 100794352 **Base Steel:** 4140 **Diam:** 7/8

Source: KREHER STEEL CO LLC **Proof Load:** 39,250 LBF

C :	.420	**Mn:**	.850	**P :**	.007	**Hardness:**	285 HBN
S :	.017	**Si:**	.290	**Ni:**	.060	**Tensile:**	75,480 LBF
Cr:	1.000	**Mo:**	.200	**Cu:**	.150	**Yield:**	0
Pb:	.000	**V :**	.005	**Cb:**	.000	**Sample Length:**	0
N :	.000			**CE:**	.6639	**Charpy:**	

RA: .00%
Elon: .00%
CVN Temp:

LOT#19529

Nuts:
ASTM A563DH HVY HX

Coatings:
ITEMS HOT DIP GALVANIZED PER ASTM F2329/A153C

Other:
ALL ITEMS MELTED & MANUFACTURED IN THE USA

By: _____
Certification Department Quality Assurance
Dane McKinnon

Figure A-44. ⅞-in. Dia. 9 UNC, 16-in. Long Hex Head Bolt, Test Nos. H42ST-1 and H42ST-2 (Item No. f6)

Apr. 12. 2018 4:32PM Fastenal-NELIN No. 4682 P. 3

FASTENAL®

Certificate of Compliance

Sold To:

UNL TRANSPORTATION

Purchase Order:

Job: TL-2 and Bullnose

Invoice Date: 03/27/2018

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

5 PCS 7/8"-9 x 8" ASTM A307 Grade A Hot Dipped Galvanized Hex Bolt SUPPLIED UNDER OUR TRACE NUMBER line35042 AND UNDER PART NUMBER 92005

20 PCS 7/8"-9 Hot Dip Galvanized Finish Grade A Finished Hex Nut SUPPLIED UNDER OUR TRACE NUMBER 110254885 AND UNDER PART NUMBER 36717

5 PCS 7/8"-9 x 8" ASTM A307 Grade A Hot Dipped Galvanized Hex Bolt SUPPLIED UNDER OUR TRACE NUMBER line35042 AND UNDER PART NUMBER 92005

5 PCS 7/8"-9 x 8" ASTM A307 Grade A Hot Dipped Galvanized Hex Bolt SUPPLIED UNDER OUR TRACE NUMBER line35042 AND UNDER PART NUMBER 92005

5 PCS 7/8"-9 x 8" ASTM A307 Grade A Hot Dipped Galvanized Hex Bolt SUPPLIED UNDER OUR TRACE NUMBER line35042 AND UNDER PART NUMBER 92005

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

Fastenal Account Representative Signature

Printed Name

4/12/18
Date

Please check current revision to avoid using obsolete copies.

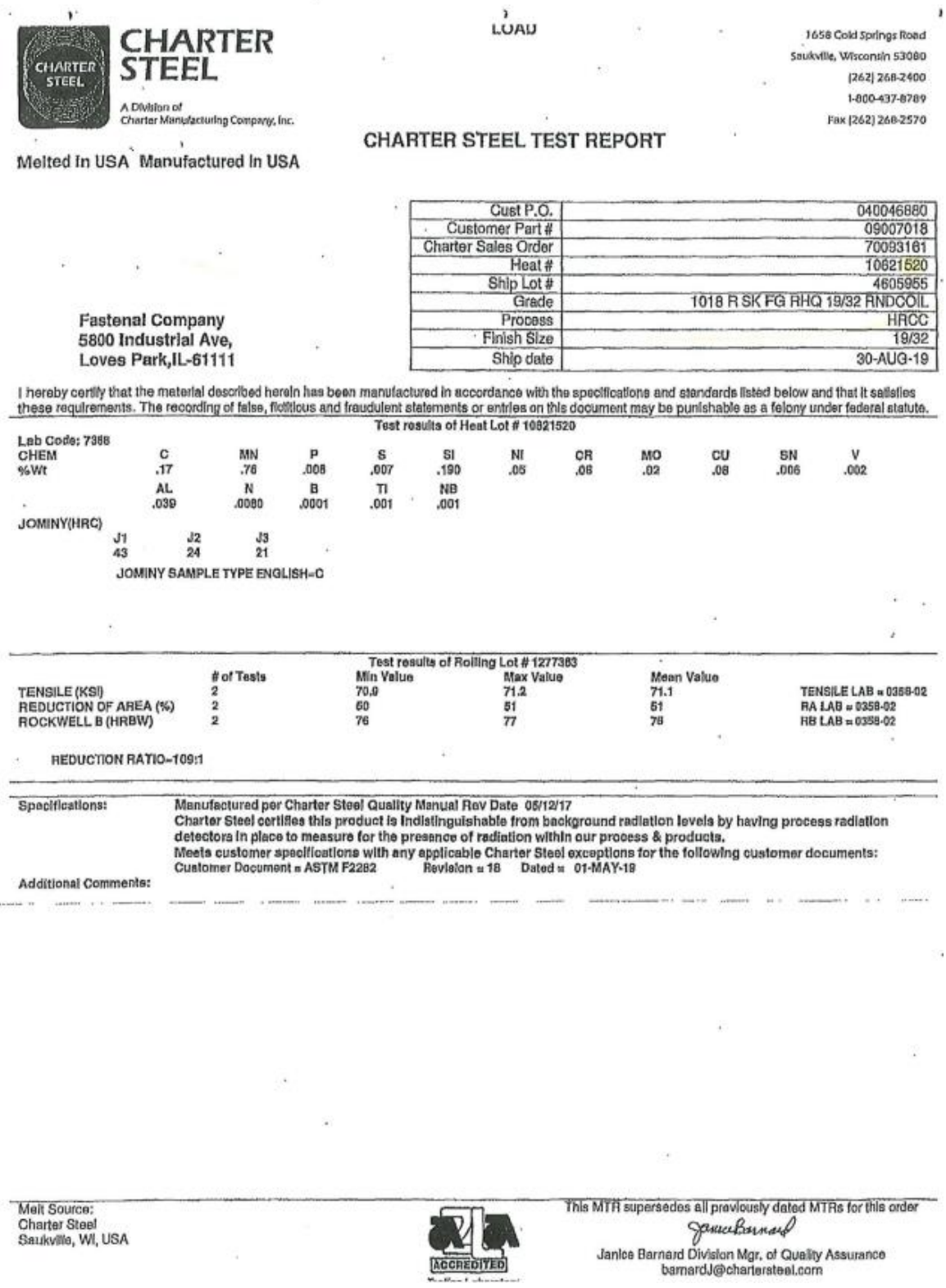
This document was printed on 04/12/2018 and was current at that time.

Fastenal Store Location/Address

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

Page 1 of 1

Figure A-45. ⅞-in. Dia. 9 UNC, 8-in. Long Hex Head Bolt, Test Nos. H42ST-1 and H42ST-2 (Item No. f7)



CHARTER STEEL
A Division of Charter Manufacturing Company, Inc.

LOAD

1658 Cold Springs Road
Saukville, Wisconsin 53080
(262) 268-2400
1-800-437-8789
Fax (262) 268-2570

Melted In USA Manufactured In USA

CHARTER STEEL TEST REPORT

Cust P.O.	040046880
Customer Part #	09007018
Charter Sales Order	70093161
Heat #	10821520
Ship Lot #	4605955
Grade	1018 R SK FG RHQ 19/32 RNDCOIL
Process	HRCC
Finish Size	19/32
Ship date	30-AUG-19

Fastenal Company
5800 Industrial Ave,
Loves Park,IL-61111

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed below and that it satisfies these requirements. The recording of false, fictitious and fraudulent statements or entries on this document may be punishable as a felony under federal statute.

Test results of Heat Lot # 10821520

Lab Code: 7368

CHEM	C	MN	P	S	SI	NI	CR	MO	CU	SN	V
%Wt	.17	.76	.008	.007	.190	.05	.08	.02	.08	.006	.002
	AL	N	B	TI	NB						
	.039	.0080	.0001	.001	.001						

JOMINY(HRC)

J1	J2	J3
43	24	21

JOMINY SAMPLE TYPE ENGLISH=C

Test results of Rolling Lot # 1277383

	# of Tests	Min Value	Max Value	Mean Value	
TENSILE (KSI)	2	70.9	71.2	71.1	TENSILE LAB = 0358-02
REDUCTION OF AREA (%)	2	50	51	51	RA LAB = 0358-02
ROCKWELL B (HRBW)	2	76	77	76	RB LAB = 0358-02

REDUCTION RATIO=109:1

Specifications: Manufactured per Charter Steel Quality Manual Rev Date 05/12/17
Charter Steel certifies this product is indistinguishable from background radiation levels by having process radiation detectors in place to measure for the presence of radiation within our process & products.
Meets customer specifications with any applicable Charter Steel exceptions for the following customer documents:
Customer Document = ASTM F2282 Revision = 18 Dated = 01-MAY-19

Additional Comments:

Melt Source:
Charter Steel
Saukville, WI, USA

ACCREDITED

This MTR supersedes all previously dated MTRs for this order

Janice Barnard Division Mgr. of Quality Assurance
barnardJ@chartersteel.com

Figure A-46. ⅝-in. Dia. 11 UNC, 2-in. Long Guardrail Bolt, Test Nos. H42ST-1 and H42ST-2 (Item No. f8)

The following statements are applicable to the material described on the front of this Test Report:

1. Except as noted, the steel supplied for this order was melted, rolled, and processed in the United States meeting DFARS compliance, LEEDS compliance, REACH compliance, ROHS-WEEE compliance, and Conflict Materials Restrictions.
2. Mercury was not used during the manufacture of this product, nor was the steel contaminated with mercury during processing.
3. Unless directed by the customer, there are no welds in any of the coils produced for this order.
4. The laboratory that generated the analytical or test results can be identified by the following key:

Certificate Number	Lab Code	Laboratory		Address
0358-01	7388	CSSM	Charter Steel Melting Division	1658 Cold Springs Road, Saukville, WI 53080
0358-02	8171	CSSR/ CSSP	Charter Steel Rolling/ Processing Division	1658 Cold Springs Road, Saukville, WI 53080
0358-03	123633	CSFP	Charter Steel Ohio Processing Division	6255 US Highway 23, Rising Sun, OH 43457
0358-04	125544	CSCM/ CSCR	Charter Steel Cleveland	4300 E. 49th St., Cuyahoga Heights, OH 44125-1004
*	*	--	Subcontracted test performed by laboratory not in Charter Steel System	

5. When run by a Charter Steel laboratory, the following tests were performed according to the latest revisions of the specifications listed below, as noted in the Charter Steel Laboratory Quality Manual:

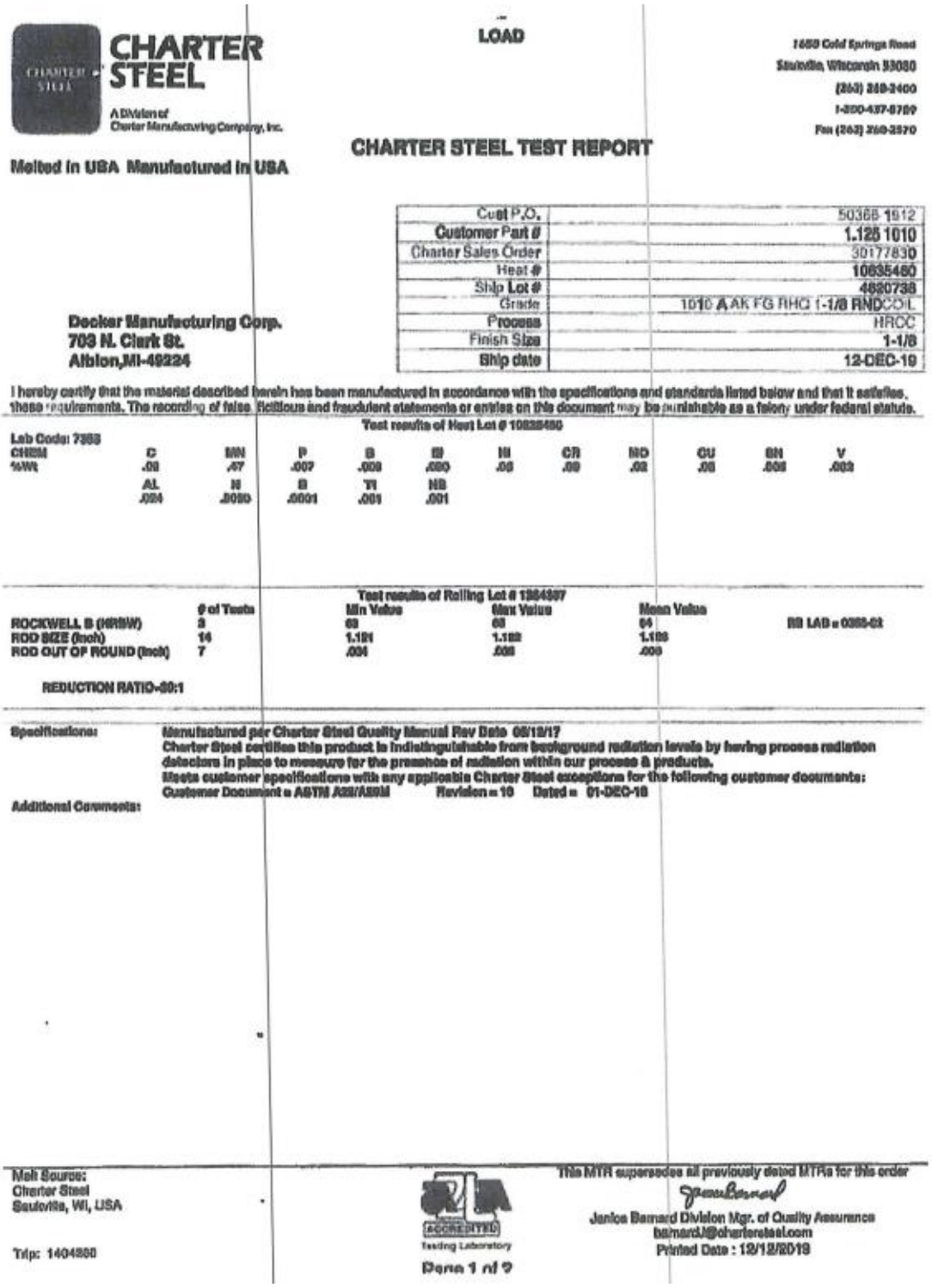
Test	Specifications	CSSM	CSSR/ CSSP	CSFP	CSCM/ CSCR
Chemistry Analysis	ASTM E415; ASTM E1019	X			X
Macroetch	ASTM E381	X			X
Hardenability (Jominy)	ASTM A255; SAE J406; JIS G0561	X			X
Grain Size	ASTM E112	X	X	X	X
Tensile Test	ASTM E8; ASTM A370		X	X	X
Rockwell Hardness	ASTM E18; ASTM A370	X	X	X	X
Microstructure (spheroidization)	ASTM A892		X	X	
Inclusion Content (Methods A, E)	ASTM E45		X		X
Decarburization	ASTM E1077		X	X	X

Charter Steel has been accredited to perform all of the above tests by the American Association for Laboratory Accreditation (A2LA). These accreditations expire 01/31/21. All other test results associated with a Charter Steel laboratory that appear on the front of this report, if any, were performed according to documented procedures developed by Charter Steel and are not accredited by A2LA.

6. The test results on the front of this report are the true values measured on the samples taken from the production lot. They do not apply to any other sample.
7. This test report cannot be reproduced or distributed except in full without the written permission of Charter Steel. The primary customer whose name and address appear on the front of this form may reproduce this test report subject to the following restrictions:
   - It may be distributed only to their customers
   - Both sides of all pages must be reproduced in full
8. This certification is given subject to the terms and conditions of sale provided in Charter Steel's acknowledgement (designated by our Sales Order number) to the customer's purchase order. Both order numbers appear on the front page of this Report.
9. Where the customer has provided a specification, the results on the front of this test report conform to that specification unless otherwise noted on this test report.

A2LA ACCREDITED Testing Laboratory

Figure A-47. ⅝-in. Dia. 11 UNC, 2-in. Long Guardrail Bolt, Test Nos. H42ST-1 and H42ST-2, Cont. (Item No. f8)



CHARTER STEEL
A Division of Charter Manufacturing Company, Inc.

LOAD

1659 Cold Springs Road
Saukville, Wisconsin 53080
(262) 268-2400
1-800-437-8769
Fax (262) 268-2370

CHARTER STEEL TEST REPORT

Melted in USA Manufactured in USA

Cust P.O.	50368 1912
Customer Part #	1.125 1010
Charter Sales Order	30177830
Heat #	10635460
Ship Lot #	4830738
Grade	1010 A AK FG RHQ 1-1/8 RNDCOIL
Process	HRCC
Finish Size	1-1/8
Ship date	12-DEC-19

Decker Manufacturing Corp.
703 N. Clark St.
Albion,MI-49224

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed below and that it satisfies these requirements. The recording of false, fictitious and fraudulent statements or entries on this document may be punishable as a felony under federal statute.

Test results of Heat Lot # 10635460

Lab Code: 7368

CHEM	C	MN	P	S	SI	NI	CR	MO	CU	SN	V
%WT	.09	.47	.007	.009	.020	.06	.09	.02	.06	.008	.002
	AL	N	B	TI	NB						
	.024	.0080	.0001	.001	.001						

Test results of Rolling Lot # 1364307

	# of Tests	Min Value	Max Value	Mean Value
ROCKWELL B (HRBW)	3	63	65	64
ROD SIZE (inch)	14	1.121	1.122	1.120
ROD OUT OF ROUND (inch)	7	.004	.008	.006

RB LAB = 0368-02

REDUCTION RATIO=80:1

Specifications: Manufactured per Charter Steel Quality Manual Rev Date 08/13/17
Charter Steel certifies this product is indistinguishable from background radiation levels by having process radiation detectors in place to measure for the presence of radiation within our process & products.
Meets customer specifications with any applicable Charter Steel exceptions for the following customer documents:
Customer Document = ASTM A29/A29M Revision = 16 Dated = 01-DEC-16

Additional Comments:

Melt Source:
Charter Steel
Saukville, WI, USA

Trip: 1404860

ACCREDITED Testing Laboratory

This MTR supersedes all previously dated MTRs for this order

Janice Barnard Division Mgr. of Quality Assurance
barnardJ@charintsteel.com
Printed Date : 12/12/2019

Page 1 of 2

Figure A-48. ⅝-in. Dia. 11 UNC, Heavy Hex Nut, Test Nos. H42ST-1 and H42ST-2 (Item No. f9)

ISO/TS 16949 BUREAU VERITAS Certification

GEM-YEAR TESTING LABORATORY
CERTIFICATE OF INSPECTION

MANUFACTURER :GEM-YEAR INDUSTRIAL CO., LTD.
ADDRESS : NO.8 GEM-YEAR ROAD,E.D.Z.,JIASHAN,ZHEJIANG,P.R.CHINA
Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2018/03/28

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 110254885
COMMODITY : FINISHED HEX NUT GR-A
SIZE : 7/8-9 NC O/T 0.56MM
LOT NO : 1N1810005
SHIP QUANTITY : 9,000 PCS
LOT QUANTITY 55,748 PCS
HEADMARKS :

PACKING NO : GEM180115010
INVOICE NO : GEM/FNL-180201WI-1
PART NO : 36717
SAMPLING PLAN : ASME B18.18-2011(Category.2)/ASTM F1470-2012
HEAT NO : 331704677
MATERIAL : XGML08
FINISH : HOT DIP GALVANIZED PER ASTM A153-2009/ASTM F2329-2013

MANUFACTURE DATE : 2018/01/05
COUNTRY OF ORIGIN : CHINA

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A563-2015

Chemistry	AL%	C%	MN%	P%	S%	SI%
Spec. : MIN.						
MAX.		0.5800		0.1300	0.2300	
Test Value	0.0360	0.0600	0.4500	0.0140	0.0030	0.0300

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.2-2015

SAMPLED BY : WDANDAN

INSPECTIONS ITEM	SAMPLE	SPECIFIED		ACTUAL RESULT	ACC.	REJ.
WIDTH ACROSS CORNERS	5 PCS		1.4470-1.5160 inch	1.4850-1.4930 inch	5	0
FIM	15 PCS	ASME B18.2.2-2015	Max. 0.0250 inch	0.0110-0.0200 inch	15	0
THICKNESS	5 PCS		0.7240-0.7760 inch	0.7460-0.7570 inch	5	0
WIDTH ACROSS FLATS	5 PCS		1.2690-1.3120 inch	1.2930-1.2980 inch	5	0
SURFACE DISCONTINUITIES	29 PCS		ASTM F812-2012	PASSED	29	0
THREAD	15 PCS		GAGING SYSTEM 21	PASSED	15	0

MECHANICAL PROPERTIES : ACCORDING TO ASTM A563-2015

SAMPLED BY : TANGHAO

INSPECTIONS ITEM	SAMPLE	TEST METHOD	REF	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS	15 PCS	ASTM F606-2014		68-107 HRB	86-90 HRB	15	0
PROOF LOAD	5 PCS	ASTM F606-2014		Min. 31,416 LBF	OK	5	0
PLATING THICKNESS(μm)	29 PCS	ASTM B568-1998		>=53	62.38-62.57	29	0

WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY .WHICH ACCREDITED BY ISO/IEC17025(CERTIFICATE NUMBER:3358.01)
WE CERTIFY THAT THE PRODUCTS SUPPLIED ARE IN COMPLIANCE WITH THE REQUIREMENTS OF THE ORDER

Quality Supervisor:

Figure A-49. ⅞-in. Dia. 9 UNC, Hex Nut, Test Nos. H42ST-1 and H42ST-2 (Item No. f10)

NUCOR
FASTENER DIVISION

LOT NO.
417521B

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

CUSTOMER NO/NAME
1554 BRIGHTON-BEST/CA

NUCOR ORDER # 175251
CUST PART # 175092
TEST REPORT SERIAL# FB594019
TEST REPORT ISSUE DATE 3/04/19
DATE SHIPPED 12/08/19
CUSTOMER P.O. # U70154
NAME OF LAB SAMPLER: DEANN WATSON, LAB TECHNICIAN

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

NUCOR PART NO	QUANTITY	LOT NO.	DESCRIPTION
175667	9900	417521B	7/8-9 GR DH HV H.D.G. HEX NUT HDG/GREEN LUBE

MANUFACTURE DATE 12/04/18

--CHEMISTRY MATERIAL GRADE -1045L

MATERIAL NUMBER	HEAT NUMBER	**CHEMISTRY COMPOSITION (WT% HEAT ANALYSIS) BY MATERIAL SUPPLIER					
		C	MN	P	S	SI	NUCOR STEEL - NEBRASKA
RM032885	100894559	.44	.67	.007	.017	.18	

--MECHANICAL PROPERTIES IN ACCORDANCE WITH ASTM A563-15

SURFACE HARDNESS (R30N)	CORE HARDNESS (RC)	PROOF LOAD 69300 LBS	TENSILE STRENGTH (LBS)	DEG-WEDGE STRESS (PSI)
N/A	30.3	PASS	N/A	N/A
N/A	31.7	PASS	N/A	N/A
N/A	31.9	PASS	N/A	N/A
N/A	29.4	PASS	N/A	N/A
N/A	29.6	PASS	N/A	N/A

AVERAGE VALUES FROM TESTS
30.6
PRODUCTION LOT SIZE 118000 PCS

--VISUAL INSPECTION IN ACCORDANCE WITH ASTM A563-15 80 PCS. SAMPLED LOT PASSED

--COATING - HOT DIP GALVANIZED TO ASTM F2329-15 - GALVANIZING PERFORMED IN THE U.S.A.

1.	0.00297	2.	0.00348	3.	0.00263	4.	0.00247	5.	0.00223	6.	0.00354	7.	0.00267
8.	0.00286	9.	0.00400	10.	0.00300	11.	0.00322	12.	0.00398	13.	0.00294	14.	0.00261
15.	0.00269												

AVERAGE THICKNESS FROM 15 TESTS .00302

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

--DIMENSIONS PER ASME B18.2.6-2010

CHARACTERISTIC	#SAMPLES TESTED	MINIMUM	MAXIMUM
Width Across Corners	8	1.616	1.623
Thickness	32	0.858	0.879

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 12/31/19

NUCOR FASTENER
A DIVISION OF NUCOR CORPORATION

BOB HAYWOOD
QUALITY ASSURANCE SUPERVISOR

Page 1 of 1

Figure A-50. ⅞-in. Dia. 9 UNC, Heavy Hex Nut, Test Nos. H42ST-1 and H42ST-2 (Item No. f11)

Nov. 26. 2018 3:47PM Fastenal-NELIN No. 5947 P. 2

FASTENAL®

Certificate of Compliance

Sold To:

UNL TRANSPORTATION

Purchase Order: STBR

Job: Item# f3, h1 and i1

Invoice Date: 11/8/2018

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

80 PCS 1"-8 Hot Dipped Galvanized A563 Grade DH Heavy Hex Nut Made In USA SUPPLIED UNDER OUR TRACE NUMBER 210157128 AND UNDER PART NUMBER 38210

450 PCS 3/4"-10 Hot Dipped Galvanized A563 Grade DH Heavy Hex Nut Made In USA SUPPLIED UNDER OUR TRACE NUMBER 210169774 AND UNDER PART NUMBER 38208

80 PCS 1"-8 Hot Dipped Galvanized A563 Grade DH Heavy Hex Nut Made In USA SUPPLIED UNDER OUR TRACE NUMBER 210157128 AND UNDER PART NUMBER 38210

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

Fastenal Account Representative Signature

Ashly Stanczyk

Printed Name

11/29/18

Date

Please check current revision to avoid using obsolete copies.

This document was printed on 11/26/2018 and was current at that time.

Fastenal Store Location/Address

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

Page 1 of 1

Figure A-51. 1-in. Dia. 8 UNC, Heavy Hex Nut, Test Nos. H42ST-1 and H42ST-2 (Item No. f12)

ISO/TS 16949 BUREAU VERITAS Certification

GEM-YEAR TESTING LABORATORY
CERTIFICATE OF INSPECTION

MANUFACTURER :GEM-YEAR INDUSTRIAL CO., LTD.
ADDRESS : NO.8 GEM-YEAR ROAD,E.D.Z.,JIASHAN,ZHEJIANG,P.R.CHINA
Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2017/03/23

PURCHASER : FASTENAL COMPANY PURCHASING
PO. NUMBER : 110216407
COMMODITY : FINISHED HEX NUT GR-A
SIZE : 5/8-11 NC O/T 0.51MM
LOT NO : IN168002?
SHIP QUANTITY : 23,400 PCS
LOT QUANTITY 170,278 PCS
HEADMARKS :

PACKING NO : GEM160919007
INVOICE NO : GEM/FNL-160929WI
PART NO : 36713
SAMPLING PLAN :
ASME B18.18-2011(Category.2)/ASTM F1470-2012
HEAT NO : 331608011
MATERIAL : ML08
FINISH : HOT DIP GALVANIZED PER ASTM A153-2009/ASTM F2329-2013

MANUFACTURE DATE : 2016/08/26
COUNTRY OF ORIGIN : CHINA

R#17-507 H#331608011
BCT Cable Bracket Nuts

PERCENTAGE COMPOSITION OF CHEMISTRY:ACCORDING TO ASTM A563-2007

Chemistry	AL%	C%	MN%	P%	S%	SI%
Spec. : MIN.						
MAX.		0.5800		0.1300	0.2300	
Test Value	0.0350	0.0700	0.4100	0.0160	0.0060	0.0500

DIMENSIONAL INSPECTIONS :ACCORDING TO ASME B18.2.2-2010

SAMPLED BY : DWTING

INSPECTIONS ITEM	SAMPLE	SPECIFIED		ACTUAL RESULT	ACC.	REJ.
WIDTH ACROSS CORNERS	6 PCS		1.0510-1.0830 inch	1.0560-1.0690 inch	6	0
FIM	15 PCS	ASME B18.2.2-2010	Max. 0.0210 inch	0.0020-0.0040 inch	15	0
THICKNESS	6 PCS		0.5350-0.5590 inch	0.5390-0.5570 inch	6	0
WIDTH ACROSS FLATS	6 PCS		0.9220-0.9380 inch	0.9240-0.9340 inch	6	0
SURFACE DISCONTINUITIES	29 PCS		ASTM F812-2012	PASSED	29	0
THREAD	15 PCS		GAGING SYSTEM 21	PASSED	15	0

MECHANICAL PROPERTIES : ACCORDING TO ASTM A563-2007

SAMPLED BY : GDAN LIAN

INSPECTIONS ITEM	SAMPLE	TEST METHOD	REF	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS	15 PCS	ASTM F606-2014		68-107 HRB	79-81 HRB	15	0
PROOF LOAD	4 PCS	ASTM F606-2014		Min. 90 KSI	OK	4	0
PLATING THICKNESS(μm)	5 PCS	ASTM B568-1998		>=53	70.02-75.81	5	0

WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY .WHICH ACCREDITED BY ISO/IEC17025(CERTIFICATE NUMBER:3358.01)
WE CERTIFY THAT THE PRODUCTS SUPPLIED ARE IN COMPLIANCE WITH THE REQUIREMENTS OF THE ORDER

Quality Supervisor:

Figure A-52. ⅝-in. Dia. 11 UNC, Heavy Hex Nut, Test Nos. H42ST-1 and H42ST-2 (Item No. f13)

CERTIFIED MATERIAL TEST REPORT
FOR USS FLAT WASHERS HDG

FACTORY: IFI & Morgan Ltd
ADDRESS: Chang'an North Road, Wuyuan Town, Haiyan,Zhejiang, China
TEL: (852)25423366
CUSTOMER:

REPORT DATE: 14/1/2021
MANUFACTURE DATE:
MFG LOT NUMBER: 1851805
PO NUMBER: 200152825

+

SAMPLING PLAN PER ASME B18.18-11
SIZE: USS 5/8 HDG QNTY(Lot size): 12000PCS
HEADMARKS: NO MARK
PART NO: 1133185

DIMENSIONAL INSPECTIONS — SPECIFICATION: ASTM B18.21.1-2011

CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
APPEARANCE	ASTM F844	PASSED	100	0
OUTSIDE DIA	1.743-1.780	1.746-1.754	10	0
INSIDE DIA	0.681-0.718	0.707-0.715	10	0
THICKNESS	0.108-0.160	0.108-0.126	10	0

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT		ACC.	REJ.
HOT DIP GALVANIZED	ASTM F2329-13	Min 0.0017"	0.0017-0.0020	in	8	0

ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE ASTM SPECIFICATION. WE CERTIFY THAT THIS DAIA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.
MFG ISO9002 CERTIFICATE NO. HK04/0105

IFI & MORGAN LTD. 检验专用章 QUALITY CONTROL

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

Figure A-53. ⅝-in. Dia. Plain USS Washer, Test Nos. H42ST-1 and H42ST-2 (Item No. g1)

CERTIFIED MATERIAL TEST REPORT
FOR USS FLAT WASHERS HDG

FACTORY: IFI & Morgan Ltd
ADDRESS: Chang'an North Road, Wuyuan Town, Haiyan,Zhejiang, China

REPORT DATE: 23/4/2019

MFG LOT NUMBER: 1844804

SAMPLING PLAN PER ASME B18.18-11
SIZE: USS 7/8 HDG QNTY(Lot size): 7200PCS
HEADMARKS: NO MARK

PO NUMBER: 170089822

PART NO: 33187

DIMENSIONAL INSPECTIONS — SPECIFICATION: ASTM B18.21.1-2011

CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
APPEARANCE	ASTM F844	PASSED	100	0
OUTSIDE DIA	2.243-2.280	2.246-2.254	10	0
INSIDE DIA	0.931-0.968	0.956-0.965	10	0
THICKNESS	0.136-0.192	0.136-0.157	10	0

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT		ACC.	REJ.
HOT DIP GALVANIZED	ASTM F2329-13	Min 0.0017"	0.0017-0.0020	in	8	0

ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE ASTM SPECIFICATION. WE CERTIFY THAT THIS DAIA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.
ISO 9001:2015 SGS Certificate # HK04/0105

IFI & MORGAN LTD.
检验专用章
QUANLITY CONTROL
(SIGNATURE OF Q.A. LAB MGR.)

Figure A-54. ⅞-in. Dia. Plain Round Washer, Test Nos. H42ST-1 and H42ST-2 (Item No. g2)

CERTIFIED MATERIAL TEST REPORT
FOR USS FLAT WASHERS HDG

FACTORY: IFI & Morgan Ltd
REPORT DATE: 22/10/2018
ADDRESS: Chang'an North Road, Wuyuan Town, Haiyan,Zhejiang, China

SAMPLING PLAN PER ASME B18.18-11
PO NUMBER: 210151571
SIZE: USS 1 HDG QNTY(Lot size): 3240PCS
HEADMARKS: NO MARK
PART NO: 33188

DIMENSIONAL INSPECTIONS SPECIFICATION: ASTM B18.21.1-2011

CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
APPEARANCE	ASTM F844	PASSED	100	0
OUTSIDE DIA	2.492-2.529	2.496-2.504	10	0
INSIDE DIA	1.055-1.092	1.080-1.089	10	0
THICKNESS	0.135-0.192	0.135-0.157	10	0

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT		ACC.	REJ.
HOT DIP GALVANIZED	ASTM F2329-13	Min 0.0017"	0.0017-0.0020	in	8	0

ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE ASTM SPECIFICATION. WE CERTIFY THAT THIS DAIA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.
ISO 9001:2015 SGS Certificate # HK04/0105

IFI & MORGAN LTD.
检验专用章
QUANLITY CONTROL
(SIGNATURE OF Q.A. LAB MGR.)

Figure A-55. 1-in. Dia. Plain USS Washer, Test Nos. H42ST-1 and H42ST-2 (Item No. g3)

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 10/10/2019
TIME 05:39:05

SOLD TO 66031-1127

SHIP TO 13716
Kansas City Warehouse
401 New Century Parkway
NEW CENTURY KS

Order	Material No.	Description	Quantity	Weight	Customer Part	Customer PO	Ship Date
40337440-0040	72896120A2	1/4 96 X 120 A572GR50 MILL PLATE	1	816.800			10/09/2019

Chemical Analysis

Heat No. A9F220 Vendor SSAB - MONTPELIER WORKS DOMESTIC Mill SSAB - MONTPELIER WORKS Melted and Manufactured in the USA

Produced from Coil

Carbon	Manganese	Phosphorus	Sulphur	Silicon	Nickel	Chromium	Molybdenum	Boron	Copper	Aluminum	Titanium	Vanadium	Columbium	Nitrogen	Tin
0.1500	0.8500	0.0120	0.0040	0.0400	0.1100	0.1200	0.0300	0.0000	0.2700	0.0250	0.0070	0.0200	0.0010	0.0000	0.0000

Mechanical / Physical Properties

Mill Coil No. A9F2200699

Tensile	Yield	Elong	Rckwl	Grain	Charpy	Charpy Dr	Charpy Sz	Temperature	Olsen
77000.000	59500.000	25.60			65	Longitudinal	5.0	-20 F	
75400.000	57600.000	26.70			71	Longitudinal	5.0	-20 F	
76700.000	58700.000	25.20			66	Longitudinal	5.0	-20 F	
74600.000	56900.000	28.30			0	NA			

Batch 0005980631 1 EA 816.800 LB

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

Figure A-56. 3-in. x 3-in. x ¼-in. or 3½-in. x 3½-in. x ¼-in. Square Washer Plate, Test Nos. H42ST-1 and H42ST-2 (Item No. g4)

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

Date: 12/13/2016

Subject: Certificate of Conformance

Product: HIT RE-500 V3 Adhesive

To Whom it May Concern:

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

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

Sincerely,

Hilti, Inc.

5400 South 122 East Avenue

Tulsa, Oklahoma 74146

800-879-8000

800-879-7000 fax

US-Sales@hilti.com

Figure A-57. Epoxy Adhesive, Test Nos. H42ST-1 and H42ST-2 (Item No. i1)

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...

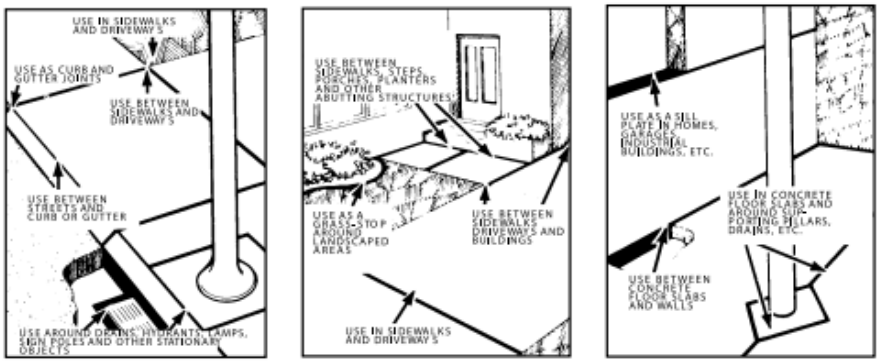
W. R. MEADOWS, INC.
P.O. Box 338 • HAMPSHIRE, IL 60140-0338
Phone: 847/214-2100 • Fax: 847/683-4544
1-800-342-5976
www.wrmeadows.com

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

Figure A-58. Expansion Joint Filler, Test Nos. H42ST-1 and H42ST-2 (Item No. i2)

PAGE 2 … FIBRE EXPANSION JOINT #320-F … APRIL 2018

TYPICAL APPLICATIONS



SPECIFICATIONS AND SIZE INFORMATION

APPLICATION

FIBRE EXPANSION JOINT is positioned against the forms, at interrupting objects or columns, and against abutting structures prior to the placement of concrete. FIBRE EXPANSION JOINT should be installed 1/2" (12.7 mm) below the concrete surface to accept a joint sealant which will provide for maximum protection from water infiltration and weathering, in addition to keeping the joint free from incompressibles. SNAP-CAP® from W. R. MEADOWS is recommended to create the reservoir for the joint sealant and the use of POURTHANE SL, POURTHANE NS, or DECK-O-SEAL as the sealant to protect the joint. Before sealing, slide SNAP-CAP over the top of the expansion joint. Place the concrete and screed to finish grade, as usual. When concrete is cured, insert a screwdriver through the top of SNAP-CAP, pull free and discard. In applications where one of the above-mentioned joint sealants is used without SNAP-CAP, W. R. MEADOWS recommends the use of KOOL-ROD or a bond-breaker tape to isolate FIBRE EXPANSION JOINT from the joint sealant material. SOF-SEAL® or any hot-applied sealant, such as HI-SPEC®, can be used to protect the joint. In this case, the use of SNAP-CAP, KOOL-ROD, or a bond-breaker tape is not necessary. Simply apply the sealant directly over FIBRE EXPANSION JOINT.

LEED INFORMATION

May help contribute to LEED credits:

- MRc9: Construction and Demolition Waste Management

For most recent data sheet, further LEED information, and SDS, visit www.wrmeadows.com.

LIMITED WARRANTY

W. R. MEADOWS, INC. warrants at the time and place we make shipment, our material will be of good quality and will conform with our published specifications in force on the date of acceptance of the order. Read complete warranty. Copy furnished upon request.

Disclaimer

The information contained herein is included for illustrative purposes only, and to the best of our knowledge, is accurate and reliable. W. R. MEADOWS, INC. cannot however under any circumstances make any guarantee of results or assume any obligation or liability in connection with the use of this information. As W. R. MEADOWS, INC. has no control over the use to which others may put its product, it is recommended that the products be tested to determine if suitable for specific application and/or our information is valid in a particular circumstance. Responsibility remains with the architect or engineer, contractor and owner for the design, application and proper installation of each product. Specifier and user shall determine the suitability of products for specific application and assume all responsibilities in connection therewith.

 04/18-400

Figure A-59. Expansion Joint Filler, Test Nos. H42ST-1 and H42ST-2, Cont. (Item No. i2)

Pecora 301 NS

Specification Data Sheet

Non-Sag Silicone Highway & Pavement Joint Sealant

PECORA CORPORATION
Architectural Weatherproofing 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

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

Figure A-60. Expansion Joint Sealant, Test Nos. H42ST-1 and H42ST-2 (Item No. i3)

Specification Data Sheet

4. TECHNICAL DATA

Applicable Standards: Complies with TT-S-00230C, TT-S-001543, ASTM C920, Class 100, Type S, Grade NS, Use T_2, M, O, ASTM D5893 Type NS. Conforms to FAA Engineering Brief No. 36. Review Pecora Technical Bulletin #81 for airfield standards. Conforms to approximately 30 state DOT specifications which require low modulus, high movement, cold applied sealant.

Joint Design: Sealant depth should be 1/4"-1/2" and joint width should be 1/4"-1". Ideally, the ratio of joint width to sealant depth should be 2:1, when appropriate. For joint widths greater than 1", consult Pecora Technical Services department.

5. INSTALLATION

Surface Preparation: New or old concrete surface must be dry and free of dust, laitance, grease, oils, curing compounds, water repellents, waxes, foreign particles, and disintegrated substrate. Restoration work requires saw cutting and sandblasting, followed by blowing out with compressed air (moisture and oil-free). Joint area should be free of all dust and foreign debris before back-up material is installed. Priming may be required. P-225 / concrete or P-200 / asphalt. Proper adhesion should be confirmed prior to full scale production.

Joint Backing: Backer rod should be used to control the sealant depth and cushion it from impact. Closed cell polyethylene is recommended. Use a size that will compress a minimum of 25% when inserted into the joint.

Application: Ideal surface temperature should be 60°F(16°C) - 85°F(29°C). Sealant should be applied to the prepared joint in a continuous operation. Tool the sealant slightly concave using dry-tooling techniques. **Sealant must be recessed below traffic surface.** (See Figure 1).

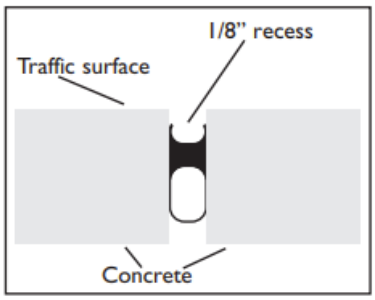


Figure 1

Initial Skin: Approximately 60 minutes at 77°F (25°C), 50% R.H. Higher temperatures and/or humidity will shorten this time period.

Cleaning: Immediately remove all excess sealant and smears adjacent to joints with mineral spirits. For equipment cleanup, also use mineral spirits. Consult manufacturer's MSDS for handling and safety precautions.

Shelf Life: Approximately one (1) year when stored in original, unopened container in a dry area at temperatures below 80°F(27°C).

Precautions: Use with adequate ventilation or wear an appropriate NIOSH-approved respirator. Contact with uncured sealant or with vapors generated during curing may cause respiratory tract irritation. Contact with skin or eyes may cause irritation or allergic reaction. Avoid contact and wash thoroughly after handling. May be harmful if swallowed. Refer to Safety Data Sheets (SDS) for more information.

FOR PROFESSIONAL USE ONLY
KEEP OUT OF THE REACH OF CHILDREN.

6. AVAILABILITY AND COST

Pecora products are available from our plants and warehouses, or from stocking distributors in all major cities. For the name and telephone number of your nearest representative call one of our locations listed below or visit our website at www.pecora.com.

7. WARRANTY

Pecora Corporation warrants its products to be free of defects. Under this warranty, we will provide, at no charge, replacement materials for, or refund the purchase price of, any product proven to be defective when used in strict accordance with our published recommendations and in applications considered by us as suitable for this product. This warranty is in lieu of any and all other warranties, expressed or implied, and in no case will Pecora be liable for incidental or consequential damages.

8. MAINTENANCE

Once sealant is in place and cured, it is basically maintenance free. If damage to sealant occurs, cut out the effected area, clean with vacuum or compressed air and recaulk.

9. TECHNICAL SERVICES

Pecora representatives are available to assist you in selecting an appropriate product and to provide on-site application instructions or to conduct jobsite inspections. For further assistance call our Technical Service Department at 800-523-6688.

10. FILING SYSTEMS

- http://: www. sweets. com
- 07 10 00 Waterproofing
- 07 92 00 Joint Sealants

PECORA CORPORATION

www.pecora.com

PEOPLE • PRODUCTS • PERFORMANCE

HARLEYSVILLE, PA
165 Wambold Road, Harleysville, PA 19438
Phone: 800-523-6688 • 215-723-6051 • FAX: 215-721-0286

PEC103
6/16

Figure A-61. Expansion Joint Sealant, Test Nos. H42ST-1 and H42ST-2, Cont. (Item No. i3)

Appendix B. Vehicle Center of Gravity Determination

		Test Name:	H42ST-1	VIN:	1C6RR6GT2GS269090
Model Year:	2016	Make:	Ram	Model:	1500

Vehicle CG Determination

	Vehicle Equipment	Weight (lb)	Vertical CG (in.)	Vertical M (lb-in.)
+	Unballasted Truck (Curb)	5258	28.945892	152197.5
+	Hub	19	15.25	289.75
+	Brake activation cylinder & frame	7	28	196
+	Pneumatic tank (Nitrogen)	30	27 1/2	825
+	Strobe/Brake Battery	10	26 1/2	265
+	Brake Receiver/Wires	6	52 3/4	316.5
+	CG Plate including DAQ	42	30 5/8	1286.25
-	Battery	-41	42 1/2	-1742.5
-	Oil	-10	16	-160
-	Interior	-113	40	-4520
-	Fuel	-162	18 1/2	-2997
-	Coolant	-13	38	-494
-	Washer fluid	-8	31	-248
+	Water Ballast (In Fuel Tank)	0	0	0
+	Onboard Supplemental Battery	0	0	0
				0
				0
Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle				145214.5

Estimated Total Weight (lb)	5025
Vertical CG Location (in.)	28.89841

Vehicle Dimensions for C.G. Calculations

Wheel Base: 140.375 in.
Front Track Width: 68.75 in.
Rear Track Width: 68.25 in.

Center of Gravity	2270P MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb)	5000 ± 110	5041	41.0
Longitudinal CG (in.)	63 ± 4	59.926007	-3.07399
Lateral CG (in.)	NA	0.7134001	NA
Vertical CG (in.)	28 or greater	28.90	0.89841

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	1521	1473	
Rear	1132	1132	
FRONT	2994		lb
REAR	2264		lb
TOTAL	5258		lb

TEST INERTIAL WEIGHT (lb)

	Left	Right	
Front	1412	1477	
Rear	1056	1096	
FRONT	2889		lb
REAR	2152		lb
TOTAL	5041		lb

Figure B-1. Vehicle Mass Distribution, Test No. H42ST-1

		Test Name:	H42ST-2	VIN:	kmhct4ae8gu947887
Model Year:	2016	Make:	Hyundai	Model:	Accent

Vehicle CG Determination

	Vehicle Equipment	Weight (lb)
+	Unballasted Car (Curb)	2543
+	Hub	19
+	Brake activation cylinder & frame	7
+	Pneumatic tank (Nitrogen)	12
+	Strobe/Brake Battery	5
+	Brake Receiver/Wires	5
+	CG Plate including DAQ	19
-	Battery	-37
-	Oil	-12
-	Interior	-64
-	Fuel	-27
-	Coolant	-7
-	Washer fluid	-6
+	Water Ballast (In Fuel Tank)	
+	Onboard Supplemental Battery	
-	Spare tire	-38

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

Estimated Total Weight (lb): 2419

Vehicle Dimensions for C.G. Calculations

Wheel Base:	101.0	in.	Front Track Width:	58.875	in.
Roof Height:	56.75	in.	Rear Track Width:	59.25	in.

Center of Gravity	1100C MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb)	2420 ± 55	2430	10.0
Longitudinal CG (in.)	39 ± 4	37.948	-1.052
Lateral CG (in.)	NA	-0.049	NA
Vertical CG (in.)	NA	22.432	NA

Note: Long. CG is measured from front axle of test vehicle

Note: Lateral CG measured from centerline - positive to vehicle right (passenger) side

CURB WEIGHT (lb)

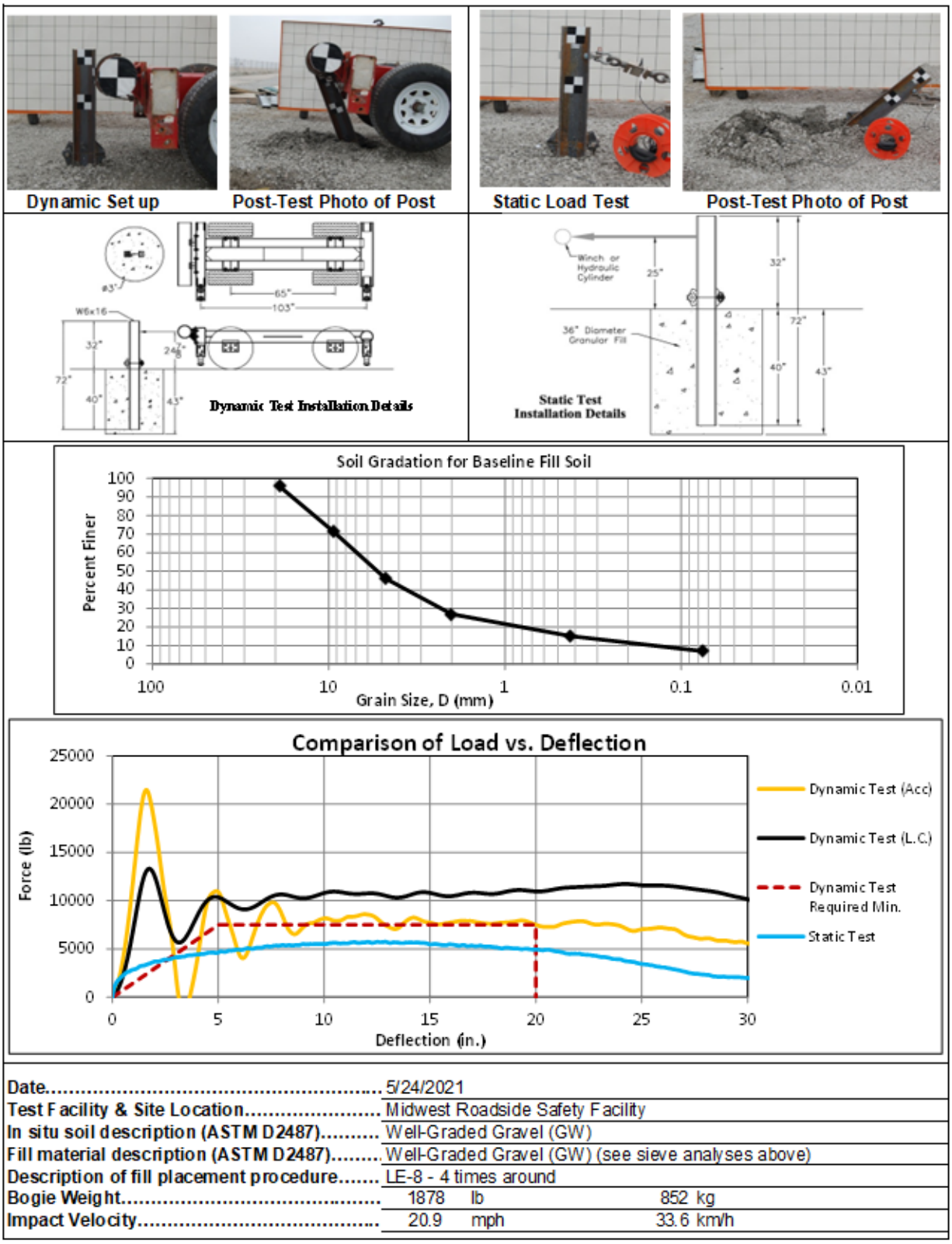
	Left	Right	
Front	810	759	
Rear	493	481	
FRONT	1569		lb
REAR	974		lb
TOTAL	2543		lb

TEST INERTIAL WEIGHT (lb)

	Left	Right	
Front	760	757	
Rear	457	456	
FRONT	1517		lb
REAR	913		lb
TOTAL	2430		lb

Figure B-2. Vehicle Mass Distribution, Test No. H42ST-2

Appendix C. Static Soil Tests



Date	5/24/2021		
Test Facility & Site Location	Midwest Roadside Safety Facility		
In situ soil description (ASTM D2487)	Well-Graded Gravel (GW)		
Fill material description (ASTM D2487)	Well-Graded Gravel (GW) (see sieve analyses above)		
Description of fill placement procedure	LE-8 - 4 times around		
Bogie Weight	1878	lb	852 kg
Impact Velocity	20.9	mph	33.6 km/h

Figure C-1. Soil Strength, Initial Calibration Test, Test No. H42ST-1

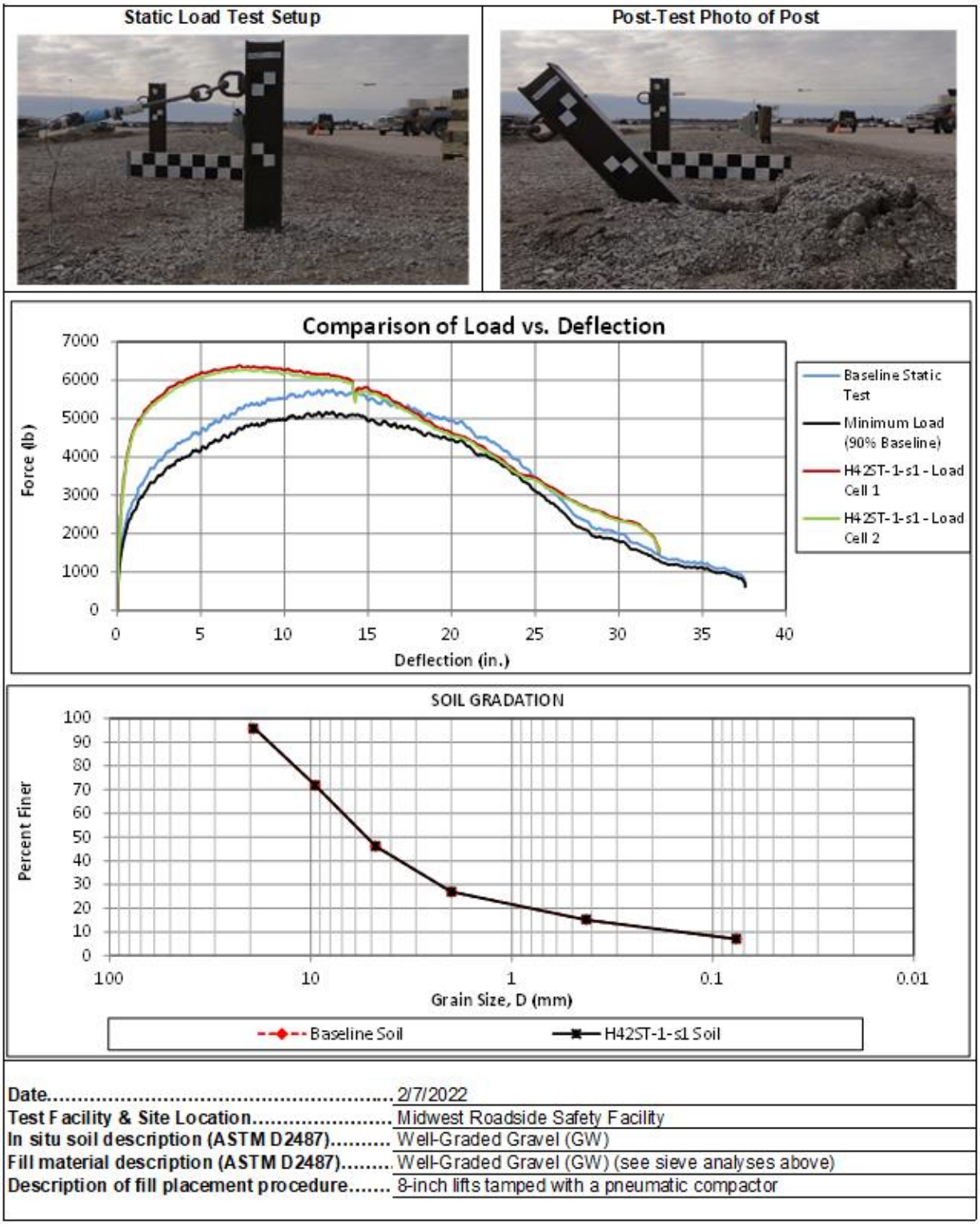
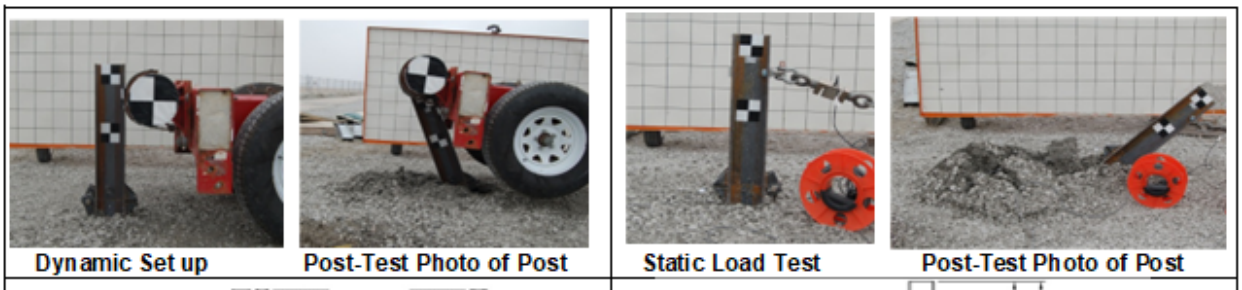
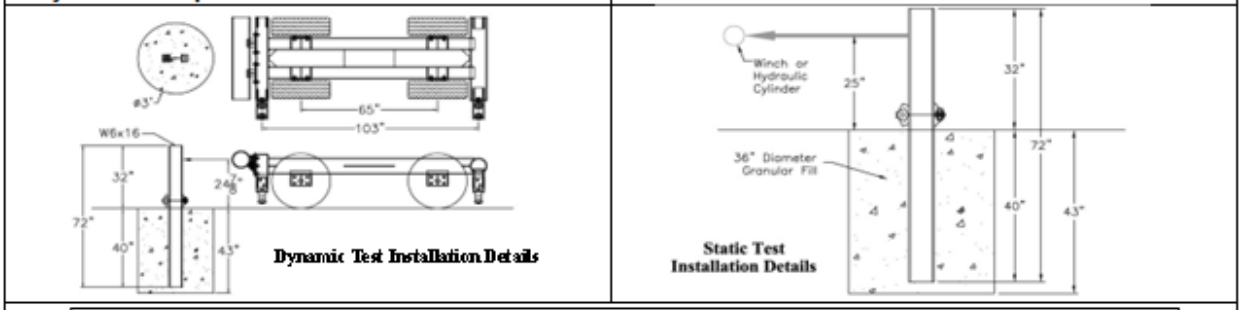
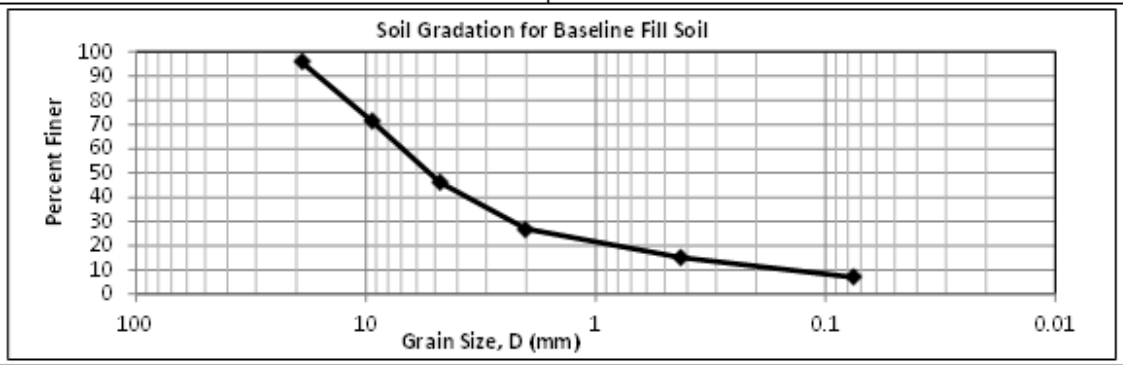
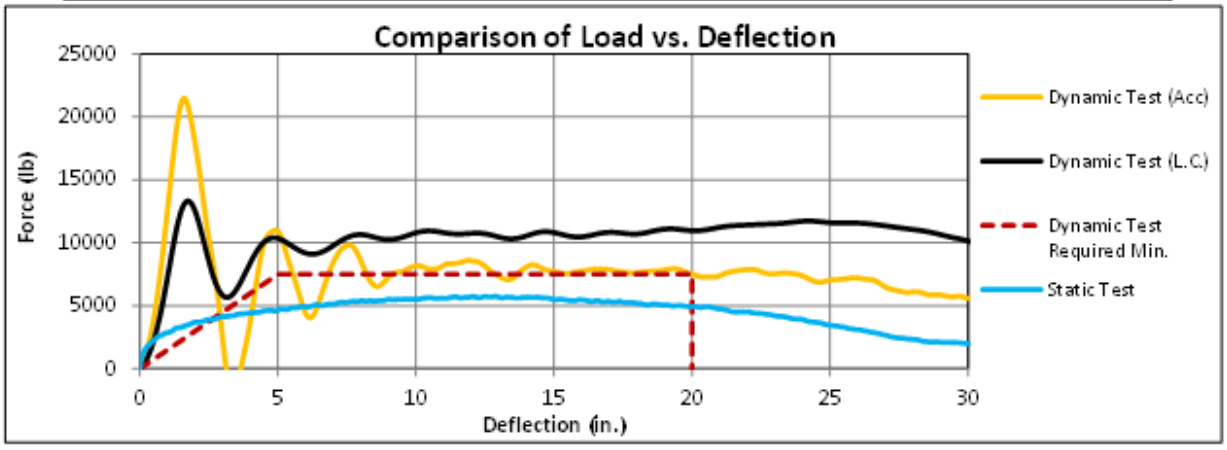


Figure C-2. Static Soil Test, Test No. H42ST-1



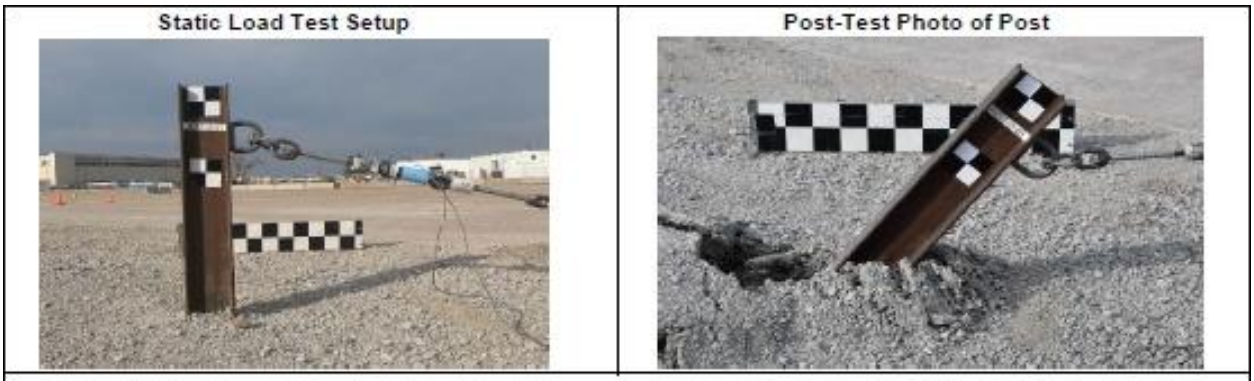


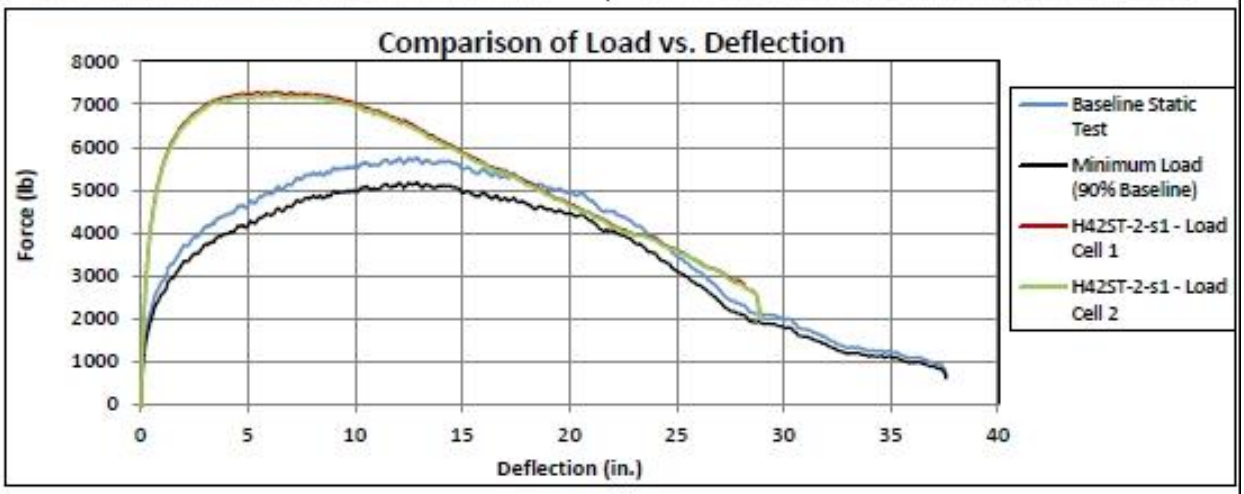


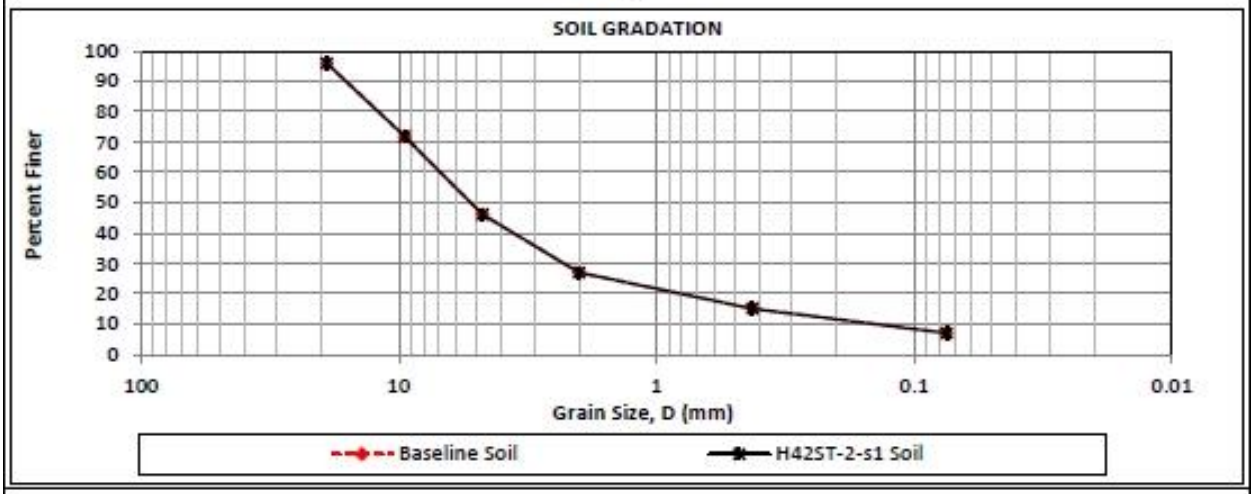


Date	5/24/2021		
Test Facility & Site Location	Midwest Roadside Safety Facility		
In situ soil description (ASTM D2487)	Well-Graded Gravel (GW)		
Fill material description (ASTM D2487)	Well-Graded Gravel (GW) (see sieve analyses above)		
Description of fill placement procedure	LE-8 - 4 times around		
Bogie Weight	1878	lb	852 kg
Impact Velocity	20.9	mph	33.6 km/h

Figure C-3. Soil Strength, Initial Calibration Test, Test No. H42ST-2







Date	3/29/2022
Test Facility & Site Location	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)	Well-Graded Gravel (GW)
Fill material description (ASTM D2487)	Well-Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure	8-inch lifts tamped with a pneumatic compactor

Figure C-4. Static Soil Test, Test No. H42ST-2

Appendix D. Vehicle Deformation Records

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

Model Year: 2018 Test Name: H42ST-1 Make: Ram VIN: 1C6RR6GT2GS269090 Model: 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	55.5826	-44.8970	-6.9656	51.4477	-39.1481	-10.0312	4.1449	5.7489	3.0656	7.7219	5.1554	X, Z
	2	56.7989	-39.5924	-4.2591	53.4966	-35.2859	-6.4061	3.3023	4.3065	2.1470	5.8362	3.9389	X, Z
	3	56.8796	-34.2463	-4.0000	55.0538	-31.5807	-4.5701	1.8258	2.6656	0.5701	3.2809	1.9127	X, Z
	4	55.4421	-29.1962	-4.8471	53.9459	-26.8617	-5.8519	1.4962	2.3345	1.0048	2.9493	1.8023	X, Z
	5	52.8133	-23.8053	-7.0772	51.1808	-22.5464	-9.4785	1.6325	1.2589	2.4013	3.1648	2.9037	X, Z
	6	49.4729	-45.3694	0.0034	44.6264	-39.3338	-3.6144	4.8465	6.0346	3.6178	8.5436	6.0479	X, Z
	7	49.0679	-39.8616	0.1140	46.7738	-36.6478	-0.5779	2.2941	3.2138	0.6919	4.0088	2.3962	X, Z
	8	48.8211	-34.8104	0.2345	46.9449	-31.6138	-0.6687	1.8762	3.1966	0.9032	3.8150	2.0823	X, Z
	9	48.9843	-29.2858	0.1547	47.0468	-26.1597	-1.5028	1.9375	3.1261	1.6575	4.0341	2.5497	X, Z
	10	47.3789	-24.1444	-5.1680	45.6417	-23.0728	-7.8303	1.7372	1.0716	2.6623	3.3547	3.1789	X, Z
FLOOR PAN (Z)	11	45.1204	-45.8012	1.7035	42.8924	-41.7111	0.1071	2.2280	4.0901	1.5964	4.9236	1.5964	Z
	12	45.1603	-40.3855	1.2074	43.2799	-37.0229	0.9910	1.8804	3.3626	0.2164	3.8587	0.2164	Z
	13	45.0925	-34.7085	1.2281	43.1283	-31.4669	0.2043	1.9642	3.2416	1.0238	3.9261	1.0238	Z
	14	45.0467	-30.0805	1.2302	42.9666	-26.8777	-0.5758	2.0801	3.2028	1.8060	4.2245	1.8060	Z
	15	43.2238	-24.3682	-4.6921	41.4475	-23.3963	-7.3192	1.7763	0.9719	2.7271	3.3966	2.7271	Z
	16	41.0237	-46.1161	1.8360	39.3611	-42.4417	1.7771	1.6626	3.6744	0.0589	4.0335	0.0589	Z
	17	40.9787	-40.7148	1.1941	39.2706	-37.4565	1.2833	1.7081	3.2583	-0.0892	3.6795	-0.0892	Z
	18	40.5522	-33.9696	1.0350	38.7133	-30.9647	-0.5462	1.8389	2.9948	1.5812	3.8536	1.5812	Z
	19	40.9094	-30.5079	1.2142	38.9411	-27.5725	-1.3317	1.9683	2.9354	2.5459	4.3557	2.5459	Z
	20	39.8753	-24.6868	-3.7674	38.0663	-23.8396	-6.6809	1.8090	0.8472	2.9135	3.5325	2.9135	Z
	21	36.1801	-46.1982	1.7959	34.5429	-43.2288	1.6543	1.6372	2.9696	0.1416	3.3940	0.1416	Z
	22	36.0783	-40.9256	1.2191	34.3169	-37.8965	1.0683	1.7614	3.0301	0.1508	3.5081	0.1508	Z
	23	35.7629	-35.2886	1.2227	33.8823	-32.4802	-0.6104	1.8806	2.8084	1.8331	3.8450	1.8331	Z
	24	36.0362	-29.9812	1.2407	34.0249	-27.3578	-2.0085	2.0114	2.6234	3.2492	4.6952	3.2492	Z
	25	35.1572	-25.4532	-1.7689	33.2453	-24.9063	-4.7712	1.9119	0.5469	3.0023	3.6011	3.0023	Z
	26	30.6823	-46.1488	0.4953	29.2511	-43.3276	1.5423	1.4312	2.8212	-1.0470	3.3922	-1.0470	Z
	27	30.5903	-40.1552	0.1750	29.3147	-37.9322	-0.9084	1.2756	2.2230	1.0834	2.7826	1.0834	Z
	28	30.7726	-33.9133	0.4256	29.0744	-31.7851	-2.1862	1.6982	2.1282	2.6118	3.7729	2.6118	Z
	29	30.6856	-29.0119	0.4363	28.5569	-27.0363	-1.1005	2.1286	1.9756	1.5358	3.2852	1.5358	Z
	30	31.2093	-25.1315	-2.6844	29.8804	-24.1553	-4.3755	1.3289	0.9762	1.6911	2.3619	1.6911	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-1. Floor Pan Deformation Data – Set 1, Test No. H42ST-1

Model Year: 2016 Test Name: H42ST-1 Make: Ram VIN: 1C6RR6GT2GS269090 Model: 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	57.6332	-24.1829	-2.8615	53.3803	-18.8552	-6.1522	4.2529	5.3277	3.2907	7.5697	5.3773	X, Z
	2	58.7142	-18.8524	-0.1530	55.4279	-14.8242	-2.7150	3.2863	4.0282	2.5620	5.7957	4.1670	X, Z
	3	58.6702	-13.5060	0.1077	56.9462	-11.0241	-1.0481	1.7240	2.4819	1.1558	3.2354	2.0756	X, Z
	4	57.1159	-8.4904	-0.7388	55.7066	-6.3780	-2.4681	1.4093	2.1124	1.7293	3.0723	2.2308	X, Z
	5	54.3634	-3.1616	-2.9688	52.7653	-2.2536	-6.1773	1.5981	0.9080	3.2085	3.6977	3.5845	X, Z
	6	51.5224	-24.7987	4.1040	46.7147	-18.9547	0.4280	4.8077	5.8440	3.6760	8.4130	6.0520	X, Z
	7	50.9892	-19.3029	4.2159	48.8728	-16.1178	3.3161	2.1164	3.1851	0.8998	3.9286	2.2997	X, Z
	8	50.6247	-14.2588	4.3377	48.9322	-11.0877	3.0443	1.6925	3.1711	1.2934	3.8201	2.1301	X, Z
	9	50.6593	-8.7319	4.2596	48.8962	-5.6659	2.0168	1.7631	3.0660	2.2428	4.1880	2.8528	X, Z
	10	48.9374	-3.6277	-1.0626	47.2786	-2.8366	-4.3795	1.6588	0.7911	3.3173	3.7924	3.7089	X, Z
FLOOR PAN (Z)	11	47.1803	-25.3333	5.8016	45.1192	-21.2335	4.2710	2.0611	4.0998	1.5306	4.8373	1.5306	Z
	12	47.0943	-19.9180	5.3071	45.4250	-16.5096	4.9601	1.6693	3.4084	0.3270	3.8093	0.3270	Z
	13	46.8942	-14.2441	5.3293	45.1344	-10.9896	4.0024	1.7598	3.2545	1.3269	3.9306	1.3269	Z
	14	46.7407	-9.6184	5.3327	44.8550	-6.4356	3.0656	1.8857	3.1828	2.2671	4.3389	2.2671	Z
	15	44.7884	-3.9485	-0.4890	43.1053	-3.2293	-3.7579	1.6831	0.7192	3.2689	3.7464	3.2689	Z
	16	43.0919	-25.7435	5.9319	41.6441	-21.9778	6.0495	1.4478	3.7657	-0.1176	4.0361	-0.1176	Z
	17	42.9215	-20.3446	5.2914	41.4334	-17.0171	5.3631	1.4881	3.3275	-0.0717	3.6458	-0.0717	Z
	18	42.3379	-13.6010	5.1339	40.6934	-10.6070	3.3402	1.6445	2.9940	1.7937	3.8582	1.7937	Z
	19	42.6145	-10.1421	5.3143	40.8293	-7.2409	2.4308	1.7852	2.9012	2.8835	4.4630	2.8835	Z
	20	41.4477	-4.3451	0.3337	39.7502	-3.7202	-3.0239	1.6975	0.6249	3.3576	3.8139	3.3576	Z
	21	38.2516	-25.9385	5.8891	36.8427	-22.8891	6.0693	1.4089	3.0664	-0.1802	3.3821	-0.1802	Z
	22	38.0273	-20.6694	5.3137	36.4873	-17.5662	5.3018	1.5400	3.1032	0.0119	3.4643	0.0119	Z
	23	37.5807	-15.0414	5.3187	35.8963	-12.2245	3.4447	1.6844	2.8169	1.8740	3.7794	1.8740	Z
	24	37.7303	-9.7290	5.3384	35.8951	-7.1533	1.8643	1.8352	2.5757	3.4741	4.6980	3.4741	Z
	25	36.7477	-5.2218	2.3295	34.9988	-4.8187	-0.9635	1.7489	0.4031	3.2930	3.7503	3.2930	Z
	26	32.7548	-26.0167	4.5856	31.5531	-23.0827	6.0871	1.2017	2.9340	-1.5015	3.5081	-1.5015	Z
	27	32.5234	-20.0268	4.2669	31.4427	-17.7780	3.4475	1.0807	2.2488	0.8194	2.6261	0.8194	Z
	28	32.5601	-13.7824	4.5193	31.0393	-11.6867	1.9604	1.5208	2.0957	2.5589	3.6404	2.5589	Z
	29	32.3589	-8.8843	4.5303	30.4440	-6.9141	2.8907	1.9149	1.9702	1.6396	3.1995	1.6396	Z
	30	32.7939	-4.9920	1.4120	31.6285	-4.1247	-0.5143	1.1664	0.8673	1.9263	2.4127	1.9263	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-2. Floor Pan Deformation Data – Set 2, Test No. H42ST-1

Model Year: 2016 Test Name: H42ST-1 Make: Ram VIN: 1C6RR6GT2GS269090 Model: 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	41.6510	-46.5314	-29.4721	41.7128	-45.2518	-31.6942	-0.0618	1.2796	-2.2221	2.5649	2.5649	X, Y, Z
	2	39.8080	-34.3863	-33.5827	40.2906	-33.0321	-35.7809	-0.4826	1.3542	-2.1982	2.6266	2.6266	X, Y, Z
	3	38.4875	-15.7462	-30.7856	38.6722	-14.3856	-32.7889	-0.1847	1.3606	-2.0033	2.4281	2.4281	X, Y, Z
	4	38.7813	-46.4763	-19.8486	37.8400	-45.2308	-22.3265	0.9413	1.2446	-2.4769	2.9274	2.9274	X, Y, Z
	5	36.8112	-34.2932	-19.1045	35.9392	-33.0745	-21.6564	0.8720	1.2187	-2.5519	2.9594	2.9594	X, Y, Z
	6	35.9369	-16.1235	-17.6584	35.3757	-15.0729	-19.7638	0.5602	1.0506	-2.1054	2.4187	2.4187	X, Y, Z
SIDE PANEL (Y)	7	48.7028	-48.3407	-8.3091	45.7789	-43.6492	-9.9978	2.9239	4.6915	-1.6887	5.7802	4.6915	Y
	8	49.0932	-48.2241	-5.4055	45.8140	-42.5658	-7.2753	3.2792	5.6583	-1.8738	6.8030	5.6583	Y
	9	51.1095	-48.1935	-7.2190	47.7064	-42.5506	-9.0662	3.4031	5.6429	-1.8502	6.8445	5.6429	Y
IMPACT SIDE DOOR (Y)	10	13.4605	-50.5768	-18.4085	12.1215	-52.3351	-18.9364	1.3390	-1.7583	-0.5279	2.2723	-1.7583	Y
	11	24.1503	-50.9123	-18.7612	22.7478	-52.8680	-19.4297	1.4025	-1.9557	-0.6685	2.4977	-1.9557	Y
	12	35.3156	-50.5906	-19.4042	33.8725	-52.2811	-20.3070	1.4431	-1.6905	-0.9028	2.3990	-1.6905	Y
	13	13.4320	-50.4771	-7.2483	12.4681	-51.5018	-7.9313	0.9639	-1.0247	-0.6830	1.5638	-1.0247	Y
	14	26.3662	-50.9863	-3.7694	25.1191	-51.5023	-4.6531	1.2471	-0.5160	-0.8837	1.6132	-0.5160	Y
	15	34.8169	-51.0768	-3.0665	33.5590	-50.9448	-4.1351	1.2579	0.1320	-1.0686	1.6558	0.1320	Y
ROOF - (Z)	16	30.4731	-40.2185	-46.1848	30.8065	-39.4318	-46.7614	-0.3334	0.7867	-0.5766	1.0308	-0.5766	Z
	17	33.7562	-27.9573	-46.6382	33.9696	-27.1277	-47.0708	-0.2134	0.8296	-0.4326	0.9552	-0.4326	Z
	18	34.4509	-16.9787	-46.9112	34.5599	-16.1697	-47.2280	-0.1090	0.8090	-0.3168	0.8756	-0.3168	Z
	19	23.5023	-39.1184	-49.2664	23.8810	-38.4432	-49.6411	-0.3787	0.6752	-0.3747	0.8514	-0.3747	Z
	20	25.4326	-28.2854	-49.8203	25.6669	-27.5439	-50.1900	-0.2343	0.7415	-0.3697	0.8610	-0.3697	Z
	21	27.0744	-18.2052	-49.8413	27.3277	-17.4067	-50.1041	-0.2533	0.7985	-0.2628	0.8780	-0.2628	Z
	22	7.8790	-37.7149	-50.6598	8.2549	-37.0985	-50.6220	-0.3759	0.6164	0.0366	0.7229	0.0366	Z
	23	8.1603	-26.8970	-51.2636	8.4335	-26.3100	-51.6143	-0.2732	0.5870	-0.3507	0.7363	-0.3507	Z
	24	8.0957	-18.1847	-51.4460	8.2602	-17.5189	-51.6925	-0.1645	0.6658	-0.2465	0.7288	-0.2465	Z
	25	-5.3613	-38.1006	-50.9699	-4.9908	-37.5696	-51.2058	-0.3705	0.5310	-0.2459	0.6926	-0.2459	Z
	26	-5.5279	-25.9555	-51.5372	-5.3152	-25.4373	-51.7775	-0.2127	0.5182	-0.2403	0.6095	-0.2403	Z
	27	-5.7553	-17.5584	-51.6594	-5.5560	-17.0841	-51.8978	-0.1993	0.4743	-0.2384	0.5670	-0.2384	Z
	28	-20.5645	-38.2079	-50.8705	-20.1988	-37.8113	-51.2754	-0.3657	0.3966	-0.4049	0.6745	-0.4049	Z
	29	-21.2144	-26.6942	-51.3050	-21.0253	-26.2982	-51.7017	-0.1891	0.3960	-0.3957	0.5909	-0.3957	Z
	30	-21.3658	-17.4866	-51.3907	-21.2388	-17.1132	-51.6973	-0.1270	0.3734	-0.3066	0.4996	-0.3066	Z
A-PILLAR Maximum (X, Y, Z)	31	46.8837	-46.5988	-34.3662	47.5518	-46.0469	-35.3764	-0.6681	0.5519	-1.0102	1.3310	0.5519	Y
	32	43.5296	-45.6939	-36.9938	44.1438	-45.1378	-38.0782	-0.6142	0.5561	-1.0844	1.3647	0.5561	Y
	33	40.7284	-45.2002	-39.0053	41.3562	-44.5915	-40.0118	-0.6278	0.6087	-1.0065	1.3333	0.6087	Y
	34	39.0112	-44.8180	-40.2089	39.5827	-44.1956	-41.1797	-0.5715	0.6224	-0.9708	1.2870	0.6224	Y
	35	36.9705	-44.3436	-41.5865	37.5223	-43.6865	-42.4725	-0.5518	0.6571	-0.8860	1.2334	0.6571	Y
	36	33.6529	-43.8034	-43.6623	34.0974	-43.0857	-44.4520	-0.4445	0.7177	-0.7897	1.1560	0.7177	Y
A-PILLAR Lateral (Y)	31	46.8837	-46.5988	-34.3662	47.5518	-46.0469	-35.3764	-0.6681	0.5519	-1.0102	1.3310	0.5519	Y
	32	43.5296	-45.6939	-36.9938	44.1438	-45.1378	-38.0782	-0.6142	0.5561	-1.0844	1.3647	0.5561	Y
	33	40.7284	-45.2002	-39.0053	41.3562	-44.5915	-40.0118	-0.6278	0.6087	-1.0065	1.3333	0.6087	Y
	34	39.0112	-44.8180	-40.2089	39.5827	-44.1956	-41.1797	-0.5715	0.6224	-0.9708	1.2870	0.6224	Y
	35	36.9705	-44.3436	-41.5865	37.5223	-43.6865	-42.4725	-0.5518	0.6571	-0.8860	1.2334	0.6571	Y
	36	33.6529	-43.8034	-43.6623	34.0974	-43.0857	-44.4520	-0.4445	0.7177	-0.7897	1.1560	0.7177	Y
B-PILLAR Maximum (X, Y, Z)	37	3.2459	-43.5366	-44.5217	3.3490	-43.0035	-44.5994	-0.1031	0.5331	-0.0777	0.5485	0.5331	Y
	38	6.3072	-44.7865	-40.9915	6.5574	-44.3047	-41.1082	-0.2502	0.4818	-0.1167	0.5563	0.4818	Y
	39	3.7646	-47.0065	-34.7602	3.8851	-46.6270	-34.8210	-0.1205	0.3795	-0.0608	0.4028	0.3795	Y
	40	7.4344	-47.8009	-29.0198	7.4807	-47.5015	-29.1028	-0.0463	0.2994	-0.0830	0.3141	0.2994	Y
B-PILLAR Lateral (Y)	37	3.2459	-43.5366	-44.5217	3.3490	-43.0035	-44.5994	-0.1031	0.5331	-0.0777	0.5485	0.5331	Y
	38	6.3072	-44.7865	-40.9915	6.5574	-44.3047	-41.1082	-0.2502	0.4818	-0.1167	0.5563	0.4818	Y
	39	3.7646	-47.0065	-34.7602	3.8851	-46.6270	-34.8210	-0.1205	0.3795	-0.0608	0.4028	0.3795	Y
	40	7.4344	-47.8009	-29.0198	7.4807	-47.5015	-29.1028	-0.0463	0.2994	-0.0830	0.3141	0.2994	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 – Set 1, Test No. H42ST-1

Model Year: 2016 Test Name: H42ST-1 Make: Ram VIN: 1C6RR6GT2GS269090 Model: 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	43.7481	-26.1506	-25.3756	43.2744	-25.9410	-27.3435	0.4737	0.2096	-1.9679	2.0349	2.0349	X, Y, Z
	2	41.8255	-14.0523	-29.4896	41.4946	-13.9077	-31.8242	0.1309	0.1446	-2.3346	2.3427	2.3427	X, Y, Z
	3	39.8711	4.5536	-26.8971	39.5441	4.7965	-29.4550	0.3270	-0.2429	-2.7579	2.7878	2.7878	X, Y, Z
	4	40.8735	-26.1592	-15.7535	39.6199	-25.6646	-17.8915	1.2536	0.4946	-2.1380	2.5273	2.5273	X, Y, Z
	5	38.6206	-14.0259	-15.0128	37.4734	-13.5341	-17.6070	1.1472	0.4918	-2.5942	2.8789	2.8789	X, Y, Z
	6	37.3228	4.1188	-13.5709	36.5657	4.5082	-16.3387	0.7571	-0.3894	-2.7678	2.8958	2.8958	X, Y, Z
SIDE PANEL (Y)	7	50.8303	-27.7913	-4.2090	47.8063	-23.4781	-5.8207	3.0240	4.3132	-1.6117	5.5087	4.3132	Y
	8	51.2165	-27.6650	-1.3053	47.8810	-22.2974	-3.1438	3.3355	5.3676	-1.8385	6.5815	5.3676	Y
	9	53.2324	-27.5880	-3.1178	49.7307	-22.3071	-4.9778	3.5017	5.2809	-1.8600	6.6037	5.2809	Y
IMPACT SIDE DOOR (Y)	10	15.6541	-30.8474	-14.3241	14.1461	-33.1747	-13.6395	1.5080	-2.3273	0.6846	2.8564	-2.3273	Y
	11	26.3489	-30.9347	-14.6718	24.7671	-33.5044	-14.3676	1.5818	-2.5697	0.3042	3.0328	-2.5697	Y
	12	37.5041	-30.3537	-15.3097	35.8533	-32.7188	-15.5309	1.6508	-2.3651	-0.2212	2.8927	-2.3651	Y
	13	15.6181	-30.7461	-3.1639	14.7294	-31.9406	-2.6821	0.8887	-1.1945	0.4818	1.5648	-1.1945	Y
	14	28.5591	-30.9541	0.3210	27.4500	-31.5613	0.2906	1.1091	-0.6072	0.0304	1.2648	-0.6072	Y
	15	37.0093	-30.8482	1.0279	35.8857	-30.8107	0.5866	1.1236	0.0375	-0.4413	1.2077	0.0375	Y
ROOF - (Z)	16	32.4344	-20.1023	-42.0947	31.8990	-20.8919	-42.3419	0.5354	-0.7896	-0.2472	0.9855	-0.2472	Z
	17	35.4320	-7.7683	-42.5502	34.7879	-8.5438	-43.1613	0.6441	-0.7755	-0.6111	1.1789	-0.6111	Z
	18	35.8716	3.2235	-42.8243	35.1379	2.4114	-43.7197	0.7337	0.8121	-0.8954	1.4141	-0.8954	Z
	19	25.4413	-19.1651	-45.1798	24.8689	-20.1513	-45.0877	0.5724	-0.9862	0.0921	1.1440	0.0921	Z
	20	27.1198	-8.2903	-45.7350	26.4260	-9.2436	-46.0644	0.6938	-0.9533	-0.3294	1.2242	-0.3294	Z
	21	28.5270	1.8254	-45.7575	27.8693	0.5224	-46.3765	0.6577	0.9030	-0.6190	1.2772	-0.6190	Z
	22	9.7903	-18.1251	-46.5794	9.2190	-19.1665	-45.7421	0.5713	-1.0414	0.8373	1.4533	0.8373	Z
	23	9.8205	-7.3037	-47.1886	9.1418	-8.4192	-47.1189	0.6787	-1.1155	0.0677	1.3075	0.0677	Z
	24	9.5537	1.4047	-47.3708	8.7771	0.3580	-47.5035	0.7766	1.0467	-0.1327	1.3101	-0.1327	Z
	25	-3.4373	-18.8183	-46.8867	-4.0235	-19.9328	-45.9919	0.5862	-1.1145	0.8948	1.5448	0.8948	Z
	26	-3.8857	-8.6805	-47.4687	-4.6227	-7.8381	-48.5840	0.7370	-1.1576	0.4827	1.4647	0.4827	Z
	27	-4.3081	1.7091	-47.5907	-5.0464	0.4986	-47.3935	0.7383	1.2105	0.1972	1.4315	0.1972	Z
	28	-18.6340	-19.2787	-46.8042	-19.2203	-20.4921	-46.6893	0.5863	-1.2134	1.1149	1.7490	1.1149	Z
	29	-19.5509	-7.7833	-47.2425	-20.3046	-9.0213	-46.5022	0.7537	-1.2380	0.7403	1.8275	0.7403	Z
	30	-19.9161	1.4183	-47.3292	-20.7160	0.1515	-46.8172	0.7999	1.2668	0.5120	1.5833	0.5120	Z
A-PILLAR Maximum (X, Y, Z)	31	48.9833	-26.0973	-30.2672	49.0423	-26.7462	-31.1339	-0.0590	-0.6489	-0.8667	1.0843	0.0000	NA
	32	45.6103	-25.2712	-32.8966	45.5538	-26.0053	-33.7838	0.0565	-0.7341	-0.8872	1.1529	0.0565	X
	33	42.7993	-24.8430	-34.9095	42.7111	-25.5867	-35.6683	0.0882	-0.7437	-0.7588	1.0661	0.0882	X
	34	41.0742	-24.5011	-36.1139	40.9028	-25.2696	-36.8067	0.1714	-0.7685	-0.6928	1.0488	0.1714	X
	35	39.0237	-24.0745	-37.4926	38.8025	-24.8501	-38.0671	0.2212	-0.7756	-0.5745	0.9902	0.2212	X
	36	35.6955	-23.6119	-39.5701	35.3205	-24.3917	-39.9841	0.3750	-0.7798	-0.4140	0.9592	0.3750	X
A-PILLAR Lateral (Y)	31	48.9833	-26.0973	-30.2672	49.0423	-26.7462	-31.1339	-0.0590	-0.6489	-0.8667	1.0843	-0.6489	Y
	32	45.6103	-25.2712	-32.8966	45.5538	-26.0053	-33.7838	0.0565	-0.7341	-0.8872	1.1529	-0.7341	Y
	33	42.7993	-24.8430	-34.9095	42.7111	-25.5867	-35.6683	0.0882	-0.7437	-0.7588	1.0661	-0.7437	Y
	34	41.0742	-24.5011	-36.1139	40.9028	-25.2696	-36.8067	0.1714	-0.7685	-0.6928	1.0488	-0.7685	Y
	35	39.0237	-24.0745	-37.4926	38.8025	-24.8501	-38.0671	0.2212	-0.7756	-0.5745	0.9902	-0.7756	Y
	36	35.6955	-23.6119	-39.5701	35.3205	-24.3917	-39.9841	0.3750	-0.7798	-0.4140	0.9592	-0.7798	Y
B-PILLAR Maximum (X, Y, Z)	37	5.2908	-24.0516	-40.4434	4.5823	-24.9524	-39.3990	0.7085	-0.9008	1.0444	1.5505	1.2620	X, Z
	38	8.3787	-25.2294	-36.9116	7.8981	-26.0609	-35.9418	0.4806	-0.8315	0.9698	1.3649	1.0824	X, Z
	39	5.8855	-27.5066	-30.6810	5.4228	-28.2113	-29.5143	0.4627	-0.7047	1.1667	1.4394	1.2551	X, Z
	40	9.5701	-28.2143	-24.9387	9.1679	-28.8057	-23.8564	0.4022	-0.5914	1.0823	1.2973	1.1546	X, Z
B-PILLAR Lateral (Y)	37	5.2908	-24.0516	-40.4434	4.5823	-24.9524	-39.3990	0.7085	-0.9008	1.0444	1.5505	-0.9008	Y
	38	8.3787	-25.2294	-36.9116	7.8981	-26.0609	-35.9418	0.4806	-0.8315	0.9698	1.3649	-0.8315	Y
	39	5.8855	-27.5066	-30.6810	5.4228	-28.2113	-29.5143	0.4627	-0.7047	1.1667	1.4394	-0.7047	Y
	40	9.5701	-28.2143	-24.9387	9.1679	-28.8057	-23.8564	0.4022	-0.5914	1.0823	1.2973	-0.5914	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 – Set 2, Test No. H42ST-1

Test Name: H42ST-1 VIN: 1C6RR6GT2GS269090

Model Year: 2016 Make: Ram Model: 1500

Driver Side Maximum Deformation

Reference Set 1				Reference Set 2			
Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]	Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]
Roof	0.0	≤ 4	Z	Roof	1.1	≤ 4	Z
Windshield[D]	0.0	≤ 3	X, Z	Windshield[D]	NA	≤ 3	X, Z
A-Pillar Maximum	0.7	≤ 5	Y	A-Pillar Maximum	0.4	≤ 5	X
A-Pillar Lateral	0.7	≤ 3	Y	A-Pillar Lateral	-0.8	≤ 3	Y
B-Pillar Maximum	0.5	≤ 5	Y	B-Pillar Maximum	1.3	≤ 5	X, Z
B-Pillar Lateral	0.7	≤ 3	Y	B-Pillar Lateral	-0.9	≤ 3	Y
Toe Pan - Wheel Well	6.0	≤ 9	X, Z	Toe Pan - Wheel Well	6.1	≤ 9	X, Z
Side Front Panel	5.7	≤ 12	Y	Side Front Panel	5.4	≤ 12	Y
Side Door (above seat)	-2.0	≤ 9	Y	Side Door (above seat)	-2.6	≤ 9	Y
Side Door (below seat)	0.1	≤ 12	Y	Side Door (below seat)	0.0	≤ 12	Y
Floor Pan	3.2	≤ 12	Z	Floor Pan	3.5	≤ 12	Z
Dash - no MASH requirement	3.0	NA	X, Y, Z	Dash - no MASH requirement	3.0	NA	X, Y, Z

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

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

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

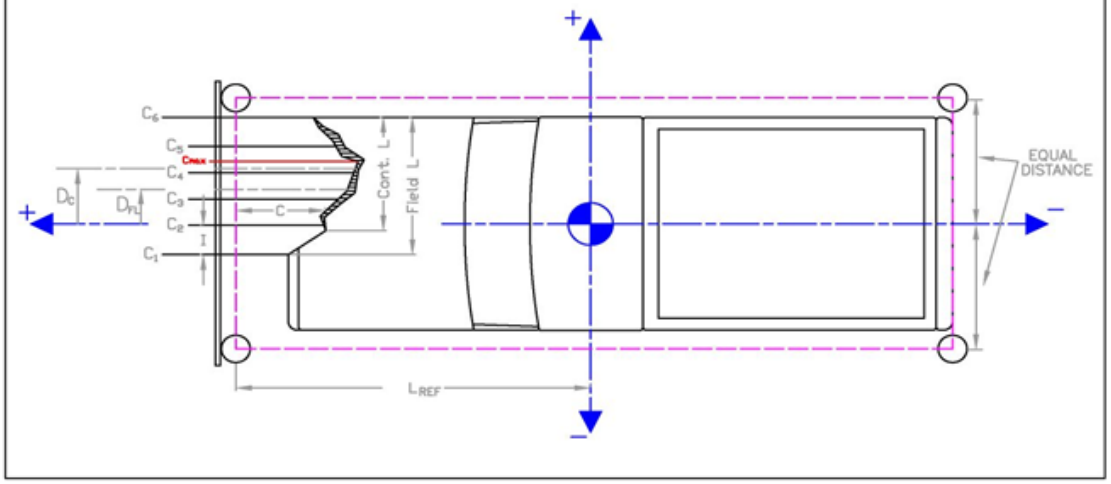
[D] If deformation is observered for the windshield then the windshield deformation is measured posttest with an examplar vehicle, therefore only one set of reference is measured and recorded.

Notes on vehicle interior crush:

Figure D-5. Maximum Occupant Compartment Deformation by Location, Test No. H42ST-1

Test Name: H42ST-1 VIN: 1C6RR6GT2GS269090

Model Year: 2016 Make: Ram Model: 1500



	In.	(mm)
Distance from C.G. to reference line - L_{REF}:	116	(2946)
Total Vehicle Width:	78 1/8	(1984)
Width of contact and induced crush - Field L:	78 1/8	(1984)
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:	27	(686)
Distance from center of vehicle to center of contact damage - D_C:	25 1/2	(648)

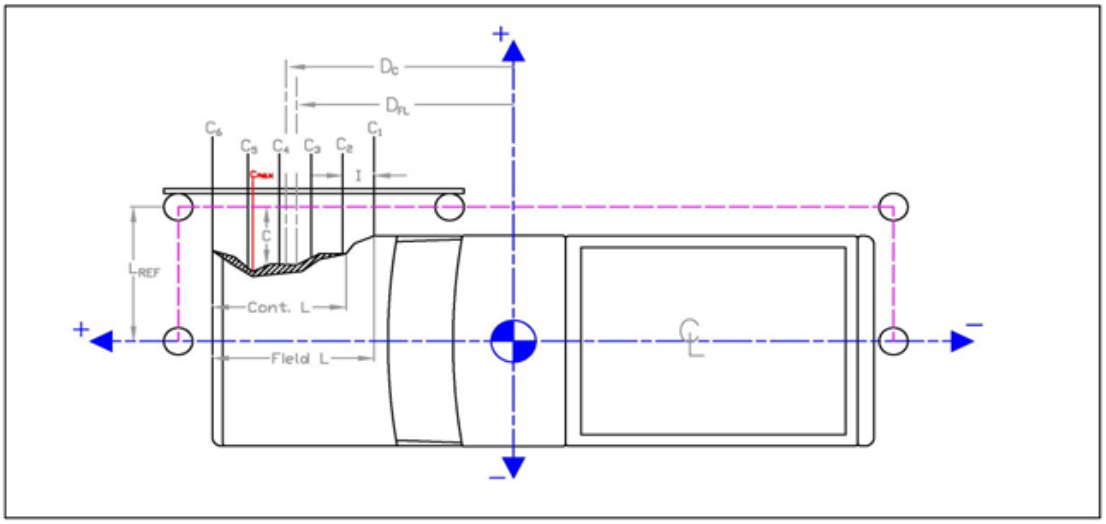
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Lateral Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	In.	(mm)	In.	(mm)	In.	(mm)	In.	(mm)	In.	(mm)
C_1	N/A	N/A	-39 1/8	-(994)	22 1/2	(572)	12	(303)	N/A	N/A
C_2	N/A	N/A	-23 1/2	-(597)	6 5/8	(168)			N/A	N/A
C_3	25	(635)	-7 7/8	-(200)	4 1/4	(108)			8 4/5	(224)
C_4	11 3/4	(298)	7 3/4	(197)	4 1/4	(108)			-4 4/9	-(113)
C_5	16	(406)	23 3/8	(594)	6 1/4	(159)			-2 1/5	-(56)
C_6	N/A	N/A	39	(991)	20 1/2	(521)			N/A	N/A
C_{MAX}	41 1/2	(1054)	20	(508)	5 5/8	(143)			24	(608)

Figure D-6. Exterior Vehicle Crush (NASS) – Front, Test No. H42ST-1

Test Name: H42ST-1 VIN: 1C6RR6GT2GS269090

Model Year: 2016 Make: Ram Model: 1500



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	47 1/2	(1207)
Total Vehicle Length:	229 3/8	(5826)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-13 3/8	-(340)
Width of contact and induced crush - Field L:	229 3/8	(5826)
Crush measurement spacing interval (L/5) - I:	45 7/8	(1165)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-13 3/8	-(340)
Width of Contact Damage:	229 3/8	(5826)
Distance from vehicle c.g. to center of contact damage - D_C:	-13 3/8	-(340)

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	16 3/4	(425)	-128 1/8	-(3254)	33 1/2	(851)	3 1/2	(89)	-20 1/4	-(514)
C_2	N/A	N/A	-82 1/4	-(2089)	5 1/2	(140)			N/A	N/A
C_3	9 3/4	(248)	-36 3/8	-(924)	5 7/8	(149)			3/8	(10)
C_4	8 3/4	(222)	9 1/2	(241)	5	(127)			1/4	(6)
C_5	N/A	N/A	55 3/8	(1407)	5 7/8	(149)			N/A	N/A
C_6	47 1/8	(1197)	101 1/4	(2572)	11 3/8	(289)			32 1/4	(819)
C_{MAX}	47 1/8	(1197)	101 1/4	(2572)	11 3/8	(289)			32 1/4	(819)

Figure D-7. Exterior Vehicle Crush (NASS) – Side, Test No. H42ST-1

Model Year: 2016 Test Name: H42ST-2 Make: Hyundai VIN: kmhct4ae8gu947887 Model: Accent

VEHICLE DEFORMATION
DRIVER SIDE FLOOR PAN - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	86.1354	-36.7884	6.0388	85.8378	-35.6971	4.8716	0.2976	1.0913	1.1672	1.6254	1.2045	X, Z
	2	86.2113	-32.2486	6.2485	85.7186	-31.6817	5.1910	0.4927	0.5669	1.0575	1.2971	1.1666	X, Z
	3	86.0794	-28.3420	6.4548	85.7674	-27.7375	5.6535	0.3120	0.6045	0.8411	1.0818	0.8971	X, Z
	4	86.4341	-24.6405	6.3584	86.2688	-24.0998	5.5057	0.1653	0.5410	0.8527	1.0233	0.9686	X, Z
	5	85.1651	-20.4574	3.4199	85.0823	-20.1564	2.6609	0.0828	0.3010	0.7590	0.8207	0.7635	X, Z
	6	82.2381	-36.9596	8.3372	82.0578	-36.3461	7.4186	0.1803	0.6135	0.9206	1.1433	0.9381	X, Z
	7	81.9161	-32.4676	8.1451	81.8324	-31.8216	7.5270	0.0837	0.6460	0.6181	0.8980	0.6237	X, Z
	8	82.0133	-28.2135	8.8659	81.8757	-27.6568	8.1027	0.1336	0.5567	0.7632	0.9541	0.7748	X, Z
	9	82.1466	-25.9603	8.8956	82.0006	-25.3655	8.0723	0.1460	0.5948	0.8233	1.0261	0.8361	X, Z
	10	81.2255	-20.0836	4.5804	81.1803	-19.8211	3.9488	0.0452	0.2625	0.6306	0.6845	0.6322	X, Z
FLOOR PAN (Z)	11	76.3307	-40.9396	9.9366	76.3145	-40.2575	9.0502	0.0162	0.6821	0.8864	1.1186	0.8864	Z
	12	75.6663	-34.0549	9.3926	75.6484	-33.5175	8.8202	0.0099	0.5374	0.5724	0.7852	0.5724	Z
	13	76.0018	-29.2100	10.1729	75.9994	-28.6513	9.6730	0.0024	0.5587	0.4999	0.7497	0.4999	Z
	14	76.0982	-24.0422	10.1374	76.0724	-23.5962	9.3415	0.0258	0.4440	0.7959	0.9117	0.7959	Z
	15	76.0920	-20.4130	6.4042	76.0486	-20.1820	5.6702	0.0434	0.2310	0.7340	0.7707	0.7340	Z
	16	72.7836	-40.2730	9.6604	72.7450	-39.6995	9.0007	0.0386	0.5735	0.6597	0.8750	0.6597	Z
	17	72.8076	-33.9730	9.3333	72.8263	-33.5252	8.7768	-0.0187	0.4478	0.5565	0.7145	0.5565	Z
	18	72.7165	-29.1130	10.1786	72.6624	-28.5911	9.7752	0.0541	0.5219	0.4034	0.6618	0.4034	Z
	19	73.0391	-23.9345	10.1433	73.0434	-23.5400	9.3648	-0.0043	0.3945	0.7785	0.8728	0.7785	Z
	20	72.7761	-19.8179	5.3511	72.8085	-19.5209	4.5545	-0.0324	0.2970	0.7966	0.8508	0.7966	Z
	21	68.8399	-40.0818	9.7587	68.8869	-39.5547	9.1007	-0.0470	0.5271	0.6580	0.8444	0.6580	Z
	22	68.9493	-33.8661	9.5356	68.9558	-33.3567	9.0066	-0.0105	0.5094	0.5290	0.7338	0.5290	Z
	23	69.4258	-28.9180	10.2020	69.3885	-28.4220	9.7466	0.0373	0.4960	0.4554	0.6744	0.4554	Z
	24	70.1337	-23.5459	10.1729	70.1080	-23.1445	9.4094	0.0257	0.4014	0.7635	0.8630	0.7635	Z
	25	72.7582	-19.8198	5.3619	69.8281	-19.4196	4.5776	2.9301	0.4002	0.7843	3.0565	0.7843	Z
	26	64.0681	-39.2407	10.0596	64.0787	-38.7746	9.5859	-0.0106	0.4661	0.4737	0.6646	0.4737	Z
	27	64.1511	-33.5061	9.6780	64.1892	-33.0471	9.1763	-0.0381	0.4590	0.5027	0.6818	0.5027	Z
	28	64.4309	-28.6669	10.4389	64.4346	-28.3226	9.7726	-0.0037	0.3443	0.6663	0.7500	0.6663	Z
	29	64.5956	-23.3377	10.4451	64.5878	-22.9325	9.6867	0.0078	0.4052	0.7584	0.8599	0.7584	Z
	30	64.9828	-19.4070	5.5276	65.0047	-19.0899	4.7811	-0.0219	0.3171	0.7465	0.8114	0.7465	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-8. Floor Pan Deformation Data – Set 1, Test No. H42ST-2

Model Year: 2016 Test Name: H42ST-2 Make: Hyundai VIN: kmhct4ae8gu947887 Model: Accent

VEHICLE DEFORMATION
DRIVER SIDE FLOOR PAN - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
TOE PAN - WHEEL WELL (X, Z)	1	84.9854	-4.2579	6.2237	84.6589	-3.6808	4.2182	0.3265	0.5771	2.0055	2.1123	2.0319	X, Z
	2	84.9946	0.2817	6.4467	84.4581	0.3341	4.5007	0.4765	-0.0524	1.9460	2.0042	2.0035	X, Z
	3	84.6938	4.1823	6.7042	84.4281	4.2828	4.9255	0.2657	-0.1005	1.7787	1.8012	1.7984	X, Z
	4	84.9450	7.8926	6.5788	84.8515	7.9288	4.7387	0.0935	-0.0362	1.8401	1.8428	1.8425	X, Z
	5	83.5584	12.0473	3.6530	83.5568	11.8186	1.8577	0.0016	0.2287	1.7953	1.7999	1.7953	X, Z
	6	81.0965	-4.5844	8.5228	80.9163	-4.3842	6.8039	0.1802	0.2002	1.7189	1.7399	1.7283	X, Z
	7	80.6480	-0.0626	8.3440	80.5968	0.1354	6.8735	0.0512	0.1980	1.4705	1.4847	1.4714	X, Z
	8	80.6267	4.1904	9.0772	80.5617	4.3057	7.4094	0.0650	-0.1153	1.6678	1.6730	1.6691	X, Z
	9	80.6970	6.4463	9.1135	80.6342	6.5986	7.3553	0.0628	-0.1523	1.7572	1.7649	1.7553	X, Z
	10	79.6104	12.3076	4.8159	79.6603	12.0846	3.1892	-0.0499	0.2230	1.6267	1.6427	1.6267	Z
FLOOR PAN (Z)	11	75.3020	-8.6925	10.1128	75.2716	-8.3991	8.5271	0.0304	0.2934	1.5855	1.6127	1.5855	Z
	12	74.4364	-1.8277	9.5890	74.4597	-1.6771	8.2396	-0.0243	0.1506	1.3494	1.3580	1.3494	Z
	13	74.6459	3.0226	10.3834	74.7181	3.2034	9.0430	-0.0722	-0.1808	1.3404	1.3545	1.3404	Z
	14	74.5980	8.1912	10.3629	74.6818	8.2535	8.6631	-0.0838	-0.0623	1.6998	1.7030	1.6998	Z
	15	74.4889	11.8296	6.6404	74.5531	11.6329	4.9600	-0.0642	0.1967	1.6804	1.6931	1.6804	Z
	16	71.7376	-8.1243	9.8396	71.6908	-7.9165	8.5052	0.0468	0.2078	1.3344	1.3513	1.3344	Z
	17	71.5855	-1.8253	9.5309	71.6402	-1.7443	8.2221	-0.0547	0.0810	1.3088	1.3124	1.3088	Z
	18	71.3691	3.0278	10.3905	71.3815	3.1946	9.1753	-0.0224	-0.1668	1.2152	1.2268	1.2152	Z
	19	71.5370	8.2134	10.3702	71.6525	8.2485	8.7137	-0.1155	-0.0351	1.6565	1.6609	1.6565	Z
	20	71.1572	12.3350	5.5902	71.2899	12.2152	3.8680	-0.1327	0.1198	1.7222	1.7315	1.7222	Z
	21	67.7902	-8.0436	9.9398	67.8316	-7.8516	8.6393	-0.0414	0.1920	1.3005	1.3152	1.3005	Z
	22	67.7258	-1.8257	9.7348	67.7732	-1.6546	8.4859	-0.0474	0.1711	1.2489	1.2615	1.2489	Z
	23	68.0643	3.1308	10.4155	68.1047	3.2949	9.1762	-0.0404	-0.1641	1.2403	1.2518	1.2403	Z
	24	68.6219	8.5206	10.4019	68.7099	8.5828	8.7815	-0.0880	-0.0622	1.6204	1.6240	1.6204	Z
	25	71.1394	12.3326	5.6010	68.3083	12.2543	3.9175	2.8311	0.0783	1.6835	3.2948	1.6835	Z
	26	62.9969	-7.3370	10.2447	63.0126	-7.1677	9.1613	-0.0157	0.1693	1.0834	1.0967	1.0834	Z
	27	62.9195	-1.8012	9.8799	62.9969	-1.4434	8.6954	-0.0784	0.1578	1.1845	1.1976	1.1845	Z
	28	63.0644	3.2417	10.6548	63.1502	3.2907	9.2468	-0.0858	-0.0490	1.4090	1.4125	1.4090	Z
	29	63.0803	8.5733	10.6766	63.1883	8.6818	9.1076	-0.1080	-0.1085	1.5650	1.5765	1.5650	Z
	30	63.3555	12.5276	5.7704	63.4811	12.4848	4.1622	-0.1256	0.0428	1.6082	1.6137	1.6082	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-9. Floor Pan Deformation Data – Set 2, Test No. H42ST-2

Model Year: 2016 | Test Name: H42ST-2 | Make: Hyundai | VIN: kmhct4ae8gu947887 | Model: Accent

VEHICLE DEFORMATION
DRIVER SIDE INTERIOR CRUSH - SET 1

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	74.3963	-41.2023	-18.0804	74.1598	-40.4144	-19.9109	0.2365	0.7879	-1.8305	2.0069	2.0069	X, Y, Z
	2	70.9527	-29.1167	-22.1506	71.0756	-28.2023	-23.7879	-0.1229	0.9144	-1.6373	1.8794	1.8794	X, Y, Z
	3	74.2071	-15.7220	-18.8300	74.4297	-15.1619	-19.7986	-0.2226	0.5601	-0.9686	1.1408	1.1408	X, Y, Z
	4	70.8196	-39.8886	-10.3249	70.3206	-38.9633	-12.2582	0.4988	0.9253	-1.9333	2.2358	2.2358	X, Y, Z
	5	72.7614	-30.3595	-7.1280	72.6963	-29.6853	-8.5068	0.0651	0.6742	-1.3788	1.5382	1.5382	X, Y, Z
	6	69.6007	-15.5239	-12.3888	69.7737	-15.1227	-13.4401	-0.1730	0.4012	-1.0513	1.1385	1.1385	X, Y, Z
SIDE PANEL (Y)	7	78.0103	-43.0522	2.2361	77.5784	-41.6110	0.5736	0.4319	1.4412	-1.6625	2.2422	1.4412	Y
	8	78.7683	-43.0396	-0.3716	78.0103	-41.5342	-2.0277	0.7580	1.5054	-1.6561	2.3629	1.5054	Y
	9	82.4537	-43.2241	1.3824	81.2214	-40.5118	-0.2228	1.2323	2.7123	-1.6052	3.3841	2.7123	Y
IMPACT SIDE DOOR (Y)	10	44.7520	-43.0701	-15.8859	44.0790	-44.8423	-16.2217	0.6730	-1.7722	-0.3358	1.9252	-1.7722	Y
	11	58.4126	-43.8513	-14.7731	57.6812	-45.9143	-15.5810	0.7314	-2.0630	-0.7879	2.3263	-2.0630	Y
	12	65.0640	-43.5897	-14.4064	64.1496	-45.2084	-15.3812	0.9144	-1.6187	-0.9748	2.0992	-1.6187	Y
	13	47.5488	-43.2270	-1.8817	47.4307	-44.5252	-2.3229	0.1181	-1.2982	-0.4412	1.3762	-1.2982	Y
	14	59.2759	-44.8331	1.0735	59.3199	-46.0357	0.1271	-0.0440	-1.4026	-0.9464	1.8928	-1.4026	Y
	15	65.4952	-45.2497	0.4052	65.4286	-46.7343	-0.5938	0.0666	-1.4846	-0.9990	1.7907	-1.4846	Y
ROOF - (Z)	16	60.6926	-32.9245	-33.7340	60.3985	-33.7736	-34.6930	0.2941	-0.8491	-0.9590	1.3142	-0.9590	Z
	17	62.4170	-24.5353	-33.8363	62.0223	-25.4406	-34.2856	0.3947	-0.9053	-0.4493	1.0850	-0.4493	Z
	18	63.0536	-16.0302	-33.8408	62.6067	-16.8755	-33.9162	0.4469	-0.8453	-0.0754	0.9591	-0.0754	Z
	19	55.4588	-32.3822	-35.7526	55.1154	-33.1088	-36.7084	0.3434	-0.7266	-0.9558	1.2305	-0.9558	Z
	20	56.2860	-23.0338	-36.1352	55.9682	-23.8214	-36.8714	0.3178	-0.7876	-0.7362	1.1240	-0.7362	Z
	21	56.0906	-16.6106	-36.2870	55.7387	-17.3960	-36.5234	0.3519	-0.7854	-0.2364	0.8925	-0.2364	Z
	22	39.6630	-30.3940	-37.5375	39.2972	-31.0627	-37.6946	0.3658	-0.6687	-0.1571	0.7782	-0.1571	Z
	23	39.9692	-22.2960	-37.8760	39.6807	-23.0629	-38.2810	0.2885	-0.7649	-0.4050	0.9123	-0.4050	Z
	24	39.9149	-16.1132	-37.9435	39.7183	-16.7821	-38.2317	0.1966	-0.6689	-0.2882	0.7544	-0.2882	Z
	25	19.9726	-30.4340	-36.5658	19.6998	-30.9692	-36.5229	0.2728	-0.5352	0.0429	0.6022	0.0429	Z
	26	19.8458	-22.5010	-36.9132	19.5192	-23.0830	-36.9225	0.3266	-0.5820	-0.0093	0.6674	-0.0093	Z
	27	20.2796	-13.5538	-37.0021	20.0256	-14.1728	-37.0544	0.2540	-0.6190	-0.0523	0.6711	-0.0523	Z
	28	10.4011	-29.8797	-34.9353	10.1229	-30.3734	-34.7152	0.2782	-0.4937	0.2201	0.6079	0.2201	Z
	29	9.7472	-21.8528	-35.2001	9.4564	-22.3817	-35.0603	0.2908	-0.5291	0.1398	0.6197	0.1398	Z
	30	9.6870	-14.5939	-35.2384	9.4835	-15.1484	-35.1709	0.2035	-0.5545	0.0655	0.5943	0.0655	Z
A-PILLAR Maximum (X, Y, Z)	31	78.7722	-41.7083	-22.5609	78.8318	-41.1152	-24.2722	-0.0596	0.5931	-1.7113	1.8121	0.5931	Y
	32	74.8352	-40.8087	-24.7623	74.8738	-40.7968	-26.5371	-0.0386	0.0119	-1.7748	1.7753	0.0119	Y
	33	71.9233	-40.1477	-26.1752	71.9698	-40.4664	-27.9297	-0.0465	-0.3187	-1.7545	1.7838	0.0000	NA
	34	68.7468	-39.1900	-28.2081	68.7520	-39.5943	-29.8103	-0.0052	-0.4043	-1.6022	1.6524	0.0000	NA
	35	64.2565	-38.0265	-29.9521	64.1542	-38.5689	-31.4391	0.1023	-0.5424	-1.4870	1.5861	0.1023	X
	36	60.4078	-37.3035	-31.8889	60.2182	-37.9729	-33.2659	0.1896	-0.6694	-1.3770	1.5428	0.1896	X
A-PILLAR Lateral (Y)	31	78.7722	-41.7083	-22.5609	78.8318	-41.1152	-24.2722	-0.0596	0.5931	-1.7113	1.8121	0.5931	Y
	32	74.8352	-40.8087	-24.7623	74.8738	-40.7968	-26.5371	-0.0386	0.0119	-1.7748	1.7753	0.0119	Y
	33	71.9233	-40.1477	-26.1752	71.9698	-40.4664	-27.9297	-0.0465	-0.3187	-1.7545	1.7838	-0.3187	Y
	34	68.7468	-39.1900	-28.2081	68.7520	-39.5943	-29.8103	-0.0052	-0.4043	-1.6022	1.6524	-0.4043	Y
	35	64.2565	-38.0265	-29.9521	64.1542	-38.5689	-31.4391	0.1023	-0.5424	-1.4870	1.5861	-0.5424	Y
	36	60.4078	-37.3035	-31.8889	60.2182	-37.9729	-33.2659	0.1896	-0.6694	-1.3770	1.5428	-0.6694	Y
B-PILLAR Maximum (X, Y, Z)	37	37.7156	-36.0111	-32.5339	37.4031	-36.8553	-32.7603	0.3125	-0.8442	-0.2264	0.9282	0.3125	X
	38	36.1341	-37.6961	-28.5160	35.8096	-38.3765	-28.7440	0.3245	-0.6804	-0.2280	0.7875	0.3245	X
	39	39.3763	-39.0567	-25.7351	39.1796	-39.7609	-26.0258	0.1967	-0.7042	-0.2907	0.7868	0.1967	X
	40	36.6087	-40.4159	-20.3727	36.3821	-40.9636	-20.5246	0.2266	-0.5477	-0.1519	0.6119	0.2266	X
B-PILLAR Lateral (Y)	37	37.7156	-36.0111	-32.5339	37.4031	-36.8553	-32.7603	0.3125	-0.8442	-0.2264	0.9282	-0.8442	Y
	38	36.1341	-37.6961	-28.5160	35.8096	-38.3765	-28.7440	0.3245	-0.6804	-0.2280	0.7875	-0.6804	Y
	39	39.3763	-39.0567	-25.7351	39.1796	-39.7609	-26.0258	0.1967	-0.7042	-0.2907	0.7868	-0.7042	Y
	40	36.6087	-40.4159	-20.3727	36.3821	-40.9636	-20.5246	0.2266	-0.5477	-0.1519	0.6119	-0.5477	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-10. Occupant Compartment Deformation Data – Set 1, Test No. H42ST-2

Model Year: 2016 Test Name: H42ST-2 Make: Hyundai VIN: kmhct4ae8gu947887 Model: Accent

VEHICLE DEFORMATION
DRIVER SIDE INTERIOR CRUSH - SET 2

	POINT	Pretest X (in.)	Pretest Y (in.)	Pretest Z (in.)	Posttest X (in.)	Posttest Y (in.)	Posttest Z (in.)	ΔX[A] (in.)	ΔY[A] (in.)	ΔZ[A] (in.)	Total Δ (in.)	Crush[B] (in.)	Directions for Crush[C]
DASH (X, Y, Z)	1	73.3796	-8.9464	-17.8418	72.8521	-8.9052	-20.3711	0.5275	0.0412	-2.5293	2.5840	2.5840	X, Y, Z
	2	69.5957	3.0423	-21.8957	69.4828	3.2029	-24.3359	0.1139	-0.1606	-2.4402	2.4481	2.4481	X, Y, Z
	3	72.4750	16.5194	-18.5592	72.6004	16.3474	-20.4991	-0.1254	0.1720	-1.9399	1.9515	1.9515	X, Y, Z
	4	69.7701	-7.7433	-10.0835	69.0491	-7.4606	-12.7391	0.7210	0.2827	-2.6556	2.7662	2.7662	X, Y, Z
	5	71.4448	1.8325	-6.8753	71.2644	1.9004	-9.0562	0.1804	-0.0679	-2.1809	2.1894	2.1894	X, Y, Z
	6	67.8671	16.5801	-12.1164	67.9991	16.3516	-14.1008	-0.1320	0.2285	-1.9844	2.0019	2.0019	X, Y, Z
SIDE PANEL (Y)	7	77.0511	-10.7196	2.4712	76.4697	-9.8344	0.0931	0.5814	0.8852	-2.3781	2.6033	0.8852	Y
	8	77.8076	-10.6824	-0.1367	76.8776	-9.7737	-2.5125	0.9300	0.9087	-2.3758	2.7083	0.9087	Y
	9	81.4973	-10.7656	1.6159	80.0822	-8.6681	-0.7454	1.4151	2.0975	-2.3613	3.4609	2.0975	Y
IMPACT SIDE DOOR (Y)	10	43.8002	-11.6484	-15.6406	42.9020	-13.9166	-16.3775	0.8982	-2.2682	-0.7369	2.5484	-2.2682	Y
	11	57.4777	-12.0472	-14.5330	56.5286	-14.7016	-15.8256	0.9491	-2.6544	-1.2926	3.1012	-2.6544	Y
	12	64.1192	-11.5994	-14.1679	62.9823	-13.8608	-15.7091	1.1369	-2.2614	-1.5412	2.9634	-2.2614	Y
	13	46.6051	-11.7442	-1.6374	46.3551	-13.3971	-2.5121	0.2400	-1.6529	-0.8747	1.8854	-1.6529	Y
	14	58.3680	-12.8243	1.3124	58.3035	-14.6386	-0.1520	0.0645	-1.8143	-1.4644	2.3324	-1.8143	Y
	15	64.6020	-13.2652	0.6414	64.4189	-15.2180	-0.9196	0.1831	-1.9528	-1.5612	2.5069	-1.9528	Y
ROOF - (Z)	16	59.4436	-1.0369	-33.4807	58.8305	-2.6916	-35.0942	0.6131	-1.6547	-1.6135	2.3911	-1.6135	Z
	17	60.9317	7.3975	-33.5730	60.2849	5.8766	-34.7795	0.6468	1.7209	-1.2065	2.1950	-1.2065	Z
	18	61.3294	15.9171	-33.5670	60.6951	14.2550	-34.4960	0.6343	1.6621	-0.9290	2.0070	-0.9290	Z
	19	54.1953	-0.6192	-35.5370	53.5177	-2.1553	-37.0695	0.6776	-1.5361	-1.5325	2.2732	-1.5325	Z
	20	54.7603	6.7291	-35.8681	54.1768	7.1458	-37.3275	0.5835	1.5833	-1.4594	2.2310	-1.4594	Z
	21	54.3846	15.1445	-36.0118	53.8173	13.5680	-37.0380	0.5673	1.5765	-1.0262	1.9648	-1.0262	Z
	22	38.3500	0.9070	-37.2746	37.8527	-0.4451	-37.9366	0.6973	1.3521	-0.6620	1.6591	-0.6620	Z
	23	38.4286	9.0089	-37.6030	37.8656	7.5549	-38.6017	0.5630	1.4540	-0.9987	1.8516	-0.9987	Z
	24	38.2007	15.1897	-37.6627	37.7736	13.8353	-38.6119	0.4271	1.3544	-0.9492	1.7082	-0.9492	Z
	25	18.6668	0.3131	-38.2989	18.0683	-0.7444	-38.5946	0.6005	1.0575	-0.2977	1.2520	-0.2977	Z
	26	18.3192	8.2397	-36.6342	17.7211	7.1323	-37.0668	0.5981	1.1074	-0.4326	1.3309	-0.4326	Z
	27	18.5016	17.1958	-36.7120	18.0419	16.0493	-37.2871	0.4597	1.1465	-0.5751	1.3625	-0.5751	Z
	28	9.0861	0.5964	-34.6627	8.4969	-0.3287	-34.7089	0.5892	0.9251	-0.0462	1.0978	-0.0462	Z
	29	8.2070	8.6023	-34.9172	7.6622	7.6438	-35.1234	0.5448	0.9585	-0.2062	1.1216	-0.2062	Z
	30	7.9430	15.8564	-34.9443	7.5388	14.8747	-35.3024	0.4042	0.9817	-0.3581	1.1204	-0.3581	Z
A-PILLAR Maximum (X, Y, Z)	31	77.7684	-9.3237	-22.3243	77.5001	-9.5514	-24.7663	0.2683	-0.2277	-2.4420	2.4670	0.2683	X
	32	73.8050	-8.5322	-24.5233	73.5172	-9.3364	-26.9994	0.2878	-0.8042	-2.4761	2.6193	0.2878	X
	33	70.8752	-7.9515	-25.9345	70.5952	-9.0793	-28.3696	0.2800	-1.1278	-2.4351	2.6982	0.2800	X
	34	67.6724	-7.0808	-27.9653	67.3440	-8.2919	-30.2302	0.3284	-1.2111	-2.2649	2.5893	0.3284	X
	35	63.1506	-6.0416	-29.7064	62.7123	-7.3771	-31.8283	0.4383	-1.3355	-2.1219	2.5452	0.4383	X
	36	59.2825	-5.4246	-31.6410	58.7493	-6.8799	-33.6281	0.5332	-1.4553	-1.9851	2.5185	0.5332	X
A-PILLAR Lateral (Y)	31	77.7684	-9.3237	-22.3243	77.5001	-9.5514	-24.7663	0.2683	-0.2277	-2.4420	2.4670	-0.2277	Y
	32	73.8050	-8.5322	-24.5233	73.5172	-9.3364	-26.9994	0.2878	-0.8042	-2.4761	2.6193	-0.8042	Y
	33	70.8752	-7.9515	-25.9345	70.5952	-9.0793	-28.3696	0.2800	-1.1278	-2.4351	2.6982	-1.1278	Y
	34	67.6724	-7.0808	-27.9653	67.3440	-8.2919	-30.2302	0.3284	-1.2111	-2.2649	2.5893	-1.2111	Y
	35	63.1506	-6.0416	-29.7064	62.7123	-7.3771	-31.8283	0.4383	-1.3355	-2.1219	2.5452	-1.3355	Y
	36	59.2825	-5.4246	-31.6410	58.7493	-6.8799	-33.6281	0.5332	-1.4553	-1.9851	2.5185	-1.4553	Y
B-PILLAR Maximum (X, Y, Z)	37	36.5627	-4.7688	-32.2775	35.9212	-6.2279	-32.9316	0.6415	-1.4591	-0.6541	1.7229	0.6415	X
	38	35.0305	-6.5025	-28.2612	34.3939	-7.7430	-28.8874	0.6366	-1.2405	-0.6262	1.5285	0.6366	X
	39	38.3106	-7.7751	-25.4831	37.8149	-9.0316	-26.1858	0.4957	-1.2565	-0.7027	1.5226	0.4957	X
	40	35.5841	-9.2181	-20.1215	35.0900	-10.2387	-20.6493	0.4941	-1.0206	-0.5278	1.2507	0.4941	X
B-PILLAR Lateral (Y)	37	36.5627	-4.7688	-32.2775	35.9212	-6.2279	-32.9316	0.6415	-1.4591	-0.6541	1.7229	-1.4591	Y
	38	35.0305	-6.5025	-28.2612	34.3939	-7.7430	-28.8874	0.6366	-1.2405	-0.6262	1.5285	-1.2405	Y
	39	38.3106	-7.7751	-25.4831	37.8149	-9.0316	-26.1858	0.4957	-1.2565	-0.7027	1.5226	-1.2565	Y
	40	35.5841	-9.2181	-20.1215	35.0900	-10.2387	-20.6493	0.4941	-1.0206	-0.5278	1.2507	-1.0206	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-11. Occupant Compartment Deformation Data – Set 2, Test No. H42ST-2

Model Year: 2016 Test Name: H42ST-2 Make: Hyundai VIN: kmhct4ae8gu947887 Model: Accent

Driver Side Maximum Deformations

Reference Set 1				Reference Set 2			
Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]	Location	Maximum Deformation[A,B] (in.)	MASH Allowable Deformation (in.)	Directions of Deformation[C]
Roof	0.2	≤ 4	Z	Roof	-1.6	≤ 4	Z
Windshield[D]	3.5	≤ 3	X, Z	Windshield[D]	NA	≤ 3	X, Z
A-Pillar Maximum	0.6	≤ 5	Y	A-Pillar Maximum	0.5	≤ 5	X
A-Pillar Lateral	0.6	≤ 3	Y	A-Pillar Lateral	-1.5	≤ 3	Y
B-Pillar Maximum	0.3	≤ 5	X	B-Pillar Maximum	0.6	≤ 5	X
B-Pillar Lateral	0.6	≤ 3	Y	B-Pillar Lateral	-1.5	≤ 3	Y
Toe Pan - Wheel Well	1.2	≤ 9	X, Z	Toe Pan - Wheel Well	2.0	≤ 9	X, Z
Side Front Panel	2.7	≤ 12	Y	Side Front Panel	2.1	≤ 12	Y
Side Door (above seat)	-2.1	≤ 9	Y	Side Door (above seat)	-2.7	≤ 9	Y
Side Door (below seat)	-1.5	≤ 12	Y	Side Door (below seat)	-2.0	≤ 12	Y
Floor Pan	0.9	≤ 12	Z	Floor Pan	1.7	≤ 12	Z
Dash - no MASH requirement	2.2	NA	X, Y, Z	Dash - no MASH requirement	2.2	NA	X, Y, Z

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

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

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

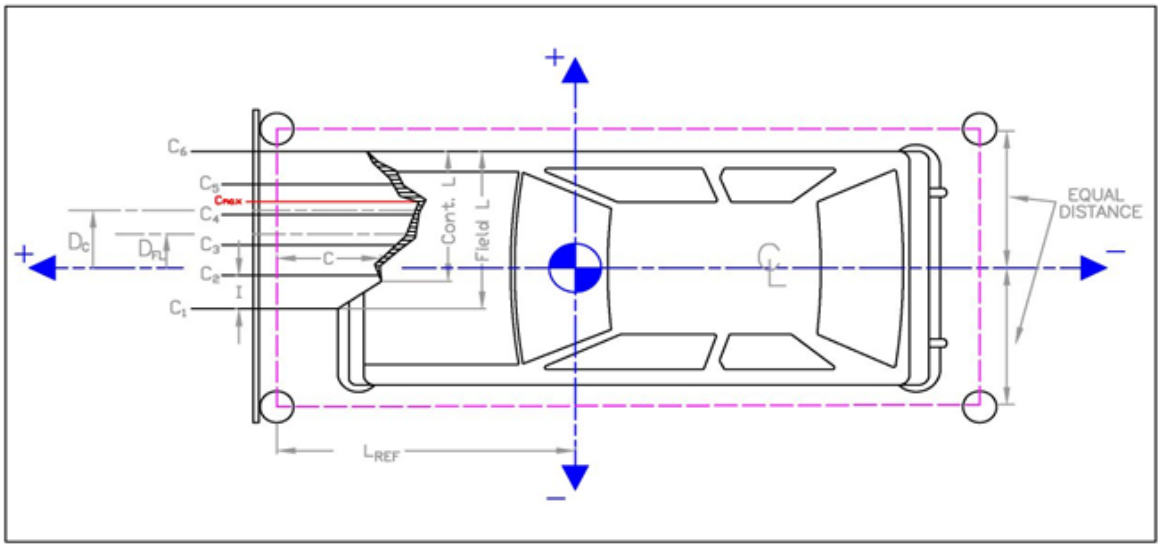
[D] If deformation is observered for the windshield then the windshield deformation is measured posttest with an examplar vehicle, therefore only one set of reference is measured and recorded.

Notes on vehicle crush:

Figure D-12. Maximum Occupant Compartment Deformation by Location, Test No. H42ST-2

Test Name: H42ST-2 VIN: kmhct4ae8gu947887

Model Year: 2016 Make: Hyundai Model: Accent



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	81	(2057)
Total Width of Vehicle:	66 3/8	(1686)
Width of contact and induced crush - Field L:	66 3/8	(1686)
Crush measurement spacing interval (L/5) - I:	13 1/4	(337)
Distance from center of vehicle to center of Field L - D_{PL}:	0	()
Width of Contact Damage:	22 1/5	(564)
Distance from center of vehicle to center of contact damage - D_C:	22	(561)

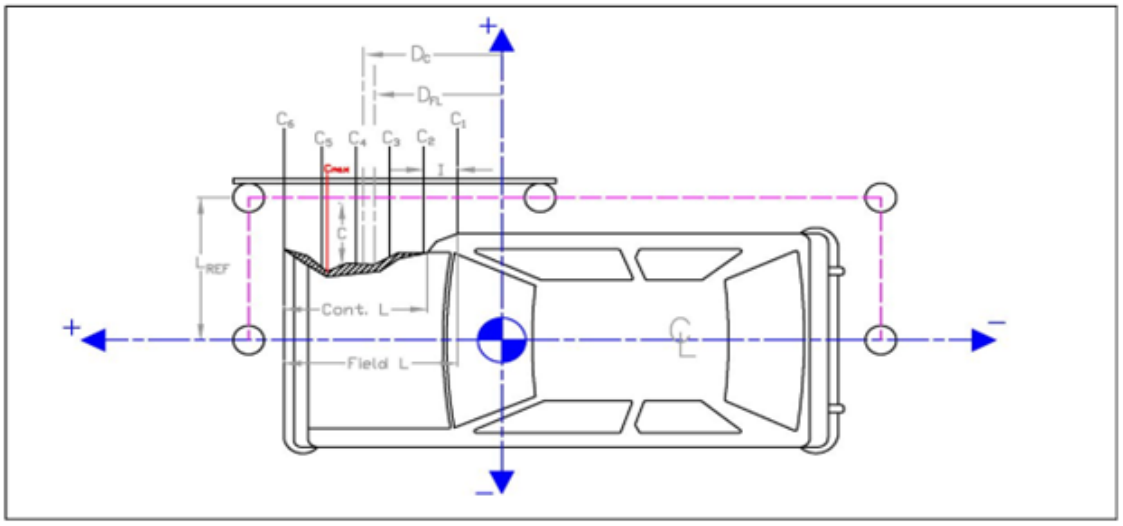
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Lateral Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	N/A	NA	-33 1/4	-(845)	24 1/8	(613)	1 4/9	(37)	NA	NA
C_2	30 1/2	(775)	-20	-(508)	11 5/8	(295)			17 4/9	(443)
C_3	12 1/4	(311)	-6 3/4	-(171)	8 7/8	(225)			2	(49)
C_4	6 1/2	(165)	6 1/2	(165)	8 7/8	(225)			-3 4/5	-(97)
C_5	3 1/2	(89)	19 3/4	(502)	11 1/2	(292)			-9 4/9	-(240)
C_6	N/A	NA	33	(838)	24 1/8	(613)			NA	NA
C_{MAX}	30 1/2	(775)	-20	-(508)	11 5/8	(295)			17 4/9	(443)

Figure D-13. Exterior Vehicle Crush (NASS) – Front, Test No. H42ST-2

Test Name: H42ST-2 VIN: kmhct4ae8gu947887

Model Year: 2016 Make: Hyundai Model: Accent



	In.	(mm)
Distance from centerline to reference line - L_{REF}:	39	(991)
Total Vehicle Length:	171 7/8	(4366)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-15 7/8	-(403)
Width of contact and induced crush - Field L:	171 7/8	(4366)
Crush measurement spacing interval (L/5) - I:	34 3/8	(873)
Distance from vehicle c.g. to center of Field L - D_{PL}:	-15 7/8	-(403)
Width of Contact Damage:	171 7/8	(4366)
Distance from vehicle c.g. to center of contact damage - D_C:	-15 7/8	-(403)

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

	Crush Measurement		Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	In.	(mm)	In.	(mm)	In.	(mm)	In.	(mm)	In.	(mm)
C_1	N/A	NA	-101 7/8	-(2588)	33 1/4	(845)	- 1/2	-(13)	NA	NA
C_2	N/A	NA	-67 1/2	-(1715)	7	(178)			NA	NA
C_3	6 1/2	(165)	-33 1/8	-(841)	6 1/4	(159)			3/4	(19)
C_4	5 5/8	(143)	1 1/4	(32)	6 1/2	(165)			- 3/8	-(10)
C_5	N/A	NA	35 5/8	(905)	7	(178)			NA	NA
C_6	N/A	NA	70	(1778)	18 1/8	(460)			NA	NA
C_{MAX}	22 3/8	(568)	60	(1524)	9 5/8	(244)			13 1/4	(337)

Figure D-14. Exterior Vehicle Crush (NASS) – Side, Test No. H42ST-2

Appendix E. Accelerometer and Rate Transducer Data Plots, Test No. H42ST-1

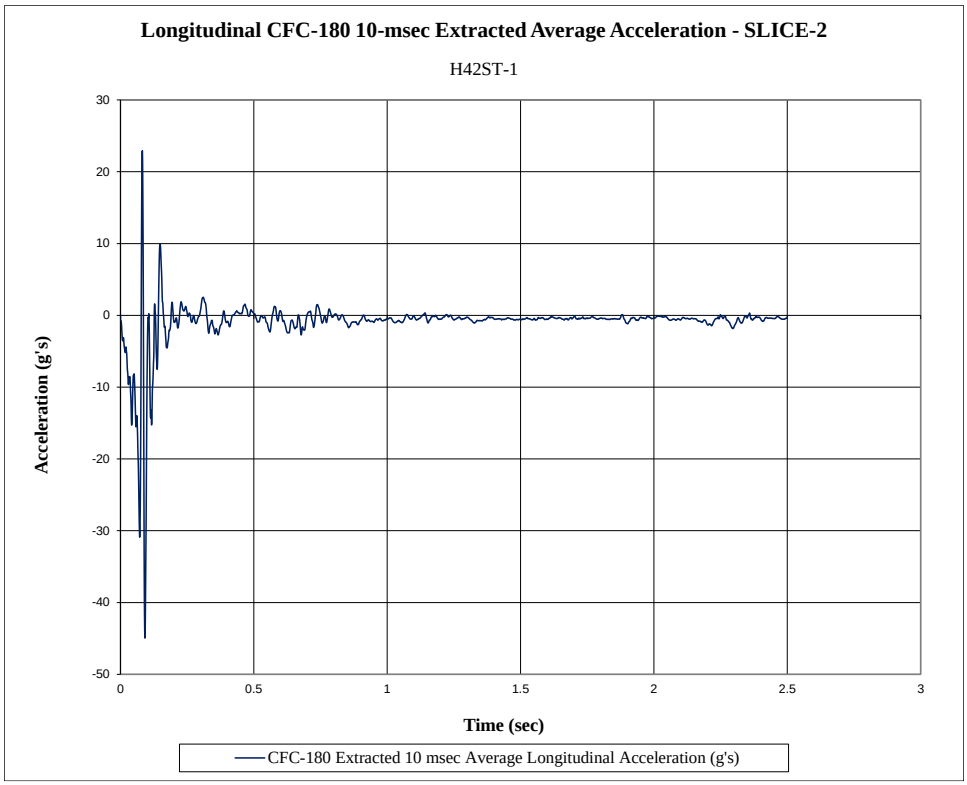


Figure E-1. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. H42ST-1

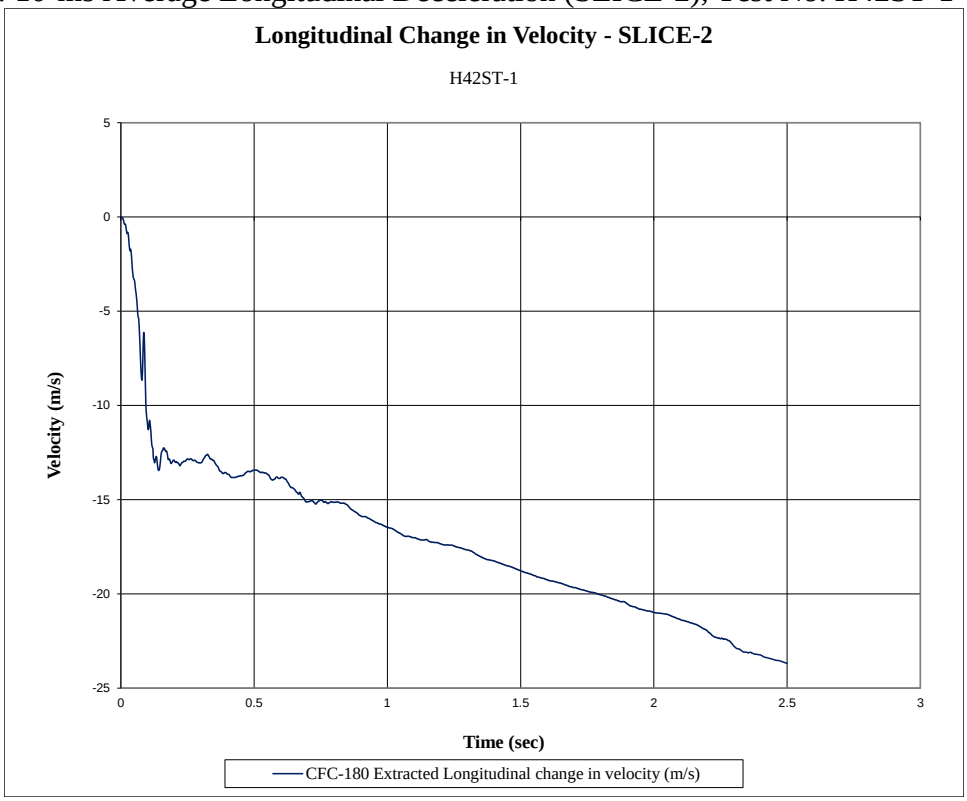


Figure E-2. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. H42ST-1

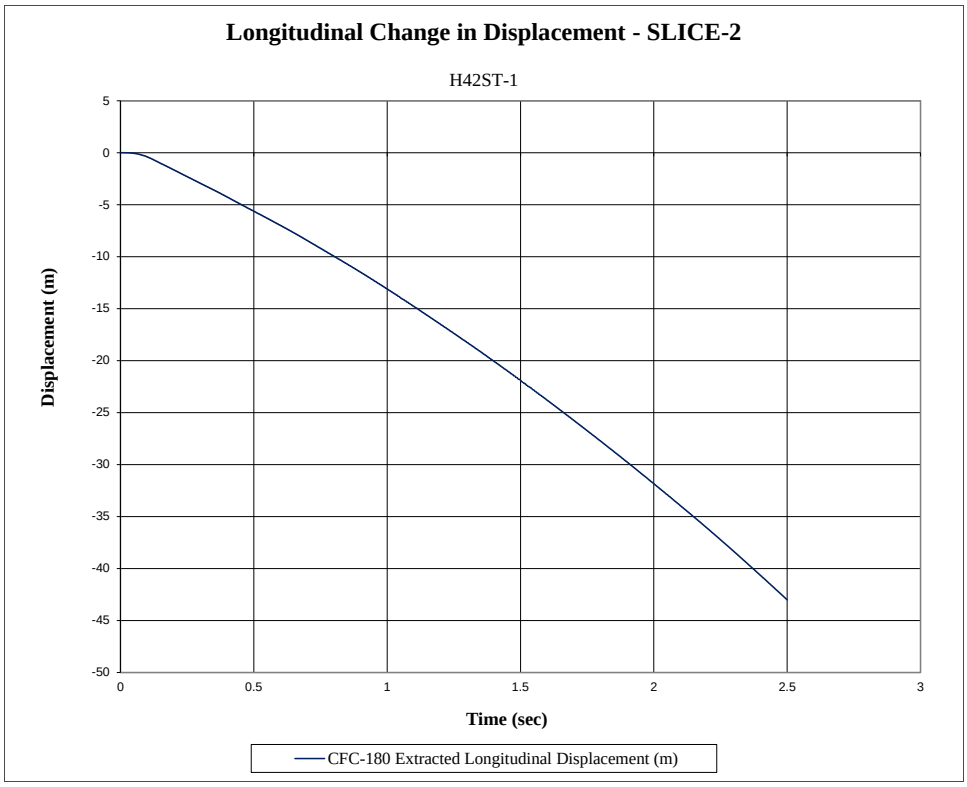


Figure E-3. Longitudinal Occupant Displacement (SLICE-2), Test No. H42ST-1

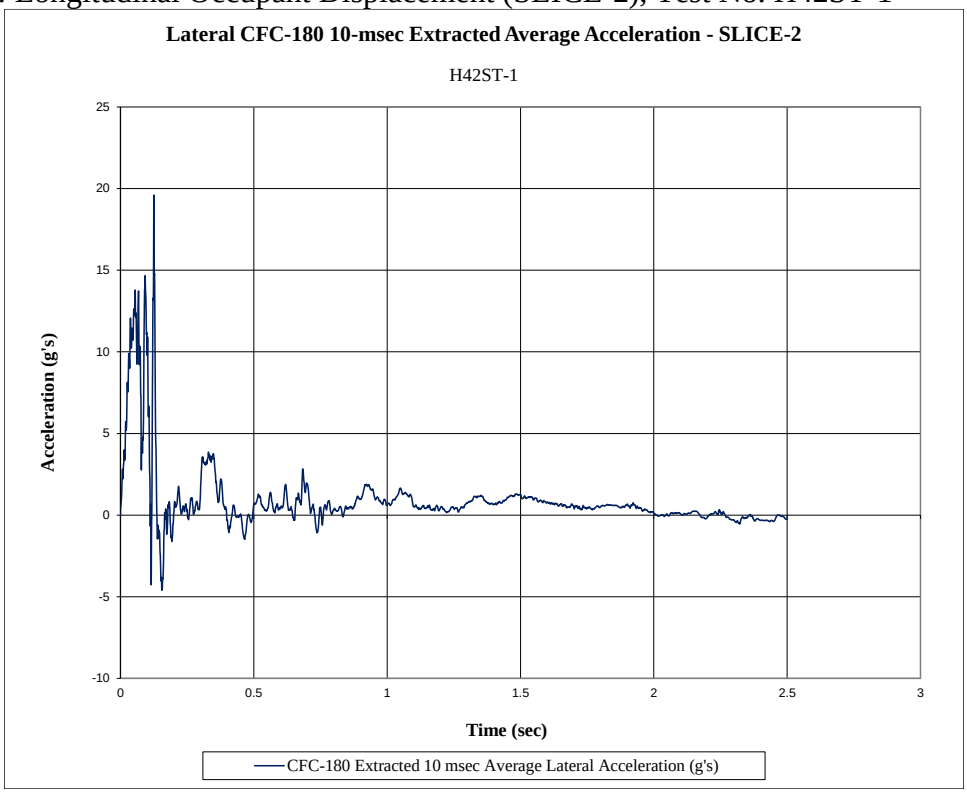


Figure E-4. 10-ms Average Lateral Deceleration (SLICE-2), Test No. H42ST-1

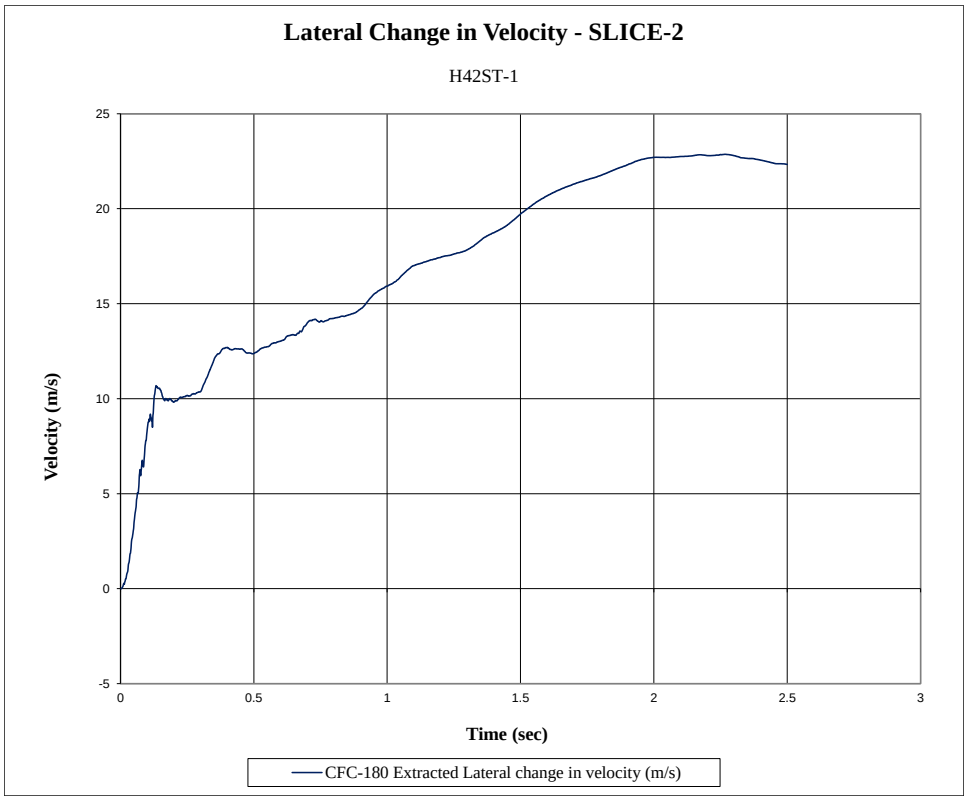


Figure E-5. Lateral Occupant Impact Velocity (SLICE-2), Test No. H42ST-1

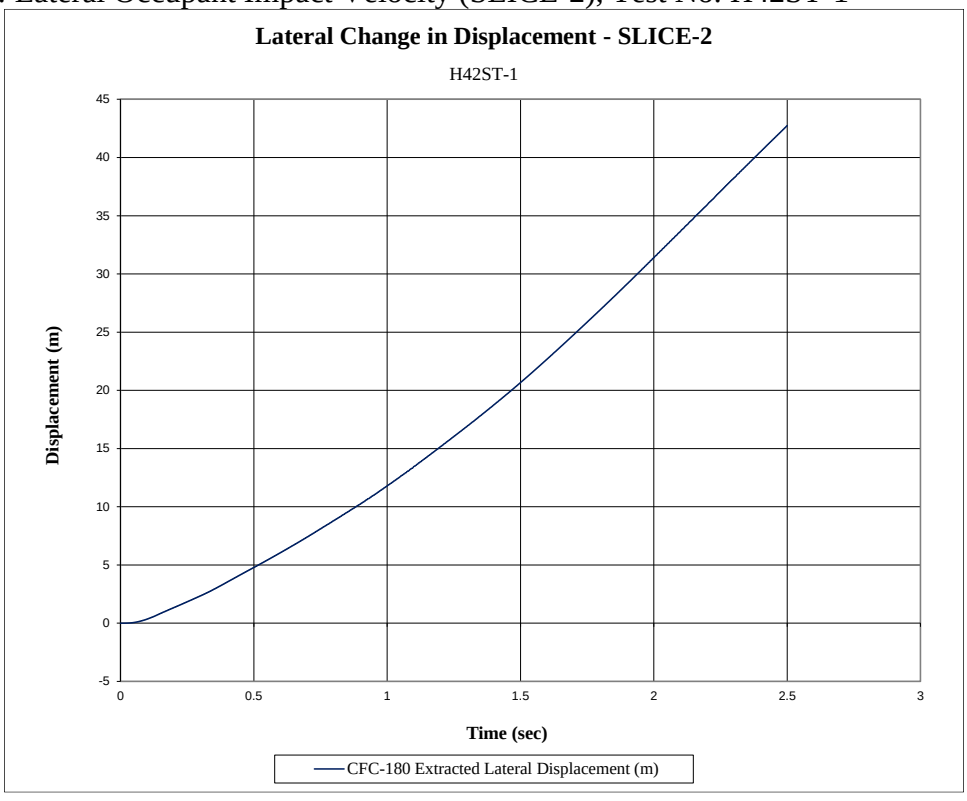


Figure E-6. Lateral Occupant Displacement (SLICE-2), Test No. H42ST-1

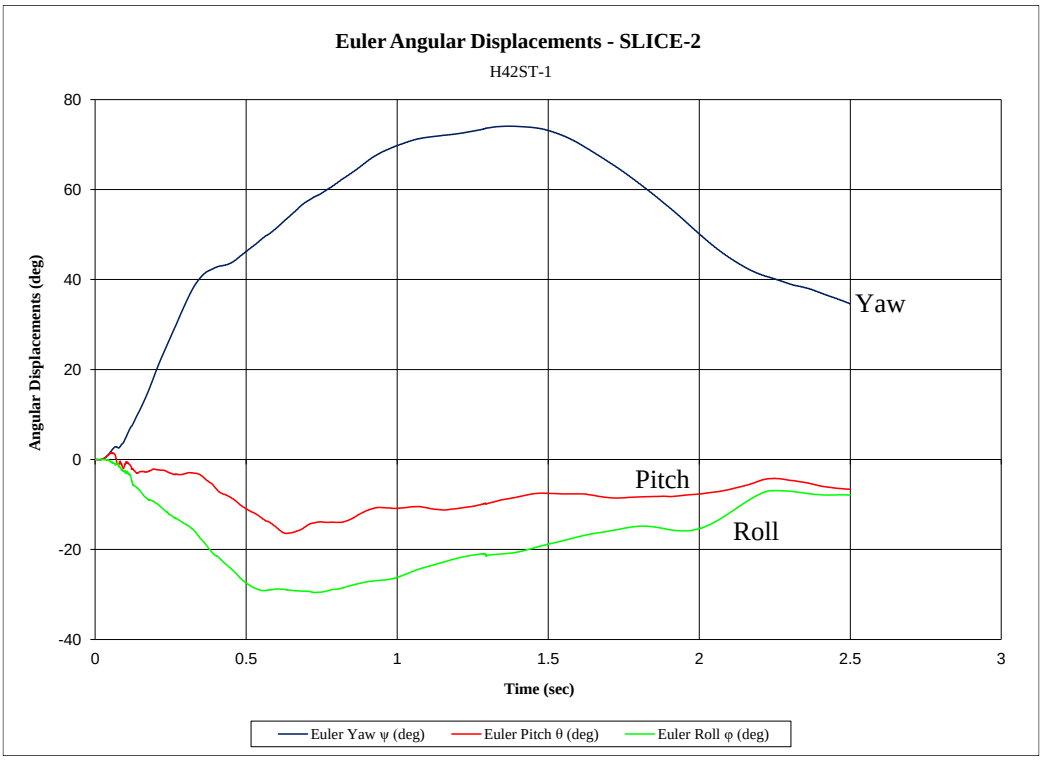


Figure E-7. Vehicle Angular Displacements (SLICE-2), Test No. H42ST-1

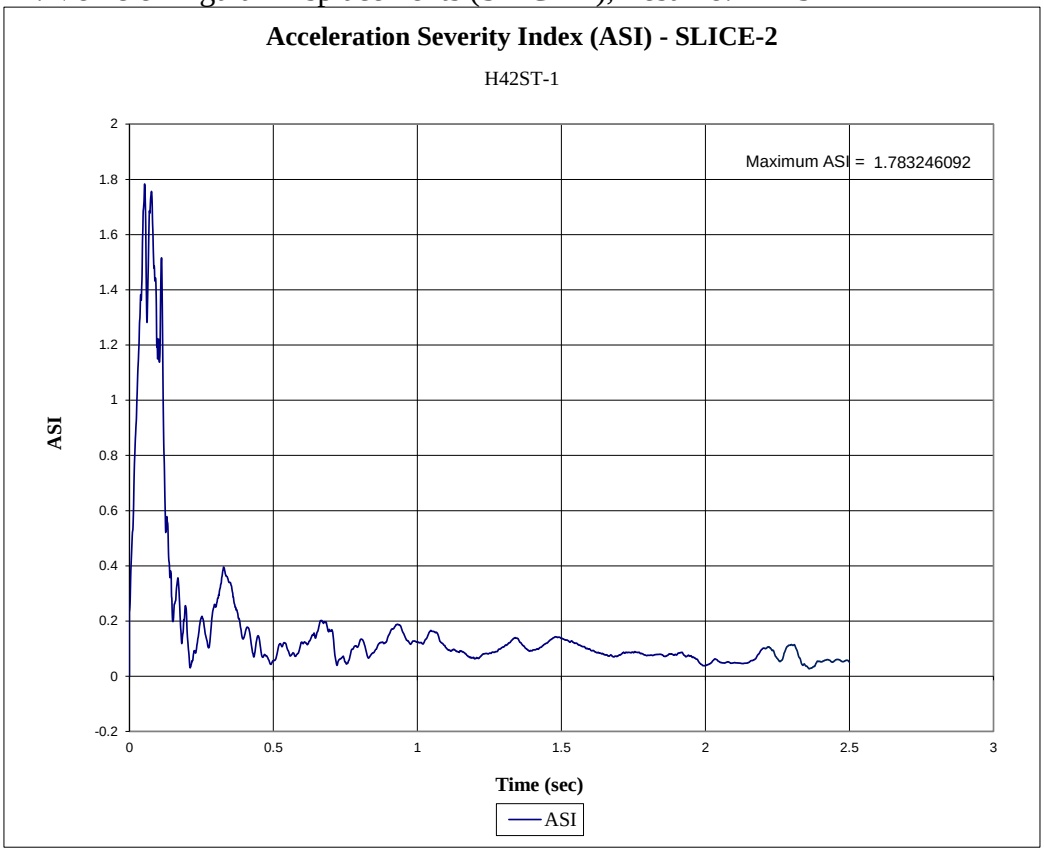


Figure E-8. Acceleration Severity Index (SLICE-2), Test No. H42ST-1

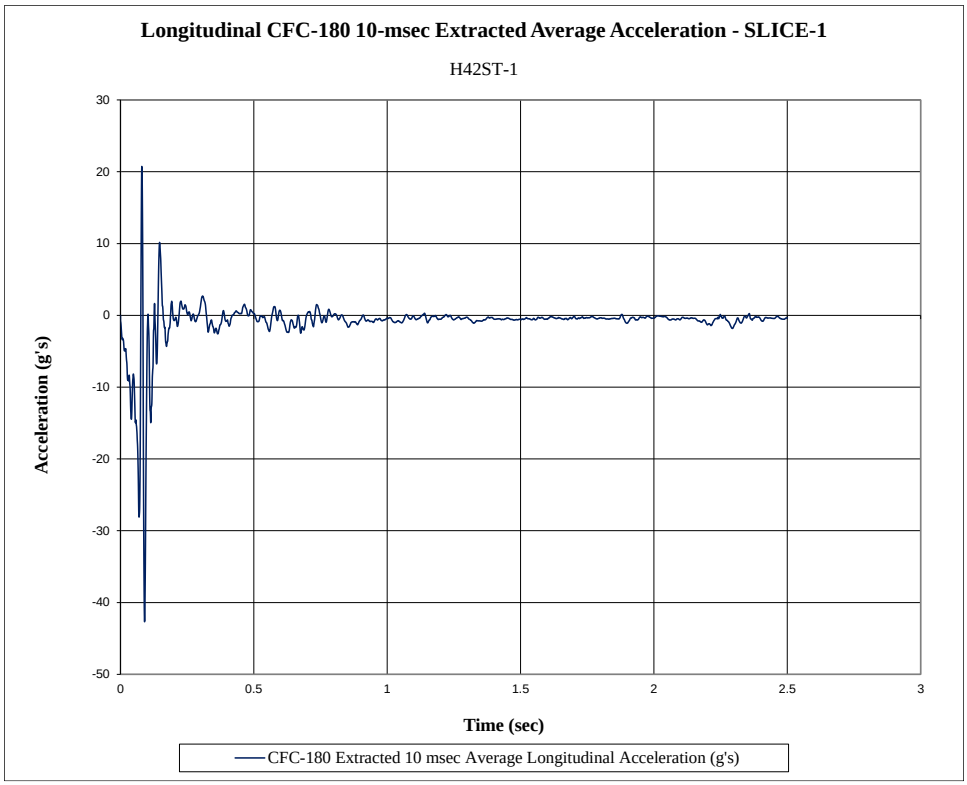


Figure E-9. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. H42ST-1

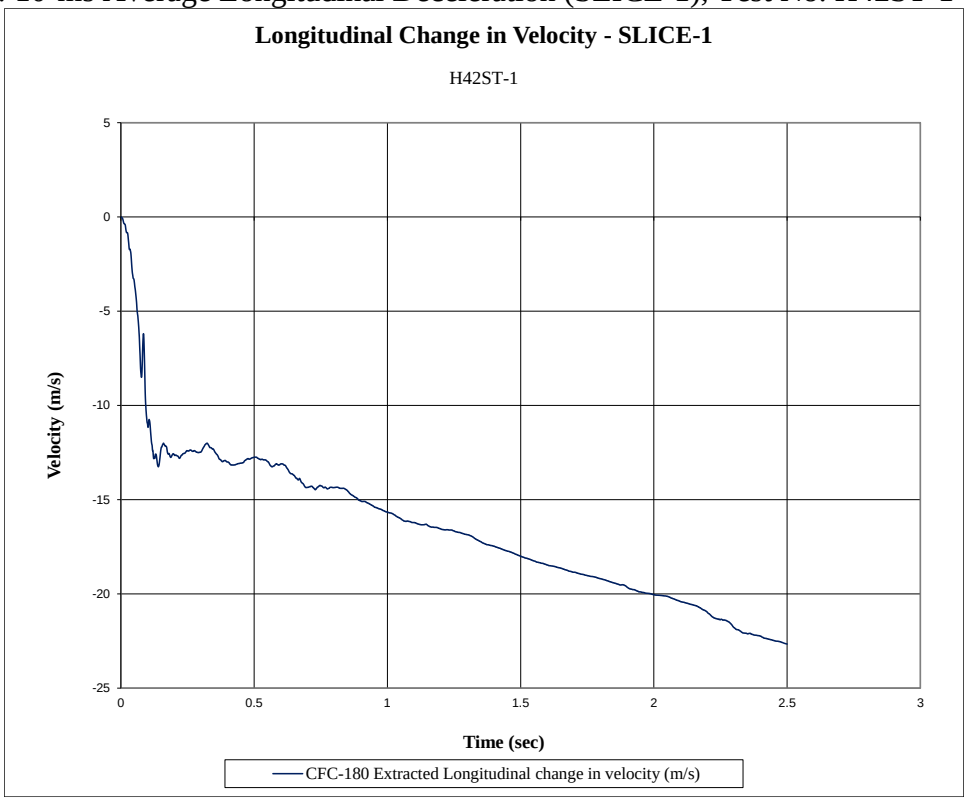


Figure E-10. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. H42ST-1

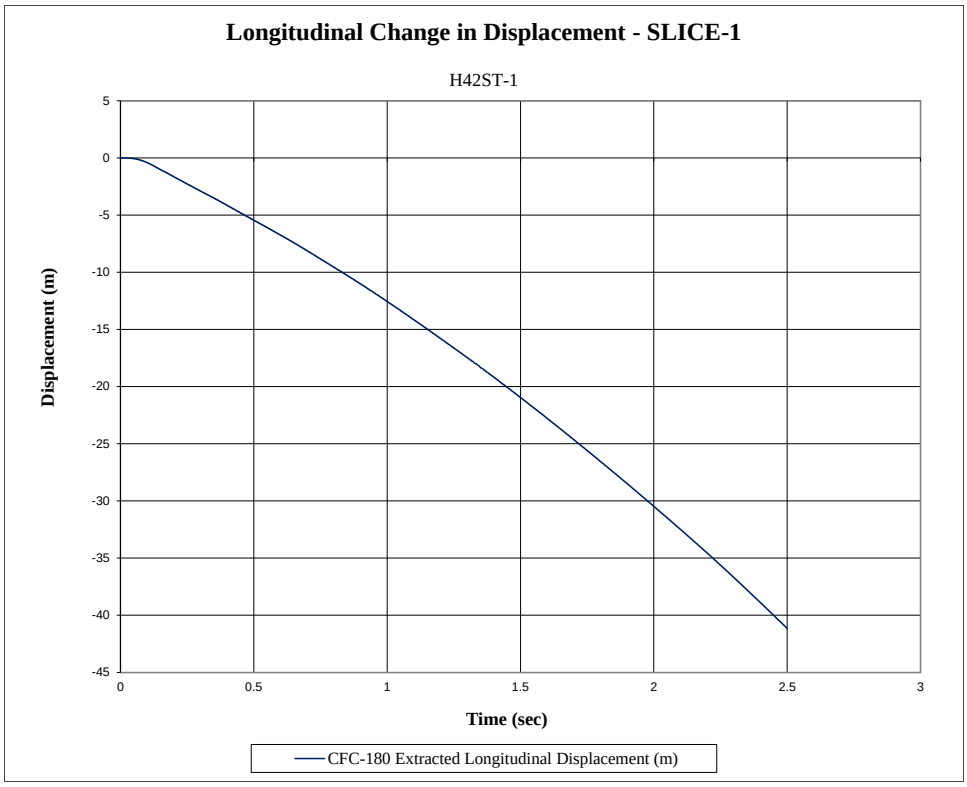


Figure E-11. Longitudinal Occupant Displacement (SLICE-1), Test No. H42ST-1

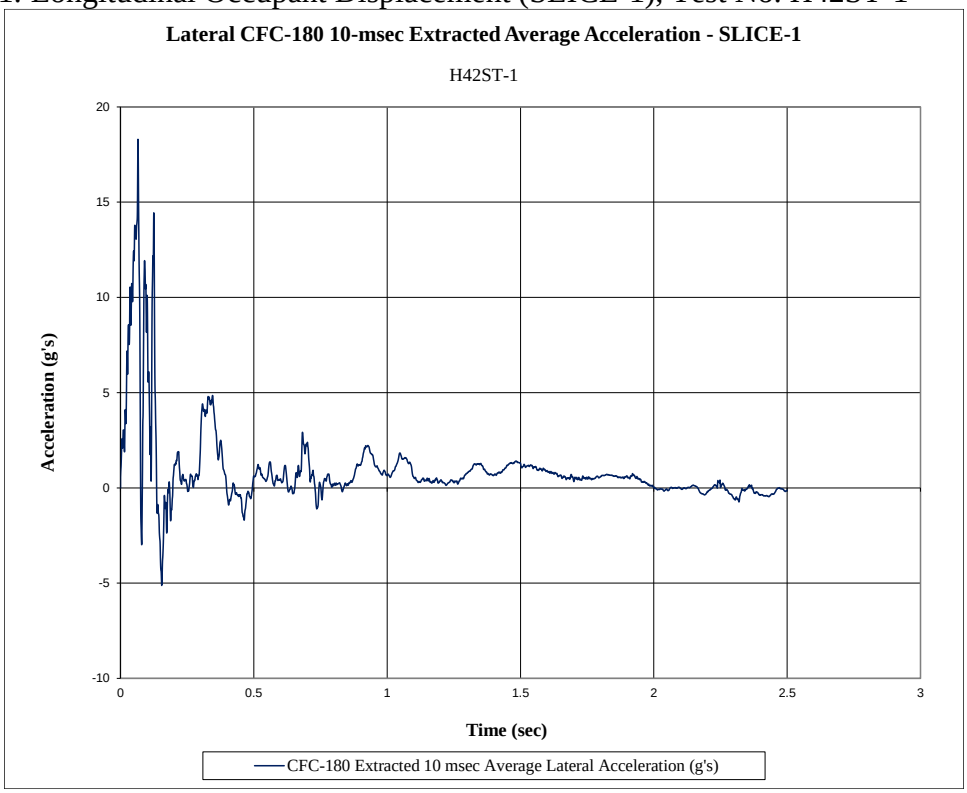


Figure E-12. 10-ms Average Lateral Deceleration (SLICE-1), Test No. H42ST-1

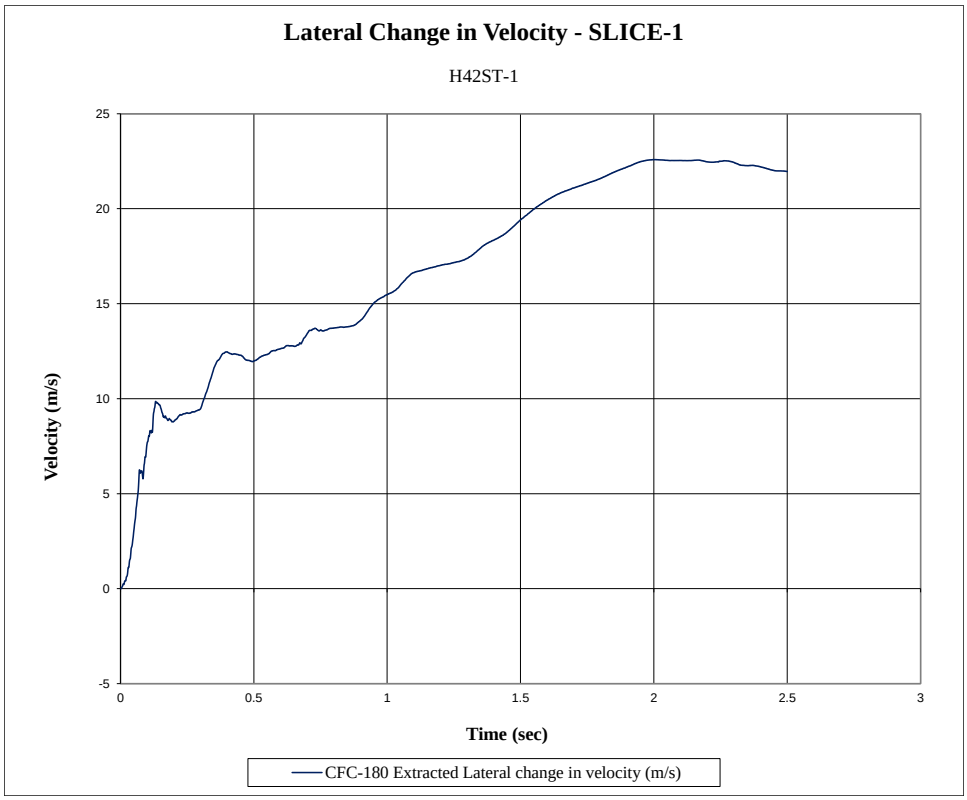


Figure E-13. Lateral Occupant Impact Velocity (SLICE-1), Test No. H42ST-1

Figure E-14. Lateral Occupant Displacement (SLICE-1), Test No. H42ST-1

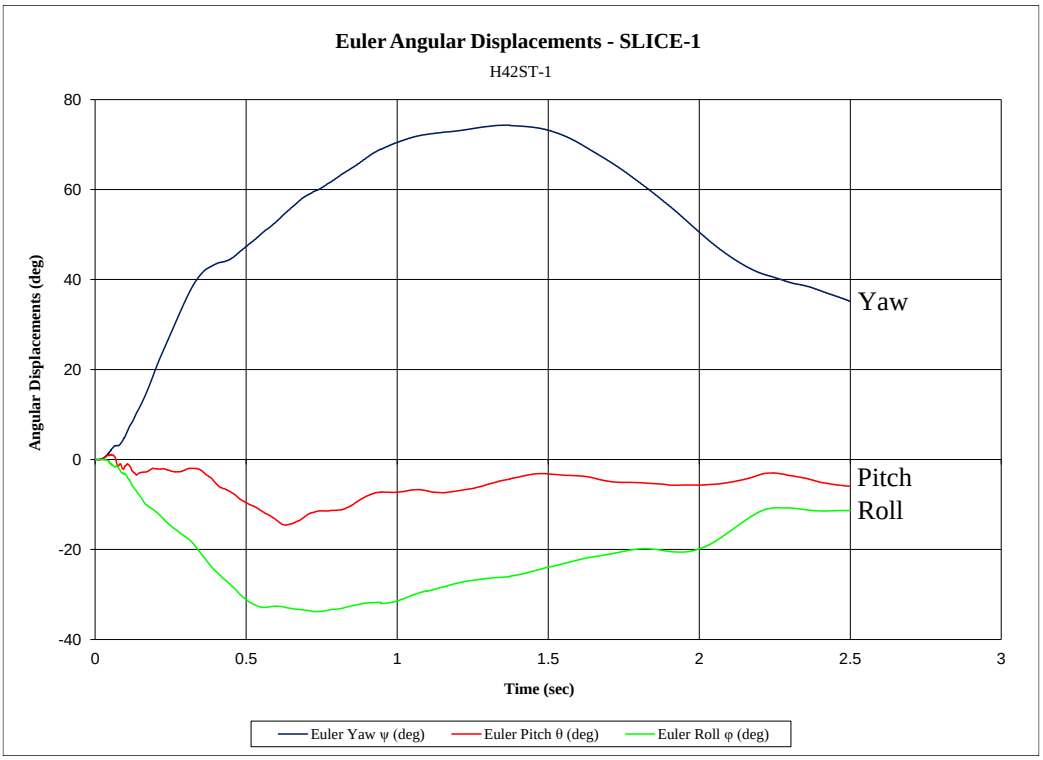


Figure E-15. Vehicle Angular Displacements (SLICE-1), Test No. H42ST-1

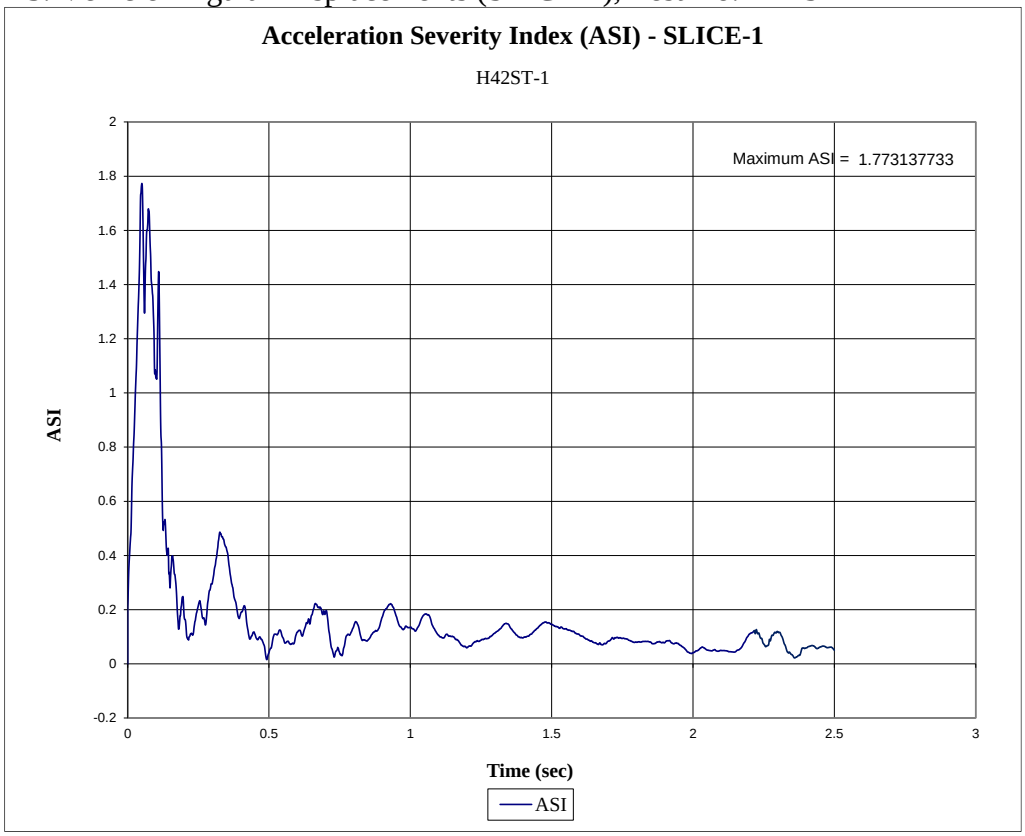


Figure E-16. Acceleration Severity Index (SLICE-1), Test No. H42ST-1

Appendix F. Accelerometer and Rate Transducer Data Plots, Test No. H42ST-2

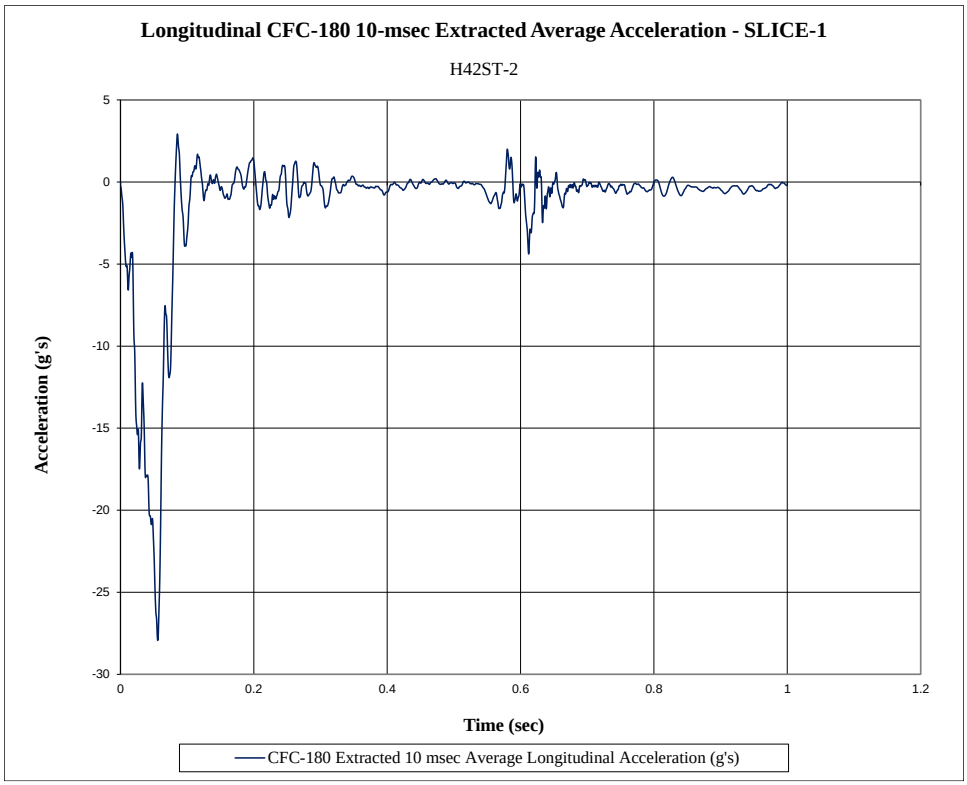


Figure F-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. H42ST-2

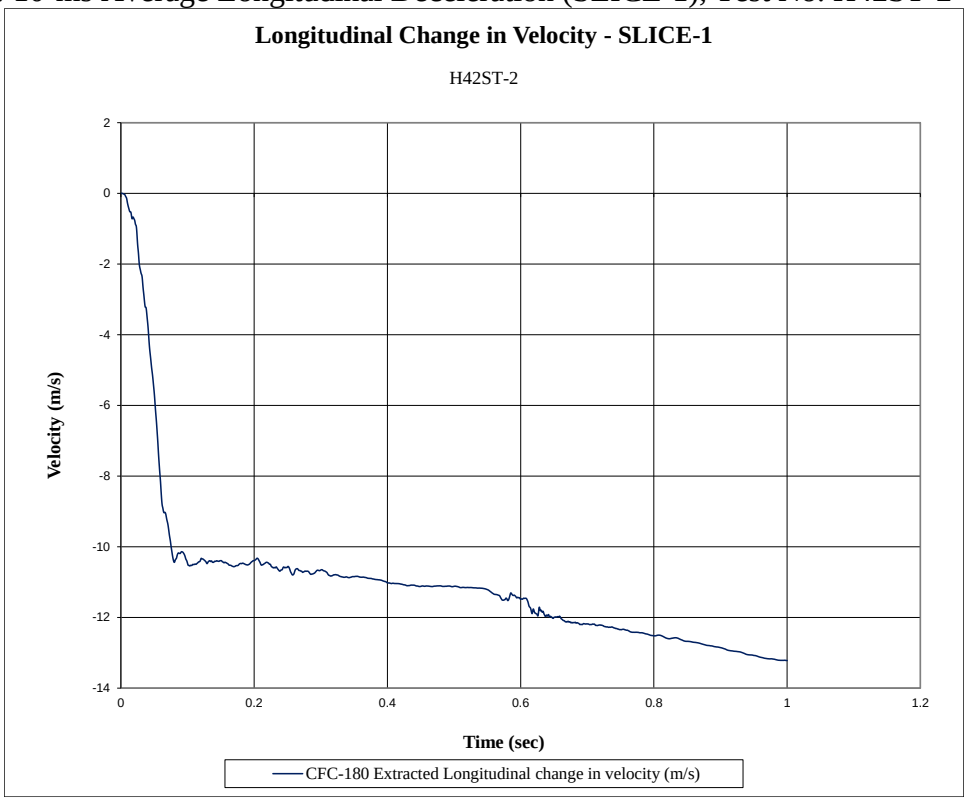


Figure F-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. H42ST-2

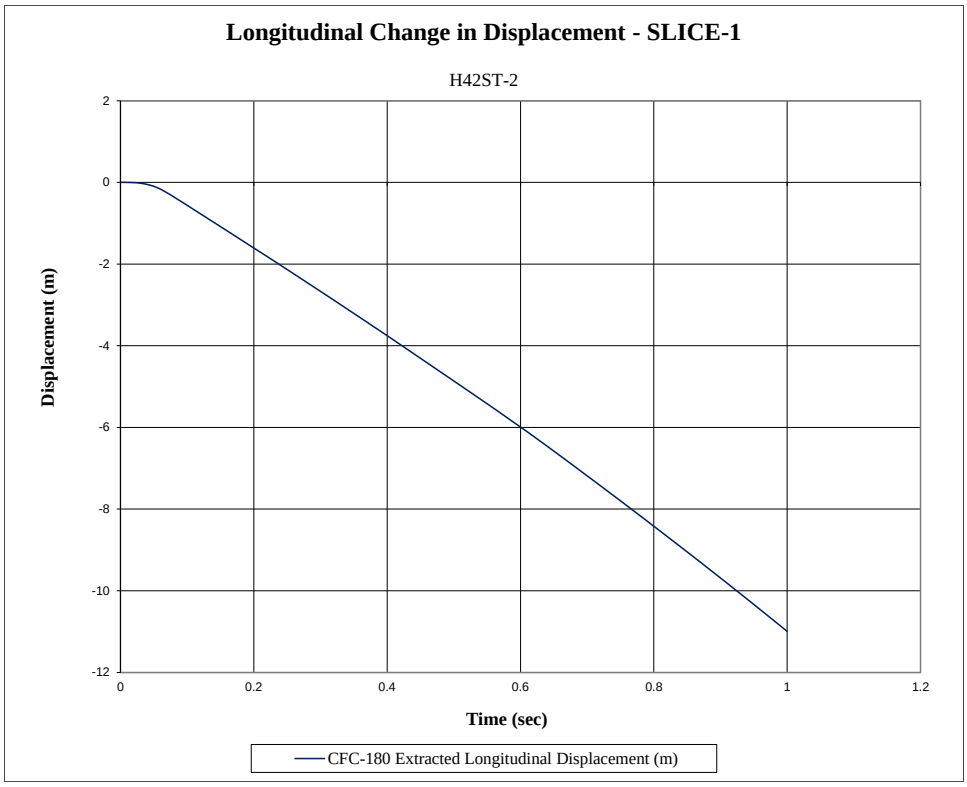


Figure F-3. Longitudinal Occupant Displacement (SLICE-1), Test No. H42ST-2

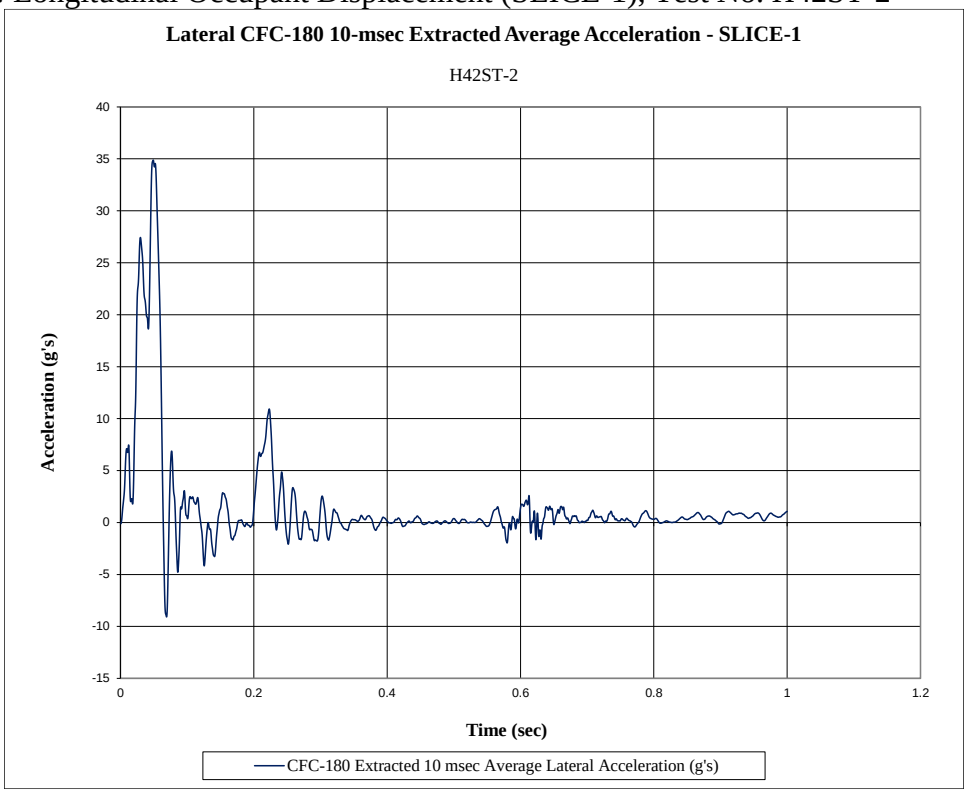


Figure F-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. H42ST-2

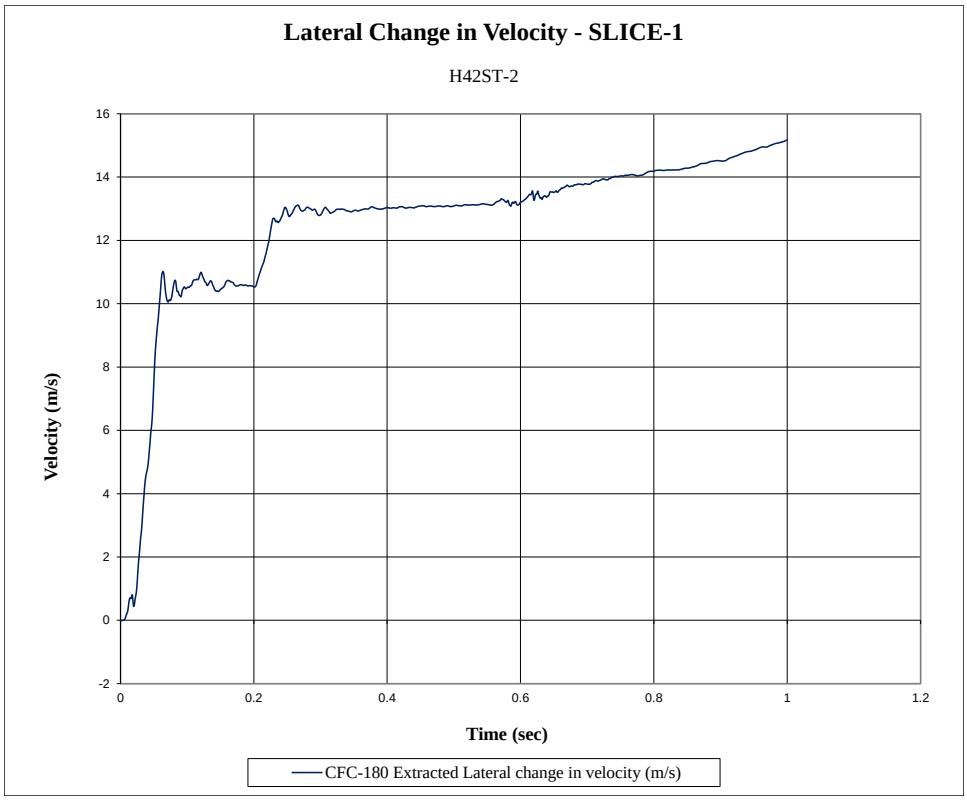


Figure F-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. H42ST-2

Figure F-6. Lateral Occupant Displacement (SLICE-1), Test No. H42ST-2

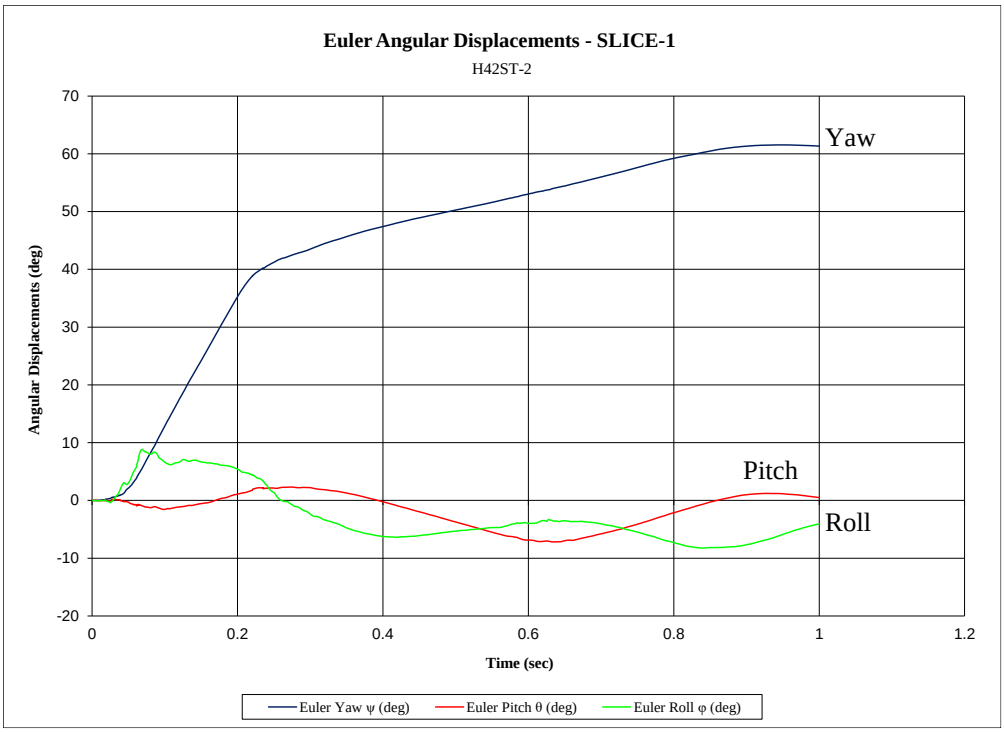


Figure F-7. Vehicle Angular Displacements (SLICE-1), Test No. H42ST-2

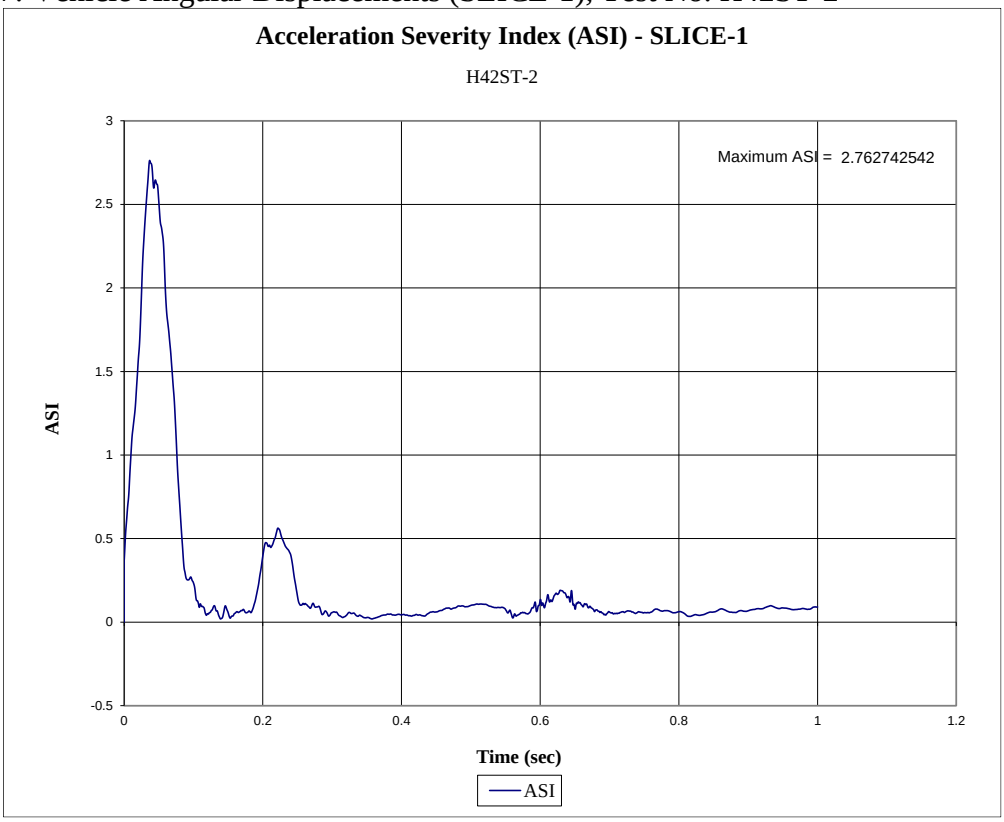


Figure F-8. Acceleration Severity Index (SLICE-1), Test No. H42ST-2

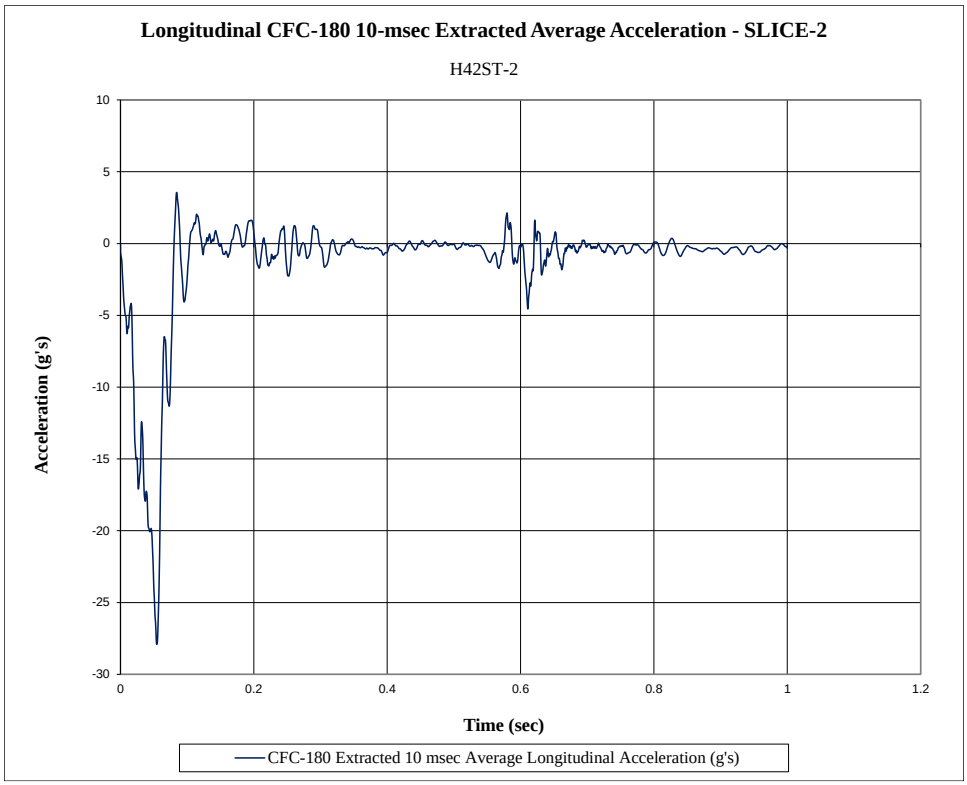


Figure F-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. H42ST-2

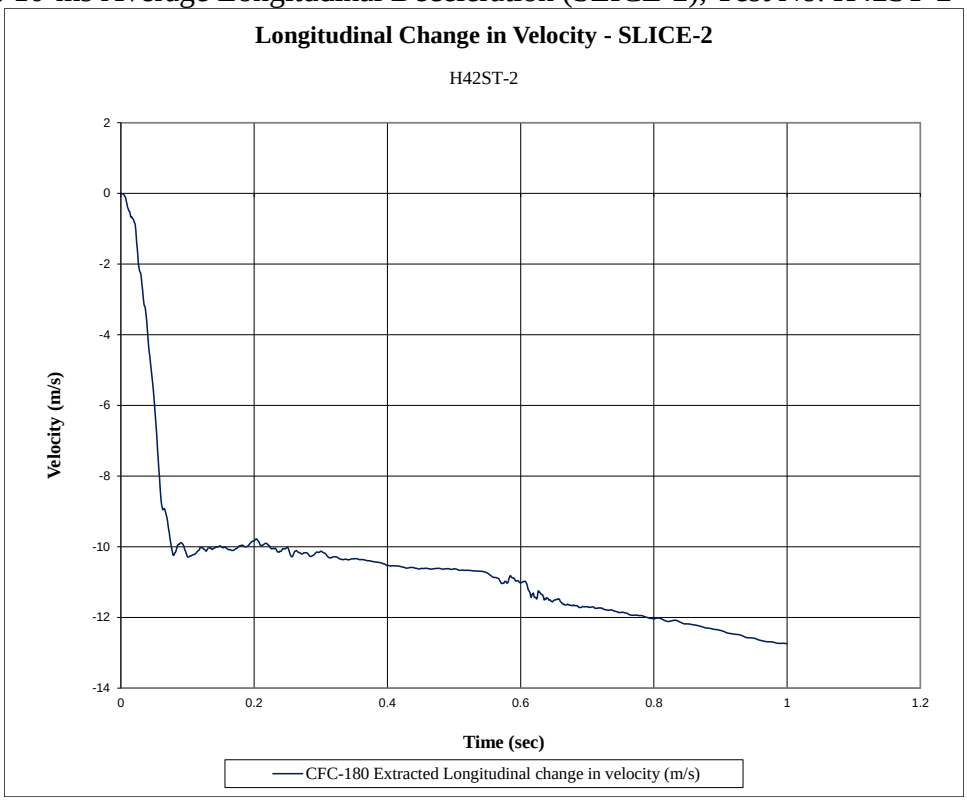


Figure F-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. H42ST-2

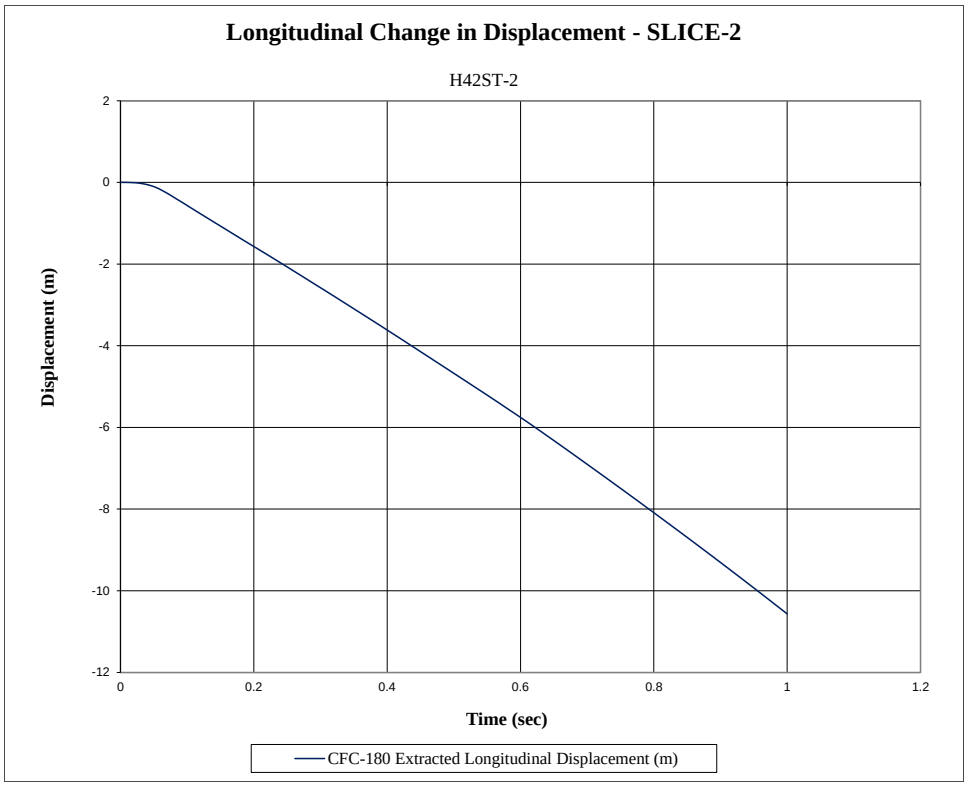


Figure F-11. Longitudinal Occupant Displacement (SLICE-2), Test No. H42ST-2

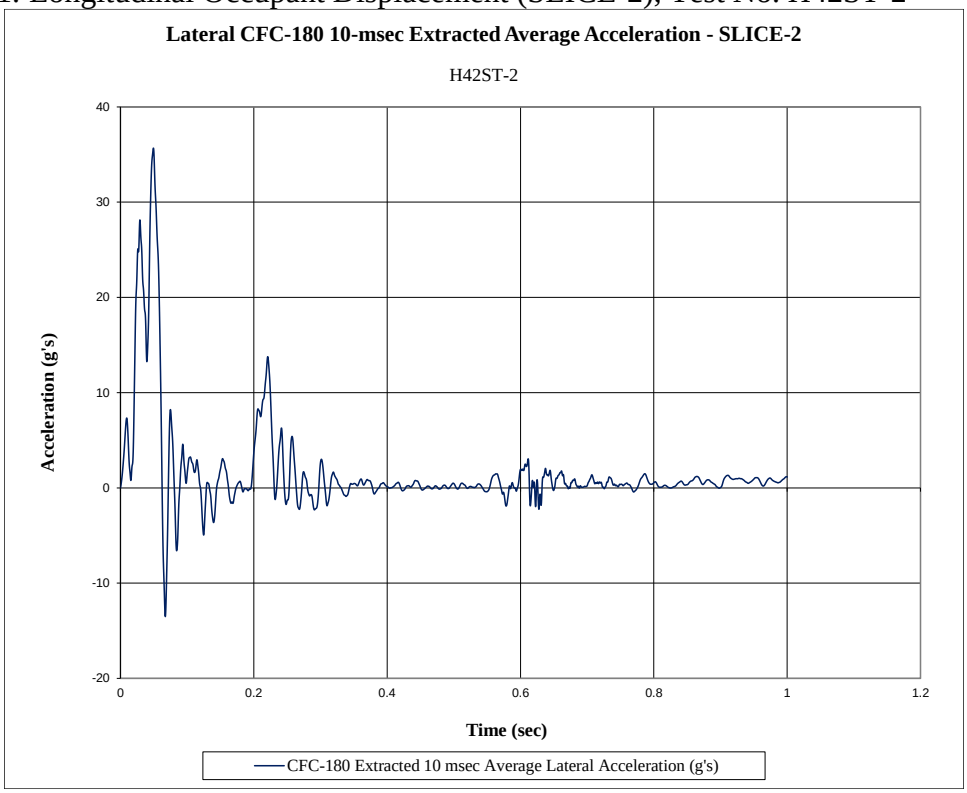


Figure F-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. H42ST-2

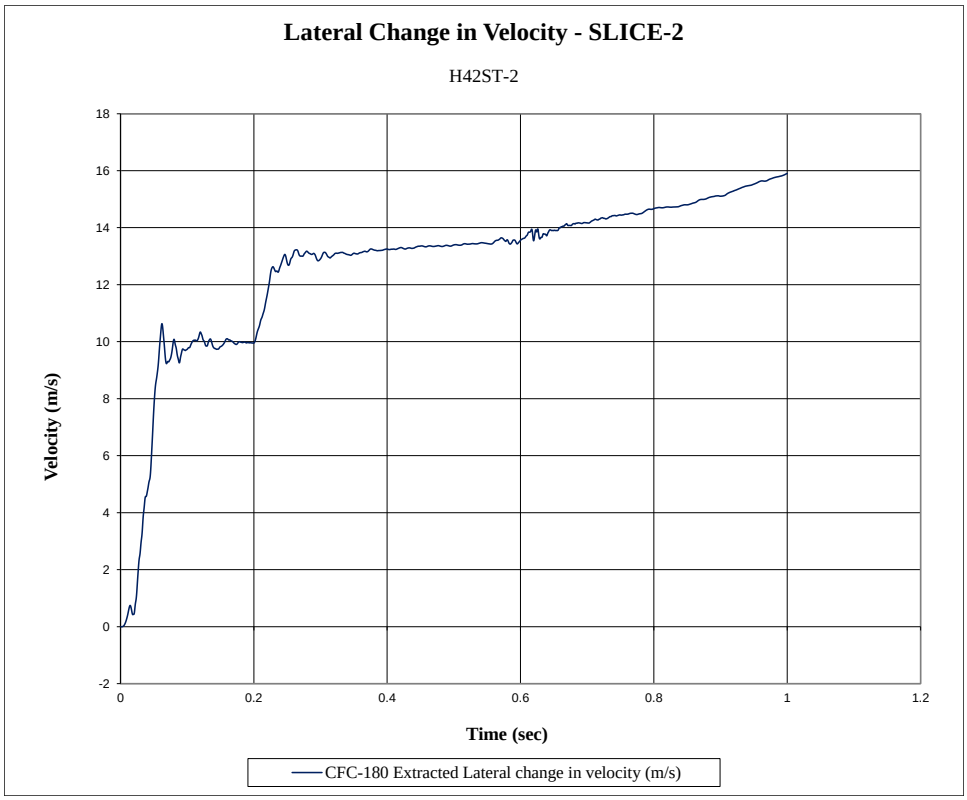


Figure F-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. H42ST-2

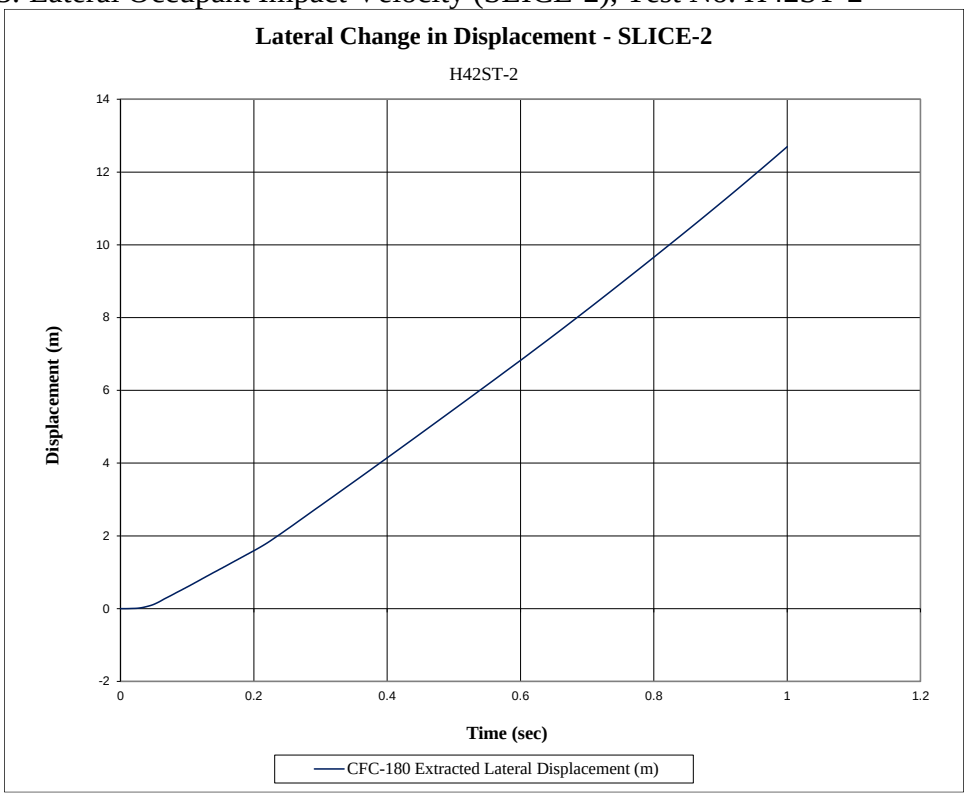


Figure F-14. Lateral Occupant Displacement (SLICE-2), Test No. H42ST-2

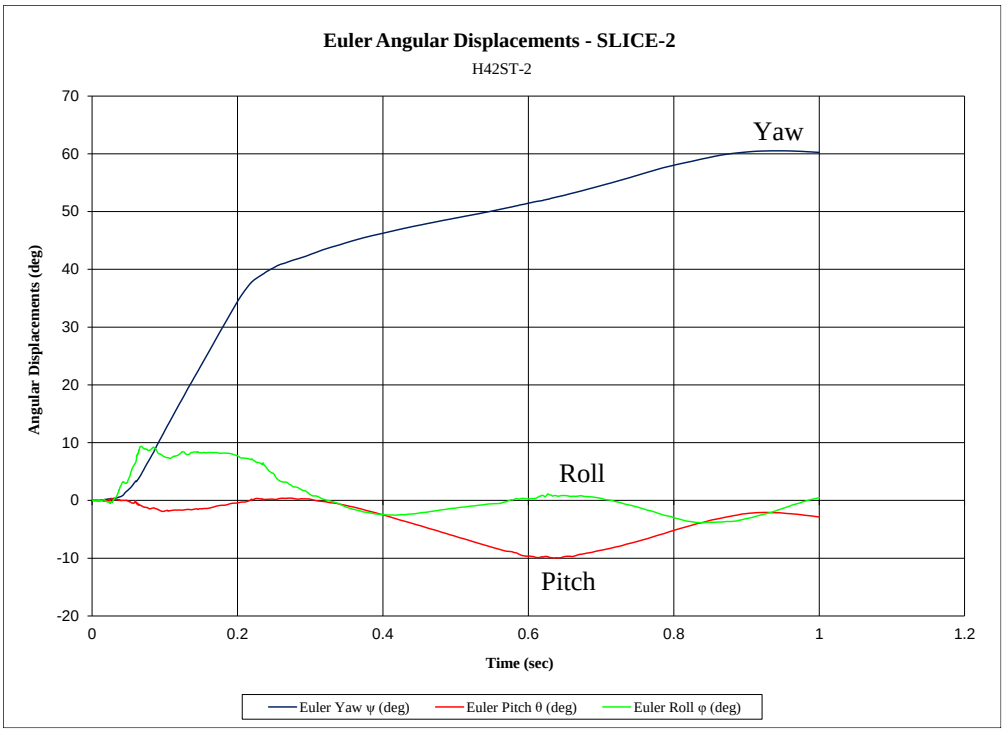


Figure F-15. Vehicle Angular Displacements (SLICE-2), Test No. H42ST-2

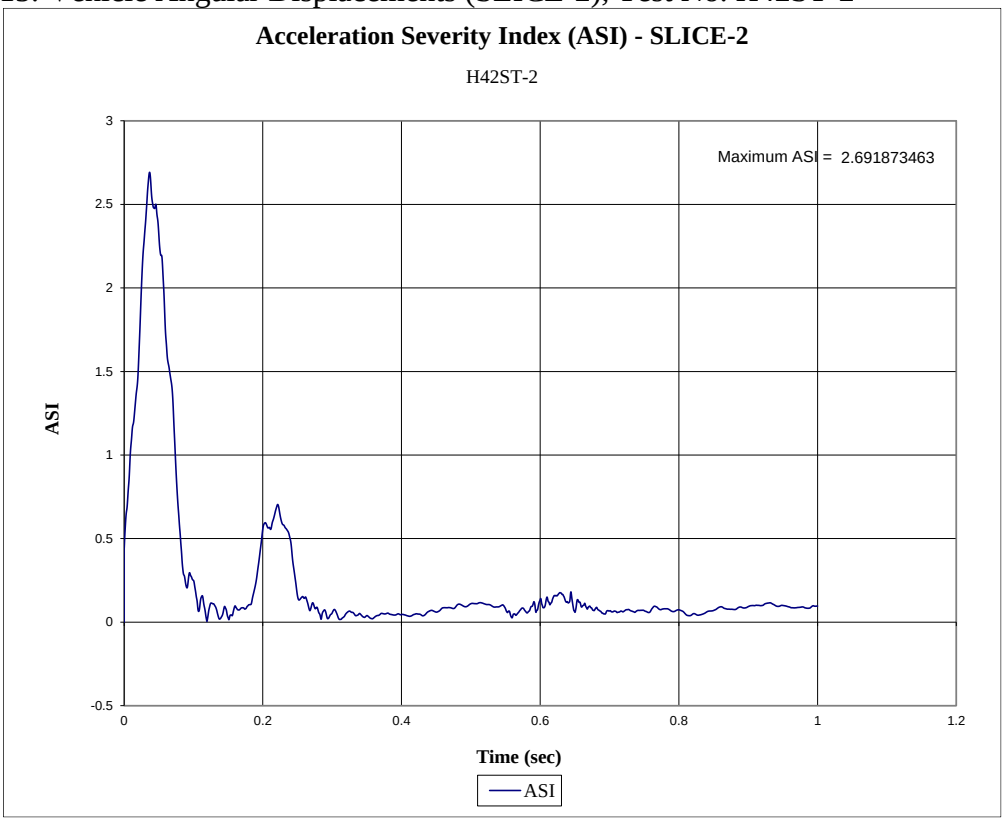


Figure F-16. Acceleration Severity Index (SLICE-2), Test No. H42ST-2

END OF DOCUMENT